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Integrated Upland Vegetation and Soils Monitoring for Petrified Forest National Park

2008 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2009/020

ON THE COVER
Integrated Upland Crew sampling vegetation in the Clayey Fan ecological site.
Photograph by: Jim DeCoster

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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).

SCPN staff and park staff selected two ecological sites for long-term monitoring of upland vegetation and soils at Petrified Forest National Park (PEFO): Clayey Fan and Sandy Loam. These ecological sites both represent large areas of the park, but they are relatively distinct from each other. 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).

In 2007 the Integrated Upland Monitoring program of SCPN began monitoring upland sites at PEFO with the installation of 10 plots in the Clayey Fan ecological site and 20 plots in the Sandy Loam ecological site, of which we are monitoring 10 (see 2007 report). We plan to sample quadrats and basal gap intercepts 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 frames from the maps of the two ecological sites, which were developed by the US Natural Resources Conservation Service (See Appendix A of DeCoster et al., in review). We modified the maps using Geographic Information System (GIS) technology by removing slopes that exceeded 20% and roads, buildings, and other infrastructure. (figs. 1a and 1b). 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 had the opportunity to reject those 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 for each sampling point and rejected the site if it did not fall within the ecological site, had a slope greater than 20%, or contained a major disturbance.

Field methods

The SCPN Upland Monitoring crew began monitoring at PEFO in 2007 with the establishment of 10 plots in each ecological site. The plots were 0.50 ha in size, measuring 71 m x 71 m. All data were collected on three 50m transects, spaced 25 meters apart, within each plot. In 2007, the crew collected the data at all the plots between mid September and early October, but in 2008, they collected data in mid October. Field methodology is provided in detail in the SCPN Integrated Upland Protocol (DeCoster et al., in review).

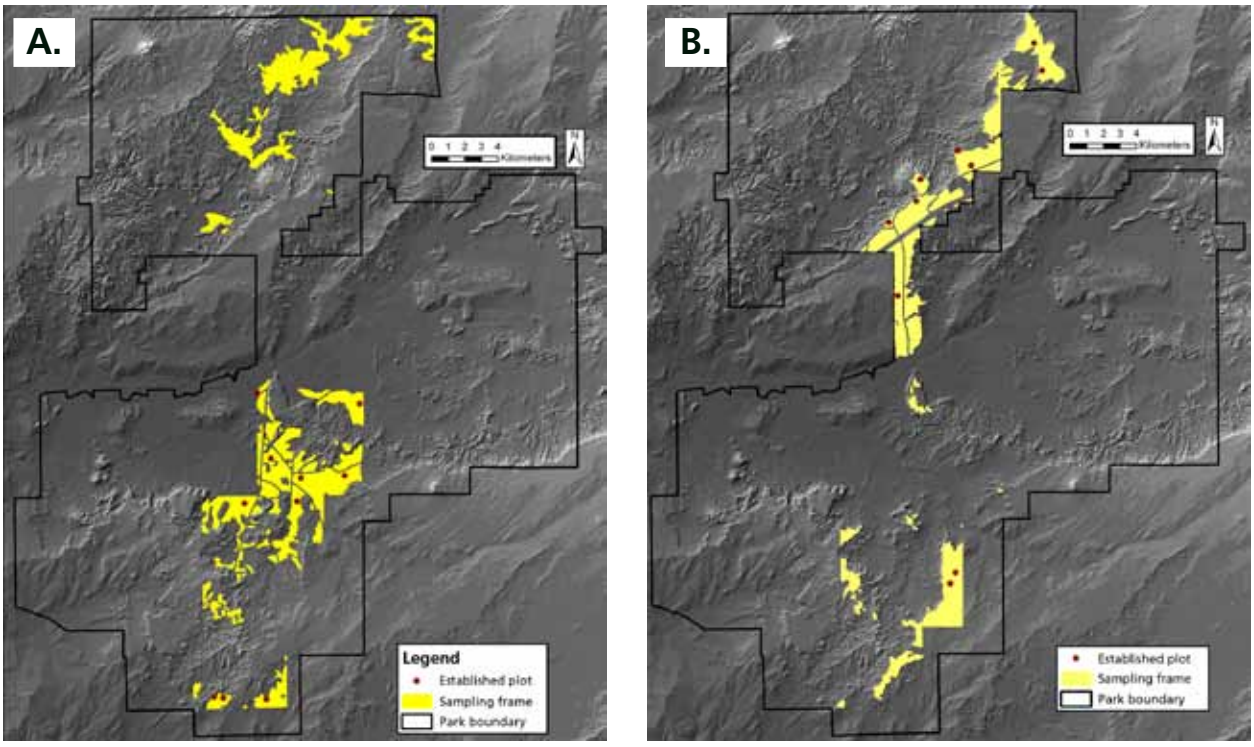

Figure 1. Sampling frames of A) Clayey Fan and B) Sandy Loam ecological sites, each showing 10 plots established in 2007.

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 m^2 (2m x 5m) with four smaller quadrats nested inside (0.01 m^2, 0.1 m^2, 1 m^2, and 5 m^2). 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 m^2 quadrat and placed in one of 12 cover classes, e.g. 2-5%, 5-10%, etc. Percent cover for 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 the basal gaps (the space between plant bases) along each transect. Percent cover of ground surface features was estimated in the 1 m^2 quadrats, in conjunction with shrub and herbaceous data, and recorded in one of 12 cover classes. A soil aggregate stability test was conducted in 2007 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, means and standard deviations were calculated from the 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 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). 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 in a site 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 (diversity among plots):

$$S_e / (S_p - 1)$$

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

Clayey Fan ecological site

Vegetation

Total live vegetative cover deceased between 2007 and 2008, from 14.91% to 11.94% (table 1 and fig. 2). The cover of functional groups decreased to varying degrees. Annual grass and forbs demonstrated relatively large decreases in cover. The large standard deviations indicate high variability in cover among plots.

While perennial grasses decreased in cover, the changes in the cover of individual species varied (table 2, fig. 3). *Sporobolus airoides* (alkali sacaton) showed a large decrease in cover, but the other dominant perennial grass species—*Pleuraphis jamesii* (James' galleta), *Bouteloua gracilis* (blue grama), and *Achnatherum hymenoides* (Indian ricegrass)—showed slight increases. Dominant shrub species—such as *Atriplex obovata* (mound saltbush), *Sarcobatus vermiculatus* (greasewood), *Eri-*

Table 1. Foliar cover of functional groups for 2007 and 2008 at the Clayey Fan ecological site.

	Foliar cover (%)			
	2007		2008	
Functional group	Mean	(SD)	Mean	(SD)
Total foliar cover	14.91	(5.58)	11.94	(3.67)
Perennial grasses	9.13	(5.10)	8.32	(3.13)
Annual grasses	2.31	(2.74)	0.05	(0.09)
Forbs	1.50	(1.52)	0.42	(0.54)
Shrubs	3.05	(3.02)	2.58	(2.91)
Cacti, succulents	0.04	(0.03)	0.03	(0.03)
Standing dead herbaceous	4.09	(1.11)	2.20	(0.68)
Standing dead woody	0.86	(0.71)	0.82	(0.93)

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

Table 2. Foliar cover and frequency of the fifteen most abundant vascular species and all nonnative species in 2007 compared to 2008 at the Clayey Fan ecological site.

