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Integrated Upland Vegetation and Soils Monitoring for Petroglyph National Monument

2008 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2009/021

ON THE COVER
Malpais ecological site at Petroglyph National Monument .
Photograph by: Jim DeCoster

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The corresponding author and project manager for this project is Jim DeCoster (jim_decoster@nps.gov). Megan Swan is the botanist and crew leader for the project. Other contributions were made by the SCPN staff. The 2008 field crew consisted of Jessica Erickson, Anna Lowell, and Eric Vasquez.

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Introduction and Background

The National Park Service Inventory and Monitoring (I&M) Program was designed to determine the current status and monitor long-term trends in the condition of park natural resources, providing park managers with a strong scientific foundation for making decisions and working with other agencies and the public for the protection of park ecosystems. The Southern Colorado Plateau Network (SCPN) is monitoring vegetation and soils as overall indicators of upland ecosystem integrity (Thomas et al. 2006).

At Petroglyph National Monument (PETR), SCPN and park staff selected the Malpais ecological site for long-term monitoring of vegetation and soils. Ecological sites are based on soil survey data and represent landscapes with characteristic soils, hydrology, plant communities, and disturbance regimes and responses (Butler et al. 2003). The Malpais ecological site, which is comprised of grassland, encompasses large portions of the monument. It faces a number of threats, including climate change, soil erosion, and invasion by non-native species.

In 2008 the Integrated Upland Monitoring program of SCPN began upland monitoring at PETR. In this report, we document monitoring activities in the 2008 field season and summarize the data that were collected.

Methods

Sampling frame

The sampling frame is the area from which we randomly select our sites, and hence the area to which statistical inferences can be made. We derived the sampling frame for Integrated Upland Monitoring at PETR from the map of the Malpais ecological site, which was developed by the US Natural Resources Conservation Service (See Appendix A of DeCoster et al., in review).

To create the sampling frame, we modified the map of the ecological site with Geographic Information System (GIS) technology by removing the roads and areas with slopes exceeding 20% (fig. 1). A set of spatially distributed sampling points was generated using the Generalized Random-Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). We submitted the points to park staff to give them the opportunity to reject those points that landed too close to archaeological sites or other sensitve resources. Before establishing a plot, the Integrated Upland crew conducted an ecological site assessment for each sampling point, and they rejected the site if it (1) did not fall within the ecological site, (2) had a slope exceeding 20%, or (3) contained a major disturbance. No points were rejected.

Field methods

The SCPN Upland Monitoring crew began monitoring at PETR in 2008 with the establishment of six plots in the Malpais ecological site. They installed and collected data in all the plots in late September. Plots are 0.50 ha in size, measuring 71 m x 71 m. Shrub and herbaceous vegetation data and soil data were collected on three 50 m transects, spaced 25 meters apart, within each plot. Field methodology is provided in detail in the SCPN Integrated Upland Protocol (DeCoster et al., in review).

Shrub and herbaceous vegetation

At 10 m intervals along each transect, the crew sampled shrub and herbaceous vegetation with five sets of nested quadrats. The largest quadrat size was 10 m^2 (2m x 5m), with four smaller quadrats

