



Integrated Upland Vegetation and Soils Monitoring for Chaco Culture National Historical Park

2007 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2009/004



ON THE COVER

Sandy Loam Ecological Site at Chaco Culture National Historical Park
Photograph by Jim DeCoster

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July 2009

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

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The field work for this project was partially funded by the National Park Service through the Colorado Plateau CESU, Cooperative Agreement # H1200040002 (Tasks NAU-169, NAU-204, NAU-229).

This report is available from the Southern Colorado Plateau Network website (<http://science.nature.nps.gov/im/units/scpn/>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/NRPM>).

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Please cite this publication as:

DeCoster, J. K., and M. C. Swan. 2009. Integrated upland vegetation and soils monitoring for Chaco Culture National Historical Park: 2007 summary report. Natural Resource Data Series NPS/SCPN/NRDS—2009/004. National Park Service, Fort Collins, Colorado.

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 the Sandy Loam Upland ecological site as an important system to monitor at Chaco Culture National Historical Park (CHCU). This ecological site comprises a large area of the upland grassland systems in the park. It faces a number of threats, including soil erosion, invasion of non-native species and climate change.

In 2007 the SCPN Integrated Upland Monitoring program began upland monitoring at CHCU. The purpose of this report is to document monitoring activities in the 2007 field season and summarize the data that were collected.

Methods

Sampling Frame

The sampling frame was derived from the Sandy Loam ecological site developed by the US Natural Resources Conservation Service (NRCS). 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 technology, several modifications were made to the

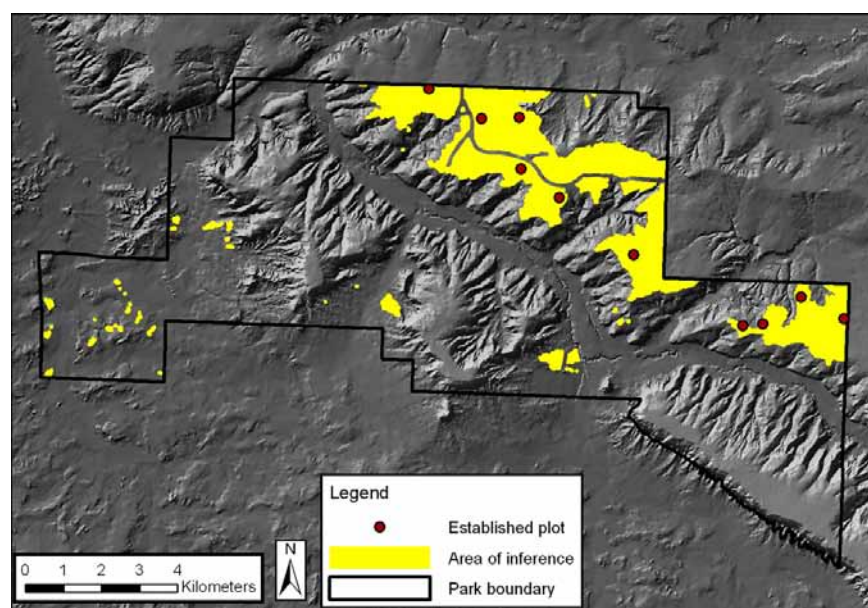


Figure 1. Sampling frame of Sandy Loam Ecological Site with the 10 plots established in 2007.

representation of the ecological site, including the removal of roads and slopes greater than 20% (Figure 1). A set of spatially distributed sampling points was created using the Generalized Random-Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). Park staff reviewed the sampling points and rejected those points that landed within close proximity of archaeological sites. Before establishing a plot, the Integrated Upland crew

conducted an ecological site assessment at each sampling point and rejected the site if it (1) did not occur within the ecological site, (2) had a slope exceeding 20%, or (3) contained a major disturbance.

Field Methods

The SCPN Upland Monitoring crew implemented monitoring at CHCU in 2007, establishing 10 plots. All plots were installed and read in the latter part of October. 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. Data were collected on three 50-m transects, spaced 25 meters apart.

Shrub and Herbaceous Vegetation

Along each transect, shrub and herbaceous vegetation is 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 is recorded for each nested sub-quadrat. For each individual herbaceous and shrub species, percent cover is estimated in the 10 m² quadrat and recorded as one of 12 cover classes. Percent cover for functional groups (e.g. perennial grasses, forbs, shrubs) is also estimated in the largest quadrat and recorded as one of 12 cover classes.

Overstory Trees and Saplings

No trees were observed in any of the plots.