	2007				2008			
Species	Mean cover (%)	SD	Quad freq	Plot freq	Mean cover (%)	SD	Quad freq	Plot freq
Sporobolus airoides	6.181	6.117	92.00	100	3.902	3.006	92.67	100
Atriplex obovata	1.589	1.453	58.00	90	1.264	1.255	56.67	100
Pleuraphis jamesii	1.266	1.172	54.67	100	1.713	1.277	61.33	100
Sporobolus coromandelianus	1.251	1.692	36.00	80	0.039	0.081	18.67	50
Bouteloua gracilis	1.21	1.588	50.67	90	1.385	1.834	54.00	90
Bouteloua barbata	1.062	1.24	55.33	90	0.034	0.07	20.00	70
Salsola tragus[a]	0.973	1.618	60.67	100	0.376	0.535	56.67	100
Atriplex canescens	0.565	1.03	21.33	50	0.529	0.921	21.33	50
Sarcobatus vermiculatus	0.293	0.928	4.00	10	0.173	0.548	4.00	10
Chamaesyce spp. Group A	0.196	0.263	61.33	100	0.006	0.011	8.00	30
Achnatherum hymenoides	0.165	0.167	34.67	90	0.255	0.193	39.33	90
Atriplex confertifolia	0.150	0.276	6.00	40	0.081	0.116	6.00	60
Ericameria nauseosa	0.119	0.178	5.33	40	0.064	0.1	4.67	40
Gutierrezia sarothrae	0.089	0.165	19.33	40	0.057	0.097	18.67	50
Sphaeralcea hastulata	0.069	0.067	30.67	90	0.027	0.03	23.33	80
Portulaca oleracea[a]	0.044	0.124	12.00	60	0	0	0	0
Bromus tectorum[a]	0.004	0.008	5.33	40	0.001	0.002	2.00	20

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

[a] Nonnative species.

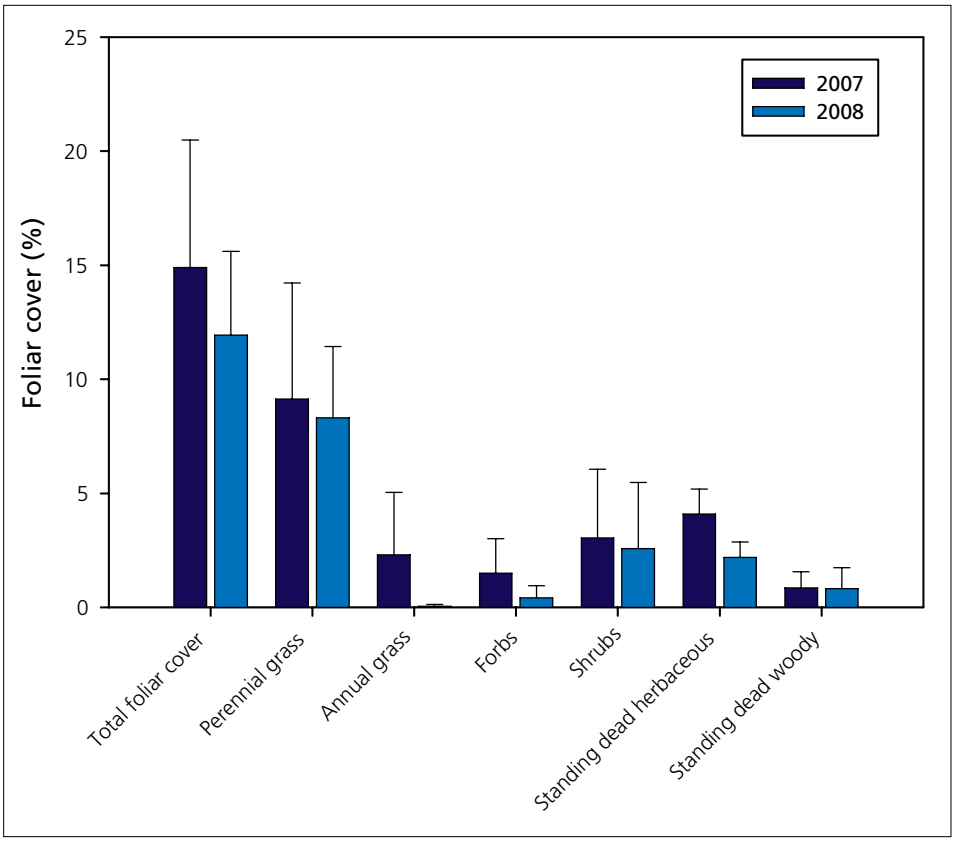

Figure 2. Mean cover of functional groups at the Clayey Fan ecological site in 2007 and 2008. Note: means for total foliar and standing dead woody cover do not include tree components in 2007. Error bars represent one standard deviation.

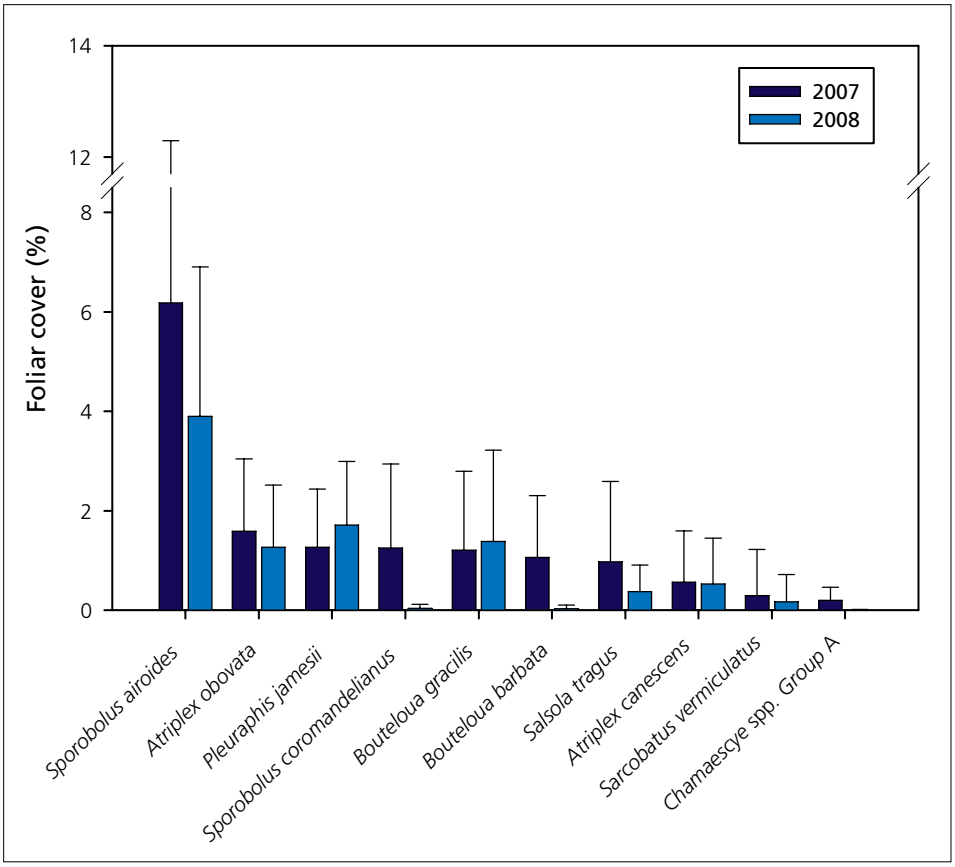

Figure 3. Mean foliar cover of the ten most abundant shrub and herbaceous species in 2007, as compared to 2008, at the Clayey Fan ecological site. Error bars represent one standard deviation.

cameria nauseosa (rubber rabbitbrush), and *Gutierrezia sarothrae* (broom snakeweed)—and forb species—such as *Salsola tragus* (prickly Russian thistle), Group A of the *Chamaesyce* spp. (annual sandmats) and *Sphaeralcea hastulata* (spear globemallow)—decreased in cover. The annual grasses *Sporobolus coromandelianus* (Madacasgar dropseed) and *Bouteloua barbata* (sixweeks grama), and *Chamaesyce* spp.(sandmats), the obovate-leaved annuals, decreased in cover and in quadrat and plot frequencies.

