



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

2011 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2013/516



ON THE COVER

Integrated upland monitoring in Chaco Culture National Historical Park
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1 Introduction and background

The National Park Service Inventory and Monitoring (I&M) Program was designed to determine the status and monitor the conditions of park natural resources, providing park managers with a scientific foundation that informs resource management decisions. The Southern Colorado Plateau Network (SCPN) is monitoring vegetation and soils as overall indicators of upland ecosystem integrity (Thomas et al. 2006).

SCPN and park staff selected the Sandy Loam ecological site for long-term monitoring of upland vegetation and soils at Chaco Culture National Historical Park (CHCU). An ecological site is a landscape division with characteristic soils, hydrology, plant communities, and disturbance regimes and responses, and its classification is based on soil survey data (Butler et al. 2003). The Sandy Loam ecological site comprises a large area of the upland grassland ecosystems at CHCU. It faces numerous threats, including soil erosion, climate change, and invasion by nonnative species.

In 2007, the SCPN integrated upland monitoring project began its work at CHCU with the installation of 10 plots in the Sandy Loam ecological site. We sampled vegetation in nested quadrats and measured basal gaps annually for 3 years to determine the range of temporal variability for key metrics. In 2010 and 2011 we established and sampled 20 additional plots, 6 in 2010 and 14 in 2011. This brings our total for this ecological site to 30 established plots. In this report, we document monitoring activities in the 2011 field season and summarize the data collected between 2007 and 2011 to describe baseline conditions for the vegetation and soils in the Sandy Loam ecological site at CHCU.

2 Methods

2.1 Sampling frame

We derived our base sampling frame (fig. 1) from the map of the Sandy Loam ecological site, which was developed by the U.S. Natural Resources Conservation Service (see appendix A of DeCoster et al. 2012). The sampling frame is the area from which we randomly select our sites, and hence the area to which statistical inferences can be made. To make final adjustments to our sampling frame, we modified the map of the ecological site using Geographical Information System (GIS) technology by removing areas within 100 m of roads and areas exceeding 20% slope.

We generated a set of spatially distributed sampling points using the Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). Park staff reviewed the sampling points and rejected those points that landed too close to archeological sites and other sensitive resources. The integrated upland crew visited the points in consecutive order and conducted an ecological site assessment, rejecting sites that deviated substantially from the ecological site, had a slope greater than 20%, or contained an archeological site or major disturbance. They rejected 4 points: 2 points were in proximity to archeological sites, one was in proximity to a power line and associated road, and one point fell in an inaccessible area.

2.2 Field methods

The SCPN integrated upland crew established 10 monitoring plots in 2007, and resampled these 10 plots in 2008 and 2009. The crew established 6 additional plots in 2010 and 14 additional plots in 2011. The 2010 and 2011 plots were each sampled only once, during the year they were established. In 2007 we conducted our field work in the latter part of October; in all other years we conducted our field work in early October.

Integrated upland monitoring plots are 0.50 ha in size, measuring 71 × 71 m, and consist of 3 parallel 50 m transects spaced 25 m apart. We collected data for shrub and herbaceous species composition, soil cover and soil stability on all 3 transects within each plot.

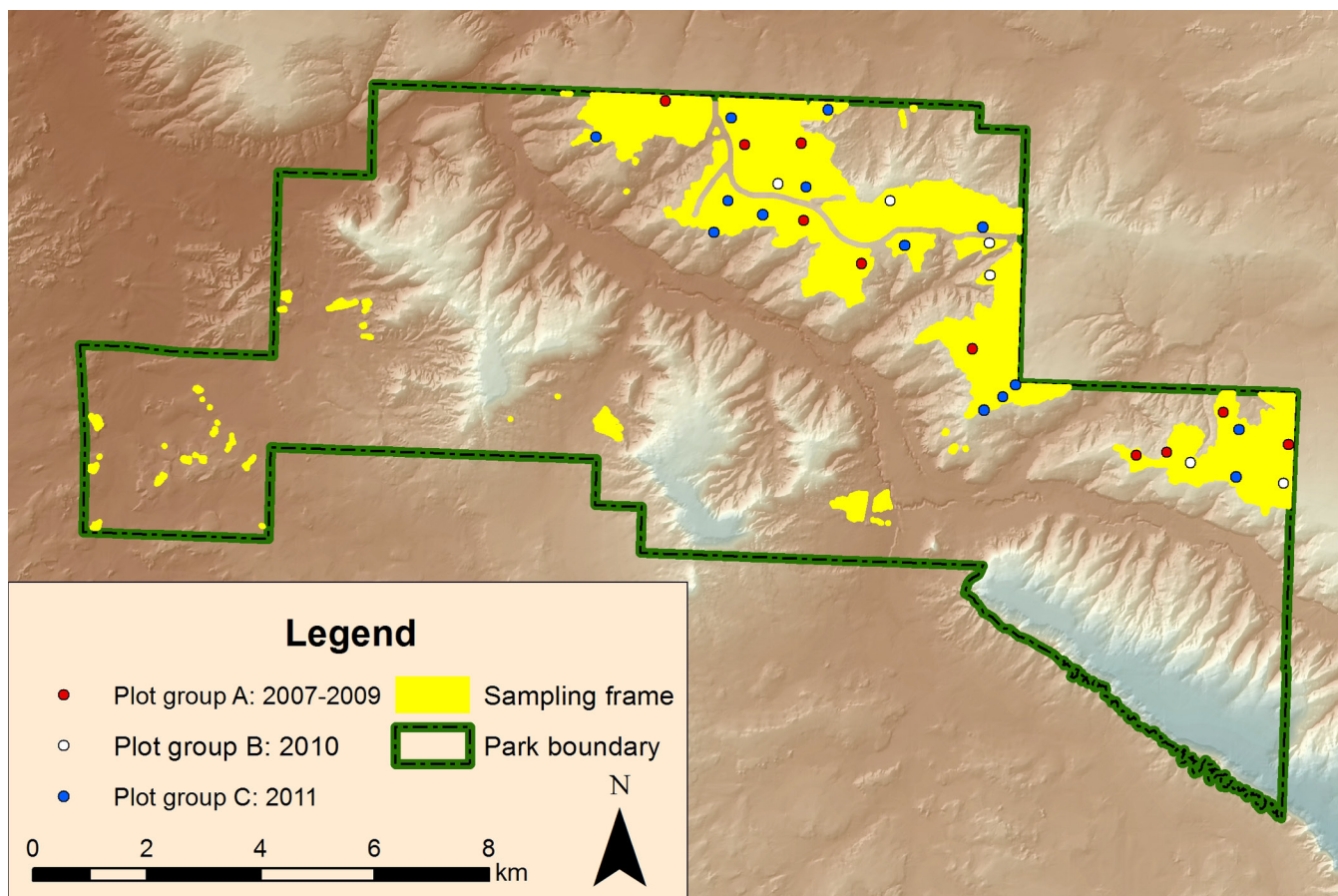


Figure 1. Sampling frame of the Sandy Loam ecological site at CHCU with the 10 plots established in 2007, the 6 plots established in 2010, and the 14 plots established in 2011.

