



Integrated Upland Monitoring in Dinosaur National Monument

Annual Report 2011 (Non-Sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2013/712.N



ON THE COVER

Grassland in Zenobia Basin, Dinosaur National Monument. NPS photo.

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Prepared by

Dana Witwicki
Northern Colorado Plateau Network
National Park Service
P.O. Box 848
Moab, UT 84532

Editing and Design

Alice Wondrak Biel
Northern Colorado Plateau Network
National Park Service
P.O. Box 848
Moab, UT 84532

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Contents

Figures..... v

Tables vii

Executive Summary ix

Acknowledgements xi

1 Introduction..... 1

2 Methods..... 3

 2.1 Integrated upland monitoring in Dinosaur National Monument..... 3

 2.2 Integrated upland monitoring procedures..... 8

 2.3 Database 8

3 Results 11

 3.1 Monitored plots..... 11

 3.2 Vegetation type summaries..... 11

4 Discussion..... 25

5 Literature Cited 27

Figures

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

Figure 2-1. Sampling frame and location of pilot monitoring plots, Dinosaur National Monument..... 7

Figure 2-2. Plot layout for upland monitoring of grasslands and shrublands..... 9

Figure 2-3. Plot layout for upland monitoring of woodlands. 9

Figure 3-1. Distribution of canopy gaps for (a) low-elevation ungrazed, (b) low-elevation grazed, (c) high-elevation ungrazed, and (d) high-elevation grazed sagebrush sites in Dinosaur National Monument, 2011. 23

Figure 3-2. Distribution of basal gaps for (a) low-elevation ungrazed, (b) low-elevation grazed, (c) high-elevation ungrazed, and (d) high-elevation grazed sagebrush sites in Dinosaur National Monument, 2011. 24

Tables

Table 2-1. Description of big sagebrush ecological sites selected for upland monitoring in Dinosaur National Monument.	5
Table 2-2. Area (ha) of each vegetation type included in the sampling frame for upland monitoring at Dinosaur National Monument.....	7
Table 3-1. Response design and number of plots monitored by dominant vegetation, elevation, and grazing status in Dinosaur National Monument, 2009–2011.	12
Table 3-2. Mean (range) number of plant species detected per monitoring plot by lifeform and vegetation type, Dinosaur National Monument, 2011.	13
Table 3-3. Mean (range) percent cover of vegetation by lifeform for each vegetation type, Dinosaur National Monument, 2011.	13
Table 3-4. Mean (range) percent cover of dominant species by vegetation type, Dinosaur National Monument, 2011.	14
Table 3-5. Mean (range) density of shrub species per hectare by vegetation type, Dinosaur National Monument, 2011.	16
Table 3-6. Mean (range) density of live seedlings, saplings, and overstory trees in PJ, Dinosaur National Monument, 2011.	18
Table 3-7. Mean (range) density, diameter at root crown (drc), and percent dead for all trees >15 cm dbh in PJ, Dinosaur National Monument, 2011.....	18
Table 3-8. Mean (range) percent cover and frequency of exotic plant species detected in Dinosaur National Monument, 2011.	19
Table 3-9. Mean (range) percent cover of surface features by vegetation type, Dinosaur National Monument, 2011.	21
Table 3-10. Mean (range) canopy- and basal-gap size by vegetation type, Dinosaur National Monument, 2011.	21
Table 3-11. Mean (range) soil-aggregate stability measures by vegetation type, Dinosaur National Monument, 2011.	22
Table 3-12. Mean (range) fuel volume and depth of litter and duff in PJ, Dinosaur National Monument, 2011.	22

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 Dinosaur National Monument (NM) 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.

Upland monitoring was initiated at Dinosaur NM in 2009. Based on discussions with park resource staff, sagebrush and pinyon-juniper (PJ) were selected for monitoring. Sagebrush was additionally stratified by two elevation zones and by grazing status, for a total of four vegetation types monitored in sagebrush. For all vegetation types, eight plots will be monitored for three consecutive years to gain an understanding of natural variability. Assessment of these data will guide development of an operational sampling design. In 2009, thirty-five monitoring plots were established and monitored. In 2010, an additional five pinyon-juniper plots were established and monitored, and the first 35 plots were revisited. In 2011, all 40 plots were revisited.

In this report, measures from 2011 were summarized for each vegetation type. Early monitoring data describe status of vegetation types; interpretation is limited until additional data are acquired and more rigorously analyzed after at least five years of monitoring are complete.

Future monitoring activities include formulating an operational survey design for each vegetation type using variance measures in conjunction with desired levels of minimum detectable change, as derived from the three years of pilot monitoring data. The full monitoring design was implemented in 2012.

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1 Introduction

Uplands represent the vast majority of land area in national park units of the Northern Colorado Plateau Network (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 lifeforms 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 also located, biological soil crusts do not play an important role because much of the soil surface is covered by vegetation and litter.

Many upland ecosystems of the region 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 threaten 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 ex-



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

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pected 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 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 integrated upland monitoring at Dinosaur National Monument are described below.

Determine status and trends in plant communities, including:

- overall species richness
- cover of vegetation by dominant species and lifeform
- density of shrubs by size class
- basal area and density of tree species
- 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 facilitate identification of drivers and distinguishing “natural” from anthropogenic change. Local weather station data can be used to interpret responses, whereas remote sensing can be used to determine change in vegetation at larger scales caused by land use or climate change. Historical upland monitoring data sets may be integrated with data collected by NCPN to allow earlier detection of trends.

2 Methods

2.1 Integrated upland monitoring in Dinosaur National Monument

2.1.1 Resource issues driving upland monitoring

Dinosaur NM resource management staff identified big sagebrush (*Artemisia tridentata*) and grassland communities as the main priority for long-term monitoring. Grasslands occur as an early successional stage of big sagebrush communities after fire and, hereafter, these communities will be referred to as “sagebrush.” Sagebrush communities within the park unit are grazed and are often invaded by aggressive exotic plant species. Exotic annual grasses, such as cheatgrass (*Bromus tectorum*), can increase fire disturbance in the system (Whisenant 1990), making it difficult for native vegetation to recover after fire (D’Antonio and Vitousek 1992). Dinosaur NM managers are interested in monitoring sagebrush because of these management issues and, more specifically, would like to compare grazed and ungrazed sagebrush areas. There is also interest in comparing Wyoming big sagebrush and mountain big sagebrush ecosystems, which appear to respond differently to fire.

Dinosaur NM resource managers are also interested in monitoring pinyon-juniper (PJ) ecosystems because of their abundance in the park unit. The goal of monitoring PJ is to provide early warning of system degradation and information on the natural variability of upland resources.

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 $\geq 50\%$ and/or isolated by steep slopes were eliminated. Due primarily to costs, areas accessible only by river were eliminated from consideration. Accessibility and slope features were generated using the Landscape Accessibility Model ([\[ence.nature.nps.gov/im/units/ncpn/Tools.cfm\]\(http://ence.nature.nps.gov/im/units/ncpn/Tools.cfm\)\).](http://sci-</p></div><div data-bbox=)

Numerous private inholdings exist within the Dinosaur NM boundary, and discussion with Dinosaur NM staff determined which areas could be used for access and which areas must be avoided. All private inholdings were excluded from the sampling frame. The original map of accessible area was based on a roads and trails layer created by Botanist Tamara Naumann on BLM Land Status maps. Discussion with former Natural Resources Program Manager Cindy Heyd added access to Pearl Park, the Iron Springs area, and the area south of Brown’s Park. After field visits, the area north of the Yampa River was considered inaccessible, as an issue with a private landowner made access possible only through lengthy hikes. In the resulting accessibility model, 50% of the park unit was deemed accessible.

