



Integrated Upland Vegetation and Soils Monitoring for Grand Canyon National Park

2009 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2011/171



ON THE COVER

Herbaceous vegetation in the Mixed Conifer ecological site in Grand Canyon National Park
Photograph by: Jim DeCoster

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The corresponding author and project manager for this project is Jim DeCoster (jim_decoaster@nps.gov). Megan Swan is the botanist and crew leader for the project. Other contributions were made by the SCPN staff. The 2009 field crew consisted of Teresa DeKoker, Lara Dickson, Hillary Hudson, and Steve Till.

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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 strong 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 mixed-conifer forest for long-term monitoring of upland vegetation at Grand Canyon National Park (GRCA). The mixed-conifer forest is a unique ecosystem. There are few extensive areas of this system on the Colorado Plateau, and climate change and altered fire regimes threaten its integrity.

In 2007 the Integrated Upland Monitoring program of SCPN began monitoring upland sites at GRCA with the installation of 16 plots in each ecological site. We have sampled the quadrats annually for three years to determine the range of temporal variability for key metrics. In this report, we document monitoring activities in the 2009 field season and compare these data with the data collected in 2007 and 2008.

Methods

Sampling frame

The sampling frame is the area from which we randomly select our sites, and hence the area to which statistical inferences can be made. We derived the sampling frame from the maps of the two ecological sites: Loamy Hills Cold and Loamy Hills ecological sites (See Appendix A of DeCoster et al., in review). The ecological site maps were developed by the US Natural Resources Conservation Service. 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 Loamy Hills Cold and Loamy Hills ecological sites are high elevation areas with mixed-conifer forests and spruce-fir forests.

To create the sampling frame, maps of the two ecological sites were merged into one, henceforth referred to as the Mixed-Conifer ecological site. To complete the sampling frame, we modified the map of the ecological site using Geographical Information System (GIS) technology. These modifications were necessary to avoid areas

- outside of the target ecological site (roads, buildings and other infrastructure, and elevations below 2500 m),
- expected to differ substantially from the norm, such as burned areas and mechanically treated areas, because these areas would have increased ecological variation and made it more difficult to detect trends
- potentially at risk for erosion as a result of sampling (slopes $\geq 30\%$) (fig. 1).

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 an archaeologist examined the sites and rejected points that landed too close to archaeological sites. Before establishing a plot, the Integrated Upland crew conducted an ecological site assessment for each sampling point and rejected sites that did not fall within the ecological site, had a slope greater

