UNIVERSITY OF CENTRAL OKLAHOMA
Edmond, Oklahoma
Jackson College of Graduate Studies

Effects of Abiotic Factors and Cattle Grazing on Gypsum Outcrop Plant Communities in the Cimarron Gypsum Hills, Northwestern Oklahoma

A THESIS

SUBMITTED TO THE GRADUATE FACULTY
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE IN BIOLOGY

By
Kristi Dawn Rice
Edmond, Oklahoma
2008

Effects of Abiotic Factors and Cattle Grazing on Gypsum Outcrop Plant Communities in the Cimarron Gypsum Hills, Northwestern Oklahoma

A THESIS

APPROVED FOR THE DEPARTMENT OF BIOLOGY

July 2008

By Gloria M. Caddell

Dr. Gloria M. Caddell Committee Chairperson

Dr. John F. Barthell Committee Member

Clark L. Ovrebo

Dr. Clark L. Ovrebo Committee Member

ACKNOWLEDGEMENTS

I would like to extend a very appreciative thank you to the following people, who volunteered their time: Dr. Gloria Caddell, Joe Rice, Crystal Hall, and Bobbie Gaskin. A huge thank you is extended to the founder and Director of the Selman Living Laboratory, Dr. William Caire, for allowing myself and my field assistants to spend the night at this wonderful establishment. I am also very grateful to all of the private land owners and Tom Creider, State Department of Parks and Recreation, for special permission to conduct this study on their properties; and an extra thank you to Dr. Paul Nighswonger for tracking and contacting the current owner of Irish's Mesa. I would like to thank my major professor, Dr. Gloria Caddell, and committee, Dr. John Barthell and Dr. Clarke Ovrebo, for all of their important input throughout this project. I would also like to thank Dr. Chris Butler for extensive knowledge of several computer programs and ecological analyses. Special thanks again to Joe Rice, for spousal support: mentally and physically. You're the best! I also need to thank my kids and my parents for their support and patience throughout this project. I would like to thank the Department of Biology, especially Sharon LaFave and Chairperson, Dr. Jenna Hellack, for employment throughout this process. The Laboratory Assistantships and teaching General Biology Laboratories have given me a wonderful opportunity to share the

things I have learned with the next generation of students, while building my resume. Thank you also to Ron Hoggard for verification of *Plantago rhodosperma* identification. A huge thank you as well to Dr. Ron Tyrl for access to the OSU herbarium, verifying the identifications of two grass species, and identification of one species that was only found in a vegetative condition.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Patterns of vascular plant species composition in relationship to abiotic factors and grazing history were quantified for gypsum outcrop communities of the Cimarron Gypsum Hills of northwestern Oklahoma. I sampled thirty-nine 100 m^2 quadrats at 13 sites during summer 2006, fall 2006, spring 2007, and summer 2007. One hundred and fifty-five species were identified, of which only seven were introduced. The dominant species were native perennial herbs, and the outcrops appear to be "islands" of predominantly native vegetation. Plant assemblages were similar enough to be considered the same community, and richness and diversity differed little among sites. However, differences were detected in species composition among sites, and Detrended Correspondence Analysis showed that these differences along axis 1 were significantly correlated with changes in average annual precipitation and temperature, longitude and elevation, with a weak grazing history gradient shown along axis 2. Indicator Species Analysis identified few significant indicators for a particular grazing history. The native plant community persists in spite of grazing; however non-vegetated substrate demonstrated higher cover on currently-grazed outcrops relative to long-ungrazed ones.

INTRODUCTION

The unique plant communities on gypsum outcrops have long been an interesting part of North American xerophytic plant community studies (Johnston, 1941; Barber, 1979; Romao and Escudero, 2005), though somewhat overlooked during drier periods (Powell and Turner, 1977). In Oklahoma, extensive gypsum outcrops are found in the Cimarron Gypsum Hills (CHG), and the need for further quantitative study of the vegetation of this physiographic region was emphasized by Hoagland (2000).

Gypsum Geology

The gypsum of the CGH formed during the Permian period, 290 to 250 million years ago. The CGH are part of the Blaine formation and extend approximately 200 km across northwestern Oklahoma. The CGH cover parts of seven counties: Blaine, Canadian, Harper, Kingfisher, Major, Woods, and Woodward. The stone consists of fine- to coarse-grained compact rock gypsum ($CaSO_4 \cdot 2H_2O$), which ranges from white through light grey to pink (Johnson, 1972a & 1972b).

According to Johnson (1972b), during the early Permian much of Oklahoma was covered by marine water. The climate began to change and by the late Permian the wet environment in Oklahoma became arid. The arid conditions caused a recession of the marine water due to evaporation. As the water evaporated, gypsum mineral precipitated out of the sea water and settled to what was

then an ocean floor (Johnson, 1996). This occurred several times throughout the Permian period. Each time the sea water rose, a layer of sand and mud from erosion of the Arbuckle, Ouachita, Ozark, and Wichita Mountains washed in on top of the previously laid gypsum layer, forming a layer of shale (Johnson, 1996). A fall in sea water would lay a substantial layer of gypsum on top of the shale, thus causing red shale deposits to occur between the gypsum deposits. The alternating layers of shale and gypsum formed what is now known as the Blaine formation (Johnson, 1972a; Oklahoma Geological Survey, 2006).

Gypsum outcrops are composed of exposed rock gypsum that lack extensive soil cover. Outcrops can be of varying thickness and coverage. The most visible outcrops and thickest gypsum reserves in the CGH are in the northwest region of the Blaine formation in Harper and Woodward Counties. However, outcrops are often found widely dispersed and irregularly placed over a large area of landscape, such as they are in other parts of the CGH (Johnson, 1972b). Thus, gypsum outcrops are a unique substrate scattered among grass and shrubland communities (Meyer and Garcia-Moya, 1989; Mota et al., 2003). Powell and Turner (1977), as well as Hicks and Whitcomb (1996), referred to gypsum outcrops as demonstrating an insular factor or island effect, which is ideal for plant evolution.

Gypsum is generally found in areas with dry or semiarid climates (Meyer and Garcia-Moya, 1989; Escudero et al., 2000; Mota et al., 2003; Olano et al., 2005; Romao and Escudero, 2005)

where it is not quickly eroded. Escudero et al. (2000) characterized gypsum soils as a stressful environment and Barber (1975) characterized them as unfavorable for plant growth. However, Cockerell and Garcia (1898) reported that pure gypsum can nourish plants as well or better than ordinary soil.

Gypsum Crust

The gypsum rock generally has a surface layer of indurate (hard) crust and a soft cryptogamic crust. Indurate crust is gypsum mineral formed from recrystallization of gypsum in solution via the evaporation of water (Watson, 1979); however, cryptogamic crust is a living biological community. The cryptogamic crust (also known as biological crust) consists of a community composed of algae, cyanobacteria, fungi, lichens, and liverworts (Meyer, 1986; Dana and Mota, 2006; Martinez et al., 2006). It can modify the harsh outcrop environment by holding moisture (Borselli et al., 1996) to ease the establishment of seedlings, but the exact mechanisms by which it facilitates seedling establishment were unclear to Meyer (1986) and Meyer and Garcia-Moya (1989). Additionally, Meyer (1986) and Pueyo et al. (2007) suggest that the indurate surface crust may inhibit growth of seedlings of gypsum plant communities.

Terminology used for Plant Species Growing on Gypsum

Many species adapted to gypsum outcrops are endemic (Meyer and Garcia-Moya, 1989; Meyer et al., 1992; Mota et al., 2003;

Akpulat and Celik, 2005; Romao and Escudero, 2005), and several terms have been used to characterize the extent to which a plant species is found on gypsum soils. For instance, a gypsophobe is never encountered on gypsum (Meyer, 1986). Gypsophiles, also referred to as gypsophytes (Escudero et al., 1997), are mainly herbs and dwarf shrubs restricted to gypsum soils (Parsons, 1976; Moore and Jansen, 2007), and can indicate the presence of concealed gypsum (Powell and Turner, 1977). Johnston (1941) proposed from his study in the northern Mexican desert that the frequent association of the same species scattered among gypsum soils is strong evidence for gypsophily as a preference, not a chance occurrence. Parsons' worldwide review of gypsophily (1976) found that only a small percentage of species present on gypsum soils are actually confined to gypsum soils; thus gypsophiles have the ability to tolerate high gypsum content soils, but the required amount of gypsum present in the soil is different for each gypsophytic species. He characterized facultative gypsophiles as occasionally growing on gypsum and obligate gypsophiles as requiring gypsum soils for growth.

Halophytic (salt-loving) gypsophiles occur in gypsum soil with a high salt content in the vicinity of gypsum outcrops (Johnston, 1941; Parsons, 1976) and a strong difference exists between saline and nonsaline gypsum soils (Parsons, 1976; Meyer, 1986). Gypsoclines essentially grow on gypsum; however they can be found growing on other unusual substrates, i.e., claybeds and high-boron shale (Meyer, 1986). Finally, gypsovags routinely

occur on both gypsum and nongypsum soils (Meyer, 1986; Escudero et al., 1997; Moore and Jansen, 2007).

Escudero et al. (1997; 1999; 2000) and Mota et al. (2003) describe gypsophiles and gypsovags as one of the most conspicuous groups of arid or semi-arid climate endemic plants. However, it has been hypothesized that gypsophiles have greater ability to germinate and establish on hard gypsum substrates (Johnston, 1941; Meyer et al., 1992; Borselli et al., 1996; Escudero et al., 2000; Mota et al., 2003) and gypsovags have a difficult time establishing on hard gypsum substrates (Romao and Escudero, 2005). Mota et al. (2003) studied plant succession on gypsum outcrops and adjacent shrubland after gypsum quarrying in central Spain. They found that over time gypsophytes re-established on gypsum, but not in the same relative abundances seen on undisturbed sites.

Gypsum Properties Affecting Plant Growth

The factors responsible for the occurrence of only a few types of vegetation on gypsum have been the focus of several studies. Campbell and Campbell (1938) as well as Pueyo and Alados (2007) found that the amount of vegetation cover located on gypsum outcrops can be attributed to a combination of physical and chemical properties. Campbell and Campbell (1938) also noted that the lack of nitrates and other essential minerals would likely hinder plant growth, because gypsum cannot hold nutrients well. Additionally, Meyer et al. (1992) described the semiarid,

southern Chihuahuan desert landscape of north central Mexican as a mosaic of shrubland and endemic gypsophile grassland communities and found that the gypsum soils were less fertile than alluvial soil.

However, Meyer (1986) conducted a study of vegetation on gypsum outcrops in the eastern Mojave Desert and found that relative to alluvial soils, gypsum was not lacking in nutrients, nor did it have increased salinity or toxic effects of ions. The abundance of specific species was most highly correlated with soil physical factors such as rock cover, cryptogamic cover, and total gypsum content rather than soil chemistry. Meyer (1986) suggested that gypsophiles may have an advantage because they have become adapted to the reduced moisture present on gypsum outcrops. This reduction in moisture may give the plants with less ability to compete in the adjacent habitats the ability to specialize and adapt to a harsher habitat. However, it is unclear whether the increased ability for gypsophiles to establish on gypsum outcrops is due to less competition on gypsum soil, thus offering more moisture for the plants that are present (Meyer, 1986; Meyer and Garcia-Moya, 1989) or if the gypsum soil directly contributes to the establishment of specific plant species (Meyer, 1986). Furthermore, Borselli et al. (1996) found that the gypsum crust actually appears to hold moisture, enhancing the moisture content of the typical dry environment in which gypsum is found.

Establishment also seems to be dependent on the season (Escudero et al., 1999) and temperature (Escudero et al., 1997). Seeds with a hard seed coat do not germinate on gypsum at any temperature (Escudero et al., 1997). Lower temperatures (5 °C to 20 °C range) enhance germination (Escudero et al., 1997) with most germination occurring in the winter and some in the early spring (Escudero et al., 1999). This is important because the temperature fluctuation on gypsum outcrops is higher than in the surrounding habitat because of the white gypsum rock and less vegetation cover (Escudero et al., 1997).

Vascular Plant Communities on Gypsum in Oklahoma

Hoagland (2000) characterized the Oklahoma plant community on gypsum as a *Schizachyrium scoparium-Castilleja purpurea* var. *citrina-Lesquerella gordonii* herbaceous association. This association is found in the CGH in northwestern Oklahoma, as well as the Mangum Gypsum Hills in southwestern Oklahoma. Barber (1979) studied the vegetation of the Mangum Gypsum Hills and the associated Redbed Plains. She found separate plant communities and associations in each of the biotic districts studied. The grassland communities separated out into two distinct communities: grasslands of the gypsum hills and mixed-grass plains. The gypsum hills grassland community was dominated by forb species in the early spring and by grasses in late summer. She concluded that some plant species only occur on gypsum soils; some plant species are good gypsum soil indicators and can

constantly be observed on gypsum, while others can occur on both gypsum and redbed soils.

Buckallew and Caddell (2003) conducted the first floristic inventory published for the CGH. The study was carried out at the Selman Living Lab (SLL), which consists of mixed-grass prairie with approximately half of the area covered with gypsum outcrops. All dominant vascular plants on the gypsum outcrops were native perennial herbs. In fact, only four species found growing on gypsum were introduced species to Oklahoma and these occurred only occasionally. They found eight of the native species only on the gypsum outcrops with two of the species reported as obligate gypsophiles (*Phacelia integrifolia* and *Nama stevensii*). The only other published study for the CGH is a floristic inventory of a gypsum-dominated site in Major County (Hoagland and Buthod, 2005). The gypsum vegetation was found to be the typical *Schizachyrium scoparium-Castilleja purpurea* var. *citrina-Lesquerella gordonii* association (Hoagland, 2000) for western Oklahoma gypsum substrate. Hoagland and Buthod (2005) found two species (*Echinocereus reichenbachii* and *Escobaria vivipara*) that are currently being tracked by the Oklahoma Natural Heritage Inventory, one of which (*E. reichenbachii*) was also found at the SLL (Buckallew and Caddell, 2003), demonstrating the importance of preserving the fragile gypsum habitat.

Grazing Studies

There are a few studies of the effects of grazing on gypsum outcrop communities. Campbell and Campbell (1938) conducted an analysis of vegetation on different soil types, including gypsum outcrops, on the Jornada Plain of New Mexico. They found that cattle, non-native herbivores, preferred grazing on sandy soil over gypsum outcrops. On the other hand, they found Pronghorned Antelope (*Antilocapra americana*), native herbivores, did not have a preference, but that they would graze on both sandy soil and gypsum outcrops. They also acknowledged the need for grazing management to improve vegetation on gypsum outcrops, because the unfavorable arid to semi-arid environment found on the outcrops influences the sparse growth of vegetation (Campbell and Campbell, 1938).

Two studies conducted on similar arid to semi-arid sites in Oregon (Ponzetti and McCune, 2001) and Mexico (Meyer and Garcia-Moya, 1989) showed that grazing did not heavily impact the vascular plant species composition. Meyer and Garcia-Moya (1989) analyzed plant community patterns and seasonal changes in soil moisture of grazed and ungrazed gypsum sites. They found two dominant grasses on exposed gypsum soil. One species, *Muhlenbergia purpusii*, dominated indurate surface crusts and another, *Bouteloua chasei*, dominated softer cryptogamic surface crusts found on gypsum outcrops. They also found the *Muhlenbergia* plant community soil moisture was higher for grazed communities than ungrazed. The opposite was found for the

Bouteloua plant community, where increased evaporation attributed to the lower soil moisture content. Meyer and Garcia-Moya (1989) also noted that the unique physical characteristics of gypsum protect it from the indirect effects of grazing (e.g. trampling, invasion by introduced species), so that the native vascular plant community persists. They also found a decrease in the cryptogamic crust cover on gypsum outcrops and alluvial plant communities in the presence of cattle grazing, but little impact on the vascular plants. Ponzetti and McCune (2001) concluded that the crust found on pasture land was impacted by cattle grazing; however, the vascular plant composition, cover, and richness were not affected.

Additionally, a study conducted in semi-arid central Arizona by Huebner and Vankat (2003) determined that generally, for chaparral, chaparral grassland, and woodland, environmental factors influenced plant communities more than disturbances (i.e., grazing). They also determined that communities influenced primarily by environment were more stable than those influenced primarily by disturbance.

A limited comparison of two recently-grazed and two long-ungrazed gypsum outcrops in Oklahoma, at the SLL and Alabaster Caverns State Park, respectively, showed that the vascular plant communities were essentially the same, but that vascular plant cover was lower on the recently-grazed outcrops (Buckallew, 2002). Buckallew (2002) used the Sorensen's method to calculate a Community Coefficient and found 55.6% similarity in plant

community composition between the recently-grazed and long-ungrazed sites.

The gypsum outcrops throughout the world are in great need of further study. A study of the Guadalupe Mountain gypsum outcrops in New Mexico led to the discovery of new varieties of *Mentzelia* and *Anulocaulis* in 1996 by Michael Howard (Spellenberg and Wootten, 1999). Even more recent is the discovery of a new species, *Cryptantha gypsophila*, on gypsum outcrops in Colorado (Reveal and Broome, 2006). Akpulat and Celik (2005) found a 35.8% endemism rate from their floristic study of gypsum areas in Turkey. Therefore, as noted by Mota et al. (2003) in their study of plant succession on abandoned gypsum quarries, a conservation strategy is extremely important for the continued existence of endemic gypsum plant communities.

Purpose of this Study

This study focused on the vascular plant community composition found on gypsum outcrops of the CGH of northwestern Oklahoma. In this part of Oklahoma, average annual precipitation decreases approximately 15 cm from east to west. No study has focused specifically on the gypsum outcrops and how the vascular plant community may vary from east to west with the decrease in precipitation. The outcrops in this region are commonly used as ranchland due to the indurate nature of the land generally being unsuitable for growing crops. The impact of grazing is well-described for other types of grasslands, i.e., high intensity

grazing is ecologically damaging (Cooper et al., 2005), and regular grazing lowers species diversity (Jantunen et al., 2002) and increases canopy cover of annual and perennial forbs and cool-season grasses (Towne et al., 2005). Furthermore, Buckallew and Caddell (2003) reported that at the SLL, evidence of grazing remained because in the spring much of the grassland was covered by introduced annual *Bromus* spp. The impact of grazing has not been well-described for the unique type of plant community found on gypsum outcrops, although Meyer and Garcia-Moya (1989) suggest that grazing may not degrade the vascular plant communities on gypsum outcrops as much as it degrades other types of grasslands.

In this study, I attempted to determine the relationship of the vascular plant community to environmental factors and grazing on gypsum outcrops in the CGH. My objectives were to: 1) describe the composition of the vascular plant communities on gypsum outcrops throughout the CGH, 2) determine if there are differences in species composition and cover among gypsum outcrop communities, and 3) determine the relative importance of the environment and grazing in influencing vascular plant community composition and cover.

My null hypotheses are: 1) There will be no significant difference in vascular plant community composition across the CGH; 2) Environmental factors (aspect, average annual precipitation, average annual temperature, cryptogamic crust cover, elevation, latitude, longitude, and year-to-date precipitation total) will not affect vascular plant community

composition or cover; and 3) Grazing history will not affect vascular plant community composition or cover, or non-vegetated substrate cover.

MATERIALS AND METHODS

Study Area

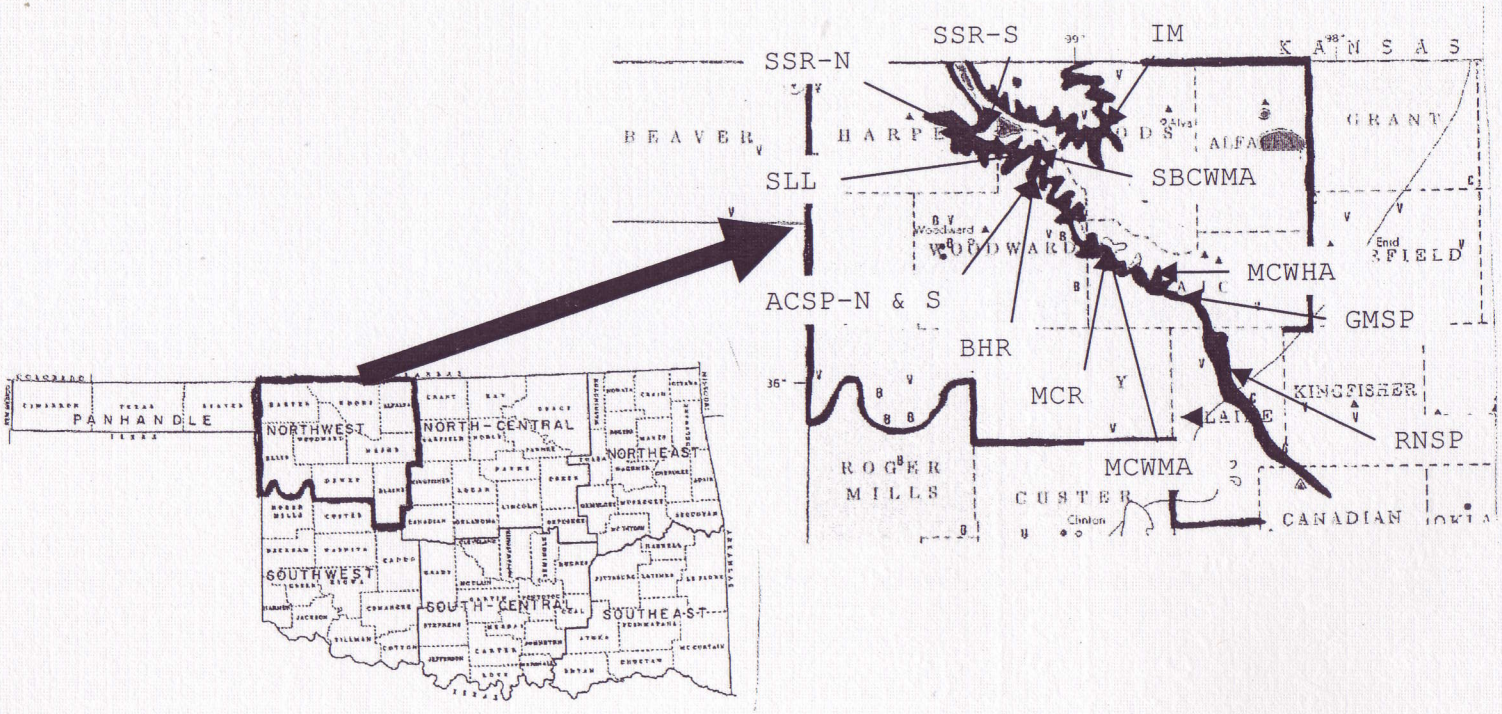
The Cimarron Gypsum Hills (CGH) stretch approximately 200 km across seven counties in the northwestern portion of Oklahoma. To establish quadrats across the CGH, I first contacted landowners and state park managers/naturalists in 2006 and asked for permission to access 11 properties to establish 13 sites. After permission was granted, I conducted verbal interviews with each landowner and park manager/naturalist to determine the land use history. Then I conducted a literature search of the sites for more information on land use history. I established three grazing history categories: 1) currently-grazed (CG), which were presently being grazed, 2) recently-grazed (RG), which had not been grazed for the past five to nine years, and 3) long-ungrazed (UG), which had not been grazed for more than ten years. The three grazing history categories were based on the occurrence of domesticated cattle (*Bos bovine*).

The 13 sites (Table 1 & Figure 1) were located in five counties: Blaine, Harper, Major, Woods, and Woodward. Seven of the 13 sites are owned by the State of Oklahoma: Alabaster Caverns State Park-North side of Cedar Canyon (ACSP-N), Alabaster Caverns State Park-South side of Cedar Canyon (ACSP-S), Roman Nose State Park (RNSP), Gloss Mountain State Park (GMSP), Major County Wildlife Hunting Area (MCWHA), Major County Wildlife Management Area (MCWMA), and Selman Bat Cave Wildlife Management

Table 1. Study sites: location, ownership, grazing history, and quadrat locations.

Property	County and Township, Range, & Section	Ownership	Grazing history	Quadrat #1 Latitude & Longitude	Quadrat #2 Latitude & Longitude	Quadrat #3 Latitude & Longitude
Alabaster Caverns State Park-north side of canyon (ACSP-N)	Woodward County, T26N R18W 28 & 33	State of Oklahoma	Recently-grazed	N 36° 42.112′ W 99° 8.943′	N 36° 42.123′ W 99° 8.914′	N 36° 42.133′ W 99° 8.687′
Alabaster Caverns State Park-south side of canyon (ACSP-S)	Woodward County, T26N R18W 28	State of Oklahoma	Long-ungrazed	N 36° 41.472′ W 99° 8.836′	N 36° 41.927′ W 99° 8.921′	N 36° 41.977′ W 99° 8.950′
Boyd Hughes Ranch (BHR)	Woodward County, T25N R18W 4 & 8	Private	Currently-grazed	N 36° 39.211′ W 99° 10.977′	N 36° 39.916′ W 99° 8.610′	N 36° 39.852′ W 99° 8.471′
Gloss Mountain State Park (GMSP)	Major County, T22N R13W 22	State of Oklahoma	Long-ungrazed	N 36° 21.878′ W 98° 34.715′	N 36° 21.997′ W 98° 34.679′	N 36° 22.174′ W 98° 34.752′
Irish's Mesa (IM)	Woods County, T28N R16W 3	Private	Long-ungrazed	N 36° 56.071′ W 99° 54.298′	N 36° 56.093′ W 99° 54.315′	N 36° 56.115′ W 99° 54.315′
Major County Ranch (MCR)	Major County, T22N R18W 4, 5, & 7	Private	Currently-grazed	N 36° 24.072′ W 98° 57.221′	N 36° 24.972′ W 98° 56.417′	N 36° 25.138′ W 98° 56.630′
Major County Wildlife Hunting Area (MCWHA)	Major County, T22N R14W 27 & 28	State of Oklahoma	Currently-grazed	N 36° 20.967′ W 98° 41.719′	N 36° 20.920′ W 98° 41.849′	N 36° 20.960′ W 98° 41.901′
Major County Wildlife Management Area (MCWMA)	Major County, T22N R16W 17	State of Oklahoma	Recently-grazed	N 36° 23.238′ W 98° 55.941′	N 36° 23.187′ W 98° 55.939′	N 36° 23.082′ W 98° 55.925′
Roman Nose State Park (RNSP)	Blaine County, T17N R12W 24 & T17N R11W 18	State of Oklahoma	Long-ungrazed	N 35° 56.158′ W 98° 25.287′	N 35° 56.165′ W 98° 25.391′	N 35° 55.971′ W 98° 26.168′
Selman Bat Cave Wildlife Management Area (SBCWMA)	Woodward County, T26N R19W 21	State of Oklahoma	Currently-grazed	N 36° 43.174′ W 99° 14.607′	N 36° 43.207′ W 99° 14.466′	N 36° 43.239′ W 99° 14.395′
Selman Living Laboratory (SLL)	Woodward County, T26N R19W 31 & 32	University of Central Oklahoma	Recently-grazed	N 36° 41.096′ W 99° 16.841′	N 36° 41.073′ W 99° 17.002′	N 36° 41.164′ W 99° 16.654′
Sue Selman Ranch-north (SSR-N)	Harper County, T27N R20W 24	Private	Currently-grazed	N 36° 48.074′ W 99° 17.841′	N 36° 48.103′ W 99° 18.324′	N 36° 48.295′ W 99° 17.799′
Sue Selman Ranch-south (SSR-S)	Woodward County, T26N R20W 15	Private	Currently-grazed	N 36° 44.162′ W 99° 20.435′	N 36° 43.630′ W 99° 20.462′	N 36° 43.641′ W 99° 20.515′

Figure 1. Map of Oklahoma, emphasizing the northwestern region and Cimarron Gypsum Hills' principal outcrop area; with data collecting sites labeled (refer to Table 1 for site names). Map of CGH principal outcrop area modified from Johnson, 1972c & map of state modified from Johnson, 1999.



Area (SBCWMA). The largest of these sites was GMSP, which consisted of approximately 259 ha. The next largest was RNSP, which consisted of 218 ha. The third largest was SBCWMA, which consisted of 137 ha. The MCWHA, ACSP (both approximately 80 ha), and MCWMA (approximately 72 ha) were the smaller sites.

Three of the state-owned sites (ACSP-S, GMSP, & RNSP) were, to the best of the park managers'/naturalists' knowledge, never grazed by cattle, at least since the sites became state-owned. No evidence of cattle defecation was observed at these long-ungrazed sites. The oldest established state park of this study was RNSP which officially opened in 1937 (Weber, 1994). Alabaster Caverns became a state park (Caywood, 2006) in 1957. Personal communication with Mark Stubsten (2006) revealed that GMSP was established in 1977 and that the top of the main park mesa used for this study, called Cathedral Mountain, was never grazed by cattle. The Cathedral Mountain area of GMSP also exhibited the most human impact of the 13 sites. Two of the seven state-owned sites, ACSP-N and MCWMA, were classified into a recently-grazed group. The land on the north side of Cedar Canyon at ACSP was leased for domesticated cattle grazing until 1997 and MCWMA discontinued cattle grazing in 2001. Evidence of cattle defecation still persisted on the recently-grazed sites. Of the seven state-owned sites, two (MCWHA & SBCWMA) were currently being grazed by cattle.

One of the 13 sites, Selman Living Laboratory (SLL), is owned by the University of Central Oklahoma (UCO), Edmond,

Oklahoma. In 1998, UCO obtained a grant to purchase the Selman Cave System from Mrs. Betty Selman. Mrs. Selman graciously donated the property around and above the cave. This property was also placed into the recently-grazed category, due to cattle grazing until the end of 1998, eight years prior to 2006.

Five of the 13 sites were privately owned: Irish's Mesa (IM), Boyd Hughes Ranch (BHR), Sue Selman Ranch-North (SSR-N), Sue Selman Ranch-South (SSR-S), and Major County Ranch (MCR). The MCR was the largest continuous study site with approximately 1821 ha. The SSR-N and BHR sites were the second largest continuous areas with approximately 1036 ha each. Sue Selman Ranch-South site consisted of approximately 388 ha. While consisting of only approximately 64 ha, IM was one of the most beautiful and untouched gypsum outcrops of this project. All of the privately owned properties were currently-grazed, with the exception of IM, which had no indication of recent cattle grazing and thus was placed in the long-ungrazed category.

Sampling Design

I established three 10 m x 10 m quadrats at each of the 13 sites for a total of 39 quadrats (Table 1). Three large and continuous gypsum outcrops were subjectively chosen at each of the 13 sites and a quadrat was established in the center of each outcrop. The location (latitude and longitude), aspect, and elevation of the southwest corner of each quadrat were recorded with a Global Positioning System (GPS unit, Garmin). Each corner

of each quadrat was labeled with an aluminum tag, with corner location and quadrat number. Pink surveyor's tape was also used at each corner; however it could only be used at sites that were currently not being grazed by cattle. When quadrats were resampled, measuring tapes were laid out between tags to ensure accuracy of quadrat size and to establish boundaries. In the event a corner marker was missing, then a new one was made to replace the missing marker.

Each site was sampled once during summer (July) 2006, fall (September-October) 2006, spring (May) 2007, and summer (July) 2007. During each season, sampling was generally conducted during a two- to five-week period starting at the southeasternmost site of the CGH then working to the northwest. Each plant species within the quadrats was identified using several plant identification references (Waterfall, 1969; McGregor and Barkley, 1977; Great Plains Flora Association, 1986; Diggs et al., 1999; Tyrl et al., 2007). Identifications were verified using University of Central Oklahoma (CSU) and Oklahoma State University (OKLA) herbaria specimens. Plant nomenclature was verified using the USDA PLANTS Database (USDA, NRCS, 2007). From outside of the quadrats a voucher specimen was collected for each species at each site. Voucher specimens were deposited in the UCO (CSU) herbarium.

