



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

2008 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2009/016



ON THE COVER

Sandy Loam Upland ecological site at Chaco Culture National Historical Park
Photograph by: Megan Swan

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The corresponding author and project manager for this project is Jim DeCoster (jim_decoster@nps.gov). Megan Swan is the botanist and crew leader for the project. Other contributions were made by the SCPN staff. The 2008 field crew consisted of Jessica Erickson, Anna Lowell, and Eric Vasquez.

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Introduction and Background

The National Park Service Inventory and Monitoring (I&M) Program was designed to determine the current status and monitor long-term trends in the condition of park natural resources, providing park managers with a strong scientific foundation for making decisions and working with other agencies and the public for the protection of park ecosystems. The Southern Colorado Plateau Network (SCPN) is monitoring vegetation and soils as overall indicators of upland ecosystem integrity (Thomas et al. 2006).

At Chaco Culture National Historical Park, SCPN and park staff selected the Sandy Loam Upland ecological site as an important system to monitor for vegetation and soils. An ecological site is a landscape division with characteristic soils, hydrology, plant communities, and disturbance regimes and responses. The classification of ecological sites is based on soil survey data (Butler et al. 2003). The Sandy Loam Upland ecological site comprises a large area of the upland grassland systems at CHCU, and it faces numerous threats, including climate change, erosion, and invasion of nonnative species.

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

Methods

Sampling frame

A sampling frame is the area from which sites are randomly selected, and hence the area to which statistical inferences can be made. We derived the sampling frame for CHCU from the map of the Sandy Loam Upland ecological site, which was developed by the US Natural Resources Conservation Service (See Appendix A of DeCoster et al., in review). To create the sampling frame, we modified the map using Geographic Information System (GIS) technology by removing the roads and areas where the slope exceeded 20% (fig.1). A set of spatially distributed sampling points was then generated using the Generalized Random-Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). Park staff reviewed the sampling points and had the opportunity to reject points that landed too close to archaeological sites and other sensitive resources. Before establishing a plot, the Integrated Upland crew conducted an ecological site assessment at each sampling point and rejected the site if it did not occur within the ecological site, had a slope exceeding 20%, or contained a major disturbance. They rejected four points: two points were in proximity to archaeological sites, one was in proximity to a powerline and associated road, and one point fell in an inaccessible area in the park.

Field methods

The SCPN Upland Monitoring crew began monitoring at CHCU in 2007 with the establishment of 10 plots. The crew collected data from all plots in the latter part of October, but in 2008, the crew collected the data earlier in the season, in early 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. All data were collected on three 50 m transects, spaced 25 meters apart, within each plot.

