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Integrated Upland Monitoring in Capitol Reef National Park

Annual Report 2009 (Non-sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2010/371.N

ON THE COVER

Overlooking the South Desert and Waterpocket Fold, Capitol Reef National Park. NPS photo.

Integrated Upland Monitoring in Capitol Reef National Park

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Executive Summary

The goal of Northern Colorado Plateau Network (NCPN) integrated upland monitoring 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 during 2009. 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 previous discussions with park resource staff, it was determined that monitoring grazed and ungrazed grassland systems in the northern portion of the park was the highest priority. Four dominant ecological sites corresponding to herbaceous systems were selected for monitoring in the retired Cathedral and Rock Springs allotments and in the actively grazed Hartnet allotment. To gain understanding of variability, 10 monitoring plots per ecological site (except for one) were monitored for three consecutive years. In 2007, a total of 19 monitoring plots were established and sampled. In 2008, 42 additional plots were established and sampled, and the initial 19 plots were re-sampled. Of those 61 total plots, 21 are in the Cathedral and Rock Springs allotments and 40 are in the Hartnet allotment.

In this report, measures were summarized for each ecological site type by allotment. The only statistical assessment performed was an ordination of vegetation cover. Results of this ordination indicated little separation of plots between the different ecological sites, probably due to low live percent cover when monitoring plots were sampled. Early monitoring data describe status of ecological site types; interpretation is limited until additional data are acquired and more rigorously analyzed.

Future monitoring activities include implementing the full monitoring design in 2010. An operational revisit design will be created for each ecological site type, using variance measures in conjunction with desired minimum detectable change levels derived from the three years of pilot monitoring data.

1 Introduction

Uplands represent the vast majority of land area in national parks of the Colorado Plateau. Plateau uplands include rock outcrops, badlands, shrublands, grasslands, woodlands, and forests, 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, 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 riparian conditions.

Upland ecosystems of the Colorado Plateau are characterized by low resistance and resilience. Even moderate disturbances can affect vegetative composition and structure, and recovery to predisturbance conditions is relatively slow. 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 2005). Increasing recreational use and unauthorized social trailing threatens the integrity of upland systems through soil disturbance and resulting increases in soil erosion by water and wind. Global climate change is expected to change levels and seasonality of dominant precipitation events, with unknown implications for plateau systems.

The Northern Colorado Plateau Network (NCPN), as part of the National Park Service's Inventory and Monitoring Program, has identified plant communities, hydrologic function, soil stability, biological soil crust (BSC), and nutrient cycling as important components to understanding the health of upland systems (O'Dell et al. 2005). The indicators that apply to these components are listed below.

Plant communities: species and functional group composition and diversity, and vegetation structure

Hydrologic function: basal-gap size, cover and development of BSC, and infiltration rate

Soil stability: cover of vegetation, litter, and BSC, and soil aggregate stability

Biological soil crust: BSC cover

Nutrient cycling is not currently measured

The goals of NCPN upland monitoring are to increase fundamental understanding of upland systems and provide managers with early warning of undesirable change. These goals will be accomplished partly through sampling design and data analysis. Evaluation of upland monitoring data relative to other vital signs will facilitate identification of drivers and distinguish "natural" from anthropogenic change. This effort will document the variability in upland systems while providing information needed for resource management decisions.

Specific objectives of the NCPN integrated upland monitoring protocol are:

1. To determine annual status and trends in ground cover (live and standing dead vegetation, litter, rock, biological soil crust, and bare ground); vegetation by life form; soil aggregate stability; hydrologic function; and nutrient cycling;
2. To determine annual status and trends in cover of biological soil crusts by morphological group; and
3. To determine annual status and trends in cover of exotic plants in upland areas.

2 Methods

2.1 Integrated Upland Monitoring Procedures

2.1.1 Response design

The response design (methods used to collect observations) for integrated upland monitoring in NCPN parks is based largely on rangeland assessment procedures (Herrick et al. 2004), with modifications by Miller and others (2007). The location of a sample unit (or site) is randomly selected using procedures described below.

At each site, observations were recorded along three parallel, 50-m transects spaced 25 m apart (Figure 2-1). A point-intercept method was used to record percent cover of understory (<2 m) and ground-cover attributes at 0.5-m intervals along each transect (Table 2-1). The number of shrubs (by species and height class) and exotic perennials (by species) was recorded in a 1-m belt upslope of each transect. Canopy and basal-gap measures were acquired along each transect using line-intercept methods. Six surface-soil samples were taken along each transect to assess soil-aggregate stability. All measures recorded along transects were sub-samples scaled to the plot level. The plot-level measures are the primary values used in summaries and statistical analyses. Disturbances observed on and around the site were also recorded.

2.1.2 Sampling design

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. 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.

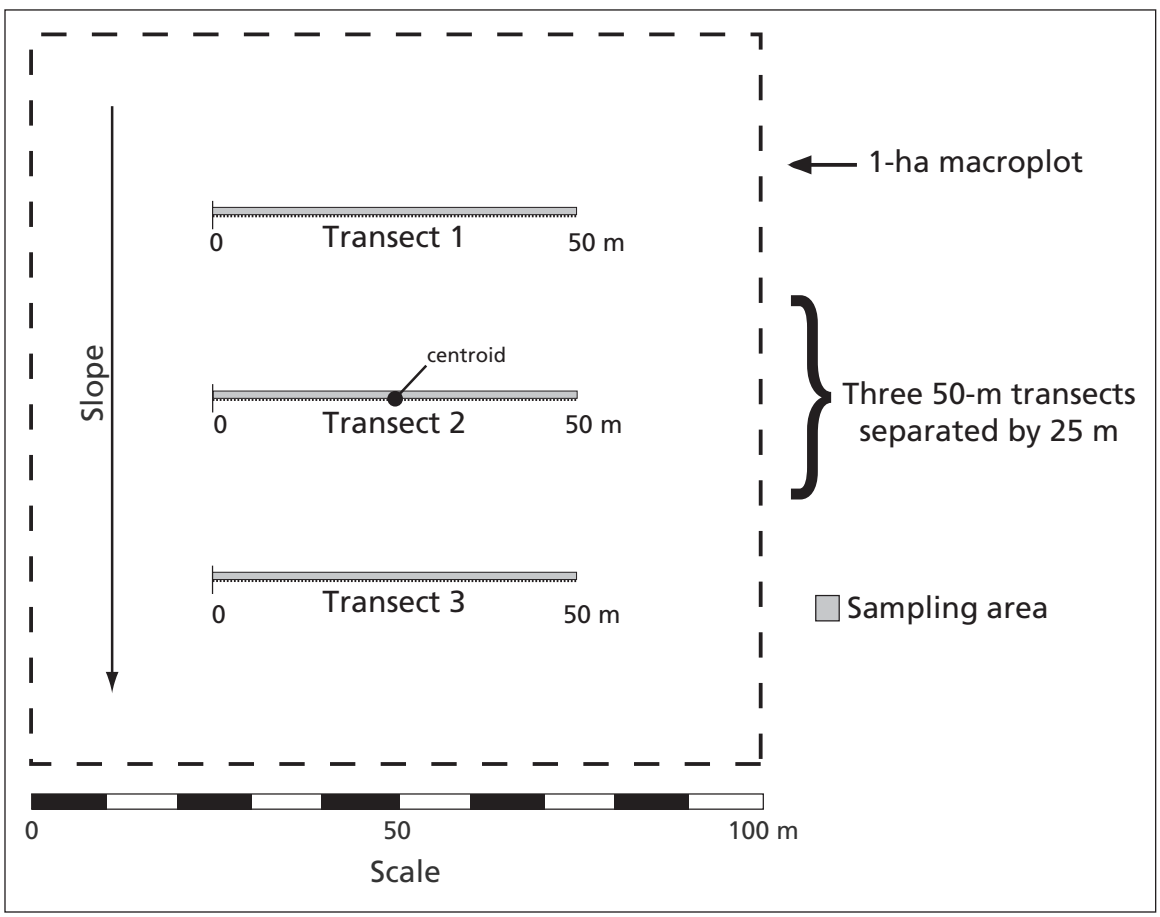


Figure 2-1. Standard macroplot and transect layout for upland monitoring of grasslands and shrublands.

