



Integrated Upland Monitoring in Arches National Park

Annual Report 2011 (Non-Sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2013/694.N



ON THE COVER

Semidesert Shallow Sandy Loam (Utah juniper/blackbrush) ecological site at Arches National Park. NPS photo.

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Prepared by

Dana Witwicki
Northern Colorado Plateau Network
National Park Service
P.O. Box 848
Moab, UT 84532

Editing and Design

Alice Wondrak Biel
Northern Colorado Plateau Network
National Park Service
P.O. Box 848
Moab, UT 84532

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Executive Summary

The goal of the Northern Colorado Plateau Network (NCPN) integrated upland monitoring effort is to provide park managers with status and trend information on vegetation and soil attributes. This information is intended to provide early warning of resource degradation and determine natural variability of upland resources.

This report summarizes NCPN upland monitoring in Arches National Park (NP) in 2011. It outlines goals and objectives of NCPN upland monitoring, methods of the upland monitoring protocol, and procedures for defining and mapping target populations for monitoring, and describes the results of this year's efforts and plans for future monitoring.

In 2011, NCPN completed its second year of monitoring at Arches NP. Twenty-four plots were monitored, including 8 deep blackbrush plots, 8 pinyon-juniper/blackbrush plots, and 8 grassland plots. Early monitoring data describe status of ecological site types; interpretation is limited until additional data are acquired and more rigorously analyzed after at least five years of monitoring are complete.

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1 Introduction

Uplands represent the vast majority of land area in national park units of the NCPN. These upland areas include rock outcrops, badlands, shrublands, grasslands, woodlands, forests, and subalpine meadows, with local vegetation determined by soil type and depth, topography, climate, and disturbance history. Upland vegetation supplies most regional primary productivity, which translates to energy for other trophic levels. The condition of upland vegetation influences soil stability and nutrient cycling that, in turn, determines potential above-ground production of native plant species and the propensity for invasion by non-native species. Vegetation also provides habitat for various organisms. The ability of uplands to retain soil and nutrients, absorb and release water, and buffer high-runoff precipitation events also influences conditions in riparian areas.

Upland ecosystems of the Colorado Plateau, where the majority of NCPN park units are located, tend to be dominated by shrubs, perennial grasses, and small trees. Although these lifeforms play an integral role in defining the structure and function of Colorado Plateau ecosystems (Whitford 2002), it is the highly pinnacled biological soil crusts that make these dryland systems unique.

Biological soil crusts are biotic communities composed of cyanobacteria, algae, microfungi, mosses, and lichens that occur on and within the upper few millimeters of the soil surface (Belnap et al. 2003). Their presence stabilizes the soil surface and reduces susceptibility to wind and water erosion (Williams et al. 1995). They also contribute to nutrient cycling by fixing C (Lange 2003) and N (Evans and Lange 2003; Belnap 2002), and affect the availability of nutrients to plants (Harper and Belnap 2001). Biological soil crusts are particularly sensitive to disturbances that affect the soil surface, such as trampling and off-road vehicle use (Rosentreter and Belnap 2003) (Figure 1-1).

In the basins neighboring the Colorado Plateau, where several NCPN park units are located, biological soil crusts also play an important role but are less dramatically

pinnacled. In the forests, shrublands, and meadows of the mountain regions surrounding the Colorado Plateau, where numerous NCPN park units are also located, biological soil crusts do not play an important role because much of the soil surface is covered by vegetation and litter.

Many upland ecosystems of the region are characterized by low resistance and resilience. Even moderate disturbances can affect vegetative composition and structure, and recovery to pre-disturbance conditions can be relatively slow. Natural disturbance regimes of the region include extreme climatic events, fire, insect and disease outbreaks, herbivory, and trampling (Miller 2005).

Grazing, which has been a traditional land use throughout much of the plateau, has resulted in shifts in vegetation composition (Harris et al. 2003) and ecological states (Miller et al. 2011) that persist for many decades or longer. Fire-regime alteration (Whelan 1995) and invasion of exotic plants (Bock et al. 1986) have additionally contributed to these shifts. Increasing recreational use and unauthorized social trailing threaten the integrity of upland systems through soil-surface disturbance and resulting increases in soil erosion by water and wind. Additional pressure inside parks may also result from land use in adjacent areas. Global climate change is expected to change levels and seasonality of



Figure 1-1. Damage caused to biological soil crust by off-road vehicle use, Arches National Park.

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dominant precipitation events (Garfin et al. 2010), and we are only beginning to understand the implications for plateau ecosystems (Munson et al. 2011a,b). Additional information on characteristics of Colorado Plateau ecosystems and ecological threats to the region is provided in Miller (2005).

The overall goal of the NCPN integrated upland monitoring program is to determine long-term trends in vegetation, soil stability, and hydrologic function in the context of changes in other ecological drivers, stressors, and processes. Monitoring will increase fundamental understanding of upland systems and provide managers with early warning of undesirable change and information for management decisions. Specific objectives of integrated upland monitoring at Arches National Park are described below.

Determine status and trends in plant communities, including:

- overall species richness
- cover of vegetation by dominant species and lifeform
- frequency of exotic invasive species
- density of shrubs by size class

Determine status and trends in soil stability, including:

- cover of biological soil crusts by morphological group (cyanobacteria, lichen, moss, and undifferentiated crust)
- cover of other surface features (e.g., litter, rock, bare ground)
- soil aggregate stability
- canopy-gap size (as an indicator of wind erosion potential)

Determine status and trends in hydrologic function, including

- basal-gap size

Evaluation of upland monitoring data relative to other vital signs will help facilitate identification of drivers and distinguishing “natural” from anthropogenic change. Local weather station data can be used to interpret responses, whereas remote sensing can be used to determine change in vegetation at larger scales caused by land use or climate change. Historical upland monitoring data sets may be integrated with data collected by NCPN to allow earlier detection of trends.

