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

2010 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2013/510

ON THE COVER
Integrated upland monitoring in Chaco Culture National Historical Park
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Natural Resource Data Series NPS/SCPN/NRDS—2013/510

James K. DeCoster
Megan C. Swan

National Park Service
Southern Colorado Plateau Network
Northern Arizona University
P.O. Box 5765
Flagstaff, AZ 86011-5765

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The corresponding author and project manager for this project is Jim DeCoster (jim_decoster@nps.gov). Megan Swan is the botanist and crew leader for the project. Other contributions were made by the SCPN staff. The 2010 field crew consisted of Lara Dickson, Natalie Melaschenko, Ryan Meszaros, Steven Till and Karen Weber.

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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, we established and sampled 6 new plots. The original 10 plots were not resampled. This brings our total for this ecological site to 16 established plots. In this report, we document monitoring activities in the 2010 field season and report these data in the context of the data collected in 2007, 2008 and 2009.

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 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 powerline and associated road, and one point fell in an inaccessible area in the park.

2.2 Field methods

The SCPN integrated upland crew established 10 monitoring plots in 2007, and resampled these 10 plots in 2008 and 2009. In 2010, the crew established 6 additional plots. The 10 plots established in 2007 were not sampled in 2010. 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.

During establishment of new plots in 2007 and 2010, we collected the full suite of data. In 2008 and 2009, we did not collect soil stability data. Field methodology is provided in detail in the SCPN integrated upland monitoring protocol (DeCoster et al. 2012).

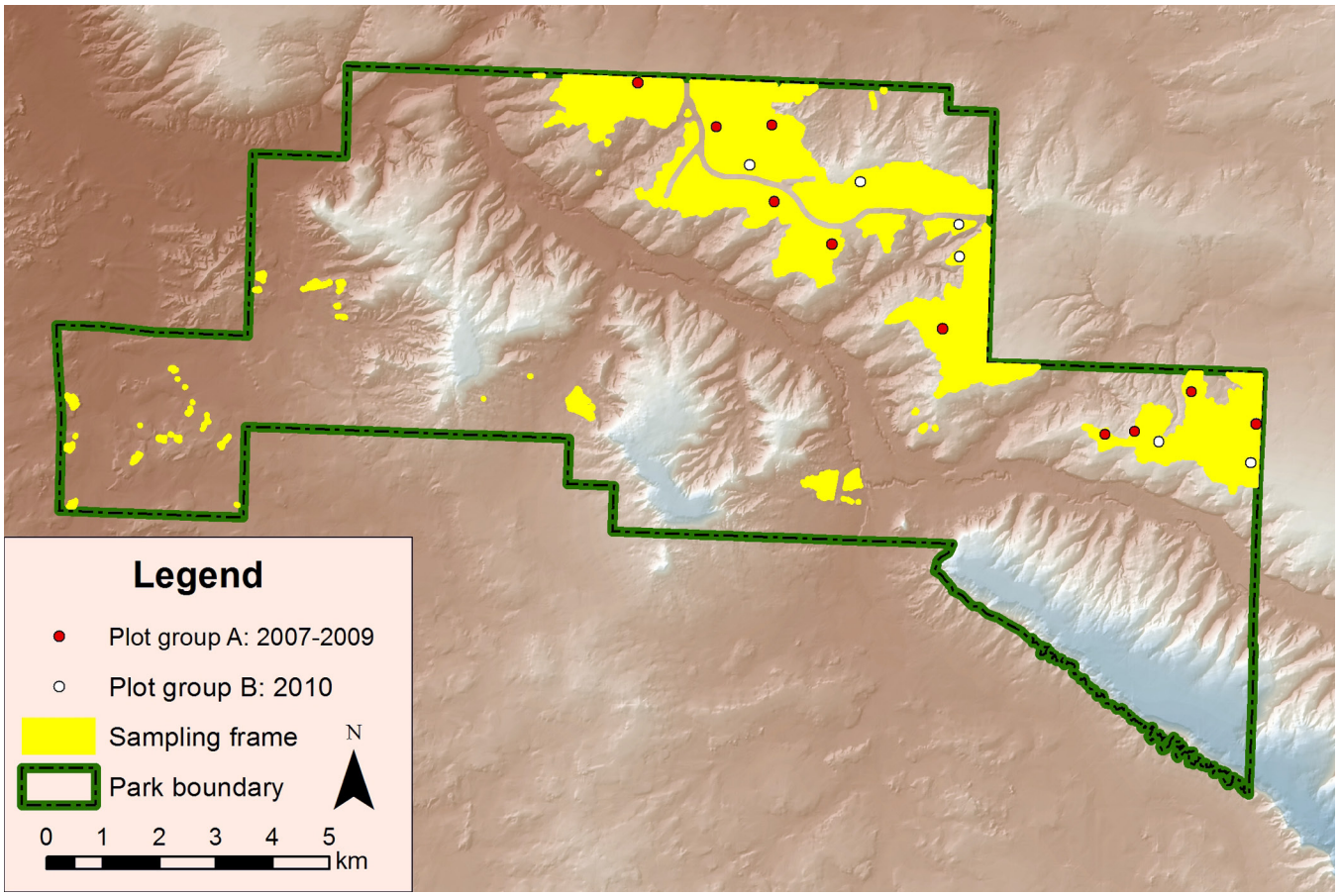

Figure 1. Sampling frame of the Sandy Loam ecological site at CHCU with the 10 plots established in 2007 and the 6 plots established in 2010.

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 m^2 (2 × 5 m), with 4 smaller quadrats nested inside (0.01 m^2, 0.1 m^2, 1 m^2, 5 m^2). We recorded the presence of each herbaceous and shrub species within each nested sub-quadrat. We estimated the percent foliar cover of each species in the 10 m^2 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 m^2 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 new plots established in 2010.

