



Integrated Upland Vegetation and Soils Monitoring for Wupatki National Monument

2008 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2009/022



ON THE COVER

Integrated Upland Crew sampling vegetation in the Sandstone Upland ecological site at Wupatki 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 Wupatki National Monument (WUPA), SCPN staff and park staff selected two ecological sites to monitor: Limy Upland and Sandstone Upland. 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 Limy Upland and Sandstone Upland ecological sites are distinct from each other, and together, they represent large areas of the park. They are threatened by climate change and the invasion of nonnative species.

In 2007 the Integrated Upland Monitoring program of SCPN began monitoring upland sites at WUPA with the installation of 10 plots in the Limy Upland ecological site and 10 plots in the Sandstone Upland ecological site. We plan to read these plots annually for 3-5 years to determine the range of temporal variability for key metrics. Power analysis will then be used to determine the total number of plots necessary to detect change in the key metrics. In this report, we document monitoring activities in the 2008 field season and compare these data with the data collected in 2007.

Methods

Sampling frame

A sampling frame is the area from which sites are randomly selected, and hence the area to which statistical inferences can be made. We derived the sampling frames from the maps of the two ecological sites, which were 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 maps of the ecological sites with Geographical 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). Park staff reviewed the sampling points, and an archeologist examined the sites and rejected points that landed too close to archaeological sites. Before establishing a plot, the Integrated Upland crew conducted an ecological site assessment for each sampling point and rejected the site if it did not fall within the ecological site, had a slope greater than 20%, or contained a major disturbance. In the Limy Upland ecological site, two points were rejected: one point was in proximity to an archaeological site and one occurred in the wrong ecological site. One point was rejected in the Sandstone Upland ecological site because it occurred in the wrong ecological site.

Field methods

The SCPN Upland Monitoring crew began monitoring at WUPA in 2007 with the establishment of 10 plots in each ecological site. They installed and collected data at all plots in late August through early September. In 2008, they collected data in late August.

Plots are 0.50 ha in size measuring 71 m x 71 m. Soil data and shrub and herbaceous vegetation data were collected on three 50 m transects, spaced 25 meters apart, within each plot. Overstory tree and

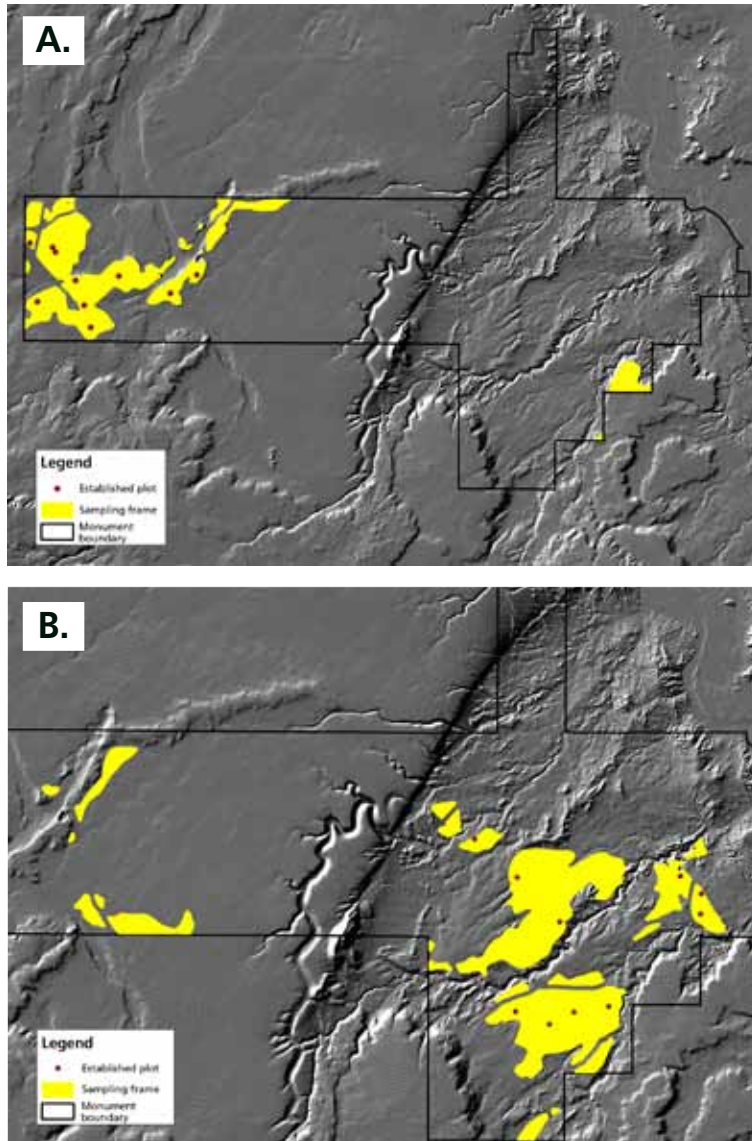


Figure 1. Sampling frames for A) the Limy Upland ecological site and B) the Sandstone Upland ecological site with the 10 plots established in each site.

sampling data were collected in a nested subplot located between two of the transects. Field methodology is provided in detail in the SCPN Integrated Upland Protocol (DeCoster et al., in review).

Shrub and herbaceous vegetation

The crew sampled shrub and herbaceous vegetation with five sets of nested quadrats at 10 m intervals along each transect. The largest quadrat size was 10 m² (2m x 5m) with four smaller quadrats nested inside (0.01 m², 0.1 m², 1 m², and 5 m²). The presence of individual vascular species was recorded for each nested sub-quadrat. Percent cover of individual vascular herbaceous and shrub species was then estimated in the 10 m² quadrat and placed in one of 12 cover classes, e.g. 2-5%, 5-10%, etc. Percent cover for each functional group (e.g. graminoids, forbs, shrubs) was also estimated in the largest quadrat and recorded as one of the 12 cover classes.

Overstory trees and saplings

Trees were not remeasured in 2008.

