



Integrated Upland Monitoring in Dinosaur National Monument

Annual Report 2009–2010 (Non-Sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2012/539.N



ON THE COVER

Sagebrush 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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Executive Summary

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

This report summarizes NCPN upland monitoring in Dinosaur National Monument (NM) during 2009 and 2010. 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. This report also 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 understanding of 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 this report, measures were summarized for each vegetation type by year. The only analysis performed was an ordination of species cover. Results of this ordination indicated a high degree of overlap between the four sagebrush site types and good separation between PJ and sagebrush sites. Early monitoring data describe status of vegetation types; interpretation will be limited until additional data are acquired and more rigorously analyzed.

Future monitoring activities include (1) re-measuring the 40 existing upland plots in 2011 and (2) 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 will be implemented in 2012.

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, which in turn determines potential above-ground production of native plant species and the propensity for invasion by non-native species. Vegetation also provides habitat for various organisms. The ability of uplands to retain soil and nutrients, absorb and release water, and buffer high-runoff precipitation events also influences 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 these dryland systems unique. Biological soil crusts are biotic communities composed of cyanobacteria, algae, micro-fungi, 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).

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 pin-

nacled. In the forests, shrublands, and meadows of the mountain regions surrounding the Colorado Plateau, where numerous NCPN park units are located, the role of biological soil crusts is less important 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 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 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 (litter, rock, bare ground, etc.)

- 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. Local weather-station data can be used to interpret responses, and 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 the 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 (hereafter, “sagebrush”) communities after fire. Sagebrush communities within the park unit are grazed and 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 staff is interested in monitoring sagebrush because of these management issues. More specifically, they would like to compare grazed and ungrazed sagebrush areas. There is also interest in comparing Wyoming big sagebrush and mountain big sagebrush ecosystems because they appear to respond differently to fire.

Pinyon-juniper (PJ) ecosystems are of interest to monument staff because of their abundance. The goal of monitoring PJ is to provide information on the natural variability of upland resources as well as early warning of system degradation.

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 river were eliminated from consideration. Accessibility and slope features were generated using the Landscape Accessibility Model (<http://science.nature.nps.gov/im/units/ncpn/Tools.cfm>).

Numerous private inholdings exist within the Dinosaur NM boundary, and discussion with monument staff determined which areas could be used for access and which must be avoided. All private inholdings were excluded from the sampling frame. The original map was based on a roads and trails layer created by Botanist Tamara Naumann on BLM Land Status maps. Discussion with former Natural Resource 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 land owner 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 (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. 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 in Utah and the old range sites used in Colorado. We expect that the old Colorado range site descriptions will no longer be used and that the existing Utah MLRA (Major Land Resource Area) 34 and 47 ecological site descriptions will be updated and added. It is unclear, however, when this update will be completed, and we will continue to use the outdated Colorado range site descriptions until that time.

Soil map units containing soil components with greater than 10% area of potential sagebrush ecological sites were evaluated for monitoring. In the Dinosaur NM Soil Survey, PJ was not well differentiated by ecological sites and occurs across the landscape on a variety of different landforms and soil

components. Soil components associated with PJ have the ecological site name “Pin-yon-Juniper;” however, no effort was 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. These 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 being developed. Any site dominated by PJ community or dominated by PJ before fire was included for potential monitoring. The only PJ sites that were excluded were ones 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 status to address management issues of concern. Elevation was divided into high and low based on the approximate ranges of Wyoming and mountain big sagebrush (Figure 2-1). *Uinta Basin Flora* (Goodrich and Neese 1986) listed the boundary of those ranges as 6,500–7,000 feet. We used 6,562 feet (2,000 m) as a dividing line for distinguishing between the two subspecies of big sagebrush in the sampling frame. This cutoff was necessary because the subspecies are known to hybridize where their ranges overlap, meaning that Wyoming 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-tier priority for upland monitoring but cover the greatest area in Dinosaur NM, there was a need to limit the PJ sampling frame. Although we considered grouping soil map units according to landform or soil characteristics to form meaningful aggregates of PJ, evaluation of the PJ points visited during site reconnaissance confirmed that there was large variability between the kinds of landforms and soil types where PJ communities occurred. From this 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 none was identified, we decided to limit sampling according to geographic area of the park unit. We divided Dinosaur NM into five areas and asked Cindy Heyd to choose one area for monitoring. The area shown in Figure 2-1 (PJ, PJ and sagebrush) was chosen, primarily because it represented a wide range of elevation.

Soil map units within this area were then 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. These included soil map 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 sagebrush as well as PJ.

The sampling frame area was restricted to a 6-km hiking distance due to the difficulty of the terrain in some sections of the monument. 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).

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

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

Ecological site name /Number	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Wyoming big sagebrush ecological sites				
Rolling Loam / R034XY298CO	Deep sandy loams, loams, & gravelly loams	Eolian deposits, alluvium, residuum, and/or colluvium	Dominated by Wyoming big sagebrush, western wheatgrass, & 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, & 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, & Sandberg bluegrass	Decreased palatable grasses & 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 & 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 & galleta	Decreased bunchgrasses and palatable shrubs from overgrazing. Bulbous bluegrass, greasewood, cheatgrass, & Russian thistle may invade.
Semidesert Loam (Wyoming Big Sagebrush) / R034XY212UT	Deep sandy loams	Alluvium & eolian deposits	Dominated by Wyoming big sagebrush & 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, & juniper may invade.
Semidesert Sand (Four-wing Saltbush) / R034XY214UT	Deep sand on footslopes and toeslopes	Eolian deposits	Dominated by Indian ricegrass, sand sagebrush, four-wing saltbush, & needle and thread	Decreased Indian ricegrass, needle and thread, and four-wing saltbush and increased snakeweed, rabbitbrush, sandhill muhly, and three-awn from overgrazing. Cheatgrass and annual weeds may invade.
Semidesert Sandy Loam / R034XB326CO	Deep sandy loams	Eolian deposits, alluvium, residuum, and/or colluvium	Dominated by Indian ricegrass, needle and thread, & 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 & alluvial deposits	Dominated by Indian ricegrass & needle and thread	Decreased Indian ricegrass, winterfat, and four-wing saltbush from overgrazing. Decreased sagebrush & four-wing saltbush from fire. Increased snakeweed, rabbitbrush, and galleta from overgrazing and fire.

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

Ecological site name /Number	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
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 & needle and thread	Decreased bunchgrasses and increased sagebrush, galleta, and snakeweed from overgrazing. Cheatgrass may invade.
Mountain big sagebrush ecological sites				
Mountain Loam (Mountain Big Sagebrush) / R047XC430UT	Deep loams	Alluvium, eolian deposits, and/or colluvium	Dominated by mountain big sagebrush & 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 & 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 & channery loam on backslopes	Colluvium	Dominated by mountain big sagebrush, snowberry, & wheatgrasses	Decreased bunchgrasses and increased sagebrush and snowberry from overgrazing. Decreased sagebrush from fire.