2.2.2 Soil stability and hydrologic function

We estimated the percent cover of soil surface features in the 1 m^2 quadrats along the transects, and recorded the cover in 1 of 12 cover classes. We measured basal gaps as the length of bare soil 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 in the plots established in 2010. 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 compare the data collected in the 6 new plots in 2010 to the data collected in the 10 original plots between 2007 and 2009. It must be stressed that the differences between these 2 plot groups do not represent change over time, but rather indicate differences in composition and structure resulting largely from spatial variation. We refer to these 2 groups of plots as Plot Group A for the plots established in 2007, and Plot Group B for the plots established in 2010.

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 the ecological site from the plot means (ecological site species diversity metrics were the exception). For Plot Group A metrics 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. For Plot Group B we calculated the mean and standard deviation based on a single year of data. Metrics with 3 years of data include species cover and frequency, functional group cover, soil surface features and basal gaps.

2.3.1 Species cover and frequency

For herbaceous and shrub vegetation, percent cover was estimated for each species from the cover class midpoints, e.g., 7.5% for cover class 5%–10%. For each year, mean cover was calculated for each plot, and the mean and standard deviation were calculated for the ecological site from the plot means. Species frequency was calculated for quadrats (mean percentage of 10 m^2 quadrats per plot where the species occurs) and for plots (percentage of plots where the species occurs).

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 year, and the mean and standard deviation were then calculated for the ecological site for each year. We calculated the ecological site means for the 2 metrics, ecological site richness and beta diversity, using 10 plot values from only one year of data from plot group A—the year with the median value for Shannon diversity—combined with the 6 plots from plot group B.

2.3.3 Basal gaps

We calculated 5 metrics for each year of basal gap data: median basal gap size, percentage of transects comprised by gaps and plant bases, percentage of transects comprised by each gap size class, and total number of gaps. Mean and standard deviation were calculated for each metric for each year. For Plot Group A, where there are 3 years of data, we calculated the mean and standard deviation of the metrics for each year, and then calculated the mean and of the means and the mean of the standard deviations for the 3 years.

2.3.4 Soil stability

We calculated the mean soil aggregate stability index for each plot and then calculated the mean and standard deviation for all plots in the plot group. This gave us a mean soil aggregate stability index for the plots established in 2007, and a separate soil aggregate stability index for the plots established in 2010. This index ranges between 1 and 6, where 1 indicates low aggregate stability and 6 indicates high aggregate stability. The index was also calculated separately for samples with vegetative cover and for samples without vegetative cover.

3 Results

3.1 Vegetation

Perennial grasses dominated the Sandy Loam ecological site, comprising 14.24 % of the live foliar cover for Plot Group A and 13.91% for Plot Group B (table 1 and fig. 2). Shrub cover was slightly more than 3% in both plot groups. The other functional groups each had cover of less than 1%, with the exception of forbs in Plot Group B with 1.05% cover. The cover of functional groups in Plot Group A was similar to that in Plot Group B, although forbs and standing dead woody had greater cover in Plot Group B than in Plot Group A.

Table 1. Foliar cover of functional groups for Plot Group A and Plot Group B in the Sandy Loam ecological site at CHCU.

	Plot Group A 2007–2009		Plot Group B 2010	
Functional groups	Mean (%)	SD	Mean (%)	SD
Total live foliar cover	18.48	3.11	18.72	3.84
Perennial grasses	14.24	4.55	13.91	5.00
Annual grasses	0.04	0.04	<.01	<.01
Forbs	0.46	0.32	1.05	0.92
Shrubs	3.19	1.70	3.13	0.89
Cacti/succulents	0.10	0.12	0.09	0.15
Standing dead herbaceous	5.32	1.95	6.08	4.36
Standing dead woody	1.54	0.60	3.18	1.16

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

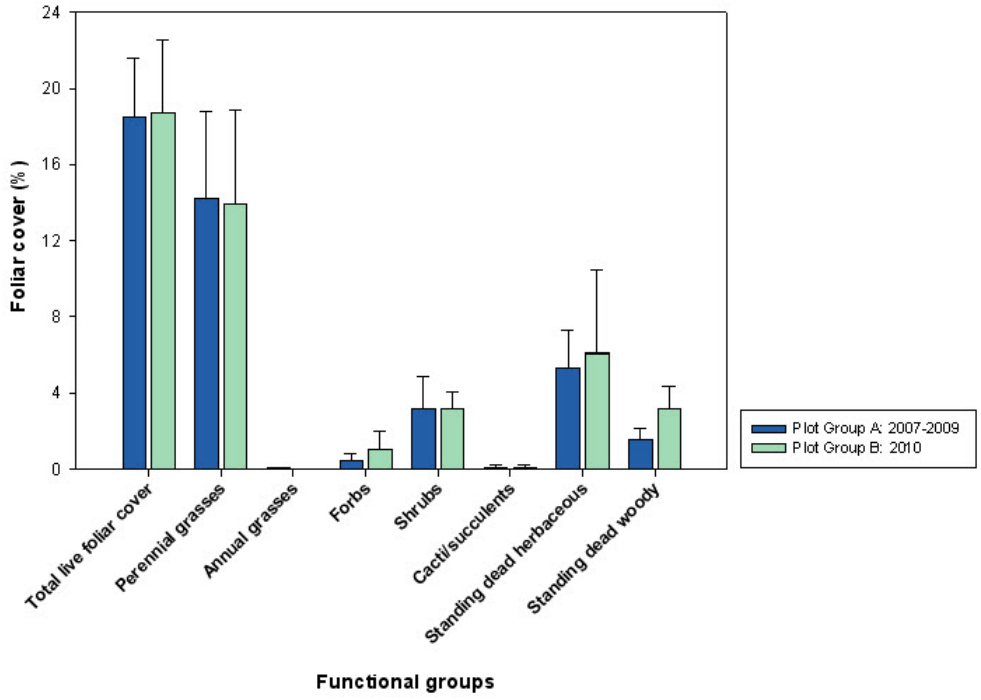

Figure 2. Mean percent foliar cover by functional group for Plot Group A and Plot Group B in the Sandy Loam ecological site at CHCU. Error bars represent one standard deviation.

