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Integrated Upland Monitoring in Canyonlands National Park

Annual Report 2009 (Non-sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2010/370.N

ON THE COVER

Grassland and pinyon-juniper/blackbrush shrubland in the Needles District, Canyonlands National Park. NPS/D. Witwicki.

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Contents

Figures v
Tables v
Executive Summary vii

1 Introduction 1

2 Methods 3
2.1 Integrated Upland Monitoring Procedures 3
2.2 Integrated Upland Monitoring in Canyonlands NP 4
2.3 Database 5

3 Results 9
3.1 Monitored Plots 9
3.2 Vegetation Type Summaries 9

4 Discussion 23

5 Literature Cited 25

Figures

Figure 2-1. Standard macroplot and transect layout for upland monitoring of grasslands and shrublands. 3

Figure 2-2. Examples of ecological sites monitored in Canyonlands National Park. 7

Figure 3-1. Location of monitoring plots in Canyonlands National Park, 2009. 10

Figure 3-2. Distribution of canopy gaps for a) grassland, b) blackbrush, and c) PJ/blackbrush sites in Canyonlands NP, 2009. 17

Figure 3-3. Distribution of basal gaps for a) grassland, b) blackbrush, and c) PJ/blackbrush sites in Canyonlands NP, 2009. 18

Figure 3-4. Non-metric multidimensional scaling (NMS) ordination of plots from the six ecological sites monitored in Canyonlands NP, 2009. 19

Tables

Table 2-1. Plot-level measures. 4

Table 2-2. Description of ecological sites selected for monitoring in Canyonlands National Park. 6

Table 3-2. Mean (range) number of plant species detected per monitoring plot by life form and vegetation type, Canyonlands NP, 2009. 12

Table 3-1. Number of plots by vegetation type and ecological site monitored in Canyonlands NP, 2006–2009. 12

Table 3-3. Mean (range) percent cover by life form for each vegetation type, Canyonlands NP, 2009. 13

Table 3-4. Mean (range) percent cover of dominant species by vegetation type, Canyonlands NP, 2009. 13

Table 3-5. Density of shrub species per hectare by vegetation type, Canyonlands NP, 2009. 14

Table 3-6. Mean (range) cover and density of exotic plant species detected in Canyonlands NP, 2009. 15

Table 3-7. Mean (range) percent cover of surface features by vegetation type, Canyonlands NP, 2009. 16

Table 3-8. Mean (range) canopy- and basal-gap size by vegetation type, Canyonlands NP, 2009. 16

Table 3-9. Mean (range) soil-aggregate stability measures by vegetation type, Canyonlands NP, 2009. 16

Executive Summary

The goal of the Northern Colorado Plateau Network (NCPN) integrated upland monitoring effort is to provide park managers with status and trend information on vegetation and soil attributes. This information is intended to determine natural variability of upland resources and provide early warning of resource degradation.

This report summarizes NCPN upland monitoring in Canyonlands National Park (NP) 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 2009, the fourth year of monitoring at Canyonlands NP, the NCPN initiated a long-term operational sampling design. A variance assessment and power analysis was performed on the first three years of monitoring data (Witwicki 2010), and the results were used to develop the long-term revisit design. A total of 46 plots were monitored in the Island in the Sky and Needles districts of the park, including 24 grassland plots, 10 blackbrush plots, and 12 pinyon-juniper/blackbrush plots.

In this report, measures for 2009 were summarized for each vegetation type. An ordination of vegetation cover by species indicated good separation of plots among all vegetation types. The results also illustrated the common species among all four grassland ecological sites and those that characterized desert and semidesert sites. Early monitoring data describe status of vegetation types, and interpretation is limited until additional data are acquired and more rigorously analyzed.

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.

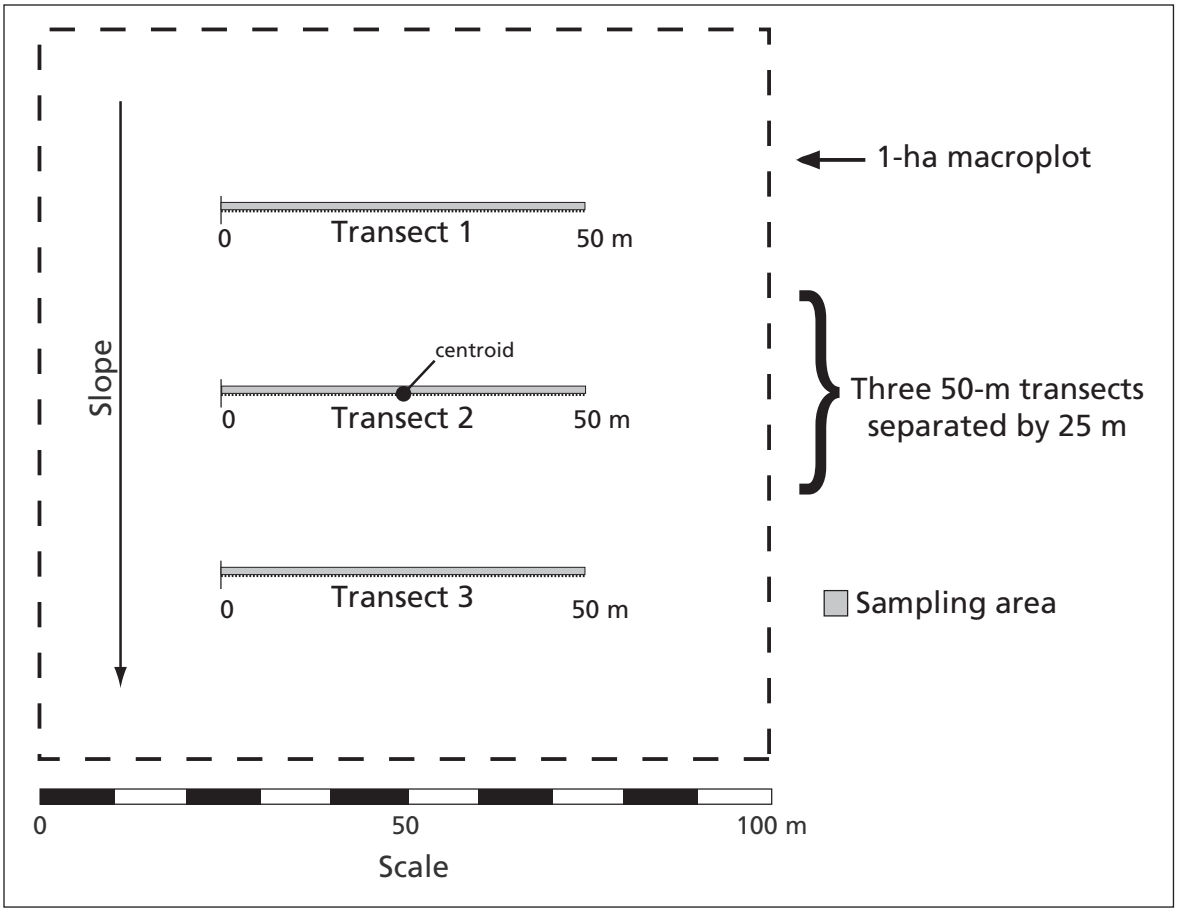


Figure 2-1. Standard macroplot and transect layout for upland monitoring of grasslands and shrublands.