2 Methods

2.1 Integrated upland monitoring in Arches National Park

2.1.1 Resource issues driving upland monitoring

Discussion with Southeast Utah Group (SEUG) resource management staff identified grasslands and shrublands as the highest priorities for long-term upland monitoring. Managers were concerned about potential system degradation due to trampling of biological crust, and subsequent increases in wind and water erosion of soil. Both NCPN and SEUG staff agreed that it was best to monitor (1) dominant vegetation types in the park (blackbrush, pinyon-juniper [PJ], and grasslands), and (2) some of the same ecological site types in Arches National Park (NP) that the NCPN monitors in Canyonlands NP. For ecological sites that occur in both parks, this will provide a larger dataset that could help detect trends more quickly. The goal of upland monitoring at Arches NP is to provide early warning of system degradation as well as information on the natural variability of upland resources.

2.1.2 Mapping and selecting target populations

2.1.2.1 Accessibility

Areas that posed safety threats, were inaccessible within budgetary limitations, and/or were anthropogenic in nature were filtered out of the sampling frame. Areas located on slopes of $\geq 50\%$ and/or isolated by steep slopes were also eliminated. Accessibility and slope features were generated using the Landscape Accessibility Model (<http://science.nature.nps.gov/im/units/ncpn/Tools.cfm>). Eighty-seven percent of the park was deemed accessible.

2.1.2.2 Selection of target ecological site types

NCPN upland monitoring uses survey designs and ecological sites (SRM 1989, 1995) to define target populations. An ecological site is defined by a combination of soil properties (texture, depth, water-holding capacity), geology, landform, climatic regime, and potential vegetation. The spatial extent of

ecological sites is largely determined by soil map units within the soil survey, although the location of an ecological site within a soil map unit is not explicit. Using the Arches Soil Survey (USDA NRCS 2010), ecological sites associated with blackbrush, PJ, and grasslands were determined.

At Canyonlands NP and other NCPN parks, ecological sites have been lumped into broader groups with similar vegetation, precipitation, and soil depth that we are calling ecological site types. Ecological site types were also used at Arches NP to group similar ecological sites in the soil survey (Table 2-1). After further discussion with SEUG resource staff, three ecological site types were selected for monitoring at Arches NP: deep blackbrush, PJ/blackbrush, and grassland.

Deep Blackbrush

The deep blackbrush ecological site type is characterized by blackbrush (*Coleogyne ramosissima*) on deep eolian sands and sandy loams. Deep blackbrush was selected as a priority ecological site type at Arches NP due to the large spatial extent in the park and because the NCPN is currently not monitoring it at Canyonlands NP. Although a substantial area of this ecological site type exists in Canyonlands NP, it was not recognized in the soil survey used to create the Canyonlands upland monitoring design, and was therefore not included. In Arches NP, the deep blackbrush ecological site type includes two ecological sites (see Table 2-1 and Figure 2-1).

PJ/Blackbrush

The PJ/blackbrush ecological site type is characterized by blackbrush and Utah juniper (*Juniperus osteosperma*) on shallow sandy soils. At both Canyonlands and Arches NPs, there is one target ecological site, 236-Semi-desert Shallow Sandy Loam (Utah juniper/blackbrush), in the PJ/blackbrush ecological site type (see Table 2-1 and Figure 2-1). Although a second ecological site, 19-Shallow Sand Rock Pocket, was mapped in the Arches Soil Survey, it contains too much bedrock to depict trends in vegetation as defined by our monitoring criteria. It was also not included in the soil survey used to develop the NCPN upland monitoring design at Canyonlands NP.

Table 2-1. Description of ecological sites selected for monitoring in Arches National Park.

Ecological site type	Ecological site name Notation / No.	Soil series	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Shrubland						
Deep blackbrush	Semidesert Sand (blackbrush) SDS210 / 210	Mido	Deep sands on dunes and sand sheets	Eolian deposits derived from sandstone	Dominated by blackbrush	<i>Description currently N/A</i>
	Semidesert Sandy Loam (blackbrush) SDSL218 / 218	Milok	Deep sandy loams on mesas and hills	Alluvium and eolian deposits derived from sandstone	Dominated by blackbrush	<i>Description currently N/A</i>
PJ / Blackbrush	Semidesert Shallow Sandy Loam (Utah juniper/blackbrush) SDSSL236 / 236	Arches, Crosscan, Reef, Simel	Shallow sandy loams on benches, mesas, and hillslopes	Residuum, colluvium and/or eolian deposits from sandstone	Dominated by blackbrush, juniper, and pinyon pine	Decreased bunchgrass and increased juniper, blackbrush, and prickly pear. Cheatgrass and annual forbs may invade.
Herbaceous						
Grassland	Semidesert Sand (fourwing saltbush) SDS212 / 212	Mido	Deep sands on dunes and sand sheets	Eolian deposits derived from sandstone	Dominated by Indian ricegrass, fourwing saltbush, and Mormon tea	Decreased bunchgrass and saltbush and increased snakeweed, prickly pear, juniper, and sand sage. Russian thistle may invade.
	Semidesert Sandy Loam (fourwing saltbush) SDSL215 / 215	Begay, Milok	Deep sandy loams on mesas and valleys	Alluvium and eolian deposits derived mainly from sandstone	Dominated by Indian ricegrass, needle and thread, fourwing saltbush, and Mormon tea	Decreased bunchgrass and increased snakeweed, Mormon tea, and prickly pear. Cheatgrass and Russian thistle may invade.

