



Integrated Upland Vegetation and Soils Monitoring for Glen Canyon National Recreation Area

2010 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2013/511



ON THE COVER

Glen Canyon National Recreation Area
Photography by: Jim DeCoster/NPS

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1 Introduction and background

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

SCPN and park staff selected the Desert Sand ecological site for long-term monitoring of upland vegetation and soils at Glen Canyon National Recreation Area (GLCA). 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 Desert Sand ecological site is a desert shrubland that is critical for grazing leases. It faces numerous threats at GLCA, including overgrazing, soil erosion, climate change, and invasion by nonnative species.

In 2008, the SCPN integrated upland monitoring project began work at GLCA with the installation of 10 plots in the Desert Sand ecological site. We sampled vegetation in nested quadrats and measured basal gaps annually for 3 years to determine the range of temporal variability for key metrics. 2010 was our third year for monitoring these plots. In this report, we document monitoring activities in the 2010 field season and report these data in the context of the data collected in 2008 and 2009.

2 Methods

2.1 Sampling frame

We typically derive our base sampling frames from maps of ecological sites developed by the U.S. Natural Resources Conservation Service (see appendix A of DeCoster et al. 2012). However, defining the Desert Sand sampling frame was challenging because the soil map was outdated, and the area was in the process of being remapped. In order to begin sampling prior to the completion of the new soil map, we selected an initial sampling frame that encompassed all potential Desert Sand sites in the park unit. We then developed a smaller, secondary sampling frame located in an area that had been mapped as Desert Sand early in the 2008 mapping effort (fig. 1). We will use the final NRCS map to create the final Desert Sand sampling frame.

We modified the initial sampling frame using Geographic Information System (GIS) technology by removing roads and areas with slopes exceeding 20%. We generated a set of spatially distributed sampling points using the Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). We then submitted the points that landed within the secondary sampling frame to Park staff to give them an opportunity to reject points that landed too close to sensitive resources. The integrated upland crew visited the points in consecutive order and conducted an ecological site assessment, rejecting sites that deviated substantially from the ecological site, had a slope greater than 20%, or contained a major disturbance.

2.2 Field methods

The SCPN integrated upland crew established 10 monitoring plots in 2008, and resampled these 10 plots in 2009 and 2010. Each year we conducted the field work in May.

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

During establishment of the 10 plots in 2008, we collected the full suite of data. In 2009 and 2010, we did not collect soil stability data. Field methodology is provided in detail in the SCPN integrated upland monitoring protocol (DeCoster et al. 2012).

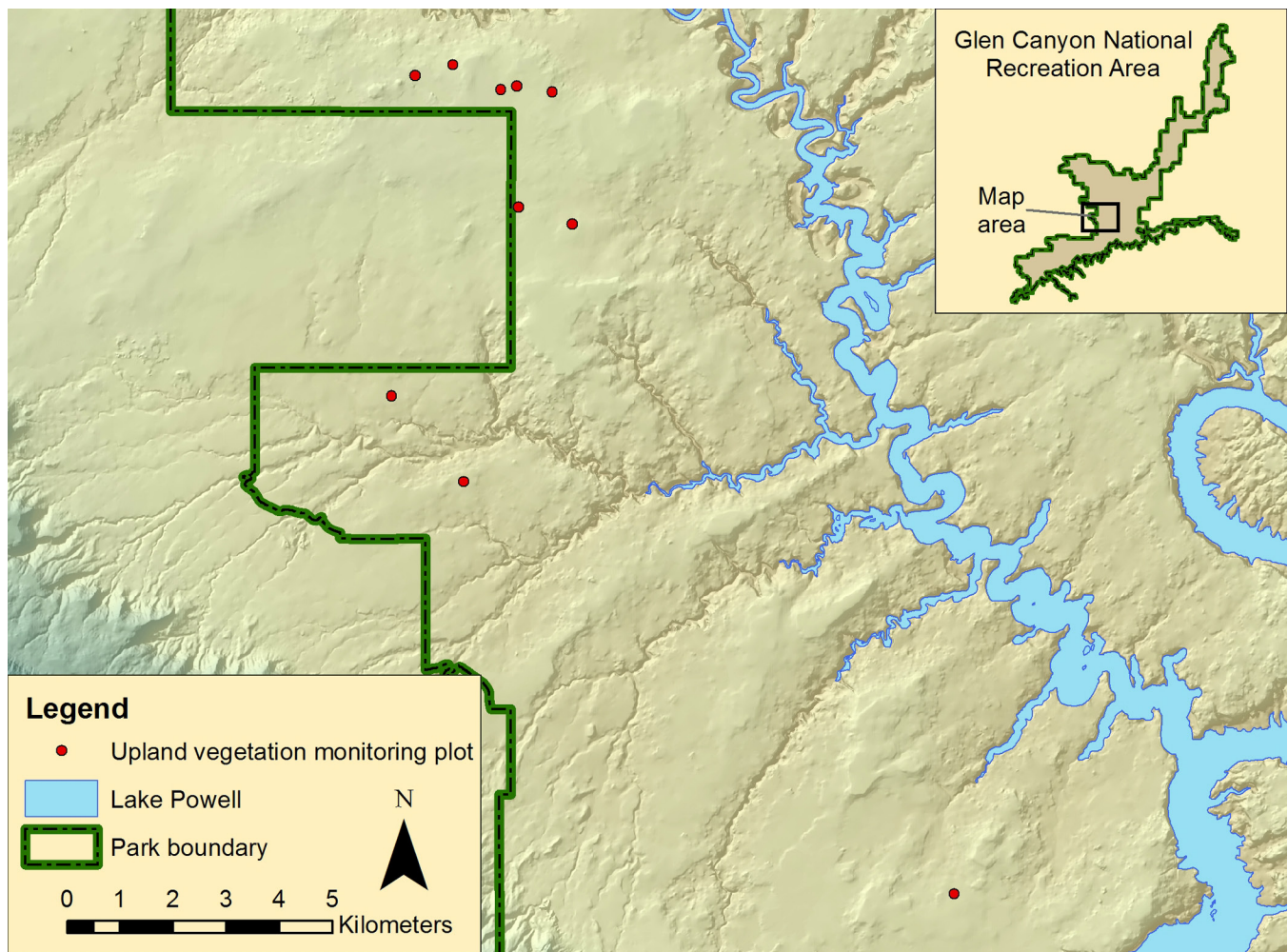


Figure 1. The 10 plots established in 2008 in the Desert Sand ecological site at GLCA.

