



Integrated Upland Monitoring in Canyonlands National Park

Annual Report 2011 (Non-Sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2013/700.N



ON THE COVER

Pinyon-juniper/blackbrush shrubland plot in the Island in the Sky District, Canyonlands National Park. NPS photo.

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Errata

As originally published, three tables in the Results chapter of this document, *Integrated Upland Monitoring in Canyonlands National Park: Annual Report 2011*, contained eight numerical errors. The corrected values are shown in red in the highlighted cells here.

Revision date: 3/25/2013

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

Ecological site type	Number of species detected				
	Total	Tree	Shrub	Perennial grass	Annual grass Forb/ Herb
Grassland	11.9 (5–19)	0.3 (0–2)	2.8 (0–8)	3.8 (2–7)	0.6 (0–2) 4.3 (1–8)
Shallow blackbrush	8.1 (4–13)	0	4.7 (2–8)	1.1 (0–2)	0.8 (0–2) 1.6 (0–5)
PJ / blackbrush	8.6 (5–13)	1.6 (0–2)	4.4 (2–8)	0.5 (0–2)	0.7 (0–2) 1.4 (0–4)

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

Ecological site type	Total		Tree		Shrub		Perennial grass		Annual grass		Forbs/Herb	
	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total
Grassland	17.1 (7.0–30.3)	31.8 (18.7–52.0)	1.6 (0–13.3)	1.8 (0–13.3)	7.3 (0–25.7)	11.1 (0–29.0)	5.5 (0.7–15.7)	14.2 (2.7–30.7)	0.4 (0–3.0)	0.5 (0–3.0)	2.9 (0–7.7)	6.3 (0.3–14.3)
Shallow blackbrush	7.5 (4.3–12.7)	13.5 (7.0–19.0)	0	0	6.7 (3.3–12.7)	10.7 (5.3–18.0)	0.6 (0–2.7)	2.4 (0–7.0)	0.1 (0–0.7)	0.1 (0–0.7)	0.3 (0–1.3)	0.7 (0–2.0)
PJ / blackbrush	16.3 (11.0–22.7)	22.9 (17.3–31.3)	7.6 (0–17.3)	9.8 (0–20.3)	8.1 (2.0–19.0)	12.3 (2.3–30.3)	0.1 (0–0.7)	0.5 (0–3.3)	0.1 (0–0.7)	0.1 (0–0.7)	0.5 (0–2.7)	0.9 (0–3.3)

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

Ecological site type	Scientific name	Common name	Lifeform	Duration	No. of plots with exotic species detected*	Percent cover		Frequency of detection (%)
						Live	Total	
Grassland	<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	5	0.2 (0–2.0)	0.2 (0–2.3)	5.4 (0–80.0)
	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	11	0.3 (0–4.0)	0.4 (0–4.0)	20.7 (0–100.0)
	<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	1	0.03 (0–0.7)	0.03 (0–0.7)	0.1 (0–3.3)
Shallow blackbrush	<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	6	0.1 (0–0.7)	0.1 (0–0.7)	9.2 (0–60.0)
	<i>Halogeton glomeratus</i>	halogeton	Forb	Annual	4	0	0	2.2 (0–10.0)
	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	1	0	0	0.3 (0–3.3)
PJ / blackbrush	<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	4	0.03 (0–0.3)	0.03 (0–0.3)	1.7 (0–6.7)

* In 2011, 23 grassland, 12 shallow blackbrush, and 12 PJ/blackbrush plots were monitored.

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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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 Canyonlands National Park (NP) during 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, the NCPN completed its sixth year of monitoring at Canyonlands NP, which was the third year of monitoring under the long-term operational sampling design. Forty-seven plots were monitored in the Island in the Sky and Needles districts of the park, including 23 grassland plots, 12 shallow blackbrush plots, and 12 pinyon-juniper/blackbrush 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. Example of 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 Canyonlands National Park are described below.

Determine status and trends in plant communities, including:

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

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 Canyonlands National Park

2.1.1 Resource issues driving upland monitoring

During discussions with NCPN staff in 2005, park resource managers identified the development and subsequent impacts of unauthorized social trails in grass- and shrub-dominated systems as their primary issue of concern in park uplands. Managers were concerned about potential system degradation due to trampling of biological crust and subsequent increases in wind and water erosion of soil. Due to various limitations, the initial monitoring effort was restricted to the Island in the Sky and Needles districts, which collectively comprise about 77% (104,818 ha) of the park land area (136,610 ha).

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 eliminated. Due primarily to costs, areas accessible only by floating the Green and Colorado rivers were also eliminated from consideration. Accessibility and slope features were generated using the Landscape Accessibility Model (<http://science.nature.nps.gov/im/units/ncpn/Tools.cfm>). A 10-m buffer was applied to paved roads and a 50-m buffer applied to dwellings; buffered areas were then eliminated from further consideration.

Monitoring near existing social trails, transportation networks, and developments (e.g., campgrounds) was considered acceptable given the emphasis on monitoring the impacts of unauthorized social trails, and the propensity for such trails to emanate from human-use areas. Creating relatively narrow buffer widths and including trails in the spatial data layers also helped accommodate the overarching monitoring goals. These filtering procedures retained 58% (61,048 ha) of

the original 104,818 ha area, and provided an accessible-area map.

