



Integrated Upland Vegetation and Soils Monitoring for Wupatki National Monument

2007 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2009/006



ON THE COVER

Limy 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_decoaster@nps.gov). Megan Swan is the botanist and crew leader for the project. Other contributions were made by the SCPN staff. The 2007 field crew consisted of Mare Nazaire and Jeff Organ.

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Introduction and Background

The National Park Service Vital Signs Monitoring Program was designed to monitor the status and trends in the condition of park natural resources, providing a strong scientific foundation for decision making and resource conservation for park managers. The Southern Colorado Plateau Network (SCPN) has selected upland vegetation and soils as indicators of the overall condition of upland ecosystems.

SCPN and park staff selected two ecological sites to monitor at Wupatki National Monument (WUPA): Limy Upland and Sandstone Upland. These represent large areas of the park, and are relatively distinct from each other. These upland sites face a number of threats, including invasion of non-native species and climate change.

In 2007 the Integrated Upland Monitoring program of SCPN began upland monitoring at Wupatki National Monument (WUPA). The purpose of this report is to document monitoring activities in the 2007 field season, and summarize the data that were collected.

Methods

Sampling Frames

The two sampling frames were derived from ecological sites developed by the US Natural Resources Conservation Service (NRCS): Limy Upland (Figure 1), and Sandstone Upland (Figure 2). 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).

Using geographic information system (GIS) technology, several modifications were made to the spatial coverages of the ecological sites, including the removal of roads and slopes greater than 20%. A set of spatially distributed sampling points was created using the Generalized Random-Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). WUPA park staff reviewed the sampling points, and an archeologist examined the sites, rejecting those that were situated in close proximity 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 contained a major disturbance or did not fall within the ecological site.

Field Methods

The Southern Colorado Plateau Upland Monitoring crew implemented monitoring at WUPA in 2007 with the establishment of 10 plots in each ecological site. All plots were established and read in late August through early September.

Field methodology is provided in detail in the SCPN Integrated Upland Protocol (DeCoster et al., in review). Plots are 0.50 ha in size measuring 71 m x 71 m. Soil and shrub and herbaceous vegetation data were collected on three 50 m transects, spaced 25 meters apart. Overstory tree and sapling data were collected in a nested subplot located between two transects.

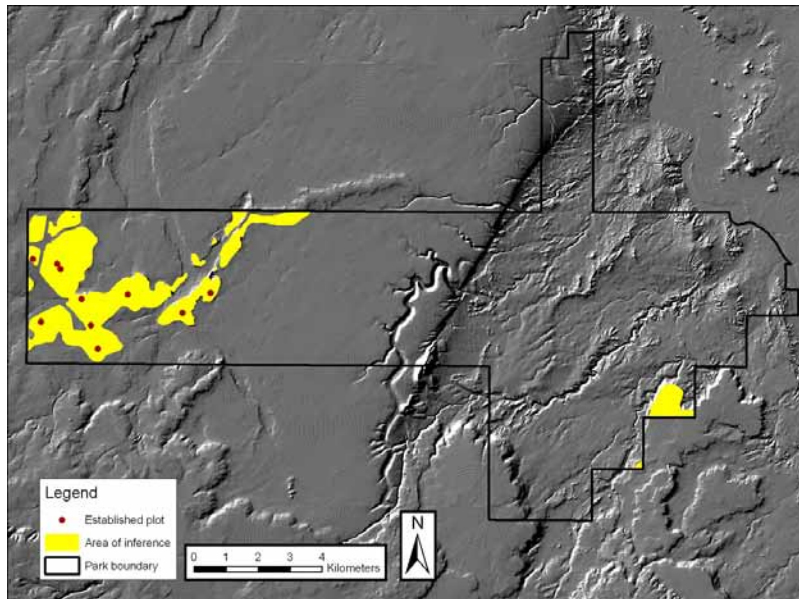


Figure 1. Sampling frame of Limy Upland Ecological Site with the 10 plots established in 2007.

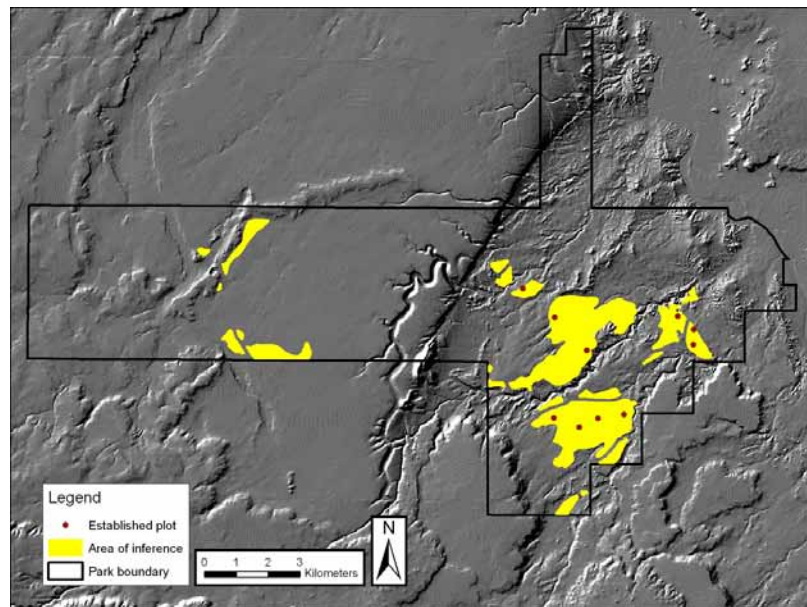


Figure 2. Sampling frame of Sandstone Upland Ecological Site with the 10 plots established in 2007

Shrub and Herbaceous Vegetation

Along each transect, shrub and herbaceous vegetation was sampled at 10 m intervals using five sets of nested quadrats. The largest quadrat size is 10 m² (2 m x 5 m) with three smaller quadrats nested inside (0.01 m², 0.1 m², and 1 m²). The presence of individual vascular species was recorded for each nested sub-quadrat. For each individual herbaceous and shrub species, percent cover was estimated in the 10 m² quadrat and recorded as one of 12 cover classes. Percent cover of functional groups (e.g. perennial grasses, forbs, shrubs) was also estimated in the largest quadrat and recorded as one of 12 cover classes.

