



Integrated Upland Monitoring in Canyonlands National Park

Annual Report 2008

Natural Resource Technical Report NPS/NCPN/NRTR—2009/236



ON THE COVER

Pinyon-juniper/blackbrush shrubland in the Needles District, Canyonlands 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 NCPN upland monitoring in Canyonlands National Park (NP) during 2008. It outlines the goals and objectives of NCPN upland monitoring, methods of the 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 2008, the third year of monitoring at Canyonlands NP, three grassland ecological sites and two shrubland ecological sites were monitored in the park's Island in the Sky and Needles districts. To gain understanding of variability, eight monitoring plots per ecological site have been monitored for three consecutive years. For this report, measures were summarized for each ecological site for 2008. The only statistical assessment performed was an ordination of vegetation cover. Results of this ordination indicated good separation of plots among all but two of the ecological sites. However, the two sites that overlap in ordination space are characterized by differences in soils, each with different susceptibility to erosion, and thus warrant separate consideration in terms of long-term monitoring.

In 2008, the 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 data from previous years. In 2008, all plots were sampled using the old and new methods so that previously collected data may be properly compared with data collected using the new methods.

In addition, a power analysis was performed on the three years of pilot data based on minimum detectable change and variability. The results (reported in a separate document) were used to create an operational sampling design for long-term ecological monitoring of uplands in Canyonlands National Park that will be implemented in 2009.

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

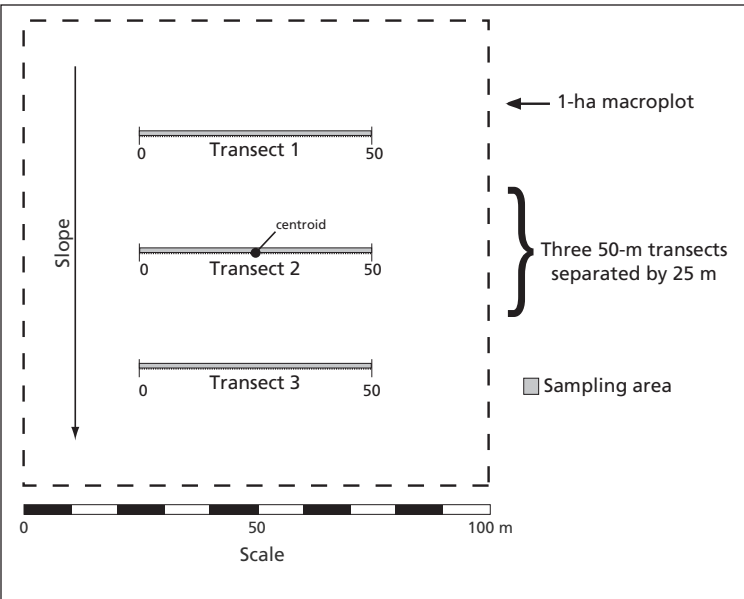


Figure 2.1.1. Standard macroplot and transect layout for upland monitoring of grasslands and shrublands.

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

plot level. The plot-level measures were the primary values used in summaries and statistical analyses. Disturbances observed 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.

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 Canyonlands National Park

2.2.1 Resource issues driving upland monitoring

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

2.2.2 Mapping and selecting target populations

2.2.2.1 Accessibility

Areas that posed safety threats, were inaccessible within budgetary limitations, and/or were

anthropogenic in nature were filtered out of the sampling frame. Areas located on slopes of $\geq 50\%$ and/or isolated by steep slopes were similarly eliminated. Due primarily to costs, areas accessible only by floating the Green and Colorado rivers were also eliminated from consideration. Accessibility and slope features were generated using the Landscape Accessibility Model (<http://science.nature.nps.gov/im/units/ncpn/Tools.cfm>). A 10-m buffer was applied to paved roads and a 50-m buffer applied to dwellings; buffered areas were then eliminated from further consideration. Monitoring near existing social trails, transportation networks, and developments (e.g., campgrounds) was considered acceptable given the emphasis on monitoring the impacts of unauthorized social trails, and the propensity for such trails to emanate from human-use areas. Creating relatively narrow buffer widths and including trails in the spatial data layers also helped accommodate the overarching monitoring goals. These filtering procedures retained 58% (61,048 ha) of the original 104,818-ha area, and provided an accessible-area map.