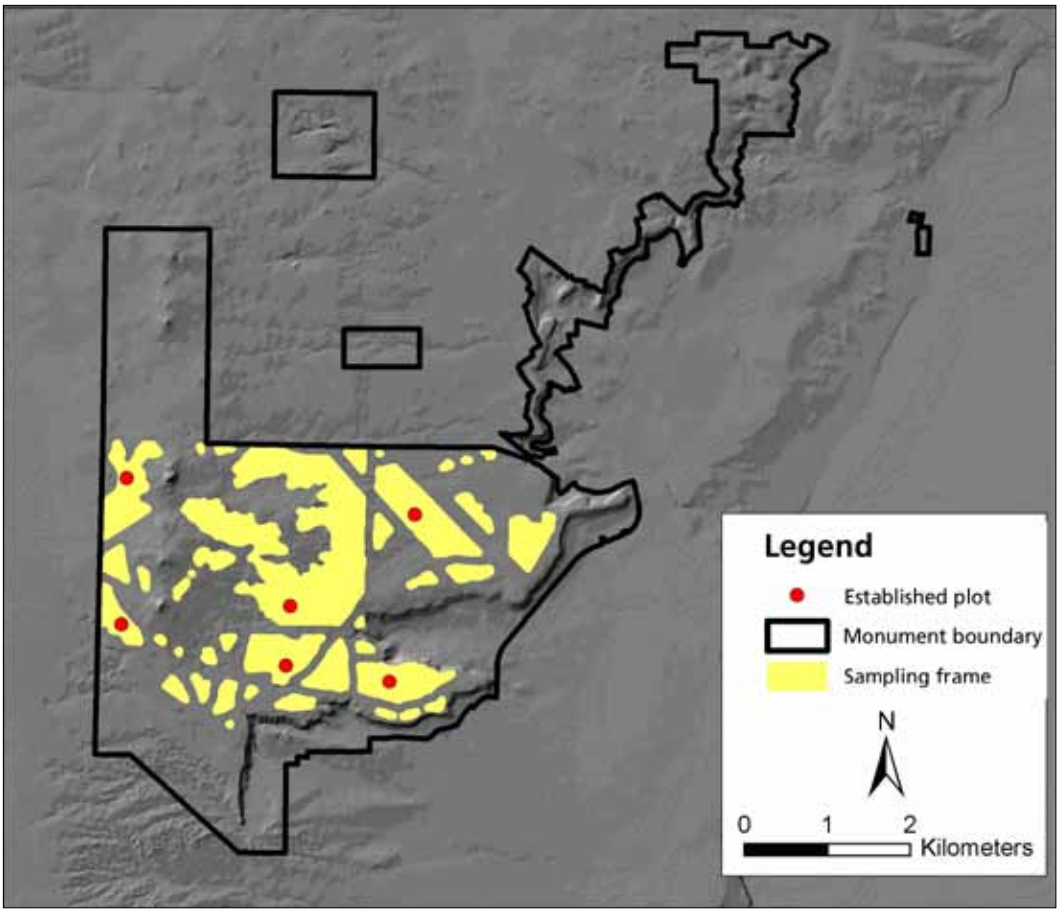

Figure 1. Sampling frame of the Malpais ecological site with the six plots established in 2008.

nested inside (0.01 m^2, 0.1 m^2, 1 m^2, 5 m^2). The presence of individual vascular species was recorded for each nested sub-quadrat. For each herbaceous and shrub species, percent cover was then estimated in the 10 m^2 quadrat and recorded as one of 12 cover classes, e.g. 2-5%, 5-10%, etc. Percent cover for functional groups (e.g. perennial grasses, forbs, shrubs) was also estimated in the largest quadrat and recorded as one of 12 cover classes.

Overstory trees and saplings

There were no trees in any of the plots.

Soil stability and hydrologic function

The crew measured the amount of bare soil by recording the length of each basal gap (the space between plant bases) along each transect. A soil aggregate stability test was conducted, using 18 soil samples collected along the transects. Percent cover of ground surface features was estimated in the 1 m^2 quadrats in conjunction with the shrub and herbaceous data and recorded as one of 12 cover classes.

Data summary

The sample unit for summary and analysis is the plot; hence, we summarized data at the level of the plot. In order to calculate summary statistics for the ecological site, means and standard deviations were calculated from the plot means.

For herbaceous and shrub vegetation, cover and frequency were calculated for each species from the cover class midpoints, e.g. using 7.5% for cover class 5-10%. The mean cover was calculated for each plot, and the mean, standard deviation (SD), and range of cover (range between the minimum and maximum of measured foliar covers, including only those plots where the species occurs) were calculated for the ecological site. Species frequency was calculated for quadrats (mean percentage of quadrats per plot where the species occurs) and for plots (percentage of plots where the species occurs). Mean cover and SD of functional groups and surface features were calculated in a similar fashion.

We calculated four diversity measures for herbaceous and shrub species (Magurran 1988)—first for all species in a site and then for native species only.

(1) Species richness (S) is the number of species at a given spatial scale, and it was calculated at all spatial scales (i.e. for each nested quadrat size, for the plot, and for the ecological site).