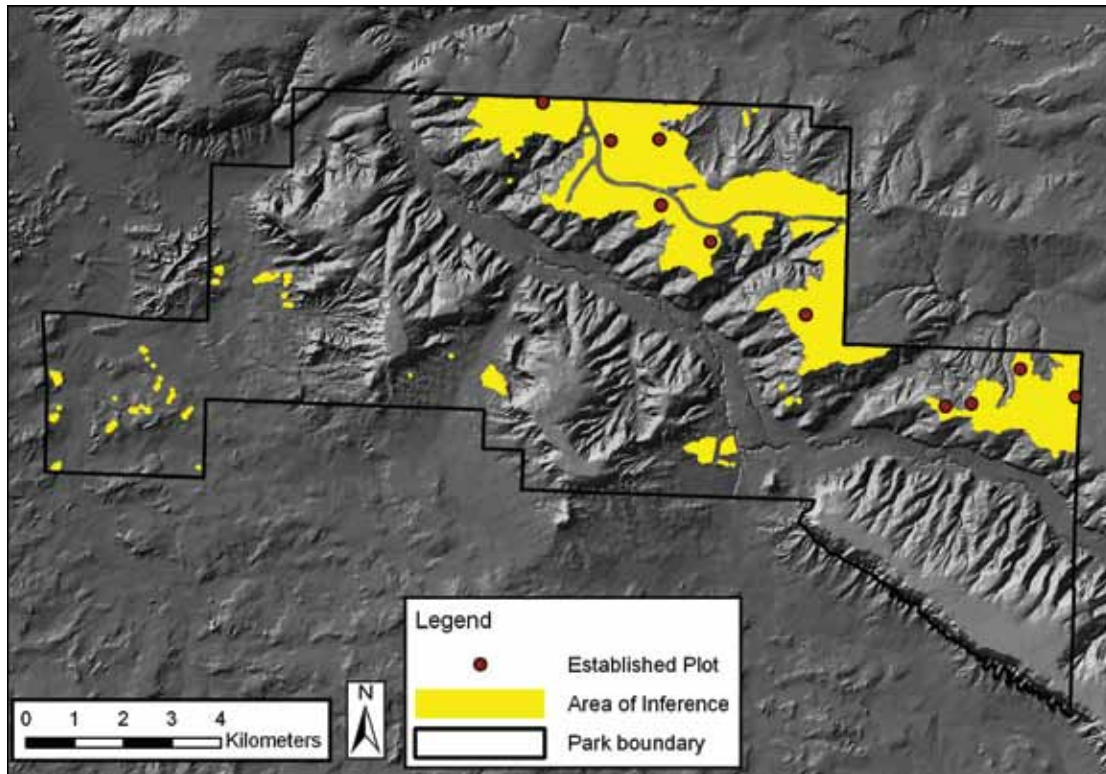


Figure 1. Sampling frame of Sandy Loam Upland ecological site with the 10 plots established in 2007.

Shrub and herbaceous vegetation

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

Overstory trees and saplings

There were no trees in any of the plots.

Soil stability and hydrologic function

The crew measured the amount of bare soil by recording the length of each basal gap (the space between plant bases) along each transect. Percent cover of ground surface features was estimated in the 1 m² quadrats in conjunction with shrub and herbaceous data and recorded in one of 12 cover classes. In 2007, a soil aggregate stability test was conducted, using 18 soil samples collected along the transects. This procedure was not repeated in 2008.

Data summary

The sample unit for summary and analysis is the plot; hence, we summarized data at the level of the plot. In order to calculate summary statistics for the ecological site, we calculated means and standard deviations from plot means.

For herbaceous and shrub vegetation, cover and frequency were calculated for each species from the cover class midpoints, e.g. using 7.5% for cover class 5-10%. The mean cover was calculated for each plot, and the mean and standard deviation (SD) were calculated for the entire 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 were calculated in a similar fashion.

We calculated four diversity measures for herbaceous and shrub species (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, and it was calculated at the level of the plot and the level of the ecological site.

(2) The Shannon Diversity Index (H') provides a measure of species diversity that takes into account the relative abundance of each species:

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

where p_i is the abundance of each species.

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

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

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

$$S_e / (S_p - 1)$$

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.

We made five calculations for the basal gaps data: median basal gap size, percentage of transects comprised by gaps, percentage of transects comprised by gaps ≥ 50 cm, number of gaps by size class, and total number of gaps. Mean and SD were calculated for each metric.

Results

Shrub and herbaceous vegetation

Perennial grasses dominated the vegetation of the CHCU Sandy Loam Upland ecological site. In 2007, we estimated the total foliar cover as 22.19% and perennial grass cover as 16.51%. In 2008, the total foliar cover declined to 17.30%, and cover of perennial grasses decreased to 13.13% (table 1 and fig. 2). All other functional groups demonstrated similar declines in cover in 2008, although the large standard deviations suggest that among-plot variation is high. Standing dead herbaceous cover also showed a large decrease in 2008.

Many individual species also decreased in cover in 2008, but quadrat and plot frequencies generally did not substantially change (table 2 and fig. 3). Of the dominant perennial grasses, *Bouteloua gracilis* (blue grama) and *Sporobolus cryptandrus* (sand dropseed) showed moderate decreases, and *Sporobolus airoides* showed a slight increase in cover and frequency.

Table 1. Foliar cover of functional groups for 2007 and 2008.

Species	Foliar cover (%)			
	2007		2008	
	Mean	(SD)	Mean	(SD)
Total foliar cover	22.19	(3.82)	17.30	(3.12)
Perennial grasses	16.51	(5.65)	13.13	(4.22)
Annual grasses	0.10	(0.10)	0.01	(0.01)
Forbs	0.78	(0.43)	0.40	(0.35)
Shrubs	4.31	(2.15)	3.00	(1.41)
Cacti, succulents	0.11	(0.12)	0.08	(0.10)
Standing dead herbaceous	8.22	(2.47)	2.20	(0.48)
Standing dead woody	1.55	(0.59)	1.26	(0.61)