We present species-level data for the most abundant herbs and shrubs in both plot groups in Figure 3 (foliar cover) and Table 2 (foliar cover and frequency).The dominant perennial grasses in this ecological site were *Bouteloua gracilis* (blue grama), *Pleuraphis jamesii* (James' galleta), *Achnatherum hymenoides* (Indian ricegrass) and *Sporobolus cryptandrus* (sand dropseed). The dominant shrubs were *Gutierrezia sarothrae* (broom snakeweed), *Chrysothamnus greenei* (Greene's rabbitbrush), *Atriplex canescens* (fourwing saltbush) and *Krascheninnikovia lantana* (winterfat). The dominant forb was *Sphaeralcea coccinea* (scarlet globemallow). The foliar cover and frequencies of the dominant species were similar between the 2 plot groups; the differences that did occur were moderated by the large standard deviations (e.g., *Bouteloua gracilis*). The greatest differences were seen in *Gutierrezia sarothrae*, which had much lower cover and frequency in Plot Group B, and *Sporobolus airoides* and *Sphaeralcea coccinea*, which did not occur in Plot Group B. Appendix A lists all species, along with common names, families, mean foliar cover and plot frequencies, by plot group.

Two nonnative species were found in the plots: *Bromus tectorum* (cheatgrass), and *Salsola tragus* (prickly Russian thistle). *Bromus tectorum* occurred in 30% of the plots in Plot Group A, with a mean foliar cover of 0.012%, and did not occur in Plot Group B. Foliar cover of *Salsola tragus* was less than 0.01% in both plot groups, and its plot frequency was 50% in Plot group B compared with 20% in Plot Group A.

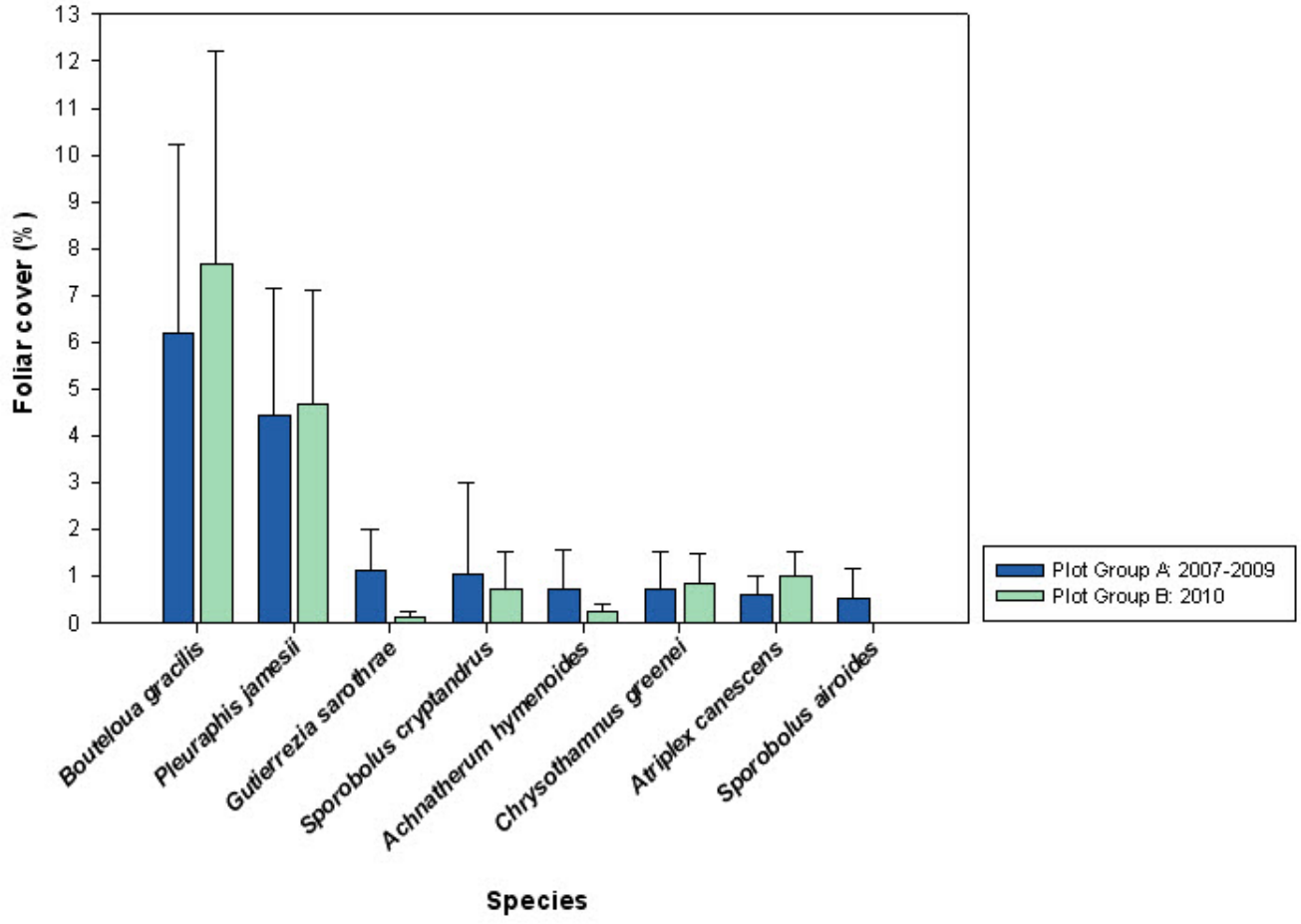

Figure 3. Mean percent foliar cover of the 8 most abundant shrub and herbaceous species for Plot Group A compared with the foliar cover of the same species in Plot Group B in the Sandy Loam ecological site at CHCU. Error bars represent one standard deviation.