Soil stability and hydrologic function

The crew estimated the percent cover of ground surface features in the 1 m² quadrats in conjunction with the shrub and herbaceous data and recorded the cover in one of 12 cover classes. In 2007, the amount of bare soil was measured by recording the length of each basal gap (the space between plant bases) along each transect. However, basal gaps were not remeasured in 2008.

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 and standard deviation (SD) 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 the level of the plot and the level of 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.

Results

Limy Upland ecological site

Vegetation

Perennial grasses dominated the Limy Upland ecological site at WUPA. The total live vegetative cover for 2008 was 15.58%, and the cover of perennial grasses was 11.12%. Between 2007 and 2008, cover

among functional groups changed very little (table 1 and fig. 2). The most notable change was the increase in forb cover from 0.72% to 2.62%.

Table 1. Foliar cover of functional groups for 2007 and 2008 at the Limy Upland ecological site.

Functional group	Foliar cover (%)			
	2007		2008	
	Mean	(SD)	Mean	(SD)
Total foliar cover	14.19	(4.56)	15.58	(3.69)
Perennial grasses	12.60	(4.97)	11.12	(3.17)
Annual grasses	0	(0)	0	(0)
Forbs	0.72	(0.60)	2.63	(2.06)
Shrubs	0.36	(0.35)	0.52	(0.64)
Cacti, succulents	0.01	(0.02)	0.01	(0.03)
Standing dead herbaceous	6.17	(2.45)	4.42	(1.31)
Standing dead woody	0.38	(0.27)	0.68	(0.56)

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

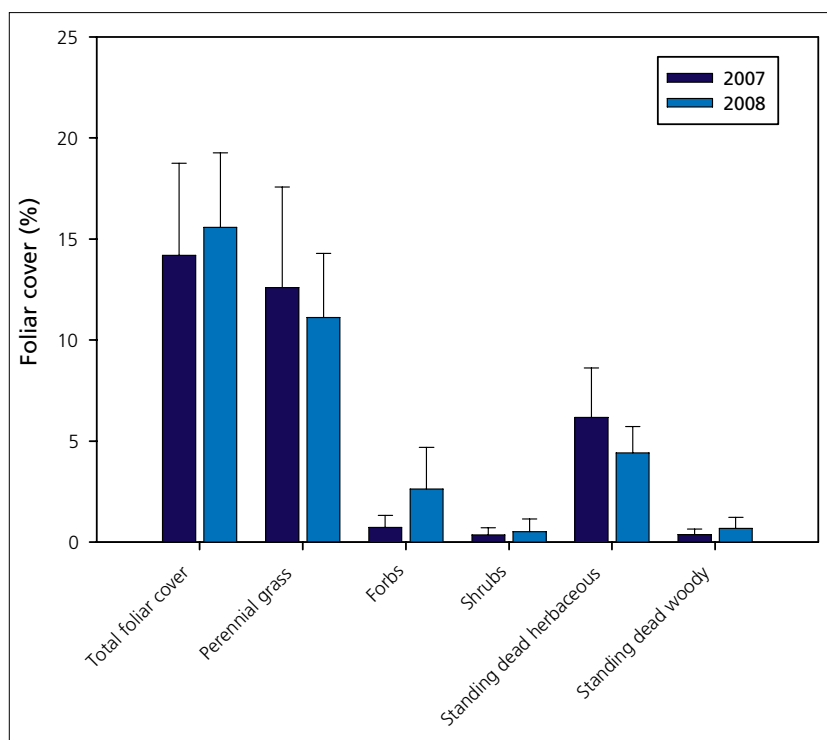


Figure 2. Mean cover of functional groups at the Limy Upland ecological site in 2007 and 2008. Error bars represent one standard deviation.

The cover of individual species had few substantial changes between years (table 2 and fig. 3). Two annual forb species showed large increases in cover. *Salsola tragus* (prickly Russian thistle) increased in quadrat frequency from 40.67% to 80.00% and in cover from 0.260% to 1.422%. *Chenopodium leptophyllum* (narrowleaf goosefoot) increased in quadrat frequency from 16.00% to 93.33%, in plot frequency from 50% to 100% and in cover from 0.115% to 0.990%. Both groups of *Chamaesyce* spp. showed decreases in frequency. The large standard deviations indicated high variability among plots. Appendix A lists all the species found, along with their common names, families, mean foliar cover, and plot frequencies.

The abundance of nonnative species increased between 2007 and 2008. In 2007, *Salsola tragus* was the only nonnative species found in the plot, and as mentioned above, it increased in cover and quadrat and plot frequency. In 2008, *Kochia scoparia* (Mexican burningbush) appeared in one plot with very low cover.

Table 2. Foliar cover and frequency of the fifteen most abundant vascular species and all nonnative species in 2007 compared to 2008 at the Limy Upland ecological site.

Species	2007				2008			
	Mean cover (%)	SD	Quad freq	Plot freq	Mean cover (%)	SD	Quad freq	Plot freq
<i>Pleuraphis jamesii</i>	6.251	4.683	96.00	100	5.618	4.285	96.67	100
<i>Bouteloua eriopoda</i>	3.492	2.538	78.67	100	3.252	3.012	78.67	100
<i>Hesperostipa comata</i>	1.691	1.718	76.67	90	2.048	2.072	78.00	100
<i>Ericameria nauseosa</i>	0.387	0.352	28.67	100	0.310	0.177	28.67	100
<i>Salsola tragus</i> ^a	0.260	0.240	40.67	80	1.422	1.456	84.00	90
<i>Chenopodium leptophyllum</i>	0.115	0.267	16.00	50	0.990	0.881	93.33	100
<i>Sporobolus airoides</i>	0.098	0.240	3.33	20	0.119	0.342	4.00	20
<i>Sphaeralcea hastulata</i>	0.090	0.141	15.33	50	0.063	0.118	14.00	50
<i>Chamaesyce</i> spp. Group A	0.074	0.136	47.33	100	0.009	0.013	14.67	50
<i>Chamaesyce</i> spp. Group B	0.068	0.080	58.67	100	0.001	0.001	1.33	20
<i>Aristida havardii</i>	0.034	0.101	4.00	20	0.002	0.006	0.67	10
<i>Bouteloua curtipendula</i>	0.023	0.074	0.67	10	0.002	0.006	0.67	10
<i>Zinnia grandiflora</i>	0.017	0.031	10.00	40	0.014	0.024	6.00	40
<i>Chaetopappa ericoides</i>	0.016	0.020	16.67	90	0.020	0.021	20.00	90
<i>Evolvulus nuttallianus</i>	0.011	0.019	12.00	50	0.009	0.020	11.33	40
<i>Kochia scoparia</i> ^a	0	0	0	0	<0.001	0.001	0.67	10

Note: Species are arranged in descending order by their 2007 cover.

