Effects of Cattle Grazing on Small Mammal Communities at Red Rock Lakes National Wildlife Refuge, Montana

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Abstract

Cattle grazing is a common land-use on public land in the Intermountain West that often has varied and complex effects on wildlife. We undertook the current study to better understand the response of small mammals to the frequency of cattle grazing in wet meadow habitats on Red Rock Lakes National Wildlife Refuge. Three adjacent grazing units were selected for study that provided a range of rested grazing units (one, three, and eight years of rest). We captured and marked 363 individuals, and had 174 recaptures on six 1.8 ha grids over 27 days. Voles (*Microtus* spp.) comprised 99 percent of individuals captured, with two deer mice (*Peromyscus maniculatus*), and one common shrew (*Sorex cinereus*). Vole abundance increased with increasing rest from grazing. Nearly 61 percent (221) of voles were captured in the unit with 8 years of rest from grazing; 26 percent (94) and 13 percent (48) of total captures were in units of three and one year of rest, respectively. Apparent 8 day survival probability estimates were 0.45 (±0.12 SE), 0.62 (±0.12) and 0.35 (±0.09) for treatments with one, three and eight years of rest, respectively. Litter depth and physiognomic classes litter, and forb, and bare ground approached an asymptote after three years rest from grazing.

Key Words: abundance, *Microtus*, Robust Design, survival, vole, wet meadow.

Introduction

Population dynamics of small mammals are often characterized by inter- and intra-annual fluctuations in abundance that can range across several orders of magnitude. Population fluctuations have been attributed to a number of variables, including plant biomass. For example, as plant biomass increases from spring to fall, small mammals are afforded increased food and cover which can allow populations of voles (*Microtus* spp.) to reach an intra-annual peak in the late summer/early fall (Birney et al. 1976, Abramsky and Tracy 1979, Erlinge et al. 1983). Peles and Barrett (1996) described a reduction in vole density as a result of decreasing plant biomass in grassland habitat. Mean vole densities were nearly 1.5 times lower in reduced plant biomass treatments than densities in the control or enhanced plant biomass treatment. Similarly, Runge (2005) found meadow voles (*M. pennsylvanicus*) and montane voles (*M. montanus*) avoided grazed grasslands with lower plant biomass than otherwise similar non-grazed grasslands.

Survival of small mammals is also shown to be linked to vegetative cover. For example, Birney et al. (1976) and Peles and Barrett (1996) demonstrated vole survival to be asymptotically related to vegetative cover with marked declines in survival below a threshold level of cover. Getz et al. (2005) showed that differential survival, among habitats and between species of *Microtus*,

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correlated with increased vegetative cover. Greater amounts of vegetative cover likely benefits small mammals through improved protection from predators, reduced territorial conflicts, and increased availability of favorable microhabitats (Birney et al. 1976, Erlinge 1987, Douglass and Frisina 1993, Korpimäki and Krebs 1996, Peles and Barrett 1996). Grazing reduces vegetative cover through consumption and trampling, and therefore may reduce small mammal survival by increasing the efficiency of avian (Baker and Brooks 1982) and mammalian (Bowman and Harris 1980) predators. Schmidt et al. (2005) found survival of field voles (*M. agrestis*) in Danish wet meadows was generally lower in plots heavily grazed by cattle relative to non-grazed plots.

Anthropogenic land-uses can also greatly affect small mammal populations, largely through one or a combination of the processes outlined above. Cattle grazing, a common land-use across the Intermountain West reduces small mammal populations by reducing plant biomass within a field (Birney et al. 1976, MacCracken et al. 1984, Fleischner 1994). Keesing (1998) has shown that pocket mouse (*Saccostomus mearnsi*) density increased as much as 100 percent in previously grazed habitats after the exclusion of large animals. Rosenstock (1996) describes non-grazed sites as having 50 percent greater species richness and 80 percent higher small mammal abundance than similar grazed sites.

