



Integrated Upland Monitoring in Capitol Reef National Park

Annual Report 2011 (Non-Sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2013/679.N



ON THE COVER

Semidesert Stony Loam grassland, Capitol Reef National Park. NPS photo.

Integrated Upland Monitoring in Capitol Reef National Park

Annual Report 2011 (Non-Sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2013/679.N

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

January 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Northern Colorado Plateau Network website, <http://www.nature.nps.gov/im/units/ncpn>, as well as at the Natural Resource Publications Management web site, <http://www.nature.nps.gov/publications/nrpm>.

Please cite this publication as:

Witwicki, D. 2013. Integrated upland monitoring in Capitol Reef National Park: annual report 2011 (non-sensitive version). Natural Resource Technical Report NPS/NCPN/NRTR—2013/679.N. National Park Service, Fort Collins, Colorado.

Contents

Figures..... v

Tables vii

Executive Summary ix

Acknowledgements xi

1 Introduction..... 1

2 Methods..... 3

 2.1 Integrated upland monitoring in Capitol Reef National Park..... 3

 2.2 Integrated upland monitoring procedures 6

 2.3 Database 8

3 Results 9

 3.1 Monitored plots..... 9

 3.2 Ecological site type summaries 9

4 Discussion..... 19

5 Literature Cited 21

Figures

Figure 1-1. Light cyanobacterial crust in an area where cattle were recently trailed, Pleasant Creek, Capitol Reef National Park. 1

Figure 2-1. Examples of ecological sites monitored in Capitol Reef National Park 5

Figure 2-2. Location of monitoring plots in Capitol Reef National Park, 2011 7

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

Figure 2-4. Plot layout for upland monitoring of grasslands and shrublands..... 8

Figure 3-1. Distribution of canopy gaps for deep grassland plots in (A) ungrazed Cathedral/Rock Springs allotments and (B) the grazed Hartnet allotment, Capitol Reef National Park, 2011. 15

Figure 3-2. Distribution of basal gaps for deep grassland plots in (A) ungrazed Cathedral/Rock Springs allotments and (B) the grazed Hartnet allotment, Capitol Reef National Park, 2011. 15

Figure 3-3. Distribution of (A) canopy gaps and (B) basal gaps for rocky grassland plots in the grazed Hartnet allotment, Capitol Reef National Park, 2011. 16

Tables

Table 2-1. Description of ecological sites selected for monitoring in Capitol Reef National Park.	4
Table 3-1. Number of plots, by ecological site type and allotment, monitored in Capitol Reef National Park, 2007–2011.	11
Table 3-2. Mean (range) number of plant species detected per monitoring plot by life form, ecological site type, and allotment, Capitol Reef National Park, 2011.	11
Table 3-3. Mean (range) percent cover by life form for each ecological site type and allotment, Capitol Reef National Park, 2011.	12
Table 3-4. Mean (range) percent cover of dominant species by ecological site type and allotment, Capitol Reef National Park, 2011.	12
Table 3-5. Mean (range) density of shrub species per hectare by ecological site type and allotment, Capitol Reef National Park, 2011.	13
Table 3-6. Mean (range) percent cover and frequency of exotic plant species detected by ecological site type and allotment in Capitol Reef National Park, 2011.	14
Table 3-7. Mean (range) percent cover of surface features by ecological site type and allotment, Capitol Reef National Park, 2011.	14
Table 3-8. Mean (range) canopy- and basal-gap size by ecological site type and allotment, Capitol Reef National Park, 2011.	17
Table 3-9. Mean (range) soil aggregate stability measures by ecological site type and allotment, Capitol Reef National Park, 2011.	17

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 Capitol Reef 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, NCPN completed its fifth year of monitoring at Capitol Reef NP, which was the second year of monitoring under the long-term operational sampling design. Forty-eight plots were monitored, including 16 deep grassland plots in the retired Cathedral and Rock Springs allotments, and 16 deep grassland plots and 16 rocky grassland plots in the Hartnet allotment, which is still actively grazed by livestock. Twenty-six of these plots were newly established.

In this report, measures from 2011 were summarized for each ecological site type by allotment. Early monitoring data describe status of ecological site types, and interpretation is limited until additional data is acquired and more rigorously analyzed after at least five years of monitoring are complete.

Acknowledgements

B. Condie, A. Randolph-Lowe, T. Crook, B. Gottung, E. Okal, and R. Weissinger conducted field work. A. Wight provided maps and managed spatial data. L. Houghton helped assemble summary data. D. Perkins and S. Borthwick improved this report with their thoughtful reviews. Data management was provided by H. Thomas. D. Perry assisted with administrative details. D. Worthington provided logistical assistance at the park.

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 life forms 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 surround-

ing 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 threatens 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 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



Figure 1-1. Light cyanobacterial crust in an area where cattle were recently trailed, Pleasant Creek, Capitol Reef National Park.

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 the integrated upland monitoring protocol are described below.

Determine status and trends in plant communities, including:

- overall species richness
- cover of vegetation by dominant species and life form
- 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 us to identify drivers and distinguish “natural” from anthropogenic change. Historical upland monitoring data sets may be integrated with data collected by the NCPN to allow earlier detection of trends. Local weather-station data can be used to interpret responses, whereas remote sensing can be used to determine vegetation change caused by land use or climate change at larger scales. NCPN upland monitoring data will assist the park units in understanding climate change over the long term and may help future park managers to develop climate-change adaptation strategies.

2 Methods

2.1 Integrated upland monitoring in Capitol Reef National Park

2.1.1 Resource issues driving upland monitoring

During discussions with NCPN staff in 2007, park resource managers identified livestock grazing impacts on grasslands as their primary issue of concern in park uplands. Of particular interest were grazing allotments that could become inactive in the near future. Park managers desired background data on conditions of these allotments in order to track recovery after grazing has ceased. Managers also expressed interest in comparing grazed areas to retired grazing allotments in order to learn about plant and soil recovery.

Due to various limitations, the initial monitoring effort was restricted to three grazing allotments in the northern part of the park, identified as priority areas by park managers. These areas represent both actively grazed (Hartnet) and previously grazed (Cathedral, retired in 1999; and Rock Springs, retired in 1989) allotments, and collectively comprise about 36% (35,159 ha) of the park area (97,895 ha). The two retired allotments were combined and treated separately from the active allotment.