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 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

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.

2.2 Integrated Upland Monitoring in Canyonlands NP

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 50% and/or isolated by steep slopes were eliminated. Due primarily to costs, areas accessible only by floating the Green and Colorado rivers were 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 selected as target ecological sites (Table 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 the six target ecological sites in Canyonlands NP (Garman 2008; Garman et al. 2010).

2.2.3 Selection of monitoring locations

Using the predicted ecological-site map, monitoring plots were selected using the Generalized Random Tessellated Stratified (GRTS) method (Stevens and Olsen 2004) to create a spatially balanced design. Coordinates corresponded to the centroid of a plot (see Figure 2-2). To accommodate rejection, 300 sites were selected per ecological site. Within each ecological site, plots were established in ascending order of plot number. If a plot was rejected (e.g., due to incorrect ecological-site type), the next sequentially ordered plot was used.

2.2.4 Pilot study and revisit design

Upland monitoring was initiated at Canyonlands National Park in 2006. Eight monitoring plots were established for each target ecological site except Desert Sand, which was not sampled during pilot monitoring due to low spatial extent across the landscape. Plots were sampled for 2–3 years and variances of measures were used to evaluate power for trend of potential operational sampling designs. Details of this analysis are provided in Witwicki (2010).

2.2.4.1 Revisit design

Based on the analysis of pilot data, a long-term operational revisit design was created and implemented in 2009. To deal with the cost of sampling extremely remote areas of the park, the sampling frame was further limited to a 4-km hiking distance. The design was based on ecological-site type (also referred to as "vegetation type" in this report), combining similar ecological sites in the sampling frame. All four deep grassland ecological sites were combined into a larger grassland sampling frame. This allowed the number of each grassland ecological site sampled to be determined by its approximate area in the sampling frame. The two shrubland ecological sites remained as separate vegetation types (blackbrush and pinyon-juniper (PJ)/blackbrush) containing one ecological site each.

Each year, 24 grassland, 12 blackbrush, and 12 PJ/blackbrush plots will be monitored. A total of 252 plots will be sampled over a seven-year revisit schedule. Half of the plots will be visited two years in a row and the other half visited only one year before being rested for 5–6 years. This revisit strategy maximizes the ability to detect trends and minimizes the impact on BSCs.

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 and are stored with the Access database on NCPN servers.

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

Vegetation type	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, 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 prickly pear. 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 prickly pear. Cheatgrass and annual forbs may invade.

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

3 Results

3.1 Monitored Plots

In 2009, forty-six plots were monitored as part of the long-term revisit design (Figure 3-1). This included 24 grassland, 10 blackbrush, and 12 PJ/blackbrush plots. Nine grassland plots were revisited, and 37 new plots were established among the three vegetation types. Table 3-1 summarizes plot visits by vegetation type, ecological site, and year.

Twelve monitoring plots were scheduled for monitoring in blackbrush in 2009. However, due to some confusion over site-selection criteria, two plots could not be used for long-term monitoring; therefore, they were not included in this summary.

3.2 Vegetation 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 full 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 vegetation type. Vegetation type summaries are simply a mean and the range (minimum, maximum) for a measured attribute. The percent cover of all species recorded for each plot is included in an electronic appendix that accompanies this report (cany09_species.xls).

Given the limited data, measures were not statistically compared among ecological sites or vegetation types. Even qualitative comparisons of summary measures could be misleading, given the small number of plots visited each year. Comparisons between years may also be misleading, because a different set of plots was visited in 2009 than in previous years. 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, and 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 reported in Table 3-2. Recorded species were compared to the NPSpecies database to determine first-time observations in Canyonlands NP, but 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 are 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 vegetation type are 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 for each vegetation type is shown in Table 3-5. In previous annual reports, shrub density was presented as shrubs/10 m^2. For 2009, we changed the unit to shrubs/ha (or 100 × 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 vegetation type.

Exotic species were detected only at grassland sites. Russian thistle (*Salsola tragus*) was detected at the greatest number of sites, with cover as high as 19.0%. Crested wheatgrass (*Agropyron cristatum*), cheatgrass (*Bromus tectorum*), lambsquarter (*Chenopodium album*), and halogeton (*Halogeton glomeratus*) were also detected at 1–2 grassland sites, but cover was less than 1% at these sites. Crested wheatgrass was the only exotic perennial detected in the 1-m belt, and it was only detected at one plot.

