



Integrated Upland Monitoring in Capitol Reef National Park

Annual Report 2010 (Non-Sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2012/540.N



ON THE COVER

Grassland in Cathedral Valley, Capitol Reef National Park. NPS photo.

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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 determine natural variability of upland resources and provide early warning of resource degradation.

This report summarizes NCPN upland monitoring in Capitol Reef National Park (NP) during 2010. 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 2010, NCPN completed its fourth year of monitoring at Capitol Reef NP, which was the first year of monitoring under the long-term operational sampling design. A total of 48 plots were established and 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.

In this report, measures 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.

1 Introduction

Uplands represent the vast majority of land area in national park units of the Northern Colorado Plateau Network (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, which 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 these dryland systems unique. Biological soil crusts are biotic communities composed of cyanobacteria, algae, micro-fungi, 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).

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 pin-

nacled. In the forests, shrublands, and meadows of the mountain regions surrounding the Colorado Plateau, where numerous NCPN park units are located, the role of biological soil crusts is less important 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 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
- basal area and density of tree species
- canopy closure
- fuel volume and litter/duff depth
- 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 (litter, rock, bare ground, etc.)

- 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. Local weather-station data can be used to interpret responses, and 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 the NCPN to allow earlier detection of trends.

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, Capitol Reef National Park (NP) 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 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. 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 eliminat-

ed 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 (USDA SCS 2004). A recent vegetation-association map (Clark 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.

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 NP (Garman and Witwicki 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 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 lim-

ited 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 NCPN upon request).

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 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. The number of plots assigned to a given ecological site type was proportional to the relative area of that ecological site type in the overall sampling frame.

2.1.4.2 Revisit design

Each year, a total of 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 two years in a row and the other half are visited only one year before being rested for 3–4 years. This revisit strategy maximizes the ability to detect trends and minimizes the impact on biological soil crusts in the park.

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

Ecological site name/ Number	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.

