

***Effects of Historic Livestock Grazing
on Vegetation
at Chaco Culture National Historic Park:***

Final Report

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M. Lisa Floyd-Hanna, Ph.D.

Thomas L. Fleischner, Ph.D.

David Hanna, M.S.

**Environmental Studies Program
Prescott College
220 Grove Avenue
Prescott, Arizona 86301**

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Introduction

Grazing has long been the most widespread land management practice in western North America. Livestock were introduced into the Southwest in the late fifteenth century from Mexico (Stewart 1936, Stoddart and Smith 1943); for almost a century and a half, grazing interests have been embedded in the political and social fabric of the West (Fleischner 1999, Chapter 4). For most of this time, grazing was a foregone conclusion on public lands. But, increasingly, a new ecological understanding—that livestock grazing often has serious consequences—has led to new management dilemmas. Determining how to manage grazing has become one of the most contentious issues facing land managers in the West—for the ubiquity of livestock does not mean that their presence in Western landscapes is benign.

Grazing has been implicated in a host of deleterious ecological relationships: it has reduced the density and biomass of species in a wide range of taxa, reduced biodiversity, aided the spread of alien species, interrupted ecological succession, impeded the cycling of the region's most important limiting nutrient (nitrogen), changed habitat structure, and disturbed elements of community organization (summarized in Fleischner 1994). Concerns about such extensive ecological deterioration led three major scientific societies—the American Fisheries Society, Society for Conservation Biology, and The Wildlife Society—to call for dramatic overhaul of grazing practices (Armour et al. 1991, Fleischner et al. 1994, The Wildlife Society 1996). In addition to the more obvious biological effects of introducing large, heavy herbivores to dry ecosystems, such as reduction of standing biomass, grazing can damage soils and accelerate erosion. Of particular concern is the role of livestock in removing microbiotic (cryptogamic) soil crusts, which provide several ecosystem functions. Most critically, these crusts perform the major share of nitrogen fixation in deserts (Rychert et al. 1978). The availability of nitrogen is a primary factor limiting primary production in arid habitats; in the Great Basin Desert, it is second only to moisture in importance (James and Jurinak 1978). In addition, crusts stabilize soils, retain moisture, and provide germination sites for higher plants. Grazing can disturb

fundamental physical factors in landscapes: for example, in the Sonoran Desert climatologists and ecologists have attributed increasing soil surface temperatures and albedo to grazing-related land degradation (Balling et al. 1998).

Most of the West is grazed—approximately 70% of the 11 western states supports livestock, while rock-and-ice peaks, urban areas, and crop agriculture dominates most of the rest. It can be difficult to identify precise ecological relationships in grazed landscapes for the simple reason that we have precious few ungrazed ecosystems to compare them to. There are virtually no representative sites left in the West that are truly ungrazed; grazing has amounted to a massive experiment without a control (Bock et al. 1993, Noss 1994). Recently, conservation biologists have called for the establishment of a federal system of large livestock exclosures so that we would have a set of ecological benchmarks to study the effects of grazing (Bock et al. 1993). Most of the handful of grazing exclosures throughout the West are on the order of 80 hectares (ha) or less; the conservation biologists' proposal suggested that the minimum size for an effective exclosure should be about 1000 ha.

Livestock were first introduced into the Chaco Canyon area of New Mexico in the last couple decades of the seventeenth century by Pueblo Indians fleeing from the Spanish onto Navajo lands. Livestock husbandry was adopted by the Navajo; large-scale cattle and sheep operations began in 1878 or 1879 (Judd 1954). Grazing by unknown numbers of sheep, goats, and to a lesser degree, cattle continued in the area well into the twentieth century. Chaco Canyon National Monument was established in 1907, but did not affect grazing practices—in fact, the prehistoric ruins of the canyon were often used as sheep corrals. In 1933 Park Custodian Julien noted that lands in the monument were overgrazed, and that livestock should be excluded. The National Park Service began fencing the boundaries of the monument (8600 ha) in 1936, and completed the task in 1948 (NPS 1995, 1998). In 1980 the monument was expanded and converted into Chaco Culture National Historic Park (CCNHP). Fencing of the four new parcels

(amounting to 5000 ha) has been completed from 1995 to the present. Consequently, Chaco currently is one of the largest grazing exclosures in western North America—one of the few that meets the size criterion of the conservation biology proposal for exclosures. There are, then, 8600 ha that have been protected from grazing for 50+ years, and an additional 5000 ha that have been protected for 5 years or less. The entire 13,600 ha exclosure is surrounded by lands that continue to be grazed by Navajo ranchers (although determining the specifics of frequency, duration, and intensity of grazing on these lands is problematic).

Chaco's location on the Colorado Plateau is a valuable site for contributing to greater understanding of grazing ecology and management. The World Wildlife Fund, in the most recent comprehensive assessment of the conservation status of North America, declared reform of grazing to be one of the priorities for the Colorado Plateau Shrubland ecoregion (Ricketts et al. 1999). The National Biological Service included ungrazed sagebrush steppe in the Intermountain West among the most “critically endangered” ecosystems in the United States—those with greater than 98% decline (Noss et al. 1995). Recent paleoecological studies on the Colorado Plateau (at Capitol Reef National Park) concluded that the most severe vegetation changes of the last 5400 years resulted from livestock grazing during the last two centuries (Cole et al. 1997). Only one previous study (Orodho et al. 1990) examined effects of grazing on Chaco vegetation. Because the vegetation and topography are heterogeneous (Floyd-Hanna and Hanna 1994), however, a single study site cannot provide a complete picture of the ecological transformations taking place after livestock are removed from an area for the first time in three hundred years.

By comparing three grazing treatments—long-term protection (50+ years), recent protection (5 years or less), and currently grazed—we hoped to illuminate effects of historic livestock grazing on biodiversity, capacity for nutrient cycling, and vegetation structure and composition in the Chaco region. Within these three broad categories, we attempted to answer the following six

questions:

Effects of grazing on ecosystem structure

- 1) Is there a difference in shrub density?
- 2) Is there a difference in grass cover between three grazing treatments?
- 3) Is there a difference in total vegetation cover between three grazing treatments?
- 4) Is there a difference in plant community composition between three grazing treatments?

Effects of grazing on biodiversity

- 5) Is there a difference in plant species richness between three grazing treatments?

Effects of grazing on capacity for nutrient cycling

- 6) Is there a difference in cover of microbiotic soil crusts between three grazing treatments?

Methods

According to the biotic communities system of classification of Southwest vegetation, Chaco Culture National Historic Park is primarily located in the Plains and Great Basin Grassland type (Brown 1994; only Chacra Mesa is in a different community type—Great Basin Conifer Woodland). The World Wildlife Fund, in a recent assessment of North American ecoregions, classified Chaco within the Colorado Plateau Shrublands (Ricketts et al. 1999). According to the ecoregion system of Bailey (1995), Chaco lies within the “Colorado Plateau Semidesert Province,” while the Potential Natural Vegetation system of Kuchler (1985) classifies Chaco within the “Grama-galleta (*Bouteloua-Hilaria*) steppe.” Chaco vegetation has been described more closely by Jones (1970, 1972), who proposed six plant associations, and most recently by Floyd-Hanna and Hanna (1994) who delineated eight vegetation communities.

