EFFECTS OF SIMULATED ELK GRAZING AND TRAMPLING (II): FREQUENCY

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ABSTRACT: The increase in western North American elk (*Cervus elaphus nelsoni*) populations is a concern to resource managers. In summer 1998, Bandelier National Monument erected a series of ungulate exclosures and paired reference areas to evaluate elk impacts on the vegetative community in piñon-juniper (*Pinus edulis* - *Juniperus* spp.), ponderosa (*Pinus ponderosa*) grassland (PG), and mixed-conifer (MC) habitat types. We assessed changes in density, percent foliar/litter cover, basal area, species richness, and composition resulting from the application of different frequencies of simulated grazing and trampling within elk exclosures from January through May of 1999 and 2000. Frequent clipping resulted in increased grass densities in PG sites and decreased total standing crops in MC sites after only 1 year. There were clipping X trampling interaction effects. Recurrent impacts from elk grazing and concomitant trampling may accelerate the rate at which plant communities reach thresholds of vulnerability. More years of treatments may detect further vegetative responses to different grazing pressure in this ecosystem, which has a history of elk grazing pressure.

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Grazing systems are partially defined by the intensity and frequency of use (Motazedian and Sharrow 1990) yet few studies have attempted to isolate these effects (McNaughton 1978, Gillen et al. 1990). Furthermore, it is often unclear whether effects are caused by the removal of vegetation or the associated trampling. Type of grazer, season and intensity of use, soil characteristics, individual plant and community characteristics (e.g., density, morphology, physiology), as well as temporal and spatial variation in environmental conditions can also influence the type and degree of impact (Weigel et al. 1990, Bastrenta et al. 1995). Conventional grazing systems control the frequency of livestock grazing events through periodic rest/rotation grazing regimes to maintain desired species composition (Ralphs et al. 1990). Derner et al. (1994) confirmed that rotational cattle grazing allows greater control of defoliation frequency and determined that stocking rate had the greatest influence on grazing intensity. Controlling grazing regimes and stocking rates is seldom possible where wild ungulates are the primary source of impacts; however, it is important to delineate between the effects of grazing intensity versus frequency so management alternatives can be evaluated.

The threat to archeological resources and naturally functioning ecosystems as a result of excessive elk trampling and graz-

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ing now rank as the highest management priority at Bandelier National Monument (BAND), New Mexico. Divergent management objectives of the state of New Mexico, Los Alamos National Laboratory (LANL), BAND, Native American communities, and privately owned areas hamper effective elk management in this region (Allen 1996). Hunting on BAND is prohibited by the Code of Federal Regulations (CFR), Title 36, Part 2, Sections 2.1-2.4 (Fettig 1997); any direct reduction of the elk herd would require a legislative act of Congress. Before any actions can be taken, however, there is a need for quantitative, scientific information on the potential impacts of the Bandelier elk herd. Elk population effects on vegetative and soil communities must be quantified.

The objectives of this study were to assess changes in density, percent foliar/litter cover, basal area, species richness, and composition through the application of different frequencies of clipping and trampling designed to simulate elk use within exclosures.

STUDY AREA

Bandelier National Monument is located in the Jemez Mountains of north central New Mexico (35:53:38N 106:17:02W) approximately 8 km south of Los Alamos in the Pajarito Plateau. Rupp et al. (2001) describe the topography, climate, fire history, and vegetative patterns for this study site in detail.

METHODS

Experimental Design

During summer of 1998, 15 60 m x 60 m ungulate exclosures (5 exclosures in each of 3 different habitats - mixed - conifer [MC], ponderosa (*Pinus ponderosa*) - grassland [PG], and piñon (*Pinus edulis*) - juniper (*Juniperus* spp.) [PJ]) were erected on BAND. In October of 1998, 16 1 m^2 experimental units were established in each exclosure to evaluate effects of frequency of simulated grazing and trampling on BAND communities. Because of vegetative complexity and diversity, experimental units in MC sites were reduced to 0.25 m^2. A 2-factor factorial, randomized block design (Steel and Torrie 1980) was used to evaluate the impacts of clipping, trampling, and their interaction. Clipping treatments were applied at 100% standing crop removal 0, 1, 2, or 3 times to represent none, light, moderate, and heavy clipping frequencies, respectively. Likewise, trampling was applied at 0, 5, 25, or 100 footfalls/m^2 at none (0 times), light (1 time), moderate (2 times), or heavy (3 times) frequencies (Fig. 1). Treatment re-applications were applied every 2-3 weeks up to 3 times depending on the assigned treatment. A split-plot arrangement with time as a subplot factor allowed for analysis over the 2 years of the study. Treatments (clipping and/or trampling) were randomly assigned to experimental units (1 m^2 or 0.25 m^2 plots) within each block (exclosure). Clipping and trampling were simulated as described in Rupp

