

Research Note

Long-Term Vegetation Trends on Grazed and Ungrazed Chihuahuan Desert Rangelands

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Abstract

Long-term information on the effects of managed grazing versus excluded grazing effects on vegetation composition of desert rangelands is limited. Our study objectives were to evaluate changes in frequency of vegetation components and ecological condition scores under managed livestock grazing and excluded livestock grazing over a 38-yr period at various locations in the Chihuahuan Desert of southwestern New Mexico. Sampling occurred in 1962, 1981, 1992, 1998, 1999, and 2000. Range sites of loamy (1), gravelly (2), sandy (2), and shallow sandy (2) soils were used as replications. Black grama (*Bouteloua eriopoda* Torr.) was the primary vegetation component at the seven locations. Dyksterhuis quantitative climax procedures were used to determine trends in plant frequency based on a 1.91-cm loop and rangeland ecological condition scores. Frequency measures of total perennial grass, black grama, tobosa (*Hilaria mutica* Buckley), total shrubs, honey mesquite (*Prosopis glandulosa* Torr.), and other vegetation components were similar on both grazed and ungrazed treatments ($P > 0.1$) at the beginning and end of the study. The amount of change in rangeland ecological condition scores was the same positive increase (14%) for both grazed and ungrazed treatments. Major changes ($P < 0.1$) occurred within this 38-yr study period in ecological condition scores and frequency of total perennial grasses and black grama in response to annual fluctuations in precipitation. Based on this research, managed livestock grazing and excluded livestock grazing had the same long-term effects on change in plant frequency and rangeland ecological condition; thus, it appears that managed livestock grazing is sustainable on Chihuahuan desert rangelands receiving over 25 cm annual precipitation.

Resumen

Existe poca información sobre los efectos que tiene el pastoreo a largo plazo sobre las áreas pastoreadas contra áreas excluidas en la composición de la vegetación en pastizales desérticos. Los objetivos de este estudio fueron la evaluación de los cambios en la frecuencia de los componentes de la vegetación así como el estado de la condición ecológica bajo condiciones de pastoreo y de la exclusión del mismo sobre un periodo de 30 años en varias localidades en el desierto Chihuahuense en el suroeste de Nuevo México. Los muestreos se llevaron a cabo durante 1962, 1981, 1992, 1998, 1999, y 2000. Diferentes sitios del pastizal con suelos (1) arcillosos, con grava (2), arenosos (2) y arenosos superficiales (2) se utilizaron como repeticiones. La especie navajita negra (*Bouteloua eriopoda* Torr.) fue el componente principal de la vegetación en las siete localidades. Se utilizó la técnica cuantitativa del clímax de Dyksterhuis para determinar la tendencia en la frecuencia de las plantas basándose en un cuadrante de 1.91 cm y las condiciones ecológicas del pastizal. Las medidas de frecuencia de las gramíneas perennes navajita negra, toboso (*Hilaria mutica* Buckley) total de arbustivas, mezquite (*Prosopis glandulosa* Torr.) y otros componentes de la vegetación fueron similares en ambos tratamientos ($P > 0.1$) pastoreo o sin pastoreo al inicio y al final del estudio. La cantidad del cambio en el estado de la condición ecológica del pastizal se incrementó positivamente (14%) para ambos tratamientos, pastoreo o sin pastoreo. Los cambios principales ($P < 0.1$) que se produjeron durante este periodo de 38 años del estudio en las puntuaciones de la condición ecológica y la frecuencia del total de las gramíneas perennes y navajita negra en respuesta a las fluctuaciones anuales de la precipitación. Basándose en esta investigación, el manejar el pastoreo del ganado o excluirlo tienen los mismos efectos a largo plazo sobre el cambio en la frecuencia de las plantas y la condición ecológica del pastizal, por lo tanto, parece que el manejo del pastoreo es sustentable en los pastizales del desierto Chihuahuense que reciben más de 25 cm de precipitación anual.