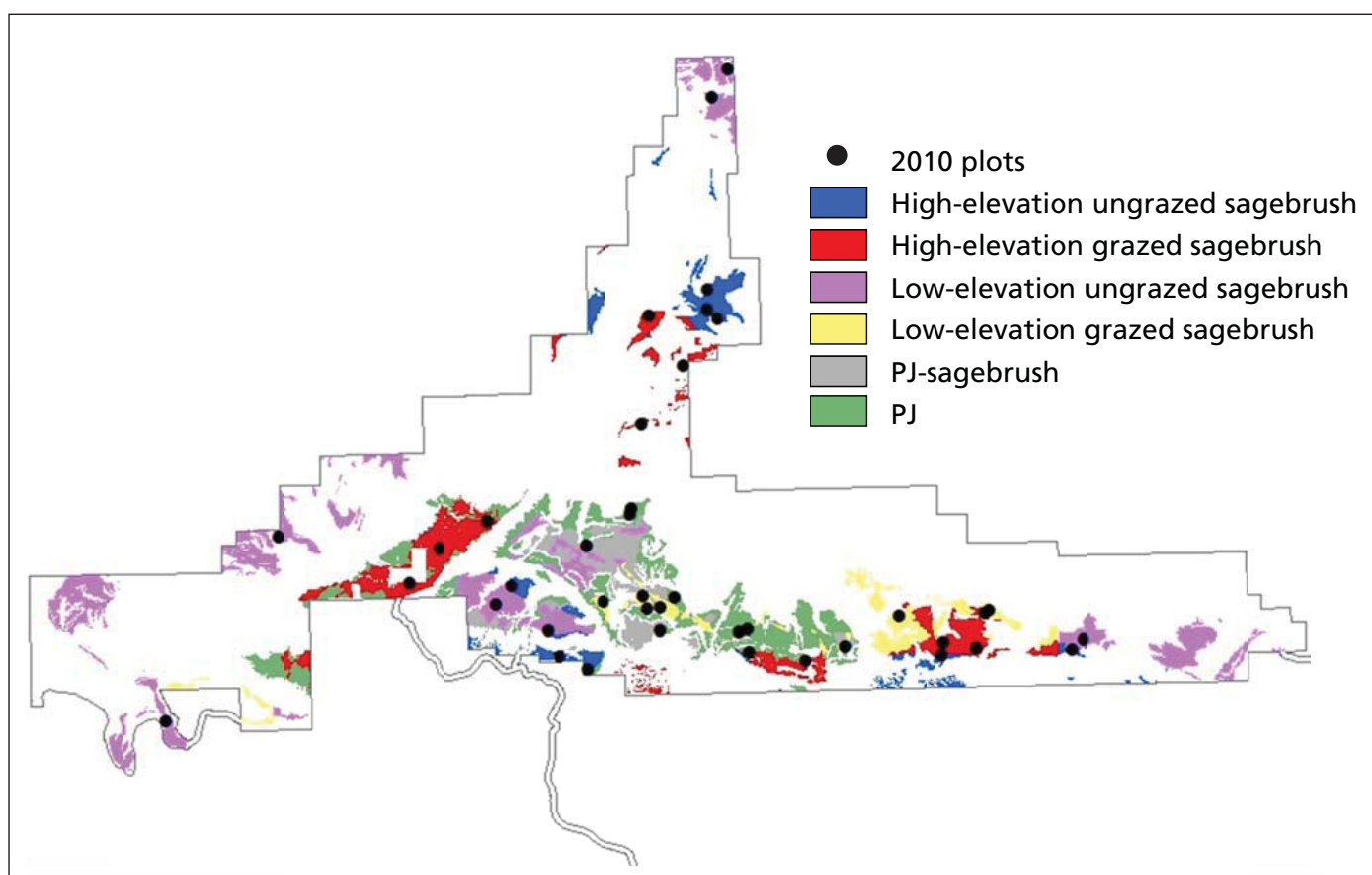


Figure 2-1. Sampling frame and location of pilot monitoring plots, Dinosaur National Monument.

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 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 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 (Figure 2-1). 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.

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 et al. (2005) and standard forest, woodland, and fuels procedures (USDI 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.

2.2.2 Grasslands and shrublands

At each plot, observations are recorded along three parallel, 50-m transects spaced 25 m

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.

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), tree seedlings (by species), and exotic perennials (by species) is recorded in a 1-m belt upslope of 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.

2.2.3 Woodlands

Because vegetation tends to be denser in woodlands, photos are taken at the origin and end of each transect in woodland plots. Using the same methods as for grasslands/shrublands, point-intercept cover of vegetation and surface features, as well as density of shrubs, tree seedlings, and exotic perennial 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 on and off 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 typically measured at breast height (dbh). Fuels are measured using Brown's planar method (Brown 1974) along four 15-m 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.

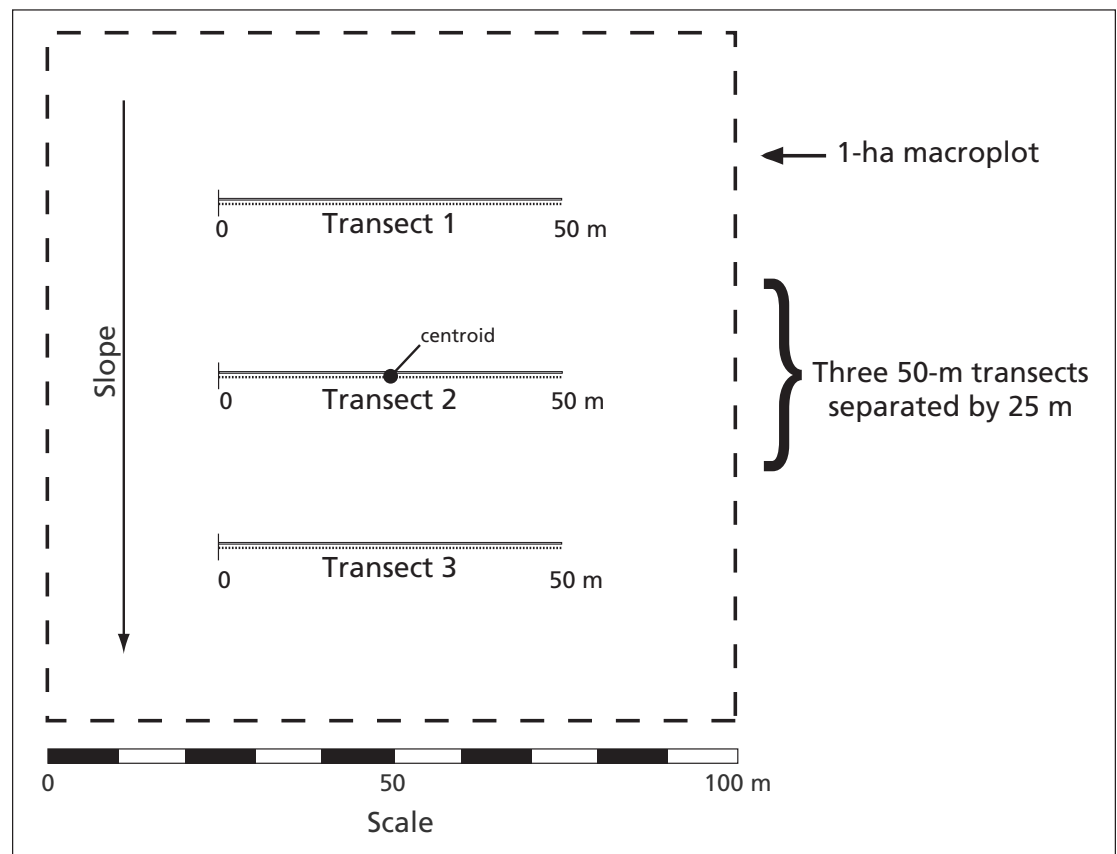


Figure 2-2. Plot layout for upland monitoring of grasslands and shrublands.

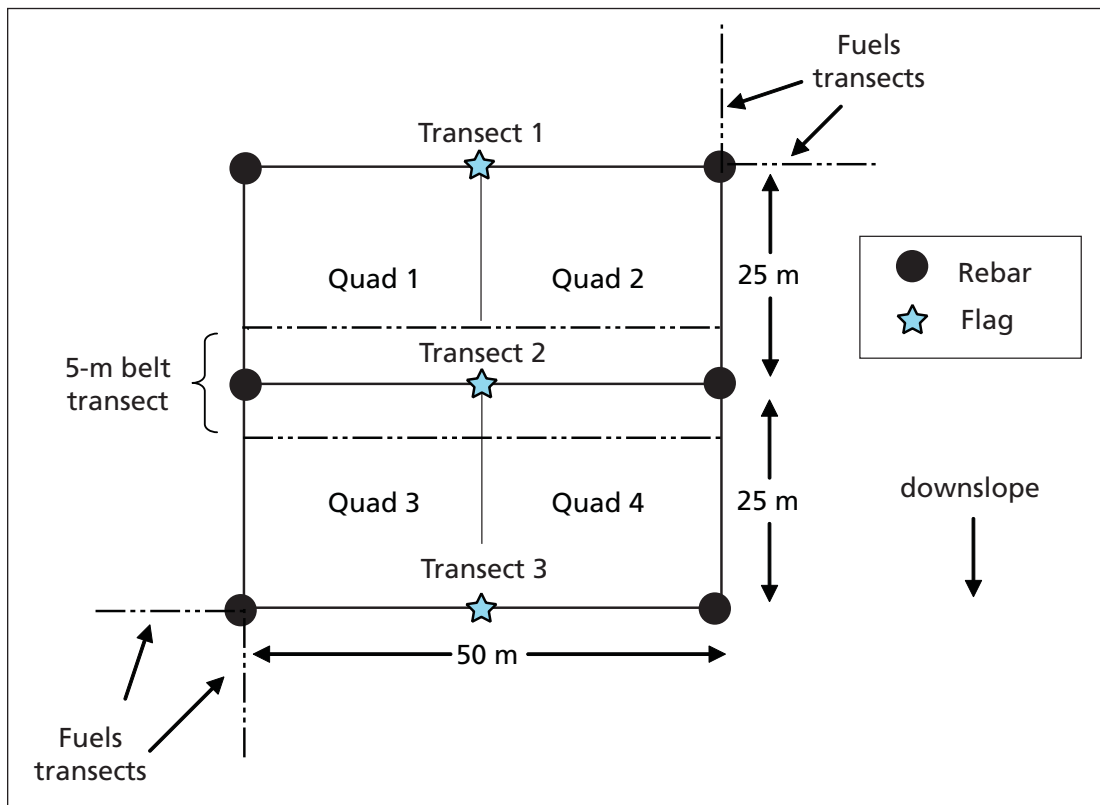


Figure 2-3. Plot layout for upland monitoring of woodlands.