Tree Overstory and

Understory. Overstory trees are trees greater than 15 cm in diameter and are measured within a 50 x 50 m (0.25 ha) subplot between the two outer transects. For each individual tree, species, diameter and status (live, dead) are recorded.

Diameter at root crown (drc)

is used for measuring size of *Juniperus* spp because of their multi-stemmed growth form. For all other species, diameter at breast height (dbh) is used. Saplings (>2.5 and ≤15 cm diameter) are sampled in a 25 m x 25 m subplot, and are tallied by species and size class. Tree seedlings are sampled in the 10 m² quadrats, and are tallied by species and size class.

Soil Stability and Hydrologic Function. Basal gaps were measured along each transect to provide a measure of the amount of bare soil. Percent cover of soil surface features were

estimated in the 1 m² quadrats in conjunction with the shrub and herbaceous data, and recorded as one of 12 cover classes.

Data Summary

The sample unit for all summary and analysis is the plot, hence, all data are summarized at the plot level. In order to calculate summary statistics for the ecological site, mean and standard deviation were calculated from the plot mean.

For herbaceous and shrub vegetation, cover and frequency are calculated for each species from the cover class midpoints. The mean cover is calculated for each plot, and the mean and standard deviation (SD) and range of cover (where that species occurs) are calculated for the ecological site. The species frequency is calculated for quadrats (mean percentage of quadrats per plot where the species occurs) and for plots (percentage of plots where the species occurs). The mean cover and SD of functional groups and surface features are calculated in a similar fashion.

Four diversity measures are calculated for herbaceous and shrub species (Magurran 1988). Calculations are made for all species first, and then for native species only.

1. Species richness (S) is the number of species at a given spatial scale, and is 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 where p_i is the mean cover of each species:

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

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

$$H' / \ln(S) \quad (2)$$

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

$$S_e / (S_p - 1) \quad (3)$$

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.

Tree basal area is calculated for each overstory tree species in terms of m²/ ha. Tree density (stems/ ha) is calculated for all species and size classes for overstory, sapling and seedling layers. Mean diameter of overstory trees is calculated by species.

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

Results

Limy Upland Ecological Site

Herbaceous and Shrub Vegetation

The herbaceous and shrub vegetation of the WUPA Limy Upland Ecological Site is dominated by perennial grasses. Table 1 lists the 15 most abundant species, and shows that the 3 most abundant species are grasses: *Pleuraphis jamesii* (James' galleta), *Bouteloua eriopoda* (black grama) and *Hesperostipa comata* (needle and thread). *Ericameria nauseosa* (rubber rabbitbrush) is the only abundant shrub. Common forbs include *Salsola tragus* (prickly Russian thistle), *Chenopodium leptophyllum* (narrowleaf goosefoot) and *Sphaeralcea hastulata* (spear globemallow). The most abundant species generally have moderately low standard deviations (smaller than their means), indicating moderately low variability among plots. A complete species list is found in Appendix A, and includes common names, plant families, mean covers and plot frequencies. There is only one non-native species found in the plots. *Salsola tragus* is the fifth most abundant species and occurs in 80% of the plots, but never exceeds 1% cover in any plot.

The cover of functional groups (Table 2) confirms the dominance of grasses. Total live vegetative cover is shown to be 14.19%, and perennial grasses comprise 12.60% cover (see Figure 3). Forbs,

Table 1. Cover and Frequency of Shrub and Herbaceous Species for Limy Upland Ecological Site. Foliar cover of the fifteen most abundant vascular species, expressed as a percentage. Annual *Chamaesyce* spp. that are not identifiable in the field to species are placed in one of two groups. All non-native species are included and are indicated by an asterisk. The range in foliar cover is provided for where the species occurs. (Many species do not occur in every plot of an ecological site; for these species, the minimum range of 0% is provided).

Species	Foliar Cover %			Frequency (%)	
	Mean	SD	Range	Quadrat	Plot
<i>Pleuraphis jamesii</i>	6.251	4.683	1.873-17.133	96.00	100
<i>Bouteloua eriopoda</i>	3.492	2.538	0.203-7.300	78.67	100
<i>Hesperostipa comata</i>	1.691	1.718	0.113-4.527	76.67	90
<i>Ericameria nauseosa</i>	0.387	0.352	0.020-1.087	28.67	100
<i>Salsola tragus</i> *	0.260	0.240	0.020-0.693	40.67	80
<i>Chenopodium leptophyllum</i>	0.115	0.267	0.003-0.850	16.00	50
<i>Sporobolus airoides</i>	0.980	0.240	0.233-0.750	3.33	20
<i>Sphaeralcea hastulata</i>	0.090	0.141	0.050-0.343	14.67	40
<i>Sporobolus airoides</i>	0.075	0.237	0.750-0.750	2.67	10
<i>Chamaesyce</i> spp. Group A	0.074	0.136	0.010-0.457	47.33	100
<i>Chamaesyce</i> spp. Group B	0.068	0.080	0.003-0.273	58.67	100
<i>Aristida havardii</i>	0.034	0.101	0.020-0.320	4.00	20
<i>Bouteloua curtipendula</i>	0.023	0.074	0.233-0.233	0.67	10
<i>Zinnia grandiflora</i>	0.017	0.031	0.003-0.093	10.00	40
<i>Chaetopappa ericoides</i>	0.016	0.020	0.003-0.060	16.67	90
<i>Senecio flaccidus</i>	0.011	0.017	0.020-0.050	3.33	40

Table 2. Cover of Functional Groups for Limy Upland Ecological Site. The cover of functional groups is expressed as a percentage. Components of total live vegetation are not strictly additive due to several factors: calculations are made from cover class midpoints, the various groups may overlap, and the cover values are estimated independently.

Functional Group	Foliar Cover (%)		
	Mean	SD	Range
Total Live Vegetation	14.19	4.56	8.90- 22.33
Perennial Grass	12.60	4.97	5.74- 20.83
Annual Grass	0	0	0
Forbs	0.72	0.60	0.05- 1.81
Shrubs, Dwarf Shrubs, Woody Vines	0.36	0.35	0- 1.09
Cacti, Succulents	0.01	0.02	0- 0.07
Standing Dead Herbaceous	6.17	2.46	2.80- 10.20
Standing Dead Woody	0.38	0.27	0.04- 0.85

shrubs, cacti/succulents and understory trees all comprise less than 1% each. Standing dead herbaceous cover is substantial (6.17%), while stand dead woody cover is less than 1%. Variability among plots is low, as indicated by relatively low standard deviations and narrow ranges.