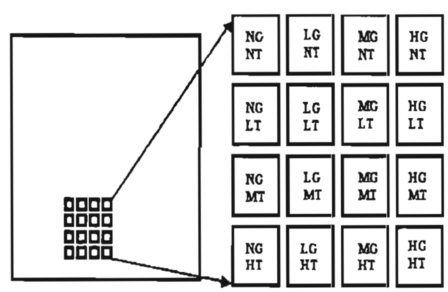

Fig. 1. Designation of clipping X trampling treatment combinations inside exclosures. Clipping treatments were applied at 100% standing crop removal either 0 (none), 1 (light), 2 (moderate), or 3 (heavy) times while trampling was applied at 0, 5, 25, or 100 footfalls/m^2 at 0 (none), 1 (light), 2 (moderate), or 3 times (heavy), respectively. Clipping treatments are designated with 'G' while trampling is designated with 'T'. Treatments were randomly assigned to 1 m^2 experimental units.

et al. (2001). Trampling in the mixed-conifer plots were applied to a full 1 m^2 area even though effects were measured only on 0.25 m^2.

Pre-treatment data were collected and treatments were applied in January through May 1999 when elk normally would use each habitat type. Post-treatment data were collected and treatments were re-applied during the same time periods in 2000. Variables measured included density, foliar/litter cover, basal area, productivity (i.e., standing crop), species richness, and composition. Plants were identified to the species level. Unknown plants were collected in the field and numbered for later identification.

Statistical Analysis

Analysis of variance (ANOVA) and mean separation were used to determine treatment effects within and across habitats for total density and foliar cover. Habitat effects for density and foliar cover estimates were tested using the Type III mean square for block (habitat) as an error term. Potential block (exclosure) X treatment interactions were tested using Tukey's test for non-additivity. When sub-divided by grass and forb growth classes, density data and foliar percentages that were not normally distributed were transformed using square root or arcsine transformations, respectively (Sokal and Rohlf 1995). Experimental units, which lacked a grass or forb class were treated as sampled units with zero grasses or forbs. Basal area, species richness, and litter cover were only analyzed within habitats. Species composition is compared descriptively. For all analyses, significance was delineated at $\alpha = 0.10$.

RESULTS

Measures of vegetation prior to any clipping or trampling treatment application showed block X treatment interactions for plant density in PJ ($F_{1,59} = 4.11$, $P = 0.047$) and MC ($F_{1,59} = 44.44$, $P < 0.001$) habitats. Initial block X treatment interactions were also detected for density in the PG habitat, but removal of exclosure PG-5, that had been burned in 1998, and exclosure PG-1, that had been burned in 1999, remedied this effect for density estimates. Block X treatment interactions were also discovered for MC ($F_{1,59} = 5.93$, $P = 0.018$) and PG ($F_{1,21} = 6.10$, $P = 0.022$) foliar cover data. In addition, a clipping effect prior to any treatment application was detected for foliar cover in PJ, indicating randomly selected plots differed prior to any treatment application. Therefore, analysis of covariance (ANCOVA) was used in subsequent within-habitat analyses, with the exception of litter cover and basal area, to account for initial differences among plots. Baseline density and foliar cover estimates were used as covariates. With the exception of density data in the PJ habitat, all first-year data were normally distributed.

Plant density differed among habitats ($F_{2,10} = 12.06$, $P = 0.002$). Mixed-conifer sites had more plants/m^2 ($\overline{X} = 402$ plants/m^2) than PG ($\overline{X} = 89$ plants/m^2) or PJ ($\overline{X} = 45$ plant/m^2) sites. Total foliar cover did not differ ($P > 0.1$) among habitats.

Piñon-Juniper Habitat

No changes in total density, foliar cover, mean basal area/plant, or species richness were found as a result of clipping, trampling, or their interaction at any frequency. Mean basal area/plant was lower in 2000 than in 1999 ($F_{1,64} = 5.60$, $P = 0.021$), but this could not be attributed to any treatment combination. Percent litter cover did not differ among treatments (Table 1). When subdivided into grasses and forbs, neither densities nor standing crop weights differed among treatments.

Changes in species composition were few. Blue grama (*Bouteloua gracilis*)

Table 1. Mean litter (percent/m^2) by habitat for different frequencies[1] of simulated clipping and trampling treatment combinations in 2000 on Bandelier National Monument, New Mexico.