Table 2. Mean foliar cover and standard deviation, and mean quadrat and plot frequency of the 15 most abundant shrub and herbaceous species for Plot Group A, and for the same species in Plot Group B in the Sandy Loam ecological site at CHCU. All nonnative species are included from both plot groups.

	Plot Group A 2007–2009				Plot Group B 2010			
Species	Foliar cover (%)	SD	Quadrat freq. (%)	Plot freq. (%)	Foliar cover (%)	SD	Quadrat freq. (%)	Plot freq. (%)
Bouteloua gracilis	6.207	4.006	84.22	100.00	7.659	4.571	93.33	100.00
Pleuraphis jamesii	4.442	2.698	85.56	100.00	4.670	2.435	92.22	100.00
Gutierrezia sarothrae	1.099	0.904	68.89	96.67	0.099	0.150	23.33	83.33
Sporobolus cryptandrus	1.053	1.942	38.44	56.67	0.731	0.781	52.22	100.00
Achnatherum hymenoides	0.700	0.843	64.89	100.00	0.225	0.157	62.22	83.33
Chrysothamnus greenei	0.699	0.826	34.67	83.33	0.850	0.608	41.11	83.33
Atriplex canescens	0.589	0.392	41.33	100.00	0.993	0.502	46.67	100.00
Sporobolus airoides	0.535	0.623	44.22	66.67	0	0	0	0
Krascheninnikovia lanata	0.331	0.449	19.78	73.33	0.898	1.469	21.11	83.33
Elymus elymoides	0.265	0.333	40.00	100.00	0.013	0.024	4.44	33.33
Sphaeralcea coccinea	0.201	0.149	65.78	100.00	0	0	0	0
Artemisia filifolia	0.176	0.467	4.67	26.67	0.012	0.020	2.22	33.33
Artemisia bigelovii	0.110	0.302	3.33	30.00	0.017	0.041	1.11	16.67
Artemisia frigida	0.103	0.201	16.44	43.33	0.102	0.159	10.00	50.00
Opuntia spp.	0.101	0.119	22.00	93.33	0.096	0.145	15.56	66.67
Bromus tectorum[a]	0.012	0.024	5.56	30.00	0	0	0	0
Salsola tragus[a]	0.009	0.023	5.11	20.00	0.007	0.010	3.33	50.00

Note: Species are arranged in descending order by their mean foliar cover for Plot Group A.
[a]Nonnative species.

Generally, this ecological site had moderate species diversity. Plot richness was 18.7 in Plot Group A, and 20.0 in Plot Group B (table 3). Shannon diversity (which takes into account the relative abundanceof each species, and generally ranges between 1.5 and 3.5) was 1.686 and 1.612 for Plot Group A and Plot Group B, respectively. Evenness (the degree to which all species are of equal abundance, ranging between 0 and 1) was 0.579 and 0.541 for Plot Group A and Plot Group B, respectively. Ecological site richness was 40.7 and 39 for Plot Group A and Plot Group B, respectively. Beta diversity (a measure of within site heterogeneity, generally ranging between 1 and 5) was similar between the plot groups, at 2.307 for Plot Group A and 2.053 for Plot Group B.

Overall, diversity indices were similar for the 2 plot groups. Plot richness values were slightly higher for Plot Group B, while the other indices were slightly higher for Plot Group A. When recalculated using only native species, all diversity indices were slightly lower, with the exception of evenness.

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.

The majority of the soil surface of both sets of plots was comprised of undifferentiated crust, which exceeded 65% in both plot groups (table 4 and fig. 4). Other important soil surface features included duff /litter, bare soil, live plant base and dead herbaceous base. The 2 plot groups had similar cover for most of the features. However, cyanobacteria and dead herbaceous base had greater cover in Plot Group B, while live plant base, bare soil and duff/litter had greater cover in Plot Group A. The difference in cyanobacteria cover was likely the result of a change in way we classified this feature in 2010.

Table 3. Species diversity metrics for all species and for native species only for Plot Group A and Plot Group B in the Sandy Loam ecological site at CHCU.

	Plot Group A (2007-2009)		Plot Group B (2010)	
	Mean	SD	Mean	SD
All species				
Plot				
Plot richness	18.7	3.5	20.0	5.0
Shannon diversity	1.686	0.356	1.612	0.302
Evenness	0.579	0.114	0.541	0.083
Ecological site				
Ecological site richness	40.7		39[a]	
Beta diversity	2.307		2.053[a]	
Native species				
Plot				
Plot richness	18.2	3.3	19.5	4.6
Shannon diversity	1.681	0.353	1.610	0.301
Evenness	0.583	0.117	0.545	0.086
Ecological site				
Ecological site richness	38.7		38[a]	
Beta diversity	2.254		2.054[a]	

[a]These are not mean values.

Table 4. Cover of soil surface features for Plot Group A and Plot Group B in the Sandy Loam ecological site at CHCU.