A total of 41 species are recorded in this ecological site, with a mean species richness of 13.8 species per plot (Table 3a). Shannon diversity is 1.175, which is low. Values generally fall between 1.5 and 3.5 (Margalef 1972). This is the result of low species richness and dominance by a few species. Evenness is moderately low—0.449. The Evenness Index is bounded by 0 and 1, where a value of 1 indicates that all species are of equal abundance. Beta diversity is 3.203, which is moderately high. High values (greater than 5) indicate large differences among plots, whereas low values (less than

1) indicate similar composition among plots (McCune and Grace 2002).

When the diversity measures are recalculated using only native species, they are somewhat lower, except for beta diversity, which is higher (Table 3b). The species area curve (Figure 4) illustrates how species accumulate with increased area. The curve is only slightly concave, indicating a relatively high species richness at the finer spatial scales and low species richness at the coarser scales. (Compare this to Figure 8).

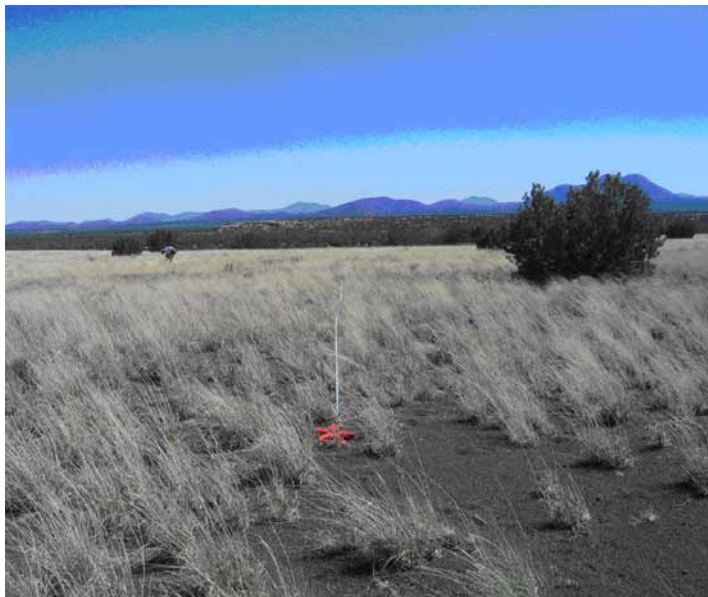


Figure 3. Photopoint from a plot in the Limy Upland Ecological Site. Note high grass cover, sparse junipers, and high cover of cinders.

Trees

Relative abundance of trees is expressed in terms of density and basal area. There is only one tree species

Table 3. Species Diversity for Limy Upland Ecological Site. Species diversity is expressed as mean, minimum and maximum species richness per plot, the total richness for the ecological site, Shannon-Weaver Diversity Index and the Evenness index. Metrics are presented for all species and only native species.

Table 3a. All Species				
Metric	Plot		Ecological Site	
	Mean (SD)	Range	Metric	
Richness	13.8 (2.4)	10 – 18	Richness	41
Shannon Diversity	1.175 (0.317)		β Diversity	3.203
Evenness	0.449 (0.114)			

Table 3b. Native Species				
Metric	Plot		Ecological Site	
	Mean (SD)	Range	Metric	
Richness	13.0(2.3)	9 – 17	Richness	40
Shannon Diversity	1.105(0.288)		β Diversity	3.333
Evenness	0.434(0.114)			

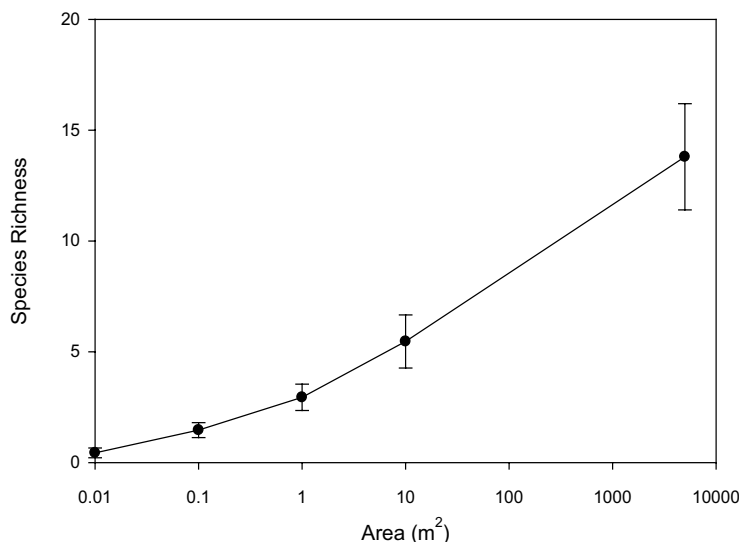


Figure 4. Mean Species Richness for Limy Upland Ecological Site at 5 spatial scales. Species richness is defined as the number of vascular species in a given area. Estimates are based on 10 plots with 15 quadrats each. The point at 5000 m² represents plot species richness. Error bars represent 1 standard deviation.

sampled within the ecological site: *Juniperus monosperma* (oneseed juniper). Table 4 and Figure 5 illustrate density and basal area of the overstory trees. Trees are sparse, and occurred in less than half the plots. Basal area was 2.65 m²/ ha and density is 12.4 stems/ha, which is very low. Snags are uncommon; only two snags occur in the plots. The tree structure indicates a variety of tree sizes with fewer larger individuals than smaller individuals. The error bars in Figure 5 are large, indicating large variability among plots. No seedlings or saplings occurred in the plots.

Soil Stability and Hydrologic Function

The amount of exposed soil is determined in two ways: soil surface feature cover estimates in quadrats and basal gap intercepts. The cover of surface features (Table 5) shows that the majority of the surface is covered with fine gravel (the volcanic cinders typically found throughout much of WUPA) and coarse gravel: 75.08% and 13.61%, respectively. Plant bases comprise 4.87%, and duff/litter comprises 3.42%.

Bare soil, undifferentiated crust, dead herbaceous base, dead woody base, cobbles and stones are minor components, comprising less than 1% each. There are no biological soil crusts (moss, lichen cyanobacteria) or woody debris.