2.2.1 Shrub and herbaceous vegetation

We sampled shrub and herbaceous vegetation within 5 sets of nested quadrats at 10 m intervals along each transect. The largest quadrat size was 10 m² (2 × 5 m), with 4 smaller quadrats nested inside (0.01 m², 0.1 m², 1 m², 5 m²). We recorded the presence of each herbaceous and shrub species within each nested sub-quadrat. We estimated the percent cover of each species in the 10 m² quadrat and assigned it to 1 of 12 cover classes (e.g., 2%–5%, 5%–10%, etc.). We also estimated the percent cover for functional groups (e.g., perennial grasses, forbs, shrubs) in the 10 m² quadrats and recorded the cover class.

2.2.2 Hydrologic function

We estimated the percent cover of soil surface features in the 1 m² quadrats along the transects, and recorded the cover in 1 of 12 cover classes. We measured basal gaps as the length of bare soil between plant bases along each transect. We collected both soil surface feature and basal gap data in all 3 years.

2.3 Data summary

In this report, we compare the data collected in the 10 plots in 2010 to the data collected in these plots in 2008 and 2009. The sample unit for summary and analysis is the plot; hence, we summarized data at the level of the plot. For most metrics, we then calculated the mean and standard deviation for the ecological site from the plot means. (Ecological site species diversity metrics were the exception.)

2.3.1 Species cover and frequency

For herbaceous and shrub vegetation, percent cover was estimated for each species from the cover class

midpoints, e.g., 7.5% for cover class 5%–10%. For each year, mean cover was calculated for each plot, and the mean and standard deviation were calculated for the ecological site from the plot means. Mean cover and standard deviation for functional groups and soil surface features were calculated in a similar fashion. Species frequency was calculated for quadrats (mean percentage of 10 m² quadrats per plot where the species occurs) and for plots (percentage of plots where the species occurs).

2.3.2 Species diversity

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

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

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

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

where p_i is the abundance of each species.

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

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

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

$$S_e / (S_p - 1)$$

where S_e is the total number of species found in the ecological site, and S_p is the mean number of species found per plot.

For plot richness, Shannon diversity and evenness, the mean was calculated for each plot and year, and the mean and standard deviation were then calculated for the ecological site for each year. Ecological site richness and beta diversity were calculated for the ecological site for each year.

2.3.3 Basal gaps

We calculated 5 metrics for each year of basal gap data: median basal gap size, percentage of transects comprised by gaps and plant bases, percent of transects comprised by each gap size class, and total number of gaps. Mean and standard deviation were calculated for each metric for each year.

3 Results

We describe results generally for all 3 years of data at these plots, but specify whenever data comes from only one of the sampling years.

3.1 Shrub and herbaceous vegetation

Shrubs dominated the Desert Sand ecological site, with less cover of forbs, perennial grasses, annual grasses and cacti/succulents (table 1 and fig. 2). Over the 3 years of sampling, the mean cover of total live vegetation ranged between 8.42% and 12.56%, while mean shrub cover ranged from 7.86% and 11.42%. Mean foliar cover of forbs was 2.23% in 2008, but was below 0.50% in the other 2 years. Mean foliar cover of perennial grasses and cacti/succulents was less than 1% for all 3 years, and demonstrated very little variation. Mean foliar cover of annual grasses was also less than 1% for all 3 years, but was much lower in 2010 than in the other 2 years.

Table 1. Foliar cover of functional groups for 2008, 2009, and 2010 in the Desert Sand ecological site at GLCA.

	2008		2009		2010	
Functional groups	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Total live foliar cover	11.58	2.68	8.42	2.30	12.56	3.20
Perennial grasses	0.52	0.29	0.56	0.15	0.50	0.34
Annual grasses	0.11	0.10	0.11	0.09	0.04	0.02
Forbs	2.23	1.30	0.23	0.16	0.42	0.48
Shrubs	8.20	2.42	7.86	2.46	11.42	3.17
Cacti/succulents	0.19	0.16	0.12	0.07	0.13	0.08
Standing dead herbaceous	0.38	0.13	0.45	0.22	0.26	0.10
Standing dead woody	2.10	0.75	2.07	0.70	1.76	0.51

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

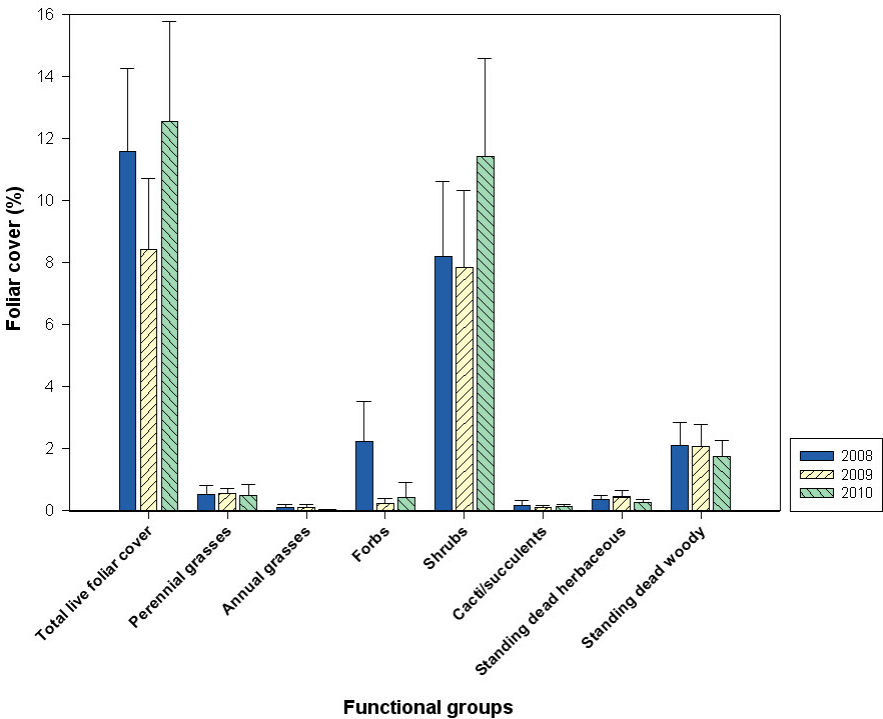


Figure 2. Mean percent foliar cover of functional groups in 2008, 2009, and 2010 in the Desert Sand ecological site at GLCA. Error bars represent one standard deviation.