Table 2-1. Plot-level measures.

Measure	Attribute or Context	Spatial scale(s) of observation
Percent cover	Individual plant species	Point-intercept along all three transects (150 m)
	Surface features (undifferentiated crust, cyanobacteria, lichen, moss, bare soil, litter, woody debris, small and large rock, bedrock)	
	Disturbance features (livestock and wildlife scat, ant mound, wildlife excavation, wildlife, livestock, human, bicycle, or motor vehicle tracks, other).	
	Life form (trees, shrubs, annual and perennial grasses, forbs/herbs)	
Density	Individual tree seedlings, shrubs, and exotic perennials by species; and tree seedlings, shrubs, and exotic perennials combined by group	1-m belt transects upslope of all 3 transects
Mean canopy gap size; frequency distribution of canopy gap size	Line-intercept length of canopy gaps	Along all three transects (150 m)
Mean basal gap size; frequency distribution of basal gap sizes	Line-intercept length of gaps between plant bases	Along all three transects (150 m)
Soil stability class (from all samples, protected areas, and unprotected areas)	Slake test stability class (1–6) Protected-area samples are collected under vegetation. Unprotected-area samples lack "overstory" vegetation	18 point samples across plot
Plant species richness	Number of species detected	Plot scale for trees, 1-m belt transects for shrubs, 5-m belt transect for saplings, point intercept for understory

2.2 Integrated Upland Monitoring in Capitol Reef NP

2.2.1 Resource issues driving upland monitoring

During discussions with NCPN staff in 2007, park resource managers identified 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.

2.2.2 Mapping and selecting target populations

2.2.2.1 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 >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 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.

2.2.2.2 Selection of target ecological site types

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 (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. The deep stony grassland group (hereafter referred to as "rocky grasslands") included Semidesert Stony Loam and Semidesert Very Steep Stony Loam (Table 2-2, Figure 2-2). 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.

2.2.2.3 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 Harnet 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.

2.2.3 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 site (see Figure 2-1). Anticipating 30–50 sites 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.

Ten monitoring plots were established for each target ecological site except Semidesert Sand, which occurred on an extremely limited area across the landscape. One plot was established for Semidesert Sand. These plots will be used for three years of pilot monitoring, and the variances of measures over this time period will then be used to analyze potential operational sampling designs.

2.3 Database

All observations recorded in the field are stored in an Access database maintained by the NCPN. 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.

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

Ecological site type	Ecological site name/ notation	Physiognomic type	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Deep alluvial/ eolian grassland (Deep grassland)	Semidesert Alkali Sandy Loam (alkali sacaton) SDASL201	Herbaceous	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	Herbaceous	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	Herbaceous	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) DStL242	Herbaceous	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	Herbaceous	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.

Figure 2-2. Examples of ecological sites monitored in Capitol Reef National Park. See Table 2-2 for descriptions of ecological sites.

3 Results

3.1 Monitored Plots

Upland monitoring was initiated in Capitol Reef NP in 2007, when 19 plots were established across three target ecological sites, mainly in the Cathedral and Rock Springs allotments. These plots were revisited in summer of 2008, when the remaining 42 plots were established and sampled, for a total of 61 plots (Figure 3-1). A total of 10 plots were established for each ecological site except Semidesert Sand. Table 3-1 (tables start on page 12) summarizes plot visits by ecological site, allotment, and year. Appendix A lists physical attributes of individual plots.

3.2 Ecological Site Type Summaries

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

For this annual report, plot-level summaries of the measures listed in Table 2-1 were generated for each monitoring plot, then summarized by ecological site type and allotment. Ecological site type summaries are simply a mean and range (minimum, maximum) for a measured attribute. The percent cover of all species recorded for each plot is included as an electronic appendix that accompanies this report (care09_species.xls).

Given the limited data, measures were not statistically compared among ecological site types. Even qualitative comparisons of summary measures could be misleading given the small number of plots visited each year. The reader is cautioned not to draw wide-reaching conclusions from this initial set of results.

The only statistical assessment provided is a multivariate assessment of the similarity of vegetative conditions within and among ecological sites (see Section 3.2.9). Data from 2009 were ordinated using NMS (non-metric multidimensional scaling), which involves scaling plots on the basis of similarity (or dissimilarity) of species composition and cover. Plots are distributed in multivariate space, typically along 1–3 axes. Within this space, plots with similar composition are located closer together and correlated with dominant species.

3.2.1 Species richness

Species richness by life form is illustrated in Table 3-2. Recorded species were compared to the NPSpecies database to determine first-time observations in Capitol Reef National Park. No new species were detected in the park in 2009.

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.

3.2.3 Shrub density

Density of shrub species is shown in Table 3-5. In previous annual reports, shrub density was presented as shrubs/10 m^2. In 2009, we changed the unit to shrubs/ha (or 100 m × 100 m) to be more intuitive.

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.

Exotic species were only detected in the Hartnet allotment. Only annual forbs and grasses were detected, including cheatgrass (*Bromus tectorum*), African mustard (*Malcolmia africana*), Russian thistle (*Salsola tragus*), and tumble mustard (*Sisymbrium altissimum*). No exotic perennial species were detected in the 1-m belt.

NCPN upland sampling methods are not intended as an early detection survey; therefore, lack of detection does not mean that other exotic species were not present in plots.