The basal gap data (Table 6) show that 96.3% of transect length is gap; consequently 3.7% intersects plant bases. (Note the similarity

Table 4. Density and Basal Area of Trees by Species and Size Class for Limy Upland Ecological Site. Density is provided for seedlings (< 2.5 cm drc), saplings (2.5-14.9 cm drc) and overstory trees (≥15 cm drc), and is expressed in stems/ha. Basal area is provided for overstory trees and snags, and is expressed as m²/ha. Mean drc of trees is provided.

Species	Seedling Density	Sapling Density	Overstory Density	Snag Density	Overstory Basal Area	Snag Basal Area	Mean DRC
<i>Juniperus monosperma</i>	0	0	12.4	0.8	1.57	0.12	44.7

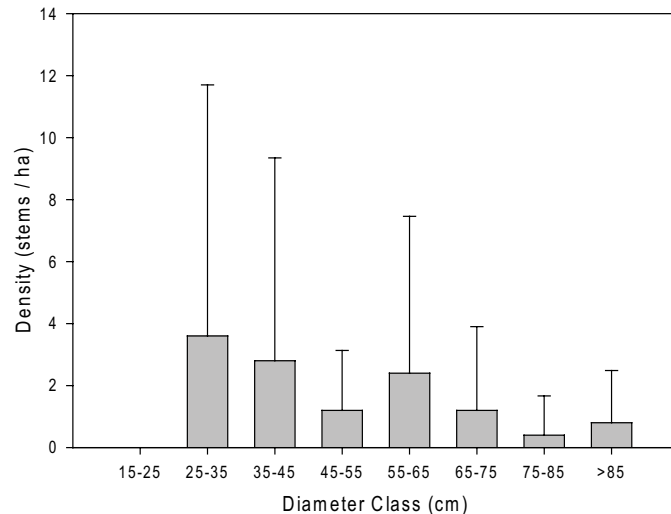


Figure 5. Tree size structure for Limy Upland Ecological Site. Density of *Juniperus monosperma* is expressed in stems/ha. Error bars represent 1 standard deviation.

Table 5. Surface Features Cover for Limy Upland Ecological Site. Cover of surface features is expressed as a percentage. The features do not add up to 100% because calculations are made from cover class midpoints, and the estimations have observer error.

Surface Feature	Cover (%)		
	Mean	SD	Range
Live Plant Base	4.87	1.60	2.23- 7.77
Dead Woody Base	0.02	0.02	0- 0.06
Dead Herbaceous Base	0.06	0.19	0- 0.59
Bare Soil	0.83	0.61	0.10- 2.04
Duff and Litter	3.42	1.67	1.48- 6.82
Undifferentiated Crust	1.35	1.35	0.07- 4.71
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	44.00- 87.50
Coarse Gravel (2cm – 7.5 cm)	13.61	15.40	1.17- 45.83
Cobble (7.5 cm – 25 cm)	0.65	0.53	0.07- 1.54
Stone, Boulder, Bedrock (>25 cm)	0.50	0.76	0- 2.40
Woody Debris	0	0	0- 0

between quadrat estimate and those resulting from basal gap intercept measurements). Large gap sizes are more frequent than smaller gaps (Figure 6). The median gap size is 68.4 cm. The percent of the transect length comprised by gaps decreases to 86.5% when only gaps greater than 50 cm are considered. These large gaps are important as these areas are most susceptible to wind and water erosion.

The SCPN Integrated Upland Monitoring program uses a soil aggregate stability procedure to test the erodibility of soils. Due to the high cover of cinders in many of the plots (fine and coarse gravel in Table 5), it was not feasible to collect surface soil samples for the soil aggregate stability test. It is presumed that the cover of cinders provides a high protective cover for wind and water erosion of soils.

Sandstone Upland Ecological Site

Herbaceous and Shrub Vegetation

The herbaceous and shrub vegetation of the WUPA Sandstone Upland Ecological Site is dominated by shrubs. Table 7 lists the 15 most abundant species, and shows that 3 of the 4 most abundant species are shrubs: *Artemisia filifolia*

Table 6. Basal Gaps for Limy Upland Ecological Site.

Basal The mean and standard deviation of each metric is calculated for the 10 plots in the ecological site.

Metric	Mean	(SD)
Gap Number	143.6	(33.3)
Median Gap Size (cm)	68.4	(11.4)
Percent of Transect in Gaps	96.3	(1.2)
Percent of Transect in Gaps ≥ 50 cm	86.5	(4.7)

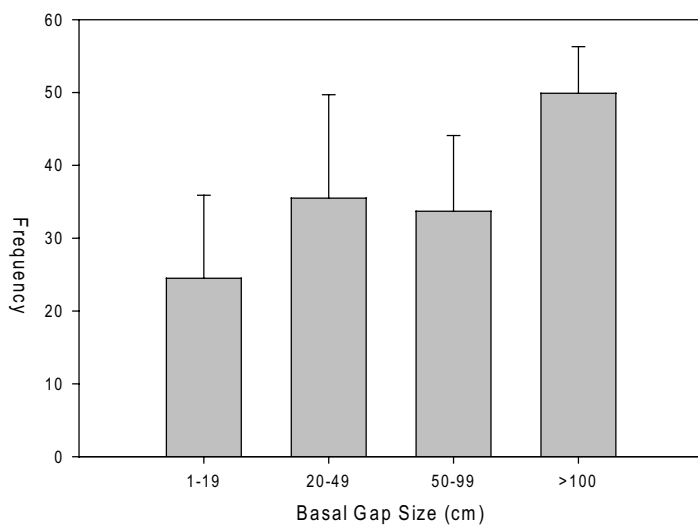


Figure 6. Basal Gap Size Distribution for Limy Upland Ecological Site. The frequency of basal gaps is shown for 4 size classes. Error bars represent 1 standard deviation.

(sand sagebrush), *Ephedra torreyana* (Torrey's jointfir), and *Fallugia paradoxa* (Apache plume). The low frequencies, in addition to the high standard deviations (relative to their means), demonstrate that shrub composition is variable. For example, *Artemisia filifolia* only occurs in 40% of the plots and *Fallugia paradoxa* occurs in 30% of the plots. Common grasses include *Pleuraphis jamesii* (James' galleta) and *Muhlenbergia porteri* (bush muhly). While both of these species occur in the majority of the plots, they exhibit large ranges in abundance. *Chamaesyce* spp. Group A (a grouping of three species of annual sandmats indeterminable in the field) is the most abundant forb. A complete species list is provided in Appendix B, and includes common names, plant families, mean covers and plot frequencies. Only 1 exotic species is found in the plots: *Salsola tragus* (Russian thistle). This only occurs in one plot and in very low abundance.