We selected six study areas, with input from Resource Manager Paul Whitefield, giving consideration to sampling from among the types of geologic substrate and plant communities. Characteristics of the six study sites are summarized in Table 1, and their locations are shown in Figure 1. During the 1999 field season, data were collected at five of the six sites during the spring; the Northern Sidecanyons site was not completed until September. All sites were revisited in September 1999 to tally fall plant species. All six sites were sampled again in June 2000.

Where possible, the three grazing treatments (long-term protection, recent protection and currently grazed) were adjacent to one another, the treatments forming a T-juncture. However, at three of the study sites (East Canyon, Kin Klizhin, and Northern Sidecanyons), such an ideal configuration was not possible because factors other than grazing treatment, such as topography or substrate, coincidentally varied at a fenceline. In these cases, then, the currently grazed treatment was separated spatially from the other two treatments to eliminate variability of other ecological factors. At each of the six study sites slope, aspect, topography, and substrate were

similar in all three grazing treatments; grazing history was isolated as the only variable at each of the six sites.

Within each of the three grazing treatments at each of the six study sites, 8-10 points were randomly chosen: each point was 100 m plus a random distance in a randomly chosen direction from the previous point. At each point the following information was collected:

1. *Shrub diversity and productivity*: Two 30 m transects were laid out, parallel to one another and 10 m apart. All shrubs that encountered the 30 m lines were recorded utilizing the line intercept method. Shrubs were identified to species and counted between the 2 lines, in a 30 by 10 m plot. Heights of five randomly selected shrubs were recorded for each species.
2. *Flora*: Two releve analyses were carried out in 10 by 10 m plots on either side of transects described above. Each species in the plot was assigned a cover/abundance value using the Braun-Blanquet scale (5-1, +, r) (Mueller-Dombois and Ellenburg 1974). Native and non-native designations were given. Plants were named according to Weber and Wittman (1997) or Welsh et al. (1987).
3. *Grass and forb cover*: The frequency of grass (by species) and forbs (all species lumped together) was recorded by placing a 25-point frame at regular intervals along one of the 30 m transects described above. At every 5 m along this line, a random distance was called from a watch, defining the distance from the transect in m to place the frame.
4. *Forb density and biotic crust cover*: A 0.5 by 0.5 m quadrat was tossed 10 times in random directions and the number of forbs was counted. Most of these data were collected in April and early May 1999 and early June 2000 during periods of drought. Therefore, few forbs were present. The cover of all biotic crusts was estimated in the same quadrat toss. Finally, the cover of black lichens within the crust—probable nitrogen fixing crusts, according to Dr. Jayne Belnap (personal communication)—was estimated.

Statistical analyses followed Sokal and Rohlf (1991) using software Statistical Program for Social Sciences, SPSS (Norusis 1993).

Results

Shrub Cover:

Is there a response by native low shrubs to release from grazing pressure? To address this question, we tested whether grazing treatments (currently grazed, recent protection, and long-term protection) influenced the growth of shrubs (as measured by cover) and whether this trend was consistent among the six study areas. In this and all analyses that follow we combined data from two years of field study (1999-2000).

Ho: There is no significant difference in shrub cover between the three grazing treatments. There is no significant difference in shrub cover between the six sites. There is no significant interaction among these variables.

A two-way ANOVA indicated a significant difference in shrub cover between the grazing treatments ($F=8.0$, $p<.05$). Shrub cover was also significantly different between sites ($F=9.6$, $p<.05$). The interactive ANOVA term is also significant ($F=5.4$, $p<.05$), indicating that the specific nature of shrub responses to release from grazing pressure was inconsistent across the six sites. We therefore reject the null hypothesis on all counts (Figure 2).

Long-term protection favored shrub regeneration and growth at four sites: Clys Mesa-top, the Northern Sidecanyons, Mockingbird Mesa-top and Kin Klizhin. This was particularly clear at Clys Mesa-top, which exhibited nearly a 5-fold increase in shrub cover compared with the currently grazed area. At East Canyon grazing treatment did not affect shrub cover. At Fajada Gap shrub cover was no different in the currently grazed and short-term enclosure; however, there was a significant reduction of shrub cover in the long-term protected area. Both Fajada

Gap and East Canyon are located on the canyon floor with deeper, alluvial soils than the other four sites.

Bare soil cover:

We tested whether grazing increases the cover of bare soils, and whether this trend was consistent among the six study sites.

Ho: There is no significant difference in bare soil cover across the three grazing treatments.

There is no significant difference in bare soil cover across the six sites. There is no significant interaction between the two variables (bare soil and site).

There was a significant difference in bare soil exposure among grazing treatments ($F=28.1$, $p<.05$) and between study sites ($F=19.3$, $p<.05$). There was also a significant interaction between the bare soil cover when the treatment response at each site was compared ($F=3.5$, $p<.05$).

Therefore we reject the null hypothesis on all counts. Currently grazed areas had greater bare soil exposure than areas under protection from grazing at all but one site (Mockingbird Mesa-top, at which all three grazing treatments were similar). This grazing effect was particularly pronounced at three sites—East Canyon, Fajada Gap, and Northern Sidecanyons (Figure 3).

Grass cover:

We tested whether grazing treatment influenced grass cover and whether this trend was consistent among the six study sites.

Ho: There is no significant difference in grass cover across the three grazing treatments. There is no significant difference in grass cover across the six sites. There is no significant variation between the two variables (grazing treatment and site).

There was a significant difference in grass cover among treatments ($F=28.1$, $p<.05$) and among

sites ($F=19.3$, $p<.05$). There was also a significant interaction between treatments and sites ($F=3.5$, $p<.05$) suggesting that response of grass cover was not consistent among sites. We reject the null hypothesis on all counts (Figure 4). At Fajada Gap, East Canyon, Clys Mesa-top, and Kin Klizhin, grass cover increased with protection from grazing. Only at Fajada Gap was grass cover significantly greater under long-term than recent protection. At East Canyon, Clys Mesa-top, and Kin Klizhin any degree of protection (short- or long-term exhibited significantly greater grass cover than the currently grazed treatment. Exceptions to this pattern were evident at the remaining two sites. At Mockingbird Mesa-top the currently grazed treatment had greatest grass cover, and long-term protection the least, while at Northern Sidecanyons the currently grazed and long-term protected treatments were statistically indistinguishable, and the recent protection showed significantly less grass cover.

Forb density and cover:

We tested whether grazing treatment influenced forb density and cover, and whether this trend was consistent among the six study sites.

Ho: There is no significant difference in forb density and cover across the three grazing treatments. There is no significant difference in forb density and cover across the six sites. There is no significant interaction among forb density or cover between grazing treatment and site.

There was a significant difference in forb density among grazing treatments ($F=8.0$, $p<.05$), and among sites ($F=8.9$, $p<.05$). The interaction is also significant ($F=11.7$, $p<.05$), suggesting different responses to grazing at different sites. We reject the null hypothesis on all counts (Figure 5). The density of forbs was greatest in the long-term exclosure at the Northern Sidecanyons, and in the currently grazed treatment at Fajada Gap. Many of these additional forb species at Fajada Gap, however, were non-native. Because of the anomalous weather patterns

during both field seasons, we consider the results on forbs to be the least reliable of our indicators of post-grazing response.

Biotic crust cover:

We focused on black biotic crusts, which often fix nitrogen on the Colorado Plateau. We tested whether grazing treatment influenced black crust cover and whether this trend was consistent among the six study sites.