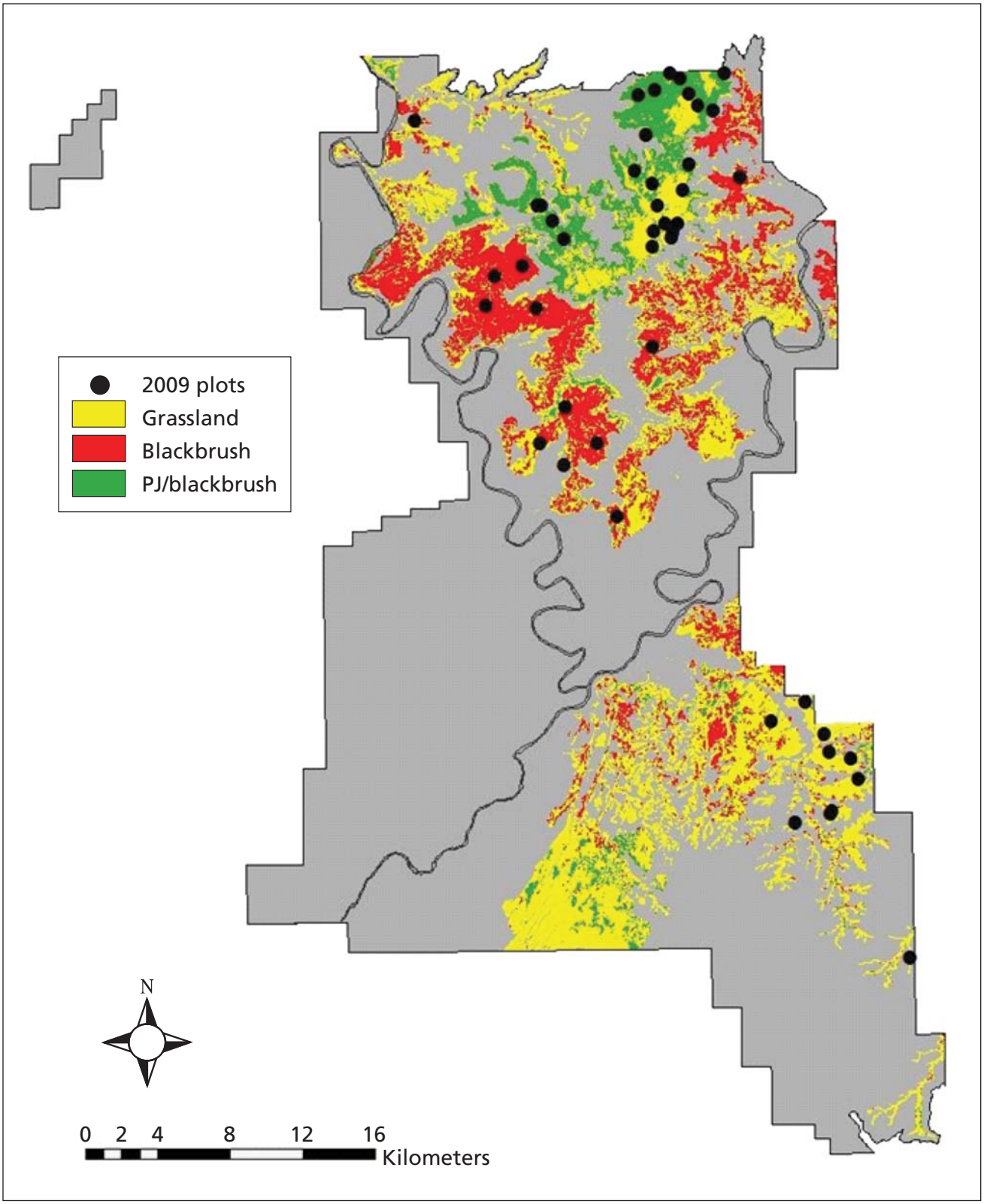


Figure 3-1. Location of monitoring plots in Canyonlands National Park, 2009.

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.

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. No threatened or endangered species were found on any plots in 2009.

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 and 3-3.

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 (NMS) ordination was performed using live species with relative cover values of >10% from all plots (Figure 3-4). 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 vegetation types and the high degree of overlap between the four grassland ecological sites. Blackbrush sites are characterized by blackbrush, Torrey's jointfir, and shadscale. Pinyon-juniper/blackbrush sites are characterized by pinyon pine, Utah juniper, and blackbrush. All grassland sites were associated with Indian ricegrass. The higher semidesert sites were also characterized by needle and thread and Mormon tea. The lower desert sites were additionally characterized by sand dropseed, galleta, and Russian thistle.

Table 3-1. Number of plots by vegetation type and ecological site monitored in Canyonlands NP, 2006–2009.

Vegetation type	Ecological site*	2006 (observations recorded August–September)	2007 (observations recorded May–June)	2008 (observations recorded April–August)	2009 (observations recorded May–June)
Grassland	Desert Sand	0	0	0	1
	Desert Sandy Loam	7	8	8	10
	Semidesert Sand	7	8	8	4
	Semidesert Sandy Loam	8	8	8	9
Blackbrush	Desert Shallow Sandy Loam	1	8	8	10
PJ / Blackbrush	Semidesert Shallow Sandy Loam	8	8	8	12

* See Table 2-1 for description of ecological sites.

Table 3-2. Mean (range) number of plant species detected per monitoring plot by life form and vegetation type, Canyonlands NP, 2009.

	Number of species detected					
Vegetation type	Total	Tree	Shrubs	Perennial grasses	Annual grasses	Forbs/Herbs
Grassland	8.5 (4–18)	0.2 (0–2)	2.6 (0–6)	3.6 (2–6)	0.1 (0–1)	2.0 (0–6)
Blackbrush	6.8 (4–11)	0.1 (0–1)	4.7 (3–8)	0.8 (0–1)	0.1 (0–1)	1.1 (0–4)
PJ / Blackbrush	7.4 (4–12)	1.9 (1–2)	4.8 (2–7)	0.3 (0–1)	0	0.4 (0–3)

Table 3-3. Mean (range) percent cover by life form for each vegetation type, Canyonlands NP, 2009.

Vegetation type	Tree		Shrubs		Perennial grasses		Annual grasses		Forbs/Herbs	
	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total
Grassland	0.5 (0–6.0)	0.5 (0–6.0)	5.9 (0–19.3)	9.3 (0–27.3)	6.4 (1.3–15.3)	16.3 (2.7–37.3)	0	0.04 (0–0.7)	2.2 (0–11.0)	4.2 (0–19.0)
Blackbrush	0.4 (0–3.7)	0.5 (0–5.3)	5.9 (3.0–7.7)	10.1 (7.7–12.7)	0.2 (0–0.7)	0.8 (0–2.0)	0	0.03 (0–0.3)	0.3 (0–1.3)	0.7 (0–2.3)
PJ / Blackbrush	8.4 (1.7–18.0)	9.7 (2.0–19.7)	7.1 (2.3–14.3)	11.5 (4.7–34.3)	0.1 (0–0.3)	0.1 (0–0.7)	0	0	0.1 (0–0.7)	0.1 (0–1.0)

Table 3-4. Mean (range) percent cover of dominant species by vegetation type, Canyonlands NP, 2009.