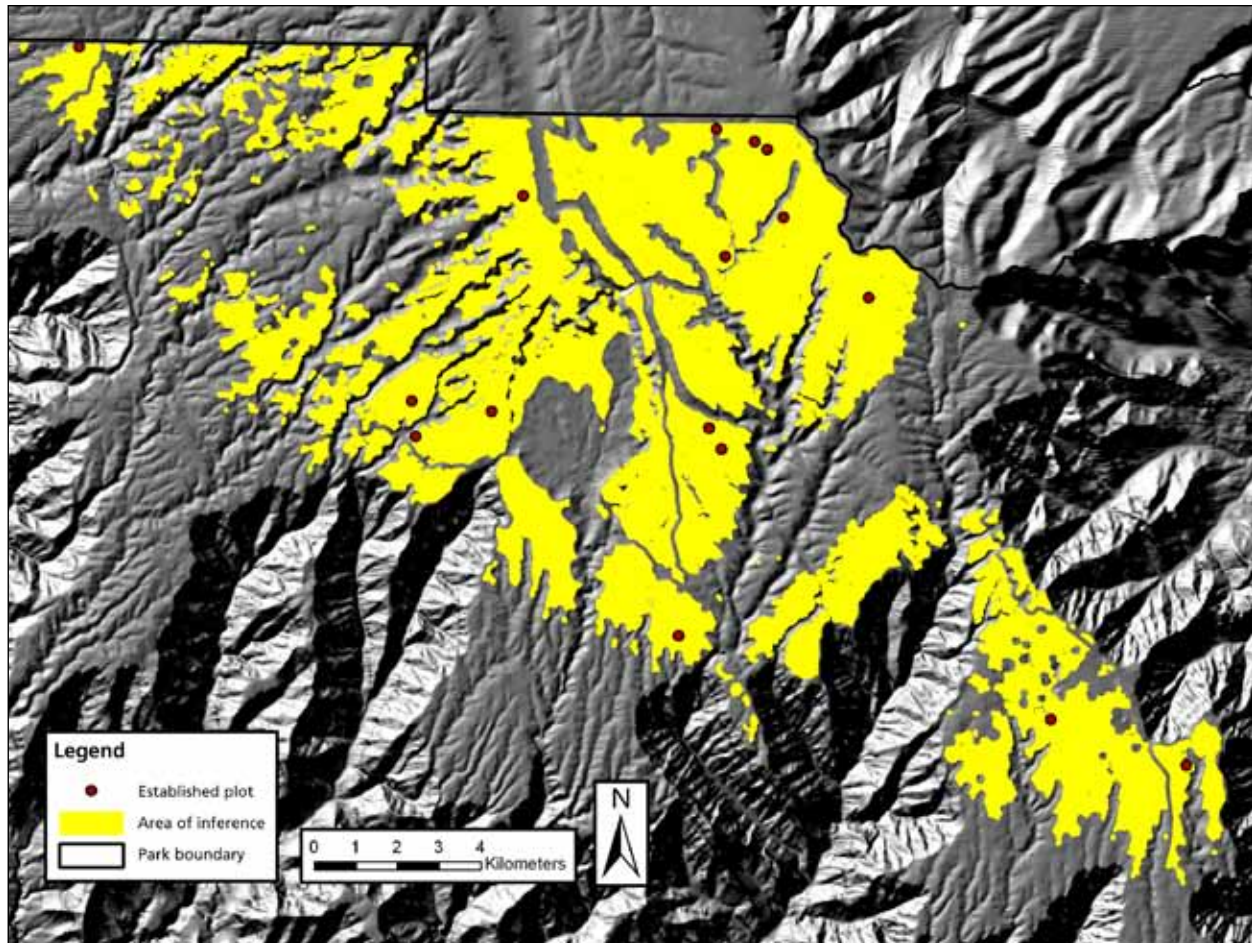


Figure 1. Sampling frame of the Mixed-Conifer ecological site showing the 16 plots sampled in 2007, 2008, and 2009

than 30%, or contained a major disturbance. They rejected five points: four points occurred on slopes >30%, and one point occurred in a ponderosa pine forest.

Field methods

In 2009, the SCPN Upland Monitoring crew sampled the same 16 plots that were established at GRCA in 2007 and read in 2008. The plots were 0.50 ha in size, measuring 71 × 71 m. Shrub and herbaceous data and soil data were collected on three 50 m transects, spaced 25 m apart, within each plot. Overstory tree and sapling data were collected in subplots located between two of the transects. In 2007 the crew collected the data in all the plots through July; in 2008 they collected data in late June and early July; and in 2009 they collected data in early through mid July. Field methodology is provided in detail in the SCPN Integrated Upland Protocol (DeCoster et al., in review).

Shrub and herbaceous vegetation

The crew sampled shrub and herbaceous vegetation within five sets of nested quadrats at 10 m intervals along each transect. The largest quadrat size was 10 m² (2 × 5 m), with four smaller quadrats nested inside (0.01 m², 0.1 m², 1 m², 5 m²). For each nested sub-quadrat we recorded the presence of individual vascular species. For each 10 m² quadrat we estimated percent cover for herbaceous

and shrub species and recorded it as one of 12 cover classes (e.g. 2%–5%, 5%–10%, etc.). We also estimated the percent cover for functional groups (e.g. perennial grasses, forbs, shrubs) in the 10 m² quadrats and recorded the cover class for each.

Overstory trees and saplings

We measured and mapped trees in 2007, but did not remeasure them in 2008 or 2009. In 2008 we measured tree canopy closure with a hemispherical densiometer at five points along each transect. In 2009 we took no measurements of the trees or canopy.

Soil stability and hydrologic function

The crew estimated the percent cover of soil surface features in the 1 m² quadrats in conjunction with shrub and herbaceous data and recorded the cover in one of 12 cover classes.

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 was 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 from the plot means. 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 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 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.

Results

Shrub and herbaceous vegetation

A mixture of perennial grasses and graminoids, forbs, and shrubs comprise the herbaceous/shrub vegetation of the Mixed-Conifer ecological site at GRCA (table 1 and fig. 2). The data shows that total live vegetative cover was 14.44% in 2007 and decreased to 5.17% in 2008 and 5.30% in 2009. This change, however, is largely due to changes in methods: in 2007, tree foliar cover (< 2 m in height) was included in the estimation of total live vegetative cover, but tree cover was not included in 2008. Also, standing dead woody cover in 2007 included trees (< 2 m) and shrubs, but in 2008 and 2009 standing dead woody cover included only shrubs. While there were some changes in the cover of the other functional groups, most of these changes were small, particularly in light of the large among-plot variability, as indicated by the large standard deviations. Perennial grass/graminoid cover ranged between 1.34% and 2.24%; forb cover ranged between 1.51% and 1.67%; shrub cover ranged between 1.40% and 2.00%. There were no annual grasses or cacti/succulents.

Dominant graminoids included *Carex siccata* (dry-spike sedge), *Carex rossii* (Ross' sedge) and *Poa fendleriana* (muttongrass); dominant shrubs included *Juniperus communis* (common juniper) and *Robinia neomexicana* (New Mexico locust); and dominant forbs included *Fragaria virginiana* (Virginia strawberry), *Pteridium aquilinum* (western bracken fern) and *Pedicularis centranthera* (dwarf lousewort). Like the functional groups, cover of individual species differed among the three years, but most of these changes were quite small, especially considering the large standard deviations (table 2 and fig. 3). The largest changes included decreases in *Carex siccata* and *Carex rossii* in 2008, a decrease in *Pteridium aquilinum* (western bracken fern) in 2008, and an increase in *Robinia*

Table 1. Mean foliar cover of functional groups for 2007, 2008, and 2009

Functional groups	Foliar cover (%)					
	2007		2008		2009	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
Total live foliar cover	14.44	(5.73)	5.17 ^a	(3.67)	5.30 ^a	(4.28)
Perennial grasses, graminoids	2.24	(1.70)	1.61	(1.74)	1.34	(0.89)
Annual grasses	0	(0)	0	(0)	0	(0)
Forbs	1.51	(1.55)	1.55	(1.53)	1.67	(1.59)
Shrubs	1.40	(1.72)	1.41	(1.45)	2.00	(3.19)
Cacti, succulents	0	(0)	0	(0)	0	(0)
Understory trees (<2 m height)	7.44	(5.30)	n/a ^a	n/a	n/a ^a	n/a
Standing dead herbaceous	1.05	(0.83)	0.87	(1.14)	0.49	0.58
Standing dead woody	0.53	(0.30)	0.07 ^b	(0.09)	0.03 ^b	0.03

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 derived independently.