For each plant species identified within each quadrat, I visually estimated cover. During the summer 2006 season, six Daubenmire cover classes were used (Table 2; Daubenmire, 1959).

However, many species had cover values less than 5%; thus to be better able to discern differences in cover for these species I modified my sampling procedures for the fall 2006, spring 2007, and summer 2007 seasons. Similar to Wiser et al. (1996), estimated cover of each plant species was placed into one of ten cover classes (Table 3; Peet et al., 1998). The summer 2006 season was eliminated from analyses that used cover values. Non-vegetated substrate and cryptogamic crust cover in each quadrat were also placed into a cover class. More accurate estimates of cover were acquired by placing a 1 m x 1 m polyvinyl chloride (pvc) pipe frame over the vegetation. Following data collection at each site, I consulted the Oklahoma Climatological Survey (2006) for the average annual temperature, average annual precipitation, and year-to-date precipitation totals for each sampling date.

Table 2. Daubenmire cover class system (Daubenmire, 1959) used in summer 2006.

Cover class	Range of coverage	Midpoint
1	< 5%	2.5
2	5 - 25%	15.0
3	25 - 50%	37.5
4	50 - 75%	62.5
5	75 - 95%	85.0
6	95 - 100%	97.5

Table 3. Cover class system (Peet et al.,1998) used in fall 2006, spring 2007, and summer 2007.

Cover class	Range of coverage	Midpoint
1	< 0.1%	0.05
2	0.1 - 1%	0.55
3	1 - 2%	1.5
4	2 - 5%	3.5
5	5 - 10%	7.5
6	10 - 25%	17.5
7	25 - 50%	37.5
8	50 - 75%	62.5
9	75 - 95%	85.0
10	95 - 100%	97.5

Using Taylor and Taylor (1994) and the USDA PLANTS Database (USDA, NRCS, 2007), I determined each plant species' growth form or habit (annual, biennial, perennial, shrub, or tree) and origin (native or introduced to Oklahoma). The Oklahoma Natural Heritage Inventory Database (2008) was consulted for state and global listings for possible imperiled species. The Oklahoma Vascular Plants Database (2008) was consulted to determine whether any species had not been collected in the counties in which they were found and deposited in Oklahoma herbaria.

Data Analyses

For each season, I compared species composition, cover for individual species, overall plant cover, species richness, and species diversity among study sites as well as among grazing

regimes. Species richness and year-to-date precipitation totals were compared between summer 2006 and summer 2007.

Hurlbert's Probability of an Interspecific Encounter (PIE), from EcoSim 7 (Gotelli and Entsminger, 2006) software, was used to calculate species diversity for the 13 sites. For Hurlbert's PIE, cover classes for the three quadrats were summed for each species at each site and divided by three to calculate the average cover for each plant species at each site. Hurlbert's PIE is the probability that, if two individuals are encountered randomly in a community, they will belong to different species (Hurlbert, 1971). Rarefaction curves, at the 95% confidence level, were used to determine significant differences in diversity among sites (Hurlbert, 1971; Olszewski, 2004). Only significant high and low confidence levels were graphed due to the excessive number of rarefaction curves.

For fall 2006, spring 2007, and summer 2007, PC-ORD 5 (McCune and Mefford, 2006) was used for Indicator Species Analysis (ISA), Cluster Analysis, and Detrended Correspondence Analysis (DCA). Indicator Species Analysis was used to determine whether plant species were indicators of one of the three grazing regimes (currently-grazed, recently-grazed, and long-ungrazed). For ISA, cover classes for the three quadrats were summed for each species at each site and divided by three to calculate the average cover for each plant species at each site. Indicator Species Analysis uses abundance and faithfulness of occurrence of each species to a particular group (i.e., grazing regime) to

calculate indicator values (IV). The IVs range from 0 to 100, and a species with an IV of 100 would be a perfect indicator for a particular group. Significance of IV ($p < 0.05$) was tested with the Monte Carlo method to determine which species were indicators of each grazing regime. Bonferroni Correction (α/n: $\alpha = 0.05$ and n = total number of species = 150; $p < 0.00033$), which can reduce alpha value inflation (or a Type I error; Holm, 1979), was also utilized to compare Monte Carlo calculated p-values from ISA. Then, I consulted Bidwell et al. (2007 & 2008) to determine if any of the species' palatability to domesticated cattle was listed.

The same calculations used for ISA were then used in Cluster Analysis (hierarchical, agglomerative classification) to calculate distance (dissimilarity) measures between sites. For the Cluster Analysis, Sorensen's distance measure (Sorensen, 1948) was used with the flexible beta linkage method ($\beta = -0.25$) to form a dendrogram. McCune and Grace (2002) consider this Cluster Analysis technique one of the most compatible and defensible. Sorensen's distance measures range from 0 to 1. Communities with a value up to 0.50 belong to the same association, thus the lower the calculated value the more similar are the communities. Cluster Analysis is a quantification of relatedness between sites. It links the most similar sites together, and then repeats the process until all sites are clustered into two groups, with sites of increasing dissimilarity being linked at increasing distances.

Detrended Correspondence Analysis (DCA), a form of ordination, was used to 1) determine the degree of similarity among sites using species composition and abundance, and 2) correlate environmental factors (aspect, average annual precipitation, average annual temperature, cryptogamic crust cover, elevation, latitude, longitude, and year-to-date precipitation totals) and species with ordination axes (Hill and Gauch, 1980). For the DCA, cover class data were converted to midpoint values. Midpoints for the three quadrats at each site were summed and divided by three to find the average plant species cover at each site, for each season. The seasonal values were also averaged to determine an average plant species cover value for three seasons combined. The PC-ORD program only plotted environmental variables that were significantly correlated with ordination axes (N = number of sites in analysis: N = 13, $-0.514 < r > 0.514$ & N = 12, $-0.532 < r > 0.532$). When a site was an outlier, it and species exclusive to the site were eliminated from the analysis to reduce its influence (Hill and Gauch, 1980; McCune and Grace, 2002) and the DCA was repeated. Different symbols were used for sites with different grazing history regimes and these were overlaid on to the ordination diagrams to detect any patterns due to grazing history.

To determine whether the amount of non-vegetated substrate on quadrats during each season (fall 2006, spring 2007, and summer 2007) was influenced by grazing history, I used SigmaStat 3.5 (Systat Software, Inc., 2006) one-way analysis of variance to

test whether there was a significant difference ($p < 0.05$) in the mean area of non-vegetated substrate among currently-grazed, recently-grazed, and long-ungrazed quadrats. If the data failed the test for normality, then I used Kruskal-Wallis one-way analysis of variance on ranks. If significant differences were found, a pairwise multiple comparison test, Dunn's method, was used to determine which groups differed significantly from one another.

RESULTS AND DISCUSSION

Community Composition

During four data collecting seasons, across 13 sites in the Cimarron Gypsum Hills (CGH), 155 species of vascular plants in 46 families were identified (Table 4). All species were angiosperms with the exception of one gymnosperm, *Juniperus virginiana* var. *virginiana*. No seedless vascular plant species were observed. Original data for the four seasons can be found in Appendices 1-4.

The typical *Schizachyrium scoparium-Castilleja purpurea* var. *citrina-Lesquerella gordonii* vegetation association (Hoagland, 2000) for western Oklahoma gypsum substrate was observed and three (1.9%) species observed were obligate gypsophiles (*Haploesthes greggii* var. *texana*, *Nama stevensii*, and *Phacelia integrifolia* var. *integrifolia*). The small percentage of obligate gypsophiles was consistent with Parsons' findings (1976).

Of the 155 species, four (*Astragalus* sp., *Evax* sp., *Trifolium* sp., and an unknown Asteraceae) lacked fruiting or flowering parts and could only be identified to the family or genus rank. Thus, I was unable to determine the origin and habit for one species, which I referred to as "unknown Asteraceae" and I was unable to determine the origin of the specimen identified as *Trifolium* sp. Where calculations for origin or habit were reported, these species were excluded.

Table 4. Vascular plants on gypsum outcrops, Cimarron Gypsum Hills, in the summer of 2006, fall of 2006, spring of 2007, and summer of 2007 with species name abbreviations, origin (I = introduced, N = native), habit (A = annual, B = biennial, P = perennial, S = shrub, T = tree), indication (*) of global (G) & state (S) rarity, and new county records.

Taxon	Name Abbreviation	Origin/Habit	New county record
CONIFEROPHYTA			
CUPRESSACEAE			
Juniperus virginiana L. var. *virginiana*	JUVIV	N/T	
MAGNOLIOPHYTA			
MAGNOLIOPSIDA			
AMARANTHACEAE			
Amaranthus albus L.	AMAL	N/A	Woodward
ANACARDIACEAE			
Rhus aromatica Aiton	RHAR4	N/S	
Rhus glabra L.	RHGL	N/S	
APIACEAE			
Ammoselinum popei Torr. & A.Gray	AMPO4	N/A	
Lomatium foeniculaceum (Nutt.) J.M.Coult. & Rose ssp. *foeniculaceum*	LOFOF2	N/P	
Spermolepis inermis (Nutt. ex DC.) Mathias & Constance	SPIN	N/A	
APOCYNACEAE			
Apocynum cannabinum L.	APCA	N/P	
ASCLEPIADACEAE			
Asclepias engelmanniana Woods.	ASEN	N/P	Harper
ASTERACEAE			
Ambrosia artemisiifolia L. var. *elatior* (L.) Descourtils	AMARE	N/A	Major, Woods, & Woodward
Ambrosia psilostachya DC.	AMPS	N/P	
Amphiachyris dracunculoides (DC.) Nutt.	AMDR	N/A	

Taxon	Name Abbreviation	Origin/Habit	New county record
Artemisia dracunculus L.	ARDR4	N/P	Woodward
Artemisia filifolia Torr.	ARFI2	N/S	
Artemisia ludoviciana Nutt. ssp. *ludoviciana*	ARLUL2	N/P	
Chaetopappa ericoides (Torr.) Nesom	CHER2	N/P	
Cirsium undulatum (Nutt.) Spreng. var. *undulatum*	CIUNU	N/P	
Conyza canadensis (L.) Cronquist var. *canadensis*	COCAC3	N/A	
Conyza canadensis (L.) Cronquist var. *glabrata* (A.Gray) Cronquist	COCAG	N/A	
Evax prolifera Nutt. ex DC.	EVPR	N/A	Harper
Evax Gaertn. sp.	EVAX	N/A	--
Gaillardia pulchella Foug. var. *pulchella*	GAPUP2	N/A	
Grindelia lanceolata Nutt.	GRLA3	N/P	Major
Grindelia squarrosa (Pursh) Dunal var. *squarrosa*	GRSQS2	N/P	Blaine & Major
Gutierrezia sarothrae (Pursh) Britt. & Rusby	GUSA2	N/P	
Haploesthes greggii A.Gray var. *texana* (J.M.Coult.) I.M.Johnst.	HAGRT	N/P	
Helianthus annuus L.	HEAN3	N/A	
Helianthus petiolaris Nutt. ssp. *petiolaris*	HEPEP	N/A	
Heterotheca stenophylla (A.Gray) Shinners var. *stenophylla*	HESTS	N/P	
Hymenopappus tenuifolius Pursh	HYTE2	N/P	
Lactuca serriola L.	LASE	N/A	
Liatris punctata Hook.	LIPU	N/P	
Psilostrophe tagetina (Nutt.) Greene var. *cerifera* (A.Nelson) B.L.Turner	PSTAC	N/P	
Pyrrhopappus grandiflorus (Nutt.) Nutt.	PYGR2	N/P	
Senecio riddellii Torr. & A.Gray	SERI2	N/P	
Solidago petiolaris Aiton var. *angusta* (Torr. & A.Gray) A.Gray	SOPEA	N/P	

Taxon	Name Abbreviation	Origin/Habit	New county record
Tetraneuris linearifolia (Hook.) Greene var. *linearifolia*	TELIL	N/A	
Tetraneuris scaposa (DC.) Greene var. *scaposa*	TESCS	N/P	
Thelesperma filifolium (Hook.) A.Gray	THFI	N/P	
Thelesperma megapotamicum (Spreng.) Kuntze	THME	N/P	
Tragopogon dubius Scop.	TRDU	I/A	
unknown Asteraceae	--	--	--
BORAGINACEAE			
Lappula occidentalis (S.Watson) Greene var. *cupulata* (A.Gray) Higgins	LAOCC	N/A	
Lithospermum incisum Lehm.	LIIN2	N/P	
BRASSICACEAE			
Descurainia pinnata (Walter) Britton	DEPI	N/A	
Draba cuneifolia Nutt. ex Torr. & A.Gray var. *cuneifolia*	DRCUC	N/A	Major
Draba platycarpa Torr. & A.Gray	DRPL	N/A	Major
Draba reptans (Lam.) Fern.	DRRE2	N/A	
Lepidium densiflorum Schrad. var. *densiflorum*	LEDED	N/A	
Lesquerella gordonii (A.Gray) S.Watson var. *gordonii*	LEGOG	N/A	
CACTACEAE			
Cylindropuntia imbricata (Haw.) F.M.Knuth var. *imbricata*; * S1	CYIMI	N/P	Woodward
Echinocereus reichenbachii (Terscheck ex Walp.) Hort ex Haage; * S2?	ECRE	N/P	
Escobaria missouriensis (Sweet) D.R.Hunt	ESMI3	N/P	Major
Escobaria vivipara (Nutt.) Buxbaum var. *vivipara*; * S2S3	ESVIV	N/P	Blaine & Woodward
Opuntia phaeacantha Engelm.	OPPH	N/P	Woodward
CAESALPINIACEAE			
Cercis canadensis L. var. *canadensis*	CECAC	N/T	

Taxon	Name Abbreviation	Origin/Habit	New county record
Pomaria jamesii (Torr. & A.Gray) Walp.	POJA5	N/P	
CAPPRACEAE			
Polanisia dodecandra (L.) DC. ssp. *trachysperma* (Torr. & A.Gray) Iltis	PODOT	N/A	
CARYOPHYLLACEAE			
Paronychia jamesii Torr. & A.Gray	PAJA	N/P	
Silene antirrhina L.	SIAN2	N/A	Major
CHENOPODIACEAE			
Atriplex subspicata (Nutt.) Rydb.	ATSU2	N/A	Woodward
Chenopodium album L. var. *album*	CHALA	I/A	
Chenopodium berlandieri Moq. var. *berlandieri*	CHBEB2	N/A	
Chenopodium pallescens Standl.; * S1S2	CHPA5	N/A	
Chenopodium pratericola Rydb.	CHPR5	N/A	
Salsola tragus L.	SATR12	I/A	
CONVOLVULACEAE			
Evolvulus nuttallianus J.A.Schultes	EVNU	N/P	
Ipomoea leptophylla Torr.	IPLE	N/P	
EUPHORBIACEAE			
Acalypha ostryifolia Riddell	ACOS	N/A	
Chamaesyce glyptosperma (Engelm.) Small	CHGL13	N/A	
Chamaesyce maculata (L.) Small	CHMA15	N/A	Woodward
Chamaesyce missurica (Raf.) Shinners	CHMI8	N/A	
Chamaesyce serpens (Kunth) Small	CHSE4	N/A	
Croton monanthogynus Michx.	CRMO6	N/A	Harper
Croton texensis (Klotzsch) Muell.-Arg. var. *texensis*	CRTET	N/A	

Taxon	Name Abbreviation	Origin/Habit	New county record
Euphorbia dentata Michx. var. *dentata*	EUDED	N/A	
Euphorbia marginata Pursh	EUMA8	N/A	
Euphorbia spathulata Lam.	EUSP	N/A	
FABACEAE			
Astragalus cf. *distortus* Torr. & A.Gray var. *distortus*	ASDID3	N/P	Major
Astragalus gracilis Nutt.	ASGR3	N/P	
Astragalus lotiflorus Hook.	ASLO4	N/P	
Astragalus missouriensis Nutt. var. *missouriensis*	ASMIM5	N/P	
Astragalus mollissimus Torr. var. *mollissimus*	ASMOM5	N/P	
Astragalus nuttallianus DC.	ASNU4	N/P	Woodward
Astragalus L. sp.	ASTRA	N/P	--
Dalea aurea Nutt. ex Pursh	DAAU	N/P	
Dalea enneandra Nutt.	DAEN	N/P	
Desmanthus leptolobus Torr. & A.Gray	DELE2	N/P	
Psoralidium tenuiflorum (Pursh) Rydb.	PSTE5	N/P	
Trifolium sp.	TRIFO	-/A	--
GERANIACEAE			
Geranium carolinianum L. var. *carolinianum*	GECAC4	N/A	
HYDROPHYLLACEAE			
Nama stevensii C.L.Hitchc.	NAST2	N/A	
Phacelia integrifolia Torr. var. *integrifolia*	PHINI5	N/A,B,P	
KRAMERIACEAE			
Krameria lanceolata Torr.	KRLA	N/P	

Taxon	Name Abbreviation	Origin/Habit	New county record
LAMIACEAE			
Hedeoma drummondii Benth.	HEDR	N/P	Woodward
Hedeoma hispida Pursh	HEHI	N/A	Blaine & Woodward
Monarda clinopodioides A.Gray	MOCL2	N/A	
LINACEAE			
Linum pratense (J.B.S.Norton) Small	LIPR	N/A	
Linum rigidum Pursh var. *rigidum*	LIRIR	N/A	
LOASACEAE			
Mentzelia nuda (Pursh) Torr. & A.Gray var. *stricta* (Osterh.) Harrington	MENUS	N/P	
Mentzelia oligosperma Nutt. ex Sims	MEOL	N/P	
MALVACEAE			
Sphaeralcea coccinea (Nutt.) Rydb. ssp. *coccinea*	SPCOC	N/P	
MIMOSACEAE			
Mimosa nuttallii (DC. ex Britton & Rose) B.L. Turner	MINU6	N/P	
NYCTAGINACEAE			
Mirabilis albida (Walt.) Heimerl	MIAL4	N/P	
ONAGRACEAE			
Calylophus berlandieri Spach	CABE6	N/P	
Calylophus hartwegii (Benth.) P.H. Raven ssp. *fendleri* (A.Gray) Towner & P.H.Raven	CAHAF	N/P	
Calylophus serrulatus (Nutt.) Raven	CASE12	N/P	
Gaura coccinea Nutt. ex Pursh	GACO5	N/P	
Gaura villosa Torr. ssp. *villosa*	GAVIV	N/P	
Stenosiphon linifolius (Nutt. ex James) Heynh.	STLI2	N/P	

Taxon	Name Abbreviation	Origin/Habit	New county record
OROBANCHACEAE			
Orobanche ludoviciana Nutt. ssp. *multiflora* (Nutt.) Collins ex H.L.White & W.C.Holmes	ORLUM	N/P	Major
OXALIDACEAE			
Oxalis dillenii Jacq.	OXDI2	N/P	
PLANTAGINACEAE			
Plantago patagonica Jacq.	PLPA2	N/A	
Plantago rhodosperma Decne.	PLRH	N/A	
POLYGALACEAE			
Polygala alba Nutt.	POAL4	N/P	
POLYGONACEAE			
Eriogonum longifolium Nutt. var. *longifolium*	ERLOL4	N/P	
PORTULACACEAE			
Portulaca oleracea L.	POOL	N/A	Woodward
Portulaca pilosa L.	POPI3	N/A	
PRIMULACEAE			
Androsace occidentalis Pursh	ANOC2	N/A	
RANUNCULACEAE			
Delphinium carolinianum Walter ssp. *virescens* (Nutt.) R.E.Brooks	DECAV2	N/P	
RHAMNACEAE			
Ceanothus herbaceus Raf.	CEHE	N/S	
RUBIACEAE			
Galium virgatum Nutt.	GAVI	N/A	Blaine
Stenaria nigricans (Lam.) Terrell var. *nigricans*	STNIN	N/P	

Taxon	Name Abbreviation	Origin/Habit	New county record
SCROPHULARIACEAE			
Castilleja purpurea (Nutt.) G.Don var. *citrina* (Pennell) Shinners	CAPUC	N/P	
Nuttallanthus canadensis (L.) D.A.Sutton	NUCA	N/A	Blaine & Major
SOLANACEAE			
Solanum elaeagnifolium Cav.	SOEL	N/P	
Solanum rostratum Dunal	SORO	N/A	Harper
ULMACEAE			
Ulmus americana L.	ULAM	N/T	
VERBENACEAE			
Glandularia pumila (Rydb.) Umber	GLPU4	N/A	
VIOLACEAE			
Viola bicolor Pursh	VIBI	N/A	
ZYGOPHYLLACEAE			
Kallstroemia parviflora J.B.S.Norton	KAPA	N/A	
LILIOPSIDA			
AGAVACEAE			
Yucca glauca Nutt. var. *glauca*	YUGLG2	N/P	Blaine
LILIACEAE			
Allium drummondii Regel	ALDR	N/P	
POACEAE			
Andropogon gerardii Vitman	ANGE	N/P	
Andropogon hallii Hack.	ANHA	N/P	
Aristida purpurea Nutt.	ARPU9	N/P	
Bothriochloa ischaemum (L.) Keng. var. *songarica* (Rupr.ex Fisch. & C.A.Mey.) Celarier & Harlan	BOISS	I/P	Woods

Taxon	Name Abbreviation	Origin/Habit	New county record
Bothriochloa laguroides (DC.) Herter ssp. *torreyana* (Steud.) Allred & Gould	BOLAT	N/P	
Bouteloua curtipendula (Michx.) Torr.	BOCU	N/P	
Bouteloua dactyloides (Nutt.) J.T.Columbus	BODA2	N/P	
Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	BOGR2	N/P	
Bouteloua hirsuta Lag. var. *hirsuta*	BOHIH	N/P	
Bromus arvensis L.	BRAR5	I/A	Blaine
Cenchrus longispinus (Hack.) Fernald	CELO3	N/P	Major
Eragrostis cilianensis (All.) Vign. ex Janchen	ERCI	I/A	
Eragrostis minor Host	ERMI5	I/A	Major
Erioneuron pilosum (Buckl.) Nash	ERPI5	N/P	
Hordeum pusillum Nutt.	HOPU	N/A	
Panicum capillare L.	PACA6	N/A	
Panicum hallii Vasey var. *hallii*	PAHAH	N/P	Major
Schizachyrium scoparium (Michx.) Nash var. *scoparium*	SCSCS	N/P	
Sporobolus cryptandrus (Torr.) A.Gray	SPCR	N/P	
Tridens muticus (Torr.) Nash var. *elongatus* (Buckl.) Shinners	TRMUE	N/P	
Trisetum interruptum Buckley	TRIN5	N/A	Harper, Major, & Woodward
Vulpia octoflora (Walter) Rydb. var. *octoflora*	VUOCO	N/A	

* G5=secure globally, rare at periphery; S1=critically imperiled (5/fewer individuals); S2=imperiled (6-20 individuals); S3=rare (21-100 individuals); ?=question about rank given (defined by Natural Heritage Rarity Ranking)

Of the 153 species for which origin could be determined, 146 (95.4%) were native and 7 (4.6%) were introduced (non-native). This was similar to the findings of Buckallew and Caddell (2003), who reported that the gypsum outcrops at the SLL supported a largely native community, with only four introduced species being occasionally found on the outcrops. In my study, the seven introduced species were *Atriplex subspicata*, *Bothriochloa ischaemum* var. *songarica*, *Bromus arvensis*, *Eragrostis cilianensis*, *Eragrostis minor*, *Salsola tragus*, and *Tragopogon dubius*. The harshness of the gypsum outcrop habitat seems to make it difficult for introduced species to become established, and therefore the outcrops are largely "islands" of native prairie, most likely similar to what was present before the introduction of non-native flora and fauna.

Of the 154 species for which habit could be determined, 81 (52.6%) were herbaceous perennials and 65 (42.2%) were annuals. One species (0.6%), *Phacelia integrifolia* var. *integrifolia* (Hydrophyllaceae), can grow as an annual, biennial, or perennial. Three species (2%) were trees, including one gymnosperm, *Juniperus virginiana* var. *virginiana*. *Juniperus virginiana* var. *virginiana* (Cupressaceae) is able to persist on gypsum, but does not appear to grow as large as it does in the deeper soils in the surrounding prairie. The other two tree species, *Cercis canadensis* var. *canadensis* (Caesalpiniaceae) and *Ulmus americana* (Ulmaceae), were found only as seedlings and do not appear to have the ability to persist. Four of the 154 species (2.6%) were

shrubs. Two of the four species (*Rhus aromatica* and *Rhus glabra*) are members of the Anacardiaceae. One (*Artemisia filifolia*) belongs to the Asteraceae and the fourth species (*Ceanothus herbaceus*) was the only representative of the Rhamnaceae. All trees and shrubs were native.

Of the seven introduced species, one (*Bothriochloa ischaemum* var. *songarica*) was a perennial herb and the other six species were annuals (Table 4). Three introduced species (*B. ischaemum* var. *songarica*, *Salsola tragus*, and *Tragopogon dubius*) were each observed at only one long-ungrazed site (IM; Table 5). One, *Chenopodium album* var. *album*, was observed on two recently-grazed sites (ACSP-N & MCWMA), and one, *Eragrostis minor*, was observed at one currently-grazed site (MCWHA). One species, *Bromus arvensis*, was observed at long-ungrazed (IM & RNSP) and currently-grazed sites (SSR-S), and *Eragrostis cilianensis* was observed at recently-grazed (ACSP-N) and currently-grazed sites (MCR). Cover of these introduced species was very low, never exceeding a cover value of 2, or covering more than 1% of any quadrat. The introduced species were also only encountered occasionally during this two year study. The occasional occurrence and low cover of introduced species were similar to the SLL gypsum outcrop study by Buckallew and Caddell (2003).

The most common family was the Asteraceae (aster family), with 33 species, of which only one (*Tragopogon dubius*) was introduced. The second most common family was the Poaceae (grass family), with 22 species. The Poaceae also had the highest

Table 5. Presence (X) or absence (-) of each plant species at each site: summer 2006, fall 2006, spring 2007, and summer 2007 combined.

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed					
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S
Acalypha ostryifolia	-	-	-	-	-	-	-	-	X	-	-	-	-
Allium drummondii	X	X	X	X	X	X	X	X	X	X	X	X	X
Amaranthus albus	-	-	-	-	-	-	-	X	-	-	-	-	-
Ambrosia artemisiifolia var. *elatior*	-	-	X	-	-	X	-	X	X	X	X	-	X
Ambrosia psilostachya	X	-	-	-	X	-	-	-	-	-	-	-	-
Ammoselinum popei	X	-	-	-	-	-	-	-	-	-	-	-	X
Amphiachyris dracunculoides	X	-	-	-	X	X	-	X	X	X	-	X	X
Andropogon gerardii	-	-	X	-	-	-	-	-	-	-	-	-	-
Andropogon hallii	-	-	-	-	-	X	-	-	-	X	-	-	X
Androsace occidentalis	-	-	-	-	-	-	-	-	X	-	-	-	-
Apocynum cannabinum	-	-	X	-	-	-	-	-	-	-	-	-	-
Aristida purpurea	X	X	-	-	X	-	X	X	-	X	X	X	X
Artemisia dracunculus	-	-	X	-	-	-	-	-	-	X	-	-	-
Artemisia filifolia	-	-	-	-	-	-	-	-	-	-	-	X	-
Artemisia ludoviciana ssp. *ludoviciana*	-	X	X	-	-	-	-	-	-	X	-	X	-
Asclepias engelmanniana	-	-	X	X	-	-	-	-	-	-	-	X	X
Astragalus distortus var. *distortus*	-	-	-	-	-	-	-	-	-	X	-	-	-
Astragalus gracilis	-	-	X	-	-	X	X	-	-	-	-	X	-
Astragalus lotiflorus	-	-	-	-	-	-	-	X	-	X	-	X	X
Astragalus missouriensis var. *missouriensis*	-	-	-	-	-	-	X	-	-	-	-	X	X
Astragalus mollissimus var. *mollissimus*	-	X	-	-	-	-	-	-	-	-	-	-	-
Astragalus nuttallianus	-	-	-	-	-	-	-	X	-	-	-	-	-
Astragalus sp.	-	X	-	-	-	-	-	-	-	-	-	-	-
Atriplex subspicata	-	-	-	-	-	-	-	X	-	-	-	-	-
Bothriochloa ischaemum var. *songarica*	-	-	X	-	-	-	-	-	-	-	-	-	-
Bothriochloa laguroides ssp. *torreyana*	-	-	-	-	-	-	-	X	-	-	X	-	-

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed					
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S
Bouteloua curtipendula	X	X	X	X	X	X	X	X	X	X	X	X	X
Bouteloua dactyloides	-	-	-	-	-	-	-	X	-	-	X	-	X
Bouteloua gracilis	X	X	X	X	X	X	-	X	X	X	X	X	X
Bouteloua hirsuta var. *hirsuta*	-	-	-	-	-	-	X	X	-	-	-	X	X
Bromus arvensis	-	-	X	X	-	-	-	-	-	-	-	-	X
Calylophus hartwegii ssp. *fendleri*	X	-	X	X	X	X	-	X	X	X	X	X	X
Calylophus serrulatus	X	X	X	X	X	X	X	X	X	X	X	X	X
Castilleja purpurea var. *citrina*	X	-	-	X	X	X	X	X	X	X	X	X	X
Ceanothus herbaceus	-	-	X	-	-	-	-	-	-	-	-	-	-
Cenchrus longispinus	-	-	-	-	-	X	-	-	-	-	-	-	-
Cercis canadensis var. *canadensis*	-	-	-	X	-	-	-	-	-	-	-	-	-
Chaetopappa ericoides	-	-	-	-	-	-	-	-	-	-	-	X	X
Chamaesyce glyptosperma	X	X	X	-	-	X	-	X	X	X	-	-	X
Chamaesyce maculata	X	-	-	-	-	-	-	-	-	-	-	-	-
Chamaesyce missurica	X	X	X	X	X	X	-	-	X	-	-	-	-
Chamaesyce serpens	X	X	-	-	-	-	-	-	-	-	-	-	-
Chenopodium album var. *album*	-	-	-	-	X	X	-	-	-	-	-	-	-
Chenopodium berlandieri var. *berlandieri*	-	-	-	-	-	-	-	X	-	-	-	-	-
Chenopodium pallescens	-	-	X	-	-	-	-	-	-	-	-	-	-
Chenopodium pratericola	-	X	X	-	-	X	-	X	-	X	-	-	-
Cirsium undulatum var. *undulatum*	-	-	X	-	-	-	-	-	-	-	-	-	X
Conyza canadensis	X	X	X	X	X	X	X	X	X	X	X	X	X
Croton monanthogynus	X	X	-	X	X	X	X	X	X	X	X	X	X
Croton texensis var. *texensis*	X	-	X	-	X	X	X	X	X	-	X	X	X
Cylindropuntia imbricata var. *imbricata*	X	-	-	-	-	-	-	-	-	-	-	-	-
Dalea aurea	-	-	-	-	-	-	-	-	-	-	-	-	X