3 Results

3.1 Monitored Plots

In 2009, thirty-five plots were established and monitored as part of the pilot sampling. In 2010, an additional five plots were established and monitored, and the first 35 plots were revisited (see Figure 2-1). Table 3-1 summarizes plot visits by vegetation, elevation, grazing status, and year (tables begin on page 13). 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. Comparing data between years could be particularly misleading for PJ because only a small number of plots were monitored in 2009 (see Table 3-1). The reader is cautioned not to draw wide-reaching conclusions from this initial set of results.

The only statistical assessment provided is a multivariate assessment of the similarity of vegetative conditions within and among vegetation types (see Section 3.2.10). Data from 2010 were ordinated using NMS (non-metric multidimensional scaling), which involves scaling plots on the basis of similarity (or dissimilarity) of species composition and cover. Plots are distributed in multivariate space, typically along 1–3 axes, and within this space, plots with similar composition are located closer together and correlated with dominant species.

3.2.1 Species richness

A total of 122 species were detected in Dinosaur NM in 2010. Species richness by life form is reported in Tables 3-2 and 3-3 for all vegetation types. Recorded species were compared to the NPSpecies database to determine first-time observations in Dinosaur NM. No new species were detected in 2009 or 2010.

Threatened and endangered plant species are not common in the areas of Dinosaur NM monitored by the network, and the NCPN does not specifically monitor them in these park units. No threatened or endangered species were found on any plots in 2009 or 2010.

3.2.2 Cover by life form and dominant species

Percent cover of live and total vegetation by life form is shown for all vegetation types in Tables 3-4 and 3-5. 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 Tables 3-6 and 3-7 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 by year is included in the electronic appendices that accompany this report (dino09_species.xls and dino10_species.xls).

3.2.3 Shrub density

Density of shrub species for all vegetation types is shown in Table 3-8.

3.2.4 Tree density

Density of live seedlings, saplings, and overstory trees is shown for PJ in Table 3-9. Density and dbh for all overstory trees >15 cm dbh are shown in Table 3-10 for this vegetation type.

3.2.5 Exotic species

Cover of exotic plant species is shown for all vegetation types in Tables 3-11 and 3-12. When exotic species were detected, cover was summarized for all plots in the vegetation type. In 2009 and 2010, NCPN upland sampling methods did not include an invasive species walk; therefore, lack of detection does not mean that other exotic species were not present in plots. In 2011, methods will be added to include early detection of exotics.

In 2009 and 2010, a total of 11 exotic species were detected during upland monitoring. Cheatgrass (*Bromus tectorum*) and desert madwort (*Alyssum desertorum*) were detected in all vegetation types. Cheatgrass was detected in the largest number of plots, including most low-elevation sagebrush plots, with cover as high as 64%. Yellow salsify (*Tragopogon dubius*) was the most commonly detected exotic perennial.

3.2.6 Biological soil crust and surface features

Biological soil crust and surface-feature cover are shown for all vegetation types in Tables 3-13 and 3-14. 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 for all sagebrush sites are shown in Table 3-15. The distribution of gaps by size class is illustrated in Figures 3-1 through 3-4 for all sagebrush sites (figures begin on page 24). Low-elevation sagebrush plots had larger canopy and basal gaps than high-elevation sagebrush plots. There was little difference between grazed and ungrazed sites or between years.

3.2.8 Soil aggregate stability

Measures of soil aggregate stability are reported for sagebrush and PJ in Table 3-16. 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 measures 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 for PJ are reported in Table 3-17.

3.2.10 Plot ordinations

Non-metric multidimensional scaling (NMS) ordination was performed using species with relative cover values of $\geq 10\%$ (Figure 3-5). Relative cover is the percent cover of the species divided by the total vegetation cover on a plot. This requirement was imposed to emphasize dominant species. The direction and relative magnitude of correlations of species are shown in the graphs for each combination of axes. The species vector from the origin shows the direction of positive correlation.

The ordination illustrates the separation of PJ from the sagebrush sites and the high degree of overlap between the four sagebrush site types. For sagebrush, there was little separation between grazed and ungrazed areas. In Axis 2 vs. 3, there was some separation between high-elevation and low-elevation sagebrush sites, with many low-elevation sites associated with cheatgrass and desert madwort.

Table 3-1. Response design and number of plots monitored by dominant vegetation and grazing status in Dinosaur National Monument, 2009–2010.

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

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

Vegetation type	Number of species detected					
	Total	Tree	Shrub	Perennial grass	Annual grass	Forb/Herb
Sagebrush– low, ungrazed	9.9 (4–15)	0.3 (0–1)	3.6 (0–7)	2.6 (0–5)	1.1 (1–2)	2.3 (1–4)
Sagebrush– low, grazed	10.5 (7–15)	0.5 (0–2)	2.8 (0–5)	4.1 (1–6)	1.0 (1–1)	2.1 (1–4)
Sagebrush– high, ungrazed	15.8 (3–31)	0.4 (0–1)	4.6 (1–9)	5.5 (2–9)	0.8 (0–1)	4.5 (0–12)
Sagebrush– high, grazed	14.1 (9–23)	0.9 (0–2)	4.0 (1–9)	4.6 (3–6)	0.5 (0–1)	4.1 (1–10)
PJ	10.3 (3–15)	1.3 (1–2)	2.7 (1–4)	3.0 (0–5)	0.7 (0–1)	2.7 (0–4)

Table 3–3. Mean (range) number of plant species detected per monitoring plot by life form and vegetation type, Dinosaur National Monument, 2010.

Vegetation type	Number of species detected					
	Total	Tree	Shrub	Perennial grass	Annual grass	Forb/Herb
Sagebrush– low, ungrazed	12.5 (6–19)	0.3 (0–1)	3.9 (0–9)	3.3 (2–5)	0.9 (0–1)	4.3 (2–8)
Sagebrush– low, grazed	13.4 (8–21)	0.6 (0–2)	3.0 (0–5)	4.6 (3–6)	1.1 (1–2)	4.0 (1–9)
Sagebrush– high, ungrazed	20.4 (9–37)	0.4 (0–1)	4.9 (1–10)	5.9 (4–11)	0.8 (0–1)	8.5 (3–18)
Sagebrush– high, grazed	20.4 (13–29)	0.9 (0–2)	4.5 (1–11)	5.9 (4–8)	0.5 (0–1)	8.6 (5–12)
PJ	12.9 (5–23)	1.6 (1–2)	2.8 (0–7)	4.4 (2–7)	0.9 (0–1)	3.3 (0–6)

Table 3-4. Mean (range) percent cover of vegetation by life form for each vegetation type, Dinosaur National Monument, 2009.

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, ungrazed	15.5 (3.7-26.7)	43.2 (33.7-66.0)	1.7 (0-7.7)	1.9 (0-9.0)	5.9 (0-10.7)	10.0 (0-15.3)	4.0 (0-11.3)	14.2 (0-37.0)	2.5 (0-11.7)	18.0 (1.0-55.3)	2.0 (0-9.0)	4.3 (0-9.7)
Sagebrush-low, grazed	23.0 (16.0-34.3)	46.8 (28.3-59.3)	2.5 (0-13.7)	2.5 (0-13.7)	8.7 (0-18.3)	13.0 (0-24.0)	4.5 (1.0-11.3)	17.3 (2.0-34.7)	6.1 (0-31.0)	16.7 (4.3-48.3)	2.0 (0-7.3)	5.1 (0.7-17.0)
Sagebrush-high, ungrazed	24.0 (10.7-36.0)	51.0 (45.0-59.7)	2.0 (0-12.0)	2.0 (0-12.0)	9.0 (0-22.3)	12.7 (0-28.3)	12.3 (4.7-17.3)	35.8 (22.3-50.0)	0.04 (0-0.3)	2.4 (0-8.7)	2.2 (0-7.0)	5.3 (0-13.0)
Sagebrush-high, grazed	29.6 (14.7-45.7)	55.6 (39.7-76.7)	3.1 (0-14.7)	3.1 (0-14.7)	13.5 (0.3-20.7)	19.9 (0.7-37.3)	12.3 (2.3-28.3)	31.4 (18.0-75.7)	0 (0-16.0)	2.8 (0-14.3)	3.3 (0-14.3)	7.9 (0.7-18.0)
PJ	26.2 (21.3-34.3)	36.7 (24.0-52.3)	23.0 (19.3-27.7)	25.9 (23.0-31.7)	2.2 (0-5.3)	5.3 (1.3-12.3)	0.6 (0-1.3)	4.7 (0-9.3)	0 (0-13.7)	4.7 (0-13.7)	0.8 (0-2.0)	2.4 (0-5.0)

Table 3-5. Mean (range) percent cover of vegetation by life form for each vegetation type, Dinosaur National Monument, 2010.

