



Integrated Upland Monitoring in Capitol Reef National Park

Annual Report 2008

Natural Resource Technical Report NPS/NCPN/NRTR—2009/237



ON THE COVER

Grassland in the South Desert, Capitol Reef National Park. NPS/D. Witwicki.

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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 for vegetation and soil attributes. This information will help to determine natural variability of upland resources and provide early warning of resource degradation.

This report summarizes the NCPN upland monitoring effort in Capitol Reef National Park during 2008. This report outlines the goals and objectives of NCPN upland monitoring, methods of the monitoring protocol, and procedures for defining and mapping target populations for monitoring, as well as the results of this year's efforts and plans for future monitoring.

In previous discussions with park resource staff, it was determined that monitoring natural and grazed grassland systems in the northern portion of the park was an important 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) will be monitored for three consecutive years, after which an operational survey design will be determined based on minimum detectable change and variability. 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.

Measures were summarized by allotment for each ecological site type and are provided in this report. The only statistical assessment performed was an ordination of vegetation cover. Results of this ordination indicated good separation of plots between deep alluvial grassland site types and deep stony grassland site types.

In 2008, NCPN refined its vegetation sampling methods to include (1) cover of plant species and surface features using a point-intercept method, and (2) shrub and exotic perennial species density using a belt transect. The change in methods is described in this annual report, and it is noted where the change might affect comparison with the previous year's data. All plots established in 2007 were sampled using both the old and new methods so that previously collected data can be properly compared with data collected using the new methods.

Future monitoring activities include (1) re-measuring the 61 existing plots in 2009 and (2) formulating an operational survey design 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. The full monitoring design will be implemented in 2010.

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 vegetation composition and structure, and recovery to pre-disturbance 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 alter 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 those 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 yet 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 et al. (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 2.1.1). 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 2.1.1). 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 of the transects using

line-intercept methods. Six surface-soil samples were taken along each of the transects to assess soil-aggregate stability. All measures recorded along transects were sub-samples scaled to the

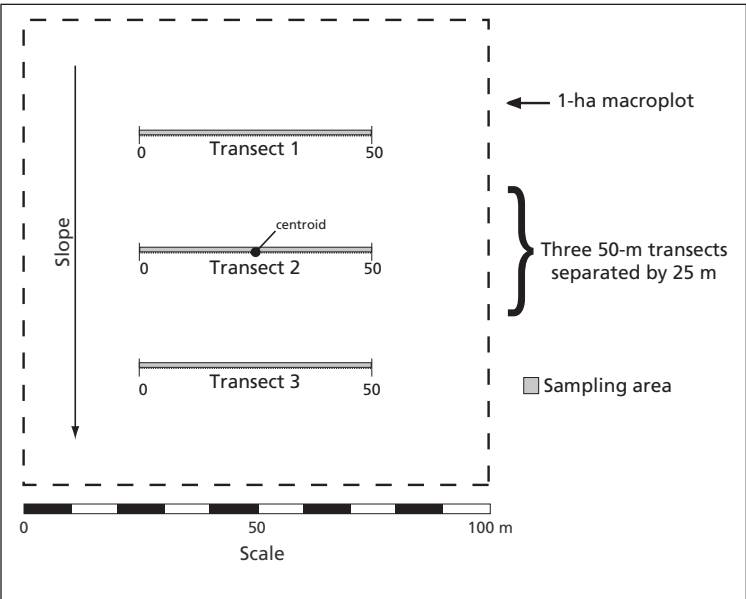


Figure 2.1.1. Standard macroplot and transect layout for upland monitoring of grasslands and shrublands.

Table 2.1.1. Plot-level measures.

Measure	Attribute or context	Spatial scale(s) of observation
Percent cover	Individual plant species 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, motor vehicle tracks, other) Life form (trees, shrubs, annual and perennial grasses, forbs/herbs)	Point-intercept along all three transects (150 m)
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 three 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

used in summaries and statistical analyses. Observations of disturbances on and around the site were also recorded.

Point-intercept cover and density in 1 × 50-m belts were added in 2008, as a way to improve efficiency and repeatability of vegetation sampling. These methods will replace quadrats, which were used to measure frequency, cover, and shrub density in 2007. This year, all plots were sampled using quadrats in addition to point-intercept cover and density in 1 × 50-m belts. This will allow a comparison between the two methods. Quadrats were not used to sample new plots established in 2008.

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, land-form, 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.

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 collec-

tively 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 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.

2.2.2.2 Selection of target ecological-site types

Ecological-site types 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 consisted of Semidesert Alkali Sandy Loam, Semidesert Sand, and Semidesert Sandy Loam. The deep stony grassland group included Semidesert Stony Loam and Semidesert Very Steep Stony Loam (Table 2.2.2.2, Figure 2.2.2.2). Collectively, the target ecological-site types account for about 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. in review). Deep alluvial/eolian

grasslands were sampled in the Cathedral and Rock Springs allotments and in the Harnet allotment. Deep stony 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 2.1.1). Anticipating 30–50 plots per ecological site and to accommodate rejection, 150 plots 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), then the next sequentially ordered plot 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. These plots will be used for three years of pilot monitoring, and the variance 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 stored with the Access database on NCPN servers.

Table 2.2.2.2. Description of ecological sites selected for monitoring in Capitol Reef National Park.