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed					
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S
Dalea enneandra	-	-	-	-	-	-	-	-	-	-	-	X	-
Delphinium carolinianum ssp. *virescens*	X	-	-	-	-	-	-	X	X	-	-	X	-
Descurainia pinnata	X	-	X	-	-	-	-	-	X	X	-	-	-
Desmanthus leptolobus	-	-	X	-	-	-	-	-	-	-	-	-	-
Draba cuneifolia var. *cuneifolia*	-	X	-	-	-	-	-	-	-	-	-	-	-
Draba platycarpa	-	-	-	-	-	-	-	-	X	-	-	-	-
Draba reptans	X	-	X	X	-	X	-	-	X	X	-	-	-
Echinocereus reichenbachii	X	-	-	-	X	X	X	X	X	-	X	-	X
Eragrostis cilianensis	-	-	-	-	X	-	-	-	X	-	-	-	-
Eragrostis minor	-	-	-	-	-	-	-	-	-	X	-	-	-
Eriogonum longifolium var. *longifolium*	-	-	-	X	-	-	-	-	-	-	-	-	-
Erioneuron pilosum	-	X	-	-	X	-	X	X	X	X	X	X	X
Escobaria missouriensis	-	-	-	-	-	-	-	-	-	X	-	-	-
Escobaria vivipara var. *vivipara*	X	-	X	X	-	X	X	-	-	-	-	-	-
Euphorbia dentata var. *dentata*	X	X	X	-	-	-	-	-	-	-	-	-	-
Euphorbia marginata	-	-	-	-	-	-	X	X	-	-	X	-	X
Euphorbia spathulata	X	X	-	-	X	X	-	X	X	X	-	-	-
Evax prolifera	X	-	X	-	X	X	-	-	-	-	-	X	X
Evax sp.	-	-	-	-	-	-	-	-	X	-	-	-	-
Evolvulus nuttallianus	-	-	-	-	-	-	-	X	-	-	-	-	X
Gaillardia pulchella var. *pulchella*	X	X	-	-	X	X	-	X	X	X	-	-	-
Galium virgatum	-	X	-	X	-	-	-	-	-	-	-	-	-
Gaura coccinea	-	-	X	-	-	-	-	-	-	-	-	-	-
Gaura villosa ssp. *villosa*	-	-	-	-	X	X	X	X	X	-	X	X	X
Geranium carolinianum var. *carolinianum*	-	-	-	X	-	X	X	X	-	-	-	-	-
Glandularia pumila	-	-	-	-	-	X	-	-	X	-	-	X	X

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed					
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S
Grindelia lanceolata	-	-	-	-	-	X	-	-	-	-	-	-	-
Grindelia squarrosa var. *squarrosa*	-	-	-	-	-	-	-	X	-	X	-	-	-
Gutierrezia sarothrae	X	-	-	X	X	X	X	X	X	X	X	X	X
Haploesthes greggii var. *texana*	-	X	-	-	-	-	-	-	-	-	-	-	-
Hedeoma drummondii	-	-	-	-	-	-	-	-	-	-	X	-	-
Hedeoma hispida	-	-	X	X	X	-	-	-	-	-	-	-	-
Helianthus annuus	X	X	X	-	X	-	-	-	-	-	-	-	-
Helianthus petiolaris ssp. *petiolaris*	-	-	X	-	-	-	-	-	-	-	-	-	-
Heterotheca stenophylla var. *stenophylla*	X	X	X	X	X	X	X	X	X	X	X	X	X
Hordeum pusillum	-	-	-	-	X	X	-	X	-	-	-	-	X
Hymenopappus tenuifolius	X	X	X	X	X	X	X	X	X	X	X	X	X
Ipomoea leptophylla	-	-	-	-	X	-	-	-	-	-	-	-	-
Juniperus virginiana var. *virginiana*	-	-	-	X	-	-	-	-	X	-	-	-	-
Kallstroemia parviflora	-	X	-	-	-	-	-	-	-	-	-	-	-
Krameria lanceolata	-	-	-	-	-	X	-	-	-	X	X	-	-
Lactuca serriola	-	X	-	-	-	-	-	-	-	-	-	-	-
Lappula occidentalis var. *cupulata*	X	X	-	-	-	-	-	-	-	-	-	X	X
Lepidium densiflorum var. *densiflorum*	-	-	-	-	-	-	-	-	X	-	-	-	-
Lesquerella gordonii var. *gordonii*	X	X	X	X	X	X	X	X	X	X	X	X	X
Liatris punctata	-	X	X	X	-	-	-	X	-	-	-	X	X
Linum pratense	-	-	-	-	X	X	-	-	X	-	-	-	-
Linum rigidum var. *rigidum*	-	-	-	X	-	-	-	-	-	-	X	-	-
Lithospermum incisum	-	X	X	-	X	X	X	X	-	X	X	X	X
Lomatium foeniculaceum ssp. *foeniculaceum*	-	X	X	-	-	-	-	-	-	-	-	-	-
Mentzelia nuda var. *stricta*	X	X	X	X	X	X	X	X	X	X	X	X	X
Mentzelia oligosperma	X	X	X	X	X	X	X	X	X	X	X	-	X

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed					
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S
Mimosa nuttallii	-	-	-	-	-	-	-	X	-	-	-	X	X
Mirabilis albida	-	-	X	-	-	-	-	-	-	X	-	-	-
Monarda clinopodioides	-	X	-	-	-	-	-	-	-	-	-	-	-
Nama stevensii	X	X	X	X	X	X	X	X	X	X	X	X	X
Nuttallanthus canadensis	X	-	-	X	-	-	-	-	X	-	-	-	-
Opuntia phaeacantha	X	X	X	X	X	X	X	X	X	X	X	-	X
Orobanche ludoviciana ssp. *multiflora*	X	X	-	-	X	X	X	-	-	-	X	-	X
Oxalis dillenii	-	-	-	X	-	X	-	-	-	-	-	-	-
Panicum capillare	X	X	X	X	X	X	-	X	X	-	X	-	-
Panicum hallii var. *hallii*	-	X	-	-	-	-	-	-	-	-	-	-	-
Paronychia jamesii	X	X	X	X	X	X	X	X	X	X	X	X	X
Phacelia integrifolia var. *integrifolia*	X	X	X	X	X	X	X	-	X	X	X	X	X
Plantago patagonica	X	X	X	X	X	X	X	X	X	X	X	X	X
Plantago rhodosperma	X	-	X	-	-	X	-	X	-	X	X	X	X
Polanisia dodecandra ssp. *trachysperma*	X	X	X	-	X	X	-	X	X	X	-	X	X
Polygala alba	X	-	X	-	-	X	X	-	X	X	X	X	-
Pomaria jamesii	-	-	-	-	-	-	-	X	-	-	-	-	-
Portulaca oleracea	-	-	-	-	-	-	-	X	-	-	-	-	-
Portulaca pilosa	X	X	X	X	X	X	X	X	X	X	X	-	X
Psilostrophe tagetina var. *cerifera*	X	X	X	X	X	X	X	X	X	X	X	X	X
Psoralidium tenuiflorum	-	X	X	-	X	-	X	X	X	X	X	X	X
Pyrrhopappus grandiflorus	-	-	-	-	X	-	-	-	-	-	-	-	-
Rhus aromatica	-	X	X	-	-	-	-	-	-	-	-	X	-
Rhus glabra	-	-	-	X	-	-	-	-	-	-	-	-	-
Salsola tragus	-	X	-	-	-	-	-	-	-	-	-	-	-
Schizachyrium scoparium var. *scoparium*	X	X	X	X	X	X	X	X	X	X	X	X	X

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed					
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S
Senecio riddellii	-	-	X	-	X	-	-	-	-	-	-	-	-
Silene antirrhina	-	-	X	-	-	X	-	-	X	-	-	-	-
Solanum elaeagnifolium	-	-	-	-	-	-	-	X	-	-	-	-	-
Solanum rostratum	-	-	X	-	X	X	X	X	X	X	X	X	X
Solidago petiolaris var. *angusta*	-	-	X	-	-	-	-	-	-	-	-	-	-
Spermolepis inermis	X	-	X	-	-	-	-	-	-	-	-	-	-
Sphaeralcea coccinea ssp. *coccinea*	X	-	-	-	-	X	-	X	-	-	X	-	X
Sporobolus cryptandrus	X	X	X	X	X	X	X	X	X	X	X	X	X
Stenaria nigricans var. *nigricans*	-	-	-	-	-	-	-	-	X	-	X	-	-
Stenosiphon linifolius	X	-	-	-	-	-	-	-	-	-	-	-	-
Tetraneuris linearifolia var. *linearifolia*	-	-	-	X	-	-	-	-	-	-	-	-	-
Tetraneuris scaposa var. *scaposa*	-	-	-	-	-	-	-	-	-	-	-	-	X
Thelesperma filifolium	-	-	-	X	-	X	-	-	X	-	-	-	-
Thelesperma megapotamicum	X	-	X	-	X	X	X	X	X	X	X	X	X
Tragopogon dubius	X	-	-	-	-	-	-	-	-	-	-	-	-
Tridens muticus var. *elongatus*	X	X	X	X	X	X	X	-	-	X	X	-	X
Trifolium sp.	-	-	X	-	-	-	-	-	-	-	-	-	-
Trisetum interruptum	-	X	-	-	-	X	-	X	-	X	-	X	-
Ulmus americana	-	-	-	X	-	-	X	X	-	-	-	-	-
unidentified Asteraceae	-	-	-	-	-	-	-	-	-	-	X	-	-
Viola bicolor	-	-	-	-	-	-	-	-	X	-	-	-	-
Vulpia octoflora var. *octoflora*	X	-	X	X	X	X	X	X	X	-	X	-	X
Yucca glauca var. *glauca*	X	X	X	X	X	X	X	X	X	X	X	X	X
Number species at each site	58	53	66	46	53	62	42	64	58	53	49	50	62
Average number species per site in each grazing history regime	55.75				52.33			56.00					

number of introduced species (*Bothriochloa ischaemum* var. *songarica*, *Bromus arvensis*, *Eragrostis cilianensis*, and *Eragrostis minor*). The third most common family was the Fabaceae (bean family). There were 12 representatives of which 11 were native perennial herbs and one, *Trifolium* sp., was an annual. The fourth most common family was the Euphorbiaceae (spurge family) with ten representatives, of which all were native annuals.

Four species (*Chenopodium pallescens*, *Cylindropuntia imbricata* var. *imbricata*, *Echinocereus reichenbachii*, and *Escobaria vivipara* var. *vivipara*) were listed (denoted with "*"; Table 4) as globally rare, with a G5 rank, and all were being tracked by the Oklahoma Natural Heritage Inventory (Oklahoma Natural Heritage Inventory Database, 2008). Of these, *C. imbricata* var. *imbricata* is critically imperiled in Oklahoma (S1) and is of the greatest concern. *Chenopodium pallescens* was listed as "critically imperiled to imperiled," with a S1S2 rank. Finally, *E. reichenbachii* and *E. vivipara* var. *vivipara* are ranked S2? and S2S3, respectively. Though still of concern, they were imperiled to rare, which were less critical rankings.

Some plants in the genera *Calylophus*, *Chenopodium*, and *Conyza* could not consistently be distinguished to species or variety and were combined with similar species or varieties. All of the *Calylophus berlandieri* ssp. *berlandieri* plants were combined with *C. serrulatus* for the analyses. The key morphological difference between these two species was stigma

position relative to the stamens (see Tyrl et al., 2007). *Calylophus serrulatus* and *C. berlandieri* grew together on some outcrops and the style lengths of some individuals were intermediate between those used to distinguish the two species. Also combined, for the analyses, was *Chenopodium berlandieri* var. *berlanieri* into *C. album* var. *album*, due to the lack of reproductive structures. *Chenopodium album* var. *album* and *C. berlandieri* var. *berlandieri* were extremely morphologically similar, and virtually impossible to distinguish in the absence of reproductive structures. A third species, *Conyza canadensis*, had two varieties commonly found growing on the gypsum outcrops. The difference between the two varieties is the presence or absence of hairs growing on the vegetative portion of the plant. I did not consistently determine the variety in the field; thus, *C. canadensis* var. *canadensis* and *C. canadensis* var. *glabrata* were analyzed without the variety specified.

Excluding the four plants I was unable to identify to species, 33 of the 151 species were new county records, i.e., not yet deposited in Oklahoma herbaria (Table 4). One species (*Ambrosia artemisiifolia* var. *elatior*) was a new record for three counties (Major, Woods, and Woodward). Another species, *Trisetum interruptum*, was also a new record for three counties (Harper, Major, and Woodward). Two species (*Grindelia squarrosa* var. *squarrosa* and *Nuttallanthus canadensis*) were new records for Blaine and Major Counties. Two species (*Escobaria vivipara* var. *vivipara* and *Hedeoma hispida*) were new records for Blaine and

Woodward Counties. The other 28 species were new records to one of the five counties represented in this study. Major County had the highest number of new records (14) and Woodward County the second highest number (13).

Species Richness and Cover

Sites that were long-ungrazed and currently-grazed had the highest average species richness (55.75 & 56.00 species, respectively; Table 5). Recently-grazed sites averaged 52.33 species per site. Irish's Mesa, which was long-ungrazed, had the highest species richness (66) and the SLL, which was recently-grazed, had the lowest species richness (42). Fifteen species (*Allium drummondii*, *Bouteloua curtipendula*, *Calylophus serrulatus*, *Conyza canadensis*, *Heterotheca stenophylla* var. *stenophylla*, *Hymenopappus tenuifolius*, *Lesquerella gordonii* var. *gordonii*, *Mentzelia nuda* var. *stricta*, *Nama stevensii*, *Paronychia jamesii*, *Plantago patagonica*, *Psilostrophe tagetina* var. *cerifera*, *Schizachyrium scoparium* var. *scoparium*, *Sporobolus cryptandrus*, and *Yucca glauca* var. *glauca*) were observed at all 13 sites. Three were grasses (Poaceae) and four were asters (Asteraceae). One species, *N. stevensii* in the Hydrophyllaceae, is characterized as an obligate gypsophile.

Of the 15 species found at all sites, ten (*B. curtipendula*, *C. serrulatus*, *H. stenophylla* var. *stenophylla*, *H. tenuifolius*, *N. stevensii*, *P. jamesii*, *P. tagetina* var. *cerifera*, *S. scoparium* var. *scoparium*, *S. cryptandrus*, and *Y. glauca* var. *glauca*) were

present in all three seasons (Tables 6, 7, & 8); all had their highest cover values in summer 2007. One species, *Conyza canadensis*, was present in only the spring and summer of 2007. One species, *P. patagonica*, was only represented in the spring of 2007. Two other species (*A. drummondii* and *L. gordonii* var. *gordonii*) are spring-flowering species and showed higher cover values in the spring, but very reduced cover values in the fall of 2006 (*A. drummondii*, 0.02; observed at one site, BHR) and in the summer of 2007 (*L. gordonii* var. *gordonii*, 0.08; observed at five sites).

Among the three seasons analyzed, spring 2007 (Table 7) showed the highest species richness (122), summer 2007 (Table 8) showed the second highest species richness (108), and fall 2006 (Table 6) had the lowest (66). However, summer 2007 showed the highest average percent plant cover value per site (35.1% cover), spring 2007 showed the second highest (21.3% cover), and fall 2006 the lowest (20.7% cover).

In fall 2006, the five species with the highest average percent plant cover values per site were *Schizachyrium scoparium* var. *scoparium* (4.3% cover), *Heterotheca stenophylla* var. *stenophylla* (3.9% cover), *Sporobolus cryptandrus* (3.2% cover), *Opuntia phaeacantha* (1.3% cover), and *Bouteloua gracilis* (0.8% cover). In spring 2007, the five species with the highest average percent plant cover values were *H. stenophylla* var. *stenophylla* (4.5% cover), *S. scoparium* var. *scoparium* (2.6% cover), *S. cryptandrus* (2.1% cover), *O. phaeacantha* (1.1% cover),

Table 6. Average of three quadrats' cover class midpoints for plant species, by site and grazing history, fall 2006.

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of averages
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	
Allium drummondii	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.02
Ambrosia artemisiifolia var. *elatior*	-	-	-	-	-	-	-	-	-	-	0.02	-	-	0.02
Ambrosia psilostachya	-	-	-	-	0.18	-	-	-	-	-	-	-	-	0.18
Amphiachyris dracunculoides	0.37	-	-	-	-	-	-	0.37	-	-	-	-	0.03	0.77
Andropogon gerardii	-	-	0.18	-	-	-	-	-	-	-	-	-	-	0.18
Andropogon hallii	-	-	-	-	-	-	-	-	-	0.18	-	-	0.02	0.20
Aristida purpurea	0.18	0.18	-	-	-	-	1.53	0.37	-	0.87	0.87	0.70	0.55	5.25
Artemisia dracunculus	-	-	0.18	-	-	-	-	-	-	0.18	-	-	-	0.37
Artemisia filifolia	-	-	-	-	-	-	-	-	-	-	-	0.18	-	0.18
Artemisia ludoviciana ssp. *ludoviciana*	-	0.02	0.70	-	-	-	-	-	-	-	-	-	-	0.72
Asclepias engelmanniana	-	-	0.02	-	-	-	-	-	-	-	-	-	-	0.02
Astragalus missouriensis var. *missouriensis*	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.02
Bothriochloa ischaemum var. *songarica*	-	-	0.02	-	-	-	-	-	-	-	-	-	-	0.02
Bothriochloa laguroides ssp. *torreyana*	-	-	-	-	-	-	-	-	-	-	0.02	-	-	0.02
Bouteloua curtipendula	0.37	0.18	0.87	0.38	0.87	0.37	0.37	2.87	1.35	0.37	0.55	0.55	0.87	9.95
Bouteloua gracilis	0.50	0.68	0.55	0.37	3.85	0.37	-	1.68	0.37	0.87	0.18	0.18	1.53	11.13
Bouteloua hirsuta var. *hirsuta*	-	-	-	-	-	-	-	-	-	-	-	0.18	0.03	0.22
Calylophus hartwegii ssp. *fendleri*	0.02	-	0.02	0.37	0.37	0.18	-	0.03	0.18	-	-	-	0.18	1.35
Calylophus serrulatus	0.87	0.55	1.18	0.55	0.55	0.55	0.55	0.37	0.55	0.87	0.38	0.55	0.55	8.07
Chaetopappa ericoides	-	-	-	-	-	-	-	-	-	-	-	0.18	-	0.18
Chamaesyce glyptosperma	0.02	0.20	-	-	-	-	-	0.18	-	-	-	-	-	0.40
Chamaesyce missurica	-	-	0.18	0.20	-	-	-	-	-	-	-	-	-	0.38
Cirsium undulatum var. *undulatum*	-	-	0.02	-	-	-	-	-	-	-	-	-	0.02	0.03
Croton monanthogynus	0.18	-	-	-	-	-	-	-	-	-	-	-	-	0.18
Croton texensis var. *texensis*	-	-	0.18	-	-	-	-	-	-	-	-	-	-	0.18
Cylindropuntia imbricata var. *imbricata*	0.18	-	-	-	-	-	-	-	-	-	-	-	-	0.18
Dalea enneandra	-	-	-	-	-	-	-	-	-	-	-	0.18	-	0.18

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of averages
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	
Echinocereus reichenbachii	0.37	-	-	-	0.22	0.55	0.03	0.20	0.68	-	0.02	-	-	2.07
Erioneuron pilosum	-	0.37	-	-	-	-	0.18	-	-	0.37	-	0.02	0.18	1.12
Escobaria vivipara var. *vivipara*	0.02	-	0.02	0.02	-	-	0.02	-	-	-	-	-	-	0.07
Evolvulus nuttallianus	-	-	-	-	-	-	-	0.02	-	-	-	-	0.02	0.03
Gaura villosa ssp. *villosa*	-	-	-	-	0.18	0.18	0.18	-	0.18	-	0.02	0.20	1.17	2.12
Gutierrezia sarothrae	0.18	-	-	0.18	0.55	0.18	0.37	0.18	0.18	0.37	0.55	0.37	1.20	4.32
Haploesthes greggii var. *texana*	-	3.67	-	-	-	-	-	-	-	-	-	-	-	3.67
Heterotheca stenophylla var. *stenophylla*	2.83	0.87	3.50	10.83	2.83	6.17	4.83	1.50	1.85	4.17	5.50	2.83	3.50	51.22
Hymenopappus tenuifolius	0.02	0.02	0.55	0.18	0.22	0.02	0.55	0.38	0.37	-	0.20	0.22	0.55	3.27
Juniperus virginiana var. *virginiana*	-	-	-	0.18	-	-	-	-	0.18	-	-	-	-	0.37
Kallstroemia parviflora	-	0.18	-	-	-	-	-	-	-	-	-	-	-	0.18
Liatris punctata	-	-	0.18	0.37	-	-	-	-	-	-	-	0.18	0.18	0.92
Lithospermum incisum	-	-	-	-	0.18	0.18	0.02	-	-	-	0.18	-	-	0.57
Mentzelia nuda var. *stricta*	0.02	-	0.55	0.18	0.02	0.55	0.70	0.18	0.37	-	0.02	0.18	-	2.77
Mentzelia oligosperma	0.38	0.22	0.50	-	-	-	-	-	-	-	-	-	-	1.10
Mimosa nuttallii	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.02
Nama stevensii	-	0.02	-	-	-	-	-	-	-	-	-	-	0.03	0.05
Opuntia phaeacantha	0.52	0.02	0.03	14.17	-	-	0.02	0.18	2.52	-	0.02	-	0.18	17.65
Panicum capillare	0.18	-	-	-	-	-	-	-	-	-	-	-	-	0.18
Panicum hallii var. *hallii*	-	0.18	-	-	-	-	-	-	-	-	-	-	-	0.18
Paronychia jamesii	0.18	0.38	0.55	2.87	0.38	0.55	0.37	0.18	0.55	0.55	0.55	0.37	0.87	8.35
Phacelia integrifolia var. *integrifolia*	0.20	0.22	0.55	0.02	0.02	0.18	0.03	-	0.02	-	-	-	-	1.23
Polanisia dodecandra ssp. *trachysperma*	0.37	-	0.37	-	-	-	-	0.18	0.18	0.18	-	-	-	1.28
Polygala alba	-	-	-	-	-	-	0.03	-	-	-	-	-	-	0.03
Pomaria jamesii	-	-	-	-	-	-	-	0.18	-	-	-	-	-	0.18
Portulaca pilosa	0.53	0.37	3.67	-	2.50	-	-	0.18	-	0.02	-	-	0.02	7.28
Psilostrophe tagetina var. *cerifera*	0.38	0.05	0.55	0.20	0.02	0.05	0.05	0.37	0.55	0.38	0.55	0.02	0.55	3.72
Psoralidium tenuiflorum	-	-	-	-	-	-	-	-	-	0.18	-	0.18	0.18	0.55

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of averages
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	
Schizachyrium scoparium var. *scoparium*	2.52	0.38	14.17	4.83	2.17	14.83	4.17	0.18	1.85	0.37	2.83	3.85	5.00	57.15
Senecio riddellii	-	-	0.18	-	0.18	-	-	-	-	-	-	-	-	0.37
Solanum elaeagnifolium	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.02
Solidago petiolaris var. *angusta*	-	-	0.18	-	-	-	-	-	-	-	-	-	-	0.18
Sphaeralcea coccinea ssp. *coccinea*	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.02
Sporobolus cryptandrus	4.83	6.33	0.55	2.52	7.18	3.85	1.85	6.83	2.83	1.53	1.18	1.68	0.55	41.73
Stenosiphon linifolius	0.02	-	-	-	-	-	-	-	-	-	-	-	-	0.02
Thelesperma filifolium	-	-	-	0.55	-	-	-	-	-	-	-	-	-	0.55
Thelesperma megapotamicum	0.22	-	0.02	-	0.37	0.37	0.22	0.02	0.20	0.18	0.18	0.55	0.55	2.87
Tridens muticus var. *elongatus*	3.50	0.18	2.68	0.37	0.18	0.55	0.18	-	-	0.37	0.38	-	0.18	8.58
Yucca glauca var. *glauca*	1.53	0.18	0.18	-	0.18	0.18	0.18	0.02	0.18	-	0.02	0.18	0.38	3.23
										total plant cover				269.60

Table 7. Average of three quadrats' cover class midpoints for plant species, by site and grazing history, spring 2007.

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of averages
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	
Acalypha ostryifolia	-	-	-	-	-	-	-	-	0.02	-	-	-	-	0.02
Allium drummondii	0.38	0.38	0.20	0.37	0.37	0.37	0.37	0.37	0.38	0.18	0.20	0.37	0.37	4.30
Ambrosia artemisiifolia var. *elatior*	-	-	0.02	-	-	-	-	0.03	0.03	0.02	-	-	-	0.10
Ambrosia psilostachya	0.02	-	-	-	0.18	-	-	-	-	-	-	-	-	0.20
Ammoselinum popei	0.02	-	-	-	-	-	-	-	-	-	-	-	0.03	0.05
Andropogon gerardii	-	-	0.50	-	-	-	-	-	-	-	-	-	-	0.50
Andropogon hallii	-	-	-	-	-	-	-	-	-	0.18	-	-	-	0.18
Androsace occidentalis	-	-	-	-	-	-	-	-	0.02	-	-	-	-	0.02
Aristida purpurea	0.18	0.18	-	-	0.18	-	0.87	0.37	-	0.55	0.87	0.55	0.37	4.12
Artemisia dracunculus	-	-	0.18	-	-	-	-	-	-	-	-	-	-	0.18
Artemisia filifolia	-	-	-	-	-	-	-	-	-	-	-	0.18	-	0.18
Artemisia ludoviciana ssp. *ludoviciana*	-	-	1.18	-	-	-	-	-	-	0.03	-	-	-	1.22
Asclepias engelmanniana	-	-	0.02	-	-	-	-	-	-	-	-	0.02	0.18	0.22
Astragalus gracilis	-	-	0.18	-	-	0.02	-	-	-	-	-	0.37	-	0.57
Astragalus lotiflorus	-	-	-	-	-	-	-	0.20	-	0.02	-	-	0.18	0.40
Astragalus missouriensis var. *missouriensis*	-	-	-	-	-	-	0.18	-	-	-	-	0.22	-	0.40
Astragalus nuttallianus	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.02
Atriplex subspicata	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.02
Bouteloua curtipendula	2.83	-	-	-	1.53	-	0.37	0.87	0.37	0.37	0.18	0.37	0.37	7.25
Bouteloua dactyloides	-	-	-	-	-	-	-	0.68	-	-	0.18	-	0.20	1.07
Bouteloua gracilis	-	-	0.18	-	1.35	-	-	0.37	0.37	0.37	-	-	0.37	3.00
Bouteloua hirsuta var. *hirsuta*	-	-	-	-	-	-	-	-	-	-	-	0.18	-	0.18
Bromus arvensis	-	-	0.18	-	-	-	-	-	-	-	-	-	0.20	0.38
Calylophus hartwegii ssp. *fendleri*	0.55	-	0.18	0.37	0.55	0.37	-	0.20	0.37	-	0.02	0.18	0.37	3.15
Calylophus serrulatus	1.18	0.38	1.18	0.68	0.87	0.55	0.87	0.37	0.55	0.55	0.55	0.55	0.55	8.83
Castilleja purpurea var. *citrina*	0.37	-	-	0.22	0.20	0.20	0.55	0.02	0.20	-	0.55	0.20	0.18	2.68
Cercis canadensis var. *canadensis*	-	-	-	0.02	-	-	-	-	-	-	-	-	-	0.02

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of averages
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	
Chaetopappa ericoides	-	-	-	-	-	-	-	-	-	-	-	0.18	0.18	0.37
Chamaesyce glyptosperma	0.02	0.03	0.02	-	-	0.05	-	0.02	0.02	-	-	-	-	0.15
Chamaesyce missurica	-	0.02	-	-	0.55	0.03	-	-	0.18	-	-	-	-	0.78
Chenopodium album var. *album*	-	-	-	-	0.02	0.02	-	-	-	-	-	-	-	0.03
Chenopodium berlandieri	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.02
Chenopodium pratericola	-	0.02	0.18	-	-	0.03	-	0.20	-	0.02	-	-	-	0.45
Cirsium undulatum var. *undulatum*	-	-	0.37	-	-	-	-	-	-	-	-	-	-	0.37
Conyza canadensis	0.37	-	0.02	0.02	0.18	0.02	-	0.37	0.02	0.03	-	0.02	0.02	1.05
Croton monanthogynus	0.55	0.03	-	0.02	0.20	0.03	-	0.38	0.22	0.38	0.37	-	0.02	2.20
Croton texensis var. *texensis*	0.18	-	0.38	-	0.37	0.03	0.02	0.38	0.02	-	0.02	0.37	0.20	1.97
Cylindropuntia imbricata var. *imbricata*	0.18	-	-	-	-	-	-	-	-	-	-	-	-	0.18
Dalea aurea	-	-	-	-	-	-	-	-	-	-	-	-	0.18	0.18
Dalea enneandra	-	-	-	-	-	-	-	-	-	-	-	0.37	-	0.37
Delphinium carolinianum ssp. *virescens*	0.20	-	-	-	-	-	-	0.18	0.18	-	-	0.02	-	0.58
Descurainia pinnata	0.18	-	0.55	-	-	-	-	-	0.18	0.18	-	-	-	1.10
Draba cuneifolia var. *cuneifolia*	-	0.20	-	-	-	-	-	-	-	-	-	-	-	0.20
Draba platycarpa	-	-	-	-	-	-	-	-	0.02	-	-	-	-	0.02
Draba reptans	0.37	-	0.02	0.03	-	0.22	-	-	0.02	0.18	-	-	-	0.83
Echinocereus reichenbachii	0.37	-	-	-	0.37	0.38	0.38	0.37	0.37	-	0.03	-	-	2.27
Eriogonum longifolium var. *longifolium*	-	-	-	0.02	-	-	-	-	-	-	-	-	-	0.02
Erioneuron pilosum	-	0.87	-	-	0.55	-	0.18	0.37	0.18	0.87	-	0.37	0.55	3.93
Escobaria missouriensis	-	-	-	-	-	-	-	-	-	0.02	-	-	-	0.02
Escobaria vivipara var. *vivipara*	0.02	-	0.20	0.03	-	0.02	0.02	-	-	-	-	-	-	0.28
Euphorbia dentata var. *dentata*	0.18	-	0.02	-	-	-	-	-	-	-	-	-	-	0.20
Euphorbia marginata	-	-	-	-	-	-	0.02	0.03	-	-	-	-	0.03	0.08
Euphorbia spathulata	0.37	0.37	-	-	0.03	0.55	-	0.18	0.38	0.02	-	-	-	1.90
Evax prolifera	0.05	-	0.18	-	0.02	0.03	-	-	-	-	-	0.02	0.02	0.32
Evolvulus nuttallianus	-	-	-	-	-	-	-	0.18	-	-	-	-	0.18	0.37

