Effects of single season and rotation harvesting on cool- and warm-season grasses of a mountain grassland

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Abstract

A mountain bunchgrass community with cool-season Parry oatgrass *(Danthonia parryi)* and warm-season slimstem muhly *(Muhlenbergia filiculmis)* as major grasses was treated with early partial harvest of cool-season grasses and late partial harvest of warm-season grasses. Warm-season grasses in these communities were greatly reduced by repeated late harvest, slightly reduced by late harvest in alternate years, and slightly promoted by early harvest of cool-season grasses. The dominant cool-season grasses responded less to repeated early harvests than did the less abundant warm-season grasses to repeated late harvests. The hypothesis that different harvest schedules may lead to alternative equilibria is supported, and rest alone may not cause a shift from a cool-season dominated equilibrium toward a greater warm-season presence in the plant community.

Key Words: bifurcation, cusp catastrophe, competition, preferential harvest, alternative steady states

Hundreds of studies have been conducted to determine the effect of clipping on subsequent growth of grass plants, but most earlier studies were concerned with individual species in isolation (Jameson 1963). More recent studies have examined competition between species in combination with harvesting treatments. These studies have shown that competition by other plants greatly aggravates the influence of clipping (Mueggler 1972, Archer and Detling 1984, Pendery and Provenza 1987). In some studies competition has been modified without clipping of the target species (Gurevitch 1986); in other studies all species in the study have been clipped the same (Banyikwa 1988). Usually competition has been considered a qualitative factor; i.e., competition occurs if a second species is present, and does not occur if the second species has been removed or is absent.

Mountain grasslands in the Colorado Front Range typically have 1/4 to 1/2 of the plant composition in warm-season species, with the remainder in cool-season species. However, some long-term exclosures have nearly pure stands of cool-season species. The purpose of this study was to determine whether or not the effect of competition as modified by partial harvest could drive a mixed warm-season/cool-season stand to an equilibrium dominated by a single component. The specific hypothesis associated with this purpose was that harvest schedule × harvest intensity interactions should be significant, and that there should be a gradation from those effects that impacted the cool-season species to those effects that impacted the warm-season species. Such findings would suggest that harvest schedules and intensities could be manipulated to produce a multiple steady state system such as demonstrated by a cusp catastrophe response surface (Jones 1977). A common interpretation of such a response is that a change into another equilibrium state, in at least one direction, may require an external influence (a "jump return"). A change in the reverse direction may not require an external influence, but may require a longer period of time (a "smooth return").

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Study Area and Methods

Through the courtesy of USDA Forest Service, the study was conducted on the Wintersteen Ridge area of the Roosevelt National Forest between Rustic and Redfeather Lakes, Colorado. The elevation of the study area is about 2,800 m. The dominant woody vegetation includes ponderosa pine *(Pinus ponderosa)* and big sagebrush *(Artemisia tridentata)*. The area is mostly grazed by elk during the winter, and at the time of study initiation had not been grazed by domestic livestock for 6 years.

Herbaceous vegetation of the study area is a mixture of both cool- and warm-season grasses and sedges (Table 1) and various forbs typical of this altitude and vegetation type. For purposes of this study, all cool-season grasses were treated alike as were all warm-season grasses. Prior to the study, warm-season grasses made up 40% of the total grass cover. To simplify interpretation of competitive effects between grass species, forbs were pulled from the treatment plots.

Table 1. Grass and sedge cover by species in a Colorado Front Range mountain grassland before treatment applications.

Species	Cover
	(%)
Parry oatgrass *(Danthonia parryi)*[1]	48.1
Slimstem muhly *(Muhlenbergia filiculmis)*	39.3
Needle-and-thread *(Stipa comata)*	2.9
June grass *(Koeleria cristata)*	2.6
Bluegrass (*Poa* spp.)	2.0
Griffith's wheatgrass *(Agropyron griffithsi)*	1.7
Squirrel tail *(Sitanion hystrix)*	1.2
Sheep fescue *(Festuca ovina)*	0.8
Sedges (*Carex* spp.)	0.5
Blue grama *(Bouteloua gracilis)*	0.3
Western wheatgrass *(Agropyron smithii)*	0.2
Bluebunch wheatgrass *(Agropyron spicatum)*	0.2
Mountain muhly *(Muhlenbergia montana)*	0.2
Total	100.0

[1]Nomenclature of grasses follows Hitchcock (1950).