Grassland

The grassland ecological site type is characterized by native perennial bunchgrasses on deep sandy soils. The two grassland ecological sites at Arches NP are the same ecological sites that NCPN monitors at Canyonlands NP (see Table 2-1 and Figure 2-1). Two additional grassland ecological sites (115-Desert Sand and 118-Desert Sandy Loam) were included in the Canyonlands sampling design, but it is expected that these will be combined with the semidesert grassland ecological sites in the new version of the Canyonlands Soil Survey (USDA NRCS 2010). That survey was recently completed, and the issues mentioned here will be re-evaluated within the context of that report.

Although a shallow blackbrush ecological site type has substantial area in Arches NP, it was not selected for monitoring due to the limitations of our affordable effort and the park's preference to monitor deep blackbrush. This ecological site type is currently being monitored at Canyonlands NP.

The estimated area of target ecological sites in Arches NP is 6,921.9 ha (Table 2-2). The area of each ecological site in the park is calculated using the estimated percentage of that ecological site within each of the soil map units where it is predicted to occur; therefore, the area of each ecological site is often substantially less than the corresponding area shown on the soil map.



Figure 2-1. Examples of ecological sites selected for upland monitoring at Arches National Park. See Table 2-1 for descriptions.

Table 2-2. Area (ha) of each ecological site type included in the sampling frame for upland monitoring, Arches National Park.

Ecological site type	Area (ha) ^a	Predicted target area ^b
Deep blackbrush	4,375	49.3%
PJ/blackbrush	3,871	62.2%
Grassland	2,509	94.1%
Total sampling frame	10,755	64.4%

^a Based on the accessible area within a 10-km hiking distance.

^b Predicted amount of target ecological site in the sampling frame.

2.1.2.3 Mapping of target ecological site types

Because the draft Arches Soil Survey provided a good estimate of locations of target ecological sites, we did not explicitly map ecological sites for Arches NP (while we did for Canyonlands NP). Instead, we developed a predictive map of deep blackbrush, PJ/blackbrush, and grassland ecological site types using the soil map units associated with the target ecological sites (Figure 2-2). All soil map units that contained >10% of a soil component associated with a target ecological site were included in the sampling frame.

The area of the sampling frame is larger than the predicted area of each ecological site (see Table 2-2) because all soil map units used to make the map contain some non-target areas. The sampling frame area represents 34.7% of the total park area and 40.1% of accessible area. Before site selection, the sampling frame was buffered by 25 m to prevent plots from crossing roads, trails, the park boundary, non-target vegetation, or inaccessible areas.

2.1.3 Selection of monitoring locations

Monitoring plots were selected using the Reversed Randomized Quadrant Recursive Raster (RRQRR) method (Theobald et al. 2007) to create a spatially balanced design within the sampling frame. RRQRR provides an ordered list of centroids for all possible monitoring plots in the sampling frame. Points were then assigned a predicted ecological site type based on the areas shown in Figure 2-2. Within each ecological site type, plots were established in ascending order of plot number. If a plot was rejected (e.g., due to incorrect vegetation type, crossing a road, trail, park unit boundary, or cliff), the next

sequentially ordered plot was used.

2.1.4 Revisit design

A rotating-panel revisit design (Figure 2-3) was created that samples eight plots each year and a total of 28 plots over seven years for each of the three priority ecological site types. A total of 84 plots are sampled among all ecological site types. Plots are sampled for two consecutive years (in order to detect annual variation due to temperature, precipitation, etc.) and then rested for five years. The sampling scheme repeats itself every seven years. The number of plots in each ecological site should approximately represent the area of each ecological site in the sampling frame. This revisit strategy maximizes our ability to detect trends and minimizes the impact on biological soil crusts in the park.

2.2 Integrated upland monitoring procedures

2.2.1 Response design

The response design (methods used to collect observations) for integrated upland monitoring in NCPN parks is based largely on rangeland monitoring procedures recommended by Herrick and colleagues (2005). All measures recorded along transects are sub-samples scaled to the plot level. The plot-level measures are the primary values used in summaries and statistical analyses.

At each plot, observations are recorded along three parallel, 50-m transects spaced 25 m apart (Figure 2-4). At the origin of each transect, a photo is taken down the length of the transect toward the end point. Photos of biological soil crusts are also taken at a specified point along each transect. A point-intercept method is used to record percent cover of plant species and ground-cover attributes at 0.5-m intervals along each transect. Density of shrubs (by species and height class) is recorded in a 1-m belt upslope of each transect. Density of exotic perennial species in the 1-m belt was discontinued beginning in the 2011 field season. Instead, frequency of all exotic species (annual and perennial) is recorded using 1×1-m quadrats placed every 5 m along each transect. Canopy and basal-gap measures are acquired along each transect using line-intercept methods. Six surface-