Ecological site name/notation	Physiognomic type	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Deep Alluvial/Eolian 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 pricklypear. 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 green ephedra	Decreased bunchgrass and saltbush and increased snakeweed, pricklypear, 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 green ephedra	Decreased bunchgrass and increased snakeweed, green ephedra, and pricklypear. Cheatgrass and Russian thistle may invade.
Deep Stony Grassland					
Semidesert Stony Loam (shadscale) SDStL242	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 Mormon tea, Bigelow's sagebrush, winterfat, and Indian ricegrass	Decreased Indian ricegrass, Torrey's Mormon tea, and Bigelow's sagebrush and increased galleta, shadscale, and snakeweed. Cheatgrass and juniper may invade.
Semidesert Very Steep Stony Loam (Salina wildrye) SDVStL260	Herbaceous	Deep stony loams on steep remnant hillsides	Basalt glacial outwash over sandstone and shale residuum	Dominated by Indian ricegrass, shadscale, Torrey's Mormon tea, Bigelow's sagebrush, and Salina wildrye	Decreased Indian ricegrass, Torrey's Mormon tea, and Bigelow's sagebrush and increased galleta, snake-weed, and juniper. Cheatgrass and halogeton may invade.



Figure 2.2.2.2. Examples of ecological sites monitored in Capitol Reef National Park. See Table 2.2.2.2 for description of ecological sites.

3 Results

3.1 Plots Established and Monitored

Upland monitoring was initiated in Capitol Reef National Park 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 2008, when the remaining 42 plots were established and sampled, for a total of 61 plots. A total of 10 plots were established for each ecological site except Semidesert Sand (Figure 3.1). Table 3.1 summarizes plot visits by ecological site, allotment, and year.

3.2 Ecological Site Summaries

Status and trend assessments are more meaningful after many years of monitoring and as the number of 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 2.1.1 were generated for each monitoring plot, then summarized by ecological site and allotment. Ecological site summaries are the mean and range (minimum, maximum) for a measured attribute. The plot-level percent cover of all live species recorded for each plot is included as an electronic appendix that accompanies this report (care08_species.xls).

Given the limited data, measures were not statistically compared among ecological sites. Even qualitative assessments of summary measures could be misleading given the small sample sizes and differences in sample sizes. 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. Data from 2008 were ordinated using NMS (non-metric multidimensional scaling), which involves scaling plots on the basis of similarity (or dissimilarity) of species composition (see Section 3.2.9). Plots are distributed in multivariate space, typically along 1–3 axes, and correlations of species with plot distributions identify reasons for the dispersion of plots in this space.

Table 3.1. Number of plots monitored in Capitol Reef National Park by ecological site and allotment, 2007–2008.

	Cathedral/ Rock Springs		Hartnet	
	2007	2008	2007	2008
Deep Alluvial/Eolian Grassland				
Semidesert Alkali Sandy Loam	6	10	1	10
Semidesert Sand	1	1	0	0
Semidesert Sandy Loam	9	10	2	10
Deep Stony Grassland				
Semidesert Stony Loam	n/a	n/a	0	10
Semidesert Very Steep Stony Loam	n/a	n/a	0	10

See Table 2.2.2.2 for description of ecological sites.

3.2.1 Species richness

Reported species richness, illustrated in Table 3.2.1, was noticeably lower in 2008 than in 2007, but this is an artifact of the change in sampling method from quadrats to point-intercept. Species richness data collected using these different methods is not comparable. Point-intercept sampling records cover of dominant species on plots, while (previously used) quadrat sampling records cover of a much greater area of each plot and records infrequently detected species. Recorded species were compared to the NPSpecies database to determine first-time observations in Capitol Reef NP; no new species were detected in 2008.

Table 3.2.1. Mean (range) number of plant species detected per monitoring plot by ecological-site type and allotment, Capitol Reef National Park, 2008.

Ecological site	Allotment	No. of plots	No. of species detected
Deep Alluvial/Eolian Grassland			
Semidesert Alkali Sandy Loam	Cathedral/ Rock Springs	10	10 (6–16)
	Hartnet	10	6 (3–11)
Semidesert Sand	Cathedral/ Rock Springs	1	7
Semidesert Sandy Loam	Cathedral/ Rock Springs	10	8 (5–11)
	Hartnet	10	9 (4–12)
Deep Stony Grassland			
Semidesert Stony Loam	Hartnet	10	8 (5–10)
Semidesert Very Steep Stony Loam	Hartnet	10	8 (5–12)

