Vegetation and Livestock Exclusion in the Sagebrush Steppe

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INTRODUCTION

Removal of domestic livestock has been suggested as a method to improve the ecologic condition of rangelands. This recommendation is based on the hypothesis that domestic livestock grazing does not irreversibly alter the plant communities' natural character and ecologic processes. Many livestock exclosures have been established across the western United States to test this hypothesis. With the establishment of the Northern Great Basin Experimental Range in 1936, 13 long-term livestock exclosures were established to monitor plant community response to removal of grazing pressure.

When the exclosures were established in 1936, range condition was poor over much of the experimental range. Plant communities had been subjected to season long continuous grazing since the introduction of cattle and sheep in the late 1800s. Sandberg's bluegrass and big sagebrush were the dominants in most of the plant communities. Periodic sampling of the exclosures since 1937 has found increases in plant density and cover on the experimental range, both inside and outside the exclosures (Rose *et. al.* 1993, Sneva *et. al.* 1984,Tueller 1962).

The current study is a more extensive examination of the plant community response to livestock exclusion in the Wyoming big sagebrush zone of the experimental range. In this study we further test the hypothesis that removal of domestic livestock will improve the ecological condition of native rangelands. We will test this hypothesis using plant density, cover, and standing crop.

Study Site

The study was conducted at the Northern Great Basin Experimental Range (NGBER) in Harney County, Oregon approximately 36 miles west of Burns. The experimental range is jointly operated by the USDA-ARS and Oregon State University Agricultural Experiment Station. The vegetation is representative of the northern Great Basin sagebrush steppe. Elevation of the NGBER ranges from 4200 ft to over 5500 ft above sea level. Climate for the is semi-arid, with cold and wet winters and hot and dry summers. Precipitation averages 11.3 inches per year, with over 80 percent of that falling between September and June. Mean January temperatures is 27° F and mean July temperature is 67°F.

Vegetation on the experimental range is dominated by western juniper (*Juniperus occidentallis* Hook.), low sagebrush (*Artemisia arbuscula* Nutt.) and big sagebrush (*Artemisia tridentata* Nutt.). Bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), Idaho fescue (*Festuca idahoensis* Elmer), Thurber's needlegrass (*Stipa thruberiana* Piper) and

Sandberg's bluegrass (*Poa sandbergii* Vasey) are the principal bunchgrasses. There are a wide variety of forbs present. Prairie lupine (*Lupinus lepidus* Doug.), speckle-pod locoweed (*Astragalus luntiginosus* Doug. ex Hook.), western hawksbeard (*Crepis occidentalis* Nutt.), bigseed lomatium (*Lomatium macrocarpum* (Nutt.) Coult. and Rose) and Menzie's larkspur (*Delphinium menziesii* DC.) are common perennial forbs throughout the experimental range. Annual forbs present include autumn willowweed (*Eppilobium paniculatum* Nutt. ex T. & G.), littleflower collinsia (*Collinsia parviflora* Lindl.), Microsteris (*Microsteris gracilis* (Hook.) Greene), and desert alyssum (*Alyssum desertorum* Stapf.).

Soils are of volcanic origin and are classified as mollisols or aridisols. Depth to bedrock varies from 2 to 4 feet, and a cemented horizon can usually be found to about 2.5 feet.

The experimental plots were established in three of the six, 160 ac pastures (ranges 8, 9, 10) near the center of the experimental range . These 160 ac pastures are the most uniform exclosures in the Wyoming big sagebrush type (*Artemisia tridentata* ssp. *wyomingensis* Beetle) in terms of vegetation and soils. In 1990, an additional exclosure was added adjacent to each of the 1936 exclosures in the 1960 ac pastures.