(2) The Shannon Diversity Index (H') provides a measure of species diversity that takes into account the relative abundance of each species:

$$- \sum_{i=1}^{n} p_i \ln p_i$$

where p_i is the abundance of each species.

(3) Species evenness (J') is a measure of the degree to which all species are equal in abundance:

$$H' / \ln(S)$$

(4) Beta diversity (β_w) is a measure of within-ecological site heterogeneity (diversity among plots):

$$S_e / (S_p - 1)$$

where S_e is the total number of species found in the ecological site, and S_p is the mean number of species found per plot.

We made five calculations for the basal gaps data: (1) median basal gap size, (2) percentage of transects comprised by gaps, (3) percentage of transects comprised by gaps ≥ 50 cm, (4) number of gaps by size class, and (5) total number of gaps. Mean and SD were calculated for each metric.

The mean soil aggregate stability index was calculated along with the standard deviation. This index ranges between 1 and 6, where 1 indicates low aggregate stability and 6 indicates high aggregate stability. The index was also calculated separately for samples with vegetative cover and for samples without vegetative cover.

Results

Shrub and herbaceous vegetation

Perennial grasses dominated the herbaceous and shrub vegetation of the PETR Malpais ecological site (table 1). The five most abundant species were grasses: *Bouteloua eriopoda* (black grama), *Pleuraphis jamesii* (James' galleta), *Sporobolus cryptandrus* (sand dropseed), *Hesperostipa comata* (needle and thread), and *Sporobolus contractus* (spike dropseed). Other common grasses included *Aristida*

Table 1. Foliar cover and frequency of the fifteen most abundant shrub and herabaceous species and all nonnative species.

	Foliar cover (%)			Frequency (%)	
Species	Mean	SD	Range	Quadrat	Plot
Bouteloua eriopoda	4.840	3.273	0.800 - 9.233	77.78	100.00
Pleuraphis jamesii	2.726	2.049	0.970 - 5.657	80.00	100.00
Sporobolus cryptandrus	2.359	1.597	0.537 - 4.420	95.56	100.00
Hesperostipa comata	0.859	1.467	0.020 - 3.783	37.78	100.00
Sporobolus contractus	0.751	0.719	0.140 - 2.007	51.11	100.00
Opuntia spp.	0.747	0.498	0.213 - 1.677	65.56	100.00
Krascheninnikovia lanata	0.653	0.483	0.020 - 1.127	42.22	100.00
Salsola tragus[a]	0.614	0.822	0.020 - 1.727	52.22	83.33
Gutierrezia sarothrae	0.530	0.375	0.060 - 1.107	56.67	100.00
Aristida purpurea	0.270	0.226	0.047 - 0.667	33.33	100.00
Solanum elaeagnifolium	0.159	0.140	0.050 - 0.387	61.11	83.33
Kochia scoparia[a]	0.132	0.324	0.793 - 0.793	11.11	16.67
Sphaeralcea hastulata	0.097	0.088	0.007 - 0.220	45.56	83.33
Kallstroemia parviflora	0.084	0.131	0.003 - 0.283	27.78	50.00
Sporobolus flexuosus	0.076	0.114	0.020 - 0.303	16.67	83.33

Note: The ranges only include plots where the species occurs. (Many species do not occur in every plot of an ecological site; for these species, we did not include the plots with 0% cover in the range).

[a]Nonnative species.

purpurea (Fendler's threeawn), and *Sporobolus flexuosus* (mesa dropseed). Common shrubs included *Krascheninnikovia lanata* (winterfat) and *Gutierrezia sarothrae* (broom snakeweed). Common forbs included mostly weedy species: *Salsola tragus* (prickly Russian thistle), *Solanum elaeagnifolium* (silverleaf nightshade), *Kochia scoparia* (Mexican burning bush), *Sphaeralcea hastulata* (spear globemallow), and *Kallstroemia parviflora* (warty caltrop). Species composition was moderately variable among plots; some species had wide ranges, standard deviations that exceed their means, and/or low quadrat frequencies. Appendix A lists all the species found, along with their common names, families, mean foliar cover, and plot frequency.

