

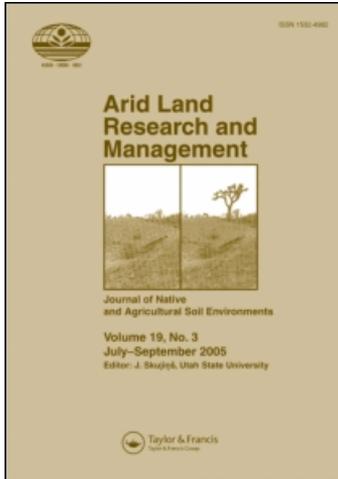
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Small Mammal and Plant Community Responses to Mechanical Disturbance and Rest in Wyoming Big Sagebrush Grassland

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Our aim in this study was to evaluate short-term (2 years) responses of several attributes of small mammal populations (species richness, abundance, diversity, and similarity) and plant community dynamics (species richness, canopy cover, above-ground biomass production, and diversity) to the mechanical disturbance associated with interseeding. Small mammal live trapping and vegetation sampling were conducted in 2004 and 2005 on replicated 1 ha study plots in a native Wyoming big sagebrush (Artemisia tridentata Nutt ssp. wyomingensis Beetle & Young)-grassland that were: 1) mechanically disturbed in April 2003 and rested from grazing during the study (mechanical); 2) rested from grazing (rested); and 3) moderately grazed by cattle (grazed). Deer mice (Peromyscus maniculatus), northern grasshopper mouse (Onychomys leucogaster), and sagebrush vole (Lemmiscus curtatus) were the primary small mammal species captured during 7776 trap nights in 2004 and 2005. Small mammal diversity was greater for the mechanical ($H' = 1.22$) than the rested ($H' = 0.85$) treatment with the grazed treatment intermediate. Plant community variables of species richness, diversity, similarity, and above-ground biomass production did not differ among treatments. Canopy cover of the dominant species, Wyoming big sagebrush, was reduced 20–34% by the mechanical disturbance ($6.9\% \pm 1.0$) compared to rested ($8.6\% \pm 0.6$) and grazed ($10.4\% \pm 1.0$) plots. The mechanical disturbance affected approximately 10.5% of the ground surface area but this had little impact on short-term small mammal or plant community dynamics in this rangeland ecosystem.

Keywords deer mice, northern grasshopper mouse, sagebrush vole, species diversity, species richness

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Introduction

Compared to large wildlife species, small mammals are particularly sensitive to habitat alterations (Lovell, Choate, and Bissell, 1985; Zou, Flinders, Black, and Whisenant, 1989; Olson, Hansen, Whitson, and Johnson, 1994). Small mammal species richness, abundance, and diversity are strongly correlated with vegetation structure and complexity (Germano and Lawhead, 1986; Kerley, 1992). Predictable fluctuations in small mammal attributes (species richness, abundance, diversity) occur as vegetation composition and production change with disturbances (Rosenzweig and Winakur, 1969; Tomoff, 1974; Yahner, 1983; Germano and Lawhead, 1986; Koehler and Anderson, 1991; Els and Kerley, 1996; Johnson, Olson, and Whitson, 1996; Olson and Whitson, 1996). Therefore, small mammals are important temporal indicators of disturbance and wildlife habitat value (Olson and Brewer, 2003).

Despite this, utilizing small mammals for monitoring responses to experimental treatments in rangeland ecosystems is infrequently used. For example, mechanical reseeding or interseeding practices implemented on rangelands often involve soil disturbance that may alter habitat structure, and subsequently influence small mammal foraging efficiency, thermoregulation, predation, and movement (Zou et al., 1989). However, monitoring small mammal responses to mechanical disturbances such as those associated with reseeding or interseeding have received little attention.