Key Words: drought, grazing management, range condition, rangelands

INTRODUCTION

Based on a review of 20 studies by Holechek et al. (2006), well-controlled livestock grazing in arid and semiarid areas has a small impact on rangeland vegetation and may be beneficial to some plant communities. However, evaluations of livestock grazing over broad areas and long time periods as it has actually occurred in the western United States are limited to

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Bartolome and Heady (1988), Yorks et al. (1992 and 1994), Herbel and Gibbens (1996), Havstad et al. (1999), Valone et al. (2002), Navarro et al. (2002), Courtois et al. (2004), and Mashiri et al. (2008). These studies have indicated that forage plants can increase in many arid shrubland and woodland areas if soil degradation has not been severe and grazing intensity was kept at light to moderate levels. Additional comparisons of vegetation trends under grazing and grazing exclusion over long time periods across broad landscapes in arid areas are needed to help resolve concerns regarding sustainable grazing practices (Wuerthner 1990).

The objective of our study was to evaluate the 38-yr trend in vegetation frequency components and ecological condition with the use of seven locatable Parker sites with paired managed livestock grazing and excluded livestock grazing treatments. These sites were dispersed across the Chihuahuan Desert of southwestern New Mexico. Data were available for 1962, 1981, 1992, 1998, 1999, and 2000. A secondary objective was to evaluate rangeland ecological condition on the paired grazed and ungrazed sites with the use of Dyksterhuis (1949) procedures. We hypothesized that managed grazed and ungrazed treatments would have the same effects on changes in vegetation composition based on plant frequency during our study.

METHODS

Study Area

In 1962, the Bureau of Land Management (BLM) initiated a study to examine the long-term trend in range vegetation in the Chihuahuan Desert of southwestern New Mexico on seven paired livestock grazed and grazing excluded sites. Transects on the various sites were evaluated in 1962, 1981, 1992, 1998, 1999, and 2000.

The majority of the study area lies within the northern end of the Chihuahuan Desert (lat 32°32'30"N 106°, long 52°30'W). The study area is bounded by Texas and Mexico to the south, Arizona to the west, and is traversed by the Rio Grande on the eastern side. This includes 2.7 million ha of US Department of the Interior–BLM–administered public land intermingled with 5.3 million ha of private, state trust, Native American, and other federal lands.

The area is characterized by an arid to semiarid continental climate, with mild winters and hot summers. Most of the study area receives from 26 cm to 35 cm annual precipitation. Annual precipitation variation during the 1950–2000 period (averaged across 20 locations in southwestern New Mexico) ranged from a low of 9.7 cm in 1953 to a high of 44.4 cm in 1986 (Fig. 1). Long-term (1950–2000) average annual precipitation was 28.3 cm. Over half of the annual precipitation arrived as rainfall during July, August, and September. The average frost-free season exceeded 200 days and extended from April to November. The average annual temperature in the area was about 20°C. During the summer months, daytime temperatures may exceed 38°C. Through the year, a daily range of 17°C or more was common. Both the rainfall distribution and temperature regime favor warm season perennial plants.

Typical landforms included rugged and steep fault-block mountain ranges, broad basins, and volcanic uplands. Eleva-