2.2.2.2 Selection of target ecological-site types

Ecological sites corresponding to grassland and shrubland systems were identified from the Canyonlands Soil Survey (SCS 1991). Given the anticipated limitations of NCPN monitoring (see Section 2.2.3), the four most spatially extensive grassland sites (Desert Sand, Desert Sandy Loam, Semidesert Sand, and Semidesert Sandy Loam) and the two most spatially extensive shrubland sites (Desert Shallow Sandy Loam [Blackbrush] and Semidesert Shallow Sandy Loam [Pinyon-juniper/Blackbrush]) were initially selected as target ecological sites (Table 2.2.2.2). Target grassland sites accounted for approximately 18% of the accessible area, but that 18% accounted for 83% of the accessible land area reported to be grassland. Target shrubland sites comprised approximately 27% of total accessible area, which accounted for 85% of accessible shrubland area.

2.2.2.3 Mapping of target ecological-site types

We used predictive mapping software to map target ecological sites in Canyonlands NP (Figure 2.2.2.2) (Garman 2008; Garman et al. in review). The four grassland ecological sites were included in the map, but Desert Sand was not sampled during pilot monitoring due to low spatial extent across the landscape. The two shrubland ecological sites were also included in the map.

2.2.3 Selection of monitoring locations

Using the predicted ecological-site map, monitoring plots were selected using the Generalized Random Tessellation Stratified (GRTS) method (Stevens and Olsen 2004) to create a spatially balanced design. Coordinates corresponded to the centroid of a site (see Figure 2.1.1). Anticipating an upper limit of 30–50 plots per ecological site and to accommodate rejection, 300 plots were selected per ecological site. An accession order was associated with plots within each site; this order was followed in establishing plots. If a plot was rejected (e.g., due to incorrect ecological-site type), then the next sequentially ordered plot was used. Eight monitoring plots were established for each of the five remaining target ecological sites. Plots were sampled for 2–3 years of pilot monitoring, and variances of measures were 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 GRTS-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 Canyonlands National Park.

Ecological site name/notation	Physiognomic type	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Grassland					
Desert Sand (sand sagebrush) DS115	Herbaceous	Deep sands on dunes and sand sheets	Eolian deposits derived from sandstone	Dominated by Indian ricegrass, dropseeds, and sand sagebrush	Decreased Indian ricegrass, needle-and-thread, dropseeds, and increased sand sagebrush, snakeweed, and low rabbitbrush.
Desert Sandy Loam (fourwing saltbush) DSL118	Herbaceous	Deep sandy loams on mesas, stream terraces, and broad valleys	Alluvium and/or eolian deposits derived from sandstone	Dominated by Indian ricegrass, galleta, dropseeds, and fourwing saltbush	Decreased Indian ricegrass and saltbush and increased snakeweed and Mormon tea. Cheatgrass and Russian thistle may invade.
Semidesert Sand (fourwing saltbush) SDS212	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, 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 Mormon tea	Decreased bunchgrass and increased snakeweed, Mormon tea, and pricklypear. Cheatgrass and Russian thistle may invade.
Blackbrush					
Desert Shallow Sandy Loam (blackbrush) DSSL133	Shrubland	Shallow sandy loams on structural benches and ledges on escarpments	Residuum and eolian deposits from sandstone, limestone, and shale	Dominated by blackbrush	Decreased bunchgrasses and Mormon tea and increased blackbrush and snakeweed. Cheatgrass and Russian thistle may invade.
Pinyon-Juniper/Blackbrush					
Semidesert Shallow Sandy Loam (Utah Juniper-Pinyon) SDSSL236	Shrubland	Shallow sandy loams on benches and mesas	Residuum and/or eolian deposits from sandstone	Dominated by blackbrush, juniper, and pinyon pine	Decreased bunchgrass and increased juniper, blackbrush, and pricklypear. Cheatgrass and annual forbs may invade.



Figure 2.2.2.2. Examples of ecological sites monitored in Canyonlands National Park. See Table 2.2.2.2 for description of ecological site codes.

3 Results

3.1 Monitored Plots

Upland monitoring was initiated at Canyonlands National Park in 2006. One grassland site, Desert Sand, was dropped from consideration in the pilot implementation phase due to extremely low areal extent across the landscape. In fall 2006, 31 plots were established across the remaining five target ecological sites. In spring 2007, these plots were revisited and nine more were established, for a total of eight plots per ecological site (Figure 3.1, next page). All plots were revisited in 2008. Table 3.1 summarizes plot visits by ecological site and year.

3.2 Ecological Site Summaries

Status and trend assessments are more meaningful after many years of monitoring, and as the number of monitoring sites 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. Ecological site summaries are simply a mean and the range (minimum, maximum) for a measured attribute. The percent cover of all live species recorded for each plot is included in an electronic appendix that accompanies this report (cany08_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. 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 2008 were ordinated using NMS (non-metric multidimensional scaling), which involves scaling plots on the basis of similarity (or dissimilarity) of species composition. 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 Canyonlands National Park by ecological site, 2006–2008.