We examine species-level data for the most abundant herbs and shrubs in Figure 3 (foliar cover) and Table 2 (foliar cover and frequency). Dominant shrubs included *Ephedra viridis* (mormon tea), *Psoralea fremontii* (Fremont's dalea), *Artemisia filifolia* (sand sagebrush), *Coleogyne ramosissima* (blackbrush), *Gutierrezia sarothrae* (broom snakeweed), and *Eriogonum leptophyllum* (sand buckwheat). The dominant perennial grass was *Sporobolus* spp. (dropseed). Dominant forbs included *Plantago patagonica* (wooly plantain), *Astragalus lentiginosus* (specklepod milkvetch), and *Oenothera pallida* (pale evening-primrose). The dominant cactus/succulent was *Opuntia* spp. (prickly pear).

Shrub species showed small variation in foliar cover and quadrat and plot frequencies over the 3 years. In contrast, the forb species showed large changes in mean foliar cover and frequencies. The foliar cover of the annual forb, *Plantago patagonica*, ranged between 0.021% and 0.873%. Quadrat frequencies for this species showed comparable variation. Similar variation in mean cover was seen for the forbs *Oenothera pallida*, *Astragalus lentiginosus* and *Abronia fragrans* (snowball sand verbena). The foliar cover of *Opuntia* spp. ranged between 0.083% and 0.194%. The perennial grass, *Sporobolus* spp., appeared to show a surprising amount of variation over the 3 years, but this likely reflects the difficulty of identifying the various species of this genus consistently (*S. contractus*, *S. cryptandrus* and *S. flexuosus*) when they were not flowering.

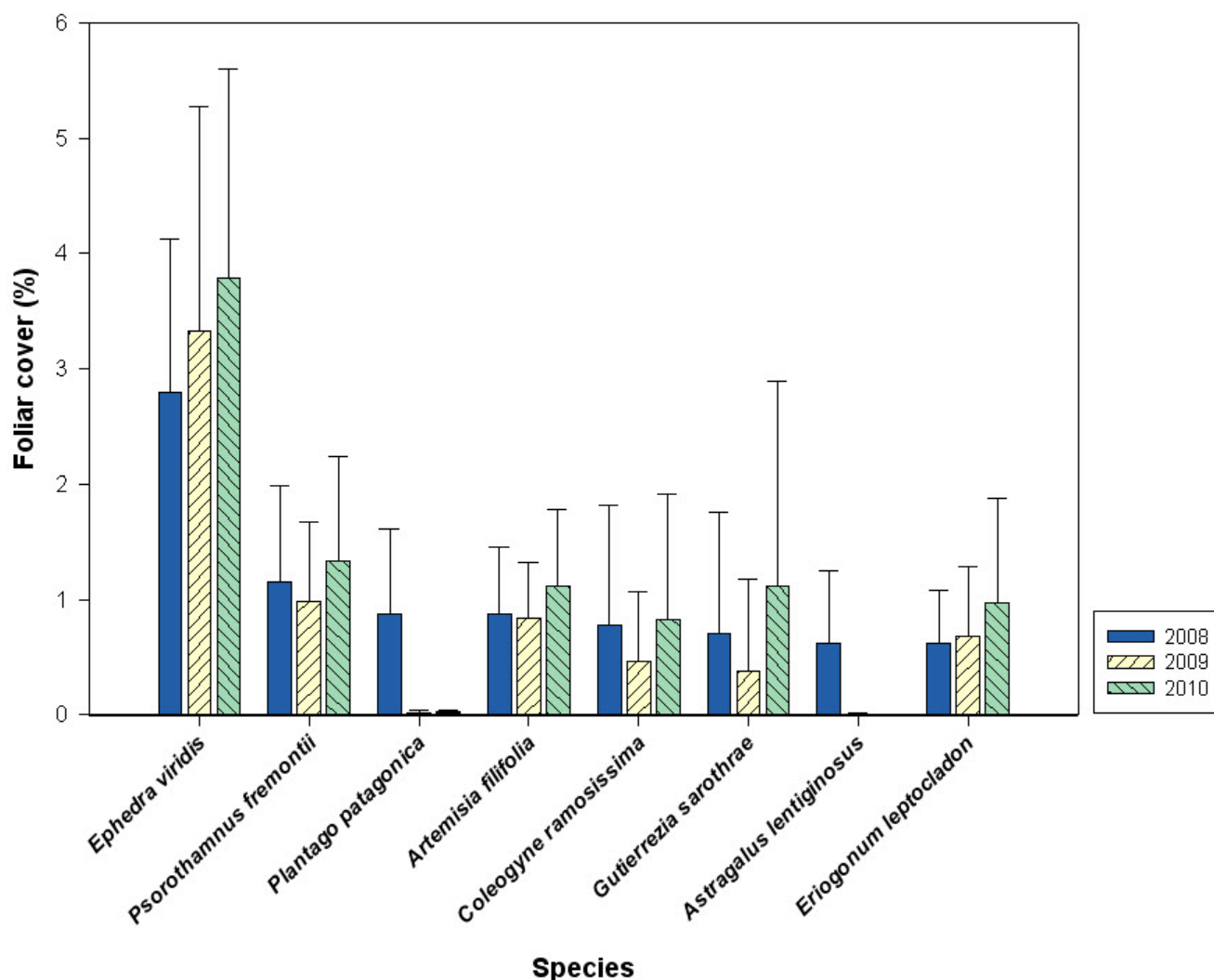


Figure 3. Mean percent foliar cover of the 8 most abundant shrub and herbaceous species in 2008, compared with the foliar cover of the same species in 2009 and 2010 in the Desert Sand ecological site at GLCA. Error bars represent one standard deviation.

Table 2. Mean foliar cover and standard deviation, and mean quadrat and plot frequencies of the 15 most abundant shrub and herbaceous species in 2008, and for the same species in 2009 and 2010, in the Desert Sand ecological site at GLCA. All nonnative species are included from all years.