2.1.2 Mapping and selecting target populations

2.1.2.1 Accessibility and sensitive areas

Areas that pose safety threats, are inaccessible within budgetary limitations, and/or are 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>). At the request of park personnel, monitoring sites near transportation corridors and within high-use areas were avoided. A 25-m buffer was applied to roads and trails, a 10-m buffer was applied to major

washes, and a ≥ 50 -m buffer was applied to specific high-use areas. Buffered areas were then eliminated from further consideration. These filtering procedures retained 78% (27,310 ha) of the original 35,159-ha area, and provided an accessible area map.

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. 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 grasslands with substantial herbaceous cover were initially identified from the Capitol Reef Soil Survey (SCS 2004). A recent vegetation-association map (Coles et. al. 2009) was also used to help identify potential target areas.

Two ecological site types were selected as targets: (1) grasslands on deep alluvial and/or eolian soils (all allotments), and (2) grasslands on deep, rocky soils of various origins (Hartnet allotment only). The deep alluvial/eolian grassland group (hereafter referred to as deep grasslands) consisted of Semidesert Alkali Sandy Loam, Semidesert Sand, and Semidesert Sandy Loam ecological sites. The deep stony grassland group (hereafter referred to as rocky grasslands) included Semidesert Stony Loam and Semidesert Very Steep Stony Loam ecological sites (Table 2-1, Figure 2-1).

Collectively, the target ecological site types account for approximately 21% of the accessible area, but that 21% accounts for 90% of the accessible land area reported to support herbaceous communities.

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

Ecological site name/ notation	Soil series	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Deep alluvial / eolian grassland (Deep grassland)					
Semidesert Alkali Sandy Loam (alkali sacaton)/ SDASL201	Begay-alkali, Naplene	Deep alkali sandy loams on dissected alluvial fans	Alluvium and eolian deposits from mixed sedimentary rocks	Dominated by alkali sacaton, greasewood, Indian ricegrass, and shadscale	Decreased bunchgrass and increased snakeweed, rabbitbrush, and prickly pear. Cheatgrass and Russian thistle may invade.
Semidesert Sand (fourwing saltbush)/ SDS212	Mido, Mivida-undulating	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	Begay, Mivida	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 pricklypear. Cheatgrass and Russian thistle may invade.
Deep stony grassland (Rocky grassland)					
Semidesert Stony Loam (shadscale)/ SDStL242	Clapper, Strych	Deep stony loams on tops of structural benches and valley sides	Alluvium and colluvium derived from sandstone and shale	Dominated by galleta, shadscale, Torrey's jointfir, Bigelow's sagebrush, winterfat, and Indian ricegrass	Decreased Indian ricegrass, Torrey's jointfir, and Bigelow's sagebrush and increased galleta, shadscale, and snakeweed. Cheatgrass and juniper may invade.
Semidesert Very Steep Stony Loam (Salina wildrye)/ SDVSStL260	Clapper-steep, Happle	Deep stony loams on steep remnant hillsides	Basalt glacial outwash over sandstone and shale residuum	Dominated by Indian ricegrass, shadscale, Torrey's jointfir, Bigelow's sagebrush, and Salina wildrye	Decreased Indian ricegrass, Torrey's jointfir, and Bigelow's sagebrush and increased galleta, snakeweed, and juniper. Cheatgrass and halogeton may invade.



Semidesert Alkali Sandy Loam



Semidesert Sand



Semidesert Sandy Loam



Semidesert Stony Loam



Semidesert Very Steep Stony Loam

Figure 2-1. Examples of ecological sites monitored in Capitol Reef National Park: Semidesert Alkali Sandy Loam (alkali sacaton), Semidesert Sand (fourwing saltbush), Semidesert Sandy Loam (fourwing saltbush), Semidesert Stony Loam (shadscale), and Semidesert Very Steep Stony Loam (Salina wildrye). See Table 2-1 for descriptions of ecological sites.

2.1.2.3 Mapping of target ecological site types

We used classification and regression trees (CART) to map target ecological site types in Capitol Reef National Park (NP) (Garman and Witwicks 2008; Garman et al. 2010). Deep grasslands were sampled in the Cathedral and Rock Springs allotments and in the Hartnet allotment. Rocky grasslands were only sampled in the Hartnet allotment. About 2,249 ha were predicted as target site type in the Cathedral and Rock Springs allotments, and 3,993 ha in the Hartnet allotment.

2.1.3 Selection of monitoring locations

Using the predicted ecological site map, monitoring plots were selected using the Reversed Randomized Quadrat-Recursive Raster (RRQRR) method (Theobald et al. 2007) to create a spatially balanced design. Coordinates corresponded to the centroid of a plot (see Figure 2-4). Anticipating 30–50 plots per ecological site and to accommodate rejection, 150 sites were selected per ecological site type. An accession order was associated with plots within each ecological site type, and this order was followed when establishing plots. If a plot was rejected (e.g., due to incorrect ecological site type), the next sequentially ordered site was used.

2.1.4 Pilot study and long-term sampling design

Upland monitoring was initiated at Capitol Reef NP in 2007. Ten monitoring plots were established for each target ecological site in the Cathedral/Rock Springs and Hartnet allotments. The exception was Semidesert Sand, which occurred on an extremely limited area across the landscape, where only one plot was established. 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 an unpublished report (available from the NCPN upon request).

2.1.4.1 Long-term sampling design

Based on an analysis of pilot data, a long-term operational sampling design was created and implemented in 2010. Using the original sampling frame (Figure 2-2), plots

were established in order within each ecological site type in the Cathedral/Rock Springs and Hartnet allotments. This allowed the number of plots of each ecological site sampled to be determined by its approximate area in the sampling frame.

2.1.4.2 Revisit design

Each year, 48 plots are monitored, including 16 deep grassland plots in the Cathedral/Rock Springs allotment, and 16 deep grassland plots and 16 rocky grassland plots in the Hartnet allotment (Figure 2-3). A total of 180 plots are sampled over a five-year revisit schedule. Half of the plots are visited for two consecutive years; the other half are visited only once before being rested for 3–4 years. This revisit strategy maximizes our ability to detect trends and minimizes impacts to the park's biological soil crusts.