Functional group cover estimates (Table 8) demonstrate that the total foliar cover of the vegetation is quite low (5.38%), and confirms the dominance of shrubs (3.51% cover). Perennial grasses comprise 1.35% cover, and forbs comprise 0.44%. Annual grass and cacti/succulents are very sparse--less than 0.005%. The standard deviation and range of the perennial grasses is notably high, indicating large variation in grass cover among plots (see Figure 7). Standing dead woody cover was substantial relative to the live cover (2.47%), while standing dead herbaceous cover was less than 1%.

A total of 34 species are recorded in this ecological site, with a mean species richness of 12.8 species per plot (Table 9a). Shannon diversity is 1.505, which is low. Values generally fall between 1.5 and 3.5 (Margalef 1972). Evenness is moderately high—0.597. The Evenness Index is bounded by 0 and 1, where a value of 1 indicates that all species are of equal abundance. Beta diversity is 2.893, which is moderate. High values (greater than 5) indicate large differences among plots, whereas low values (less than 1) indicate similar composition among plots (McCune and Grace 2002). These indices change very little when they are recalculated for native species (Table 9b). The species area curve (Figure 8) illustrates how species accumulate with increase area. The concave shape of the curve indicates low species richness at the finer spatial scales.

Table 7. Cover and Frequency of Shrub and Herbaceous Species for the Sandstone Upland Ecological Site. Foliar cover of the fifteen most abundant vascular species, expressed as a percentage. All exotic species are included and are indicated by an asterisk. A complete list of species and their abundances is provided in Appendix A. The minimum range in foliar cover is provided for where the species occurs. (Many species do not occur in every plot of an ecological site; for these species, the minimum range of 0% is not provided).

Species	Foliar Cover %			Frequency (%)	
	Mean	SD	Range	Quadrat	Plot
<i>Artemisia filifolia</i>	1.161	1.510	2.453- 3.183	34.00	40
<i>Ephedra torreyana</i>	0.933	0.984	0.070- 3.440	40.00	100
<i>Pleuraphis jamesii</i>	0.777	1.145	0.023- 3.470	41.33	70
<i>Fallugia paradoxa</i>	0.633	1.392	0.423- 4.337	12.67	30
<i>Muhlenbergia porteri</i>	0.305	0.452	0.003- 1.323	28.00	80
<i>Chamaesyce</i> spp.	0.230	0.274	0.040- 0.793	44.00	70
<i>Ericameria nauseosa</i>	0.173	0.260	0.050- 0.833	11.33	60
<i>Atriplex confertifolia</i>	0.170	0.298	0.307- 0.803	18.00	30
<i>Bouteloua eriopoda</i>	0.111	0.231	0.003- 0.693	12.00	40
<i>Gutierrezia sarothrae</i>	0.106	0.130	0.020- 0.403	18.00	60
<i>Atriplex canescens</i>	0.064	0.105	0.050- 0.340	6.67	50
<i>Tetradlea coulteri</i>	0.049	0.076	0.020- 0.233	5.33	50
<i>Sporobolus airoides</i>	0.047	0.100	0.233- 0.240	3.33	20
<i>Sphaeralcea grossulariifolia</i>	0.035	0.067	0.003- 0.200	6.00	40
<i>Sphaeralcea parvifolia</i>	0.030	0.080	0.050- 0.253	2.00	20
<i>Salsola tragus</i> *	0.002	0.006	0.020-0.020	0.67	10

Table 8. Cover of Functional Groups for Sandstone Upland Ecological Site. The cover of various functional groups is expressed as a percentage. Components of total live vegetation are not strictly additive due to several factors: calculations are made from cover class midpoints, various components may overlap, and the cover values are estimated independently.

Functional Group	Foliar Cover (%)		
	Mean	SD	Range
Total Live Vegetation	5.38	2.95	1.00- 9.58
Perennial Grass	1.35	1.56	0- 4.72
Annual Grass	<0.01	<0.01	0- 0.003
Forbs	0.44	0.35	0.03- 1.07
Shrubs, Dwarf Shrubs, Woody Vines	3.51	1.87	0.71- 5.37
Cacti, Succulents	<0.01	0.01	0- 0.02
Standing Dead Herbaceous	0.82	0.88	0.003- 2.95
Standing Dead Woody	2.47	1.18	1.16- 4.43