Species	2008				2009				2010			
	Foliar cover (%)	SD	Quadrat frequency (%)	Plot frequency (%)	Foliar cover (%)	SD	Quadrat frequency (%)	Plot frequency (%)	Foliar cover (%)	SD	Quadrat frequency (%)	Plot frequency (%)
<i>Ephedra viridis</i>	2.794	1.328	52.00	100	3.327	1.948	53.33	100	3.790	1.804	54.67	100
<i>Psoorhannus fremontii</i>	1.156	0.833	36.00	100	0.989	0.685	39.33	100	1.338	0.902	40.00	100
<i>Plantago patagonica</i>	0.873	0.737	86.67	100	0.021	0.024	28.00	70	0.024	0.016	38.00	90
<i>Artemisia filifolia</i>	0.871	0.584	50.67	100	0.834	0.486	55.33	100	1.117	0.663	54.00	100
<i>Coleogyne ramosissima</i>	0.776	1.046	16.00	80	0.460	0.613	16.00	80	0.831	1.088	16.00	80
<i>Gutierrezia sarothrae</i>	0.702	1.051	33.33	70	0.377	0.804	20.67	40	1.112	1.785	32.00	60
<i>Astragalus lentiginosus</i>	0.621	0.626	30.00	80	0.005	0.016	1.33	20	0	0	0	0
<i>Eriogonum leptoclodon</i>	0.618	0.464	39.33	80	0.681	0.600	42.67	80	0.972	0.910	46.67	80
<i>Chrysothamnus Greenei</i>	0.474	1.036	12.67	20	0.304	0.645	12.67	20	0.541	1.147	12.67	20
<i>Vancleavea stylosa</i>	0.311	0.349	14.67	50	0.214	0.294	17.33	50	0.384	0.477	18.67	50
<i>Sporobolus</i> spp.	0.307	0.360	52.00	60	0.416	0.175	91.33	100	0.162	0.154	50.67	60
<i>Opuntia</i> sp.	0.194	0.202	21.33	100	0.083	0.075	22.00	80	0.083	0.068	22.00	100
<i>Oenothera pallida</i>	0.177	0.303	21.33	30	0.009	0.027	4.00	10	0.003	0.009	2.67	10
<i>Sporobolus cryptandrus</i>	0.114	0.145	32.67	50	0	0	0	0	0.209	0.332	39.33	50
<i>Abronia fragrans</i>	0.101	0.305	10.67	20	0.014	0.033	10.67	30	0.009	0.030	8.67	10
<i>Bromus tectorum</i> ^a	0.023	0.033	26.67	60	0.013	0.022	16.00	70	0.004	0.008	8.67	40
<i>Descurainia sophia</i> ^a	0	0	0	0	0.005	0.012	6.00	30	0	0	0	0
<i>Salsola tragus</i> ^a	0	0	0	0	<0.001	0.001	0.67	10	0	0	0	0

Note: Species are arranged in descending order by their 2008 cover.

^aNonnative species.

Variation was also seen in species with low abundance. A number of species were only encountered in one of the 3 years. *Amsonia tomentosa* (wooly bluestar), *Dimorphocarpa wislizeni* (spectacle pod), *Linum aristatum* (bristle flax) and *Mentzelia multiflora* were only encountered in 2007. *Descurainia sophia* (herb sophia), *Quercus* sp. (oak) and *Salsola tragus* (prickly Russian thistle) were only found in 2009. *Ambrosia* sp. (ragweed), *Delphinium scaposum* (barestem larkspur), *Gilia* sp. (gilia), *Malacothrix sonchoides* (sowthistle desert dandelion), *Streptanthella longirostris* (longbeak streptanthella), and *Tripterocalyx carnea* (winged sandpuffs) were only found in 2010. Appendix A lists all species, along with common names, families, mean foliar covers and plot frequencies by year.

We encountered 3 nonnative species in the plots over the 3 years. *Bromus tectorum* (cheat grass) ranged in foliar cover from 0.004% to 0.023%, and ranged in plot frequency from 40% to 70%. *Descurainia sophia* and *Salsola tragus* were only found in 2009, both with foliar covers less than 0.01%; the former was found in 3 plots, and the latter was found in 1 plot.

Species diversity metrics generally showed moderate variation over the 3 years (table 3). Exceptions were for plot richness and ecological site richness. Over the 3 years, plot richness varied between 24.5 and 26.8. Ecological site richness varied between 50 and 55. Shannon diversity (which takes into account relative abundance of species and generally ranges from 1.5 to 3.5) varied between 2.237 and 1.957; evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) ranged from 0.688 to 0.597; beta diversity (a measure of within site heterogeneity, generally ranging between 1 and 5) ranged from 2.209 to 1.977. When these metric were recalculated using only native species, they did not change substantially.

Table 3. Species diversity metrics for all species and for native species only in the Desert Sand ecological site at GLCA.

	2008		2009		2010	
	Mean	SD	Mean	SD	Mean	SD
All species						
Plot						
Plot richness	25.9	4.2	24.5	4.0	26.8	4.8
Shannon diversity	2.237	0.224	1.965	0.291	1.957	0.249
Evenness	0.688	0.043	0.615	0.072	0.597	0.059
Ecological site						
Ecological site richness	55 ^a		50 ^a		51 ^a	
Beta diversity	2.209 ^a		2.128 ^a		1.977 ^a	
Native species						
Plot						
Plot richness	25.3	4.2	23.4	3.9	26.4	4.7
Shannon diversity	2.229	0.225	1.955	0.285	1.956	0.248
Evenness	0.691	0.043	0.621	0.074	0.599	0.059
Ecological site						
Ecological site richness	54 ^a		47 ^a		50 ^a	
Beta diversity	2.222 ^a		2.098 ^a		1.969 ^a	

Note: Diversity values we report here for 2008 and 2009 differ slightly from those reported in earlier years due to adjusted calculations.

^aThese are not mean values.

3.2 Soil stability and hydrologic function

We measured the amount of soil surface potentially subject to erosion in 2 ways: cover estimates of soil surface features in quadrats and measurements of basal gaps along transects. We took these measurements in all 3 years.