Trampling Frequency	MC HABITAT[2] Clipping Frequency H	M	L	N	Mean[4] Trampling	PG HABITAT Clipping Frequency H	M	L	N[5]	Mean[4] Trampling	PJ HABITAT[3] Clipping Frequency H	M	L	N	Mean[4] Trampling
H	55.6 (±10.59)	65.2 (±14.37)	72.0 (±9.72)	68.0 (±15.81)	65.2 **A** (±6.07)	13.1 (±6.46)	24.0 (±6.00)	7.7 (±2.19)	N/A	14.9 **A** (±3.55)	10.2 (±8.20)	8.7 (±3.62)	2.8 (±1.02)	7.3 (±2.51)	7.3 **A** (±2.24)
M	62.8 (±14.19)	69.2 (±8.57)	76.4 (±9.02)	72.4 (±10.67)	70.2 **A** (±5.10)	6.9 (±4.60)	22.5 (±4.75)	37.4 (±6.73)	N/A	22.3 **A** (±5.18)	6.6 (±3.10)	5.9 (±2.03)	14.1 (±10.59)	6.0 (±1.70)	8.1 **A** (±2.72)
L	72.8 (±6.86)	69.2 (±10.59)	76.4 (±12.37)	71.6 (±12.04)	69.0 **A** (±4.99)	12.6 (±2.26)	30.1 (±12.30)	20.8 (±15.29)	N/A	21.2 **A** (±6.20)	8.3 (±5.61)	2.7 (±1.23)	9.0 (±4.70)	11.1 (±7.40)	7.8 **A** (±2.51)
N	78.4 (±6.40)	69.2 (±14.80)	62.4 (±13.47)	55.2 (±11.53)	66.3 **A** (±5.84)	11.4 (±3.53)	10.9 (±6.24)	18.0 (±3.52)	N/A	13.4 **A** (±2.57)	16.1 (±6.33)	20.0 (±14.13)	7.1 (±5.41)	5.1 (±1.23)	11.4 **A** (±4.34)
Mean[4] Clipping	67.4 (±5.02)**A**	68.2 (±5.69)**A**	70.6 (±5.31)**A**	64.5 (±6.00) **A**		11.0 (±2.05) **A**	21.9 (±3.93)**A**	21.0 (±4.88)**A**	N/A		9.9 (±2.90)**A**	9.3 (±3.71)**A**	8.2 (±3.09)**A**	7.0 (±2.02)**A**	

[1] Clipping was applied at 100% standing crop removal 0 (none), 1 (light), 2 (moderate), 3 (heavy) times per unit area while trampling was applied at 0, 5, 25, or 100 footfalls/m^2 0 (none), 1 (light), 2 (moderate), or 3 (heavy) times, respectively.

[2] MC = mixed-conifer, PG = ponderosa grassland, PJ = piñon-juniper.

[3] Data in PJ habitat failed to meet assumptions for normality.

[4] Grand means (within a treatment) with the same letter are not statistically different at $\alpha = 0.10$.

[5] Non-grazed experimental units in PG habitat were excluded due to observer error.

decreased at the highest frequency of trampling (-14.5%) compared to moderate (+0.2%), light (+2.7%), or no (+0.1%) trampling. There were also increases in purple three-awn (*Aristida purpurea*) across all treatments regardless of frequency of treatment. Snakeweed (*Gutierriza sarothrae*) was negatively affected by increased frequency of clipping, steadily decreasing between years by -0.3% with no clipping to -4.0% at the heaviest frequency of clipping (Table 2).

Ponderosa-Grasslands Habitat

Total grass densities were affected by clipping ($F_{2,21}$ = 2.63, P = 0.096). Units clipped 3 times had higher densities than those clipped twice. Units clipped only once did not differ from those clipped 2 or 3 times (Table 3).

Clipping X trampling treatment combinations had affected ($F_{6,22}$ = 2.43, P = 0.059) total litter cover (Table 1). Litter cover (Fig. 2) was negatively correlated with clipping frequency at moderate frequencies of trampling. In contrast, at high and low frequencies of trampling litter cover was highest at moderate clipping frequencies but declined at the extremes. When no trampling was applied, low frequencies of clipping had more litter cover than moderate or high frequencies of clipping.

With the exception of a year effect ($F_{1,24}$ = 11.50, P = 0.002) for basal area measurements, no other significant effects were detected. Mean basal area/plant was lower in 2000 than in 1999, but this was probably in response to abiotic factors and could not be attributed to treatment applications.