Ho: There is no significant difference in black biotic crust cover across the three grazing treatments. There is no significant difference in black biotic crust cover across the six sites. There is no significant interaction between grazing treatment and site.

There was a significant difference in black crust cover between grazing treatments ($F=19.6$, $p<.05$) and study sites ($F=14.6$, $p<.05$). A significant interactive term ($F=2.0$, $p<.05$) suggests that black crust development in the absence of grazing is inconsistent among these six sites. We reject the null hypothesis on all counts. Black crust cover was greatest under long-term protection at all sites (Figure 6). The most well-developed crusts were found on the Menefee shale substrate at the Kin Klizhin study site, and on the Quaternary alluvial soils of the Northern Sidecanyons and East Canyon sites. At Kin Klizhin this had developed into a dense cover with recent protection from grazing, suggesting rapid recovery; the crust cover was even denser with long-term protection. In contrast, crusts at Northern Sidecanyons and East Canyon, while present in the short-term enclosure, developed dense cover only in the long-term treatment, suggesting a slower recovery. Black crusts are virtually absent at Clys Mesa-top and Mockingbird Mesa-top, except for very low densities under long-term protection.

Plant Diversity:

We tested whether grazing treatment influenced the diversity (in terms of species richness) of plants.

Ho: There is no significant difference in plant species diversity across the three grazing treatments. There is no significant difference in plant species diversity across the six sites.

In each of the six study sites, there were more plant species represented in the protected areas than in the grazed areas (Figure 7, Appendix). These data suggest that the number of species increases with the length of protection.

Discussion

Ecological effects of historic livestock grazing could be seen most clearly in terms of biodiversity and biotic soil crusts (and their potential role in nitrogen cycling). Trends in plant diversity were remarkably consistent: species richness was higher under long-term protection than current grazing at all six sites. Similarly, biotic crusts showed a consistent response to grazing pressure: there was significantly more cover of the potentially nitrogen-fixing black crusts at all six sites. From a conservation biology perspective, these results affirm the significance of livestock grazing as a key ecological and conservation factor in the semiarid West.

Generally, there was denser shrub cover, more grass, and less bare soil on protected sites than on currently grazed sites. Cover of shrubs, grasses, and bare soil showed more heterogeneous responses to protection from grazing, however, than did plant diversity and biotic crust cover.

Shrub cover increased with protection at all four upland sites, while the two sites on the deeper alluvial soils of the canyon bottom exhibited different trends. At East Canyon there was no significant difference in shrub cover between long-term protection and current grazing

treatments, while shrub cover was significantly less under recent protection. At Fajada Gap shrub cover was lowest under long-term protection, while current grazing and recent protection treatments showed no significant differences.

None of the sites exhibited identical patterns of grass cover in relationship to grazing treatment. At four of the six sites grass cover was greater with protection than with current grazing. At Fajada Gap—which had the highest grass cover of any site—currently grazed and recently protected treatments showed no significant difference, but under long-term protection cover was significantly higher. This site, on alluvial soils of the canyon bottom, most closely resembles a true grassland community type, with over 50% cover of grasses under long-term protection. The other canyon bottom site, East Canyon, also showed dramatic recovery of grasses under protection, but here there was no significant difference between the two protection treatments. At Kin Klizhin, cover was greatest on the recently protected treatment; both protected treatments showed significantly greater grass cover than the currently grazed treatment. At Clys Mesa-top--the site with lowest overall grass cover--both protected treatments were significantly higher than the currently grazed treatment. The two anomalous sites in terms of grass cover were Northern Sidecanyons and Mockingbird Mesa-top. At the former, the currently grazed and long-term protection treatments showed no significant difference, while the recent protection treatment was lowest. At Mockingbird Mesa-top, grass cover was highest under current grazing and lowest under long-term protection. This makes sense when grass and shrub cover at this site are compared: apparently, with protection from livestock, shrub cover has increased, leaving less space for grasses. At this same site, bare ground cover was essentially the same under all three treatments—also an anomalous response.

The ways these interrelated responses (shrub, grass, and bare ground cover) to the removal of livestock have played out at sites that sometimes appear quite similar underscores the delicate ecological nuance involved in recovery from long-term human-related disturbance in the

marginal setting of desert landscapes.

The topic of shrub “invasion” of grasslands has been noted in the Southwest for decades, and is the focus of a great deal of management controversy. Branson (1985) referred to “the widespread change of semidesert grassland to shrubland...one of the most impressive examples of vegetation modification to be found on western rangelands.” In southern Arizona and New Mexico, mesquite (*Prosopis*) increased as grass cover decreased (Bahre 1991, Bahre and Shelton 1993, York and Dick-Peddie 1969). Throughout the Intermountain West, juniper (*Juniperus*) woodlands have increased in both density and distribution since Euro-American settlement (Miller and Wigand 1994). The consensus among most range ecologists is that overgrazing by livestock has been the primary cause of woody plant encroachment (Archer 1994, Branson 1985).

This does not mean, however, that shrubs are necessarily “invading” when they increase on a site in the arid West. Because the regional vegetation in the Chaco area is a mix of desert grassland and shrublands, woody vegetation is “normal” in many sites. The general trend we observed—shrubs increasing in uplands and decreasing in the canyon bottom—demonstrates the different biological potentialities of sites with different soils and habitat characteristics. Canyon bottom sites, with deeper, more recently developed alluvial soils, may be more naturally inclined towards grassland conditions than are the upland sites, which tend more toward shrubs. The inherent potential of different sites to support different vegetation types—probably determined by an interaction of physical factors such as soil type and water infiltration capacity—must be taken into account when interpreting post-grazing responses of these communities. In southern Arizona desert grasslands, after 18 years of exclosure, Brown (1950) found that shrubs increased more on protected areas than on currently grazed sites. This is similar to what we and Orodho et al. (1990) have observed thus far at Chaco.

Recent studies of stream ecosystems in eastern North America discovered that land use practice of 40 years earlier was a more accurate predictor of ecosystem conditions within a watershed than was current management. Past land-use activity can result in long-term modifications to diversity and other aspects of ecosystem dynamics; these authors referred to this as “the ghost of land use past” (Harding et al. 1998). This is undoubtedly true on arid rangelands as well. Fleischner (1994) pointed out that the initial impacts from livestock grazing—often long in the past—caused the most dramatic changes to ecosystems. Branson (1985) suggested that the loss of topsoil may impede efforts to reestablish former grasslands impacted by livestock abuse. Changes that result from the establishment of alien species—for example, cheatgrass (*Bromus tectorum*, present at almost all our study sites)—exacerbate this situation (D’Antonio and Vitousek 1992, Hobbs and Huenneke 1992, Mack 1981). For these and other reasons, intentional projects to reestablish overgrazed arid lands have met with limited success (Allen and Jackson 1992). It comes as no surprise, then, that Chaco, which was grazed longer than most parts of the American West, should recover slowly, and only partially. From this perspective, the conspicuous increase of biotic crust and plant species richness can be seen as very encouraging signs of healing.