^a Foliar cover of understory trees was not estimated or included in the total foliar cover in 2008 and 2009.

^b Standing dead woody cover did not include tree components in 2008 and 2009.

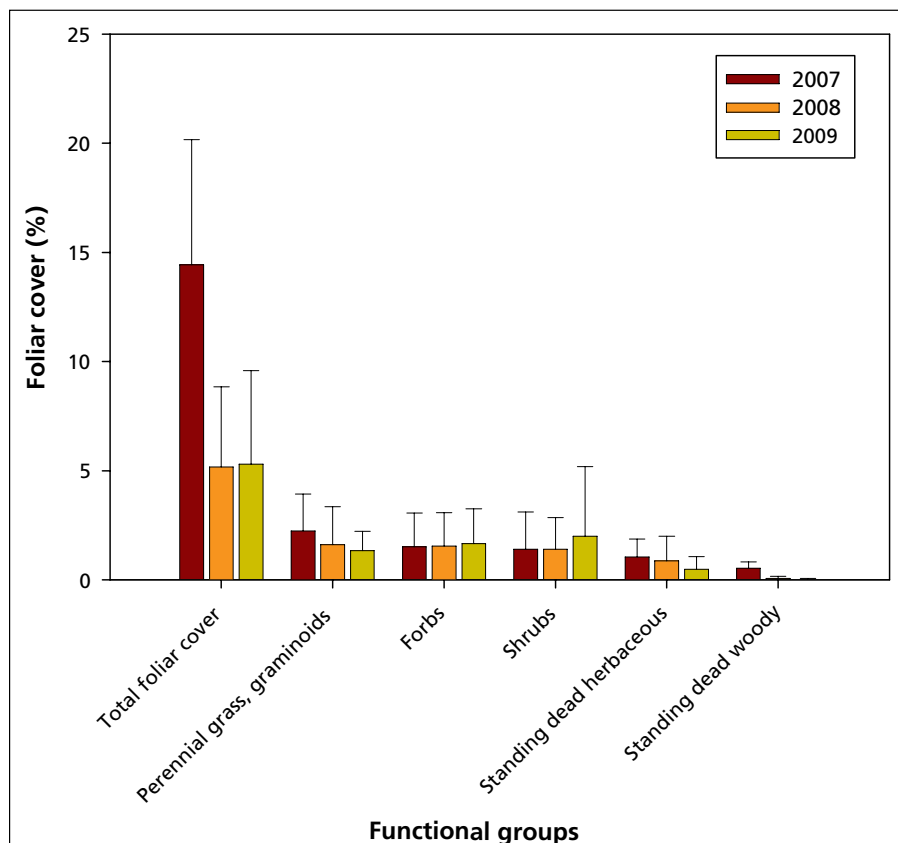


Figure 2. Mean cover of functional groups in 2007, 2008, and 2009. Error bars represent one standard deviation.

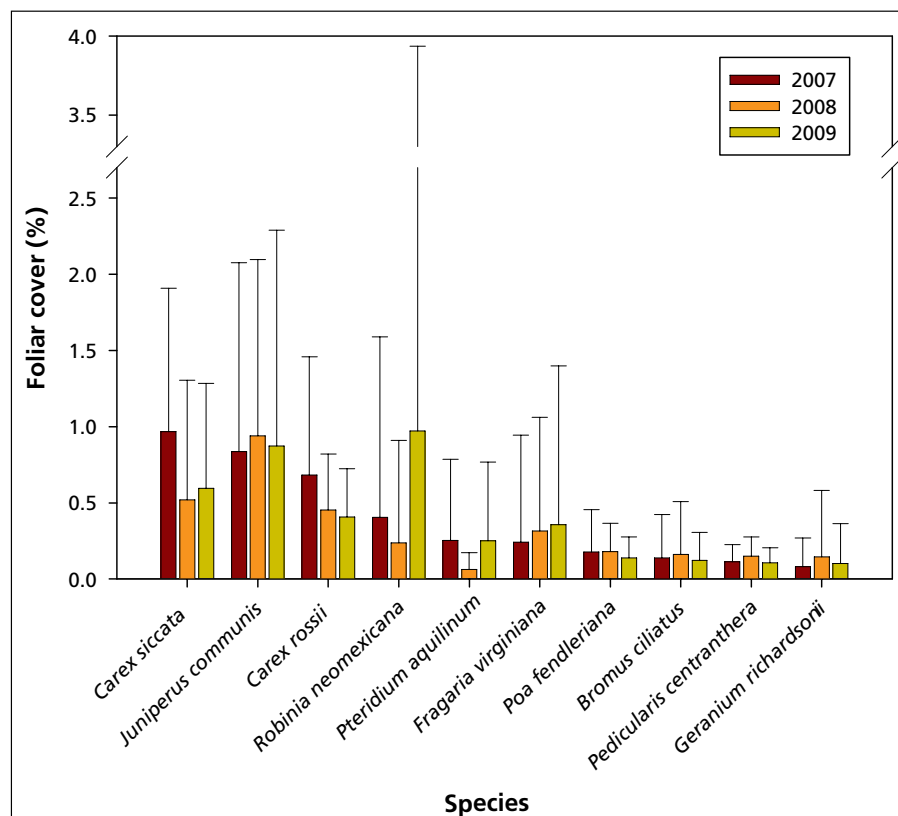


Figure 3. Mean foliar cover of the ten most abundant shrub and herbaceous species in 2007, 2008, and 2009. Error bars represent one standard deviation.