The most notable change in species composition between 1999 and 2000 occurred with the complete loss of goosefoot (*Chenopodium* spp.) species across all treatments. Mountain muhly (*Muhlenbergia montana*) increased (+9.5%) at the highest frequency of trampling as well as with the highest clipping/trampling treatment combination (+13.5%). Sages (*Artemisia* spp.) showed the greatest relative increases in composition between years at moderate frequencies of clipping (+15.5%) or trampling (+14.6%), but tapered off at the extremes. Western wheatgrass (*Agropyron smithii*) showed the greatest increase in relative density at the highest frequency of clipping (+5.8%) or trampling (+4.8%) with changes between years being com-

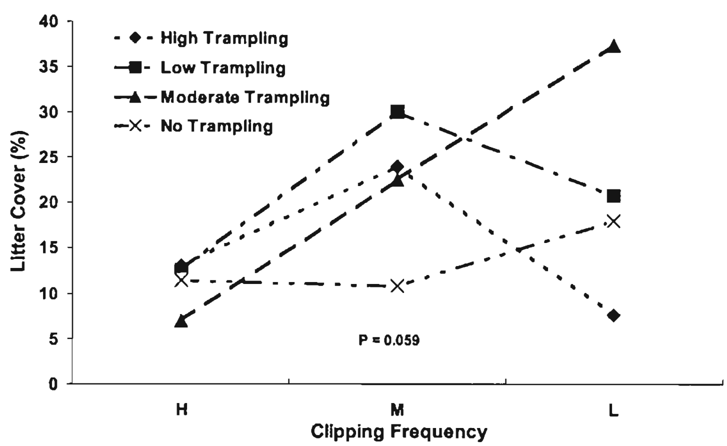

Fig. 2. Mean litter cover (%) for different frequencies of clipping X trampling treatment combinations in PG exclosures (Spring 2000) - Bandelier National Monument, New Mexico. Clipping was applied at 0, 40-60%, or 100% standing crop removal while trampling was applied at 0, 5, 25, or 100 footfalls/ unit area either 0 (none), 1 (light), 2 (moderate), or 3 (heavy) times, respectively.

Table 2. Relative composition (%) of common species in 1999 vs. 2000 by habitat for different frequencies[1] of clipping and trampling treatment combinations on Bandelier National Monument, New Mexico.

	Clipping Frequency								Trampling Frequency							
	Heavy		Moderate		Light		None		Heavy		Moderate		Light		None	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Mixed-Conifer Habitat																
Juncus ssp.	5.1	2.3	—	—	—	—	11.1	7.6	9.1	1.9	15	0.9	—	—	6.4	6.9
Carex ssp.	12.6	8.0	10.5	12.4	13.1	12.1	8.6	11.1	9.6	11.4	16.1	12.1	7.0	7.6	12.1	12.0
Erigeron ssp.	5.3	7.5	4.8	7.3	6.8	6.1	5.8	7.3	3.0	5.4	7.4	9.0	5.6	7.5	6.8	6.3
Taraxacum officinale	4.5	6.5	6.8	6.1	5.6	6.0	4.9	6.6	6.0	7.0	5.4	5.1	4.6	6.2	5.3	6.9
Trifolium repens	0.3	3.9	2.3	4.7	1.5	1.6	2.1	2.6	0.1	1.4	1.0	1.1	3.2	7.9	1.8	2.9
Poa ssp.	16.9	14.6	23.9	21.4	18.6	20.6	—	—	11.8	19.8	14.0	23.7	18.6	22.1	18.7	19.0
Bromus ssp.	4.3	5.9	8.9	6.8	9.9	6.7	5.9	27.3	5.7	4.7	8.0	5.6	6.7	6.9	7.5	6.4
Galium boreale	0.8	1.1	1.4	0.6	2.6	1.5	2.2	2.3	1.2	1.5	2.9	1.3	—	—	2.1	1.8
Achillea lanulosa	7.0	8.9	5.7	5.3	8.0	7.9	3.3	4.5	5.5	7.4	5.0	5.6	8.4	9.0	5.1	5.0
Fragaria americana	2.5	5.1	2.5	3.5	6.1	8.5	2.9	3.7	3.7	6.3	2.8	3.6	2.4	4.6	4.1	6.2
Antennaria ssp.	4.0	7.2	4.4	5.7	2.0	3.8	2.5	2.5	2.7	3.2	5.3	7.6	3.8	4.8	1.8	3.3
Koeleria cristata	0.8	4.5	2.1	2.5	2.5	1.8	—	—	1.3	2.6	2.2	2.0	1.7	2.9	0.7	2.7
Ponderosa-Grassland Habitat																
Chenopodium ssp.	16.2	0.0	8.2	0.0	1.4	0.0	3.3	0.0	16.8	0.0	—	—	10.3	0.0	3.5	0.0
Artemesia ssp.	13.1	21.8	8.9	24.4	9.4	20.3	6.3	8.8	5.4	11.0	13.7	28.3	15.2	22.3	5.5	14.7
Agropyron smithii	12.9	18.6	26.8	30.0	3.4	4.1	1.3	0.9	8.6	13.4	13.7	12.9	9.7	12.9	16.9	21.4
Schizachrium scoparium	7.9	5.7	2.9	0.9	10.5	5.8	5.2	7.8	5.5	8.4	6.7	6.0	7.9	3.3	6.1	0.9
Chrysopsis villosa	7.6	5.2	4.8	3.3	11.1	8.0	12.9	8.2	10.4	8.7	10.8	4.0	7.2	5.7	6.9	5.3

