



Integrated Upland Monitoring in Black Canyon of the Gunnison National Park and Curecanti National Recreation Area

Annual Report 2011 (Non-Sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2012/657.N



ON THE COVER

Sagebrush shrublands surrounding Blue Mesa Reservoir, Curecanti National Recreation Area. NPS photo.

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Executive Summary

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

This report summarizes NCPN upland monitoring in Black Canyon of the Gunnison National Park (BLCA) and Curecanti National Recreation Area (CURE) during 2011. 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 2011, NCPN completed the first year of monitoring under the long-term operational sampling design at BLCA and CURE, and the fourth year of monitoring overall. Forty-two plots were monitored, including 24 plots at BLCA (12 pinyon-juniper and 12 Gambel oak/mixed montane shrub) and 18 plots at CURE (1 aspen and 17 sagebrush). Early monitoring data describe status of ecological site types; interpretation will be limited until additional data are acquired and more rigorously analyzed after at least five years of monitoring.

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1 Introduction

Uplands represent the vast majority of land area in national park units of the NCPN. These upland areas include rock outcrops, badlands, shrublands, grasslands, woodlands, forests, and subalpine meadows, with local vegetation determined by soil type and depth, topography, climate, and disturbance history. Upland vegetation supplies most regional primary productivity, which translates to energy for other trophic levels. The condition of upland vegetation influences soil stability and nutrient cycling that, in turn, determines potential above-ground production of native plant species and the propensity for invasion by non-native species. Vegetation also provides habitat for various organisms. The ability of uplands to retain soil and nutrients, absorb and release water, and buffer high-runoff precipitation events also influences conditions in riparian areas.

Upland ecosystems of the Colorado Plateau, where the majority of NCPN park units are located, tend to be dominated by shrubs, perennial grasses, and small trees. Although these life forms play an integral role in defining the structure and function of Colorado Plateau ecosystems (Whitford 2002), it is the highly-pinnacled biological soil crusts that make these dryland systems unique. Biological soil crusts are biotic communities composed of cyanobacteria, algae, microfungi, mosses, and lichens that occur on and within the upper few millimeters of the soil surface (Belnap et al. 2003). Their presence stabilizes the soil surface and reduces susceptibility to wind and water erosion (Williams et al. 1995). They also contribute to nutrient cycling by fixing C (Lange 2003) and N (Evans and Lange 2003; Belnap 2002) and affect the availability of nutrients to plants (Harper and Belnap 2001). Biological soil crusts are particularly sensitive to disturbances that affect the soil surface, such as trampling and off-road vehicle use (Rosentreter and Belnap 2003; Figure 1-1).

In the basins neighboring the Colorado Plateau, where several NCPN park units are located, biological soil crusts also play an important role but are less dramatically pinnacled. In the forests, shrublands, and meadows of the mountain regions surrounding the

Colorado Plateau, where numerous NCPN park units are located, biological soil crusts do not play an important role since much of the soil surface is covered by vegetation and litter.

Many of the region's upland ecosystems are characterized by low resistance and resilience. Even moderate disturbances can affect vegetative composition and structure, and recovery to pre-disturbance conditions can be relatively slow. Natural disturbance regimes of the region include extreme climatic events, fire, insect and disease outbreaks, herbivory, and trampling (Miller 2005).

Grazing, which has been a traditional land use throughout much of the plateau, has resulted in shifts in vegetation composition (Harris et al. 2003) and ecological states (Miller et al. 2011) that persist for many decades or longer. Fire-regime alteration (Whelan 1995) and invasion of exotic plants (Bock et al. 1986) have additionally contributed to these shifts. Increasing recreational use and unauthorized social trailing threatens the integrity of upland systems through soil-surface disturbance and resulting increases in soil erosion by water and wind. Additional pressure inside parks may also result from land use in adjacent areas. Global climate change is expected to change levels and seasonality of dominant precipitation events (Garfin et al. 2010), and we are only beginning to understand the implications for plateau ecosystems (Munson et al. 2011a,b). Additional information on characteristics of Colorado Plateau



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Figure 1-1. Example of damage caused to biological soil crust by off-road vehicle use, Arches National Park.

ecosystems and ecological threats to the region is provided in Miller (2005).

The overall goal of the NCPN integrated upland monitoring program is to determine long-term trends in vegetation, soil stability, and hydrologic function in the context of changes in other ecological drivers, stressors, and processes. Monitoring will increase fundamental understanding of upland systems and provide managers with early warning of undesirable change and information for management decisions. Specific objectives of the integrated upland monitoring protocol are described below.

Determine status and trends in plant communities, including:

- overall species richness
- cover of vegetation by dominant species and life form
- density of shrubs by size class
- basal area and density of tree species
- canopy closure
- fuel volume and litter/duff depth
- frequency of exotic invasive species

Determine status and trends in soil stability, including:

- cover of biological soil crusts by morphological group (cyanobacteria, lichen, moss, and undifferentiated crust)

- cover of other surface features (e.g., litter, rock, bare ground)
- soil aggregate stability
- canopy-gap size (as an indicator of wind erosion potential)

Determine status and trends in hydrologic function, including:

- basal-gap size

Evaluation of upland monitoring data relative to other vital signs will help us to identify drivers and distinguish “natural” from anthropogenic change. Historical upland monitoring data sets may be integrated with data collected by the NCPN to allow earlier detection of trends. Local weather-station data can be used to interpret responses, whereas remote sensing can be used to determine vegetation change caused by land use or climate change at larger scales. NCPN upland monitoring data will assist the park units in understanding climate change over the long term and may help future park managers to develop climate-change adaptation strategies.

2 Methods

2.1 Integrated upland monitoring in Black Canyon of the Gunnison National Park and Curecanti National Recreation Area

2.1.1 Resource issues driving upland monitoring

Park resource management staff identified big sagebrush (*Artemisia tridentata*) shrublands (hereafter referred to as sagebrush), and pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) woodlands (hereafter referred to as pinyon-juniper [PJ]), Gambel oak (*Quercus gambelii*) / mixed montane shrublands (hereafter referred to as oak or oak scrub), and aspen (*Populus tremuloides*) forests as high priority for long-term monitoring. Sagebrush, PJ, and oak scrub are the dominant vegetation types in the park units. Aspen communities have limited spatial extent but are of special concern to park managers.

The overall goal of monitoring in these park units is to provide early warning of system degradation as well as information on the natural variability of upland resources. There are additional management concerns associated with sagebrush, the most extensive community type in the park units. Although sagebrush has historically been grazed over the entire Gunnison Basin, it is not currently grazed in parts of Black Canyon of the Gunnison National Park (BLCA) and Curecanti National Recreation Area (CURE), providing a unique opportunity to compare grazed and ungrazed sagebrush communities.

2.1.2 Mapping and selecting target populations

2.1.2.1 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 reservoir or river 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>).

Creation of the BLCA/CURE accessibility map involved many challenges not found in other NCPN park units. BLCA contains numerous parcels of private property within its boundary, and boundaries change regularly as Bureau of Land Management and private parcels are transitioned to National Park Service (NPS) ownership. Only private property with conservation easements and agreeable landowners was considered for the accessibility map. Parcels that were heavily managed (e.g., active hay fields or elk ranching) were eliminated from the accessibility map. Additional discussion with park staff included NPS land in the Blue Creek and Pine Creek areas accessible by crossing private land with agreeable owners or established NPS access easements through private property.

2.1.2.2 Selection of target vegetation and ecological site types

Defining a target population typically involves determining the ecological sites that correspond to the resource of interest. An ecological site is defined by a combination of soil properties (texture, depth, water-holding capacity), geology, landform, climatic regime, and potential vegetation. The spatial extent of ecological sites is largely determined by soil map units within the soil survey, although the location of an ecological site within a soil map unit is not explicit.

Two dated soil surveys (USDA NRCS 1975, 1981) covered much of the area of the park units; however, neither BLCA nor CURE has had a complete survey. In addition, the extant soil surveys only provided site descriptions of limited range instead of more thorough ecological site descriptions. Ecological sites for aspen were not well defined by the soil surveys, and soil map units with PJ were not paired with any ecological sites. Existing ecological site descriptions for Major Land Resource Area (MLRA) 48 mostly did not match range sites from the soil surveys. Thus, delineating ecological sites for BLCA and CURE upland monitoring was a challenge and ecological sites are approximate, based on both range sites and available ecological site descriptions for MLRA 48. NCPN vegetation maps of BLCA and CURE provided a

more recent spatial distribution of target vegetation types, and were used to help develop a sampling frame for monitoring.