2.1.2.2 Selecting and mapping 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. Stratifying by ecological site allows us to tease out varying responses to anthropogenic and natural disturbances; however, ecological sites may be aggregated and analyzed by vegetation type or ecological-site type for general summary purposes.

Ecological sites corresponding to grassland and shrubland systems were identified from the Canyonlands Soil Survey (SCS 1991). Given the anticipated limitations of NCPN monitoring, the four most spatially extensive grassland sites (Desert Sand, Desert Sandy Loam, Semidesert Sand, and Semidesert Sandy Loam) and the two most spatially extensive shrubland sites (Desert Shallow Sandy Loam [Blackbrush] and Semidesert Shallow Sandy Loam [Pinyon-Juniper/Blackbrush]) were selected as target ecological sites (Table 2-1, Figure 2-1). Target grassland sites accounted for approximately 18% of the accessible area, but that 18% accounted for 83% of the accessible land area reported to be grassland. Target shrubland sites comprised approximately 27% of total accessible area, which accounted for 85% of accessible shrubland area.

We used predictive mapping software to map the six target ecological sites in Canyonlands NP (Garman 2008; Garman et al. 2010).

2.1.3 Selection of monitoring locations

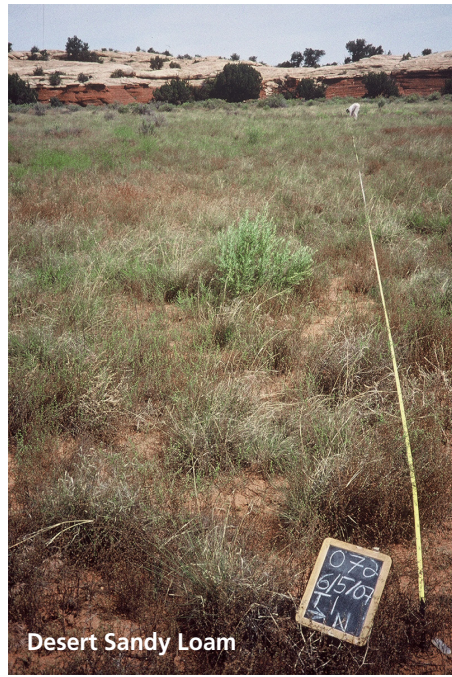
Using the predicted ecological site map, monitoring plots were selected using the Generalized Random Tessellated Stratified (GRTS) method (Stevens and Olsen 2004) to create a spatially balanced design. Coordinates corresponded to the centroid of a plot. To accom-

Table 2-1. Description of ecological sites selected for monitoring in Canyonlands National Park by physiognomic type.

Ecological site type	Ecological site name/ Notation	Soil series	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Herbaceous						
Grassland	Desert Sand (sand sagebrush) / DS115	Sheppard	Deep sands on dunes and sand sheets	Eolian deposits derived from sandstone	Dominated by Indian ricegrass, dropseeds, and sand sagebrush	Decreased Indian ricegrass, needle and thread, dropseeds, and increased sand sagebrush, snakeweed, and low rabbitbrush.
	Desert Sandy Loam (fourwing saltbush) / DSL118	Bluechief, Nakai, Thoroughfare	Deep sandy loams on mesas, stream terraces, and broad valleys	Alluvium and/or eolian deposits derived from sandstone	Dominated by Indian ricegrass, galleta, dropseeds, and fourwing saltbush	Decreased Indian ricegrass and saltbush and increased snakeweed and Mormon tea. Cheatgrass and Russian thistle may invade.
	Semidesert Sand (fourwing saltbush) / SDS212	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.
Shrubland	Semidesert Sandy Loam (fourwing saltbush) / SDSL215	Begay, Ignacio, Redbank	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.
	Desert Shallow Sandy Loam (blackbrush) / DSSL133	Arches, Moenkopie	Shallow sandy loams on structural benches and ledges on escarpments	Residium and eolian deposits from sandstone, limestone, and shale	Dominated by blackbrush	Decreased bunchgrasses and Mormon tea and increased blackbrush and snakeweed. Cheatgrass and Russian thistle may invade.
	Semidesert Shallow Sandy Loam (Utah Juniper-Pinyon) / SDSSL236	Rizno	Shallow sandy loams on benches and mesas	Residium 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.



Desert Sand



Desert Sandy Loam



Semidesert Sand



Semidesert Sandy Loam



Desert Shallow Sandy Loam



Semidesert Shallow Sandy Loam

Figure 2-1. Examples of ecological sites monitored in Canyonlands National Park: Desert Sand (sand sagebrush), Desert Sandy Loam (fourwing saltbush), Semidesert Sand (fourwing saltbush), Semidesert Sandy Loam (fourwing saltbush), Desert Shallow Sandy Loam (blackbrush), and Semidesert Shallow Sandy Loam (Utah juniper/pinyon). See Table 2-1 for descriptions of ecological sites.

moderate rejection, 300 sites were selected per ecological site. Within each ecological site, plots were established in ascending order of plot number. If a plot was rejected (e.g., due to incorrect ecological site type), the next sequentially ordered plot was used.