Although livestock grazing is a controversial public land-use in western North America (Fleischner 1994), grazing by large herbivores is a disturbance that Intermountain West grasslands and wet meadows evolved with over recent millennia (e.g., Carpenter 1940, Russell and Haines 1965, Frisina and Mariani 1995). Grazing as a land management tool, if timed properly, can provide diverse and favorable habitat for small mammals (Clark et al. 1997, Bouska and Jenks 2006). While continuous grazing may reduce plant biomass and structure, negatively affecting small mammal communities, periodic grazing has been shown to increase abundance of small mammals such as voles and mice (*Peromyscus* spp.) (Bouska and Jenks 2006). Light or moderate levels of herbivory can also increase plant productivity in some systems (Dyer et al. 1993, Milchunas and Lauenroth 1993, Frank et al. 2002). Moreover, the mechanical action of hooves can help break up hard soil as well as aid in seed dispersal and establishment (Frisina and Keigley 2004). Therefore, periodic grazing may provide greater biomass and diversity of vegetation favorable to small mammals.

The current study investigated the response of small mammal abundance, survival, and community composition to the frequency of cattle grazing in wet meadow habitats on Red Rock Lakes National Wildlife Refuge. We hypothesized that species diversity, apparent survival and abundance would be positively related to time since last grazed (Reynolds and Trost 1980, Fleischner 1994, Rosenstock 1996, Keesing 1998). Deer mouse (*Peromyscus maniculatus)* abundance is positively related to disturbances that produce lower vegetation biomass and increased proportions of exposed soil (Grant et al.1982, Fleischner 1994, Matlack et al. 2001, Hadley and Wilson 2004). Therefore, we also hypothesized that deer mouse abundance would decrease as the time since grazed increased.

Study Area

The study was conducted on Red Rock Lakes National Wildlife Refuge (hereafter Refuge) in southwestern Montana. The Refuge encompasses 18,210 ha of the Centennial Valley, with elevations ranging from 2013 m above mean sea level (msl) to > 2926 m msl. Average annual precipitation, as measured at Refuge headquarters (2039 m msl), is 49.5 cm with 27 percent occurring during May and June. Annual average temperature is 1.7º C. The *Juncus balticus – Carex praegracilis* vegetative alliance (National Vegetation Classification Standard [NVCS]; Anderson et al. 1998) (hereafter wet meadow), is a predominant habitat on the Refuge, covering ~2,869 ha.

Wet meadow habitat is characterized by an elevated water table, which results in relatively dense graminoid ground cover.

The Refuge grassland management plan (USFWS 1994) recommended two full growing seasons of rest between grazing treatments. Cattle were put on units no earlier than 10 July of the third year since last grazed. Stocking rates (Animal-unit-month, or AUM) for each grazing unit were determined by a US Soil Conservation Survey range assessment conducted in 1987 (USFWS unpubl. report). Grazing units were grazed at ~100 percent of the recommended AUMs during the year of grazing treatment (Table 1).

Methods

Three adjacent Refuge grazing units that differed in the number of years rested since grazed (one [1YSG], three [3YSG], and eight [8YSG] years) were selected for study (Table 1; Fig. 1). Two trapping grids per unit were located by selecting random points within wet meadow habitat using the Systematic Point Sampling tool extension (Minnesota DNR Sampling Tool V. 2.8) in ArcView GIS 3.3 (ESRI, Redlands, California) and a 100 m buffer from the grazing treatment boundary. Small mammal trapping followed Hadley (2002). Grids comprised 100 Sherman© live traps (23.5 x 8 x 9 cm in size) placed in a 10 trap x 10 trap configuration (1.8 ha), with traps spaced 15 m apart.

Trapping followed a Robust Design (Pollock 1982; see Data Analysis below) procedure with three primary trapping occasions each divided into 18 secondary trapping occasions (*2 secondary occasions day-1x3 days unit-1x3 grazing units*). Between the primary sampling occasions the population was open to gains and losses; during secondary sampling occasions the population is assumed to be closed. Trapping grids were deployed for three days in each unit during each of three nine-day primary trapping occasions. Traps were checked twice daily before 1200 hrs, resulting in two secondary occasions each day. Traps were closed after the second daily check and reopened each evening. Primary occasions were separated by two days during which trapping did not occur, resulting in eight days between primary occasions for a given grazing unit. The order of trapping by unit in the first primary occasion was randomly selected; the same order was followed during the second and third primary occasions. Traps were baited with rolled oats and peanut butter and a polyester wad was placed in each trap to reduce small mammal deaths due to hypothermia. A cedar shingle was placed over each trap to provide shade in order to reduce the risk of hyperthermia for trapped individuals. Individuals were identified according to species, gender, weighed, and on first capture marked with a uniquely numbered ear tag (size 1005-1, National Band and Tag Company, Newport, Kentucky). Ear tag number was recorded each time the individual was captured. We were not able to accurately differentiate between montane and meadow voles in the field for this study, therefore interpretations and discussions are presented for these species combined.