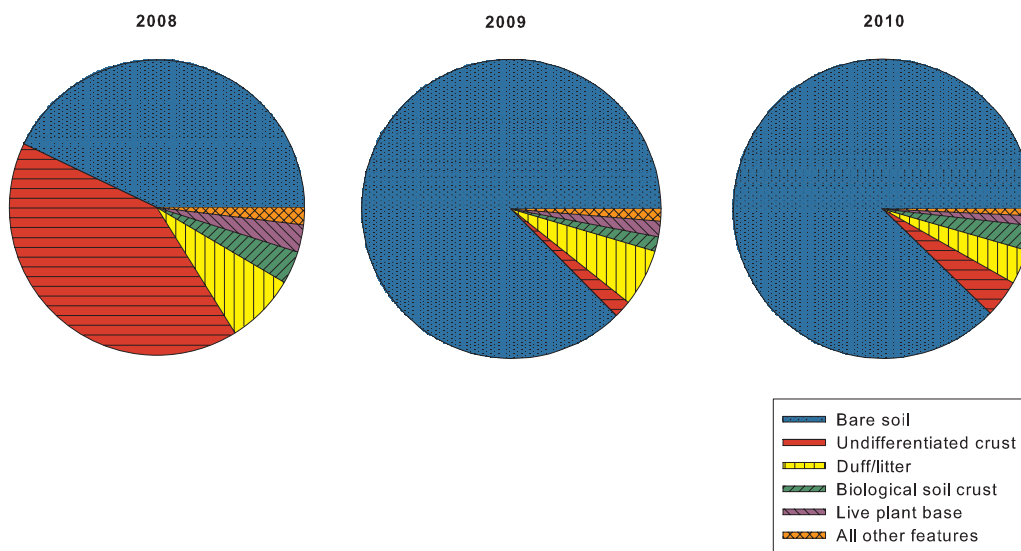
The dominant soil surface features were bare soil and undifferentiated crust. Mean cover of bare soil ranged from 41.73% to 84.08%; mean cover of undifferentiated crust ranged from 1.81% to 39.88% (table 4 and fig. 4). Three other features had covers greater than 1.00%: mean cover of cyanobacteria ranged from 1.42% to 3.13%, mean cover of litter/duff ranged from 3.52% to 7.48%, and cover of live plant bases ranged from 0.98% to 2.91%. As expected, most changes over the 3 years in the soil surface features were relatively small. The exceptions were bare soil and undifferentiated crust. In 2008 the cover of bare soil was much lower than the other 2 years, while the cover of undifferentiated crust was much higher.

Table 4. Cover of soil surface features for 2008, 2009, and 2010 in the Desert Sand ecological site at GLCA.

Soil surface feature	2008		2009		2010	
	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Live plant base	2.91	0.77	1.61	0.55	0.98	0.50
Dead woody base	0.75	0.25	0.67	0.33	0.37	0.16
Dead herbaceous base	0.48	0.27	0.22	0.15	0.13	0.05
Bare soil	41.73	30.57	84.08	4.09	82.05	10.37
Duff/litter ^a	7.48	4.52	5.93	4.80	3.52	1.46
Undifferentiated crust	39.88	29.53	1.81	1.23	3.77	9.68
Moss	0.38	0.49	0.10	0.21	0.08	0.18
Lichen	<0.01	<0.01	0	0	0	0
Cyanobacteria ^b	3.13	2.31	1.42	1.13	2.42	2.64
Fine gravel (0.2 to <2 cm)	0.09	0.11	0.28	0.58	0.11	0.13
Coarse gravel (2 to <7.5 cm)	0.05	0.09	0.06	0.18	0.05	0.15
Cobble (7.5 to <25 cm)	0.01	0.02	<0.01	<0.01	0.01	0.02
Stone, bedrock (>25 cm)	0	0	0	0	0	0
Woody debris	0.44	0.35	0.04	0.06	0.04	0.07

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

Figure 4. Mean percent cover of soil surface features for 2008, 2009, and 2010 in the Desert Sand ecological site at GLCA.



The basal gap data shows that the ecological site was dominated by large gaps (table 5 and fig. 5). The percentage of the transects in gaps greater than 100 cm exceeded 90%. The median gap size ranged from 158.6 to 207.9. Gaps metrics showed small annual variation.

Table 5. Number of basal gaps, median gap size, and percentage of transect in different gap size classes for 2008, 2009, and 2010 in the Desert Sand ecological site at GLCA.

Metric	2008		2009		2010	
	Mean	SD	Mean	SD	Mean	SD
Number of gaps	42.3	9.5	47.4	7.2	58.5	5.6
Median gap size (cm)	207.9	81.3	176.6	51.1	158.6	54.2
Percentage of transect in gaps	99.0	0.2	98.6	0.6	98.2	0.6
Percentage of transect in gaps 0-19 cm	0.4	0.2	0.5	0.2	0.6	0.4
Percentage of transect in gaps 20-49 cm	0.8	0.6	1.0	0.5	1.5	0.8
Percentage of transect in gaps 50-99 cm	1.6	1.1	2.1	0.9	3.3	1.8
Percentage of transect in gaps ≥ 100 cm	96.2	1.5	94.9	1.6	92.8	2.1
Percentage of transect in plant bases	1.0	0.2	1.4	0.6	1.8	0.6