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 exotics species (annual and perennial) is recorded using 1-m by 1-m quadrats placed

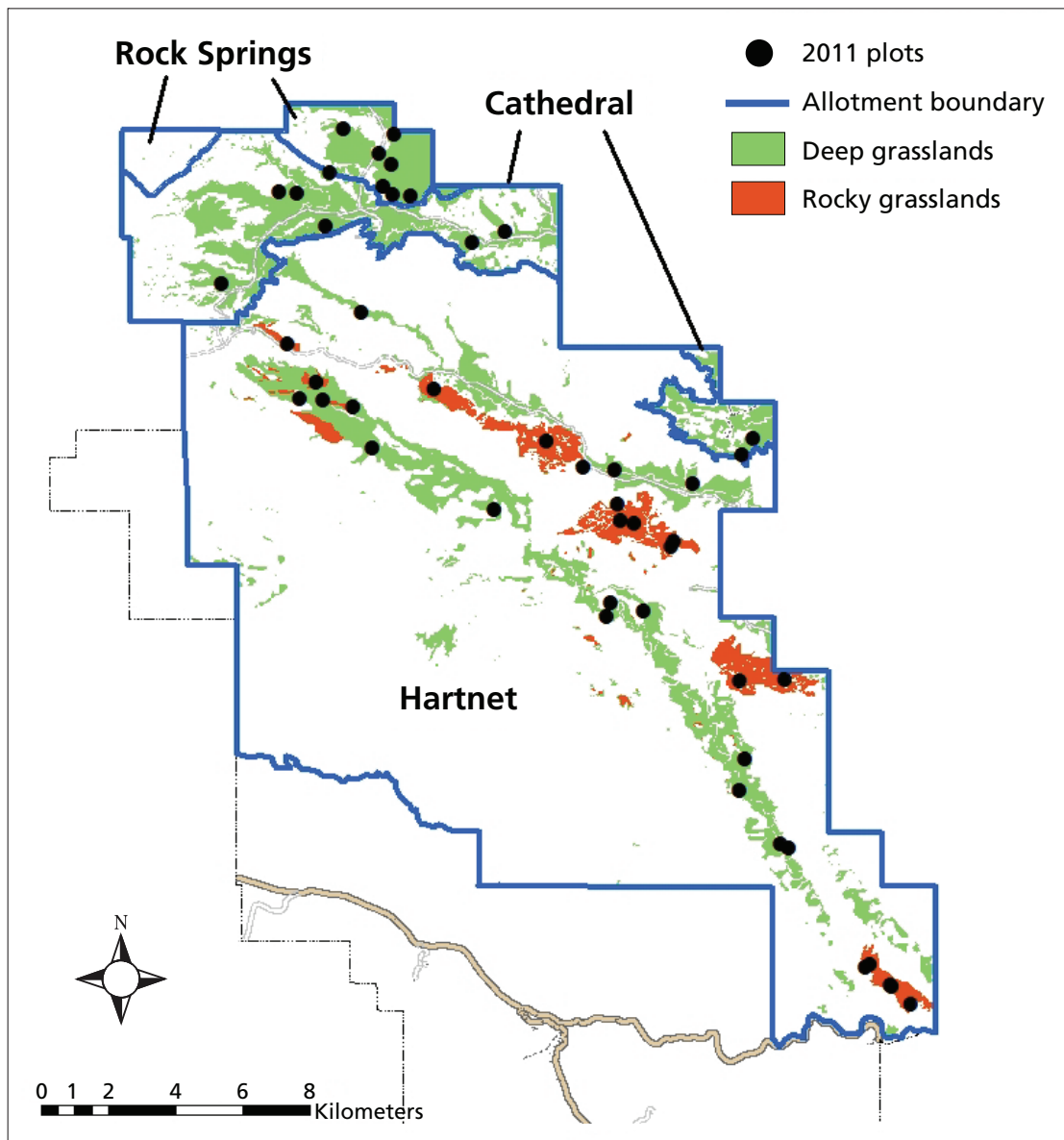


Figure 2-2. Location of monitoring plots in Capitol Reef National Park, 2011.

Panel	Year									
	1	2	3	4	5	6	7	8	9	10
1	4	4				4	4			
2		4	4				4	4		
3			4	4				4	4	
4				4	4				4	4
5	4				4	4				4
6	8					8				
7		8					8			
8			8					8		
9				8					8	
10					8					8

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

every 5 m along each transect. Canopy and basal-gap measures are acquired along each of the transects 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.

ity 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 RRQRR-generated sampling locations are GIS-ArcMap shape files and are stored with the Access database on NCPN servers.

2.3 Database

All observations recorded in the field are stored in an NCPN Access database. Qual-

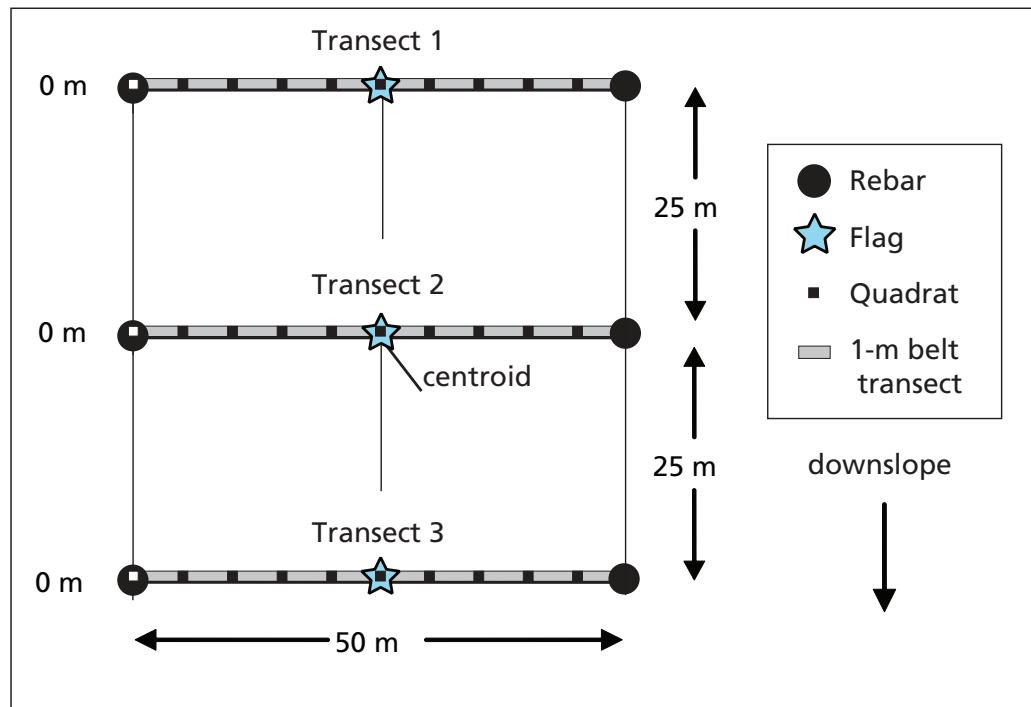


Figure 2-4. Plot layout for upland monitoring of grasslands and shrublands.