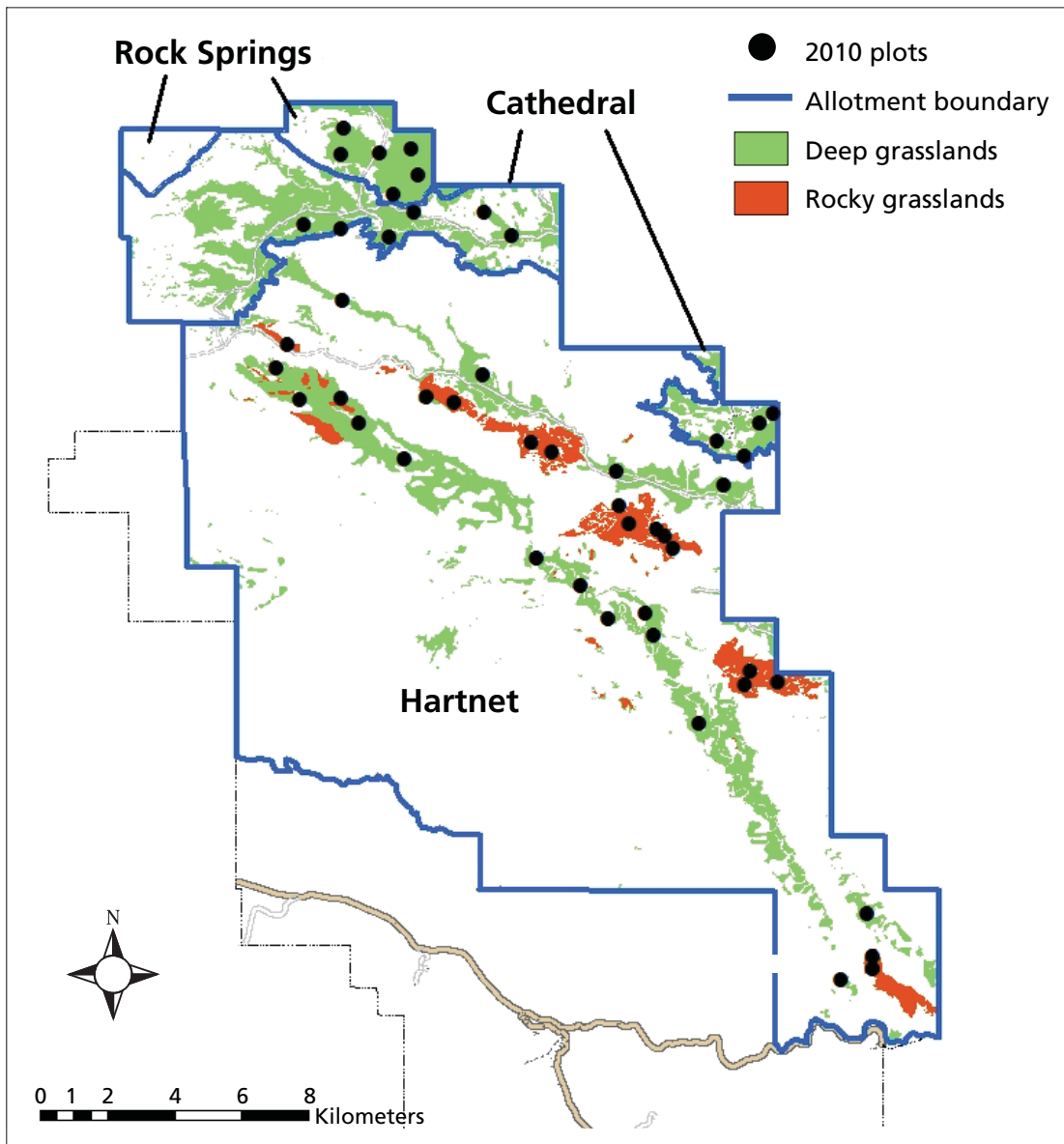


Figure 2-2. Location of monitoring plots in Capitol Reef National Park, 2010.

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 5-year rotating panel revisit design for long-term upland monitoring at Capitol Reef National Park.

2.2 Integrated Upland Monitoring Procedures

2.2.1 Response design

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

At each plot, observations are recorded along three parallel, 50-m transects spaced 25 m apart (Figure 2-4). At the origin of each transect, a photo is taken down the length of the transect toward the end point. Photos of biological soil crusts are also taken at a specified point along each transect. A point-intercept method is used to record percent cover of plant species and ground-cover attributes at 0.5-m intervals along each transect. Density

of shrubs (by species and height class) and exotic perennials (by species) is recorded in a 1-m belt upslope of 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.