Field scouting was performed in order to assess (1) the suitability of vegetation map units to delineate target vegetation types and (2) the extent of ecological sites associated with target vegetation types. The most common sagebrush ecological sites were Mountain Loam and Dry Mountain Loam, and we decided that the sagebrush sampling frame should cover the range of these two ecological sites. They seemed to form a continuum across the landscape, however, making it extremely difficult to classify sites in the middle of the range. We attempted to distinguish Mountain Loam and Dry Mountain Loam for the initial effort but realize that we may eventually have to lump these sites together.

The dominant ecological sites for PJ were Upland Shallow Loam and Upland Stony Loam. These ecological sites are similar and were often mixed on the landscape; therefore, we decided to monitor both sites and any combination of the two. Oak scrub within the park units was predominantly the Brushy Loam ecological site, and this was used to define the target oak community for monitoring. We did not attempt to determine ecological sites of aspen communities due to issues with the soil survey and the small number of monitoring plots in this vegetation type. Details and photos of target ecological sites and vegetation types are provided in Table 2-1 and Figure 2-1.

2.1.2.3 Mapping of target vegetation types

The vegetation map was used to create a sampling frame to predict the location of target ecological sites and vegetation types. Specific polygons were changed based on field assessments. The sampling frame delineated accessible sagebrush, PJ, oak scrub, and aspen vegetation types in BLCA and CURE (see Figures 2-2 and 2-3). Sagebrush was additionally divided into grazed and ungrazed areas.

2.1.3 Selection of monitoring locations

Monitoring plots were selected using the Reversed Randomized Quadrant Recursive Raster (RRQRR) method (Theobald et al. 2007) to create a spatially balanced design

within the sampling frame. RRQRR provides an ordered list of centroids for all possible monitoring plots in the sampling frame. The sampling frame was buffered by 20 m; any points within the buffer were not used for monitoring. This reduced the number of points rejected for overlapping multiple vegetation types, roads, trails, or the park boundary. Within each vegetation type, plots were established in ascending order of plot number. If a plot was rejected (e.g., due to incorrect vegetation type), the next sequentially ordered plot was used.

2.1.4 Pilot study and long-term sampling design

Upland monitoring was initiated at BLCA and CURE in 2008. For pilot monitoring, a total of 51 plots were monitored, including 8 ungrazed Dry Mountain Loam sagebrush, 8 grazed Dry Mountain Loam sagebrush, 7 ungrazed Mountain Loam sagebrush, 8 grazed Mountain Loam sagebrush, 8 PJ, 8 oak scrub, and 4 aspen plots. Plots were sampled for 2–3 years, and variances of measures were used to evaluate power for trend of potential operational sampling designs. Details of this analysis are provided in an unpublished report (available from the NCPN upon request).

2.1.4.1 Long-term sampling design

Based on the analysis of pilot data, a long-term operational sampling design was created and implemented in 2011. The four aspen plots were retained in the long-term sampling design but only one is sampled every year (see Figure 2-4b). The number of PJ and oak plots monitored each year increased, but sampling in these two vegetation types otherwise remained the same.

The two sagebrush ecological sites seemed to be more continuous than distinct, which prompted us to change the long-term sampling design for sagebrush plots. Instead of monitoring an even number of plots from (1) each of the two target ecological sites and (2) grazed and ungrazed areas, sagebrush plots were selected from anywhere within the sampling frame for the vegetation type. This means that a different number of plots is monitored in each ecological site and in grazed and ungrazed areas, but these numbers should represent the area of each ecological site and grazing use across the

Table 2-1. Description, by vegetation type, of target vegetation and ecological sites selected for upland monitoring in Black Canyon of the Gunnison National Park and Curecanti National Recreation Area.

Ecological sites	Physiognomic type	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states	Potential non-target areas
Big sagebrush (sagebrush)						
Mountain Loam	Shrubland	Deep loams on valleys, benches, and hillslopes	Alluvium, slope alluvium, or glacial deposits	Tall big sagebrush (<i>Artemisia tridentata</i>) with dense cover of grasses; may also include small amounts of mixed montane shrubs	Grazing: decreased perennial grasses, increased big sagebrush. Fire: decreased big sagebrush, increased green rabbitbrush (<i>Chrysothamnus viscidiflorus</i>) and mountain snowberry (<i>Symphoricarpos oreophilus</i>).	Very shallow sandy areas with black sagebrush (<i>Artemisia nova</i>); depressions with basin big sagebrush (<i>A. tridentata</i> ssp. <i>tridentata</i>) and Great Basin wildrye (<i>Elymus cinereus</i>)
Dry Mountain Loam	Shrubland	Shallow to moderately deep loams to stony loams on benches, ridges, and hills	Residuum, alluvium, glacial deposits	Smaller big sagebrush with bunchgrasses and gravelly/stony interspaces	Grazing: decreased perennial grasses, increased big sagebrush and snakeweed (<i>Gutierrezia</i> sp.). Fire: decreased big sagebrush.	
Pinyon pine/Utah juniper (PJ)						
Upland Shallow/Stony Loam	Woodland	Shallow to moderately deep loams and stony loams on ridges and mountain sides	Residuum or colluvium	Pinyon pine (<i>Pinus edulis</i>) and Utah juniper (<i>Juniperus osteosperma</i>) with sparse to moderate understory cover of shrubs, grasses, and forbs	Grazing: decreased understory plants, increased PJ. Fire: temporarily decreased PJ, increased perennial grasses and shrubs.	Sparse PJ on badlands; sparse PJ in dense oak scrub, PJ on deep soils
Gambel oak/mixed montane shrubs (oak/oak scrub)						
Brushy Loam	Shrubland	Deep loams on uplands and mountain sides	Alluvium, slope alluvium, or glacial deposits	Dominated by Gambel oak (<i>Quercus gambelii</i>), Utah serviceberry (<i>Amelanchier utahensis</i>), mountain snowberry, and mountain big sagebrush (<i>A. tridentata</i> ssp. <i>vaseyana</i>)	Grazing: Decreased perennial grasses, increased woody shrubs. Fire: increased Gambel oak, mountain snowberry, and rabbitbrush (<i>Chrysothamnus</i> sp.), decreased perennial grasses, forbs, and other shrubs.	Shallow, rocky areas dominated by grasses and forbs; steep colluvial slopes with oak scrub/ mixed montane shrubs
Aspen (aspen)						
No stratification	Forest	Deep loams on mountain sides	Alluvium, glacial till, or colluvium	Dominated by aspen (<i>Populus tremuloides</i>), chokecherry (<i>Prunus virginiana</i>), Saskatoon serviceberry (<i>Amelanchier alnifolia</i>), and mountain snowberry	Ranges from skeleton to climax forest.	Areas with no live aspen

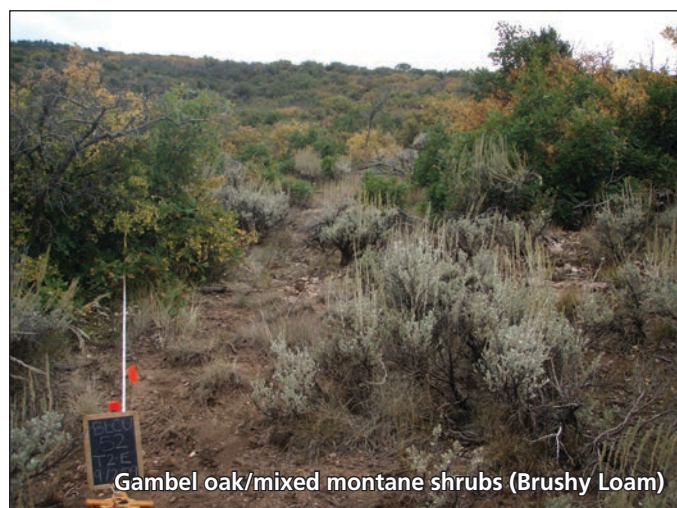


Figure 2-1. Examples of target vegetation (ecological site) types monitored in Black Canyon of the Gunnison NP and Curecanti NRA: Sagebrush (Mountain Loam), Sagebrush (Dry Mountain Loam), Pinyon-juniper (Upland Shallow/Stony Loam), Gambel oak/mixed montane shrubs (Brushy Loam), and Aspen. See Table 2-1 for a description of vegetation types and ecological sites.