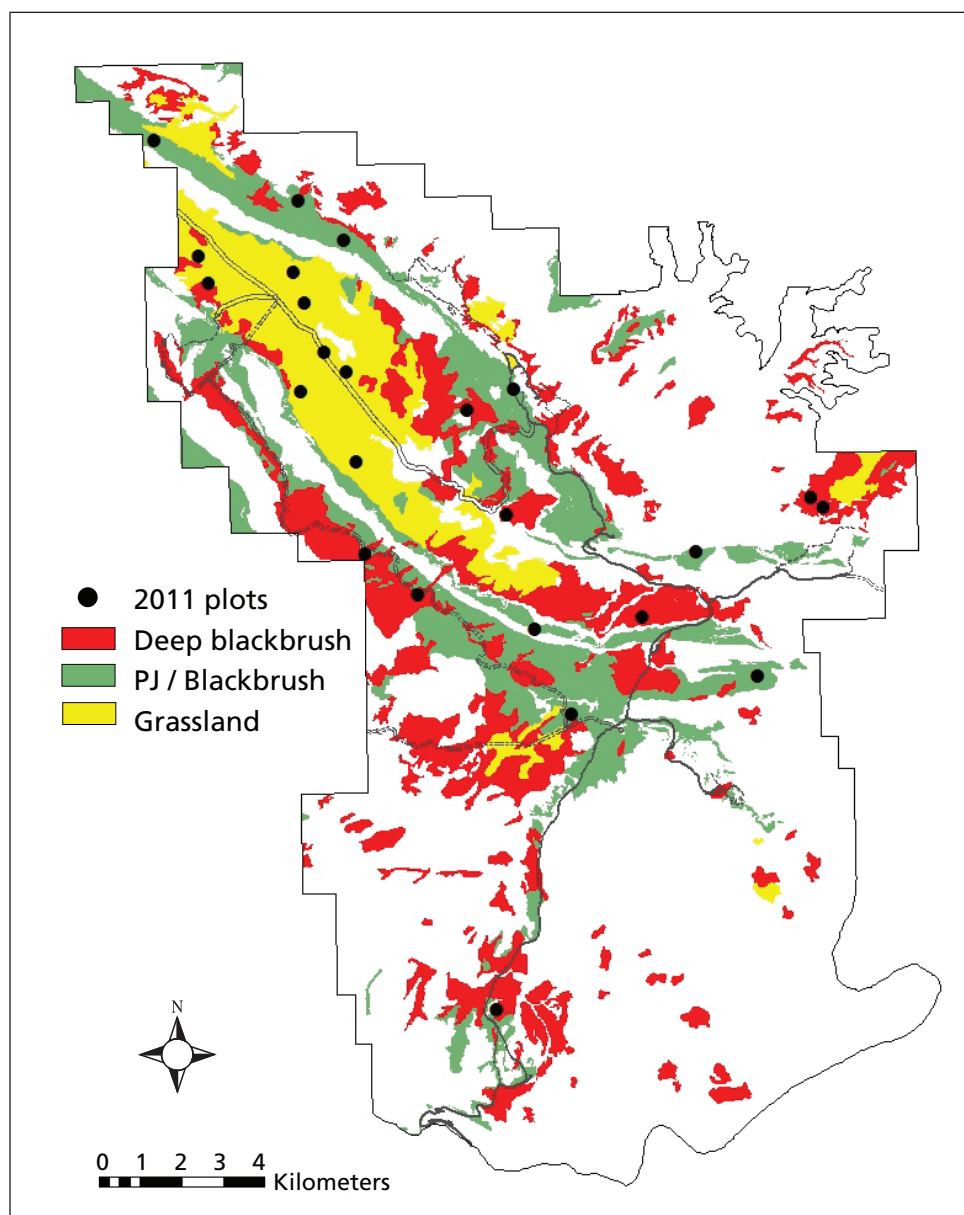


Figure 2-2. Sampling frame and location of monitoring plots in Arches National Park, 2011.

Panel	Year						
	1	2	3	4	5	6	7
1	4	4					
2		4	4				
3			4	4			
4				4	4		
5					4	4	
6						4	4
7	4						4

Figure 2-3. Number of plots sampled each year per ecological site type based on 7-year rotating panel revisit design for long-term upland monitoring at Arches National Park.

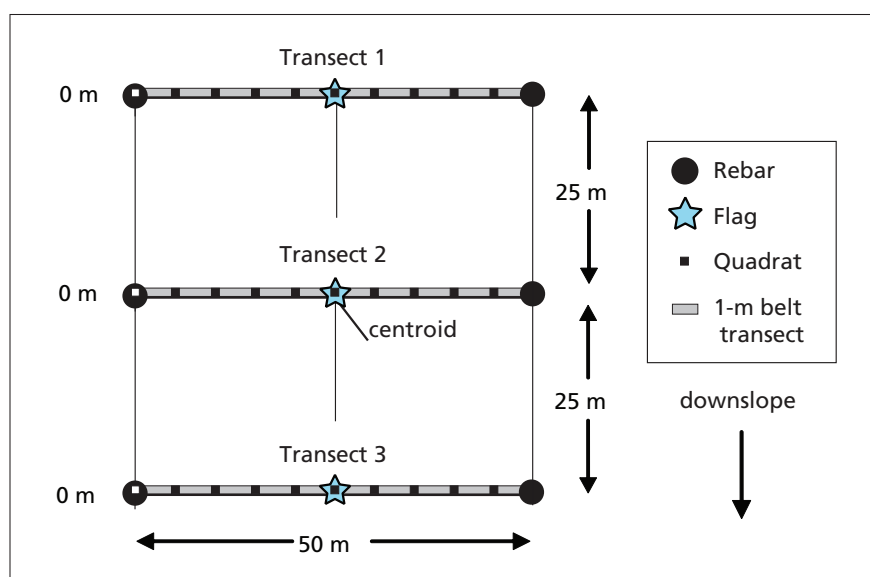


Figure 2-4. Plot layout for upland monitoring of grasslands and shrublands.

soil samples are taken along each transect to assess soil-aggregate stability. Disturbances observed on and around the site are also recorded. Beginning in 2011, an “exotic species walk” was added to search for other exotic plants present in plots.

2.3 Database

All observations recorded in the field are stored in an NCPN Access database. Quality assurance and quality control (QA/QC)

procedures include domain checking in data-entry procedures, checks for missing values, and logic checks. All spatial data used in selecting monitoring locations, the sampling frame, and the RRQRR-generated sampling locations are GIS-ArcMap shape files and are stored with the Access database on NCPN servers.

3 Results

3.1 Monitored plots

In April and May 2011, twenty-four plots were monitored as part of the long-term revisit design, including 8 deep blackbrush, 8 PJ/blackbrush, and 8 grassland plots (see Figure 2-2). Half of the plots were revisited and half were established in each ecological site type. Table 3-1 (tables and figures begin on page 11) summarizes plot visits by ecological site and year. Each plot was sampled using the suite of measures appropriate for that vegetation type.

