Vegetation Change After 65 Years of Grazing and Grazing Exclusion

Danielle R. Courtois, Barry L. Perryman, and Hussein S. Hussein

Authors are rangeland technician, Bureau of Land Management, Socorro, NM 87801; and assistant professor and associate professor, respectively, Department of Animal Biotechnology, University of Nevada, Reno, NV 89557.

Abstract

The Nevada Plots exclosure system was constructed in 1937 following passage of the Taylor Grazing Act to assess long-term effects of livestock grazing on Nevada rangelands. A comparison of vegetation characteristics inside and outside exclosures was conducted during 2001 and 2002 at 16 sites. Data analysis was performed with a paired t test. Out of 238 cover and density comparisons between inside and outside exclosures at each site, 34 (14% of total) were different ($P < 0.05$). Generally, where differences occurred, basal and canopy cover were greater inside exclosures and density was greater outside. Shrubs were taller inside exclosures at 3 sites grazed by sheep (*Ovis aries*). Perennial grasses showed no vertical height difference. Aboveground plant biomass production was different at only 1 site. Plant community diversity inside and outside exclosures were equal at 11 of 16 sites. Species richness was similar at all sites and never varied > 4 species at any site. Few changes in species composition, cover, density, and production inside and outside exclosures have occurred in 65 years, indicating that recovery rates since pre-Taylor Grazing Act conditions were similar under moderate grazing and grazing exclusion on these exclosure sites.

Resumen

El sistema de exclusiones de Nevada se construyó en 1937, después de ser aprobada el Acta Taylor de Apacentamiento, para evaluar los efectos a largo plazo del apacentamiento del ganado sobre los pastizales de Nevada. Durante los años 2001 y 2002, en 16 sitios se condujo una comparación de las características de la vegetación dentro y fuera de las exclusiones. El análisis de los datos se llevo a cabo mediante pruebas de t-student para muestras apareadas. De 238 comparaciones de cobertura y densidad de la vegetación dentro y fuera de las exclusiones, 34 de ellas (14% del total) fueron diferentes ($P < 0.05$). Generalmente, donde ocurrieron las diferencias, la cobertura basal y de la copa fueron mayores dentro de las exclusiones y la densidad fue mayor fuera de ellas. En tres sitios apacentados con ovinos (*Ovis aries*) los arbustos fueron mas altos dentro de las exclusiones. Los zacates perennes no mostraron diferencias verticales de altura. La producción de biomasa vegetal aérea fue diferente solo en un sitio. La diversidad de la comunidad vegetal dentro y fuera de las exclusiones fue igual en 11 de los 16 sitios. La riqueza de especies fue similar en todos los sitios y nunca varió por más de 4 especies en ninguno de ellos. Pocos cambios han ocurrido en 65 años en la composición de especies, cobertura, densidad y producción dentro y fuera de las exclusiones, indicando que en estos sitos de exclusión las tasas de recuperación anteriores a las condiciones establecidas por el Acta Taylor fueron similares bajo un apacentamiento moderado y la exclusión al apacentamiento.

Key Words: exclosures, diversity, succession, herbivory effects

Introduction

Great Basin plant communities have remained essentially unchanged in terms of species composition for at least the last 1.2 million years (Tidwell et al 1972; Barnosky et al 1987). These plant communities have evolved with an assemblage of herbivores including domestic livestock within the last 150 years. There are those among the public that have questioned the use of Great Basin public lands for domestic livestock grazing. Advocates for the removal of livestock often do not provide empirical evidence of deleterious long-term effects from properly managed livestock grazing on western rangelands. Public land livestock grazing supporters likewise have little documented evidence that moderate long-term grazing will not adversely affect Great Basin plant communities.

After the overuse of Great Basin rangelands from the mid-1850s until 1934, rangeland managers sought methods of quantifying the effect of livestock grazing on the landscape. In 1936, the US Forest Service Intermountain Forest and Range Experiment Station, the University of Nevada Agricultural Experiment Station, and the Taylor Grazing Service designed a long-term study to observe secondary plant succession dynamics on overgrazed semiarid ranges in Nevada (Holmgren 1976). Twenty-eight sites were chosen in 9 Nevada counties from 1936 to 1939 on lands then administered by the US Department of Interior, Division of Grazing. These sites became known as the Nevada Plots.

The twenty-eight sites were originally established to study patterns and rates of vegetation change under continued grazing and compared with vegetation within exclosures that were not grazed. Exclosures were located in areas that had been subjected to uncontrolled grazing pressure by domestic animals for 4 to 5 decades prior to 1937. Each exclosure was about 100 × 160 m (1.6 ha) in size (McGinnies 1951). All the exclosures have barbed

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Correspondence: Dr Barry L. Perryman, Dept of Animal Biotechnology, Mail Stop 202, University of Nevada–Reno, Reno, NV 89557. Email: bperryman@cabnr.unr.edu

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Table 1. Nevada plot exclosure locations, elevations, annual precipitation zone (PZ), GPS coordinates, and dominant plant community descriptions (USDA 2003).