2.1.2.2 Selection of target vegetation and ecological-site types

Defining the 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 (e.g., 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 a soil survey, although the location of an ecological site within a soil map unit is not explicit. Although the soils portion of the recently published Dinosaur National Monument Soil Survey (USDA NRCS 2007) is complete, additional work remains to remedy differences between the ecological sites used for some portions of the survey and the older range sites used for other portions. We expect that the old range site descriptions eventually will no longer be used and that the existing Utah MLRA (Major Land Resource Area) ecological site descriptions 34 and 47 (USDA NRCS 2007) will be updated and expanded. It is unclear, however, when this update will be completed, and until then, we will continue to use the outdated range site descriptions.

Soil map units containing soil components with greater than 10% area of potential sagebrush ecological sites were evaluated

for monitoring. PJ is not well differentiated by ecological sites in the Dinosaur NM Soil Survey and occurs across the landscape on a variety of different landforms and soil components. Although soil components associated with PJ have the ecological site name “pinyon-juniper,” no effort has been made to distinguish between the different types of PJ ecological sites that exist within Dinosaur NM.

Field scouting was performed to determine which soil map units should be included in the sampling frame for each vegetation type. Due to the current condition of ecological site descriptions for Dinosaur NM (see previous paragraphs), all potential sagebrush ecological sites were used in upland monitoring. This included the 11 Wyoming big sagebrush ecological sites and three mountain big sagebrush ecological sites described in Table 2-1.

Ecological sites were not used for monitoring PJ because none existed in June 2009, when the sampling design was developed. Any site dominated by a PJ community, or dominated by PJ before fire, was included for potential monitoring. The only PJ sites that were excluded were those that could be recognized as sagebrush ecological sites with PJ invasion. Ecological site descriptions for PJ are not included in Table 2-1 because they have not yet been determined for Dinosaur NM.

2.1.2.3 Mapping of target vegetation types

A sampling frame was developed based on soil map units associated with target ecological sites and vegetation types. Changes were made to specific polygons based on field assessments. The sampling frame delineated accessible sagebrush and PJ types in Dinosaur NM (see Figure 2-1).

The sagebrush sampling frame was further stratified by elevation and grazing to highlight management issues of concern. Elevation was divided into high and low based on the approximate ranges of Wyoming and mountain big sagebrush. *Uinta Basin Flora* (Goedrich and Neese 1986) listed the boundary of the ranges as 6,500–7,000 feet. We used 2,000 m (6,562 ft) to distinguish between the two subspecies of big sagebrush in the sampling frame. A cutoff was necessary because the subspecies are known to hybridize where their ranges overlap. This meant that Wyo-

ming big sagebrush ecological sites could occur in the high-elevation sampling frame and mountain big sagebrush ecological sites could occur in the low-elevation sampling frame. This was not common, however, and should be rectified when the ecological sites are updated in the future.

Because PJ communities are the second priority for upland monitoring but cover the greatest area in Dinosaur NM, there was a need to limit the PJ sampling frame. Originally, we thought that soil map units could be grouped to form meaningful aggregates of PJ according to landform or soil characteristics. Evaluation of the PJ points visited during site reconnaissance confirmed large variability between landforms and soil types where PJ communities occurred. From these data, we concluded that there was no easy way to stratify PJ using soil map units. As an alternative, we consulted with resource management staff for ideas on how to stratify PJ based on management concerns. When no ideas were identified, we decided to limit sampling by geographic area of the park unit. Dinosaur NM was divided into five areas and park managers were asked to choose which area should be monitored. The area in Figure 2-1 was chosen (PJ, PJ and sagebrush), mainly because it represented a wide range of elevation.

Soil map units within the chosen area were evaluated for their ability to predict PJ communities. Many soil map units from the reconnaissance effort were eliminated from the sampling frame because they did not occur in the area selected for sampling. This included units that were predominantly PJ communities as well as a few that were dominated by both sagebrush and PJ. The five soil map units dominated by both vegetation types were included in the sampling frame for both sagebrush and PJ.

The sampling frame area was restricted to a 6-km hiking distance due to the difficulty of negotiating the terrain in some sections of the park unit. The total area of the sampling frame is approximately 20.8% of the total park area (see Table 2-2 for area of each stratum).

Table 2-1. Description of big sagebrush ecological sites selected for upland monitoring in Dinosaur National Monument.

Ecological site name	Ecological site number	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Rolling Loam	R034XY298CO	Deep sandy loams, loams, and gravelly loams	Eolian deposits, alluvium, residuum, and/or colluvium	Dominated by Wyoming big sagebrush, western wheatgrass, and needle and thread	Decreased bunchgrasses from overgrazing. PJ, cheatgrass, and exotic annuals may invade.
Sandy Foothills	R034XY310CO	Shallow to moderately deep loamy sands	Eolian deposits over residuum weathered from shale or just residuum	Dominated by Wyoming big sagebrush and needle and thread	Decreased bunchgrass and increased sagebrush from overgrazing. Decreased antelope bitterbrush from excessive browsing. Cheatgrass, Russian thistle, annual mustards, and juniper may invade.
Sandyland	R034XY330CO	Deep loamy sands	Alluvium and/or residuum	Dominated by Wyoming big sagebrush, Indian ricegrass, and needle and thread	Decreased bunchgrass and increased sagebrush from overgrazing. Cheatgrass, Russian thistle, annual mustards, and juniper may invade.
Semidesert Clay Loam	R034XB328CO	Deep clay loams on footslopes and toeslopes	Alluvium and/or colluvium over residuum weather from shale	Dominated by Wyoming big sagebrush, western wheatgrass, bluebunch wheatgrass, and Sandberg bluegrass	Decreased palatable grasses and shrubs and increased big sagebrush from overgrazing. Cheatgrass, Russian thistle, annual mustards, and juniper may invade.
Semidesert Gravelly Sandy Loam (Wyoming big sagebrush)	R034XY206UT	Deep gravelly loams	Alluvium, colluvium, and/or reworked eolian from sandstone or limestone	Dominated by Wyoming big sagebrush and galleta	Decreased bunchgrasses and increased shrubs from overgrazing. Increased rabbitbrush and decreased sagebrush from fire. Cheatgrass and juniper may invade.
Semidesert Loam	R034XY327CO	Deep loams on footslopes and toeslopes	Alluvium derived from sandstone and shale	Dominated by Wyoming big sagebrush and galleta	Decreased bunchgrasses and palatable shrubs from overgrazing. Bulbous bluegrass, greasewood, cheatgrass, and Russian thistle may invade.
Semidesert Loam (Wyoming big sagebrush)	R034XY212UT	Deep sandy loams	Alluvium and eolian deposits	Dominated by Wyoming big sagebrush and Indian ricegrass	Decreased bunchgrasses and increased sagebrush from overgrazing. Decreased sagebrush from fire or fall/winter grazing by sheep. Increased grasses and forbs after fire. Cheatgrass, annual weeds, and juniper may invade.
Semidesert Sand (fourwing saltbush)	R034XY214UT	Deep sand on footslopes and toeslopes	Eolian deposits	Dominated by Indian ricegrass, sand sagebrush, fourwing saltbush, and needle and thread	Decreased Indian ricegrass, needle and thread, and fourwing saltbush and increased snakeweed, rabbitbrush, sandhill muhly, and threewain from overgrazing. Cheatgrass and annual weeds may invade.

Table 2-1. Description of big sagebrush ecological sites selected for upland monitoring in Dinosaur National Monument, cont.