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of averages
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	
Gaillardia pulchella var. *pulchella*	0.38	0.20	-	-	0.18	0.37	-	0.20	0.02	0.18	-	-	-	1.53
Galium virgatum	-	0.38	-	0.03	-	-	-	-	-	-	-	-	-	0.42
Gaura coccinea	-	-	0.18	-	-	-	-	-	-	-	-	-	-	0.18
Gaura villosa ssp. *villosa*	-	-	-	-	0.18	0.18	0.18	0.18	0.18	-	0.18	0.18	0.50	1.78
Geranium carolinianum var. *carolinianum*	-	-	-	0.02	-	0.02	0.02	0.18	-	-	-	-	-	0.23
Glandularia pumila	-	-	-	-	-	-	-	-	0.02	-	-	-	0.18	0.20
Gutierrezia sarothrae	0.37	-	-	-	0.55	-	0.37	0.18	0.18	0.37	0.37	0.18	0.55	3.12
Haploesthes greggii var. *texana*	-	3.67	-	-	-	-	-	-	-	-	-	-	-	3.67
Hedeoma hispida	-	-	0.02	0.02	0.02	-	-	-	-	-	-	-	-	0.05
Helianthus annuus	-	0.02	0.18	-	0.50	-	-	-	-	-	-	-	-	0.70
Heterotheca stenophylla var. *stenophylla*	5.50	2.87	4.83	9.50	6.17	4.83	3.50	4.83	1.67	1.00	4.17	4.83	4.83	58.53
Hordeum pusillum	-	-	-	-	0.02	0.18	-	0.37	-	-	-	-	0.20	0.77
Hymenopappus tenuifolius	0.38	0.02	0.55	0.20	-	0.38	0.87	0.55	0.37	0.37	0.70	0.37	0.55	5.30
Ipomoea leptophylla	-	-	-	-	0.18	-	-	-	-	-	-	-	-	0.18
Juniperus virginiana var. *virginiana*	-	-	-	0.18	-	-	-	-	0.18	-	-	-	-	0.37
Krameria lanceolata	-	-	-	-	-	0.18	-	-	-	0.18	-	-	-	0.37
Lappula occidentalis var. *cupulata*	0.18	0.20	-	-	-	-	-	-	-	-	-	0.02	0.18	0.58
Lepidium densiflorum var. *densiflorum*	-	-	-	-	-	-	-	-	0.02	-	-	-	-	0.02
Lesquerella gordonii var. *gordonii*	0.38	0.87	0.55	0.22	0.55	0.87	0.05	0.38	0.22	0.55	0.03	0.37	0.22	5.25
Liatris punctata	-	-	0.18	-	-	-	-	0.02	-	-	-	-	-	0.20
Linum pratense	-	-	-	-	0.18	0.38	-	-	0.22	-	-	-	-	0.78
Linum rigidum var. *rigidum*	-	-	-	0.03	-	-	-	-	-	-	0.18	-	-	0.22
Lithospermum incisum	-	-	0.18	-	0.18	0.18	0.55	0.37	-	0.20	0.37	0.02	0.18	2.23
Lomatium foeniculaceum ssp. *foeniculaceum*	-	0.03	0.20	-	-	-	-	-	-	-	-	-	-	0.23
Mentzelia nuda var. *stricta*	0.22	0.37	0.55	0.18	0.20	0.55	0.37	0.37	0.55	0.55	0.02	0.18	-	4.10
Mentzelia oligosperma	0.55	0.20	0.38	0.02	0.02	0.20	0.03	-	0.18	0.22	0.02	-	-	1.82
Mimosa nuttallii	-	-	-	-	-	-	-	0.18	-	-	-	0.18	-	0.37
Mirabilis albida	-	-	0.37	-	-	-	-	-	-	0.02	-	-	-	0.38

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of averages
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	
Monarda clinopodioides	-	0.02	-	-	-	-	-	-	-	-	-	-	-	0.02
Nama stevensii	0.38	0.55	0.55	0.03	0.02	0.38	0.02	0.37	0.20	0.22	0.03	0.02	0.38	3.15
Nuttallanthus canadensis	0.02	-	-	0.02	-	-	-	-	0.02	-	-	-	-	0.05
Opuntia phaeacantha	0.52	-	0.02	10.83	-	0.03	0.02	0.50	2.35	-	-	-	0.18	14.45
Orobanche ludoviciana ssp. *multiflora*	-	-	-	-	-	-	0.02	-	-	-	-	-	-	0.02
Oxalis dillenii	-	-	-	0.02	-	-	-	-	-	-	-	-	-	0.02
Panicum capillare	0.18	-	-	-	-	-	-	-	0.02	-	-	-	-	0.20
Paronychia jamesii	-	0.38	0.55	0.55	0.37	0.37	0.37	0.37	0.18	0.55	0.55	0.37	0.55	5.15
Phacelia integrifolia var. *integrifolia*	0.03	0.37	0.55	-	0.03	0.37	0.18	-	0.02	0.38	-	0.18	0.05	2.17
Plantago patagonica	0.55	0.02	0.55	0.37	0.55	0.55	0.03	0.03	0.22	0.20	0.02	0.18	0.22	3.48
Plantago rhodosperma	0.18	-	0.37	-	-	0.20	-	0.02	-	0.02	0.02	0.03	0.02	0.85
Polanisia dodecandra ssp. *trachysperma*	0.18	0.22	0.05	-	0.02	0.18	-	0.18	0.37	0.70	-	-	0.02	1.92
Polygala alba	-	-	0.18	-	-	0.37	0.55	-	0.18	-	0.55	0.22	-	2.05
Pomaria jamesii	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.02
Portulaca pilosa	-	-	-	-	-	-	-	-	-	0.03	-	-	0.02	0.05
Psilostrophe tagetina var. *cerifera*	0.87	0.55	0.55	0.37	0.37	0.55	0.55	0.37	0.55	0.68	0.55	0.22	0.55	6.72
Psoralidium tenuiflorum	-	0.02	1.18	-	0.18	-	0.18	0.50	0.02	0.20	0.18	1.02	0.37	3.85
Pyrrhopappus grandiflorus	-	-	-	-	0.18	-	-	-	-	-	-	-	-	0.18
Rhus aromatica	-	-	0.20	-	-	-	-	-	-	-	-	-	-	0.20
Rhus glabra	-	-	-	0.18	-	-	-	-	-	-	-	-	-	0.18
Schizachyrium scoparium var. *scoparium*	2.33	-	4.83	7.50	3.85	4.83	2.83	0.18	1.85	0.55	2.17	3.18	0.37	34.48
Silene antirrhina	-	-	0.02	-	-	0.20	-	-	0.02	-	-	-	-	0.23
Solanum rostratum	-	-	-	-	0.02	-	0.02	-	0.05	0.02	-	0.02	0.03	0.15
Spermolepis inermis	0.18	-	0.38	-	-	-	-	-	-	-	-	-	-	0.57
Sphaeralcea coccinea ssp. *coccinea*	0.18	-	-	-	-	0.02	-	-	-	-	0.18	-	0.02	0.40
Sporobolus cryptandrus	2.87	7.18	0.87	0.18	4.83	1.67	0.87	1.85	3.18	1.85	0.55	1.85	0.38	28.13
Stenaria nigricans var. *nigricans*	-	-	-	-	-	-	-	-	0.18	-	-	-	-	0.18
Tetraneuris linearifolia var. *linearifolia*	-	-	-	0.02	-	-	-	-	-	-	-	-	-	0.02

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	averages
Tetraneuris scaposa var. *scaposa*	-	-	-	-	-	-	-	-	-	-	-	-	0.18	0.18
Thelesperma filifolium	-	-	-	1.85	-	0.02	-	-	0.55	-	-	-	-	2.42
Thelesperma megapotamicum	0.37	-	0.55	-	0.38	0.37	0.55	0.18	0.18	0.18	0.20	0.55	0.87	4.38
Tragopogon dubius	0.18	-	-	-	-	-	-	-	-	-	-	-	-	0.18
Tridens muticus var. *elongatus*	-	-	0.55	-	0.02	-	-	-	-	0.37	0.37	-	0.02	1.32
Trifolium sp.	-	-	0.02	-	-	-	-	-	-	-	-	-	-	0.02
Trisetum interruptum	-	0.22	-	-	-	0.03	-	0.05	-	0.38	-	0.02	-	0.70
Ulmus americana	-	-	-	0.18	-	-	0.02	0.18	-	-	-	-	-	0.38
Viola bicolor	-	-	-	-	-	-	-	-	0.02	-	-	-	-	0.02
Vulpia octoflora var. *octoflora*	0.55	-	0.55	0.55	0.03	0.03	0.18	0.05	0.37	-	0.50	-	0.38	3.20
Yucca glauca var. *glauca*	0.87	0.18	0.18	-	0.37	0.02	0.18	-	0.18	0.02	-	0.18	0.55	2.73
										total plant cover				277.48

Table 8. Average of three quadrats' cover class midpoints for plant species, by site and grazing history, summer 2007.

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	averages
Acalypha ostryifolia	-	-	-	-	-	-	-	-	0.02	-	-	-	-	0.02
Amaranthus albus	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.02
Ambrosia artemisiifolia var. *elatior*	-	-	0.02	-	-	0.18	-	0.37	0.20	0.18	0.20	-	0.02	1.17
Ambrosia psilostachya	-	-	-	-	0.20	-	-	-	-	-	-	-	-	0.20
Amphiachyris dracunculoides	0.37	-	-	-	0.18	0.18	-	0.38	0.18	0.37	-	0.18	0.18	2.03
Andropogon gerardii	-	-	0.50	-	-	-	-	-	-	-	-	-	-	0.50
Andropogon hallii	-	-	-	-	-	0.18	-	-	-	0.37	-	-	-	0.55
Aristida purpurea	0.50	0.68	-	-	0.18	-	1.53	0.37	-	0.55	1.53	0.68	0.87	6.90
Artemisia dracunculus	-	-	0.50	-	-	-	-	-	-	0.18	-	-	-	0.68
Artemisia filifolia	-	-	-	-	-	-	-	-	-	-	-	0.18	-	0.18
Artemisia ludoviciana ssp. *ludoviciana*	-	0.20	0.68	-	-	-	-	-	-	0.37	-	-	-	1.25
Asclepias engelmanniana	-	-	-	0.02	-	-	-	-	-	-	-	-	-	0.02
Astragalus distortus var. *distortus*	-	-	-	-	-	-	-	-	-	0.18	-	-	-	0.18
Astragalus gracilis	-	-	-	-	-	-	-	-	-	-	-	0.18	-	0.18
Astragalus lotiflorus	-	-	-	-	-	-	-	0.02	-	-	-	0.18	-	0.20
Astragalus missouriensis var. *missouriensis*	-	-	-	-	-	-	0.02	-	-	-	-	-	-	0.02
Astragalus sp.	-	0.18	-	-	-	-	-	-	-	-	-	-	-	0.18
Bothriochloa laguroides ssp. *torreyana*	-	-	-	-	-	-	-	0.50	-	-	-	-	-	0.50
Bouteloua curtipendula	1.35	0.37	2.17	0.87	15.50	1.67	1.35	8.83	1.67	0.87	1.85	1.50	4.83	42.82
Bouteloua dactyloides	-	-	-	-	-	-	-	2.68	-	-	-	-	-	2.68
Bouteloua gracilis	0.50	0.50	0.55	0.18	6.33	0.68	-	1.00	0.68	1.85	0.18	0.87	0.68	14.02
Bouteloua hirsuta var. *hirsuta*	-	-	-	-	-	-	0.18	0.18	-	-	-	0.87	0.37	1.60
Calylophus hartwegii ssp. *fendleri*	0.18	-	0.18	0.18	0.55	0.55	-	0.18	0.18	0.18	-	0.18	0.55	2.93
Calylophus serrulatus	1.18	0.87	1.18	0.70	0.87	0.55	0.87	0.37	0.55	0.55	0.55	0.55	0.55	9.33
Castilleja purpurea var. *citrina*	0.02	-	-	-	-	0.02	-	-	0.18	0.37	-	-	-	0.58
Cenchrus longispinus	-	-	-	-	-	0.18	-	-	-	-	-	-	-	0.18
Chaetopappa ericoides	-	-	-	-	-	-	-	-	-	-	-	0.50	0.18	0.68

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of averages
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	
Chamaesyce glyptosperma	0.87	0.37	0.02	-	-	0.18	-	0.18	0.20	0.02	-	-	0.18	2.02
Chamaesyce maculata	0.18	-	-	-	-	-	-	-	-	-	-	-	-	0.18
Chamaesyce missurica	0.18	0.18	-	0.68	1.50	1.00	-	-	0.50	-	-	-	-	4.05
Chamaesyce serpens	0.18	0.18	-	-	-	-	-	-	-	-	-	-	-	0.37
Chenopodium album var. *album*	-	-	-	-	0.18	0.18	-	-	-	-	-	-	-	0.37
Chenopodium berlandieri	-	-	-	-	-	-	-	0.02	-	-	-	-	-	0.02
Chenopodium pallescens	-	-	0.18	-	-	-	-	-	-	-	-	-	-	0.18
Chenopodium pratericola	-	0.18	0.02	-	-	0.18	-	0.18	-	0.37	-	-	-	0.93
Cirsium undulatum var. *undulatum*	-	-	0.02	-	-	-	-	-	-	-	-	-	-	0.02
Conyza canadensis	1.53	0.55	0.55	0.37	0.38	0.55	0.02	0.37	0.37	0.37	0.02	0.02	0.18	5.27
Croton monanthogynus	1.50	0.87	-	0.37	1.00	0.55	0.18	0.55	0.87	0.55	0.55	0.37	-	7.35
Croton texensis var. *texensis*	0.18	-	0.55	-	0.55	0.55	0.18	0.37	0.20	-	0.18	0.87	0.37	4.00
Cylindropuntia imbricata var. *imbricata*	0.50	-	-	-	-	-	-	-	-	-	-	-	-	0.50
Dalea aurea	-	-	-	-	-	-	-	-	-	-	-	-	0.18	0.18
Dalea enneandra	-	-	-	-	-	-	-	-	-	-	-	0.37	-	0.37
Desmanthus leptolobus	-	-	0.02	-	-	-	-	-	-	-	-	-	-	0.02
Echinocereus reichenbachii	0.37	-	-	-	0.38	0.38	0.20	0.37	0.68	-	0.37	-	0.02	2.77
Eragrostis cilianensis	-	-	-	-	0.18	-	-	-	0.18	-	-	-	-	0.37
Eragrostis minor	-	-	-	-	-	-	-	-	-	0.18	-	-	-	0.18
Erioneuron pilosum	-	0.87	-	-	0.18	-	0.18	0.37	0.18	1.18	0.18	0.68	0.37	4.20
Escobaria vivipara var. *vivipara*	0.02	-	0.03	0.02	-	0.18	0.02	-	-	-	-	-	-	0.27
Euphorbia dentata var. *dentata*	0.18	0.18	0.18	-	-	-	-	-	-	-	-	-	-	0.55
Euphorbia marginata	-	-	-	-	-	-	0.18	0.20	-	-	0.02	-	0.03	0.43
Evax sp.	-	-	-	-	-	-	-	-	0.02	-	-	-	-	0.02
Evolvulus nuttallianus	-	-	-	-	-	-	-	0.18	-	-	-	-	0.18	0.37
Gaillardia pulchella var. *pulchella*	0.37	0.55	-	-	0.18	0.37	-	-	-	-	-	-	-	1.47
Galium virgatum	-	0.38	-	-	-	-	-	-	-	-	-	-	-	0.38
Gaura villosa ssp. *villosa*	-	-	-	-	0.50	0.50	0.18	0.18	0.20	-	0.18	0.18	3.50	5.43

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of averages
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	
Glandularia pumila	-	-	-	-	-	0.37	-	-	0.18	-	-	0.02	0.18	0.75
Grindelia lanceolata	-	-	-	-	-	0.02	-	-	-	-	-	-	-	0.02
Grindelia squarrosa var. *squarrosa*	-	-	-	-	-	-	-	0.03	-	0.02	-	-	-	0.05
Gutierrezia sarothrae	0.18	-	-	-	0.68	0.18	0.37	0.18	0.50	0.37	0.18	0.68	0.55	3.88
Haploesthes greggii var. *texana*	-	3.67	-	-	-	-	-	-	-	-	-	-	-	3.67
Hedeoma drummondii	-	-	-	-	-	-	-	-	-	-	0.18	-	-	0.18
Helianthus annuus	0.18	0.18	-	-	0.50	-	-	-	-	-	-	-	-	0.87
Helianthus petiolaris ssp. *petiolaris*	-	-	0.02	-	-	-	-	-	-	-	-	-	-	0.02
Heterotheca stenophylla var. *stenophylla*	6.17	1.18	3.50	17.50	4.00	4.83	6.17	9.50	3.18	1.85	3.50	6.17	4.83	72.38
Hymenopappus tenuifolius	0.37	0.18	0.38	0.37	0.37	0.37	0.55	0.87	0.18	0.37	0.55	0.55	0.55	5.65
Juniperus virginiana var. *virginiana*	-	-	-	0.18	-	-	-	-	0.18	-	-	-	-	0.37
Krameria lanceolata	-	-	-	-	-	0.18	-	-	-	0.18	0.18	-	-	0.55
Lactuca serriola	-	0.02	-	-	-	-	-	-	-	-	-	-	-	0.02
Lesquerella gordonii var. *gordonii*	-	0.02	-	-	-	0.02	0.02	-	-	0.02	0.02	-	-	0.08
Liatris punctata	-	0.18	0.18	0.37	-	-	-	-	-	-	-	0.18	0.02	0.93
Linum rigidum var. *rigidum*	-	-	-	-	-	-	-	-	-	-	0.02	-	-	0.02
Lithospermum incisum	-	0.20	0.18	-	0.18	0.18	0.55	0.37	-	0.18	0.37	-	0.02	2.23
Mentzelia nuda var. *stricta*	0.20	-	0.55	0.18	0.37	0.55	0.68	0.37	0.55	0.37	0.18	0.50	-	4.50
Mentzelia oligosperma	0.55	0.87	0.55	0.18	0.18	0.55	0.18	0.02	0.18	0.55	0.37	-	0.18	4.37
Mimosa nuttallii	-	-	-	-	-	-	-	0.18	-	-	-	-	0.18	0.37
Mirabilis albida	-	-	0.37	-	-	-	-	-	-	-	-	-	-	0.37
Nama stevensii	0.38	0.55	0.55	-	-	0.55	0.02	0.37	0.65	0.55	0.20	0.18	0.18	4.18
Opuntia phaeacantha	0.68	-	0.02	14.17	0.02	0.02	0.03	0.50	2.52	0.02	-	-	0.20	18.17
Orobanche ludoviciana ssp. *multiflora*	0.18	0.18	-	-	0.02	0.02	0.02	-	-	-	0.02	-	0.02	0.45
Oxalis dillenii	-	-	-	-	-	0.02	-	-	-	-	-	-	-	0.02
Panicum capillare	0.87	0.18	0.18	0.37	0.52	1.18	-	0.18	1.00	-	0.02	-	-	4.50
Panicum hallii var. *hallii*	-	0.18	-	-	-	-	-	-	-	-	-	-	-	0.18
Paronychia jamesii	0.18	1.18	0.87	6.17	0.18	0.37	0.37	0.37	0.37	0.55	0.87	0.37	0.55	12.38

Grazing History	Long-ungrazed				Recently-grazed			Currently-grazed						sum of averages
Site	ACSP-S	GMSP	IM	RNSP	ACSP-N	MCWMA	SLL	BHR	MCR	MCWHA	SBCWMA	SSR-N	SSR-S	
Phacelia integrifolia var. *integrifolia*	0.02	1.50	0.55	0.18	0.38	0.37	0.18	-	0.18	0.55	0.18	0.55	0.37	5.02
Polanisia dodecandra ssp. *trachysperma*	0.18	0.55	0.87	-	0.18	0.18	-	0.18	0.68	1.85	-	0.02	0.18	4.88
Polygala alba	0.05	-	-	-	-	0.37	0.38	-	0.18	0.18	0.37	0.68	-	2.22
Pomaria jamesii	-	-	-	-	-	-	-	0.18	-	-	-	-	-	0.18
Portulaca oleracea	-	-	-	-	-	-	-	0.18	-	-	-	-	-	0.18
Portulaca pilosa	0.38	0.20	0.38	-	0.38	0.18	0.20	0.20	0.03	0.05	0.18	-	0.18	2.38
Psilostrophe tagetina var. *cerifera*	0.87	0.87	0.55	0.37	0.55	0.55	0.55	0.37	0.37	0.87	0.55	0.37	0.55	7.37
Psoralidium tenuiflorum	-	0.18	2.17	-	0.18	-	0.18	0.18	-	0.18	-	3.00	0.37	6.45
Rhus aromatica	-	0.03	0.18	-	-	-	-	-	-	-	-	0.02	-	0.23
Rhus glabra	-	-	-	0.18	-	-	-	-	-	-	-	-	-	0.18
Salsola tragus	-	0.18	-	-	-	-	-	-	-	-	-	-	-	0.18
Schizachyrium scoparium var. *scoparium*	2.52	0.37	6.17	7.50	2.83	16.17	5.50	0.18	5.50	0.37	3.50	13.85	3.67	68.12
Senecio riddellii	-	-	0.18	-	-	-	-	-	-	-	-	-	-	0.18
Solanum elaeagnifolium	-	-	-	-	-	-	-	0.18	-	-	-	-	-	0.18
Solanum rostratum	-	-	0.02	-	0.18	0.37	0.02	0.03	0.65	0.18	0.18	0.02	0.20	1.85
Solidago petiolaris var. *angusta*	-	-	0.02	-	-	-	-	-	-	-	-	-	-	0.02
Sphaeralcea coccinea ssp. *coccinea*	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.02
Sporobolus cryptandrus	4.83	21.83	0.55	10.83	2.83	3.50	0.55	2.83	4.83	1.85	3.50	1.18	1.18	60.32
Stenaria nigricans var. *nigricans*	-	-	-	-	-	-	-	-	0.18	-	0.18	-	-	0.37
Thelesperma filifolium	-	-	-	0.87	-	-	-	-	0.87	-	-	-	-	1.73
Thelesperma megapotamicum	0.37	-	0.55	-	0.55	0.68	0.55	0.37	0.18	0.18	0.37	0.55	0.87	5.22
Tridens muticus var. *elongatus*	7.50	0.68	1.35	0.37	0.37	0.87	0.02	-	-	0.37	0.37	-	0.18	12.07
Ulmus americana	-	-	-	-	-	-	0.02	0.50	-	-	-	-	-	0.52
unidentified Asteraceae	-	-	-	-	-	-	-	-	-	-	0.02	-	-	0.02
Yucca glauca var. *glauca*	0.87	0.18	0.18	0.02	0.68	-	0.18	-	-	0.18	-	0.50	0.68	3.48
													total plant cover	456.38

and *Calylophus serrulatus* (0.6% cover). In summer 2007, *H. stenophylla* var. *stenophylla* (5.5% cover), *S. scoparium* var. *scoparium* (5.2% cover), *S. cryptandrus* (4.6% cover), *Bouteloua curtipendula* (3.2% cover), and *O. phaeacantha* (1.3% cover) were the five species with the highest average percent plant cover values. Therefore, consistent with Buckallew and Caddell's findings (2003), the gypsum outcrop plant communities' dominant species consist of native perennial herbs.

A comparison of summer 2006 (Appendix 1) and 2007 (Table 8) species richness data (66 & 108, respectively) showed considerably higher species richness in summer 2007. The larger number of species in 2007 could have been due to the difference in year-to-date precipitation totals, which ranged from 18 cm to 38 cm in the summer of 2006, and from 56 cm to 86 cm in the summer of 2007 (Table 9). Three species (*Apocynum cannabinum*, *Astragalus mollissimus* var. *mollissimus*, and *Ceanothus herbaceus*) were present in the summer of 2006 and absent in the summer of 2007. Two of the species, *A. cannabinum* and *C. herbaceus*, were observed at IM; however they were not encountered the following data collecting seasons. Additionally, *A. mollissimus* var. *mollissimus*, was only observed at GMSP during the summer of 2006.

Environmental Data

There were differences in precipitation (average annual and year-to-date) across the CGH during the three data collecting seasons (Table 9). Fall 2006 year-to-date precipitation total

Table 9. Environmental data, by site & quadrat, for precipitation (cm), temperature (°C), cryptogamic crust cover class, elevation (m), and aspect: summer 2006, fall 2006, spring 2007, & summer 2007.

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA		
Grazing history	Recently-grazed			Long-ungrazed			Currently-grazed			Long-ungrazed			Long-ungrazed			Currently-grazed			Currently-grazed		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
average annual precipitation midpoint		65			65			65			80			65			72			72	
average annual temperature midpoint		14			14			14			15			14			15			15	
Summer 06 year-to-date precipitation midpoint		28			28			28			28			23			18			23	
Fall 06 year-to-date precipitation midpoint	27		34		27			34			34			42			34			34	
Spring 07 year-to-date precipitation midpoint		36			36			36			36			36			36			36	
Summer 07 year-to-date precipitation midpoint		56			56			56			66			66			66			66	
cryptogamic crust cover class	6	6	7	5	5	5	4	7	6	7	6	7	7	8	7	7	5	6	7	7	7
elevation	536	525	521	521	543	535	532	517	527	472	512	479	531	533	525	484	485	483	475	484	495
aspect	S	SE	NE	N	S	N	SW	S	S	SW	NW	none	E	E	E	SW	W	SW	S	W	S

Site	MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing history	Recently-grazed			Long-ungrazed			Currently-grazed			Recently-grazed			Currently-grazed			Currently-grazed		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
average annual precipitation midpoint		72			80			65			65			65			65	
average annual temperature midpoint		15			15			14			14			14			14	
Summer 06 year-to-date precipitation midpoint		23			38			28			23			28			28	
Fall 06 year-to-date precipitation midpoint		34			50			34			34			42			34	
Spring 07 year-to-date precipitation midpoint		36			46			36			36			36			36	
Summer 07 year-to-date precipitation midpoint		66			86			56			56			56			56	
cryptogamic crust cover class	6	5	5	7	6	5	6	6	8	6	6	5	5	7	7	7	5	6
elevation	490	492	495	432	433	452	514	523	527	544	546	514	523	528	516	507	520	522
aspect	NW	SW	SW	NW	NW	N	S	SE	W	SW	SW	SE	W	S	SW	S	N	S

varied from 27 cm (several of the northwestern sites) to 50 cm in RNSP. Spring 2007 year-to-date precipitation total varied little, totaling 36 cm at every site except RNSP (46 cm). However, by the summer of 2007, RNSP received 86 cm, IM and four sites in Major County received 66 cm, and the remaining seven sites received 56 cm. The average annual precipitation measurements, which are calculated over 30 years, only range from 65 cm to 80 cm, thus by summer 2007, RNSP received 6 cm more year-to-date precipitation relative to the average annual precipitation. Average annual temperature only varies from 14 °C to 15 °C across the CGH. Aspect varied among quadrats. Elevation ranged from 432 m to 546 m. Cryptogamic crust cover ranged among quadrats from a cover class of 4 (2% to 5% cover) to as high as 8 (50% to 75% cover).

Species Diversity

Hurlbert's PIE, species diversity, was graphed for the 13 sites with the three seasons combined, using 95% confidence lines to express significance (Figure 2). Sites were compared at an abundance of approximately 21 individuals, which was the highest level for MCWHA. Gloss Mountain State Park was significantly less diverse than five sites: ACSP-N, ACSP-S, MCR, MCWHA, and SSR-S (Table 10). Major County Wildlife Management Area was only significantly less diverse than one site, MCWHA. Diversity did not differ significantly among the other sites. Diversity of gypsum outcrop communities, therefore, does not appear to be

Figure 2. Species diversity rarefaction curves, calculated by Hurlbert's PIE, 13 sites and three seasons combined, significance expressed at 95% confidence level (H = high & L = low).

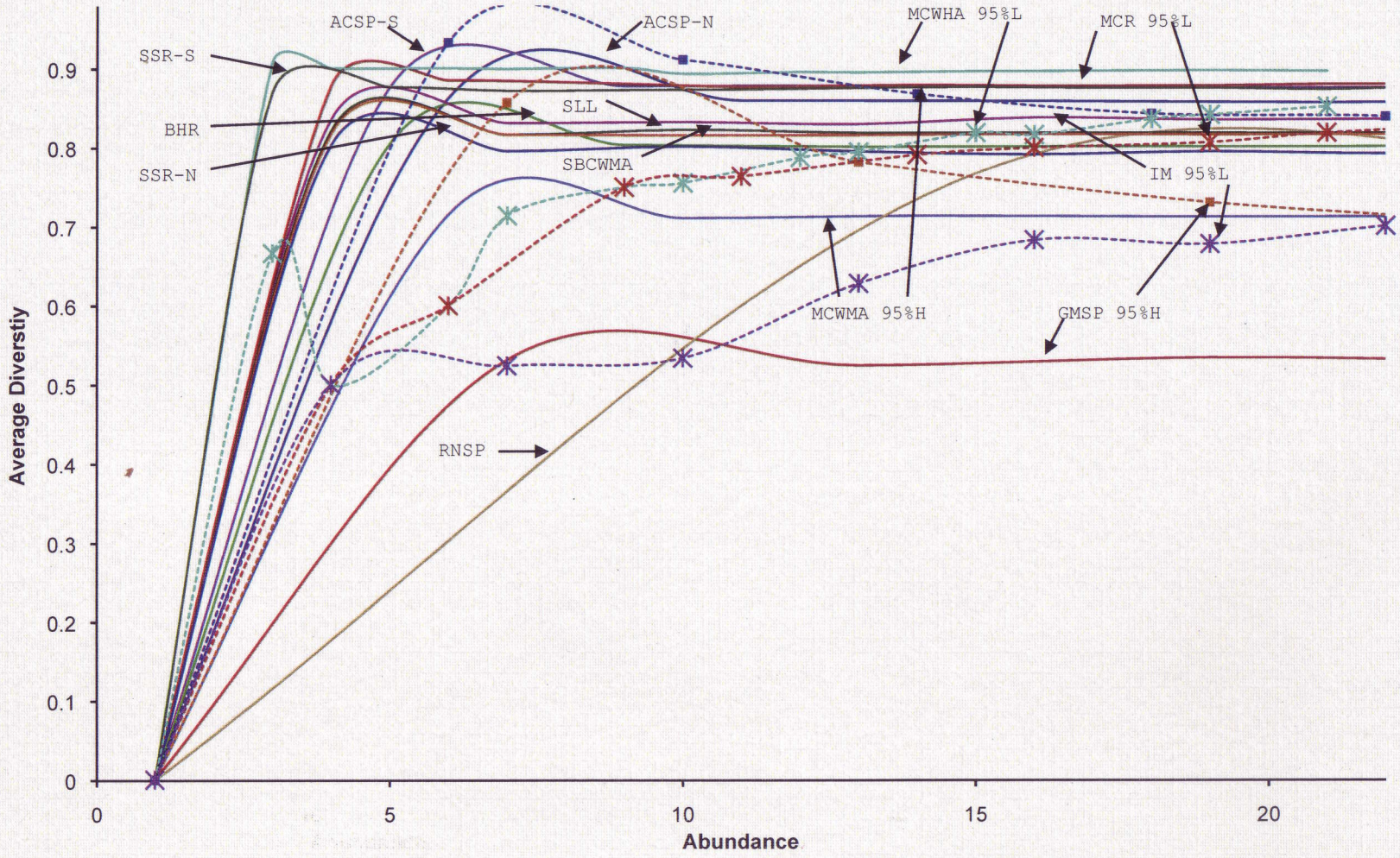


Table 10. Pairwise comparison of species diversity between sites (yes = significantly different & no = not significantly different).

	ACSP-N	ACSP-S	BHR	GMSP	IM	MCR	MCWHA	MCWMA	RNSP	SBCWMA	SLL	SSR-N	SSR-S
ACSP-N	_	NO	NO	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO
ACSP-S		_	NO	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO
BHR			_	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
GMSP				_	YES	YES	YES	NO	YES	NO	NO	NO	YES
IM					_	NO	NO	NO	NO	NO	NO	NO	NO
MCR						_	NO	NO	NO	NO	NO	NO	NO
MCWHA							_	YES	NO	NO	NO	NO	NO
MCWMA								_	NO	NO	NO	NO	NO
RNSP									_	NO	NO	NO	NO
SBCWMA										_	NO	NO	NO
SLL											_	NO	NO
SSR-N												_	NO
SSR-S													_

significantly influenced by differences in abiotic factors or grazing history.

Indicator Species

Table 11 contains a list of six species that were the best indicators for each of the three grazing history categories, based on Indicator Species Analysis. Four of the species were correlated significantly with one of the categories by the randomized Monte Carlo test ($p < 0.05$). *Astragalus lotiflorus* ($p = 0.0486$) was a significant indicator of currently-grazed sites, and *Chenopodium album* var. *album* ($p = 0.0366$) was a significant indicator of recently-grazed sites. Finally, two species, *Euphorbia dentata* var. *dentata* ($p = 0.0142$) and *Mentzelia oligosperma* ($p = 0.0444$), were significant indicators of long-ungrazed sites. However, when the Bonferroni Correction ($p < 0.00033$) was applied none of the species were significant indicators.