Soil Stability and Hydrologic Function

Basal gaps are measured in each of the transects providing measures of the amount of bare soil. A soil aggregate stability test is conducted, using 18 soil samples collected along the transects. Percent cover of soil surface features is 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 summary and analysis is the plot, hence, all data are summarized at the level of the plot. In order to calculate summary statistics for the ecological site, means and standard deviations are calculated from the plot means.

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. 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). 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 in the site, and recalculated 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:

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

where p_i is the mean cover of each species.

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.

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 by gaps ≥ 50 cm, (4) number of gaps by size class and (5) total number of gaps. Mean and SD are calculated for each metric.

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

Results

Herbaceous and Shrub Vegetation

The vegetation of the CHCU Sandy Loam Upland ecological site is dominated by grasses. Table 1 lists the 15 most abundant species, and shows that four of the five most abundant species are perennial grasses: *Bouteloua gracilis* (blue grama), *Pleuraphis jamesii* (James' galleta), *Sporobolus cryptandrus* (sand dropseed), and *Achnatherum hymenoides* (Indian ricegrass). *Sporobolus cryptandrus* is locally abundant in half of the plots. The most abundant shrub is *Gutierrezia sarothrae* (broom snakeweed), but other shrubs are common including *Atriplex canescens* (fourwing saltbush), *Chrysothamnus Greenei* (Greene's rabbitbrush) and *Krascheninnikovia lanata* (winterfat). Forbs are relatively uncommon, the most abundant being *Sphaeralcea coccinea* (scarlet globemallow). The dominant species show moderate variability through their standard deviation and ranges. The standard deviations tend to increase relative to their means as the plot and quadrat frequencies decrease. A complete list of species is provided in Appendix A and includes their common name, family, percent cover, and plot frequency.

Only 2 non-native species are found in the plots, both in low abundance. *Bromus*

Table 1. Cover and Frequency of Shrub and Herbaceous Species. Foliar cover of the fifteen most abundant vascular species, expressed as a percentage. 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 not provided).

Species	Foliar Cover %			Frequency (%)	
	Mean	SD	Range	Quadrat	Plot
<i>Bouteloua gracilis</i>	6.939	3.945	1.673-12.167	84.00	100
<i>Pleuraphis jamesii</i>	4.679	2.476	0.393-8.050	85.33	100
<i>Gutierrezia sarothrae</i>	2.083	1.682	0.410-5.700	82.00	100
<i>Sporobolus cryptandrus</i>	1.385	2.274	0.04-5.737	36.67	50
<i>Achnatherum hymenoides</i>	0.946	1.091	0.043-3.617	65.33	100
<i>Atriplex canescens</i>	0.670	0.408	0.107-1.127	40.67	100
<i>Sporobolus airoides</i>	0.629	0.874	0.137-2.157	46.00	60
<i>Chrysothamnus Greenei</i>	0.697	0.774	0.020-2.340	33.33	80
<i>Elymus elymoides</i>	0.396	0.673	0.003-2.250	35.33	100
<i>Krascheninnikovia lanata</i>	0.387	0.548	0.070-1.317	19.33	70
<i>Sphaeralcea coccinea</i>	0.256	0.183	0.013-0.550	67.33	100
<i>Artemisia filifolia</i>	0.219	0.539	0.500-1.687	4.00	20
<i>Artemisia frigida</i>	0.183	0.301	0.050-0.863	22.00	50
<i>Plantago patagonica</i>	0.139	0.091	0.020-0.267	84.67	100
<i>Artemisia bigelovii</i>	0.112	0.302	0.050-0.967	3.33	30
<i>Bromus tectorum</i> *	0.032	0.059	0.003-0.187	14.00	60
<i>Salsola tragus</i> *	0.018	0.050	0.020-0.160	9.33	20

tectorum (cheatgrass) occurred in 60% of the plots and *Salsola tragus* (prickly Russian thistle) occurred in 20% of the plots.

The overall cover of herbs and shrubs is low, comprising less than 25% (Table 2). The cover of the functional groups confirms the dominance of perennial grasses. The total live cover is shown to be 22.19%, and perennial grasses comprise 16.51% of that cover. Shrubs comprise 4.31%. Forbs, annual grasses and cacti/succulents each comprise less than 1% foliar cover. Standard deviations are relatively low compared with standard deviations of species. Standing dead herbaceous cover is relatively high with 8.22%. This may be due to sampling occurring in late October after a frost, making it difficult to distinguish the previous year's dead herbaceous cover from the current year's senesced cover. Standing dead woody cover is low at 1.55%.