Three nonnative annual species were observed in the plots: *Salsola tragus* (prickly Russian thistle), *Portulaca oleracea* (little hogweed), and *Bromus tectorum* (cheatgrass). Both *Salsola tragus* and *Bromus tectorum* decreased in cover between 2007 and 2008, and *Bromus tectorum* also decreased in frequency. *Portulaca oleracea* (little hogweed), which appeared in six of the plots in 2007, did not occur in any of the plots in 2008. Appendix A lists all the species, along with common names, families, mean foliar cover, and plot frequencies.

Species diversity indices generally declined between 2007 and 2008 (table 3). Mean plot species richness decreased from 24.3 to 19.2. Ecological site species richness declined from 69 to 61. Shannon diversity (which takes into account relative species abundance and generally ranges between 1.5 and 3.5) also decreased. Evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) (Margalef 1972) and beta diversity (a measure of within site heterogeneity, generally ranging between 1 and 5) increased, suggesting that plots became less similar to each other over the two years. When these indices were recalculated using only native species, they did not change substantially (table 3).

Table 3. Species diversity metrics at Clayey Fan ecological site for all species and for native species only.

	2007		2008	
Metric	Mean	(SD)	Mean	(SD)
All species				
Plot				
Plot richness	24.3	(7.1)	19.2	(7.3)
Shannon diversity	1.755	(0.506)	1.657	(0.379)
Evenness	0.552	(0.143)	0.569	(0.081)
Ecological site				
Ecological site richness	69		61	
Beta diversity	2.961		3.352	
Native species				
Plot				
Plot richness	22.3	(7.4)	18.0	(7.2)
Shannon diversity	1.706	(0.503)	1.593	(0.373)
Evenness	0.554	(0.148)	0.561	(0.080)
Ecological site				
Ecological site richness	66		59	
Beta diversity	3.099		3.471	

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. Changes in the ground surface features between the two years were generally small, as expected (table 4 and fig. 4). However, the cover of bare soil showed a surprisingly large decrease. Basal gaps increased in number, but decreased in size (table 5 and fig. 5). The number of gaps increased from 119.0 to 158.8, the median gap size decreased from 78.7 cm to 54.2 cm, and the percentage of the transect in gaps decreased from 96.7% to 94.6%. Moreover, the number of smaller gaps increased.

Table 4. Cover of ground surface features at Clayey Fan ecological site.

	2007		2008	
Surface feature	Mean (%)	(SD)	Mean (%)	(SD)
Live plant base	5.86	(2.51)	5.10	(1.54)
Dead woody base	0.35	(0.26)	0.26	(0.46)
Dead herbaceous base	2.59	(0.89)	1.70	(0.74)
Bare soil	14.68	(7.16)	7.52	(5.05)
Duff and litter	6.26	(3.65)	7.26	(4.75)
Undifferentiated crust	70.51	(6.57)	71.67	(7.99)
Moss	0.50	(0.93)	0.20	(0.44)
Lichen	0	(0)	0	(0)
Cyanobacteria	0.13	(0.42)	0.05	(0.09)
Fine gravel (0.2 cm- 2cm)	0.78	(1.28)	0.95	(1.40)
Coarse gravel (2cm – 7.5 cm)	0.14	(0.22)	0.61	(1.78)
Cobble (7.5 cm – 25 cm)	0	(0)	0	(0)
Stone, bedrock (>25 cm)	0	(0)	0	(0)
Woody debris	0	(0)	0.02	(0.05)

Note: The surface feature 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 at Clayey Fan ecological site.

	2007		2008	
Metric	Mean	(SD)	Mean	(SD)
Gap number	119.0	(42.1)	158.8	(39.5)
Median gap size (cm)	78.7	(29.6)	54.2	(24.0)
Percent of transect in gaps	96.7	(1.3)	94.6	(1.5)
Percent of transect in gaps ≥ 50 cm	89.0	(4.8)	82.8	(5.2)

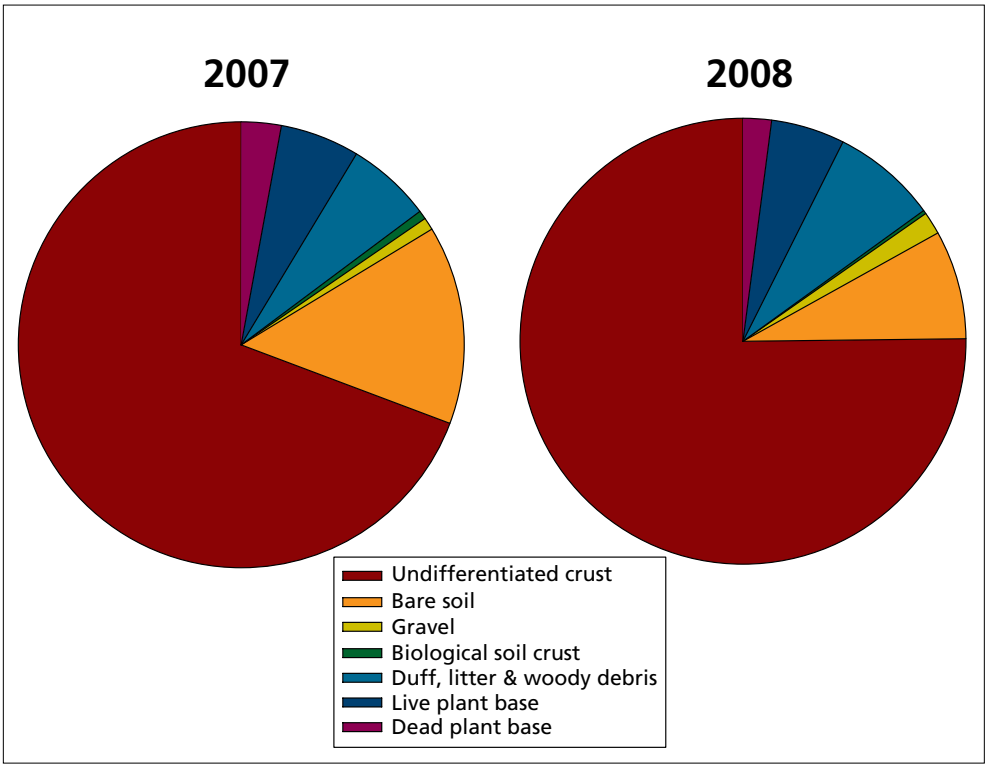

Figure 4. Mean cover of ground surface features at the Clayey Fan ecological site in 2007 and 2008. Error bars represent one standard deviation.