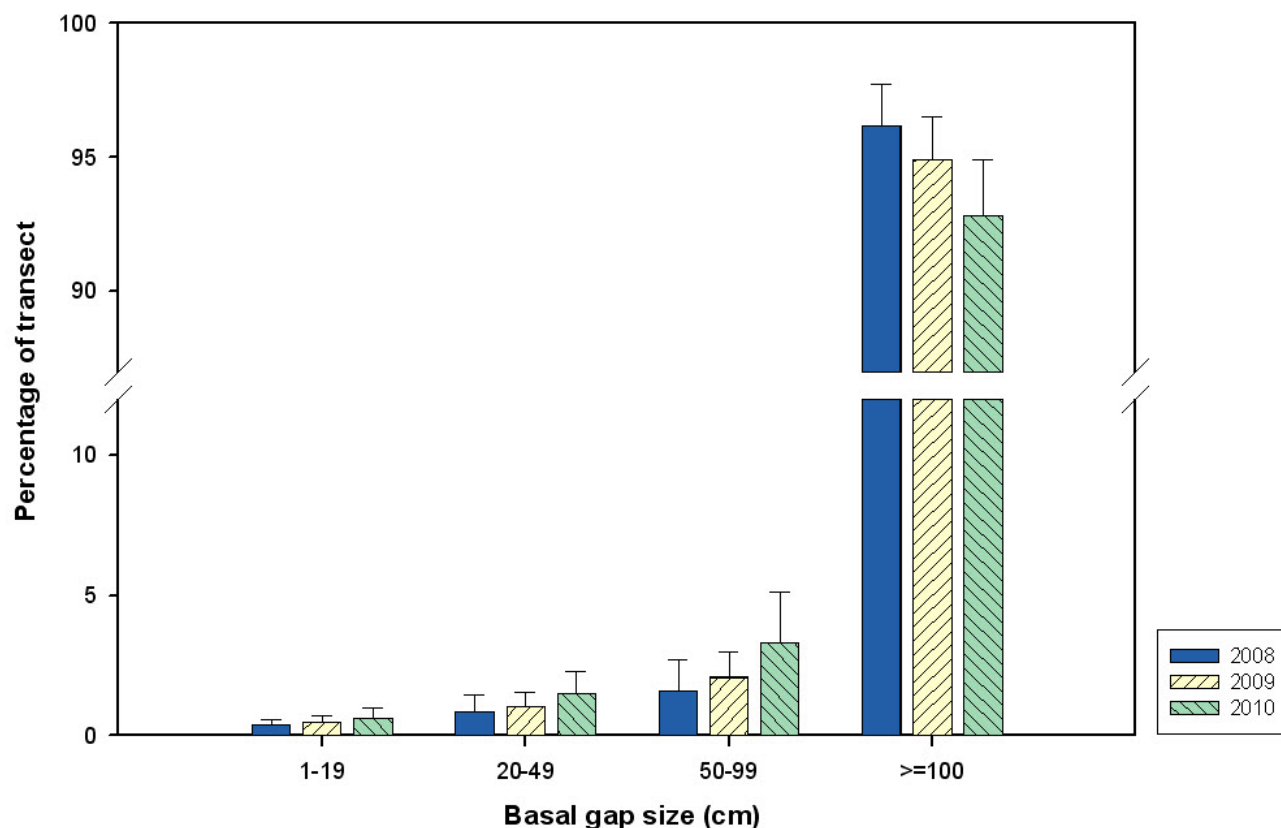


Figure 5. Percentage of transect by gap size class for 2008, 2009, and 2010 in the Desert Sand ecological site at GLCA. Error bars represent one standard deviation.

3.3 Western Regional Climate Center precipitation data

Precipitation records for GLCA are available from the Western Regional Climate Center (2013). Figure 6 shows the total monthly precipitation for each of the 3 years of monitoring described in this report, compared with the long term average precipitation by month for the period 1948–2012.

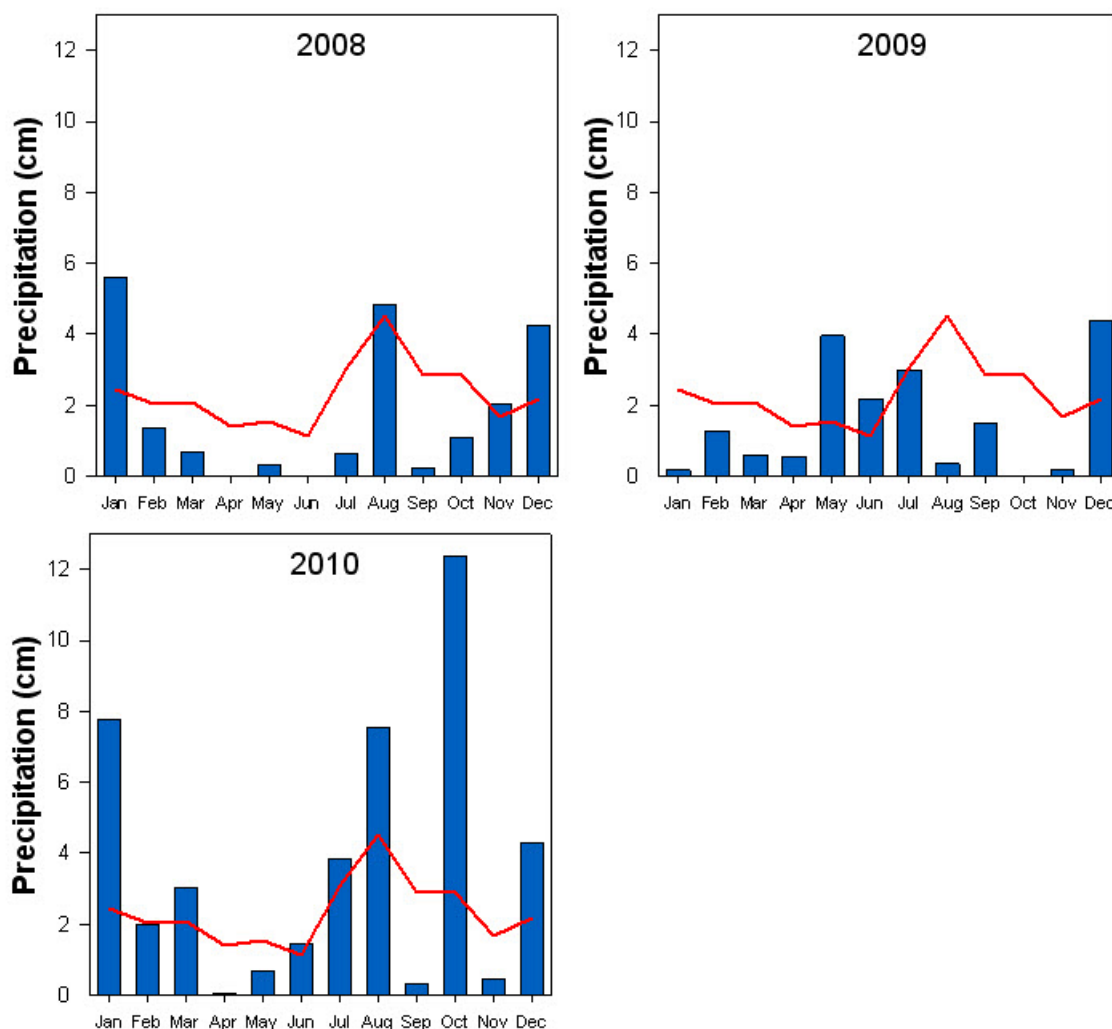


Figure 6. Total monthly precipitation for 2008, 2009, and 2010. The red line represents the long term average precipitation by month for 1948 through 2012, collected by the Western Regional Climate Center.

4 Discussion

The data presented here indicate a moderate level of annual variation in the vegetation and soil characteristics of the Desert Sand ecological site among the years 2008, 2009, and 2010. For functional groups, our coarsest metric, foliar cover, was greatest for forbs in 2008, and foliar cover of shrubs was greatest in 2010. Shrub species demonstrated some interannual variation in cover, although frequency did not vary substantially. Individual forb species displayed large interannual variation in both foliar cover and quadrat frequencies, with 2008 being the year with highest abundance values.