Ecological site	2006 ¹	2007 ²	2008 ³
Grassland			
Desert Sandy Loam	7	8	8
Semidesert Sand	7	8	8
Semidesert Sandy Loam	8	8	8
Blackbrush			
Desert Shallow Sandy Loam	1	8	8
PJ/Blackbrush			
Semidesert Shallow Sandy Loam	8	8	8

¹observations recorded August–September

²observations recorded May–June

³observations recorded April–August

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 are not comparable because point-intercept sampling detects only dominant species on plots, while (previously used) quadrat sampling records cover of a much greater area of each plot and records species that are infrequently detected. Recorded species were compared to the NPSpecies database to determine first-time observations in Canyonlands NP, and no new species were detected in 2008.

Table 3.2.1. Mean and range of the number of plant species detected per monitoring plot for each ecological site, Canyonlands National Park, 2008.

Ecological site	Mean	Range
Grassland		
Desert Sandy Loam	9	(6–16)
Semidesert Sand	11	(8–14)
Semidesert Sandy Loam	10	(8–12)
Blackbrush		
Desert Shallow Sandy Loam	7	(5–9)
PJ/Blackbrush		
Semidesert Shallow Sandy Loam	7	(4–10)

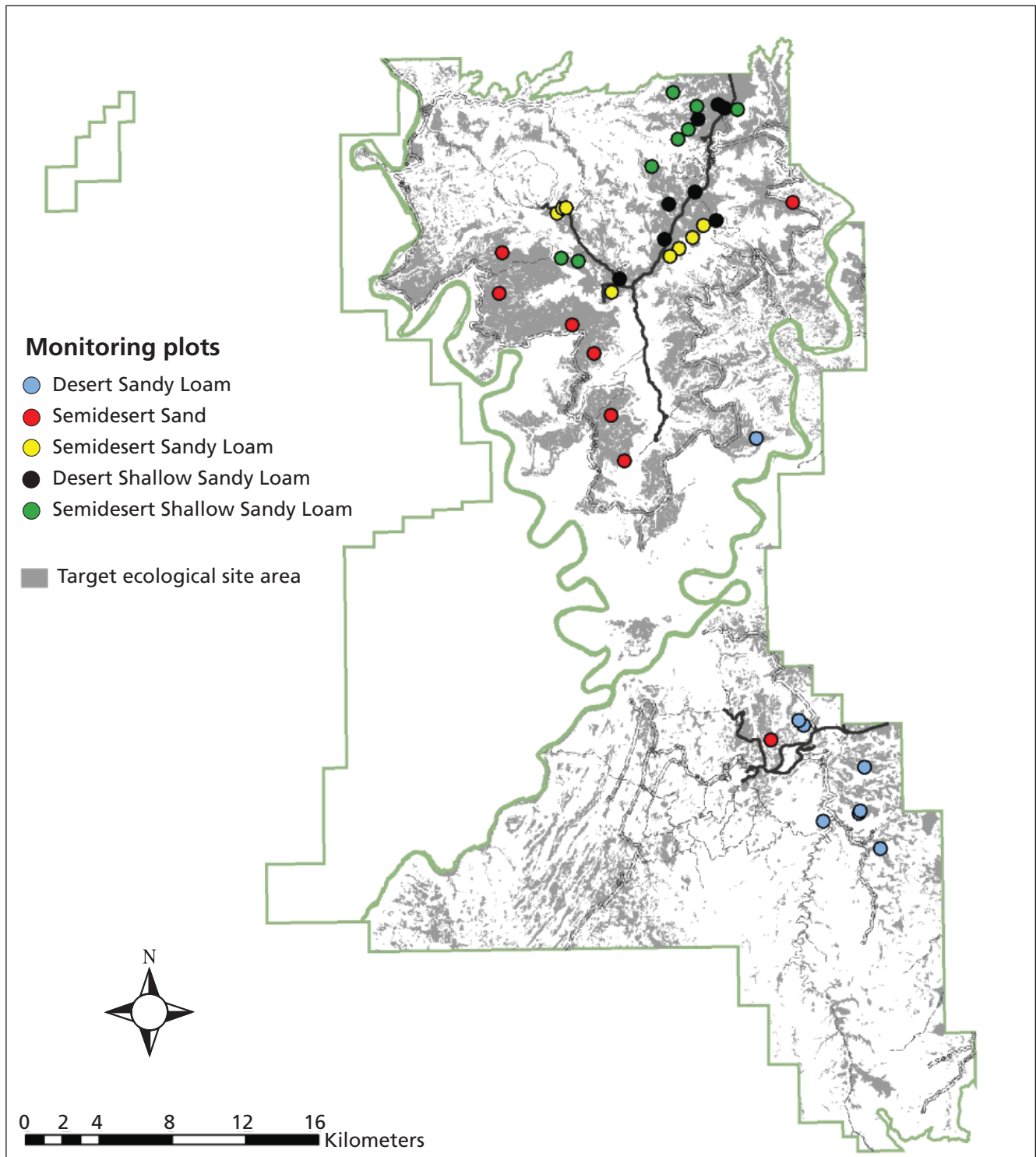


Figure 3.1. Location of pilot monitoring plots in Canyonlands National Park.

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

Ecological site	Tree	Shrubs	Perennial grasses	Annual grasses	Forbs/Herbs
Grassland					
Desert Sandy Loam	0	6.3 (0–19.3)	6.1 (1.0–17.0)	1.7 (0–5.3)	14.7 (0–28.3)
Semidesert Sand	2.5 (0–9.7)	9.9 (3.0–14.0)	11.1 (2.7–23.3)	0.1 (0–0.7)	4.1 (0.7–9.3)
Semidesert Sandy Loam	0.1 (0–1.0)	12.3 (6.7–23.3)	14.8 (4.7–23.3)	0.2 (0–1.3)	2.6 (0.3–9.0)
Blackbrush					
Desert Shallow Sandy Loam	0.4 (0–2.0)	10.3 (4.7–18.3)	2.2 (0–5.7)	0.04 (0–0.3)	1.1 (0.3–1.7)
PJ/Blackbrush					
Semidesert Shallow Sandy Loam	6.0 (0.7–16.0)	10.0 (6.3–16.3)	0.04 (0–0.3)	0	0.2 (0–1.3)

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 crosswalk 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 among 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, rather than only for those plots in which a shrub species was detected.[†] The density of shrubs was recorded in three 50 ×

1-m 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, rather than only for those plots in which the species was detected.[†]

Exotic species were detected most frequently at Desert Sandy Loam grassland sites. Cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola tragus*) were detected at most of these sites, with Russian thistle cover as high as 22.7%. Cheatgrass was also detected at one Semidesert Sandy Loam grassland site and one blackbrush site, but cover was less than 2% at these sites. Additionally, halogeton (*Halogeton glomeratus*) was detected at one blackbrush site. Exotic species were not detected at Semidesert Sand grassland sites or at PJ/blackbrush sites. No exotic perennial species were detected in the 1-m belt.