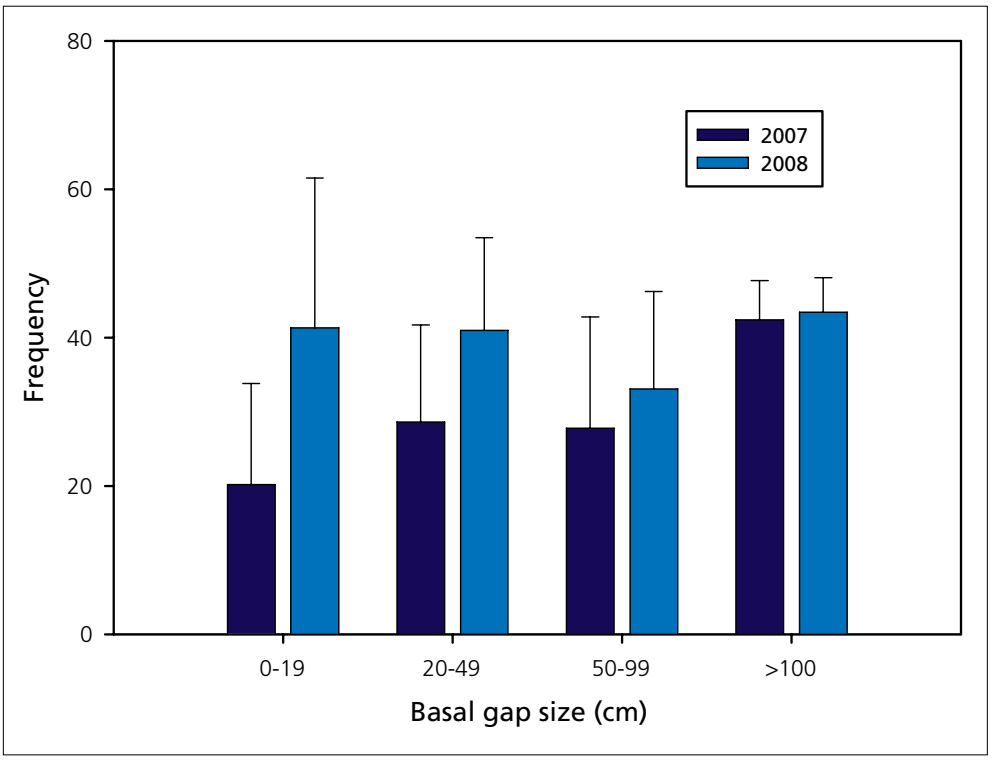

Figure 5. The frequency distribution of basal gaps sizes in 2007 and 2008 at Clayey Fan ecological site. Error bars represent one standard deviation.

Sandy Loam ecological site

Vegetation

While total live vegetative cover in the Sandy Loam ecological site did decrease, the total live vegetative cover did not decrease as much as it did at the Clayey Fan ecological site (table 6 and fig. 6). All the functional groups decreased in cover, but to varying degrees. Annual grass cover decreased from 0.71% to 0.02%.

Table 6. Foliar cover and frequency of functional groups for 2007 and 2008 at the Sandy Loam ecological site.

	Foliar cover (%)			
	2007		2008	
Functional group	Mean	(SD)	Mean	(SD)
Total foliar cover	18.58	(5.33)	17.76	(3.51)
Perennial grasses	11.21	(4.99)	10.99	(4.65)
Annual grasses	0.71	(2.03)	0.02	(0.03)
Forbs	0.92	(1.18)	0.81	(1.87)
Shrubs	5.35	(2.92)	5.19	(2.50)
Cacti, succulents	0.15	(0.15)	0.13	(0.15)
Standing dead herbaceous	5.01	(2.78)	1.94	(1.23)
Standing dead woody	1.232	(0.84)	1.32	(0.51)

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

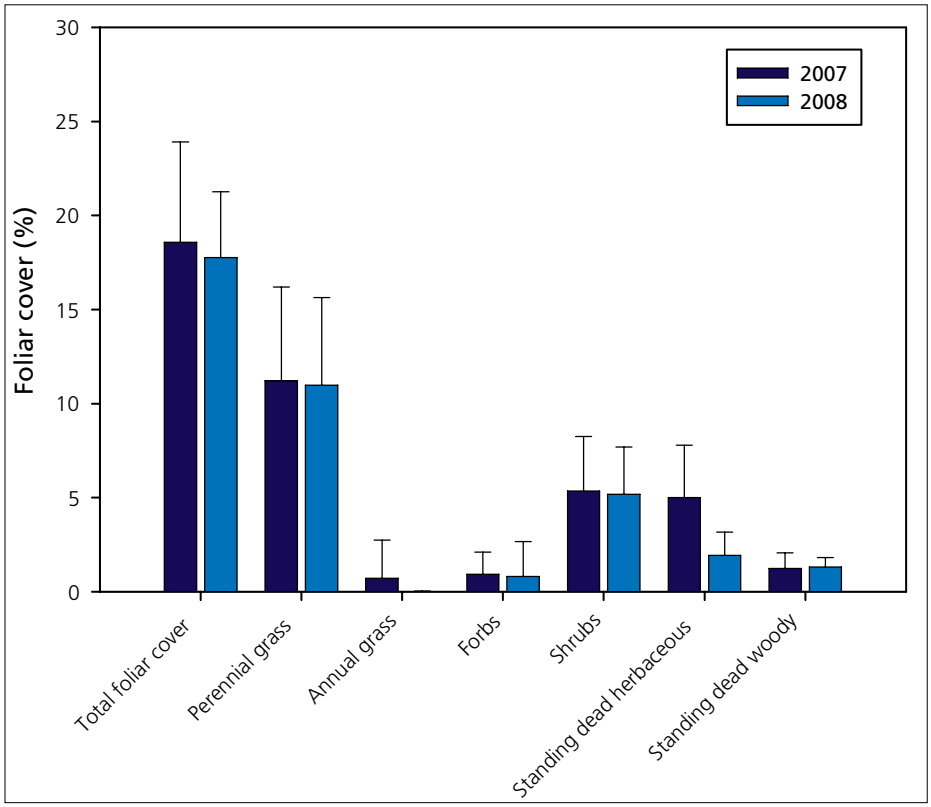

Figure 6. Mean foliar cover of functional groups in 2007 and 2008 at Sandy Loam ecological site. Error bars represent one standard deviation.

The foliar cover of many of the dominant species, including *Bouteloua gracilis*, *Chrysothamnus greenei*, and *Achnatherum hymenoides*, also decreased slightly in 2008 (table 7 and fig. 7). The cover of only a few species increased. Frequencies generally did not show substantial changes; however the annual species *Bromus tectorum*, *Salsola tragus*, and *Sporobolus flexousus*, showed moderate decreases in frequencies. The large standard deviations indicate large among-plot variability.

Four nonnative species occurred in the plots. In 2008, *Bromus tectorum* showed a large decrease in cover, while *Salsola tragus* showed a large increase. However, both species decreased in frequency. *Portulaca oleracea* and *Polygonum aviculare* (prostate hogweed), both with very low abundances in 2007, were not found in 2008. Appendix B lists all the species, along with common names, families, mean foliar cover, and plot frequencies.

Plot species diversity indices generally decreased between 2007 and 2008 (table 8). Ecological site richness decreased from 63 to 55, and mean plot richness decreased from 23.6 to 20.9. Shannon diversity (which takes into account relative species abundance, and generally ranges between 1.5 and 3.5) and beta diversity (a measure of within site heterogeneity, generally ranging between 1 and 5) similarly showed small decreases (Margalef 1972). Only evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) increased. When these indices were recalculated using only native species, they did not change substantially (table 8).

Table 7. Foliar cover and frequency of the fifteen most abundant vascular species and all nonnative species in 2007 compared to 2008 at the Sandy Loam ecological site.

	2007				2008			
Species	Mean cover (%)	SD	Quad freq	Plot freq	Mean cover (%)	SD	Quad freq	Plot freq
Bouteloua gracilis	3.712	3.512	65.33	80	3.815	3.469	66.67	80
Sporobolus airoides	2.622	4.457	44.00	90	2.142	3.54	41.33	70
Pleuraphis jamesii	2.589	2.562	75.33	100	2.444	2.68	74.00	100
Gutierrezia sarothrae	1.495	0.99	70.67	90	1.225	0.651	72.00	90
Atriplex canescens	1.085	1.092	43.33	90	0.686	0.651	42.67	90
Chrysothamnus greenei	0.776	1.405	22.00	50	0.980	1.54	24.67	60
Artemisia filifolia	0.743	1.551	14.67	30	0.602	1.115	15.33	30
Bromus tectorum[a]	0.726	2.198	20.67	60	0.098	0.291	10.00	50
Bouteloua eriopoda	0.714	1.735	20.67	60	0.536	1.159	22.00	60
Achnatherum hymenoides	0.484	0.685	50.00	90	0.764	1.036	59.33	90
Salsola tragus[a]	0.365	0.745	36.67	70	0.632	1.757	27.33	60
Artemisia bigelovii	0.363	0.783	13.33	30	0.364	0.833	14.67	40
Ephedra torreyana	0.279	0.425	12.00	60	0.306	0.354	11.33	60
Hesperostipa comata	0.256	0.403	26.00	60	0.323	0.544	27.33	60
Sporobolus flexuosus	0.224	0.694	6.67	20	0.012	0.032	2.00	20
Portulaca oleracea[a]	0.002	0.006	0.67	10	0	0	0	0
Polygonum aviculare[a]	<.001	0.001	0.67	10	0	0	0	0

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

[a] Nonnative species.