Location	Elevation (m)	PZ (cm)	GPS (lat/long)	Plant community description
Baker	1 600	20–30	38°56′42.32″N 114°03′12.62″W	Basin sagebrush/squirreltail
Conner's Station	1 846	20–30	39°01′55.86″N 114°33′14.06″W	Black sagebrush/winterfat
Cushman Well	1 208	13–18	39°06′26.85″N 119°38′09.35″W	Black greasewood/Indian ricegrass
Dinner Station	1 789	31–39	41°08′35.05″N 115°50′55.84″W	Wyoming sagebrush/basin wildrye
Lower Squaw Creek	1 411	20–30	40°50′55.70″N 119°34′08.72″W	Wyoming sagebrush/squirreltail
Upper Squaw Creek	1 726	20–30	40°53′17.18″N 119°36′46.88″W	Low sagebrush/Sandberg bluegrass
Newark Valley #1	1 909	20–30	39°24′48.20″N 115°35′27.64″W	Black sagebrush/Indian ricegrass
Newark Valley #2	1 850	20–30	39°25′35.20″N 115°38′18.75″W	Winterfat/squirreltail
Paradise Valley #1	1 339	20–30	41°22′18.16″N 117°33′51.57″W	Wyoming sagebrush/squirreltail
Paradise Valley #2	1 472	20–30	41°33′43.91″N 117°32′43.03″W	Wyoming/low sagebrush/Sandberg bluegrass
Pyramid Lake #1	1 277	13–18	39°50′21.35″N 119°39′23.67″W	Basin sagebrush/Indian ricegrass
Pyramid Lake #2	1 266	13–18	39°52′13.50″N 119°38′30.18″W	Lahontan sagebrush/squirreltail
Zenobia	1 215	13–18	40°08′39.37″N 119°44′50.82″W	Lahontan sagebrush/squirreltail
Wadsworth	1 261	13–18	39°39′06.00″N 119°19′21.87″W	Bailey greasewood/Indian ricegrass
Ward Mountain	1 920	31–39	39°08′27.89″N 115°02′47.45″W	Black sagebrush/Indian ricegrass
Wellington	1 549	20–30	38°42′20.70″N 119°18′28.44″W	Black sagebrush/squirreltail

wire attached to the upper portions of the juniper perimeter posts (3 strands), with a 10-cm square-pattern heavy-gauge wire attached 30 cm above the soil surface and extending 15–18 cm below the soil surface (there are a few exceptions to the wire used in the lower portion). Seven of the exclosures also have rodent exclosures on 0.4 ha within the larger exclosure.

The initial sampling of all exclosures in 1937 included an estimation of the proportion of ground cover by species, as well as a density count of the most important perennials (McGinnies 1951; Holmgren 1976). Holmgren noted in his summary report that the original 28 study sites were chosen by the degree of grazing (heavy) that the land had undergone and that changes in the exclosures themselves should be "considered recovery trends from prior probable retrogression trends and the resultant plant communities might be goals for grazing management to aim for, with the knowledge that response may not be as rapid nor the end quite the same under grazing as under the treatment without grazing" (p. 54).

Today, 16 of the original 28 Nevada Plots are intact. Some of the sites have been lost to land swap arrangements between the Bureau of Land Management and private landowners. Other sites have been used by members of the public as cattle or horse holding pens and have lost their value as ecological study areas. A few of the sites have lost some of their integrity because repairs were not implemented, and these sites were excluded.

This study constitutes an assessment of vegetation characteristics inside and outside exclosures that have been subjected to 65 years of protection from large herbivores compared with adjacent areas that have been moderately grazed continuously over the same period.

This project was designed to assess the effects of moderate grazing and grazing exclusion on semiarid plant communities since grazing was regulated in 1937 with passage of the Taylor Grazing Act. Total shrub and herbaceous plant cover and density, cover and density of cheatgrass (*Bromus tectorum* L.), soil biotic crust cover, vertical height of shrubs and perennial grasses, aboveground plant biomass production, and species richness and diversity were measured and compared inside and outside exclosures.

Materials and Methods

Study Area

The Great Basin is the largest temperate semidesert in North America (Miller et al 1994; Morris and Stubben 1994). The ecosystem is characterized primarily by sagebrush steppe grasslands and salt-desert shrubland ecological communities that cover about 44.8×10^6 and 17.6×10^6 ha, respectively (Kuchler 1970; Holecheck et al 1989). Three borders define the physiographic Great Basin: the Sierra Nevada and southern Cascades to the west, the Rocky Mountains on the east, and the Columbia Plateau to the north (Morris and Stubben 1994). The Great Basin contains a series of 33 different mountain ranges that are long, generally narrow, and orientated north to south (Tueller 1989). Sixteen ranges have peaks that reach above 3 352 m. Valley floors are between 1 615 and 2 321 m in the central and eastern portions of Nevada, but in the northeast, they decline to 1 158 to 1 767 m (Morris and Stubben 1994). Sixty percent of precipitation falls primarily as snow in winter and averages 5 to 23 cm in Nevada (Miller et al 1994). The rain shadow effect prevents much of the Pacific moisture from crossing the Sierra Nevada range; however, summer thundershowers can be heavy and cause localized flooding. Temperatures range from −22°C in winter to 38°C in the summer (Tueller 1989). Soils are mostly Aridisols or Entisols and vary in salinity. Upper soil profiles are generally sandy loam, and sometimes nearly all sand, with very low organic content (USDA 1993). Lower portions of the soil profile can contain layers in which clay particles have accumulated. Salts accumulate on the soil surface in depressions in which water has collected with finer sediments from upland sites and has evaporated. Wind removes fine soil particles, leaving a desert pavement comprising small rocks and gravel.