Ecological site name	Ecological site number	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Semidesert Sandy Loam	R034XB326CO	Deep sandy loams	Eolian deposits, alluvium, residuum, and/or colluvium	Dominated by Indian ricegrass, needle and thread, and Wyoming big sagebrush	Decreased bunchgrasses and winterfat from overgrazing. Cheatgrass, Russian thistle, annual mustards, and juniper may invade.
Semidesert Sandy Loam (fourwing saltbush)	R034XY216UT	Deep sandy loams	Eolian and alluvial deposits	Dominated by Indian ricegrass and needle and thread	Decreased Indian ricegrass, winterfat, and fourwing saltbush from overgrazing. Decreased sagebrush and fourwing saltbush from fire. Increased snakeweed, rabbitbrush, and galleta from overgrazing and fire.
Semidesert Shallow Loam (Wyoming big sagebrush)	R034XY225UT	Shallow cobbly sandy loams	Slope alluvium and/or colluvium over residuum from sandstone and limestone	Dominated by Wyoming big sagebrush and needle and thread	Decreased bunchgrasses and increased sagebrush, galleta, and snakeweed from overgrazing. Cheatgrass may invade.
Mountain Loam (mountain big sagebrush)	R047XC430UT	Deep loams	Alluvium, eolian deposits, and/or colluvium	Dominated by mountain big sagebrush and western wheatgrass	Decreased bunchgrasses and antelope bitterbrush and increased sagebrush, rabbitbrush, and western wheatgrass from overgrazing. Decreased sagebrush and increased rabbitbrush and western wheatgrass from fire.
Mountain Shallow Loam (mountain big sagebrush)	R047XC446UT	Shallow, extremely flaggy, sandy loams on shoulders and summits	Slope alluvium and/or colluvium derived from sandstone	Dominated by mountain big sagebrush and bluebunch wheatgrass	Decreased bunchgrasses and increased sagebrush and western wheatgrass from overgrazing. Decreased sagebrush and increased rabbitbrush and western wheatgrass from fire.
Mountain Stony Loam (bitterbrush)	R047XC460UT	Deep loams and channery loam on backslopes	Colluvium	Dominated by mountain big sagebrush, snowberry, and wheatgrasses	Decreased bunchgrasses and increased sagebrush and snowberry from overgrazing. Decreased sagebrush from fire.

Ecological site descriptions for PJ are not included because they have not yet been determined for Dinosaur NM.

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. Points were then assigned a predicted vegetation type based on the areas shown in Figure 2-1. Points predicted as sagebrush could only be accepted if they were one of the 14 sagebrush ecological sites. Points predicted as PJ could only be accepted if they were PJ communities. Points predicted as PJ-sagebrush could be accepted as either as one of the sagebrush ecological sites or as PJ. 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 or crossing a road, trail, park unit boundary, or cliff), the next sequentially ordered plot was used.

Sagebrush points were further categorized by elevation (low or high) and grazing (grazed or ungrazed), creating four strata for sagebrush (Figure 2-1). For pilot monitoring, a

Table 2-2. Area (ha) of each vegetation type included in the sampling frame for upland monitoring at Dinosaur National Monument.

Vegetation type	Elevation	Grazing	Area (ha)*
Mountain big sagebrush	High	Grazed	3,328
		Ungrazed	1,680
Wyoming big sagebrush	Low	Grazed	2,111
		Ungrazed	5,917
Total big sagebrush			13,035
Total PJ			6,082
PJ/sagebrush**			(1,812)
Total sampling frame			17,306

Numbers are approximate.

* Based on the accessible area within a 6-km hiking distance.

** The PJ/sagebrush area has already been included in the estimated areas for all of the sagebrush types and PJ.

total of 40 plots were monitored, including 8 ungrazed low-elevation sagebrush, 8 grazed low-elevation sagebrush, 8 ungrazed high-elevation sagebrush, 8 grazed high-elevation sagebrush, and 8 PJ. Plots will be monitored for three consecutive years to gain understanding of variability, and assessment of these data will guide the development of an operational survey design.

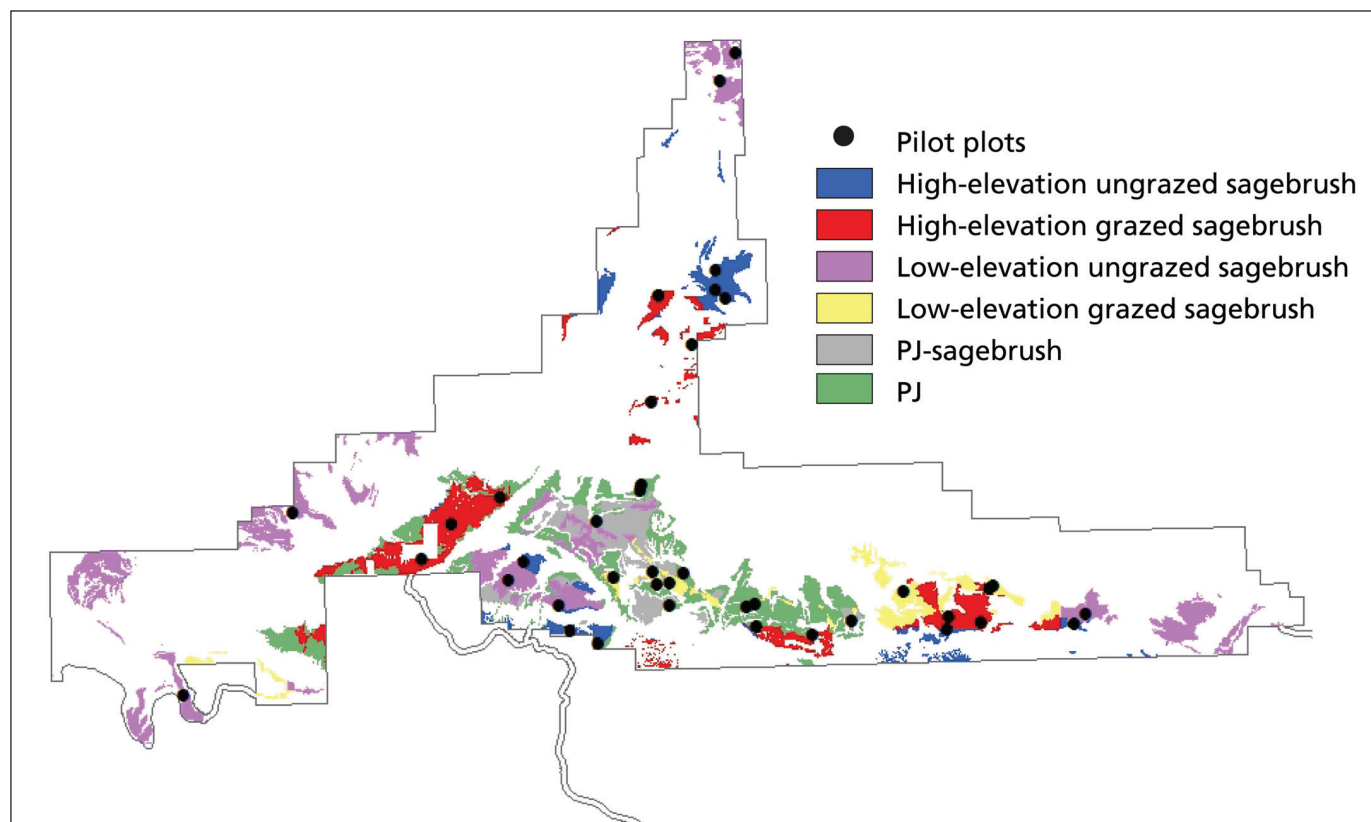


Figure 2-1. Sampling frame and location of pilot monitoring plots, Dinosaur National Monument.

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 rangeland monitoring procedures recommended by Herrick and colleagues (2005) and standard forest, woodland, and fuels procedures (NPS 2003; Brown 1974). Sagebrush is sampled using grassland/shrubland methods, while pinyon-juniper is sampled using woodland methods. All measures recorded along transects are sub-samples scaled to the plot level. The plot-level measures are the primary values used in summaries and statistical analyses.

2.2.1.1 Grasslands and shrublands

At each plot, observations are recorded along three parallel, 50-m transects spaced 25 m apart (Figure 2-2). 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 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 line-intercept methods. Six surface-soil 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 search for other exotic plants present in plots.

2.2.1.2 Woodlands

Photos of each transect are taken from the origin and end because vegetation tends

to be denser in woodlands. 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. Gaps are not recorded in woodland systems, but soil stability measurements are recorded at 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 woodland systems in order to capture the dynamics of stand replacement (Figure 2-3). 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 measured at breast height, except for woodland species that typically have multistem growth forms—for example, pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*), which are measured at the root crown (drc). Before 2011, all trees were measured at breast height (dbh). 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.