[†] In the 2007 report (Garman 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, Canyonlands NP, 2008.

Ecological site	Scientific name	Common name	Life form	Duration	Nativity	Percent cover
Grassland						
Desert Sandy Loam	<i>Bouteloua gracilis</i>	blue grama	Graminoid	Perennial	Native	0
	<i>Ephedra viridis</i>	green ephedra	Shrub	Perennial	Native	0
	<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf shrub	Perennial	Native	0.2 (0–1.3)
	<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	2.4 (0–7.7)
	<i>Lappula occidentalis</i>	western stickseed	Forb	Annual	Native	4.0 (0–9.7)
	<i>Opuntia</i> species	pricklypear	Dwarf shrub	Perennial	Native	0.04 (0–0.3)
	<i>Sporobolus cryptandrus</i>	sand dropseed	Graminoid	Perennial	Native	3.1 (0–9.0)
	<i>Stipa comata</i>	needle-and-thread	Graminoid	Perennial	Native	0
	<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	0.5 (0–3.3)
Semidesert Sand	<i>Bouteloua gracilis</i>	blue grama	Graminoid	Perennial	Native	1.8 (0–8.7)
	<i>Ephedra viridis</i>	green ephedra	Shrub	Perennial	Native	5.9 (0.7–10.7)
	<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf shrub	Perennial	Native	0.7 (0–1.7)
	<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	0.04 (0–0.3)
	<i>Opuntia</i> species	pricklypear	Dwarf shrub	Perennial	Native	1.6 (0–3.7)
	<i>Sporobolus cryptandrus</i>	sand dropseed	Graminoid	Perennial	Native	0.8 (0–3.3)
	<i>Stipa comata</i>	needle-and-thread	Graminoid	Perennial	Native	2.8 (0–15.0)
	<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	4.9 (1.0–9.7)
Semidesert Sandy Loam	<i>Bouteloua gracilis</i>	blue grama	Graminoid	Perennial	Native	2.3 (0–9.0)
	<i>Ephedra viridis</i>	green ephedra	Shrub	Perennial	Native	9.2 (5.7–15.7)
	<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf shrub	Perennial	Native	0.3 (0–1.3)
	<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	2.2 (0–6.7)
	<i>Opuntia</i> species	pricklypear	Dwarf shrub	Perennial	Native	1.0 (0–2.7)
	<i>Sporobolus cryptandrus</i>	sand dropseed	Graminoid	Perennial	Native	0.4 (0–1.3)
	<i>Stipa comata</i>	needle-and-thread	Graminoid	Perennial	Native	1.7 (0–6.0)
	<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	7.6 (1.0–17.3)
Blackbrush						
Desert Shallow Sandy Loam	<i>Atriplex confertifolia</i>	shadscale	Shrub	Perennial	Native	2.0 (0–4.3)
	<i>Coleogyne ramosissima</i>	blackbrush	Shrub	Perennial	Native	6.3 (0–15.0)
	<i>Ephedra torreyana</i>	Torrey's Mormon tea	Shrub	Perennial	Native	1.0 (0–2.3)
	<i>Hilaria jamesii</i>	galleta	Graminoid	Perennial	Native	2.1 (0–5.7)
PJ/Blackbrush						
Semidesert Shallow Sandy Loam	<i>Coleogyne ramosissima</i>	blackbrush	Shrub	Perennial	Native	6.4 (0.3–15.0)
	<i>Ephedra viridis</i>	green ephedra	Shrub	Perennial	Native	1.0 (0–2.0)
	<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	2.5 (0–6.0)
	<i>Opuntia</i> species	pricklypear	Dwarf shrub	Perennial	Native	0.5 (0–1.7)
	<i>Pinus edulis</i>	two-needle pinyon	Tree	Perennial	Native	3.5 (0–11.0)