The palatability for cattle grazing was listed on Table 11 for species listed in Bidwell et al. (2007 & 2008). Four species (*Ambrosia artemisiifolia* var. *elatior*, *Erioneuron pilosum*, *Gutierrezia sarothrae*, and *Lithospermum incisum*) were characterized as undesirable species for cattle grazing and these four species had high indicator values for currently- or recently-grazed sites. Three species (*Bouteloua dactyloides*, *Chenopodium album* var. *album*, and *Mimosa nuttallii*) were characterized as desirable species for cattle grazing, although

they also had high indicator values for currently-grazed or recently-grazed sites.

Table 11. Indicator Species Analysis (fall 2006, spring 2007, & summer 2007) six best indicator species' indicator values (IV) for each grazing history category (CG = currently-grazed, RG = recently-grazed, & UG = long-ungrazed), plant palatability to cattle (D = desirable & U = undesirable), and "*" indicates significance ($p < 0.05$) by Monte Carlo randomized test.

Species name	IV CG	IV RG	IV UG	p-value
Ambrosia artemisiifolia var. *elatior* (U)	52	9	3	0.1884
Astragalus lotiflorus *	67	0	0	0.0486*
Bouteloua dactyloides (D)	50	0	0	0.1634
Erioneuron pilosum (U)	53	18	5	0.0850
Gutierrezia sarothrae (U)	44	41	8	0.1924
Mimosa nuttallii (D)	50	0	0	0.1526
Chenopodium album var. *album* (D)*	0	67	0	0.0366*
Echinocereus reichenbachii	20	53	4	0.1412
Gaura villosa ssp. *villosa*	42	50	0	0.1676
Linum pratense	3	53	0	0.0750
Lithospermum incisum (U)	26	48	10	0.0998
Thelesperma megapotamicum	37	44	9	0.1708
Chamaesyce serpens	0	0	50	0.1122
Euphorbia dentata var. *dentata* *	0	0	75	0.0142*
Galium virgatum	0	0	50	0.1196
Lomatium foeniculaceum ssp. *foeniculaceum*	0	0	50	0.1092
Mentzelia oligosperma *	20	32	44	0.0444*
Phacelia integrifolia var. *integrifolia*	22	31	43	0.0950

Cluster Analysis

Cluster Analysis (Figure 3), using Sorensen distances (Table 12) and the flexible beta linkage method, produced a dendrogram with two major groups. One included five currently-grazed and one recently-grazed site; the other included the four long-ungrazed sites as well as a sub-group of one currently-grazed and two recently-grazed sites. SBCWMA (a currently-grazed site) and SLL (a recently-grazed site) were most closely linked; thus they possessed the lowest distance value (0.03765) and they were the two most similar sites. These two sites are geographically very close to one another. Other sites that were geographically close to each other also clustered together: i.e., SSR-N with SSR-S, and MCR with MCWMA. The four long-ungrazed sites (ACSP-S, IM, GMSP, & RNSP) were added to the dendrogram one at a time to existing groups, a phenomenon referred to as "chaining." Two of the recently-grazed sites were linked close to one another (ACSP-N & MCWMA); however, SLL (the third recently-grazed site) was most closely linked to the currently-grazed sites.

The two sites with the highest distance value (0.27900), i.e., those that were the most dissimilar, were BHR (a currently-grazed site) and IM (a long-ungrazed site). Sorensen's distance measure values range from 0 to 1 (0 = lowest & 1 = highest) and values higher than 0.50 generally indicate two different associations. My findings were similar to a previous smaller scale study by Buckallew (2002), who compared gypsum outcrop

Figure 3. Cluster Analysis dendrogram based on three seasons combined and cover classes averaged by site (1 = currently-grazed, 2 = recently-grazed, & 3 = long-ungrazed).

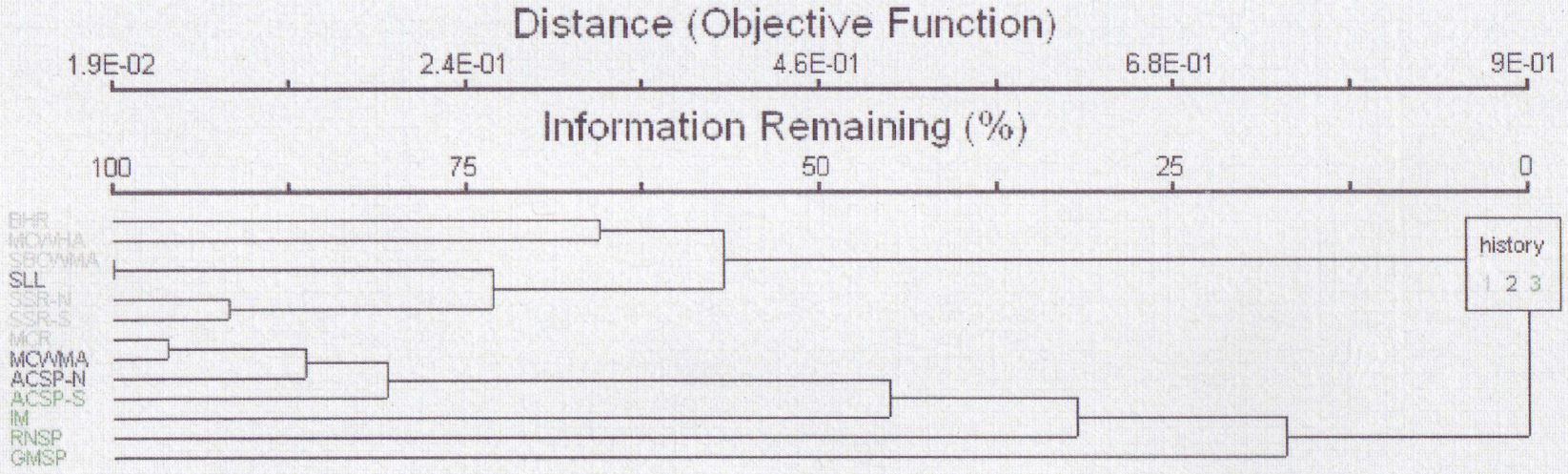


Table 12. Sorensen's distance measures (Bray-Curtis coefficient) used for Cluster Analysis hierarchy.

	ACSP-N	ACSP-S	BHR	GMSP	IM	MCR	MCWHA	MCWMA	RNSP	SBCWMA	SLL	SSR-N	SSR-S
ACSP-N	0	0.10460	0.13600	0.20070	0.18190	0.10100	0.12980	0.07890	0.19240	0.11300	0.10910	0.15140	0.11110
ACSP-S		0	0.16710	0.17440	0.16000	0.09067	0.15020	0.09130	0.17860	0.15230	0.17750	0.20790	0.15660
BHR			0	0.21780	0.27900	0.14170	0.13330	0.12980	0.26080	0.12250	0.15100	0.14840	0.09537
GMSP				0	0.21280	0.24600	0.14500	0.21830	0.26850	0.23910	0.25000	0.26540	0.24040
IM					0	0.20070	0.16850	0.14060	0.24400	0.21250	0.20530	0.19220	0.19750
MCR						0	0.12410	0.06678	0.12930	0.11880	0.15430	0.16470	0.15470
MCWHA							0	0.08813	0.23410	0.09766	0.14460	0.13570	0.12920
MCWMA								0	0.17450	0.10220	0.12690	0.15620	0.11600
RNSP									0	0.18850	0.17870	0.22440	0.24370
SBCWMA										0	0.03765	0.12380	0.09702
SLL											0	0.08854	0.10360
SSR-N												0	0.07518
SSR-S													0

communities at the SLL and ACSP-S using Sorensen's Community Coefficient. She also found similar communities and that grazing did not seriously impact species composition. Thus, abiotic factors and cattle grazing did not appear to affect the plant communities enough to consider them different associations.

Site and Species Ordinations

When all three seasons (Figures 4 & 5) were combined and DCA was performed, the only environmental variable correlated with axis 1 was latitude ($r = -0.585$). Axis 1 had an eigenvalue of 0.324 and axis 2 had an eigenvalue of 0.145. There were 150 species in the analysis, with 1.360 total variance in the species data. As shown on Figure 4, the currently- and recently-grazed sites were in the center and the long-ungrazed on the periphery. The long-ungrazed sites were widely spaced indicating differences in species composition and abundance among them.

Nineteen species demonstrated significant positive correlation with axis 1 (Figure 5 & Table 13; $r > 0.514$). Eight of the nineteen species most highly positively correlated with axis 1 were *Astragalus* sp., *Draba cuneifolia* var. *cuneifolia*, *Haploesthes greggii* var. *texana*, *Kallstroemia parviflora*, *Lactuca serriola*, *Monarda clinopodioides*, *Panicum hallii* var. *hallii*, and *Salsola tragus* ($r = 0.892$). Gloss Mountain State Park, which appears to be heavily impacted by human traffic (i.e., hiking), was an outlier on the positive end of axis 1. Similar to Cooper et al. (2005) human recreational activities can cause ecological

Figure 4. Biplot of site scores and environmental correlations for Detrended Correspondence Analysis for the three seasons combined, using cover class midpoints averaged for plant species composition (1 = currently-grazed, 2 = recently-grazed, & 3 = long-ungrazed).

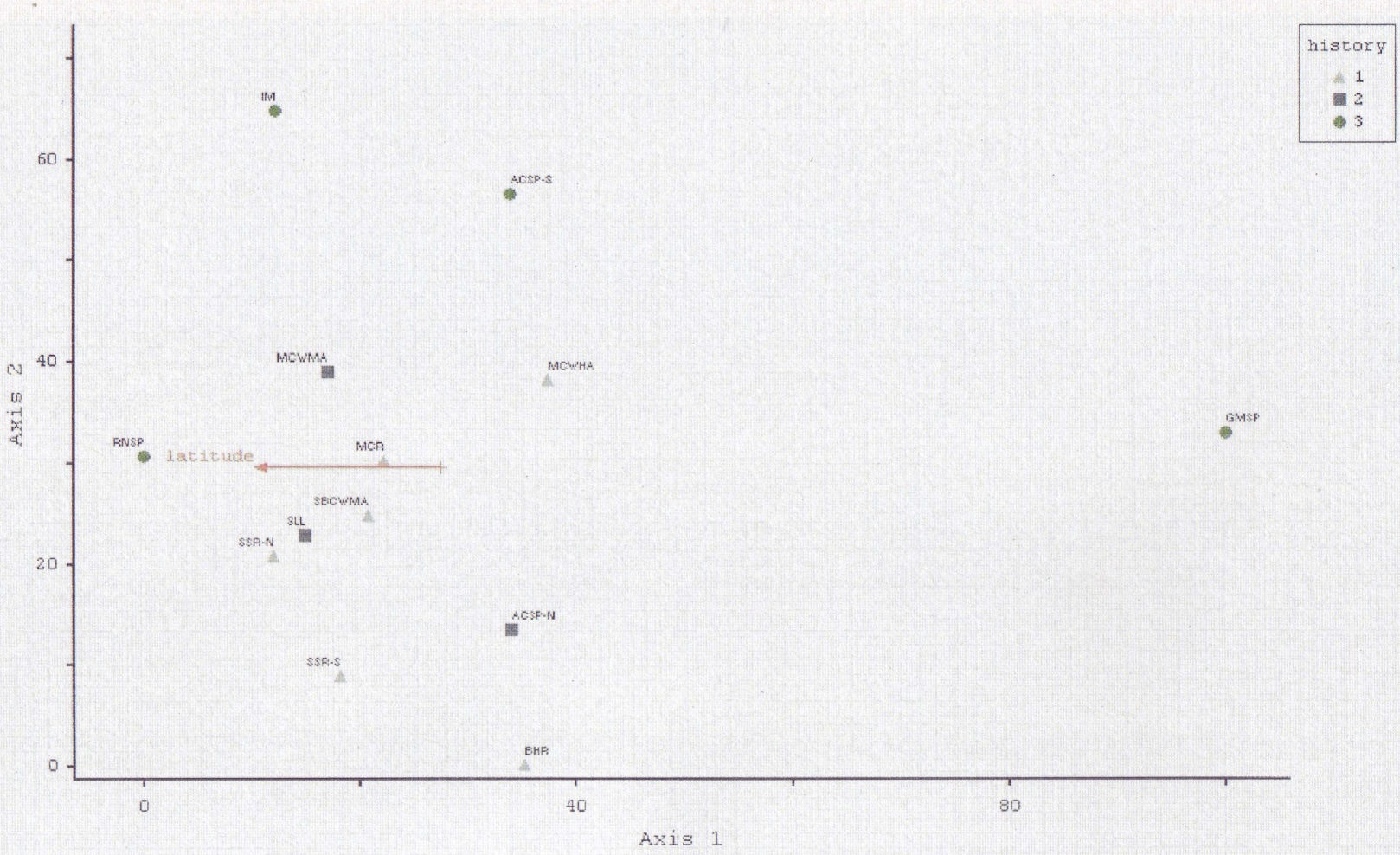


Figure 5. Detrended Correspondence Analysis diagram of plant species ordination for the three seasons combined, using cover class midpoints averaged.

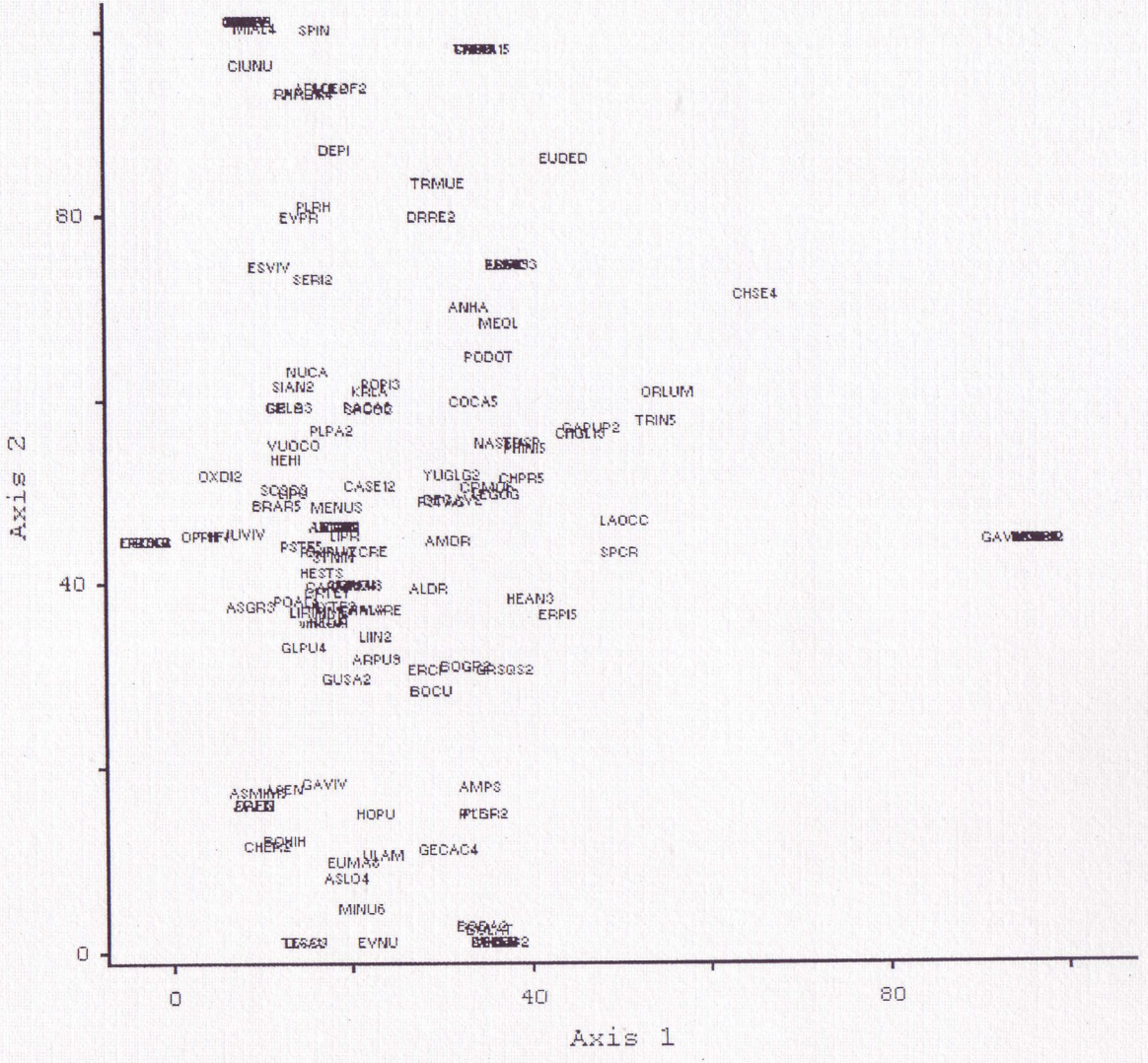


Table 13. Plant species significantly correlated (-0.514 < r > 0.514, GMSP included & -0.532 < r > 0.532, GMSP excluded) with either axis of Detrended Correspondence Analyses (I = introduced; UG = long-ungrazed, RG = recently-grazed, & CG = currently-grazed species that were good indicator species and * indicates significant indicator species: p < 0.05).

Species	all seasons		all seasons, excluding GMSP		fall 2006, excluding GMSP		spring 2007, excluding GMSP		summer 2007, excluding GMSP	
	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2
Allium drummondii	--	--	--	--	--	0.628	--	--	--	--
Amaranthus albus	--	--	--	-0.603	--	--	--	--	--	-0.641
Andropogon gerardii	--	0.593	--	0.617	--	-0.599	--	0.897	--	--
Andropogon hallii	--	--	--	--	--	--	--	--	--	0.541
Artemisia dracunculus	--	0.622	--	0.545	--	--	--	0.897	--	0.673
Artemisia ludiviciana ssp. *ludiviciana*	--	0.624	--	0.602	--	-0.599	--	0.898	--	0.726
Asclepias engelmanniana	--	--	--	--	--	-0.599	--	--	0.833	--
Astragalus distortus var. *distortus*	--	--	--	--	--	--	--	--	--	0.542
Astragalus lotiflorus (CG*)	--	-0.637	--	--	--	--	--	--	--	--
Astragalus nuttallianus	--	--	--	-0.603	--	--	--	--	--	--
Astragalus sp.	0.892	--	--	--	--	--	--	--	--	--
Atriplex subspicata	--	--	--	-0.603	--	--	--	--	--	--
Bouteloua curtipendula	--	--	--	-0.693	--	0.648	--	--	--	-0.570
Bouteloua dactyloides (CG)	--	-0.521	--	-0.617	--	--	--	--	--	-0.641
Bouteloua gracilis	--	--	--	--	--	0.595	--	--	--	--
Bothriochloa ischaemum var. *songarica* (I)	--	0.593	--	0.617	--	-0.599	--	--	--	--
Bothriochloa laguroides ssp. *torreyana*	--	--	--	-0.606	--	--	--	--	--	-0.641
Calylophus serrulatus	--	0.786	--	0.550	--	-0.563	--	0.543	--	--
Cercis canadensis var. *canadensis*	--	--	0.898	--	--	--	0.909	--	--	--
Chamaesyce glyptosperma	0.566	--	--	--	--	0.620	--	--	--	--
Chamaesyce serpens (UG)	0.716	--	--	--	--	--	--	--	--	--
Chenopodium berlandieri var. *berlandieri*	--	--	--	-0.603	--	--	--	--	--	-0.641
Chenopodium pallescens	--	0.593	--	0.617	--	--	--	--	--	--
Cirsium undulatum var. *undulatum*	--	0.578	--	0.612	--	--	--	0.897	--	--

Species	all seasons		all seasons, excluding GMSP		fall 2006, excluding GMSP		spring 2007, excluding GMSP		summer 2007, excluding GMSP	
	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2
Croton texensis var. *texensis*	--	--	--	--	--	-0.599	--	--	--	--
Descurainia pinnata	--	0.755	--	0.544	--	--	--	0.788	--	--
Desmanthus leptolobus	--	0.593	--	0.617	--	--	--	--	--	--
Draba cuneifolia var. *cuneifolia*	0.892	--	--	--	--	--	--	--	--	--
Draba reptans	--	0.573	--	--	--	--	--	--	--	--
Eragrostis minor (I)	--	--	--	--	--	--	--	--	--	0.542
Eriogonum longifolium var. *longifolium*	--	--	0.898	--	--	--	0.909	--	--	--
Erioneuron pilosum (CG)	0.642	--	--	--	--	--	--	--	--	--
Escobaria vivipara var. *vivipara*	--	0.664	--	0.707	--	-0.534	--	0.918	--	--
Euphorbia dentata var. *dentata* (UG*)	--	0.701	--	--	--	--	--	--	--	--
Euphorbia marginata	--	-0.558	--	--	--	--	--	--	--	-0.601
Evax prolifera	--	0.670	--	0.656	--	--	--	0.847	--	--
Evolvulus nuttallianus	--	-0.619	--	-0.550	--	0.588	--	--	--	-0.605
Gaillardia pulchella var. *pulchella*	0.622	--	--	--	--	--	--	--	--	--
Galium virgatum (UG)	0.881	--	0.898	--	--	--	0.909	--	--	--
Gaura coccinea	--	0.593	--	0.617	--	--	--	0.897	--	--
Gaura villosa ssp. *villosa* (RG)	--	-0.517	--	--	--	--	--	--	--	--
Geranium carolinianum var. *carolinianum*	--	--	--	-0.572	--	--	--	--	--	--
Grindelia squarrosa var. *squarrosa*	--	--	--	-0.585	--	--	--	--	--	--
Gutierrezia sarothrae (CG)	--	-0.559	--	--	--	--	--	-0.567	--	--
Haploesthes greggii var. *texana*	0.892	--	--	--	--	--	--	--	--	--
Helianthus petiolaris ssp. *petiolaris*	--	0.593	--	0.617	--	--	--	--	--	--
Heterotheca stenophylla var. *stenophylla*	-0.557	--	0.772	--	0.738	--	0.611	--	0.697	--
Hordeum pusillum	--	-0.541	--	--	--	--	--	--	--	--
Hymenopappus tenuifolius	--	--	--	--	--	--	--	--	--	-0.607
Juniperus virginiana var. *virginiana*	--	--	0.894	--	0.868	--	0.870	--	0.832	--

Species	all seasons		all seasons, excluding GMSP		fall 2006, excluding GMSP		spring 2007, excluding GMSP		summer 2007, excluding GMSP	
	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2
Kallstroemia parviflora	0.892	--	--	--	--	--	--	--	--	--
Lactuca serriola	0.892	--	--	--	--	--	--	--	--	--
Lappula occidentalis var. *cupulata*	0.573	--	--	--	--	--	--	--	--	--
Lesquerella gordonii var. *gordonii*	0.564	--	--	--	--	--	--	--	--	--
Liatris punctata	--	--	0.543	--	0.610	--	--	0.860	0.644	--
Lomatium foeniculaceum ssp. *foeniculaceum* (UG)	--	0.603	--	0.617	--	--	--	0.897	--	--
Mentzelia nuda var. *stricta*	--	--	--	--	--	-0.551	--	--	--	--
Mentzelia oligosperma (UG*)	--	0.864	--	--	--	-0.555	--	--	--	0.704
Mimosa nuttallii (CG)	--	-0.656	--	--	--	--	--	--	--	-0.605
Mirabilis albida	--	0.598	--	0.616	--	--	--	0.899	--	--
Monarda clinopodioides	0.892	--	--	--	--	--	--	--	--	--
Nuttallanthus canadensis	--	--	0.704	--	--	--	0.694	--	--	--
Opuntia phaeacantha	--	--	0.952	--	0.927	--	0.960	--	0.885	--
Orobanche ludoviciana ssp. *multiflora*	0.707	--	--	--	--	--	--	--	--	--
Oxalis dillenii	--	--	0.652	--	--	--	0.909	--	--	--
Panicum hallii var. hallii	0.892	--	--	--	--	--	--	--	--	--
Paronychia jamesii	--	--	0.864	--	0.901	--	--	--	0.826	--
Phacelia integrifolia var. *integrifolia* (UG)	0.560	--	--	0.734	--	-0.719	--	0.773	--	0.665
Plantago patagonica	--	0.548	--	--	--	--	--	--	--	--
Plantago rhodosperma	--	0.765	--	0.674	--	--	--	0.775	--	--
Polanisia dodecandra ssp. *trachysperma*	--	--	--	--	--	--	--	--	--	0.682
Pomaria jamesii	--	--	--	-0.603	--	0.628	--	--	--	-0.641
Portulaca oleracea	--	--	--	-0.603	--	--	--	--	--	-0.641
Psilostrophe tagetina var. *cerifera*	--	0.532	--	--	--	--	--	--	--	--
Psoralidium tenuiflorum	--	--	--	0.552	--	--	--	0.565	--	--
Rhus aromatica	--	0.594	--	0.636	--	--	--	0.897	--	--

Species	all seasons		all seasons, excluding GMSP		fall 2006, excluding GMSP		spring 2007, excluding GMSP		summer 2007, excluding GMSP	
	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2
Rhus glabra	--	--	0.898	--	--	--	0.909	--	0.833	--
Salsola tragus (I)	0.892	--	--	--	--	--	--	--	--	--
Schizachyrium scoparium var. *scoparium*	-0.572	--	--	0.740	--	-0.816	0.683	--	--	--
Solanum elaeagnifolium	--	--	--	-0.603	--	0.628	--	--	--	-0.641
Solidago petiolaris var. *angusta*	--	0.593	--	0.617	--	-0.599	--	--	--	--
Spermolepis inermis	--	0.755	--	0.595	--	--	--	0.780	--	--
Sphaeralcea coccinea ssp. *coccinea*	--	--	--	--	--	0.628	--	--	--	--
Sporobolus cryptandrus	0.883	--	--	--	--	0.583	--	--	0.863	--
Tetraneuris linearifolia var. *linearifolia*	--	--	0.898	--	--	--	0.909	--	--	--
Thelesperma filifolium	--	--	0.980	--	0.881	--	0.972	--	0.832	--
Thelesperma megapotamicum (RG)	--	--	-0.580	--	--	--	--	--	-0.613	--
Tridens muticus var. *elongatus*	--	0.708	--	--	--	--	--	0.688	--	--
Trifolium sp.	--	0.593	--	0.617	--	--	--	0.897	--	--
Trisetum interruptum	0.577	--	--	--	--	--	--	--	--	--
Ulmus americana	--	--	--	-0.587	--	--	0.575	--	--	-0.646

damage large enough to cause the species composition and cover to impact the interpretability of the DCA gradient. The eight species with the highest positive correlations with axis 1 were restricted to GMSP. Two plant species (*Heterotheca stenophylla* var. *stenophylla* and *Schizachyrium scoparium* var. *scoparium*) demonstrated significant negative correlation with axis 1 ($r < -0.514$).

Twenty-six plant species demonstrated significant positive correlation with axis 2 ($r > 0.514$), of which three (*Euphorbia dentata* var. *dentata**, *Lomatium foeniculaceum* var. *foeniculaceum*, and *Mentzelia oligosperma**) were indicator species for the long-ungrazed category ("*" signifies the two species that were significant indicator species). Eight species demonstrated significant negative correlation with axis 2 ($r < -0.514$), of which one (*Gaura villosa* ssp. *villosa*) was an indicator species for the recently-grazed category and four (*Astragalus lotiflorus**, *Bouteloua dactyloides*, *Gutierrezia sarothrae*, and *Mimosa nuttallii*) were indicator species for the currently-grazed category ("*" signifies the species that was a significant indicator species). The significant positive correlation of long-ungrazed indicator species with axis 2 and the significant negative correlation of currently-grazed indicator species with axis 2 suggests that grazing history may help explain the placement of sites along axis 2.

In Hurlbert's PIE (Figure 2), Cluster Analysis (Figure 3), and Detrended Correspondence Analysis (DCA) of all 13 sites

(Figures 4 & 5) GMSP was least similar or an outlier to the other sites. Thus, GMSP and the eight species (*Astragalus* sp., *D. cuneifolia* var. *cuneifolia*, *H. greggii* var. *texana*, *K. parviflora*, *L. serriola*, *M. clinopodioides*, *P. hallii* var. *hallii*, and *S. tragus*) restricted to the GMSP site were excluded from the remaining DCA ordinations (Figures 6-13). When GMSP was excluded, RNSP consistently became the outlier site located far to the right on axis 1. However, several environmental variables demonstrated significant correlation with axis 1, i.e., longitude and elevation consistently correlated negatively, as well as average annual temperature and average annual precipitation consistently correlated positively.

Ordination of sites for the three seasons combined, excluding GMSP and species exclusive to it (Figures 6 & 7), resulted in axis 1 showing significant negative correlations with longitude ($r = -0.710$) and elevation ($r = -0.820$), and significant positive correlations with average annual temperature ($r = 0.566$) and average annual precipitation ($r = 0.805$). The eigenvalues for axes 1 and 2 (0.288 & 0.186, respectively) were considerably lower than DCA with GMSP included. There were 142 species in the analysis, with 1.103 total variance in the species data. The long-ungrazed sites did not all lie to the periphery (Figure 6), as they did when GMSP was included (Figure 4). Two long-ungrazed sites (IM & RNSP) were outliers. One, IM, had a high score on axis 2 and the other, RNSP, had a high score on axis 1. The third long-ungrazed site (ACSP-S) was positioned

Figure 6. Biplot of site scores and environmental correlations for Detrended Correspondence Analysis for the three seasons combined, using cover class midpoints averaged for plant species composition, excluding GMSP and species exclusive to GMSP (1 = currently-grazed, 2 = recently-grazed, & 3 = long-ungrazed).

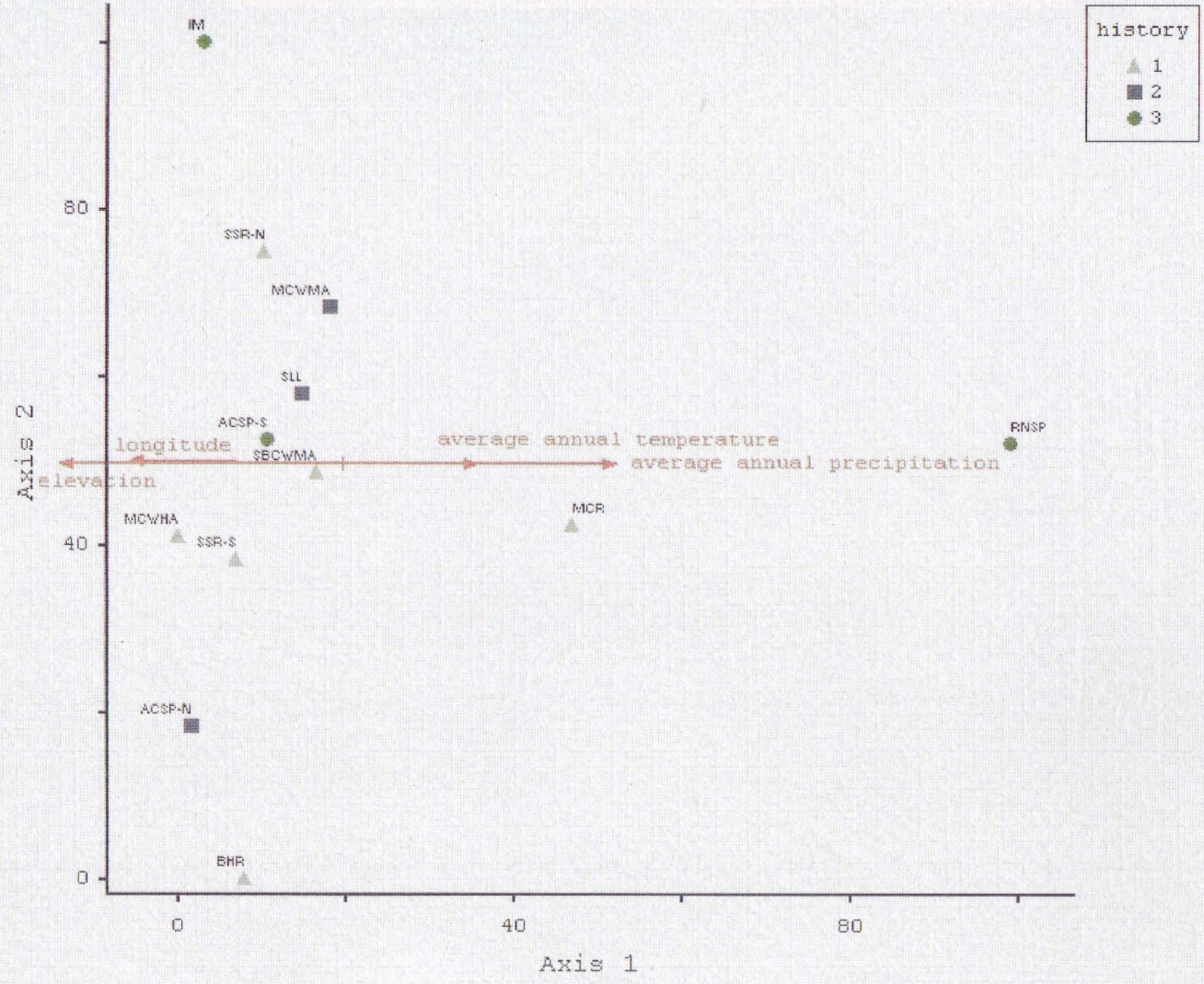


Figure 7. Detrended Correspondence Analysis diagram of plant species ordination for the three seasons combined, using cover class midpoints averaged for plant species, excluding GMSP and species exclusive to GMSP.