2.1.4 Pilot study and long-term sampling design

Upland monitoring was initiated at Canyonlands National Park in 2006. Eight monitoring plots were established for each target ecological site except Desert Sand, which was not sampled during pilot monitoring due to low spatial extent across the landscape. Plots were sampled for 2–3 years and variances of measures were used to evaluate power for trend of potential operational sampling designs. Details of this analysis are provided in Witwicki (2010).

2.1.4.1 Long-term sampling design

Based on the analysis of pilot data, a long-term operational sampling design was created and implemented in 2009. To deal with the cost of sampling extremely remote areas of the park, the sampling frame was further limited to a 4-km hiking distance. Ecological sites were lumped into broader groups with similar vegetation, precipitation, and soil depth that we are calling ecological site types, and the sampling design at Canyonlands NP (Figure 2-2) was based on this. All four deep grassland ecological sites were combined

into a larger grassland sampling frame, and plots were established in order within this ecological site type. This allowed the number of plots for each grassland ecological site sampled to be determined by its approximate area in the sampling frame. The two shrubland ecological sites remained as separate ecological site types (shallow blackbrush and pinyon-juniper (PJ)/blackbrush) containing one ecological site each.

2.1.4.2 Revisit design

Each year, 24 grassland, 12 blackbrush, and 12 PJ/blackbrush plots are monitored (Figure 2-3). A total of 252 plots are sampled over a seven-year revisit schedule. Half of the plots are visited for two consecutive years; the other half are visited only once before being rested for 5–6 years. This revisit strategy maximizes the ability to detect trends and minimizes the impact on biological soil crusts.

Plots in the Needles backcountry, defined as the western part of the Needles district accessed by driving very technical 4-wheel drive roads, either over Elephant Hill or down Bobby's Hole, are considered the most remote in the sampling design. These plots have been lumped into panels 9 and 12 so that they are only visited in two of the seven years of the revisit design. This was done to minimize travel time and costs associated with getting to this remote part of the park and to maximize the number of plots that could be sampled overall.

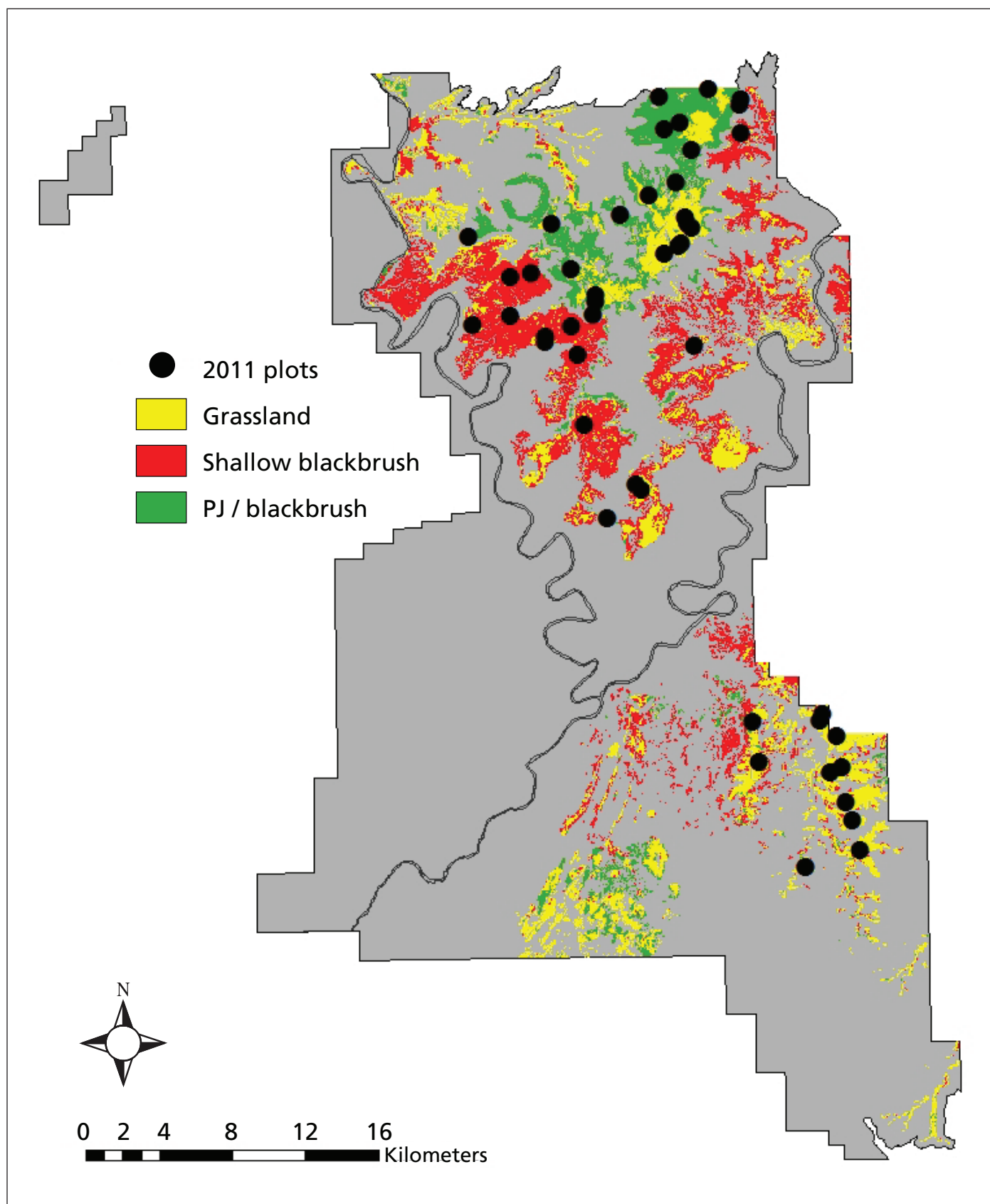


Figure 2-2. Location of monitoring plots in Canyonlands National Park, 2011.