^a Nonnative species.

Diversity changed little between the two years. Species richness decreased slightly between 2007 and 2008, while the other species diversity indices increased slightly (table 3). Mean plot species richness decreased from 13.8 species/plot to 13.1 species/plot. Ecological site richness decreased by one species, from 41 to 40. Some species in low abundance disappeared from the plots in 2008, while others appeared for the first time (Appendix A). In contrast, Shannon diversity (which takes into account relative species abundance and generally ranges between 1.5 and 3.5), evenness (the degree to which

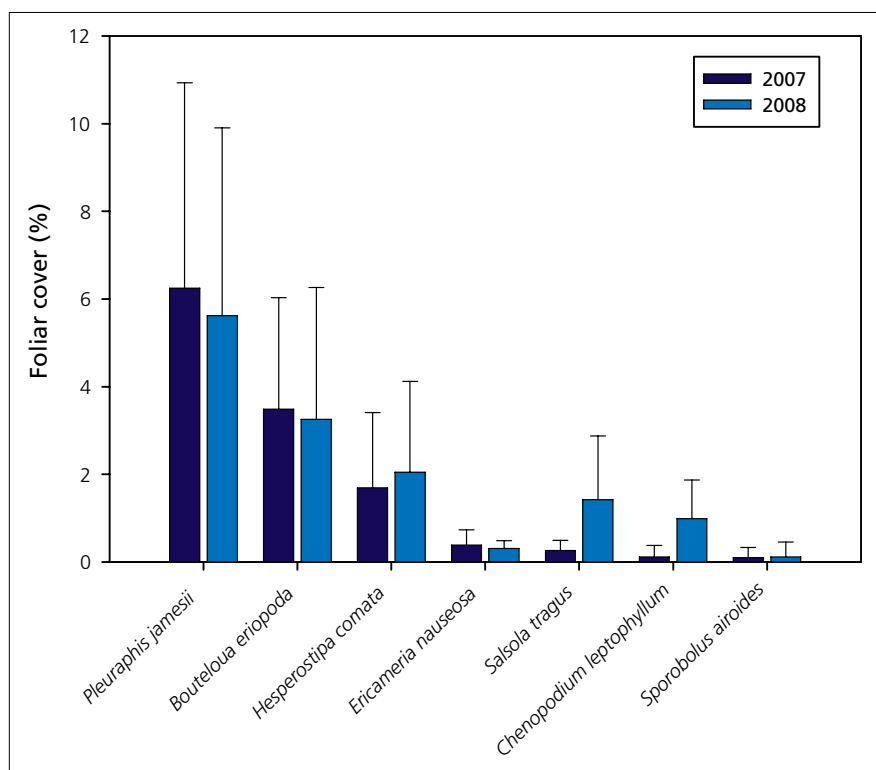


Figure 3. Mean foliar cover of the seven most abundant shrub and herbaceous species in 2007, as compared to 2008, at the Limy Upland ecological site. Error bars represent one standard deviation.

Table 3. Species diversity metrics at Limy Upland ecological site for all species and for native species only.

Metric	2007		2008	
	Mean	(SD)	Mean	(SD)
All species				
Plot				
Plot richness	13.8	(2.4)	13.1	(2.3)
Shannon diversity	1.175	(0.317)	1.365	(0.268)
Evenness	0.449	(0.114)	0.538	(0.119)
Ecological site				
Ecological site richness	41		40	
Beta diversity	3.203		3.306	
Native species				
Plot				
Plot richness	13.0	(2.3)	12.1	(2.5)
Shannon diversity	1.105	(0.288)	1.208	(0.213)
Evenness	0.434	(0.114)	0.494	(0.109)
Ecological site				
Ecological site richness	40		38	
Beta diversity	3.333		3.423	

all species are of equal abundance, ranging from 0 to 1), and beta diversity (a measure of within site heterogeneity, generally ranging between 1 and 5) all increased slightly. When these indices were recalculated using only native species, they did not change substantially (table 3).

Soil stability and hydrologic function

The cover of ground surface features was measured in both 2007 and 2008 (table 4 and fig. 4). Fine gravel in the form of volcanic cinders was a major component at this site. As expected, most features did not show much variation between years. The most notable changes were an increase in dead herbaceous base from 0.06% to 1.83% and an increase in duff and litter from 3.42% to 5.48%.

Table 4. Cover of ground surface features at Limy Upland ecological site.

Surface feature	2007		2008	
	Mean cover (%)	(SD)	Mean cover (%)	(SD)
Live plant base	4.87	(1.60)	4.64	(1.96)
Dead woody base	0.02	(0.02)	0.07	(0.08)
Dead herbaceous base	0.06	(0.19)	1.83	(0.68)
Bare soil	0.83	(0.61)	0.28	(0.28)
Duff and litter	3.42	(1.67)	5.48	(2.42)
Undifferentiated crust	1.35	(1.35)	2.02	(0.99)
Moss	0	(0)	0	(0)
Lichen	0	(0)	0	(0)
Cyanobacteria	0	(0)	0	(0)
Fine gravel (0.2 cm- 2cm)	75.08	(14.77)	75.22	(12.27)
Coarse gravel (2cm – 7.5 cm)	13.61	(15.40)	10.26	(11.99)
Cobble (7.5 cm – 25 cm)	0.65	(0.53)	0.81	(0.65)
Stone, bedrock (>25 cm)	0.50	(0.76)	0.48	(0.62)
Woody debris	0	(0)	0	(0)

