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Recovery of a high elevation plant community after packhorse grazing

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Abstract

We evaluated the impact of packstock grazing on a dry, upper timberline meadow. Horses were picketed on 15 m ropes for different durations, months, and frequencies over 3 summers. Before horse grazing, we estimated vegetal, bare soil, litter, rock, and moss cover, measured grass and forb plant heights, counted grass and forb stems per area, and determined the percent of plants grazed. These measurements were repeated 1 growing season later. More bare ground and less litter and vegetal cover were recorded 1 year following single 8- or 18-hour grazing events. Single grazing events of 4-hour duration had no effect on cover. Decreases in vegetal cover were associated with reduced stem numbers. Eighteen hour picket durations reduced subsequent year production of grass and forb stems. We discuss the difficulties encountered in this study, including estimates of necessary sample sizes, to help in the design of future studies.

Key Words: horse, grazing response, ground cover, plant growth

Management of wilderness or natural areas is no longer a question of whether it is necessary but how it should be carried out. Although wildland ecosystems may sustain some human or domestic animal use without altering the processes that sustain the native plant and animal communities, the need to manage such areas (hereafter referred to as wildland areas) has been recognized for many years (Krumpe and McLaughlin 1987). Policy makers and managers of wildlands are faced with the paradox of protecting unique ecosystems or areas with little human development while allowing recreational use (Kuss and Graefe 1985, Cole 1987, McClaran 1989, McClaran and Cole 1993).

One impact of wildland recreational use is packstock grazing. The level of grazing impact is affected by the intensity, frequency, and season of defoliation and the status (grazed or ungrazed) of neighboring plants. In areas with short growing seasons, grazing impacts on plants may not be expressed until the following growing season (Olson and Richards 1988). From livestock grazing studies, we know that heavy and multiple defoliations will result in changes that are apparent the following growing season such as reductions in biomass production (Cook et al. 1958, Trlica et al. 1977, Miller and Donart 1981), leaf or culm length (Cook et al. 1958, Trlica et al. 1977, Edwards 1985, Olson and Richards 1988), number of seed heads or flowers (Cook et al. 1958, Mueggler 1975, Edwards 1985), crown size, root and crown TNC concentrations (Trlica et al. 1977, Miller and Donart 1981), root growth (Cook et al. 1958, Richards 1984), and number of tillers per area (Stout et al. 1981). Declines in some or all of these measures suggest an adverse affect on plant growth and reproduction which can create opportunity for invasion or expansion of other species (Forcella and Wood 1986, Silvertown and Smith 1989). Invasion of wildland plant communities by species that are not native to the area or expansion of species restricted to certain habitat types will change the character of the area, possibly reducing its pristine wilderness value.

While the principles of livestock grazing may apply to packstock grazing, the response of high elevation plant communities has received little study. Also, management objectives of wildland areas often differ from those of livestock production systems (McClaran and Cole 1993). Wildland management objectives may include maintenance of species diversity or to protect specific organisms. The ideal may be to manage for no change, yet limits of acceptable change should be defined (Krumpe and McLaughlin 1987). Grazing management research in wildland areas needs to address how such areas respond to use, and which community responses can be used to indicate acceptable or unacceptable change (McClaran and Cole 1993). Our objective was to determine the tolerance of a mountain meadow plant community to packstock grazing. Such information can help managers develop packstock grazing guidelines.

Methods

The study site is a dry, southwest sloping, upper timberline meadow at 2660 m on the Burntfork of the Bacon Rind drainage in the Lee Metcalf Wilderness Area in southwestern Montana. The area is classified as a *Festuca idahoensis/Elymus trachycaulus* habitat type (Mueggler and Stewart 1980) with fine tex-

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tured soils of the Cryoboroll or Cryochrept group (Montagne et al. 1982). Records of the Hebgen Ranger District, Gallatin National Forest, indicate that the area was never part of a livestock grazing allotment. There are no lakes or streams and the area is closed to hunting, therefore, the meadow is used little by recreational packstock, but is used frequently by elk (*Cervus elaphus elaphus*).