3 Results

3.1 Monitored plots

In 2011, forty-eight plots were monitored as part of the long-term revisit design, including 32 deep grassland plots (half in Cathedral/Rock Springs and half in Hartnet) and 16 rocky grassland plots (Hartnet only; see Figure 2-2). Twelve plots were revisited (1/4 of the plots in each ecological site type/allotment combination), and 36 new plots were established among the ecological site types and allotments. Table 3-1 summarizes plot visits by ecological site type, ecological site, and year.

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 at least 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 and allotment. 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 might 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

Species richness by life form is reported in Table 3-2. Recorded species were compared to the NPSpecies database to determine first-time observations in Capitol Reef NP. No new species were detected in the park in 2011.

3.2.2 Cover by life form and dominant species

Percent cover of live and total vegetation by life form 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 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 (care11_species.xls).

3.2.3 Shrub density

Density of shrub species for each ecological site type and allotment is shown in Table 3-5. At deep grassland plots, sand wild buckwheat (*Eriogonum leptocladon*) had the highest density in the Cathedral/Rock Springs allotments, and winterfat (*Krascheninnikovia lanata*) had the highest density in the Hartnet. Shadscale (*Atriplex confertifolia*) was found at nearly all rocky grassland plots and had the highest density in this ecological site type.

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 was summarized for all plots in the ecological site type by allotment.

Russian thistle (*Salsola tragus*) was detected more than any other exotic plant species, although its cover was relatively low during our spring sampling (never exceeding 4% cover at a plot). Halogeton (*Halogeton glomeratus*) was detected in one plot in each allotment/ecological site type group, and had low cover and frequency of detection. Cheatgrass (*Bromus tectorum*) was detected at two rocky grassland plots. No exotic perennial species were detected in cover or frequency sampling.

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 (care11_exotics.xls).

3.2.5 Threatened and endangered species

Capitol Reef National Park has documented populations of four threatened or endangered plant species that are likely to be encountered in the target ecological site types. In 2011, no threatened or endangered plant species were detected with NCPN sampling methods. When crews encountered *Pediocactus* and Wright's fishhook cactus (*Sclerocactus wrightiae*) near monitoring plots, the locations of these plants were recorded so that crews can avoid trampling them during future plot visits.

3.2.6 Biological soil crust and surface features

Biological soil crust and surface-feature cover are shown in Table 3-7. Undifferentiated crust was the predominant surface cover at deep grassland plots. Surface cover at rocky grassland plots was largely a combination of undifferentiated crust, litter, and small and large rocks.

3.2.7 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, 3-2, and 3-3. Canopy and basal gaps >2 m in length were the most common gap size for all ecological site types and allotments.

3.2.8 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.

Table 3-1. Number of plots, by ecological site type and allotment, monitored in Capitol Reef National Park, 2007–2011.

Ecological site	Number of plots									
	Cathedral / Rock Springs					Hartnet				
	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Deep grassland										
Semidesert Alkali Sandy Loam	6	10	10	5	4	1	10	10	9	7
Semidesert Sand	1	1	1	4	5	0	0	0	3	1
Semidesert Sandy Loam	9	10	10	7	7	2	10	10	4	8
Rocky grassland										
Semidesert Stony Loam	n/a	n/a	n/a	n/a	n/a	0	10	10	7	8
Semidesert Very Steep Stony Loam	n/a	n/a	n/a	n/a	n/a	0	10	10	9	8
Total	16	21	21	16	16	16	40	40	32	32

See Table 2-1 for description of ecological sites.

Table 3-2. Mean (range) number of plant species detected per monitoring plot by life form, ecological site type, and allotment, Capitol Reef National Park, 2011.

Allotment	Number of species detected					
	Total	Tree	Shrub	Perennial grass	Annual grass	Forb/ Herb
Deep grassland						
Cathedral / Rock Springs (ungrazed)	12.4 (8–17)	0.2 (0–2)	4.4 (1–7)	4.6 (2–7)	0	3.1 (1–5)
Hartnet (grazed)	11.4 (6–14)	0.1 (0–2)	4.4 (1–7)	3.4 (1–5)	0.1 (0–1)	3.4 (1–6)
Rocky grassland						
Hartnet (grazed)	12.7 (6–23)	0.6 (0–2)	5.5 (3–8)	3.3 (2–6)	0.2 (0–1)	3.1 (0–8)

Table 3-3. Mean (range) percent cover by life form for each ecological site type and allotment, Capitol Reef National Park, 2011.

Allotment	Total		Tree		Shrub		Perennial grass		Annual grass		Forb/Herb	
	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total
Deep grassland												
Cathedral / Rock Springs (ungrazed)	13.7 (3.3–26.0)	28.4 (12.0–42.0)	0.5 (0–8.0)	0.5 (0–8.0)	3.2 (0.3–9.3)	5.8 (1.7–12.7)	8.1 (2.0–21.0)	17.4 (9.7–33.0)	0.02 (0–0.3)	0.02 (0–0.3)	2.3 (0–6.3)	6.4 (0.7–14.7)
Hartnet (grazed)	10.2 (5.0–15.7)	14.9 (9.0–20.7)	0.4 (0–6.0)	0.4 (0–6.0)	2.6 (0.3–5.3)	3.9 (0.7–9.3)	5.1 (1.0–9.7)	7.7 (1.3–14.0)	0.1 (0–1.7)	0.1 (0–1.7)	2.1 (0–6.0)	3.2 (0–8.3)
Rocky grassland												
Hartnet (grazed)	14.1 (9.3–19.3)	22.8 (17.0–30.0)	1.6 (0–9.3)	1.9 (0–11.3)	4.5 (1.0–10.3)	7.4 (1.7–19.7)	6.6 (3.0–11.7)	11.9 (5.0–20.3)	0.1 (0–0.7)	0.1 (0–0.7)	1.9 (0–5.7)	2.8 (0–9.0)