METHODS

Within each pasture, plant cover, density and standing crop were sampled inside and outside of the 1936 exclosures. Sampling was conducted in Late April thru mid June of 1992 and 1993. Plant cover was determined using the line intercept method using six, 98 ft (30 m) transects. Shrub density was determined using a 646 m^2 (6.6 ft x 98 ft) plot. Plant density and cover were determined by placing 10, 2.2 ft^2 (0.2 m^2) plots along the cover transect (one every 9.8 ft (3 m). Cryptogamic soil crust cover was estimated visually from within the 2.2 ft^2 (0.2 m^2) density plots. Every other density plot was clipped to determine net above ground primary production.

Plots were arranged in a randomized complete block design, with two grazed and ungrazed treatments in each of the three blocks. Data were analyzed using PROC ANOVA in the SAS statistical package (SAS 1986).

RESULTS AND DISCUSSION

The two years of the study were dramatically different in annual precipitation. Annual precipitation was 9.6 inches in 1992 and 21.1 inches in 1993. Precipitation in 1993 was a record for the over 50 years of data at the experimental range and nearly double the long-term average of 11.3 inches. As a result, where the year effect is significant cover, and density were always greater in 1993 than in 1992.

Plant Cover

Total plant and shrub cover were significantly higher inside of the exclosures than outside in 1992 and 1993 (Table 1). Wyoming big sagebrush cover was greater inside the exclosures than outside, but the cover of green rabbitbrush was greater outside of the exclosures. Shrub cover results from early studies, including all of the exclosures (Rose *et. al.* 1993, Sneva *et. al.* 1984, Tueller 1962), showed no significant difference in total and total shrub cover.

Total grass cover inside the exclosures was significantly greater than outside during both years of the study (Table 1). Sandberg's bluegrass was the only grass species in which we found treatment differences, and only in 1992. There was no difference in Sandberg's bluegrass cover in 1993. Cover values for the grazed plots were slightly greater than the excluded plots. This low-growing perennial grass has often been found to increase with grazing. Better growing conditions in 1993 may have reduced the differences between the grazed and excluded plots.

Total forb cover was significantly higher outside of the exclosure in 1992, but significantly higher inside of the exclosures in 1993. No single forb species showed significant response to position (Table 1). Western hawksbeard, larkspur, big seed lomatium, and longleaf phlox all tended to have greater cover outside the exclosure than inside.

Soil cryptogamic cover was greatest inside the exclosure in both years of the study (Table 1). These findings are consistent with other studies from across the west (Anderson *et. al.* 1982, Archer and Smeins 1991) These small lichens, fungi, algae and mosses occupy the upper two inches and are thought to play some role in nutrient cycling of semi arid ecosystems (Rychert *et. al.* 1978). Their location close to the soil surface makes them very susceptible to physical disturbance.

Plant Density

Total shrub, Wyoming big sagebrush and green rabbitbrush density was not significantly different inside and outside the exclosures (Table 2). Density of granite gilia was greater in the exclosures than in the grazed areas. In a study from Utah (West *et. al.* 1984) and earlier studies from the Northern Great Basin Experimental Range (Rose *et. al.* 1993, Sneva *et. al.* 1984, Tueller 1962), granite gilia decreased under grazing pressure. This small shrub from the phlox family is a minor component of the plant community both inside and outside of the exclosures. Granite gilia is relatively palatable and not very resistant to grazing. There was a trend for more Wyoming big sagebrush outside of the exclosures than inside, but the data was not significant.

Total grass, perennial grass, and cheatgrass (the only annual grass found during the study) density was similar in and out of the exclosures (Table 2). Prairie junegrass was the only species to exhibit significant differences between exclosure location. In 1993, prairie junegrass density was greatest in the grazed areas. This grass is often considered sensitive to grazing, therefore these results were surprising. Sandberg's bluegrass, Idaho fescue, and bottlebrush squirreltail also had greater density outside of the exclosures compared to inside, but the data was not statistically significant. Although Sandberg's bluegrass is a small stature plant, its density was 46 percent to 55 percent of the total grass density and 25 percent to 45 percent of the total grass cover. This plant is often considered a lower seral plant, common in moderate to heavily disturbed areas of the sagebrush steppe. The abundance of it across the Northern Great Basin Experimental Range may be attributed to the past grazing history of the station.