	Plot Group A 2007–2009		Plot Group B 2010	
Soil surface feature	Mean (%)	SD	Mean (%)	SD
Live plant base	7.42	1.82	3.78	2.32
Dead woody base	0.41	0.26	0.35	0.23
Dead herbaceous base	3.08	1.14	8.20	5.36
Bare soil	8.64	7.64	5.09	5.20
Duff/litter[a]	9.62	3.98	6.84	1.82
Undifferentiated crust	69.80	12.85	75.19	3.30
Moss	0.07	0.20	<0.01	<0.01
Lichen	<0.01	<0.01	0	0
Cyanobacteria[b]	0.02	0.07	2.09	3.27
Fine gravel (0.2 to <2 cm)	0.51	0.91	0.10	0.12
Coarse gravel (2 to <7.5 cm)	0.29	0.62	0.06	0.11
Cobble (7.5 to <25 cm)	0.04	0.09	0	0
Stone, bedrock (>25 cm)	0.07	0.21	0	0
Woody debris	<0.01	0.01	0	0

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.
[a]Duff did not occur in these plots
[b]In 2010 we used a different method for classifying cyanobacteria.

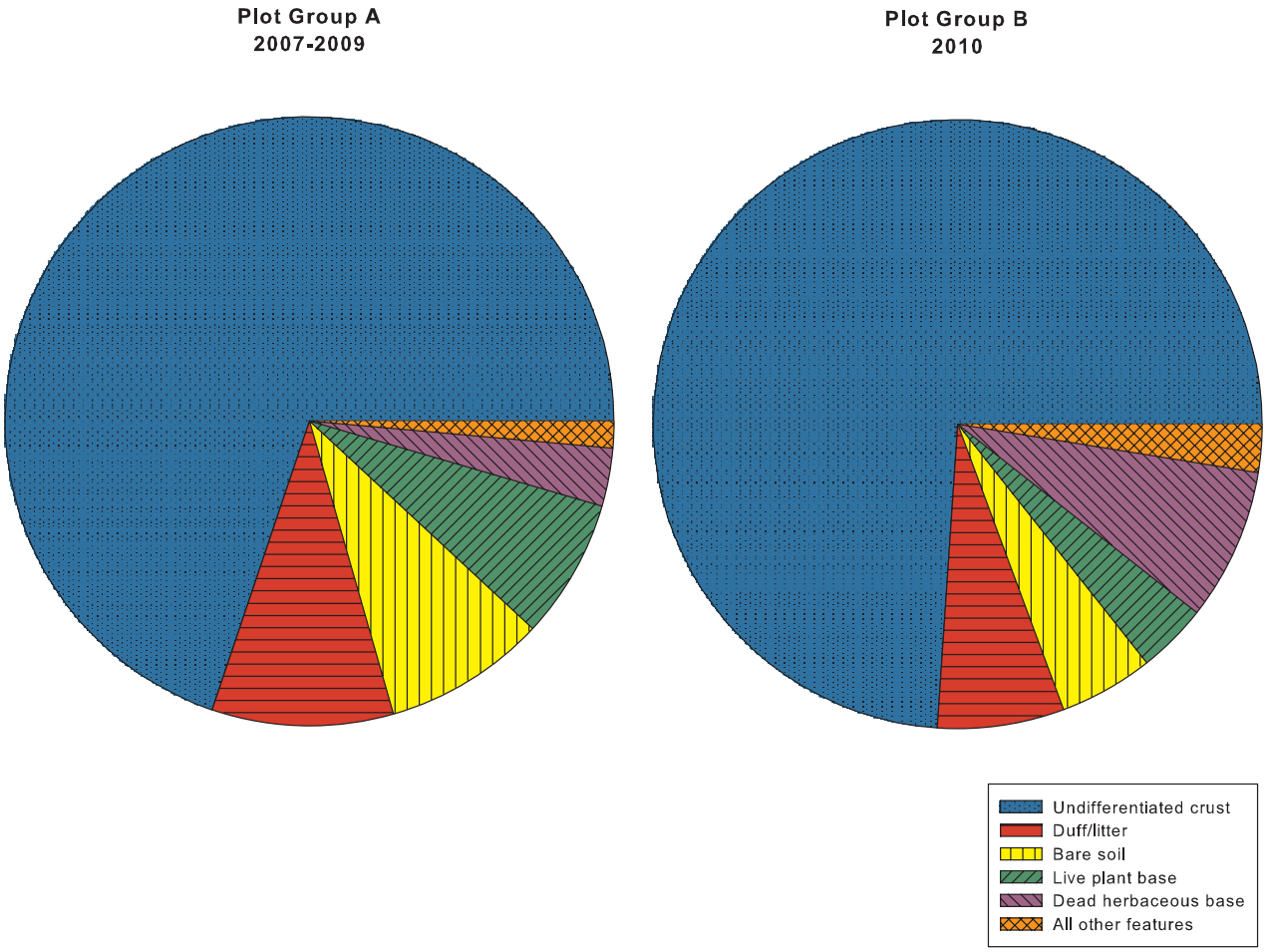

Figure 4. Mean percent cover of soil surface features for Plot Group A and Plot Group B in the Sandy Loam ecological site at CHCU.

The basal gap data shows a relatively large number of small gaps compared to other grasslands and shrublands we monitor. The mean number of gaps per transect was 304.3 and 395.8 for Plot Group A and plot Group B, respectively, and the mean of the median gap size was 30.5 and 20.7 (table 5 and fig. 5). The largest gap sizes comprised more of the transect than the smaller gap sizes, but the amount of transect in each of the gap sizes was fairly similar. The gap distribution was similar for the 2 plot groups, but Plot Group B had more gaps of a smaller size.

The soil stability of the ecological site was moderate (table 6). The rating ranges from 1 to 6, with 6 indicating the highest stability. The ratings were 3.61 and 3.26 for Plot Group A and Plot Group B, respectively. Samples collected under vegetative cover had higher ratings than those collected where there was no cover.