Vegetation type	Scientific name	Common name	Life form	Duration	Nativity	Percent cover	
						Live	Total
Grassland	*Atriplex canescens*	fourwing saltbush	Shrub	Perennial	Native	0.5 (0–3.0)	0.9 (0–6.0)
	Bouteloua gracilis	blue grama	Graminoid	Perennial	Native	0.6 (0–6.7)	1.6 (0–11.3)
	Ephedra viridis	Mormon tea	Shrub	Perennial	Native	2.8 (0–9.7)	4.2 (0–11.7)
	Gutierrezia sarothrae	broom snakeweed	Dwarf Shrub	Perennial	Native	0.3 (0–2.0)	0.7 (0–4.0)
	Hilaria jamesii	galleta	Graminoid	Perennial	Native	0.8 (0–3.3)	2.2 (0–7.3)
	Opuntia species	pricklypear	Dwarf Shrub	Perennial	Native	0.6 (0–3.7)	0.8 (0–5.3)
	Sporobolus cryptandrus	sand dropseed	Graminoid	Perennial	Native	1.3 (0–9.3)	2.5 (0–13.0)
	Stipa comata	needle and thread	Graminoid	Perennial	Native	1.0 (0–4.3)	3.6 (0–16.7)
	Stipa hymenoides	Indian ricegrass	Graminoid	Perennial	Native	1.1 (0–3.3)	3.3 (0–10.3)
	Stipa species*		Graminoid	Perennial	Native	1.0 (0–6.7)	2.6 (0–18.0)
Blackbrush	*Atriplex confertifolia*	shadscale	Shrub	Perennial	Native	1.1 (0–4.0)	2.9 (0–8.3)
	Coleogyne ramosissima	blackbrush	Shrub	Perennial	Native	2.5 (0.7–6.0)	4.9 (1.7–9.7)
	Ephedra torreyana	Torrey's jointfir	Shrub	Perennial	Native	0.8 (0–2.0)	1.4 (0–2.7)
	Hilaria jamesii	galleta	Graminoid	Perennial	Native	0.1 (0–0.7)	0.8 (0–2.0)
PJ / Blackbrush	*Coleogyne ramosissima*	blackbrush	Shrub	Perennial	Native	4.3 (0.3–9.7)	7.3 (0.3–28.0)
	Ephedra viridis	Mormon tea	Shrub	Perennial	Native	0.6 (0–2.0)	0.7 (0–2.7)
	Juniperus osteosperma	Utah juniper	Tree	Perennial	Native	3.9 (0–8.3)	4.8 (0–10.0)
	Opuntia species	pricklypear	Dwarf Shrub	Perennial	Native	0.7 (0–4.7)	1.0 (0–6.3)
	Pinus edulis	two-needle pinyon	Tree	Perennial	Native	4.5 (0–13.7)	4.9 (0–15.7)

* Flowers or seeds are necessary to distinguish Stipa comata and Stipa hymenoides. Stipa species represents indistinguishable vegetative forms of these two grasses that were detected during upland monitoring.

Table 3-5. Density of shrub species per hectare by vegetation type, Canyonlands NP, 2009.

Vegetation type	Scientific name	Common name	No. of plots with species present	Density (number of shrubs/ha)		
				Mean	Minimum	Maximum
Grassland	*Artemisia filifolia*	sand sagebrush	1	42	0	1,000
	Artemisia tridentata	big sagebrush	1	33	0	800
	Atriplex canescens	fourwing saltbush	13	158	0	933
	Chrysothamnus nauseosus	rubber rabbitbrush	1	3	0	67
	Chrysothamnus viscidiflorus	green rabbitbrush	1	3	0	67
	Coleogyne ramosissima	blackbrush	3	83	0	1,667
	Ephedra torreyana	Torrey's jointfir	1	3	0	67
	Ephedra viridis	Mormon tea	1	11	0	267
	Eriogonum leptocladon	sand wild buckwheat	2	153	0	3,333
	Fraxinus anomala	singleleaf ash	1	3	0	67
	Juniperus osteosperma	Utah juniper	1	3	0	67
	Krascheninnikovia lanata	winterfat	7	281	0	3,867
	Purshia mexicana	cliffrose	1	8	0	200
	Quercus gambelii	Gambel oak	1	17	0	400
	Sarcobatus vermiculatus	greasewood	2	6	0	67
Blackbrush	*Artemisia bigelovii*	Bigelow's sagebrush	2	33	0	200
	Artemisia spinescens	budsage	3	127	0	600
	Atriplex confertifolia	shadscale	9	1,340	0	3,933
	Brickellia microphylla	littleleaf brickellbush	1	7	0	67
	Brickellia oblongifolia	Mojave brickellbush	1	60	0	600
	Chrysothamnus nauseosus	rubber rabbitbrush	3	33	0	200
	Coleogyne ramosissima	blackbrush	10	2,167	533	6,600
	Ephedra torreyana	Torrey's jointfir	10	413	67	733
	Ephedra viridis	Mormon tea	1	7	0	67
	Eriogonum corymbosum	crisp-leaf wild buckwheat	2	47	0	267
	Juniperus osteosperma	Utah juniper	1	7	0	67
	Purshia mexicana	cliffrose	1	7	0	67
	Rhus trilobata	skunkbush sumac	2	60	0	467
PJ / Blackbrush	*Amelanchier utahensis*	Utah serviceberry	1	6	0	67
	Artemisia bigelovii	Bigelow's sagebrush	1	6	0	67
	Atriplex canescens	fourwing saltbush	1	6	0	67
	Cercocarpus intricatus	dwarf mountain mahogany	1	50	0	600
	Chrysothamnus nauseosus	rubber rabbitbrush	6	72	0	267
	Chrysothamnus viscidiflorus	green rabbitbrush	3	17	0	67
	Coleogyne ramosissima	blackbrush	12	2,044	0	4,867
	Ephedra torreyana	Torrey's jointfir	2	11	0	67
	Ephedra viridis	Mormon tea	8	361	0	2,667
	Eriogonum corymbosum	crisp-leaf wild buckwheat	1	11	0	133
	Eriogonum microthecum	slender wild buckwheat	2	22	0	133
	Fraxinus anomala	singleleaf ash	3	17	0	67
	Juniperus osteosperma	Utah juniper	10	94	0	267

Table 3-5. Density of shrub species per hectare by vegetation type, Canyonlands NP, 2009, cont.

Vegetation type	Scientific name	Common name	No. of plots with species present	Density (number of shrubs/ha)		
				Mean	Minimum	Maximum
PJ / Blackbrush, cont.	*Mahonia fremontii*	Fremont's mahonia	2	17	0	133
	Pinus edulis	two-needle pinyon	8	94	0	400
	Purshia mexicana	cliffrose	6	89	0	600
	Symphoricarpos longiflorus	long-flower snowberry	3	28	0	200

Table 3-6. Mean (range) cover and density of exotic plant species detected in Canyonlands NP, 2009.

Vegetation type	Scientific name	Common name	Life form	Duration	No. of plots with exotic species detected	Percent cover*		Density (number of exotic perennials/ha)
						Live	Total	
Grassland	*Agropyron cristatum*	crested wheatgrass	Graminoid	Perennial	1	0.04 (0–1.0)	0.04 (0–1.0)	8.3 (0–200)
	Bromus tectorum	cheatgrass	Graminoid	Annual	2	0	0.04 (0–0.7)	na
	Chenopodium album	lambsquarter	Forb	Annual	1	0.01 (0–0.3)	0.01 (0–0.3)	na
	Halogeton glomeratus	halogeton	Forb	Annual	1	0	0.04 (0-1.0)	na
	Salsola tragus	Russian thistle	Forb	Annual	7	1.3 (0–11.0)	2.3 (0–19.0)	na
Blackbrush	-	-	-	-	0	0	0	na
PJ / Blackbrush	-	-	-	-	0	0	0	na

*Mean and range are based on all plots within a vegetation type where an exotic species was detected.