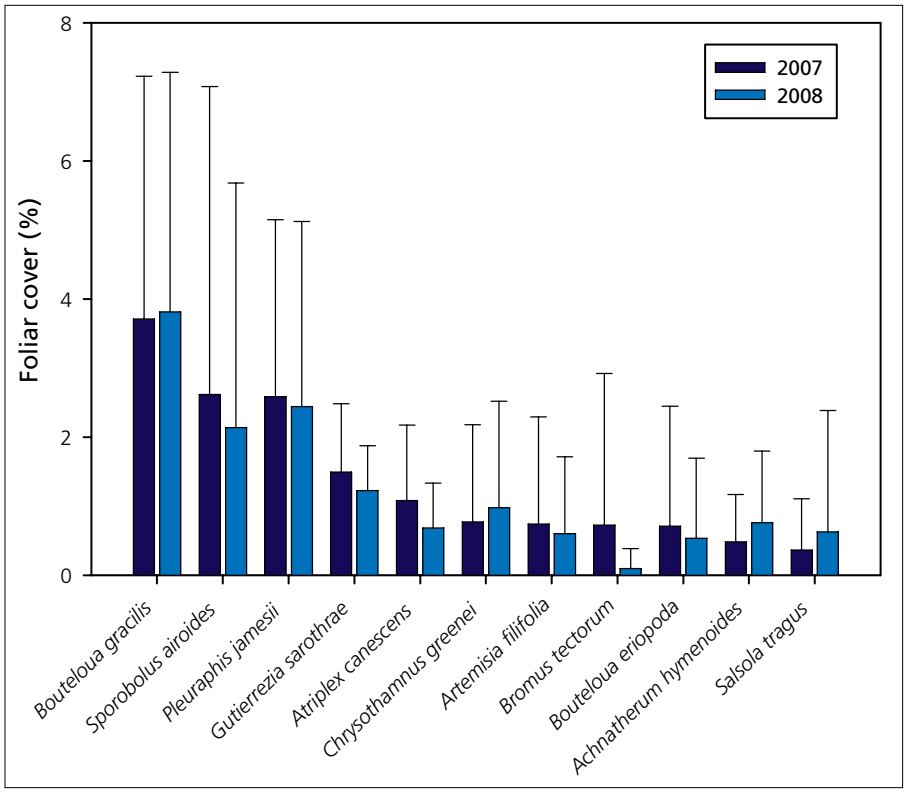

Figure 7. Mean foliar cover of the ten most abundant shrub and herbaceous species in 2007, as compared to 2008, at the Sandy Loam ecological site. Error bars represent one standard deviation.

Table 8. Species diversity metrics at Sandy Loam ecological site for all species and for native species only.

	2007		2008	
Metric	Mean	(SD)	Mean	(SD)
All species				
Plot				
Plot richness	23.6	(5.0)	20.9	(5.7)
Shannon diversity	1.859	(0.482)	1.789	(0.492)
Evenness	0.586	(0.125)	0.590	(0.125)
Ecological site				
Ecological site richness	63		55	
Beta diversity	2.788		2.764	
Native species				
Plot				
Plot richness	22.1	(4.8)	19.7	(5.4)
Shannon diversity	1.804	(0.493)	1.771	(0.500)
Evenness	0.581	(0.132)	0.597	(0.123)
Ecological site				
Ecological site richness	59		52	
Beta diversity	2.796		2.781	

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. As expected, surface feature data showed relatively little change between 2007 and 2008 (table 9 and fig. 8). However, undifferentiated crust did increase, and bare soil decreased. The cover of cyanobacteria also decreased. From 2007 to 2008, the number of basal gaps increased, the median gap size decreased, and the percentage of the transect in gaps (both for all gaps and for gaps greater than 50 cm) decreased (table 10). The number of gaps in all size classes increased, with the exception of the largest size class, which decreased (fig. 9).

Table 9. Cover of ground surface features at Sandy Loam ecological site.

	2007		2008	
Surface feature	Mean (%)	(SD)	Mean (%)	(SD)
Live plant base	6.69	(2.74)	7.48	(2.95)
Dead woody base	0.28	(0.34)	0.40	(0.42)
Dead herbaceous base	3.00	(1.61)	1.76	(1.19)
Bare soil	19.91	(20.06)	5.37	(3.30)
Duff and litter	7.00	(2.31)	8.03	(3.35)
Undifferentiated crust	59.39	(20.18)	73.07	(8.95)
Moss	0.10	(0.29)	0.04	(0.10)
Lichen	0	(0)	0.05	(0.15)
Cyanobacteria	0.50	(1.58)	0.01	(0.02)
Fine gravel (0.2 cm- 2cm)	1.93	(5.82)	2.01	(6.10)
Coarse gravel (2cm – 7.5 cm)	0.15	(0.45)	0.06	(0.16)
Cobble (7.5 cm – 25 cm)	0	(0)	0	(0)
Stone, bedrock (>25 cm)	0	(0)	0	(0)
Woody debris	0.52	(1.31)	0.05	(0.11)

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

Table 10. Number of basal gaps, gap size, and percentage of total transect length comprised by gaps in 2007 and 2008 at Sandy Loam ecological site.

	2007		2008	
Metric	Mean	(SD)	Mean	(SD)
Gap number	145.5	(51.3)	221.7	(85.9)
Median gap size (cm)	78.7	(61.2)	49.4	(31.2)
Percent of transect in gaps	95.5	(1.7)	91.3	(3.1)
Percent of transect in gaps ≥ 50 cm	84.7	(7.7)	72.4	(13.1)

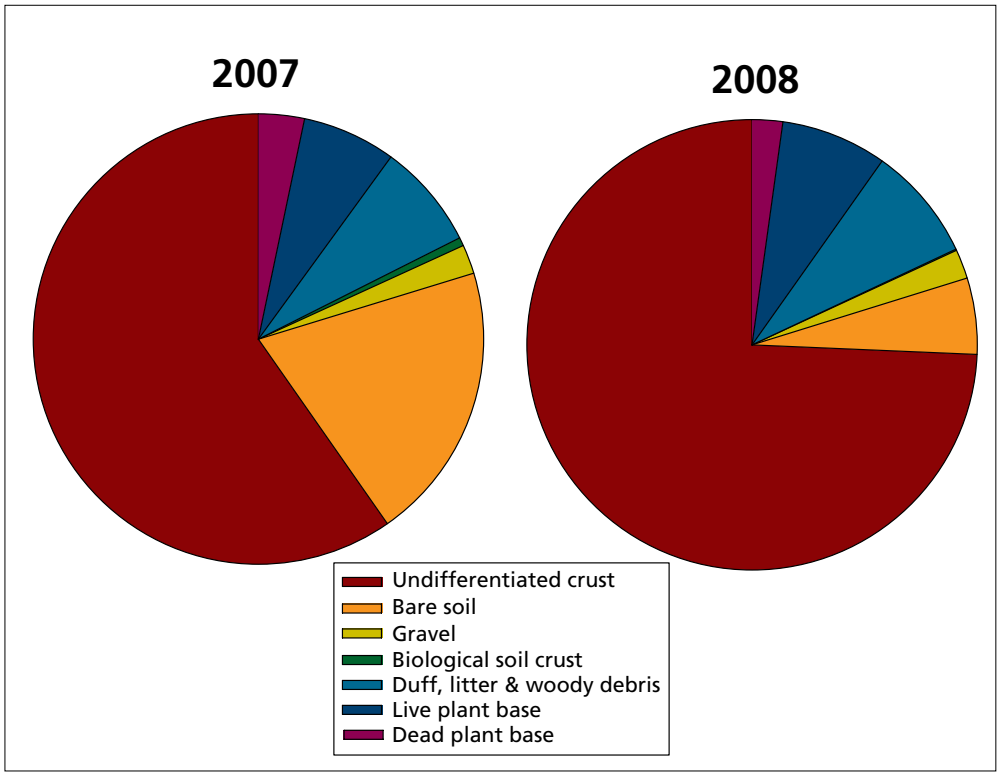

Figure 8. Mean cover of ground surface features at the Sandy Loam ecological site in 2007 and 2008. Error bars represent one standard deviation.