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

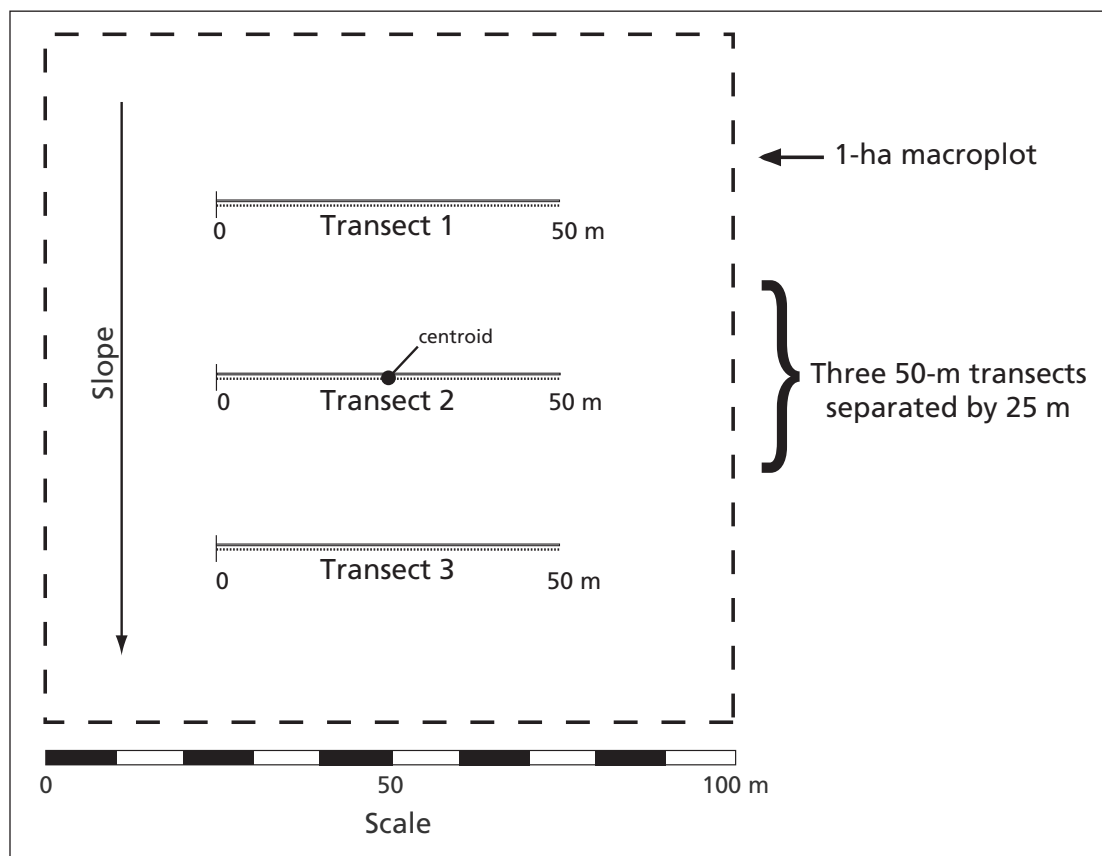


Figure 2-4. Plot layout for upland monitoring of grasslands and shrublands.

3 Results

3.1 Monitored Plots

In 2010, forty-eight plots were established and 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). Table 3-1 summarizes plot visits by ecological site type, ecological site, and year (tables start on page 11).

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 increase. More intensive evaluation of monitoring data is slated to commence after five full years of monitoring.

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 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 this initial set of results.

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. Two new species, prenanthella (*Prenanthes exigua*) and smooth wild buckwheat (*Eriogonum salsuginosum*), were detected in the park in 2010. A voucher was created for each species.

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 are shown in Table 3-4. Dominant species were selected using species predicted by ecological site descriptions and species frequently detected in plots. The percent cover of all species recorded for each plot is included in an electronic appendix that accompanies this report (care10_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 Cathedral/Rock Springs, and winterfat (*Krascheninnikovia lanata*) had the highest density at the Hartnet. Shadscale (*Atriplex confertifolia*) had the next-highest density at deep grassland plots in both allotments. Shadscale was also found at nearly all rocky grassland plots and had the highest density in this ecological site type. Green rabbitbrush (*Chrysothamnus vicidifloris*) and Torrey's jointfir (*Ephedra torreyana*) were also found at high densities in most rocky grassland plots.

3.2.4 Exotic species

Cover of exotic plant species is shown in Table 3-6. When exotic species were detected, cover 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, including at half of the deep grassland plots and one-fourth of the rocky grassland plots. Cover of this species was relatively low (i.e.,

never exceeding 4% at a given plot). Russian thistle was the only exotic detected in the Cathedral/Rock Springs allotment. Five other exotic species were detected in the Hartnet allotment, but cover was low (no more than 1%) for all of these species. Tamarisk (*Tamarix chinensis*) was the only exotic perennial species detected, and it was only found at one deep grassland plot in the Hartnet allotment.

In 2010, NCPN upland sampling methods did not include an invasive species walk; therefore, lack of detection does not mean that other exotic species were not present in plots. In 2011, methods will be added to include early detection of exotics.

3.2.5 *Threatened and endangered species*

Capitol Reef NP has documented populations of four threatened or endangered plant species that are likely to be encountered in the target ecological site types. In 2010, no threatened or endangered plant species were detected with NCPN sampling methods; however, crews encountered numerous pin-cushion cactus (*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 (figures start on page 16).

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 and allotment, monitored in Capitol Reef National Park, 2007–2010.

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

*See Table 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, 2010.

Ecological site type	Allotment	Number of species detected					
		Total	Tree	Shrub	Perennial grass	Annual grass	Forb/ Herb
Deep grassland	Cathedral/Rock Springs (ungrazed)	11.9 (7–16)	0	4.8 (2–8)	4.1 (2–7)	0	3.1 (1–5)
	Hartnet (grazed)	10.4 (4–16)	0	4.6 (1–7)	3.1 (2–5)	0.1 (0–1)	2.6 (0–6)
Rocky grassland	Hartnet (grazed)	13.1 (7–18)	0.6 (0–2)	5.4 (3–9)	3.1 (2–5)	0.1 (0–1)	3.9 (0–7)

Table 3-3. Mean (range) percent cover by life form for each ecological site type and allotment, Capitol Reef National Park, 2010.

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)	15.3 (4.7–26.0)	26.6 (9.0–43.7)	0	0	2.7 (0–5.0)	6.5 (1.0–12.0)	10.4 (4.3–18.7)	18.9 (7.7–37.0)	0	0	2.4 (0.3–6.3)	2.6 (0.3–6.3)
Hartnet (grazed)	11.1 (4.3–19.0)	16.3 (8.7–26.7)	0	0	3.5 (0.3–10.0)	5.7 (0.3–11.0)	6.1 (1.0–18.0)	8.9 (1.7–22.0)	0.02 (0–0.3)	0.02 (0–0.3)	1.6 (0–7.7)	2.0 (0–7.7)
Rocky grassland												
Hartnet (grazed)	15.1 (9.7–20.0)	21.4 (15.3–27.3)	1.5 (0–8.7)	1.8 (0–11.3)	5.2 (0.3–10.7)	8.0 (1.0–17.3)	5.9 (0.7–10.0)	9.5 (4.3–15.7)	0.04 (0–0.7)	0.1 (0–1.0)	3.0 (0–7.7)	3.4 (0–8.0)

Table 3-4. Mean (range) percent cover of dominant species by ecological site type and allotment, Capitol Reef National Park, 2010.