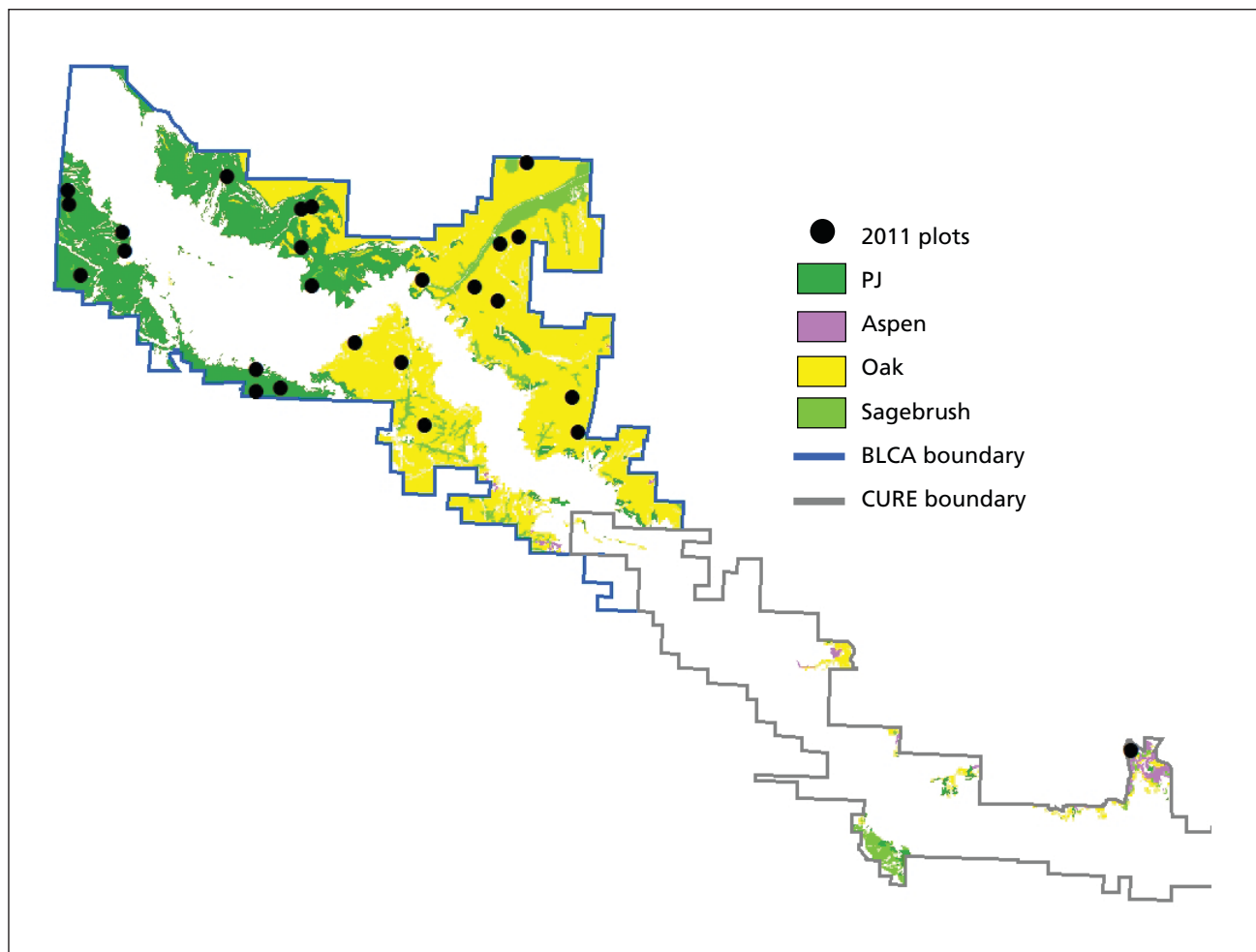


Figure 2-2. Location of monitoring plots in Black Canyon of the Gunnison National Park and the west side of Curecanti National Recreation Area, 2011.

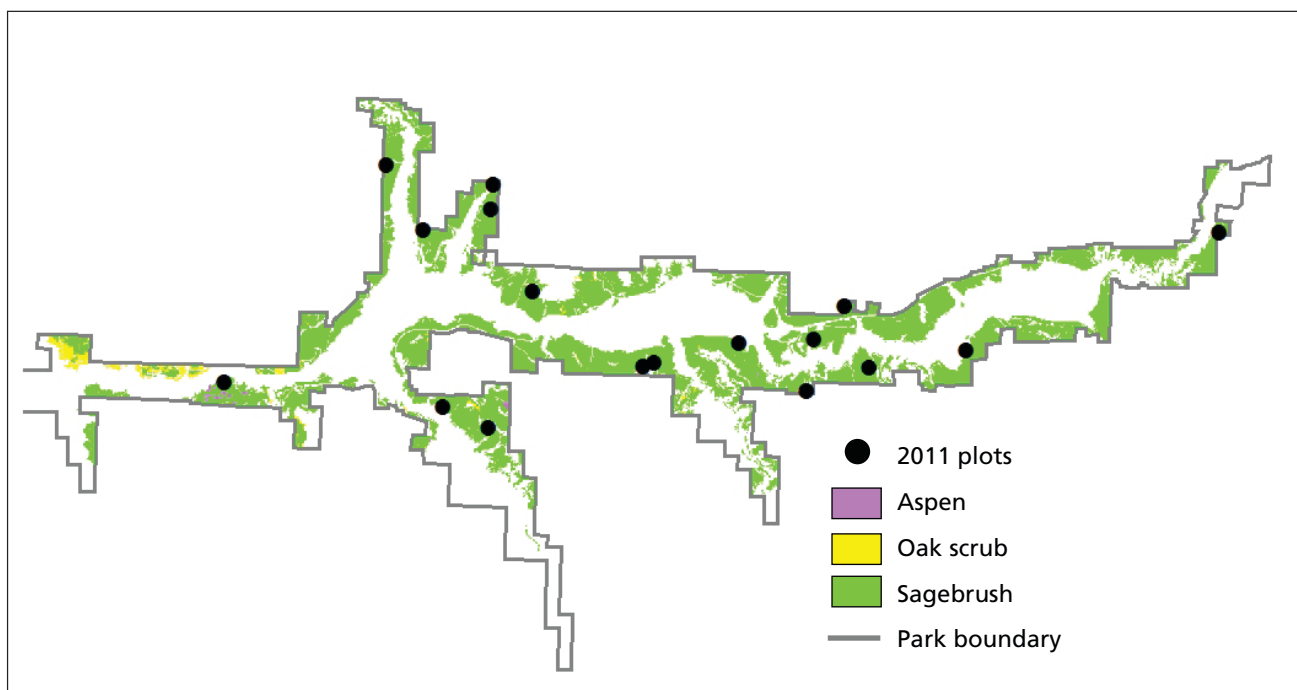


Figure 2-3. Location of monitoring plots on the east side of Curecanti National Recreation Area, 2011.

a) Sagebrush

Panel	Year Number of plots sampled									
	1	2	3	4	5	6	7	8	9	10
1	4	4				4	4			
2		4	4				4	4		
3			4	4				4	4	
4				4	4				4	4
5	4				4	4				4
6	9					9				
7		9					9			
8			9					9		
9				6					6	
10					6					6

b) Aspen

Panel	Year Number of plots sampled									
	1	2	3	4	5	6	7	8	9	10
1	1	1	1	1	1	1	1	1	1	1
2				3	3				3	3

c) Pinyon-juniper & Oak

Panel	Year Number of plots sampled									
	1	2	3	4	5	6	7	8	9	10
1	3	3				3	3			
2		3	3				3	3		
3			3	3				3	3	
4				3	3				3	3
5	3				3	3				3
6	6					6				
7		6					6			
8			6					6		
9				6					6	
10					6					6

Figure 2-4. Number of (a) sagebrush, (b) aspen, and (c) pinyon juniper and oak plots sampled each year based on five-year rotating panel revisit designs for long-term upland monitoring at Black Canyon National Park and Curecanti National Recreation Area. In sagebrush, 14 or 17 plots are sampled each year, and 59 unique plots are sampled over five years. In aspen, 1 or 4 plots are sampled each year, and 4 unique plots are sampled over five years. In pinyon juniper and oak, 12 plots are sampled each year in each vegetation type, and 45 unique plots are sampled in each vegetation type over five years.

landscape. Fewer sagebrush plots will be sampled than in the pilot study, but more plots of sagebrush will be sampled than of any other vegetation type at BLCA and CURE. The larger sample size of sagebrush plots should help facilitate comparisons between grazed and ungrazed areas of the park units in future analyses.

2.1.4.2 Revisit design

Each year, 1 or 4 aspen, 14 or 17 sagebrush, 12 PJ, and 12 oak plots are monitored (Figure 2-4). A total of 153 plots are sampled over a five-year revisit schedule. For aspen, one plot is visited every year, and the remaining plots are visited two out of five years. For the other vegetation types, approximately one-third of the plots are visited for two consecutive years and the other two-thirds are visited only once before being rested for 3–4 years. Additional sagebrush plots are visited in years when only one aspen plot is sampled. This revisit strategy maximizes the ability to detect trends and minimizes the impact on biological soil crusts in the park.

2.2 Integrated upland monitoring procedures

2.2.1 Response design

The response design (methods used to collect observations) for integrated upland monitoring in NCPN parks is based largely on range-land monitoring procedures recommended by Herrick and colleagues (2005) and standard forest, woodland, and fuels procedures (USDI 2003; Brown 1974). Specific measurements taken at each plot depend on the vegetation type (see the response-design column in Table 3-1).