A. Grassland

Panel	Year						
	1	2	3	4	5	6	7
1	6	6					
2		6	6				
3			6	6			
4				6	6		
5					6	6	
6						6	6
7	6						6
8	12						
9		12					
10			12				
11				12			
12					12		
13						12	
14							12

B. Shallow blackbrush and PJ/blackbrush

Panel	Year						
	1	2	3	4	5	6	7
1	3	3					
2		3	3				
3			3	3			
4				3	3		
5					3	3	
6						3	3
7	3						3
8	6						
9		6					
10			6				
11				6			
12					6		
13						6	
14							6

Figure 2-3. Number of plots sampled each year in grassland (A), shallow blackbrush (B), and PJ/blackbrush (B) based on 7-year rotating panel revisit designs for long-term upland monitoring at Canyonlands National Park.

In grasslands, 24 plots are sampled each year among the 4 target grassland ecological sites, and 126 unique plots are sampled over 7 years. In shallow blackbrush and PJ/blackbrush, 12 plots are sampled each year in each ecological site type, and 63 unique plots are sampled in each ecological site type over 7 years.

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). The location of a sample unit (or plot) is randomly selected using procedures described above. 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-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 predicted ecological site map, and the GRTS-generated sampling locations are GIS-ArcMap shape files and are stored with the Access database on NCPN servers.

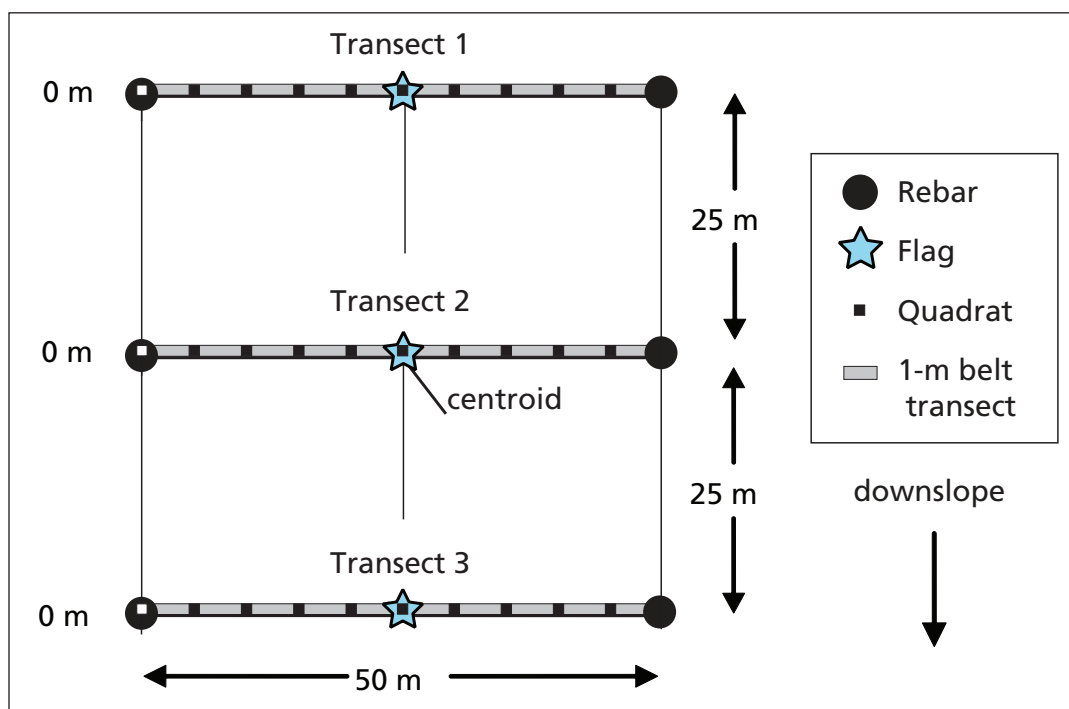


Figure 2-4. Plot layout for upland monitoring of grasslands and shrublands.

3 Results

3.1 Monitored plots

In 2011, forty-eight plots were monitored as part of the long-term revisit design, including 24 grassland, 12 shallow blackbrush, and 12 PJ/blackbrush plots (see Figure 2-2). Twelve plots were revisited (1/4 of the plots in each ecological site type), and 36 new plots were established among the three ecological site types. Table 3-1 summarizes plot visits by ecological site type, ecological site, and year (tables begin on page 13).

Only 23 grassland plots, instead of the 24 original plots, are included in this report. One plot was later determined to be a non-target ecological site. Rebar was removed from this plot, and it will not be included in the long-term data set.

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 the 2012 field season.

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 78 species were detected in Canyonlands 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 Canyonlands NP. No new species were detected in the park in 2011.