Cover of soil surface features did not show much variation, with the exception of undifferentiated crust and bare soil. There were small changes in the basal gap size distribution over the 3 years. The proportion of the transect occupied by gaps greater than 100 cm was greatest in 2008, and showed decreases over the next 2 years, which is surprising given that 2008 showed the highest frequency of forbs.

The variation in species composition reflected in our data was likely attributable, in part, to variation in precipitation. Abundance of all species, but especially annual forbs, is expected to vary with precipitation, with increasing biomass following increased precipitation. The precipitation data from Figure 6 based on WRCC summaries for a station in Escalante, UT, does not appear to support this pattern, however. Total winter precipitation (Dec–Mar) was highest for 2010 and lowest for 2008. 2009 had the wettest April and the wettest May, and May precipitation was well below normal in both of the other sampling years. It is possible that the local climate at the study site is not accurately reflected by the weather station data, due to the distance between the 2 locations. It is not clear what is causing the variation in forb abundance.

Precipitation may have also influenced the high cover of undifferentiated crust in 2008. Part of the variation in undifferentiated crust and bare soil may be attributable to how the soil surface features appear in wet conditions versus dry conditions. When the ground surface is wet, it is difficult to distinguish undifferentiated crust from bare soil. Moreover, undifferentiated crust is formed by raindrop impact and decreases with time since the last rainfall as the soil surface becomes unconsolidated and sand blows on top of the crust. A number of the plots were sampled shortly after rain events in 2008, and in these plots we classified much of the soil surface as undifferentiated crust.

We stress that the differences noted among the years should not be interpreted as being ecologically significant, and are not indicative of any trend. Trends cannot be determined with only 3 years of sampling. Much of the difference is likely the result of interannual variation in precipitation/climate variability. Variation in the data may in part be due to sampling error. Cover estimation may vary among individuals (and crews), species may be misidentified, slight differences among observers in applying sampling methods may go unnoticed, and the locations of the transects and quadrats vary slightly from year to year. We strive to minimize these errors by ensuring that the transect lines are as straight as possible, field crews are thoroughly trained on methods and species identification, and field crews remain calibrated on cover estimation throughout the field season.

Now that the soils map has been completed, we will finalize the Desert Sand sampling frame for this area, which will require establishing additional plots. We also plan to expand our monitoring of this ecological site by installing additional plots in the Bullfrog area, and areas near Page. We will then create a temporal sampling design, and as more data are collected, we will conduct trend analyses.

5 Literature cited

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Appendix A: Complete species list with mean foliar cover and mean plot frequency values for 2008, 2009, and 2010 for the Desert Sand ecological site at GLCA.

Species	Common name	Family	2008			2009			2010		
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Foliar cover (%)	Plot frequency (%)	Plot frequency (%)
<i>Abronia fragrans</i>	snowball sand verbena	Nyctaginaceae	0.101	20	0.014	0.014	30	0.009	0.009	10	10
<i>Achnatherum hymenoides</i>	Indian ricegrass	Poaceae	0.055	80	0.103	0.103	100	0.076	0.076	100	100
<i>Ambrosia</i> sp.	ragweed	Asteraceae	0	0	0	0	0	0.004	0.004	10	10
<i>Amsonia tomentosa</i>	woolly bluestar	Apocynaceae	0.004	10	0	0	0	0	0	0	0
<i>Artemisia filifolia</i>	sand sagebrush	Asteraceae	0.871	100	0.834	0.834	100	1.117	1.117	100	100
<i>Asclepias asperula</i>	antelope horns	Asclepiadaceae	0.005	20	0.001	0.001	10	0	0	0	0
<i>Asclepias cryptoceras</i>	pallid milkweed	Asclepiadaceae	<0.001	10	<0.001	<0.001	10	0.007	0.007	30	30
<i>Astragalus</i> spp.	milkvetch	Fabaceae	0	0	0	0	0	0.002	0.002	40	40
<i>Astragalus amphioxys</i>	Crescent milkvetch	Fabaceae	<0.001	10	0	0	0	0	0	0	0
<i>Astragalus lentiginosus</i>	specklepod milkvetch	Fabaceae	0.621	80	0.005	0.005	20	0	0	0	0
<i>Bromus tectorum</i> ^a	cheatgrass	Poaceae	0.023	60	0.013	0.013	70	0.004	0.004	40	40
<i>Chaenactis stevioides</i>	Steve's dustymaiden	Asteraceae	0.062	60	0.008	0.008	70	0.066	0.066	90	90
<i>Chamaesyce parryi</i>	Parry's sandmat	Euphorbiaceae	0.018	40	0.008	0.008	60	0.081	0.081	90	90
<i>Chrysothamnus Greenei</i>	Greene's rabbitbrush	Asteraceae	0.474	20	0.304	0.304	20	0.541	0.541	20	20
<i>Coleogyne ramosissima</i>	blackbrush	Rosaceae	0.776	80	0.460	0.460	80	0.831	0.831	80	80
<i>Comandra umbellata</i>	bastard toadflax	Santalaceae	0.066	40	0.035	0.035	60	0.025	0.025	50	50
<i>Cordylanthus wrightii</i>	Wright's bird's beak	Scrophulariaceae	0.014	20	0.004	0.004	20	0.008	0.008	20	20
<i>Cryptantha</i> spp.	cryptantha	Boraginaceae	0.046	100	0.032	0.032	100	0.029	0.029	100	100
<i>Cryptantha flava</i>	Brenda's yellow cryptantha	Boraginaceae	0.002	10	0.001	0.001	10	0.006	0.006	20	20
<i>Cryptantha micrantha</i>	redroot cryptantha	Boraginaceae	0	0	0	0	0	0.027	0.027	100	100
<i>Delphinium nuttallianum</i>	upland larkspur	Ranunculaceae	0	0	0	0	0	<0.001	<0.001	10	10
<i>Descurainia pinnata</i>	western tansymustard	Brassicaceae	0.001	20	<0.001	<0.001	10	0	0	0	0
<i>Descurainia sophia</i> ^a	herb sophia	Brassicaceae	0	0	0.005	0.005	30	0	0	0	0
<i>Dimorphocarpa wislizeni</i>	spectacle pod	Brassicaceae	0.008	20	0	0	0	0	0	0	0
<i>Ephedra viridis</i>	mormon tea	Ephedraceae	2.794	100	3.327	3.327	100	3.790	3.790	100	100
<i>Eremocrinum albomarginatum</i>	lonely lily	Liliaceae	0.028	50	0.025	0.025	50	0.020	0.020	70	70
<i>Erigeron bellidiastrum</i>	western daisy fleabane	Asteraceae	0.029	70	0	0	0	<0.001	<0.001	10	10