Table 2. Nevada Plot exclosure allotment grazing histories (current state of knowledge) by site.

Location	Grazing history
Baker	Winter sheep 1952–1955. Fall/winter sheep 1956–1962. Spring/fall/winter sheep 1963–1967. Winter cattle 1970–1977. 1978–1980 sheep and cattle spring/fall/winter. 1981–1986 cattle spring/fall/winter; sheep fall/spring. 2001–2002 3 758 sheep AUMs from 1 December to 30 April and 491 cattle AUMs from 1 November to 10 June.
Conner's Station	Heavy sheep/cattle use until 1945. 50% reduction 1947–1959. 1960–1963 no use. 1964–1965 cattle only winter. Spring cattle 1966–1986 with much lower stocking rate. 1994–2002 spring cattle 7 572 AUMs.
Cushman Well	Winter cattle 1937–1970. No use 1970–1980. 1981 to present, cattle winter range.
Dinner Station	Summer cattle before 1950 with 30% reduction over period, concurrent spring sheep before 1965. Spring/fall cattle 1966–1986. Spring through fall cattle and spring/early summer sheep 1987 to present.
Lower Squaw Creek	Before 1965, cattle, sheep, and feral horse. Continuous cattle 1965–1975. 1974 horse die-off closed allotment until 1982. Spring/fall cattle 1982–1986. 1987 to present, early spring cattle with rest rotation between 2 pastures.
Upper Squaw Creek	Historic sheep trail area, extensively grazed by sheep and cattle. 1995 to present, spring/summer cattle. 1982 EIS listed AUM use as: cattle 14 054, horses 4 500, mule deer 6 340, antelope 1 150, and bighorn sheep 1 228.
Newark Valley #1	Early 1900s to 1968 heavy sheep use fall/winter/spring. Spring sheep 1969–1976. Fall/winter cattle 1977–1986. 1987 to present, winter/spring 2 465 cattle AUMs and 1 552 sheep AUMs.
Newark Valley #2	Early 1900s to 1968 heavy sheep use fall/winter/spring. Spring sheep 1969–1976. Fall/winter cattle 1977–1986. 1987 to present, winter/spring 2 465 cattle AUMs and 1 552 sheep AUMs.
Paradise Valley #1	Unknown until 1986. 1986 to present winter/spring 624 cattle AUMs.
Paradise Valley #2	Spring cattle since 1919. Current, spring cattle at low stocking rates.
Pyramid Lake #1	Cattle and sheep continuous prior to 1960. Continuous cattle 1961–2000. 2001 to present winter cattle.
Pyramid Lake #2	Sheep and cattle winter range until 1960. Spring/summer/fall cattle 1961–1986. Rate as high as 1 023 AUMs 1963–1973. AUMs increasing since 1984.
Zenobia	Continuous sheep prior to 1936. Continuous cattle 1937–1965. Fall/winter/spring cattle 1966–2000. 2001 to present winter cattle.
Wadsworth	Before 1950, used as cattle holding area for rail shipping yards at Wadsworth, NV. Fall/winter cattle 1951–1986. Winter cattle 1987 to present.
Ward Mountain	Winter/spring sheep 1940–1978. Spring/summer alternate years sheep/cattle 1979–1986. Spring/summer cattle 1987 to present.
Wellington	Continuous sheep prior to 1936. Area was sheep trail until early 1940s. Fall/winter cattle 1945–1986. Winter cattle 1987 to present.

Description of Exclosure Sites

The 16, 1.6-ha exclosure sites used in this assessment were located within 7 distinct plant communities (Table 1). Grazing history information was assembled from Bureau of Land Management office archives (Holmgren 1976; Burnside 1988; Table 2). Four of the sites were communities dominated by black sagebrush (*Artemisia nova* A. Nelson) associated with Indian ricegrass (*Achnatherum hymenoides* [Roem. & Schult.] Barkworth) and bottlebrush squirreltail (*Elymus elymoides* [Raf.] Swezey). Four sites were Wyoming big sagebrush (*Artemisia tridentata* [Nutt.] subsp. *wyomingensis* Beetle & A.L. Young) communities codominant with bottlebrush squirreltail, and 3 were codominant with bud sage (*Artemisia spinescens* D.C. Eaton.), Indian ricegrass and Great Basin wildrye [*Leymus cinereus* Scribn. & Merr.] Á. Löve). Two of the sites were dominated by basin big sagebrush (*A. tridentata* subsp. *tridentata*) with bottlebrush squirreltail and Indian ricegrass in the understory. Two sites were dominated by Lahontan sagebrush (*Artemisia arbuscula* subsp. *longicaulis* Winward & McArthur) with a bottlebrush squirreltail understory. Two sites were dominated by greasewood, either Bailey greasewood (*Sarcobatus baileyi* [Cov.] Jeps.) or black greasewood (*Sarcobatus vermiculatus* [Hook.] Torr.), with Indian ricegrass understories. The Bailey greasewood site also contained a substantial quantity of Nevada dalea (*Psorothamnus polydenius* [Torr. ex S. Watts.] Rydb.). One site was a low sagebrush (*A. arbuscula* Nutt.)–Sandberg bluegrass (*Poa secunda* J. Presl.) community, and 1 site was essentially a winterfat (*Krascheninnikovia lanata* [Pursh] A. Meeuse & A. Smit) monoculture.