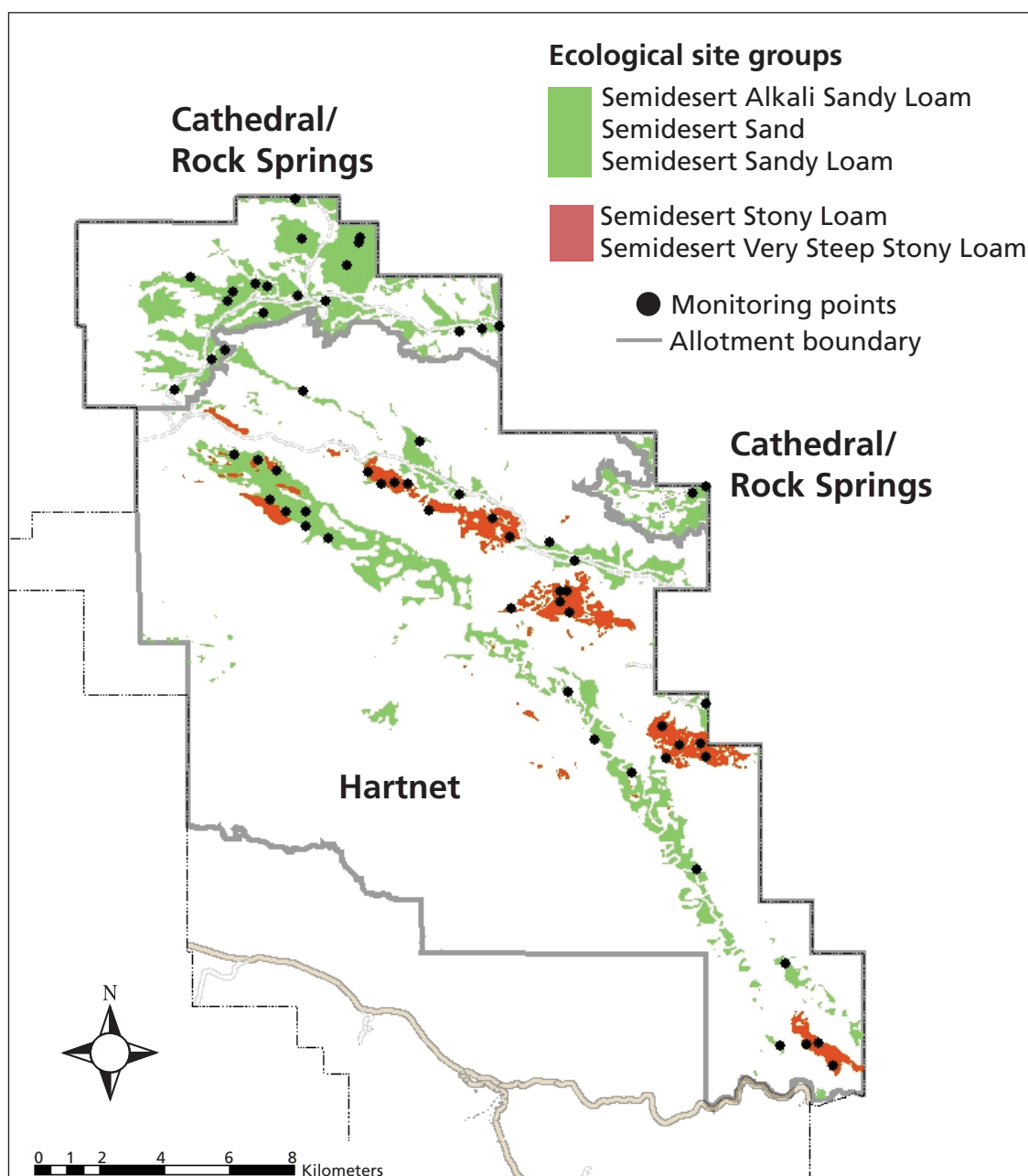


Figure 3.1. Location of pilot monitoring plots in Capitol Reef National Park.

Table 3.2.2-1. Mean (range) percent cover of live vegetation by life form for each ecological-site type and allotment, Capitol Reef National Park, 2008.

Ecological site	Allotment	No. of plots	Tree	Shrubs	Perennial grasses	Annual grasses	Forbs/ Herbs
Deep Alluvial/Eolian Grassland							
Semidesert Alkali Sandy Loam	Cathedral/ Rock Springs	10	0.5 (0–2.7)	7.8 (3.0–20.3)	15.8 (6.0–24.0)	0	0.5 (0–2.0)
	Hartnet	10	0 (0–0)	5.1 (1.0–9.7)	6.1 (0.7–17.7)	0	1.8 (0–8.3)
Semidesert Sand	Cathedral/ Rock Springs	1	0	6.0	18.0	0	0
Semidesert Sandy Loam	Cathedral/ Rock Springs	10	0.1 (0–1.0)	7.7 (2.7–11.3)	15.4 (10.3–25.7)	0	0.1 (0–0.3)
	Hartnet	10	0 (0–0)	6.5 (1.3–11.7)	7.1 (3.3–11.3)	0	0.3 (0–0.7)
Deep Stony Grassland							
Semidesert Stony Loam	Hartnet	10	0.8 (0–3.7)	8.1 (3.3–13.0)	9.9 (5.0–17.3)	0	0.4 (0–2.0)
Semidesert Very Steep Stony Loam	Hartnet	10	3.2 (0–9.0)	4.9 (1.0–11.0)	9.8 (3.3–21.7)	0.03 (0–0.3)	0.5 (0–1.7)

3.2.2 Cover by life form and dominant species

Percent cover of vegetation by life form is shown in Table 3.2.2-1. These values also may vary somewhat from those reported in 2007, due to the change in methods from quadrats to point-intercept sampling. For instance, it is known that point-intercept sampling tends to record a higher cover of grasses than quadrat sampling. Measurements from both methods will be used to provide a cross walk between the two types of sampling.

Cover of dominant live species for each ecological-site type, as measured by the point-intercept method, is shown in Table 3.2.2-2. Dominant species were selected using species predicted by ecological site descriptions and species frequently detected in plots. To allow for comparison across years, the same species are shown for each group of ecological-site types.

3.2.3 Shrub density

Density of shrub species is shown in Table 3.2.3. This year, shrub density was summarized for all plots in an ecological site by allotment.[†] In 2008,

the density of shrubs was recorded in three 50 × 1-m² belts instead of 15 quadrats of 10-m², so the same areal extent was sampled using both methods. Measurements from both methods will be compared to see if there are differences in detection between the two sampling frames.

3.2.4 Exotic species

Cover of exotic plant species is shown in Table 3.2.4. This year, when exotic species were detected, cover was summarized for all plots in the ecological site by allotment.[†]

The only exotic species detected were in the Semidesert Alkali Sandy Loam and Semidesert Sandy Loam plots of the Hartnet allotment. Only exotic annual forbs were detected, including African mustard (*Malcolmia africana*), halogeton (*Halogeton glomeratus*), and Russian thistle (*Sal-sola tragus*). Exotic species were not detected in any other ecological sites, or in the Cathedral/ Rock Springs allotments. No exotic perennial species were detected in the 1-m belts, nor were any exotic annual grass species detected in point-intercept sampling.

[†] In the 2007 report (Garman and Witwicki 2008), plots in which shrub and exotic species were not detected were not included in the averages for shrub density and exotic species. However, because the NCPN desires to know the species average across all plots in a site, rather than the average only across those plots in which shrub/exotic species were detected, density and cover were summarized across all plots in a site in 2008. This change was made to make the data more comparable across years.

Table 3.2.2-2. Mean (range) percent cover of dominant live species by ecological-site type and allotment, Capitol Reef National Park, 2008.