2.2.1.1 Grasslands and shrublands

At each plot, observations are recorded along three parallel, 50-m transects spaced 25 m apart (Figure 2-5). At the origin of each transect, a photo is taken down the length of the transect toward the end point. Photos of biological soil crusts are also taken at a specified point along each transect. A point-intercept method is used to record percent cover of plant species and ground-cover attributes at 0.5-m intervals along each transect. Density of shrubs (by species and height class) and tree seedlings (by species) is recorded in a 1-m belt

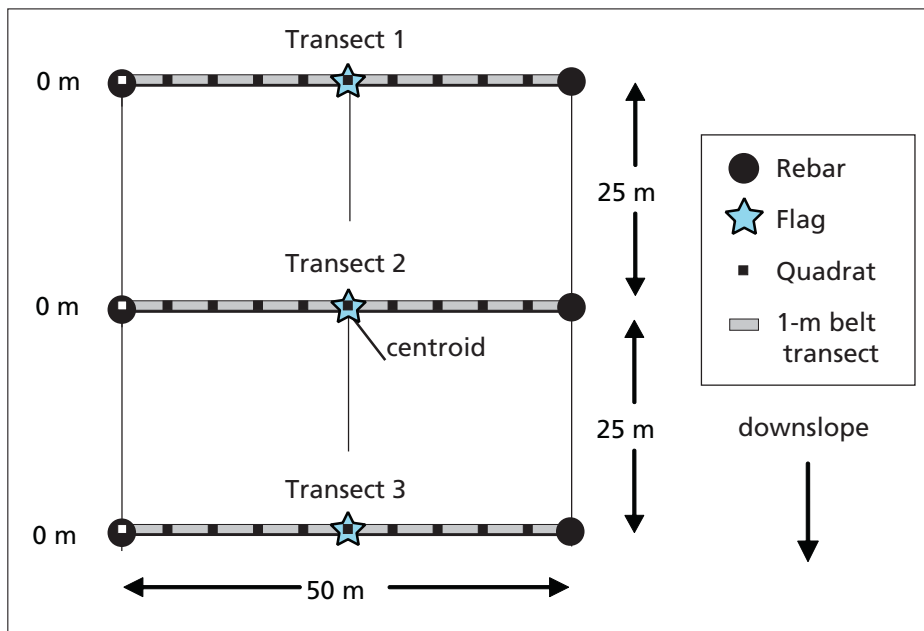


Figure 2-5. Plot layout for upland monitoring of grasslands and shrublands.

upslope of each transect. Density of exotic perennial species in the 1-m belt was discontinued beginning in the 2011 field season. Instead, frequency of all exotic species (annual and perennial) is recorded using 1 × 1-m quadrats placed every 5 m along each transect. Canopy and basal-gap measures are acquired along each transect using a line-intercept method. Six soil surface samples are taken along each transect to assess soil aggregate stability. Disturbances observed on and around the site are also recorded. Beginning in 2011, an “exotic-species walk” was added to augment the search for exotic plants in plots.

2.2.1.2 Forests and woodlands

Because vegetation tends to be denser in forests and woodlands, photos of each transect are taken from the origin and end of each transect. Using the same methods as for grasslands/shrublands, point-intercept cover of vegetation and surface features, density of shrubs and tree seedlings, and frequency of exotic species are recorded for each transect. Vegetation cover is recorded in the understory (<2 m) in forests and at all heights for woodlands. Gaps are not recorded in forest or woodland systems, but soil stability measurements may be recorded for woodland ecological sites with potential erosion issues. Using the same methods as for grasslands/shrublands, disturbances and exotic plant species on and around the monitoring plot are recorded.

Additional measurements are taken in forest and woodland systems in order to capture stand-replacement and gap dynamics (Figure 2-6). Saplings (2.5–15 cm diameter) are identified to species, and density by size class is tallied in a 5-m belt transect centered on Transect 2. All overstory trees (>15 cm diameter) in Quadrant 1 are identified to species, tagged with unique numbers, and measured for diameter. Diameter of trees is typically measured at breast height (dbh), except for woodland species that typically have multi-stem growth forms (e.g., pinyon pine and Utah juniper), which are measured at the root crown (drc). Before 2011, all trees were measured at breast height.

Crown-health classes that describe the percent of live foliage for each tree are additionally recorded for forest plots and are used to indicate standing dead trees in the other vegetation types. Crown classes that describe the relative position of each live overstory tree in the canopy are recorded for forest plots. The NCPN uses the following crown classes (Figure 2-7):

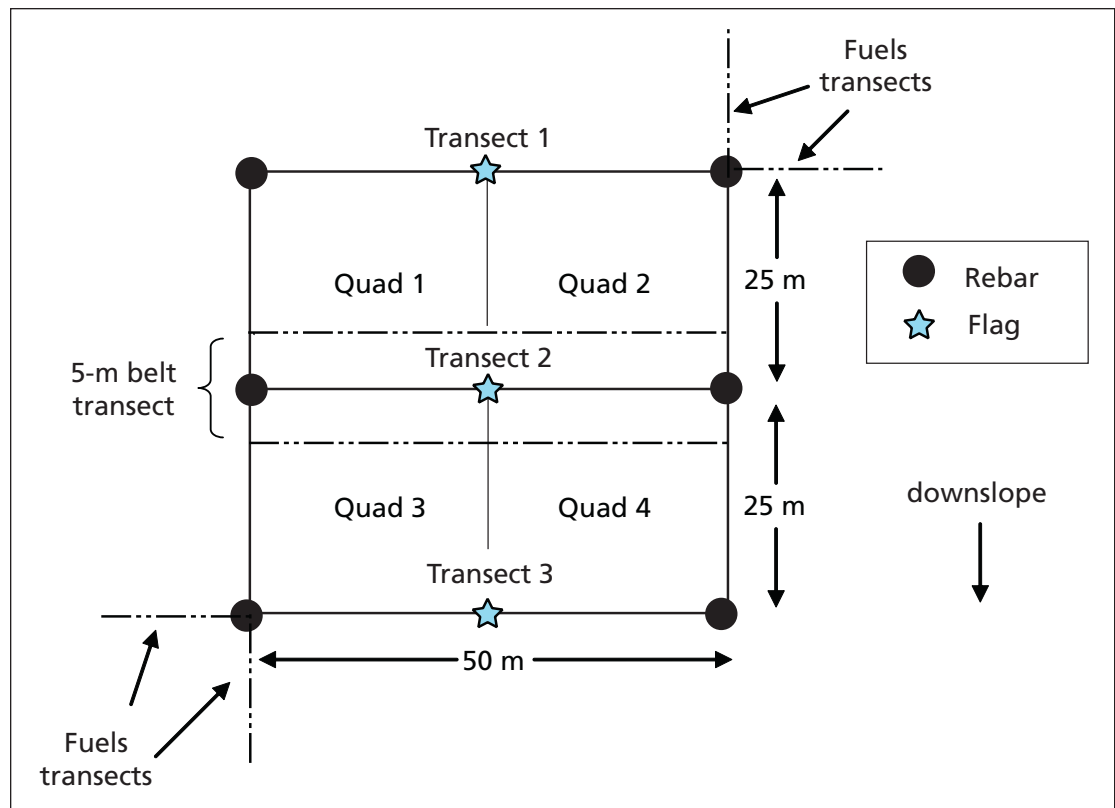


Figure 2-6. Plot layout for upland monitoring of forests and woodlands.

Dominant. Trees have crowns extending above the general level of the main canopy of adjacent trees and receive full light from above and partly from the sides.

Codominant. Trees have crowns forming the general level of the main canopy of adjacent trees and receive full light from above and comparatively little from the sides.

Intermediate. Trees have crowns extending into the lower portion of the main canopy of adjacent trees, but are shorter in height than the codominants. They receive little direct light from above and none from the sides. Intermediate crown-classed trees usually have small crowns that are crowded on the sides.

Overtopped/Suppressed. Trees have crowns entirely below the general level of the canopy of adjacent trees, and receive no direct light from above or from the sides.

Overstory canopy closure is measured every 10 m along the transects in forest plots. Fuels are measured using Brown's planar method (Brown 1974) along four 50-ft transects that extend beyond the plot on two corners. Counts of fine woody fuels and diameters of coarse woody fuels are recorded to derive volumes of each fuel class. Depth of litter and duff are also recorded.