Table 5. Number of basal gaps, median gap size, and percentage of transect in different gap size classes for Plot Group A and Plot Group B in the Sandy Loam ecological site at CHCU.

	Plot Group A 2007–2009		Plot Group B 2010	
Metric	Mean	SD	Mean	SD
Number of gaps	304.3	71.2	395.7	99.1
Median gap size (cm)	30.5	7.8	20.7	5.8
Percentage of transect in gaps	89.8	3.0	89.0	2.1
Percentage of transect in gaps 0-19 cm	7.7	3.1	12.5	4.7
Percentage of transect in gaps 20-49 cm	20.8	6.4	22.6	5.1
Percentage of transect in gaps 50-99 cm	26.3	3.4	26.9	3.1
Percentage of transect in gaps ≥100 cm	35.1	13.7	27.0	10.6
Percentage of transect in plant bases	10.2	3.0	11.0	2.1

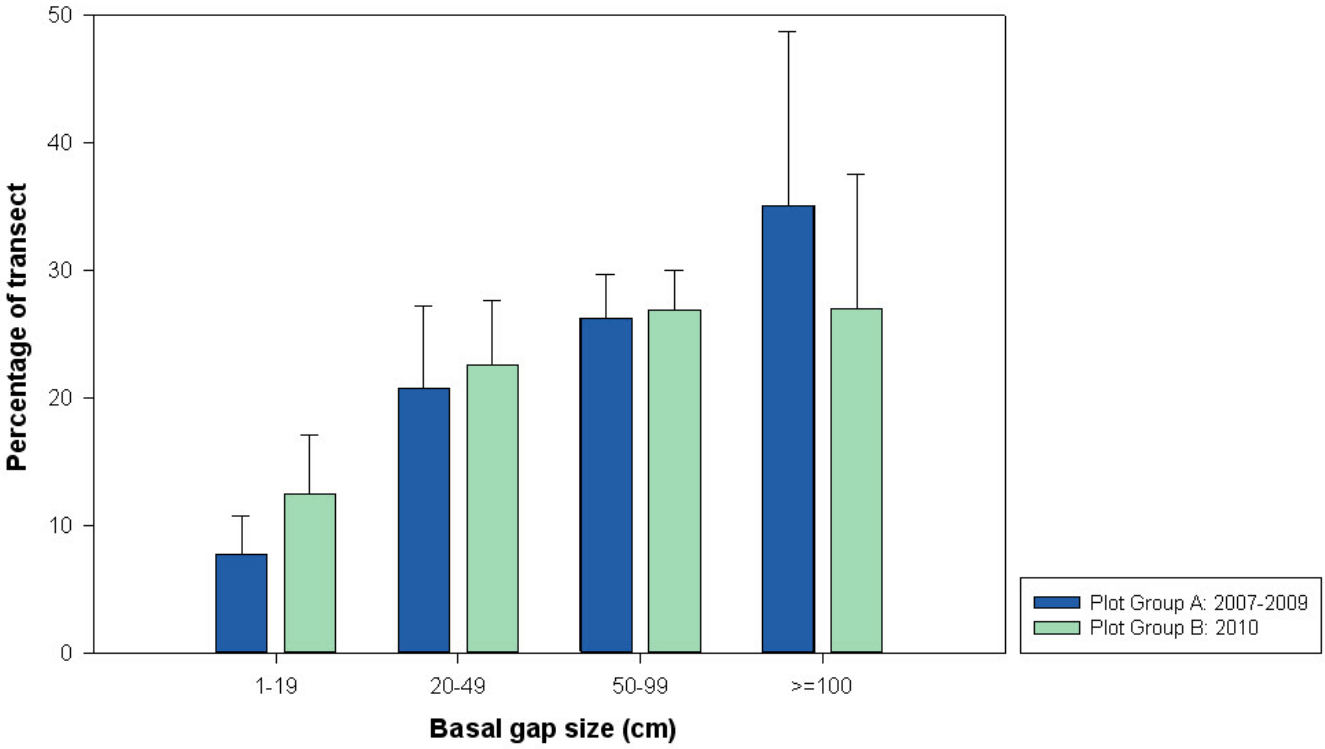

Figure 5. Mean percentage of transect by gap size class for Plot Group A and Plot Group B in the Sandy Loam ecological site at CHCU. Error bars represent 1 standard deviation.

Table 6. Soil stability rating for all samples, and for samples with and without vegetative cover, in Plot Group A and Plot Group B in the Sandy Loam ecological site at CHCU.

	Plot Group A 2007		Plot Group B 2010	
	Mean	SD	Mean	SD
All samples	3.61	0.62	3.26	0.25
Samples under vegetative cover	4.14	0.83	3.96	0.37
Samples not under vegetative cover	2.91	0.47	2.52	0.42

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

3.3 Western Regional Climate Center precipitation data

Precipitation records for CHCU are available from the Western Regional Climate Center (2012). Figure 6 shows the total monthly precipitation for each of the 4 years of monitoring described in this report, compared with the long term average precipitation by month for the period 1933–2010.