Scientific name	Common name	Life form	Duration	Nativity	Percent cover	
					Cathedral/ Rock Springs	Hartnet
Deep Alluvial/Eolian Grassland						
Semidesert Alkali Sandy Loam						
<i>Bouteloua gracilis</i>	blue grama	Graminoid	Perennial	Native	1.8 (0–9.3)	1.5 (0–15.3)
<i>Chrysothamnus nauseosus</i>	rabbitbrush	Shrub	Perennial	Native	1.8 (0–5.3)	0.1 (0–0.7)
<i>Eriogonum leptocladon</i>	sand wild buckwheat	Shrub	Perennial	Native	0.9 (0–5.7)	0.2 (0–2.0)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf shrub	Perennial	Native	1.6 (0.3–4.3)	0.6 (0–4.3)
<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	1.6 (0.3–4.3)	0.4 (0–1.3)
<i>Muhlenbergia pungens</i>	sandhill muhly	Graminoid	Perennial	Native	0.4 (0–1.7)	1.2 (0–12.0)
<i>Opuntia</i> species	pricklypear	Dwarfshrub	Perennial	Native	0.6 (0–1.3)	0.5 (0–1.3)
<i>Sarcobatus vermiculatus</i>	greasewood	Shrub	Perennial	Native	0.6 (0– 3.0)	0.8 (0–2.7)
<i>Sporobolus airoides</i>	alkali sacaton	Graminoid	Perennial	Native	9.8 (3.7–19.3)	2.0 (0–9.7)
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	2.2 (0.7–4.3)	0.9 (0.7–4.3)
Semidesert Sand						
<i>Bouteloua gracilis</i>	blue grama	Graminoid	Perennial	Native	4.7	–
<i>Chrysothamnus nauseosus</i>	rabbitbrush	Shrub	Perennial	Native	1.3	–
<i>Eriogonum leptocladon</i>	sand wild buckwheat	Shrub	Perennial	Native	3.7	–
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf shrub	Perennial	Native	0	–
<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	0	–
<i>Muhlenbergia pungens</i>	sandhill muhly	Graminoid	Perennial	Native	5.3	–
<i>Opuntia</i> species	pricklypear	Dwarf shrub	Perennial	Native	0	–
<i>Sarcobatus vermiculatus</i>	greasewood	Shrub	Perennial	Native	0	–
<i>Sporobolus airoides</i>	alkali sacaton	Graminoid	Perennial	Native	0.7	–
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	7.3	–
Semidesert Sandy Loam						
<i>Bouteloua gracilis</i>	blue grama	Graminoid	Perennial	Native	5.6 (0–18.0)	1.5 (0–7.3)
<i>Chrysothamnus nauseosus</i>	rabbitbrush	Shrub	Perennial	Native	0.2 (0–2.0)	0.1 (0–0.7)
<i>Eriogonum leptocladon</i>	sand wild buckwheat	Shrub	Perennial	Native	0.2 (0–1.7)	0.5 (0–2.7)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf shrub	Perennial	Native	4.3 (1.3–9.0)	2.6 (0–9.0)
<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	1.8 (0–9.3)	2.4 (0–4.3)
<i>Muhlenbergia pungens</i>	sandhill muhly	Graminoid	Perennial	Native	1.6 (0–6.0)	0.1 (0–0.3)
<i>Opuntia</i> species	pricklypear	Dwarf shrub	Perennial	Native	0.4 (0–1.0)	0.1 (0–1.0)
<i>Sarcobatus vermiculatus</i>	greasewood	Shrub	Perennial	Native	0.3 (0–1.3)	0.4 (0–2.7)
<i>Sporobolus airoides</i>	alkali sacaton	Graminoid	Perennial	Native	2.4 (0–8.0)	0.8 (0–2.7)
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	3.9 (0.3–8.3)	1.9 (0.3–8.3)
Deep Stony Grassland						
Semidesert Stony Loam						
<i>Atriplex confertifolia</i>	shadscale	Shrub	Perennial	Native	–	3.1 (1.3–6.3)
<i>Ephedra torreyana</i>	Torrey’s Mormon tea	Shrub	Perennial	Native	–	2.2 (0–8.3)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf shrub	Perennial	Native	–	1.6 (0–4.0)
<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	–	7.7 (2.0–13.0)
<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	–	0.8 (0–3.7)
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	–	0.3 (0–1.0)

Table 3.2.2-2. Mean (range) percent cover of dominant live species by ecological-site type and allotment, Capitol Reef National Park, 2008, cont.

Scientific name	Common name	Life form	Duration	Nativity	Percent cover	
					Cathedral/ Rock Springs	Hartnet
Semidesert Very Steep Stony Loam						
<i>Atriplex confertifolia</i>	shadscale	Shrub	Perennial	Native	–	1.5 (0–4.3)
<i>Ephedra torreyana</i>	Torrey's Mormon tea	Shrub	Perennial	Native	–	1.2 (0–8.0)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf shrub	Perennial	Native	–	0.9 (0–3.0)
<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	–	7.0 (2.0–17.7)
<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	–	3.0 (0–9.0)
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	–	1.3 (0–8.7)

Table 3.2.3. Mean (range) density of shrub species per 10-m² area by ecological-site type and allotment, Capitol Reef National Park, 2008.