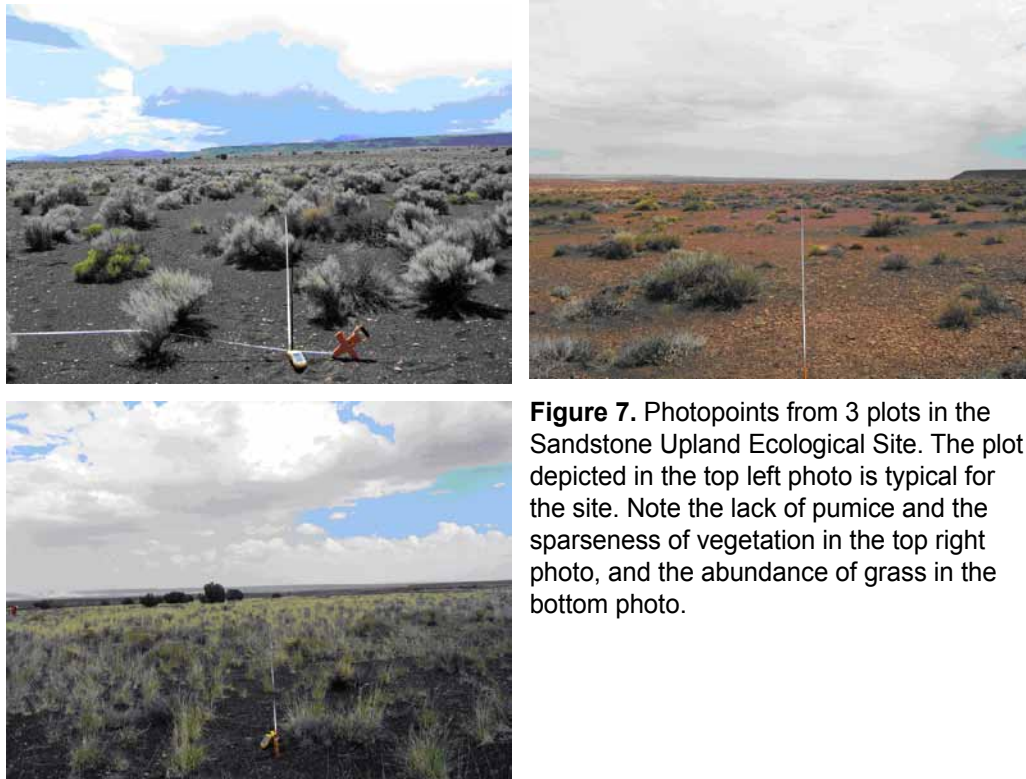


Figure 7. Photopoints from 3 plots in the Sandstone Upland Ecological Site. The plot depicted in the top left photo is typical for the site. Note the lack of pumice and the sparseness of vegetation in the top right photo, and the abundance of grass in the bottom photo.

Trees

Relative abundance of trees is expressed in terms of density and basal area. Only one tree species was sampled within the ecological site: *Juniperus monosperma*. Table 10 and Figure 9 illustrate density and basal area of the overstory trees. Trees were very sparse; 3 plots had a single tree in each. Basal area for both live trees and snags is 0.16 m²/ha and 0.12 m²/ha, respectively. Densities of live trees and snags are 1.2 stems/ha, and 0.4 stems/ha, respectively. Due to the small sample size, it is difficult to make generalizations about the tree structure in this site. No seedlings or saplings were observed in the plots.

Soil Stability and Hydrologic Function

The amount of exposed soil is monitored in two ways: soil surface feature cover estimates in quadrats and basal gap intercepts. The cover of surface features (Table 11) shows that the majority of the surface, 70.56%, is covered with fine gravel (cinders) with another 8.28% covered with coarse gravel, and 1.17% covered with cobbles. Bare soil and undifferentiated crust comprise 4.08 and 5.22%, respectively. Many of the features, undifferentiated crust in particular, show wide ranges and large standard deviations, indicating high variability. This suggests that several plots may be susceptible to erosion. Live plant base comprised 1.22% and dead woody base, dead herbaceous base, woody debris and stone comprised less than 1%. No biological soil crusts (moss, lichen and cyanobacteria) were observed.

The basal gap data (Table 12) show that 99.0% of transect length were composed of gap.

Consequently 1.0% intersects plant bases. (Note the similarity between quadrat estimates and those resulting from basal gap intercept measurements)he amount of plant base in Table 12 and the surface feature data in Table 10). The gaps are few and large: 30.4 in number with a median size of 494.9 cm. When only gaps greater than 50 cm are considered in the percentage of transect in gaps, the figure only drops to 97.9%. The size distribution of gaps (Figure 10) demonstrates the predominance of large size gaps.

Table 9. Species Diversity for Sandstone Upland Ecological Site.

Species diversity is expressed as mean, minimum and maximum species richness per plot, the total richness for the ecological site, Shannon-Weaver Diversity Index ,Evenness index, and Beta Diversity. Metrics are presented for all species and only native species.

Table 9a. All Species				
Metric	Plot		Ecological Site	
	Mean (SD)	Range	Metric	
Richness	12.8 (3.3)	9 – 20	Richness	34
Shannon Diversity	1.505 (0.259)		β Diversity	2.881
Evenness	0.597 (0.076)			

Table 9b. Native Species				
Metric	Plot		Ecological Site	
	Mean (SD)	Range	Metric	
Richness	12.7 (3.4)	8 – 20	Richness	33
Shannon Diversity	1.501 (0.262)		β Diversity	2.821
Evenness	0.598 (0.077)			

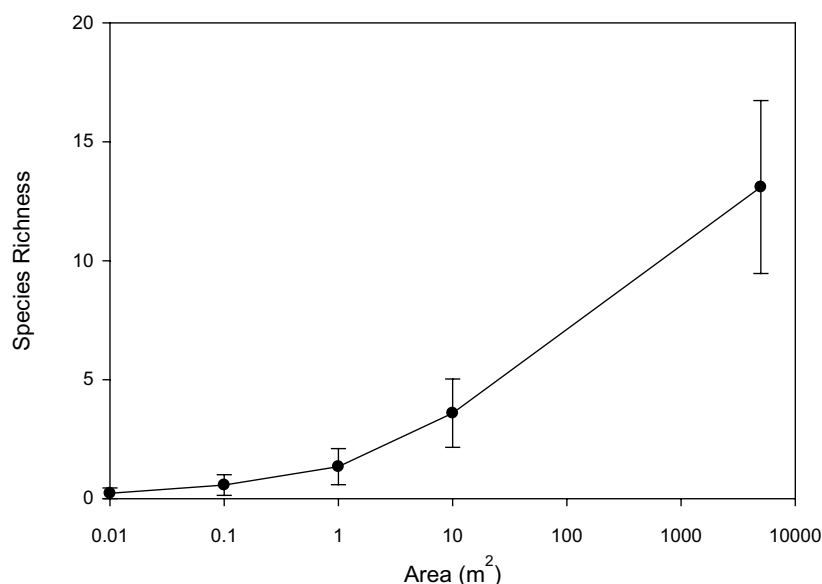


Figure 8. Mean Species Richness for Sandstone Upland Ecological Site. at 5 spatial scales. Species richness is the number of vascular species in a given area. Estimates are based on 10 plots with 15 quadrats each. Error bars represent 1 standard deviation.

The SCPN Integrated Upland Monitoring program uses a soil aggregate stability procedure to test the erodibility of soils. Due to the high cover of cinders in many of the plots, it was not feasible to collect surface soil samples for the soil aggregate stability test. It is presumed that the cover of cinders (fine and coarse gravel in Table 5) provides a high protective cover for wind and water erosion of soils.

Discussion

These data represent the first year baseline of sampling for the Limy Upland and Sandstone Upland Ecological Sites of WUPA. The two ecological sites are distinct from one another.