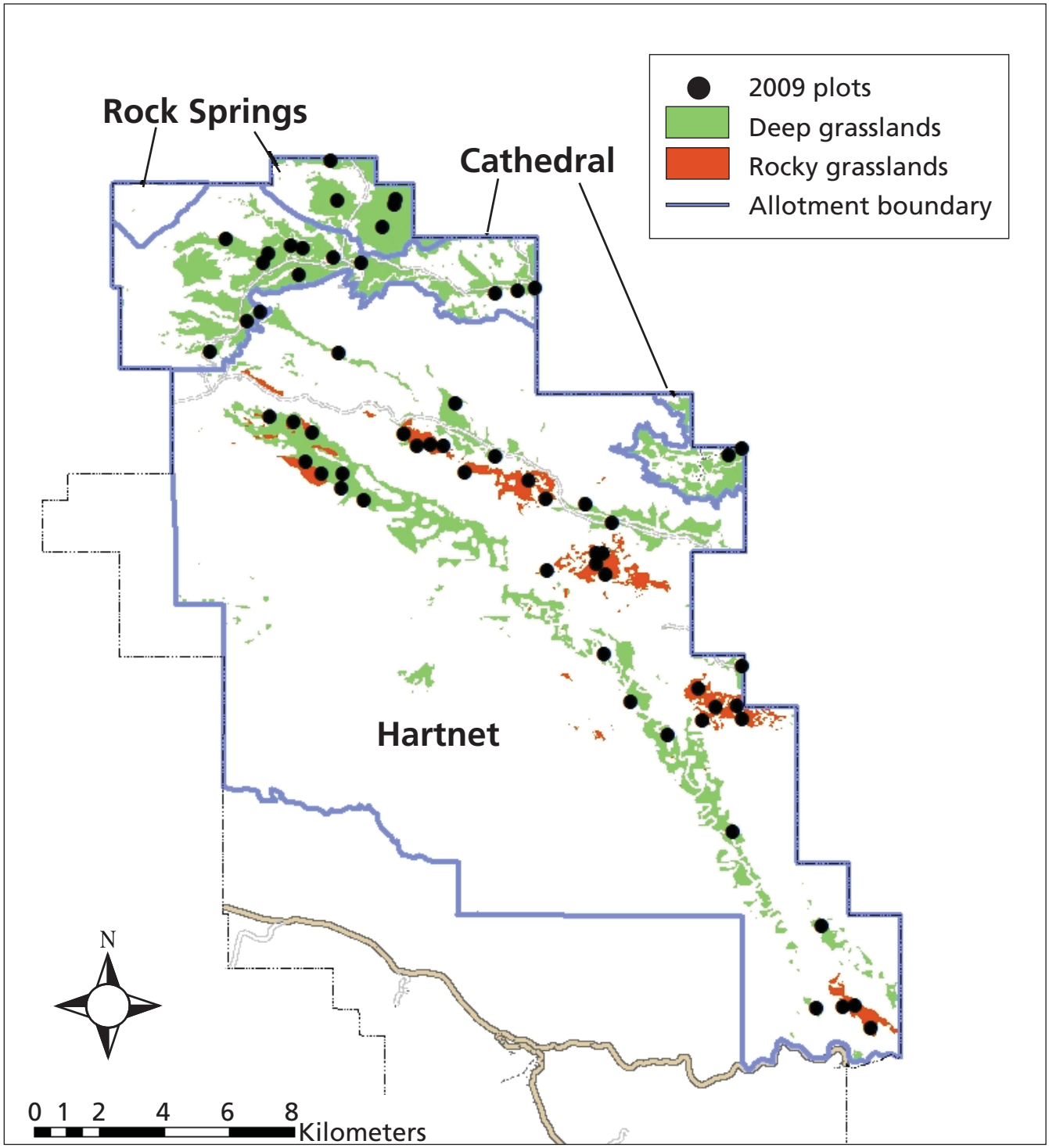


Figure 3-1. Location of pilot monitoring plots in Capitol Reef National Park.

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 2009, a single Winkler's pincushion cactus (*Pediocactus winkleri*) was detected in one plot via the point-intercept sampling method. Crews also encountered numerous hedgehog cacti (*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.

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 3-2, 3-3, and 3-4.

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.

3.2.9 Plot ordinations

Non-metric multidimensional scaling ordination was performed using all plots except the single Semidesert Sand plot (Figure 3-5). Only live species with relative cover values of $\geq$10% were included. Relative cover is the percent cover of the species divided by the total cover on a plot. This requirement was imposed to emphasize dominant species. The direction and relative magnitude of correlations of species are shown in the graphs for each combination of axes. The species vector from the origin shows the direction of positive correlation.

The ordination illustrates both the separation of ecological site types and the high degree of overlap within ecological site types. The two rocky grassland sites (242 & 260) are grouped together, with galleta, shadscale, Torrey's jointfir, and Utah juniper as the distinguishing species. Deep grassland plots in both Cathedral/Rock Springs and Hartnet allotments were distributed across the ordination in 2009, but tended to be characterized by Indian ricegrass and alkali sacaton.

Table 3-1. Number of plots, by ecological site and allotment, monitored in Capitol Reef NP, 2007–2009.

Ecological site type	Ecological site*	Cathedral / Rock Springs			Hartnet		
		2007	2008	2009	2007	2008	2009
Deep grassland	Semidesert Alkali Sandy Loam	6	10	10	1	10	10
	Semidesert Sand	1	1	1	0	0	0
	Semidesert Sandy Loam	9	10	10	2	10	10
Rocky grassland	Semidesert Stony Loam	n/a	n/a	n/a	0	10	10
	Semidesert Very Steep Stony Loam	n/a	n/a	n/a	0	10	10

*See Table 2-2 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 NP, 2009.

Ecological site type	Number of species detected					
	Total	Tree	Shrubs	Perennial grasses	Annual grasses	Forbs/ Herbs
Cathedral/Rock Springs (ungrazed)						
Deep grassland	9.7 (6–15)	0.2 (0–2)	5.0 (2–8)	3.7 (1–6)	0	0.9 (0–3)
Hartnet (grazed)						
Deep grassland	8.4 (2–14)	0	4.8 (1–10)	2.8 (0–6)	0	0.8 (0–3)
Rocky grassland	9.7 (5–14)	0.6 (0–2)	5.8 (3–9)	2.6 (1–4)	0.1 (0–1)	0.7 (0–4)

Table 3-3. Mean (range) percent cover by life form for each ecological site type and allotment, Capitol Reef NP, 2009.

Ecological site type	Allotment	Tree		Shrubs		Perennial grasses		Annual grasses		Forbs/Herbs	
		Live	Total	Live	Total	Live	Total	Live	Total	Live	Total
Deep grassland	Cathedral/Rock Springs (ungrazed)	0.3 (0–3.0)	0.3 (0–3.0)	2.8 (0.7–8.7)	8.6 (4.0–22.3)	3.9 (0.7–9.3)	16.2 (7.3–35.3)	0	0	0.2 (0–1.3)	0.5 (0–2.0)
	Hartnet (grazed)	0	0	3.3 (0.3–8.3)	6.1 (0.7–14.3)	4.0 (0–8.7)	6.9 (0–18.7)	0	0	0.4 (0–3.3)	0.6 (0–4.7)
Rocky grassland	Hartnet (grazed)	2.0 (0–8.7)	2.3 (0–9.7)	4.5 (1.0–10.3)	7.0 (2.0–14.7)	4.8 (1.7–13.7)	9.4 (3.3–18.0)	0.02 (0–0.3)	0.02 (0–0.3)	0.3 (0–1.7)	0.4 (0–1.7)

Table 3-4. Mean (range) percent cover of dominant species by ecological site type and allotment, Capitol Reef NP, 2009.

Ecological site type	Scientific name	Common name	Life form	Duration	Nativity	Percent cover			
						Cathedral/Rock Springs (ungrazed)		Hartnet (grazed)	
						Live	Total	Live	Total
Deep grassland	*Bouteloua gracilis*	blue grama	Graminoid	Perennial	Native	0.4 (0–2.0)	3.5 (0–21.7)	0.4 (0–3.7)	1.2 (0–14.7)
	Chrysothamnus nauseosus	rubber rabbitbrush	Shrub	Perennial	Native	0.5 (0–2.7)	1.0 (0–6.0)	0.1 (0–0.7)	0.2 (0–1.0)
	Eriogonum leptocladon	sand wild buckwheat	Shrub	Perennial	Native	0.3 (0–2.3)	0.7 (0–3.7)	0.2 (0–2.0)	0.4 (0–4.0)
	Gutierrezia sarothrae	broom snakeweed	Dwarf Shrub	Perennial	Native	0.2 (0–1.7)	3.3 (0–9.3)	0.2 (0–2.0)	1.3 (0–6.0)
	Hilaria jamesii	galleta	Graminoid	Perennial	Native	0.4 (0–2.0)	2.3 (0–9.7)	1.2 (0–3.7)	2.0 (0–6.3)
	Muhlenbergia pungens	sandhill muhly	Graminoid	Perennial	Native	0.4 (0–3.3)	1.4 (0–10.3)	0.3 (0–5.3)	0.6 (0–11.7)
	Opuntia species	pricklypear	Dwarf Shrub	Perennial	Native	0.5 (0–2.0)	0.6 (0–2.0)	0.6 (0–5.0)	0.8 (0–7.3)
	Sarcobatus vermiculatus	greasewood	Shrub	Perennial	Native	0.2 (0–1.7)	0.4 (0–3.0)	0.4 (0–2.3)	0.6 (0–3.3)
	Sporobolus airoides	alkali sacaton	Graminoid	Perennial	Native	1.3 (0–4.7)	5.4 (0–18.0)	1.1 (0–7.3)	1.5 (0–9.7)
	Stipa hymenoides	Indian ricegrass	Graminoid	Perennial	Native	1.3 (0–5.0)	3.4 (0–14.7)	0.8 (0–3.0)	1.2 (0–4.0)
Rocky grassland	*Atriplex confertifolia*	shadscale	Shrub	Perennial	Native	n/a	n/a	1.7 (0–5.0)	2.6 (0–6.3)
	Ephedra torreyana	Torrey's jointfir	Shrub	Perennial	Native	n/a	n/a	1.3 (0–8.7)	1.8 (0–10.3)
	Gutierrezia sarothrae	broom snakeweed	Dwarf Shrub	Perennial	Native	n/a	n/a	0.5 (0–2.3)	1.2 (0–5.0)
	Hilaria jamesii	galleta	Graminoid	Perennial	Native	n/a	n/a	3.2 (0.7–13.3)	6.3 (0.7–13.3)
	Juniperus osteosperma	Utah juniper	Tree	Perennial	Native	n/a	n/a	1.9 (0–8.7)	2.2 (0–9.7)
	Stipa hymenoides	Indian ricegrass	Graminoid	Perennial	Native	n/a	n/a	0.6 (0–2.3)	0.9 (0–4.0)
	Stipa species*		Graminoid	Perennial	Native	n/a	n/a	0.2 (0–1.3)	0.5 (0–4.7)