Acknowledgments

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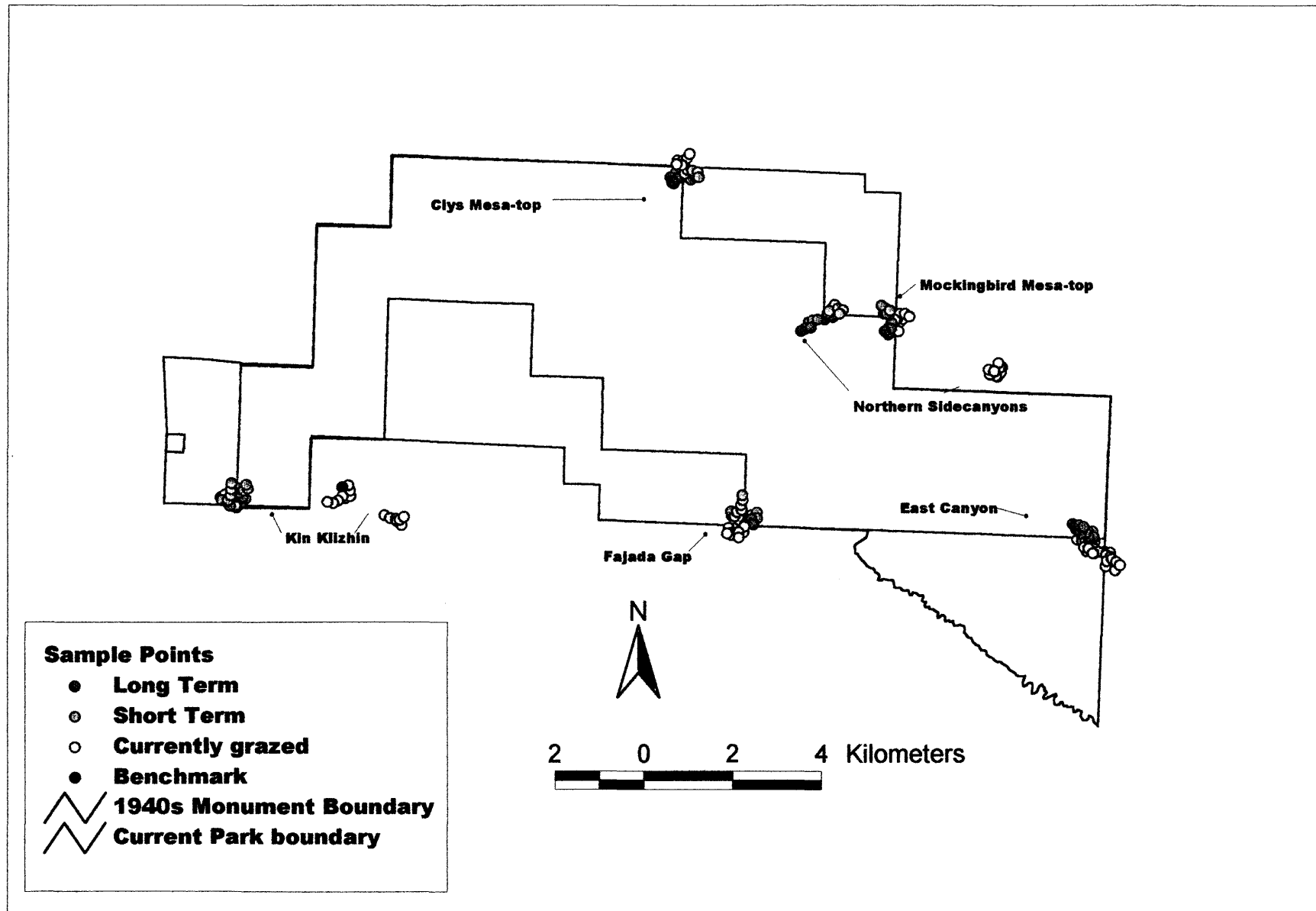
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Figure 1.

Location of six study sites at Chaco Culture National Historic Park



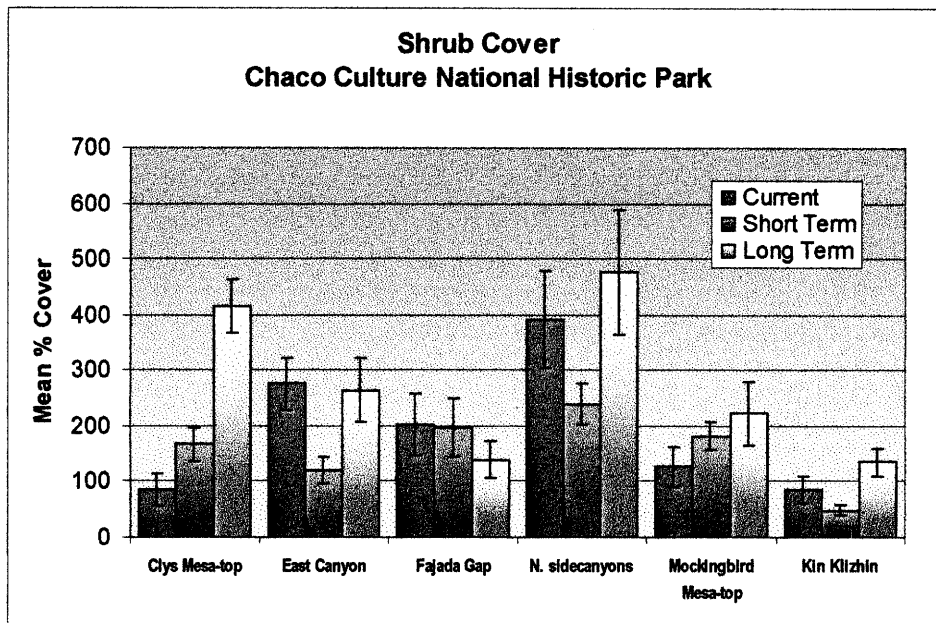


Figure 2. The cover of shrubs compared at six study sites at Chaco Culture National Historic Park under three grazing treatments. Data are mean percent cover of shrubs in currently grazed, short term exclosure and long term exclosure treatments.

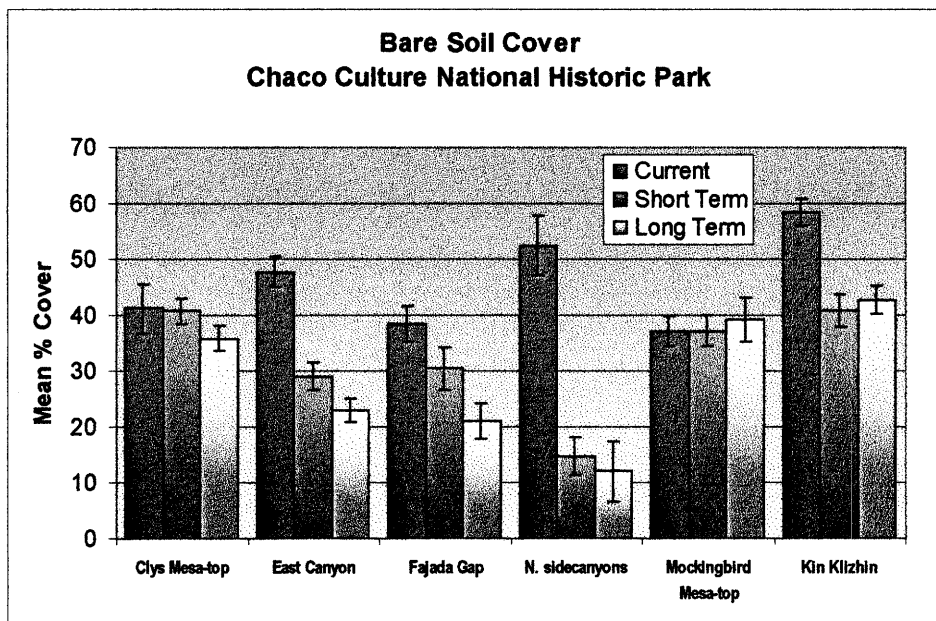


Figure 3. The cover of bare soil compared at six study sites at Chaco Culture National Historic Park under three grazing treatments. Data are mean percent cover of bare soil in currently grazed, short term exclosure and long term exclosure treatments.