Percent cover									
Cathedral/Rock Springs (ungrazed)					Hartnet (grazed)				
Scientific name	Common name	Life form	Duration	Nativity	Live	Total	Live	Total	
Deep grassland									
<i>Bouteloua gracilis</i>	blue grama	Graminoid	Perennial	Native	1.5 (0–12.0)	4.4 (0–27.7)	0.4 (0–4.7)	1.1 (0–10.0)	
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	Shrub	Perennial	Native	0.1 (0–1.0)	0.2 (0–1.0)	0.5 (0–3.3)	0.8 (0–4.0)	
<i>Eriogonum leptoclodon</i>	sand wild buckwheat	Shrub	Perennial	Native	0.4 (0–3.7)	0.8 (0–6.7)	0.4 (0–2.7)	0.7 (0–5.7)	
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.4 (0–2.0)	1.9 (0–7.3)	0.02 (0–0.3)	0.5 (0–2.3)	
<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	2.2 (0–5.0)	3.9 (0–8.3)	0.9 (0–3.3)	1.2 (0–4.0)	
<i>Muhlenbergia pungens</i>	sandhill muhly	Graminoid	Perennial	Native	0.3 (0–2.3)	0.6 (0–3.7)	0.1 (0–1.3)	0.3 (0–3.3)	
<i>Opuntia species</i>	pricklypear	Dwarf Shrub	Perennial	Native	0.7 (0–4.3)	1.0 (0–5.7)	0.4 (0–3.0)	0.7 (0–5.0)	
<i>Sarcobatus vermiculatus</i>	greasewood	Shrub	Perennial	Native	0.02 (0–0.3)	0.04 (0–0.7)	0.6 (0–2.3)	0.8 (0–3.7)	
<i>Sporobolus airoides</i>	alkali sacaton	Graminoid	Perennial	Native	1.8 (0–8.3)	3.0 (0–14.3)	3.2 (0–12.0)	4.4 (0–15.7)	
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	4.1 (0–9.0)	6.2 (0–13.7)	1.1 (0–2.7)	1.3 (0–3.3)	
Rocky grassland									
<i>Atriplex confertifolia</i>	shadscale	Shrub	Perennial	Native	NA	NA	2.5 (0–8.3)	3.8 (0–12.3)	
<i>Ephedra torreyana</i>	Torrey's jointfir	Shrub	Perennial	Native	NA	NA	0.9 (0–4.0)	1.3 (0–8.0)	
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	NA	NA	0.5 (0–2.3)	1.2 (0–10.0)	
<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	NA	NA	3.9 (0.7–9.3)	6.5 (1.7–15.0)	
<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	NA	NA	1.4 (0–7.3)	1.6 (0–7.7)	
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	NA	NA	1.1 (0–4.3)	1.4 (0–6.3)	

Table 3-5. Mean (range) density of shrub species per hectare by ecological site type and allotment, Capitol Reef National Park, 2010.