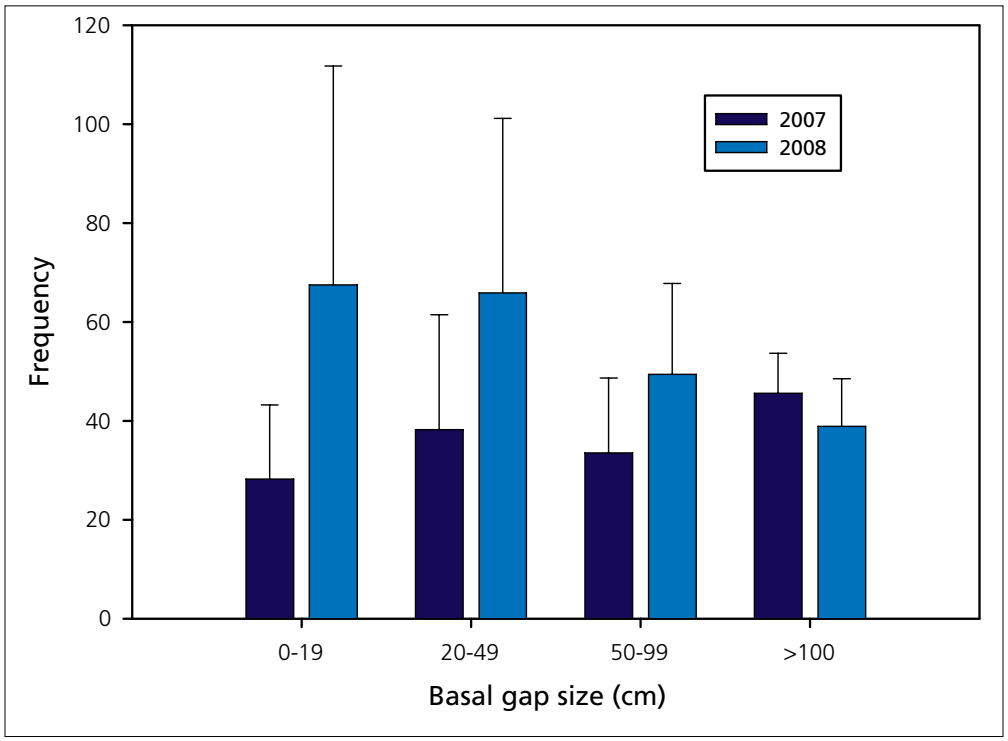

Figure 9. The frequency distribution of basal gaps sizes in 2007 and 2008 at Sandy Loam ecological site. Error bars represent one standard deviation.

Discussion

The Clayey Fan and Sandy Loam ecological sites had differences not only in their vegetative structure, but also in way their vegetation and soil components changed between the years 2007 and 2008. The Clayey Fan ecological site showed decreases in total live vegetative cover, decreases in the cover of most functional groups, and decreases in cover for many individual species in 2008. The Sandy Loam ecological site, in contrast, showed a smaller decrease in total live vegetative cover and smaller decreases in the cover of most functional groups and species. Annual grasses, however, showed large decreases in both sites. Most of these changes in cover are likely due to climatic fluctuation between years. July 2007 was extremely wet, causing increased germination and growth, especially of annuals (fig. 10, WRCC 2009). This strong monsoon likely affected the Clayey Fan site over a longer period than at the Sandy Loam site, since its clay soils have a higher water holding capacity than the soils at the Sandy Loam ecological site. In contrast, plant species in the Sandy Loam ecological site are likely more adapted to the drought conditions of sandy soils.

Foliar cover of nonnative species decreased at both ecological sites, with the exception of *Salsola tragus*, which increased in cover, but decreased in frequency at the Sandy Loam site. Several nonnative species that were in low abundance in 2007 were not found in 2008. All the nonnative species found in the plots were annuals, and were likely strongly affected by the wet July in 2007, as described above. Species diversity indices decreased from 2007 to 2008, with the exceptions of beta diversity in the Clayey Fan site and evenness in the Sandy Loam site. We attribute these changes to the loss of several annual species at both ecological sites between 2007 and 2008.

The soils data were more difficult to interpret. In both sites, the cover of undifferentiated crust increased and the cover of bare soil decreased. Cyanobacteria decreased in cover in the Sandy Loam ecological site in 2008. These changes may be attributable to how ground surface features appear in wet conditions versus dry conditions. When the soil surface is wet, cyanobacteria are much more visible, and undifferentiated crust becomes more difficult to distinguish from bare soil.

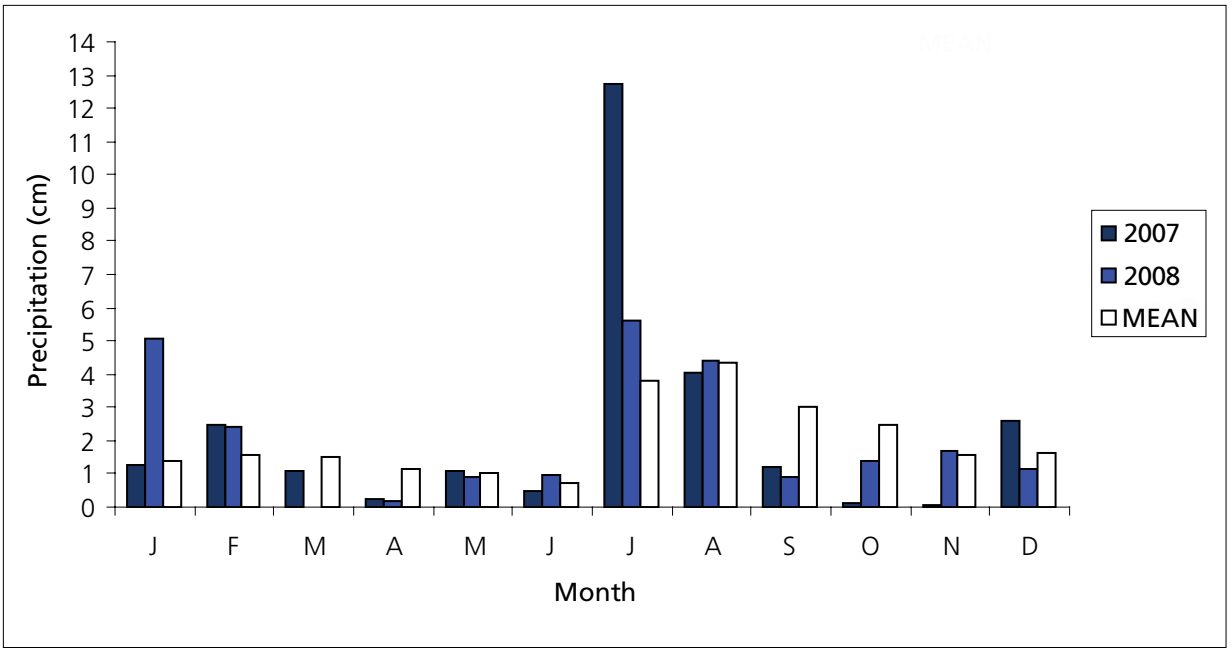

Figure 10. Monthly precipitation in 2007 and 2008 and the average precipitation (1931-2009) at Petrified Forest National Park (WRCC 2009).