During establishment of new plots in 2007, 2010 and 2011, we collected the full suite of data. When we remeasured the original 10 plots in 2008 and 2009, we collected data for all metrics except for soil aggregate stability. Field methodology is provided in detail in the SCPN integrated upland monitoring protocol (DeCoster et al. 2012).

2.2.1 Vegetation

No trees occurred in our plots. We sampled shrub and herbaceous vegetation within 5 sets of nested quadrats at 10 m intervals along each transect. The largest quadrat size was 10 m² (2 × 5 m), with 4 smaller quadrats nested inside (0.01 m², 0.1 m², 1 m², 5 m²). We recorded the presence of each herbaceous and shrub species within each nested sub-quadrat. We estimated the percent cover of each species in the 10 m² quadrat and assigned it to 1 of 12 cover classes (e.g., 2%–5%, 5%–10%, etc.). We also estimated the percent cover for functional groups (e.g., perennial grasses, forbs, shrubs) in the 10 m² quadrats and recorded the cover class. We collected these data in the initial 10 plots in 2007, 2008 and 2009, and collected the same data for the 6 plots established in 2010 and the 14 plots established in 2011.

2.2.2 Soil stability and hydrologic function

We estimated the percent cover of soil surface features in the 1 m² quadrats along the transects, and recorded the cover in 1 of 12 cover classes. We measured basal gaps as the length of bare ground between plant bases along each transect. We collected both soil surface feature and basal gap data for 3 years in the plots established in 2007, and for one year each in the plots established in 2010 and 2011. In 2011, however, we modified our methods, measuring only gaps 20 cm and larger. We also conducted a soil aggregate stability test one time in all plots, using 18 soil samples per plot collected along the transects. For these we noted whether there was vegetation cover over the sample point.

2.3 Data summary

In this report, we summarized data for all 30 plots as the ecological site mean. These data represent the baseline conditions for the vegetation and soils in the Sandy Loam ecological site. We also compare the 3 plot groups to one another. It must be stressed that the differences between these 3 plot groups do not represent change over time, but rather indicate differences in composition and structure resulting largely from spatial variation. We refer to the 3 groups of plots as plot group A for the 10 plots established in 2007 (and resampled in 2008 and 2009), plot group B for the 6 plots established in 2010, and plot group C for the 14 plots established in 2011.

The sample unit for summary and analysis is the plot; hence, we summarized data at the level of the plot. For most metrics, we then calculated the mean and standard deviation for plot groups and for the ecological site from the plot means. For plot group A, where there were 3 years of data, we calculated the mean value and standard deviation for the 10 plots for each year, and then calculated the mean of the means and the mean of the standard deviations for the 3 years. Metrics with 3 years of data include species cover and frequency, functional group cover, soil surface features and basal gaps. For plot group B and plot group C, we calculated the mean and standard deviation based on a single year of data. We then calculated the ecological site means from all 30 plots, where the values for each of the 10 plots from plot group A are averaged across all 3 years. Three metrics—plot frequency, ecological site richness and beta diversity—were not calculated using plot means and therefore were summarized differently. We discuss how we summarized these data below in section 2.3.1 and 2.3.2.

2.3.1 Species cover and frequency

For herbaceous and shrub vegetation, percent foliar cover was estimated for each species from the cover class midpoints, e.g., 7.5% for cover class 5%–10%. Mean percent foliar cover was calculated for each plot, the 3 plot groups and the ecological site. Mean cover and standard deviation of functional groups and surface features were calculated in a similar fashion. Species frequency was calculated for quadrats (mean percentage of 10 m² quadrats per plot where the species occurs) and for plots (percentage of plots where the species occurs). We calculated plot frequency for all 30 plots at the ecological site using a weighted mean based on the 3-year mean value for plot group A, and the single year values for plot group B and plot group C.

2.3.2 Species diversity

Four diversity measures were calculated for herbaceous and shrub species for each year (Magurran 1988), first for all species and then for native species only:

(1) Species richness (S) is the number of species at a given spatial scale. This was calculated at the level of the plot and at 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 (E) 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:

$$S_e / (S_p - 1)$$

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.

For plot richness, Shannon diversity, and evenness, the mean was calculated for each plot, and then for the plot groups and the ecological site. For ecological site richness and beta diversity, calculations were more complicated. Plot group A values were means based on averaging across all 3 years of sampling. Plot group B and plot group C values were each based on the one year of sampling at those plots; thus they are not means. The values for all plots combined (ecological site mean) were based on combining data across all 3 plot groups, using only one year of data from plot group A (the year with the median Shannon diversity value). Thus, ecological site level values are not means for the ecological site richness and beta diversity metrics.

2.3.3 Basal gaps

We calculated the percentage of the transects in each plot comprised of 3 gap sizes: 20 to <50 cm, 50 to <100 cm and ≥ 100 cm. We then calculated the mean and standard deviation for each size class within plot groups, and for the ecological site. Because we used a slightly different method for collecting these data in 2011, we were not able to compare the following metrics with those reported in previous years: number of gaps, median gap size, and percentage of transects comprised of plant bases.

2.3.4 Soil stability

We calculated the mean soil aggregate stability index for each plot. The index was also calculated separately for samples with vegetative cover and for samples without vegetative cover. We then calculated the mean and standard deviation for the plot groups and then for the ecological site.

3 Results

We describe results generally for the ecological site mean based on all plots, but specify whenever data comes from only one of the plot groups.

3.1 Vegetation composition

Perennial grasses dominated the Sandy Loam ecological site at CHCU. Perennial grasses had a mean cover of 10.87%, while the mean total live foliar cover was 14.56% (table 1 and fig. 2). The mean foliar cover of shrubs was 2.77%. The other living functional groups had less than 1% mean cover. Mean cover of standing dead herbaceous was 4.68%, and mean cover of standing dead woody was 2.06%. The mean covers of functional groups were similar among the plot groups, with the exception of total live foliar cover and perennial grasses, which were much lower in plot group C. These differences, however, were offset by the large standard deviations, which indicate large among-plot variability.

We examine species-level data for the most abundant herbs and shrubs in Figure 3 (foliar cover) and Table 2 (foliar cover and frequency). The most abundant perennial grasses included *Bouteloua gracilis* (blue grama), *Pleuraphis jamesii* (James' galleta), *Sporobolus* spp. (dropseed), and *Achnatherum hymenoides* (Indian ricegrass). (The 2 most abundant species of *Sporobolus* were *Sporobolus airoides* and *Sporobolus cryptandrus*). The most abundant shrubs included *Krascheninnikovia lanata* (winterfat), *Atriplex canescens* (fourwing saltbush), *Chrysothamnus Greenei* (Greene's rabbitbrush), *Gutierrezia sarothrae* (broom snakeweed), and *Ephedra torreyana* (Torrey's jointfir). *Sphaeralcea coccinea* (scarlet globemallow) and *Chenopodium fremontii* were the most abundant forbs. Dominant perennial grasses had high plot frequencies and high quadrat frequencies, indicating a relatively even distribution across the plots. Dominant shrubs, on the other hand, had high plot frequencies and low quadrat frequencies, indicating clumped distributions within the plots.