Scientific name	Common name	Cathedral/Rock Springs (ungrazed)		Hartnet (grazed)	
		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	6	333 (0–1,600)	5	117 (0–600)
<i>Artemisia filifolia</i>	sand sagebrush	2	46 (0–533)	1	4 (0–67)
<i>Artemisia tridentata</i>	big sagebrush	0	-	1	21 (0–333)
<i>Atriplex canescens</i>	fourwing saltbush	13	483 (0–2,333)	9	133 (0–933)
<i>Atriplex confertifolia</i>	shadscale	7	617 (0–3,133)	10	908 (0–4,667)
<i>Atriplex gardneri</i>	Gardner's saltbush	3	158 (0–2,000)	4	233 (0–3,333)
<i>Chrysothamnus linifolius</i>	spearleaf rabbitbrush	0	-	1	75 (0–1,200)
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	8	88 (0–267)	7	238 (0–1,267)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	1	17 (0–267)	0	-
<i>Ephedra torreyana</i>	Torrey's jointfir	5	96 (0–600)	4	108 (0–1,067)
<i>Ephedra viridis</i>	Mormon tea	1	8 (0–133)	0	-
<i>Eriogonum bicolor</i>	pretty wild buckwheat	1	4 (0–67)	0	-
<i>Eriogonum leptocladon</i>	sand wild buckwheat	9	858 (0–5,333)	7	492 (0–3,733)
<i>Eriogonum microthecum</i>	slender wild buckwheat	2	388 (0–4,867)	2	63 (0–867)
<i>Krascheninnikovia lanata</i>	winterfat	1	13 (0–200)	7	2,742 (0–37,000)
<i>Sarcobatus vermiculatus</i>	greasewood	2	8 (0–67)	6	129 (0–467)
<i>Tamarix chinensis</i>	tamarisk	0	-	1	4 (0–67)
<i>Tetradymia canescens</i>	spineless horsebrush	1	4 (0–67)	0	-
<i>Zuckia brandegeei</i>	siltbush	2	29 (0–333)	0	-
Rocky grassland					
<i>Amelanchier utahensis</i>	Utah serviceberry	NA	NA	1	8 (0–133)
<i>Artemisia bigelovii</i>	Bigelow's sagebrush	NA	NA	6	229 (0–2,220)
<i>Artemisia tridentata</i>	big sagebrush	NA	NA	1	8 (0–133)
<i>Atriplex confertifolia</i>	shadscale	NA	NA	15	5,029 (0–16,800)
<i>Atriplex gardneri</i>	Gardner's saltbush	NA	NA	6	900 (0–5,267)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	NA	NA	10	879 (0–3,333)
<i>Ephedra torreyana</i>	Torrey's jointfir	NA	NA	12	575 (0–2,267)
<i>Eriogonum bicolor</i>	pretty wild buckwheat	NA	NA	1	33 (0–533)
<i>Eriogonum microthecum</i>	slender wild buckwheat	NA	NA	4	338 (0–3,000)
<i>Glossopetalon spinescens</i>	spiny greaseweed	NA	NA	2	29 (0–333)
<i>Juniperus osteosperma</i>	Utah juniper	NA	NA	6	75 (0–333)
<i>Krascheninnikovia lanata</i>	winterfat	NA	NA	6	375 (0–4,333)
<i>Pinus edulis</i>	two-needle pinyon	NA	NA	1	4 (0–67)
<i>Sarcobatus vermiculatus</i>	greasewood	NA	NA	1	4 (0–67)
<i>Shepherdia rotundifolia</i>	roundleaf buffaloberry	NA	NA	4	21 (0–133)
<i>Tetradymia canescens</i>	spineless horsebrush	NA	NA	5	133 (0–1,267)

* A total of 16 plots were monitored in each ecological site type in each allotment in 2010.

Table 3-6. Mean (range) cover and density of exotic plant species detected by ecological site type and allotment in Capitol Reef National Park, 2010.

Allotment	Scientific name	Common name	Life form	Duration	No. of plots with exotic species detected*	Percent cover**		Density (number of exotic perennials/ha)
						Live	Total	
Deep grassland								
Cathedral/Rock Springs (ungrazed)	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	8	0.4 (0–2.0)	0.5 (0–2.0)	NA
Hartnet (grazed)	<i>Halogeton glomeratus</i>	halogeton	Forb	Annual	1	0.04 (0–0.7)	0.04 (0–0.7)	NA
	<i>Malcolmia africana</i>	African mustard	Forb	Annual	1	0.02 (0–0.3)	0.02 (0–0.3)	NA
	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	8	0.4 (0–3.3)	0.7 (0–3.3)	NA
	<i>Tamarix chinensis</i>	tamarisk	Shrub	Perennial	1	0.02 (0–0.3)	0.02 (0–0.3)	25 (0–200)
Rocky grassland								
Hartnet (grazed)	<i>Alyssum minus</i> var. <i>micranthum</i>	European madwort	Forb	Annual	1	0.02 (0–0.3)	0.02 (0–0.3)	NA
	<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	1	0.04 (0–0.7)	0.1 (0–1.0)	NA
	<i>Halogeton glomeratus</i>	halogeton	Forb	Annual	1	0.02 (0–0.3)	0.02 (0–0.3)	NA
	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	4	0.1 (0–0.7)	0.1 (0–0.7)	NA

* A total of 16 plots were monitored in each ecological site type in each allotment in 2010.

** Mean and range are based on all plots within an ecological site type and allotment where an exotic species was detected.