Reseeding efforts in Wyoming big sagebrush- (*Artemisia tridentata* Nutt ssp. *wyomingensis* Beetle & Young) dominated rangelands often involve complete removal of all vegetation prior to reseeding (McArthur, Monsen, and Welch, 1987). In contrast, minimal mechanical disturbance associated with interseeding permits seeded species to compete with existing vegetation for soil nutrients and water (McArthur et al., 1987), while preserving existing plant species diversity and composition which are important for maintaining ecosystem function and health (Schulze and Mooney, 1994). Here, we evaluated short-term (2 years) responses of small mammal species richness, abundance, diversity, and similarity, and plant species richness, canopy cover, above-ground biomass production, and diversity to mechanical disturbance associated with interseeding in Wyoming big sagebrush grassland.

Materials and Methods

Study Area

Study plots were established on the McGuire ranch 40 km northeast of Laramie, Albany County, Wyoming (lat 41°24'0"N, long 105°18'0"W), at an elevation of 2200 m near the western foothills of the Laramie Mountain Range. Mean annual precipitation, collected approximately 30 km southeast of the McGuire ranch, is 27 cm (1948–2007), with a mean annual maximum temperature of 12.6°C, mean annual minimum temperature of -2.7°C, and a frost-free period of 93 days (WRCC, 2008).

Soils are sandy loams with a complex including low relief mounds of the Rock River series (fine-loamy, mixed, super active, frigid Ustic Calcicargids) and intermounds represented by the Alcova series (fine-loamy, mixed, super active, frigid Ustic Haplargids) having an A horizon approximately 10–15 cm in depth (Reckner, 1998). Elevation differences between mounds and intermounds is typically <0.25 m.

These soils are moderately suited for mechanical range renovation and range seeding; however, limitations include susceptibility to wind erosion, soil phosphorus levels, and low annual precipitation.

Vegetation is mainly shrub and grass species including Wyoming big sagebrush, rubber rabbitbrush [*Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & Baird], Sandberg bluegrass (*Poa secunda* J. Presl), western wheatgrass [*Pascopyrum smithii* (Rydb.) A. Löve], and prairie junegrass [*Koeleria macrantha* (Ledeb.) Schult]. The primary forb species is spiny phlox (*Phlox hoodii* Richardson) (nomenclature follows Dorn (2001)). This area is used primarily for livestock grazing and wildlife habitat, largely pronghorn antelope (*Antilocapra americana*). Information pertaining to the small mammal community is lacking. For the past 12 years, the 1800 ha pasture was grazed by 250 cow-calf pairs from June to mid-October resulting in a stocking rate of 0.8 animal unit months/ha, the recommended rate by the United States Department of Agriculture (USDA) Natural Resources Conservation Service for this site.

Experimental Design

Three treatments were randomly assigned to 1 ha (100 × 100 m) plots within each of three blocks resulting in a total of nine plots with 10 m buffer strips between plots. Treatments included: 1) mechanical disturbance associated with interseeding in spring 2003 and rested from grazing throughout the duration of this study (mechanical); 2) rested from grazing (rested); and 3) moderately grazed by cattle season-long (June to mid-October, grazed). Vegetation composition, soil type, elevation, slope, and aspect did not differ among the plots. Mechanical disturbance was imposed on 23 April 2003 using a Truax rangeland drill (Traux Company, Inc. New Hope, MN) modified with two chisel plow V-sweeps spaced 142 cm apart. These V-sweeps had double-disk openers with a 2.5-cm depth band, which cleared strips of native sod 15 cm wide and 5 cm deep. The legume yellow-flowered alfalfa [*Medicago sativa* L. ssp. *falcata* (L.) Arcangeli] was interseeded. Woven wire fence and two strands of barbed wire were constructed prior to grazing in 2003 around the mechanical and rested plots to exclude large herbivores. To mitigate possible immediate effects of the mechanical disturbance on small mammal populations, both the small mammal and vegetation sampling ensued 1 year later.