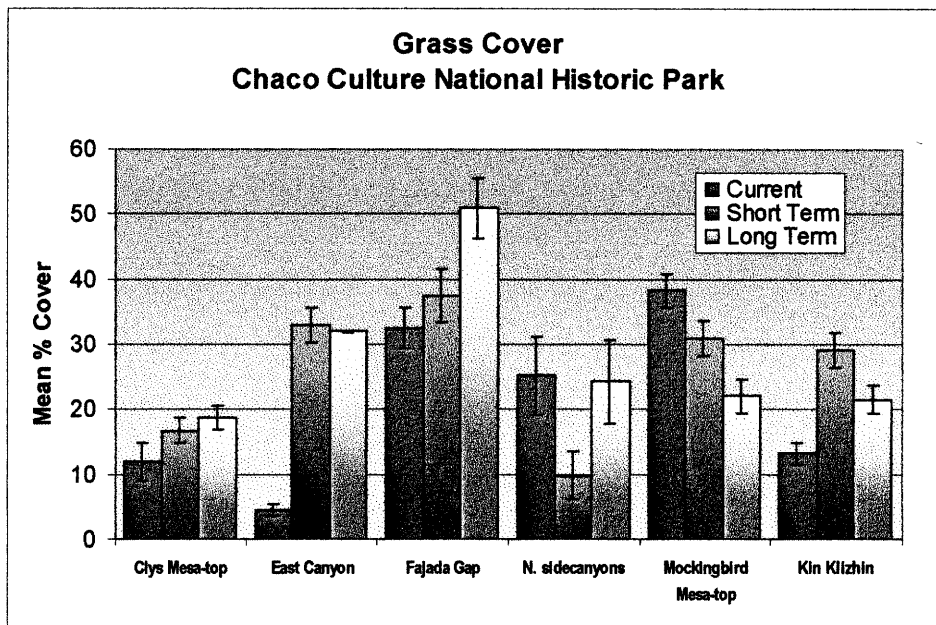


Figure 4. The cover of grass compared at six study sites at Chaco Culture National Historic Park under three grazing treatments. Data are mean percent cover of grass in currently grazed, short term exclosure and long term exclosure treatments.

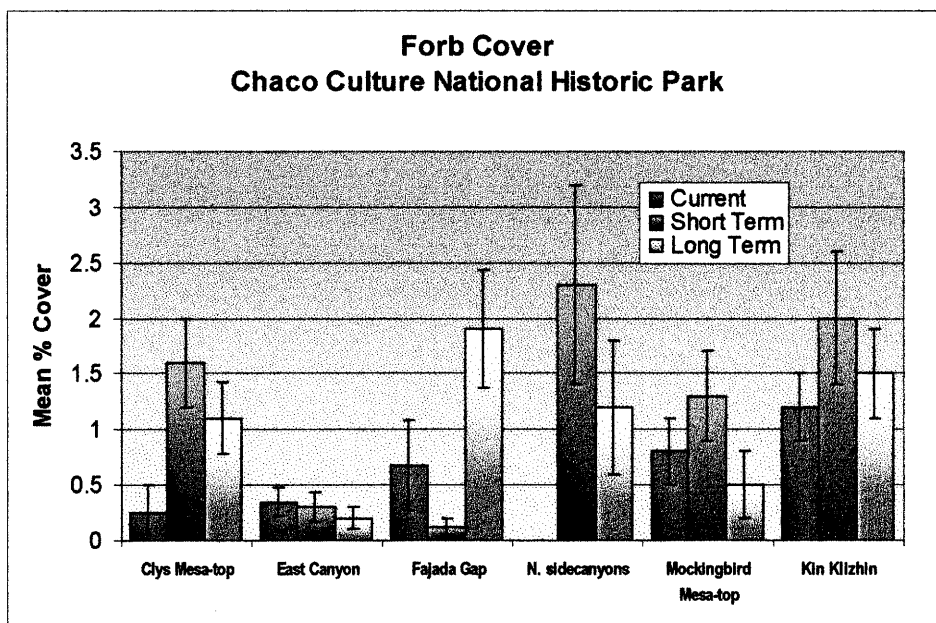


Figure 5a. The cover of forbs compared at six study sites at Chaco Culture National Historic Park under three grazing treatments. Data are mean percent cover of forbs in currently grazed, short term exclosure and long term exclosure treatments.

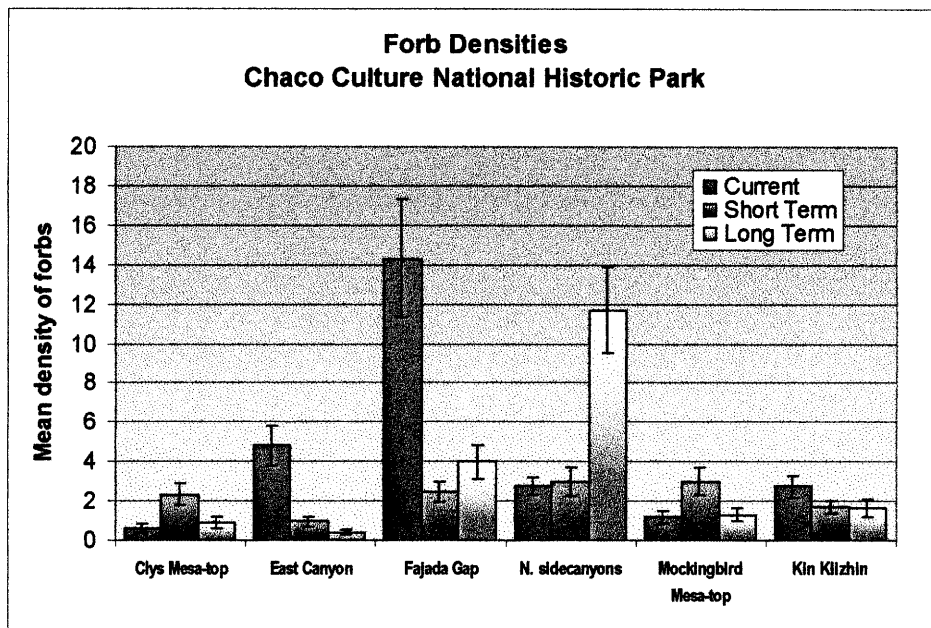


Figure 5b. Density of forbs (#individuals/0.25 m²) at six study sites at Chaco Culture National Historic Park under three grazing treatments. Data are mean density of forbs in currently grazed, short term exclosure and long term exclosure treatments.