2.3 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.

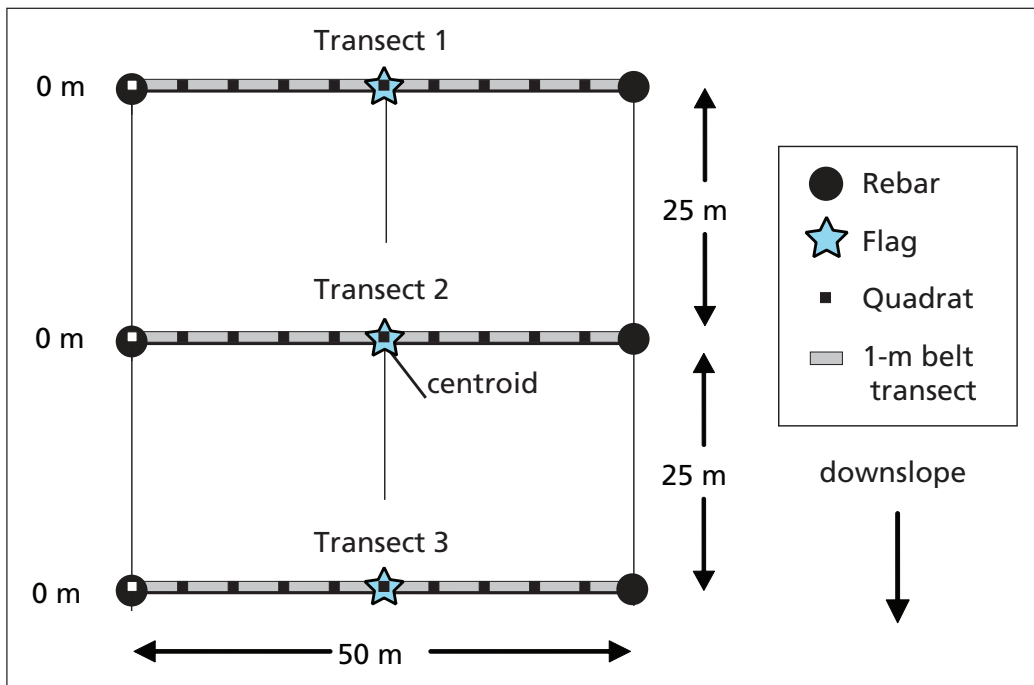


Figure 2-2. Plot layout for upland monitoring of grasslands and shrublands.

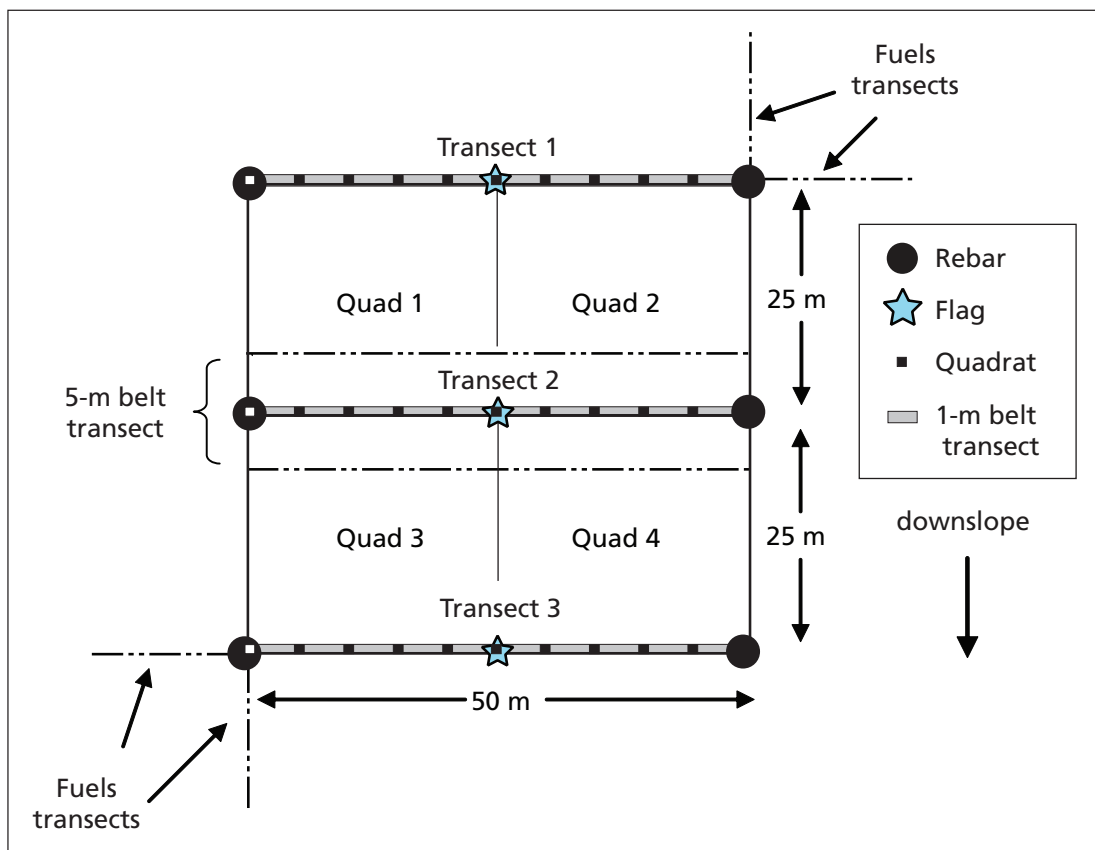


Figure 2-3. Plot layout for upland monitoring of woodlands.

3 Results

3.1 Monitored plots

In 2011, all 40 previously established plots were revisited in the third year of pilot monitoring (Figure 2-1). Table 3-1 summarizes plot visits by vegetation, elevation, grazing status, and year (tables start on page 12). Each plot was sampled using the suite of measures appropriate for that vegetation type.

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 and year. 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. The reader is cautioned not to draw wide-reaching conclusions from these preliminary summaries.

3.2.1 Species richness

A total of 131 species were detected in Dinosaur NM in 2011. Species richness by lifeform is reported in Table 3-2 for all vegetation types. Recorded species were compared to the NPSpecies database to determine first-time observations in Dinosaur NM. Two new species, redroot wild buckwheat (*Eriogonum racemosum*) and stork's bill (*Erodium cicutarium*), were detected in 2011.

Although Dinosaur NM has populations of only one federally listed threatened or endangered plant species within its borders, at least 80 rare plant species exist within the monument (Fertig 2009). One of these species, plains spring parsley (*Cymopterus acaulis*), was detected at a low-elevation, ungrazed sagebrush plot in 2011.

3.2.2 Cover by lifeform and dominant species

Percent cover of live and total vegetation by lifeform is 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 understory 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. The percent cover of all species recorded for each plot is included in an electronic appendix that accompanies this report (dino11_species.xls).

3.2.3 Shrub density

Density of shrub species is shown in Table 3-5 for all vegetation types. Big sagebrush had the highest density in all vegetation types.

3.2.4 Tree density

Density of live seedlings, saplings, and overstory trees is shown in Table 3-6 for PJ. Density and diameter of all overstory trees >15 cm diameter at root crown are shown in Table 3-7 for this vegetation type.

3.2.5 Exotic species

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

In 2011, a total of 15 exotic species were detected during upland monitoring. Most of the exotic plant species detected were annuals. Cheatgrass (*Bromus tectorum*) and desert madwort (*Alyssum desertorum*) were detected in all vegetation types. Cheatgrass was detected in the largest number of plots, including all PJ and low-elevation sagebrush plots, with cover as high as 70%.

Beginning in 2011, NCPN upland sampling methods also included an “exotic species walk” to search for other exotic plants present in plots. A list of all exotic plant species detected, and descriptions of the number of plants, size of invasions, and approximate locations, are included in an electronic appendix that accompanies this report (dino11_exotics.xls).