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

Scientific name	Common name	Life form	Duration	Nativity	Percent cover							
					Cathedral / Rock Springs (ungrazed)		Hartnet (grazed)		Live	Total		
					Live	Total	Live	Total				
Deep grassland												
<i>Bouteloua gracilis</i>	blue grama	Graminoid	Perennial	Native	1.9 (0–10.0)	4.5 (0–18.3)	0.2 (0–3.0)	0.3 (0–4.3)				
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	Shrub	Perennial	Native	0.2 (0–1.7)	0.3 (0–2.7)	0.2 (0–1.3)	0.3 (0–1.7)				
<i>Eriogonum cernuum</i>	nodding wild buckwheat	Forb	Annual	Native	0.9 (0–3.3)	4.2 (0–12.0)	0	0.4 (0–3.0)				
<i>Eriogonum leptoclodon</i>	sand wild buckwheat	Shrub	Perennial	Native	0.3 (0–1.3)	0.7 (0–4.3)	0.5 (0–3.7)	0.7 (0–4.7)				
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.2 (0–1.7)	0.4 (0–2.7)	0.04 (0–0.3)	0.1 (0–0.3)				
<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	0.9 (0–2.3)	2.6 (0–8.7)	1.7 (0–6.0)	3.1 (0–10.0)				
<i>Muhlenbergia pungens</i>	sandhill muhly	Graminoid	Perennial	Native	0.2 (0–1.7)	0.8 (0–5.3)	0.04 (0–0.3)	0.04 (0–0.3)				
<i>Opuntia</i> species	pricklypear	Dwarf Shrub	Perennial	Native	1.4 (0–6.7)	1.7 (0–9.0)	0.3 (0–1.0)	0.4 (0–1.7)				
<i>Sarcobatus vermiculatus</i>	greasewood	Shrub	Perennial	Native	0	0	0.5 (0–2.7)	0.7 (0–3.0)				
<i>Sporobolus airoides</i>	alkali sacaton	Graminoid	Perennial	Native	0.9 (0–3.7)	2.0 (0–7.0)	1.3 (0–8.7)	1.7 (0–12.0)				
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	3.9(0.3–9.3)	6.5(0.3–14.0)	1.5 (0–4.3)	1.8(0.3–5.0)				
Rocky grassland												
<i>Atriplex confertifolia</i>	shadscale	Shrub	Perennial	Native	na	na	1.5 (0–4.0)	2.9 (0–8.7)				
<i>Ephedra torreyana</i>	Torrey's jointfir	Shrub	Perennial	Native	na	na	1.2 (0–5.7)	1.6 (0–8.3)				
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	na	na	1.0 (0–5.0)	1.4 (0–8.3)				
<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	na	na	3.4 (0.7–7.3)	7.1 (3.0–16.0)				
<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	na	na	1.5 (0–7.7)	1.7 (0–8.7)				
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	na	na	1.8 (0–7.7)	2.5 (0–9.0)				

Table 3-5. Mean (range) density of shrub species per hectare by ecological site type and allotment, Capitol Reef National Park, 2011.

		Cathedral / Rock Springs (ungrazed)		Hartnet (grazed)	
Scientific name	Common name	No. of plots with species present*	Density (no. of shrubs/ha)	No. of plots with species present*	Density (no. of shrubs/ha)
Deep grassland					
<i>Artemisia bigelovii</i>	Bigelow's sagebrush	9	588 (0–3,267)	4	92 (0–933)
<i>Artemisia frigida</i>	fringed sagebrush	1	142 (0–2,267)	1	8 (0–133)
<i>Artemisia tridentata</i>	big sagebrush	0	0	2	154 (0–2,133)
<i>Atriplex canescens</i>	fourwing saltbush	10	263 (0–1,400)	10	150 (0–667)
<i>Atriplex confertifolia</i>	shadscale	4	379 (0–3,267)	9	1042 (0–6,667)
<i>Atriplex gardneri</i>	Gardner's saltbush	3	200 (0–2,200)	1	29 (0–467)
<i>Chrysothamnus linifolius</i>	spearleaf rabbitbrush	0	0	1	4 (0–67)
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	8	142 (0–667)	7	96 (0–533)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	0	0	3	117 (0–1,000)
<i>Ephedra torreyana</i>	Torrey's mormon tea	6	113 (0–533)	5	54 (0–467)
<i>Eriogonum corymbosum</i>	crisp-leaf wild buckwheat	1	4 (0–67)	0	0
<i>Eriogonum leptocladon</i>	sand wild buckwheat	11	808 (0–2,867)	8	1,550 (0–8,733)
<i>Eriogonum microthecum</i>	slender wild buckwheat	3	67 (0–800)	0	0
<i>Eriogonum</i> sp.	buckwheat species	1	4 (0–67)	0	0
<i>Juniperus osteosperma</i>	Utah juniper	1	25 (0–400)	1	4 (0–67)
<i>Krascheninnikovia lanata</i>	winterfat	5	104 (0–1,133)	7	2,304 (0–35,467)
<i>Pinus edulis</i>	two-needle pinyon	1	4 (0–67)	0	0
<i>Sarcobatus vermiculatus</i>	greasewood	0	0	6	117 (0–600)
<i>Tetradymia canescens</i>	spineless horsebrush	1	4 (0–67)	0	0
Rocky grassland					
<i>Artemisia bigelovii</i>	Bigelow's sagebrush	na	na	11	308 (0–1,800)
<i>Artemisia spinescens</i>	budsage	na	na	1	4 (0–67)
<i>Atriplex canescens</i>	fourwing saltbush	na	na	2	29 (0–267)
<i>Atriplex confertifolia</i>	shadscale	na	na	14	4,558 (0–15,733)
<i>Atriplex gardneri</i>	Gardner's saltbush	na	na	4	388 (0–4,733)
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	na	na	2	8 (0–67)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	na	na	8	450 (0–2,933)
<i>Ephedra torreyana</i>	Torrey's mormon tea	na	na	12	650 (0–1,867)
<i>Eriogonum microthecum</i>	slender wild buckwheat	na	na	7	2,233 (0–20,400)
<i>Juniperus osteosperma</i>	Utah juniper	na	na	6	92 (0–400)
<i>Krascheninnikovia lanata</i>	winterfat	na	na	6	292 (0–2,467)
<i>Pinus edulis</i>	two-needle pinyon	na	na	1	13 (0–200)
<i>Purshia mexicana</i>	cliffrose	na	na	1	4 (0–67)
<i>Shepherdia rotundifolia</i>	roundleaf buffaloberry	na	na	3	13 (0–67)
<i>Tetradymia canescens</i>	spineless horsebrush	na	na	4	121 (0–1,267)

*A total of 16 plots were monitored in each ecological site type in each allotment in 2011.