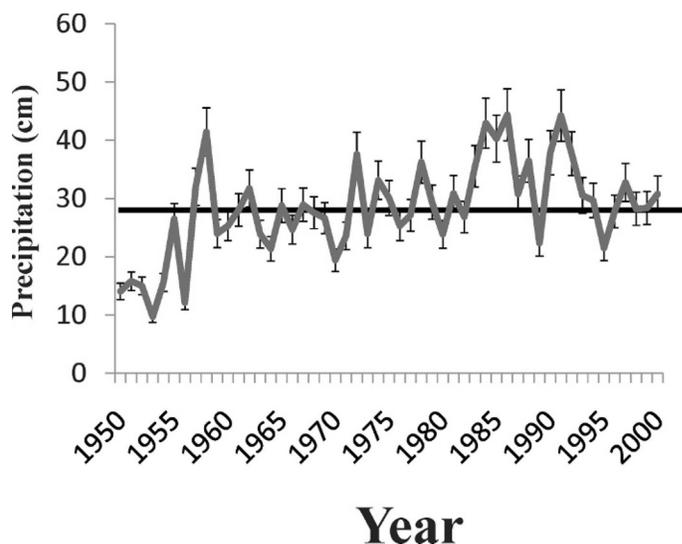


Figure 1. Annual precipitation (cm) in southwestern New Mexico for the years 1950–2000 (National Oceanic and Atmospheric Administration 2000). Bold line indicates average annual precipitation was 28.3 ± 0.4 cm.

tions on BLM-administered public lands range from a low of approximately 1 050 m in the southern Mesilla Valley to a high of over 2 450 m in some of the mountain ranges. Average elevation is approximately 1 370 m. Study sites were in broad basins with an average elevation of 1 436 m.

Vegetation varies greatly in its diversity and herbage yields due to differences in elevation, climate, soils, and topography. Plant communities included desert grasslands, mixed desert shrublands, desert shrublands, mountain brush, and piñon-juniper/oak woodland. Study sites were confined primarily to the desert grasslands. The seven study areas included four major range sites based on US Department of Agriculture–Natural Resources Conservation Service (USDA–NRCS) guides. These were gravelly (2), sandy (2), shallow sandy (2), and loamy (1). These descriptions, recent stocking rates, and forage use levels for the study areas are provided in Table S1 (available at <http://dx.doi.org/10.2111/REM-D-09-00097.st1>), but long-term stocking and use levels over the past 38 yr are unknown. Grazing was applied continuously across the study areas.

Sampling Procedures

Seven different sites well scattered over five counties in southwestern New Mexico were studied. Site selection was based on ease of access, distance from water, soil type, vegetation type, size of pasture, and terrain. Ecotones where soil types and vegetation were in transition were avoided. All study sites were uniform in profile, flat terrain and had similar homogenous plant communities. All sites were within 1.2–1.6 km of permanent water, and were grazed throughout the 38-yr study. An area 1 ha in size was used at each location to study long-term managed grazing and excluded grazing effects on rangeland vegetation. This 1-ha area was evenly divided into two 0.5-ha units for grazed and ungrazed treatments by a barbed wire fence. To exclude livestock and pronghorn antelope (*Antilocapra americana* Ord) from the enclosure, four

Table 1. Mean frequency (percent) \pm standard error of autumn black grama and total perennial grasses for grazed and ungrazed treatments on Chihuahuan Desert rangelands in south-central New Mexico (1962–2000).¹

Year	Black grama frequency		Total perennial grasses frequency	
	Grazed	Ungrazed	Grazed	Ungrazed
1962	4.0 \pm 0.4 B	7.2 \pm 0.7 B	9.1 \pm 0.9 B	11.5 \pm 1.0 B
1981	3.0 \pm 0.3 B	5.1 \pm 0.4 B	9.6 \pm 0.9 B	9.9 \pm 0.9 B
1992	14.1 \pm 1.0 A	24.2 \pm 2.4 A	30.8 \pm 3.0 A	37.5 \pm 3.5 A
1998	1.2 \pm 0.1 B	2.6 \pm 0.3 B	7.0 \pm 0.7 B	5.7 \pm 0.5 B
1999	1.5 \pm 0.1 B	2.7 \pm 0.3 B	5.5 \pm 0.5 B	5.7 \pm 0.5 B
2000	3.7 \pm 0.3 B	3.8 \pm 0.3 B	9.6 \pm 0.9 B	9.7 \pm 0.9 B
Mean	4.6 \pm 0.4	7.6 \pm 0.7	11.9 \pm 1.0	13.3 \pm 1.3

¹Means within columns with different letters differ at $P < 0.1$

strands of barbed wire were used. The top wire measured 1.2 m from the ground and the bottom wire measured 30.5 cm from the ground. Based on our observations of pictures, review of records, and discussions with BLM personnel involved with the sites, we believe the enclosure fences were well maintained at all sites during the study period. We do not believe our study was biased by unplanned grazing of any enclosures.