2.2.1.3 Gambel oak/mixed montane shrublands

Gambel oak/mixed montane shrub systems are structurally different from other vegetation types on the Colorado Plateau, and their dense, tall vegetation is not easily sampled us-

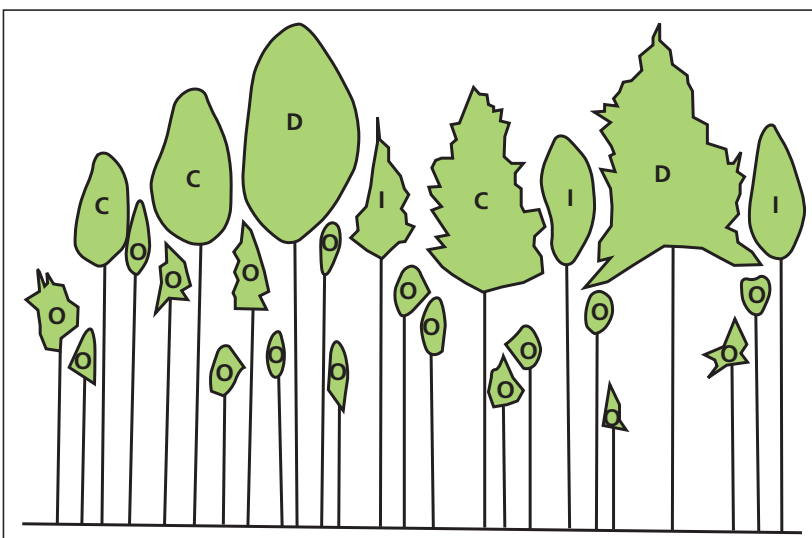


Figure 2-7. The relative positions of trees using four classes for crown classification. D =Dominant, C = Codominant, I = Intermediate, and O = Overtopped/Suppressed.

ing standard upland methods. This vegetation type is sampled using three 20-m transects (Figure 2-8), with photos taken at the origin and end of each transect. Point-intercept cover is collected at 0.25-m intervals, and exotic frequency is collected at smaller intervals along transects. Within the 20 × 20-m plot, species and diameter are recorded for all mature trees and exceptionally large individuals of Gambel oak. Beginning in 2011, density, gaps, soil stability, and fuels were not recorded in this vegetation type. Disturbances and exotic plants on and around the monitoring plot are recorded using the same methods as the other vegetation types.

2.3 Database

All observations recorded in the field are stored in an NCPN Access database. Quality assurance and quality control (QA/QC) procedures include domain checking in data-entry procedures, checks for missing values, and logic checks. All spatial data used in selecting monitoring locations, the sampling frame, and the RRQRR-generated sampling locations are GIS-ArcMap shape files and are stored with the Access database on NCPN servers.

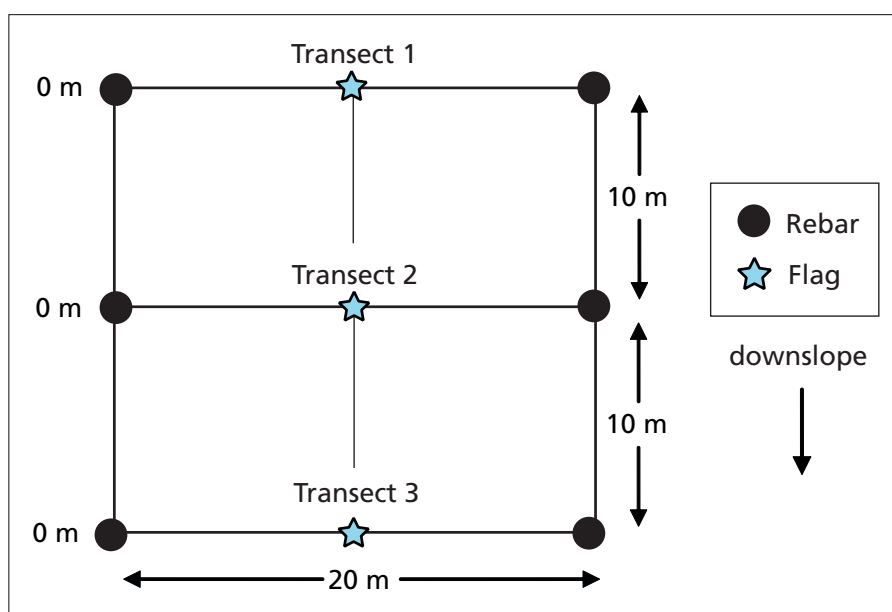


Figure 2-8. Plot layout for upland monitoring of Gambel oak/mixed montane shrublands.

3 Results

3.1 Monitored plots

Forty-two plots were monitored as part of the long-term revisit design in August and September 2011, including 1 aspen, 17 sagebrush, 12 PJ, and 12 oak plots (see Figures 2-2 and 2-3). All of these plots were newly established in 2011, except for the aspen plot. Table 3-1 summarizes plot visits by vegetation, ecological site, and year (tables begin on page 15). Each plot was sampled using the suite of measures appropriate for that vegetation type (see response-design column in Table 3-1).

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 are complete.

For this annual report, plot-level summaries of the measures listed in Chapter 1 were generated for each monitoring plot, then summarized by vegetation type. Summaries are simply a mean and the range (minimum, maximum) for a measured attribute. Given the limited data, measures were not statistically compared among vegetation types. Comparisons between years may also be misleading because a different set of plots is visited each year. The reader is cautioned not to draw wide-reaching conclusions from this initial set of results.

3.2.1 Species richness

A total of 122 species were detected in BLCA and CURE in 2011. Species richness by life form is reported in Table 3-2 for all vegetation types. Recorded species were compared to the NPSpecies database to determine first-time observations in BLCA and CURE. Five new native species were detected in 2011. Small-leaf pussytoes (*Antennaria microphylla*), purpledisk sunflower (*Helianthella microcephala*), and Eastwood plant (*Chamaechaenactis scaposa*) were detected in BLCA, and Ross' sedge (*Carex rossii*) and foothills death camas (*Zigadenus paniculatus* or *Toxicoscordion paniculatum*) were de-

tected in CURE. Vouchers were created for purpledisk sunflower and Eastwood plant.

Although BLCA and CURE do not have any populations of federally listed threatened or endangered plant species within their borders, at least 28 species of special concern exist within the units (Hogan et al. 2009a,b). No plants of special concern were found on any plots in 2011.

3.2.2 Overstory canopy closure and cover by life form and dominant species

Overstory canopy closure and percent cover of live and total vegetation by life form are shown in Table 3-3 for all vegetation types. 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 are shown in Table 3-4 for all vegetation types. Dominant species were selected using species predicted by ecological site descriptions and species frequently detected in plots. The percent cover of all species recorded for each plot is included in the electronic appendices that accompany this report (blca11_species.xls and cure11_species.xls).

3.2.3 Shrub density

Density of shrub species is shown in Table 3-5 for sagebrush and PJ. All sagebrush plots had a high density of big sagebrush, and most also contained green rabbitbrush (*Chrysothamnus viscidiflorus*) at high densities. In general, PJ plots had low shrub density, and none of the shrub species was found consistently across plots. No shrubs were detected at the aspen plot, but chokecherry (*Prunus virginiana*), Woods' rose (*Rosa woodsii*), Saskatoon serviceberry (*Amelanchier alnifolia*), Scouler's willow (*Salix scouleriana*), and mountain snowberry (*Symphoricarpos oreophilus*), which are common in aspen communities at CURE, are not counted in our shrub density counts. Their multi-stemmed lifeform in this ecosystem makes it extremely difficult to distinguish individuals, and measuring density of these shrubs in CURE aspen is not

repeatable. Cover can alternatively be used to assess the status of these species.

3.2.4 Tree density

Density of live seedlings, saplings, and overstory trees is shown in Table 3-6 for all vegetation types. Crown classes that describe the relative position of each live overstory tree in the canopy are also included in this table for the aspen plot. Density and diameter for all overstory trees >15 cm diameter are shown in Table 3-7 for PJ, oak, and aspen. Crown health classes that describe the percent of live foliage for each tree are also summarized in this table for the aspen plot and are used to indicate standing dead trees in the other vegetation types.

3.2.5 Exotic species

Percent cover and detection frequency of exotic plant species are shown in Table 3-8 for all vegetation types. When exotic species were detected, cover was summarized for all plots in the vegetation type.

In 2011, exotic species were detected in all vegetation types, and exotic perennial species were detected in all vegetation types except PJ. Cheatgrass (*Bromus tectorum*) was detected in the largest number of plots and had the highest cover and frequency of any exotic plant species found in PJ plots. Kentucky bluegrass (*Poa pratensis*) had the highest cover and frequency at oak and aspen plots. Common dandelion (*Taraxacum officinale*) was also frequently detected at the aspen plot. Cover and frequency of exotic plant species was relatively low in sagebrush plots.

Lists of all exotic species detected on the “exotic plant walk,” initiated in 2011, are included in an electronic appendix that accompanies this report (ExoticPlantWalk.xls). The file contains information by park and plot, and includes descriptions of the number of plants, size of invasions, and approximate locations of species found.