Table 3-7. Mean (range) percent cover of surface features by vegetation type, Canyonlands NP, 2009.

Vegetation type	Crust, undifferentiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Grassland	49.0 (17.7–69.7)	5.7 (0–41.3)	0.1 (0–1.7)	4.6 (0–20.7)	2.1 (0–25.3)	30.8 (0–52.7)	0.04 (0–1.0)	0.1 (0–3.3)	0.03 (0–0.3)	0
Blackbrush	21.3 (6.3–67.9)	0.03 (0–0.3)	0.03 (0–0.3)	0.5 (0–2.3)	1.0 (0–4.3)	6.3 (4.0–10.7)	0	61.4 (22.3–73.3)	5.5 (0–17.7)	0.5 (0–2.7)
PJ / Blackbrush	41.8 (21.3–68.7)	8.4 (0–27.3)	0.2 (0–1.3)	2.0 (0–6.7)	1.5 (0–9.3)	16.1 (0–29.3)	0.2 (0–2.0)	7.3 (0–19.7)	1.2 (0–10.7)	6.5 (0–38.3)

Table 3-8. Mean (range) canopy- and basal-gap size by vegetation type, Canyonlands NP, 2009.

Vegetation type	Canopy gap (cm)	Basal gap (cm)
Grassland	155 (61–742)	251 (79–1,355)
Blackbrush	342 (239–423)	711 (340–1,356)
PJ / Blackbrush	317 (91–605)	722 (120–1,357)

Table 3-9. Mean (range) soil-aggregate stability measures by vegetation type, Canyonlands NP, 2009.

Vegetation type	Total	Protected*	Unprotected*
Grassland	3.8 (1.7–5.8)	3.8 (0–5.7)	3.6 (1.2–5.8)
Blackbrush	1.6 (1.1–2.3)	2.4 (0–4.4)	1.4 (1.0–2.0)
PJ / Blackbrush	3.9 (1.9–5.4)	4.3 (2.5–6.0)	3.7 (1.8–5.6)

*Protected are samples collected under vegetation; unprotected are samples collected in the open. Numbers range from 1 (least stable) to 6 (most stable).

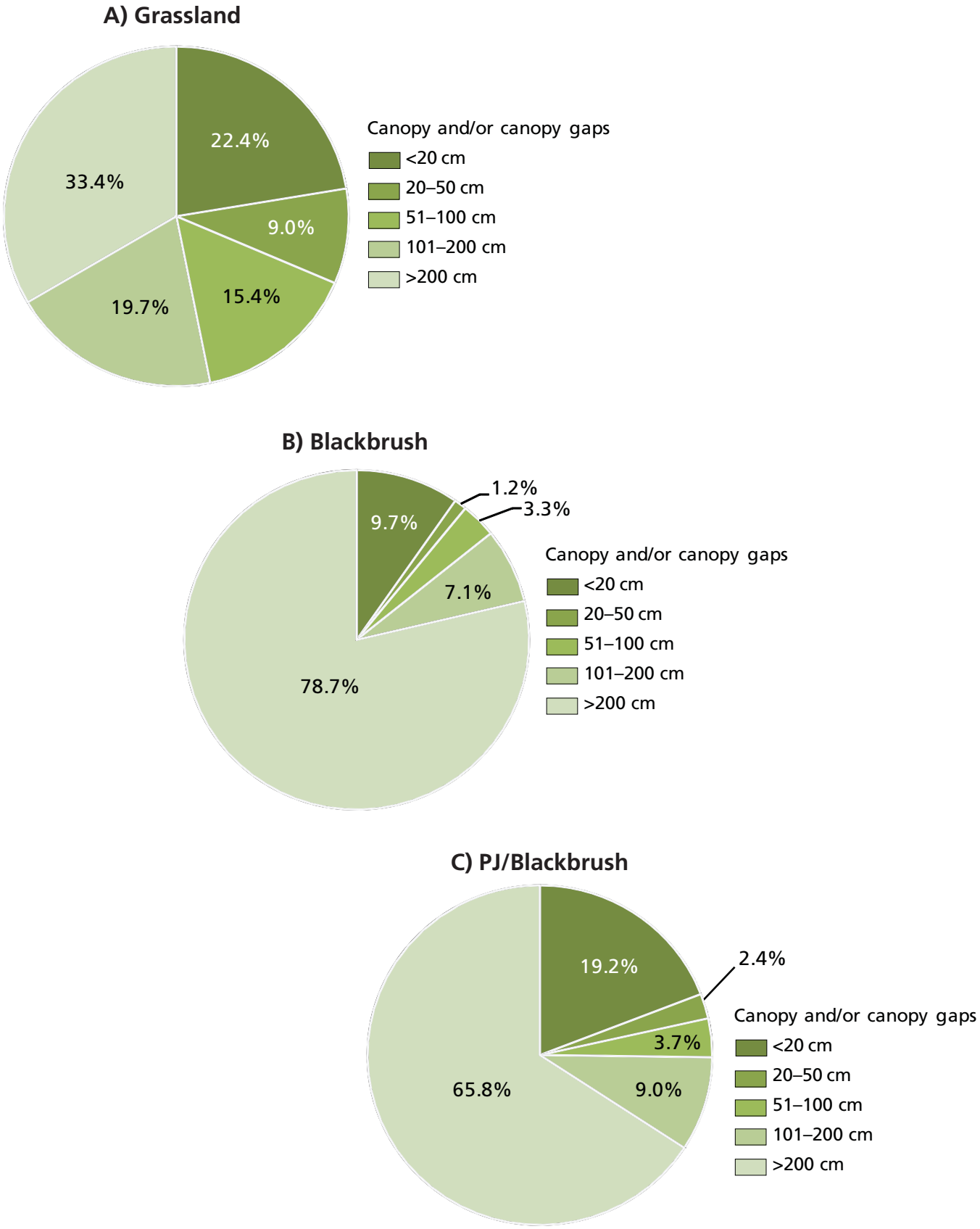
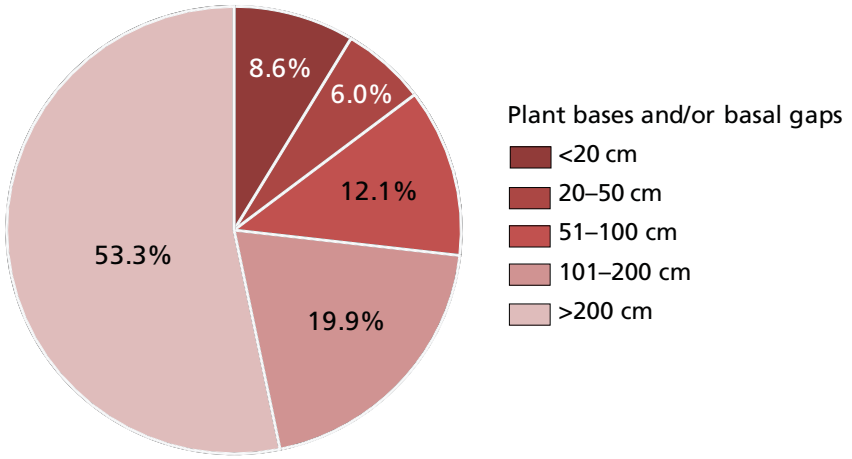
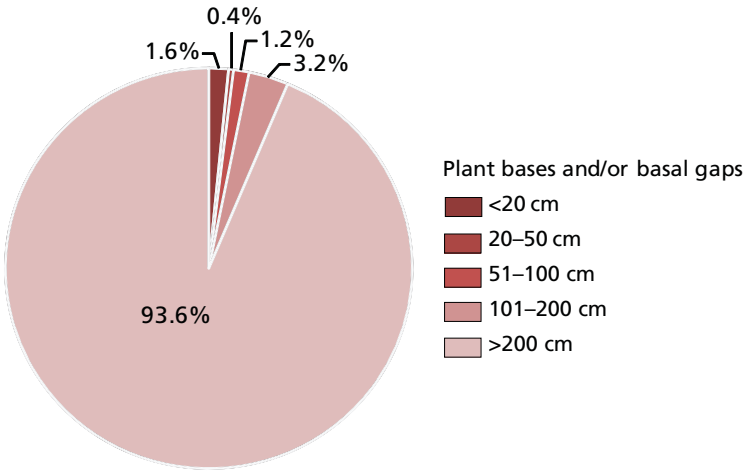