No threatened or endangered species were found on any plots in 2011. Threatened and endangered plant species are not common in the areas of Canyonlands 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.

Percent cover of live and total dominant species for each ecological site type is 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 (cany11_species.xls).

3.2.3 Shrub density

Density of shrub species for each ecological site type is shown in Table 3-5. In grasslands, fourwing saltbush (*Atriplex canescens*) occurred in the highest number of plots and winterfat (*Krascheninnikovia lanata*) had the highest density. Blackbrush (*Coleogyne ramosissima*) occurred in all shallow blackbrush and PJ blackbrush plots and had the highest shrub density in both ecological site types. In shallow blackbrush plots, shadscale (*Atriplex confertifolia*) and Torrey's jointfir (*Ephedra torreyana*) also had high densities.

Green ephedra (*Ephedra viridis*) is common in grasslands at Canyonlands 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 Canyonlands 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 is shown in Table 3-6. When exotic species were detected, cover and frequency were summarized for all plots in the ecological site type.

Cover of exotic species was relatively low in all ecological site types. Exotic species were detected at a higher percentage of shallow blackbrush plots (83% of plots) than in the other ecological site types (65% of grassland plots and 33% of PJ/blackbrush plots). Russian thistle (*Salsola tragus*) in grasslands had the highest frequency of detection, with frequency as high as 100% in one plot. Cheatgrass (*Bromus tectorum*) was detected in all ecological site types.

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 (cany11_exotics.xls).

3.2.5 Biological soil crust and surface features

Biological soil crust and surface-feature cover are shown in Table 3-7. The surface cover at grassland plots was predominantly undifferentiated crust with substantial portions of litter and some more developed biological soil crust components. Similarly, the surface cover at PJ/blackbrush plots had the highest

amounts of undifferentiated crust and litter and more well-developed biological soil crust components than any other ecological site type. Shallow blackbrush plots tended to have a surface cover of small rocks and undifferentiated crust.

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 (Figures begin on page 16). The most common size of both canopy and basal gaps was >2 m in length 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. The numbers are affected by soil texture, so 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.

The mean soil stability was generally lower in shallow blackbrush than the other two ecological site types. The soil surface has a high cover of rocks (mean of nearly 65% cover of small and large rocks and bedrock), and is generally well-armored despite this low soil stability rating.

Table 3-1. Number of plots by ecological site type and ecological site monitored in Canyonlands National Park, 2006–2011.

Ecological site type	Ecological site	Number of plots monitored					
		2006 (August– September)	2007 (May– June)	2008 (April– August)	2009 (May– June)	2010 (April– May)	2011 (April– May)
Grassland	Desert Sand	0	0	0	1	2	6
	Desert Sandy Loam	7	8	8	10	12	5
	Semidesert Sand	7	8	8	4	2	3
	Semidesert Sandy Loam	8	8	8	9	8	9
	Non-target	-	-	-	-	-	1
Shallow blackbrush	Desert Shallow Sandy Loam	1	8	8	10	12	12
PJ / blackbrush	Semidesert Shallow Sandy Loam	8	8	8	12	12	12
Total		31	40	40	46	48	48

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, Canyonlands National Park, 2011.

Ecological site type	Number of species detected					
	Total	Tree	Shrub	Perennial grass	Annual grass	Forb/ Herb
Grassland	11.9 (5–19)	0.3 (0–2)	2.8 (0–8)	3.8 (2–7)	0.6 (0–2)	4.3 (1–8)
Shallow blackbrush	7.6 (4–13)	0	4.4 (2–8)	1.0 (0–2)	0.6 (0–2)	1.6 (0–5)
PJ / blackbrush	8.6 (5–13)	1.6 (0–2)	4.4 (2–8)	0.5 (0–2)	0.7 (0–2)	1.4 (0–4)

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

Ecological site type	Total		Tree		Shrub		Perennial grass		Annual grass		Forbs/Herb	
	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total
Grassland	17.1 (7.0–30.3)	31.8 (18.7–52.0)	1.6 (0–13.3)	1.8 (0–13.3)	7.3 (0–25.7)	11.1 (0–29.0)	5.5 (0.7–15.7)	14.2 (2.7–30.7)	0.4 (0–3.0)	0.5 (0–3.0)	2.9 (0–7.7)	6.3 (0.3–14.3)
Shallow blackbrush	7.5 (4.3–22.7)	13.5 (7.0–31.3)	0	0	6.7 (3.3–12.7)	10.7 (5.3–18.0)	0.6 (0–2.7)	2.4 (0–7.0)	0.1 (0–0.7)	0.1 (0–0.7)	0.3 (0–1.3)	0.7 (0–2.0)
PJ / blackbrush	16.3 (11.0–22.7)	22.9 (17.3–31.3)	7.6 (0–17.3)	9.8 (0–20.3)	8.1 (2.0–19.0)	12.3 (2.3–30.3)	0.1 (0–0.7)	0.5 (0–3.3)	0.1 (0–0.7)	0.1 (0–0.7)	0.5 (0–2.7)	0.9 (0–3.3)