Cheatgrass was the only annual grass encountered in the exclosure study (Table 2). Its density was 4 percent to 5 percent of the total in 1992 and 7 percent to 9 percent or the total in 1993. The increased precipitation probably helped increase its density. Continued monitoring in 1994 will help to determine if this increase is is correlated with the high precipitation in 1993. Past work has found cheatgrass to be only a minor component at the NGBER (EOARC file data).

Perennial forb density, comprised mainly of specklepod locoweed, Menzie's larkspur, western hawksbeard, and bigseed lomatium, was greatest outside the exclosures in 1992, but not different between treatments in 1993 (Table 2). Bigseed lomatium density was greater outside than inside the exclosures in both years of the study. Specklepod locoweed density was greater outside the exclosures than inside in 1993, but in 1992 there was no difference between the two locations. Western hawksbeard was the only perennial forb to have significantly greater density inside than outside the exclosure during both years of the study. Menzies larkspur also had significantly greater density inside than outside the exclosures, but only in 1992. Cover and density of western hawksbeard density has also been found to be greatest inside the exclosures across the experimental range (Rose *et. al.* 1993), possibly indicating sensitivity to grazing. However, Menzie's larkspur, a poisonous plant, also had greater densities inside compared to outside of the exclosures. A possible answer is that the livestock are not consuming clinical quantities of the plant, but are consuming enough to reduce its density. The actual numbers of plants consumed may be low.

Annual forbs constitute the majority of plants found in the density plots (Table 2). Their total density was greatest outside of the exclosure. Little flower collinsia, microsteris, and desert alyssum were the three most prominent annual forbs. Microsteris and desert alyssum density was greater outside than inside of the exclosures in 1992 and 1993. Little flower collinsia density was greatest inside the exclosures only in 1993. Density was greater in 1993 than in 1992 for all species of annual forbs. The increase in density in 1993 was probably attributed to the 200 percent increase in precipitation. Density of cryptogamic crusts patches was significantly greater inside the exclosures compared to the grazed areas (Table 2).

Standing Crop

There was no significant difference in standing crop between the two locations

(Table 3). standing crop was significantly greater in 1993 than in 1992. Once again the increased rain fall from 1992 to 1993 had a significant impact on productivity and thus standing biomass standing crop. Litter levels were greater inside of the exclosures than outside, but litter mass was not significantly different from 1992 to 1993.

Species Richness and Diversity

The effect of climate on species composition can be readily seen in the actual abundance data. In 1992 the exclosures and grazed areas had 35 and 36 species respectively (Table 4). In 1993, there was an increase in actual number of species. A 12 species increase occurred in the exclosures and a 7-species increase in the grazed areas. In the vegetation in 1993, there were 11 annual forbs and 3 perennial forbs not found in 1992, but there was 1 annual forb and 1 fungi present in 1992 not found in 1993. This resulted in a net change of 12 species. However actual abundance data can be misleading. The "new" species found in 1993 may have been there in 1992, but unfavorable conditions did not permit them to express themselves.

Species richness indices show that there is little difference between grazed and ungrazed locations and that the sites are fairly rich in species (Table 4). The Margalef and Menhinick indices increased for both treatments from 1992 to 1993. Richness indices take into account the number of species present and the sample size, but do not take into account how the species relate to each other in the community.

Pielou's Index and the modified Hill ratio are a measure of evenness or how species abundance is distributed among the species in a community. As the indices approach 1, then a single species would become very abundant and the density of the rest of the species would decline. For example, in a simple plant community with 10 plant species (A thru J) and a random sample of 100 plants the evenness value would be close to 0 if 91 of the samples were from species A and the remaining 9 samples were species B thru J. The evenness values would be close to 1 if all 10 species were represented by 10 samples each. Peilou values for all locations and years are above 0.84, indicating that the communities are fairly even. The modified Hill ratio also indicates that the communities are fairly even, with values between 0.70 and 0.87. Both indexes showed a reduction in evenness from 1992 to 1993. This reduction is related to the increase in annual plant density in 1993 due the increased precipitation. Annual forb density increased 40 percent outside and 130 percent inside the exclosures. Year seemed to have a more dramatic affect on the evenness of the communities than treatment.