Table 2 (cont.)

Thelesperma filifolium	6.6	1.4	10.8	3.2	10.2	5.5	8.6	6.3	7.9	4.1	12.0	3.5	8.2	4.1	8.7	3.5
Aristida arizonica	7.2	7.5	3.9	6.3	—	—	—	—	3.4	7.2	5.7	4.4	6.5	8.7	6.9	7.5
Muhlenbergia montana	6.1	11.	8.7	10.1	13.8	19.2	12.3	18.3	9.1	18.7	12.9	15.7	8.3	9.5	9.9	11.8
Bahia dissecta	4.7	3.0	4.5	2.5	3.8	1.5	3.8	2.7	5.1	5.0	3.1	1.0	3.9	1.5	4.8	2.6
Erigeron divergens	3.3	1.1	—	—	4.7	0.5	4.2	0.9	2.5	0.5	4.4	0.4	3.4	0.9	2.6	0.6
Lotus wrightii	2.5	2.4	2.4	3.7	3.6	4.5	2.8	4.1	2.4	3.2	2.6	4.1	3.0	2.7	3.1	4.1
Erigeron flagellaris	2.3	6.7	0.1	1.6	5.5	2.6	2.3	5.0	5.2	1.7	0.0	7.4	1.7	4.9	2.5	1.0
Bouteloua gracilis	1.6	1.9	0.5	1.1	1.1.	1.3	1.5	2.3	0.5	1.4	1.9	1.9	1.3	1.3	1.0	1.7
Koeleria cristata	1.3	1.5	7.6	6.3	4.2	6.5	6.4	10.3	3.1	5.5	4.7	3.0	6.3	11.9	5.6	3.3
Piñon-Juniper Habitat																
Bouteloua gracilis	36.8	38.8	46.5	45.5	42.8	44.1	43.7	43.2	44.9	30.4	53.9	53.7	40.0	42.7	30.4	30.4
Lotus wrightii	12.4	9.4	10.3	8.1	12.8	9.1	12.0	11.5	10.8	10.7	10.2	9.6	11.7	9.4	15.1	10.7
Schizachrium scoparium	11.7	8.0	9.8	7.7	8.5	7.2	8.1	6.7	8.0	7.2	10.1	7.8	9.5	7.7	10.4	7.2
Aristida purpurea	7.6	16.8	3.4	15.8	3.8	16.1	4.2	9.5	4.4	18.7	2.0	10.5	7.8	8.4	4.9	18.7
Gutierrezia sarothrae	5.5	1.5	4.4	1.2	4.2	1.1	4.7	4.4	3.6	2.6	3.9	1.7	5.4	2.7	5.9	2.6
Bahia dissecta	2.6	1.4	4.0	2.9	2.1	1.4	3.5	1.9	2.9	1.7	3.6	1.3	2.8	2.5	2.9	1.7
Ipomopsis aggregata	2.6	0.6	1.5	1.0	—	—	3.6	0.9	—	—	4.6	0.8	1.9	1.4	1.9	0.4
Cryptantha jamesii	2.0	0.8	1.6	1.2	4.3	1.4	1.6	0.8	2.8	2.0	1.9	0.7	1.3	0.5	3.6	2.0

[1] Clipping was applied at 100 (Heavy), 40-60 (Moderate), or 0 (None) percent standing crop removal while trampling was applied at 100 (Heavy), 25 (Moderate), 5 (Light), or 0 (None) footfalls per unit area.

Table 3. Adjusted[1] mean density (number of plants/m^2 ± SE) by vegetative type for different frequencies[2] of simulated clipping and trampling treatment combinations in 2000 in ponderosa-grassland (PG) habitat on Bandelier National Monument, New Mexico.