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

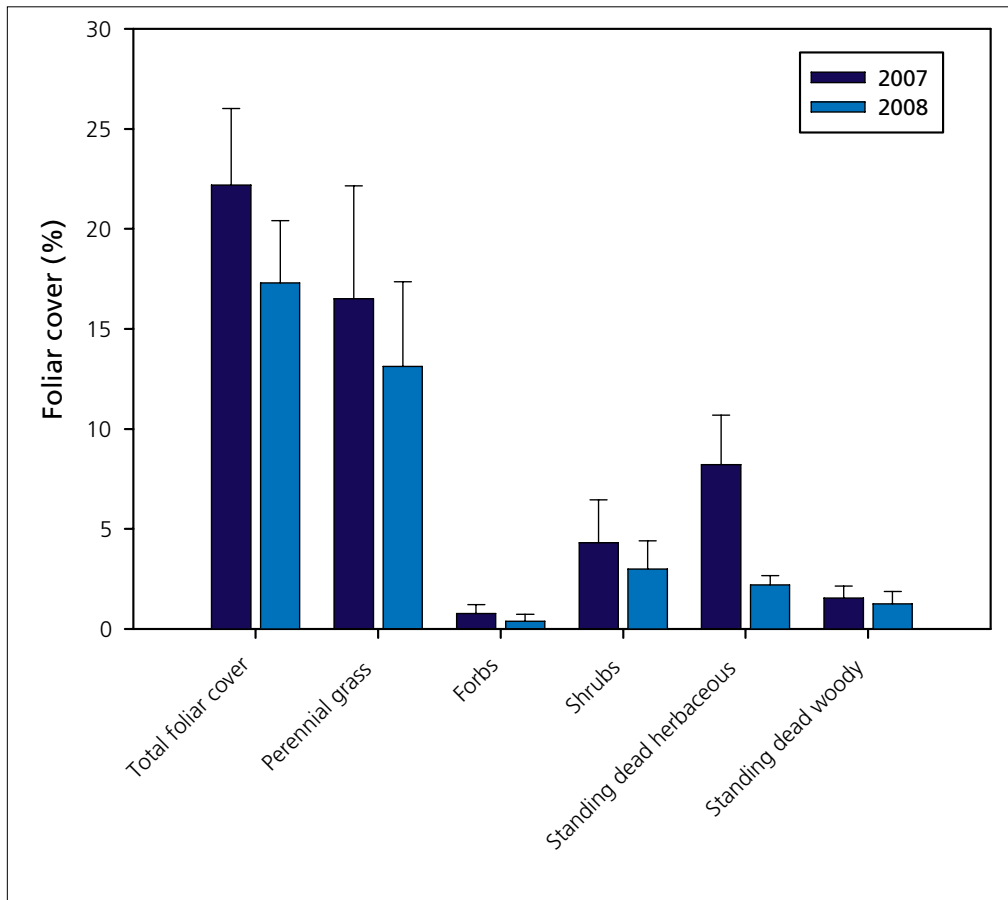


Figure 2. Mean cover of functional groups at the Sandy Loam Upland ecological site in 2007 and 2008. Error bars represent one standard deviation.

Table 2. Foliar cover and frequency of the fifteen most abundant vascular species and all nonnative species in 2007, as compared to 2008.

Species	2007				2008			
	Mean cover (%)	SD	Quad Freq	Plot Freq	Mean cover (%)	SD	Quad Freq	Plot Freq
<i>Bouteloua gracilis</i>	6.939	3.945	84.00	100	5.741	3.847	85.33	100
<i>Pleuraphis jamesii</i>	4.679	2.476	85.33	100	4.437	3.195	87.33	100
<i>Gutierrezia sarothrae</i>	2.084	1.682	82.00	100	0.864	0.607	76.00	100
<i>Sporobolus cryptandrus</i>	1.405	2.262	44.67	60	0.349	0.767	28.67	40
<i>Achnatherum hymenoides</i>	0.946	1.091	65.33	100	0.565	0.618	63.33	100
<i>Chrysothamnus Greenei</i>	0.697	0.774	33.33	80	0.774	0.949	38.00	90
<i>Atriplex canescens</i>	0.670	0.408	40.67	100	0.661	0.523	42.67	100
<i>Sporobolus airoides</i>	0.609	0.887	38.00	60	0.745	0.686	60.67	90
<i>Elymus elymoides</i>	0.396	0.673	35.33	100	0.207	0.215	38.00	100
<i>Krascheninnikovia lanata</i>	0.387	0.548	19.33	70	0.330	0.448	20.00	80
<i>Sphaeralcea coccinea</i>	0.256	0.183	67.33	100	0.232	0.146	81.33	100
<i>Artemisia filifolia</i>	0.219	0.539	4.00	20	0.141	0.363	6.00	40
<i>Artemisia frigida</i>	0.183	0.301	22.00	50	0.064	0.133	17.33	50
<i>Plantago patagonica</i>	0.139	0.091	84.67	100	0.001	0.002	1.33	10
<i>Artemisia bigelovii</i>	0.112	0.302	3.33	30	0.107	0.303	3.33	30
<i>Bromus tectorum</i> ^a	0.032	0.059	14.00	60	0.002	0.007	1.33	10
<i>Salsola tragus</i> ^a	0.018	0.050	9.33	20	0.007	0.017	4.67	20

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

^a Nonnative species.