Vegetation Characteristics

To quantify vegetation characteristics in each trapping grid, we used the point-line intercept method (Bonham 1989). We

Table 1. Grazing unit area and grazing history for units selected for small mammal trapping at Red Rock Lakes National Wildlife Refuge, 2007.

Grazing unit	Total area (ha)	Wet meadow (ha)	Year last grazed	Recommended AUMs	AUMs Used
15a	358	237	2004	608	700
15b	348	278	1999	643	605
15c	502	421	2006	1035	1031

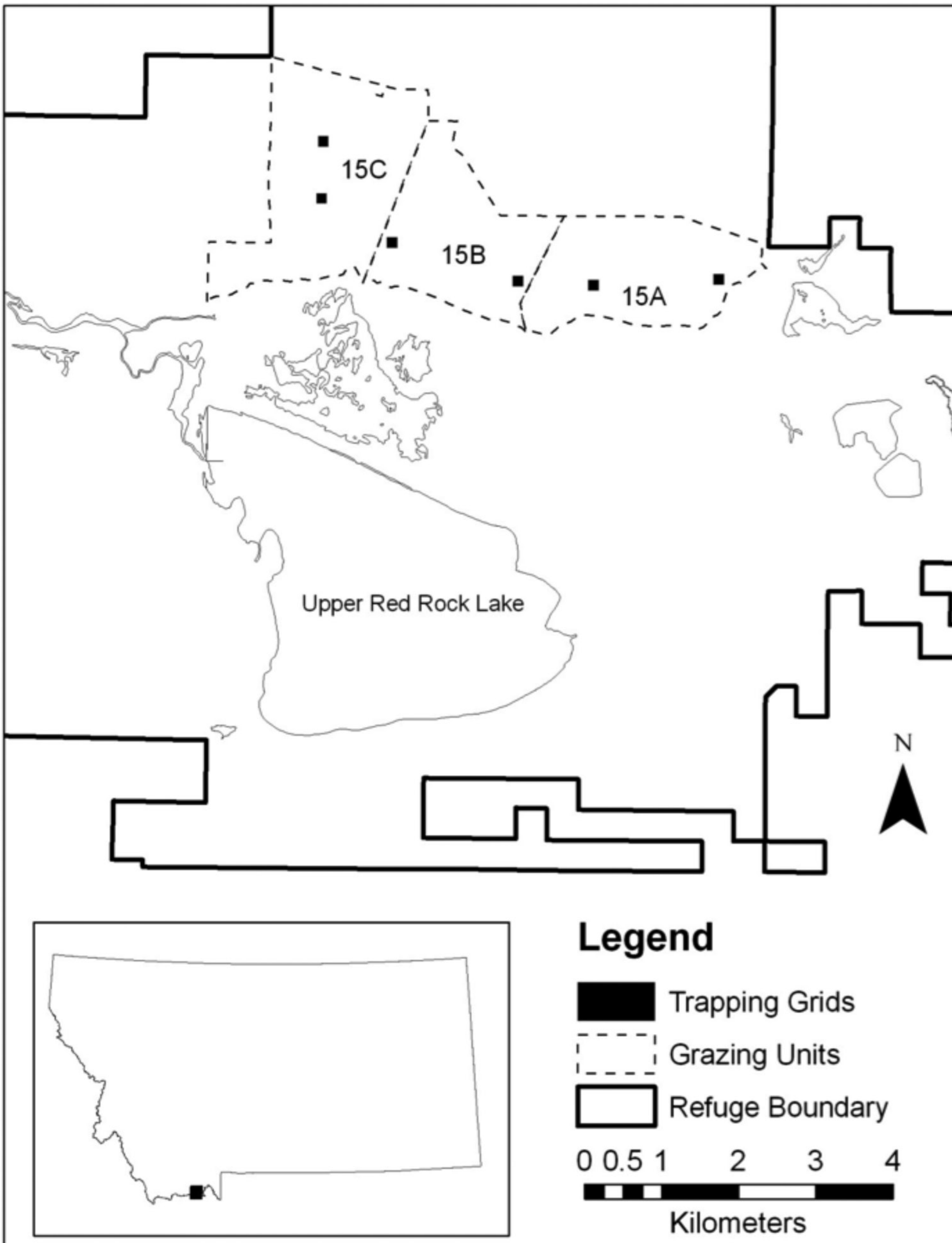

Figure 1. Location of study area, grazing units, and small mammal trapping grids at Red Rock Lakes National Wildlife Refuge, Montana. Grazing treatments were one, three, and eight years of rest for units 15c, 15a, and 15b, respectively. Inset map shows the Refuge location within Montana.