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, ungrazed	23.1 (13.0-40.3)	52.6 (32.7-78.7)	1.6 (0-7.0)	1.7 (0-7.7)	6.8 (0.3-11.3)	11.2 (0.3-19.0)	12.4 (0.7-28.3)	20.0 (2.0-49.0)	0.4 (0-1.7)	21.5 (0-63.7)	3.3 (0.3-7.7)	6.0 (0.7-14.3)
Sagebrush-low, grazed	21.6 (4.7-31.0)	48.6 (30.0-72.3)	2.7 (0-12.3)	2.7 (0-12.3)	8.3 (0-18.7)	12.0 (0-22.0)	9.1 (2.3-24.7)	18.8 (3.0-38.0)	0.1 (0-0.7)	16.4 (1.7-61.3)	2.5 (0-6.0)	7.2 (1.0-22.7)
Sagebrush-high, ungrazed	37.0 (19.3-53.7)	57.1 (43.0-69.0)	1.7 (0-11.0)	1.7 (0-11.3)	9.3 (0.3-26.3)	13.0 (0.3-33.0)	22.5 (11.3-40.0)	40.4 (21.3-67.0)	0.2 (0-0.7)	1.8 (0-5.0)	7.5 (1.7-17.3)	9.1 (3.3-23.3)
Sagebrush-high, grazed	46.0 (32.7-59.7)	59.1 (46.7-72.7)	3.4 (0-16.0)	3.4 (0-16.0)	14.5 (0-26.0)	20.5 (0-37.0)	21.3 (10.7-32.7)	32.0 (16.0-53.0)	0.6 (0-3.7)	1.1 (0-6.3)	14.3 (1.3-34.3)	16.5 (1.3-40.0)
PJ	22.9 (13.0-37.3)	33.4 (18.7-50.3)	17.5 (12.0-24.0)	21.5 (14.0-27.0)	1.9 (0.3-7.0)	3.4 (0.3-12.3)	3.5 (0-8.7)	7.6 (0.7-18.0)	0.2 (0-1.0)	3.7 (0-10.0)	1.6 (0-3.7)	2.8 (0-5.7)

Table 3-6. Mean (range) percent cover of dominant species by vegetation type, Dinosaur National Monument, 2009.

Scientific name	Common name	Life form	Duration	Nativity	Percent cover	
					Live	Total
Sagebrush– low, ungrazed						
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	3.1 (0–9.0)	5.7 (0–12.3)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	0	0
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.8 (0–4.0)	1.0 (0–4.7)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	0.2 (0–1.0)	0.3 (0–1.7)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	0.04 (0–0.3)	0.9 (0–4.0)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	2.3 (0–7.3)	7.3 (0–23.7)
Sagebrush– low, grazed						
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	7.8 (0–17.7)	11.5 (0–22.7)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	0.3 (0–2.0)	2.0 (0–15.3)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.6 (0–3.3)	0.9 (0–4.0)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	0.6 (0–2.7)	0.9 (0–4.3)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	0.3 (0–1.7)	0.8 (0–4.0)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	1.9 (0.3–7.3)	8.3 (1.7–25.0)
Sagebrush– high, ungrazed						
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	5.4 (0–16.3)	8.2 (0–17.3)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	0.8 (0–4.0)	3.1 (0–10.7)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	1.3 (0–7.7)	1.6 (0–9.0)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	0.9 (0–3.7)	1.5 (0–4.7)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	2.0 (0–10.7)	11.7 (0–36.3)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	4.0 (0–12.7)	10.7 (0–25.7)
Sagebrush– high, grazed						
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	11.0 (0–20.0)	16.5 (0–32.3)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	2.0 (0–8.0)	3.5 (0–12.7)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	1.0 (0–4.3)	1.4 (0–6.7)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	1.6 (0–5.3)	2.8 (0–8.0)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	2.2 (0–7.3)	7.9 (0–29.0)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	3.4 (0–21.3)	9.4 (0–57.3)
PJ						
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.7 (0–1.3)	1.1 (0.7–1.3)
<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	22.9 (19.0–27.7)	25.7 (22.3–31.7)
<i>Pinus edulis</i>	two-needle pinyon	Tree	Perennial	Native	0.1 (0–0.3)	0.3 (0–1.0)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	0.1 (0–0.3)	0.9 (0–2.3)
<i>Poa secunda</i>	Sandberg’s bluegrass	Graminoid	Perennial	Native	0	1.8 (0–4.3)

Table 3-7. Mean (range) percent cover of dominant species by vegetation type, Dinosaur National Monument, 2010.

Scientific name	Common name	Life form	Duration	Nativity	Percent cover	
					Live	Total
Sagebrush– low, ungrazed						
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	3.5 (0–10.3)	6.3 (0–15.7)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	0	0
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.8 (0–3.3)	1.3 (0–4.0)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	0.2 (0–1.3)	0.3 (0–1.7)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	0.1 (0–0.3)	0.1 (0–0.3)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	7.0 (0–21.7)	8.6 (0–25.7)
Sagebrush– low, grazed						
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	7.1 (0–18.0)	10.4 (0–21.3)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	0.8 (0–6.3)	1.8 (0–13.3)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.6 (0–2.7)	0.9 (0–3.3)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	0.5 (0–1.7)	0.7 (0–2.0)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	0.04 (0–0.3)	0.2 (0–1.0)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	5.5 (0.3–16.0)	9.5 (0.3–26.7)
Sagebrush– high, ungrazed						
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	5.7 (0–19.7)	8.3 (0.3–20.7)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	1.8 (0–6.0)	3.2 (0–12.3)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.7 (0–3.0)	1.3 (0–7.3)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	1.3 (0–4.0)	1.9 (0–6.0)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	0.6 (0–3.3)	1.7 (0–11.0)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	6.8 (0–15.3)	9.3 (0–24.0)
Sagebrush– high, grazed						
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	11.8 (0–24.0)	17.0 (0–34.0)
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	1.9 (0–6.3)	2.2 (0–7.3)
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.8 (0–5.0)	1.4 (0–8.0)
<i>Koeleria macrantha</i>	junegrass	Graminoid	Perennial	Native	1.4 (0–4.3)	2.0 (0–6.0)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	3.2 (0–8.3)	5.4 (0–12.3)
<i>Stipa comata</i>	needle and thread	Graminoid	Perennial	Native	4.0 (0–25.7)	5.8 (0–37.7)
PJ						
<i>Gutierrezia sarothrae</i>	broom snakeweed	Dwarf Shrub	Perennial	Native	0.5 (0–2.3)	0.7 (0–2.7)
<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	15.0 (9.0–24.0)	18.1 (10.0–27.0)
<i>Pinus edulis</i>	two-needle pinyon	Tree	Perennial	Native	2.9 (0–8.7)	3.8 (0–13.0)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	0.5 (0–2.3)	1.7 (0–4.7)
<i>Poa secunda</i>	Sandberg's bluegrass	Graminoid	Perennial	Native	1.2 (0–5.0)	3.0 (0–11.0)

Table 3-8. Mean (range) density of shrub species per hectare by vegetation type, Dinosaur National Monument, 2009 and 2010.