There was moderate variation in the mean cover of species among the plot groups. In particular, *Gutierrezia sarothrae* had high mean foliar cover in plot group A; *Bouteloua gracilis* and *Pleuraphis jamesii* had lower mean foliar cover in plot group C; *Ephedra torreyana* was not present in plot group A. These differences, however, were offset by the large standard deviations, indicating large among-plot variation. Plot and quadrat frequencies demonstrated moderately low variation among the plot groups.

Table 1. Foliar cover of functional groups for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Sandy Loam ecological site at CHCU.

	Plot group A 2007–2009 (n = 10)		Plot group B 2010 (n = 6)		Plot group C 2011 (n = 14)		Ecological site (n = 30)	
Functional groups	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Total live foliar cover	18.48	3.11	18.72	3.84	9.96	7.27	14.56	6.88
Perennial grasses	14.24	4.55	13.91	5.00	7.16	7.48	10.87	6.85
Annual grasses	0.04	0.04	<0.01	<0.01	0.02	0.02	0.02	0.03
Forbs	0.46	0.32	1.05	0.92	0.37	0.25	0.54	0.53
Shrubs	3.19	1.70	3.13	0.89	2.31	2.00	2.77	1.71
Cacti/succulents	0.10	0.12	0.09	0.15	0.08	0.09	0.09	0.10
Standing dead herbaceous	5.32	1.95	6.08	4.36	3.62	1.85	4.68	2.56
Standing dead woody	1.54	0.60	3.18	1.16	1.94	1.37	2.06	1.23

Note: The live functional groups do not add up to the total live foliar cover because the calculations were made from cover class midpoints, components may overlap, and the estimations have observer error.

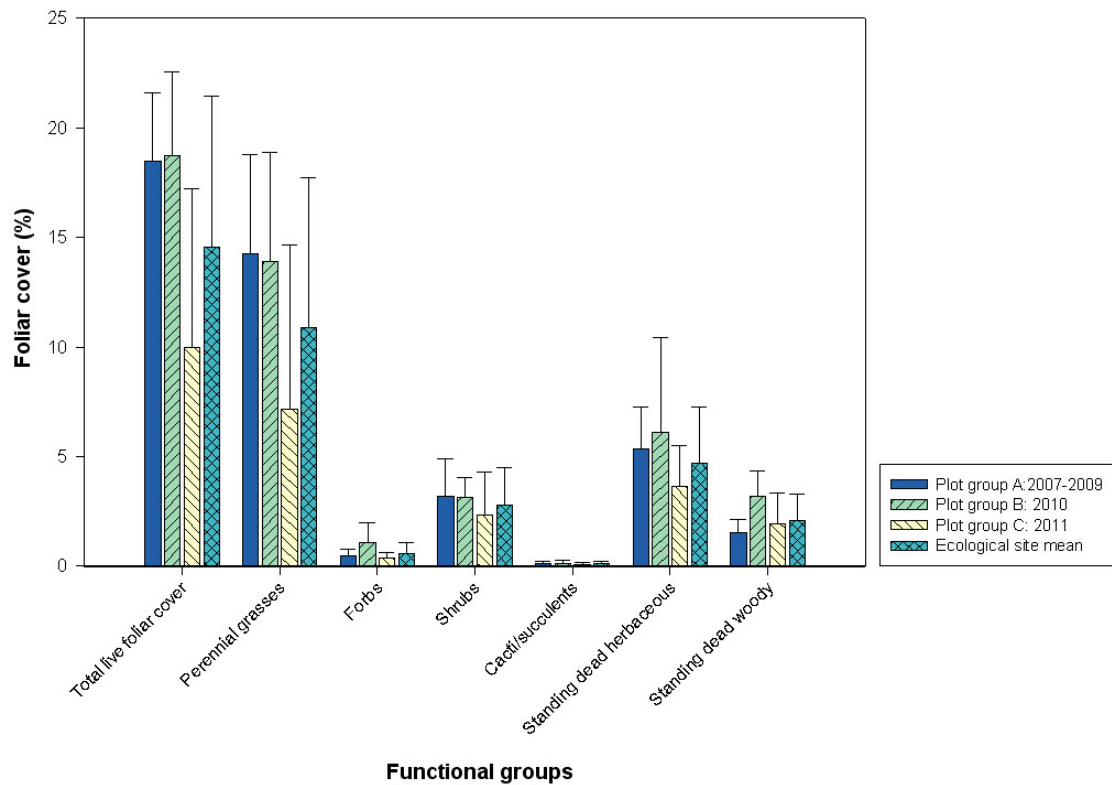


Figure 2. Mean percent foliar cover of functional groups for plot group A, plot group B, plot group C, and the ecological site mean (all plots) in the Sandy Loam ecological site at CHCU. Annual grasses had a mean foliar cover of <0.5%, and were therefore not graphed. Error bars represent one standard deviation.