Two nonnative species occurred in the plots. *Salsola tragus* (prickly Russian thistle) occurred in 83.33% of the plots (five of the six plots), with a mean cover value of 1.727%. *Kochia scoparia* (burningbush) occurred in only one plot, with a cover value of 0.793%.

Cover estimates by functional groups confirm the dominance of perennial grass. Total live vegetation on the site had a mean cover of 16.04%, and grasses had a mean cover of 13.42% (table 2). The cover of shrubs and forbs was each between 1 and 2 %. Cover of cacti/ succulents and annual grass was each less than 1%. Cover of standing dead herbaceous was 3.83%, and cover of standing dead woody plant material was 0.85%. Standard deviations and ranges for the functional groups were generally lower than the standard deviations and ranges for individual species.

A total of 41 species was recorded in this ecological site, with a mean species richness of 20.0 species per plot (table 3). Shannon diversity was 1.892, which is low. Values generally fall between 1.5 and 3.5 (Margalef 1972). Evenness was moderately high— 0.637. The evenness index is bounded by 0

Table 2. Foliar cover of functional groups at Petroglyph National Monument.

	Foliar cover (%)		
Functional group	Mean	SD	Range
Total live vegetation	16.04	3.55	10.83 - 21.50
Perennial grass	13.42	4.00	7.50 - 19.00
Annual grass	0.04	0.05	0.00 - 0.09
Forbs	1.07	1.07	0.17 - 2.81
Shrubs, dwarf shrubs	1.24	0.68	0.26 - 1.99
Cacti, succulents	0.63	0.25	0.21 - 0.89
Standing dead herbaceous	3.83	1.23	2.15 - 5.23
Standing dead woody	0.85	0.35	0.45 - 1.28

Note: Components of total live vegetation are not strictly additive because calculations were made from cover class midpoints, the various components may have overlapped, and estimations were made independently.

Table 3. Species diversity metrics for all species and for native species only.

Metric	Mean	SD	Range
All species			
Plot			
Plot richness	20.0	4.7	16 – 27
Shannon diversity	1.892	0.299	
Evenness	0.585	0.101	
Ecological site			
Ecological site richness	41		
Beta diversity	2.158		
Native species			
Plot			
Plot richness	19.0	4.4	15 – 26
Shannon diversity	1.814	0.260	
Evenness	0.623	0.101	
Ecological site			
Ecological site richness	39		
Beta diversity	2.167		

and 1, where a value of 1 indicates that all species are of equal abundance. Beta diversity was 2.158, which is moderately low. High values (greater than 5) indicate large differences among plots, whereas low values (less than 1) indicate similar composition (McCune and Grace 2002). When these indices were recalculated using only native species, all lowered slightly, except beta diversity, which was slightly raised (table 3). The species area curve (fig. 2) illustrates how species richness accumulates with increased area. The shape of the curve is surprisingly linear, unlike the concave shape typical of grasslands in the region. The linear shape indicates relatively high species richness at the finer, quadrat scales, but relatively low richness at the plot scale.

Soil stability and hydrologic function

The crew monitored the amount of exposed soil in two ways: cover estimates of ground surface features in quadrats and measurements of basal gap along transects. The dominant ground surface features were undifferentiated crust (46.51%), duff and litter (17.62%), bare soil (15.85%), and live plant base (6.97%) (table 4). Cover of dead herbaceous base and fine gravel each comprised between 1 and 2%. Dead woody base, coarse gravel, cobble, and stone each occupied less than 1%. There was no biological soil crust, that is, cyanobacteria, moss, or lichen. Variability of surface features among plots was generally low.

Basal gap data (table 5) show that the median gap size is 46.3 cm and that 93.1% of the total transect length was composed of gap; consequently 6.9% of the transect length intersected plant bases. (Note the similarity between the amount of plant base in the basal gap data and in the ground surface feature data). When only gaps greater than 50 cm were considered in the percentage of transect in gaps, the percentage dropped to 77.7%. These large gaps are the areas with soil most suspectible to erosion. The size distribution of gaps (fig. 3) shows a similar number of gaps for each size class.

Soil aggregate stability provides a measurement of the erodibility of the soil (table 6). The mean rating was 3.13, indicating moderately low stability. Soil occurring under vegetative cover had a slightly higher aggregate stability rating than bare soil without cover: 3.41 compared to 2.60.