Scientific name	Common name	No. of plots with species present*		Density (number of shrubs/ha)	
		2009	2010	2009	2010
Sagebrush– low, ungrazed					
<i>Artemisia nova</i>	black sagebrush	1	1	292 (0–2,333)	300 (0–2,400)
<i>Artemisia tridentata</i>	big sagebrush	7	7	3,142 (0–7,000)	2,675 (0–6,067)
<i>Atriplex confertifolia</i>	shadscale	3	3	83 (0–467)	100 (0–533)
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	1	1	142 (0–1,133)	142 (0–1,133)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	3	3	275 (0–1,333)	408 (0–1,800)
<i>Eriogonum microthecum</i>	slender wild buckwheat	4	3	233 (0–1,267)	283 (0–1,533)
<i>Grayia spinosa</i>	spiny hopsage	0	2	0	158 (0–1,067)
<i>Juniperus osteosperma</i>	Utah juniper	2	2	42 (0–267)	25 (0–133)
<i>Krascheninnikovia lanata</i>	winterfat	1	1	42 (0–333)	58 (0–467)
<i>Leptodactylon pungens</i>	prickly-phlox	0	1	0	8 (0–67)
<i>Sarcobatus vermiculatus</i>	greasewood	2	2	42 (0–200)	75 (0–467)
<i>Tetradymia canescens</i>	spineless horsebrush	1	0	108 (0–867)	0
<i>Tetradymia nuttallii</i>	Nuttall’s horsebrush	1	1	100 (0–800)	108 (0–867)
Sagebrush– low, grazed					
<i>Artemisia tridentata</i>	big sagebrush	7	7	5,358 (0–10,000)	5,350 (0–9,467)
<i>Atriplex confertifolia</i>	shadscale	2	1	158 (0–1,200)	108 (0–867)
<i>Chrysothamnus</i> sp.	rabbitbrush (sp)	1	0	8 (0–67)	0
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	0	3	0	25 (0–67)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	0	1	0	8 (0–67)
<i>Eriogonum corymbosum</i>	crisp-leaf wild buckwheat	2	2	25 (0–133)	25 (0–133)
<i>Eriogonum microthecum</i>	slender wild buckwheat	1	1	108 (0–867)	142 (0–1,333)
<i>Juniperus osteosperma</i>	Utah juniper	2	2	117 (0–600)	167 (0–733)
<i>Krascheninnikovia lanata</i>	winterfat	2	2	67 (0–467)	108 (0–533)
<i>Pinus edulis</i>	two-needle pinyon	2	1	25 (0–133)	33 (0–267)
<i>Sarcobatus vermiculatus</i>	greasewood	1	1	67 (0–533)	67 (0–533)
<i>Tetradymia canescens</i>	spineless horsebrush	1	0	8 (0–67)	0
Sagebrush– high, ungrazed					
<i>Amelanchier utahensis</i>	Utah serviceberry	4	4	175 (0–533)	350 (0–1,400)
<i>Artemisia nova</i>	black sagebrush	1	1	17 (0–133)	17 (0–133)
<i>Artemisia tridentata</i>	big sagebrush	7	7	2,858 (0–8,533)	3,075 (0–10,533)
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	2	3	50 (0–267)	58 (0–333)
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	1	1	8 (0–67)	8 (0–67)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	2	1	75 (0–533)	117 (0–933)
<i>Eriogonum lonchophyllum</i>	spearleaf buckwheat	0	1	0	17 (0–133)
<i>Eriogonum microthecum</i>	slender wild buckwheat	2	2	350 (0–2,400)	392 (0–2,933)
<i>Juniperus osteosperma</i>	Utah juniper	1	1	133 (0–1,067)	142 (0–1,133)
<i>Krascheninnikovia lanata</i>	winterfat	1	1	8 (0–67)	8 (0–67)
<i>Pinus edulis</i>	two-needle pinyon	1	1	8 (0–67)	17 (0–133)
<i>Prunus virginiana</i>	chokecherry	2	2	42 (0–267)	33 (0–133)
<i>Purshia tridentata</i>	antelope bitterbrush	2	1	117 (0–867)	58 (0–467)
<i>Symphoricarpos oreophilus</i>	mountain snowberry	4	3	125 (0–467)	292 (0–1,400)
<i>Tetradymia canescens</i>	spineless horsebrush	2	2	225 (0–1,400)	250 (0–1,533)

Table 3-8. Mean (range) density of shrub species per hectare by vegetation type, Dinosaur National Monument, 2009 and 2010, cont.

		No. of plots with species present*		Density (number of shrubs/ha)	
Scientific name	Common name	2009	2010	2009	2010
Sagebrush– high, grazed					
<i>Amelanchier utahensis</i>	Utah serviceberry	2	2	142 (0–667)	242 (0–1,133)
<i>Artemisia frigida</i>	fringed sagebrush	1	1	8 (0–67)	8 (0–67)
<i>Artemisia tridentata</i>	big sagebrush	7	7	4,650 (0–10,267)	4,375 (0–10,067)
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	1	1	742 (0–5,933)	925 (0–7,400)
<i>Chrysothamnus depresses</i>	dwarf rabbitbrush	0	1	0	25 (0–200)
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	1	1	67 (0–533)	50 (0–400)
<i>Chrysothamnus parryi</i>	Parry’s rabbitbrush	1	1	25 (0–200)	25 (0–200)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	3	5	108 (0–600)	167 (0–533)
<i>Eriogonum corymbosum</i>	crisp-leaf wild buckwheat	1	1	117 (0–933)	108 (0–867)
<i>Eriogonum lonchophyllum</i>	spearleaf buckwheat	3	3	875 (0–6,200)	658 (0–4,667)
<i>Eriogonum microthecum</i>	slender wild buckwheat	2	2	333 (0–2,133)	283 (0–1,533)
<i>Juniperus osteosperma</i>	Utah juniper	4	4	92 (0–467)	100 (0–467)
<i>Leptodactylon pungens</i>	prickly-phlox	2	2	142 (0–933)	17 (0–67)
<i>Pinus edulis</i>	two-needle pinyon	2	3	233 (0–1,200)	183 (0–1,000)
<i>Purshia tridentata</i>	antelope bitterbrush	1	0	8 (0–67)	0
<i>Symphoricarpos oreophilus</i>	mountain snowberry	1	2	75 (0–600)	92 (0–533)
<i>Tetradymia canescens</i>	spineless horsebrush	3	4	92 (0–333)	158 (0–733)
PJ					
<i>Amelanchier utahensis</i>	Utah serviceberry	0	1	0	17 (0–133)
<i>Artemisia nova</i>	black sagebrush	1	3	444 (0–1,333)	317 (0–1,600)
<i>Artemisia tridentata</i>	big sagebrush	2	5	756 (0–2,200)	558 (0–2,200)
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	0	1	0	8 (0–67)
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush	0	1	0	8 (0–67)
<i>Eriogonum microthecum</i>	slender wild buckwheat	1	3	44 (0–133)	300 (0–1,533)
<i>Glossopetalon spinescens</i>	spiny greasebush	0	1	0	17 (0–133)
<i>Purshia tridentata</i>	antelope bitterbrush	1	0	44 (0–133)	0
<i>Tetradymia canescens</i>	spineless horsebush	0	1	0	50 (0–400)

* A total of 8 plots were monitored in each sagebrush vegetation type in 2009 and 2010. A total of 3 PJ plots were monitored in 2009 and a total of 8 PJ plots were monitored in 2010.

Table 3-9. Mean (range) density of live seedlings, saplings, and overstory trees, pinyon-juniper, Dinosaur National Monument, 2009 and 2010.

		Density of live trees by dbh class (no. of trees/ha)				
Scientific name	Common name	Seedling (<2.5 cm)	Sapling			Tree (>15 cm)
			2.5–5.0 cm	5.1–10.0 cm	10.1–15.0 cm	
2009						
<i>Juniperus osteosperma</i>	Utah juniper	267 (67–467)	67 (0–160)	240 (0–520)	173 (40–400)	240 (96–320)
<i>Pinus edulis</i>	two-needle pinyon	0	0	0	0	0
2010						
<i>Juniperus osteosperma</i>	Utah juniper	375 (67–1,067)	60 (0–360)	55 (0–360)	20 (0–80)	176 (32–320)
<i>Pinus edulis</i>	two-needle pinyon	242 (0–1,400)	25 (0–80)	15 (0–80)	0	10 (0–48)

Table 3-10. Mean (range) density and diameter at breast height (dbh) for all trees >15 cm dbh, pinyon-juniper, Dinosaur National Monument, 2009 and 2010.

Scientific name	Common name	Density (no. of trees/ha)	Dbh (cm)	% dead
2009				
<i>Juniperus osteosperma</i>	Utah juniper	245 (112–320)	21.2 (18.3–24.4)	5 (0–14)
<i>Pinus edulis</i>	two-needle pinyon	16	26.0	100
2010				
<i>Juniperus osteosperma</i>	Utah juniper	200 (32–384)	20.9 (16.7–24.3)	8 (0–38)
<i>Pinus edulis</i>	two-needle pinyon	14 (0–64)	23.5 (17.5–27.0)	42 (0–100)

Table 3-11. Mean (range) cover and density of exotic plant species detected in Dinosaur National Monument, 2009.

Scientific name	Common name	Life form	Duration	No. of plots with exotic species detected*	Percent cover**		Density (number of exotic perennials/ha)
					Live	Total	
Sagebrush– low, ungrazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	3	0.4 (0–2.3)	0.9 (0–4.0)	NA
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	8	2.5 (0–11.7)	17.8 (1.0–55.3)	NA
<i>Euphorbia myrsinites</i>	blue spurge	Forb	Perennial	1	0.1 (0–0.7)	0.1 (0–1.0)	0
<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	1	0.04 (0–0.3)	0.8 (0–6.7)	NA
<i>Salsola tragus</i>	Russian-thistle	Forb	Annual	1	0.8 (0–6.0)	0.8 (0–6.0)	NA
<i>Sisymbrium altissimum</i>	tumble musard	Forb	Annual	1	0	0.1 (0–0.7)	NA
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	4	0	0.04 (0–0.3)	483 (0–2,000)
Sagebrush– low, grazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	6	1.1 (0–6.7)	3.0 (0–15.3)	NA
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	8	6.1 (0–31.0)	16.7 (4.3–48.3)	NA
Sagebrush– high, ungrazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	5	0.2 (0–1.0)	0.7 (0–2.3)	NA
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	6	0.04 (0–0.3)	2.4 (0–8.7)	NA
<i>Poa pratensis</i>	Kentucky bluegrass	Graminoid	Perennial	1	0	0.3 (0–2.3)	+
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	2	0	0	1,142 (0–9,067)
Sagebrush– high, grazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	2	0	0.1 (0–0.3)	NA
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	4	0	2.8 (0–16.0)	NA
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	1	0	0	125 (0–1,000)
PJ							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	1	0	0.2 (0–0.7)	NA
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	2	0	4.7 (0–13.7)	NA

* A total of 8 plots were monitored in each sagebrush vegetation type in 2009 and 2010. A total of 3 PJ plots were monitored in 2009 and a total of 8 PJ plots were monitored in 2010.