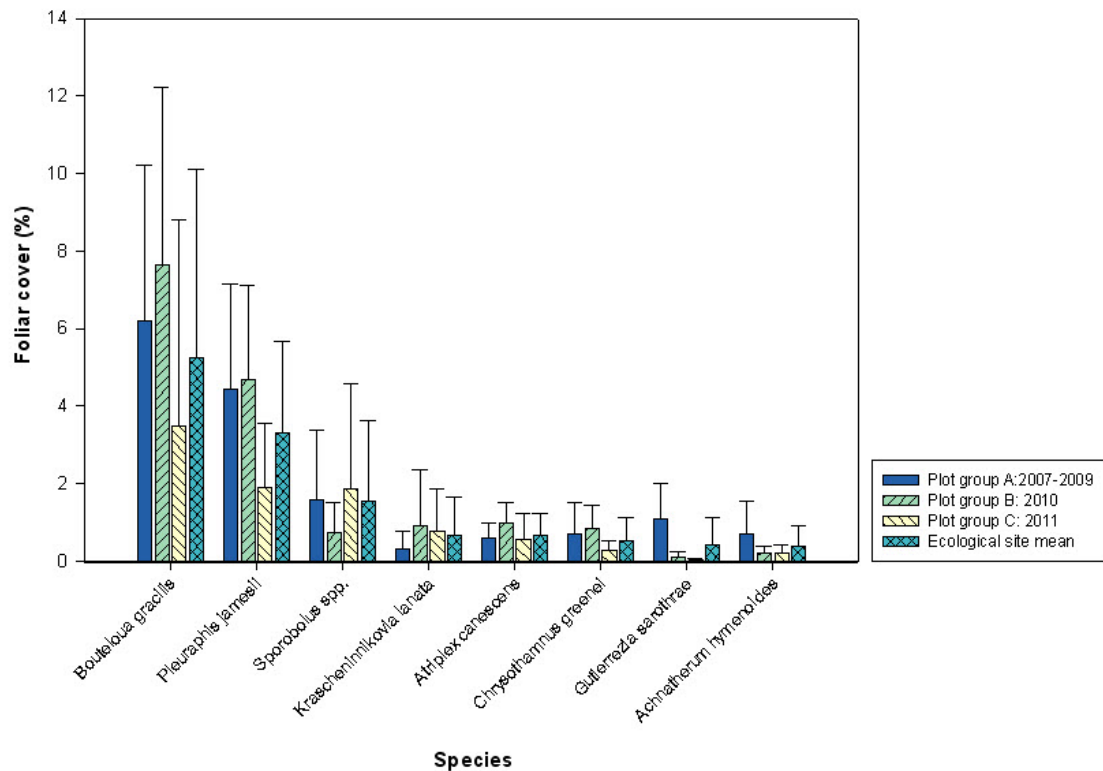


Figure 3. Mean percent foliar cover of the 8 most abundant shrub and herbaceous species for the ecological site mean compare to the mean foliar cover for plot group A, plot group B, and plot group C in the Sandy Loam ecological site at CHCU. Error bars represent one standard deviation.

Table 2. Mean foliar cover and standard deviation, and mean quadrat and plot frequencies of the 15 most abundant vascular species and all nonnative species for the ecological site compared with the values for plot group A, plot group B, and plot group C in the Sandy Loam ecological site at CHCU.

Species	Plot group A 2007–2009 (n = 10)				Plot group B 2010 (n = 6)				Plot group C 2011 (n = 14)				Ecological site mean (n = 30)			
	Foliar cover (%)	SD	Quad. freq. (%)	Plot freq. (%)	Foliar cover (%)	SD	Quad. freq. (%)	Plot freq. (%)	Foliar cover (%)	SD	Quad. freq. (%)	Plot freq. (%)	Foliar cover (%)	SD	Quad. freq. (%)	Plot freq. (%)
<i>Bouteloua gracilis</i>	6.207	4.006	84.22	100.00	7.659	4.571	93.33	100.00	3.496	5.308	71.43	92.86	5.232	4.875	80.07	96.67
<i>Pleuraphis jamesii</i>	4.442	2.698	85.56	100.00	4.670	2.435	92.22	100.00	1.911	1.646	86.19	100.00	3.306	2.376	87.19	100.00
<i>Sporobolus</i> spp.	1.599	1.791	81.11	100.00	0.731	0.781	52.22	100.00	1.859	2.762	87.62	100.00	1.547	2.115	78.37	100.00
<i>Krascheninnikovia lanata</i>	0.331	0.449	19.78	73.33	0.898	1.469	21.11	83.33	0.780	1.074	37.14	71.43	0.654	1.003	28.15	74.44
<i>Atriplex canescens</i>	0.589	0.392	41.33	100.00	0.993	0.502	46.67	100.00	0.550	0.686	42.86	92.86	0.652	0.574	43.11	96.67
<i>Chrysothamnus Greenei</i>	0.702	0.824	34.89	83.33	0.850	0.608	41.11	83.33	0.265	0.276	32.86	71.43	0.528	0.606	35.19	77.78
<i>Gutierrezia sarothrae</i>	1.096	0.903	68.67	96.67	0.099	0.150	23.33	83.33	0.044	0.040	20.48	85.71	0.405	0.704	37.11	88.89
<i>Achnatherum hymenoides</i>	0.700	0.843	64.89	100.00	0.225	0.157	62.22	83.33	0.218	0.195	63.81	92.86	0.380	0.536	63.85	93.33
<i>Ephedra torreyana</i>	0	0	0	0	0.008	0.020	1.11	16.67	0.382	0.823	6.19	21.43	0.180	0.584	3.11	13.33
<i>Sphaeralcea coccinea</i>	0.204	0.147	67.33	100.00	0	0	0	0	0.075	0.065	40.00	92.86	0.103	0.119	41.11	76.67
<i>Chenopodium fremontii</i>	<0.001	<0.001	0.22	3.33	0.472	0.911	34.44	50.00	0.015	0.031	6.19	28.57	0.101	0.423	9.85	24.44
<i>Artemisia filifolia</i>	0.175	0.467	4.44	23.33	0.012	0.020	2.22	33.33	0.086	0.322	4.76	7.14	0.101	0.342	4.15	17.78
<i>Elymus elymoides</i>	0.265	0.333	40.00	100.00	0.013	0.024	4.44	33.33	0.005	0.008	4.76	42.86	0.093	0.217	16.44	60.00
<i>Opuntia</i> spp.	0.101	0.119	22.00	93.33	0.096	0.145	15.56	66.67	0.076	0.089	16.19	78.57	0.088	0.106	18.00	81.11
<i>Artemisia frigida</i>	0.103	0.201	16.67	43.33	0.102	0.159	10.00	50.00	0.033	0.051	4.76	42.86	0.070	0.135	9.78	44.44
<i>Salsola tragus</i> ^a	0.009	0.023	5.11	20.00	0.007	0.010	3.33	50.00	0.006	0.012	4.76	35.71	0.007	0.016	4.59	33.33
<i>Bromus tectorum</i> ^a	0.012	0.024	5.56	30.00	0	0	0	0	0	0	0	0	0.004	0.015	1.85	10.00

Note: Species are arranged in descending order by their mean foliar cover for the ecological site.

^aNonnative species.

Appendix A lists all species, along with their common names, families, mean foliar cover and plot frequencies, by plot group, and for the Sandy Loam ecological site as a whole.

Two nonnative species were found in the plots: *Salsola tragus* (prickly Russian thistle) and *Bromus tectorum* (cheatgrass). Both occurred in low abundance. *Salsola tragus* had a mean foliar cover of 0.007% and occurred in 4.59% of the quadrats and 33.33% of the plots. *Bromus tectorum* had a mean foliar cover of 0.004%, and occurred in 1.85% of the quadrats and 10.00% of the plots.

Species diversity was low to moderate on the scale of the plot, and moderately high on the scale of the ecological site (table 3). On the scale of the plot, richness was 20.2 species. Shannon diversity (which takes the relative abundance of each species into account, and generally ranges between 1.5 and 3.5) was 1.690. Evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) was 0.564. On the scale of the ecological site, species richness was 71, and beta diversity (a measure of within-ecological site heterogeneity, generally ranging between 1 and 5) was 3.704. The fact that ecological site richness and beta diversity were substantially larger for the entire ecological site than the plot groups is a result of unique species found within each plot group, and substantial differences in species composition among the plots. The diversity metrics among plot groups were similar, but plot group C had higher ecological site richness and higher beta diversity than the other 2 groups. This was probably a result of a larger sample size—14 plots in group C compared to 10 in plot group A and 6 in plot group B. When we calculated the metric using only native species, evenness increased slightly and all the other metrics decreased slightly.

Table 3. Species diversity metrics for all species and for native species only for plot group A, plot group B, plot group C and all plots (ecological site mean) in the Sandy Loam ecological site at CHCU.