By picketing horses (*Equus caballus*) on this meadow we were able to impose a known amount and season of horse use. In 1988, horses were picketed on a set of circles for 4 durations (0, 4, 8, 18 hours) in each of 3 months (early July, mid August, mid September). The 4-hour circles were grazed for 4 consecutive hours, the 8-hour circles for 4 hours in both morning and evening, and the 18-hour circles for 9 hours a day for 2 consecutive days. There were 4 replicate picket circles per grazing treatment (duration by month) for a total of 48 circles. Horses were initially assigned randomly to duration and replicate. When possible, the same horse was assigned to the same duration in subsequent months.

In 1989 we repeated the treatments on another ungrazed part of the same meadow. In addition to the earlier grazing duration by month treatments, we added another treatment involving repeated use of the same picket circles. To achieve this treatment, 4 circles were grazed for 4 hours and another 4 were grazed for 8 hours each month (July, August, and September). This treatment was identified as JAS. In 1990, the 1989 circles were regrazed with the same grazing treatment as applied in 1989.

Circles were 15 m in diameter. Four transect lines (bearing N, S, E, W) were marked in each circle. A 2 × 5 cm frame (Morris 1973) was placed perpendicular to the transect line at 0.30 m intervals. Twenty-five such frames were read on the N and S transects. Only the outer 4 m of the E and W transects (14 frames each) were sampled to avoid oversampling the circles' centers.

Before grazing the following data were collected from each frame: 1) estimated percent cover of mineral soil, rock, moss/lichen, litter, and basal vegetation in 10% increments, 2) separate stem counts of grasses and forbs, 3) height class (0 = no plants, 1 = 0–2 cm, 2 = 2–4 cm, 3 = 4–12 cm, 4 = 12–24 cm, 5 = > 24 cm) of the tallest plant material of the dominant (according to stem count) vegetation type (grass or forb) in 1988, and of the tallest grass and forb thereafter, 4) whether grasses or forbs were grazed to quantify elk grazing (except in 1988), and 5) penetration resistance of the top 1 cm soil layer with a pocket ring penetrometer. We collected four, 20 cm soil cores from each circle to determine percentage of soil water content. In September 1988, 6 inches of snow prevented us from taking pregrazing measurements.

All parameters were remeasured in August 1989 on the circles grazed in 1988, and in July 1990 and 1991 on the circles grazed in 1989 and regrazed in 1990. All data were summarized to a mean measurement per circle. We calculated the proportion of frames with plants in each height class and the percent of frames with grazed plants. Cover, height class, and grazed plant frequency were arcsine-squareroot transformed to achieve a near normal data distribution to accommodate analysis of variance.

Initially we calculated a relative index of change (Cole 1987) from pregrazing values to measurements taken 1 year later. However, high standard errors and high index values for the controls (sometimes greater than 7,000 when they should be 1), made the validity of this index for these data questionable and the index was not used. To control for external environmental variables and differences among circles before grazing, we calculated the difference between the initial, and 1 or 2 year later values (1989-1988, 1990- 1989, 1991-1989). These values include an effect of month when pregrazing data were collected, therefore we can only compare grazing durations within a month.

We used analysis of variance with duration (hours on picket), vegetation type (grass or forb), and vegetation type by duration interaction in the model. Replication within duration was used as the error term. We included soil moisture, soil penetration resistance, and soil, vegetal, and litter cover as covariates in the analyses of stem counts. Covariates were excluded if they were not significant or parameter estimates (slope or intensity of the influence) were biologically insignificant. We used $\alpha = 0.10$ for all tests.

We failed to find statistically significant differences among treatments. Therefore, we calculated power curves (Rotenberry and Wiens 1985) to estimate the number of replicate picket circles (N) necessary for us to detect differences among grazing durations ($\alpha = 0.10$, $\beta = 0.25$, effect size selected according to variable tested) or the difference among durations (effect size) necessary for us to detect a grazing effect with 75% probability ($\alpha = 0.10$, $N = 4$, $\beta = 0.25$).