Small mammals were sampled with live traps using trapping web configurations (Anderson, Burnham, and Laake, 1983; Buckland, Anderson, Burnham, and Laake, 1993). Trapping webs, placed in the center of each plot, employed 12 equal length trap lines radiating from the center at equal angles (Anderson et al., 1983). On each trap line, nine Sherman live traps were located at 4.5 m intervals starting 2.25 m from the center of the web. The area of each web was approximately 0.47 ha. A total of 108 traps were used in each trapping web. We realize this sampling area is relatively small (Parmenter et al., 2003), but it does represent approximately 50% of the treatment area and encompasses the maximum home range area (0.45 ha) of deer mice (*Peromyscus maniculatus* Wagner; Clark and Stromberg, 1987). Live trapping was conducted over four consecutive nights during three trapping periods (weeks) from 24 June through 19 July in 2004 and 2005. A short small mammal trapping period in midsummer was chosen to coincide with peak vegetation production and sampling to effectively evaluate both plant and small mammal community interactions. We realize the limitations of assessing

long-term small mammal population dynamics, changes in sex and age ratios, and fluctuating densities of various small mammal species with this sampling strategy. Captured small mammals were identified by species, sexed, weighed, and the tail and hind foot measured before toes were uniquely marked with fingernail polish. Inadequate numbers of individuals for each species prohibited population density estimates. Relative species abundance was calculated by summing total individuals of one species (abundance) divided by total individuals for all species for each treatment replication. Species richness was the average number of species trapped for each replicated treatment plot. Small mammal species diversity was calculated using the Shannon–Wiener diversity index (Krebs, 1999) for each treatment from species relative abundance data.

Vegetation sampling was conducted from 24 June to 19 July in 2004 and 2005, coinciding with the small mammal sampling. One block was randomly sampled each week. Three permanently marked 80-m line transects were randomly located in each plot with 10 0.25 m² circular quadrats located at equidistant intervals on the north side of each transect in 2004 and the south side in 2005. Using a modified Daubenmire (1959) approach, percent canopy cover was estimated within each quadrat for all plant species, litter, and bare ground, and averaged by transect. Current year plant growth was clipped at ground level within each quadrat, pooled by species for each transect, oven dried at 60°C for 48 hours, and weighed. Plant species above-ground biomass and frequency were determined by calculating mean values across transects within each treatment. Importance values (Curtis and McIntosh, 1951) were calculated for each species by summing mean relative cover, biomass production, and frequency. A Shannon–Wiener diversity index (Krebs, 1999) was calculated from relative importance values to assess proportional equivalence of plant species and heterogeneity in the community.

Statistical Analyses

Small mammal and vegetation data were analyzed as a split-plot in time arrangement of a randomized complete block design using analysis of variance (ANOVA). Years were considered to be fixed effects and blocks to be random terms in the model. Statistical calculations were facilitated using the PROC MIXED procedure of the Statistical Analysis System (SAS Institute, 2003). An alpha level of 0.05 was used in all comparisons to determine significance. When a significant treatment × year interaction occurred, a one-way ANOVA was conducted by year to determine treatment differences. When the main effect of treatment was significant but no treatment × year interaction occurred, then values for each treatment were pooled across sampled years for mean separation. Similarly, when the main effect of year was significant and no treatment × year interaction occurred, then values for each year were pooled across treatments for mean comparison. Means were separated using Fisher's protected Least Significant Difference (LSD) (Hoshmand, 1994).

Results

Vegetation Dynamics

Total vegetation and shrub cover did not differ among treatments (Table 1). Wyoming big sagebrush cover across years was significantly less ($F_{2,4} = 7.30$,

$P=0.05$) on the mechanically disturbed plots ($6.9\% \pm 1.0$) than the rested ($8.6\% \pm 0.6$) and grazed ($10.4\% \pm 1.0$) plots. There was a significant year \times treatment interaction for litter cover ($F_{2,4} = 9.95$, $P = 0.03$) and nearly significant interaction for grass cover ($F_{2,4} = 5.81$, $P = 0.07$). Mechanically disturbed and rested plots did not differ for grass cover in 2004, but was lower for rested plots in 2005 (Table 1). Litter cover did not differ among treatments in 2004. However, in 2005, litter cover was lower on mechanically disturbed ($17.5\% \pm 1.9$) than rested ($20.8\% \pm 3.3$) and grazed plots ($22.3\% \pm 2.2$).