	Plot group A 2007–2009 (n = 10)		Plot group B 2010 (n = 6)		Plot group C 2011 (n = 14)		Ecological site (n = 30)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All species								
Plot								
Plot richness	18.3	3.3	19.8	4.7	21.7	4.5	20.2	4.3
Shannon diversity	1.684	0.358	1.611	0.301	1.728	0.396	1.690	0.354
Evenness	0.581	0.1154	0.542	0.084	0.562	0.106	0.564	0.101
Ecological site								
Ecological site richness ^a	38.7		38		54		71	
Beta diversity ^a	2.244		2.018		2.607		3.704	
Native species								
Plot								
Plot richness	17.8	3.1	19.3	4.3	21.4	4.7	19.8	4.3
Shannon diversity	1.679	0.354	1.608	0.300	1.723	0.402	1.685	0.356
Evenness	0.585	0.118	0.545	0.087	0.564	0.107	0.567	0.103
Ecological site								
Ecological site richness ^a	36.7		37		53		69	
Beta diversity ^a	2.188		2.018		2.604		3.670	

^aEcological site richness and beta diversity values are not means, except for the plot group A values which were derived from averaging across all 3 years.

3.2 Soil stability and hydrologic function

We measured the amount of soil surface potentially subject to erosion in 2 ways: cover estimates of soil surface features in quadrats and measurements of basal gaps along transects. Undifferentiated crust and bare soil were the dominant soil surface feature, with mean covers of 46.58% and 32.63%, respectively (fig. 4 and table 4). Duff/litter, live plant base and dead herbaceous base all had covers ranging between 4% and 8%. All remaining soil surface features had covers less than 1%. Several of the soil surface features showed large variation among the plot groups. Plot group C had much lower cover of undifferentiated crust and much high cover of bare soil than the other 2 groups. Live plant base cover was much higher in plot group A than the other 2 groups. Cyanobacteria cover was much higher in plot group B than the other 2 groups. The among-group differences in mean cover for undifferentiated crust, bare soil, and cyanobacteria are probably a result of differences in classification by the crews between years.

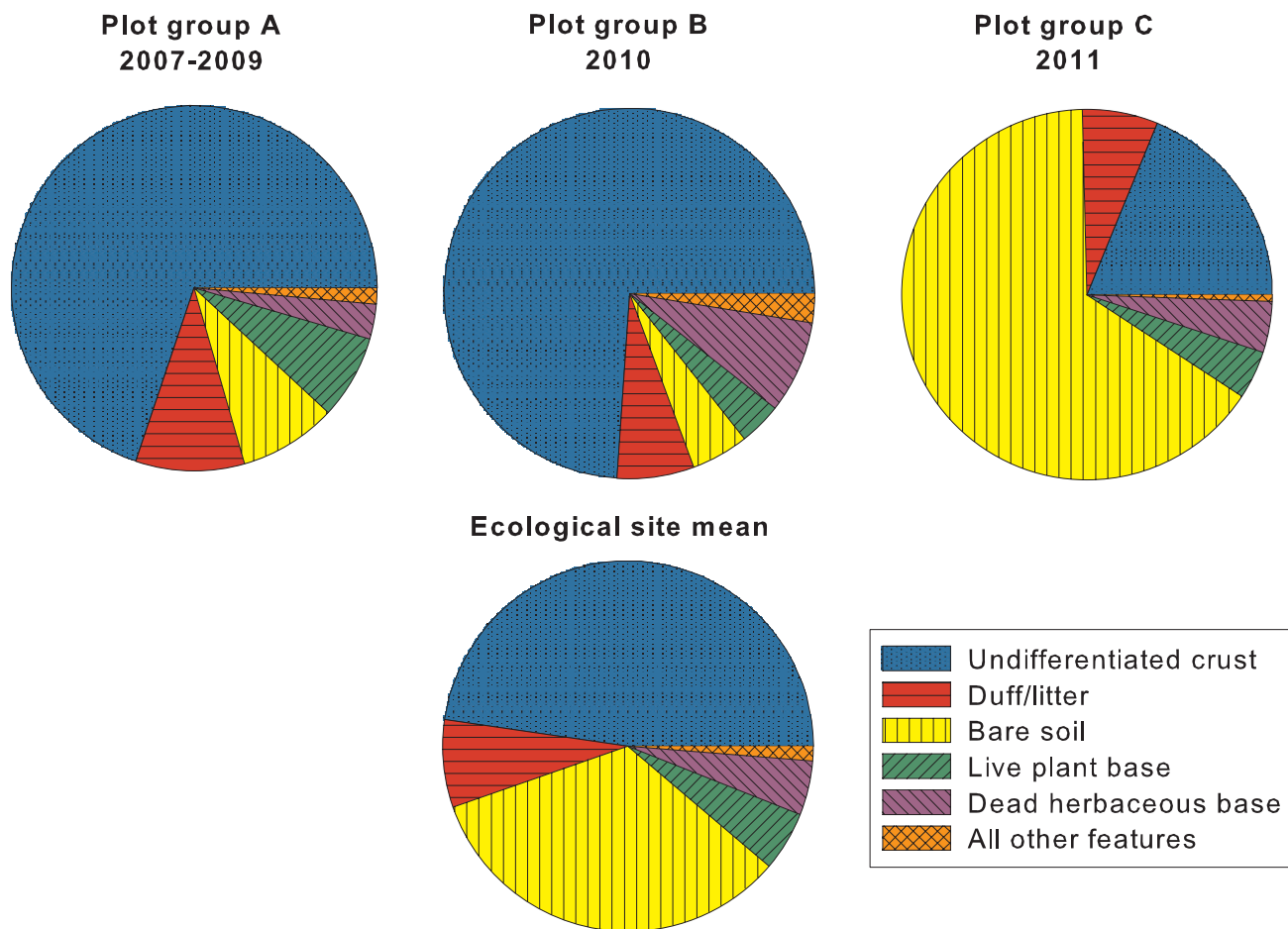


Figure 4. Mean percent cover of soil surface features for plot group A, plot group B, plot group C and all plots (ecological site mean) in the Sandy Loam ecological site at CHCU.

The basal gap data showed that gaps ≥ 100 cm comprised more of the transects than the smaller gap size classes (fig. 5 and table 5). The largest size class comprised 32.0% of the transect while the smallest size class comprised 20.1% of the transect. Overall, however, the basal gap size class distribution was relatively uniform, compared to the basal gap size class distributions of other grasslands and shrublands that we monitor on the Southern Colorado Plateau, which have higher representation of the largest gap size sizes. Differences among plot groups were relatively small and the standard deviations were moderately large, particularly for the large gap size class.

Table 4. Cover of soil surface features for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Sandy Loam ecological site at CHCU.