At each site, a comparison of parameters inside and outside the exclosure was performed with a paired *t* test. Percent basal and canopy cover values were arcsine transformed before analysis to achieve normal distribution (Zar 1999); however, values are reported as percentages. Differences were determined to be significant at $P < 0.05$ for all analyses. Field sampling was conducted during spring and early summer of 2001 and 2002, prior to the livestock grazing season. The effects of wildlife herbivory and feral horse (*Equus caballus*) were not controlled inside or outside exclosures; however, no visual evidence of their grazing activity was detected.

Basal cover of herbaceous species and canopy cover of shrubs (by species) were determined by the line intercept method (Canfield 1941), which is valid for measuring shrub communities within central Nevada (Hanley 1978). Within each exclosure, a center point was located and permanently marked with a concrete reinforcing rod. Random compass headings were selected and 3, 50-m transects were extended from the central point out toward the perimeter of each 1.6-ha exclosure. Outside the exclosure, 3, 50-m transects were randomly located away from the immediate area surrounding the exclosure (Mueller-Dumbois and Ellenberg 1974; Pieper

Table 3. Mean (SE) total vegetation cover, density, and probability values (P) inside (In) and outside (Out) exclosures in 2001 and 2002.

		2001				2002			
Location	Exclosure	Cover (%)	P	Density (plants/m^2)	P	Cover (%)	P	Density (plants/m^2)	P
Baker	In	2 (1)	0.152	6 (1)	0.403	3 (2)	0.770	5 (1)	0.044
	Out	3 (1)		8 (4)		3 (1)		4 (0)	
Conner's Station	In	17 (3)	0.023	7 (2)	0.073	7 (2)	0.044	9 (9)	0.720
	Out	4 (1)		13 (1)		4 (0)		11 (3)	
Cushman Well	In	3 (2)	0.428	2 (1)	0.485	4 (3)	0.799	4 (2)	0.757
	Out	2 (2)		3 (1)		5 (5)		4 (1)	
Dinner Station	In	20 (2)	0.012	7 (2)	0.979	19 (9)	0.374	6 (1)	0.232
	Out	8 (1)		7 (2)		15 (3)		4 (1)	
Lower Squaw Creek	In	9 (3)	0.242	127 (57)	0.343	11 (4)	0.445	71 (13)	0.832
	Out	9 (3)		66 (25)		8 (2)		66 (46)	
Upper Squaw Creek	In	18 (8)	0.983	27 (8)	0.965	17 (7)	0.084	41 (1)	0.046
	Out	18 (4)		27 (6)		22 (8)		17 (9)	
Newark Valley #1	In	17 (4)	0.028	7 (3)	0.571	5 (1)	0.860	6 (1)	0.002
	Out	4 (1)		6 (1)		5 (1)		9 (1)	
Newark Valley #2	In	5 (1)	0.030	12 (2)	0.220	4 (0)	0.861	5 (1)	0.038
	Out	18 (3)		10 (1)		4 (1)		8 (2)	
Paradise Valley #1	In	15 (6)	0.268	18 (3)	0.384	22 (19)	0.862	31 (15)	0.179
	Out	9 (5)		33 (25)		21 (6)		40 (9)	
Paradise Valley #2	In	21 (5)	0.386	76 (23)	0.101	16 (11)	0.949	63 (19)	0.211
	Out	24 (9)		58 (13)		17 (11)		28 (17)	
Pyramid Lake #1	In	18 (5)	0.146	13 (2)	0.024	10 (5)	0.217	19 (5)	0.733
	Out	14 (2)		6 (4)		11 (5)		23 (13)	
Pyramid Lake #2	In	13 (4)	0.131	17 (3)	0.417	8 (4)	0.426	25 (9)	0.977
	Out	17 (3)		12 (6)		10 (6)		25 (13)	
Zenobia	In	24 (1)	0.035	18 (6)	0.118	11 (5)	0.970	21 (4)	0.197
	Out	9 (4)		56 (30)		11 (1)		36 (18)	
Wadsworth	In	6 (4)	0.299	29 (12)	0.236	7 (7)	0.704	10 (3)	0.760
	Out	9 (7)		11 (8)		9 (4)		9 (4)	
Ward Mountain	In	20 (1)	0.003	5 (2)	0.038	9 (2)	0.256	5 (4)	0.773
	Out	7 (1)		8 (1)		6 (1)		6 (3)	
Wellington	In	18 (3)	0.108	20 (4)	0.227	6 (2)	0.196	8 (3)	0.037
	Out	15 (1)		22 (4)		13 (6)		14 (5)	

1978; Krebs 1999) to avoid fence line–associated animal effects. Plant density by species was determined with 1-m^2 quadrats located at 5-m intervals along each transect. Only 1 species, thickspike wheatgrass (*Elymus lanceolatus* [Scribn. & J. G. Sm.] Gould) had a strongly rhizomatous growth form, and each plant that broke the soil surface was counted as a separate plant. Plant heights and a live plant census for shrubs and perennial grasses were also recorded for all plants in the density transect quadrats during the 2002 field season. Plant heights were averaged to determine mean shrub and grass height. Live and dead plants were counted, and dead plants were expressed as a percentage of total plants.