	FORBS[3]					GRASSES				
	Clipping Frequency					Clipping Frequency				
Trampling Frequency	H	M	L	N	Mean[4] Trampling	H	M	L	N	Mean[4] Trampling
H	39 (±18.54)	37 (±18.67)	15 (±18.49)	N/A	31 **A** (±10.64)	76 (±10.00)	56 (±9.78)	40 (±9.79)	N/A	57 **A** (±5.75)
M	35 (±18.43)	77 (±18.39)	45 (±18.35)	N/A	52 **A** (±10.62)	39 (±9.77)	37 (±10.29)	48 (±10.04)	N/A	41 **A** (±5.65)
L	63 (±19.08)	34 (±18.51)	22 (±18.36)	N/A	40 **A** (±10.64)	54 (±9.87)	41 (±10.00)	48 (±9.87)	N/A	48 **A** (±5.69)
N	41 (±18.37)	33 (±18.65)	48 (±18.41)	N/A	41 **A** (±10.67)	56 (±10.32)	23 (±12.46)	47 (±9.77)	N/A	42 **A** (±5.84)
Mean[4] Clipping	45 **A** (±9.18)	45 **A** (±9.22)	33 **A** (±9.18)	N/A		56 **A** (±4.99)	39 **A** (±5.32)	46 **AB** (±5.0)	N/A	

[1] ANCOVA adjusted means account for pre-treatment (1999) foliar cover estimates.

[2] Clipping was applied at 100 (H), 40-60 (M), or 0 (N) percent standing crop removal while trampling was applied at 100 (H), 25 (M), 5 (L), or 0 (N) footfalls per unit area.

[3] Non-clipped units were excluded from all ponderosa-grassland habitat analyses due to observer error.

[4] Means (within treatment) with the same letter are not statistically different at $\alpha = 0.10$.

parative among the other treatments. Finally, little bluestem (*Schizachyrium scoparium*) decreased in non-trampled (-5.2%) sites or when only trampled once (-4.7%). At moderate frequencies of trampling, composition of little bluestem did not change between years (6.7% and 6.0% in 1999 and 2000, respectively). However, at the highest frequency of trampling, there was more little bluestem (+3.0%) in spring 2000 than in spring 1999 (Table 2).

Mixed-Conifer Habitat

No effects were detected for density, foliar cover, or litter. However, total grass foliar cover was affected by clipping frequency ($F_{3,59}$ = 2.83, P = 0.046). Non-clipped areas had higher grass cover than heavily and lightly clipped plots (Table 4).

Total species richness was affected by clipping X trampling treatment combinations ($F_{9,59}$ = 1.98, P = 0.057). Species richness increased at light and moderate frequencies of trampling when coupled with moderate frequencies of clipping, but decreased at light and heavy clipping frequencies. While at no trampling and heavy trampling with moderate clipping frequencies there was a decrease in species richness and increased species richness at light and heavy clipping levels (Fig. 3). When no clipping was applied, treatments where no trampling was applied had the highest number of species ($\overline{X}$=10 species/0.25 m^2) followed by treatments with light ($\overline{X}$= 9 species/0.25 m^2), moderate ($\overline{X}$= 9 species/0.25 m^2), and heavy ($\overline{X}$= 8 species/0.25 m^2) trampling frequencies.

A clipping effect ($F_{2,43}$ = 2.44, P = 0.099) was also found for total standing crop. Productivity was lower for heavily clipped plots ($\overline{X}$=7.93g/0.25 m^2, P=0.050) than lightly clipped ($\overline{X}$=10.59g/0.25 m^2) areas. Moderately clipped sites had higher productivity ($\overline{X}$=10.30g/0.25 m^2, P=0.083) than heavily clipped plots, but they were not different from lightly clipped plots (P = 0.828). The only other significant effect detected indicated that mean basal area/plant was lower in 2000 than in 1999 ($F_{1,64}$ = 52.18, P < 0.001), this effect could not be attributed to any treatment and may be the result of abiotic influences.

Increased frequency of clipping had deleterious effects on bluegrasses (*Poa* spp.). Relative percent composition of

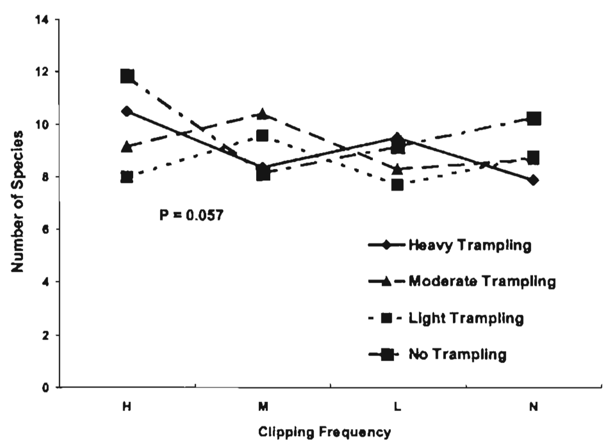

Fig. 3. Species richness in response to different frequencies of clipping X trampling treatment combinations in MC exclosures (Spring 2000) - Bandelier National Monument, New Mexico. Clipping was applied at 0, 40-60%, or 100% standing crop removal while trampling was applied at 0, 5, 25, or 100 footfalls/unit area either 0 (none), 1 (light), 2 (moderate), or 3 (heavy) times, respectively.