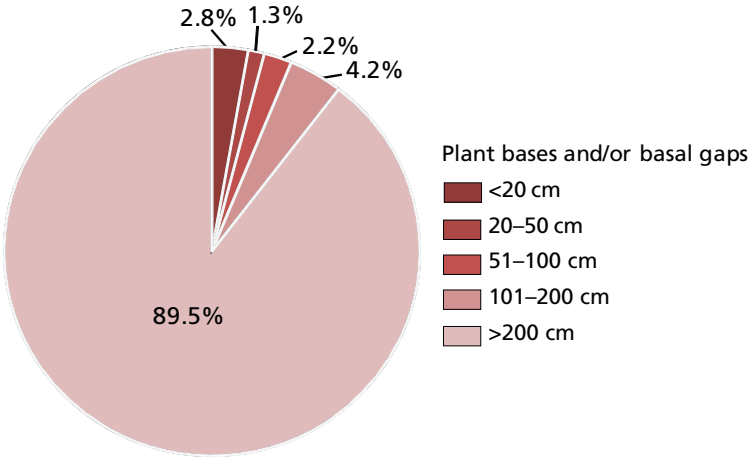
Figure 3-2. Distribution of canopy gaps for a) grassland, b) blackbrush, and c) PJ/blackbrush sites in Canyonlands NP, 2009.



A) Grassland



B) Blackbrush



C) PJ/Blackbrush

Figure 3-3. Distribution of basal gaps for a) grassland, b) blackbrush, and c) PJ/blackbrush sites in Canyonlands NP, 2009.

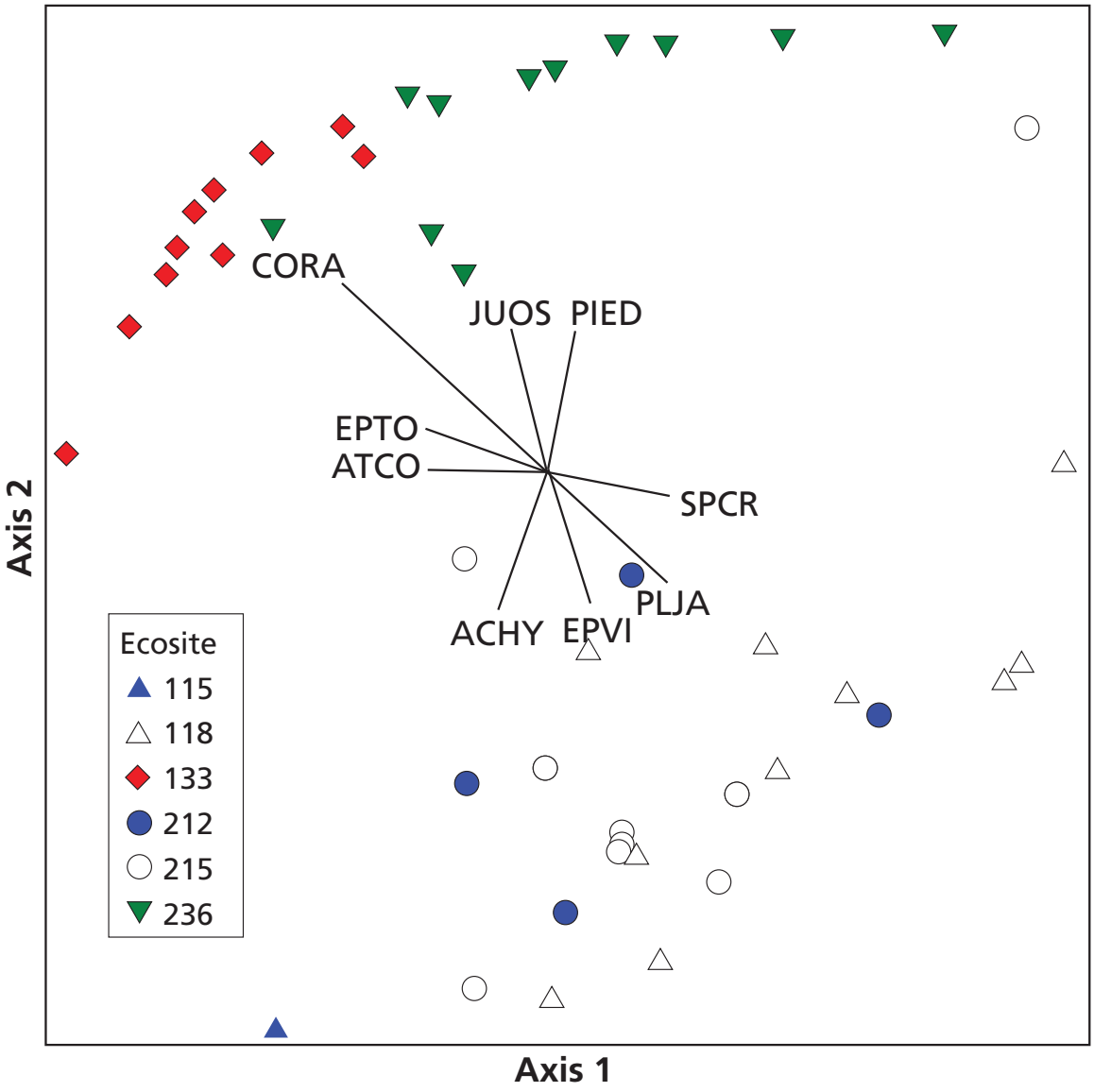


Figure 3-4a. Non-metric multidimensional scaling (NMS) ordination of plots from the six ecological sites monitored in Canyonlands NP, 2009.