3.2 Ecological site type summaries

Status and trend assessments are more meaningful after many years of monitoring, and as the number of monitoring plots increases. More intensive evaluation of monitoring data is slated to commence after five full years of monitoring are complete.

For this annual report, plot-level summaries of the measures listed in Chapter 1 were generated for each monitoring plot, then summarized by ecological site type. Summaries are simply a mean and the range (minimum, maximum) for a measured attribute. Given the limited data, measures were not statistically compared among ecological site types. Qualitative comparisons of summary measures could be misleading, given the small number of plots visited each year. Comparisons between years may also be misleading, because a different set of plots is visited each year. The reader is cautioned not to draw wide-reaching conclusions from these preliminary summaries.

3.2.1 Species richness

A total of 53 species were detected in Arches NP in 2011. Species richness by lifeform is reported in Table 3-2. Recorded species were compared to the NPSpecies database to determine first-time observations in Arches NP. No new species were detected in the park in 2011.

No threatened or endangered species or other plants of special concern were found on any plots in 2011. Arches NP does not have

any federally listed threatened or endangered plant species. Plants of special concern are not common in the areas of Arches NP monitored by the network, and the NCPN does not specifically monitor them in this park.

3.2.2 Cover by lifeform and dominant species

Percent cover of live and total vegetation by lifeform is shown in Table 3-3. Live cover includes photosynthetic and live woody tissue. Total cover additionally includes dead plants, dead parts of live plants, and senesced tissue that was alive earlier in the growing season.

Live and total percent cover of dominant species for each ecological site type are shown in Table 3-4. Dominant species were selected using species predicted by ecological site descriptions and species frequently detected in plots. The percent cover of all species recorded for each plot is included in an electronic appendix that accompanies this report (arch11_species.xls).

3.2.3 Shrub density

Density of shrub species for each ecological site type is shown in Table 3-5. In both shrubland ecological site types, there was a high density of blackbrush, and numerous other shrub species were detected. Grassland plots had a relatively high density of winterfat (*Krascheninnikovia lanata*), but few other shrub species were detected.

Green ephedra (*Ephedra viridis*) is common in grasslands at Arches NP but is not counted in our shrub density counts. Its low, sprawling lifeform in this ecosystem makes it extremely difficult to distinguish individuals, and measuring density of *E. viridis* in Arches NP grasslands is not repeatable. Cover can alternatively be used to assess the status of this species.

3.2.4 Exotic species

Percent cover and frequency of detection of exotic plant species are shown in Table 3-6. When exotic species were detected, cover and frequency were summarized for all plots in the ecological site type.

Cheatgrass (*Bromus tectorum*) was detected in all ecological site types, but it had the highest cover (4.6% mean total cover) and frequency of detection (34.2% mean frequency) in grassland plots. Russian thistle (*Salsola tragus*) was also detected at many grassland and deep blackbrush plots. Few exotic plant species were detected in PJ/blackbrush plots.

Beginning in 2011, NCPN upland sampling methods also included an “exotic species walk” to search for other exotic plants present in plots. A list of all exotic species detected, and descriptions of the number of plants, size of invasions, and approximate locations, are included in an electronic appendix that accompanies this report (arch11_exotics.xls).

3.2.5 Biological soil crust and surface features

Biological soil crust and surface-feature cover are shown in Table 3-7. Undifferentiated crust was the dominant surface cover for all vegetation types. Dark cyanobacteria and lichen, indicators of well-developed crust, had the highest cover in PJ/blackbrush plots and were not recorded in grassland plots.

3.2.6 Canopy and basal gaps

Canopy- and basal-gap sizes are shown in Table 3-8. The distribution of gaps by size class is illustrated in Figures 3-1 and 3-2. A length of more than two meters was the most common canopy- and basal-gap size for all ecological site types.

3.2.7 Soil aggregate stability

Measures of soil aggregate stability are reported in Table 3-9. Soil stability numbers range from 1 (least stable) to 6 (most stable) and are correlated with current erosion resistance and soil biotic integrity. They also usually reflect hydrologic function because stable soils are less likely to disperse and clog soil pores during rainstorms. Because the numbers are affected by soil texture, it is important to limit comparisons to similar soils that have comparable amounts of sand, silt, and clay. Extremely sandy soils may not have maximum soil stability values of 6.

Table 3-1. Number of plots by ecological site type and ecological site monitored, Arches National Park, 2010–2011.

Ecological site type	Ecological site*	# of plots	
		2010 (September–October)	2011 (April–May)
Deep blackbrush	Semidesert Sand	8	8
	Semidesert Sandy Loam	0	0
PJ / blackbrush	Semidesert Shallow Sandy Loam	8	8
Grassland	Semidesert Sand	1	2
	Semidesert Sandy Loam	7	6

* See Table 2-1 for description of ecological sites.

Table 3-2. Mean (range) number of plant species detected per monitoring plot by lifeform and ecological site type, Arches National Park, 2011.

Ecological site type	Number of species detected					
	Total	Tree	Shrub	Perennial grass	Annual grass	Forb/Herb
Deep blackbrush	9.8	0.5	3.8	0.8	1.4	3.4
	(5–16)	(0–1)	(2–5)	(0–2)	(0–2)	(0–6)
PJ / blackbrush	8.3	1.8	5.1	0.3	0.1	1.0
	(6–12)	(1–2)	(3–8)	(0–1)	(0–1)	(0–3)
Grassland	10.4	0	1.9	3.1	1.0	4.4
	(6–15)		(1–4)	(2–5)	(0–2)	(2–7)

Table 3-3. Mean (range) percent cover by lifeform for each ecological site type, Arches National Park, 2011.