A total of 41 species are recorded in this ecological site, with a mean species richness of 20.4 species per plot (Table 3a). Shannon diversity is 1.827, which is low. Values generally fall between 1.5 and 3.5 (Margalef 1972). Evenness is moderate. 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 2.113, which is also moderate. High values (greater than 5) indicate large differences among plots, whereas low values (less than 1) indicate similar composition among plots (McCune and

Table 2. Cover of Functional Groups. 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 cover values are estimated independently.

Functional Group	Foliar Cover (%)		
	Mean	SD	Range
Total Live Vegetation	22.19	3.82	18.00-27.67
Perennial Grass	16.51	5.65	9.47-24.67
Annual Grass	0.10	0.10	0.03-0.36
Forbs	0.78	0.43	0.27-1.87
Shrubs, Dwarf Shrubs, and Woody Vines	4.31	2.15	1.48-8.63
Cacti, Succulents	0.11	0.12	0-0.34
Standing Dead Herbaceous	8.22	2.47	4.17-12.00
Standing Dead Woody	1.55	0.59	0.55-2.15

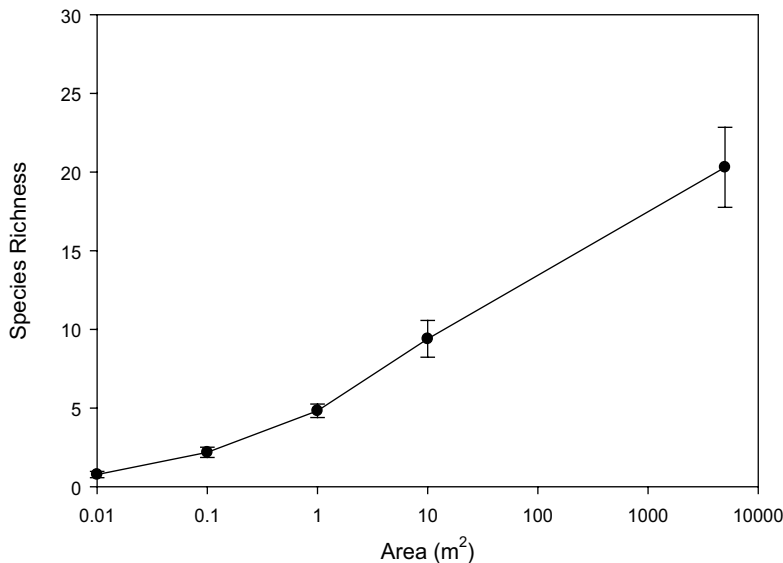


Figure 2. Mean Species Richness at 5 spatial scales. Species richness is defined as the number of vascular species in a given area. Estimates are based on 10 plots with 15 quadrats each. The point at 5000 m² represents plot species richness. Error bars represent 1 standard deviation.

This is relatively high for grasslands and shrublands of this region. Duff/litter comprises 9.09%. Rock components, differentiated biological soil crust components (moss, and cyanobacteria) and dead woody base all comprise less than 1%. Standard deviations and ranges are relatively low.

The basal gap data (Table 5) show that 93.0% of transect length is composed of gap. Consequently 7.0% intersects plant bases. (Note that quadrat cover estimates yielded higher

Grace 2002). When these indices are recalculated using only native species most of the indices are lowered by a small amount, except evenness, which shows a slight increase (Table 3b). The species area curve (Figure 2) illustrates how species accumulate with increased area. The generally linear shape of the species area curve is fairly atypical of grasslands and shrublands in the region. In most of the grassland and shrubland sites we monitor, this curve has a concave shape, indicating low species richness at fine spatial scales (1 m² and smaller). The linear shape for this site indicates relatively high species richness at small spatial scales.

Soil Stability and Hydrologic Function

The amount of exposed soil is monitored in two ways: surface feature cover estimates in quadrats and basal gap intercepts. The cover of surface features (Table 4) shows that the majority of the soil surface is exposed as undifferentiated crust (65.62%) and bare soil (9.35%). Live plant bases comprise 9.87% of the surface, and dead herbaceous bases comprise an additional 4.31%.