The Limy Upland Ecological Site is dominated by grasses, *Pleuraphis jamesii* in particular, with very low abundance of shrubs, forbs, trees and cacti/ succulents. Species diversity is low in terms of species richness, Shannon diversity and evenness. Only beta diversity is moderately high, indicating high heterogeneity among

Table 10. Density and Basal Area of Trees by Species and Size Class for the Sandstone Upland Ecological Site. Density is provided for seedlings (< 2.5 cm drc), saplings (2.5-14.9 cm drc) and overstory trees (≥15 cm drc), and is expressed in stems/ha. Basal area is provided for overstory trees and snags, and is expressed as m2/ha. Mean dbh of trees is provided.

Species	Seedling Density	Sapling Density	Over-story Density	Snag Density	Overstory Basal Area	Snag Basal Area	Mean DBH
<i>Juniperus monosperma</i>	0	0	1.2	0.4	0.16	0.12	41.0

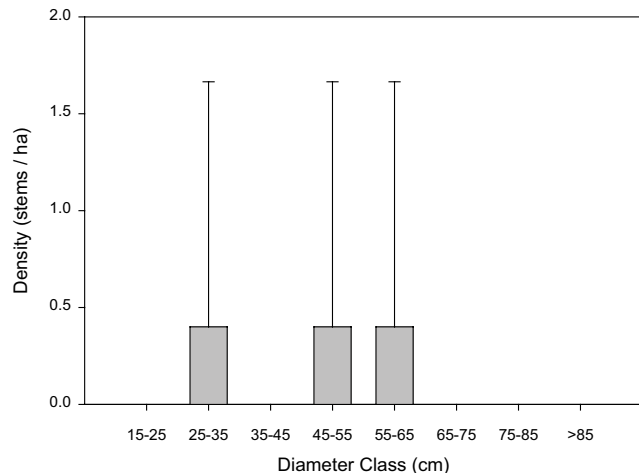


Figure 9. Tree size structure for the Sandstone Upland Ecological Site. Density of *Juniperus monosperma* is expressed in stems/ha. Error bars represent 1 standard deviation.

Table 11. Surface Features Cover for the Sandstone Upland Ecological Site. Cover of surface features is expressed as a percentage. The features do not add up to 100% due to the fact that calculations are made from cover class midpoints, and that the estimations have observer error.

Surface Feature	Cover (%)		
	Mean	SD	Range
Live Plant Base	1.22	0.98	0.02-2.93
Dead Woody Base	0.34	0.21	0.05-0.67
Dead Herbaceous Base	0.10	0.21	0-0.68
Bare Soil	4.08	3.99	0.09-11.15
Duff and Litter	4.09	1.86	1.17-7.31
Undifferentiated Crust	5.22	7.17	0.73- 24.37
Moss	0	0	0-0
Lichen	0	0	0-0
Cyanobacteria	0	0	0-0
Fine Gravel (0.2 cm-2 cm)	70.56	15.88	39.78-84.50
Coarse Gravel (2 cm-7.5 cm)	8.28	9.06	0.09-26.13
Cobble (7.5 cm-25 cm)	1.17	1.83	0-5.98
Stone, Boulder, Bedrock (>25 cm)	0.85	1.65	0-4.57
Woody Debris	0.08	0.18	0- 0.55

plots. Of the two non-native species present, *Salsola tragus* presents a threat. It is the fifth most abundant species, and has the potential to increase its abundance.

In contrast, the Sandstone Upland Ecological Site is dominated by shrubs, with low abundance of forbs, trees, and cacti/succulents and variable abundance of perennial grasses. While plot species richness is similar to the Limy Upland Ecological Site, Shannon diversity and Evenness are both higher, and ecological site richness and beta diversity are lower than the Limy Upland Ecological Site. This suggests that dominance is shared by a number of shrub species. *Salsola tragus* is the only non-native species in our plots and it is low in abundance.

Trees are low in abundance in both ecological sites. There are relatively more trees in the Limy Upland Ecological Site, but trees are sparse throughout our sampling areas.

Despite the high percentage of total transect length occupied by basal gaps, and by gaps greater than 50 cm in particular, both ecological sites are probably fairly resistant to wind and water erosion due to the high cover of cinders (fine and coarse gravel) on the soil surface. However, the high variation in bare soil and undifferentiated crust in the Sandstone Upland Ecological Site suggests a potential for erosion in some of the plots.

Our plan is to sample the quadrats and gap intercept transects annually for the next 3-5 years to determine the range of 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 previous year's data to demonstrate change in vegetation composition and structure, and change in hydrologic function and soil stability. More thorough trend analyses will be conducted once sufficient data have been collected.

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Appendix A

Complete species list for Limy Upland Ecological Site with foliar cover and frequency values. The one tree species is presented with basal area and frequency values. Exotic species are indicated by an asterisk. Annual *Chamaesyce* spp. that were not identifiable in the field to species were placed in one of two groups—Group A or Group B.