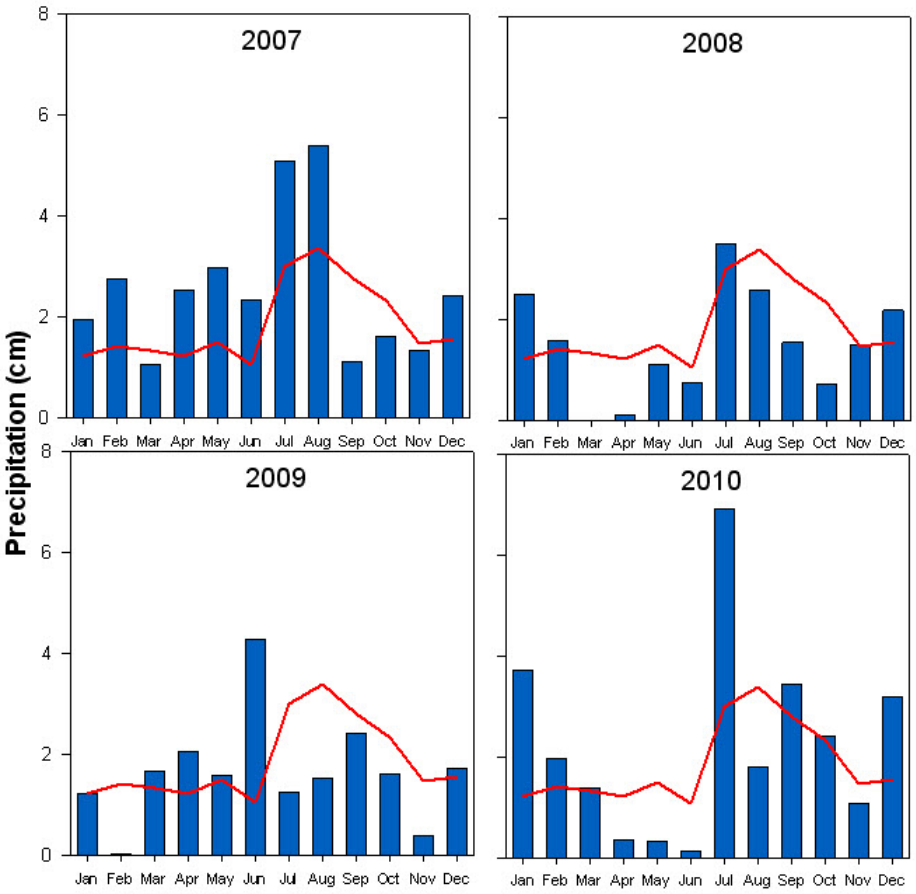

Figure 6. Total monthly precipitation for the 4 years of sampling. The red line represents the long term average for the Chaco Canyon Natl Monument (291647) weather station for the period 1933–2010, collected by the Western Regional Climate Center.

4 Discussion

The data presented here indicates that the second set of plots established in 2010 in the Sandy Loamy ecological site were quite similar to the first set of plots established in 2007 in terms of vegetation composition and structure and soil characteristics. Plot Group B had higher forb cover and smaller basal gaps, and there were differences in species abundance among the 2 plot groups. We would expect minor differences in species composition and soil characteristics between the 2 groups, particularly for groups with small sample sizes, due to random spatial variation. The groups represent different plots in different locations. Due to endogenous and exogenous factors, the species composition and structure and soil characteristics naturally vary.

While spatial variability likely accounts for the majority of the differences between the 2 plot groups, additional variation may result from annual climatic variation. At CHCU, variation in precipitation has been associated with changes in cover and frequency of herbaceous plants, particularly annual species, and to a lesser extent, perennial forbs. Precipitation records for CHCU gathered by the Western Regional Climate Center indicate that 2008 and 2009 were drier than 2007 and 2010, which may have reduced cover and frequency of herbaceous species. These differences in precipitation, however, likely are a minor factor contributing to differences between plot groups.

Variability may also be attributable to sampling error. Although we strive to reduce sampling error through training and diligence while collecting data, sampling error is inevitable. Cover estimation may vary among individuals (and crews), species may be misidentified, slight differences among observers in applying sampling methods may go unnoticed, and the location of transects and quadrats vary slightly from year to year. We minimize this source of error by ensuring that transect lines are as straight as possible, quadrats are placed correctly, and field crews are thoroughly trained on methods and species identification and remain calibrated on cover estimation.

In 2011, we installed and sampled an additional 14 plots in the Sandy Loam ecological site. These data will be reported once they have been verified, validated and summarized. Power analysis indicates that a total of 30 plots should provide a large enough sample size to detect trends in key metrics. Data from these 30 plots will be used to describe baseline conditions of the vegetation and soils of this ecological site and monitor long-term changes.

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Appendix A: Complete species list with mean foliar cover and mean plot frequency for Plot Group A and Plot Group B in the Sandy Loam ecological site at CHCU.