Soil surface feature	Plot group A 2007–2009 (n = 10)		Plot group B 2010 (n = 6)		Plot group C 2011 (n = 14)		Ecological site (n = 30)	
	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Live plant base	7.42	1.82	3.78	2.32	3.96	4.63	5.08	3.75
Dead woody base	0.41	0.26	0.35	0.23	0.35	0.26	0.37	0.24
Dead herbaceous base	3.08	1.14	8.20	5.36	4.19	2.32	4.63	3.33
Bare soil	8.64	7.64	5.09	5.20	61.57	24.81	32.63	32.50
Duff/litter ^a	9.62	3.98	6.84	1.82	6.21	3.31	7.47	3.51
Undifferentiated crust	69.80	12.85	75.19	3.30	17.72	26.60	46.58	33.45
Moss	0.07	0.20	<0.01	<0.01	0.01	0.02	0.03	0.11
Lichen	<0.01	<0.01	0	0	<0.01	<0.01	<0.01	<0.01
Cyanobacteria ^b	0.02	0.07	2.09	3.27	0	0	0.43	1.60
Fine gravel (0.2 to <2 cm)	0.51	0.91	0.10	0.12	0.11	0.18	0.24	0.55
Coarse gravel (2 to <7.5 cm)	0.29	0.62	0.06	0.11	0.06	0.12	0.14	0.37
Cobble (7.5 to <25 cm)	0.04	0.09	0	0	<0.01	0.01	0.02	0.05
Stone, bedrock (≥25 cm)	0.07	0.21	0	0	0	0	0.02	0.12
Woody debris	<0.01	0.01	0	0	0.03	0.04	0.01	0.03

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

^aDuff did not occur in these plots.

^bIn 2010 we used a different method for classifying cyanobacteria.

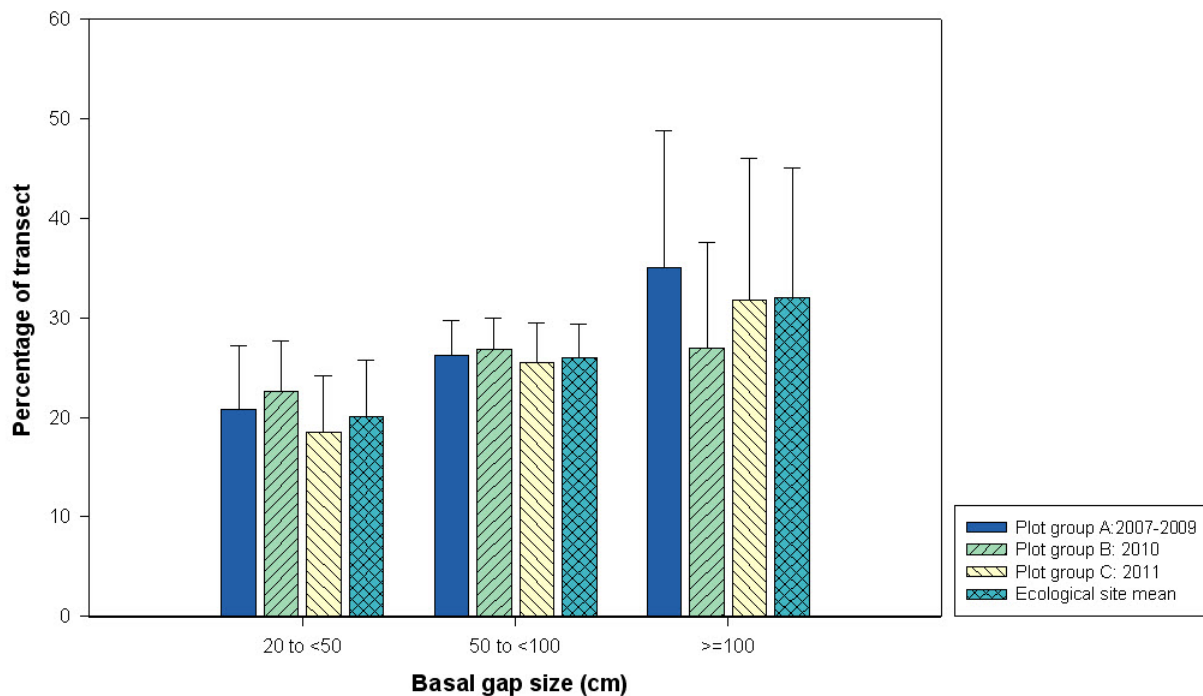


Figure 5. Mean percentage of transect by gap size class for plot group A, plot group B, plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at CHCU. Error bars represent 1 standard deviation.

Table 5. Percentage of transect in different gap size classes for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Sandy Loam ecological site at CHCU.

Metric	Plot group A 2008–2009 (n = 10)		Plot group B 2010 (n = 6)		Plot group C 2011 (n = 14)		Ecological site (n = 30)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Percentage of transect in gaps 20 to <50 cm	20.8	6.4	22.6	5.1	18.5	5.6	20.1	5.6
Percentage of transect in gaps 50 to <100 cm	26.3	3.4	26.9	3.1	25.5	4.0	26.0	3.4
Percentage of transect in gaps ≥100 cm	35.1	13.7	27.0	10.6	31.8	14.2	32.0	13.1

Note: We used a different method to collect basal gap data in 2011, so we cannot compare 2011 results with some of the metrics we reported in past years, such as number of gaps, median gap size, and percentage of the transect in plant bases.

Soil aggregate stability provides a measure of the erodibility of the soil. This index ranges between 1 and 6, with 1 indicating low stability and 6 indicating high stability. The mean stability for the ecological site was 3.58, suggesting moderate stability (table 6). Stability was substantially higher for soil below vegetative cover. There was some variability in these metrics among the plot groups: mean soil stability for plot group B was lower than for the other plot groups.

Table 6. Soil stability rating for all samples, and for samples with and without vegetative cover, in plot group A, plot group B, plot group C, and in all plots (ecological site mean) in the Sandy Loam ecological site at CHCU.

	Plot group A 2007 (n = 10)		Plot group B 2010 (n = 6)		Plot group C 2011 (n = 14)		Ecological site (n = 30)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All samples	3.61	0.62	3.26	0.25	3.64	1.15	3.58	0.88
Samples under vegetative cover	4.14	0.83	3.96	0.37	4.37	1.07	4.23	0.90
Samples not under vegetative cover	2.91	0.47	2.52	0.42	2.87	1.20	2.83	0.90

Note: Ratings ranged from 1–6, with 1 being the lowest stability and 6 being the highest.

4 Discussion

The data summarized in this report represents baseline conditions for monitoring vegetation and soils in the Sandy Loam ecological site at CHCU.

The vegetation represents an example of a relatively undisturbed grassland with a shrub component. Dominant grasses included *Bouteloua gracilis*, *Pleuraphis jamesii* and *Sporobolus* spp. The shrub layer was moderately diverse and included *Krascheninnikovia lanata*, *Atriplex canescens*, *Chrysothamnus Greenei* and *Gutierrezia sarothrae*. Two nonnative species occurred in the plots, *Salsola tragus* and *Bromus tectorum*. Both occurred with low foliar covers and moderately low frequencies. Species diversity was low to moderate on the scale of the plot, and moderately high at the landscape scale.