Most shrub species showed slight decreases in cover; *Gutierrezia sarothrae* (broom snakeweed), in particular, showed a relatively large decrease. The annual forb *Plantago patagonica* (wooly plantain) showed a large decrease in frequency. It appeared in 100% of plots in 2007 and only 10% in 2008. As with the functional groups, the large standard deviations indicate generally high among-plot variability. The two nonnative species, *Bromus tectorum* (cheatgrass) and *Salsola tragus* (prickly Russian thistle), both showed relatively large decreases in cover. *Bromus tectorum* decreased in plot frequency from 60% to 10%. Appendix A lists all the species, along with common names, families, mean foliar cover, and plot frequencies.

On the plot scale, diversity decreased between 2007 and 2008 (table 3); plot species richness, Shannon diversity (which takes into account relative species abundance, and generally ranges between 1.5 and 3.5), and evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) all decreased (Margalef 1972). However, on the ecological scale, diversity increased; ecological site species richness and beta diversity (a measure of within site heterogeneity, generally ranging between 1 and 5) both increased. Four more species were found in the plots in 2008 than in 2007. (While four more species appeared in the plots in 2008 than in 2007, there were also several species that were observed in the plots in 2007 that were not observed in 2008. See Appendix A). When these diversity indices were recalculated using only native species, they did not change substantially (table 3).

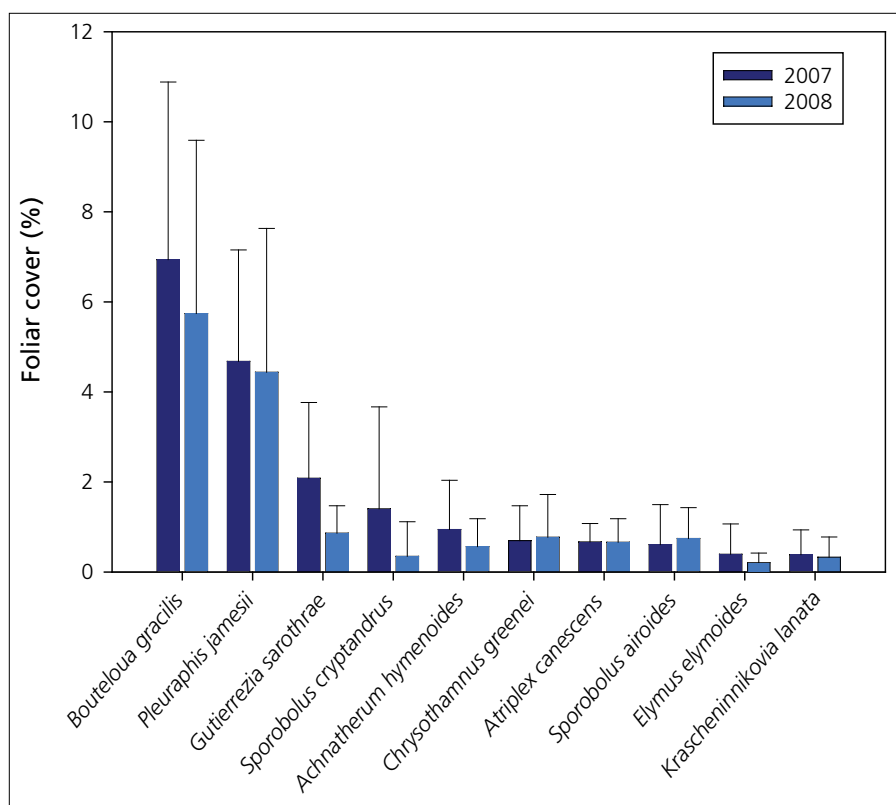


Figure 3. Mean foliar cover of the ten most abundant vascular species in 2007, as compared to 2008. Error bars represent one standard deviation.

Table 3. Species diversity metrics for all species and for native species only.

Metric	2007		2008	
	Mean	(SD)	Mean	(SD)
All species				
Plot				
Plot richness	20.4	(2.6)	18.8	(4.7)
Shannon diversity	1.827	(0.319)	1.687	(0.370)
Evenness	0.608	(0.105)	0.580	(0.117)
Ecological site				
Ecological site richness	41		45	
Beta diversity	2.113		2.528	
Native species				
Plot				
Plot richness	19.6	(2.6)	18.5	(4.5)
Shannon diversity	1.815	(0.312)	1.684	(0.366)
Evenness	0.613	(0.109)	0.582	(0.119)
Ecological site				
Ecological site richness	39		43	
Beta diversity	2.097		2.457	

Soil stability and hydrologic function

The crew monitored the amount of exposed soil in two ways: cover estimates of ground surface features in quadrats and measurements of basal gaps along transects. The cover of ground surface features shows that live plant base, dead herbaceous base and duff/litter decreased, while the amount of bare soil increased (table 4 and fig. 4). The basal gap data show relatively large differences between 2007 and 2008. The number of gaps increased, the mean gap size decreased, and the percent of the transect comprised of gaps decreased (table 5). Similarly, the number of gaps in the two smaller size classes increased (fig. 5).