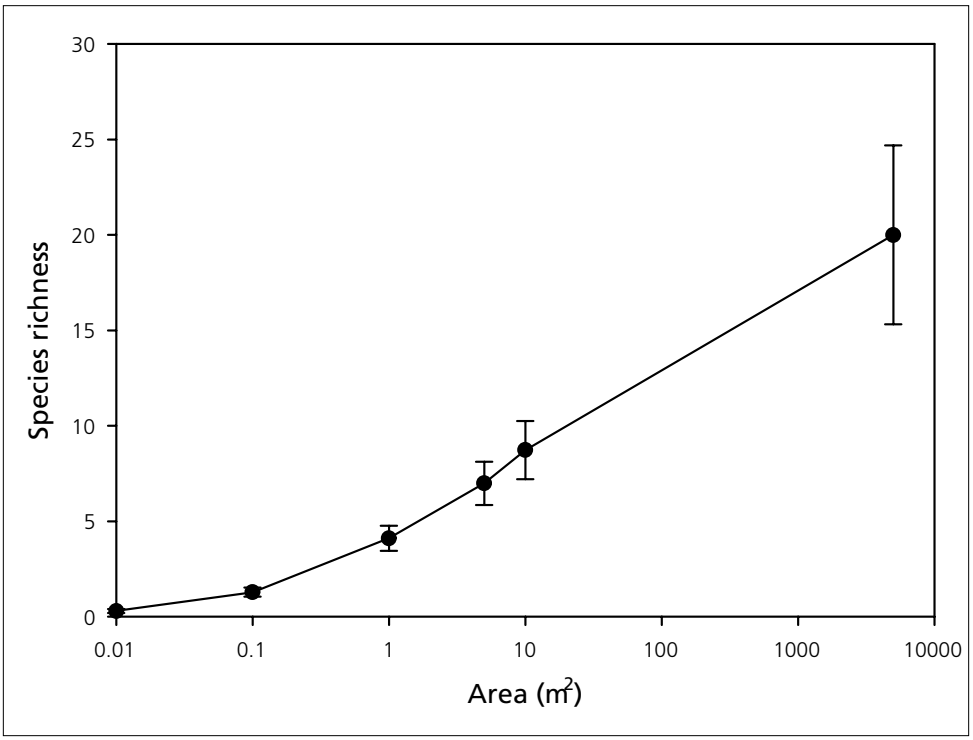

Figure 2. Species-area curve, showing species richness at six spatial scales. Estimates are based on 10 plots with 15 quadrats each. The point at 5000 m^2 represents plot species richness. Error bars represent one standard deviation.

Table 4. Cover of ground surface features at Glen Canyon National Recreation Area.

	Cover (%)		
Surface feature	Mean	SD	Range
Live plant base	6.97	2.00	3.53 - 8.87
Dead woody base	1.98	0.59	1.10 - 2.65
Dead herbaceous base	0.31	0.09	0.22 - 0.42
Bare soil	15.85	5.55	6.72 - 20.92
Duff and litter	17.62	3.00	13.40 - 21.07
Undifferentiated crust	46.51	5.73	40.73 - 57.17
Moss	0.00	0.00	0.00 - 0.00
Lichen	0.00	0.00	0.00 - 0.00
Cyanobacteria	0.00	0.00	0.00 - 0.00
Fine gravel (0.2 cm- 2cm)	1.56	2.13	0.06 - 5.26
Coarse gravel (2cm – 7.5 cm)	0.25	0.10	0.15 - 0.44
Cobble (7.5 cm – 25 cm)	0.11	0.13	0.00 - 0.27
Stone, bedrock (>25 cm)	0.07	0.13	0.00 - 0.33
Woody debris	0.00	0.00	0.00 - 0.00

Note: The features do not add up to 100% because the calculations are made from cover class midpoints, and the estimations have observer error.

Table 5. Number of basal gaps, mean gap size and percentage of total transect length comprised by gaps.

Metric	Mean	(SD)
Gap number	198.8	(45.6)
Median gap size (cm)	46.3	(7.6)
Percent of transect in gaps	93.1	(0.8)
Percent of transect in gaps ≥ 50 cm	77.6	(6.9)

Table 6. Soil stability rating for samples with and without vegetative cover.