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

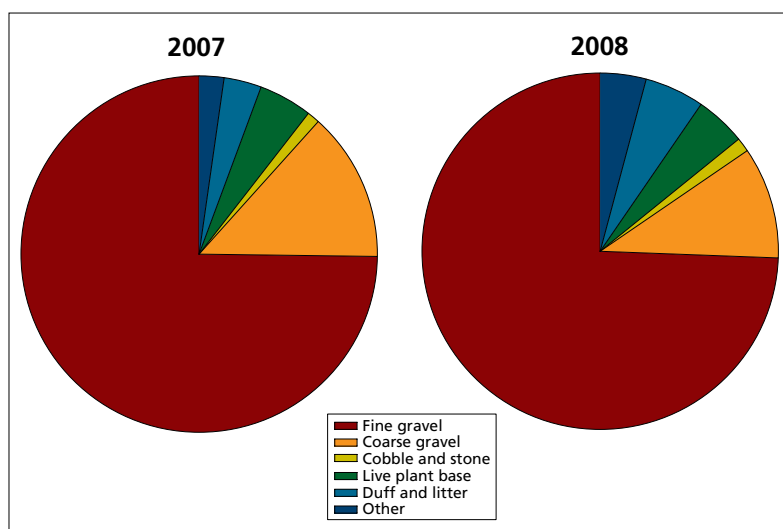


Figure 4. Mean cover of ground surface features at the Limy Upland ecological site in 2007 and 2008.

Sandstone Upland ecological site

Vegetation

In contrast to the Limy Upland ecological site, shrubs dominated the Sandstone Upland ecological site at WUPA. Between 2007 and 2008, total live vegetative cover increased from 5.38% to 8.07 % (table 5 and fig. 5). All functional groups increased in cover, with the exception of cacti/succulents, which occurred in trace amounts.

Table 5. Foliar cover of functional groups for 2007 and 2008 at the Sandstone Upland ecological site.

Functional group	Foliar cover (%)			
	2007		2008	
	Mean	(SD)	Mean	(SD)
Total foliar cover	5.38	(2.95)	8.07	(3.70)
Perennial grasses	1.35	(1.56)	2.46	(3.19)
Annual grasses	0	(0)	0	(0)
Forbs	0.44	(0.35)	0.66	(0.80)
Shrubs	3.51	(1.87)	4.76	(2.49)
Cacti, succulents	<0.01	(<0.01)	<0.01	(<0.01)
Standing dead herbaceous	0.82	(0.88)	1.05	(1.19)
Standing dead woody	2.47	(1.18)	3.50	(1.38)

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

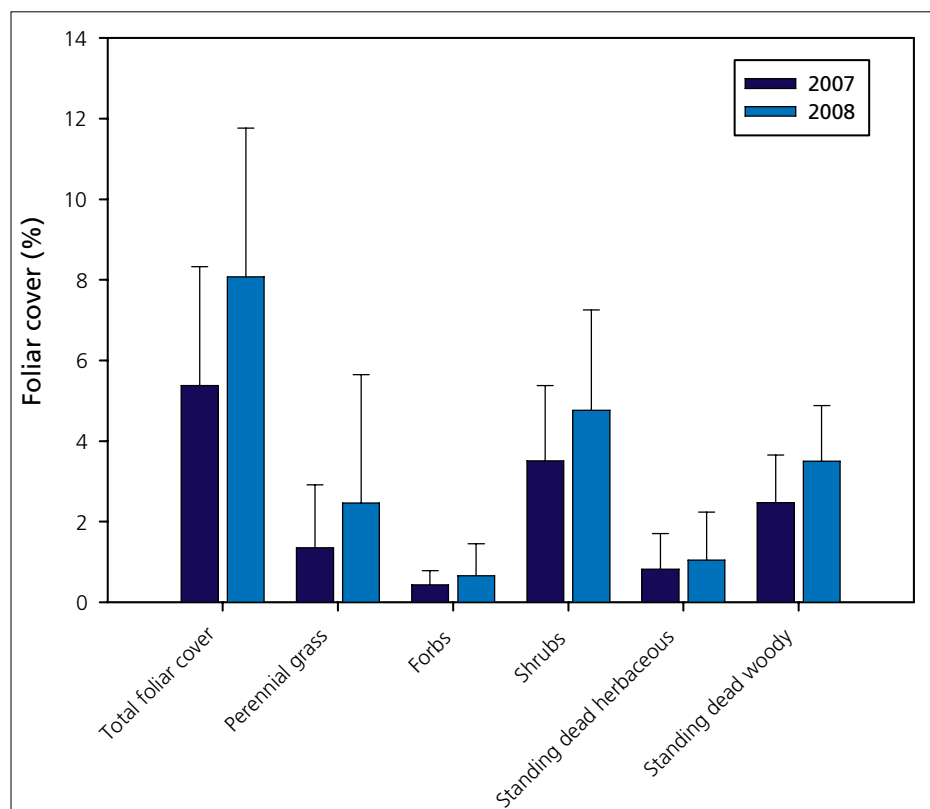


Figure 5. Mean percent cover of functional groups in 2007 and 2008 at Sandstone Upland ecological site. Error bars represent one standard deviation.

Most of the dominant species showed little change in their quadrat and plot frequencies (table 6 and fig. 6). However, the shrub and perennial grass species generally increased in cover, with the exception of *Fallugia paradoxica* (Apache plume). Forbs showed no clear trend. *Chamaesyce* spp. Group A decreased in quadrat frequency and in cover. The only nonnative species in the ecological site, *Salsola tragus*, showed large increases in quadrat frequency (0.67% to 26.00%), plot frequency (10% to 50%), and cover (0.002% to 0.330%). The large standard deviations and low quadrat and plot frequencies indicate high variability among plots. Appendix B lists all the species found in this ecological site, along with common names, families, mean foliar cover, and plot frequencies.

Table 6. Foliar cover and frequency of the fifteen most abundant vascular species and all nonnative species in 2007 compared to 2008 at the Sandstone Upland ecological site.