* Flowers or seeds are necessary to distinguish *Stipa comata* and *Stipa hymenoides*.

Table 3-5. Mean (range) density of shrub species per hectare by ecological site type and allotment, Capitol Reef NP, 2009.

			Cathedral/Rock Springs (ungrazed)		Hartnet (grazed)	
Ecological site type	**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	*Artemisia bigelovii*	Bigelow's sagebrush	8	168 (0–933)	6	237 (0–1,600)
	Artemisia nova	black sagebrush	1	3 (0–67)	0	-
	Artemisia tridentata	big sagebrush	1	175 (0–3,667)	3	67 (0–733)
	Atriplex canescens	fourwing saltbush	15	302 (0–1,733)	11	140 (0–533)
	Atriplex confertifolia	shadscale	7	175 (0–2,067)	16	2087 (0–13,667)
	Atriplex corrugata	mat saltbush	0		1	7 (0–133)
	Atriplex gardneri	Gardner's saltbush	1	6 (0–133)	7	763 (0–9,267)
	Chrysothamnus linifolius	spearleaf rabbitbrush	1	16 (0–333)	0	-
	Chrysothamnus nauseosus	rubber rabbitbrush	13	390 (0–1,200)	6	73 (0–467)
	Chrysothamnus viscidiflorus	green rabbitbrush	2	79 (0–1,200)	2	13 (0–200)
	Ephedra torreyana	Torrey's jointfir	5	140 (0–1,600)	3	80 (0–933)
	Eriogonum leptocladon	sand wild buckwheat	8	921 (0–5,200)	5	347 (0–3,200)
	Eriogonum microthecum	slender wild buckwheat	4	632 (0–6,400)	1	7 (0–133)
	Juniperus osteosperma	Utah juniper	1	3 (0–67)	0	-
	Krascheninnikovia lanata	winterfat	5	25 (0–200)	10	3,260 (0–33,200)
	Pinus edulis	two-needle pinyon	1	3 (0–67)	0	
	Sarcobatus vermiculatus	greasewood	11	130 (0–733)	6	167 (0–1,000)
	Shepherdia rotundifolia	roundleaf buffaloberry	1	3 (0–67)	0	-
	Tetradymia canescens	spineless horsebrush	0		3	23 (0–333)
Rocky grassland	*Artemisia bigelovii*	Bigelow's sagebrush	n/a	n/a	10	907 (0–8,267)
	Artemisia tridentata	big sagebrush	n/a	n/a	2	30 (0–533)
	Atriplex confertifolia	shadscale	n/a	n/a	19	3,920 (0–15,667)
	Atriplex gardneri	Gardner's saltbush	n/a	n/a	4	137 (0–1,333)
	Chrysothamnus viscidiflorus	green rabbitbrush	n/a	n/a	12	660 (0–4,800)
	Ephedra torreyana	Torrey's jointfir	n/a	n/a	17	980 (0–5,533)
	Ephedra viridis	Mormon tea	n/a	n/a	4	27 (0–333)
	Eriogonum microthecum	slender wild buckwheat	n/a	n/a	7	327 (0–2,333)
	Fraxinus anomala	singleleaf ash	n/a	n/a	1	3 (0–67)
	Juniperus osteosperma	Utah juniper	n/a	n/a	11	110 (0–400)
	Krascheninnikovia lanata	winterfat	n/a	n/a	11	210 (0–1,467)
	Leptodactylon pungens	prickly phlox	n/a	n/a	1	3 (0–67)
	Shepherdia rotundifolia	roundleaf buffaloberry	n/a	n/a	2	7 (0–67)
	Tetradymia canescens	spineless horsebrush	n/a	n/a	7	130 (0–1,133)

Table 3-6. Mean (range) cover of exotic plant species detected in Capitol Reef NP, 2009.

Ecological site type	Scientific name	Common name	Life form	Duration	No. of plots with exotic species detected	Percent cover*	
						Live	Total
Cathedral/Rock Springs (ungrazed)							
Deep grassland	-	-	-	-	0	0	0
Hartnet (grazed)							
Deep grassland	*Malcolmia africana*	African mustard	Forb	Annual	1	0	0.02 (0–0.3)
	Salsola tragus	Russian thistle	Forb	Annual	5	0.3 (0–3.3)	0.3 (0–3.3)
	Sisymbrium altissimum	Tumble mustard	Forb	Annual	1	0	0.1 (0–1.7)
Rocky grassland	*Bromus tectorum*	Cheatgrass	Graminoid	Annual	1	0.02 (0–0.3)	0.02 (0–0.3)

*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 NP, 2009.

Ecological site type	Crust, undifferentiated	Cyano-bacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Cathedral/Rock Springs (ungrazed)										
Deep grassland	68.3 (46.3–85.7)	4.8 (0–20.3)	0.1 (0–1.7)	0.5 (0–7.7)	4.6 (0–12.7)	13.2 (5.0–34.7)	0.1 (0–1.7)	1.5 (0–10.7)	0.1 (0–0.7)	0
Hartnet (grazed)										
Deep grassland	68.5 (34.7–89.0)	0.8 (0–5.7)	0.1 (0–1.3)	0	11.4 (0–42.3)	8.7 (0–22.0)	0	6.0 (0–29.3)	0.1 (0–1.0)	0
Rocky grassland	32.4 (8.3–66.7)	0.7 (0–4.0)	0.2 (0–1.3)	0.2 (0–1.3)	0.3 (0–3.0)	11.2 (0–20.3)	0.02 (0–3)	32.5 (16.0–43.7)	17.3 (0–40.7)	0.03 (0–0.7)

Table 3-8. Mean (range) canopy- and basal-gap size by ecological site type and allotment, Capitol Reef NP, 2009.