Metric	Mean	(SD)
With vegetative cover	3.41	(0.49)
Without vegetative cover	2.60	(0.37)
All samples	3.13	(0.46)

Note: A rating of 1 is the lowest stability, and a rating of 6 is the highest stability.

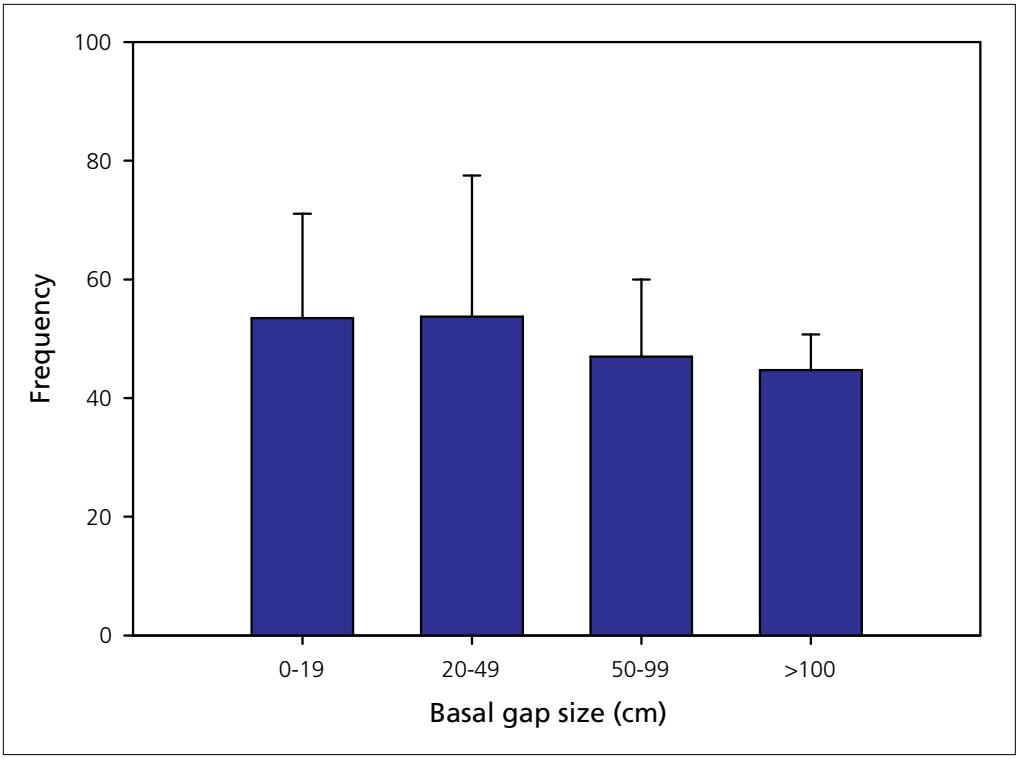

Figure 3. Frequency distribution of the basal gap sizes. Error bars indicate one standard deviation.

Discussion

These data represent the first year baseline of sampling for the Malpais ecological site of PETR. The data indicate that the vegetation consisted of a mixture of grasses, shrubs, and forbs. Common grasses included *Bouteloua eriopoda*, *Pleuraphis jamesii*, *Sporobolus cryptandrus*, *Hesperostipa comata*, and *Sporobolus contractus*. Common shrubs included *Krascheninnikovia lanata* and *Gutierrezia sarothrae*. Common forbs included *Salsola tragus*, *Solanum elaeagnifolium*, *Sphaeralcea hastulata* (spear globemallow), and *Kallstroemia parviflora* (warty caltrop). Two nonnative species were found: *Salsola tragus* occurred in five of the six plots, and *Kochia scoparia* occurred in one plot. Species diversity indices indicate overall moderately low diversity.

Soil aggregate stability and the amount of exposed soil are measurements that quantify the potential of the site for soil erosion. The complete absence of biological soil crusts and the low soil aggregate stability indicate that there is a relatively high potential for soil erosion. However, the erosion potential is somewhat moderated by the cover of plant bases and duff and litter, and the abundance of relatively small basal gaps.