Scientific name	Common name	Cathedral/Rock Springs		Hartnet	
		No. of plots with species present	Density (no. of shrubs/10 m²)	No. of plots with species present	Density (no. of shrubs/10 m²)
Deep Alluvial/Eolian Grassland					
Semidesert Alkali Sandy Loam					
<i>Artemisia bigelovii</i>	Bigelow's sagebrush	3	0.1 (0–0.5)	2	0.2 (0–1.1)
<i>Artemisia filifolia</i>	sand sagebrush	0	0	1	0.01 (0–0.1)
<i>Artemisia tridentata</i>	big sagebrush	1	0.5 (0–4.6)	2	0.1 (0–1.1)
<i>Atriplex canescens</i>	fourwing saltbush	6	0.1 (0–0.5)	4	0.1 (0–0.4)
<i>Atriplex confertifolia</i>	shadscale	4	0.2 (0–1.9)	8	2.5 (0–10.9)
<i>Chrysothamnus linifolius</i>	spear-leaf rabbitbrush	1	0.1 (0–0.8)	0	0
<i>Chrysothamnus nauseosus</i>	rabbitbrush	8	0.6 (0–1.5)	3	0.02 (0–0.1)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	0	0	1	0.01 (0–0.1)
<i>Ephedra torreyana</i>	Torrey's Mormon tea	3	0.1 (0–0.5)	1	0.01 (0–0.1)
<i>Eriogonum corymbosum</i>	crispleaf wild buckwheat	1	0.01 (0–0.1)	0	0
<i>Eriogonum leptocladon</i>	sand wild buckwheat	4	1.0 (0–6.2)	1	0.2 (0–1.9)
<i>Juniperus osteosperma</i>	Utah juniper	1	0.01 (0–0.1)	0	0
<i>Krascheninnikovia lanata</i>	winterfat	3	0.03 (0–0.1)	5	5.5 (0–30.3)
<i>Pinus edulis</i>	two-needle pinyon	1	0.01 (0–0.1)	0	0
<i>Sarcobatus vermiculatus</i>	greasewood	6	0.1 (0–0.6)	4	0.3 (0–1.0)
<i>Suaeda torreyana</i>	Torrey's seepweed	0	0	2	1.5 (0–13.3)
<i>Tetradymia canescens</i>	spineless horsebrush	0	0	1	0.01 (0–0.1)
Semidesert Sand					
<i>Chrysothamnus nauseosus</i>	rabbitbrush	1	1.3	–	–
<i>Eriogonum leptocladon</i>	sand wild buckwheat	1	4.5	–	–
Semidesert Sandy Loam					
<i>Artemisia bigelovii</i>	Bigelow's sagebrush	4	0.4 (0–1.9)	5	0.4 (0–1.5)
<i>Artemisia tridentata</i>	big sagebrush	0	0	3	0.1 (0–0.5)
<i>Atriplex canescens</i>	fourwing saltbush	8	0.5 (0–1.9)	7	0.2 (0–0.7)
<i>Atriplex confertifolia</i>	shadscale	4	0.1 (0–0.5)	8	1.8 (0–7.6)
<i>Chrysothamnus nauseosus</i>	rabbitbrush	4	0.1 (0–1.1)	5	0.1 (0–0.6)
<i>Ephedra torreyana</i>	Torrey's Mormon tea	1	0.2 (0–1.7)	3	0.1 (0–0.7)
<i>Eriogonum leptocladon</i>	sand wild buckwheat	4	0.3 (0–2.8)	3	0.6 (0–4.0)
<i>Grayia spinosa</i>	spiny hopsage	0	0	1	0.01 (0–0.1)
<i>Juniperus osteosperma</i>	Utah juniper	1	0.01 (0–0.1)	1	0.01 (0–0.1)
<i>Krascheninnikovia lanata</i>	winterfat	1	0.01 (0–0.1)	5	0.1 (0–0.2)
<i>Sarcobatus vermiculatus</i>	greasewood	4	0.2 (0–1.0)	3	0.2 (0–1.8)
<i>Shepherdia rotundifolia</i>	roundleaf buffaloberry	1	0.01 (0–0.1)	0	0
<i>Tetradymia canescens</i>	spineless horsebrush	0	0	1	0.01 (0–0.1)
<i>Tetradymia spinosa</i>	shortspine horsebrush	0	0	1	0.03 (0–0.3)

Table 3.2.3. Mean (range) density of shrub species per 10-m² area by ecological-site type and allotment, Capitol Reef National Park, 2008, cont.

Scientific name	Common name	Cathedral/Rock Springs		Hartnet	
		No. of plots with species present	Density (no. of shrubs/10 m²)	No. of plots with species present	Density (no. of shrubs/10 m²)
Deep Stony Grassland					
Semidesert Stony Loam					
<i>Artemisia bigelovii</i>	Bigelow's sagebrush	–	–	4	0.8 (0–7.0)
<i>Atriplex confertifolia</i>	shadscale	–	–	10	5.2 (1.3–14.8)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	–	–	3	0.2 (0–0.9)
<i>Ephedra torreyana</i>	Torrey's Mormon tea	–	–	8	1.0 (0–4.3)
<i>Ephedra viridis</i>	green ephedra	–	–	1	0.01 (0–0.1)
<i>Juniperus osteosperma</i>	Utah juniper	–	–	3	0.1 (0–0.2)
<i>Krascheninnikovia lanata</i>	winterfat	–	–	4	0.1 (0–0.8)
<i>Tetradymia canescens</i>	spineless horsebrush	–	–	4	0.2 (0–0.9)
Semidesert Very Steep Stony Loam					
<i>Artemisia bigelovii</i>	Bigelow's sagebrush	–	–	8	0.8 (0–3.9)
<i>Atriplex confertifolia</i>	shadscale	–	–	9	2.4 (0–5.1)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	–	–	7	0.9 (0–3.5)
<i>Ephedra torreyana</i>	Torrey's Mormon tea	–	–	9	0.8 (0–4.3)
<i>Ephedra viridis</i>	green ephedra	–	–	2	0.01 (0–0.1)
<i>Fraxinus anomala</i>	singleleaf ash	–	–	1	0.01 (0–0.1)
<i>Juniperus osteosperma</i>	Utah juniper	–	–	9	0.2 (0–0.5)
<i>Krascheninnikovia lanata</i>	winterfat	–	–	4	0.1 (0–0.5)
<i>Pinus edulis</i>	two-needle pinyon	–	–	2	0.01 (0–0.1)
<i>Suaeda torreyana</i>	Torrey's seepweed	–	–	1	0.3 (0–2.7)
<i>Tetradymia canescens</i>	spineless horsebrush	–	–	3	0.03 (0–0.2)

Table 3.2.4. Mean (range) live exotic plant species detected in Hartnet Allotment, Capitol Reef NP, 2008.