Table 2. Foliar cover and frequency of the fifteen most abundant vascular species and all nonnative species in 2007, 2008, and 2009

Species	2007				2008				2009			
	Mean cover (%)	SD	Quad freq	Plot freq	Mean cover (%)	SD	Quad freq	Plot freq	Mean cover (%)	SD	Quad freq	Plot freq
<i>Carex siccata</i>	0.966	0.942	42.08	87.50	0.519	0.785	42.50	81.25	0.595	0.690	43.75	81.25
<i>Juniperus communis</i>	0.836	1.240	20.42	68.75	0.939	1.159	17.92	62.50	0.874	1.415	20.42	68.75
<i>Carex rossii</i>	0.682	0.777	65.42	100.00	0.452	0.367	74.17	100.00	0.406	0.317	72.50	100.00
<i>Robinia neomexicana</i>	0.404	1.185	7.50	12.50	0.236	0.674	7.50	12.50	0.971	2.963	7.92	12.50
<i>Pteridium aquilinum</i>	0.254	0.532	9.17	37.50	0.062	0.111	7.50	31.25	0.251	0.516	8.33	37.50
<i>Fragaria virginiana</i>	0.242	0.703	23.33	100.00	0.315	0.747	23.33	100.00	0.357	1.042	24.58	100.00
<i>Poa fendleriana</i>	0.178	0.277	36.67	100.00	0.179	0.186	37.08	100.00	0.139	0.137	35.83	81.25
<i>Bromus ciliatus</i>	0.139	0.284	30.83	100.00	0.161	0.348	34.17	100.00	0.121	0.185	32.92	100.00
<i>Pedicularis centranthera</i>	0.114	0.112	38.75	87.50	0.15	0.125	37.92	87.50	0.105	0.100	38.33	93.75
<i>Geranium richardsonii</i>	0.081	0.187	10.00	25.00	0.145	0.438	12.08	25.00	0.101	0.261	10.83	25.00
<i>Mahonia repens</i>	0.069	0.082	17.50	68.75	0.099	0.121	17.08	68.75	0.099	0.155	17.08	68.75
<i>Ligusticum porteri</i>	0.064	0.147	9.58	43.75	0.045	0.100	10.00	43.75	0.075	0.183	8.33	43.75
<i>Chamerion angustifolium</i>	0.061	0.128	8.75	50.00	0.053	0.096	10.42	50.00	0.118	0.280	9.17	50.00
<i>Chenopodium album</i>	0.060	0.231	4.17	12.50	0.033	0.129	4.17	18.75	0.002	0.006	4.58	12.50
<i>Lotus utahensis</i>	0.042	0.065	12.08	50.00	0.032	0.044	12.50	56.25	0.048	0.076	15.42	62.50
<i>Taraxacum officinale</i> ^a	0.003	0.012	0.83	12.50	0.003	0.008	1.67	12.50	0.003	0.008	2.08	18.75

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

^a Nonnative species.

neomexicana (New Mexico locust) in 2009.

Quadrat and plot frequencies did not change substantially between years. The plot frequencies of *Poa fendleriana* and *Chenopodium album* changed the most; frequencies of *Poa fendleriana* decreased in 2009 and frequencies of *Chenopodium album* increased in 2008. Despite large changes in cover, *Robinia neomexicana* did not show substantial changes in frequencies. There were, however, a number of species that were not present in the plots in all three years. Some species were present in only one of the three years and are referred to here as unique species. Others were present in two of the three years. In 2008 there were two unique species (not including the unknown), and in 2009 there were four unique species (See Appendix A).

Only one nonnative species occurred in the plots over the three years: *Taraxacum officinale* (common dandelion). It occurred all three years with low cover (0.003%) and frequency, although in 2009 it increased in plot frequency. Appendix A lists all species, along with common names, families, mean foliar covers, and plot frequencies by year.

Plant diversity showed little variation among the three years. On the scale of the plot, species richness ranged between 22.6 to 23.7 species per plot, with 2008 being the lowest (table 3). Shannon diversity (which takes into account relative species abundance, and generally ranges between 1.5 and 3.5)

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

	2007		2008		2009	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
All species						
Plot						
Plot richness	22.9	(5.7)	22.6	(5.6)	23.7	(6.2)
Shannon diversity	1.828	(0.358)	1.985	(0.491)	1.904	(0.473)
Evenness	0.588	(0.097)	0.637	(0.134)	0.605	(0.135)
Ecological site						
Ecological site richness	87		87		87	
Beta diversity	3.977		4.035		3.835	
Native species						
Plot						
Plot richness	22.8	(5.7)	22.4	(5.5)	23.4	(6.0)
Shannon diversity	1.826	(0.358)	1.981	(0.488)	1.900	(0.471)
Evenness	0.588	(0.097)	0.637	(0.134)	0.605	(0.135)
Ecological site						
Ecological site richness	86		86		86	
Beta diversity	3.954		4.012		3.822	

ranged between 1.828 and 1.985, and evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) ranged between 0.588 and 0.637 (Margalef 1972). On the scale of the ecological site, species richness remained constant with 87 species, and beta diversity (a measure of within site heterogeneity, generally ranging between 1 and 5) ranged between 3.835 and 4.035 (McClune and Grace 2002). When these indices were recalculated using only native species, all indices were slightly lower or remained the same.