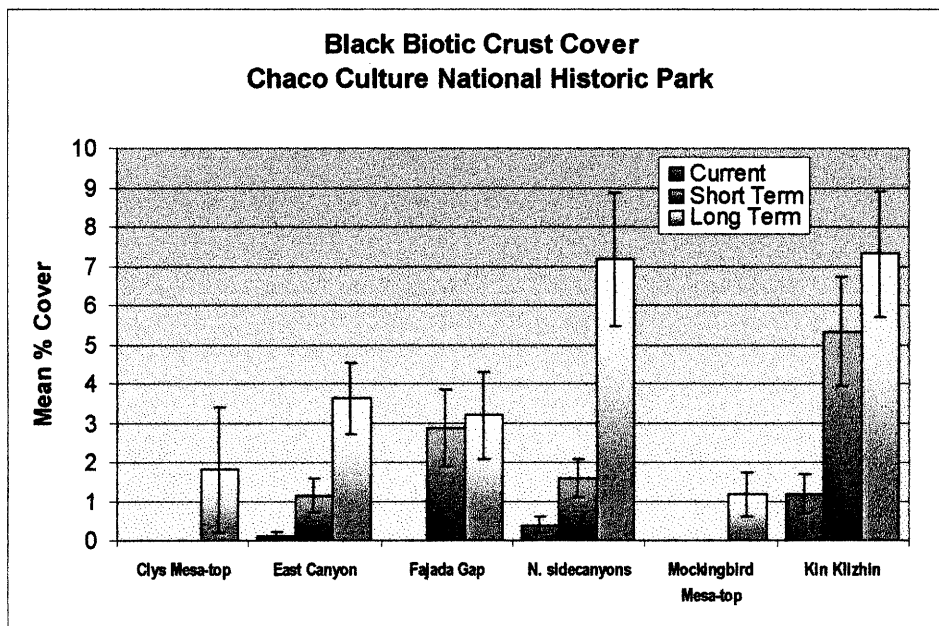


Figure 6. The cover of black biotic crusts compared at six study sites at Chaco Culture National Historic Park under three grazing treatments. Data are mean percent cover of black biotic crusts in currently grazed, short term exclosure and long term exclosure treatments.

Number of Plant Species in Grazing Treatments

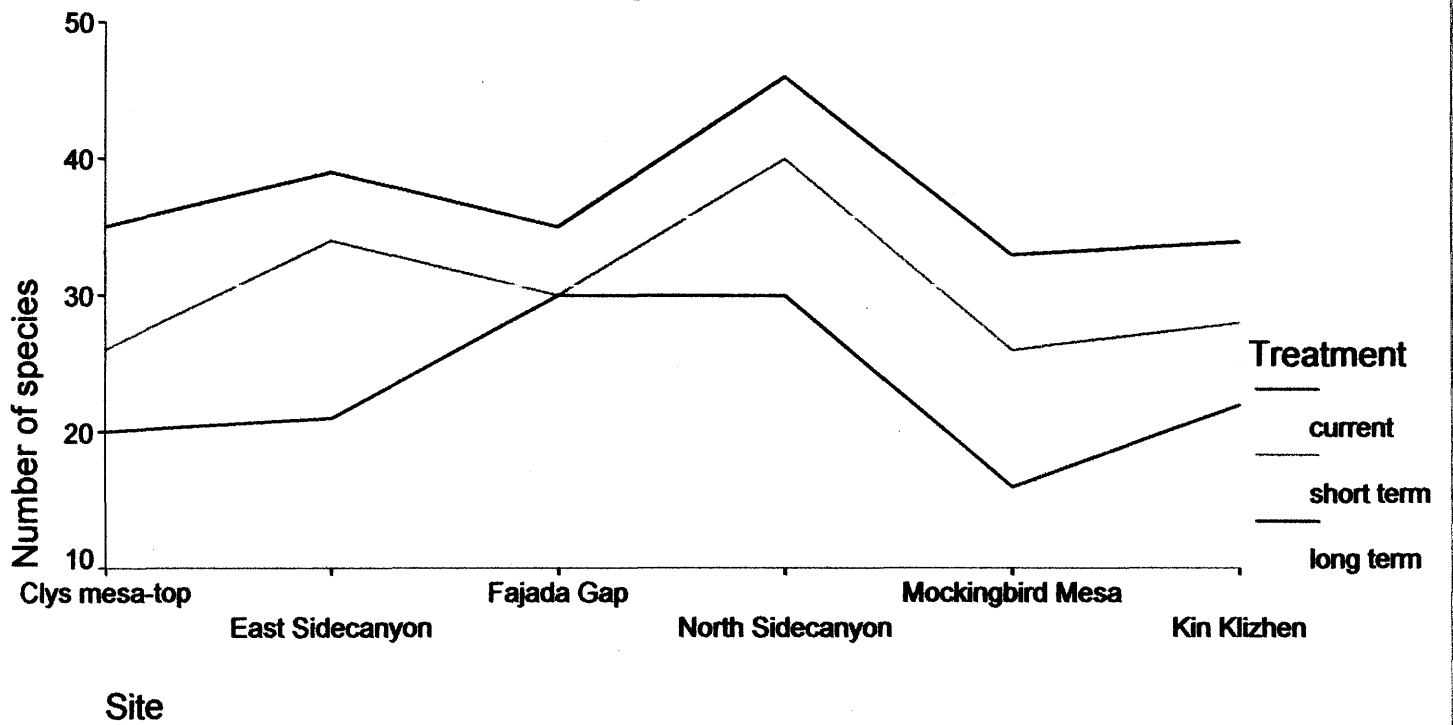


Figure 7. Plant species richness at six study sites, Chaco Canyon National Historic Park under three grazing treatments. See text for further descriptions of each treatment.

Appendix 1

Diversity of plant species at six sites, under three levels of protection from livestock grazing, at Chaco Culture National Historic Park, New Mexico (*denotes non-native species)

Site 1: Clys Mesa-top

Species	Years of Protection		
	50	5	0
Apiaceae			
<i>Cymopterus purpurascens</i>	*	*	*
Asteraceae			
<i>Artemisia nova</i>			
<i>Chrysothamnus Greenei</i>	*	*	*
<i>Erigeron</i> sp.	*	*	*
<i>Gutierrezia sarothrae</i>	*	*	*
<i>Leucelina ericoides</i>	*	*	*
<i>Lygodesmia grandiflora</i>	*	*	*
<i>Machaeranthera bigelovii</i>	*	*	*
<i>Senecio multilobatus</i>	*	-	-
<i>Tetradymia canescens</i>	*	*	*
<i>Townsendia incana</i>	*	-	-
Brassicaceae			
<i>Erysimum capitatum</i>	*	*	
Cactaceae			
<i>Opuntia polyacantha</i>	*	*	-
Chenopodiaceae			
<i>Atriplex canescens</i>	*	*	*
<i>Ceratoides lanata</i>	*	*	*
<i>Chenopodium leptophyllum</i>	*	-	-
* <i>Salsola iberica</i>	-	*	*
Euphorbiaceae			
<i>Euphorbia fendleri</i>	*	*	-
Fabaceae			
<i>Astragalus mollisimus</i>	*	*	-
Hydrophyllaceae			
<i>Nema densum</i>	*	-	-
Liliaceae			
<i>Allium</i> sp.	*	-	-
Malvaceae			
<i>Sphaeralcea coccinea</i>	*	*	-
Onagraceae			
<i>Oenothera caespitosa</i>	*	*	*
Orobanchaceae			
<i>Orobancha multiflora</i>	*	-	-