Table 3-7. Mean (range) percent cover of surface features by ecological site type and allotment, Capitol Reef National Park, 2010.

Allotment	Crust, undifferentiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Deep grassland										
Cathedral/Rock Springs (ungrazed)	71.0 (45.0-85.0)	3.0 (0-16.0)	0.1 (0-1.0)	0.2 (0-1.3)	4.2 (0-33.0)	9.7 (4.7-20.7)	0.02 (0-0.3)	4.0 (0-20.7)	0.5 (0-6.7)	0.04 (0-0.7)
Hartnet (grazed)	76.8 (64.7-86.0)	1.5 (0-7.0)	0 (0-2.3)	0.4 (0-2.3)	5.3 (0.3-14.3)	9.8 (3.7-19.0)	0.04 (0-0.3)	2.4 (0-14.0)	0.2 (0-1.0)	0
Rocky grassland										
Hartnet (grazed)	30.0 (9.3-77.3)	0.4 (0-3.3)	0.6 (0-4.7)	0.3 (0-2.0)	0.4 (0-2.0)	13.8 (7.3-28.7)	0.02 (0-0.3)	31.9 (9.0-51.3)	18.2 (0-43.7)	0.1 (0-1.0)

Table 3-8. Mean (range) canopy- and basal-gap size by ecological site type and allotment, Capitol Reef National Park, 2010.

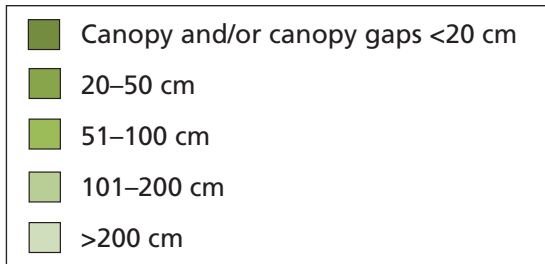
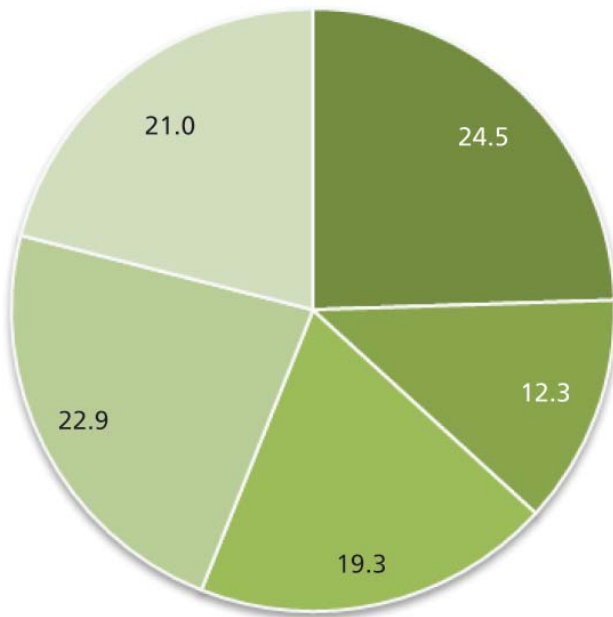
Ecological site type	Allotment	Canopy gap (cm)	Basal gap (cm)
Deep grassland	Cathedral/Rock Springs (ungrazed)	93 (45–140)	129 (45–226)
	Hartnet (grazed)	197 (70–583)	267 (88–735)
Rocky grassland	Hartnet (grazed)	115 (68–175)	183 (92–303)

Table 3-9. Mean (range) soil-aggregate stability measures by ecological site type and allotment, Capitol Reef National Park, 2010. Numbers range from 1 (least stable) to 6 (most stable).