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

Ecological site type	Scientific name	Common name	Lifeform	Duration	Nativity	Percent cover	
						Live	Total
Grassland	<i>Atriplex canescens</i>	fourwing saltbush	Shrub	Perennial	Native	0.5 (0–3.0)	1.1 (0–4.7)
	<i>Bouteloua gracilis</i>	blue grama	Graminoid	Perennial	Native	0.4 (0–3.0)	0.9 (0–5.3)
	<i>Ephedra viridis</i>	Mormon tea	Shrub	Perennial	Native	3.2 (0–12.0)	4.0 (0–14.7)
	<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.1 (0–0.7)	0.6 (0–7.3)
	<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	0.6 (0–3.3)	2.5 (0–20.0)
	<i>Opuntia</i> species	pricklypear	Dwarf Shrub	Perennial	Native	0.3 (0–1.3)	0.5 (0–2.0)
	<i>Sporobolus cryptandrus</i>	sand dropseed	Graminoid	Perennial	Native	0.7 (0–5.7)	2.0 (0–15.3)
	<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	1.8 (0–10.0)	3.4 (0–18.3)
	<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	1.3 (0–5.0)	2.2 (0–6.3)
	<i>Stipa</i> species*		Graminoid	Perennial	Native	0.4 (0–4.3)	1.0 (0–6.3)
Shallow blackbrush	<i>Atriplex confertifolia</i>	shadscale	Shrub	Perennial	Native	1.0 (0–2.7)	2.2 (0–6.3)
	<i>Coleogyne ramosissima</i>	blackbrush	Shrub	Perennial	Native	3.7 (0.3–11.7)	5.7 (0.3–15.7)
	<i>Ephedra torreyana</i>	Torrey's jointfir	Shrub	Perennial	Native	1.6 (0.3–4.7)	2.2 (0.7–6.0)
	<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	0.6 (0–2.7)	2.3 (0–7.0)
PJ / blackbrush	<i>Coleogyne ramosissima</i>	blackbrush	Shrub	Perennial	Native	4.7 (0.3–15.3)	7.4 (0.3–24.7)
	<i>Ephedra viridis</i>	Mormon tea	Shrub	Perennial	Native	1.1 (0–2.3)	1.3 (0–2.3)
	<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	4.8 (0–11.7)	6.2 (0–14.3)
	<i>Opuntia</i> species	pricklypear	Dwarf Shrub	Perennial	Native	0.3 (0–2.0)	0.5 (0–3.3)
	<i>Pinus edulis</i>	two-needle pinyon	Tree	Perennial	Native	2.9 (0–8.7)	3.8 (0–11.0)

*Flowers or seeds are necessary to distinguish *Stipa comata* and *Stipa hymenoides*. *Stipa* species represents indistinguishable vegetative forms of these two grasses that were detected during upland monitoring.

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

Scientific name	Common name	No. of plots with species present*	Density (number of shrubs/ha)		
			Mean	Minimum	Maximum
Grassland					
<i>Artemisia tridentata</i>	big sagebrush	2	81	0	1,533
<i>Atriplex canescens</i>	fourwing saltbush	13	168	0	800
<i>Atriplex confertifolia</i>	shadescale	1	46	0	1,067
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	3	29	0	400
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	2	386	0	6,133
<i>Coleogyne ramosissima</i>	blackbrush	6	168	0	2,133
<i>Ephedra torreyana</i>	Torrey's jointfir	1	12	0	267
<i>Eriogonum leptocladon</i>	sand wild buckwheat	2	130	0	1,667
<i>Juniperus osteosperma</i>	Utah juniper	1	6	0	133
<i>Krascheninnikovia lanata</i>	winterfat	9	820	0	7,267
<i>Mahonia fremontii</i>	Fremont's mahonia	1	3	0	67
<i>Sarcobatus vermiculatus</i>	greasewood	1	6	0	133
<i>Symphoricarpos longiflorus</i>	long-flower snowberry	1	9	0	200
Shallow blackbrush					
<i>Artemisia bigelovii</i>	Bigelow's sagebrush	2	22	0	200
<i>Artemisia spinescens</i>	budsage	2	33	0	333
<i>Atriplex confertifolia</i>	shadscale	11	1,294	0	3,667
<i>Brickellia microphylla</i>	littleleaf brickellbush	1	11	0	133
<i>Brickellia oblongifolia</i>	Mojave brickellbush	1	39	0	467
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	6	83	0	467
<i>Coleogyne ramosissima</i>	blackbrush	12	2,400	200	6,867
<i>Ephedra torreyana</i>	Torrey's Mormon tea	11	639	0	1,200
<i>Philadelphus microphyllus</i>	littleleaf mock-orange	1	6	0	67
<i>Rhus trilobata</i>	skunkbush sumac	2	17	0	133
PJ / blackbrush					
<i>Artemisia bigelovii</i>	Bigelow's sagebrush	3	56	0	333
<i>Atriplex canescens</i>	fourwing saltbush	2	11	0	67
<i>Cercocarpus intricatus</i>	dwarf mountain mahogany	2	17	0	133
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	1	44	0	533
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	3	44	0	267
<i>Coleogyne ramosissima</i>	blackbrush	12	2,228	133	6,333
<i>Ephedra torreyana</i>	Torrey's jointfir	3	61	0	600
<i>Ephedra viridis</i>	Mormon tea	8	178	0	467
<i>Eriogonum microthecum</i>	slender wild buckwheat	1	17	0	200
<i>Fraxinus anomala</i>	singleleaf ash	5	50	0	200
<i>Juniperus osteosperma</i>	Utah juniper	9	122	0	267
<i>Pinus edulis</i>	two-needle pinyon	7	56	0	267
<i>Purshia mexicana</i>	cliffrose	5	167	0	933
<i>Symphoricarpos longiflorus</i>	long-flower snowberry	1	33	0	400

* In 2011, 23 grassland, 12 shallow blackbrush, and 12 PJ/blackbrush plots were monitored.