Scientific name	Common name	Life form	Duration	No. of plots with exotic species detected	Mean (range) percent cover
Deep Alluvial/Eolian Grassland					
Semidesert Alkali Sandy Loam					
<i>Malcolmia africana</i>	African mustard	Forb	Annual	2	1.4 (0–8.3)
<i>Halogeton glomeratus</i>	Halogeton	Forb	Annual	1	0.03 (0–0.3)
<i>Salsola tragus</i>	Russian thistle	Forb	Annual	1	0.03 (0–0.3)
Semidesert Sandy Loam					
<i>Salsola tragus</i>	Russian thistle	Forb	Annual	1	0.1 (0–0.7)

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

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. With the switch from quadrat to point-intercept sampling, it is even more likely that uncommon exotic species will not be detected in monitoring plots.

3.2.5 Threatened and endangered species

Capitol Reef National Park has documented populations of four threatened or endangered plant species within its borders. None of these species was detected in monitoring plots in 2008, via the point-intercept sampling method. However, the crew encountered numerous rare plants and recorded their locations as specified by park staff.

3.2.6 Biological soil crust and surface features

Biological soil crust and surface-feature cover are shown in Table 3.2.6. Although differences are not necessarily expected between quadrat and point-intercept sampling methods, measurements from both methods will be used to provide a crosswalk between the two types of sampling.

3.2.7 Canopy and basal gaps

Canopy and basal-gap size are shown in Table 3.2.7. These methods did not change between 2007 and 2008.

3.2.8 Soil aggregate stability

Measures of soil aggregate stability are shown in Table 3.2.8. Soil stability numbers range from 1 (least stable) to 6 (most stable) and are correlated with 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 (NMS) ordination was performed using all plots except the single Semidesert Sand plot (Figure 3.2.9). 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 deep stony grassland sites (242 and 260) are separated from the others, with galleta and shadscale as the distinguishing species. Plots of the deep alluvial/eolian grasslands exhibit a high degree of overlap; however, alkali sacaton tended to characterize the Semidesert Alkali Sandy Loam sites, while Indian ricegrass and blue grama tended to characterize the Semidesert Sandy Loam sites. Semidesert Sandy Loam sites were fairly consistent between the Cathedral/Rock Springs and Hartnet allotments. For Semidesert Alkali Sandy Loam, sites in the Cathedral/Rock Springs allotments were fairly consistent, while sites in the Hartnet allotment varied floristically more than any other group.

Table 3.2.6. Mean (range) percent cover of surface features by ecological-site type and allotment, Capitol Reef National Park, 2008.

Ecological site	Allotment	No. of plots	Crust, undifferentiated	Cyano-bacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Deep Alluvial/Eolian Grassland												
Semidesert Alkali Sandy Loam	Cathedral/Rock Springs	10	70.3 (54.0–88.3)	5.5 (0–23.3)	0.2 (0–1.7)	1.2 (0–6.7)	9.1 (1.7–29.3)	2.0 (0–7.3)	0.3 (0–1.7)	3.2 (0–10.7)	0.4 (0–1.7)	0.1 (0–0.7)
	Hartnet	10	73.5 (62.7–94.7)	1.9 (0–11.3)	0 (0–0.3)	0.3 (0–1.0)	12.4 (0–28.0)	2.3 (0–9.3)	0.3 (0–1.0)	5.1 (0–17.3)	0.5 (0–3.7)	0 (0–0)
Semidesert Sand	Cathedral/Rock Springs	1	76.7	6.7	0.3	0.3	6.7	0	0.7	0.3	0	0
Semidesert Sandy Loam	Cathedral/Rock Springs	10	64.4 (29.0–92.0)	6.0 (0.3–12.3)	0.3 (0–2.7)	0.3 (0–1.7)	16.5 (0.3–58.0)	1.7 (0–6.7)	0.1 (0–0.7)	2.5 (0–11.7)	0.3 (0–2.0)	0 (0–0)
	Hartnet	10	75.9 (61.7–91.0)	0.3 (0–2.0)	0 (0–0)	0.3 (0–1.0)	10.1 (1.7–22.3)	1.9 (0–8.0)	0.1 (0–0.3)	6.9 (0–22.0)	0.3 (0–1.3)	0 (0–0)
Deep Stony Grassland												
Semidesert Stony Loam	Hartnet	10	37.3 (9.7–59.3)	0.2 (0–1.3)	0.1 (0–0.3)	0.8 (0–2.7)	2.4 (0–6.0)	9.3 (6.0–14.0)	0.1 (0–0.7)	34.2 (15.3–47.3)	10.7 (0–39.0)	0 (0–0)
Semidesert Very Steep Stony Loam	Hartnet	10	21.4 (6.0–45.7)	0.3 (0–1.7)	0.6 (0–2.3)	0.6 (0–2.7)	3.7 (0.3–20.3)	9.0 (0–14.3)	0.3 (0–0.7)	35.3 (20.7–50.0)	24.3 (11.3–38.7)	0.5 (0–3.0)