Soil stability and hydrologic function

The crew monitored soil surface features in all three years. As expected, most changes in the surface features were relatively small (table 4 and fig. 4). Duff/litter was the dominant feature, ranging from 79.53% to 80.97%. Woody debris, however, did show an increase over the three years, from 6.54% in 2007 to 11.22% in 2009.

Discussion

The data presented here indicate relatively small variation in the vegetation and surface features in the Mixed-Conifer ecological site among the years 2007, 2008, and 2009. Variation in functional group cover and species cover and frequencies were small, especially considering the high variability among plots. Similarly, the species diversity indices showed small among-year variation. We stress that the differences noted between years are not indicative of any trend, since trends cannot be

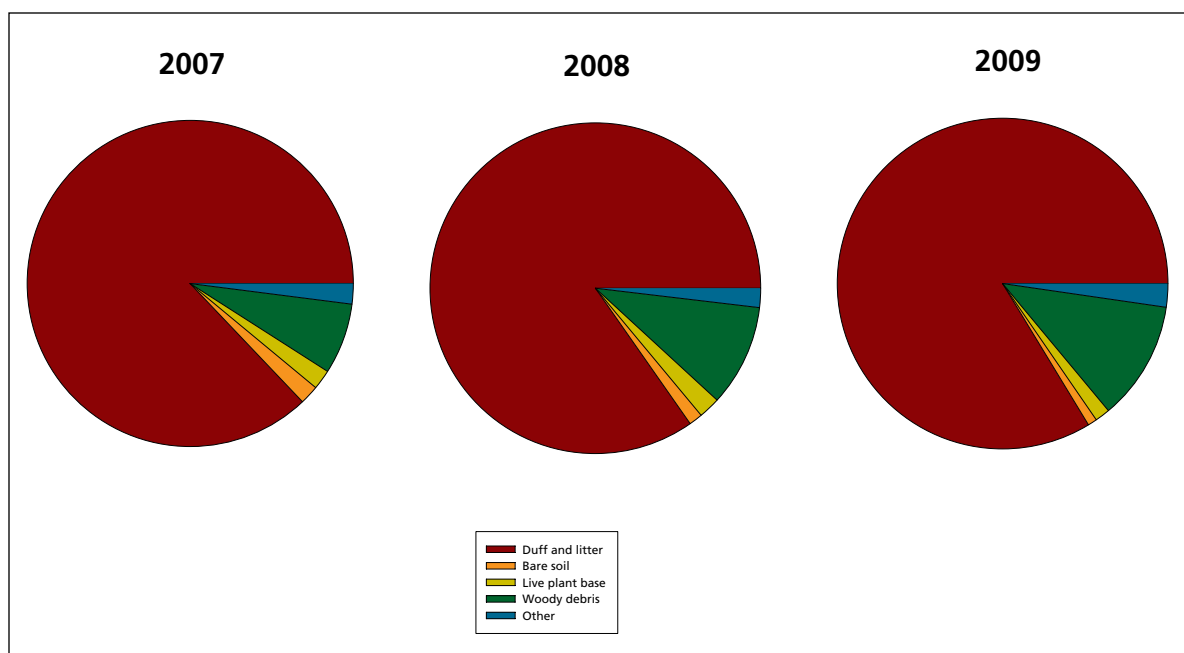


Figure 4. Mean cover of soil surface features in 2007, 2008, and 2009

Table 4. Cover of soil surface features

Surface feature	2007		2008		2009	
	Mean (%)	(SD)	Mean (%)	(SD)	Mean (%)	(SD)
Live plant base	1.82	(1.66)	2.00	(1.52)	1.40	(1.56)
Dead woody base	0.51	(1.02)	0.60	(0.71)	0.30	(0.52)
Dead herbaceous base	n/a	n/a	0.23	(0.21)	0.19	(0.33)
Bare soil	1.75	(2.67)	0.98	(0.89)	0.73	(1.24)
Duff and litter	80.97	(4.99)	79.73	(4.12)	80.58	(5.91)
Undifferentiated crust	0	(0)	0.26	(1.04)	0.13	(0.47)
Moss	0.46	(0.39)	0.33	(0.30)	0.23	(0.23)
Lichen	0.14	(0.25)	0.06	(0.06)	0.08	(0.14)
Cyanobacteria	0	(0)	0	(0)	0	(0)
Fine gravel (0.2–2 cm)	0.14	(0.19)	0.20	(0.32)	0.24	(0.35)
Coarse gravel (2–7.5 cm)	0.29	(0.30)	0.61	(1.09)	0.48	(0.81)
Cobble (7.5–25 cm)	0.24	(0.41)	0.47	(1.05)	0.30	(0.64)
Stone, bedrock (>25 cm)	0.65	(1.80)	0.35	(0.98)	0.39	(0.93)
Woody debris	6.54	(3.61)	9.36	(4.56)	11.22	(5.60)

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.

determined with only three years of sampling, nor should they be interpreted as being ecologically significant. Differences are due to a variety of factors.