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

Ecological site type	Scientific name	Common name	Lifeform	Duration	No. of plots with exotic species detected*	Percent cover		Frequency of detection (%)
						Live	Total	
Grassland	<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	5	0.2 (0–2.0)	0.2 (0–2.3)	5.1 (0–80.0)
	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	11	0.3 (0–4.0)	0.4 (0–4.0)	19.9 (0–100.0)
	<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	1	0.03 (0–0.7)	0.03 (0–0.7)	0.1 (0–3.3)
Shallow blackbrush	<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	6	0.1 (0–0.7)	0.1 (0–0.7)	9.2 (0–60.0)
	<i>Halogeton glomeratus</i>	halogeton	Forb	Annual	4	0	0	2.2 (0–10.0)
	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	1	0	0	0.3 (0–3.3)
PJ / blackbrush	<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	4	0.03 (0–0.3)	0.03 (0–0.3)	1.7 (0–6.7)

* In 2011, 23 grassland, 12 shallow blackbrush, and 12 PJ/blackbrush plots were monitored.

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

Surface feature	Ecological site type		
	Grassland	Shallow blackbrush	PJ / blackbrush
Crust, undifferentiated	54.1 (27.7–90.7)	25.3 (5.7–78.0)	49.5 (28.0–78.0)
Cyanobacteria	1.7 (0–9.0)	0.1 (0–1.0)	5.9 (0–19.0)
Lichen	0.1 (0–1.0)	0.1 (0–1.3)	0.9 (0–4.0)
Moss	6.4 (0–19.3)	0.6 (0–3.7)	3.6 (0.3–9.3)
Bare soil	0.3 (0–3.3)	0.9 (0–4.3)	0.9 (0–4.3)
Litter	31.1 (6.3–44.3)	6.9 (3.7–9.3)	19.4 (8.0–32.3)
Woody debris	0.1 (0–1.0)	0 (0–2.3)	0.5 (0–2.3)
Small rock	0.4 (0–2.0)	58.2 (9.7–80.3)	6.5 (0–21.7)
Large rock	0.01 (0–0.3)	4.8 (0–13.7)	1.2 (0–5.7)
Bedrock	0	1.9 (0–5.0)	9.9 (0–24.3)

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

Ecological site type	Canopy gap (cm)	Basal gap (cm)
Grassland	135 (65–284)	187 (82–386)
Shallow blackbrush	331 (184–606)	520 (317–930)
PJ / blackbrush	300 (146–493)	658 (211–1,355)

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

Ecological site type	Total	Protected*	Unprotected*
Grassland	3.9 (1.6–5.7)	4.2 (1.0–6.0)	3.5 (1.5–5.8)
Shallow blackbrush	2.0 (1.0–3.1)	3.7 (1.0–5.0)	1.7 (1.0–2.5)
PJ / blackbrush	3.9 (2.3–5.3)	4.5 (3.0–5.7)	3.6 (1.2–5.2)

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

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

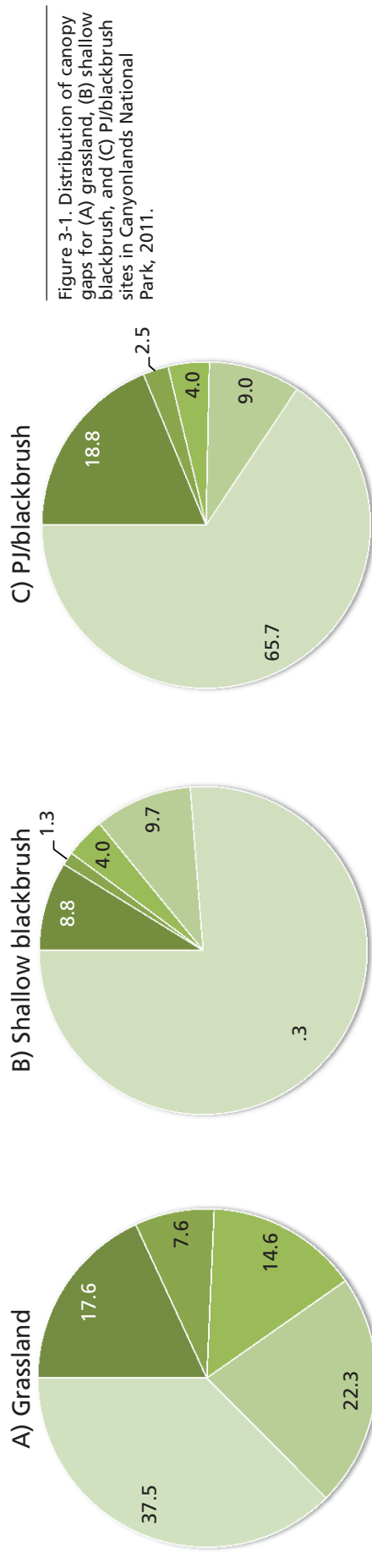


Figure 3-1. Distribution of canopy gaps for (A) grassland, (B) shallow blackbrush, and (C) PJ/blackbrush sites in Canyonlands National Park, 2011.