3.2.6 Biological soil crust and surface features

Biological soil crust and surface-feature cover are shown in Table 3-9 for all vegetation types. Litter was the dominant surface cover for all vegetation types. Sagebrush and PJ also had substantial amounts of undifferentiated crust and small rock surface cover.

3.2.7 Canopy and basal gaps

The distribution of gaps by size class is illustrated in Figure 3-1 (page 23) for sagebrush. The mean canopy gap size was 64 cm (range 47–101 cm), while mean basal gap size was 97 cm (range 57–216 cm).

3.2.8 Soil aggregate stability

Measures of soil aggregate stability are reported in Table 3-10 for sagebrush and PJ. 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 Fuels

Fuel volumes and depth of litter and duff are reported in Table 3-11 for aspen and PJ. The aspen plot had a high volume of fuel, especially sound 1,000-hr fuels. Fuels in PJ varied greatly among plots.

Table 3-1. Response design and number of plots by dominant vegetation and ecological site monitored in Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2008–2011.

Dominant vegetation	Response design	Ecological site*	Number of plots			
			2008 (August–September)	2009 (July–September)	2010 (August–September)	2011 (August–September)
Sagebrush	Grassland/shrubland	Dry Mountain Loam/ Mountain Loam	30	31	31	17
PJ	Woodland	Upland Shallow/ Stony Loam	1	8	8	12
Oak	Oak	Brushy Loam	4	8	8	12
Aspen	Forest	n/a	1	4	4	1
Total			36	51	51	42

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

Table 3-2. Mean (range) number of plant species detected per monitoring plot by life form and vegetation type, Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2011.

Vegetation type	Number of species detected					
	Total	Tree	Shrub	Perennial grass	Annual grass	Forb/Herb
Sagebrush	15.8 (8–21)	0.4 (0–1)	6.4 (4–10)	5.8 (3–7)	0.2 (0–1)	3.1 (0–8)
PJ	11.4 (7–21)	2.0 (2–2)	3.8 (1–9)	2.3 (0–5)	0.7 (0–1)	2.8 (0–6)
Oak	15.1 (8–21)	0.1 (0–1)	5.3 (3–11)	4.4 (1–7)	0.5 (0–1)	4.8 (1–8)
Aspen	29	1	5	6	0	17

Table 3-3. Mean (range) percent overstory canopy closure and percent cover of vegetation by life form for each vegetation type, Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2011.

Vegetation type	Overstory canopy closure	Total*		Tree		Shrub		Perennial grass		Annual grass		Forb/Herb	
		Live	Total	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total
Sagebrush	na	34.4 (19.3–58.0)	50.0 (34.3–73.3)	0.5 (0–6.3)	0.6 (0–6.3)	22.8 (10.0–41.3)	31.3 (15.7–48.3)	12.0 (3.7–28.0)	22.9 (8.7–47.0)	0	0.4 (0–4.0)	3.3 (0–13.7)	5.3 (0–17.3)
PJ	na	38.1 (22.3–57.3)	47.7 (27.0–67.7)	29.7 (20.0–41.7)	33.8 (23.0–48.3)	7.6 (0.3–29.3)	9.8 (0.7–39.3)	2.4 (0–7.0)	6.0 (0–16.0)	0	3.2 (0–14.3)	1.1 (0–3.0)	2.4 (0.3–8.3)
Oak	na	59.9 (32.1–86.3)	74.2 (48.8–92.1)	2.8 (0–33.3)	2.9 (0–34.6)	44.0 (12.9–73.8)	51.8 (20.4–80.0)	22.2 (11.3–40.4)	37.7 (20.0–52.5)	0	0.2 (0–1.7)	4.0 (0–12.9)	7.2 (0.8–14.6)
Aspen	54.9	80.3	86.3	0.7	0.7	27.7	29.0	48.7	58.7	0	0	41.0	50.3

*Total vegetation cover at all canopy heights for sagebrush, PJ, and oak; total understory cover for aspen.

Table 3-4. Mean (range) percent cover of dominant species by vegetation type, Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2011.

Scientific name	Common name	Life form	Duration	Nativity	No. of plots with species present*	Percent cover**	
						Live	Total
Sagebrush							
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	17	16.2 (8.3–25.0)	23.8 (13.0–38.7)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	Shrub	Perennial	Native	13	2.3 (0–9.0)	2.6 (0–11.0)
<i>Elymus elymoides</i>	squirreltail	Graminoid	Perennial	Native	17	0.7 (0–2.7)	1.7 (0.3–5.0)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	7	0.8 (0–5.3)	1.5 (0–8.3)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	16	5.9 (0–20.0)	11.8 (0–33.3)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	12	0.9 (0–4.3)	1.5 (0–6.3)
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	10	0.6 (0–2.7)	0.9 (0–3.7)
<i>Stipa lettermanii</i>	Letterman's needlegrass	Graminoid	Perennial	Native	11	0.7 (0–3.3)	1.7 (0–5.0)
<i>Symphoricarpos oreophilus</i>	mountain snowberry	Shrub	Perennial	Native	9	1.1 (0–11.7)	1.3 (0–13.0)
PJ							
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	Shrub	Perennial	Native	6	0.6 (0–4.0)	0.8 (0–4.7)
<i>Ephedra viridis</i>	Mormon tea	Shrub	Perennial	Native	6	0.6 (0–2.0)	0.6 (0–2.3)
<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	12	15.8 (2.3–29.0)	18.8 (3.3–38.3)
<i>Pinus edulis</i>	two-needle pinyon	Tree	Perennial	Native	12	14.6 (2.0–39.7)	16.1 (3.0–42.0)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	10	1.4 (0–5.3)	3.4 (0–15.3)
Oak							
<i>Amelanchier utahensis</i>	Utah serviceberry	Shrub	Perennial	Native	12	14.9 (3.3–42.9)	17.8 (4.6–48.3)
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	10	5.7 (0–21.7)	9.0 (0–32.1)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	12	9.3 (0.8–18.3)	18.4 (2.5–29.6)
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	9	21.5 (0–65.0)	24.1 (0–70.8)
<i>Stipa lettermanii</i>	Letterman's needlegrass	Graminoid	Perennial	Native	5	0.2 (0–0.8)	0.3 (0–1.7)
<i>Symphoricarpos oreophilus</i>	mountain snowberry	Shrub	Perennial	Native	11	4.8 (0–14.6)	5.3 (0–16.3)
Aspen							
<i>Achillea millefolium</i>	common yarrow	Forb	Perennial	Native	1	8.3	11.3
<i>Bromus carinatus</i>	mountain brome	Graminoid	Perennial	Native	1	3.7	4.0
<i>Bromus ciliatus</i>	fringed brome	Graminoid	Perennial	Native	1	2.0	2.0
<i>Elymus glaucus</i>	blue wildrye	Graminoid	Perennial	Native	1	2.0	2.0
<i>Geranium richardsonii</i>	Richardson's crane's-bill	Forb	Perennial	Native	1	0.7	0.7
<i>Populus tremuloides</i>	quaking aspen	Tree	Perennial	Native	1	0.7	0.7
<i>Rosa woodsii</i>	Woods' rose	Shrub	Perennial	Native	1	0.7	0.7
<i>Symphoricarpos oreophilus</i>	mountain snowberry	Shrub	Perennial	Native	1	22.0	23.3
<i>Vicia americana</i>	American vetch	Forb	Perennial	Native	1	13.0	18.7

* 1 aspen, 17 sagebrush, 12 PJ, and 12 oak plots were monitored in 2011.

** Cover at all canopy heights for sagebrush, PJ, and oak; understory cover (< 2 m) for aspen.

Table 3-5. Density of shrub species per hectare by vegetation type, Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2011.

Scientific name	Common name	No. of plots with species present*	Density (number of shrubs/ha)		
			Mean	Minimum	Maximum
Sagebrush					
<i>Artemisia frigida</i>	fringed sagebrush	7	506	0	4,200
<i>Artemisia nova</i>	black sagebrush	5	102	0	600
<i>Artemisia tridentata</i>	big sagebrush	17	10,392	6,200	19,933
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	2	24	0	267
<i>Chrysothamnus depressus</i>	dwarf rabbitbrush	8	1,871	0	12,267
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	2	125	0	1,133
<i>Chrysothamnus parryi</i>	Parry's rabbitbrush	2	90	0	1,400
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	16	5,353	0	24,267
<i>Eriogonum lonchophyllum</i>	spearleaf buckwheat	3	271	0	2,400
<i>Krascheninnikovia lanata</i>	winterfat	2	153	0	1,867
<i>Leptodactylon pungens</i>	prickly-phlox	3	16	0	133
<i>Pinus edulis</i>	two-needle pinyon	1	4	0	67
<i>Purshia tridentata</i>	antelope bitterbrush	8	424	0	4,533
<i>Ribes cereum</i>	wax current	1	4	0	67
<i>Tetradymia canescens</i>	spineless horsebrush	5	239	0	3,000
PJ					
<i>Artemisia nova</i>	black sagebrush	1	78	0	933
<i>Artemisia tridentata</i>	big sagebrush	3	622	0	4,667
<i>Atriplex canescens</i>	fourwing saltbrush	2	11	0	67
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	9	200	0	733
<i>Chrysothamnus depressus</i>	dwarf rabbitbrush	2	50	0	400
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	1	39	0	467
<i>Ephedra viridis</i>	Mormon tea	6	289	0	933
<i>Glossopetalon spinescens</i>	spiny greasebush	1	28	0	333
<i>Mahonia fremontii</i>	Fremont's mahonia	2	39	0	333
<i>Purshia tridentata</i>	antelope bitterbrush	1	78	0	933
<i>Tetradymia canescens</i>	spineless horsebrush	1	22	0	267

* 17 sagebrush and 12 PJ plots were monitored in 2011.