The soils data indicate that there is some potential for erosion, as the majority of the soil surface was comprised of bare soil and undifferentiated crust, and the cover of cyanobacteria was low. The soil stability ratings were moderate. Despite the majority of transects being comprised of basal gaps greater than 50 cm, however, large gaps represented a smaller percentage of plot transects at CHCU than in any of the other grasslands and shrublands we monitor on the Southern Colorado Plateau.

The different plot groups showed a range of variability in species composition and structure, and in soil characteristics. We would expect such differences as a result of random spatial variation, especially for sample sizes of 10 or fewer plots. The plot groups represent different plots in different locations. Due to endogenous factors such as soils and topography, and exogenous factors such as climate and disturbance, species composition and soil characteristics naturally vary. Spatial variability accounts for the majority of the differences among the plot groups, but additional variation may result from annual climatic variation. Variation in precipitation has been associated with changes in cover and frequency of herbaceous plants, particularly for annual species and forbs. The 2 nonnative species we detected are annuals, so their presence or absence in a given year may be associated with the amount of rainfall in the weeks prior to sampling. Given that 2 of the plot groups were sampled only once, their species composition values were influenced by that year's precipitation regime. Unfortunately, precipitation data for all of the 5 years are not available.

Now that we have completed the baseline monitoring for this ecological site, we will begin to implement the revisit design. Our power analysis indicates that a sample size of 30 plots should provide a large enough sample size to detect trends in key metrics.

We will implement the revisit design using a panel design. Panel designs describe the temporal plan for revisiting monitoring plots through time. Between the extremes of monitoring the same set of plots with each revisit, and monitoring a new set of sites with each revisit, there are designs that provide some balance between repeated visit to individual plots and the total number of sites visited. Our general revisit design is a connected design in both spatial and temporal aspects that balances the allocation of effort between addressing temporal (year to year) variability and spatial variability within the ecological site. We will split the 30 plots into 3 panels, and sample 2 of the panels every other year (table 7).

Table 7. Panel design for the revisit design at CHCU. "X" represents 10 plots, for a total of 30 plots across 3 panels for the ecological site.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	X				X		X				X	
2	X		X				X		X			
3			X		X				X		X	
Sum/yr	2X	0	2X	0	2X	0	2X	0	2X	0	2X	0

5 Literature cited

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Appendix A: Complete species list with mean foliar cover and mean plot frequency for plot group A, plot group B, plot group C, and all plots in the Sandy Loam ecological site at CHCU.

Species	Common name	Family	Plot group A 2007–2009		Plot group B 2010		Plot group C 2011		All plots	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Achnatherum hymenoides</i>	Indian ricegrass	Poaceae	0.700	100.00	0.225	83.33	0.218	92.86	0.380	93.33
<i>Aristida purpurea</i>	Fendler's threeawn	Poaceae	0.087	56.67	0.123	83.33	0.026	42.86	0.066	55.56
<i>Artemisia bigelovii</i>	Bigelow sage	Asteraceae	0.110	30.00	0.017	16.67	0.022	21.43	0.050	23.33
<i>Artemisia filifolia</i>	sand sagebrush	Asteraceae	0.175	23.33	0.012	33.33	0.086	7.14	0.101	17.78
<i>Artemisia frigida</i>	fringed sagebrush	Asteraceae	0.103	43.33	0.102	50.00	0.033	42.86	0.070	44.44
<i>Artemisia tridentata</i>	basin big sagebrush	Asteraceae	0	0	0	0	0.060	7.14	0.028	3.33
<i>Asclepias macrotis</i>	longhood milkweed	Asclepiadaceae	0	0	0.001	16.67	0	0	<0.001	3.33
<i>Astragalus</i> spp.	milkvetch	Fabaceae	0.001	16.67	0.012	50.00	0.002	28.57	0.003	28.89
<i>Atriplex canescens</i>	fourwing saltbush	Chenopodiaceae	0.589	100.00	0.993	100.00	0.550	92.86	0.652	96.67
<i>Atriplex obovata</i>	mound saltbush	Chenopodiaceae	0	0	0	0	0.034	7.14	0.016	3.33
<i>Bouteloua gracilis</i>	blue grama	Poaceae	6.207	100.00	7.659	100.00	3.496	92.86	5.232	96.67
<i>Bromus tectorum</i> ^a	cheatgrass	Poaceae	0.012	30.00	0	0	0	0	0.004	10.00
<i>Chaetopappa ericoides</i>	rose heath	Asteraceae	0.036	76.67	0.031	83.33	0.035	85.71	0.034	82.22
<i>Chamaesaracha coronopus</i>	greenleaf five eyes	Solanaceae	0	0	0.004	16.67	<0.001	7.14	0.001	6.67
<i>Chamaesyce</i> spp.	annual sandmat	Euphorbiaceae	0.004	23.33	0.007	16.67	0.136	71.43	0.066	44.44
<i>Chamaesyce fendleri</i>	Fendler's sandmat	Euphorbiaceae	0	0	0	0	0.002	14.29	0.001	6.67
<i>Chenopodium</i> spp.	goosefoot	Chenopodiaceae	0.001	13.33	0.188	50.00	0	0	0.038	14.44
<i>Chenopodium fremontii</i>	Fremont's goosefoot	Chenopodiaceae	<0.001	3.33	0.472	50.00	0.015	28.57	0.101	24.44
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0.021	36.67	0.033	50.00	0.015	28.57	0.021	35.56
<i>Chrysothamnus greenei</i>	Greene's rabbitbrush	Asteraceae	0.702	83.33	0.850	83.33	0.265	71.43	0.528	77.78
<i>Chrysothamnus pulchellus</i>	southwestern rabbitbrush	Asteraceae	0	0	0	0	<0.001	7.14	<0.001	3.33
<i>Comandra umbellata</i>	bastard toadflax	Santalaceae	<0.001	3.33	0.004	16.67	0	0	0.001	4.44
<i>Cryptantha</i> spp.	cryptantha	Boraginaceae	0.002	13.33	0.021	83.33	0.138	85.71	0.069	61.11
<i>Descurainia pinnata</i>	western tansymustard	Brassicaceae	0	0	0.002	16.67	0.015	78.57	0.007	40.00
<i>Echinocereus triglochidiatus</i>	kingcup cactus	Cactaceae	0.005	16.67	0	0	0	0	0.002	5.56

Appendix A (continued)