Diversity measures incorporate species richness and evenness into a single index. Species diversity measures indicated little difference between the grazed and excluded sites and from year to year (Table 4). Simpson's Index indicates that the grazed plots were a slightly more diverse, but Shannon's Index showed the opposite trend. Simple communities have Simpson's Indices approaching 1 and Shannon's Indices approaching 0.

SUMMARY

This study reports the results of 57 years of livestock exclusion for Wyoming bigsagebrush communities in the northern Great Basin. When exclosures were established in 1936, the rangeland was dominated by Wyoming big sagebrush and Sandberg's bluegrass, and was considered to be in poor condition. The vegetation had changed dramatically from the time the exclosures were established. Today high seral perennial grasses are a major component of the current communities. Although there are subtle differences between exclosures and grazed areas, the diversity, herbaceous plant biomass, cover and density were not dramatically different. Averaged over the two years of the study, cover of grasses was 6 percent higher inside the exclosure and density was 5 percent higher outside of the exclosure. In general, our results indicate that cover is higher inside the exclosures and density is slightly higher in the grazed areas.

Cryptogamic soil crusts appeared to fare better inside the exclosures. Their fragile nature may not hold up to the physical disturbance. These organisms are active during the short time of the year when soil surfaces are moist. Negative impacts to these organisms may be reduced by grazing areas with extensive soil crusts after the soil surface is dry.

Removal of livestock grazing does not appear to have drastic effects on the Wyoming big sagebrush communities of the NGBER. Most studies examining livestock exclusion and adjacent grazed areas compare excluded areas with heavily grazed areas. The NGBER has had moderate grazing regime since its establishment. This moderate use may not be heavy enough to produce significant differences.

The below-normal in 1992, and near-twice normal precipitation in 1993 are two dramatically different years. Yet under these conditions, the general trends in the data remained consistent over the two years. Chambers and Norton (1993) found the negative affects of grazing during a drought occurred primarily under heavy grazing (Chambers and Norton 1993). As stated previously, the grazing has been moderate since the establishment of the station. This level of use has allowed the vegetation to improve from the original 1936 conditions. Complete protection from livestock grazing may be relatively ineffective in the reduction of sagebrush and increase in herbaceous biomass because of the long life and competitive nature of sagebrush (Daddy *et. al.* 1988).

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Table 1. Percent plant cover of major vegetation groups and selected species for 1992 and 1993. Northern Great Basin Experimental Range.

	1992		1993	
	Outside	Inside	Outside	Inside
	%	%	%	%
Total Vegetation	22.0Aa*	25.3Ba	26.9Ab	30.9Bb
Total Shrub	12.7Aa	16.8B	15.8Ab	17.1B
Wyoming Big Sagebrush	9.6A	14.8B	12.3A	8.3B
Green Rabbitbrush	2.9A	1.8B	3.2A	1.5B
Granite Gilia	0.01A	0.2B	0.01A	0.2B
Total Grass	6.4Aa	6.6Ba	7.6Ab	8.3Bb
Bluebunch Wheatgrass	1.0	1.0	1.1	1.0
Idaho Fescue	0.8	0.5	0.8	1.0
Prairie Junegrass	0.3	0.1	0.4	0.5
Sandberg's Bluegrass	2.4A	1.6B	3.2	3.1
Bottlebrush Squirreltail	0.7	0.6	0.8	0.4
Thurber's Needlegrass	1.2	2.7	1.1	2.4
Total Forbs	1.84a	2.87a	1.51b	3.21b
Western Hawksbeard	0.23	0.49	0.80	0.90
Menzie's Larkspur	0.22	0.31	0.35	0.87
Bigseed Lomatium	0.65	0.26	0.49	0.73
Longleaf Phlox	0.45	0.19	0.60	0.36

*Upper case letters indicate significant differences between exclosure locations within year and lower case letters indicate significant differences between years within exclosure location.