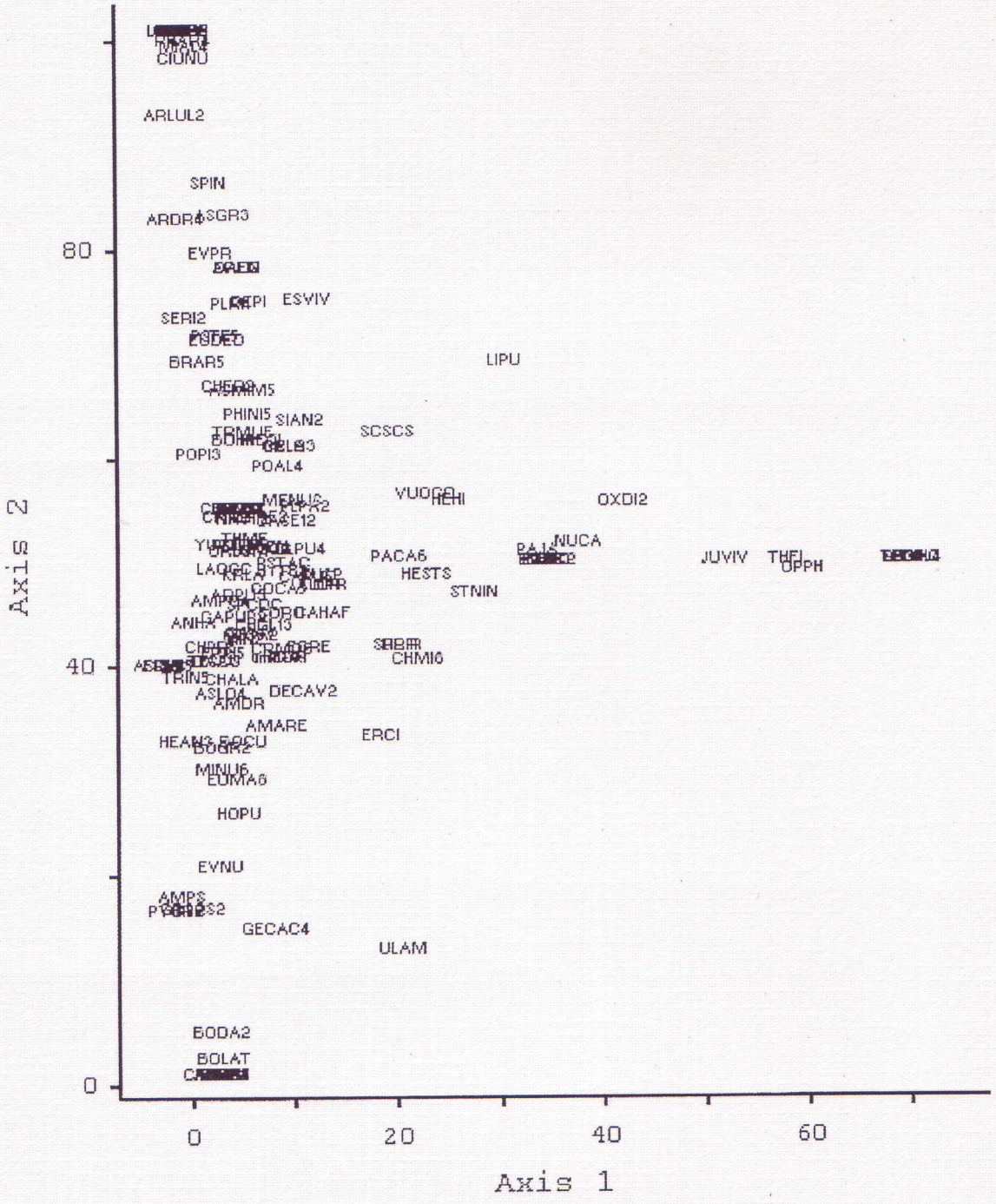


Figure 8. Biplot of site scores and environmental correlations for Detrended Correspondence Analysis for the fall 2006, using cover class midpoints averaged for plant species composition, excluding GMSP and species exclusive to GMSP (1 = currently-grazed, 2 = recently-grazed, & 3 = long-ungrazed).

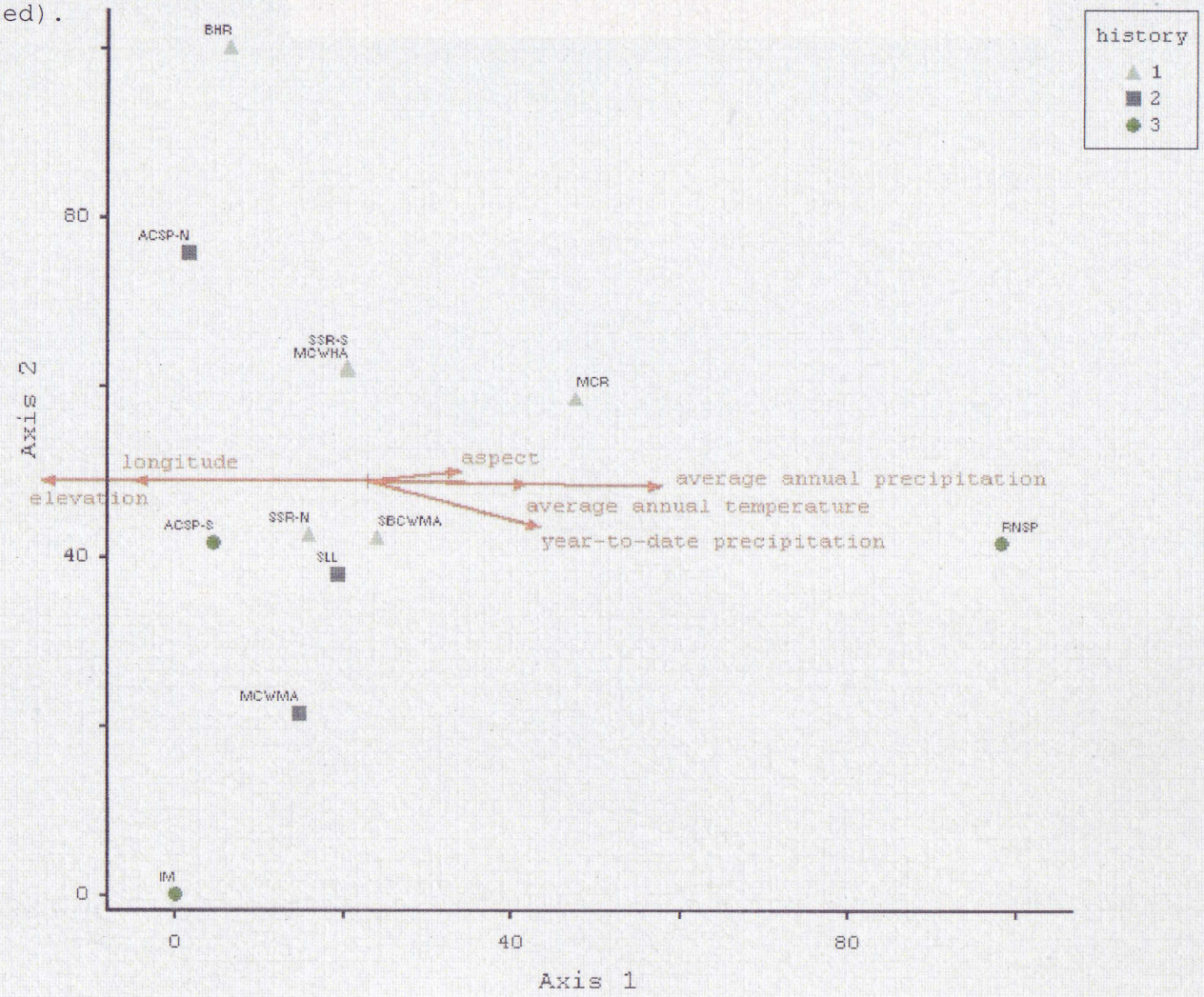


Figure 9. Detrended Correspondence Analysis diagram of plant species ordination for the fall 2006, using cover class midpoints averaged, excluding GMSP and species exclusive to GMSP.

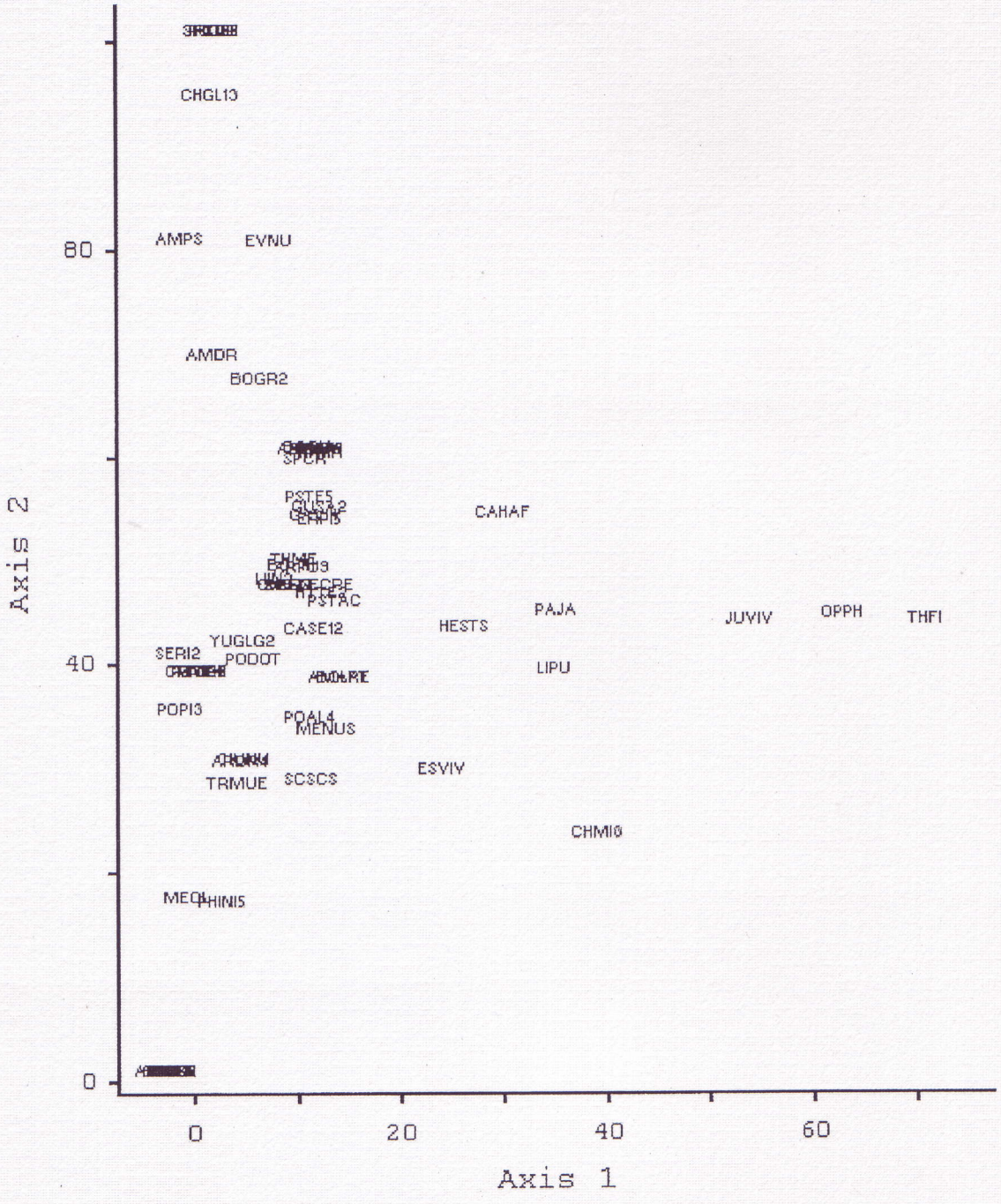


Figure 10. Biplot of site scores and environmental correlations for Detrended Correspondence Analysis for the spring 2007, using cover class midpoints averaged for plant species composition, excluding GMSP and species exclusive to GMSP (1 = currently-grazed, 2 = recently-grazed, & 3 = long-ungrazed).

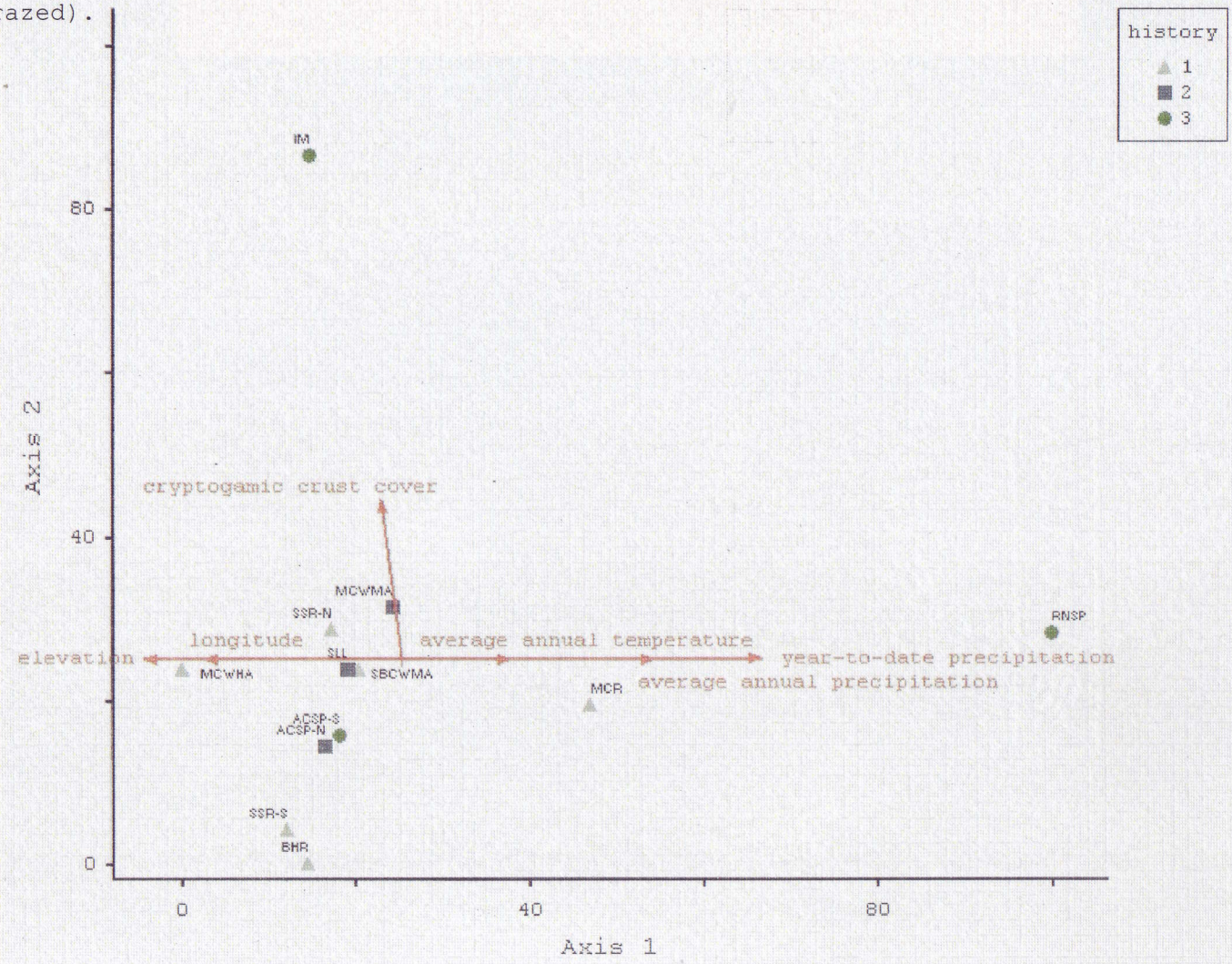


Figure 11. Detrended Correspondence Analysis diagram of plant species ordination for the spring 2007, using cover class midpoints averaged for plant species, excluding GMSP and species exclusive to GMSP.

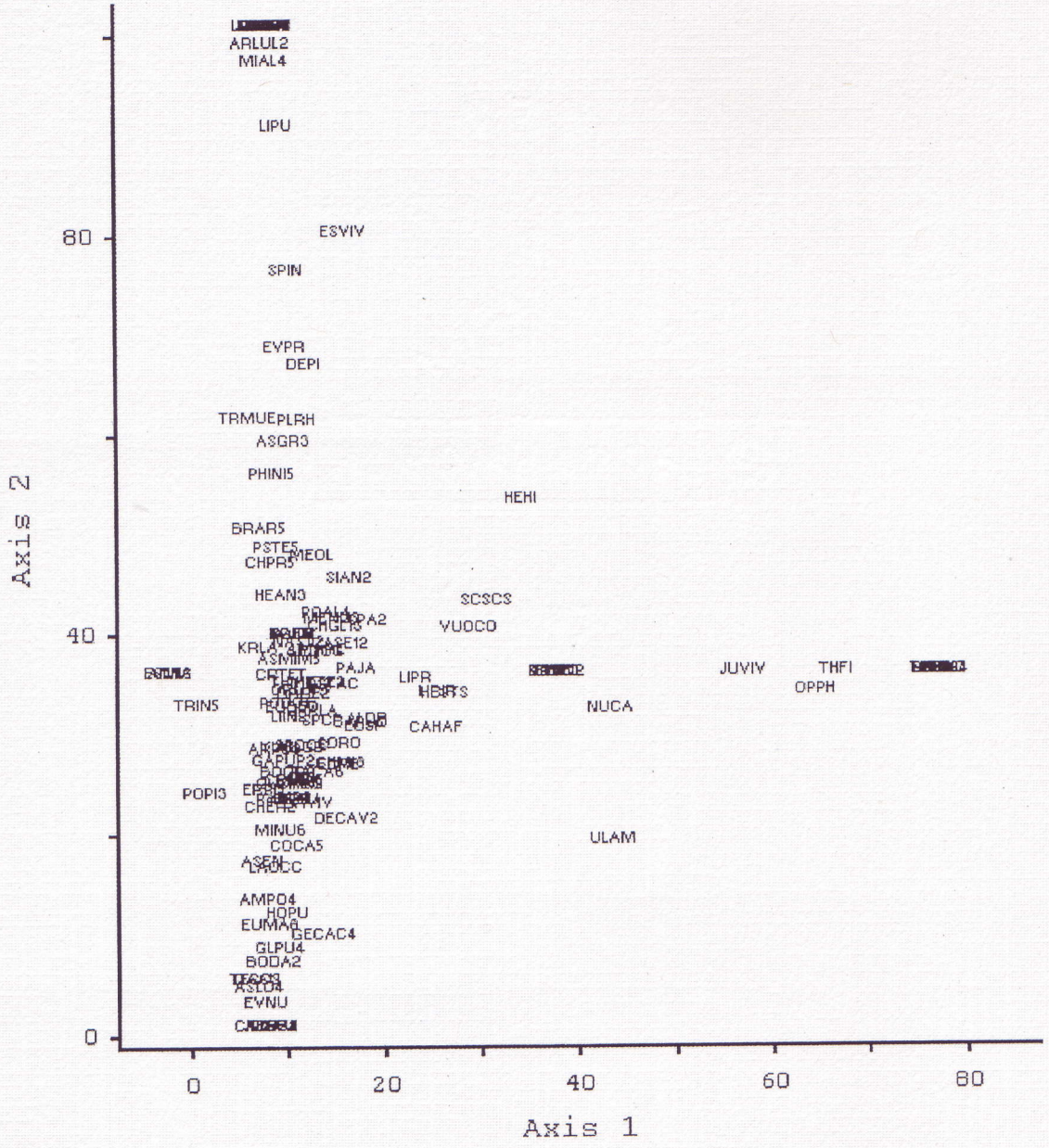


Figure 12. Biplot of site scores and environmental correlations for Detrended Correspondence Analysis for the summer 2007, using cover class midpoints averaged for plant species composition, excluding GMSP and species exclusive to GMSP (1 = currently-grazed, 2 = recently-grazed, & 3 = long-ungrazed).

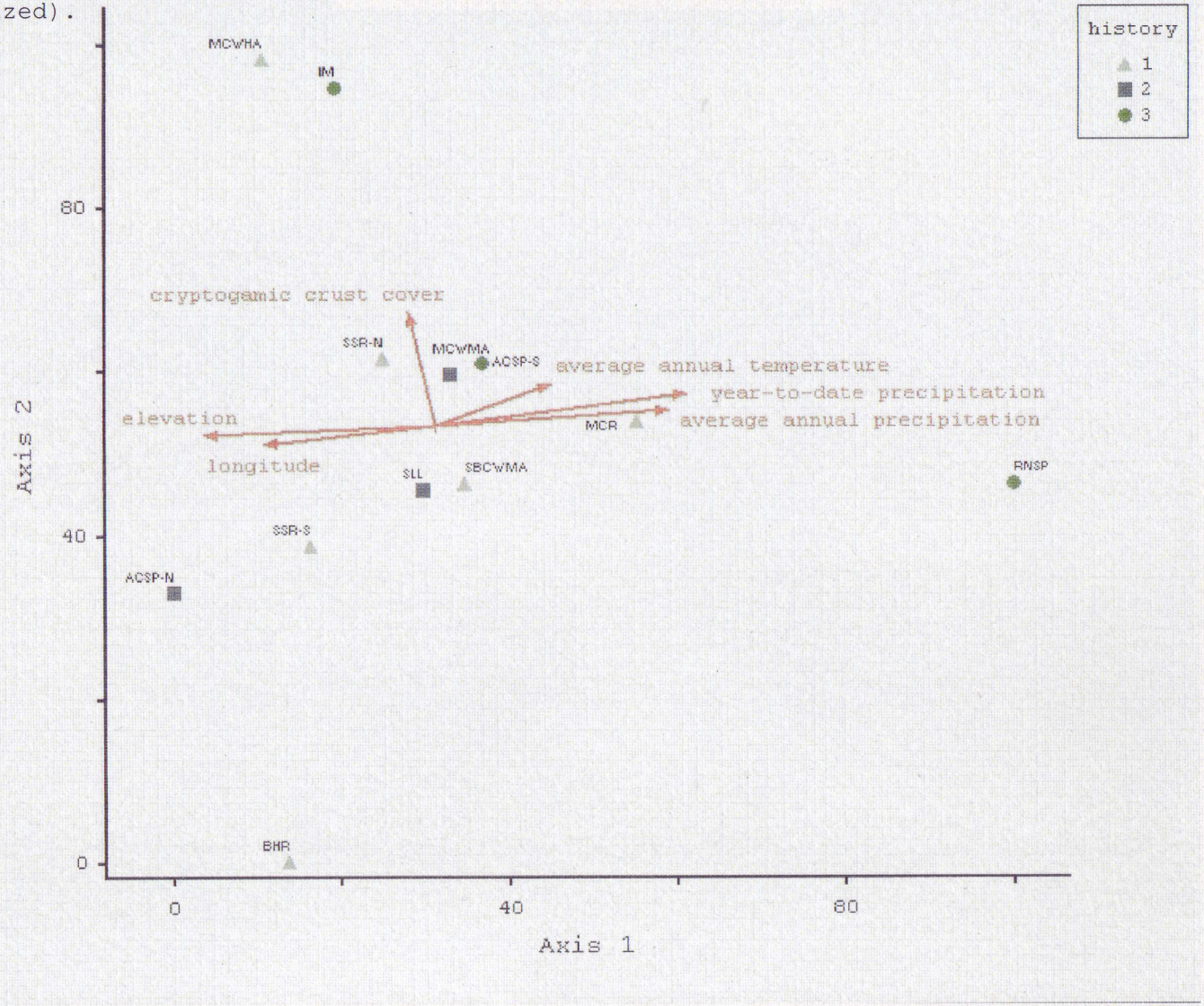
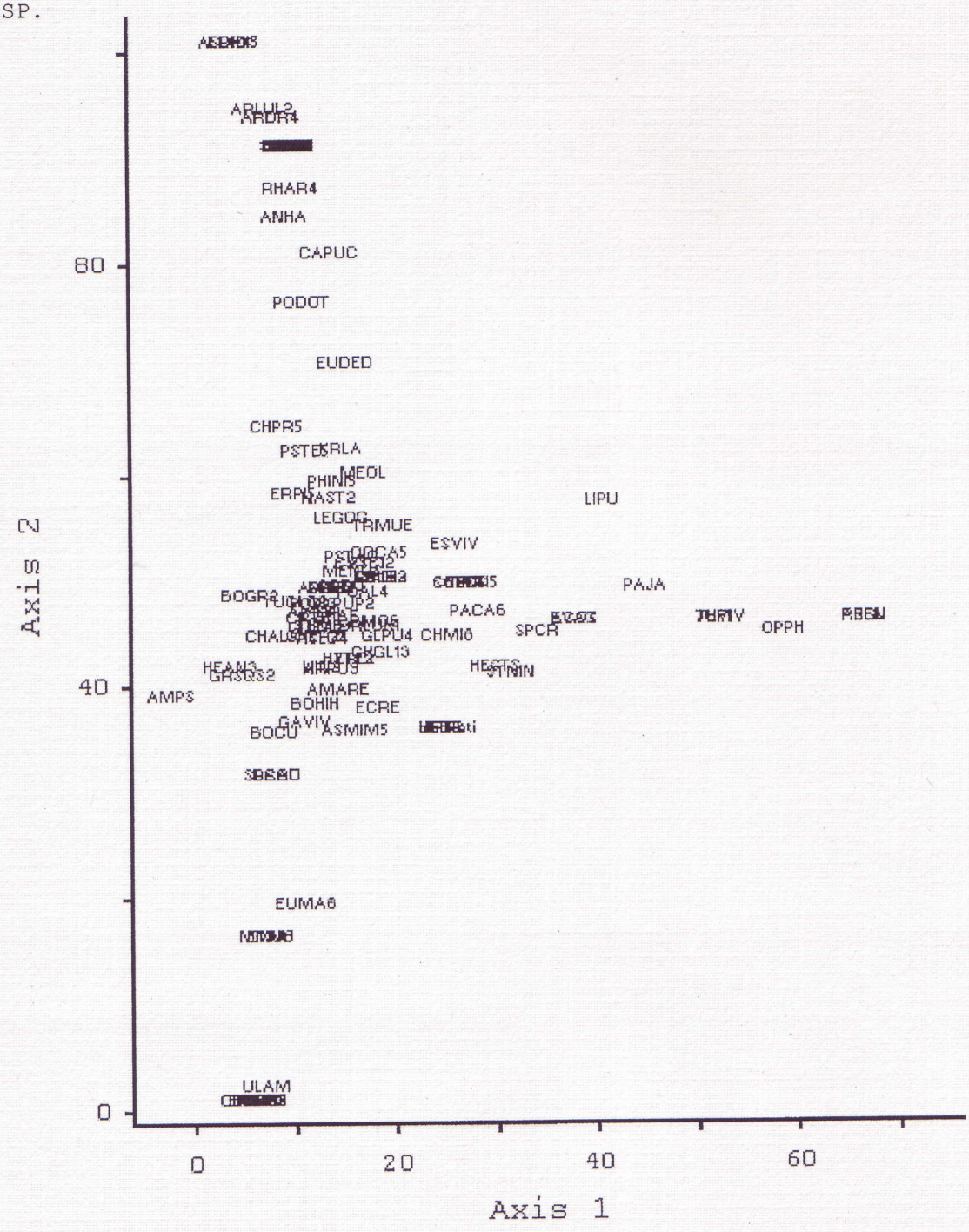


Figure 13. Detrended Correspondence Analysis diagram of plant species ordination for the summer 2007, using cover class midpoints averaged for plant species, excluding GMSP and species exclusive to GMSP.



among the recently-grazed and currently-grazed sites. All but one recently-grazed site (ACSP-N) had fairly high scores on axis 2. All of the currently-grazed sites except one (SSR-N) had low scores on axis 2 and somewhat clustered together.

Thirteen of the 142 plant species demonstrated significant positive correlation with axis 1 (Figure 7 & Table 13; $r > 0.532$). *Opuntia phaeacantha* ($r = 0.952$) and *Thelesperma filifolium* ($r = 0.980$) were the species with the highest significant correlation with axis 1. Only one species (*Thelesperma megapotamicum*; $r = -0.580$) demonstrated significant negative correlation with axis 1 ($r < -0.532$). The two *Thelesperma* species (*T. filifolium* and *T. megapotamicum*), were therefore at opposite ends of axis 1.

Twenty-three species demonstrated significant positive correlation with axis 2 ($r > 0.532$), of which two (*Lomatium foeniculaceum* var. *foeniculaceum* and *Phacelia integrifolia* var. *integrifolia*) were good indicators of long-ungrazed sites. Fourteen plant species demonstrated significant negative correlation with axis 2 ($r < -0.532$). One species (*Bouteloua dactyloides*) was categorized as a good indicator for currently-grazed sites. This pattern was similar to Figure 5, suggesting that grazing history influenced the placement of sites and species along axis 2.

Fall 2006 DCA (Figures 8 & 9) demonstrated similar trends to the DCA for the three seasons combined. Elevation ($r = -0.877$) and longitude ($r = -0.742$) both demonstrated significant

negative correlation with axis 1. Average annual temperature (r = 0.615), average annual precipitation (r = 0.834), and year-to-date precipitation total (r = 0.642) all demonstrated significant positive correlation with axis 1. Aspect (r = 0.471) was also highly correlated with axis 1. There were 63 species in this analysis, with 1.226 total variance in the species data. The eigenvalues for axis 1 (0.342) and 2 (0.228) were slightly higher than the previous two DCA analyses. Some of the sites were placed differently than prior analyses, e.g. IM scored low on axis 2. As shown on Figure 8, currently-grazed sites had higher scores on axis 1 than recently-grazed, with the exception of ACSP-N, a recently-grazed site.

Six species (*Heterotheca stenophylla* var. *stenophylla*, *Juniperus virginiana* var. *virginiana*, *Liatris punctata*, *Opuntia phaeacantha*, *Paronychia jamesii*, and *Thelesperma filifolium*) demonstrated significant positive correlation with axis 1 (Figure 9 & Table 13; $r > 0.532$). No species demonstrated significant negative correlation with axis 1 ($r < -0.532$).