The timing and the amount of precipitation differentially influences germination, growth, and flowering of species. Annual species are particularly affected by precipitation. Sampling error is inherent in the field sampling process. Cover estimation may vary among individuals (and crews), species may be mis-identified, slight differences between observers in applying sampling methods may go unnoticed, and the location of transects and quadrats vary slightly from year to year. We strive to minimize these errors 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. Timing of sampling may also influence cover and presence of species. In 2007 we sampled throughout July; in 2008 we sampled in late June and early July; and in 2009 we sampled in early to mid July. Although little ecological change would be expected to occur in three years, the increase in woody debris is likely the result of fallen trees and branches in the quadrats.

We plan to conduct power analysis using the three years of data, which will help 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. 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 species in 2007, 2008, and 2009

Species	Common name	Family	2007			2008			2009		
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Foliar cover (%)	Plot frequency (%)	Plot frequency (%)
<i>Achillea millefolium</i>	western yarrow	Asteraceae	0.035	37.50	0.029	0.037	37.50	0.037	0.037	37.50	37.50
<i>Agoseris glauca</i>	pale agoseris	Asteraceae	<0.001	6.25	<0.001	<0.001	12.50	<0.001	<0.001	6.25	6.25
<i>Agrostis scabra</i>	rough bentgrass	Poaceae	0.002	12.50	0.002	0.002	12.50	0.002	0.002	18.75	18.75
<i>Amelanchier alnifolia</i>	Saskatoon serviceberry	Rosaceae	<0.001	6.25	<0.001	<0.001	6.25	<0.001	<0.001	6.25	6.25
<i>Amelanchier utahensis</i>	Utah serviceberry	Rosaceae	0.003	6.25	0.002	0.002	6.25	0	0	0	0
<i>Androsace septentrionalis</i>	pygmy rock jasmine	Primulaceae	0.001	12.50	0.001	0.001	18.75	0.001	0.001	12.50	12.50
<i>Antennaria marginata</i>	white margin pussytoes	Asteraceae	0.039	37.50	0.064	0.064	37.50	0.047	0.047	43.75	43.75
<i>Antennaria parvifolia</i>	small leaf pussytoes	Asteraceae	0.035	56.25	0.027	0.027	50.00	0.053	0.053	56.25	56.25
<i>Aquilegia caerulea</i>			0.003	6.25	0.003	0.003	6.25	0.003	0.003	6.25	6.25
<i>Arenaria fendleri</i>	Fendler's sandwort	Caryophyllaceae	0.004	12.50	0.003	0.003	12.50	0.004	0.004	25.00	25.00
<i>Arenaria lanuginosa</i>	spreading sandwort	Caryophyllaceae	0.003	12.50	0.001	0.001	12.50	0.002	0.002	12.50	12.50
<i>Bahia dissecta</i>	ragleaf bahia	Asteraceae	<0.001	6.25	<0.001	<0.001	6.25	<0.001	<0.001	6.25	6.25
<i>Blepharoneuron tricholepis</i>	pine dropseed	Poaceae	0.011	18.75	0.006	0.006	18.75	0.006	0.006	6.25	6.25
<i>Brickellia grandiflora</i>	mountain brickellbush	Asteraceae	0.011	6.25	0.010	0.010	6.25	0.044	0.044	6.25	6.25
<i>Bromus anomalus</i>	nodding brome	Poaceae	0.001	12.50	0.002	0.002	12.50	0	0	0	0
<i>Bromus ciliatus</i>	fringed brome	Poaceae	0.139	100.00	0.161	0.161	100.00	0.122	0.122	100.00	100.00
<i>Carex rossii</i>	Ross' sedge	Cyperaceae	0.682	100.00	0.452	0.452	100.00	0.407	0.407	100.00	100.00
<i>Carex siccata</i>	dry-spike sedge	Cyperaceae	0.967	87.50	0.519	0.519	81.25	0.595	0.595	81.25	81.25
<i>Castilleja austromontana</i>	Rincon Indian paintbrush	Scrophulariaceae	0.002	12.50	0.002	0.002	12.50	0.001	0.001	12.50	12.50
<i>Castilleja linariifolia</i>	Wyoming Indian paintbrush	Scrophulariaceae	<0.001	6.25	<0.001	<0.001	6.25	0	0	0	0
<i>Ceanothus fendleri</i>	Fendler's ceanothus	Rhamnaceae	0.002	18.75	0.005	0.005	18.75	0.006	0.006	18.75	18.75
<i>Chamerion angustifolium</i>	fireweed	Onagraceae	0.061	50.00	0.053	0.053	50.00	0.118	0.118	50.00	50.00
<i>Chenopodium album</i>	lambsquarters	Chenopodiaceae	0.060	12.50	0.033	0.033	18.75	0.002	0.002	12.50	12.50
<i>Chenopodium graveolens</i>	fetid goosefoot	Chenopodiaceae	0.020	6.25	0.005	0.005	6.25	0.003	0.003	6.25	6.25