Ecological site type	Total		Tree		Shrub		Perennial grass		Annual grass		Forb/Herb	
	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total
Deep blackbrush	17.5 (13.0–24.7)	25.4 (17.7–36.7)	1.3 (0–4.0)	1.3 (0–4.3)	14.8 (9.0–22.0)	21.1 (13.3–33.3)	0.2 (0–1.0)	0.5 (0–2.0)	0.7 (0–1.7)	0.7 (0–1.7)	1.0 (0–3.3)	2.5 (0–8.0)
PJ / blackbrush	13.2 (7.3–25.3)	18.3 (11.0–32.0)	5.7 (2.3–16.7)	6.7 (2.3–18.7)	7.4 (3.7–11.0)	11.4 (5.3–15.0)	0.1 (0–0.3)	0.1 (0–0.3)	0	0	0.1 (0–0.3)	0.6 (0–1.0)
Grassland	15.9 (8.3–24.0)	25.3 (14.0–32.0)	0	0	4.7 (0–11.0)	6.5 (0–13.7)	3.3 (0.7–10.0)	11.4 (5.3–26.3)	4.8 (0–15.0)	5.1 (0–15.3)	4.0 (1.0–8.0)	4.5 (1.3–8.7)

Table 3-4. Mean (range) percent cover of dominant species by ecological site type, Arches National Park, 2011.

Ecological site type	Scientific name	Common name	Lifeform	Duration	Nativity	Percent cover	
						Live	Total
Deep blackbrush	<i>Artemisia filifolia</i>	sand sagebrush	Shrub	Perennial	Native	0.5 (0–2.0)	1.1 (0–5.7)
	<i>Coleogyne ramosissima</i>	blackbrush	Shrub	Perennial	Native	10.8 (4.0–20.0)	15.3 (5.3–31.3)
	<i>Ephedra viridis</i>	Mormon tea	Shrub	Perennial	Native	2.0 (0–7.3)	2.3 (0–8.3)
	<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0	0.1 (0–0.7)
	<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	1.3 (0–4.0)	1.3 (0–4.3)
	<i>Opuntia</i> sp.	pricklypear	Dwarf Shrub	Perennial	Native	0.8 (0–2.0)	1.2 (0–3.0)
	<i>Quercus welshii</i>	Havard oak	Shrub	Perennial	Native	0.2 (0–1.3)	0.3 (0–2.0)
PJ / blackbrush	<i>Coleogyne ramosissima</i>	blackbrush	Shrub	Perennial	Native	5.3 (2.0–9.0)	8.0 (2.7–12.0)
	<i>Ephedra viridis</i>	Mormon tea	Shrub	Perennial	Native	0.6 (0–1.7)	0.8 (0–2.3)
	<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	4.3 (0.7–9.3)	4.7 (1.3–11.0)
	<i>Opuntia</i> species	pricklypear	Dwarf Shrub	Perennial	Native	0.4 (0–1.7)	0.5 (0–3.0)
	<i>Pinus edulis</i>	two-needle pinyon	Tree	Perennial	Native	1.5 (0–7.3)	2.0 (0–7.7)
	<i>Artemisia filifolia</i>	sand sagebrush	Shrub	Perennial	Native	0	0.1 (0–0.7)
Grassland	<i>Ephedra viridis</i>	Mormon tea	Shrub	Perennial	Native	2.3 (0–7.0)	2.9 (0–7.7)
	<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	0.5 (0–1.7)	3.5 (0.3–9.3)
	<i>Krascheninnikovia lanata</i>	winterfat	Shrub	Perennial	Native	1.8 (0–9.7)	2.6 (0–13.7)
	<i>Opuntia</i> species	pricklypear	Dwarf Shrub	Perennial	Native	0.3 (0–2.0)	0.6 (0–4.0)
	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	NonNative	0.1 (0–0.7)	0.3 (0–0.7)
	<i>Sporobolus cryptandrus</i>	sand dropseed	Graminoid	Perennial	Native	0.7 (0–2.3)	3.0 (1.0–6.7)
	<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	0.04 (0–0.3)	0.1 (0–1.0)
	<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	0.9 (0–1.7)	1.3 (0–2.7)

Table 3-5. Density of shrub species per hectare by ecological site type, Arches National Park, 2011.

Scientific name	Common name	No. of plots with species present*	Density (number of shrubs/ha)		
			Mean	Minimum	Maximum
Deep blackbrush					
<i>Artemisia filifolia</i>	sand sagebrush	3	217	0	1,000
<i>Atriplex canescens</i>	fourwing saltbush	1	8	0	67
<i>Coleogyne ramosissima</i>	blackbrush	8	5,292	1,133	8,800
<i>Ephedra torreyana</i>	Torrey's jointfir	2	42	0	200
<i>Ephedra viridis</i>	Mormon tea	2	58	0	267
<i>Eriogonum leptocladon</i>	sand wild buckwheat	4	208	0	1,133
<i>Juniperus osteosperma</i>	Utah juniper	3	25	0	67
<i>Poliomintha incana</i>	purple sage	1	50	0	400
<i>Purshia mexicana</i>	cliffrose	2	17	0	67
PJ / blackbrush					
<i>Cercocarpus intricatus</i>	dwarf mountain mahogany	1	8	0	67
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	2	25	0	133
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	3	33	0	133
<i>Coleogyne ramosissima</i>	blackbrush	8	5,217	1,133	8,867
<i>Ephedra torreyana</i>	Torrey's jointfir	5	92	0	267
<i>Ephedra viridis</i>	Mormon tea	6	300	0	1,000
<i>Eriogonum bicolor</i>	pretty wild buckwheat	1	8	0	67
<i>Eriogonum corymbosum</i>	crisp-leaf wild buckwheat	2	25	0	133
<i>Eriogonum microthecum</i>	slender wild buckwheat	1	25	0	200
<i>Fraxinus anomala</i>	singleleaf ash	1	17	0	133
<i>Juniperus osteosperma</i>	Utah juniper	6	100	0	200
<i>Pinus edulis</i>	two-needle pinyon	5	58	0	133
<i>Purshia mexicana</i>	cliffrose	5	142	0	533
Grassland					
<i>Artemisia filifolia</i>	sand sagebrush	1	83	0	667
<i>Atriplex canescens</i>	fourwing saltbush	2	58	0	267
<i>Coleogyne ramosissima</i>	blackbrush	1	42	0	333
<i>Krascheninnikovia lanata</i>	winterfat	6	3,225	0	13,800

* 8 plots were monitored in each ecological site type in 2011.