Total herbaceous (grass and forb) current year standing crop was collected at the peak production stage during the 2002 field season for 8 sites with 0.25-m^2 quadrats located at 5-m intervals along each transect. Herbaceous biomass was clipped at ground level, segregated in the field into herbaceous forb or grass categories, and oven-dried at 60°C for 48 hours to determine dry weight per unit area (Krebs 1999).

Species richness (number of species) and diversity (richness and evenness) assessments were performed with the use of cover data. A Shannon–Weaver (Shannon and Weaver 1949) index value was calculated for each site, and a modified t test was performed for each paired set of index values (Zar 1999). Percent similarity ([number of shared species/total species] × 100) was also determined for each set of paired plots.

Results and Discussion

Cover and Density

Total vegetation cover was different between inside and outside exclosures within 6 of the 16 sites in 2001 (Table 3). Percent total cover was greater inside exclosures at Connor's Station, Dinner Station, Newark Valley #1, Ward Mountain, and Zenobia locations. Newark Valley #2 had greater total cover outside of the exclosure. In 2002, total cover inside and outside exclosures was equal at all sites except Conner's Station.

Table 4. Mean (SE) shrub cover, density, and probability values (*P*) inside (In) and outside (Out) exclosures in 2001 and 2002.

		2001				2002			
Location	Exclosure	Cover (%)	*P*	Density (plants/m^2)	*P*	Cover (%)	*P*	Density (plants/m^2)	*P*
Baker	In	1 (0)	0.086	6 (1)	0.403	3 (1)	0.943	5 (1)	0.049
	Out	3 (1)		8 (4)		3 (0)		4 (0)	
Conner's Station	In	15 (4)	0.030	2 (1)	0.052	5 (3)	0.180	3 (0)	0.028
	Out	3 (1)		8 (1)		3 (1)		5 (1)	
Cushman Well	In	1 (2)	0.165	< 1 (0)	0.990	3 (3)	0.892	1 (1)	0.321
	Out	1 (2)		< 1 (0)		4 (4)		> 1 (0)	
Dinner Station	In	19 (2)	0.009	2 (0)	0.270	13 (6)	0.347	1 (1)	0.483
	Out	6 (1)		3 (1)		11 (3)		1 (0)	
Lower Squaw Creek	In	3 (5)	0.918	< 1 (1)	0.990	3 (3)	0.227	1 (1)	0.532
	Out	3 (3)		< 1 (1)		> 1 (0)		> 1 (0)	
Upper Squaw Creek	In	10 (8)	0.659	2 (1)	0.859	13 (7)	0.766	1 (0)	0.195
	Out	12 (4)		2 (1)		12 (4)		1 (1)	
Newark Valley #1	In	16 (5)	0.052	4 (1)	0.203	5 (2)	0.394	3 (0)	0.042
	Out	3 (0)		5 (1)		3 (1)		4 (1)	
Newark Valley #2	In	4 (1)	0.029	5 (1)	0.026	4 (1)	0.506	5 (1)	0.038
	Out	17 (3)		8 (2)		3 (0)		8 (2)	
Paradise Valley #1	In	8 (5)	0.674	1 (1)	0.321	14 (11)	0.631	2 (1)	0.635
	Out	5 (6)		3 (2)		15 (6)		1 (0)	
Paradise Valley #2	In	10 (4)	0.126	2 (1)	0.097	7 (5)	0.565	2 (0)	0.153
	Out	25 (10)		3 (0)		12 (7)		3 (1)	
Pyramid Lake #1	In	16 (4)	0.212	1 (1)	0.214	9 (4)	0.603	< 1 (0)	0.097
	Out	13 (2)		> 1 (0)		9 (4)		1 (0)	
Pyramid Lake #2	In	10 (5)	0.270	5 (7)	0.737	6 (4)	0.537	1 (0)	0.626
	Out	15 (3)		3 (3)		4 (4)		1 (1)	
Zenobia	In	21 (7)	0.055	1 (0)	0.277	9 (5)	0.921	2 (0)	0.070
	Out	8 (5)		6 (6)		9 (1)		1 (1)	
Wadsworth	In	4 (3)	0.205	1 (0)	0.990	4 (4)	0.886	1 (1)	0.477
	Out	8 (7)		1 (0)		5 (4)		< 1 (0)	
Ward Mountain	In	18 (1)	0.008	5 (2)	0.038	8 (3)	0.295	3 (1)	0.490
	Out	7 (1)		8 (1)		5 (1)		3 (0)	
Wellington	In	15 (1)	0.104	3 (1)	0.268	5 (3)	0.184	3 (1)	0.635
	Out	12 (2)		2 (1)		9 (4)		3 (1)	

Total plant density in 2001 (Table 3) was different inside and outside exclosures at only 2 sites: Pyramid Lake #1 and Ward Mountain. Density was greater inside Pyramid Lake #1 and greater outside Ward Mountain. In 2002, density was greater outside than inside at Newark Valley #1, Newark Valley #2, and Wellington. Density at Upper Squaw Creek and Baker was greater inside exclosures.

Shrub cover and density (Table 4) at 4 sites were different inside and outside exclosures in 2001. Shrub cover was greater inside on all but 1 of the 4 sites, Newark Valley. In 2002, shrub cover was equal at all sites. In 2001, densities were greater outside the exclosures at Newark Valley #2 and Ward Mountain. In 2002, densities were greater outside the exclosure at Connor's Station, Newark Valley #1, and Newark Valley #2.