There were no differences in grass, forb, shrub, or total biomass among treatments within or across years (Table 1). Grass production did differ between years with biomass 72% higher in 2005 than 2004 across treatments, and total forage production was 47% higher in 2005 (Table 1), reflecting wet June conditions in 2005 which enhanced the production of C3 perennial grasses (Figure 1, Derner, Hess, Olson, and Schuman, 2008). Although annual precipitation was similar in 2004 (18.4cm) and 2005 (19.4cm), precipitation in 2004 occurred later in the growing season (July–September).

A total of 30 plant species were identified across treatments and years. Plant species richness did not differ among treatments within or across years (Table 1). However, species richness across treatments was greater ($F_{1,2} = 150.91$, $P = 0.01$) in 2005 (16.6 ± 0.4) than 2004 (13.0 ± 0.5), primarily due to increased forb species in 2005 ($F_{1,2} = 634.25$, $P = 0.002$) (Table 1). Plant species diversity did not differ among treatments within or across years (Table 1). However, when values were pooled across treatments by year, plant diversity was higher in 2005 ($H' = 3.36$) than 2004 ($H' = 3.09$) ($F_{1,2} = 130.35$, $P = 0.01$). Increased diversity was attributable to higher forb species richness in 2005.

Small Mammal Dynamics

A total of 241 individuals representing seven species were captured during 7776 trap nights (trap night = one trap set) in 2004 and 2005. Substantially more small mammals were captured across treatments in 2004 (192) compared to 2005 (39) (Table 2). Common species were the deer mouse ($n = 147$), northern grasshopper mouse (*Onychomys leucogaster*, $n = 27$), and sagebrush vole (*Lemmiscus curtatus*, $n = 27$). Less common species included the Wyoming ground squirrel (*Spermophilus elegans*), 13-lined ground squirrel (*Spermophilus tridecemlineatus*), northern pocket gopher (*Thomomys talpoides*), and long-tailed vole (*Microtus longicaudus*). Small mammal species richness did not differ ($P = 0.13$) between treatments in either year, but richness was higher across treatments in 2004 than in 2005.

When deer mice captures were pooled across treatments by year, mean abundance was 8-fold greater in 2004 (44.3) than in 2005 (5.3) ($F_{1,2} = 20.46$, $P = 0.05$) (Table 2). Deer mice were the most abundant species captured on all treatment plots in 2004, but only in the grazed treatment in 2005. In both years, deer mice were more abundant in the disturbed treatments (mechanical and grazed) compared to the rested treatment. Northern grasshopper mice were the second most abundant species on all treatments in 2004, but not in 2005. Sagebrush voles were the most abundant species in the rested treatment in 2005, and equally abundant to deer mice in the mechanically disturbed treatment (Table 1). Across years, small mammal diversity trended higher in the mechanically disturbed treatment ($H' = 1.22$), compared to the rested, ($H' = 0.85$) ($F_{2,4} = 4.38$, $P = 0.09$), but the grazed treatment

Table 1. Canopy cover, species richness, diversity, and above-ground biomass by plant functional groups for mechanical, rested, and grazed plots on a Wyoming big sagebrush grassland 40 km northeast of Laramie, WY