We stress that the changes noted between these two years are not indicative of long-term trends, since trends cannnot be determined with only two years of sampling, nor should they be viewed as being ecologically significant. As mentioned, much of the change is undoubtedly due to annual climatic fluctuations, for example, 2008 being a drier year than 2007. Some of the observed changes were 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 misidentified, and the location of the quadrats will vary slightly from year to year. We strive to minimize these errors by ensuring transect lines are as straight as possible, quadrats are placed correctly, and field crews are trained continuously on species identification and cover estimation.

The SCPN Upland Crew plans to sample the quadrats annually for 3-5 years to determine the range of annual variability for key metrics. Power analysis will then be used to determine the total number of plots necessary to detect change in the key metrics. A temporal sampling design will then be implemented, with the installation of additional plots in subsequent years. Each year's data will be compared to the previously collected data to analyze changes through time in vegetation composition and structure and in soil stability and hydrologic function. 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 for the Clayey Fan ecological site. *Chamaesyce* spp. not identifiable to species are placed in one of two groups based on leaf morphology.

			2007		2008	
Species	Common name	Family	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
Achnatherum hymenoides	Indian ricegrass	Poaceae	0.165	90	0.255	90
Aristida adscensionis	sixweeks threeawn	Poaceae	0	0	0.001	10
Aristida purpurea	Fendler's threeawn	Poaceae	<.001	10	<.001	10
Artemisia bigelovii	Bigelow sage	Asteraceae	0.002	10	0.002	10
Artemisia filifolia	sand sagebrush	Asteraceae	0.005	10	0.010	10
Astragalus sp.	milkvetch	Fabaceae	0.017	60	0.002	40
Atriplex canescens	fourwing saltbush	Chenopodiaceae	0.565	50	0.529	50
Atriplex confertifolia	shadscale saltbush	Chenopodiaceae	0.150	40	0.081	60
Atriplex obovata	mound saltbush	Chenopodiaceae	1.589	90	1.264	100
Bouteloua barbata	sixweeks grama	Poaceae	1.062	90	0.034	70
Bouteloua eriopoda	black grama	Poaceae	0.050	10	0.050	10
Bouteloua gracilis	blue grama	Poaceae	1.210	90	1.385	90
Bromus tectorum[a]	cheatgrass	Poaceae	0.004	40	0.001	20
Calochortus aureus	golden mariposa lily	Liliaceae	0	0	0.001	10
Chaetopappa ericoides	rose heath	Asteraceae	0.009	50	0.008	50
Chamaesyce spp. Group A	annual sandmats	Euphorbiaceae	0.196	100	0.006	30
Chamaesyce spp. Group B	annual sandmats	Euphorbiaceae	0.021	40	0	0
Chamaesaracha coronopus	greenleaf five eyes	Solanaceae	0.014	30	<.001	10
Chenopodium fremontii	Fremont's goosefoot	Chenopodiaceae	0	0	<.001	10
Chenopodium leptophyllum	narrowleaf goosefoot	Chenopodiaceae	<.001	10	0	0
Cordylanthus wrightii	Wright's bird's beak	Scrophulariaceae	0	0	0.002	10
Dalea candida	white prairieclover	Fabaceae	0.027	30	0.002	10
Dimorphocarpa wislizeni	spectacle pod	Brassicaceae	0	0	<.001	10

Appendix A, continued.

Elymus elymoides	squirreltail	Poaceae	0.006	20	0.02	40
Ephedra cutleri	Cutler's jointfir	Ephedraceae	0.015	20	0.095	20
Ephedra torreyana	Torrey's jointfir	Ephedraceae	0.060	20	0.020	20
Ephedra viridis	mormon tea	Ephedraceae	0.050	10	0.050	10
Eragrostis pectinacea	desert lovegrass	Poaceae	0.031	10	0	0
Eriastrum diffusum	miniature woollystar	Polemoniaceae	<.001	10	0	0
Ericameria nauseosa	rubber rabbitbrush	Asteraceae	0.119	40	0.064	40
Erigeron concinnus	Navajo fleabane	Asteraceae	0.001	10	<.001	10
Erigeron divergens	spreading fleabane	Asteraceae	0	0	0.013	50
Eriogonum cernuum	nodding buckwheat	Polygonaceae	0	0	0.001	20
Eriogonum deflexum	flatcrown buckwheat	Polygonaceae	0.007	40	0.015	30
Eriogonum divaricatum	divergent buckwheat	Polygonaceae	0.006	50	0.002	20
Escobaria vivipara	spinystar	Cactaceae	0	0	0	10
Gaillardia pinnatifida	red dome blanketflower	Asteraceae	<.001	10	0	0
Gutierrezia sarothrae	broom snakeweed	Asteraceae	0.089	40	0.057	50
Heliomeris multiflora	showy goldeneye	Asteraceae	<.001	10	<.001	10
Hesperostipa comata	needle and thread	Poaceae	0	0	0.009	30
Hymenopappus flavescens	college flower	Asteraceae	0.004	10	0	0
Ipomopsis sp.	ipomopsis	Polemoniaceae	0.001	20	0	0
Isocoma drummondii	Drummond's goldenbush	Asteraceae	0.027	20	0.012	20
Krascheninnikovia lanata	winterfat	Chenopodiaceae	0.016	30	0.016	20
Machaeranthera canescens	hoary tansyaster	Asteraceae	0.002	20	<.001	10
Mentzelia albicaulis	whitestem blazingstar	Loasaceae	0.002	30	0.002	10
Monroa squarrosa	false buffalograss	Poaceae	0.030	80	0.005	30
Muhlenbergia pungens	sandhill muhly	Poaceae	0.009	20	0.008	20
Oenothera sp.	evening primrose	Onagraceae	0.019	40	0.001	10
Opuntia sp.	prickly pear	Cactaceae	0.011	40	0.006	30
Opuntia whipplei	Whipple's cholla	Cactaceae	0.007	20	0.012	20
Panicum hirticaule	Mexican panicgrass	Poaceae	0.001	10	0	0

Appendix A, continued.