Species	Common name	Family	Plot group A 2007–2009		Plot group B 2010		Plot group C 2011		All plots	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Elymus elymoides</i>	squirreltail	Poaceae	0.265	100.00	0.013	33.33	0.005	42.86	0.093	60.00
<i>Ephedra torreyana</i>	Torrey's jointfir	Ephedraceae	0	0	0.008	16.67	0.382	21.43	0.180	13.33
<i>Ephedra viridis</i>	mormon tea	Ephedraceae	0	0	0	0	0.036	7.14	0.017	3.33
<i>Ericameria nauseosa</i>	rubber rabbitbrush	Asteraceae	0.072	20.00	0	0	0.024	14.29	0.035	13.33
<i>Erigeron</i> sp.	fleabane	Asteraceae	<0.001	3.33	0	0	0	0	<0.001	1.11
<i>Eriogonum cernuum</i>	nodding buckwheat	Polygonaceae	0.019	10.00	0.043	66.67	0.010	35.71	0.020	33.33
<i>Eriogonum corymbosum</i>	crisp-leaf buckwheat	Polygonaceae	0	0	0	0	0.003	21.43	0.002	10.00
<i>Escobaria vivipara</i>	spiny star	Cactaceae	0	0	0	0	<0.001	14.29	<0.001	6.67
<i>Evolvulus nuttallianus</i>	shaggy dwarf morning-glory	Convolvulaceae	<0.001	3.33	0	0	0	0	<0.001	1.11
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	1.096	96.67	0.099	83.33	0.044	85.71	0.405	88.89
<i>Helianthus annuus</i>	common sunflower	Asteraceae	0	0	0.008	33.33	0	0	0.002	6.67
<i>Hesperostipa comata</i>	needle and thread	Poaceae	0.056	70.00	0.045	16.67	0.013	50.00	0.034	50.00
<i>Hymenopappus filifolius</i>	fine-leaf hymenopappus	Asteraceae	<0.001	6.67	0	0	0	0	<0.001	2.22
<i>Krascheninnikovia lanata</i>	winterfat	Chenopodiaceae	0.331	73.33	0.898	83.33	0.780	71.43	0.654	74.44
<i>Lappula occidentalis</i>	flatspine stickseed	Boraginaceae	0.002	10.00	0.002	33.33	0.050	71.43	0.025	43.33
<i>Linum puberulum</i>	plains flax	Linaceae	0	0	0	0	0.003	14.29	0.001	6.67
<i>Lycium pallidum</i>	pale desert-thorn	Solanaceae	0.016	10.00	0.003	16.67	0	0	0.006	6.67
<i>Machaeranthera canescens</i>	hoary tansyaster	Asteraceae	0.003	13.33	0	0	<0.001	14.29	0.001	11.11
<i>Mentzelia albicaulis</i>	whitestem blazingstar	Loasaceae	0	0	0.017	33.33	0	0	0.003	6.67
<i>Muhlenbergia pungens</i>	sandhill muhly	Poaceae	0	0	0	0	0.024	7.14	0.011	3.33
<i>Muhlenbergia torreyi</i>	ring muhly	Poaceae	0.045	46.67	0.162	66.67	0.011	21.43	0.053	38.89
<i>Munroa squarrosa</i>	false buffalograss	Poaceae	0.002	10.00	0.001	16.67	0.013	64.29	0.007	36.67
<i>Oenothera</i> spp.	evening primrose	Onagraceae	<0.001	10.00	0	0	<0.001	7.14	<0.001	6.67
<i>Opuntia</i> spp.	prickly pear	Cactaceae	0.101	93.33	0.096	66.67	0.076	78.57	0.088	81.11
<i>Opuntia whipplei</i>	Whipple's cholla	Cactaceae	<0.001	3.33	0	0	0	0	<0.001	1.11
<i>Orobancha ludoviciana</i>	Louisiana broomrape	Orobanchaceae	0	0	0	0	0.001	14.29	<0.001	6.67
<i>Penstemon</i> sp.	penstemon	Scrophulariaceae	0	0	0	0	0.001	7.14	0.001	3.33
<i>Penstemon angustifolius</i>	narrowleaf penstemon	Scrophulariaceae	0	0	0	0	<0.001	7.14	<0.001	3.33

Appendix A (continued)

Species	Common name	Family	Plot group A 2007–2009		Plot group B 2010		Plot group C 2011		All plots	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Phacelia</i> spp.	scorpionweed	Hydrophyllaceae	0.019	23.33	0	0	<0.001	7.14	0.006	11.11
<i>Plantago patagonica</i>	woolly plantain	Plantaginaceae	0.047	43.33	0.001	33.33	0.014	64.29	0.023	51.11
<i>Pleuraphis jamesii</i>	James' galleta	Poaceae	4.442	100.00	4.670	100.00	1.911	100.00	3.306	100.00
<i>Rumex hymenosepalus</i>	canaigre dock	Polygonaceae	0.001	6.67	0	0	0.008	35.71	0.004	18.89
<i>Salsola tragus</i> ^a	prickly Russian thistle	Chenopodiaceae	0.009	20.00	0.007	50.00	0.006	35.71	0.007	33.33
<i>Sanvitalia abertii</i>	Albert's creeping zinnia	Asteraceae	<0.001	3.33	0	0	0	0	<0.001	1.11
<i>Sarcobatus vermiculatus</i>	greasewood	Chenopodiaceae	0.017	3.33	0	0	0	0	0.006	1.11
<i>Schkuhria multiflora</i>	many-flower false threadleaf	Asteraceae	0.003	13.33	0	0	0.001	21.43	0.001	14.44
<i>Senecio spartioides</i>	broomlike ragwort	Asteraceae	0	0	0	0	0.001	7.14	0.001	3.33
<i>Solanum jamesii</i>	wild potato	Solanaceae	0.002	3.33	0	0	<0.001	7.14	0.001	4.44
<i>Sphaeralcea</i> spp.	globemallow	Malvaceae	0.006	6.67	0.194	100.00	0	0	0.041	22.22
<i>Sphaeralcea coccinea</i>	scarlet globemallow	Malvaceae	0.204	100.00	0	0	0.075	92.86	0.103	76.67
<i>Sphaeralcea incana</i>	soft globemallow	Malvaceae	0.003	3.33	0	0	0	0	0.001	1.11
<i>Sporobolus</i> spp.	dropseed	Poaceae	1.599	100.00	0.731	100.00	1.859	100.00	1.547	100.00
<i>Stephanomeria pauciflora</i>	brownplume wirelettuce	Asteraceae	<0.001	3.33	0	0	0	0	<0.001	1.11
<i>Tetradymia canescens</i>	spineless horsebrush	Asteraceae	0	0	0.028	33.33	0	0	0.006	6.67
<i>Townsendia annua</i>	annual Townsend daisy	Asteraceae	0	0	0	0	0.014	57.14	0.006	26.67
<i>Verbesina encelioides</i>	golden crownbeard	Asteraceae	<0.001	3.33	0	0	0	0	<0.001	1.11
<i>Vulpia octoflora</i>	sixweeks fescue	Poaceae	0.025	33.33	0	0	0.003	50.00	0.010	34.44
Unknown 20110928_3			0	0	0	0	0.001	7.14	<0.001	3.33
Unknown CHCU20071020_4			<0.001	3.33	0	0	0	0	<0.001	1.11
Unknown CHCU20071020_5			<0.001	3.33	0	0	0	0	<0.001	1.11
Unknown CHCU20081003_1			<0.001	3.33	0	0	0	0	<0.001	1.11
Unknown CHCU20081003_3			<0.001	3.33	0	0	0	0	<0.001	1.11

^aNonnative species.