Results

Four picket circle replicates were insufficient to detect a statistically significant effect of grazing duration on bare soil, litter, vegetation, rock, and moss cover, and stem counts the year following grazing. Therefore, we present treatment means and standard errors (Table 1, Table 2, Fig. 1) and discuss patterns of change which are consistent among years and with known possible influences of grazing on plant communities.

Ground Cover

To detect a difference among grazing durations of a change in cover of 10 % (e.g. treatment A changed from 10 to 20% litter, while treatment B changed from 10 to 30% litter), we would have needed 4 to 190 replicate circles, depending on cover type, month, and year grazed. However, the means suggest a pattern of grazing induced change (Table 1). Eighteen hours grazing in August 1988, and 4, 8, and 18 hours grazing in August and September 1989 reduced the percentage of vegetal cover relative to the ungrazed circles the following year. There was a corresponding increase in percentage of bare soil. Grazing did not affect litter or rock cover differently from the ungrazed controls. Changes in moss cover varied from year to year but were not influenced by grazing. Circles grazed repeatedly through the summer (JAS) were not impacted more than circles grazed only once.

After 2 years of grazing (Table 2) most grazing treatments had more bare soil with a corresponding loss of litter rather than vegetal cover. All treatments (grazed and ungrazed) had less moss cover in 1991 than in 1989, but slightly more vegetal cover. Rock cover did not change over this period.

Plant Stem Numbers

Stem counts on the ungrazed circles averaged 4 per 10 cm^2 for grasses, and ranged from 3 to 7 for forbs, depending on month. To detect differences among grazing durations in the change in

Table 1. The change in % of ground cover from year grazed to the following summer by year, month, and duration (hours) grazed (mean ± SE).

Year & Month	Duration Grazed	Cover Soil	Vegetal	Litter	Rock	Moss
	(Hours)	(%)				
1988	0	8 ± 3[1]	-11 ±.5	1 ± 6	0 ± 0	2 ± 4
Jul	4	15 ±.9	-6 ± 5	-6 ± 8	1 ± 2	-5 ± 6
	8	12± 6	-11 ± 3	-3 ± 6	1 ± 1	1 ± 9
	18	9 ±.1	-12 ± 2	-2 ± 5	4 ±.1	1 ± 5
Aug	0	5 ± 4	1 ± 7	-15 ± 3	0 ±.1	9 ± 7
	4	6 ± 7	0 ± 5	8 ± 4	2 ± 1	2 ± 6
	8	8 ±6	-1 ± 15	-9 ± 5	3 ± 2	-1 ± 2
	18	18 ± 4	-12 ± 5	-10 ± 7	3 ± 1	2 ± 4
Sep[2]						
1989	0	10 ± 93	5 ± 1	-8 ± 1	1 ± 1	-7 ±.3
Jul	4	14 ± 8	7 ± 1	-2 ± 14	-2 ± 1	-18 ± 7
	8	5 ± 10	8 ± 2	-7 ± 11	0 ± 1	-6 ±.3
	18	10 ± 8	4 ± 2	-7 ± 12	0 ± 1	-7 ± 8
Aug	0	3 ± 6	10 ± 4	-5 ± 7	0 ± 1	-7 ± 3
	4	13 ± 6	2 ± 1	-6 ± 8	0 ± 0	-9 ± 4
	8	12 ± 5	2 ± 2	-1 ± 12	1 ± 1	-14 ± 8
	18	11 ± 5	3 ± 2	-5 ± 7	-1 ± 1	-8 ± 5
Sep	0	9 ± 4	6 ± 1	-7 ± 4	-1 ± 1	-9 ± 4
	4	11 ± 2	2 ±.1	-8 ± 6	1 ± 1	-9 ± 6
	8	16 ± 9	3 ± 3	-10 ± 10	0 ± 0	-7 ± 14
	18	22 ± 4	2 ± 1	-14 ± 4	-1 ± 0	-9 ± 2
JAS[4]	4	7 ± 5	4 ± 1	-7 ± 7	0 ± 0	-4 ± 3
	8	12 ± 6	6 ± 2	-11 ± 9	0 ± 1	-6 ± 4