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

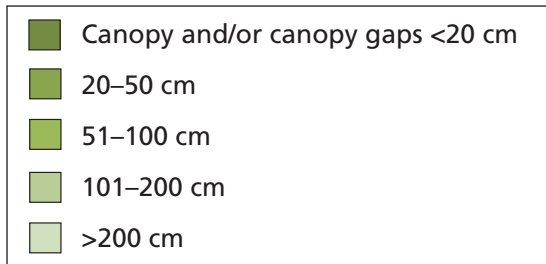
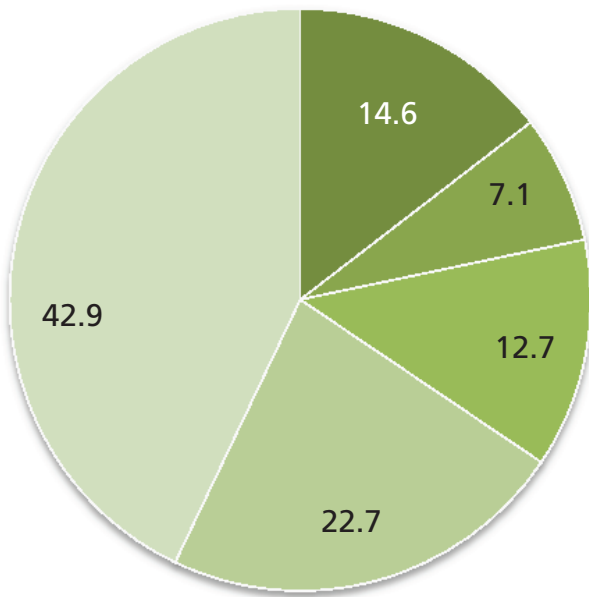
Allotment	Scientific name	Common name	Life form	Duration	No. of plots with exotic species detected*	Percent cover		Frequency of detection (%)
						Live	Total	
Deep grassland								
Cathedral / Rock Springs (ungrazed)	<i>Halogeton glomeratus</i>	Halogeton	Forb	Annual	1	0.02 (0–0.3)	0.02 (0–0.3)	0.8 (0–13.3)
	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	10	0.02 (0–1.7)	0.5 (0–3.3)	21.0 (0–86.7)
Hartnet (grazed)	<i>Halogeton glomeratus</i>	halogeton	Forb	Annual	1	0.02 (0–0.3)	0.02 (0–0.3)	0
	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	14	0.3 (0–1.7)	0.7 (0–4.0)	36.3 (0–86.7)
Rocky grassland								
Hartnet (grazed)	<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	2	0.1 (0–0.7)	0.1 (0–0.7)	4.8 (0–60.0)
	<i>Halogeton glomeratus</i>	halogeton	Forb	Annual	1	0	0	0.2 (0–3.3)
	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	6	0.02 (0–0.3)	0.1 (0–1.0)	6.0 (0–53.3)

* A total of 16 plots were monitored in each ecological site type in each allotment in 2011.

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

Allotment	Crust, undifferentiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Deep grassland										
Cathedral / Rock Springs (ungrazed)	70.1 (38.7–89.7)	2.4 (0–11.7)	0.1 (0–0.7)	0.4 (0–2.0)	0.4 (0–1.0)	13.5 (5.0–24.7)	0.1 (0–0.7)	5.0 (0–24.0)	1.0 (0–13.3)	0.04 (0–0.7)
	79.3 (62.3–87.7)	1.0 (0–7.0)	0.1 (0–0.7)	0.04 (0–0.3)	1.7 (0–5.3)	9.9 (1.7–15.0)	0.1 (0–0.3)	4.6 (0–15.0)	0.3 (0–1.7)	0
Rocky grassland										
Hartnet (grazed)	37.8 (8.0–69.0)	0.1 (0–1.0)	0.2 (0–1.3)	0.2 (0–1.7)	0.2 (0–2.0)	12.1 (7.7–19.0)	0	29.3 (11.3–42.3)	16.0 (0–44.0)	0.1 (0–0.7)

A) Ungrazed Cathedral/Rock Springs



B) Grazed Hartnet

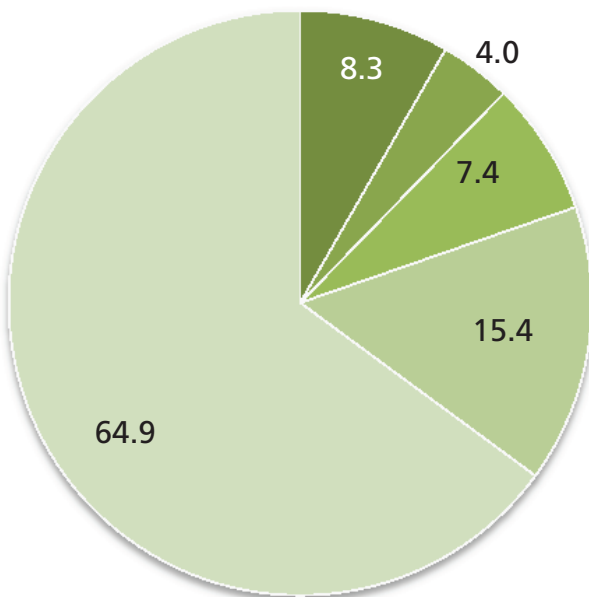
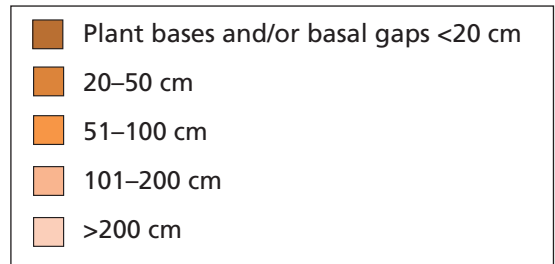
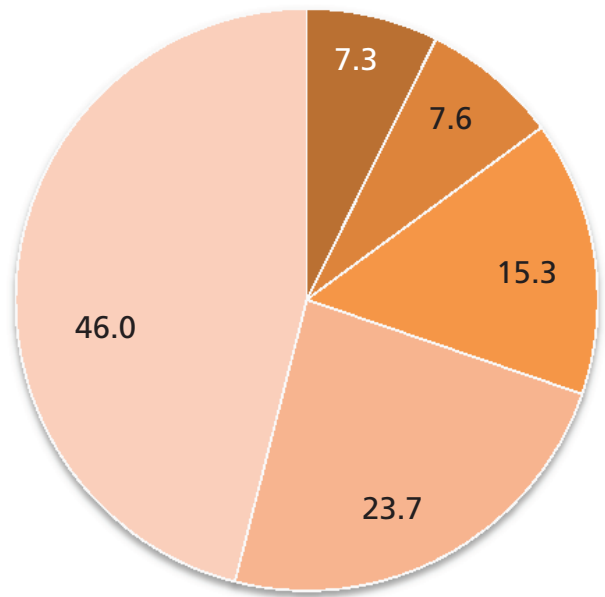


Figure 3-1. Distribution of canopy gaps for deep grassland plots in (A) ungrazed Cathedral/Rock Springs allotments and (B) the grazed Hartnet allotment, Capitol Reef National Park, 2011.