Poaceae

<i>Aristida purpurea</i>	*	*	-	
<i>Bouteloua gracilis</i>	*	*	*	
* <i>Bromus tectorum</i>	-	-	*	
<i>Elymus elymoides</i>	*	*	*	-
<i>Hilaria jamesii</i>	*	*	*	
<i>Hordeum jubatum</i>	*	*	-	
<i>Oryzopsis hymenoides</i>	*	*	*	
<i>Sporobolus airoides</i>	*	-	-	
<i>Sporobolus cryptandrus</i>	*	*	*	
<i>Stipa comata</i>	*	-	-	
<i>unknown grass</i>	*	-	*	

Polygonaceae

<i>Eriogonum leptophyllum</i>	*	*	*	
<i>Rumex hymenosepalus</i>	-	*	*	

Scrophulariaceae

<i>Penstemon strictus</i>	*	*	*	
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Unknown

<i>unknown forb</i>	*	-	-	
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Total # species:	35	26	20	
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Site 2: East Canyon

Species	Years of Protection		
	50	2	0
Asteraceae			
<i>Artemisia</i> sp.	-	*	-
<i>Artemisia campestris</i>	*	-	*
<i>Artemisia frigida</i>	-	*	*
<i>Artemisia tridentata</i>	*	-	*
<i>Chrysothamnus nauseosus</i>	*	-	-
<i>Chrysothamnus viscidiflorus</i>	*	*	-
* <i>Conyza canadensis</i>	-	*	-
<i>Erigeron pumila</i>	*	*	-
<i>Gutierrezia sarothrae</i>	*	*	*
<i>Helianthus annuus</i>	*	*	-
<i>Heterotheca villosa</i>	*	-	-
<i>Leucelene ericoides</i>	*	-	-
<i>Machaeranthera bigelovii</i>	*	*	*
<i>Townsendia incana</i>	*	-	-
* <i>Tragopogon dubius</i>	*	*	-
Boraginaceae			
<i>Lappula redowski</i>	-	*	*
<i>Phacelia incana</i>	-	*	-
Brassicaceae			
<i>Lesquerella</i> sp.	-	*	-
Cactaceae			
<i>Opuntia polycantha</i>	-	*	*
Chenopodiaceae			
<i>Atriplex canescens</i>	*	*	*
<i>Atriplex obovata</i>	*	*	*
<i>Atriplex truncata</i>	*	-	-
<i>Chenopodium leptophyllum</i>	*	*	*
* <i>Salsola iberica</i>	*	*	*
<i>Sarcobatus vermiculatus</i>	*	*	*
Euphorbiaceae			
<i>Euphorbia fendleri</i>	*	-	-
Malvaceae			
<i>Sphaeralcea fendleri</i>	*	*	*
Plantaginaceae			
* <i>Plantago major</i>	*	*	*
Poaceae			
<i>Agropyron smithii</i>	*		
<i>Aristida purpurea</i>	*	*	*
* <i>Bromus tectorum</i>	-	*	*
<i>Bouteloua eriopoda</i>	*	-	-
<i>Bouteloua gracilis</i>	*	*	-
<i>Elymus elymoides</i>	*	*	*
<i>Hilaria jamesii</i>	*	*	*
<i>Hordeum jubatum</i>	*	*	-
<i>Oryzopsis hymenoides</i>	*	*	*
<i>Sporobolus airoides</i>	*	*	*
<i>Sporobolus cryptandrus</i>	*	*	-
<i>Stipa comata</i>	*	-	-
unknown grass	*	-	-

Polygonaceae*Rumex hymenosepalus*

* * -

Portulacaceae**Portulaca oleracea*

* * *

Salicaceae*Populus fremontii*

* - -

Solanaceae*Lycium pallidum*

* * *

Tamaricaceae**Tamarix sp.*

- * -

Unknown*unknown shrub*

- * -

unknown forb

- * -

Total # species:

39 34 21

Site 3: Fajada Gap

Species	Years of Protection		
	50	5	0
Asteraceae			
<i>Artemisia campestris</i>	*	-	-
<i>Artemisia frigida</i>	*	*	*
<i>Chrysothamnus viscidiflorus</i>	*	-	*
* <i>Conyza canadensis</i>	*	-	-
<i>Erigeron divergens</i>	*	*	*
<i>Gutierrezia sarothrae</i>	*	*	*
<i>Gutierrezia microphylla</i>	-	*	-
<i>Helianthus annuus</i>	*	*	-
<i>Leucelene ericoides</i>	*	*	*
<i>Machaeranthera bigelovii</i>	*	*	*
<i>Senecio multilobatus</i>	*	*	*
<i>Taraxicum officinalis</i>	-	*	*
<i>Tetradymia canescens</i>	-	-	*
* <i>Tragopogon dubius</i>	*	*	-
unknown composite 1	*	-	-
unknown composite 2	*	-	-
Boraginaceae			
<i>Cryptantha bakeri</i>	*	*	*
<i>Cryptantha flava</i>	*	-	*
Brassicaceae			
<i>Erysium capitatum</i>	*	*	*
Cactaceae			
<i>Opuntia polycantha</i>	*	*	*
<i>Mammalaria sp.</i>	*	-	-
Chenopodiaceae			
<i>Atriplex canescens</i>	*	*	*
<i>Ceratoides lanata</i>	*	*	*
<i>Chenopodium leptophyllum</i>	*	*	-
<i>Halogeton glomeratus</i>	-	-	*
* <i>Salsola iberica</i>	*	*	*
Euphorbiaceae			
<i>Euphorbia micromera</i>	-	*	*
Fabeaceae			
<i>Astragalus mollissimum</i>	*	-	-
<i>Astragalus sp.</i>	-	*	*
Malvaceae			
<i>Sphaeralcea ambigua</i>	-	-	*
<i>Sphaeralcea coccinea</i>	*	*	*
<i>Sphaeralcea fendleri</i>	*	*	*
Onagraceae			
<i>Oenothera caespitosa</i>	-	*	*
Plantaginaceae			
* <i>Plantago major</i>	*	-	-
Poaceae			
<i>Aristida purpurea</i>	*	*	*
* <i>Bromus tectorum</i>	*	*	*
<i>Bouteloua gracilis</i>	*	*	*
<i>Elymus elymoides</i>	*	*	*

<i>Hilaria jamesii</i>	*	*	*
<i>Oryzopsis hymenoides</i>	*	*	*
<i>Sporobolus airoides</i>	*	*	*
unknown grass	*	-	-
Polygonaceae			
<i>Rumex hymenosepalus</i>	-	-	*
Portulacaceae			
* <i>Portulaca oleracea</i>	*	-	-
Ranaunculaceae			
<i>Delphinium nelsoni</i>	-	*	-
Total # species:	35	30	30