Table 3-6. Mean (range) percent cover and frequency of exotic plant species detected by ecological site type, Arches National Park, 2011.

Scientific name	Common name	Lifeform	Duration	No. of plots with exotic species detected*	Percent cover		Frequency of detection (%)
					Live	Total	
Deep blackbrush							
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	6	0.3 (0–1.0)	0.4 (0–1.0)	19.6 (0–66.7)
<i>Salsola tragus</i>	Russian thistle	Forb	Annual	5	0	0.2 (0–1.0)	9.6 (0–26.7)
PJ / blackbrush							
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	1	0	0	0.4 (0–3.3)
<i>Malcolmia africana</i>	African mustard	Forb	Annual	1	0	0	0.8 (0–6.7)
Grassland							
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	5	4.3 (0–15.0)	4.6 (0–15.3)	34.2 (0–90.0)
<i>Chorispora tenella</i>	blue mustard	Forb	Annual	1	0	0	0.4 (0–3.3)
<i>Descurainia sophia</i>	flixweed	Forb	Annual	1	0.04 (0–0.3)	0.04 (0–0.3)	0
<i>Salsola tragus</i>	Russian thistle	Forb	Annual	6	0.1 (0–0.7)	0.3 (0–0.7)	10.0 (0–43.3)

* 8 plots were monitored in each ecological site type in 2011.

Table 3-7. Mean (range) percent cover of surface features by ecological site type, Arches National Park, 2011.

Ecological site type	Crust, undifferentiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Deep blackbrush	75.8 (67.0–84.7)	1.0 (0–3.7)	0.04 (0–0.3)	3.3 (0–12.0)	1.1 (0–2.7)	14.2 (8.7–19.0)	0	2.1 (0–9.7)	0	0
PJ / blackbrush	45.3 (24.7–60.3)	4.4 (0–13.0)	0.7 (0–3.0)	3.8 (0.3–7.3)	1.4 (0–4.0)	16.5 (7.7–34.7)	0.4 (0–1.3)	18.6 (0.7–42.7)	3.3 (0–18.7)	4.1 (0.3–17.0)
Grassland	52.8 (44.7–64.3)	0	0	2.6 (0–10.3)	1.4 (0–2.7)	37.0 (25.3–47.3)	0	0.3 (0–1.0)	0	0