Table 4. Cover of ground surface features, expressed as a percentage.

Surface feature	2007		2008	
	Mean (%)	(SD)	Mean (%)	(SD)
Live plant base	9.87	(2.71)	6.95	(1.32)
Dead woody base	0.49	(0.28)	0.46	(0.34)
Dead herbaceous base	4.31	(1.69)	1.90	(0.57)
Bare soil	9.35	(6.31)	15.24	(15.58)
Duff and litter	9.09	(3.03)	7.52	(3.24)
Undifferentiated crust	65.62	(13.22)	66.49	(16.59)
Moss	0.08	(0.25)	0.05	(0.11)
Lichen	0.00	(0.00)	<0.01	(<0.01)
Cyanobacteria	0.01	(0.02)	0.05	(0.16)
Fine gravel (0.2 cm- 2cm)	0.40	(0.59)	0.50	(0.93)
Coarse gravel (2cm – 7.5 cm)	0.20	(0.35)	0.27	(0.52)
Cobble (7.5 cm – 25 cm)	0.04	(0.08)	0.03	(0.09)
Stone, bedrock (>25 cm)	0.03	(0.09)	0.08	(0.26)
Woody debris	0.00	(0.00)	0.01	(0.03)

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

Table 5. Number of basal gaps, gap size, and percentage of total transect length comprised by gaps in 2007 and 2008.

Metric	2007		2008	
	Mean	(SD)	Mean	(SD)
Gap number	259.7	(74.2)	340.9	(64.3)
Median gap size (cm)	38.4	(10.5)	24.4	(4.4)
Percent of transect in gaps	93.0	(2.4)	88.2	(3.3)
Percent of transect in gaps ≥ 50 cm	69.6	(12.2)	55.5	(11.8)

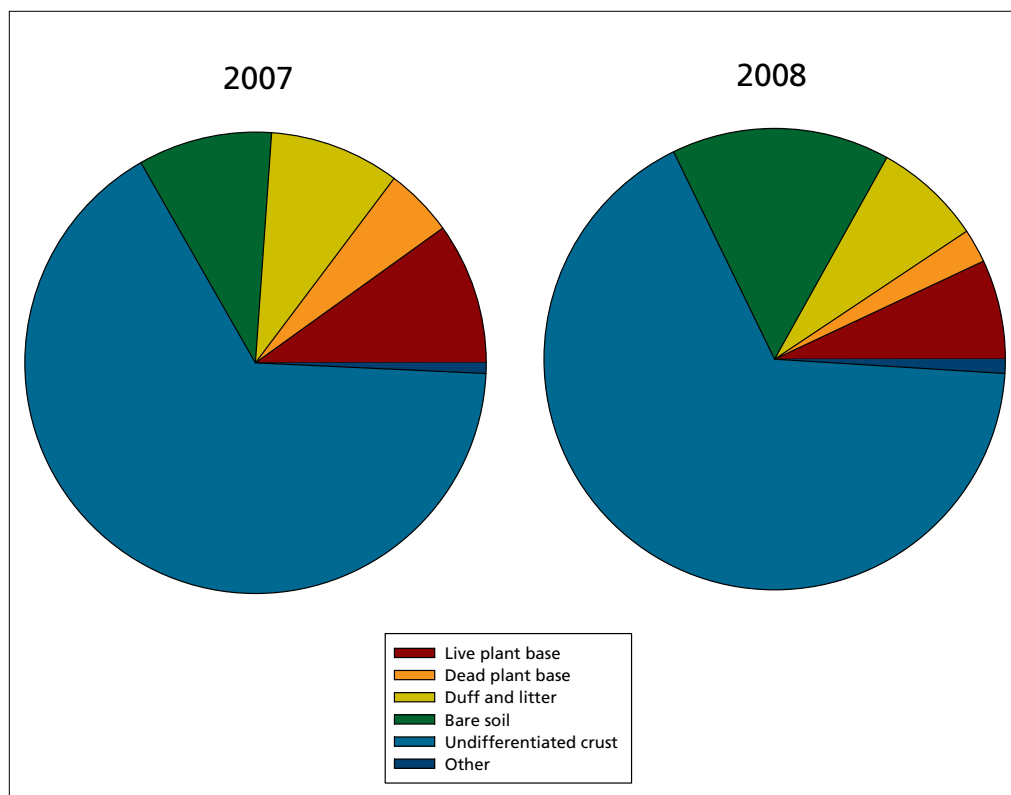


Figure 4. Mean cover of ground surface features in 2007 and 2008.