Species	2007				2008			
	Mean cover (%)	SD	Quad freq	Plot freq	Mean cover (%)	SD	Quad freq	Plot freq
<i>Artemisia filifolia</i>	1.161	1.510	34.00	40	1.760	2.321	34.67	40
<i>Ephedra torreyana</i>	0.933	0.984	40.00	100	1.792	1.361	42.67	100
<i>Pleuraphis jamesii</i>	0.777	1.145	41.33	70	1.437	2.469	40.67	70
<i>Fallugia paradoxa</i>	0.633	1.392	12.67	30	0.449	0.904	13.33	30
<i>Muhlenbergia porteri</i>	0.305	0.452	28.00	80	0.550	0.864	33.33	80
<i>Chamaesyce</i> spp. Group A	0.254	0.267	59.33	80	0.024	0.026	22.67	80
<i>Ericameria nauseosa</i>	0.173	0.260	11.33	60	0.189	0.227	13.33	60
<i>Atriplex confertifolia</i>	0.170	0.298	18.00	30	0.223	0.390	16.00	30
<i>Bouteloua eriopoda</i>	0.111	0.231	12.00	40	0.194	0.404	10.00	30
<i>Gutierrezia sarothrae</i>	0.106	0.130	18.00	60	0.152	0.187	16.67	50
<i>Atriplex canescens</i>	0.064	0.105	6.67	50	0.100	0.133	8.67	60
<i>Tetradlea coulteri</i>	0.049	0.076	5.33	50	0.012	0.017	5.33	50
<i>Sporobolus airoides</i>	0.047	0.100	3.33	20	0.070	0.164	2.00	20
<i>Sphaeralcea grossulariifolia</i>	0.035	0.067	6.00	40	0.041	0.093	5.33	30
<i>Sphaeralcea hastulata</i>	0.030	0.049	12.00	50	0.056	0.108	10.00	40
<i>Salsola tragus</i> ^a	0.002	0.006	0.67	10	0.330	0.796	26.00	50

Note: Species are arranged in descending order by their 2007 cover.

^a Nonnative species.

Three of the species diversity indices increased between 2007 to 2008: mean plot richness increased from 12.8 to 14.8, ecological site richness increased by 6 species (see Appendix B), and beta diversity (a measure of within site heterogeneity, generally ranging between 1 and 5) increased slightly (table 7). In contrast, Shannon diversity (which takes into account relative species abundance and generally ranges between 1.5 and 3.5) and evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) both decreased. When these indices were recalculated using only native species, they did not change substantially (table 7).

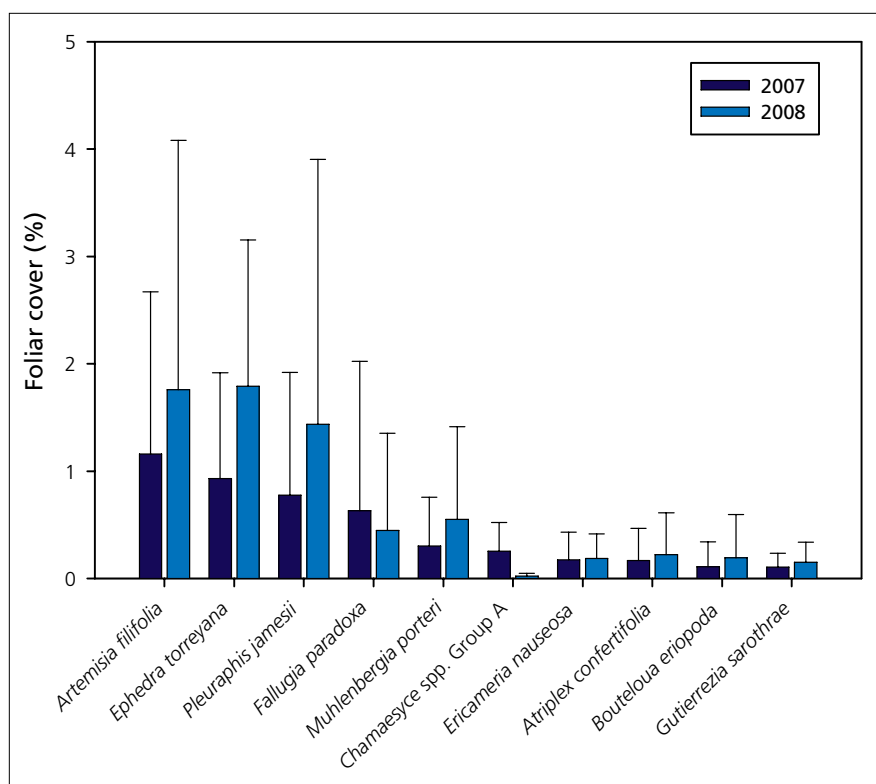


Figure 6. Mean foliar cover of the ten most abundant shrub and herbaceous species in 2007, as compared to 2008, at the Sandstone Upland ecological site. Error bars represent one standard deviation.

Table 7. Species diversity metrics at Sandstone Upland ecological site for all species and for native species only.

Metric	2007		2008	
	Mean	(SD)	Mean	(SD)
All species				
Plot				
Plot richness	12.8	(3.3)	14.8	(2.8)
Shannon diversity	1.505	(0.259)	1.494	(0.226)
Evenness	0.597	(0.076)	0.558	(0.081)
Ecological site				
Ecological site richness	34		40	
Beta diversity	2.881		2.899	
Native species				
Plot				
Plot richness	12.7	(3.4)	14.3	(2.7)
Shannon diversity	1.501	(0.262)	1.481	(0.200)
Evenness	0.598	(0.077)	0.560	(0.065)
Ecological site				
Ecological site richness	33		39	
Beta diversity	2.821		2.932	

Soil stability and hydrologic function

The cover of ground surface features was measured in both 2007 and 2008 (table 8 and fig. 7). As expected, the cover of the surface features changed only slightly. Standard deviations were moderately high relative to their means, indicating high among-plot variability.

Table 8. Cover of ground surface features at Sandstone Upland ecological site.