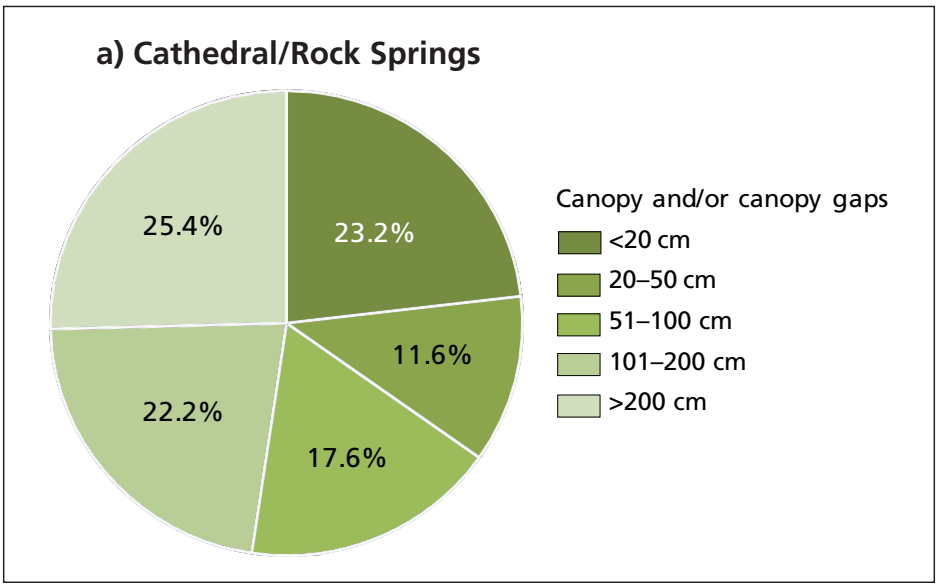
Ecological site type	Allotment	Canopy gap (cm)	Basal gap (cm)
Deep grassland	Cathedral/Rock Springs (ungrazed)	99 (58–225)	132 (69–275)
	Hartnet (grazed)	217 (68–489)	258 (85–647)
Rocky grassland	Hartnet (grazed)	119 (63–194)	163 (93–287)

Table 3-9. Mean (range) soil-aggregate stability measures by ecological site type and allotment, Capitol Reef NP, 2009.

Ecological site type	Allotment	Total	Protected*	Unprotected*
Deep grassland	Cathedral/Rock Springs (ungrazed)	3.0 (1.3–5.6)	3.5 (1.7–5.7)	2.7 (1.2–5.6)
	Hartnet (grazed)	2.4 (1.2–3.7)	2.0 (1.0–5.0)	2.3 (1.1–3.2)
Rocky grassland	Hartnet (grazed)	2.7 (1.3–5.0)	3.5 (1.5–6.0)	2.5 (1.2–4.9)

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

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



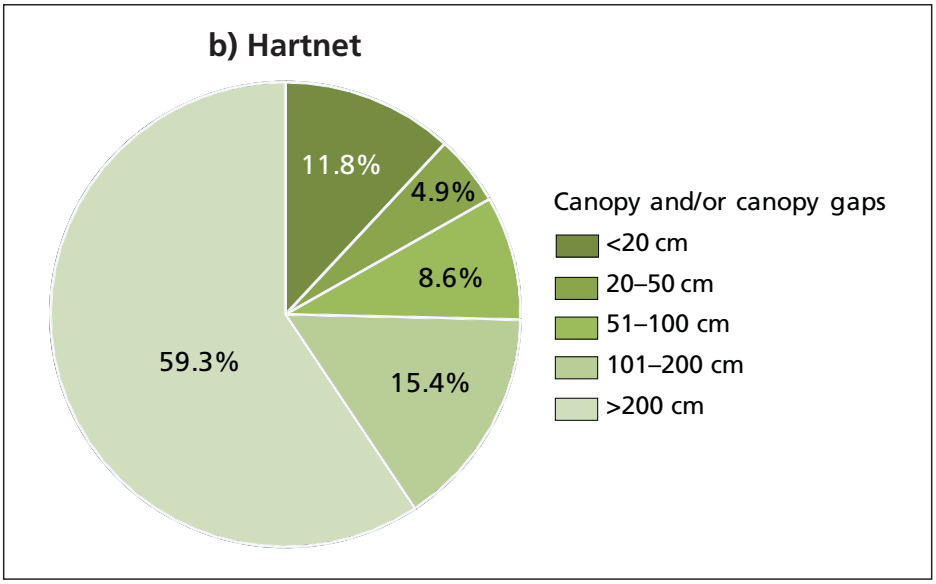
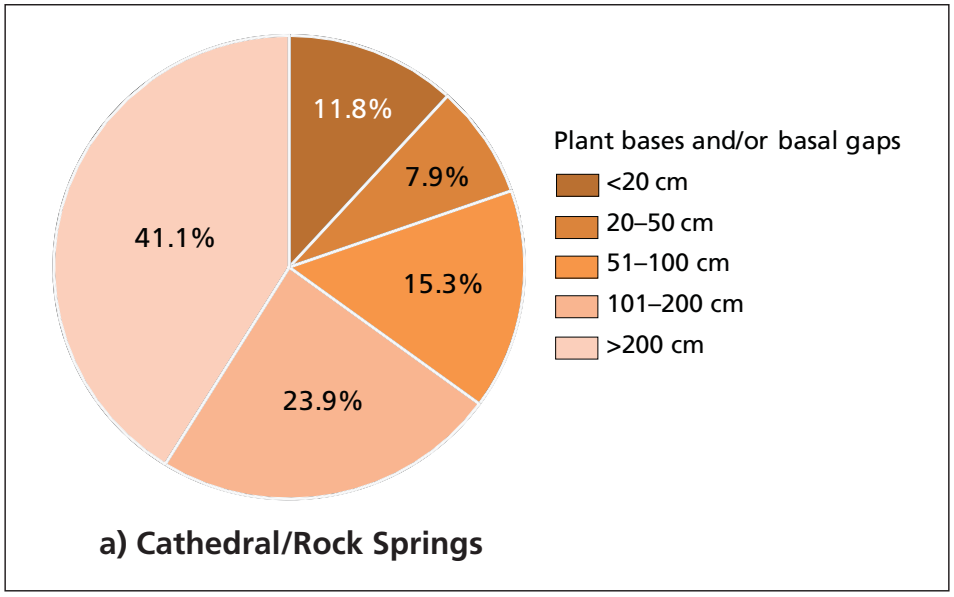


Figure 3-2. Distribution of canopy gaps for deep grassland plots in a) Cathedral/Rock Springs allotments and b) the Hartnet allotment, Capitol Reef NP, 2009.



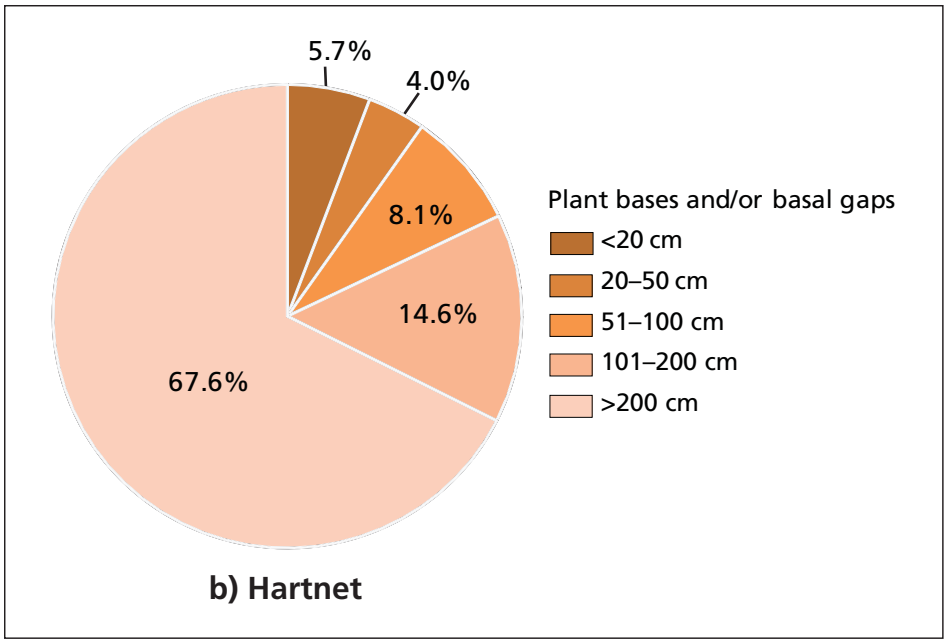
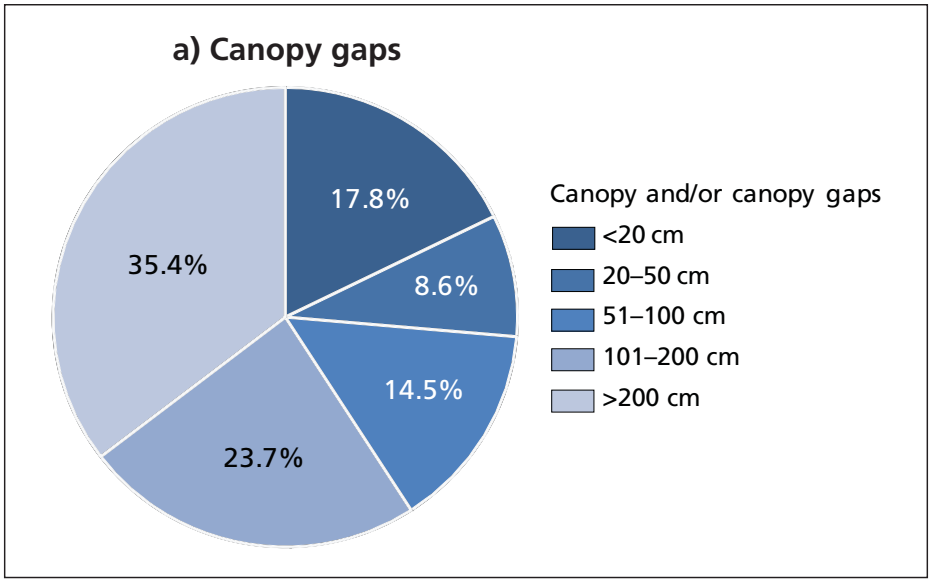