[1]These values were calculated by subtracting the 1988 from the 1989 cover values. A negative value indicates a decrease in cover from 1988 to 1989.
[2]September 1988 pregrazing data missing.
[3]These values were calculated by subtracting the 1989 from the 1990 cover values. A negative value indicates a decrease in cover from 1989 to 1990.
[4]Circles were grazed each month, July - September.

stem counts, 1 grazing treatment would have to change by more than 3.5 stems than another treatment during the year. For example, a grazing treatment would have to increase from 4 stems per 10 cm^2 1 year to 12 stems the next year to be significantly different from a treatment which changed from 4 to 8 stems. To reduce the detectable difference (3.5 stems) to 1 stem would require 10 to 50 replicate circles depending on vegetation type, month, and year grazed.

There were, however, trends in grazing impacts on grass and forb stem counts (Fig. 1). Forb stem counts declined from 1988 to 1989 on all July circles, but the decline was less on the grazed than on the ungrazed circles (Fig. 1a). Eighteen hours of grazing in August 1988 reduced both grass and forb stem counts the following year (Fig. 1a).

The meadow grazed in 1989 responded similarly. Eight and 18 hours of grazing in July increased the number of forb stems relative to the ungrazed circles. Forb stem counts were not affected by grazing in August and September (Fig. 1b). Grazing for 18 hours in July 1989, any grazing in August and September 1989, and repeated grazing during the summer 1989 (JAS) reduced grass stem counts in 1990 when compared to ungrazed circles (Fig. 1b). Changes in stem counts from 1988 to 1989 and 1989 to 1990 were not influenced by soil moisture, soil penetration resistance, or ground cover.

After 2 consecutive years of grazing, the July 8- and 18-hour circles had less grass and more forb stems (Fig. 1c) than the controls. August and September grazing had little influence on forb numbers. However, 8 hours of grazing in August and 8 and 18 hours of grazing in September reduced grass stem counts (Fig. 1c). Two summers of repeated grazing during the summer (JAS) did not affect grass or forb stem counts (Fig. 1c).

The grazing treatments did not influence elk grazing the following summer. Elk grazed 14.7 ± 1.1% (mean ± standard error) of the grasses and 9.9 ± 1.0% of the forbs by August 1989 across all circles grazed by horses in 1988. By July 1990, elk had grazed 7.7 ± 0.8 and 8.9 ± 0.7% of the grasses and forbs, respectively, on circles grazed by horses in 1989. After 2 years of horse grazing the elk grazing was uniform across all circles. By July 1991, elk had grazed 6.9 ± 0.6% of the forbs and 7.3 ± 0.7% of the grasses.

Discussion

While the meadow we worked on appears to be resilient to 2 summers of moderate to heavy grazing, our ability to detect significant grazing effects may have been limited by too few picket circle replicates. Yet, consistent patterns among grazing treatment means indicate that picketed horses could cause some changes on grazed areas depending on season and duration of grazing.

Picketing for 8 or 18 hours in mid- to late summer increased bare soil the following year and decreased vegetal or litter cover. The decrease in basal vegetal cover was reflected in reduced grass stem counts. Grasses grazed during flowering produce fewer tillers per unit area (Stout et al. 1980, Stout et al. 1981) or have lower tiller replacement (Olson and Richards 1988) than ungrazed plants. Forbs similarly produce fewer inflorescence if defoliated just before or during flowering (Blaisdell and Pechanec 1949, Mueggler 1967, Edwards 1985).

Mid-summer 1988 was extremely dry (NOAA 1988) and the grasses were flowering in July. Grazing at this time may have given the forbs a competitive advantage, thus the smaller decrease in forb stem counts from 1988 to 1989 on the grazed than the ungrazed circles (Fig. 1a). By August the forbs were either flowering, and thus sensitive to defoliation, or dried and

Table 2. The change in % of ground cover from 1989 to 1991 by month and duration (hours) grazed (mean ± SE).