Appendix A (continued)

Species	Common name	Family	2008			2009			2010		
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Plot frequency (%)
<i>Eriogonum leptoclodon</i>	sand buckwheat	Polygonaceae	0.618	80	0.681	80	0.972	80	0.972	80	80
<i>Gilia</i> sp.	gilia	Polemoniaceae	0	0	0	0	<0.001	10	<0.001	10	10
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	0.702	70	0.377	40	1.112	60	1.112	60	60
<i>Helianthus annuus</i>	common sunflower	Asteraceae	<0.001	10	0.001	30	0.004	80	0.004	80	80
<i>Hymenopappus filifolius</i>	fineleaf hymenopappus	Asteraceae	0.042	60	0.023	70	0.028	50	0.028	50	50
<i>Ipomopsis gunnisonii</i>	sanddune ipomopsis	Polemoniaceae	0.050	100	0.012	90	0.077	100	0.077	100	100
<i>Lepidium montanum</i>	mountain pepperweed	Brassicaceae	0.040	10	0.031	10	0.078	10	0.078	10	10
<i>Linum aristatum</i>	bristle flax	Linaceae	0.008	60	0	0	0	0	0	0	0
<i>Lupinus pusillus</i>	rusty lupine	Fabaceae	0.019	70	0.013	70	0.047	90	0.047	90	90
<i>Machaeranthera canescens</i>	hoary tansyaster	Asteraceae	<0.001	10	0.003	10	0	0	0	0	0
<i>Malacothrix sonchoides</i>	sowthistle desert dandelion	Asteraceae	0	0	0	0	<0.001	10	<0.001	10	10
<i>Mentzelia albicaulis</i>	whitestem blazingstar	Loasaceae	<0.001	10	0.003	40	0.008	60	0.008	60	60
<i>Mentzelia multiflora</i>	Adonis blazingstar	Loasaceae	0.010	30	0	0	0	0	0	0	0
<i>Monroa squarrosa</i>	false buffalograss	Poaceae	0.001	20	0.015	50	0	0	0	0	0
<i>Muhlenbergia pungens</i>	sandhill muhly	Poaceae	0.007	30	0.015	20	0.010	20	0.010	20	20
<i>Oenothera pallida</i>	pale evening-primrose	Onagraceae	0.177	30	0.009	10	0.003	10	0.003	10	10
<i>Opuntia</i> spp.	prickly pear	Cactaceae	0.194	100	0.083	80	0.083	100	0.083	100	100
<i>Penstemon ambiguus</i>	pink plains beardtongue	Scrophulariaceae	0.053	20	0.066	30	0.064	30	0.064	30	30
<i>Phacelia ivesiana</i>	lives' phacelia	Hydrophyllaceae	0.004	10	0.004	20	0	0	0	0	0
<i>Plantago patagonica</i>	woolly plantain	Plantaginaceae	0.873	100	0.021	70	0.024	90	0.024	90	90
<i>Pleuraphis jamesii</i>	James' galleta	Poaceae	0.044	20	0.069	20	0.037	20	0.037	20	20
<i>Poliomintha incana</i>	frosted mint	Lamiaceae	0.054	30	0.089	30	0.083	30	0.083	30	30
<i>Psoralea fremontii</i>	Fremont's dalea	Fabaceae	1.156	100	0.989	100	1.338	100	1.338	100	100
<i>Quercus</i> sp.	oak	Fagaceae	0	0	<0.001	10	0	0	0	0	0
<i>Rumex hymenosepalus</i>	canagire dock	Polygonaceae	0	0	0.004	10	0.004	10	0.004	10	10
<i>Salsola tragus</i> ^a	prickly Russian thistle	Chenopodiaceae	0	0	<0.001	10	0	0	0	0	0
<i>Sphaeralcea grossulariifolia</i>	gooseberryleaf globemallow	Malvaceae	0.037	90	0.033	90	0.050	80	0.050	80	80
<i>Sporobolus</i> spp.	dropseed	Poaceae	0.307	60	0.416	100	0.162	60	0.162	60	60
<i>Sporobolus contractus</i>	spike dropseed	Poaceae	0.013	30	0	0	0.012	10	0.012	10	10
<i>Sporobolus cryptandrus</i>	sand dropseed	Poaceae	0.114	50	0	0	0.209	50	0.209	50	50

Appendix A (continued)

Species	Common name	Family	2008			2009			2010		
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Plot frequency (%)
<i>Sporobolus flexuosus</i>	mesa dropseed	Poaceae	0.018	20	0	0	0	0	0	0	0
<i>Stephanomeria exigua</i>	small wirelettuce	Asteraceae	0.055	100	0.031	100	0.136	100	0.136	100	100
<i>Streptanthella longirostris</i>	longbeak streptanthella	Brassicaceae	0	0	0	0	0.004	50	0.004	50	50
<i>Townsendia incana</i>	hoary Townsend daisy	Asteraceae	<0.001	10	0.002	10	0	0	0	0	0
<i>Tripterocalyx carnea</i>	winged sandpuffs	Nyctaginaceae	0	0	0	0	0.005	40	0.005	40	40
<i>Vandervea stylosa</i>	pillar false gumweed	Asteraceae	0.311	50	0.214	50	0.384	50	0.384	50	50
<i>Vulpia octoflora</i>	sixweeks fescue	Poaceae	0.095	90	0.099	90	0.034	90	0.034	90	90
<i>Yucca angustissima</i>	narrowleaf yucca	Agavaceae	0.037	80	0.038	80	0.049	80	0.049	80	80
unknownGLCA20080513_4			0.020	10	0.469	60	0	0	0	0	0
unknownGLCA20080521_2			<0.001	10	0	0	0	0	0	0	0
unknownGLCA20090516_1			0	0	0.001	20	0	0	0	0	0
unknownGLCA20100519_1			0	0	0	0	<0.001	10	<0.001	10	10
unknownGLCA20100525_1			0	0	0	0	<0.001	10	<0.001	10	10

^aNonnative species.