Surface feature	2007		2008	
	Mean (%)	(SD)	Mean (%)	(SD)
Live plant base	1.22	(0.98)	1.71	(1.43)
Dead woody base	0.34	(0.21)	0.64	(0.30)
Dead herbaceous base	0.10	(0.21)	0.50	(0.52)
Bare soil	4.08	(3.99)	1.53	(1.17)
Duff and litter	4.09	(1.86)	7.09	(3.64)
Undifferentiated crust	5.22	(7.17)	4.19	(2.36)
Moss	0	(0)	0	(0)
Lichen	0	(0)	0	(0)
Cyanobacteria	0	(0)	0	(0)
Fine gravel (0.2 cm- 2cm)	70.56	(15.88)	68.79	(16.66)
Coarse gravel (2cm – 7.5 cm)	8.28	(9.06)	11.13	(13.00)
Cobble (7.5 cm – 25 cm)	1.17	(1.83)	1.71	(2.22)
Stone, bedrock (>25 cm)	0.85	(1.65)	0.79	(1.55)
Woody debris	0.08	(0.18)	0.04	(0.05)

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

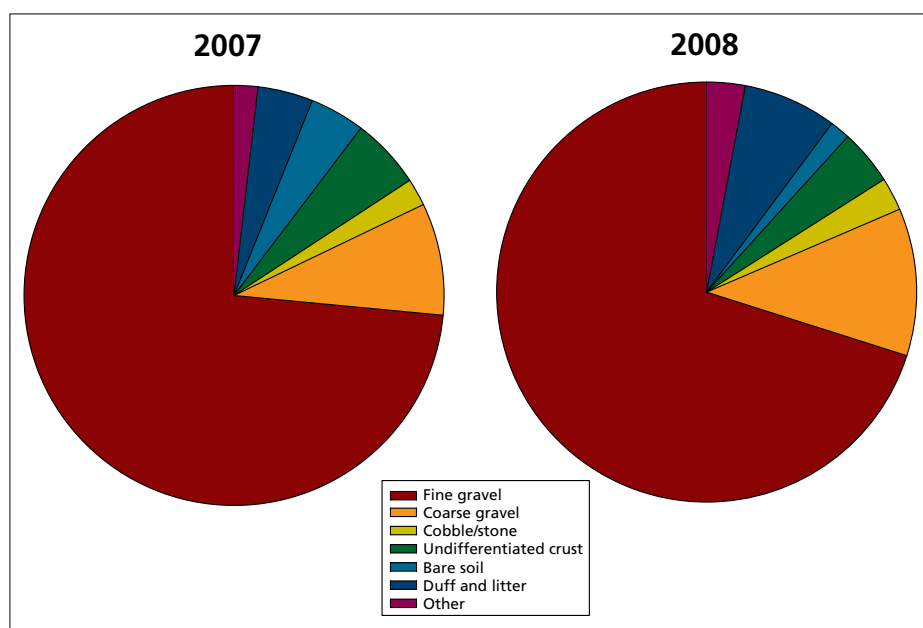


Figure 7. Mean cover of ground surface features at the Sandstone Upland ecological site in 2007 and 2008.

Discussion

The Limy Upland ecological site and the Sandstone Upland ecological site represent two contrasting ecosystems, not only in their composition and structure, but also in how they changed from 2007 to 2008. Both sites showed slight to moderate increases in total live vegetative cover and increases in cover of most functional groups between 2007 and 2008. The most striking exception was the decrease in cover of the perennial grasses in the Limy Upland site. However, the decrease was very slight, especially relative to its large standard deviation. Cover and frequency for the dominant species did not substantially change, with several exceptions. Three of the four dominant shrubs in the Sandstone Upland site increased in cover. The nonnative *Salsola tragus* showed relatively large increases in frequency at both sites. As a winter annual, the higher than normal precipitation in January and February in 2008 likely facilitated its establishment in that year (fig. 8). In contrast, *Chamaesyce* spp. decreased between the two years. Its high abundance in 2007 was likely the result of a strong germination response following the strong monsoon in August.

Changes in species diversity showed contrasting trends at each site. At the Limy Upland ecological site, the mean plot richness and the ecological site richness decreased, but the other diversity indices increased. In spite of an increase in species richness, Shannon diversity decreased slightly in the Sandstone Upland site; this was probably due to a decrease in species richness. Conversely, increased Shannon diversity in the Limy Upland site can likely be attributed to increased cover of subdominant species in 2008. The cover of ground surface features at both sites changed only by small amounts between years.

We stress that the changes noted between these two years are not indicative of long-term trends, nor should they be viewed as being ecologically significant. As mentioned, much of the change is undoubtedly due to annual climatic fluctuations. Some of the changes observed are due to small differ-