A) Ungrazed Cathedral/Rock Springs



B) Grazed Hartnet

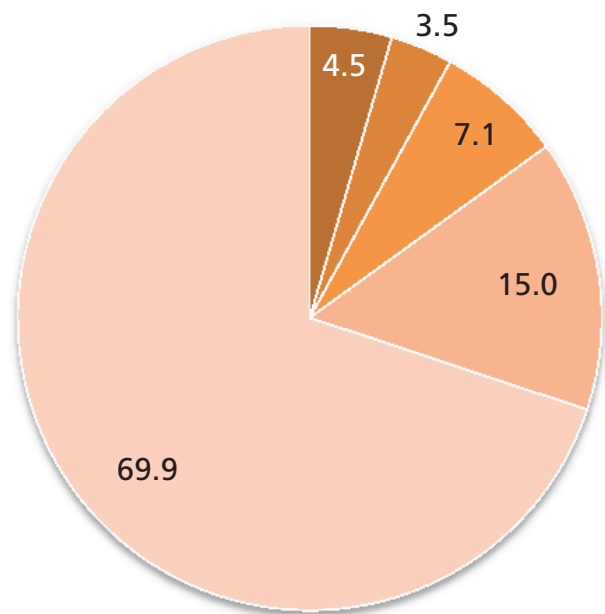


Figure 3-2. Distribution of basal gaps for deep grassland plots in (A) ungrazed Cathedral/Rock Springs allotments and (B) the grazed Hartnet allotment, Capitol Reef National Park, 2011.

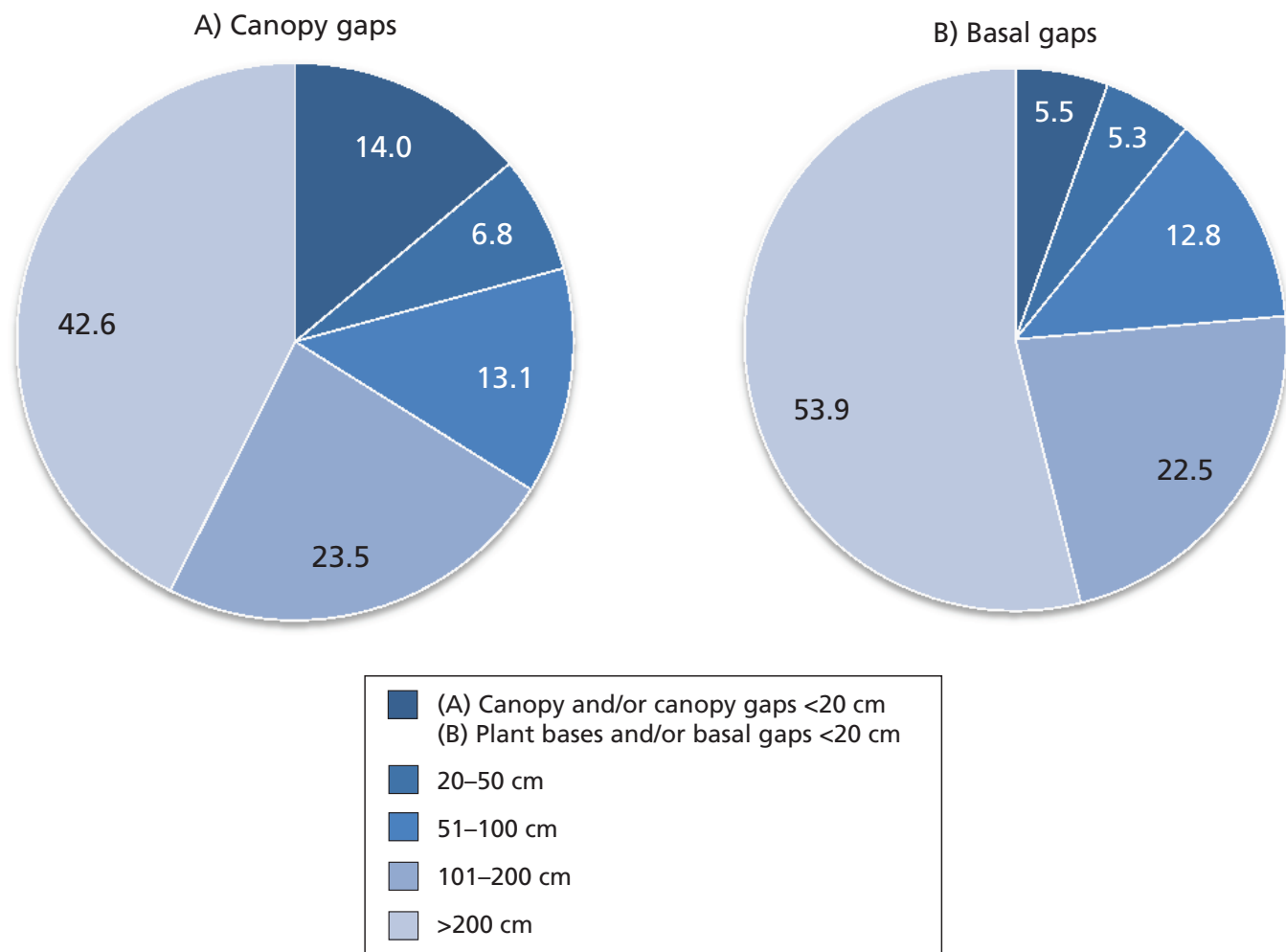


Figure 3-3. Distribution of (A) canopy gaps and (B) basal gaps for rocky grassland plots in the grazed Hartnet allotment, Capitol Reef National Park, 2011.