Attribute	Mechanical			Rested			Grazed		
	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
Canopy cover (%)									
Grasses	14.2	23.1	18.6 (2.7) ¹	14.2	20.4	17.4 (1.9)	16.1	23.4	19.9 (2.3)
Forbs	4.3	7.5	5.9 (0.8)	4	6.7	5.3 (0.8)	4.1	6.4	5.3 (0.6)
Shrubs	10.7	14	12.3 (1.7)	13	14.8	14.4 (0.8)	16.3	18	17.1 (1.1)
Total	29.2	44.6	36.9 (4.5)	31.5	41.8	36.7 (3.0)	36.5	47.8	42.2 (3.2)
Species richness									
Grasses	5.3	5.7		4.7	4.9		4.7	5.3	
Forbs	5.9	8.1		5	8.3		4.2	8.3	
Shrubs	3	3.1		3.1	3		3	3	
Total	14.2	16.9		12.8	16.2		11.9	16.7	
Diversity index	3.2	3.39	3.31 (0.1)	3	3.33	3.17 (0.1)	3	3.34	3.18 (0.1)
Biomass production (kg·ha⁻¹)									
Grasses	397	604	500 (54.6)	308	533	419 (56)	282	565	424 (69.6)
Forbs	70	104	87 (16.0)	60	74	67 (6.8)	57	72	65 (6.1)
Shrubs	333	362	347 (59)	280	323	302 (31.9)	247	357	302 (28.4)
Total	799	1071	931 (94)	647	930	788 (76.1)	587	994	791 (95.1)

¹Standard error of mean.

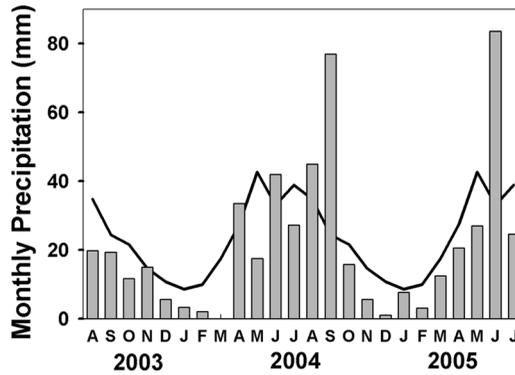


Figure 1. Actual (bars) and long-term mean (30-year, solid line) monthly precipitation amounts (from Derner et al., 2008).

Table 2. Small mammal species, abundance, diversity, and richness for mechanical, rested, and grazed plots on a Wyoming big sagebrush grassland 40 km northeast of Laramie, WY

Species	Abundance		Diversity		Richness	
	2004	2005	2004	2005	2004	2005
Mechanical						
<i>Peromyscus maniculatus</i>	42 (3.0) ¹ a*	6				
<i>Lemmyscus curtatus</i>	5 (0.5)	6				
<i>Onychomys leucogaster</i>	10 (1.3)*	2				
Other species	13*	1				
Total	70*	15	1.33 (0.26)*	1.11b	4.3 (0.7)*	2.3
Rested						
<i>Peromyscus maniculatus</i>	36 (2.9)a	2				
<i>Lemmyscus curtatus</i>	6 (0.6)	7				
<i>Onychomys leucogaster</i>	8 (0.8)	0				
Other species	7	1				
Total	57	10	1.20 (0.33)*	0.50a	3.3 (0.6)*	1.7
Grazed						
<i>Peromyscus maniculatus</i>	55 (3.7)b	8				
<i>Lemmyscus curtatus</i>	1 (0.2)	2				
<i>Onychomys leucogaster</i>	5 (0.5)	2				
Other species	14	2				
Total	75	14	1.08 (0.30)	1.07b	3.7 (0.5)*	2.7

¹Standard error of mean.

Different letters within a column for each species indicates a significant ($P \leq 0.05$) difference among treatments. Asterisks indicate significant ($P < 0.05$) differences between years.

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was not significantly different from the others (Table 2). Small mammal communities displayed higher species similarity between treatment plots in 2004 compared to 2005 (data not shown). Higher species dissimilarity between plots in 2005 was related to shifts in abundance of deer mice and sagebrush voles (Table 2).

Discussion

The initial mechanical disturbance associated with interseeding, which affected 10.5% of the ground surface area, had little impact on plant community dynamics (species richness, canopy cover, production, diversity) or small mammal populations (species richness, abundance) measured 2 years following the disturbance year (2003). Stable or increased plant and small mammal community diversity on mechanically disturbed plots, compared to rested or grazed plots, suggests that disturbance from interseeding is not impacting short-term biodiversity in this semi-arid ecosystem. If the degree of disturbance was greater or the time since disturbance longer (Parmenter et al., 1985), responses of plant and small mammal community attributes may differ from our observed results.