Site 4: Northern Sidecanyons

Species	Years of Protection		
	50	2	0
Amaranthaceae			
<i>Amaranthus retroflexus</i>	*	-	-
Asteraceae			
<i>Artemisia campestris</i>	*	*	-
<i>Artemisia frigida</i>	*	*	-
<i>Artemisia nova</i>	*	*	-
<i>Brickellia californica</i>	*	*	-
<i>Artemisia tridentata</i>	*	*	-
<i>Chrysothamnus parryi</i>	-	*	-
<i>Chrysothamnus nauseosus</i>	*	-	*
<i>Chrysothamnus viscidiflorus</i>	*	-	*
* <i>Conyza canadensis</i>	*	*	-
<i>Erigeron sp.</i>	*	*	*
<i>Heterotheca villosa</i>	-	-	*
<i>Gutierrezia sarothrae</i>	-	*	*
<i>Heterotheca villosa</i>	-	*	*
<i>Leucelene ericoides</i>	-	-	*
<i>Machaeranthera bigelovii</i>	*	*	-
<i>Tetradymia canescens</i>	*	*	-
<i>Townsendia incana</i>	*	-	*
* <i>Tragopogon dubius</i>	-	-	*
Boraginaceae			
<i>Cryptantha sp.</i>	*	*	-
<i>Lappula redowskii</i>	*	*	-
Brassicaceae			
<i>Descurania pinnata</i>	*	*	-
Cactaceae			
<i>Opuntia polyacantha</i>	*	*	-
Chenopodiaceae			
<i>Atriplex canescens</i>	*	*	*
<i>Atriplex obovata</i>	*	*	*
<i>Chenopodium fremontii</i>	*	-	-
<i>Chenopodium leptophyllum</i>	*	*	-
<i>Ceratoides lanata</i>	-	*	-
* <i>Halogeton glomeratus</i>	-	-	*
* <i>Salsola iberica</i>	*	*	*
Ephedraceae			
<i>Ephedra torreyana</i>	-	*	-
Euphorbiaceae			
<i>Euphorbia fendleri</i>	*	*	*
<i>Euphorbia micromera</i>	*	*	*
Fabaceae			
<i>Astragalus mollissimus</i>	*	*	-
<i>Gleditsia triacanthos</i>	*	-	-
Fumariaceae			
<i>Corydalis aurea</i>	-	*	-
Hydrophyllaceae			
<i>Phacelia sp.</i>	*	-	-

Malvaceae*Sphaeralcea coccinea*

* * *

Sphaeralcea fendleri

* * *

Nyctaginaceae*Mirabilis multiflora*

* - *

Onagraceae*Oenothera caespitosa*

- - *

Poaceae*Agropyron smithii*

* - *

Aristida purpurea

* * *

**Bromus tectorum*

* * -

Bouteloua gracilis

* * *

Elymus elymoides

* * -

Hilaria jamesii

* * -

Hordeum jubatum

* * *

Oryzopsis hymenoides

* * *

Sporobolus cryptandrus

* * -

Stipa comata

- * *

unknown grass

* * *

Polygonaceae*Eriogonum leptophyllum*

* - *

Rumex hymenosepalus

* * -

Portulacaceae**Portulaca oleracea*

* * *

Scrophulariaceae*Penstemon sp.*

* - *

Solanaceae*Lycium pallidum*

* - *

Solanum sp.

* * -

Total # species:

46 40 30

Site 5: Mockingbird Mesa-top

Species	Years of Protection		
	50	2	0
Asteraceae			
<i>Artemisia frigida</i>	*	*	-
<i>Artemisia nova</i>	*	-	-
<i>Chrysothamnus parryi</i>	-	-	*
<i>Chrysothamnus viscidiflorus</i>	*	*	-
<i>Gutierrezia sarothrae</i>	*	*	*
<i>Leucelene ericoides</i>	*	*	
<i>Tetradymia canescens</i>	*	*	-
* <i>Lygodesmia grandiflora</i>	*	-	-
<i>Machaeranthera bigelovii</i>	*	*	-
* <i>Tragopogon dubius</i>	-	*	-
<i>unknown composite</i>	*	-	-
Brassicaceae			
<i>Erysimum capitatum</i>	*	*	-
Boraginaceae			
<i>Phacelia incana</i>	*		
Cactaceae			
<i>Mammillaria tetrancistra</i>	*	-	-
<i>Opuntia polyacantha</i>	*	*	*
<i>Opuntia whipplei</i>	-	*	*
Chenopodiaceae			
<i>Atriplex canescens</i>	*	*	*
<i>Ceratoides lanata</i>	-	*	*
<i>Chenopodium sp.</i>	*	*	*
Ephedraceae			
<i>Ephedra viridis</i>	*	-	-
Euphorbiaceae			
<i>Euphorbia fendleri</i>	-	*	-
Fabaceae			
<i>Astragalus mollissimus</i>	*	-	-
Malvaceae			
<i>Sphaeralcea coccinea</i>	*	*	*
Poaceae			
<i>Aristida purpurea</i>	*	-	-
<i>Bouteloua gracilis</i>	*	*	*
<i>Elymus elymoides</i>	*	*	*
<i>Hilaria jamesii</i>	*	*	*
<i>Oryzopsis hymenoides</i>	*	*	-
<i>Muhlenbergia sp.</i>	*	-	-
<i>Sporobolus cryptandrus</i>	*	*	*
<i>Stipa comata</i>	*	*	-
<i>unknown grass</i>	*	*	*
Polemoniaceae			
<i>unknown Polemoniaceae</i>	*	-	-
Polygonaceae			
<i>Rumex hymenosepalus</i>	*	*	*

Site 6: Kin Klizhin

Species	Years of Protection		
	50	1	0
Asteraceae			
<i>Chrysanthamnus greenii</i>	-	*	*
<i>Chrysanthamnus visidiflorus</i>	*	-	-
<i>Conyza canadense</i>	*		
<i>Erigeron divergens</i>	*	*	-
<i>Gutierrezia sarothrae</i>	*	*	*
<i>Leucelene ericoides</i>	*	*	*
<i>Machaeranthera bigelovii</i>	*	*	*
<i>Senecio mulilobatus</i>	-	*	-
<i>Tetradymia canescens</i>	*	*	-
Brassicaceae			
<i>Physaria incana</i>	*	-	-
Boraginaceae			
<i>Cryptantha bakerii</i>	-	-	*
<i>Cryptantha flava</i>	*	*	-
Cactaceae			
<i>Opuntia polycantha</i>	*	*	*
Chenopodiaceae			
<i>Atriplex canescens</i>	*	*	*
<i>Atriplex confertifolia</i>	*	-	-
<i>Atriplex gardneri</i>	*	*	*
<i>Atriplex obovata</i>	*	*	-
<i>Atriplex procombens</i>	*	*	-
<i>Ceratoides lanata</i>	*	-	-
<i>Chenopodium leptophyllum</i>	*	-	-
* <i>Halogeton glomeratus</i>	*	*	*
* <i>Salsola iberica</i>	*	*	*
<i>Sarcobatus vermiculatus</i>	-	*	*
Euphorbiaceae			
<i>Euphorbia micromera</i>	*	*	*
Fabaceae			
<i>Lupinus sp.</i>	-	*	-
Nyctaginaceae			
<i>Abronia incana</i>	*	*	-
Malvaceae			
<i>Sphaeralcea ambigua</i>	-	*	-
<i>Sphaeralcea coccinea</i>	*	-	*
<i>Sphaeralcea fendleri</i>	*	-	*
Poaceae			
<i>Aristida purpurea</i>	*	-	-
<i>Bouteloua eriopoda</i>	*	*	*
* <i>Bromus tectorum</i>	*	-	*
<i>Elymus elymoides</i>	*	*	*
<i>Hilaria jamesii</i>	*	*	*
<i>Muhlenbergia pungens</i>	-	*	*
<i>Oryzopsis hymenoides</i>	*	*	*
<i>Sporobolus airoides</i>	*	*	*
<i>Sporobolus cryptandrus</i>	*	-	-

Polygonaceae*Eriogonum alatum**Rumex hymenosepalus*

*	-	-
*	*	*

Scrophulariaceae*Penstemon micronata**Penstemon strictus*

*	*	*
*	*	-

Total # species:

33	26	16
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