established four 25-m line transects within each trapping grid by randomly generating Universal Transverse Mercator (UTM) locations and randomly selecting a north or south orientation to place the transect. Transects were placed due north or south of random points to prevent intersecting a trap line and the associated vegetation disturbance created from repeatedly checking traps. We used point-intercept methods to measure percent cover of herbaceous vegetation, litter, and bare ground and litter depth (± 0.1 cm). Point intercept data were recorded at one meter intervals with a vertically placed five mm diameter sharpened dowel marked at decimeter intervals. We recorded each physiognomic class (shrub, bunchgrass, rhizomatous grass, forb, litter, and bare ground) that intercepted the dowel. We included height data for litter and number of hits per transect for other physiognomic groups.

Data Analysis

We modeled vole apparent survival using Robust Design capture-recapture models (Pollock 1982) in Program MARK (White and Burnham 1999). To test for differences in vole apparent survival among grazing units, we compared models with grazing unit as a categorical covariate (*g*) to models of constant (.) and time varying (*t*) apparent survival. Because vegetation structure as measured during this study did not differ between units 3YSG and 8YSG (see Results below), we included models that allowed survival to differ between the most recently grazed unit (1YSG) and the other units to test for a relationship between vegetation structure and vole apparent survival. Models allowed capture (*p*) and recapture (*c*) probabilities to be constant or vary by grazing unit or time. Due to low number of captures during the first primary occasion, we also tested models in which *p* during the first occasion differed from *p* during the second and third occasions. Due to modest sample sizes, we did not examine additive models in our model set. Candidate models were ranked using Akaike's Information Criterion corrected for small sample size (AIC_c) (Burnham and Anderson 1998). From the most parsimonious model of apparent survival, we derived vole abundance by grazing unit using Huggins' conditional likelihood method (Huggins 1989, 1991).

We further investigated relationships among grazing and small mammals using vegetation characteristics. We tested for differences among grazing treatments for each physiognomic class with one-way ANOVAs. *P* values < 0.05 were considered significant. For physiognomic classes that did not have constant variation among treatments (i.e., failed a Fligner–Killeen test at $\alpha = 0.05$), we employed a nonparametric Kruskal–Wallis test (Crawley 2007).

Effective trap area was estimated by adding the area of the grid (1.8 ha) to the area of the buffer determined by the mean maximum distance moved (MMDM) (Wilson and Anderson 1985).

Results

We captured 363 individuals and had 174 recaptures during 54 secondary occasions from 9 July – 7 August 2007. Close to 61 percent (221) of small mammals marked were captured in the grazing unit with eight years of rest. The number of individuals captured in the grazing units with three years of rest and in one year of rest was 25.9 percent (94) and 13.2 percent (48), of the total captures, respectively. Voles comprised 99 percent of the small mammals captured, with only two deer mice and one common shrew (*Sorex cinereus*) comprising the remaining nearly one percent of individuals captured. Of the 26 vole mortalities occurring during capture, seven were processed with four identified as meadow voles, two montane voles, and one undetermined.

Our most parsimonious model of survival indicated that 1) vole apparent survival (φ) varied among grazing units; 2) capture rates (*p*) varied among grazing units and between capture sessions one and capture sessions two and three; and, 3) recapture rates varied among capture sessions but not among grazing units (Table 2).