Vegetation production differences between study years parallel those observed on an adjacent study site (Derner et al., 2008). Production is more responsive to differences in spring precipitation amounts compared to basal or foliar cover attributes, and production of cool-season perennial grasses, including western wheatgrass, demonstrated the greatest response to increased spring precipitation (Derner et al., 2008). Lack of differences in vegetation production among the disturbance treatments in this study, but similar responsiveness associated with precipitation differences between years, indicate that precipitation is the primary factor influencing vegetation responses in this ecosystem. In western North Dakota, total forage production was not influenced by disturbance associated with interseeding (Nyren, Goetz, and Williams, 1978), but interseeding increased existing native cool season grasses in eastern Montana (Houston and Adams, 1971; Wight and White, 1974) mainly due to greater western wheatgrass production due to enhanced rhizome production following mechanical disturbance (Rauzi, 1975).

All trapped small mammals in this study, except for the northern grasshopper mouse and the 13-lined ground squirrel, depend on small seeds and fine-stemmed grasses as their primary food source. Northern grasshopper mice are considered carnivorous, although seeds and grasses are commonly consumed (Clark and Stromberg, 1987). Both northern grasshopper mice and deer mice capture decreased across all treatments in 2005. Differences in species capture rates between years are likely due to contrasting above-ground biomass in 2004 and 2005 related to varying climatic conditions (Snyder and Best, 1988). Lower spring precipitation in 2004 associated with high June temperatures resulted in decreased plant biomass production (Table 1), thereby reducing available herbaceous forage and seed production. With reduced food sources, small mammals were likely more susceptible to trap bait in 2004 (Kurz, 1995). Likewise, greater plant biomass in 2005, with likely higher seed production, probably contributed to lower capture rates (Kurz, 1995). Additionally, limited food supply in 1 year can cause lower small mammal reproductive activity and fecundity rates the succeeding year (Taitt, 1981; Stapp, 1997).

Higher abundance of deer mice in the disturbed treatments was not surprising given demonstrated preferences for disturbed habitat (Forde, 1983). Deer mice

are reported to reach peak abundance on disturbed areas within 1–3 years after disturbance (Tevis, 1956; Quinn, 1979; Forde, 1983; Kaufman, Finck, and Kaufman, 1990). Likewise, a high abundance of northern grasshopper mice is consistent with a preference for disturbed silty or sandy soils for burrowing and grooming activities (Clark and Stromberg, 1987). The mechanical disturbance associated with interseeding may also have attracted more small mammal species, thereby increasing species richness. Robertson and Pearse (1945) found that mechanical disturbance stimulated growth and seed production of big sagebrush which enhances small mammal habitat.

Differences in annual plant biomass production influenced deer mice captures, despite their ability as opportunistic feeders to alter diet in response to food availability (Parmenter and MacMahon, 1983; Clark and Stromberg, 1987). In north-central Colorado, high June temperatures and low precipitation reduced seed and arthropod production, leading to decreased deer mice populations the following year (Stapp, 1997). In another big sagebrush rangeland, deer mice captures also varied due to yearly precipitation differences and corresponding graminoid growth and seed production (Ayers, Anderson, and Lindzey, 2000).

Reseeding in Wyoming big sagebrush-dominated rangelands traditionally results in complete removal of existing big sagebrush and other rangeland vegetation during seedbed preparation (McArthur et al., 1987). Here, we demonstrate that interseeding, an alternative to reseeded where mechanical disturbance only affects 10.5% of the soil surface, preserves vegetation production, diversity, and composition, along with original small mammal population attributes. This is important for maintaining ecosystem function and health (Schulze and Mooney, 1994). Our findings suggest that land managers can comfortably utilize limited mechanical disturbance to enhance big sagebrush grassland areas while maintaining ecosystem function and health.

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