Appendix A continued

Species	Common name	Family	2007			2008			2009		
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0	0	<0.001	6.25	0	6.25	0	0	0
<i>Chimaphila umbellata</i>	common pipsissewa	Pyrolaceae	0.001	6.25	0.002	12.50	0.002	12.50	0.002	6.25	6.25
<i>Cirsium wheeleri</i>	Wheeler's thistle	Asteraceae	0.011	25.00	0.009	25.00	0.010	25.00	0.010	25.00	25.00
<i>Collinsia parviflora</i>	blue-eyed Mary	Scrophulariaceae	0	0	<0.001	12.50	0	12.50	0	0	0
<i>Conyza canadensis</i>	Canadian horseweed	Asteraceae	<0.001	6.25	0	0	<0.001	6.25	<0.001	6.25	6.25
<i>Corallorrhiza maculata</i>	spotted coralroot	Orchidaceae	0.001	25.00	<0.001	12.50	0.001	12.50	0.001	31.25	31.25
<i>Elymus canadensis</i>	Canada wildrye	Poaceae	0.026	12.50	0.028	12.50	0.025	12.50	0.025	18.75	18.75
<i>Elymus elymoides</i>	squirreltail	Poaceae	0.028	75.00	0.012	62.50	0.015	62.50	0.015	68.75	68.75
<i>Epilobium brachycarpum</i>	autumn willowherb	Onagraceae	0	0	0	0	<0.001	6.25	<0.001	6.25	6.25
<i>Erigeron divergens</i>	spreading fleabane	Asteraceae	0.011	18.75	0.015	12.50	0.005	12.50	0.005	18.75	18.75
<i>Erigeron formosissimus</i>	beautiful fleabane	Asteraceae	0.035	31.25	0.072	43.75	0.115	50.00	0.115	50.00	50.00
<i>Erigeron speciosus</i>	aspen fleabane	Asteraceae	0.023	25.00	0.030	18.75	0.040	18.75	0.040	18.75	18.75
<i>Eriogonum racemosum</i>	redroot buckwheat	Polygonaceae	0.003	25.00	0.007	25.00	0.010	25.00	0.010	25.00	25.00
<i>Euphorbia brachycera</i>	horned spurge	Euphorbiaceae	<0.001	6.25	0	0	0.001	6.25	0.001	6.25	6.25
<i>Fragaria virginiana</i>	Virginia strawberry	Rosaceae	0.242	100.00	0.315	100.00	0.357	100.00	0.357	100.00	100.00
<i>Fritillaria atropurpurea</i>	spotted fritillary	Liliaceae	0	0	<0.001	6.25	<0.001	6.25	<0.001	6.25	6.25
<i>Gayophytum diffusum</i>	spreading groundsmoke	Onagraceae	0.002	12.50	0.006	31.25	0.004	25.00	0.004	25.00	25.00
<i>Geranium caespitosum</i>	piney-woods geranium	Geraniaceae	0.001	6.25	0.001	6.25	0.001	6.25	0.001	6.25	6.25
<i>Geranium richardsonii</i>	Richardson's geranium	Geraniaceae	0.081	25.00	0.145	25.00	0.101	25.00	0.101	25.00	25.00
<i>Goodyera oblongifolia</i>	western rattlesnake plantain	Orchidaceae	0.040	81.25	0.053	81.25	0.047	93.75	0.047	93.75	93.75
<i>Heliomeris multiflora</i>	showy goldeneye	Asteraceae	<0.001	6.25	0	0	0.008	6.25	0.008	6.25	6.25
<i>Hesperidanthus linearifolius</i>	slimleaf plains mustard	Brassicaceae	<0.001	6.25	0.001	6.25	0	0	0	0	0
<i>Hesperostipa comata</i>	needle and thread	Poaceae	0.003	6.25	0.001	6.25	0.007	6.25	0.007	6.25	6.25
<i>Heterotheca villosa</i>	hairy false goldenaster	Asteraceae	0.001	6.25	0.001	6.25	<0.001	6.25	<0.001	6.25	6.25
<i>Hieracium fendleri</i>	yellow hawkweed	Asteraceae	0.011	56.25	0.018	68.75	0.012	75.00	0.012	75.00	75.00
<i>Hymenoxys subintegra</i>	Arizona rubberweed	Asteraceae	0.001	6.25	0.000	6.25	<0.001	6.25	<0.001	6.25	6.25
<i>Juniperus communis</i>	common juniper	Cupressaceae	0.836	68.75	0.939	62.50	0.874	68.75	0.874	68.75	68.75