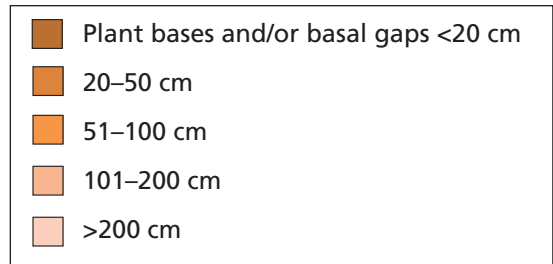
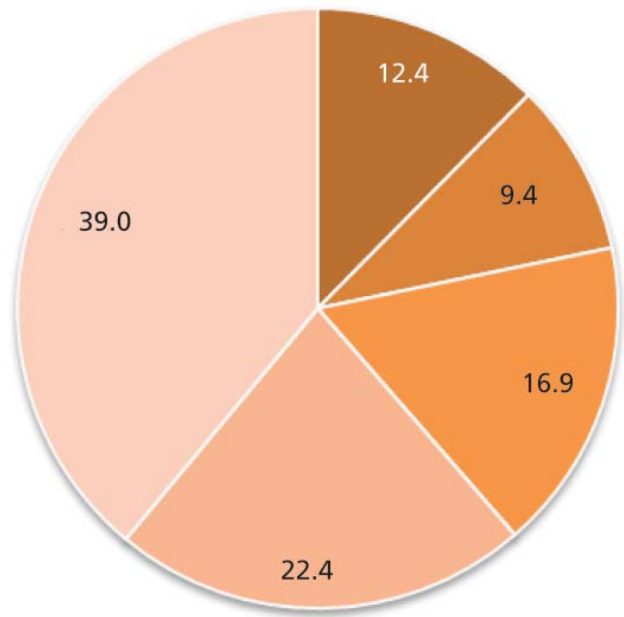
Ecological site type	Allotment	Total	Protected*	Unprotected*
Deep grassland	Cathedral/Rock Springs (ungrazed)	2.9 (1.0–4.7)	3.2 (1.0–5.0)	2.6 (1.0–4.8)
	Hartnet (grazed)	2.5 (1.2–5.1)	2.9 (1.0–5.5)	2.4 (1.0–5.2)
Rocky grassland	Hartnet (grazed)	3.1 (2.3–4.4)	3.6 (2.5–6.0)	2.9 (1.7–4.4)

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

A) Ungrazed Cathedral/Rock Springs



A) Ungrazed Cathedral/Rock Springs



B) Grazed Hartnet

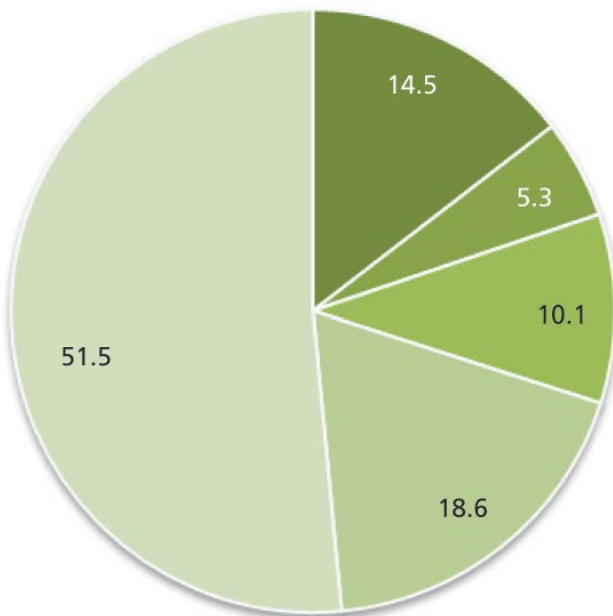


Figure 3-1. Distribution of canopy gaps for deep grassland plots in (A) ungrazed Cathedral/Rock Springs allotments and (B) the grazed Hartnet allotment, Capitol Reef National Park, 2010.

B) Grazed Hartnet

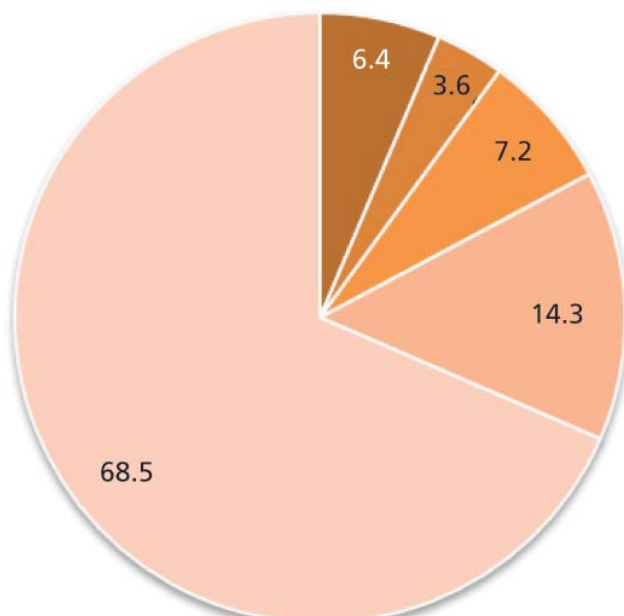


Figure 3-2. Distribution of basal gaps for deep grassland plots in (A) ungrazed Cathedral/Rock Springs allotments and (B) the grazed Hartnet allotment, Capitol Reef National Park, 2010.