Table 3.2.3. Mean (range) density of shrub species per 10-m² area by ecological site, Canyonlands NP, 2008.

Ecological site	Scientific name	Common name	No. of plots with species present	Density (no. of shrubs/10 m ²)	
				Mean	Range
Grassland					
Desert Sandy Loam	<i>Atriplex canescens</i>	fourwing saltbush	4	0.5	0–1.5
	<i>Atriplex confertifolia</i>	shadscale	1	0.02	0–0.1
	<i>Chrysothamnus nauseosus</i>	rabbitbrush	1	0.01	0–0.1
	<i>Coleogyne ramosissima</i>	blackbrush	2	0.5	0–3.8
	<i>Ephedra torreyana</i>	Torrey's Mormon tea	1	0.1	0–0.8
	<i>Krascheninnikovia lanata</i>	winterfat	2	0.2	0–1.5
	<i>Sarcobatus vermiculatus</i>	greasewood	2	0.03	0–0.1
	<i>Suaeda torreyana</i>	Torrey's seepweed	1	0.05	0–0.4
Semidesert Sand	<i>Atriplex canescens</i>	fourwing saltbush	6	0.1	0–0.3
	<i>Ephedra viridis</i>	green ephedra	6	1.4	0–7.3
	<i>Eriogonum leptocladon</i>	sand wild buckwheat	1	0.01	0–0.1
	<i>Juniperus osteosperma</i>	Utah juniper	2	0.03	0–0.1
	<i>Krascheninnikovia lanata</i>	winterfat	3	0.07	0–0.3
Semidesert Sandy Loam	<i>Atriplex canescens</i>	fourwing saltbush	1	0.01	0–0.1
	<i>Coleogyne ramosissima</i>	blackbrush	2	0.2	0–1.5
	<i>Ephedra viridis</i>	green ephedra	7	6.1	0–9.7
	<i>Juniperus osteosperma</i>	Utah juniper	1	0.01	0–0.1
	<i>Krascheninnikovia lanata</i>	winterfat	2	0.03	0–0.1
Blackbrush					
Desert Shallow Sandy Loam	<i>Amelanchier utahensis</i>	Utah serviceberry	1	0.02	0–0.1
	<i>Artemisia bigelovii</i>	Bigelow's sagebrush	1	0.02	0–0.1
	<i>Atriplex canescens</i>	fourwing saltbush	1	0.01	0–0.1
	<i>Atriplex confertifolia</i>	shadscale	7	1.2	0–2.4
	<i>Chrysothamnus nauseosus</i>	rabbitbrush	3	0.03	0–0.1
	<i>Coleogyne ramosissima</i>	blackbrush	7	2.3	0–3.9
	<i>Ephedra torreyana</i>	Torrey's Mormon tea	7	0.3	0–0.5
	<i>Ephedra viridis</i>	green ephedra	1	0.01	0–0.1
	<i>Eriogonum corymbosum</i>	crispleaf wild buckwheat	1	0.09	0–0.7
	<i>Juniperus osteosperma</i>	Utah juniper	1	0.02	0–0.1
	<i>Rhus trilobata</i>	skunkbush sumac	1	0.01	0–0.1
PJ/Blackbrush					
Semidesert Shallow Sandy Loam	<i>Artemisia bigelovii</i>	Bigelow's sagebrush	1	0.01	0.1
	<i>Cercocarpus intricatus</i>	dwarf mountain mahogany	1	0.03	0–0.2
	<i>Chrysothamnus nauseosus</i>	rabbitbrush	2	0.04	0–0.3
	<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	1	0.04	0–0.3
	<i>Coleogyne ramosissima</i>	blackbrush	7	2.8	0–11.6
	<i>Ephedra torreyana</i>	Torrey's Mormon tea	1	0.03	0.2
	<i>Ephedra viridis</i>	green ephedra	6	0.3	0–1.2
	<i>Eriogonum corymbosum</i>	crispleaf wild buckwheat	1	0.02	0.1