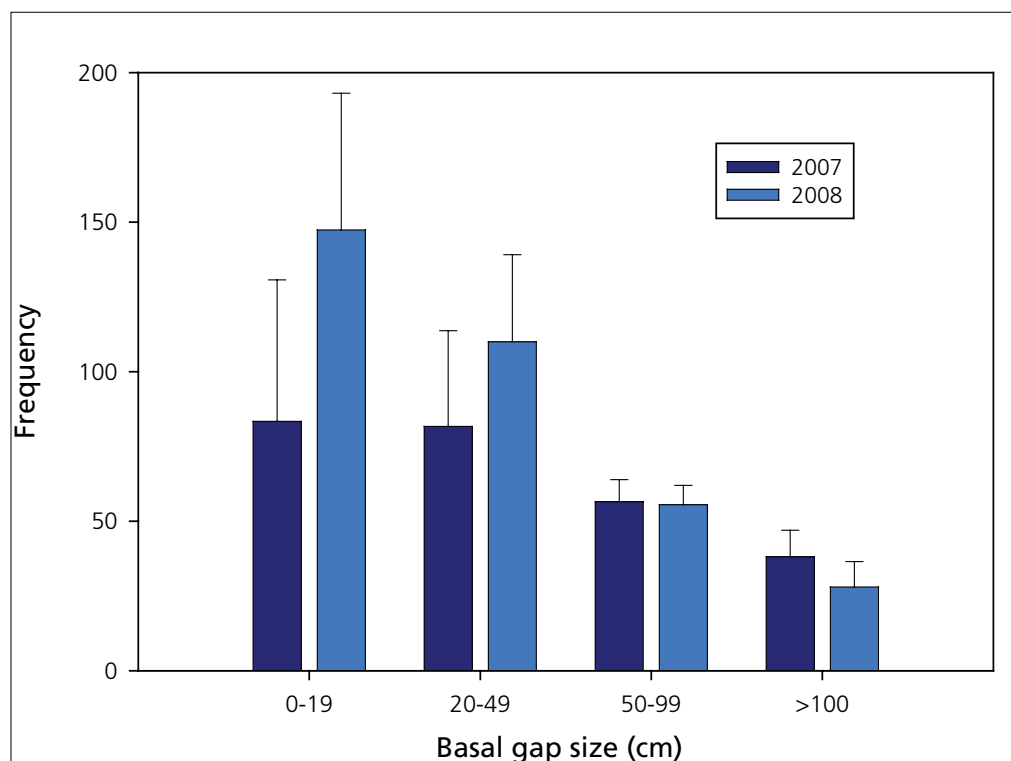


Figure 5. The frequency distribution of basal gap sizes in 2007 and 2008. Error bars represent one standard deviation.

Discussion

The 2007 and 2008 data presented here indicate changes in the vegetation cover between years. Much of these changes can be attributed to the species responding to normal annual variation in climate. The year 2007 was unusually wet. Total precipitation for the year was approximately 13 cm higher than in 2008, and approximately 10 cm higher than average (fig. 6) (WRCC 2009). Not surprisingly, there was an overall decline in total foliar cover in 2008 and decreases in cover for all functional groups.

A number of species such as *Bouteloua gracilis*, *Gutierrezia sarothrae*, and *Sporobolus cryptandrus* showed substantial decreases in cover; however, many species showed small changes (increases and decreases) in cover. Two nonnative annual species, *Bromus tectorum* (cheatgrass) and *Salsola tragus* (prickly Russian thistle), both decreased in frequency and cover. This echoes results for native annuals and indicates that all annual species likely had reduced germination and establishment during the drier 2008 season.

The large decrease in standing dead herbaceous cover may be attributable to a later sampling date in 2007 than in 2008. In 2007, sampling occurred after a hard frost had hit the area, making it much more difficult to distinguish live, senesced grass material from the previous year's standing dead material. Therefore, the crew may have overestimated the amount of standing dead herbaceous cover in 2007.

Changes in diversity showed two contrasting trends: plot species diversity decreased between the two years while ecological site diversity increased. Much of the decrease in plot diversity is attributable to a large decrease in the frequency of the annual forb *Plantago patagonica* (woolly plantain).