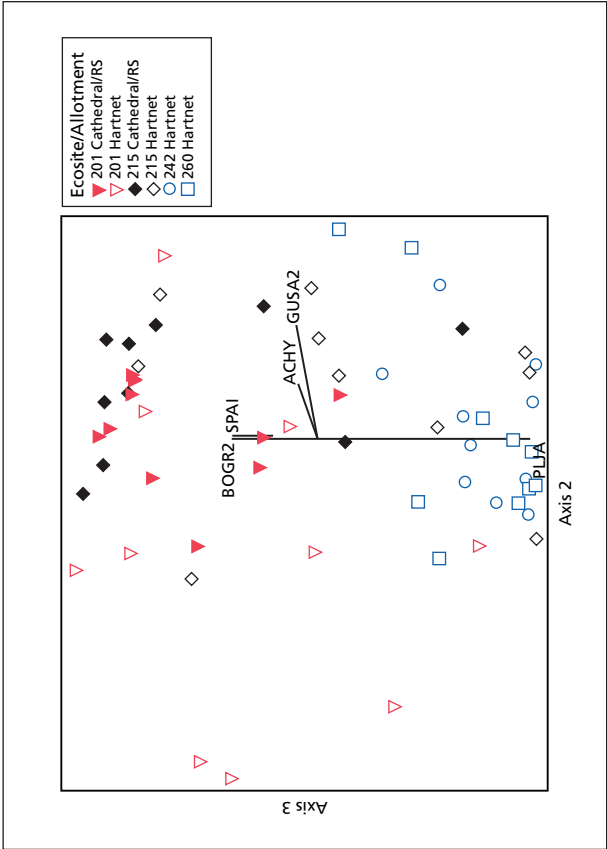
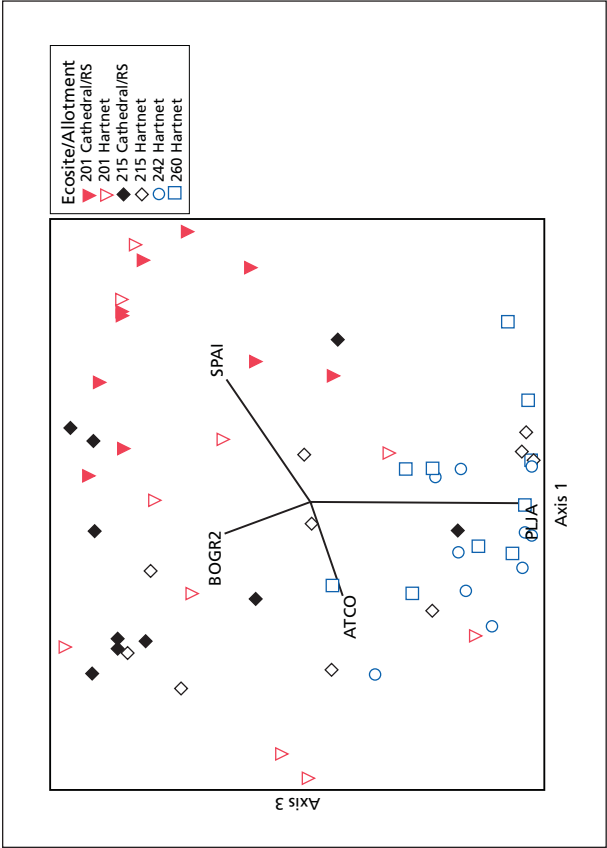
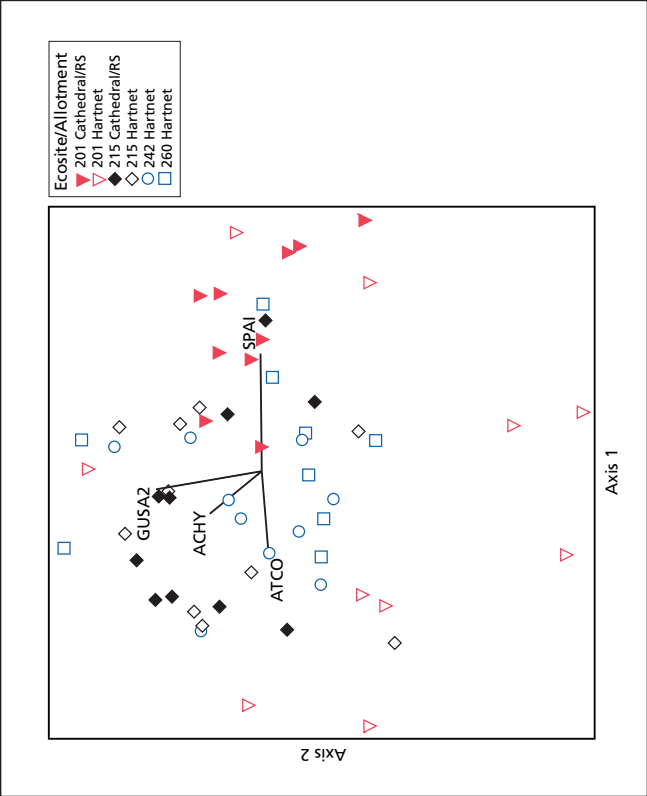
Table 3.2.7. Mean (range) canopy and basal gap size by ecological-site type and allotment, Capitol Reef National Park, 2008.

Ecological site	Allotment	No. of plots	Canopy gap (cm)	Basal gap (cm)
Deep Alluvial/Eolian Grassland				
Semidesert Alkali Sandy Loam	Cathedral/Rock Springs	10	111 (82–184)	179 (112–319)
	Hartnet	10	222 (75–454)	312 (91–534)
Semidesert Sand	Cathedral/Rock Springs	1	100	117
Semidesert Sandy Loam	Cathedral/Rock Springs	10	82 (53–121)	118 (72–151)
	Hartnet	10	150 (79–266)	225 (136–446)
Deep Stony Grassland				
Semidesert Stony Loam	Hartnet	10	96 (63–132)	154 (87–218)
Semidesert Very Steep Stony Loam	Hartnet	10	116 (67–173)	194 (92–389)

Table 3.2.8. Mean (range) soil-aggregate stability measures by ecological site and allotment, Capitol Reef National Park, 2008.