Table 3.2.3. Mean (range) density of shrub species per 10-m² area by ecological site, Canyonlands NP, 2008, cont.

			No. of plots with species present	Density (no. of shrubs/10 m²)	
Ecological site	Scientific name	Common name		Mean	Range
PJ/Blackbrush, cont.					
Semidesert Shallow	Fraxinus anomala	singleleaf ash	3	0.03	0.1
Sandy Loam, cont.	Juniperus osteosperma	Utah juniper	4	0.1	0–0.5
	Pinus edulis	two-needle pinyon	4	0.1	0–0.5
	Purshia mexicana	cliffrose	5	0.2	0–0.5
	Symphoricarpos longiflorus	long-flower snowberry	1	0.01	0.1

Table 3.2.4. Mean (range) live exotic plant species detected in Canyonlands National Park, 2008.

Ecological site	Scientific name	Common name	Life form	Duration	No. of plots with exotic species detected	Mean (range) percent cover*
Grassland						
Desert Sandy Loam	<i>Salsola tragus</i>	Russian thistle	Forb	Annual	6	6.3 (0–22.7)
	<i>Bromus tectorum</i>	Cheatgrass	Graminoid	Annual	7	1.7 (0–4.3)
Semidesert Sandy Loam	<i>Bromus tectorum</i>	Cheatgrass	Graminoid	Annual	1	0.2 (0–1.3)
Blackbrush						
Desert Shallow Sandy Loam	<i>Halogeton glomeratus</i>	Halogeton	Forb	Annual	1	0.1 (0–0.7)
	<i>Bromus tectorum</i>	Cheatgrass	Graminoid	Annual	1	0.04 (0–0.3)

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

NCPN upland sampling methods are not intended to serve 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

Threatened and endangered plant species are not common in the areas of Canyonlands NP monitored by the network, and the NCPN does not specifically monitor them in this park.

3.2.6 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 measurements from 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 reported in Table 3.2.8. 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 (NMS) ordination was performed using live species with relative cover values of $\geq 10\%$ from all plots (Figure 3.2.9). 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 site types and the high degree of overlap between the two semidesert grassland site types. Blackbrush and pinyon-juniper/blackbrush sites are dominated by the species in their vegetation-type names. The Desert Sandy Loam grassland type generally separated from the others along all axes, with plots characterized by sand dropseed, western stickseed, and the exotic, Russian thistle. Semidesert Sand and Sandy Loam grassland types exhibited a high degree of overlap and were characterized by Indian ricegrass (*Stipa hymenoides*) and green ephedra. Overall, ecological sites appeared to be distinctive from a floristic perspective, with the exception of Semidesert Sand and Sandy Loam types. For these two sites, the obvious underlying differences in soil warrants separate consideration, because since the sand site type is expected to be more susceptible to disturbance-induced changes.