Herbaceous and Shrub Species				
Species	Common Name	Family	Foliar Cover (%)	Plot Frequency (%)
<i>Aristida havardii</i>	Havard's threeawn	Poaceae	0.034	20
<i>Aristida purpurea</i>	Fendler's threeawn	Poaceae	0.004	20
<i>Bouteloua curtipendula</i>	sideoats grama	Poaceae	0.023	10
<i>Bouteloua eriopoda</i>	black grama	Poaceae	3.492	100
<i>Caesalpinia drepanocarpa</i>	sicklepod holdback	Fabaceae	0.002	20
<i>Caesalpinia jamesii</i>	James' holdback	Fabaceae	0.002	20
<i>Chaetopappa ericoides</i>	rose heath	Asteraceae	0.016	90
<i>Chamaesyce</i> spp. Group A	annual sandmats	Euphorbiaceae	0.074	100
<i>Chamaesyce</i> spp. Group B	annual sandmats	Euphorbiaceae	0.068	100
<i>Chenopodium fremontii</i>	Fremont's goosefoot	Chenopodiaceae	<0.001	10
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0.115	50
<i>Ericameria nauseosa</i>	rubber rabbitbrush	Asteraceae	0.387	100
<i>Euphorbia exstipulata</i>	squareseed spurge	Euphorbiaceae	0.006	20
<i>Evolvulus nuttallianus</i>	shaggy dwarf morning-glory	Convolvulaceae	0.011	50
<i>Glandularia gooddingii</i>	southwestern mock vervain	Verbenaceae	0.007	10
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	<0.001	10
<i>Hesperostipa comata</i>	needle and thread	Poaceae	1.691	90
<i>Kallstroemia californica</i>	California caltrop	Zygophyllaceae	<0.001	10
<i>Krascheninnikovia lanata</i>	winterfat	Chenopodiaceae	0.005	10
<i>Lithospermum incisum</i>	narrowleaf stoneseed	Boraginaceae	<0.001	10
<i>Machaeranthera canescens</i>	hoary tansyaster	Asteraceae	0.001	10
<i>Opuntia</i> sp.	prickly pear	Cactaceae	0.005	10
<i>Opuntia whipplei</i>	Whipple cholla	Cactaceae	0.002	20
<i>Pleuraphis jamesii</i>	James' galleta	Poaceae	6.251	100
<i>Polanisia dodecandra</i>	red whisker clammyweed	Capparaceae	0.001	10
<i>Salsola tragus</i> *	prickly Russian thistle	Chenopodiaceae	0.260	80
<i>Senecio flaccidus</i>	threadleaf ragwort	Asteraceae	0.011	40
<i>Sphaeralcea</i> sp.	globemallow	Malvaceae	0.007	50
<i>Sphaeralcea hastulata</i>	spear globemallow	Malvaceae	0.090	40
<i>Sporobolus airoides</i>	alkali sacaton	Poaceae	0.075	10
<i>Sporobolus cryptandrus</i>	sand dropseed	Poaceae	0.001	10
<i>Sporobolus flexuosus</i>	mesa dropseed	Poaceae	0.023	10

Appendix A *continued*

Species	Common Name	Family	Foliar Cover (%)	Plot Frequency (%)
<i>Stephanomeria pauciflora</i>	brownplume wirelettuce	Asteraceae	0.002	10
<i>Stephanomeria thurberi</i>	Thurber's wirelettuce	Asteraceae	<0.001	10
<i>Tragopogon dubius</i> *	yellow salsify	Asteraceae	0.004	10
<i>Zinnia grandiflora</i>	Rocky Mountain zinnia	Asteraceae	0.017	40
Unknown WUPA011			0.005	10
Unknown WUPA08212007-1			<0.001	10

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Species	Common Name	Family	Foliar Cover (%)	Plot Frequency (%)
Unknown WUPA08212007-2			<0.001	10
Unknown WUPA08232007-5			<0.001	10

Tree Species

Species	Common Name	Family	Basal Area	Plot Frequency (%)
<i>Juniperus monosperma</i>	oneseed juniper	Cupressaceae	2.65	70

Appendix B

Complete species list for Sandstone Upland Ecological Site with foliar cover and frequency values. The one tree species is presented with basal area and frequency values. Exotic species are indicated by an asterisk.

Herbaceous and Shrub Species				
Species	Common Name	Family	Foliar Cover (%)	Plot Frequency (%)
<i>Achnatherum hymenoides</i>	Indian ricegrass	Poaceae	0.015	50
<i>Aristida purpurea</i>	Fendler's threeawn	Poaceae	0.014	20
<i>Artemisia filifolia</i>	sand sagebrush	Asteraceae	1.161	40
<i>Atriplex canescens</i>	fourwing saltbush	Chenopodiaceae	0.064	50
<i>Atriplex confertifolia</i>	shadscale saltbush	Chenopodiaceae	0.170	30
<i>Bouteloua eriopoda</i>	black grama	Poaceae	0.111	40
<i>Brickellia oblongifolia</i>	Mohave brickellbush	Asteraceae	0.011	40
<i>Chaetopappa ericoides</i>	rose heath	Asteraceae	0.001	20
<i>Chamaesaracha coronopus</i>	greenleaf five eyes	Solanaceae	0.001	10
<i>Chamaesyce</i> spp.	annual sandmats	Euphorbiaceae	0.230	70
<i>Chamaesyce fendleri</i>	Fendler's sandmat	Euphorbiaceae	0.007	40
<i>Chamaesyce micromera</i>	Sonoran sandmat	Euphorbiaceae	0.024	40
<i>Dasyochloa pulchella</i>	low woollygrass	Poaceae	0.020	40
<i>Ephedra torreyana</i>	Torrey's jointfir	Ephedraceae	0.933	100
<i>Ephedra viridis</i>	mormon tea	Ephedraceae	0.007	20
<i>Ericameria nauseosa</i>	rubber rabbitbrush	Asteraceae	0.173	60
<i>Eriogonum corymbosum</i>	crispleaf buckwheat	Polygonaceae	0.008	30
<i>Eriogonum leptocladon</i>	sand buckwheat	Polygonaceae	0.015	10
<i>Fallugia paradoxa</i>	Apache plume	Rosaceae	0.633	30
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	0.106	60
<i>Muhlenbergia porteri</i>	bush muhly	Poaceae	0.305	80
<i>Pleuraphis jamesii</i>	James' galleta	Poaceae	0.777	70
<i>Salsola tragus</i> *	prickly Russian thistle	Chenopodiaceae	0.002	10
<i>Sphaeralcea</i> sp.	globemallow	Malvaceae	0.001	20
<i>Sphaeralcea grossulariifolia</i>	gooseberryleaf globemallow	Malvaceae	0.035	40
<i>Sphaeralcea hastulata</i>	spear globemallow	Malvaceae	0.030	50
<i>Sphaeralcea parvifolia</i>	smallflower globemallow	Malvaceae	0.030	20
<i>Sporobolus airoides</i>	alkali sacaton	Poaceae	0.047	20
<i>Stephanomeria</i> sp.	wirelettuce	Asteraceae	0.006	50
<i>Stephanomeria pauciflora</i>	brownplume wirelettuce	Asteraceae	0.009	40
<i>Tetradlea coulteri</i>	Coulter's wrinklefruit	Verbenaceae	0.049	50
<i>Yucca angustissima</i>	narrowleaf yucca	Agavaceae	0.002	10
<i>Zinnia grandiflora</i>	Rocky Mountain zinnia	Asteraceae	0.002	10
Unknown WUPA08212007-1			<0.001	10

Appendix B *continued*

Tree Species				
Species	Common Name	Family	Foliar Cover (%)	Plot Frequency (%)
<i>Juniperus monosperma</i>	oneseed juniper	Cupressaceae	0.202	30