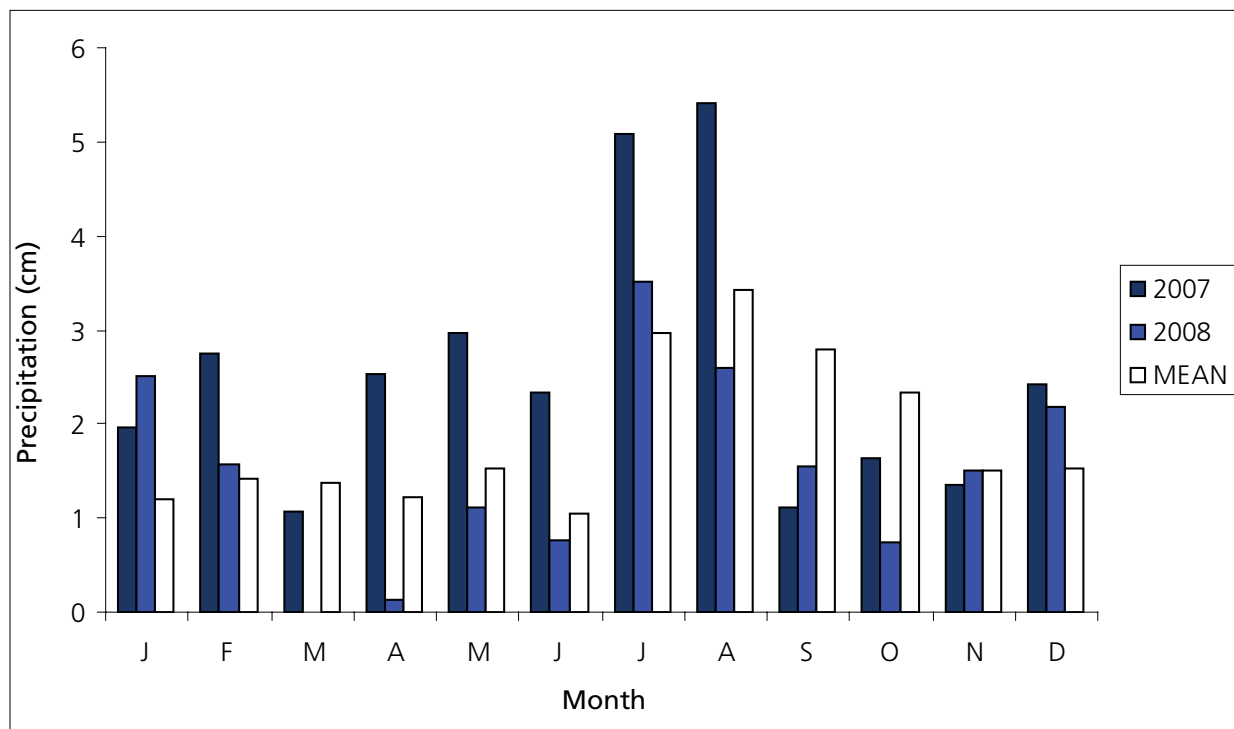


Figure 6. Monthly precipitation in 2007 and 2008 and the average precipitation (1909-2009) at Chaco Culture National Historical Park (WRCC 2009).

The number of species found across the ecological site increased, however, which in turn caused beta diversity to increase.

Changes in cover of ground surface features are more difficult to interpret. The surface feature data showed an increase in bare soil and a decrease in live plant base, which was expected, as 2007 was an unusually wet year. However, basal gap intercept data showed the opposite: a decrease in the amount of bare soil (i.e. everything that is not plant base), and hence an increase in live and dead plant bases. This pattern is found in all parks where we sampled base intercepts. We suspect that there were inconsistencies in sampling methods between years. In 2009 we are working to ensure greater consistency among observers sampling basal gap intercepts.

It should be stressed that the changes noted between these two years are not indicative of long-term trends, nor should they be viewed as being ecologically significant. As mentioned, much of the change is undoubtedly due to annual climatic fluctuations—2008 being a drier year than 2007, for example. Some of the observed changes are due to small differences in the timing of the sampling (which will become more standardized over time). Other changes are attributable to sampling error inherent in the field sampling process. Cover estimation may vary among individuals (and crews), similar species may occasionally be mis-identified, and the location of the quadrats will vary slightly from year to year. We strive to minimize these errors by ensuring that transect lines are as straight as possible, that quadrats are placed correctly, and that field crews are continuously trained on species identification and cover estimation.

The SCPN Upland Crew plans to sample the quadrats and gap intercept transects annually for the 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 significant change in key metrics. A temporal sampling design will then be implemented with the installation of additional plots in subsequent years. Each year's data will be compared to the previously collected data to analyze changes through time in vegetation composition and structure and in soil stability and hydrologic function through time. More thorough trend analyses will be conducted once sufficient data have been collected.