Nine species demonstrated significant positive correlation with axis 2 ($r > 0.532$) and twelve species demonstrated significant negative correlation with axis 2 ($r < -0.532$). Two of the twelve species (*Mentzelia oligosperma** and *Phacelia integrifolia* var. *integrifolia*) were long-ungrazed indicator species ("*" signifies the species that was a significant indicator species); thus the grazing pattern appears to be

switched with currently-grazed sites higher scored and long-ungrazed sites lower scored on axis 2.

Spring 2007 DCA (Figures 10 & 11) was somewhat different than the previous analyses (Figures 6 & 8). The eigenvalues for axis 1 (0.323) and 2 (0.190) were similar to those seen in the analysis for the three seasons combined, which included GMSP. There were 119 species in this analysis, with 1.243 total variance in the species data. Similar to the previous analyses, elevation ($r = -0.772$) and longitude ($r = -0.672$) again demonstrated significant negative correlation with axis 1; and average annual temperature ($r = 0.500$), average annual precipitation ($r = 0.761$), and year-to-date precipitation total ($r = 0.909$) all showed significant positive correlation with axis 1. Different from previous analyses, cryptogamic crust cover demonstrated significant positive correlation with axis 2 ($r = 0.608$), as well as showing a slight negative correlation with axis 1 ($r = -0.215$). As shown on Figure 10, two of the long-ungrazed sites (IM & RNSP) were outliers, IM highly scored on axis 2 and RNSP highly scored on axis 1. The other nine sites clustered in the lower left part of the ordination diagram, with no apparent pattern.

Thirteen species demonstrated significant positive correlation with axis 1 (Figure 11 & Table 13; $r > 0.532$). *Opuntia phaeacantha* had the highest positive correlation with axis 1 ($r = 0.960$). No species, similar to fall 2006,

demonstrated significant negative correlation with axis 1 ($r < -0.532$).

Nineteen species demonstrated significant positive correlation with axis 2 ($r > 0.532$). Of the nineteen, two species (*Lomatium foeniculaceum* ssp. *foeniculaceum* and *Phacelia integrifolia* var. *integrifolia*) were long-ungrazed indicator species. One species, *Gutierrezia sarothrae* ($r = -0.567$), demonstrated significant negative correlation with axis 2 ($r < -0.532$). This species was also a good indicator species for currently-grazed sites, thus again suggesting grazing history influenced the distribution along axis 2.

Summer 2007 DCA (Figure 12 & 13) environmental variables were somewhat differently correlated with the ordination axes than prior analyses. Longitude and elevation still demonstrated significant negative correlation with axis 1 ($r = -0.640$ & $r = -0.744$, respectively), however longitude was somewhat, though not significantly, correlated negatively with axis 2 ($r = -0.210$) as well. Average annual temperature, average annual precipitation, and year-to-date precipitation totals all showed significant positive correlation with axis 1 ($r = 0.525$, $r = 0.746$, & $r = 0.774$, respectively); however average annual temperature and year-to-date precipitation total were somewhat, but not significantly, correlated positively with axis 2 ($r = 0.318$ & $r = 0.280$, respectively). Similar to spring 2007, cryptogamic crust demonstrated significant positive correlation with axis 2 ($r = 0.520$) and a slight negative correlation with axis 1 ($r = -$

0.257). Axis 1 had an eigenvalue of 0.300 and axis 2 had an eigenvalue of 0.169. There were 102 species in the analysis, with 1.344 total variance in the species data. The sites were also somewhat differently placed along the axes. As shown on Figure 12, IM (long-ungrazed site) was placed at the top of the second axis alone in the other ordinations, but this analysis placed MCWHA (currently-grazed site) above IM and to the left. Roman Nose State Park, as usual, was located far to the right on axis 1. The remaining long-ungrazed site (ACSP-S) was in the center, and closest to MCWMA. The recently-grazed sites (ACSP-N, MCWMA, & SLL) were scattered (not clustering together) along axis 1, with two (ACSP-N & SLL) having low scores on axis 2 and the other (MCWMA) having a higher score on axis 2.

Nine species demonstrated significant positive correlation with axis 1 (Figure 13 & Table 13; $r > 0.532$). The two species with the highest correlation values were *Opuntia phaeacantha* ($r = 0.885$) and *Sporobolus cryptandrus* ($r = 0.863$). One species, *Thelesperma megapotamicum* ($r = -0.613$), demonstrated significant negative correlation with axis 1 ($r < -0.532$).

Eight species demonstrated significant positive correlation with axis 2 ($r > 0.532$). Two (*Mentzelia oligosperma** and *Phacelia integrifolia* var. *integrifolia*) of the eight were indicator species for long-ungrazed sites ("*" signifies the species that was a significant indicator species). Thirteen species demonstrated significant negative correlation with axis 2 ($r < -0.532$) and two (*Bouteloua dactyloides* and *Mimosa nuttallii*)

of these species were good indicator species for currently-grazed sites, again suggesting grazing history influenced the distribution of sites along axis 2.

Non-vegetated Substrate

The area covered by non-vegetated substrate was significantly higher ($p < 0.05$) on currently-grazed outcrops relative to long-ungrazed outcrops during all seasons (fall 2006 $P = 0.014$, spring 2007 $P = 0.003$, & summer 2007 $P = 0.014$). This was similar to the limited study conducted in 2002 by Buckallew on outcrops at the SLL and ACSP-S in that vascular plant cover was lower on the recently-grazed outcrops compared to the long-ungrazed outcrops. These two studies are important because they suggest that in the absence of domesticated cattle, i.e., that indirectly trample the vegetation, plant species may possess a greater ability to establish and persist on the harsh indurate surface of the gypsum outcrops. Thus conservation of the gypsum outcrops and their species are important for their continued success and further study, as others have emphasized (Powell and Turner, 1977; Barber, 1979; Meyer and Garcia-Moya, 1989; Romao and Escudero, 2005).

CONCLUSIONS

In an attempt to study the plant community composition found on gypsum outcrops in the Cimarron Gypsum Hills (CGH), 39 representative quadrats were placed at 13 sites and sampled across two years encompassing four seasons. Unlike recent gypsum outcrop substrate studies (Spellenberg and Wootten, 1999; Reveal and Broome, 2006), no new species were identified during this study. However, 154 angiosperms in 45 families, and one gymnosperm were identified. Fewer than five percent of the species identified on gypsum outcrops were introduced and these species never covered more than 1% of any quadrat. Thus, the harsh environment of the gypsum outcrops apparently inhibits the establishment of non-native species and exhibits an island or insular effect also noted by Powell and Turner (1977) as well as Hicks and Whitcomb (1996). Additionally, it appears that gypsum outcrops provide a refuge for native species.

The presence of many native species, three obligate gypsophiles, and four species being tracked by the Oklahoma Natural Heritage Inventory, demonstrates the importance of conservation of the gypsum outcrops, both in the CGH and worldwide. Furthermore, the 33 species that were new county records for Oklahoma herbaria emphasizes the importance of further studies.

More than half of the species found growing on the outcrops were perennial herbs and the most common families represented

were the Asteraceae and Poaceae. Three species, one aster and two grasses, consistently dominated species cover values for the communities. These three species were also native perennial herbs. The highest cover per site was in the summer of 2007, which was also the season with the highest recorded precipitation. Additionally, a comparison of summer 2006 and 2007 species richness demonstrated that the wetter 2007 season supported 42 more species than the drier 2006 season. The highest species richness was in the spring of 2007; however, average species richness was very similar among the three grazing categories, as well as between sites. Species diversity also demonstrated very little variation among sites and few species were significant indicators of a grazing history category.

Gloss Mountain State Park was consistently an outlier in the Cluster Analysis, initial Detrended Correspondence Analysis (DCA), and Hurlbert's Probability of an Interspecific Encounter. This was possibly due to human impact (i.e., hiking) on the top of the park's main cathedral outcrops, causing ecological damage similar to findings by Cooper et al. (2005) on machair grasslands.

Thus, with the elimination of GMSP from the latter four DCA analyses, each demonstrated a significant negative correlation of elevation and longitude with axis 1; however, average annual temperature and average annual precipitation demonstrated significant positive correlation with axis 1. Additionally, DCA ordinations for individual seasons each demonstrated a

significant positive correlation for year-to-date precipitation totals with axis 1.

During spring and summer 2007, cryptogamic crust cover demonstrated significant positive correlation with axis 2. Cryptogamic crust cover also influenced gypsum vegetation in an eastern Mojave desert study by Meyer (1986). Axis 2 also generally demonstrated a weak grazing history gradient with long-ungrazed and currently-grazed sites on opposite ends and recently-grazed sites in the middle. Similar to results found by Ponzetti and McCune (2001) as well as Meyer and Garcia-Moya (1989), grazing did not heavily impact the vascular plant species composition. Furthermore, as found by Huebner and Vankat (2003) for some semi-arid vegetation types in Arizona, abiotic factors appeared to influence the sites' plant community composition more than grazing history. However, grazing does appear to impact the amount of non-vegetated substrate on outcrops, as currently-grazed outcrops showed significantly higher non-vegetated substrate relative to long-ungrazed ones.

In conclusion, I reject the null hypothesis of no difference in vascular plant community composition on the gypsum outcrops across the CGH, although communities are similar enough to be classified into the same vegetation association. I also reject my null hypothesis that abiotic factors will not affect the vascular plant community composition or cover, as several abiotic factors were correlated with axis 1 of the ordination. Additionally, I accept part of the null hypothesis that grazing

will not significantly affect the species composition or cover; however, I reject that grazing history will not affect non-vegetated substrate, because currently-grazed outcrops demonstrated significantly higher non-vegetated substrate cover relative to long-ungrazed ones.

This study could be improved by adding more long-ungrazed and recently-grazed sites to the analysis, although outcrops that are long-ungrazed and recently-grazed were very difficult to find. In the future, I would like to conduct a succession study that follows the recently-grazed sites into the long-ungrazed category, of longer than ten years without domesticated cattle grazing. I would also like to compare vascular plant communities on gypsum outcrops across the United States and Mexico, spanning east to the Mojave desert, north through Kansas, and south to the Chihuahuan desert.

Additionally, further study into the insular or "island" effects of the gypsum outcrop plant community would be interesting. The island-like nature of the gypsum outcrops provides an opportunity for speciation events (via evolution) to occur in an environment with otherwise limited establishment of species. Thus, a genetic study of plant species found growing on and off gypsum outcrops could be fruitful, and could even lead to the discovery of new gypsophile species.

LITERATURE CITED

Akpulat, H.A. and N. Celik. 2005. Flora of gypsum areas in Sivas in the eastern part of Cappadocia in Central Anatolia, Turkey. Journal of Arid Environments 61:27-46.

Barber, S.C. 1975. A floristic study of the vascular plants of the gypsum hills and redbed plains area of southwestern Oklahoma. Unpublished master's thesis. Stillwater, OK: Oklahoma State University.

Barber, S.C. 1979. Floristic components of the gypsum hills and redbed plains area of southwestern Oklahoma. The Southwestern Naturalist 24:431-437.

Bidwell, T.G., M.E. Moseley, H.L. Fritzler, and S.J. Glasgow. 2007. The National Rangeland Judging Contest: Judging Rangeland for Livestock and Wildlife Values, 7th edition. (http://www.rangejudging.com/rangeland 7th.pdf). Cooperative Extension Service, Oklahoma State University, Stillwater, OK. Retrieved November 2007.

Bidwell, T.G., R.E. Masters, and R.J. Tyrl. 2008. A checklist of prairie, shrubland, and forest understory plants of Oklahoma: characteristics and value to deer, quail, turkey, and cattle. (http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-2701/NREM-2872web.pdf). Cooperative Extension Service, Oklahoma State University, Stillwater, OK. Retrieved May 2008.

Borselli, L., R. Biancalani, C. Giordani, S. Carnicelli, and G.A. Ferrari. 1996. Effect of gypsum on seedling emergence in a kaolinitic crusting soil. Soil Technology 9:71-81.

Buckallew, R.R. 2002. A floristic survey and description of vascular plant communities at the Selman Living Laboratory, Woodward County, Oklahoma. Unpublished master's thesis. Edmond, OK: University of Central Oklahoma.

Buckallew, R.R. and G.M. Caddell. 2003. Vascular flora of the University of Central Oklahoma Selman Living Laboratory, Woodward County, Oklahoma. Proceedings of the Oklahoma Academy of Science 83:31-45.

Campbell, R.S. and I.F. Campbell. 1938. Vegetation on gypsum soils of the Jornada Plain, New Mexico. Ecology 19:572-577.

Caywood, M. 2006. Park Manager, Alabaster Caverns State Park, Freedom, OK. Personal Communication.

Cockerell, T.D.A. and F. Garcia. 1898. Preliminary note on the growth of plants in gypsum. Science 8:119-121.

Cooper, A., T. McCann, and E. Ballard. 2005. The effects of livestock grazing and recreation on Irish machair grassland vegetation. Plant Ecology 181:255-267.

Dana, E.D. and J.F. Mota. 2006. Vegetation and soil recovery on gypsum outcrops in semi-arid Spain. Journal of Arid Environments 65:444-459.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-64.

Diggs, G.M., B.L. Lipscomb, and R.J. O'Kennon. 1999. Shinners & Mahler's illustrated flora of north central Texas. Botanical Research Institute of Texas, Fort Worth, TX. 1626 p.

Escudero, A., L.F. Carnes, and F. Perez-Garcia. 1997. Seed germination of gypsophytes and gypsovags in semi-arid central Spain. Journal of Arid Environments 36:487-497.

Escudero, A, R.C. Somolinos, J.M. Olano, and A. Rubio. 1999. Factors controlling the establishment of *Helianthemum squamatum*, an endemic gypsophile of semi-arid Spain. Journal of Ecology 87:290-302.

Escudero, A., J.M. Iriondo, J.M. Olano, A. Rubio, and R.C. Somolinos. 2000. Factors affecting establishment of a gypsophyte: The case of *Lepidium subulatum* (Brassicaceae). American Journal of Botany 87:861-871.

Great Plains Flora Association. 1986. Flora of the Great Plains. University Press of Kansas, Lawrence, KS. 1402 p.

Gotelli, N.J. and G.L. Entsminger. 2006. EcoSim: Null models software for ecology. Version 7. Acquired Intelligence Inc. and Kesey-Bear. Jericho, VT. http://garyents-minger.com/ecosim.htm

Hicks, A.L. and R.F. Whitcomb. 1996. Diversity of the leafhopper (Homoptera: Cicadellidae) fauna of northern Chihuahuan grasslands, with emphasis on gypsum grasslands and description of a new species of *Athysanella* (Cicadellidae: Deltocephalinae). Proceedings of the Entomological Society of Washington 98:145-157.

Hill, M.O. and H.G. Gauch. 1980. Detrended Correspondence Analysis: An improved ordination technique. Vegetatio 42:47-58.

Hoagland, B.W. 2000. The vegetation of Oklahoma: A classification for landscape mapping and conservation planning. The Southwestern Naturalist 45:385-420.

Hoagland, B.W. and A.K. Buthod. 2005. Vascular flora of a gypsum dominated site in Major County, Oklahoma. Proceedings of the Oklahoma Academy of Science 85:1-8.

Holm, S. 1979. A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics 6:65-70.

Huebner, C.D. and J.L. Vankat. 2003. The importance of environment vs. disturbance in the vegetation mosaic of Central Arizona. Journal of Vegetation Science 14:25-34.

Hurlbert, S.H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52:577-586.

Jantunen, J., K. Saarinen, and O. Marttila. 2002. A comparison of vegetation in grazed, formerly grazed and ungrazed valuable semi-natural grasslands in SE Finland. Memoranda Society of Fauna Flora Fennica 78:55-61.

Johnson, K.S. 1972a. Guidebook for geologic field trips in Oklahoma; Book II northwestern Oklahoma: Oklahoma Geological Survey, Educational Publication 3.

Johnson, K.S. 1972b. Gypsum and salt resources in Oklahoma. Industrial Minerals 62:33-39.

Johnson, K.S. 1972c. Mineral resources map of Oklahoma: Oklahoma Geological Survey, Educational Publication 1.

Johnson, K.S. 1996. Geology of Oklahoma. Rockhounding and Earth-Science activities in Oklahoma, 1995 workshop SP96-5:1-9.

Johnson, K.S. 1999. Geologic field trips in northwest Oklahoma: Oklahoma Geological Survey, Educational Publication 3.

Johnston, I.M. 1941. Gypsophily among Mexican desert plants. Journal of the Arnold Arboretum 22:145-170.

Martinez, I., A. Escudero, F.T. Maestre, A. de la Cruz, C. Guerrero, and A. Rubio. 2006. Small-scale patterns of abundance of mosses and lichens forming biological soil crusts in two semi-arid gypsum environments. Australian Journal of Botany 54:339-348.

McCune, B.P. and J.B. Grace. 2002. Analysis of Ecological Communities. MjM Software Design. Gleneden Beach, OR. 300 p.

McCune, B.P. and M.J. Mefford. 2006. PC-ORD: Multivariate Analysis of Ecological data. Version 5. MjM Software, Gleneden Beach, OR.

McGregor, R.L., coordinator and T.M. Barkley, editor. 1977. Atlas of the flora of the Great Plains. The Iowa State University Press. 600 p.

Meyer, S.E. 1986. The ecology of gypsophile endemism in the eastern Mojave desert. Ecology 67:1303-1313.

Meyer, S.E. and E. Garcia-Moya. 1989. Plant community patterns and soil moisture regime in gypsum grasslands of north central Mexico. Journal of Arid Environments 16:147-155.

Meyer, S.E., E. Garcia-Moya, and Luz del Carmen Lagunes-Espinoza. 1992. Topographic and soil surface effects on gypsophile plant community patterns in central Mexico. Journal of Vegetation Science 3:429-438.

Moore, M.J. and R.K. Jansen. 2007. Origins and biogeography of gypsophily in the Chihuahuan desert plant group *Tiquilia* subgenus *Eddya* (Boraginaceae). Systematic Botany 32:392-414.

Mota, J.F., A.J. Sola, E.D. Dana, and M.L. Jimenez-Sanchez. 2003. Plant succession in abandoned gypsum quarries in SE Spain. Phytocoenologia 33:13-28.

Oklahoma Climatological Survey. 2006. Precipitation statistics, overall precipitation and normal precipitation. (http://climate.ocs.ou.edu/precipitation_update.html). The Oklahoma Climatological Survey, Norman, OK. Retrieved July 2007.

Oklahoma Geological Survey. 2006. Permian rocks of Oklahoma. (www.ogs.ou.edu/earthscience/intgeol/7perm.htm). The Oklahoma Geological Survey, Norman, OK. Retrieved June 2006.

Oklahoma Natural Heritage Inventory Database. 2008. Working list of rare Oklahoma plants. (http://www.oknaturalheritage.ou.edu/index.htm). Oklahoma Biological Survey, Norman, OK. Retrieved February 2008.

Oklahoma Vascular Plants Database. 2008. (http://www.coordinatesolutions.com/ovpd/ovpd.aspx). Oklahoma Biological Survey, Norman, OK. Retrieved February 2008.

Olano, J.M., I. Caballero, J. Loidi, and A. Escudero. 2005. Prediction of plant cover from seed bank analysis in a semi-arid plant community on gypsum. Journal of Vegetation Science 16:215-222.

Olszewski, T.D. 2004. A unified mathematical framework for the measurement of richness and evenness within and among multiple communities. Oikos 104:377-387.

Parsons, R.F. 1976. Gypsophily in plants - A review. The American Midland Naturalist 96:1-20.

Peet, R.K., T.R. Wentworth, and P.S. White. 1998. A flexible, multipurpose method for recording vegetation composition and structure. Castanea 63:262-274.

Ponzetti, J.M. and B.P. McCune. 2001. Biotic soil crusts of Oregon's shrub steppe: Community composition in relation to

soil chemistry, climate, and livestock activity. The Bryologist 104:212-225.

Powell, A.M. and B.L. Turner. 1977. Aspects of the plant biology of the gypsum outcrops of the Chihuahuan desert. In: Wauer, R.H. and D.H. Riskind (eds), Transactions of the Symposium of Biological Resources of the Chihuahuan desert region, United States and Mexico. U.S. Department of Interior, National Park Service, Washington D.C., USA, Transactions and Proceedings Series 3:315-325.

Pueyo, Y. and C.L. Alados. 2007. Abiotic factors determining vegetation patterns in a semi-arid Mediterannean landscape: Different responses on gypsum and non-gypsum substrates. Journal of Arid Environments 69:490-505.

Pueyo, Y., C.L. Alados, M. Maestro, and B. Komac. 2007. Gypsophile vegetation patterns under a range of soil properties induced by topographical position. Plant Ecology 189:301-311.

Reveal, J.L. and C.R. Broome. 2006. *Cryptantha gypsophila* (Boraginaceae: Boraginoideae), a new species from western Colorado. Brittonia 58:178-181.

Romao, R.L. and A. Escudero. 2005. Gypsum physical soil crusts and the existence of gypsophytes in semi-arid central Spain. Plant Ecology 181:127-137.

Systat Software, Inc. 2006. SigmaStat. Version 3.5. Systat Software, Inc., San Jose, CA.

Sorensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. Det Kongelige Danske Videnskabernes Selskab, Biologiske Skrifter 5:1-34.

Spellenberg, R. and T. Wootten. 1999. Vascular plants on a gypsum outcrop in southern New Mexico: A listing, a new variety and taxonomic realignments in the *Anulocaulis leiosolenus* complex (Nyctaginaceae), and a new variety of *Mentzelia humilis* (Loasaceae). SIDA 18:987-999.

Stubsten, M. 2006. President, Gloss Mountain Conservancy, Inc., Fairview, OK. Personal Communication.

Taylor, R.J. and C.E.S. Taylor. 1994. An annotated list of the ferns, fern allies, gymnosperms, and flowering plants of Oklahoma. Southeastern Oklahoma State University, Durant, OK. 133 p.

Towne, E.G., D.C. Hartnett, and R.C. Cochran. 2005. Vegetation trends in tallgrass prairie from bison and cattle grazing. Ecological Society of America 15:1550-1559.

Tyrl, R.J., S.C. Barber, P. Buck, W.J. Elisens, J.R. Estes, P. Folley, L.K. Magrath, C.L. Murray, B.A. Smith, C.E.S. Taylor, and R.A. Thompson. 2007. Keys and descriptions for the vascular plants of Oklahoma, fourth edition. Flora of Oklahoma Incorporated, Noble, OK. 316 p.

USDA, NRCS. 2007. The PLANTS Database. (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA. Retrieved December 2007.

Waterfall, U.T. 1969. Keys to the flora of Oklahoma. Oklahoma State University, Stillwater, OK. 246 p.

Watson, A. 1979. Gypsum crusts in deserts. Journal of Arid Environments 2:3-20.

Weber, M.C. 1994. Roman Nose: A history of the park. Oak Haven Books, Southard, OK. 151 p.

Wiser, S.K., R.K. Peet, and P.S. White. 1996. High-elevation rock outcrop vegetation of the southern Appalachian Mountains. Journal of Vegetation Science 7:703-722.

Appendix 1. Summer 2006 cover class (refer to Table 2) data for plant species by site, grazing history (CG = currently-grazed, RG = recently-grazed, & UG = long-ungrazed), date, and quadrat.

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	07/28/06	07/29/06		07/28/06	07/29/06		07/28/06			07/03/06			07/30/06			07/14/06	07/15/06		07/14/06			07/17/06			07/01/06			07/28/06			07/14/06	07/15/06		07/29/06			07/29/06		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	2	1	3	1	2	3	1	2	3
Ambrosia psilostachya	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphiachyris dracunculoides	1	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Andropogon gerardii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Andropogon hallii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apocynum cannabinum	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aristida purpurea	-	1	-	-	1	-	-	1	1	1	-	1	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	1	1	1	1	1	1	1	1	-	1	1	1
Artemisia dracunculus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Artemisia ludoviciana ssp. *ludoviciana*	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Asclepias engelmanniana	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	1	-	1
Astragalus gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-
Astragalus mollissimus var. *mollissimus*	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bothriochloa laguroides ssp. *torreyana*	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Bouteloua curtipendula	1	1	1	1	-	-	1	1	2	1	-	-	1	1	1	-	1	-	-	-	-	1	-	-	-	1	1	-	1	1	-	1	1	1	1	1	1	-	1
Bouteloua gracilis	-	1	1	-	1	1	1	1	1	-	-	1	-	-	-	-	1	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
Bromus arvensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Calylophus hartwegii ssp. *fendleri*	1	-	1	-	-	-	-	-	1	-	-	-	-	-	1	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1
Calylophus serrulatus	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Castilleja purpurea var. *citrina*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	1	1	1	-	-	1	-	-	-
Ceanothus herbaceus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaetopappa ericoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Chamaesyce glyptosperma	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chamaesyce missurica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cirsium undulatum var. *undulatum*	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Croton monanthogynus	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cylindropuntia imbricata var. *imbricata*	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	07/28/06	07/29/06		07/28/06	07/29/06		07/28/06			07/03/06			07/30/06			07/14/06	07/15/06		07/14/06			07/17/06			07/01/06			07/28/06			07/14/06	07/15/06		07/29/06			07/29/06		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	2	1	3	1	2	3	1	2	3
Dalea aurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Dalea enneandra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-
Echinocereus reichenbachii	1	1	-	1	1	-	-	1	1	-	-	-	-	-	-	-	1	1	-	-	-	1	1	1	-	-	-	1	1	-	1	1	-	-	-	-	-	-	-	-
Eriogonum longifolium var. *longifolium*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Erioneuron pilosum	-	-	1	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	1
Escobaria vivipara var. *vivipara*	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Evolvulus nuttallianus	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Gaura villosa ssp. *villosa*	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	1	-	1	-	-	1	-	-	2	1	-
Gutierrezia sarothrae	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	1	1	1	-	1	1	-	1	1	-	1	1
Haploesthes greggii var. *texana*	-	-	-	-	-	-	-	-	-	3	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heterotheca stenophylla var. *stenophylla*	1	1	1	1	1	1	1	2	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1	2	1	1	2	1	1	1	1	1	1	-
Hymenopappus tenuifolius	1	1	1	-	1	-	1	1	1	-	1	-	1	-	1	1	-	1	1	-	-	-	1	-	-	1	-	1	1	-	1	1	1	1	1	1	1	1	1
Juniperus virginiana var. *virginiana*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Krameria lanceolata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Liatris punctata	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Lithospermum incisum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	-	1	-	-	-	-	-	-
Mentzelia nuda var. *stricta*	1	-	-	1	-	-	-	1	-	-	-	-	1	1	1	1	-	1	-	1	1	1	1	1	-	1	-	1	-	1	1	1	-	-	1	-	-	1	-
Mentzelia oligosperma	-	-	-	1	1	1	-	-	-	-	1	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mirabilis albida	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nama stevensii	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	1	-	-	-	-	-	-
Opuntia phaeacantha	-	-	-	1	1	-	-	1	-	-	1	-	-	1	-	1	1	1	-	-	-	1	-	-	2	2	3	1	-	-	1	-	-	-	-	-	-	-	-
Orobanche ludoviciana ssp. *multiflora*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Panicum hallii var. *hallii*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paronychia jamesii	1	1	1	-	1	-	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	-	1	1	-	1	1	1
Phacelia integrifolia var. *integrifolia*	-	-	1	1	-	1	-	-	-	1	1	1	1	1	1	-	-	1	-	-	1	-	1	-	-	1	-	-	-	-	1	-	1	-	-	-	-	1	1
Plantago patagonica	1	1	-	-	1	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1

Site	ACSP-N						BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	07/28/06		07/29/06	07/28/06		07/29/06	07/28/06			07/03/06			07/30/06			07/14/06		07/15/06	07/14/06			07/17/06			07/01/06			07/28/06			07/14/06		07/15/06	07/29/06			07/29/06		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	2	1	3	1	2	3	1	2	3
Polygala alba	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	1	1	1	1	-	1	1	-	-	-
Pomaria jamesii	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Portulaca pilosa	-	1	-	-	-	1	1	-	-	-	1	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-
Psilostrophe tagetina var. *cerifera*	1	-	-	1	1	1	-	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	-	1	-	1	1	1	1	-	1	1	1	1	1
Psoralidium tenuiflorum	1	-	-	-	-	-	-	-	1	-	1	-	1	1	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	1
Rhus aromatica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schizachyrium scoparium var. *scoparium*	1	1	1	1	-	-	-	1	-	1	-	1	2	2	1	2	1	1	1	1	1	2	3	1	2	2	2	1	1	1	2	1	1	2	1	1	1	1	1
Solanum elaeagnifolium	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphaeralcea coccinea ssp. *coccinea*	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sporobolus cryptandrus	1	1	1	1	1	1	2	1	1	1	4	1	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1	-	1	1	1	-	1	-	1	1	1	1	1	1
Thelesperma filifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Thelesperma megapotamicum	1	1	1	-	-	1	-	-	1	-	-	-	1	1	1	1	-	-	-	-	1	1	1	-	-	-	-	1	-	-	1	1	1	1	1	1	1	1	1	1
Tridens muticus var. *elongatus*	-	-	1	1	1	2	-	-	-	-	-	-	1	1	1	-	-	-	-	-	1	1	1	1	-	-	-	1	-	-	-	-	-	-	-	-	1	1	-
Yucca glauca var. *glauca*	-	1	1	1	1	1	-	-	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	1	-	-	1	-
number species in each quadrat	16	17	15	16	15	15	11	13	16	12	15	15	16	23	23	13	18	14	10	10	16	14	14	10	12	15	13	16	12	12	19	15	17	13	16	16	16	15	21
number species at each site	25			25			26			22			33			26			18			19			22			20			24			25			27		

Appendix 2. Fall 2006 cover class (refer to Table 3) data for plant species and non-vegetated substrate by site, grazing history (CG = currently-grazed, RG = recently-grazed, & UG = long-ungrazed), date, and quadrat.