Table 3-6. Mean (range) density of live seedlings, saplings, and overstory trees, and crown class of live overstory trees by vegetation type, Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2011.

Scientific name	Common name	No. of plots with species detected ^a	Density of live trees by diameter ^b class (no. of trees/ha)					Crown class			
			Seedling	Sapling		Tree	% O	% I	% C	% D	
			<2.5 cm	2.5–5.0 cm	5.1–10.0 cm	10.1–15.0 cm					>15 cm ^c
Sagebrush											
<i>Juniperus scopulorum</i>	Rocky-mountain juniper	2	12 (0–133)	0	0	0	na	na	na	na	na
PJ											
<i>Juniperus osteosperma</i>	Utah juniper	12	167 (0–333)	57 (0–280)	80 (0–320)	73 (0–240)	259 (16–576)	na	na	na	na
<i>Pinus edulis</i>	two-needle pinyon	12	583 (0–1,400)	73 (0–400)	60 (0–240)	43 (0–160)	72 (0–336)	na	na	na	na
Oak											
<i>Pinus edulis</i>	two-needle pinyon	1	na	na	na	na	8	na	na	na	na
<i>Quercus gambelii</i>	Gambel oak	1	na	na	na	na	1	na	na	na	na
Aspen											
<i>Populus tremuloides</i>	quaking aspen	1	1,400	80	200	240	160	0	10	90	0

Crown class codes: O=Overtopped, I=Intermediate, C=Codominant, D=Dominant. Crown class is not recorded in PJ, oak, or sagebrush.

^a 1 aspen, 17 sagebrush, 12 PJ, and 12 oak plots were monitored in 2011.

^b Diameter was measured at root crown for Utah juniper and two-needle pinyon and at breast height for all other species.

^c This category also includes Gambel oak >10 cm dbh.

Table 3-7. Mean (range) density, diameter, and crown health for all trees >15 cm and Gambel oak >10 cm diameter by vegetation type, Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2011.

Scientific name	Common name	No. of plots with species detected ^a	Density (no. of trees/ha)	Diameter ^b (cm)	Crown health				
					% 1	% 2	% 3	% 4	% 5
PJ									
<i>Juniperus osteosperma</i>	Utah juniper	12	284 (16–624)	31.8 (19.3–47.4)	na	na	na	na	8 (0–27)
<i>Pinus edulis</i>	two-needle pinyon	9	76 (0–336)	27.2 (17.9–66.7)	na	na	na	na	16 (0–100)
Oak									
<i>Pinus edulis</i>	two-needle pinyon	1	8	33.2	na	na	na	na	0
<i>Quercus gambelii</i>	Gambel oak	1	1	10.5	na	na	na	na	0
Aspen									
<i>Populus tremuloides</i>	quaking aspen	1	384	24.0	17	25	0	0	58

Crown health codes: 1=90–100% live foliage, 2=50–89% live foliage, 3=16–49% live foliage, 4=0.1–15% live foliage, 5=standing dead. Crown health is not recorded in PJ or oak except to denote standing dead trees.

^a 1 aspen, 12 PJ, and 12 oak plots were monitored in 2011.

^b Diameter was measured at root crown for Utah juniper and two-needle pinyon and at breast height for all other species.

Table 3-8. Mean (range) percent cover and frequency of exotic plant species detected by vegetation type in Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2011.

Scientific name	Common name	Life form	Duration	No. of plots with exotic species detected*	Percent cover		Frequency of detection (%)
					Live	Total	
Sagebrush							
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	3	0	0.4 (0–4.0)	5.1 (0–43.3)
<i>Cirsium arvense</i>	Canada thistle	Forb	Perennial	1	0.02 (0–0.3)	0.02 (0–0.3)	0.2 (0–3.3)
<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	1	0.02 (0–0.3)	0.02 (0–0.3)	0
<i>Poa pratensis</i>	Kentucky bluegrass	Graminoid	Perennial	2	0.02 (0–0.3)	0.1 (0–1.0)	0.6 (0–6.7)
PJ							
<i>Alyssum alyssoides</i>	pale madwort	Forb	Annual	2	0.03 (0–0.3)	0.2 (0–2.0)	3.9 (0–43.3)
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	3	0	0.03 (0–0.3)	2.8 (0–20.0)
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	8	0	3.2 (0–14.3)	34.4 (0–100)
<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	2	0	0	0.6 (0–3.3)
<i>Sisymbrium altissimum</i>	tumble mustard	Forb	Annual	1	0	0.03 (0–0.3)	0.3 (0–3.3)
Oak							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	2	0.03 (0–0.4)	0.1 (0–1.3)	3.9 (0–33.3)
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	6	0	0.2 (0–1.7)	3.9 (0–13.3)
<i>Poa pratensis</i>	Kentucky bluegrass	Graminoid	Perennial	9	1.9 (0–10.0)	3.6 (0–18.8)	19.2 (0–63.3)
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	2	0	0	0.6 (0–3.3)
Aspen							
<i>Poa pratensis</i>	Kentucky bluegrass	Graminoid	Perennial	1	37.3	49.7	100
<i>Taraxacum officinale</i>	common dandelion	Forb	Perennial	1	4.3	7.0	66.7

* 1 aspen, 17 sagebrush, 12 PJ, and 12 oak plots were monitored in 2011.

Table 3-9. Mean (range) percent cover of surface features by vegetation type, Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2011.

Vegetation type	Crust, undifferentiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Sagebrush	19.0 (4.7–46.0)	0.04 (0–0.7)	0.5 (0–3.7)	1.4 (0–4.7)	2.4 (0–17.7)	44.2 (19.0–73.7)	0.2 (0–1.0)	17.1 (0.7–40.3)	6.0 (0–22.7)	0.6 (0–5.3)
PJ	15.5 (3.0–24.3)	2.0 (0–7.7)	0.4 (0–1.3)	2.6 (0–7.3)	2.1 (0–9.3)	53.1 (32.0–77.7)	2.2 (0.7–5.3)	11.8 (0.3–33.3)	5.8 (0–17.0)	1.4 (0–3.7)
Oak	7.2 (0–25.0)	0	0.03 (0–0.4)	0.9 (0–6.7)	2.7 (0–7.9)	80.3 (48.8–94.6)	0.7 (0–2.1)	1.7 (0–5.4)	0.8 (0–3.8)	0
Aspen	0.7	0	0	0	2.0	74.0	6.0	0.7	2.0	0

Table 3-10. Mean (range) soil-aggregate stability measures by vegetation type, Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2011.

Vegetation type	Total	Protected*	Unprotected*
Sagebrush	2.9 (1.9–4.5)	3.1 (1.9–4.9)	2.5 (1.4–3.9)
PJ	4.2 (2.3–5.1)	4.3 (2.4–5.6)	4.0 (1.0–5.4)

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

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

Table 3-11. Mean (range) fuel volume and depth of litter and duff by vegetation type, Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2011.

Vegetation type	Total	Fuel volume (tons/acre)				Depth (cm)	
		1-hr	10-hr	100-hr	1,000-hr	Litter	Duff
PJ	7.6 (1.4–28.8)	0.1 (0–0.1)	0.4 (0.1–0.9)	1.1 (0.3–2.7)	Sound* 5.1 (0–23.2)	Rotten* 1.0 (0–3.6)	0.8 (0.3–1.9)
Aspen	17.7	0.02	0.4	0	14.8	2.5	2.7
							1.7

* A piece of fuel is rotten when it is obviously punky or can be easily kicked apart at the intersection point; otherwise it is considered sound.