Vole apparent survival, i.e., the combined probability of surviving and not permanently emigrating, was greatest in the unit rested for three years from cattle grazing, lowest in the unit with eight years of rest, and intermediate in the unit most recently grazed. Apparent survival estimates, for the eight day interval between primary occasions, were 0.45 (±0.12 SE), 0.62 (±0.12) and 0.35 (±0.09) for treatments

Table 2. Ranking of Robust Design capture-recapture models investigating effects of cattle grazing on vole (*Microtus* spp.) apparent survival (ψ), capture (*p*), and recapture (*c*) probabilities. We tested models in which φ, *p* and *c* were constant (.) or varied with time (*t*) or grazing unit (*g*). Models with φ differing between the most recently grazed unit (1 year since grazed [YSG]) and units with more rest (3YSG and 8YSG) were also included to test for an influence of vegetation structure on φ (*VS*). Due to low number of captures during the first primary occasion, we also tested models in which p(g) during the first occasion differed from *p*(*g*) during the second and third occasions (*p*2&3(*g*)). Only the 95% confidence interval of models (i.e., model weights sum to ≥ 0.95) are given. For models presented immigration (γ') and emigration (γ") = 0.

Model structure	ΔAIC_c [a]	Akaike weight[b]	*k*[c]
$\psi_{(g)} + p1_{(g)} + p2\&3_{(g)} + c_{(t)}$	0.00	0.490	12
$\psi_{(g)} + p1_{(g)} + p2\&3_{(g)} + c_{(.)}$	1.79	0.200	10
$\psi_{(g)} + p_{(t*g)} + c_{(t)}$	4.06	0.064	15
$\psi_{(t)} + p1_{(g)} + p2\&3_{(g)} + c_{(t)}$	4.21	0.060	11
$\psi_{(VS)} + p1_{(g)} + p2\&3_{(g)} + c_{(t)}$	4.23	0.059	11
$\psi_{(t*g)} + p1_{(g)} + p2\&3_{(g)} + c_{(t)}$	5.93	0.025	15
$\psi_{(t)} + p_{(t1*g)} + p_{(t2\&t3*g)} + c(.)$	6.03	0.024	9
$\psi_{(VS)} + p1_{(g)} + p2\&3_{(g)} + c(.)$	6.04	0.024	9

[a] The difference in AIC_c scores between the present model and the best model (1534.19).
[b] Normalized relative model likelihood.
[c] Number of estimated parameters in the model.

with one, three and eight years of rest, respectively (Fig. 2). We did not find support for our hypothesis that vole survival would be influenced by vegetation structure; models that included vegetation structure as a covariate were >4.2 AIC_c units from the best model. Capture rates were 0.43 (±0.18 SE), 0.23 (±0.05), and 0.38 (±0.10) for treatments with one, three and eight years of rest, respectively. The recapture rates did not vary among grazing treatments but did vary among primary sessions. Recapture rates were 0.11 (±0.07 SE), 0.26 (±0.04), and 0.17 (±0.02) for primary session one, two and three, respectively.

Vole abundance increased with increasing rest from grazing, and throughout the trapping period for units with at least three years of rest from grazing. Too few captures occurred during the first primary occasion to allow estimation of vole abundance corrected for detection probability. Estimated vole abundances by treatment during the secondary occasion were 35.7 (±8.0 SE), 59.0 (±12.7) and 108.4 (± 22.5) individuals for one, three and eight years of rest, respectively. Estimated vole abundances during the third primary occasion were 30.2 (± 6.9 SE), 82.3 (± 17.3 SE) and 196.1 (± 40.1 SE) individuals for treatments with one, three and eight years of rest, respectively (Fig. 3).

Litter depth did not differ between units with three and eight years of rest, but was significantly lower in the unit with only one year of rest, apparently approaching an asymptote (Fig. 4). Mean litter depth was 3.3 cm (±0.23 SE), 9.5 cm (±0.42), and 9.6 cm (±0.34) for treatments with one, three, and eight years of rest, respectively. Physiognomic classes that differed significantly for ground cover among grazing treatments included forbs, bare ground and litter (Table 3). Both forb and litter cover increased with time since last grazed, while bare ground decreased