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Appendix A

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

Species	Common name	Family	2007		2008	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Achnatherum hymenoides</i>	Indian ricegrass	Poaceae	0.946	100	0.565	100
<i>Aristida purpurea</i>	Fendler's threeawn	Poaceae	0.101	50	0.076	70
<i>Artemisia bigelovii</i>	Bigelow sage	Asteraceae	0.112	30	0.107	30
<i>Artemisia filifolia</i>	sand sagebrush	Asteraceae	0.219	20	0.141	40
<i>Artemisia frigida</i>	fringed sagebrush	Asteraceae	0.183	50	0.064	50
<i>Astragalus</i> sp.	milkvetch	Fabaceae	0.002	40	0.001	10
<i>Atriplex canescens</i>	fourwing saltbush	Chenopodiaceae	0.670	100	0.661	100
<i>Bouteloua gracilis</i>	blue grama	Poaceae	6.939	100	5.741	100
<i>Bromus tectorum</i> ^a	cheatgrass	Poaceae	0.032	60	0.002	10
<i>Chaetopappa ericoides</i>	rose heath	Asteraceae	0.055	70	0.028	80
<i>Chamaesyce</i> spp. Group A	annual sandmats	Euphorbiaceae	0.004	30	0.002	20
<i>Chamaesyce</i> spp. Group B	annual sandmats	Euphorbiaceae	0	0	0.003	10
<i>Chenopodium fremontii</i>	Fremont's goosefoot	Chenopodiaceae	0	0	<.001	10
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0.045	50	0.013	40
<i>Chrysothamnus Greenei</i>	Greene's rabbitbrush	Asteraceae	0.697	80	0.774	90
<i>Echinocereus triglochidiatus</i>	kingcup cactus	Cactaceae	0.005	10	0.006	30
<i>Elymus elymoides</i>	squirreltail	Poaceae	0.396	100	0.207	100
<i>Ericameria nauseosa</i>	rubber rabbitbrush	Asteraceae	0.080	20	0.083	20
<i>Eriogonum cernuum</i>	nodding buckwheat	Polygonaceae	0.004	10	0.038	10
<i>Evolvulus nuttallianus</i>	shaggy dwarf morning-glory	Convolvulaceae	<.001	10	0	0
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	2.084	100	0.864	100
<i>Hesperostipa comata</i>	needle and thread	Poaceae	0.066	70	0.041	80
<i>Hymenopappus filifolius</i>	fineleaf hymenopappus	Asteraceae	<.001	10	<.001	10
<i>Krascheninnikovia lanata</i>	winterfat	Chenopodiaceae	0.387	70	0.330	80

Appendix A, continued.

<i>Lycium pallidum</i>	pale desert-thorn	Solanaceae	0.028	10	0.019	20
<i>Machaeranthera canescens</i>	hoary tansyaster	Asteraceae	0.008	30	<.001	10
<i>Monroa squarrosa</i>	false buffalograss	Poaceae	0.003	20	0.003	10
<i>Muhlenbergia torreyi</i>	ring muhly	Poaceae	0.066	50	0.035	50
<i>Oenothera</i> sp.	evening primrose	Onagraceae	0	0	0.001	30
<i>Opuntia polyacantha</i>	El Paso pricklypear	Cactaceae	0.106	90	0.084	100
<i>Opuntia whipplei</i>	Whipple's cholla	Cactaceae	0	0	<.001	10
<i>Phacelia</i> sp.	scorpionweed	Hydrophyllaceae	0.056	40	0.001	20
<i>Plantago patagonica</i>	woolly plantain	Plantaginaceae	0.139	100	0.001	10
<i>Pleuraphis jamesii</i>	James' galleta	Poaceae	4.679	100	4.437	100
<i>Rumex</i> sp.	dock	Polygonaceae	0	0	0.001	10
<i>Salsola tragus</i> ^a	prickly Russian thistle	Chenopodiaceae	0.018	20	0.007	20
<i>Sanvitalia abertii</i>	Albert's creeping zinnia	Asteraceae	0	0	0.001	10
<i>Schkuhria multiflora</i>	many-flower false threadleaf	Asteraceae	0.008	30	0	0
<i>Solanum jamesii</i>	wild potato	Solanaceae	0	0	0.007	10
<i>Sphaeralcea</i> spp.	globemallow	Malvaceae	0.014	10	0	0
<i>Sphaeralcea coccinea</i>	scarlet globemallow	Malvaceae	0.256	100	0.232	100
<i>Sphaeralcea incana</i>	soft globemallow	Malvaceae	0	0	0.009	10
<i>Sporobolus airoides</i>	alkali sacaton	Poaceae	0.609	60	0.745	90
<i>Sporobolus contractus</i>	spike dropseed	Poaceae	0	0	0.002	10
<i>Sporobolus cryptandrus</i>	sand dropseed	Poaceae	1.405	60	0.349	40
<i>Stephanomeria pauciflora</i>	brownplume wirelettuce	Asteraceae	<.001	10	0	0
<i>Verbesina enceloides</i>	golden crownbeard	Asteraceae	0	0	<.001	10
<i>Vulpia octoflora</i>	sixweeks fescue	Poaceae	0.076	100	0	0
Unknown 20071020-2			0.002	10	0	0
Unknown 20071020-4			0.001	10	0	0
Unknown 20071020-5			<.001	10	0	0
Unknown 20081003-1			0	0	<.001	10
Unknown 20081003-3			0	0	<.001	10

^aNonnative species.