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 had the highest cover and undifferentiated crust had the second-highest cover for all vegetation types.

3.2.7 Canopy and basal gaps

Canopy- and basal-gap sizes are shown in Table 3-10 for all sagebrush sites. The distribution of gaps by size class is illustrated in Figures 3-1 and 3-2 for all sagebrush sites (figures start on page 23). Low-elevation sagebrush plots had larger canopy and basal

gaps than high-elevation sagebrush plots. There was little difference between grazed and ungrazed sites.

3.2.8 Soil aggregate stability

Measures of soil aggregate stability are reported in Table 3-11 for all vegetation types. 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 3-12 for PJ. Fuels consisted largely of sound 1,000-hr fuels.

Table 3-1. Response design and number of plots monitored by dominant vegetation, elevation, and grazing status in Dinosaur National Monument, 2009–2011.

Dominant vegetation	Response design	Elevation	Grazing status	Number of plots monitored		
				2009 (September–October)	2010 (June–July)	2011 (June–July)
Sagebrush	Grassland/ shrubland	High	Ungrazed	8	8	8
			Grazed	8	8	8
		Low	Ungrazed	8	8	8
			Grazed	8	8	8
PJ	Woodland	none	na	3	8	8
Total				35	40	40

Table 3-2. Mean (range) number of plant species detected per monitoring plot by lifeform and vegetation type, Dinosaur National Monument, 2011.

Vegetation type	Number of species detected					
	Total	Tree	Shrub	Perennial grass	Annual grass	Forb/Herb
Sagebrush–Low-elevation, Ungrazed	15.6 (12–24)	0.4 (0–2)	4.1 (1–8)	4.4 (3–7)	1.4 (1–2)	5.4 (0–12)
Sagebrush–Low-elevation, Grazed	16.3 (9–22)	0.6 (0–2)	3.4 (2–6)	4.8 (3–7)	1.4 (1–2)	6.1 (2–11)
Sagebrush–High-elevation, Ungrazed	22.4 (10–30)	0.4 (0–1)	4.8 (1–10)	6.5 (4–8)	0.9 (0–1)	9.9 (5–14)
Sagebrush–High-elevation, Grazed	23.5 (17–37)	0.9 (0–2)	4.3 (1–9)	6.4 (5–10)	0.6 (0–1)	11.4 (8–18)
PJ	16.3 (10–28)	1.9 (1–2)	2.6 (0–5)	4.1 (1–7)	1.0 (1–1)	6.6 (2–13)

Table 3-3. Mean (range) percent cover of vegetation by lifeform for each vegetation type, Dinosaur National Monument, 2011.

Vegetation type	Total		Tree		Shrub		Perennial grass		Annual grass		Forb/Herb	
	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total
Sagebrush–Low-elevation, Ungrazed	25.6 (11.7–38.7)	55.4 (35.7–84.7)	1.7 (0–7.7)	1.8 (0–9.0)	8.3 (1.0–15.3)	11.5 (1.0–18.7)	12.4 (0–22.0)	21.6 (2.0–44.3)	0.3 (0–0.7)	23.6 (1.0–70.3)	4.4 (0–10.0)	6.0 (0–11.3)
Sagebrush–Low-elevation, Grazed	31.8 (17.3–49.3)	50.9 (29.7–68.7)	2.6 (0–11.7)	2.6 (0–11.7)	10.8 (1.0–21.7)	13.2 (1.0–23.0)	13.1 (4.3–33.3)	20.8 (10.0–42.0)	4.3 (0–20.7)	14.2 (4.0–49.7)	4.8 (1.3–12.7)	10.3 (2.0–19.0)
Sagebrush–High-elevation, Ungrazed	42.9 (33.0–54.7)	60.7 (51.3–69.0)	1.8 (0–11.0)	1.8 (0–11.0)	11.7 (0.3–32.3)	14.6 (0.3–37.0)	25.0 (8.3–38.3)	40.5 (15.0–66.7)	0.2 (0–1.0)	0.8 (0–2.3)	9.9 (3.7–20.7)	12.1 (3.7–20.7)
Sagebrush–High-elevation, Grazed	55.0 (31.0–72.7)	65.6 (50.7–81.0)	3.6 (0–16.0)	3.7 (0–16.0)	16.1 (0–29.7)	21.0 (0–36.7)	23.8 (11.7–60.7)	31.7 (15.0–76.3)	0.7 (0–3.3)	0.8 (0–3.7)	22.0 (7.3–50.0)	23.7 (7.7–51.7)
PJ	32.2 (21.0–48.3)	39.8 (26.0–54.7)	24.8 (17.0–31.7)	27.8 (20.7–34.3)	1.8 (0–4.3)	2.7 (0–8.7)	3.9 (1.3–12.0)	6.7 (1.3–17.3)	1.5 (0–8.3)	4.7 (0–12.3)	4.5 (0.7–9.7)	6.5 (1.0–11.7)

Table 3-4. Mean (range) percent cover of dominant species by vegetation type, Dinosaur National Monument, 2011.

Scientific name	Common name	Lifeform	Duration	Nativity	No. of plots with species present*	Percent cover	
						Live	Total
Sagebrush–Low-elevation, ungrazed							
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	7	4.1 (0–11.3)	5.9 (0–15.0)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	1	0.04 (0–0.3)	0.04 (0–0.3)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	6	1.3 (0–5.3)	1.6 (6.3)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	2	0.5 (0–2.0)	0.6 (0–2.7)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	3	0.3 (0–2.3)	1.0 (0–7.3)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	8	6.5 (0–15.0)	9.8 (0.3–23.3)
Sagebrush–Low-elevation, grazed							
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	7	8.8 (0–20.3)	11.0 (0–21.7)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	2	1.1 (0–7.3)	1.6 (0–11.7)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	5	1.3 (0–5.7)	1.4 (0–5.7)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	3	0.9 (0–2.7)	1.1 (0–3.3)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	4	1.2 (0–5.0)	1.7 (0–8.0)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	8	7.5 (2.3–26.7)	9.8 (3.0–32.7)
Sagebrush–High-elevation, ungrazed							
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	8	7.2 (0.3–24.0)	9.6 (0.3–25.0)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	2	1.1 (0–8.0)	1.3 (0–8.3)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	4	0.7 (0–3.3)	1.0 (0–4.0)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	6	1.2 (0–3.7)	1.3 (0–4.0)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	8	1.3 (0.3–3.3)	2.0 (0.3–4.0)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	7	10.0 (0–23.7)	12.9 (0–34.0)

Table 3-4. Mean (range) percent cover of dominant species by vegetation type, Dinosaur National Monument, 2011.

Scientific name	Common name	Lifeform	Duration	Nativity	No. of plots with species present*	Percent cover	
						Live	Total
Sagebrush–High-elevation, grazed							
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	7	13.9 (0–29.7)	18.4 (0–36.7)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	4	2.0 (0–8.0)	2.3 (0–9.7)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	2	0.6 (0–3.3)	0.8 (0–4.7)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	7	2.8 (0–9.0)	3.0 (0–9.3)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	6	2.8 (0–9.0)	3.0 (0–9.7)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	6	8.9 (0–57.7)	10.3 (0–64.7)
PJ							
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	6	0.7 (0–1.7)	0.8 (0–1.7)
<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	8	20.6 (12.7–31.7)	23.1 (15.0–34.3)
<i>Pinus edulis</i>	two-needle pinyon	Tree	Perennial	Native	5	4.6 (0–14.7)	5.2 (0–15.0)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	8	1.3 (0–4.7)	1.7 (0.3–5.7)
<i>Poa secunda</i>	Sandberg’s bluegrass	Graminoid	Perennial	Native	5	0.5 (0–1.0)	1.5 (0–3.3)

* Eight plots were monitored in PJ and in each sagebrush vegetation type in 2011.

Table 3-5. Mean (range) density of shrub species per hectare by vegetation type, Dinosaur National Monument, 2011.