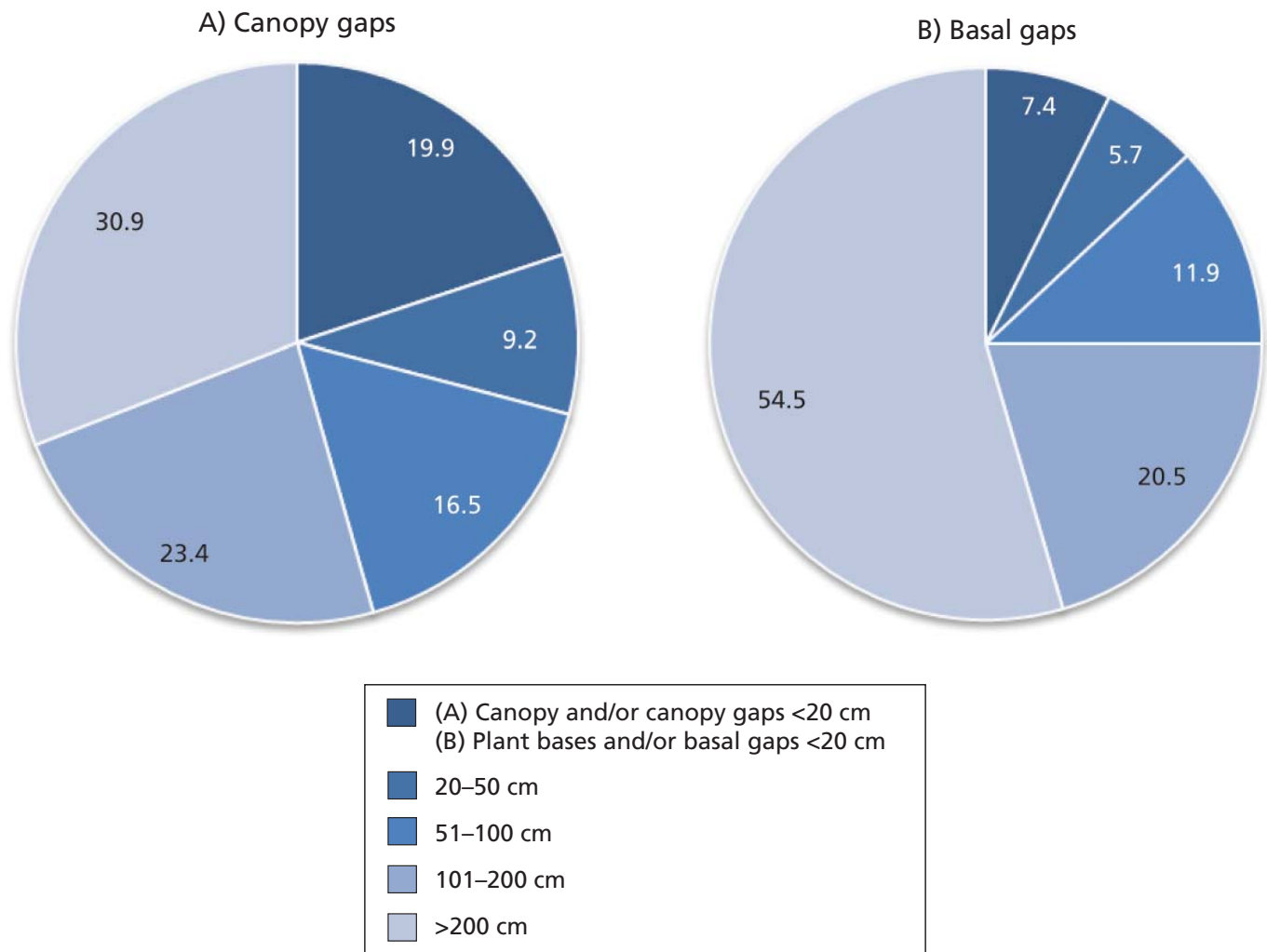


Figure 3-3. Distribution of (A) canopy gaps and (B) basal gaps for rocky grassland plots in the grazed Hartnet allotment, Capitol Reef National Park, 2010.

4 Discussion

In general, data from 2010 were similar to those from previous years. All plots monitored in 2010 were newly established, and 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. This variation will be accounted for in status and trend analyses after plots have been revisited, and it is too early to draw conclusions from this preliminary data.

In 2011, 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 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 in 2012 after five full years of monitoring are complete.

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