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

+ Exotic perennial density was not measured in 2009.

Table 3-12. Mean (range) cover and density of exotic plant species detected in Dinosaur National Monument, 2010.

Scientific name	Common name	Life form	Duration	No. of plots with exotic species detected*	Percent cover**		Density (number of exotic perennials/ha)
					Live	Total	
Sagebrush– low, ungrazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	4	0.1 (0–0.3)	1.6 (0–5.0)	NA
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	7	0.4 (0–1.7)	21.5 (0–63.7)	NA
<i>Erodium cicutarium</i>	stork's-bill	Forb	Annual	1	0	0.3 (0–2.3)	NA
<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	1	0.2 (0–1.3)	0.5 (0–3.7)	NA
<i>Salsola tragus</i>	Russian-thistle	Forb	Annual	1	0.2 (0–1.7)	0.4 (0–3.0)	NA
<i>Sisymbrium altissimum</i>	tumble mustard	Forb	Annual	2	0	0.1 (0–0.7)	NA
<i>Taraxacum officinale</i>	common dandelion	Forb	Perennial	1	0	0	8 (0–67)
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	4	0.1 (0–0.3)	0.1 (0–0.3)	75 (0–600)
Sagebrush– low, grazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	6	0.3 (0–1.3)	4.3 (0–19.3)	NA
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	8	0.1 (0–0.7)	16.3 (1.7–61.3)	NA
<i>Malcomia africana</i>	African mustard	Forb	Annual	1	0.04 (0–0.3)	0.04 (0–0.3)	NA
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	1	0	0	25 (0–200)
Sagebrush– high, ungrazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	4	0.5 (0–3.7)	0.9 (0–4.7)	NA
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	6	0.2 (0–0.7)	1.8 (0–5.0)	NA
<i>Poa pratensis</i>	Kentucky bluegrass	Graminoid	Perennial	1	0.7 (0–5.3)	1.2 (0–9.7)	8 (0–67)
<i>Taraxacum officinale</i>	common dandelion	Forb	Perennial	1	0	0	100 (0–800)
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	6	0.1 (0–0.3)	0.1 (0–0.3)	925 (0–6,600)
Sagebrush– high, grazed							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	2	0.1 (0–0.3)	0.3 (0–2.3)	NA
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	4	0.6 (0–3.7)	1.1 (0–6.3)	NA
<i>Taraxacum officinale</i>	common dandelion	Forb	Perennial	3	0.04 (0–0.3)	0.04 (0–0.3)	117 (0–467)
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	3	0	0	733 (0–5,467)
PJ							
<i>Alyssum desertorum</i>	desert madwort	Forb	Annual	2	0	0.1 (0–0.7)	NA
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	7	0.2 (0–1.0)	3.7 (0–10.0)	NA

* A total of 8 plots were monitored in each sagebrush vegetation type in 2009 and 2010. A total of 3 PJ plots were monitored in 2009 and a total of 8 PJ plots were monitored in 2010.

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

Table 3-13. Mean (range) percent cover of surface features by vegetation type, Dinosaur National Monument, 2009.

Vegetation type	Crust, undifferentiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Sagebrush-low, ungrazed	22.0 (12.3–37.3)	0.9 (0–3.3)	0.4 (0–1.7)	6.4 (0–27.0)	0.4 (0–1.7)	46.2 (26.3–66.0)	0.3 (0–1.3)	12.2 (0–38.7)	1.3 (0–4.3)	0.1 (0–0.7)
Sagebrush-low, grazed	24.0 (14.3–49.0)	1.3 (0–4.7)	0.6 (0–2.7)	15.2 (0.3–28.3)	0.8 (0–2.7)	44.2 (31.0–59.0)	0.8 (0.3–1.7)	2.8 (0–15.0)	1.1 (0–5.3)	0.1 (0–0.7)
Sagebrush-high, ungrazed	17.7 (8.0–24.3)	0.04 (0–0.3)	0.04 (0–0.3)	1.8 (0–6.3)	0.8 (0–2.3)	62.6 (50.0–70.3)	0.6 (0–3.3)	2.0 (0–8.0)	1.2 (0–2.3)	0.8 (0–4.0)
Sagebrush-high, grazed	16.2 (1.7–30.0)	0 (0–0.7)	0.1 (0–0.7)	2.8 (0–16.7)	0.7 (0–2.3)	61.5 (37.7–80.3)	0.7 (0–2.7)	4.3 (0–19.7)	2.4 (0–10.7)	0.2 (0–1.3)
PJ	21.8 (12.7–29.0)	5.1 (0.7–13.0)	3.2 (1.0–6.3)	4.2 (2.3–5.7)	0.7 (0.3–1.0)	45.6 (37.7–58.7)	0.1 (0–0.3)	9.6 (8.0–11.3)	2.4 (2.0–3.0)	4.1 (0.7–8.7)

Table 3-14. Mean (range) percent cover of surface features by vegetation type, Dinosaur National Monument, 2010.

Vegetation type	Crust, undifferentiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Sagebrush-low, ungrazed	28.2 (13.7–42.7)	2.1 (0–9.7)	1.1 (0–2.3)	3.0 (0–6.0)	2.2 (0–8.0)	41.0 (24.7–61.7)	0.5 (0–2.7)	9.5 (0–33.7)	1.4 (0–4.3)	0.2 (0–1.3)
Sagebrush-low, grazed	31.0 (14.3–60.0)	1.1 (0–4.7)	0.2 (0–0.7)	10.0 (0.7–18.3)	1.3 (0–7.3)	42.6 (25.3–63.0)	1.0 (0–2.0)	2.2 (0–10.7)	1.5 (0–6.3)	0
Sagebrush-high, ungrazed	19.3 (11.3–37.0)	0.04 (0–0.3)	0.1 (0–0.3)	0.9 (0–2.0)	2.3 (0.3–11.3)	58.8 (45.7–67.7)	0.3 (0–1.0)	1.8 (0–7.0)	0.7 (0–2.0)	0.5 (0–3.0)
Sagebrush-high, grazed	18.9 (4.0–52.7)	0 (0–21.3)	0.3 (0–1.7)	1.4 (0–10.0)	3.5 (0–9.0)	52.9 (27.7–75.7)	0.8 (0–2.0)	5.0 (0–23.0)	2.9 (0–12.0)	0.1 (0–0.7)
PJ	24.0 (14.7–33.7)	7.5 (0–21.3)	1.8 (0–5.7)	2.2 (0–5.3)	0.5 (0–1.7)	42.7 (35.0–54.7)	0.7 (0–1.3)	10.6 (5.0–22.3)	3.5 (1.0–6.7)	2.7 (0–12.7)

Table 3-15. Mean (range) canopy- and basal-gap size by vegetation type, Dinosaur National Monument, 2009 and 2010.

Vegetation type	2009		2010	
	Canopy gap (cm)	Basal gap (cm)	Canopy gap (cm)	Basal gap (cm)
Sagebrush– low, ungrazed	116 (54–231)	203 (43–490)	101 (42–184)	160 (41–298)
Sagebrush– low, grazed	114 (44–363)	141 (51–432)	87 (40–195)	157 (63–313)
Sagebrush– high, ungrazed	51 (27–72)	56 (29–89)	41 (26–56)	57 (31–97)
Sagebrush– high, grazed	54 (29–69)	63 (37–111)	44 (34–53)	56 (41–76)

Table 3-16. Mean (range) soil-aggregate stability measures by vegetation type, Dinosaur National Monument, 2009 and 2010. Numbers range from 1 (least stable) to 6 (most stable).