The study was designed to determine the effect of early (June 15) partial harvest on cool-season grasses, and of late (July 15) partial harvest on warm-season grasses. The first phase of the study was initiated in 1986 and evaluated in 1988. The study was repeated in a second phase during 1987–1989. Harvesting treatments extended over 2 years. Eight harvest schedules tested included early–early, no harvest-early, early-no harvest, early-late, late-early, late-no harvest, no harvest-late, and late-late in the first and second years, respectively, of both phases. At early harvest times, only cool-season grasses were clipped; at late harvest times, only warm-season grasses were clipped. For each harvest schedule, plots were clipped to remove an estimated 10, 30, 50, 70, and 90% of the weight of species being clipped. Only the 50, 70, and 90% clippings were included in final evaluations in 1988, but all treatments were evaluated in 1989. Herbage weights were determined by clipping 1-m^2 circular plots. For treatments, these plots, plus an additional area of about 2 dm outside the evaluation plots, were clipped as described above. For the 40 treatments (8 schedules × 5 harvest intensities), 15 replications were established. Plots were selected for a balance of warm-season and cool-season grasses within each plot, and then treatments were assigned at random to plots within each replication.

For evaluation, plots were clipped during mid-August, and plants were separated by cool- and warm-season species. Samples were dried at 65° C for 24 hours and weighed. Data were expressed as g/m² of cool- and warm-season species, and warm-season percentage of total dry weight. Main effects tested included harvest schedules, harvest intensities, and treatment years. Interactions tested included the pairwise interactions of these effects.

Results and Discussion

Dry Weight Data

For all weight data, year effects were nonsignificant ($p>0.05$), and pairwise interactions were also nonsignificant. The harvest intensity effect only significant ($p<0.01$) for cool-season species only, declining from about 24 g/m² at 10% and 30% harvest to about 19 g/m² for 90% harvest.

For interpretation, data were arranged from the greatest early season effect (early-early) to the greatest late season effect (late-late) (Table 2). Harvest schedule effects were significant ($p<0.01$) for both cool- and warm-season species. The weight of cool-season species increased from about 18 g/m² with strong early harvest treatments to about 24 g/m² with strong late harvest treatments. The weight of warm-season species declined from about 9 g/m² with strong early harvest treatments to about 6 g/m² with strong late harvest treatments. However, the lack of a significant harvest schedule × harvest intensity effect did not support the hypothesis that an equilibrium of either warm- or cool-season domination could be achieved by the treatments as applied.

Table 2. Effect of harvest schedules on weights of grasses in a Colorado Front Range mountain grassland.

Harvest schedule	Cool-season	Warm-season
	g/m²)	
Early-early[1]	16.8	9.2
No harvest-early	19.6	9.2
Early-no harvest	19.0	8.7
Late-early	19.3	8.2
Early-late	18.1	5.8
Late-no harvest	26.6	6.9
No harvest-late	20.4	7.3
Late-late	24.8	4.1

[1]Harvest schedule effects were significant for both cool- and warm-season species ($p<0.01$). The least significant differences ($p<0.05$) for cool-season species was 4.6, and for warm-season species 2.6.

Warm-season Percentage Data

When data were expressed as warm-season percentage of total dry weight, there was a significant harvest schedule × harvest intensity interaction ($p>0.01$ for 2 years' combined data, $p>0.05$ for 1 year's data), thus supporting the hypothesis that the system could be driven to alternative states by the treatments. The single early season harvests and a late harvest followed the next year by an early harvest had similar results and were combined for presentation (Fig. 1). Single late season harvests and an early harvest followed by a late harvest the next year also had similar results and were also combined. The harvest schedule effects, when tested against the mean square for harvest schedule × harvest intensity interaction, were significant ($p<0.01$), but the harvest intensity effect was not significant ($p>0.05$) when tested against this interaction.

Two consecutive late harvests reduced warm-season grass percentage to about half that of all other schedules for most harvest intensities. Unlike the other schedules, these treatments had an effect even with 30 and 50% harvests.