Herbaceous plant cover in 2001 was greater inside exclosures for Newark Valley #1 and Paradise Valley #2 (Table 5). In 2002, herbaceous cover inside and outside exclosures was equal at all sites. Density was greater inside in 2001 at Newark Valley #2 and Pyramid Lake #1, but greater outside exclosures at Ward Mountain. Densities in 2002 were greater outside exclosures at Newark Valley #1 and Wellington and greater inside the exclosure at Upper Squaw Creek.

Cheatgrass cover inside and outside exclosures was not different in either 2001 or 2002 (Table 6). However, cheatgrass density was greater inside exclosures in 2001 at Upper Squaw Creek and in 2002 at Newark Valley #1.

Out of 238 cover and density comparisons inside and outside exclosures, only 34 (14% of total) were different. Generally, where cover differences occurred, cover was greater inside than outside exclosures. However, for native perennial shrub and herbaceous species, density was generally greater outside exclosures when differences were detected. An accumulation of shrub and herbaceous cover over time in areas not subjected to grazing might be expected . Hennessey et al (1983) found that grass cover had not increased after 50 years of grazing exclusion in an arid grassland site in southern New Mexico. However, Valone et al (2002) reported that recovery time lags might occur in some systems and that the combination of herbivory exclusion and infrequent or unusual climatic events might accelerate recovery after extended periods of

Table 5. Mean (SE) herbaceous cover, density, and probability values (*P*) inside (In) and outside (Out) exclosures in 2001 and 2002.

		2001				2002			
Location	Exclosure	Cover (%)	*P*	Density (plants/m^2)	*P*	Cover (%)	*P*	Density (plants/m^2)	*P*
Baker	In	< 1 (0)	0.324	1 (0)	0.104	< 1 (1)	0.551	< 1 (1)	0.990
	Out	< 1 (0)		5 (2)		< 1 (0)		< 1 (0)	
Conner's Station	In	2 (1)	0.099	4 (1)	0.469	2 (2)	0.338	7 (9)	0.966
	Out	1 (0)		5 (1)		3 (1)		7 (3)	
Cushman Well	In	1 (0)	0.538	2 (1)	0.504	1 (0)	0.778	4 (2)	0.786
	Out	1 (1)		3 (1)		1 (1)		4 (1)	
Dinner Station	In	1 (0)	0.427	5 (2)	0.855	6 (4)	0.373	4 (1)	0.187
	Out	2 (1)		5 (2)		3 (1)		3 (1)	
Lower Squaw Creek	In	6 (2)	0.861	124 (57)	0.343	9 (4)	0.781	71 (12)	0.829
	Out	6 (1)		66 (25)		8 (2)		66 (46)	
Upper Squaw Creek	In	8 (2)	0.365	26 (7)	0.936	4 (1)	0.192	41 (2)	0.043
	Out	6 (1)		25 (5)		10 (5)		16 (8)	
Newark Valley #1	In	2 (0)	0.042	6 (5)	0.546	1 (1)	0.380	2 (1)	0.009
	Out	1 (0)		4 (1)		1 (0)		5 (2)	
Newark Valley #2	In	1 (0)	0.963	7 (3)	0.028*	< 1 (0)	0.151	< 1 (0)	0.129
	Out	1 (1)		2 (2)		1 (0)		3 (2)	
Paradise Valley #1	In	6 (4)	0.353	17 (3)	0.437	8 (8)	0.662	30 (14)	0.146
	Out	4 (3)		30 (26)		5 (4)		39 (10)	
Paradise Valley #2	In	11 (2)	0.020	76 (23)	0.101	8 (3)	0.469	62 (19)	0.205
	Out	6 (2)		58 (13)		30 (47)		25 (17)	
Pyramid Lake #1	In	4 (5)	0.293	12 (2)	0.011	1 (1)	0.418	19 (5)	0.743
	Out	1 (1)		6 (4)		5 (8)		23 (13)	
Pyramid Lake #2	In	3 (2)	0.794	15 (4)	0.509	3 (2)	0.701	24 (9)	0.964
	Out	2 (2)		11 (6)		4 (3)		24 (11)	
Zenobia	In	2 (1)	0.115	18 (6)	0.096	1 (1)	0.527	19 (4)	0.179
	Out	1 (1)		50 (24)		2 (0)		35 (18)	
Wadsworth	In	2 (1)	0.491	28 (12)	0.261	2 (3)	0.777	9 (3)	0.802
	Out	1 (1)		11 (8)		3 (0)		9 (4)	
Ward Mountain	In	1 (0)	0.608	2 (1)	0.027	1 (0)	0.936	3 (3)	0.474
	Out	2 (3)		4 (1)		1 (0)		4 (1)	
Wellington	In	3 (1)	0.802	17 (3)	0.143	1 (1)	0.273	5 (3)	0.046
	Out	3 (1)		21 (4)		2 (2)		11 (5)	

little change. This is a basic principle of the Dyksterhuis Range Classification Model (Stoddart et al 1975). Similarly, recruitment in semiarid systems is often episodic (Went 1955; Chew and Chew 1965; West et al 1979; Perryman et al 2001), and stable species composition states might persist for long periods of time until some series of events occur (Laycock 1991).