Table 3.2.6. Mean (range) percent cover of surface features by ecological site, Canyonlands National Park, 2008.										
Ecological site	Crust, undiffer- entiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Grassland										
Desert Sandy Loam	66.2 (28.3–87.0)	4.8 (0–17.3)	0.9 (0–5.3)	7.6 (0.7–44.3)	10.9 (4.0–17.0)	5.7 (0–16.0)	0.1 (0–0.7)	1.1 (0–5.0)	0	0
Semidesert Sand	52.3 (19.3–74.0)	3.9 (0.3–11.0)	0.1 (0–0.3)	5.6 (0.3–8.7)	19.4 (0–46.7)	11.5 (0.3–27.7)	0.04 (0–0.3)	0.1 (0–1.0)	0	1.1 (0–8.7)
Semidesert Sandy Loam	64.0 (50.0–72.3)	6.3 (0.3–26.3)	0.1 (0–1.0)	15.1 (6.0–23.0)	3.0 (0.3–8.3)	3.9 (0.3–11.7)	0.04 (0–0.3)	0.1 (0–0.3)	0	0
Blackbrush										
Desert Shallow Sandy Loam	27.3 (6.7–69.0)	2.1 (0–15.0)	0.1 (0–0.7)	1.2 (0–6.7)	9.0 (2.0–15.7)	1.9 (0.3–4.3)	0.2 (0–0.7)	51.5 (3.3–73.3)	4.6 (0–12.3)	1.4 (0.3–6.3)
PJ/Blackbrush										
Semidesert Shallow Sandy Loam	44.7 (0–73.7)	9.1 (0–13.7)	1.5 (0–3.0)	4.7 (0.3–14.3)	10.7 (0.7–38.7)	4.3 (0–13.0)	0.5 (0–1.0)	10.1 (2.7–23.7)	2.8 (1.3–5.7)	11.0 (0–29.7)

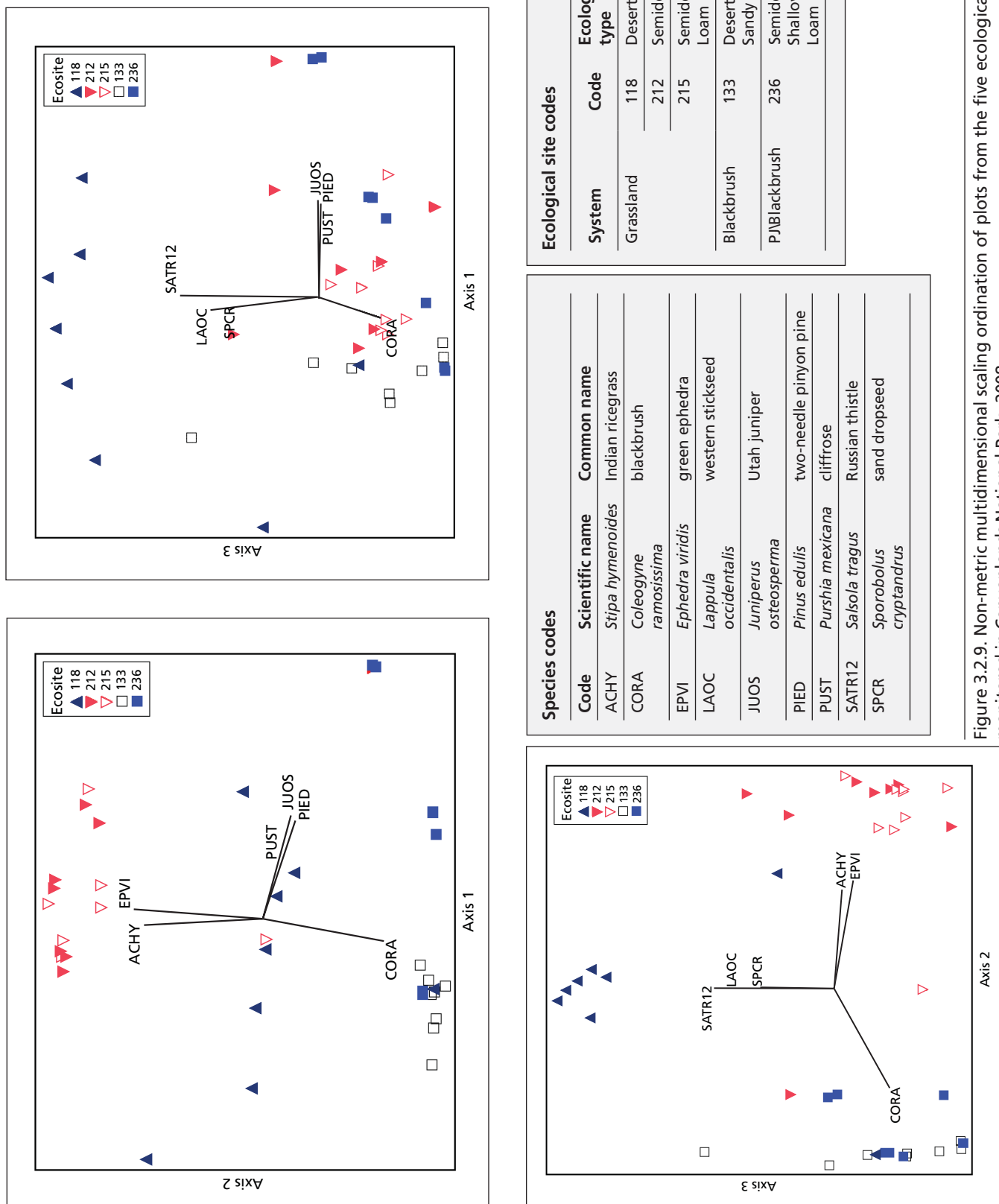
Table 3.2.7. Mean (range) canopy and basal gap size by ecological site, Canyonlands National Park, 2008.