Table 2. Plant density (# / 10 ft^2) of major vegetation groups and selected species for 1992 and 1993. Northern Great Basin Experimental Range.

	1992		1993	
	Outside	Inside	Outside	Inside
	# / 10 ft^2	# / 10 ft^2	# / 10 ft^2	# / 10 ft^2
Total Shrub	0.95	0.84	0.94	0.83
Wyoming Big Sagebrush	0.68	0.52	0.68	0.53
Green Rabbitbrush	0.21	0.20	0.21	0.18
Granite Gilia	0.04A	0.10B	0.04	0.11
Total Grasses	25.99	23.03	23.38	24.12
Perennial Grasses	24.62	21.00	21.26	22.99
Bluebunch Wheatgrass	2.07	1.01	0.88	1.13
Idaho Fescue	1.13	0.75	0.75	0.93
Prairie Junegrass	0.63a	0.40	1.33Ab	0.35B
Sandberg's Bluegrass	12.75	12.70	11.16	11.97
Bottlebrush Squirreltail	2.424	1.540	1.313	1.742
Thurber's Needlegrass	5.606	5.556	4.343	5.758
Perennial Forbs	22.172A	15.051B	17.551	16.641
Specklepod Locoweed	1.212a	1.263	3.081Ab	0.981B
Menzie's Larkspur	1.49A	2.65B	1.38	2.02
Bigseed Lomatium	2.57Aa	1.91Ba	2.24Ab	1.03Bb
Western Hawksbeard	1.41Aa	2.02Ba	0.63Ab	1.33Bb
Annual Forbs	97.50Aa	53.76Ba	136.59Ab	122.04Bb
Desert Alyssum	44.06Aa	12.42Ba	68.01Ab	31.79Ba
Littleflower Collinsia	35.91a	29.67a	27.50Ab	55.76Ab
Microsteris	9.44Aa	5.78Ba	27.25Ab	19.54Bb
Cryptogamic Crusts	3.33Aa	16.54Ba	7.10Ab	13.79Bb

*Upper case letters indicate significant differences between exclosure locations within year and lower case letters indicate significant differences between years within exclosure location.

Table 3. Standing biomass of major vegetation groups for 1992 and 1993. Northern Great Basin Experimental Range.

	1992		1993	
	Outside	Inside	Outside	Inside
Total	203.5a	231.1a	495.0b	468.6b
Total Grasses	148.5a	137.5a	335.1b	311.1b
Perennial Grasses	145.6a	135.2a	325.0b	300.9b
Cheatgrass	2.9a	2.3a	10.1b	10.2b
Total Forbs	55.0a	93.6a	159.9b	157.5b
Perennial Forbs	37.4	47.8	60.4	68.7
Annual Forbs	17.6a	45.8a	99.5b	88.8b
Litter	122.7A	249.6B	131.3A	252.5B

*Upper case letters indicate significant differences between exclosure locations within year and lower case letters indicate significant differences between years within exclosure location.

Table 4. Plant species richness, diversity and evenness for plant communities inside and outside the exclosures. Northern Great Basin Experimental Range.

	1992		1993	
	Outside	Inside	Outside	Inside
Actual Abundance	36	35	43	48
Species Richness				
Margelef - R_1	7.645	7.872	9.338	9.972
Menhinick - R_2	3.649	4.039	4.537	4.668
Species Diversity				
Simpson's - λ	0. 051	0.050	0.058	0.042
Shannon's - H'	3.155	3.136	3.192	3.363
Species Evenness				
Pielou - J'	0.881	0.882	0.874	0.849
Modified Hill Ratio	0.864	0.833	0.813	0.702

Figure 1. Map of original pastures at the Northern Great Basin Experimental Range