The SCPN Upland Monitoring crew will revisit these six plots at a regular interval (e.g. every 5-6 years). Each visit's data will be compared to the previously collected data to assess changes through time in vegetation composition and structure and in soil stability and hydrologic function. More thorough trend analyses will be conducted once sufficient data have been collected.

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Appendix A

Complete species list with foliar cover and frequency values for herbaceous and shrub species.

Species	Common name	Family	Foliar cover (%)	Plot frequency (%)
Achnatherum hymenoides	Indian ricegrass	Poaceae	0.010	16.67
Aristida purpurea	Fendler's threeawn	Poaceae	0.270	100.00
Astragalus sp.	milkvetch	Fabaceae	0.007	16.67
Atriplex canescens	fourwing saltbush	Chenopodiaceae	0.028	50.00
Bouteloua barbata	sixweeks grama	Poaceae	0.004	16.67
Bouteloua eriopoda	black grama	Poaceae	4.840	100.00
Caesalpinia jamesii	James' holdback	Fabaceae	0.007	33.33
Chamaesyce parryi	Parry's sandmat	Euphorbiaceae	0.013	33.33
Chamaesyce spp.	annual sandmats	Euphorbiaceae	0.004	16.67
Chenopodium dessicatum[b]	narrowleaf goosefoot	Chenopodiaceae	0.003	16.67
Chenopodium incanum	mealy goosefoot	Chenopodiaceae	0.036	16.67
Echinocereus fendleri	pinkflower hedgehog cactus	Cactaceae	0.001	16.67
Elymus elymoides	squirreltail	Poaceae	0.048	33.33
Eriogonum sp.	buckwheat	Polygonaceae	0.001	16.67
Evolvulus nuttallianus	shaggy dwarf morning-glory	Convolvulaceae	0.001	16.67
Gutierrezia sarothrae	broom snakeweed	Asteraceae	0.530	100.00
Hesperostipa comata	needle and thread	Poaceae	0.859	100.00
Hoffmannseggia glauca	Indian rushpea	Fabaceae	0.001	16.67
Kallstroemia parviflora	warty caltrop	Zygophyllaceae	0.084	50.00
Kochia scoparia[a]	Mexican burningbush	Chenopodiaceae	0.132	16.67
Krascheninnikovia lanata	winterfat	Chenopodiaceae	0.653	100.00
Lycium pallidum	pale desert-thorn	Solanaceae	0.002	16.67
Machaeranthera gracilis	slender goldenweed	Asteraceae	0.016	83.33
Monroa squarrosa	false buffalograss	Poaceae	0.037	50.00
Muhlenbergia arenicola	sand muhly	Poaceae	0.003	16.67
Muhlenbergia torreyi	ring muhly	Poaceae	0.007	33.33
Opuntia sp.	prickly pear	Cactaceae	0.747	100.00
Pleuraphis jamesii	James' galleta	Poaceae	2.726	100.00
Salsola tragus[a]	prickly Russian thistle	Chenopodiaceae	0.614	83.33
Sanvitalia abertii	Albert's creeping zinnia	Asteraceae	0.004	33.33
Solanum elaeagnifolium	silverleaf nightshade	Solanaceae	0.159	83.33
Sphaeralcea sp.	Globemalllow	Malvaceae	0.001	16.67
Sphaeralcea fendleri	Fendler's globemallow	Malvaceae	0.001	16.67
Sphaeralcea hastulata	spear globemallow	Malvaceae	0.097	83.33
Sporobolus airoides	alkali sacaton	Poaceae	0.023	33.33
Sporobolus contractus	spike dropseed	Poaceae	0.751	100.00

Appendix A, continued.

Sporobolus cryptandrus	sand dropseed	Poaceae	2.359	100.00
Sporobolus flexuosus	mesa dropseed	Poaceae	0.076	83.33
Stephanomeria pauciflora	brownplume wirelettuce	Asteraceae	0.003	33.33
Zinnia grandiflora	Rocky Mountain zinnia	Asteraceae	0.012	33.33
Unknown 2008Sep24-2			0.002	16.67

[a] Nonnative species

[b] Species found in the plots that are not included on the park's species list.