			Plot Group A 2007–2009		Plot Group B 2010	
Species	Common name	Family	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
Achnatherum hymenoides	Indian ricegrass	Poaceae	0.700	100.00	0.225	83.33
Aristida purpurea	Fendler's threeawn	Poaceae	0.087	56.67	0.123	83.33
Artemisia bigelovii	Bigelow sage	Asteraceae	0.110	30.00	0.017	16.67
Artemisia filifolia	sand sagebrush	Asteraceae	0.176	26.67	0.012	33.33
Artemisia frigida	fringed sagebrush	Asteraceae	0.103	43.33	0.102	50.00
Asclepias sp.	longhood milkweed	Asclepiadaceae	0	0	0.001	16.67
Astragalus spp.	milkvetch	Fabaceae	0.001	16.67	0.012	50.00
Atriplex canescens	fourwing saltbush	Chenopodiaceae	0.589	100.00	0.993	100.00
Bouteloua gracilis	blue grama	Poaceae	6.207	100.00	7.659	100.00
Bromus tectorum[a]	cheatgrass	Poaceae	0.012	30.00	0	0
Chaetopappa ericoides	rose heath	Asteraceae	0.036	76.67	0.031	83.33
Chamaesaracha coronopus	greenleaf five eyes	Solanaceae	0	0	0.004	16.67
Chamaesyce spp. Group A	annual sandmats	Euphorbiaceae	0.003	23.33	0.007	16.67
Chamaesyce spp. Group B	annual sandmats	Euphorbiaceae	0.001	3.33	0	0
Chenopodium spp.	goosefoot	Chenopodiaceae	0.002	16.67	0.188	50.00
Chenopodium fremontii	Fremont's goosefoot	Chenopodiaceae	<0.001	3.33	0.472	50.00
Chenopodium leptophyllum	narrowleaf goosefoot	Chenopodiaceae	0.019	33.33	0.033	50.00
Chrysothamnus greenei	Greene's rabbitbrush	Asteraceae	0.699	83.33	0.850	83.33
Comandra umbellata	bastard toadflax	Santalaceae	<0.001	3.33	0.004	16.67
Cryptantha spp.	cryptantha	Boraginaceae	0.002	13.33	0.021	83.33
Descurainia pinnata	western tansymustard	Brassicaceae	0	0	0.002	16.67
Echinocereus triglochidiatus	kingcup cactus	Cactaceae	0.005	16.67	0	0
Elymus elymoides	squirreltail	Poaceae	0.265	100.00	0.013	33.33
Ericameria nauseosa	rubber rabbitbrush	Asteraceae	0.072	20.00	0	0
Ephedra torreyana	Torrey's jointfir	Ephedraceae	0	0	0.008	16.67
Erigeron sp.	fleabane	Asteraceae	<0.001	3.33	0	0
Eriogonum cernuum	nodding buckwheat	Polygonaceae	0.019	10.00	0.043	66.67

Appendix A (*continued*)

			Plot Group A 2007–2009		Plot Group B 2010	
Species	Common name	Family	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
Evolvulus nuttallianus	shaggy dwarf morning-glory	Convolvulaceae	<0.001	3.33	0	0
Gutierrezia sarothrae	broom snakeweed	Asteraceae	1.099	96.67	0.099	83.33
Helianthus annuus	common sunflower	Asteraceae	0	0	0.008	33.33
Hesperostipa comata	needle and thread	Poaceae	0.056	70.00	0.045	16.67
Hymenopappus filifolius	fineleaf hymenopappus	Asteraceae	<0.001	6.67	0	0
Krascheninnikovia lanata	winterfat	Chenopodiaceae	0.331	73.33	0.898	83.33
Lappula occidentalis	flatspine stickseed	Boraginaceae	0.002	10.00	0.002	33.33
Lycium pallidum	pale desert-thorn	Solanaceae	0.016	10.00	0.003	16.67
Machaeranthera canescens	hoary tansyaster	Asteraceae	0.003	13.33	0	0
Mentzelia albicaulis	whitestem blazingstar	Loasaceae	0	0	0.017	33.33
Monroa squarrosa	false buffalograss	Poaceae	0.002	10.00	0.001	16.67
Muhlenbergia torreyi	ring muhly	Poaceae	0.045	46.67	0.162	66.67
Oenothera sp.	evening primrose	Onagraceae	<0.001	10.00	0	0
Opuntia spp.	prickly pear	Cactaceae	0.101	93.33	0.096	66.67
Opuntia whipplei	Whipple's cholla	Cactaceae	<0.001	3.33	0	0
Phacelia spp.	scorpionweed	Hydrophyllaceae	0.019	23.33	0	0
Plantago patagonica	woolly plantain	Plantaginaceae	0.047	43.33	0.001	33.33
Pleuraphis jamesii	James' galleta	Poaceae	4.442	100.00	4.670	100.00
Rumex hymenosepalus	Canaigre dock	Polygonaceae	0.001	6.67	0	0
Salsola tragus[a]	prickly Russian thistle	Chenopodiaceae	0.009	20.00	0.007	50.00
Sanvitalia abertii	Albert's creeping zinnia	Asteraceae	<0.001	3.33	0	0
Sarcobatus vermiculatus	greasewood	Chenopodiaceae	0.017	3.33	0	0
Schkuhria multiflora	many-flower false threadleaf	Asteraceae	0.003	10.00	0	0
Solanum jamesii	wild potato	Solanaceae	0.002	3.33	0	0
Sphaeralcea spp.	globemallow	Malvaceae	0.009	10.00	0.194	100.00
Sphaeralcea coccinea	scarlet globemallow	Malvaceae	0.201	100.00	0	0
Sphaeralcea incana	soft globemallow	Malvaceae	0.003	3.33	0	0
Sporobolus airoides	alkali sacaton	Poaceae	0.535	66.67	0	0
Sporobolus contractus	spike dropseed	Poaceae	0.001	3.33	0.003	16.67

Appendix A (*continued*)

			Plot Group A 2007–2009		Plot Group B 2010	
Species	Common name	Family	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
Sporobolus cryptandrus	sand dropseed	Poaceae	1.053	56.67	0.731	100.00
Stephanomeria pauciflora	brownplume wirelettuce	Asteraceae	<0.001	3.33	0	0
Tetradymia canescens	spineless horsebrush	Asteraceae	0	0	0.028	33.33
Verbesina encelioides	golden crownbeard	Asteraceae	<0.001	3.33	0	0
Vulpia octoflora	sixweeks fescue	Poaceae	0.025	33.33	0	0
unknownCHCU20081003_1			<0.001	3.33	0	0
unknownCHCU20081003_3			<0.001	3.33	0	0
unknownCHCU20071020_2			0.001	3.33	0	0
unknownCHCU20071020_4			<0.001	3.33	0	0
unknownCHCU20071020_5			<0.001	3.33	0	0

Note: Annual species of *Chamaesyce* spp. were placed into 2 groups based on morphological characteristics.
[a]Nonnative species.