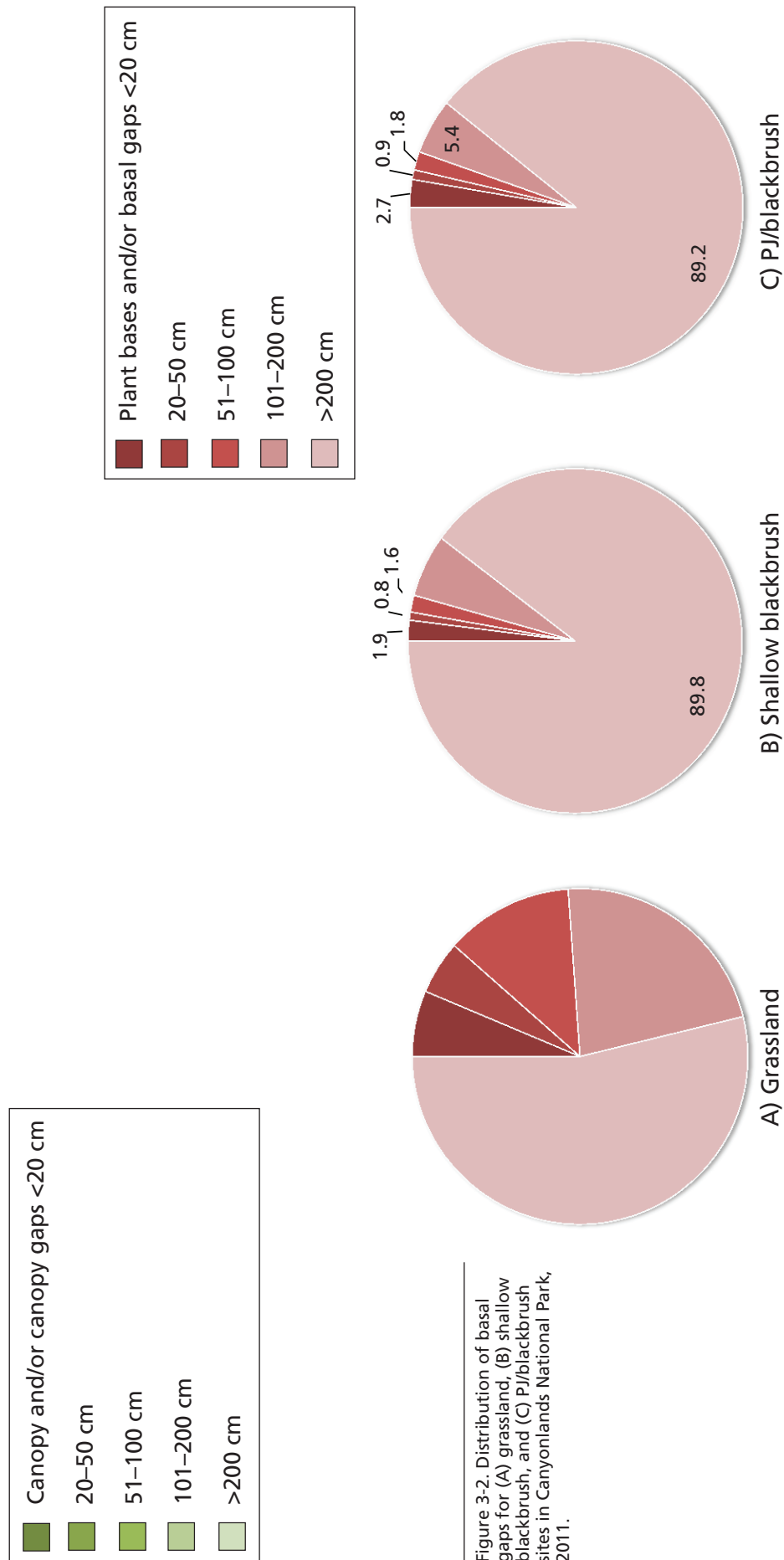


Figure 3-2. Distribution of basal gaps for (A) grassland, (B) shallow blackbrush, and (C) PJ/blackbrush sites in Canyonlands National Park, 2011.

4 Discussion

In general, data from 2011 were similar to those from previous years. Three-quarters of the 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 these preliminary data.

One notable difference in the 2011 data, compared to those of previous years, is the amount of exotic plant species detected. Exotic species were much more likely to be detected at plots using the new frequency method than by using cover derived from point-intercept sampling or density of exotic perennials in the 1-m belt (which excluded the common exotic annual species at Canyonlands NP). This difference is most likely because the exotic frequency methods are better-suited for detecting exotic species in these ecological site types, and not due to an actual increase in exotic plant species in the park in 2011.

In 2012, forty-eight plots will be monitored according to the full operational monitoring design, including 36 plots that will be newly established. Continued discussion will occur with Canyonlands National Park resource staff to ensure that park expectations and needs are satisfied by NCPN integrated upland monitoring. A status and trend report will be produced after the 2012 field season.

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