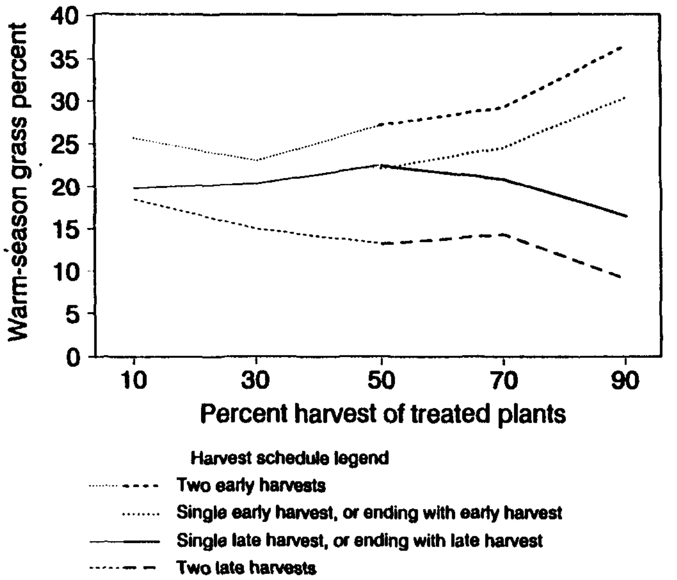

Fig. 1. Relationship of warm-season grass yield (as a percentage of total yield) to intensity of harvest of treated plants under different harvest schedules. The points at 50, 70, and 90% harvest intensity (joined by heavy lines) represent 2 years' data, the points at 10 and 30% harvest include only 1 year's data. Harvest schedule effects were significant ($p>0.01$), and harvest schedule × harvest intensity interactions were also significant ($p>0.05$ for 1 year's data). The standard error of the interaction means was 3.1 for 2 years' combined data, and 4.6 for 1 year's data.

A major hypothesis in design of this study was that the chosen treatments would result in a response surface with more than 1 equilibrium state. With this hypothesized model, moderate to light harvests might not show differences resulting from different harvest schedules. The harvest intensity at which the schedule effects become indistinguishable is the "bifurcation point" of a multiple equilibrium system. For this study, the single harvest treatments and the rotation harvests (early-late and late-early) produced nearly the same results at the 50% harvest intensity. The early-early schedule reached this level at 30% harvest. However, the plots harvested late both years seemed to have a different response, and a harvest intensity of no more than 10% was necessary to reach a level of warm-season percentage weight the same as the other schedules.

The results as presented in Figure 1 show that harvests resulted in responses that were related to harvest intensities, but that the early harvest effects were opposite in direction to the late harvest effects. Except for the late-late harvests, there were no differences at lesser harvest intensities. Thus, a bifurcation property of this system has been identified. It appears that the effects of most treatments at higher harvest intensities could be ameliorated by reducing the harvest intensity to less than 50% for a sufficient length of time, as is consistent with a "smooth return" behavior. At slightly lower elevations, where slimstem muhly is replaced by blue grama *(Bouteloua gracilis)* as the major warm-season species, warm-season dominated equilibria commonly occur. However, at the elevation of this study, a warm-season dominated situation would likely be temporary.

For continued late harvests, however, the harvest effect was evident even at lesser harvest intensities. This result agrees with observations on nearby grazed ranges. In some exclosures mixtures of cool- and warm-season grasses occur, but in other ungrazed exclosures a stable equilibrium of cool-season dominance is apparent following several previous years of late season grazing. This suggests that the change in composition as a result of continued late harvest treatments would not be reversed by a lesser harvest intensity, but would require an external influence (i.e., early harvest) in order to show a "jump return."

Management Implications

These results strongly suggest that early or rotation grazing is necessary to achieve a good balance of warm-season and cool-season grasses in a mountain bunchgrass community. Complete protection from grazing following repeated grazing in late season seems to result in dominance of cool-season grasses such as Parry oatgrass over warm-season grasses such as slimstem muhly. The effects of these treatments on mountain muhly *(Muhlenbergia montana)* were not determined in this experiment because of a lack of the latter species. However, similar observations in mountain bunchgrass areas of northern Arizona indicate that both species of *Muhlenbergia* benefit from early or rotation grazing. Delaying the starting date of grazing in these communities would exacerbate the dominance of cool-season grasses.

Whether management objectives of a particular area are to achieve a balance of grasses, to promote cool-season grasses, or to promote warm-season grasses, it appears that increases in either of these 2 groups of grasses can be achieved by concentrating grazing during the main growth period of the other group and grazing intensively. Opportunistic management (Westoby et al. 1989) through changes in stocking rate would be successful in some cases but not in others. Reduced grazing intensity and rotational grazing schedules could be effective ways to change plant composition away from a warm-season dominated community. However, if repeated late grazing has resulted in a cool-season dominated community, a shift to increased warm-season grasses does not appear likely to result from rest alone, but would require offsetting early season grazing often enough and intensively enough to effect the change. From this study, it would appear easier to shift from warm-season to cool-season grasses in these communities by rest or reduction in stocking rate than to accomplish the reverse shift. At lower elevations with dominant warm-season grasses, it might be easier to shift from cool-season grasses to warm-season grasses.

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