Ecological site	Allotment	No. of plots	Total	Protected	Unprotected
Deep Alluvial/Eolian Grassland					
Semidesert Alkali Sandy Loam	Cathedral/Rock Springs	10	3.1 (1.9–4.3)	3.8 (1.8–5.1)	2.8 (1.9–3.7)
	Hartnet	10	2.9 (1.4–4.8)	3.6 (1.0–5.3)	2.8 (1.4–5.2)
Semidesert Sand	Cathedral/Rock Springs	1	3.4	3.3	3.6
Semidesert Sandy Loam	Cathedral/Rock Springs	10	3.5 (2.2–4.7)	3.9 (2.4–5.4)	3.2 (1.8–5.3)
	Hartnet	10	2.4 (1.2–3.1)	2.8 (2.0–3.7)	2.4 (1.1–3.5)
Deep Stony Grassland					
Semidesert Stony Loam	Hartnet	10	2.9 (1.7–4.6)	3.9 (2.3–6.0)	2.5 (1.5–4.4)
Semidesert Very Steep Stony Loam	Hartnet	10	3.0 (1.5–4.0)	3.6 (1.5–5.0)	2.7 (1.0–3.8)

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



Species codes		
Code	Scientific name	Common name
ACHY	<i>Stipa hymenoides</i>	Indian ricegrass
ATCO	<i>Atriplex confertifolia</i>	shadscale
BOGR2	<i>Bouteloua gracilis</i>	blue grama
GUSA2	<i>Gutierrezia sarothrae</i>	snakeweed
PLJA	<i>Hilaria jamesii</i>	galleta
SPAI	<i>Sporobolus airoides</i>	alkali sacaton

Ecological site codes		
System	Code	Ecological-site type
Deep alluvial/eolian grassland	201	Semidesert Alkali Sandy Loam
	215	Semidesert Sandy Loam
Deep stony grassland	242	Semidesert Stony Loam
	260	Semidesert Very Steep Stony Loam

Figure 3.2.9. Non-metric multidimensional scaling ordination of plots from the four ecological-site types monitored in Capitol Reef National Park, 2008.

4 Discussion

In 2009, NCPN crews will revisit the 61 established plots. In winter 2009–2010, pilot monitoring data will be analyzed for estimates of variance components. These components will serve as the basis for determining our ability to detect a minimum trend and will be used to evaluate operational survey designs. Determining a minimum detectable change level is problematic, as it per-

tains to ecological thresholds and management assessment points, and quantitative measures for both of these are difficult to ascertain. However, conservative estimates will be generated and used in concert with the empirical variance estimates to evaluate the necessary number of sample units and a revisit design. Recommendations for an operational survey design will be presented to Capitol Reef National Park resource staff for discussion and eventual approval.

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Appendix A. Supplemental Information

Table A. Physical attributes and visitation frequency of monitoring plots in Capitol Reef National Park, 2007–2008.

Ecological site	Allotment	Plot ID	Elevation (m)	Percent slope	Aspect (degrees)	Year visited	
						2007	2008
Deep Alluvial/Eolian Grassland							
Semidesert Alkali Sandy Loam	Cathedral/ Rock Springs	5	1,732	2	280	X	X
		11	1,721	2	80	X	X
		13	1,740	0	38	X	X
		15	1,801	1	100	X	X
		22	1,618	1	125	X	X
		25	1,918	1	262	X	X
		30	1,837	9	330		X
		33	1,909	15	295		X
		34	1,870	11	344		X
		38	1,846	5	8		X
	Hartnet	156	1,833	0	110	X	X
		159	1,773	1	322		X
		160	1,562	5	330		X
		167	1,680	4	137		X
		172	1,840	1	304		X
		176	1,859	3	34		X
		179	1,830	1	310		X
		181	1,923	7	10		X
		186	1,689	4	100		X
		190	1,849	1	0		X
Semidesert Sand	Cathedral/ Rock Springs	10	1,840	4	45	X	X
Semidesert Sandy Loam	Cathedral/ Rock Springs	1	1,837	2	312	X	X
		3	1,824	1	44	X	X
		7	1,837	8	217	X	X
		9	1,964	3	100	X	X
		16	1,910	3	150	X	X
		17	1,623	0	145	X	X
		20	1,841	9	150	X	X
		21	1,852	1	260	X	X
		23	1,860	4	270	X	X
		26	1,867	2	158		X
	Hartnet	153	1,828	1	16		X
		162	1,598	5	110		X
		165	1,693	2	197		X
		169	1,861	10	92	X	X
		173	1,887	1	73	X	X
		174	1,520	1	220		X
		178	1,787	3	70		X

Table A. Physical attributes and visitation frequency of monitoring plots in Capitol Reef National Park, 2007–2008, cont.

Ecological site	Allotment	Plot ID	Elevation (m)	Percent slope	Aspect (degrees)	Year visited	
						2007	2008
Semidesert Sandy Loam	Hartnet	183	1,867	3	157		X
		185	1,875	4	82		X
		192	1,678	5	340		X
Deep Stony Grassland							
Semidesert Stony Loam	Hartnet	384	1,900	8	360		X
		386	1,615	6	105		X
		387	1,614	3	100		X
		388	1,780	14	260		X
		389	1,958	3	10		X
		395	1,885	3	120		X
		399	1,777	25	120		X
		400	1,869	34	90		X
		404	1,898	0	0		X
		406	1,963	2	277		X
Semidesert Very Steep Stony Loam	Hartnet	376	1,936	10	330		X
		378	1,819	21	350		X
		382	1,745	22	240		X
		385	1,918	10	108		X
		394	1,886	29	290		X
		397	1,938	31	250		X
		401	1,882	26	340		X
		403	1,634	25	330		X
		405	1,961	6	240		X
409	1,769	26	290		X		

See Table 2.2.2.2 for description of ecological sites.

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.

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