Table 3. Species Diversity. Species diversity is expressed as mean 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 3a. All Species					
Metric	Plot			Ecological Site	
	Mean	(SD)	Range	Metric	
Richness	20.4	(2.6)	17 – 24	Richness	41
Shannon Diversity	1.827	(0.319)		β Diversity	2.113
Evenness	0.608	(0.105)			
Table 3b. Native Species					
Metric	Plot			Ecological Site	
	Mean	(SD)	Range	Metric	
Richness	19.6	(2.55)	16 – 23	Richness	39
Shannon Diversity	1.815	(0.312)		β Diversity	2.097
Evenness	0.613	(0.109)			

Table 4. Surface Features Cover. The 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	9.87	2.71	4.27-13.23
Dead Woody Base	0.49	0.28	0.09-0.90
Dead Herbaceous Base	4.31	1.69	2.11-7.17
Bare Soil	9.35	6.31	2.64-20.17
Duff and Litter	9.09	3.03	4.43-13.93
Undifferentiated Crust	65.62	13.22	47.17-82.50
Moss	0.08	0.25	0-0.78
Lichen	0	0	0-0
Cyanobacteria	0.01	0.02	0-0.05
Fine Gravel (0.2 cm- 2cm)	0.40	0.59	0.02-1.69
Coarse Gravel (2cm – 7.5 cm)	0.20	0.35	0-1.14
Cobble (7.5 cm – 25 cm)	0.04	0.08	0-0.22
Stone, Boulder, Bedrock (>25 m)	0.03	0.09	0-0.28
Woody Debris	0	0	0-0

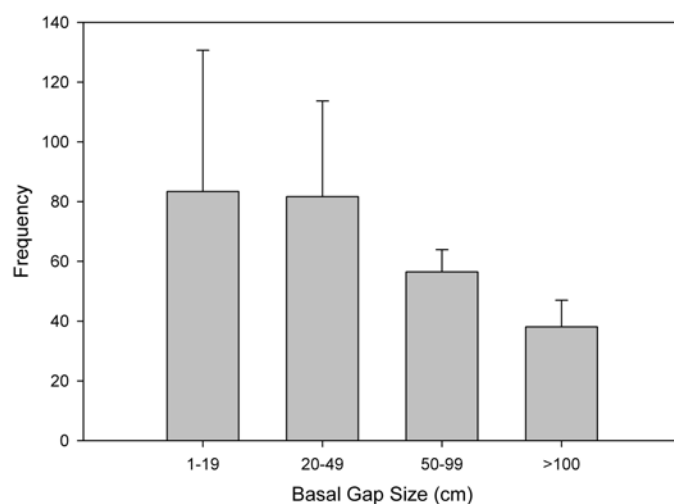


Figure 3. Basal Gap Size Distribution. The frequency of basal gaps is shown for 4 size classes. Error bars represent 1 standard deviation.

Table 5. Basal Gaps. Basal gaps are measured along three 50 m transects in each plot. The mean and standard deviation of each metric is calculated for the 10 plots in the ecological site.

Metric	Mean	(SD)
Gap Number	259.7	(74.2)
Median Gap Size (cm)	38.4	(10.5)
Percent of Transect in Gaps	93.0	(2.4)
Percent of Transect in Gaps $\geq$ 50 cm	69.6	(12.2)

Table 6. Soil Stability. Mean soil stability rating by cover. 18 points were measured in each of the 10 plots. Ratings range from 1-6: 1 being the lowest stability and 6 being the highest.

	Soil Stability Rating	
	Mean	(SD)
Cover	4.14	(0.83)
No Cover	2.91	(0.47)
Total	3.61	(0.62)

plant base cover values than basal gap intercept methods—9.87% for live plant bases and 4.31% for dead plant bases). While all four gap size classes are represented (Figure 3), the smaller gap size classes are the most abundant. This results in a relatively low median gap size (38.4 cm) and a substantially lower figure for percentage of transect length comprised of gaps greater than 50 cm – 69.6%. This is important as it is in the larger gaps that the soil is most susceptible to water and wind erosion.

Soil aggregate stability provides a measurement of erodibility of soil (Table 6). The mean rating is 3.61, which is considered a moderate rating. Soil occurring under vegetative cover has a higher stability rating than bare soil without cover: 4.14 compared to 2.91.

Discussion

These data represent the first year baseline of sampling for the Sandy Loam ecological site of CHCU. This ecological site is a moderately diverse grassland. Dominant grasses include *Bouteloua gracilis*, *Pleuraphis jamesii*, *Sporobolus cryptandrus*, and *Achnatherum hymenoides*; common shrubs include *Gutierrezia sarothrae*, *Atriplex canescens*, *Chrysothamnus Greenei* and *Krascheninnikovia lanata*. Only two non-native species were recorded, *Bromus tectorum* and *Salsola tragus*, neither of which is abundant. The species indices and species area curve indicate that this is a moderately diverse grassland.