Year & Month	Duration Grazed	Cover Soil	Vegetal	Litter	Rock	Moss
	(Hours)	(%)				
Jul	0	1 ± 6[1]	6 ± 6	4 ± 7	-1 ± 0	-8 ± 4
	4	12 ± 6	10 ± 7	-2 ± 6	-2 ± 1	-18 ± 8
	8	3 ± 3	5 ± 6	-3 ± 4	2 ± 2	-6 ± 3
	18	9 ± 6	5 ± 5	0 ± 9	0 ± 1	-13 ± 14
Aug	0	0 ± 2	7 ± 5	4 ± 5	0 ± 1	-11 ± 5
	4	8 ± 7	7 ± 5	-2 ± 4	-2 ± 1	-1 ± 5
	8	10 ± 7	6 ± 5	-2 ± 4	1 ± 0	-15 ± 9
	18	5 ± 3	6 ± 6	0 ± 7	-1 ± 1	-9 ± 5
Sep	0	5 ± 5	8 ± 5	-5 ± 6	-1 ± 1	-7 ± 4
	4	18 ± 5	8 ± 9	-8 ± 5	0 ± 0	-18 ± 11
	8	9 ± 5	3± 6	3 ± 8	0 ± 0	-15 ± 5
	18	20 ± 4	6 ± 5	-16 ± 3	-1 ± 0	-9 ± 2
JAS[2]	4	1 ± 3	6 ± 7	-1 ± 7	0 ± 0	-6 ± 4
	8	10 ± 3	9 ± 7	-8 ± 5	-1 ± 0	-8 ± 6

[1]These values were calculated by subtracting the 1989 from the 1991 cover values. A negative value indicates a decrease cover from 1989 to 1991.
[2]These circles were grazed each month, July –September.

brittle, and thus broken by trampling. The grasses were more resistant. After 18 hours of grazing both grasses and forbs were defoliated by grazing or trampling and produced fewer stems the following year (Fig. 1a).

Even though grazing in July 1989 occurred during the flowering phase of most grasses the number of grass stems were not reduced until the grazing duration reached 18 hours (Fig. 1b). Forbs appeared to benefit from heavy grazing (8 and 18 hours) in July (Fig. 1b), but were not influenced by grazing in August or September. In contrast, grazing during August and September or repeated grazing (JAS circles) reduced the number of grass stems per $10cm^2$ when compared to the ungrazed controls during 1990.

Defoliation may reduce leaf (Mueggler 1972, 1975, Edwards 1985) or stem lengths (Mueggler 1967, 1972, Trlica et al. 1977, Stout et al. 1980, Stout and Brooke 1987, Olson and Richards 1988) the following growing season. However, our height class categories were too broad (<2, 2–4, 4–12, 12–24, and >24 cm) for us to detect changes in plant heights in response to grazing the previous year. Plant height reductions following defoliation in other studies (Mueggler 1972, 1975, Trlica et al. 1977, Stout et al. 1980, Stout and Brooke 1987) would not have resulted in placing the plants in lower height classes in our study. We also had high variability among circles, making data interpretation difficult. Therefore, these data were not presented.

We encountered several difficulties in the design, analysis, and interpretation of this study. First, stem counts and plant heights vary through a summer and among species. By counting stems