Table 4. Adjusted[1] arcsine transformed mean foliar cover (percent/m^2) by vegetative type for different frequencies[2] of simulated clipping and trampling treatment combinations in 2000 in mixed-conifer (MC) habitat on Bandelier National Monument, New Mexico.

	FORBS					GRASSES				
	Clipping Frequency					Clipping Frequency				
Trampling Frequency	H	M	L	N	Mean[3] Trampling	H	M	L	N	Mean[3] Trampling
H	0.20	0.19	0.27	0.15	0.20 **A**	0.11	0.21	0.17	0.19	0.17 **A**
M	0.13	0.21	0.23	0.17	0.18 **A**	0.18	0.23	0.17	0.19	0.19 **A**
L	0.17	0.22	0.18	0.22	0.20 **A**	0.17	0.15	0.20	0.24	0.19 **A**
N	0.18	0.12	0.25	0.19	0.18 **A**	0.15	0.19	0.14	0.31	0.20 **A**
Mean[3] Clipping	0.17**A**	0.18**A**	0.23**A**	0.18**A**		0.15**A**	0.20**AB**	0.17**A**	0.23**B**	

[1] ANCOVA adjusted means account for pre-treatment (1999) foliar cover estimates.
[2] Clipping was applied at 100 (H), 40-60 (M), or 0 (N) percent standing crop removal while trampling was applied at 100 (H), 25 (M), 5 (L), or 0 (N) footfalls per unit area.
[3] Means (within treatment) with the same letter are not statistically different at $\alpha = 0.10$.

bluegrasses decreased between 1999 and 2000 from +21.5% on non-clipped units to +2.0%, -2.5%, and -2.3% on light, moderate, and heavy clipping, respectively. The opposite occurred with trampling as relative composition of bluegrasses increased by +0.3%, +1.5%, +9.7%, and +8.0% for no, light, moderate, and heavy frequencies of trampling, respectively. In contrast, rushes (*Juncus* spp.) were negatively affected by the highest trampling frequency. They decreased by -7.2% compared to -0.6% and +0.5% for moderate and no trampling, respectively. June grass increased (+3.7%) at the highest frequency of clipping whereas white clover (*Trifolium repens*) showed the greatest increase between years (+4.7%) at light levels of trampling (Table 2).

DISCUSSION

During this study, BAND experienced 2 unseasonably warm years. Plant communities can be influenced by abiotic variables (e.g., inter-annual differences in growing season precipitation) as much as by ungulate populations (Peterson et al. 1997). Winkel and Roundy (1991) found seedling emergence in response to cattle trampling differed among years and treatments relative to precipitation patterns and periods of available water. Olson et al. (1985) indicated that each species reacts to precipitation regimes and grazing pressures in a unique manner. In addition, control of vegetation dynamics by precipitation is much more likely in arid and semiarid regions (Petersen et al. 1997) - a condition prevalent in the Jemez Mountains of north central New Mexico.

Plant densities were higher in plots clipped 3 times in PG habitat than those clipped twice or not at all. Bunchgrasses in these sites responded to heavy clipping pressure with above average seasonal temperatures and lower moisture by the breakup of the original bunchgrass plants which were then counted as more individuals the following year. Trampling applied to those plots exacerbated this effect by pulverizing the dead or dying connective portions of bunchgrasses. We saw a similar response to treatment intensity in PJ habitat (Rupp et al. 2001).

Litter cover in PG habitat was negatively correlated with clipping frequency in the absence of trampling, although increased trampling confounded effects. Litter cover has also been found to be negatively correlated with clipping intensity in PJ and MC sites (Rupp et al. 2001). Biondini et al. (1998) also reported a negative correlation between grazing intensity and litter cover. Further data are needed to accurately define the negative relationship to clipping frequency suggested here.