Greater densities outside than inside exclosures might be a result of seed dispersal and seed-to-soil contact improvements resulting from foraging and associated behavior of grazing animals. In the 2 instances in which cheatgrass density was different, density was greater inside than outside exclosures. Protection from grazing for 65 years has not prevented cheatgrass invasion. Wagner et al (2001) discovered the same phenomenon with medusahead rye (*Taeniatherum asperum* [Simonkai] Nevski) in a northeast California exclosure. Anecdotal and documented evidence (Johnson-Barnard 1995) from exclosures in Wyoming indicated that cheatgrass density was often greater inside exclosures than outside. Litter accumulations trend higher in ungrazed areas (Perryman et al 2002) and could serve as refugia for cheatgrass seeds.

Vertical Structure and Live Plant Census

Shrubs were taller inside exclosures at 3 sites (mean ± SE): Dinner Station (33 ± 7 cm inside, 22 ± 4 cm outside), Paradise Valley #1 (55 ± 7 cm inside, 47 ± 15 cm outside), and Ward Mountain (21 ± 3 cm inside, 8 ± 3 cm outside). Perennial grass heights were not different. Where shrub height differences occurred, shrubs were taller inside exclosures. Two allotments where exclosures were located (Dinner Station and Ward Mountain) were grazed by sheep for several months each season for the past few decades (Table 2). (Bureau of Land Management documentation of allotment grazing history where the Paradise Valley #1 exclosure is located was unclear prior to 1986, but anecdotal evidence indicated it had also been grazed by sheep before the 1970s.) Shorter shrub morphology would be expected with sheep grazing. Johnson-Barnard (1995) identified the same response in southwest Wyoming exclosures. Vertical structure is an important wildlife habitat characteristic and can be affected by domestic livestock grazing.

A live plant census of shrubs and perennial grasses conducted in 2002 indicated that 5 sites had 1% dead plants inside and outside exclosures, and 11 sites had no dead plants for

Table 6. Mean (SE) cheatgrass cover, density, and probability values (P) inside (In) and outside (Out) exclosures in 2001 and 2002.

		2001				2002			
Location	Exclosure	Cover (%)	P	Density (plants/m^2)	P	Cover (%)	P	Density (plants/m^2)	P
Baker	In	1 (0)	0.169	2 (2)	0.458				
	Out	<1 (0)		1 (1)					
Conner's Station	In	1(0)	0.082	7 (1)	0.023				
	Out	<1 (0)		2 (2)					
Cushman Well	In					1 (1)	0.756	2 (1)	0.709
	Out					1 (1)		2 (1)	
Lower Squaw Creek	In	5 (4)	0.971	108 (67)	0.814	7 (4)	0.525	38 (6)	0.184
	Out	5 (1)		89 (59)		5 (2)		51 (1)1	
Upper Squaw Creek	In	1 (1)	0.661	9 (3)	0.045	1 (0)	0.055	6 (1)	0.096
	Out	<1 (0)		1 (0)		<1 (0)		3 (2)	
Newark Valley #1	In	1 (1)	0.169	3 (2)	0.229	1 (0)	0.061	2 (1)	0.039
	Out	<1 (0)		1 (0)		1 (0)		1 (0)	
Paradise Valley #1	In	<1 (0)	0.965	1 (1)	0.527	1 (0)	0.588	13 (6)	0.087
	Out	<1 (0)		2 (1)		1 (1)		23 (10)	
Paradise Valley #2	In	4 (2)	0.237	30 (10)	0.101	<1 (0)	0.737	18 (5)	0.704
	Out	2 (2)		8 (4)		1 (0)		15 (7)	
Pyramid Lake #1	In	1 (1)	0.389	7 (2)	0.278	1 (1)	0.220	12 (4)	0.826
	Out	<1 (0)		5 (4)		<1 (0)		14 (1)	
Pyramid Lake #2	In	1 (0)	0.870	14 (3)	0.513	1 (0)	0.068	10 (4)	0.439
	Out	1 (0)		10 (7)		<1 (0)		15 (5)	
Zenobia	In	2 (1)	0.389	17 (6)	0.096	3 (1)	0.202	26 (15)	0.743
	Out	1 (1)		50 (23)		1 (1)		31 (5)	
Wadsworth	In	1 (0)	0.759	29 (12)	0.216	1 (1)	0.088	20 (7)	0.059
	Out	10 (1)		10 (7)		<1 (0)		11 (5)	
Wellington	In	1 (0)	0.991	15 (6)	0.925	1 (0)	0.335	6 (1)	0.376
	Out	1 (0)		15 (4)		1 (0)		9 (4)	

comparison; therefore, values were equal for all sites. Grazing and grazing exclusion has no measurable effect on plant mortality.

Aboveground Biomass Production

An assessment of herbaceous aboveground biomass production was made at only 8 sites because of drought conditions and minimal production levels during 2002. Production at Upper Squaw Creek (43 ± 11 kg/ha inside, 9 ± 8 kg/ha outside) was greater inside than outside the exclosure because of recent accidental domestic livestock use outside the exclosure just before sampling. With a worldwide data set, Milchunas and Lauenroth (1993) predicted increases in aboveground net primary production with grazing under conditions of long evolutionary history, low consumption rates, and low aboveground net primary production potentials (conditions characteristic of Great Basin plant communities). Our results do not directly support their conclusion but do indicate that the grazing disturbances our systems have been subjected to over the past 6 decades have had no measurable effect on herbaceous aboveground biomass production potentials.