Figure 3-3. Distribution of basal gaps for deep grassland plots in a) Cathedral/Rock Springs allotments and b) the Hartnet allotment, Capitol Reef NP, 2009.



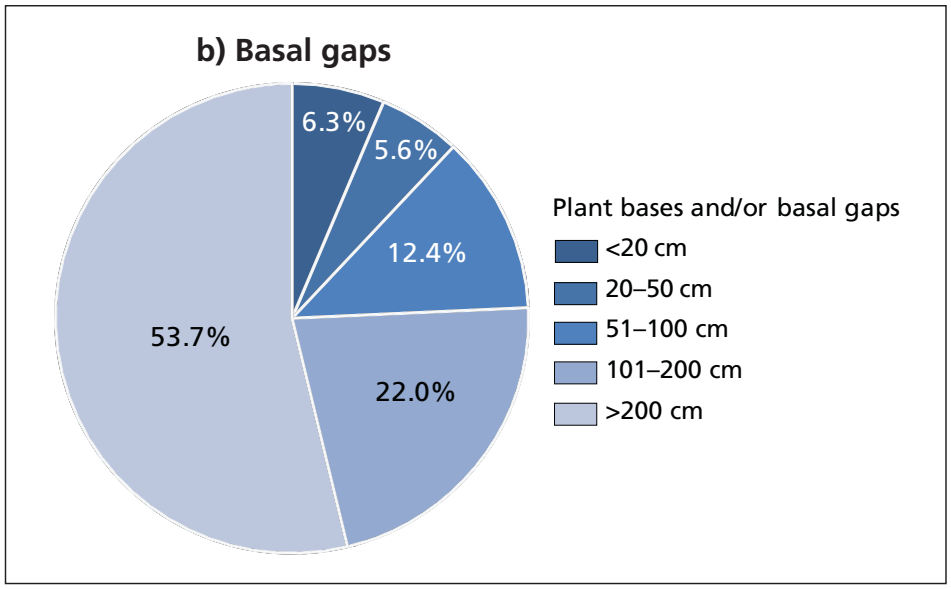


Figure 3-4. Distribution of a) canopy gaps and b) basal gaps for rocky grassland plots in the Harnet allotment, Capitol Reef NP, 2009.

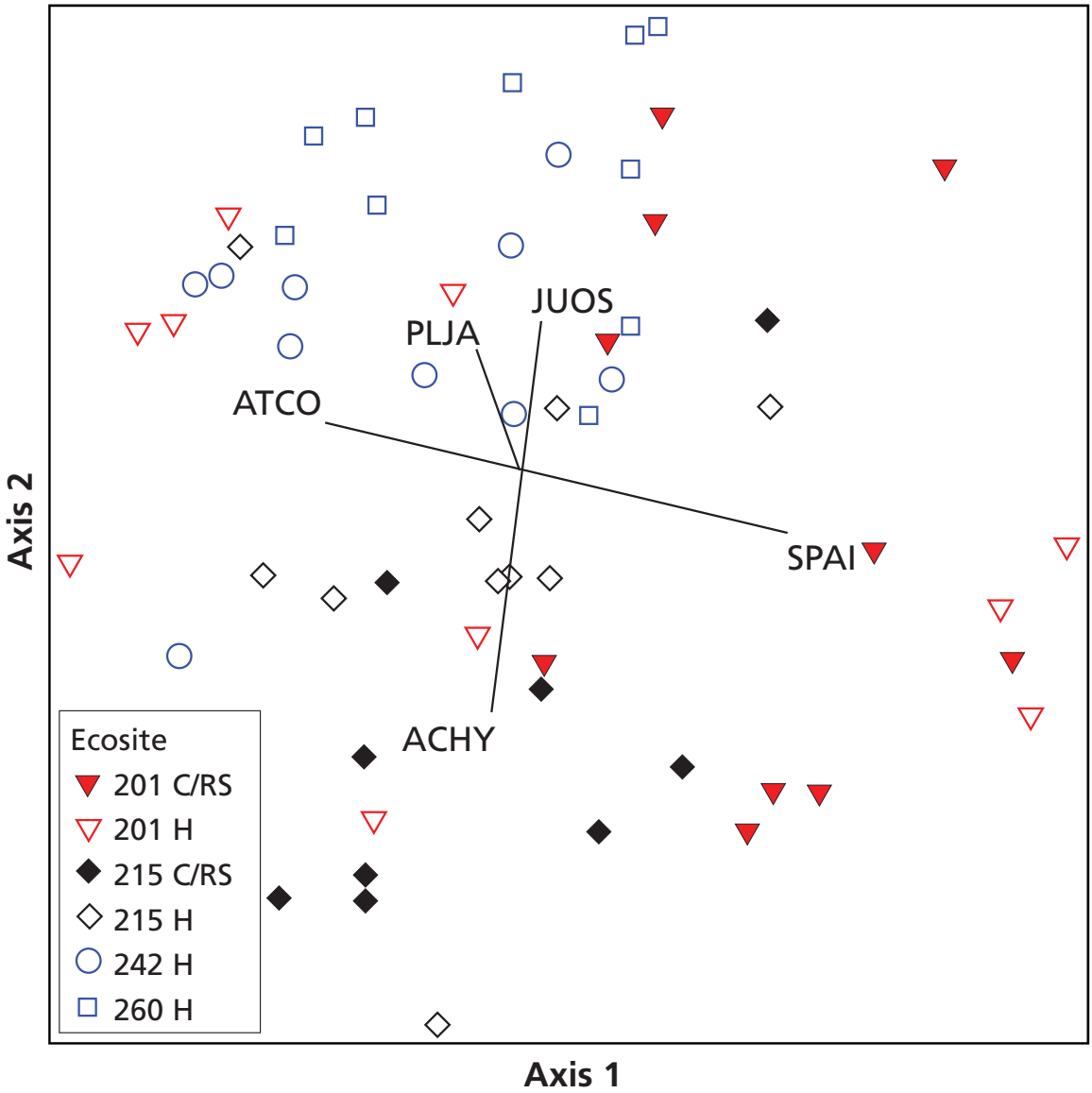


Figure 3-5a. Non-metric multidimensional scaling (NMS) ordination of plots from the four ecological site types monitored in Capitol Reef National Park in 2009 by allotment.