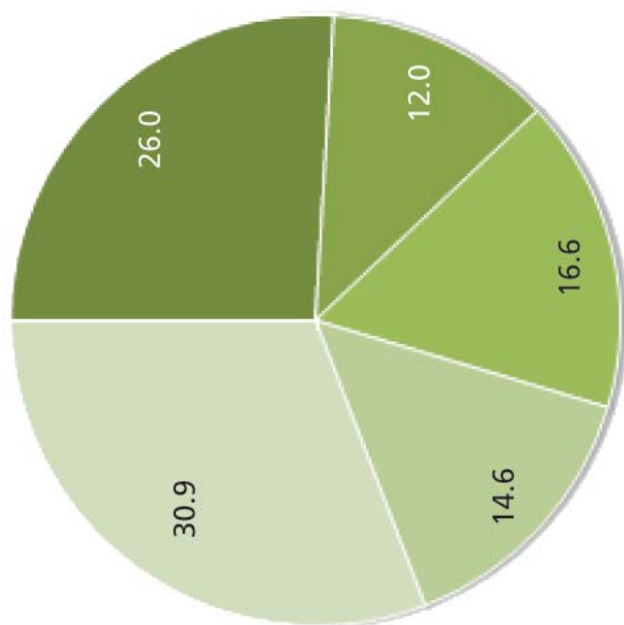
Vegetation type	2009			2010		
	Total	Protected*	Unprotected*	Total	Protected*	Unprotected*
Sagebrush– low, ungrazed	4.7 (3.6–5.6)	5.2 (3.8–6.0)	4.6 (3.6–5.6)	4.7 (3.9–5.4)	5.0 (3.5–5.7)	4.6 (3.0–5.6)
Sagebrush– low, grazed	4.9 (3.8–5.6)	5.4 (4.7–6.0)	4.8 (3.7–5.6)	4.6 (3.8–5.4)	4.7 (3.5–5.8)	4.5 (4.1–5.1)
Sagebrush– high, ungrazed	3.9 (2.8–4.5)	4.0 (2.6–5.0)	3.9 (3.1–5.3)	4.5 (2.4–5.3)	4.5 (2.7–5.8)	4.1 (1.8–5.5)
Sagebrush– high, grazed	4.2 (2.9–5.1)	4.4 (2.0–6.0)	4.3 (3.1–5.6)	4.1 (3.0–5.4)	4.1 (2.8–5.4)	4.3 (3.0–5.8)
PJ	5.2 (5.2–5.2)	4.0 (4.0–4.0)	5.5 (5.4–5.6)	4.7 (3.3–5.7)	4.6 (3.6–6.0)	4.8 (2.9–5.7)

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

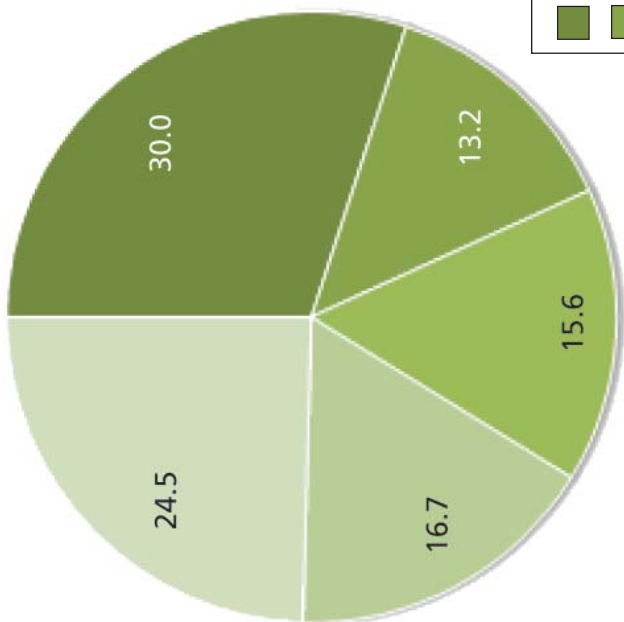
Table 3-17. Mean (range) fuel volume and depth of litter and duff, pinyon-juniper, Dinosaur National Monument, 2009 and 2010.

Year	Fuel volume (tons/acre)					Depth (cm)		
	Total	1-hr	10-hr	100-hr	1,000-hr		Litter	Duff
					Sound	Rotten		
2009	3.7 (0.7–9.5)	0.1 (0.03–0.2)	0.6 (0.1–1.3)	0.4 (0–1.1)	2.4 (0–6.9)	0.1 (0–0.2)	0.8 (0.7–0.9)	0.2 (0.1–0.3)
2010	4.4 (1.6–14.7)	0.2 (0.04–0.7)	0.5 (0.1–0.9)	0.7 (0–3.0)	1.8 (0–10.3)	1.2 (0–5.1)	0.7 (0.5–1.1)	0.4 (0–1.7)