Species Diversity

Shannon-Weaver index value differences were detected for Lower Squaw Creek, Paradise Valley #2, Pyramid Lake #1, Upper Squaw Creek, and Wadsworth (Table 7). Three sites had greater index values outside the exclosures, and 2 sites had greater index values inside; however, species richness differences were relatively small, ranging between 1 and 4 species. This relatively small richness difference and a review of the raw data confirmed that diversity index value differences were caused primarily by the evenness or relative proportion component in the index equation. Percent composition similarity for these 5 exclosure sites ranged between 78% and 97%.

Species richness results were variable depending on the site (Table 7). Eight sites had greater richness outside, 6 had greater richness inside, and 2 had equivalent species numbers. Richness never varied > 4 species at any site. Species composition similarity between inside and outside exclosures ranged between 63% and 97% (Table 7). Only the simple majority of sites in this study had greater species richness outside the exclosure. Although Hart (2001) concluded that species richness and diversity in shortgrass prairie trended higher in moderately grazed plots compared with ungrazed plots in a 55-year-long study, we found no such trend on these shrub-dominated sites. Although lower species richness in areas completely excluded from large ungulate grazing has been noted since at least the 1930s (Larson and Whitman 1942), and Fuhlendorf and Engle (2001) proposed new grazing scenarios to foster diversity in Great Plains grasslands, our results were

Table 7. Shannon Weaver Index values (H′), degrees of freedom (df), probability values (*P*), species richness, total species, shared species and percent similarity ([number of shared species/total species] × 100) inside and outside Nevada plot exclosures, in 2002.

Location	Exclosure	H′	df	*P*	Species richness	Total species	Shared species	Similarity (%)
Baker	In	0.291	10	0.877	8	12	8	66
	Out	0.310			12			
Conner's Station	In	0.300	19	0.154	14	15	12	80
	Out	0.484			15			
Cushman Well	In	0.340	14	0.277	22	25	21	84
	Out	0.470			24			
Dinner Station	In	0.520	35	0.925	10	11	9	81
	Out	0.512			10			
Lower Squaw Creek	In	0.767	17	0.005	12	26	21	81
	Out	0.461			13			
Upper Squaw Creek	In	0.390	58	0.003	30	32	27	84
	Out	0.652			33			
Newark Valley #1	In	0.164	15	0.093	10	11	8	73
	Out	0.362			9			
Newark Valley #2	In	0.015	8	0.161	5	6	4	66
	Out	0.120			5			
Paradise Valley #1	In	0.450	73	0.213	11	14	10	71
	Out	0.340			10			
Paradise Valley #2	In	0.800	50	0.008	36	40	31	78
	Out	0.480			32			
Pyramid Lake #1	In	0.620	35	0.034	45	47	42	90
	Out	0.390			42			
Pyramid Lake #2	In	0.600	23	0.097	34	33	29	88
	Out	0.800			30			
Zenobia	In	0.673	26	0.059	15	18	13	72
	Out	0.460			16			
Wadsworth	In	0.505	36	0.019	28	29	28	97
	Out	0.699			30			
Ward Mountain	In	0.102	20	0.513	11	13	9	70
	Out	0.170			12			
Wellington	In	0.250	26	0.627	6	8	5	63
	Out				7			

variable. Species richness and similarity differences between paired areas are often variable by year and spatial arrangement on the landscape and should fall within a natural range of variation because most plant communities are dynamically affected by amount and timing of precipitation and seed dispersal events that differentially favor selected species (Perryman et al 2002). A few species of difference might not indicate a difference at all and might even be an artifact of observer bias and species area curve influences. A longer term assessment of diversity is needed to delineate the natural range of variation.

Conclusions

The purpose of this project was to conduct an assessment of the vegetation characteristics on 16 Nevada Plot exclosure sites both inside and outside each exclosure after 65 years of livestock exclusion. The original hypothesis was that there would be no difference in vegetation parameters inside and outside grazing exclosures. Few differences were indicated for cover and density. Cheatgrass proliferation inside exclosures might indicate a potential problem if moderate, regular, large ungulate herbivory disturbance was terminated in low-density cheatgrass areas of the Great Basin, but more research is needed to answer this question. Herbivory exclusion has not conclusively increased species richness, but at the simple majority of sites, richness was greater under grazing. It is also important to note that this study was conducted during a period of low precipitation (National Oceanic and Atmospheric Association 2003). If differences are detectable, they should be more pronounced during times of stress.

Although exclosed areas do not exemplify the "original" condition that would have existed prior to introduction of domestic livestock, these exclosed sites do serve as indicators of vegetation change and recovery from pre-Taylor grazing overuse and are expected to correspond with potential natural vegetation trends (USDA 1982). However, it is important to understand that these communities could have been driven across thresholds into new stable states prior to Taylor regulation or have transitioned across composition thresholds during the intervening period. Stable plant community states can persist indefinitely without additional energy inputs (Laycock 1991). For this assessment, few changes in vegetation characteristics between the inside and outside of exclosures have occurred in 65 years, indicating that recovery rates have been similar under moderate grazing and exclusion.

The live plant census reported few dead shrub and grass plants, but the vegetation inside exclosures often exhibited decadent growth characteristics. Sagebrush and other shrubs inside exclosures might be approaching their life expectancy, and changes caused by the removal of herbivory might not have reached a detectable level. Long-term climatic changes can also affect patterns of dominance and species composition (Tausch et al 1993); however, 65 years is a meaningful period of time with respect to management.

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