Soil aggregate stability and the amount of exposed soil are means by which to quantify the potential of the site for soil erosion. While there is some potential for soil erosion on this ecological site, it doesn't appear to be critical. The moderate rating for soil

aggregate stability is buffered by the relatively small median gap size.

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 with foliar cover and frequency values. Non-native species are indicated by an asterisk (*).

Species	Common Name	Family	Foliar Cover (%)	Plot Frequency (%)
<i>Achnatherum hymenoides</i>	Indian ricegrass	Poaceae	0.946	100
<i>Aristida purpurea</i>	Fendler's threeawn	Poaceae	0.101	50
<i>Artemisia bigelovii</i>	Bigelow sage	Asteraceae	0.112	30
<i>Artemisia filifolia</i>	sand sagebrush	Asteraceae	0.219	20
<i>Artemisia frigida</i>	prairie sagewort	Asteraceae	0.183	50
<i>Astragalus</i> spp.	milkvetch	Fabaceae	0.002	40
<i>Atriplex canescens</i>	fourwing saltbush	Chenopodiaceae	0.670	100
<i>Bouteloua gracilis</i>	blue grama	Poaceae	6.939	100
<i>Bromus tectorum</i> *	cheatgrass	Poaceae	0.032	60
<i>Chaetopappa ericoides</i>	rose heath	Asteraceae	0.055	70
<i>Chamaesyce</i> spp.	sandmat	Euphorbiaceae	0.004	30
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0.045	50
<i>Chrysothamnus Greenei</i>	Greene's rabbitbrush	Asteraceae	0.697	80
<i>Echinocereus triglochidiatus</i>	kingcup cactus	Cactaceae	0.005	10
<i>Elymus elymoides</i>	squirreltail	Poaceae	0.396	100
<i>Ericameria nauseosa</i>	rubber rabbitbrush	Asteraceae	0.080	20
<i>Eriogonum cernuum</i>	nodding buckwheat	Polygonaceae	0.004	10
<i>Evolvulus nuttallianus</i>	shaggy dwarf morning-glory	Convolvulaceae	<0.001	10
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	2.084	100
<i>Hesperostipa comata</i>	needle and thread	Poaceae	0.066	70
<i>Hymenopappus filifolius</i>	fineleaf hymenopappus	Asteraceae	<0.001	10
<i>Krascheninnikovia lanata</i>	winterfat	Chenopodiaceae	0.387	70
<i>Lathyrus eucosmus</i>	bush vetchling	Fabaceae	0.001	20
<i>Lycium pallidum</i>	pale desert-thorn	Solanaceae	0.028	10
<i>Machaeranthera canescens</i>	hoary tansyaster	Asteraceae	0.008	30
<i>Monroa squarrosa</i>	false buffalograss	Poaceae	0.003	20
<i>Muhlenbergia torreyi</i>	ring muhly	Poaceae	0.066	50
<i>Opuntia polyacantha</i>	El Paso pricklypear	Cactaceae	0.106	90
<i>Phacelia</i> spp.	phacelia	Hydrophyllaceae	0.056	40
<i>Plantago patagonica</i>	woolly plantain	Plantaginaceae	0.139	100
<i>Pleuraphis jamesii</i>	James' galleta	Poaceae	4.679	100
<i>Salsola tragus</i> *	prickly Russian thistle	Chenopodiaceae	0.018	20
<i>Schkuhria multiflora</i>	manyflower false threadleaf	Asteraceae	0.008	30

Appendix A *continued*

Species	Common Name	Family	Foliar Cover (%)	Plot Frequency (%)
<i>Sphaeralcea</i> spp.	globemallow	Malvaceae	0.014	10
<i>Sphaeralcea coccinea</i>	scarlet globemallow	Malvaceae	0.256	100
<i>Sporobolus airoides</i>	alkali sacaton	Poaceae	0.629	60
<i>Sporobolus cryptandrus</i>	sand dropseed	Poaceae	1.385	50
<i>Stephanomeria pauciflora</i>	brownplume wirelettuce	Asteraceae	<0.001	10
<i>Vulpia octoflora</i>	sixweeks fescue	Poaceae	0.076	100
Unknown CHCU10202007-2			0.002	10
Unknown PEFO10202007-4			0.001	10
Unknown PEFO10202007-5			<0.001	10