C/RS = Cathedral/Rock Springs
H = Hartnet

Species codes
ACHY = *Stipa hymenoides* (Indian ricegrass)
ATCO = *Atriplex confertifolia* (shadscale)
JUOS = *Juniperus osteosperma* (Utah juniper)
PLJA = *Hilaria jamesii* (galleta)
SPAI = *Sporobolus airoides* (alkali sacaton)

Ecological site codes
Deep grassland 201 = Semidesert Alkali Sandy Loam
215 = Semidesert Sandy Loam

Rocky grassland 242 = Semidesert Stony Loam
260 = Semidesert Very Steep Stony Loam

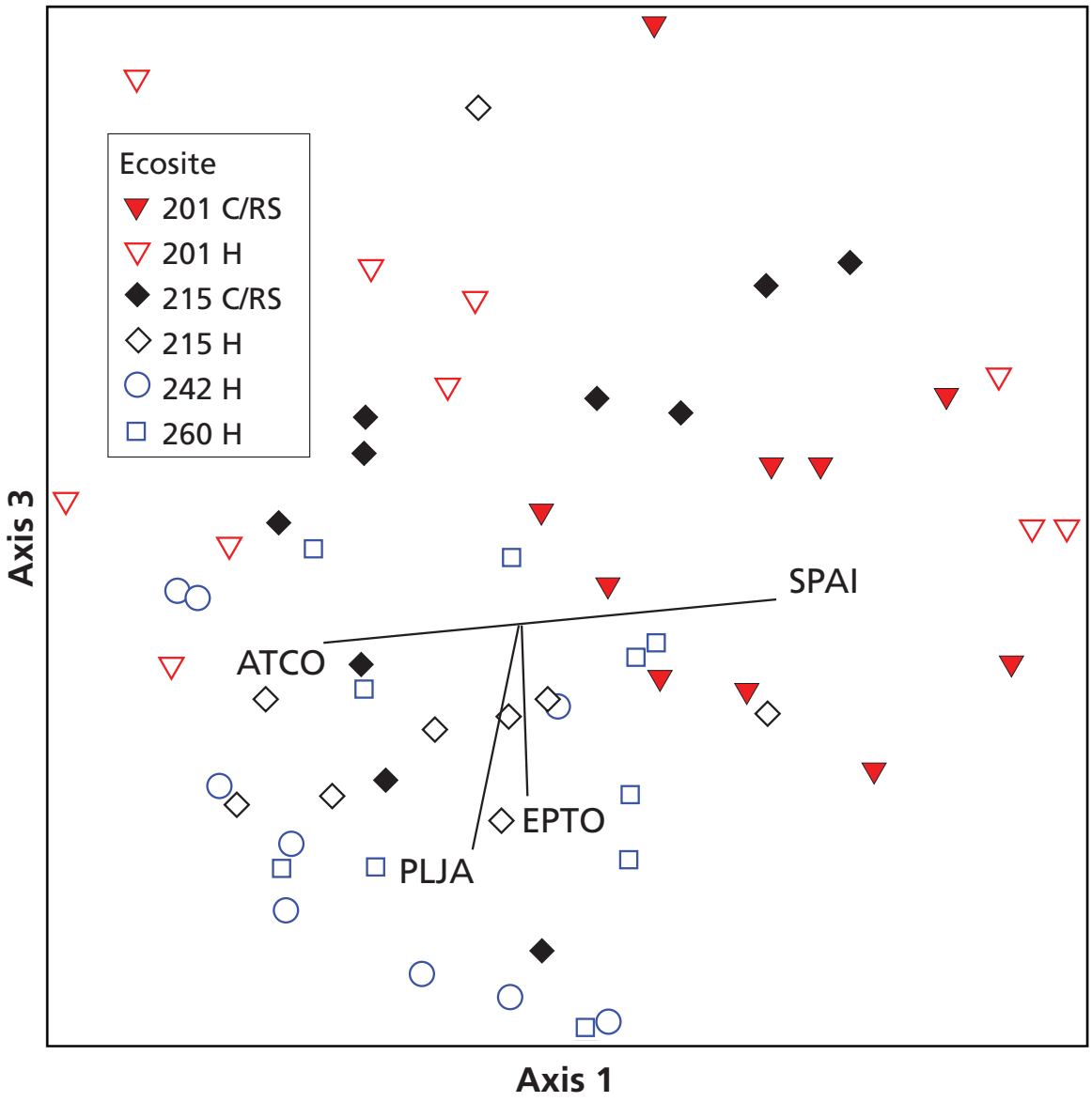


Figure 3-5b. Non-metric multidimensional scaling (NMS) ordination of plots from the four ecological site types monitored in Capitol Reef National Park in 2009 by allotment.

C/RS = Cathedral/Rock Springs
H = Hartnet

Species codes
ATCO = *Atriplex confertifolia* (shadscale)
EPTO = *Ephedra torreyana* (Torrey's jointfir)
PLJA = *Hilaria jamesii* (galleta)
SPAI = *Sporobolus airoides* (alkali sacaton)

Ecological site codes
Deep grassland 201 = Semidesert Alkali Sandy Loam
215 = Semidesert Sandy Loam

Rocky grassland 242 = Semidesert Stony Loam
260 = Semidesert Very Steep Stony Loam