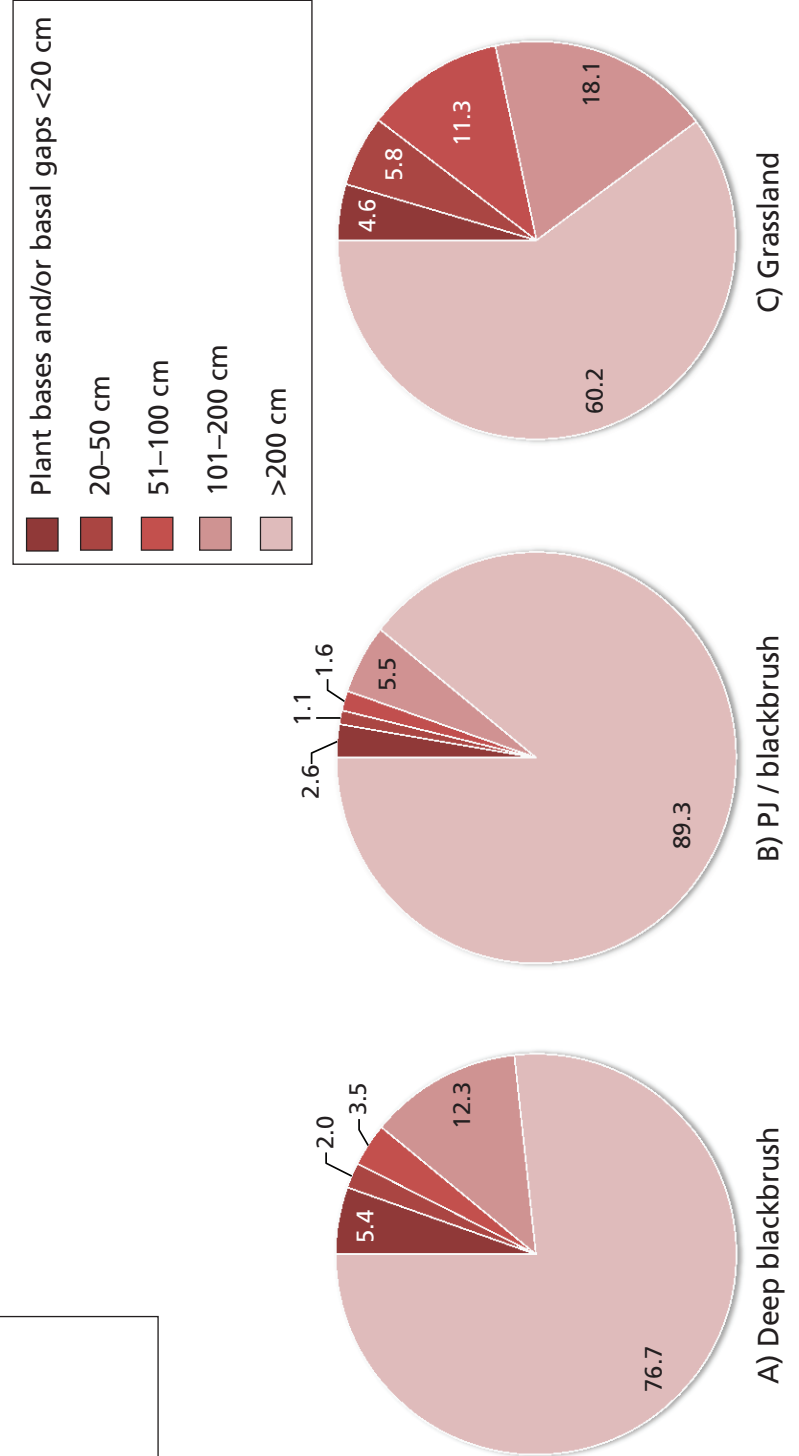
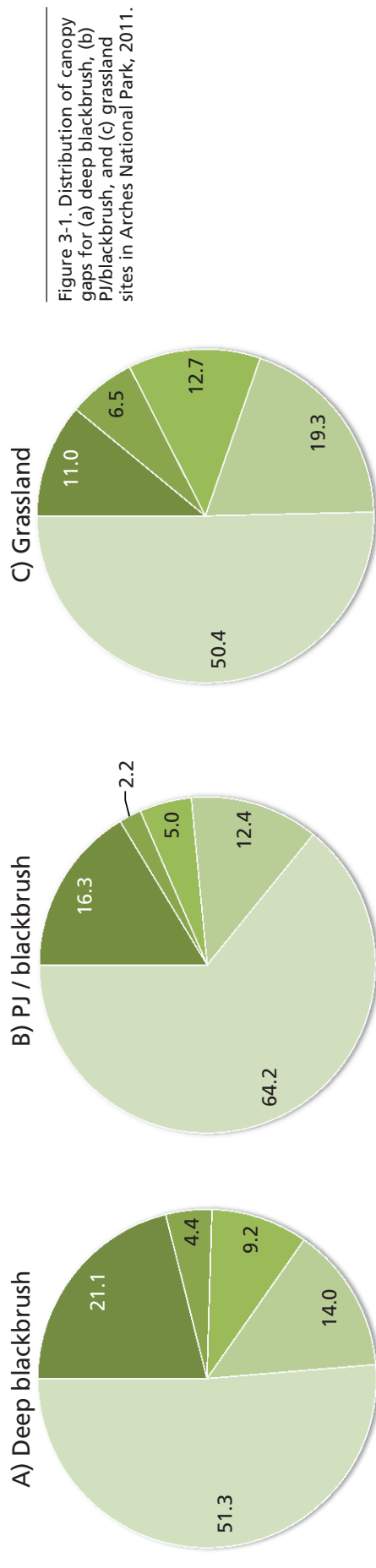


Figure 3-2. Distribution of basal gaps for (a) deep blackbrush, (b) PJ/blackbrush, and (c) grassland sites in Arches National Park, 2011.

Table 3-8. Mean (range) canopy- and basal-gap size by ecological site type, Arches National Park, 2011.

Ecological site type	Canopy gap (cm)	Basal gap (cm)
Deep blackbrush	169 (107–206)	307 (193–408)
PJ / blackbrush	246 (169–342)	565 (336–1,145)
Grassland	176 (92–384)	215 (89–478)

Table 3-9. Mean (range) soil-aggregate stability measures by ecological site type, Arches National Park, 2011.

Ecological site type	Total	Protected*	Unprotected*
Deep blackbrush	2.8 (1.9–4.1)	3.5 (1.0–4.9)	2.4 (1.4–3.4)
PJ / blackbrush	3.2 (1.9–4.8)	3.9 (1.8–5.3)	2.9 (1.6–4.8)
Grassland	3.1 (1.9–4.3)	4.0 (2.5–5.1)	2.6 (1.4–3.8)

*Protected are samples collected under vegetation; unprotected are samples collected in the open.

Numbers range from 1 (least stable) to 6 (most stable).

4 Discussion

In general, data from 2011 were similar to those from the previous year. One-half of plots monitored in 2011 were newly established, and it is important to remember that any differences between years could be due to the different suite of plots sampled, rather than actual changes in ecological site types. This variation will be accounted for in status and trend analyses after plots have been revisited; it is too early to draw conclusions from this preliminary data.

One notable difference in the 2011 data compared to those from the previous year was that total grassland cover was much lower in 2011 than in 2010 (25.3% cover in 2011 vs. 40.3% in 2010; Witwicki 2012). This lower grassland cover can be attributed to a much higher cover of annual forbs in 2010, particularly Russian thistle (0.3% cover in 2011 vs. 20.1% in 2010; Witwicki 2012). The higher cover of annual forbs was likely due to

the timing of sampling. Whereas plots were monitored in the fall of 2010, after the annual forbs had had the entire growing season to mature, plots were sampled in the spring of 2011—too early to detect much Russian thistle cover, because plants would be very small at that time of year. Future monitoring at Arches NP is scheduled for spring; thus, frequency data, in which individuals are detected regardless of size, will probably be more useful than cover data for monitoring changes in Russian thistle populations.

In 2012, twenty-four plots will be monitored according to the full operational monitoring design, including 12 plots that will be newly established. Continued discussion will occur with Arches NP resource staff to ensure park expectations and needs are satisfied by NCPN integrated upland monitoring. A status and trend report will be produced after five full years of monitoring have been completed.

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