Measures of basal area did not change with this first year's treatments. Species richness was affected in MC sites where a combination of the extreme frequencies (i.e., 0 or 3 times) of clipping or trampling coupled with moderate levels of the other treatment resulted in fewer species. The responses we observed can be explained in 3 ways. First, only a single year's post-treatment data are reported here. Longer time periods may be needed to detect vegetative changes - especially in ecosystems that have developed with a history of grazing pressure. Secondly, vegetative parameters measured had high intrinsic variability. Though trends may be developing (as in the case of trampling), this variability probably conceals most treatment effects. Finally, there may be an intermediate threshold at which trampling stimulates plant productivity, especially in terms of forb response (Rupp et al. 2001) which may confound results of clipping treatments. Cole (1995a, b) stated that certain vegetation types might exhibit thresholds of vulnerability in response to trampling that, when exceeded, may result in even greater damage to the plant.

Blue grama is tolerant of grazing (Santos and Trlica 1978, Bock and Bock, 1986) and may even increase in overgrazed range (USDA Forest Service, Fire Effects Information System, http://www.fs.fed.us/database/feis, March 12, 1998). In contrast, mountain muhly appears to be intolerant to grazing pressure (Arnold 1950). Results from long-term exclosures indicated that mountain muhly showed the greatest increase in ungrazed quadrats, occurred in "patches" when moderately grazed, and disappeared when overgrazed (Arnold 1950). Similarly, in Colorado muhly cover increased as grazing decreased (Johnson 1956) comprising 20% of the composition in ponderosa habitat on heavily grazed areas compared to 45% on those not grazed. Our results do not support these patterns. Blue grama decreased with increasing trampling frequency whereas mountain muhly increased at the highest frequencies of trampling as well as the highest clipping/trampling treatment combination.

Seasons and phenological development of individual plants may confound effects of defoliation frequency and intensity (Briske and Richards 1995). Climate may also confound interpretation since blue grama is drought-tolerant (U.S. Forest Service 1937, Menke and Trlica 1981; USDA Forest Service, Fire Effects Information System, http://www.fs.fed.us/database/feis, March 12, 1998) - drought conditions prevailed the last couple of years in this region of the Jemez Mountains.

At mid-elevational ponderosa grassland sites, western wheatgrass and goosefoot species exhibited compositional shifts. Western wheatgrass is drought- and grazing-tolerant and is good winter forage for elk and deer (*Odocoileus* spp.) (U.S. Forest Service 1937), but is less tolerant than blue grama to clipping at higher temperatures (Boryslawski and Bentley 1985). We observed an increase in composition of wheatgrass at the highest frequencies of clipping and trampling. At this point we cannot explain the disappearance of goosefoot in our sites. However, treatments were applied at the earliest part of the growing season when these plants were seedlings and they were probably unable to tolerate extreme conditions.

In mixed-conifer, noticeable shifts in relative composition occurred with white-clover, bluegrasses, sedges, and pussytoes. White clover is considered excellent forage for ungulates (USDA Forest Service, Fire Effects Information System, http://www.fs.fed.us/database/feis, March 12, 1998) and withstands trampling well (U.S. Forest Service 1937), but it is not drought tolerant (Gibson and Cope 1985). Our results support this with the greatest relative increases in white clover occurring at low frequencies of trampling. In addition, white clover exhibits a high degree of phenotypic plasticity, which can result in large fluctuations in size of individual plants (Hay et al. 1989). Plants can adapt to severe defoliation by developing smaller leaves and more stolons (Ryle et al. 1989) and it has been reported that white clover may become more robust when grazed (U.S. Forest Service 1937, Hay et al. 1989, Chapman et al. 1992).

Different *Poa* species respond to grazing pressures and climate differently (U.S. Forest Service 1937) making it difficult to interpret our results, which are based on generic classifications. In general, *Poa* species are good to excellent forage and resistant to heavy trampling, grazing, and drought conditions (U.S. Forest Service 1937, Stubbendieck et al. 1985) because growing points are below ground throughout the growing season for most species (Ehrenreich and Aikman 1963). *Poa* decreased as clipping frequency increased during this study while, in contrast, they increased with increasing clipping intensity in a paired study (Rupp et al. 2001).

Rupp et al. (2001) suggested that an intermediate threshold may exist at which trampling intensity stimulates plant productivity, especially forb response. With the exception of individual species' responses, a threshold was not evident due to trampling frequency alone. However, the interaction of clipping X trampling may be responsible for this effect. Clipping X trampling frequencies had a significant effect on litter cover in PG habitat and species richness in MC sites. In both cases, intermediate levels of one treatment coupled with low or high levels of the other treatment resulted in the greatest response for that variable. Such information is critical to land managers for 2 reasons. First, it implies that certain vegetation types might exhibit thresholds of vulnerability that, when exceeded, may result in even greater damage to the plant (Cole 1995a, b). Secondly, recurrent impacts from grazing and concomitant trampling may accelerate the rate at which plant communities reach these thresholds of vulnerability.

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