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

Allotment	Canopy gap (cm)	Basal gap (cm)
Deep grassland		
Cathedral / Rock Springs (ungrazed)	136 (57–190)	138 (72–208)
Hartnet (grazed)	250 (116–616)	253 (125–618)
Rocky grassland		
Hartnet (grazed)	141 (88–211)	163 (95–255)

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

Allotment	Total	Protected*	Unprotected*
Deep grassland			
Cathedral / Rock Springs (ungrazed)	4.1 (2.6–5.6)	4.5 (2.8–5.3)	3.8 (2.1–5.8)
Hartnet (grazed)	3.0 (1.2–4.6)	3.7 (1.0–6.0)	2.8 (1.3–3.9)
Rocky grassland			
Hartnet (grazed)	3.3 (2.0–5.3)	3.8 (2.3–5.8)	2.9 (1.3–5.0)

*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

Based on a cursory review, data from 2011 were generally similar to those from previous years. Because three-quarters of the plots monitored in 2011 were newly established, it is important to remember that any differences between years could be due to the different suite of plots sampled and not due to actual changes in ecological site types or allotments. This variation will be accounted for in status and trend analyses after plots have been revisited. It is currently too early to draw conclusions from this preliminary data.

One notable difference in the 2011 data compared to those of previous years was the amount of exotic plant species detected. Exotic species were much more likely to be detected at plots using the new frequency method than 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 Capitol Reef NP). This difference is most likely because the new exotic frequency methods are better-suited to 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 new plots that will be established. Continued discussion will occur with Capitol Reef NP 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 at least five full years of monitoring are complete.

5 Literature Cited

- Belnap, J. 2002. Nitrogen fixation in biological soil crusts from southeast Utah, U.S.A. *Biology and Fertility of Soils* 35:128–135.
- Belnap, J., B. Budel, and O. L. Lange. 2003. Biological soil crusts: Characteristics and distribution. Pages 3–30 in J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.). Ecological studies series 150. Berlin: Springer-Verlag.
- Bock, C. E., J. H. Bock, K. L. Jepsen, and J. C. Ortega. 1986. Ecological effects of planting African lovegrass in Arizona. *National Geographic Research* 2(4):456–463.
- Coles, J., D. Clark, M. Dela Cruz, T. Clark, S. Topp, A. Evenden, A. Wight, G. Wakefield, and J. Von Loh. 2009. Vegetation classification and mapping project report, Capitol Reef National Park. Natural Resource Technical Report NPS/NCPN/NRTR—2009/187. National Park Service, Fort Collins, Colorado.
- Evans, R. D., and O. L. Lange. 2003. Biological soil crusts and ecosystem nitrogen and carbon dynamics. Pages 263–279 in J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.). Ecological studies series 150. Berlin: Springer-Verlag.
- Garfin, G. M., J. K. Eischeid, M. T. Lenart, K. L. Cole, K. Ironside, and N. Cobb. 2010. Downscaling climate projections in topographically diverse landscapes of the Colorado Plateau in the arid southwestern United States. In C. van Riper III, C., B. F. Wakeling, and T. D. Sisk, eds., *The Colorado Plateau IV: Shaping conservation through science and management*. Tucson: The University of Arizona Press.
- Garman, S. L., and D. Witwicks. 2008. Integrated upland monitoring, Capitol Reef National Park: Annual report, 2007. Northern Colorado Plateau Network, Moab, Utah.
- Garman, S. L., D. Witwicks, and A. Wight. 2010. Mapping ecological sites for long-term monitoring in national parks. In C. van Riper III, C., B. F. Wakeling, and T. D. Sisk, eds., *The Colorado Plateau IV: Shaping conservation through science and management*. Tucson: The University of Arizona Press.
- Harper, K. T., and J. Belnap. 2001. The influence of biological soil crusts on mineral uptake by associated vascular plants. *Journal of Arid Environments* 47(3):347–357.
- Harris, T. A., G. P. Asner, and M. E. Miller. 2003. Changes in vegetation structure after long-term grazing in pinyon-juniper ecosystems: Integrating imaging spectroscopy and field studies. *Ecosystems* 6(4):368–383.
- Herrick, J. E., J. W. Van Zee, K. M. Havstad, L. M. Burkett, and W. G. Whitford. 2005. Monitoring manual for grassland, shrubland, and savanna ecosystems. Published as 2 volumes. U.S. Department of Agriculture Jornada Experimental Range, Las Cruces, New Mexico.
- Lange, O. L. 2003. Photosynthesis of soil-crust biota as dependent on environmental factors. Pages 217–240 in J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.). Ecological studies series 150. Berlin: Springer-Verlag.
- Miller, M. E. 2005. The structure and functioning of dryland ecosystems: Conceptual models to inform long-term ecological monitoring. U.S. Geological Survey Scientific Investigations Report 2005-5197.
- Miller, M. E., R. T. Belote, M. A. Bowker, and S. L. Garman. 2011. Alternative states of a semiarid grassland ecosystem: implications for ecosystem services. *Ecosphere* 2(5):1–18.
- Munson, S. M., J. Belnap, C. D. Schelz, M. Moran, and T. W. Carolin. 2011a. On the brink of change: plant responses to climate change on the Colorado Plateau. *Ecosphere* 2(6):1–15.
- Munson, S. M., J. Belnap, and G. S. Okin. 2011b. Responses of wind erosion to climate-induced vegetation changes on the Colorado Plateau. *Proceedings of the National Academy of Sciences of the USA* 108(10):3854–3859.

- Rosentreter, R., and J. Belnap. 2003. Biological soil crusts of North America. Pages 31–51 *in* J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.). Ecological studies series 150. Berlin: Springer-Verlag.
- Society for Range Management (SRM). 1989. *Glossary of terms used in range management*. Third edition. Society for Range Management, Denver, Colorado.
- . 1995. New concepts for assessment of rangeland condition. *Journal of Range Management* 48:271–282.
- Theobald, D. M., D. L. Stevens, Jr., D. White, S. Urquhart, A. R. Olsen, and J. B. Norman. 2007. Using GIS to generate spatially balanced random survey designs for natural resource applications. *Environmental Management* 40:134–146.
- U.S. Department of Agriculture Soil Conservation Service (SCS). 2004. *Ecological Sites of Capitol Reef National Park, Utah*. Salt Lake City: U.S. Department of Agriculture, Natural Resources Conservation Service.
- Whelan, R. J. 1995. *The ecology of fire*. Cambridge: Cambridge University Press.
- Whitford, W. G. 2002. *Ecology of desert systems*. San Diego, Calif.: Academic Press.
- Williams, J. D., J. P. Dombrowski, D. A. Gillette, and N. E. West. 1995. Microphytic crust influence on wind erosion. *Transactions of the American Society of Agricultural Engineers* 38:131–137.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 158/119687, January 2013

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™