Parryella filifolia	common dunebroom	Fabaceae	0.038	10	0.017	10
Pectis angustifolia	lemonscent	Asteraceae	0.008	20	0.001	20
Plantago patagonica	woolly plantain	Plantaginaceae	0.030	80	0.002	20
Pleuraphis jamesii	James' galleta	Poaceae	1.266	100	1.713	100
Portulaca oleracea[a]	little hogweed	Portulacaceae	0.044	60	0	0
Psilostrophe tagetina	woolly paperflower	Asteraceae	0.001	10	<.001	10
Salsola tragus[a]	prickly Russian thistle	Chenopodiaceae	0.973	100	0.376	100
Sanvitalia abertii	Albert's creeping zinnia	Asteraceae	0.012	20	0.001	20
Sarcobatus vermiculatus	greasewood	Chenopodiaceae	0.293	10	0.173	10
Schkuhria multiflora	many-flower false threadleaf	Asteraceae	0.001	20	0	0
Senecio flaccidus	threadleaf ragwort	Asteraceae	0.004	10	0.004	10
Sphaeralcea hastulata	spear globemallow	Malvaceae	0.069	90	0.027	80
Sporobolus airoides	alkali sacaton	Poaceae	6.181	100	3.902	100
Sporobolus contractus	spike dropseed	Poaceae	0.056	30	0.022	10
Sporobolus coromandelianus	Madagascar dropseed	Poaceae	1.251	80	0.039	50
Sporobolus cryptandrus	sand dropseed	Poaceae	0.008	40	0.014	50
Sporobolus flexuosus	mesa dropseed	Poaceae	0.020	20	0.222	30
Thelesperma megapotamicum	Hopi tea greenthread	Asteraceae	<.001	10	0	0
Vulpia octoflora	sixweeks fescue	Poaceae	0.005	40	0	0
Yucca angustissima	narrowleaf yucca	Agavaceae	0.009	40	0.007	50
Unknown 09172007-1			<.001	10	0	0
Unknown 09272007-2			0.007	10	0	0
Unknown 10012007-1			<.001	10	0	0
Unknown 10022007-2			0.002	10	0	0
Unknown 10022007-3			<.001	10	0	0
Unknown 10042007-2			0.001	10	0	0
Unknown 10212008-1			0	0	0.003	10

[a] Nonnative species.

Appendix B

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

			2007		2008	
Species	Common name	Family	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
Achnatherum hymenoides	Indian ricegrass	Poaceae	0.484	90	0.764	90
Amaranthus sp.	pigweed	Amaranthaceae	<.001	10	0	0
Aristida purpurea	Fendler's threeawn	Poaceae	0.040	40	0.052	50
Artemisia bigelovii	Bigelow sage	Asteraceae	0.363	30	0.364	40
Artemisia filifolia	sand sagebrush	Asteraceae	0.743	30	0.602	30
Asclepias subverticillata	western whorled milkweed	Asclepiadaceae	<.001	10	<.001	10
Astragalus sp.	milkvetch	Fabaceae	0.004	50	<.001	10
Atriplex canescens	fourwing saltbush	Chenopodiaceae	1.085	90	0.686	90
Atriplex confertifolia	shadscale saltbush	Chenopodiaceae	0.096	20	0.194	20
Atriplex obovata	mound saltbush	Chenopodiaceae	0.224	10	0.144	10
Bouteloua barbata	sixweeks grama	Poaceae	0.005	20	0.001	20
Bouteloua eriopoda	black grama	Poaceae	0.714	60	0.536	60
Bouteloua gracilis	blue grama	Poaceae	3.712	80	3.815	80
Bromus tectorum[a]	cheatgrass	Poaceae	0.726	60	0.098	50
Chaetopappa ericoides	rose heath	Asteraceae	0.093	90	0.073	90
Chamaesyce spp. Group A	annual sandmats	Euphorbiaceae	0.042	80	0.001	20
Chamaesyce spp. Group B	annual sandmats	Euphorbiaceae	0.010	50	0.001	20
Chamaesaracha coronopus	greenleaf five eyes	Solanaceae	0.001	10	0	0
Chenopodium leptophyllum	narrowleaf goosefoot	Chenopodiaceae	0.002	10	0	0
Chrysothamnus greenei	Greene's rabbitbrush	Asteraceae	0.776	50	0.980	60
Cryptantha sp.	cryptantha	Boraginaceae	0	0	0.001	20
Dasyochloa pulchella	low woollygrass	Poaceae	0	0	<.001	10
Elymus elymoides	squirreltail	Poaceae	0.021	60	0.058	90

Appendix B, continued.

Ephedra cutleri	Cutler's jointfir	Ephedraceae	0.083	10	0.076	10
Ephedra torreyana	Torrey's jointfir	Ephedraceae	0.279	60	0.306	60
Ericameria nauseosa	rubber rabbitbrush	Asteraceae	0.028	20	0.060	20
Erigeron divergens	spreading fleabane	Asteraceae	0.005	10	<.001	10
Eriogonum corymbosum	crispleaf buckwheat	Polygonaceae	<.001	10	0.002	10
Eriogonum ericifolium	Yavapai buckwheat	Polygonaceae	0.002	10	0.002	10
Eriogonum jamesii	James' buckwheat	Polygonaceae	0.002	10	0.002	10
Eriogonum leptocladon	sand buckwheat	Polygonaceae	0	0	0.001	20
Escobaria vivipara	spinystar	Cactaceae	0.002	10	0.002	10
Evolvulus nuttallianus	shaggy dwarf morning-glory	Convolvulaceae	0.011	20	0.006	20
Gutierrezia sarothrae	broom snakeweed	Asteraceae	1.495	90	1.225	90
Hesperostipa comata	needle and thread	Poaceae	0.256	60	0.323	60
Hymenopappus flavescens	college flower	Asteraceae	0.003	20	0	0
Ipomopsis longiflora	whiteflower ipomopsis	Polemoniaceae	0.050	50	0.009	30
Krascheninnikovia lanata	winterfat	Chenopodiaceae	0.091	50	0.097	50
Machaeranthera canescens	hoary tansyaster	Asteraceae	0.015	20	0.003	30
Machaeranthera gracilis	slender goldenweed	Asteraceae	<.001	10	0	0
Mentzelia albicaulis	whitestem blazingstar	Loasaceae	0.002	10	0	0
Monroa squarrosa	false buffalograss	Poaceae	0.019	40	<.001	10
Muhlenbergia pungens	sandhill muhly	Poaceae	0.038	20	0.032	20
Muhlenbergia torreyi	ring muhly	Poaceae	0.069	60	0.046	60
Oenothera caespitosa	tufted evening-primrose	Onagraceae	0.002	10	0	0
Opuntia sp.	prickly pear	Cactaceae	0.022	60	0.012	60
Opuntia whipplei	Whipple's cholla	Cactaceae	0.085	60	0.081	70
Plantago patagonica	woolly plantain	Plantaginaceae	0.035	80	0.004	30
Pleuraphis jamesii	James' galleta	Poaceae	2.589	100	2.444	100
Polygonum aviculare	prostrate knotweed	Polygonaceae	0	10	0	0
Polygonum douglasii	Douglas' knotweed	Polygonaceae	0	0	0.002	10
Portulaca oleracea[a]	little hogweed	Portulacaceae	0.002	10	0	0

Appendix B, continued.

Salsola tragus[a]	prickly Russian thistle	Chenopodiaceae	0.365	70	0.632	60
Schkuhria multiflora	many-flower false threadleaf	Asteraceae	<.001	10	0	0
Senecio flaccidus	threadleaf ragwort	Asteraceae	<.001	10	0	0
Sisymbrium altissimum	tumblemustard	Brassicaceae	0	0	<.001	10
Sphaeralcea hastulata	spear globemallow	Malvaceae	0.142	70	0.073	80
Sporobolus airoides	alkali sacaton	Poaceae	2.622	90	2.142	70
Sporobolus contractus	spike dropseed	Poaceae	0.039	10	0.033	20
Sporobolus coromandelianus	Madagascar dropseed	Poaceae	0.036	20	0.001	10
Sporobolus cryptandrus	sand dropseed	Poaceae	0.035	10	0.152	60
Sporobolus flexuosus	mesa dropseed	Poaceae	0.224	20	0.012	20
Verbena bracteata	bigbract verbena	Verbenaceae	0.023	10	0.002	10
Vulpia octoflora	sixweeks fescue	Poaceae	0.018	70	0	0
Yucca angustissima	narrowleaf yucca	Agavaceae	0.036	50	0.028	40
Yucca baccata	banana yucca	Agavaceae	0.002	10	0.002	10
Zinnia grandiflora	Rocky Mountain zinnia	Asteraceae	0.085	30	0.026	30
Unknown 09122007-2			<.001	10	0	0

[a] Nonnative species.