Appendix A continued

Species	Common name	Family	2007		2008		2009	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Kelloggia galloides</i>	milk kelloggia	Rubiaceae	0.002	6.25	0.004	6.25	0.002	6.25
<i>Koeleria macrantha</i>	prairie junegrass	Poaceae	0.002	12.50	0.001	6.25	0.002	12.50
<i>Ligusticum porteri</i>	Porter's licorice root	Apiaceae	0.064	43.75	0.045	43.75	0.075	43.75
<i>Lotus utahensis</i>	Utah bird's-foot trefoil	Fabaceae	0.042	50.00	0.032	56.25	0.048	62.50
<i>Lotus wrightii</i>	Wright's deerweetch	Fabaceae	0.002	12.50	0.002	6.25	0	0
<i>Lupinus hillii</i>	hill lupine	Fabaceae	0.002	12.50	0.002	12.50	0.001	6.25
<i>Mahonia repens</i>	creeping barberry	Berberidaceae	0.069	68.75	0.099	68.75	0.099	68.75
<i>Maianthemum stellatum</i>	starry false solomon's-seal	Liliaceae	<0.001	6.25	<0.001	6.25	0.002	6.25
<i>Muhlenbergia montana</i>	mountain muhly	Poaceae	0.017	25.00	0.017	31.25	0.026	31.25
<i>Oreochrysum parryi</i>	Parry's goldenrod	Asteraceae	0.034	50.00	0.050	43.75	0.017	31.25
<i>Orthilia secunda</i>	sidebells wintergreen	Pyrolaceae	0.009	25.00	0.005	25.00	0.010	31.25
<i>Osmorhiza depauperata</i>	blunt-fruit sweet-cicely	Apiaceae	0.006	25.00	0.009	18.75	0.010	18.75
<i>Packera multilobata</i>	lobeleaf groundsel	Asteraceae	0.008	31.25	0.017	37.50	0.010	37.50
<i>Packera wernerifolia</i>	hoary groundsel	Asteraceae	0.004	18.75	0.004	18.75	0.003	18.75
<i>Pascopyrum smithii</i>	Western wheatgrass	Poaceae	<0.001	6.25	0.001	6.25	<0.001	6.25
<i>Pedicularis centranthera</i>	dwarf lousewort	Scrophulariaceae	0.114	87.50	0.150	87.50	0.105	93.75
<i>Penstemon barbatus</i>	beardlip penstemon	Scrophulariaceae	0.019	18.75	0.018	18.75	0.015	18.75
<i>Penstemon virgatus</i>	upright blue pestemon	Scrophulariaceae	0.005	31.25	0.020	18.75	0.004	31.25
<i>Phacelia heterophylla</i>	variable-leaf scorpionweed	Hydrophyllaceae	0.012	25.00	0.010	25.00	0.020	18.75
<i>Poa fendleriana</i>	muttongrass	Poaceae	0.178	100.00	0.179	100.00	0.139	81.25
<i>Polygonum douglasii</i>	Douglas' knotweed	Polygonaceae	0.001	18.75	0	0	0.001	25.00
<i>Potentilla hippiana</i>	wooly cinquefoil	Rosaceae	0	0	0	0	<0.001	6.25
<i>Pseudocymopterus montanus</i>	alpine false springparsley	Apiaceae	0.013	43.75	0.008	37.50	0.004	37.50
<i>Pseudognaphalium macounii</i>	Macoun's cudweed	Asteraceae	0.008	12.50	0.001	18.75	0.001	18.75
<i>Pseudostellaria jamesiana</i>	tuber starwort	Caryophyllaceae	0.036	43.75	0.065	37.50	0.027	37.50
<i>Pteridium aquilinum</i>	western bracken fern	Dennstaedtiaceae	0.254	37.50	0.063	31.25	0.251	37.50

Appendix A continued

Species	Common name	Family	2007			2008			2009		
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Foliar cover (%)	Plot frequency (%)	Plot frequency (%)
<i>Pterospora andromedea</i>	woodland pinedrops	Monotropaceae	0	0	0	0	0	<0.001	<0.001	6.25	6.25
<i>Pyrola chlorantha</i>	green flowered wintergreen	Pyrolaceae	0.001	18.75	<0.001	<0.001	6.25	0.001	0.001	18.75	18.75
<i>Pyrola picta</i>	white veined wintergreen	Pyrolaceae	0.003	25.00	0.007	0.007	25.00	0.005	0.005	31.25	31.25
<i>Robinia neomexicana</i>	New Mexico locust	Fabaceae	0.404	12.50	0.237	0.237	12.50	0.972	0.972	12.50	12.50
<i>Rubus idaeus</i>	western red raspberry	Rosaceae	0.011	18.75	0.007	0.007	18.75	0.016	0.016	18.75	18.75
<i>Salix bebbiana</i>	Bebb's willow	Salicaceae	0	0	0	0	0	0.001	0.001	6.25	6.25
<i>Sambucus nigra</i>	common elderberry	Caprifoliaceae	0.003	6.25	0.001	0.001	6.25	0	0	0	0
<i>Schoenocrambe linifolia</i>	flaxleaf plainsmustard	Brassicaceae	0	0	0	0	0	<0.001	<0.001	6.25	6.25
<i>Senecio wootonii</i>	Wooton's ragwort	Asteraceae	0.002	12.50	0.003	0.003	18.75	0.002	0.002	12.50	12.50
<i>Silene scouleri</i>	simple campion	Caryophyllaceae	0.001	25.00	0.003	0.003	18.75	0.003	0.003	37.50	37.50
<i>Solidago velutina</i>	threenerve goldenrod	Asteraceae	0.029	12.50	0.071	0.071	12.50	0.035	0.035	12.50	12.50
<i>Solidago wrightii</i>	Wright's goldenrod	Asteraceae	0.019	6.25	0.024	0.024	6.25	0.015	0.015	6.25	6.25
<i>Sorbus dumosa</i>	Arizona mountain ash	Rosaceae	0.008	6.25	0.007	0.007	6.25	0.021	0.021	6.25	6.25
<i>Symphoricarpos oreophilus</i>	mountain snowberry	Caprifoliaceae	0.037	6.25	0.065	0.065	6.25	0.038	0.038	6.25	6.25
<i>Taraxacum officinale</i> ^a	common dandelion	Asteraceae	0.003	12.50	0.003	0.003	12.50	0.003	0.003	18.75	18.75
<i>Thalictrum fendleri</i>	meadow-rue	Ranunculaceae	0.007	6.25	0.009	0.009	6.25	0.008	0.008	12.50	12.50
<i>Thlaspi montanum</i>	alpine pennycress	Brassicaceae	0.003	18.75	0.004	0.004	31.25	0.003	0.003	31.25	31.25
Unknown 07072007-1			<0.001	6.25	0	0	0	<0.001	<0.001	6.25	6.25
Unknown 19062008-1			0	0	<0.001	<0.001	6.25	0	0	0	0

^a Nonnative species