Species codes

ACHY = *Stipa hymenoides* (Indian ricegrass)
ATCO = *Atriplex confertifolia* (shadscale)
CORA = *Coleogyne ramosissima* (blackbrush)
EPTO = *Ephedra torreyana* (Torrey's jointfir)
EPVI = *Ephedra viridis* (Mormon tea)
JUOS = *Juniperus osteosperma* (Utah juniper)
PIED = *Pinus edulis* (two-needle pinyon pine)
PLJA = *Hilaria jamesii* (galleta)
SPCR = *Sporobolus cryptandrus* (sand dropseed)

Ecological site codes

Grassland	115 = Desert Sand
	118 = Desert Sandy Loam
	212 = Semidesert Sand
	215 = Semidesert Sandy Loam
Blackbrush	133 = Desert Shallow Sandy Loam
PJ \ blackbrush	236 = Semidesert Shallow Sandy Loam

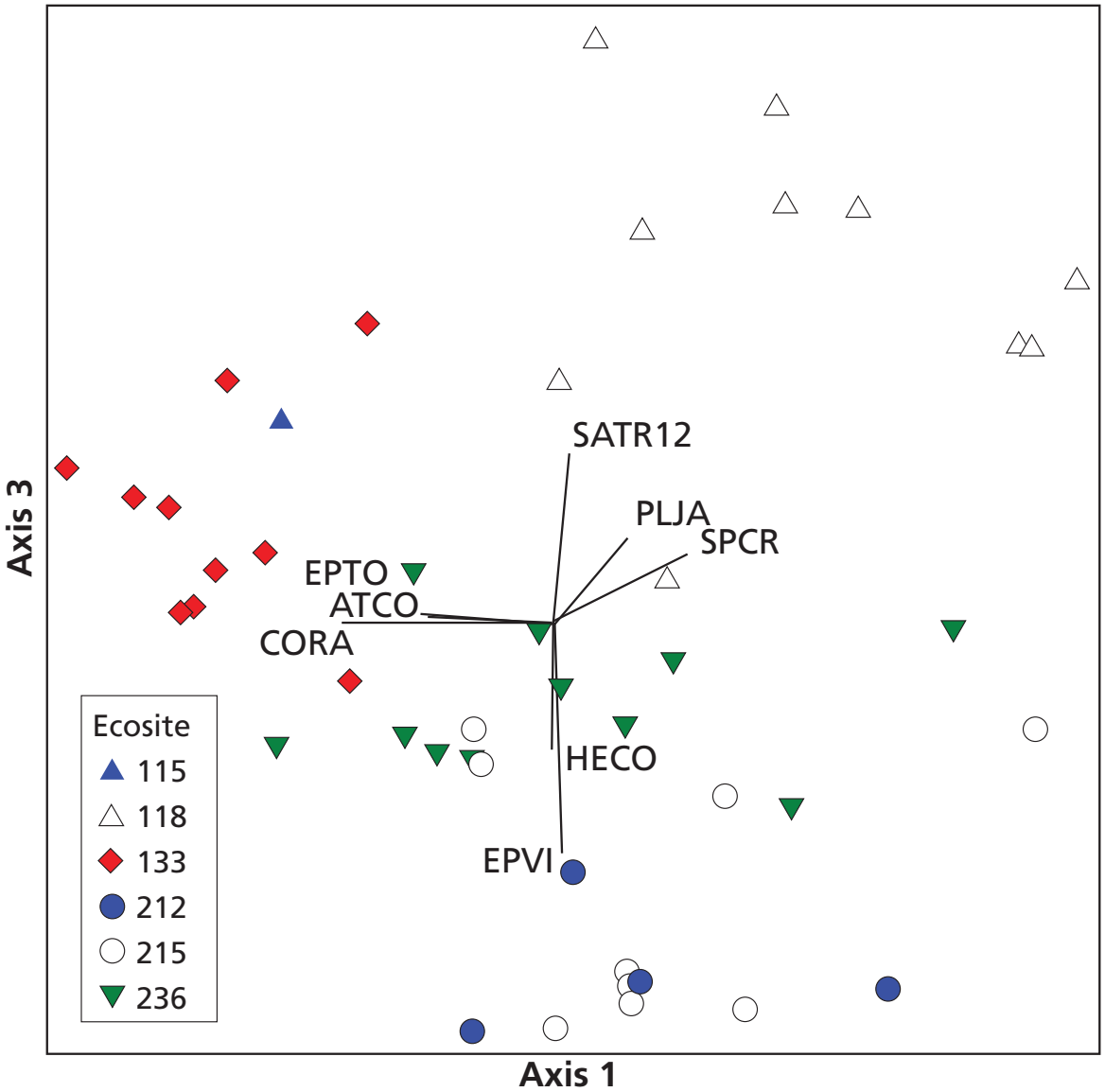


Figure 3-4b. Non-metric multidimensional scaling (NMS) ordination of plots from the six ecological sites monitored in Canyonlands NP, 2009.