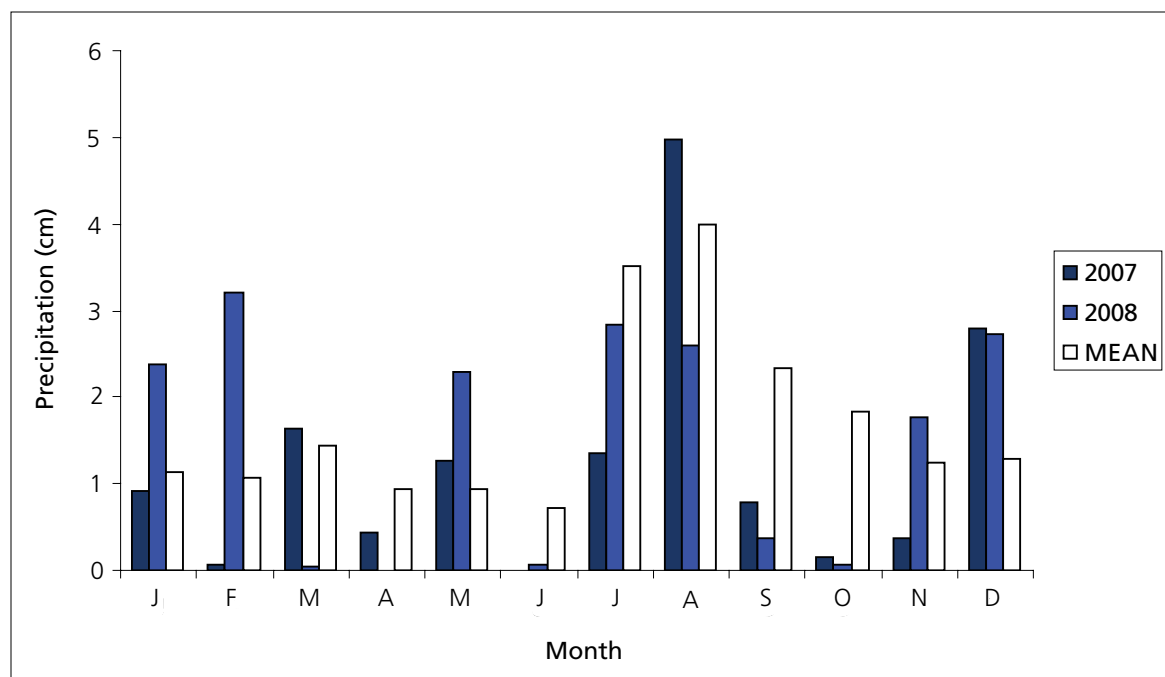


Figure 8. Monthly precipitation in 2007 and 2008 and the average precipitation (1940-2009) at Wupatki National Monument (WRCC 2009).

ences in the timing of the sampling (which will become more standardized over time). Other changes are attributable to sampling error inherent in the field sampling process. Cover estimation may vary among individuals (and crews), similar species may occasionally be mis-identified, and the location of the quadrats will vary slightly from year to year. We strive to minimize these errors by ensuring that transect lines are as straight as possible, quadrats are placed correctly, and field crews are trained continuously on species identification and cover estimation.

The SCPN Upland Crew plans to sample the quadrats annually for the next 3-5 years to determine the range of annual variability for key metrics. Power analysis will then be used to determine the total number of plots necessary to detect change in the key metrics. A temporal sampling design will then be implemented, with the installation of additional plots in subsequent years. Each year's data will be compared to the previously collected data to analyze 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 mean foliar cover and frequency for herbaceous and shrub species in 2007 and 2008 for the Limy Upland ecological site. *Chamaesyce* spp. not identifiable to species were placed in one of two groups based on leaf morphology.

Species	Common name	Family	2007		2008	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Aristida havardii</i>	Havard's threeawn	Poaceae	0.034	20	0.002	10
<i>Aristida purpurea</i>	Fendler's threeawn	Poaceae	0.004	20	0.030	50
<i>Bouteloua curtipendula</i>	sideoats grama	Poaceae	0.023	10	0.002	10
<i>Bouteloua eriopoda</i>	black grama	Poaceae	3.492	100	3.252	100
<i>Bouteloua gracilis</i>	blue grama	Poaceae	0	0	0.002	10
<i>Caesalpinia drepanocarpa</i>	sicklepod holdback	Fabaceae	0.002	20	0.002	10
<i>Caesalpinia jamesii</i>	James' holdback	Fabaceae	0.002	20	0	0
<i>Chaetopappa ericoides</i>	rose heath	Asteraceae	0.016	90	0.020	90
<i>Chamaesyce</i> spp. Group A	annual sandmats	Euphorbiaceae	0.074	100	0.009	50
<i>Chamaesyce</i> spp. Group B	annual sandmats	Euphorbiaceae	0.068	100	0.001	20
<i>Chamaesyce albomarginata</i>	whitemargin sandmat	Euphorbiaceae	0	0	<.001	10
<i>Chamaesyce fendleri</i>	Fendler's sandmat	Euphorbiaceae	0.001	10	0.004	10
<i>Chenopodium fremontii</i>	Fremont's goosefoot	Chenopodiaceae	<.001	10	0.012	10
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0.115	50	0.990	100
<i>Cuscuta</i> sp.	Dodder	Cuscutaceae	0	0	0.002	10
<i>Ericameria nauseosa</i>	rubber rabbitbrush	Asteraceae	0.387	100	0.310	100
<i>Euphorbia exstipulata</i>	squareseed spurge	Euphorbiaceae	0.006	20	0	0
<i>Evolvulus nuttallianus</i>	shaggy dwarf morning-glory	Convolvulaceae	0.011	50	0.009	40
<i>Gilia</i> sp.	gilia	Polemoniaceae	0	0	<.001	10
<i>Glandularia gooddingii</i>	southwestern mock vervain	Verbenaceae	0.007	10	0	0
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	<.001	10	<.001	10
<i>Hesperostipa comata</i>	needle and thread	Poaceae	1.691	90	2.048	100
<i>Kallstroemia californica</i>	California caltrop	Zygophyllaceae	<.001	10	0	0

Appendix A, continued.

<i>Kochia scoparia</i>	Mexican burningbush	Chenopodiaceae	0	0	<.001	10
<i>Krascheninnikovia lanata</i>	winterfat	Chenopodiaceae	0.005	10	0.010	10
<i>Lithospermum incisum</i>	narrowleaf gromwell	Boraginaceae	<.001	10	0.001	10
<i>Lycium andersonii</i>	water jacket	Solanaceae	0	0	0.010	10
<i>Machaeranthera canescens</i>	hoary tansyaster	Asteraceae	0.001	10	0	0
<i>Opuntia</i> sp.	prickly pear	Cactaceae	0.005	10	0.005	10
<i>Opuntia whipplei</i>	Whipple's cholla	Cactaceae	0.002	20	0.005	10
<i>Pleuraphis jamesii</i>	James' galleta	Poaceae	6.251	100	5.618	100
<i>Polanisia dodecandra</i>	redwhisker clammyweed	Capparaceae	0.001	10	0	10
<i>Salsola tragus</i> ^a	prickly Russian thistle	Chenopodiaceae	0.260	80	1.422	90
<i>Senecio flaccidus</i>	threadleaf ragwort	Asteraceae	0.011	40	0.017	30
<i>Sphaeralcea</i> sp.	globemallow	Malvaceae	0.006	50	0.007	60
<i>Sphaeralcea hastulata</i>	spear globemallow	Malvaceae	0.090	50	0.063	50
<i>Sporobolus airoides</i>	alkali sacaton	Poaceae	0.098	20	0.119	20
<i>Sporobolus cryptandrus</i>	sand dropseed	Poaceae	0.001	10	0.002	10
<i>Stephanomeria minor</i>	lesser wirelettuce	Asteraceae	<.001	10	<.001	10
<i>Stephanomeria pauciflora</i>	brownplume wirelettuce	Asteraceae	0.002	10	0.008	30
<i>Stephanomeria thurberi</i>	Thurber wire lettuce	Asteraceae	<.001	10	<.001	10
<i>Tragia ramosa</i>	branched noseburn	Euphorbiaceae	0.004	10	0.002	10
<i>Zinnia grandiflora</i>	Rocky Mountain zinnia	Asteraceae	0.017	40	0.014	40
Unknown WUPA011			0.005	10	0	0
Unknown 21Aug2007-1			<.001	10	0	0
Unknown 21Aug2007-2			<.001	10	0	0
Unknown 23Aug2007-5			<.001	10	0	0
Unknown 22Aug2008-2			0	0	0.001	10
Unknown 23Aug2008-1			0	0	0.001	20