Ecological site	Canopy gap (cm)	Basal gap (cm)
Grassland		
Desert Sandy Loam	410 (83–1,494)	789 (150–2,996)
Semidesert Sand	100 (52–197)	161 (86–244)
Semidesert Sandy Loam	68 (53–91)	113 (85–158)
Blackbrush		
Desert Shallow Sandy Loam	253 (137–315)	520 (308–824)
PJ/Blackbrush		
Semidesert Shallow Sandy Loam	286 (151–366)	589 (302–823)

Table 3.2.8. Mean (range) soil aggregate stability measures by ecological site, Canyonlands National Park, 2008.

Ecological site	Total	Protected	Unprotected
Grassland			
Desert Sandy Loam	4.4 (3.6–5.4)	2.3 (0–5.0)	4.3 (3.4–5.4)
Semidesert Sand	3.1 (1.8–4.1)	3.3 (1.8–4.7)	2.9 (1.6–4.7)
Semidesert Sandy Loam	3.1 (2.1–4.1)	3.7 (2.4–4.8)	2.3 (1.0–3.6)
Blackbrush			
Desert Shallow Sandy Loam	2.0 (1.1–3.9)	2.3 (0–5.0)	1.8 (1.0–3.6)
PJ/Blackbrush			
Semidesert Shallow Sandy Loam	3.4 (1.2–4.6)	4.4 (1.5–6.0)	3.1 (1.2–4.2)

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



4 Discussion

The full operational monitoring design will be implemented in 2009. In winter 2008, 2–3 years of monitoring data were analyzed for estimates of variance. Variance serves as the basis for determining the 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 pertains to ecological thresholds and management assessment points, and quantitative measures for both of these are

difficult to ascertain. However, conservative estimates were 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 were presented to Canyonlands National Park resource staff for discussion and approval in spring 2009. Further 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. Physical attributes and visitation frequency of monitoring plots in Canyonlands National Park, 2006–2008.

Ecological site*	Plot ID	Elevation (m)	Percent slope	Azimuth (degrees)	Year visited		
					2006	2007	2008
Grassland							
Desert Sandy Loam	14	1,474	3	340		X	X
	24	1,471	3	297	X	X	X
	40	1,507	8	290	X	X	X
	52	1,544	2	251	X	X	X
	72	1,469	1	274	X	X	X
	100	1,521	2	312	X	X	X
	148	1,511	1	54	X	X	X
	164	1,521	3	320	X	X	X
Semidesert Sand	10	1,834	6	70	X	X	X
	41	1,871	4	82	X	X	X
	43	1,709	6	100	X	X	X
	69	1,824	5	4	X	X	X
	89	1,861	10	0	X	X	X
	91	1,717	7	211	X	X	X
	155	1,715	4	262	X	X	X
	177	1,843	3	358		X	X
Semidesert Sandy Loam	3	1,836	2	46	X	X	X
	5	1,824	3	102	X	X	X
	9	1,839	5	206	X	X	X
	25	1,808	3	196	X	X	X
	33	1,735	2	350	X	X	X
	37	1,850	5	223	X	X	X
	61	1,768	3	292	X	X	X
	125	1,779	3	274	X	X	X
Blackbrush							
Desert Shallow Sandy Loam	6	1,449	13	275		X	X
	18	1,360	4	280		X	X
	22	1,301	7	198		X	X
	42	1,561	16	346		X	X
	50	1,503	13	298		X	X
	54	1,388	10	316		X	X
	55	1,331	9	306		X	X
	136	1,520	2	56	X	X	X
PJ/Blackbrush							
Semidesert Shallow Sandy Loam	13	1,684	11	176	X	X	X
	66	1,670	3	88	X	X	X
	75	1,724	16	48	X	X	X
	77	1,665	3	290	X	X	X
	93	1,792	20	312	X	X	X
	109	1,726	23	340	X	X	X
	139	1,790	15	40	X	X	X
	157	1,759	10	181	X	X	X

*See Table 2.2.2.2 for description of ecological sites.

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