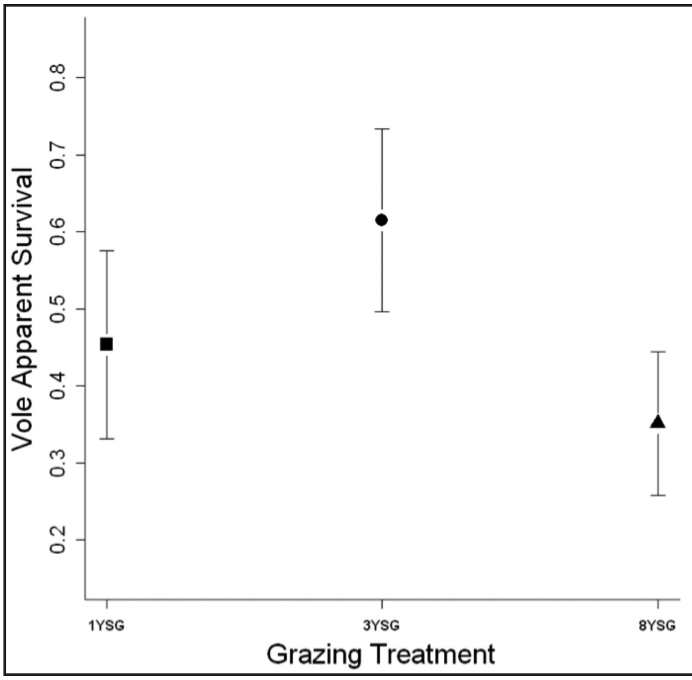

Figure 2. Apparent survival (±1 SE) by grazing treatment in grazed wet meadow at Red Rock Lakes National Wildlife Refuge, Montana, 2007. Grazing treatments include one year since grazed (1YSG), three years since grazed (3YSG), and eight years since grazed (8YSG).

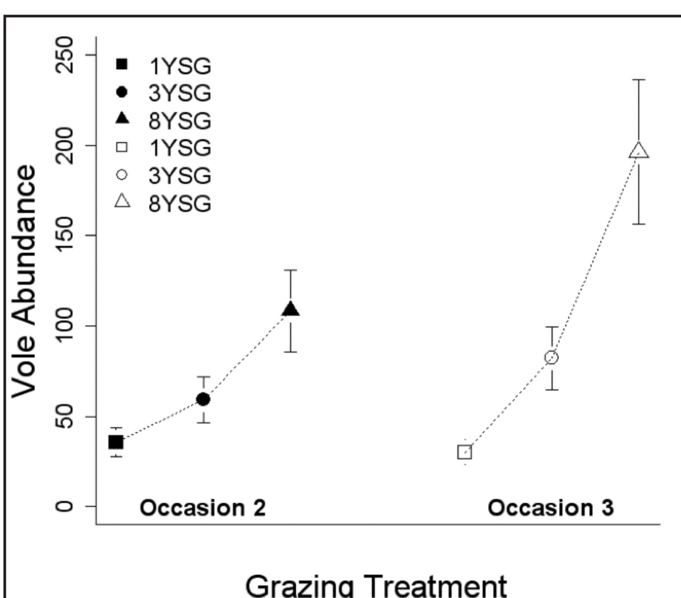

Figure 3. Vole abundance (±1 SE) by grazing treatment and primary trapping occasion (second and third occasions only) in grazed wet meadow, Red Rock Lakes National Wildlife Refuge, Montana, 2007. Grazing treatments include one year since grazed (1YSG), three years since grazed (3YSG), and eight years since grazed (8YSG). Abundance estimates for primary session one were imprecise due to small sample size and are therefore not given.

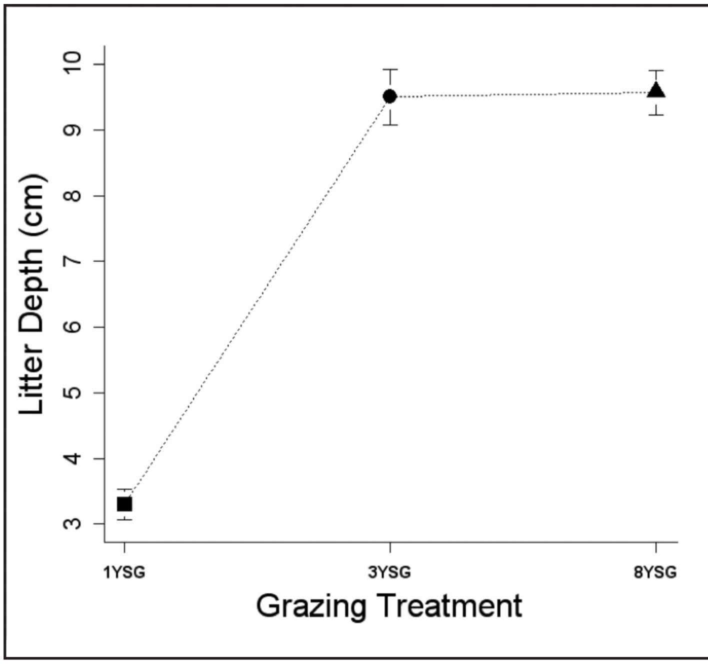

Figure 4. Mean litter depth (±1 SE) by grazing treatment in grazed wet meadow at Red Rock Lakes National Wildlife Refuge, Montana, 2007. Grazing treatments include one year since grazed (1YSG), three years since grazed (3YSG), and eight years since grazed (8YSG).