Scientific name	Common name	No. of plots with species present*	Density (number of shrubs/ha)		
			Mean	Minimum	Maximum
Sagebrush–Low-elevation, ungrazed					
<i>Artemisia nova</i>	black sagebrush	1	358	0	2,867
<i>Artemisia tridentata</i>	big sagebrush	7	3,483	0	7,067
<i>Atriplex confertifolia</i>	shadscale	3	92	0	467
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	1	125	0	1,000
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	3	392	0	1,933
<i>Eriogonum lonchophyllum</i>	spearleaf buckwheat	2	75	0	533
<i>Eriogonum microthecum</i>	slender wild buckwheat	4	250	0	1,400
<i>Grayia spinosa</i>	spiny hopsage	1	117	0	933
<i>Juniperus osteosperma</i>	Utah juniper	2	33	0	200
<i>Krascheninnikovia lanata</i>	winterfat	1	42	0	333
<i>Pinus edulis</i>	two-needle pinyon	1	17	0	133
<i>Sarcobatus vermiculatus</i>	greasewood	2	25	0	133
<i>Tetradymia nuttallii</i>	Nuttall's horsebrush	1	117	0	933
Sagebrush–Low-elevation, grazed					
<i>Artemisia tridentata</i>	big sagebrush	7	10,700	0	22,267
<i>Atriplex confertifolia</i>	shadscale	2	267	0	2,067
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	3	25	0	67
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	1	8	0	67
<i>Eriogonum corymbosum</i>	crisp-leaf wild buckwheat	2	25	0	133
<i>Eriogonum microthecum</i>	slender wild buckwheat	2	117	0	867
<i>Juniperus osteosperma</i>	Utah juniper	2	175	0	867
<i>Krascheninnikovia lanata</i>	winterfat	2	92	0	533
<i>Leptodactylon pungens</i>	prickly-phlox	2	33	0	133
<i>Pinus edulis</i>	two-needle pinyon	1	33	0	267
<i>Sarcobatus vermiculatus</i>	greasewood	1	75	0	600
Sagebrush–High-elevation, ungrazed					
<i>Artemisia nova</i>	black sagebrush	1	25	0	200
<i>Artemisia tridentata</i>	big sagebrush	7	10,775	0	41,133
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	3	200	0	933
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	1	17	0	133
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	1	42	0	333
<i>Eriogonum lonchophyllum</i>	spearleaf buckwheat	1	8	0	67
<i>Eriogonum microthecum</i>	slender wild buckwheat	2	442	0	3,200
<i>Juniperus osteosperma</i>	Utah juniper	1	67	0	533
<i>Krascheninnikovia lanata</i>	winterfat	1	8	0	67
<i>Pinus edulis</i>	two-needle pinyon	1	8	0	67
<i>Purshia tridentata</i>	antelope bitterbrush	1	92	0	733
<i>Tetradymia canescens</i>	spineless horsebrush	2	300	0	1,867
Sagebrush–High-elevation, grazed					
<i>Artemisia frigida</i>	fringed sagebrush	1	17	0	133
<i>Artemisia nova</i>	black sagebrush	1	33	0	267
<i>Artemisia tridentata</i>	big sagebrush	6	4,583	0	9,933
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	1	842	0	6,733

Table 3-5. Mean (range) density of shrub species per hectare by vegetation type, Dinosaur National Monument, 2011.

Scientific name	Common name	No. of plots with species present*	Density (number of shrubs/ha)		
			Mean	Minimum	Maximum
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	1	92	0	733
<i>Chrysothamnus parryi</i>	Parry's rabbitbrush	1	25	0	200
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	5	142	0	467
<i>Eriogonum corymbosum</i>	crisp-leaf wild buckwheat	1	142	0	1,133
<i>Eriogonum lonchophyllum</i>	spearleaf buckwheat	3	842	0	6,000
<i>Eriogonum microthecum</i>	slender wild buckwheat	2	92	0	667
<i>Juniperus osteosperma</i>	Utah juniper	4	100	0	400
<i>Leptodactylon pungens</i>	prickly-phlox	1	8	0	67
<i>Pinus edulis</i>	two-needle pinyon	2	167	0	1,000
<i>Purshia tridentata</i>	antelope bitterbrush	1	8	0	67
<i>Tetradymia canescens</i>	spineless horsebrush	4	117	0	400
PJ					
<i>Artemisia nova</i>	black sagebrush	3	108	0	333
<i>Artemisia tridentata</i>	big sagebrush	5	892	0	3,267
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	1	25	0	200
<i>Ephedra viridis</i>	Mormon tea	1	17	0	133
<i>Eriogonum microthecum</i>	slender wild buckwheat	2	542	0	3,467
<i>Purshia tridentata</i>	antelope bitterbrush	1	17	0	133
<i>Rhus trilobata</i>	skunkbush sumac	1	8	0	67
<i>Tetradymia canescens</i>	spineless horsebush	1	83	0	667

* Eight plots were monitored in PJ and in each sagebrush vegetation type in 2011.

Table 3-6. Mean (range) density of live seedlings, saplings, and overstory trees in PJ, Dinosaur National Monument, 2011.

Scientific name	Common name	No. of plots with species detected*	Density of live trees by diameter** class (no. of trees/ha)			
			Seedling <2.5 cm	Sapling 5.1–10.0 cm	10.1–15.0 cm	Tree >15 cm
<i>Juniperus osteosperma</i>	Utah juniper	8	258 (0–733)	95 (0–280)	165 (0–320)	328 (176–592)
<i>Pinus edulis</i>	two-needle pinyon	7	467 (0–1,267)	5 (0–40)	10 (0–40)	20 (0–96)

* Eight PJ plots were monitored in 2011.

** Diameter was measured at root crown for Utah juniper and two-needle pinyon.

Table 3-7. Mean (range) density, diameter at root crown (drc), and percent dead for all trees >15 cm dbh in PJ, Dinosaur National Monument, 2011.

Scientific name	Common name	No. of plots with species detected*	Density (no. of trees/ha)	Drc (cm)	% dead
<i>Juniperus osteosperma</i>	Utah juniper	8	342 (176–592)	24.0 (19.0–26.6)	4 (0–13)
<i>Pinus edulis</i>	two-needle pinyon	4	22 (0–96)	22.1 (16.8–29.4)	13 (0–50)

* Eight PJ plots were monitored in 2011.

Table 3-8. Mean (range) percent cover and frequency of exotic plant species detected in Dinosaur National Monument, 2011.

Scientific name	Common name	Lifeform	Duration	No. of plots with exotic species detected*	Percent cover		Frequency of detection (%)
					Live	Total	
Sagebrush–Low-elevation, ungrazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	6	0.1 (0–0.7)	1.1 (0–3.3)	53.8 (0–100)
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	8	0.3 (0–0.7)	23.5 (1.0–70.3)	75.4 (26.7–100)
<i>Eremopyrum triticeum</i>	annual wheatgrass	Graminoid	Annual	1	0	0	0.4 (0–3.3)
<i>Erodium cicutarium</i>	stork’s bill	Forb	Annual	1	0	0	0.4 (0–3.3)
<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	2	0.8 (0–6.7)	0.9 (0–7.3)	12.5 (0–93.3)
<i>Ranunculus testiculatus</i>	bur buttercup	Forb	Annual	2	0	0.04 (0–0.3)	2.1 (0–10.0)
<i>Salsola tragus</i>	Russian-thistle	Forb	Annual	1	0.1 (0–0.7)	0.3 (0–2.3)	4.2 (0–33.3)
<i>Sisymbrium altissimum</i>	tumble mustard	Forb	Annual	4	0.1 (0–0.3)	0.1 (0–0.3)	3.8 (0–13.3)
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	3	0	0	5.0 (0–23.3)
Sagebrush–Low-elevation, grazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	7	0.3 (0–1.7)	5.5 (0–15.3)	57.5 (0–100)
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	8	4.0 (0–20.3)	13.8 (2.3–49.7)	79.6 (63.3–100)
<i>Malcolmia africana</i>	African mustard	Forb	Annual	1	0	0.04 (0–0.3)	2.9 (0–23.3)
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	3	0.1 (0–0.7)	0.1 (0–0.7)	2.5 (0–13.3)
Sagebrush–High-elevation, ungrazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	5	0.04 (0–0.3)	1.2 (0–6.3)	33.3 (0–100)
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	7	0.2 (0–1.0)	0.8 (0–2.3)	15.4 (0–46.7)
<i>Chorispora tenella</i>	blue mustard	Forb	Annual	1	0	0	0.4 (0–3.3)
<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	3	0	0	5.0 (0–16.7)
<i>Poa pratensis</i>	Kentucky bluegrass	Graminoid	Perennial	1	1.0 (0–7.7)	1.1 (0–9.0)	3.3 (0–26.7)
<i>Ranunculus testiculatus</i>	bur buttercup	Forb	Annual	1	0	0.3 (0–2.7)	4.6 (0–36.7)
<i>Taraxacum officinale</i>	common dandelion	Forb	Perennial	2	0.04 (0–0.3)	0.04 (0–0.3)	4.6 (0–23.3)
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	5	0.3 (0–1.3)	0.3 (0–1.3)	15.4 (0–70.0)