^a Nonnative species.

Appendix B

Complete species list with mean foliar cover and frequency for herbaceous and shrub species in 2007 and 2008 for the Sandstone Upland ecological site. *Chamaesyce* spp. not identifiable to species were placed in one of two groups based on leaf morphology.

Species	Common name	Family	2007		2008	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Achnatherum hymenoides</i>	Indian ricegrass	Poaceae	0.015	50	0.037	50
<i>Aristida purpurea</i>	Fendler's threeawn	Poaceae	0.014	20	0.025	20
<i>Artemisia filifolia</i>	sand sagebrush	Asteraceae	1.161	40	1.760	40
<i>Atriplex canescens</i>	fouwing saltbush	Chenopodiaceae	0.064	50	0.100	60
<i>Atriplex confertifolia</i>	shadscale saltbush	Chenopodiaceae	0.170	30	0.223	30
<i>Bouteloua eriopoda</i>	black grama	Poaceae	0.111	40	0.194	30
<i>Brickellia oblongifolia</i>	Mohave brickellbush	Asteraceae	0.011	40	0.016	30
<i>Chaetopappa ericoides</i>	rose heath	Asteraceae	0.001	20	0.005	20
<i>Chamaesaracha coronopus</i>	greenleaf five eyes	Solanaceae	0.001	10	0.001	20
<i>Chamaesyce</i> spp. Group A	annual sandmats	Euphorbiaceae	0.254	80	0.024	80
<i>Chamaesyce</i> spp. Group B	annual sandmats	Euphorbiaceae	0	0	<.001	10
<i>Chamaesyce fendleri</i>	Fendler's sandmat	Euphorbiaceae	0.007	40	0.005	50
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0	0	<.001	10
<i>Dasyochloa pulchella</i>	low woollygrass	Poaceae	0.020	40	0.022	50
<i>Ephedra torreyana</i>	Torrey's jointfir	Ephedraceae	0.933	100	1.792	100
<i>Ephedra viridis</i>	mormon tea	Ephedraceae	0.007	20	0.020	30
<i>Ericameria nauseosa</i>	rubber rabbitbrush	Asteraceae	0.173	60	0.189	60
<i>Eriogonum cernuum</i>	nodding buckwheat	Polygonaceae	0	0	0.064	40
<i>Eriogonum corymbosum</i>	crispleaf buckwheat	Polygonaceae	0.008	30	0.010	20
<i>Eriogonum leptoclodon</i>	sand buckwheat	Polygonaceae	0.015	10	0.010	20
<i>Fallugia paradoxa</i>	Apache plume	Rosaceae	0.633	30	0.449	30
<i>Gilia</i> sp.	gilia	Polemoniaceae	0	0	0.012	90
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	0.106	60	0.152	50

Appendix B, continued.

<i>Mentzelia pumila</i>	dwarf mentzelia	Loasaceae	0	0	0.002	10
<i>Muhlenbergia porteri</i>	bush muhly	Poaceae	0.305	80	0.550	80
<i>Pleuraphis jamesii</i>	James' galleta	Poaceae	0.777	70	1.437	70
<i>Salsola tragus</i> ^a	prickly Russian thistle	Chenopodiaceae	0.002	10	0.330	50
<i>Sphaeralcea</i> sp.	globemallow	Malvaceae	0.001	20	0.019	50
<i>Sphaeralcea grossulariifolia</i>	gooseberryleaf globemallow	Malvaceae	0.035	40	0.041	30
<i>Sphaeralcea hastulata</i>	spear globemallow	Malvaceae	0.030	50	0.056	40
<i>Sphaeralcea parvifolia</i>	smallflower globemallow	Malvaceae	0.030	20	0.002	10
<i>Sporobolus airoides</i>	alkali sacaton	Poaceae	0.047	20	0.070	20
<i>Stephanomeria</i> sp.			0.002	50	0	0
<i>Stephanomeria minor</i>	lesser wirelettuce	Asteraceae	0.002	10	0.001	20
<i>Stephanomeria pauciflora</i>	brownplume wirelettuce	Asteraceae	0.011	60	0.010	50
<i>Tetradlea coulteri</i>	Coulter's wrinklefruit	Verbenaceae	0.049	50	0.012	50
<i>Tiquilia hispidissima</i>	hairy crinklemat	Boraginaceae	0	0	0.025	10
<i>Yucca angustissima</i>	narrowleaf yucca	Agavaceae	0.002	10	0.002	10
<i>Zinnia grandiflora</i>	Rocky Mountain zinnia	Asteraceae	0.002	10	0.002	10
Unknown 2007Aug21-1			<.001	10	0	0
Unknown 24Aug2008-1			0	0	0.003	10
Unknown 27Aug2008-1			0	0	0.001	20
Unknown 09122007-2			<.001	10	0	0

^a Nonnative species.