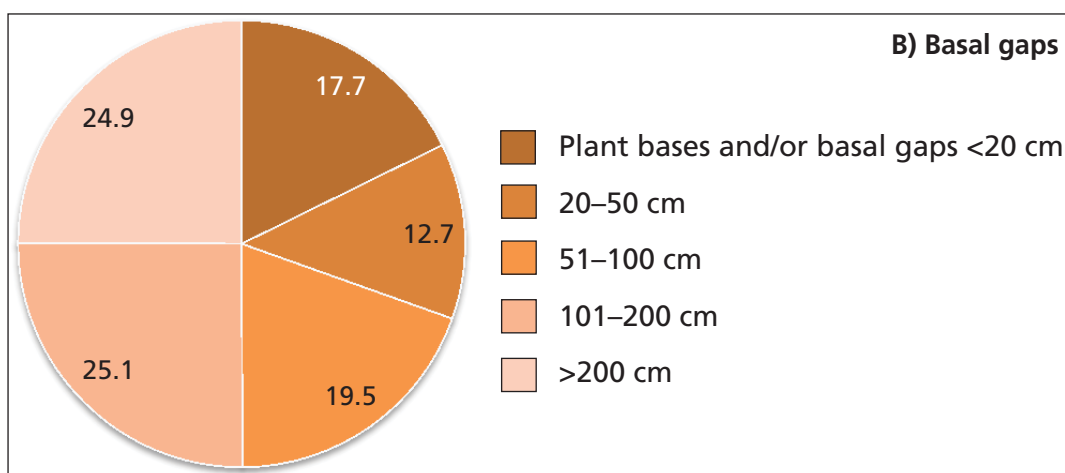
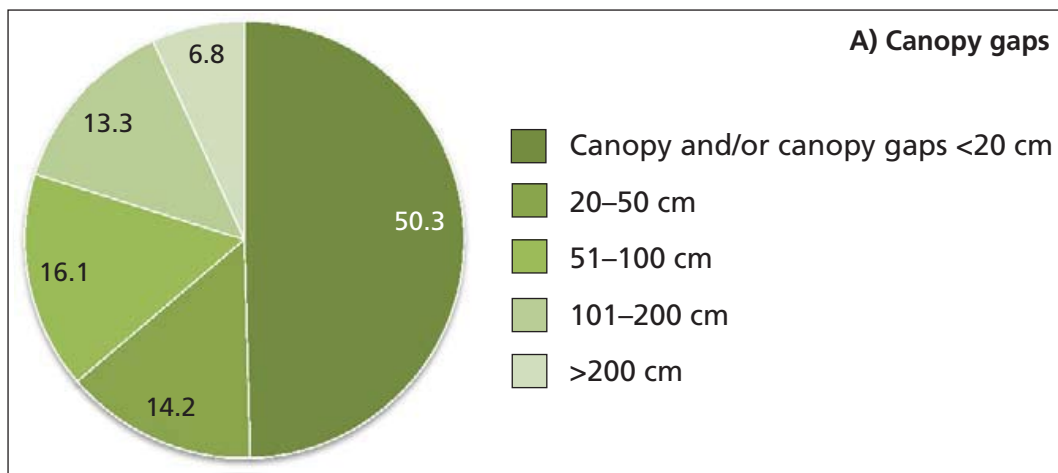


Figure 3-1. Distribution of (a) canopy gaps and (b) basal gaps at sagebrush sites in Curecanti National Recreation Area, 2011.*

*There were no sagebrush plots at Black Canyon of the Gunnison National Park in 2011. Also, part A of this figure has been revised from a previous version of this report.

4 Discussion

In general, data from 2011 were similar to data from previous years. All but one of the plots monitored in 2011 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 the 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.

After five full years of monitoring are complete, data will be analyzed for status and trends. Continued discussion with park resource staff will occur to ensure that park expectations and needs are satisfied by NCPN integrated upland monitoring.

5 Literature Cited

- Belnap, J. 2002. Nitrogen fixation in biological soil crusts from southeast Utah, U.S.A.: *Biology and Fertility of Soils* 35:128–135.
- Belnap, J., B. Budel, and O. L. Lange. 2003. Biological soil crusts: Characteristics and distribution. Pages 3–30 in J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.), Ecological studies series 150: Berlin: Springer-Verlag.
- Bock, C. E., J. H. Bock, K. L. Jepsen, and J. C. Ortega. 1986. Ecological effects of planting African lovegrass in Arizona. *National Geographic Research* 2(4):456–463.
- Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA Forest Service General Tech. Report INT-16, Intermountain Forest and Range Experiment Station, Ogden, Utah.
- Evans, R. D., and O. L. Lange. 2003. Biological soil crusts and ecosystem nitrogen and carbon dynamics. Pages 263–279 in J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.), Ecological studies series 150: Berlin: Springer-Verlag.
- Garfin, G. M., J. K. Eischeid, M. T. Lenart, K. L. Cole, K. Ironside, and N. Cobb. 2010. Downscaling climate projections in topographically diverse landscapes of the Colorado Plateau in the arid southwestern United States. In C. van Riper III, B. F. Wakeling, and T. D. Sisk, eds., *The Colorado Plateau IV: Shaping conservation through science and management*. Tucson: The University of Arizona Press.
- Harper, K. T., and J. Belnap. 2001. The influence of biological soil crusts on mineral uptake by associated vascular plants: *Journal of Arid Environments* 47(3):347–357.
- Harris, T. A., G. P. Asner, and M. E. Miller. 2003. Changes in vegetation structure after long-term grazing in pinyon-juniper ecosystems: Integrating imaging spectroscopy and field studies: *Ecosystems* 6(4):368–383.
- Herrick, J. E., J. W. Van Zee, K. M. Havstad, L. M. Burkett, and W. G. Whitford. 2005. *Monitoring manual for grassland, shrubland, and savanna ecosystems*. Published as 2 volumes. USDA Jornada Experimental Range, Las Cruces, New Mexico.
- Hogan, T., N. Lederer, D. Clark, and W. Fertig. 2009a. Annotated checklist of vascular flora: Black Canyon of the Gunnison National Park. Natural Resource Technical Report NPS/NCPN/NRTR—2009/227. National Park Service, Fort Collins, Colorado.
- Hogan, T., N. Lederer, D. Clark, and W. Fertig. 2009b. Annotated checklist of vascular flora: Curecanti National Recreation Area. Natural Resource Technical Report NPS/NCPN/NRTR—2009/232. National Park Service, Fort Collins, Colorado.
- Lange, O. L. 2003. Photosynthesis of soil-crust biota as dependent on environmental factors. Pages 217–240 in J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.), Ecological studies series 150: Berlin: Springer-Verlag.
- Miller, M. E. 2005. The structure and functioning of dryland ecosystems: Conceptual models to inform long-term ecological monitoring. U.S. Geological Survey Scientific Investigations Report 2005-5197.
- Miller, M. E., R. T. Belote, M. A. Bowker, and S. L. Garman. 2011. Alternative states of a semiarid grassland ecosystem: Implications for ecosystem services. *Ecosphere* 2(5):1–18.
- Munson, S. M., J. Belnap, C. D. Schelz, M. Moran, and T. W. Carolin. 2011a. On the brink of change: Plant responses to climate change on the Colorado Plateau. *Ecosphere* 2(6):1–15.
- Munson, S. M., J. Belnap, and G. S. Okin. 2011b. Responses of wind erosion to climate-induced vegetation changes on the Colorado Plateau. *Proceedings of the National Academy of Sciences of the USA* 108(10):3854–3859.

- National Park Service. 2003. Fire monitoring handbook. Fire Management Program Center, National Interagency Fire Center, Boise, Idaho. 274p.
- Rosentreter, R., and J. Belnap. 2003. Biological soil crusts of North America. Pages 31–51 *in* J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.), Ecological studies series 150: Berlin: Springer-Verlag.
- Theobald, D. M., D. L. Stevens Jr., D. White, S. Urquhart, A. R. Olsen, and J. B. Norman. 2007. Using GIS to generate spatially balanced random survey designs for natural resource applications. *Environmental Management* 40:134–146.
- U.S. Department of Agriculture Natural Resources Conservation Service (USDA NRCS). 1975. Soil survey of Gunnison area, Colorado, parts of Gunnison, Hinsdale, and Saguache counties. U.S. Department of Agriculture, Natural Resources Conservation Service, Denver, Colorado. 86 p.
- . 1981. Soil survey of Paonia area, Colorado, parts of Delta, Gunnison, and Montrose counties. U.S. Department of Agriculture, Natural Resources Conservation Service, Denver, Colorado. 184 p.
- Whelan, R. J. 1995. *The ecology of fire*. Cambridge, U.K.: Cambridge University Press.
- Whitford, W. G. 2002. *Ecology of desert systems*. San Diego, Calif.: Academic Press.
- Williams, J. D., J. P. Dombrowski, D. A. Gillette, and N. E. West. 1995. Microphytic crust influence on wind erosion. *Transactions of the American Society of Agricultural Engineers* 38:131–137.

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