Five permanent 30.5-m line transects were established both in the enclosures and open grazed experimental areas at each of the seven sites. Plant occurrence inside a 1.91-cm-diameter loop was recorded at 30.5-cm intervals along a tape stretched between two permanent rebar stakes. Data recorded within the loop involved plant presence or absence. Only a single species of herbaceous plants or shrub occurred within the various loop readings at the sites (i.e., multiple plant species did not occur within loop readings). Evaluations were conducted during the dormant period of the year (late fall through early spring). Transect data were collected for the years of 1962, 1981, 1992, 1998, 1999, and 2000.

Range ecological condition scores were calculated for grazed and ungrazed treatments from current USDA–NRCS, New Mexico range site guides using the Dyksterhuis (1949) procedure. Plant frequency within the 1.91-cm loop as an indicator of cover was used instead of biomass in calculating scores. Cover and biomass indices gave similar ecological condition scores across several sites on Chihuahuan Desert rangeland (Molinar 1999).

Statistical Analyses

Plant frequency effects for grazing treatments (2), years (6), and grazing treatment \times year interactions were analyzed with the use of a repeated-measures analysis within PROC MIXED of SAS (Ver. 9.2; Littell et al. 1996). Locations (7) were used as replications. Basically the same group of plant species was encountered at all seven locations. Black grama (*Bouteloua eriopoda* Torr.) was the primary perennial grass at all seven locations based on plant frequency. Therefore we considered it valid to use the seven locations as replications. We also tested replicates as a source of variation in the statistical model; however, it was nonsignificant, and so was omitted. Mean separation tests in these analyses were completed as preplanned pairwise comparisons of least-squares means generated with the PDIF algorithm of SAS. These test were executed with the use of the within option LSMEANS of the mixed procedure.

RESULTS AND DISCUSSION

The main effect of grazing treatment and its interactions with year were nonsignificant ($P > 0.1$) for frequency of perennial plant components. Black grama, the primary decreaser forage grass in southern New Mexico, showed no difference ($P > 0.1$) in frequency among grazed and ungrazed treatments during any period of study (Table 1). Frequency of black grama was similar ($P > 0.1$) in grazed and ungrazed areas at the beginning and end of the study. Parallel results were observed for measures of total perennial grasses, tobosa, burrograss, other perennial grasses, honey mesquite, and total shrubs (Table 2). The primary factor influencing the frequency of plants in this study was year, which was a significant source of variation ($P < 0.1$) for black grama, threeawns, other perennial grasses, broom snakeweed, other shrubs, and total shrubs (Table 2). Therefore, our study was consistent with Paulsen and Ares (1962), Havstad et al. (1999), Navarro et al. (2002), Holechek et al. (2003), and Khumalo and Holechek (2005) in showing that fluctuation in the contribution of species greatly influenced vegetation dynamics in the Chihuahuan Desert. The 1980s and 1990s were the wettest decades in New Mexico during the past 100 yr, and the 1950s were the driest (Fig. 1). Specifically, black grama, other perennial grasses, and total perennial grasses had a sharp increase ($P < 0.1$) in frequency in the 1981–1992 period and then sharply declined in the following years (Table 2). This increase is attributed to several consecutive years of favorable precipitation from 1983 to 1992. At the Chihuahuan Desert Rangeland Research Center in southwestern New Mexico, Khumalo and Holechek (2005) found perennial grass production with a high black grama component nearly quadrupled in 1992 compared to the 34-yr average. This was explained by three consecutive years of well-above-average precipitation (1990–1992).