Table 3-8. Mean (range) percent cover and frequency of exotic plant species detected in Dinosaur National Monument, 2011, cont.

Scientific name	Common name	Lifeform	Duration	No. of plots with exotic species detected*	Percent cover		Frequency of detection (%)
					Live	Total	
Sagebrush–High-elevation, grazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	4	0	0.8 (0–4.3)	26.7 (0–100)
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	5	0.7 (0–3.3)	0.8 (0–3.7)	25.4 (0–80.0)
<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	1	0	0	0.8 (0–6.7)
<i>Poa bulbosa</i>	bulbous bluegrass	Graminoid	Perennial	1	0	0	0.4 (0–3.3)
<i>Taraxacum officinale</i>	common dandelion	Forb	Perennial	2	0.04 (0–0.3)	0.04 (0–0.3)	1.3 (0–10.0)
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	3	0.2 (0–1.3)	0.2 (0–1.3)	9.2 (0–63.3)
PJ							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	5	0.1 (0–0.7)	0.2 (0–1.0)	18.3 (0–76.7)
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	8	1.5 (0–8.3)	4.7 (0–12.3)	54.6 (3.3–100)
<i>Descurainia sophia</i>	flixweed	Forb	Annual	2	0	0	1.7 (0–6.7)
<i>Ranunculus testiculatus</i>	bur buttercup	Forb	Annual	1	0	0	0.4 (0–3.3)
<i>Salsola tragus</i>	Russian thistle	Forb	Annual	1	0	0	1.3 (0–10.0)
<i>Sisymbrium altissimum</i>	tumble mustard	Forb	Annual	1	0.1 (0–0.7)	0.1 (0–0.7)	2.9 (0–23.3)

* Eight plots were monitored in PJ and in each sagebrush vegetation type in 2011.

Table 3-9. Mean (range) percent cover of surface features by vegetation type, Dinosaur National Monument, 2011.

Surface feature	Vegetation type				
	Sagebrush–Low-elevation, ungrazed	Sagebrush–Low-elevation, grazed	Sagebrush–High-elevation, ungrazed	Sagebrush–High-elevation, grazed	PJ
Crust, undifferentiated	27.9 (12.3–49.3)	30.8 (14.7–62.0)	24.0 (14.7–43.7)	21.7 (9.0–41.7)	29.9 (26.3–36.3)
Cyanobacteria	1.8 (0–7.3)	0.5 (0–1.7)	0	0	2.1 (0–5.3)
Lichen	0.8 (0–3.7)	0.5 (0–2.0)	0.04 (0–0.3)	0.1 (0–0.7)	0.9 (0–6.7)
Moss	2.2 (0–6.7)	12.3 (0.3–21.3)	1.3 (0–5.3)	1.1 (0–5.3)	1.4 (0.7–3.0)
Bare soil	0.3 (0–1.0)	0.3 (0–1.0)	1.2 (0–3.7)	1.3 (0–5.0)	1.0 (0–3.7)
Litter	46.3 (31.0–72.3)	41.9 (22.7–61.0)	57.8 (37.7–71.7)	57.1 (40.0–77.7)	45.6 (37.3–55.0)
Woody debris	0.5 (0–1.3)	0.5 (0–1.3)	0.3 (0–1.0)	0.7 (0–1.7)	0.7 (0–1.3)
Small rock	9.0 (0–25.7)	3.0 (0–14.3)	2.1 (0–7.3)	3.2 (0–16.7)	10.3 (3.7–19.3)
Large rock	1.6 (0–3.0)	1.1 (0–4.7)	1.0 (0–2.7)	3.1 (0–14.0)	3.2 (1.3–5.0)
Bedrock	0	0	0.5 (0–2.7)	0	2.7 (0–11.7)

Table 3-10. Mean (range) canopy- and basal-gap size by vegetation type, Dinosaur National Monument, 2011.

Vegetation type	Canopy gap (cm)	Basal gap (cm)
Sagebrush–Low-elevation, ungrazed	103 (39–198)	157 (41–325)
Sagebrush–Low-elevation, grazed	86 (52–141)	110 (51–201)
Sagebrush–High-elevation, ungrazed	45 (28–59)	53 (32–76)
Sagebrush–High-elevation, grazed	46 (36–57)	54 (40–73)

Table 3-11. Mean (range) soil-aggregate stability measures by vegetation type, Dinosaur National Monument, 2011.

Vegetation type	Total	Protected*	Unprotected*
Sagebrush–Low-elevation, ungrazed	5.3 (4.1–5.8)	5.5 (4.5–6.0)	5.1 (3.7–5.9)
Sagebrush–Low-elevation, grazed	5.2 (3.8–5.8)	5.4 (4.2–6.0)	4.3 (1.0–5.8)
Sagebrush–High-elevation, ungrazed	4.4 (2.4–5.2)	4.4 (2.5–5.2)	4.0 (2.0–5.0)
Sagebrush–High-elevation, grazed	4.4 (2.8–5.5)	4.5 (2.9–5.6)	3.7 (2.3–5.8)
PJ	4.4 (3.1–5.6)	4.3 (3.0–5.6)	4.4 (3.1–5.5)

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

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

Table 3-12. Mean (range) fuel volume and depth of litter and duff in PJ, Dinosaur National Monument, 2011.

Fuel volume (tons/acre)					Depth (cm)	
Total	1-hr	10-hr	100-hr	1,000-hr	Litter	Duff
				Sound* Rotten*		
3.5 (0.5–12.1)	0.1 (0.03–0.3)	0.4 (0–1.3)	0.7 (0–3.0)	2.3 (0–7.1) 0.1 (0–0.7)	0.8 (0.2–1.5)	0.05 (0–0.2)

*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.