Species codes

ATCO = *Atriplex confertifolia* (shadscale)
CORA = *Coleogyne ramosissima* (blackbrush)
EPTO = *Ephedra torreyana* (Torrey's jointfir)
EPVI = *Ephedra viridis* (Mormon tea)
HECO = *Stipa comata* (needle and thread)
PLJA = *Hilaria jamesii* (galleta)
SATR12 = *Salsola tragus* (Russian thistle)
SPCR = *Sporobolus cryptandrus* (sand dropseed)

Ecological site codes

Grassland	115 = Desert Sand
	118 = Desert Sandy Loam
	212 = Semidesert Sand
	215 = Semidesert Sandy Loam
Blackbrush	133 = Desert Shallow Sandy Loam
PJ \ blackbrush	236 = Semidesert Shallow Sandy Loam

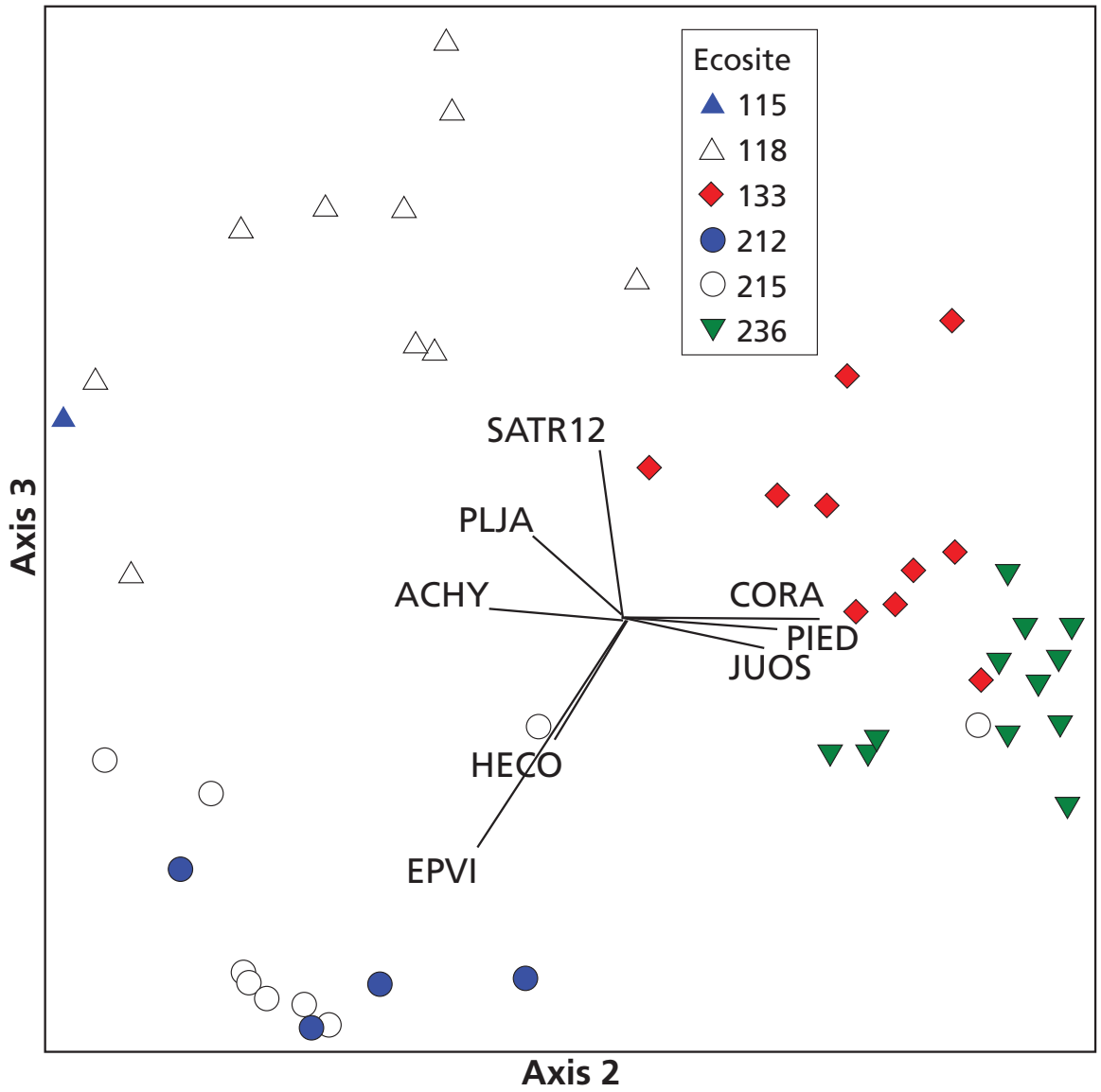


Figure 3-4c. Non-metric multidimensional scaling (NMS) ordination of plots from the six ecological sites monitored in Canyonlands NP, 2009.

Species codes

ACHY = *Stipa hymenoides* (Indian ricegrass)
CORA = *Coleogyne ramosissima* (blackbrush)
EPVI = *Ephedra viridis* (Mormon tea)
HECO = *Stipa comata* (needle and thread)
JUOS = *Juniperus osteosperma* (Utah juniper)
PIED = *Pinus edulis* (two-needle pinyon pine)
PLJA = *Hilaria jamesii* (galleta)
SATR12 = *Salsola tragus* (Russian thistle)

Ecological site codes

Grassland	115 = Desert Sand
	118 = Desert Sandy Loam
	212 = Semidesert Sand
	215 = Semidesert Sandy Loam
Blackbrush	133 = Desert Shallow Sandy Loam
PJ \ blackbrush	236 = Semidesert Shallow Sandy Loam

4 Discussion

This was the fourth year of monitoring at Canyonlands NP, and the first year of the full operational monitoring design. Early monitoring data describe status of sites, and conditions of sites inside the park may be useful in understanding reference conditions of more intensively managed sites outside the park.

Grassland plots had the highest number of species and the highest cover of forbs and perennial grasses. Blackbrush and PJ/blackbrush plots had similar cover and richness for all life forms except trees. Exotics were only detected in grasslands, and each species was typically detected in 1–2 plots. Russian thistle was the exception, detected at 29% of grassland plots and 70% of grassland plots in the Needles.

Larger gaps between plants are associated with a higher potential of soil erosion by wind or water. The percentage of basal and canopy gaps of >50 cm is much higher in blackbrush and PJ/blackbrush than in grasslands. The soil surface in blackbrush is protected by a high percent cover of small rocks; therefore, these sites should have an overall low risk of erosion. Many PJ/blackbrush sites have well-developed BSCs that protect soil in gaps from erosion. Despite the good condition of most sites in Canyonlands NP, soil stability is often low due the high sand content of surface soils. It is critical to minimize soil disturbance due to the high potential for wind and water erosion if sites are disturbed.

In general, data from 2009 were similar to those from previous years. Over three-quarters of plots monitored in 2009 were newly established, and it is important to remember that any differences between years could be due to the different suite of plots sampled and not due to actual changes in vegetation types. This variation will be accounted for in status and trend analyses after plots have been revisited, and it is too early to draw conclusions from these preliminary data.

In 2010, 48 plots will be monitored according to the full operational monitoring design. One quarter of the plots visited in 2009 will be revisited and the remaining plots will be established. Continued discussion will occur with Canyonlands NP resource staff to ensure that park expectations and needs are satisfied by NCPN integrated upland monitoring. A status and trend report will be produced after the 2011 field season, when five full years of monitoring have been completed.

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