For rangeland ecological condition score, the grazing treatment and year main effects were significant ($P < 0.1$), but the interaction between grazing treatment and year was nonsignificant ($P > 0.1$; Table S2, available at <http://dx.doi.org/10.2111/REM-D-09-00097.st2>). Throughout our study, rangeland ecological condition was higher ($P < 0.1$) on the ungrazed than on the grazed treatment. Rangeland ecological condition scores were higher ($P < 0.1$) on both grazed (56% remaining climax vegetation) and ungrazed (66% remaining climax vegetation) treatments in 2000 than in 1962 (grazed = 42%,

Table 2. Frequency (percent) \pm standard error main effect of year on various vegetation components for a 38-yr period on Chihuahuan Desert rangelands in south-central New Mexico (1962–2000).¹

Variable	Years					
	1962	1981	1992	1998	1999	2000
Grasses						
Black grama	3.6 \pm 0.3 b	4.0 \pm 0.4 b	19.1 \pm 2.0 a	1.9 \pm 2.0 b	2.0 \pm 0.2 b	4.1 \pm 0.4 b
Tobosa	0.3 \pm 0.03	0.5 \pm 0.03	0.4 \pm 0.03	0.2 \pm 0.01	0.1 \pm 0.01	0.1 \pm 0.01
Threeawns	0.2 \pm 0.02 b	0.9 \pm 0.01 b	4.7 \pm 0.5 a	1.1 \pm 0.1 b	0.8 \pm 0.1 b	1.2 \pm 0.1 b
Burrograss	2.3 \pm 0.2	2.2 \pm 0.2	2.2 \pm 0.2	1.3 \pm 0.1	0.8 \pm 0.1	1.3 \pm 0.1
Other perennial grasses	3.8 \pm 0.3 b	2.1 \pm 0.2 b	8.0 \pm 0.5 a	2.2 \pm 0.2 b	1.9 \pm 0.2 b	2.9 \pm 0.2 b
Total perennial grasses	10.7 \pm 1.0 b	9.7 \pm 1.0 b	34.4 \pm 3.5 a	6.3 \pm 6.0 b	5.6 \pm 5.5 b	9.6 \pm 1.0 b
Annual grasses	0.2 \pm 0.01	0.1 \pm 0.01	0.3 \pm 0.02	0	0	0.2 \pm 0.02
Total grasses	10.4 \pm 1.0 b	9.8 \pm 1.0 b	34.7 \pm 3.5 a	6.4 \pm 6.5 b	5.6 \pm 5.5 b	9.9 \pm 1.0 b
Forbs						
Globemallow	0	0.3 \pm 0.02	0.4 \pm 0.02	0.3 \pm 0.02	0.2 \pm 0.02	0.3 \pm 0.02
Other perennial forbs	0.4 \pm 0.02	0.5 \pm 0.02	0.4 \pm 0.02	0.2 \pm 0.02	0.2 \pm 0.02	0.6 \pm 0.02
Annual forbs	3.5 \pm 0.3 a	0.4 \pm 0.02 b	0.4 \pm 0.02 b	0.1 \pm 0.01 b	0.1 \pm 0.01 b	0.2 \pm 0.02 b
Total forbs	3.9 \pm 0.2 a	1.3 \pm 0.1 b	1.2 \pm 0.1 b	0.6 \pm 0.1 b	0.7 \pm 0.1 b	1.2 \pm 0.1 b
Shrubs						
Snakeweed	0.6 \pm 0.1 b	0.8 \pm 0.1 b	1.3 \pm 0.1 a	0.3 \pm 0.05 b	0.3 \pm 0.05 b	0.7 \pm 0.05 b
Mesquite	0.2 \pm 0.1	0.2 \pm 0.1	0.2 \pm 0.1	0.1 \pm 0.1	0.1 \pm 0.1	0.2 \pm 0.1
Other shrubs	0.1 \pm 0.1	0.2 \pm 0.1	0.4 \pm 0.1	0.2 \pm 0.1	0.1 \pm 0.1	0.2 \pm 0.1
Total shrubs	0.9 \pm 0.1 b	1.0 \pm 0.1 b	1.8 \pm 0.1 a	0.5 \pm 0.01 b	0.4 \pm 0.01 b	1.2 \pm 0.1 b

¹Means within rows with different letters differ at $P < 0.1$.

ungrazed = 52%). The amount of positive change was the same (14% increase in climax vegetation) on both treatments. Therefore, we conclude neither treatment was advantageous in terms of facilitating range improvement.