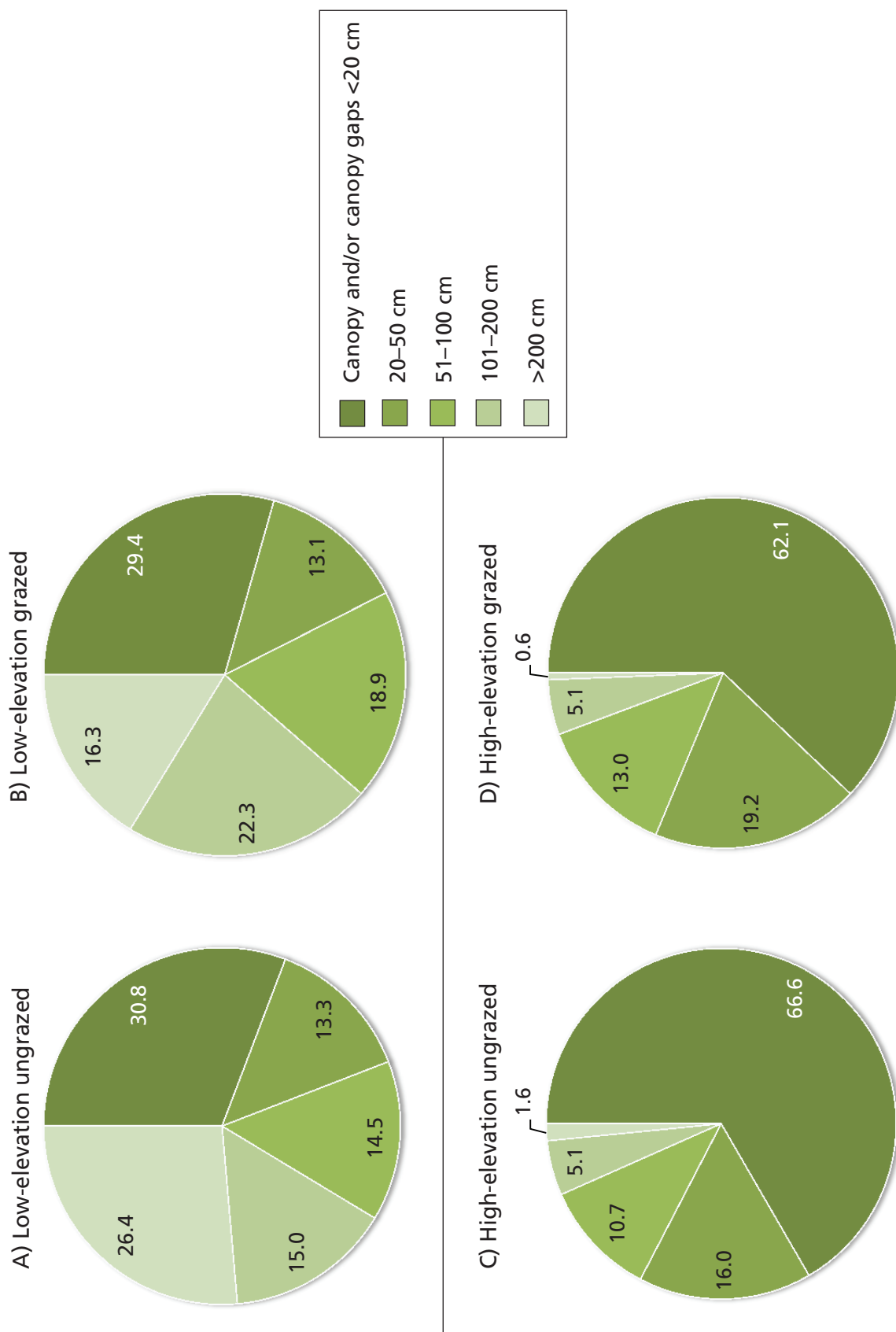


Figure 3-1. Distribution of canopy gaps for (a) low-elevation ungrazed, (b) low-elevation grazed, (c) high-elevation ungrazed, and (d) high-elevation grazed sagebrush sites in Dinosaur National Monument, 2011.

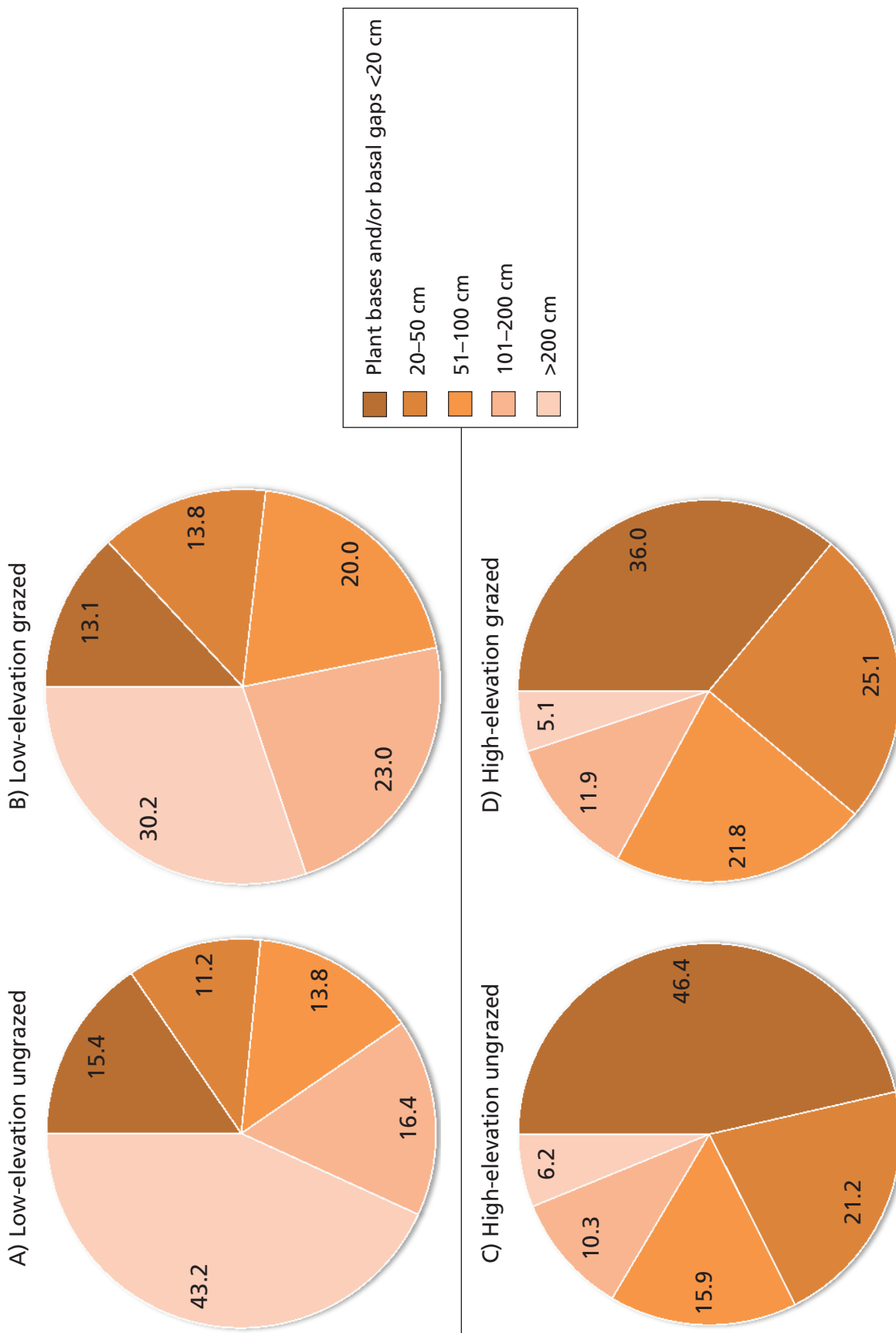


Figure 3-2. Distribution of basal gaps for (a) low-elevation ungrazed, (b) low-elevation grazed, (c) high-elevation ungrazed, and (d) high-elevation grazed sagebrush sites in Dinosaur National Monument, 2011.

4 Discussion

Based on a cursory review, data from 2011 were similar to those from previous years. One notable difference was in the amount of exotic plant species detected. Exotic species were much more likely to be detected at plots using the new frequency method than by using cover derived from point-intercept sampling or density of exotic perennials in the 1-m belt. This difference is most likely because the exotic frequency methods are better-suited for detecting exotic species in these vegetation types, and not due to an actual increase in exotic plant species in the monument in 2011.

After the 2011 field season, the 2–3 years of pilot monitoring data will be analyzed for estimates of variance. Variance serves as the basis for determining the ability to detect a minimum trend and is used to evaluate the number of plots needed and potential revisit designs. Recommendations for an operational survey design were presented to Dinosaur NM resource staff for discussion and approval, and new plots were established and monitored according to the long-term sampling design in 2012. 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.

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