Table 3. Vegetation physiognomic class ground cover frequency by grazing treatment and results of one-way ANOVA tests of mean hits by transect. *F* statistics and *P* values for each test are given. Grazing treatments are one year since grazed (1YSG) (15 C), three years since grazed (3YSG) (15 a), and eight years since grazed (8YSG) (15 B).

Class	**15A (%)**	**15B (%)**	**15C (%)**	$F_{2,21}$	P
Bunch grass	1.13	2.17	2.61	0.40	0.674
Rhizomatous grass	29.43	28.16	30.88	2.43	0.112
Sedge/ Rush[a]	15.47	17.33	11.40	5.22	0.074
Forbs	16.41	16.25	10.21	4.17	**0.030**
Bare ground	0.56	0.18	3.33	15.59	**<0.001**
Moss	1.13	0.72	0.00	1.14	0.339
Litter	35.85	35.20	39.68	4.71	**0.020**
Standard Error	±1.35	±1.31	±1.41		

[a] A Kruskal–Wallis nonparametric test was run on this vegetation class, therefore the result is a χ^2 statistic and not an *F* statistic.

(Fig. 5). Mean forb hits per transect by grazing treatment were 5.38 (±2.3 SE), 10.88 (±2.3), and 11.25 (±2.3) for one, three, and eight years of rest, respectively. Mean litter hits per transect by grazing treatment were 20.88 (±1.22 SE), 23.75 (±1.22), and 24.38 (±1.22) for one, three, and eight years of rest, respectively. Mean bare ground hits per transect by grazing treatment were 1.75 (±0.31 SE), 0.38 (±0.31), and 0.13 (±0.31) for one, three, and eight years of rest, respectively. Similar to litter depth, lack of significant differences between treatments with three and eight years of rest across these habitat attributes indicated little change in vegetation structural attributes with additional rest from grazing.

Discussion

Small mammals are important components of grassland ecosystems. They provide prey for meso-predators and aid in seed dispersal and vegetative recovery of the habitats in which they reside (Milton et al. 1997, Fields 1999). Cattle grazing, a common practice on western grasslands, has been shown to have varied effects on small mammal populations. Grazing has been demonstrated to both increase and decrease small mammal abundance. Keesing (1998) showed continual cattle grazing decreased small mammal populations as much as two-fold. However, Bouska and Jenks (2006) demonstrated an increase in deer mice and meadow vole abundance in a rest rotation grazing system. Our results provide further insight into the effects of cattle grazing on small mammal communities in a wet meadow habitat.

Similar to studies that found decreased vole abundance in grazed grassland (Reynolds and Trost 1980, Fleischner 1994, Rosenstock 1996, and Keesing 1998), we found support for our prediction of increasing vole abundance with increasing rest from grazing. Vole abundance was consistently highest in the unit with the longest rest from grazing. In the two units with at least three years of rest, vole abundance increased during the study;