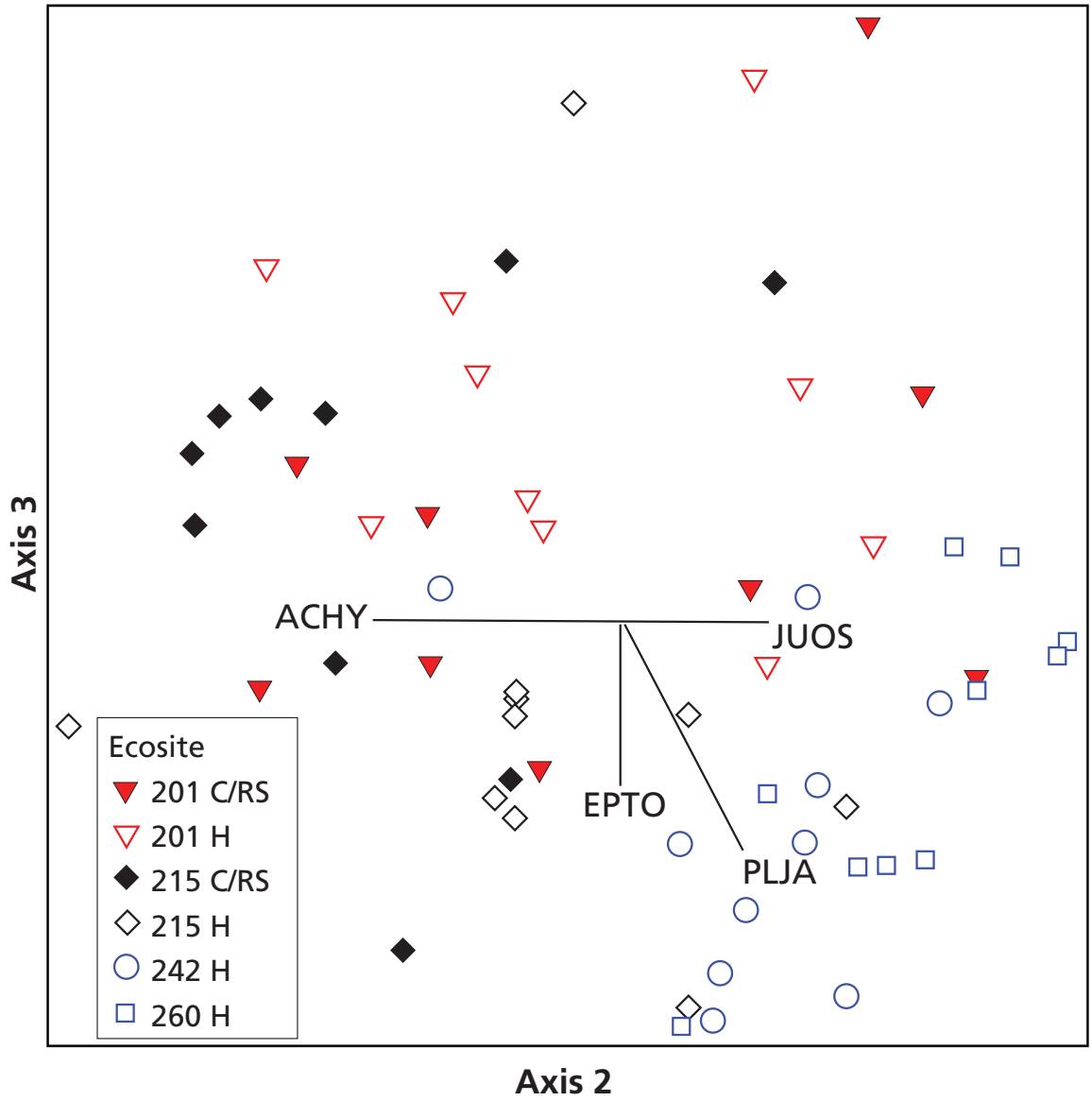


Figure 3-5c. Non-metric multidimensional scaling (NMS) ordination of plots from the four ecological site types monitored in Capitol Reef National Park in 2009 by allotment.

C/RS = Cathedral/Rock Springs
H = Hartnet

Species codes
ACHY = *Stipa hymenoides* (Indian ricegrass)
EPTO = *Ephedra torreyana* (Torrey's jointfir)
JUOS = *Juniperus osteosperma* (Utah juniper)
PLJA = *Hilaria jamesii* (galleta)

Ecological site codes

Deep grassland	201 = Semidesert Alkali Sandy Loam
	215 = Semidesert Sandy Loam
Rocky grassland	242 = Semidesert Stony Loam
	260 = Semidesert Very Steep Stony Loam

4 Discussion

Although no statistical analyses have been performed on most of the data, some preliminary patterns are emerging. There are numerous differences between deep grassland sites in the Cathedral/Rock Springs and Hartnet allotments. The Cathedral/Rock Springs allotment has higher cover of perennial grass, cyanobacteria, and moss. In the Hartnet allotment, gaps between vegetation are larger, soil stability is lower, and cover of bare soil is higher. In addition, exotic species were detected in Hartnet, but not in Cathedral/Rock Springs. Causes of these patterns cannot be determined from this initial data and statistical tests are needed to validate the significance of possible patterns. Although grazed vs. previously grazed is the primary factor of comparison between these allotments, elevation and other environmental factors will need to be considered in an analysis, because the Hartnet allotment is situated at a lower elevation than the Cathedral and Rock Springs allotments.

In general, detection of exotic species was extremely low in the areas monitored by the NCPN. Most exotic species were only detected in one plot. The only exception was Russian thistle, which was detected in five plots. Although five was more than twice the number of plots where Russian thistle was detected in 2008, it is possible that the increase was due to the timing of sampling rather than an actual increase in the species; senesced Russian thistle may have blown off of plots before sampling occurred in 2008. Future visits at the same time of year will be required to determine if a trend is occurring.

This was the third year of pilot monitoring at Capitol Reef NP, and only the second year that all 61 plots were sampled. Data collected in 2009 were similar to those collected in 2008, with one notable exception: live cover of many plant species was substantially lower in 2009 than in 2008. However, spring temperatures were cooler than average at Capitol Reef NP in 2009, and plots were visited in April and May, before many plants had enough time to fully develop live photosynthetic tissue for the growing season. In contrast, plots were visited much later in the growing season during 2008 (June and July). Thus, the low live cover recorded in 2009 was likely an artifact of our sampling and does not indicate an actual decline in live cover. It is also likely that deep grassland plots in the NMS ordination were less tightly clustered in 2009 than in 2008 due to the low amount of live plant cover.

In order to avoid this problem in the future, monitoring at Capitol Reef NP will be scheduled later in the growing season (late May or June). Although sampling dates varied widely in early years of monitoring, the NCPN plans to sample all monitoring plots in a park within a much smaller window (the same 1–2 month period each year) in the future.

The full operational monitoring design will be implemented during the 2010 field season. In winter 2010, 2–3 years of monitoring data were analyzed for estimates of variance. Variance served as the basis for determining the ability to detect a minimum trend and was used to evaluate the number of plots needed, as well as potential revisit designs. Recommendations for an operational survey design were presented to Capitol Reef NP resource staff for discussion and approval in spring 2010. After five full years of monitoring, data will be analyzed for status and trends. Continued discussion with park resource staff will occur to ensure that park expectations and needs are satisfied by NCPN integrated upland monitoring.

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Appendix A. Supplemental Information

Table A-1. Physical attributes and visitation frequency of monitoring plots in Capitol Reef NP, 2007–2009.

Ecological site*	Allotment	Plot ID	Elevation (m)	Percent slope	Aspect (degrees)	Year visited		
						2007	2008	2009
Semidesert Alkali Sandy Loam	Cathedral/Rock Springs	5	1732	2	280	X	X	X
		11	1721	2	80	X	X	X
		13	1740	0	38	X	X	X
		15	1801	1	100	X	X	X
		22	1618	1	125	X	X	X
		25	1918	1	262	X	X	X
		30	1837	9	330		X	X
		33	1909	15	295		X	X
		34	1870	11	344		X	X
		38	1846	5	8		X	X
	Hartnet	156	1833	0	110	X	X	X
		159	1773	1	322		X	X
		160	1562	5	330		X	X
		167	1680	4	137		X	X
		172	1840	1	304		X	X
		176	1859	3	34		X	X
		179	1830	1	310		X	X
		181	1923	7	10		X	X
		186	1689	4	100		X	X
		190	1849	1	0		X	X
Semidesert Sand	Cathedral/Rock Springs	10	1840	4	45	X	X	X
Semidesert Sandy Loam	Cathedral/Rock Springs	1	1837	2	312	X	X	X
		3	1824	1	44	X	X	X
		7	1837	8	217	X	X	X
		9	1964	3	100	X	X	X
		16	1910	3	150	X	X	X
		17	1623	0	145	X	X	X
		20	1841	9	150	X	X	X
		21	1852	1	260	X	X	X
		23	1860	4	270	X	X	X
		26	1867	2	158		X	X
	Hartnet	153	1828	1	16		X	X
		162	1598	5	110		X	X
		165	1693	2	197		X	X
		169	1861	10	92	X	X	X
		173	1887	1	73	X	X	X
		174	1520	1	220		X	X
		178	1787	3	70		X	X
		183	1867	3	157		X	X
		185	1875	4	82		X	X
		192	1678	5	340		X	X

Table A-1. Physical attributes and visitation frequency of monitoring plots in Capitol Reef NP, 2007–2009, cont.

Ecological site*	Allotment	Plot ID	Elevation (m)	Percent slope	Aspect (degrees)	Year visited		
						2007	2008	2009
Semidesert Stony Loam	Hartnet	384	1900	8	360		X	X
		386	1615	6	105		X	X
		387	1614	3	100		X	X
		388	1780	14	260		X	X
		389	1958	3	10		X	X
		395	1885	3	120		X	X
		399	1777	25	120		X	X
		400	1869	34	90		X	X
		404	1898	0	0		X	X
		406	1963	2	277		X	X
Semidesert Very Steep Stony Loam	Hartnet	376	1936	10	330		X	X
		378	1819	21	350		X	X
		382	1745	22	240		X	X
		385	1918	10	108		X	X
		394	1886	29	290		X	X
		397	1938	31	250		X	X
		401	1882	26	340		X	X
		403	1634	25	330		X	X
		405	1961	6	240		X	X
		409	1769	26	290		X	X

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

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