We acknowledge that our study had experimental limitations. These include a lack of knowledge of actual stocking and grazing-use levels on the seven sites during most of the study, the fact that the loop frequency procedure we used to sample vegetation is an indicator rather than absolute measure of plant cover, the possibilities that our sampling procedure underestimated shrub frequency, that our range condition scores were based on frequency rather than actual cover, and that if our study locations involved closer distances to water the outcome would be altered. On the first limitation, we believe that grazing-use levels were kept at conservative or moderate rates in most years based on the 50-yr observations of BLM range conservationists who worked on the seven study sites. In regard to the second, third, and fourth points, we recognize that the loop procedure used in our study has some biases as an indicator of actual cover as discussed by Hutchings and Holmgren (1959) and Cook et al. (1994). However, studies by Heady et al. (1959), Cook and Box (1961), and Smith (1962) indicate loop sampling can be reliable in reflecting trends in vegetation composition if transect lines are precisely relocated and the loop is carefully plumbed.

It is our interpretation that the loop procedures used in this study adequately reflected plant composition changes through the time period sampled and between the grazed and ungrazed treatments. We allow that shrub frequency on our study could have been underestimated, but do not believe this influenced the outcome of the treatments. Our study locations were

dominated by grasses, and shrubs were a minor component throughout the period of study. We do allow that if our study locations involved closer distances to water the outcome may have been different. However, based on our overall inspection of the pastures and where our study sites occurred, we consider them to be a valid representation of overall grazing pressure. In summary, based on available evidence, we do not believe any bias in our data was large enough for flawed data interpretations and (or) conclusions. Therefore, we accept our hypothesis that grazed and ungrazed treatments had the same effects on vegetation composition change during our study.

MANAGEMENT IMPLICATIONS

Our study and that of Navarro et al. (2002) indicated that livestock grazing as actually practiced in the Chihuahuan Desert of southern New Mexico has been sustainable across large landscapes and extended time periods. In a study similar to ours involving widely scattered sites in the cold desert of Nevada, Courtois et al. (2004) concluded that moderately grazed and ungrazed sites had few differences in plant species composition, cover, density, and production after 65 yr. Studies by Yorks et al. (1992) in the salt desert of Utah and Yorks et al. (1994) on piñon-juniper range in Utah further indicate that livestock grazing as actually practiced has been sustainable on arid and semiarid rangelands in the western United States. Although our research and the other studies previously reviewed indicated managed livestock grazing is sustainable on desert rangeland receiving over 25 cm of precipitation, we recommend more research be conducted on this subject.