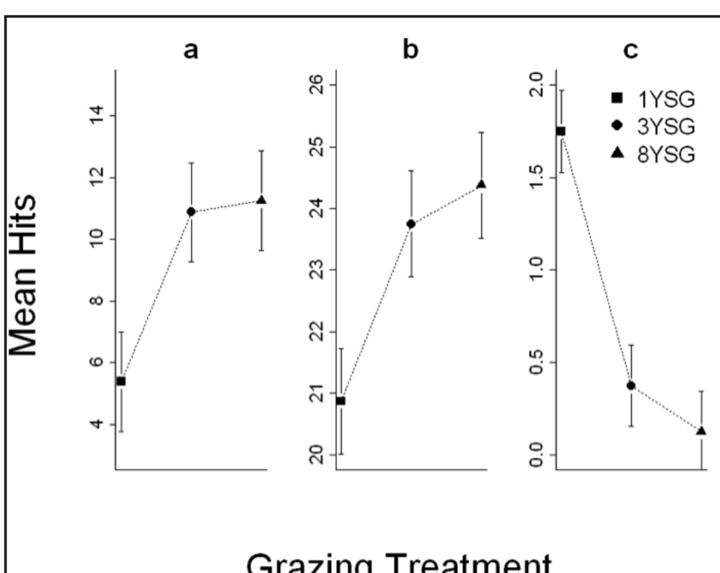

Figure 5. Mean a) forb, b) litter cover, and c) bare ground hits (±1 SE) per point-intercept transect by grazing treatment at Red Rock Lakes National Wildlife Refuge, Montana, 2007. Grazing treatments are one year since grazed (1YSG), three years since grazed (3YSG), and eight years since grazed (8YSG).

these units also had similar litter depth and litter and forb cover. Vole abundance did not increase during the study in the most recently grazed unit, which had significantly lower litter depth and litter and forb cover than the other treatments. This provides further evidence of the link between vole abundance and plant biomass (Peles and Barrett 1996).

We predicted that vole apparent survival would be positively related to vegetation structure. However, models that allowed survival to vary between units based on vegetation structure were not well supported. Instead, apparent survival was lowest in the grazing unit with the most rest from grazing and greatest in the unit with an intermediate level of rest from grazing. Vegetative cover did not differ between these two units, but vole abundance was significantly higher in the unit with the lowest estimated apparent survival. Reduced survival in an area of high small mammal abundance could be due to a positive response of predators to prey density. Korpimäki and Norrdahl (1989, 1991) described rapid immigration of raptors to areas of high vole density. Alternatively, emigration of voles from the unit with greatest abundance could have also accounted for lower apparent survival. We assumed a closed population, i.e., no emigration or immigration, in our modeling of apparent survival due to modest sample sizes. However, emigration is common in high-density small mammal populations (Runge 2005), and if occurring, would result in a low-biased estimate of apparent survival (Runge et al. 2006).

The community composition of small mammals during this study was very homogenous; virtually all of the small mammals captured were *Microtus* spp. We hypothesized that deer mice would represent a high percentage of captures in the most recently grazed unit due to the species' affinity for disturbed habitat (Grant et al.1982, Fleischner 1994, Matlack et al. 2001, Hadley and Wilson 2004). However, only two deer mice were captured during this study, and none were captured in the most recently grazed unit. Disturbance levels from grazing were apparently not enough to attract deer mice. Alternatively, deer mice may negatively select for wet meadow habitats. Austin and Pyle (2004) similarly had very low capture rates for deer mice in montane wet meadow habitat. Contrary to our original prediction that species diversity would increase with time since last grazed, species diversity did not appear to be linked to grazing treatment.

Vegetation structure in wet meadow habitat at the Refuge did not change significantly with rest from grazing greater than three years. Results indicated litter depth and forb and litter cover in grazed wet meadows approached an asymptote with no significant increase between three and eight years of rest from grazing. Bare soil was significantly greater in the most recently grazed unit, but similarly did not differ significantly between units with three and eight years of rest. Most studies of riparian or wet meadow habitat vegetation response to grazing compare grazed to non-grazed sites (e.g., Leege et al 1981, Schulz and Leininger 1990), which generally precludes comparison of our results with existing work. For example, Leege et al. (1981) found more abundant litter in moist and wet montane meadow sites in Idaho after 12 years of excluding grazing. No interim data were collected during this study, however, so it is not possible to determine when, or if, litter approached an asymptote in the exclosures similar to what was observed in this study. Results such as ours provide greater understanding of temporal changes in vegetation structure in habitats that are managed using periodic disturbance.

Our results indicated complex relationships among vole abundance and apparent survival, and vegetation structure, on grazed wet meadow habitat at Red Rock Lakes National Wildlife Refuge. The recommended two years of rest between grazing treatments utilized by the Refuge (USFWS 1994) appeared to have been sufficient for recovery of vegetation structure in wet meadows during this study.

However, vole abundance consistently increased with the number of years of rest from grazing, indicating two years of rest was not adequate for vole populations to reach maximum abundance in the wet meadow habitats. Vole apparent survival did not appear to be related to wet meadow vegetation structure. Given the dynamic inter-annual variation commonly observed in vole populations, multiple year studies similar to ours would be beneficial in more thoroughly understanding the interactions of vole population dynamics and cattle grazing in wet meadow habitat.

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