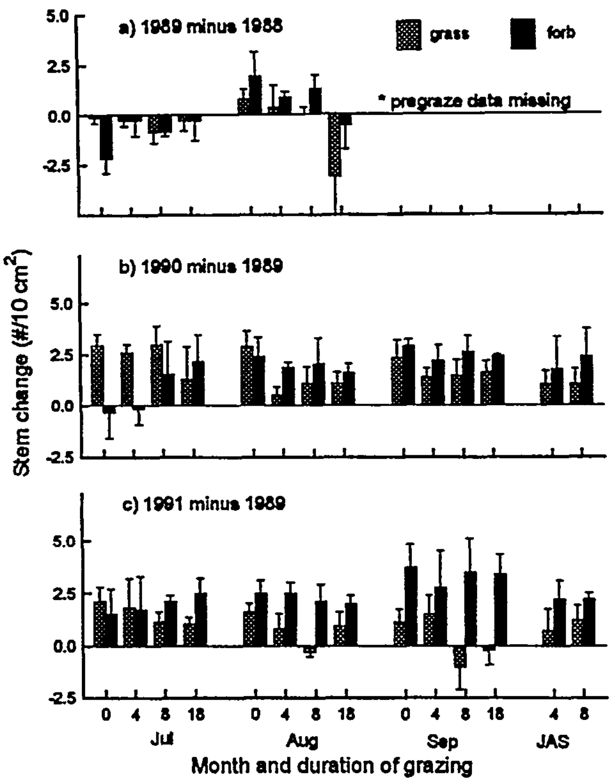

Fig. 1. Change in stem counts (following year minus initial year) per $10cm^2$ by year, month and duration grazed. a) pregrazing 1988 to 1989, b) pregrazing 1989 to 1990, and d) pregrazing 1989 to 1991. Lines depict 1 standard error.

and measuring height classes across species within a vegetation type, the data had high variance. Grazing and sampling the number of picket circles required to adjust for such variance is not feasible. This point is critical because wilderness rangers often do not have the time to measure more than a few points within a meadow of interest during any given year. Although managers hope to set grazing guidelines which minimize community changes, we may need to select keystone genera or species because the systematic categorization of all plant community types' response to grazing may be an unrealistic goal. Use of a keystone species would allow a more rigorous evaluation of the effects of intensity, timing, and frequency of defoliation on selected plant species in high elevation plant communities. Measuring changes in ground cover over time may require less intensive sampling but may miss impacts on critical plant species.

Evaluation of community response becomes difficult from a statistical perspective. Ideally, measures on all grazed circles would be taken at the same time, regardless of month grazed. However, high elevation meadows change rapidly through the summer. Some species such as those in the Liliaceae family go through their life cycle within weeks and may not be accounted for if the meadow is "measured" at only 1 point during the growing season. Yet, by taking pregrazing measurements at different times during the summer, we could not statistically compare effects of grazing in different months.

The cumulative impact of several years' grazing depends on plant phenology at the time of grazing. Our circles were grazed according to calendar dates rather than plant phenology because of logistical constraints. Plant phenology on a given date differs from year to year. Therefore, we did not get a strong cumulative effect after just 2 years grazing. From an ecological perspective, grazing by calendar dates makes interpretation of plant response difficult. However, wildland area managers have limited resources and may be unable to manage packstock grazing according to plant phenology. Therefore, from a manager's perspective, studying community response based on calendar dates may be most appropriate. Either way, the plant communities must be monitored over more than 2 years to assure objectivity when determining packstock grazing effects.

Finally, some plant communities have evolved with disturbance, for example by heavy elk grazing or burrowing animals. These communities may show little change in response to the added disturbance of 2 or 3 years of packstock grazing. The meadow we worked on may be such a type and many years of packstock use may be necessary before demonstrable changes occur.

Conclusion

We had insufficient replication (N = 4) per grazing treatment to detect statistically significant changes in stems counts, ground cover, and plant heights after 1 and 2 years of grazing. The required sample sizes, as well as other difficulties encountered in a study are probably indicative of the monitoring limitations wildland managers face. The data do, however, suggest that a single period of heavy grazing (18 hours per picket circle) or moderate (8 hours) repeated grazing through a summer can reduce vegetal and litter cover, increase bare soil cover, and reduce grass stem counts. These changes could be the precursors to a shift in plant community composition.

Measures of plant productivity which best indicate plant response to grazing vary among species (Cook and Child 1971, Mueggler 1975). While the appropriate plant response to measure depends on the management objective, plant stem counts or ground cover may be useful indicators of the effects of packstock grazing on wildland plant communities. These measures integrate all direct and indirect effects of grazing on a plant species or vegetation type. The critical consideration is how many measurements can be taken within each grazing area with the resources available to the local manager.

By controlling when, how long, and how frequent packstock graze a meadow, recreational horse use may be managed to meet desired wildland management objectives. The challenge of managing wildland packstock use is to develop a mutually supported packstock management plan which can then be monitored with the resources available to the local wildland manager.

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