LITERATURE CITED

- BARTOLOME, J., AND H. F. HEADY. 1988. Grazing management 1962 to 1986. *In*: The Vale rangeland rehabilitation program: an evaluation. Washington, DC, USA: US Department of Agriculture Forest Service, Research Bulletin PNW-RB-157. 151 p.
- COOK, C. W., AND T. W. BOX. 1961. A comparison of the loop and point methods of analyzing vegetation. *Journal of Range Management* 14:22–27.
- COOK, J. W., W. W. BRADY, AND B. F. ALDON. 1994. The effect of grass plant size on basal frequency estimates. *Grass and Forage Science* 49:414–421.
- COURTOIS, D. R., B. L. PERRYMAN, AND H. S. HUSSEIN. 2004. Vegetation change after 65 years of grazing and grazing exclusion. *Rangeland Ecology & Management* 57:574–583.
- DYKSTERHUIS, E. J. 1949. Condition and management of rangeland based on quantitative ecology. *Journal of Range Management* 2:104–115.
- HAVSTAD, K. M., R. P. GIBBENS, C. A. KNORR, AND L. W. MURRAY. 1999. Long-term influences of shrub removal and lagomorph exclusion on Chihuahuan Desert vegetation dynamics. *Journal of Arid Environments* 42:155–166.
- HEADY, H. F., R. P. GIBBENS, AND R. W. POWELL. 1959. A comparison of the charting line intercept and line point methods of sampling shrub types of vegetation. *Journal of Range Management* 12:180–188.
- HERBEL, C. H., AND R. P. GIBBENS. 1996. Post-drought vegetation dynamics on arid rangelands in southern New Mexico. Las Cruces, NM, USA: New Mexico Agricultural Experiment Station Bulletin 776. 102 p.
- HOLECZEK, J. L., T. T. BAKER, J. C. BOREN, AND D. GALT. 2006. Grazing impacts on rangeland vegetation: what we have learned. *Rangelands* 27:7–13.
- HOLECZEK, J. L., AND D. GALT. 2000. Grazing intensity guidelines. *Rangelands* 22:11–14.
- HOLECZEK, J., D. GALT, J. JOSEPH, J. NAVARRO, G. KHUMALO, F. MOLINAR, AND M. THOMAS. 2003. Moderate and light grazing effects on Chihuahuan Desert rangelands. *Journal of Range Management* 56:133–139.
- HUTCHINGS, S. S., AND R. C. HOLMGREN. 1959. Interception of loop-frequency data as a measure of plant cover. *Ecology* 40:668–677.
- KHUMALO, G. Z., AND J. L. HOLECZEK. 2005. Relationships between Chihuahuan Desert perennial grass production and precipitation. *Rangeland Ecology & Management* 58:239–246.
- LITTELL, R. C., G. A. MILLIKEN, W. W. STROUP, AND W. D. WOLFINGER. 1996. SAS system for mixed models. Cary, NC, USA: SAS Institute, Inc. 656 p.
- MASHIRI, F. B., M. P. McCLARAN, AND J. S. FEHMI. 2008. Short and long-term vegetation change related to grazing systems, precipitation, and mesquite cover. *Rangeland Ecology & Management* 61:368–379.
- MOLINAR, F. 1999. Effect of honey mesquite cover and soil depth on forage production in the Chihuahuan Desert [dissertation]. Las Cruces, NM, USA: New Mexico State University. 184 p.
- NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION. 2000. Climatological data annual summary, New Mexico, 2000. Asheville, NC, USA: National Climatic Data Center. 188 p.
- NAVARRO, J. M., D. GALT, J. HOLECZEK, J. McCORMICK, AND F. MOLINAR. 2002. Long term impacts of livestock grazing on Chihuahuan Desert rangelands. *Journal of Range Management* 55:400–405.
- PAULSEN, H. A., AND F. N. ARES. 1962. Grazing values and management of black grama and tobosa grasslands and associated shrub ranges in the southwest. Washington, DC, USA: US Department of Agriculture, Technical Bulletin 1270. 56 p.
- SMITH, J. G. 1962. An appraisal of the loop transect method for estimating root crown area changes. *Journal of Range Management* 15:72–78.
- VALONE, T. J., M. MEYER, J. BROWN, AND R. M. CHEW. 2002. Timescale of perennial grass recovery in desertified arid grasslands following livestock removal. *Conservation Biology* 16:995–1002.
- WUERTHNER, G. 1990. The price is wrong. *Sierra* 25:38–48.
- YORKS, T. P., N. E. WEST, AND K. M. CAPELS. 1992. Vegetation differences in desert shrublands of western Utah's Pine Valley between 1933 and 1989. *Journal of Range Management* 45:569–578.
- YORKS, T. P., N. E. WEST, AND K. M. CAPELS. 1994. Changes in piñon-juniper woodlands in western Utah's Pine Valley. *Journal of Range Management* 47:359–365.