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	09/24/06	10/24/06	10/28/06	09/24/06			10/27/06	10/28/06		10/01/06			10/22/06			10/07/06			10/07/06			10/07/06			10/01/06			10/28/06			10/22/06			10/28/06			11/05/06		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Allium drummondii	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ambrosia artemisiifolia var. *elatior*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Ambrosia psilostachya	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Amphiachyris dracunculoides	–	–	–	2	–	2	2	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–
Andropogon gerardii	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Andropogon hallii	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Aristida purpurea	–	–	–	–	2	–	–	2	2	2	–	–	–	–	–	–	–	–	2	2	3	–	–	–	–	–	–	3	2	2	2	2	4	2	3	1	2	2	2
Artemisia dracunculus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Artemisia filifolia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–
Artemisia ludoviciana ssp. *ludoviciana*	–	–	–	–	–	–	–	–	–	–	1	–	1	2	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Asclepias engelmanniana	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Astragalus missouriensis var. *missouriensis*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Bothriochloa ischaemum var. *songarica*	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bothriochloa laguroides ssp. *torreyana*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Bouteloua curtipendula	2	2	3	2	–	2	2	2	5	2	–	–	2	2	3	–	4	2	2	–	2	2	–	2	2	1	2	2	2	2	2	–	2	2	2	2	2	2	3
Bouteloua gracilis	2	5	4	–	3	–	4	1	3	2	3	–	2	2	2	–	2	2	2	3	2	2	–	2	2	–	2	2	–	–	–	–	–	–	2	–	2	2	4
Bouteloua hirsuta var. *hirsuta*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	1	1	–
Calylophus hartwegii ssp. *fendleri*	2	–	2	1	–	–	–	1	1	–	–	–	1	–	–	–	2	–	–	–	–	–	–	2	–	2	2	–	–	–	–	–	–	–	–	–	2	–
Calylophus serrulatus	2	2	2	2	2	3	–	2	2	2	2	2	2	3	3	2	2	2	2	3	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2
Chaetopappa ericoides	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–
Chamaesyce glyptosperma	–	–	–	–	–	1	2	–	–	1	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chamaesyce missurica	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	2	–	1	–	–	–	–	–	–	–	–	–	–	–	–
Cirsium undulatum var. *undulatum*	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Croton monanthogynus	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	09/24/06	10/24/06	10/28/06	09/24/06			10/27/06	10/28/06		10/01/06			10/22/06			10/07/06			10/07/06			10/07/06			10/01/06			10/28/06			10/22/06			10/28/06			11/05/06		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Croton texensis var. *texensis*	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cylindropuntia imbricata var. *imbricata*	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dalea enneandra	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–
Echinocereus reichenbachii	2	1	1	2	2	–	–	1	2	–	–	–	–	–	–	–	3	2	–	–	–	2	2	2	–	–	–	1	–	–	1	1	–	–	–	–	–	–	–	–
Erioneuron pilosum	–	–	–	–	–	–	–	–	–	2	–	2	–	–	–	–	–	–	–	2	2	–	–	–	–	–	–	–	–	–	2	–	–	–	1	–	2	–	–
Escobaria vivipara var. *vivipara*	–	–	–	–	–	1	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–
Evolvulus nuttallianus	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Gaura villosa ssp. *villosa*	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	2	–	–	–	–	–	–	1	–	–	2	–	2	–	1	4	–	–
Gutierrezia sarothrae	2	2	2	2	–	–	–	2	–	–	–	–	–	–	–	2	–	–	2	–	2	–	2	–	2	–	–	2	2	2	2	–	2	–	2	2	1	4	1
Haploesthes greggii var. *texana*	–	–	–	–	–	–	–	–	–	5	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Heterotheca stenophylla var. *stenophylla*	3	4	4	4	4	3	3	3	3	2	3	2	4	4	4	3	4	2	3	4	5	5	5	4	6	5	5	5	5	3	4	5	4	3	4	4	4	4	4
Hymenopappus tenuifolius	1	1	2	1	–	–	2	2	1	1	–	–	2	2	2	2	–	2	–	–	–	–	1	–	–	2	–	1	2	–	2	2	2	1	2	1	2	2	2
Juniperus virginiana var. *virginiana*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Kallstroemia parviflora	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Liatris punctata	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	2	2	–	–	–	–	–	–	–	–	2	–	–	2	–
Lithospermum incisum	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	2	–	–	1	–	–	–	–	–	–
Mentzelia nuda var. *stricta*	1	–	–	1	–	–	–	2	–	–	–	–	2	2	2	2	–	2	–	–	–	2	2	2	–	2	–	1	–	–	2	3	1	–	2	–	–	–	–
Mentzelia oligosperma	–	–	–	2	1	2	–	–	–	1	2	1	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mimosa nuttallii	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Nama stevensii	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
Opuntia phaeacantha	–	–	–	1	3	–	–	2	–	–	1	–	1	1	–	2	4	4	–	–	–	–	–	–	6	5	6	1	–	–	–	–	1	–	–	–	–	–	2
Panicum capillare	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Panicum hallii var. *hallii*	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Paronychia jamesii	2	1	2	–	2	–	–	2	–	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	5	2	2	2	2	2	–	2	2	–	2	2	3
Phacelia integrifolia var. *integrifolia*	–	–	1	1	–	2	–	–	–	2	1	1	2	2	2	–	–	1	–	–	–	–	2	–	–	1	–	–	–	–	–	1	1	–	–	–	–	–	–
Polanisia dodecandra ssp. *trachysperma*	–	–	–	–	2	2	2	–	–	–	–	–	–	2	2	–	2	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	09/24/06	10/24/06	10/28/06	09/24/06			10/27/06	10/28/06		10/01/06			10/22/06			10/07/06			10/07/06			10/07/06			10/01/06			10/28/06			10/22/06			10/28/06			11/05/06		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Polygala alba	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–
Pomaria jamesii	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Portulaca pilosa	–	5	–	1	1	3	2	–	–	–	2	2	–	5	4	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Psilostrophe tagetina var. *cerifera*	–	–	1	2	1	2	–	2	2	1	1	1	2	2	2	2	2	2	2	2	1	1	1	1	1	2	–	2	2	2	1	1	1	–	1	–	2	2	2
Psoralidium tenuiflorum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	2	–
Schizachyrium scoparium var. *scoparium*	3	3	4	4	4	2	–	2	–	2	1	2	6	6	5	4	2	3	2	–	2	4	7	4	4	4	5	4	4	3	3	5	4	5	2	4	3	4	–
Senecio riddellii	2	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Solanum elaeagnifolium	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Solidago petiolaris var. *angusta*	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sphaeralcea coccinea ssp. *coccinea*	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sporobolus cryptandrus	2	6	4	4	5	4	6	3	3	5	8	4	2	2	2	3	4	4	2	4	2	4	2	5	2	4	4	3	2	3	2	4	3	1	4	3	2	2	2
Stenosiphon linifolius	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Thelesperma filifolium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	2	2	–	–	–	–	–	–	–	–	–	–	–	–
Thelesperma megapotamicum	2	–	2	1	1	2	–	–	1	–	–	–	1	–	–	2	1	–	–	–	2	2	2	–	–	–	2	–	–	2	1	1	2	2	2	2	2	2
Tridens muticus var. *elongatus*	–	–	2	4	4	4	–	–	–	2	–	–	–	2	5	–	–	–	2	–	2	2	2	2	2	2	–	1	2	2	–	–	2	–	–	–	2	–	–
Yucca glauca var. *glauca*	–	2	–	2	4	2	–	–	1	–	2	–	–	–	2	2	–	–	–	–	–	2	–	–	–	–	–	–	1	–	2	–	–	–	2	–	1	2	2
number species in each quadrat	14	14	16	21	16	18	12	15	15	16	16	12	18	21	20	13	13	14	11	11	15	14	14	12	16	15	11	18	13	11	15	15	16	12	15	14	18	24	15
number species at each site	22			29			26			23			31			20			18			19			20			21			22			22			29		
non-vegetated substrate cover	8	7	8	5	5	6	7	8	9	7	6	8	8	8	7	8	7	7	8	8	7	6	5	6	7	7	6	7	8	9	8	7	8	8	8	8	8	7	8

Appendix 3. Spring 2007 cover class (refer to Table 3) data for plant species and non-vegetated substrate by site, grazing history (CG = currently-grazed, RG = recently-grazed, & UG = long-ungrazed), date, and quadrat.

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	05/28/07			05/28/07			05/27/07			05/20/07			05/29/07			05/25/07	05/26/07		05/25/07			05/21/07			05/20/07			05/28/07			05/29/07			05/27/07			05/27/07		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Acalypha ostryifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Allium drummondii	2	2	-	1	2	2	2	2	-	2	2	1	2	1	-	1	2	2	-	2	-	-	2	2	-	2	2	1	2	-	2	2	-	2	2	-	2	2	-
Ambrosia artemisiifolia var. *elatior*	-	-	-	-	-	-	1	-	1	-	-	-	-	1	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ambrosia psilostachya	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammoselinum popei	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Andropogon gerardii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Andropogon hallii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Androsace occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aristida purpurea	-	2	-	-	2	-	-	2	2	2	-	-	-	-	-	-	-	-	2	2	2	-	-	-	-	-	-	3	2	2	2	2	3	2	2	2	2	2	-
Artemisia dracunculus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Artemisia filifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Artemisia ludoviciana ssp. *ludoviciana*	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asclepias engelmanniana	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2
Astragalus gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	-	2	-	-	-
Astragalus lotiflorus	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Astragalus missouriensis var. *missouriensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1	1	2	-	-	-
Astragalus nuttallianus	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Atriplex subspicata	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bouteloua curtipendula	2	2	4	3	4	4	2	2	3	-	-	-	-	-	-	-	2	2	2	-	2	-	-	-	-	-	-	-	2	2	-	-	2	2	-	2	2	-	2
Bouteloua dactyloides	-	-	-	-	-	-	3	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2	1
Bouteloua gracilis	-	4	2	-	-	-	2	-	2	-	-	-	-	-	2	-	2	2	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-
Bouteloua hirsuta var. *hirsuta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Bromus arvensis	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-
Calylophus hartwegii ssp. *fendleri*	2	2	2	2	2	2	-	1	2	-	-	-	-	-	2	-	2	2	-	-	-	-	2	2	-	2	2	1	-	-	-	-	-	-	2	-	-	2	2
Calylophus serrulatus	2	3	2	2	3	3	-	2	2	1	2	2	2	3	3	2	2	2	2	2	2	2	2	2	3	2	-	2	2	2	2	2	3	2	2	2	2	2	2

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	05/28/07			05/28/07			05/27/07			05/20/07			05/29/07			05/25/07	05/26/07		05/25/07			05/21/07			05/20/07			05/28/07			05/29/07			05/27/07			05/27/07		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Castilleja purpurea var. citrina	-	1	2	2	2	-	-	1	-	-	-	-	-	-	-	1	-	2	-	-	-	2	1	-	1	2	1	2	2	2	2	2	2	1	-	2	-	-	2
Cercis canadensis var. *canadensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaetopappa ericoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2
Chamaesyce glyptosperma	-	-	-	-	-	1	1	-	-	1	-	1	-	-	1	-	1	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chamaesyce missurica	2	2	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium album var. *album*	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium berlandieri	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium pratericola	-	-	-	-	-	-	1	-	2	1	-	-	-	-	2	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cirsium undulatum var. *undulatum*	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conyza canadensis	-	2	-	2	-	2	2	-	2	-	-	-	-	1	-	-	1	-	-	1	1	-	-	1	1	-	-	-	-	-	-	-	-	-	1	-	-	1	-
Croton monanthogynus	-	2	1	2	2	2	2	2	1	1	1	-	-	-	-	1	2	1	2	2	1	-	1	1	1	-	-	2	-	2	-	-	-	-	-	-	-	1	-
Croton texensis var. *texensis*	-	2	2	2	-	-	2	1	2	-	-	-	-	2	3	1	-	-	-	-	-	1	-	1	-	-	-	-	1	-	-	1	-	-	2	2	-	1	2
Cylindropuntia imbricata var. *imbricata*	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dalea aurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Dalea enneandra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	-	-	-
Delphinium carolinianum ssp. *virescens*	-	-	-	2	-	1	-	-	2	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Descurainia pinnata	-	-	-	2	-	-	-	-	-	-	-	-	2	2	2	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Draba cuneifolia var. *cuneifolia*	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Draba platycarpa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Draba reptans	-	-	-	-	2	2	-	-	-	-	-	-	-	-	1	-	1	-	-	2	-	2	1	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Echinocereus reichenbachii	2	2	-	2	2	-	-	2	2	-	-	-	-	-	-	-	2	2	-	-	-	2	1	2	-	-	-	1	1	-	2	2	1	-	-	-	-	-	-
Eriogonum longifolium var. *longifolium*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erioneuron pilosum	2	2	2	-	-	-	-	2	2	2	3	2	-	-	-	-	-	2	2	2	3	-	-	-	-	-	-	-	-	-	-	-	2	-	2	2	2	2	2
Escobaria missouriensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Escobaria vivipara var. *vivipara*	-	-	-	1	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	1	-	-	1	1	-	-	-	-	1	-	-	-	-	-	-	-	-
Euphorbia dentata var. *dentata*	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	05/28/07			05/28/07			05/27/07			05/20/07			05/29/07			05/25/07	05/26/07		05/25/07			05/21/07			05/20/07			05/28/07			05/29/07			05/27/07			05/27/07		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Euphorbia marginata	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	1
Euphorbia spathulata	1	1	-	2	-	2	-	-	2	2	2	-	-	-	-	1	2	2	-	-	1	2	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Evax prolifera	-	1	-	1	1	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-
Evolvulus nuttallianus	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Gaillardia pulchella var. *pulchella*	-	2	-	2	1	2	2	-	1	1	2	-	-	-	-	1	-	-	-	2	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Galium virgatum	-	-	-	-	-	-	-	-	-	1	2	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Gaura coccinea	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gaura villosa ssp. *villosa*	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	-	-	2	-	-	2	-	2	-	-	3	-	-
Geranium carolinianum var. *carolinianum*	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-
Glandularia pumila	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Gutierrezia sarothrae	2	2	2	2	2	-	-	2	-	-	-	-	-	-	-	2	-	-	2	-	2	-	-	-	-	-	-	-	2	2	2	-	2	-	-	2	2	2	2
Haploesthes greggii var. *texana*	-	-	-	-	-	-	-	-	-	5	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hedeoma hispida	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Helianthus annuus	-	3	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heterotheca stenophylla var. *stenophylla*	4	5	5	5	5	3	4	4	5	2	5	2	5	4	4	3	4	-	3	-	3	5	4	4	6	5	4	4	5	3	4	4	4	4	4	5	4	5	4
Hordeum pusillum	-	1	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-
Hymenopappus tenuifolius	-	-	-	2	2	1	2	2	2	1	-	-	2	2	2	2	-	2	2	-	2	1	2	2	1	2	-	2	3	1	2	2	3	2	2	-	2	2	2
Ipomoea leptophylla	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juniperus virginiana var. *virginiana*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Krameria lanceolata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lappula occidentalis var. *cupulata*	-	-	-	-	-	2	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-
Lepidium densiflorum var. *densiflorum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lesquerella gordonii var. *gordonii*	2	2	2	2	1	2	2	1	2	2	2	3	2	2	2	1	2	1	2	2	2	3	2	2	1	1	2	1	1	-	1	1	1	-	2	2	2	1	1
Liatris punctata	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Linum pratense	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1	2	1	-	-	-	1	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Linum rigidum var. *rigidum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	-	-	-	-	-	-	-	-	-	-

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	05/28/07			05/28/07			05/27/07			05/20/07			05/29/07			05/25/07	05/26/07		05/25/07			05/21/07			05/20/07			05/28/07			05/29/07			05/27/07			05/27/07		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Lithospermum incisum	-	-	2	-	-	-	-	2	2	-	-	-	-	-	2	-	-	-	-	1	2	-	2	-	-	-	-	2	-	2	2	2	2	-	1	-	-	-	2
Lomatium foeniculaceum ssp. *foeniculaceum*	-	-	-	-	-	-	-	-	-	-	1	1	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mentzelia nuda var. *stricta*	2	1	-	2	1	1	-	2	2	2	2	-	2	2	2	2	2	2	2	2	2	2	2	2	-	2	-	-	-	1	2	2	-	-	2	-	-	-	-
Mentzelia oligosperma	-	-	1	2	2	2	-	-	-	1	2	-	2	1	2	-	2	-	1	2	1	1	-	2	1	-	-	-	1	-	-	1	1	-	-	-	-	-	-
Mimosa nuttallii	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Mirabilis albida	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Monarda clinopodioides	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nama stevensii	-	-	1	2	1	2	2	-	2	2	2	2	2	2	2	1	2	-	2	1	1	1	2	2	-	1	1	1	1	-	-	-	1	-	1	-	1	2	2
Nuttallanthus canadensis	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Opuntia phaeacantha	-	-	-	1	3	-	-	3	-	-	-	-	-	1	-	1	4	4	-	-	-	1	1	-	5	5	6	-	-	-	-	1	-	-	-	-	-	2	-
Orobanche ludoviciana ssp. *multiflora*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Oxalis dillenii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Panicum capillare	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paronychia jamesii	2	2	-	-	-	-	-	2	2	2	1	2	2	2	2	2	-	-	2	2	2	2	2	-	2	2	2	2	2	2	2	2	-	2	2	-	2	2	2
Phacelia integrifolia var. *integrifolia*	1	1	-	1	-	1	-	-	-	-	2	2	2	2	2	-	-	1	2	1	2	2	2	-	-	-	-	-	-	-	-	2	-	-	2	1	1	1
Plantago patagonica	2	2	2	2	2	2	1	1	-	1	-	-	2	2	2	1	2	1	-	2	1	2	2	2	2	-	2	1	-	-	-	1	1	-	2	-	1	2	1
Plantago rhodosperma	-	-	-	2	-	-	1	-	-	-	-	-	2	2	-	-	-	-	-	1	-	-	2	1	-	-	-	1	-	-	-	-	-	-	1	1	-	-	1
Polanisia dodecandra ssp. *trachysperma*	1	-	-	-	-	2	2	-	-	1	2	1	1	1	1	-	2	2	3	1	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Polygala alba	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	2	2	-	-	-	-	2	2	2	2	2	2	1	1	2	-	-	-
Pomaria jamesii	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Portulaca pilosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Psilostrophe tagetina var. *cerifera*	2	-	2	2	2	3	-	2	2	2	2	2	2	2	2	2	2	2	2	3	-	2	2	2	2	2	-	2	2	2	2	2	2	1	2	1	2	2	2
Psoralidium tenuiflorum	2	-	-	-	-	-	-	-	3	-	1	-	3	2	3	1	-	-	-	1	2	-	-	-	-	-	-	-	2	-	-	-	2	3	1	3	-	2	2
Pyrrhopappus grandiflorus	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhus aromatica	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhus glabra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	05/28/07			05/28/07			05/27/07			05/20/07			05/29/07			05/25/07	05/26/07		05/25/07			05/21/07			05/20/07			05/28/07			05/29/07			05/27/07			05/27/07		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Spermolepis inermis	-	-	-	2	-	-	-	-	-	-	-	-	1	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphaeralcea coccinea ssp. coccinea	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1
Sporobolus cryptandrus	4	5	4	2	2	5	4	3	2	2	6	4	2	2	3	2	5	3	3	4	2	4	-	3	-	-	2	2	2	2	2	2	3	2	4	3	2	2	1
Stenaria nigricans var. nigricans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tetraneuris linearifolia var. linearifoli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Tetraneuris scaposa var. scaposa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Thelesperma filifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2	-	-	-	-	1	-	2	4	3	-	-	-	-	-	-	-	-	-	-	-	-
Thelesperma megapotamicum	2	1	2	-	2	2	-	-	2	-	-	-	2	2	2	2	-	-	-	-	2	2	2	-	-	-	-	2	1	-	2	2	2	2	2	2	3	2	2
Tragopogon dubius	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tridens muticus var. elongatus	-	-	1	-	-	-	-	-	-	-	-	-	2	2	2	-	-	-	-	2	2	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	1	-	-
Trifolium sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trisetum interruptum	-	-	-	-	-	-	1	1	1	2	1	1	-	-	-	-	-	-	1	2	2	1	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Ulmus americana	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	-	-
Viola bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vulpia octoflora var. octoflora	1	1	-	2	2	2	1	1	1	-	-	-	2	2	2	-	2	2	-	-	-	1	1	-	2	2	2	-	3	-	-	-	2	-	-	-	2	2	1
Yucca glauca var. glauca	-	2	2	2	3	2	-	-	-	-	2	-	-	-	2	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	2	-	-	-	2	-	2	2	2
number species in each quadrat	22	36	24	36	28	29	28	24	38	28	23	16	29	35	38	28	37	28	21	32	31	33	34	28	19	21	21	23	22	16	22	24	23	22	27	23	25	35	33
number species at each site	45			46			51			32			53			54			43			46			34			32			36			41			49		
non-vegetated substrate cover	9	7	7	7	7	8	8	9	8	7	5	8	8	8	8	8	7	9	9	8	8	6	6	7	6	5	5	8	8	9	8	8	8	7	9	8	9	8	8

Appendix 4. Summer 2007 cover class (refer to Table 3) data for plant species and non-vegetated substrate by site, grazing history (CG = currently-grazed, RG = recently-grazed, & UG = long-ungrazed), date, and quadrat.

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	07/20/07			07/20/07			07/22/07			07/20/07			07/28/07			07/22/07			07/27/07			07/22/07			07/20/07			07/22/07			07/28/07			07/27/07			07/27/07		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Acalypha ostryifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amaranthus albus	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ambrosia artemisiifolia var. *elatior*	-	-	-	-	-	-	2	-	2	-	-	-	-	1	-	-	2	1	-	2	-	2	-	-	-	-	-	2	1	-	-	-	-	-	-	-	1	-	-	-
Ambrosia psilostachya	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphiachyris dracunculoides	-	2	-	2	-	2	2	1	2	-	-	-	-	-	-	2	-	-	-	2	2	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-
Andropogon gerardii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Andropogon hallii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aristida purpurea	-	2	-	-	3	-	-	2	2	3	2	-	-	-	-	-	-	-	2	2	2	-	-	-	-	-	-	4	2	2	2	2	4	2	3	-	3	2	2
Artemisia dracunculus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Artemisia filifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Artemisia ludoviciana ssp. *ludoviciana*	-	-	-	-	-	-	-	-	-	2	1	-	2	-	3	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asclepias engelmanniana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Astragalus distortus var. *distortus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Astragalus gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Astragalus lotiflorus	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Astragalus missouriensis var. *missouriensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Astragalus sp.	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bothriochloa laguroides ssp. *torreyana*	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bouteloua curtipendula	3	5	7	4	-	2	5	3	6	2	2	-	3	3	4	-	4	3	2	2	3	4	3	-	2	2	3	3	4	2	2	-	4	3	3	3	4	4	5
Bouteloua dactyloides	-	-	-	-	-	-	5	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bouteloua gracilis	-	6	3	-	3	-	3	-	3	-	3	-	2	2	2	-	3	2	2	3	4	2	-	3	2	-	-	2	-	-	-	-	-	2	3	2	2	3	-
Bouteloua hirsuta var. *hirsuta*	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	3	2	2	2	-	2
Calylophus hartwegii ssp. *fendleri*	2	2	2	-	-	2	-	-	2	-	-	-	-	-	2	-	2	-	-	2	-	2	2	2	-	2	-	-	-	-	-	-	-	-	2	-	2	2	2

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	07/20/07			07/20/07			07/22/07			07/20/07			07/28/07			07/22/07			07/27/07			07/22/07			07/20/07			07/22/07			07/28/07			07/27/07			07/27/07		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Calylophus serrulatus	2	3	2	2	3	3	-	2	2	2	3	2	3	3	2	2	2	2	2	2	2	2	2	2	2	1	3	2	2	2	2	2	3	2	2	2	2	2	2
Castilleja purpurea var. *citrina*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cenchrus longispinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaetopappa ericoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	2
Chamaesyce glyptosperma	-	-	-	2	3	2	2	-	-	2	-	2	-	-	1	1	2	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Chamaesyce maculata	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chamaesyce missurica	3	3	3	2	-	-	-	-	-	2	-	-	-	-	-	-	-	3	-	-	-	3	-	3	2	-	3	-	-	-	-	-	-	-	-	-	-	-	-
Chamaesyce serpens	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium album var. *album*	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium berlandieri	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium pallescens	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium pratericola	-	-	-	-	-	-	-	-	2	2	-	-	-	1	-	-	-	-	-	2	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cirsium undulatum var. *undulatum*	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conyza canadensis	2	2	1	4	2	2	2	-	2	2	2	2	2	2	2	-	2	2	-	2	2	2	2	2	2	-	2	-	-	1	-	1	-	-	-	1	-	2	-
Croton monanthogynus	-	3	3	3	3	3	2	2	2	3	2	2	-	-	-	2	3	2	2	2	2	2	2	2	-	2	2	2	2	2	-	2	-	-	2	2	-	-	-
Croton texensis var. *texensis*	2	2	2	2	-	-	2	-	2	-	-	-	2	2	2	1	2	-	-	-	-	2	2	2	-	-	-	-	2	-	-	2	-	2	3	2	-	2	2
Cylindropuntia imbricata var. *imbricata*	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dalea aurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Dalea enneandra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	-	-	-
Desmanthus leptolobus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Echinocereus reichenbachii	2	2	1	2	2	-	-	2	2	-	-	-	-	-	-	-	3	2	-	-	-	2	1	2	-	-	-	2	2	-	2	1	-	-	-	-	1	-	-
Eragrostis cilianensis	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eragrostis minor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erioneuron pilosum	2	-	-	-	-	-	-	2	2	2	3	2	-	-	-	-	-	2	2	3	3	-	-	-	-	-	-	2	-	-	-	-	2	-	3	2	-	2	2

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	07/20/07			07/20/07			07/22/07			07/20/07			07/28/07			07/22/07			07/27/07			07/22/07			07/20/07			07/22/07			07/28/07			07/27/07			07/27/07		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Escobaria vivipara var. *vivipara*	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	2	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Euphorbia dentata var. *dentata*	-	-	-	-	2	-	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphorbia marginata	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-	1	1
Evax sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Evolvulus nuttallianus	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Gaillardia pulchella var. *pulchella*	-	2	-	2	-	2	-	-	-	2	2	2	-	-	-	-	-	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Galium virgatum	-	-	-	-	-	-	-	-	-	1	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gaura villosa ssp. *villosa*	-	3	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	1	-	-	-	3	-	-	-	-	-	-	2	-	-	2	-	2	-	-	4	-	-
Glandularia pumila	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-
Grindelia lanceolata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grindelia squarrosa var. *squarrosa*	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gutierrezia sarothrae	-	3	2	-	2	-	-	2	-	-	-	-	-	-	-	3	-	-	2	-	2	-	2	-	-	-	-	-	-	2	2	-	2	-	3	2	2	2	2
Haploesthes greggii var. *texana*	-	-	-	-	-	-	-	-	-	5	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hedeoma drummondii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Helianthus annuus	-	3	-	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Helianthus petiolaris ssp. *petiolaris*	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heterotheca stenophylla var. *stenophylla*	5	4	4	5	5	4	5	4	6	2	3	3	4	4	4	5	3	2	2	4	3	5	4	4	6	6	6	4	4	4	4	5	5	4	5	5	5	4	4
Hymenopappus tenuifolius	2	2	-	-	2	2	3	2	2	2	-	-	2	1	2	2	-	-	2	-	2	-	2	2	2	-	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Juniperus virginiana var. *virginiana*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Krameria lanceolata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Lactuca serriola	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lesquerella gordonii var. *gordonii*	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-
Liatris punctata	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	2	-	-	-	1
Linum rigidum var. *rigidum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	07/20/07			07/20/07			07/22/07			07/20/07			07/28/07			07/22/07			07/27/07			07/22/07			07/20/07			07/22/07			07/28/07			07/27/07			07/27/07		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Lithospermum incisum	-	-	2	-	-	-	-	2	2	-	2	1	2	-	-	-	-	-	-	-	2	-	2	-	-	-	-	2	-	2	2	2	-	-	-	-	-	1
Mentzelia nuda var. *stricta*	2	2	-	2	1	-	-	2	2	-	-	-	2	2	2	2	2	2	2	-	2	2	2	2	-	2	-	-	-	2	2	3	-	-	3	-	-	-	-
Mentzelia oligosperma	-	-	2	2	2	2	-	1	-	2	3	2	2	2	2	-	2	-	2	2	2	2	2	2	2	-	-	-	2	2	-	-	2	-	-	-	-	-	2
Mimosa nuttallii	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Mirabilis albida	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nama stevensii	-	-	-	2	1	2	2	-	2	2	2	2	2	2	2	1	2	1	2	2	2	2	2	2	-	-	-	1	2	-	-	-	1	-	2	-	-	2	-
Opuntia phaeacantha	-	1	-	2	3	-	-	3	-	-	-	-	-	1	-	2	4	4	-	-	1	-	1	-	5	6	6	-	-	-	1	1	-	-	-	-	1	2	-
Orobanche ludoviciana ssp. *multiflora*	-	1	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	1	-	-	-	-	1	-	-
Oxalis dillenii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Panicum capillare	-	3	1	2	2	3	2	-	-	-	-	2	-	-	2	-	3	3	-	-	-	3	3	2	-	2	2	1	-	-	-	-	-	-	-	-	-	-	-
Panicum hallii var. *hallii*	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paronychia jamesii	2	-	-	-	2	-	-	2	2	3	3	2	3	2	2	2	2	-	2	2	2	2	2	-	5	4	5	2	3	2	2	2	-	2	2	-	2	2	2
Phacelia integrifolia var. *integrifolia*	1	2	2	-	-	1	-	-	-	3	3	3	2	2	2	-	-	2	2	2	2	2	2	-	-	2	-	-	2	-	-	-	2	2	2	2	-	2	
Polanisia dodecandra ssp. *trachysperma*	2	-	-	-	-	2	2	-	-	2	2	2	2	2	3	-	3	2	4	2	3	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-
Polygala alba	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	2	2	-	-	-	-	-	2	2	2	2	1	-	3	2	-	-	-
Pomaria jamesii	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Portulaca oleracea	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Portulaca pilosa	1	2	2	1	2	2	1	-	2	2	1	-	2	2	1	-	1	1	1	1	1	2	-	-	-	-	-	-	-	2	-	1	2	-	-	-	-	2	-
Psilostrophe tagetina var. *cerifera*	2	2	2	2	2	3	-	2	2	2	2	3	2	2	2	2	-	2	2	3	2	2	2	2	2	2	-	2	2	2	2	2	2	-	2	2	2	2	2
Psoralidium tenuiflorum	2	-	-	-	-	-	-	-	2	-	2	-	3	3	4	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2	3	-	5	-	2	2
Rhus aromatica	-	-	-	-	-	-	-	-	-	1	-	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Rhus glabra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Salsola tragus	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schizachyrium scoparium var. *scoparium*	4	4	3	4	4	2	-	2	-	2	2	-	5	5	4	5	3	5	2	-	2	5	7	4	5	5	5	4	4	4	3	5	5	7	2	4	4	-	5

Site	ACSP-N			ACSP-S			BHR			GMSP			IM			MCR			MCWHA			MCWMA			RNSP			SBCWMA			SLL			SSR-N			SSR-S		
Grazing History	RG			UG			CG			UG			UG			CG			CG			RG			UG			CG			RG			CG			CG		
Date	07/20/07			07/20/07			07/22/07			07/20/07			07/28/07			07/22/07			07/27/07			07/22/07			07/20/07			07/22/07			07/28/07			07/27/07			07/27/07		
Quadrat	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Senecio riddellii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanum elaeagnifolium	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanum rostratum	-	2	-	-	-	-	1	1	-	-	-	-	-	1	-	2	1	1	-	2	-	-	2	2	-	-	-	2	-	-	1	-	-	-	1	-	-	1	2
Solidago petiolaris var. *angusta*	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphaeralcea coccinea ssp. *coccinea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Sporobolus cryptandrus	4	4	3	5	4	4	4	4	3	3	8	3	2	2	2	4	5	4	2	3	4	4	4	4	5	5	6	4	4	4	2	2	2	2	3	3	3	2	3
Stenaria nigricans var. *nigricans*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Thelesperma filifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	2	-	-	-	-	-	-	2	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Thelesperma megapotamicum	2	2	2	-	2	2	-	2	2	-	-	-	2	2	2	2	-	-	-	-	2	2	3	-	-	-	-	2	2	-	2	2	2	2	2	2	3	2	2
Tridens muticus var. *elongatus*	2	-	2	4	3	6	-	-	-	2	3	-	-	2	4	-	-	-	-	2	2	2	2	3	2	2	-	2	-	2	-	-	1	-	-	-	2	-	-
Ulmus americana	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
unidentified Asteraceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Yucca glauca var. *glauca*	-	2	3	2	3	2	-	-	-	-	2	-	-	-	2	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-	2	-	-	-	3	-	2	-	3
number species in each quadrat	21	32	23	28	26	24	23	21	34	29	28	22	26	29	30	22	26	25	22	30	31	29	28	30	19	17	14	23	21	21	21	22	20	16	27	24	21	26	28
number species at each site	39			40			47			45			43			40			42			45			25			37			36			36			42		
non-vegetated substrate cover	8	7	8	7	8	7	8	8	7	8	5	7	8	7	8	8	7	8	8	8	8	6	7	7	5	5	5	8	8	9	8	7	8	7	8	8	7	8	8