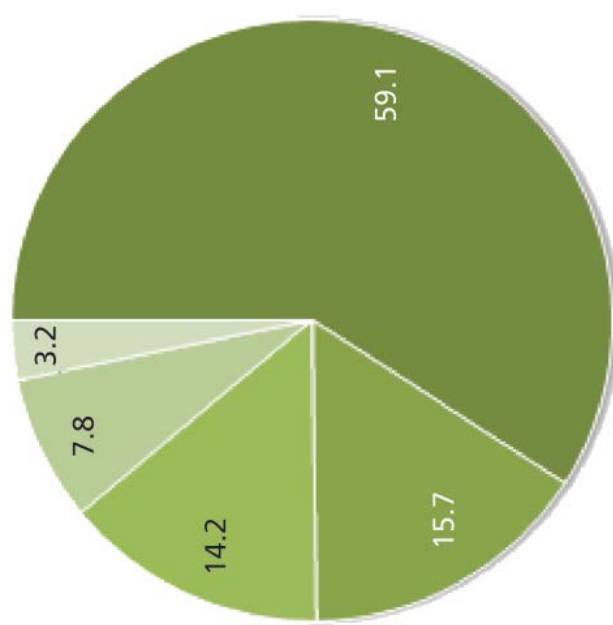
A) Low-elevation ungrazed



B) Low-elevation grazed



C) High-elevation ungrazed



D) High-elevation grazed

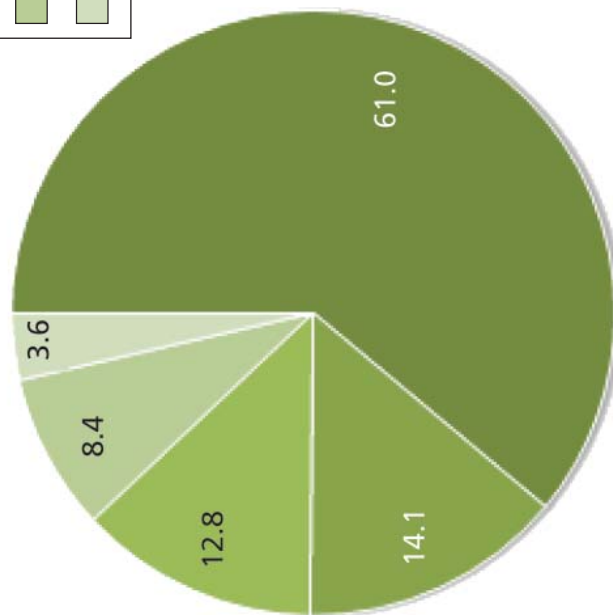
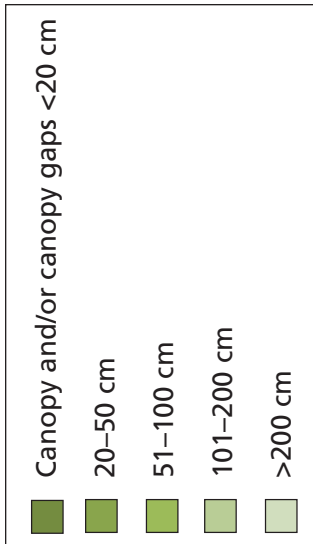
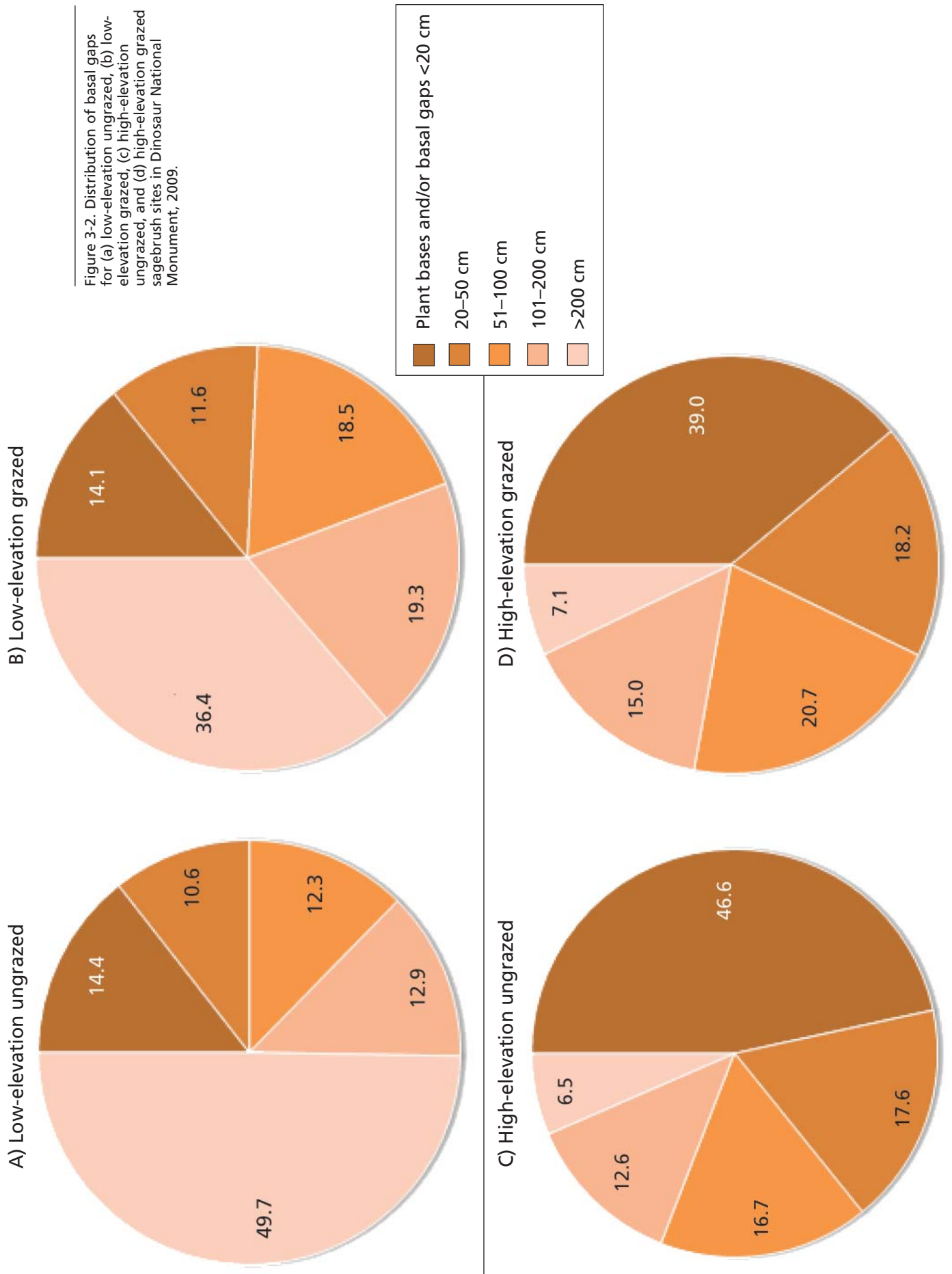
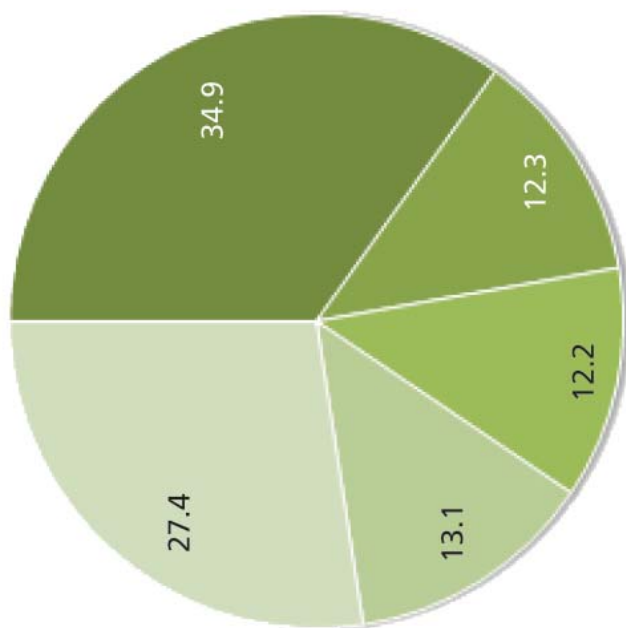


Figure 3-1. Distribution of canopy gaps for (a) low-elevation ungrazed, (b) low-elevation grazed, (c) high-elevation ungrazed, and (d) high-elevation grazed sagebrush sites in Dinosaur National Monument, 2009.

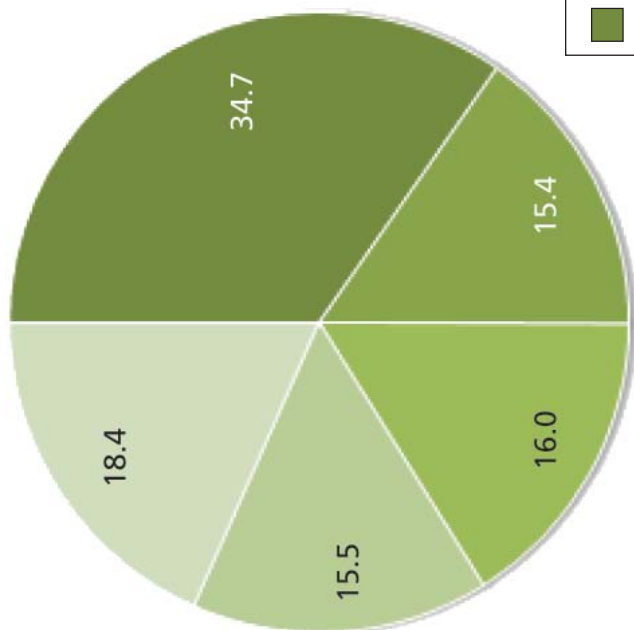




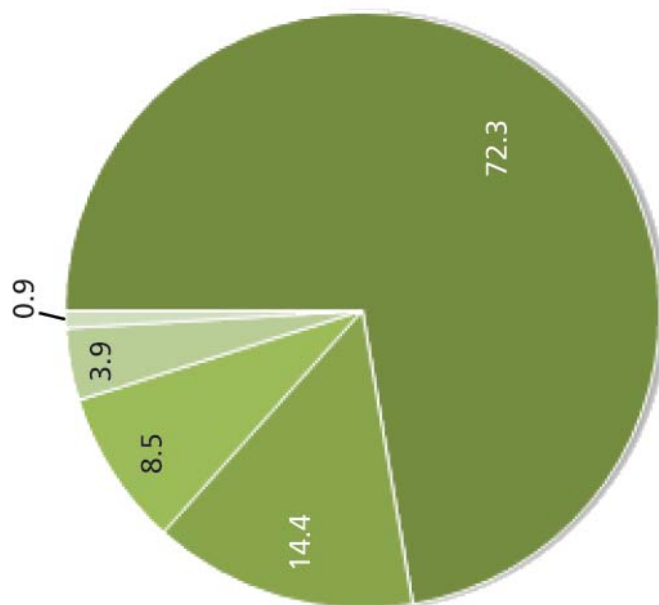
A) Low-elevation ungrazed



B) Low-elevation grazed



C) High-elevation ungrazed



D) High-elevation grazed

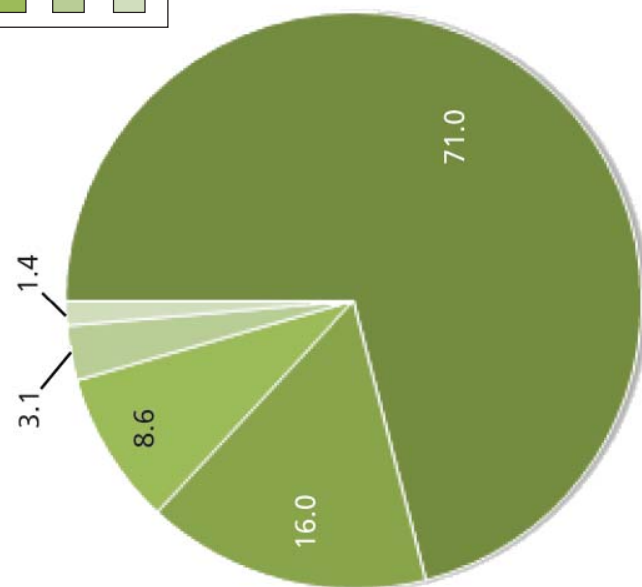
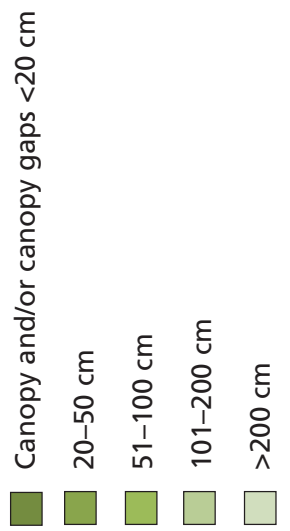
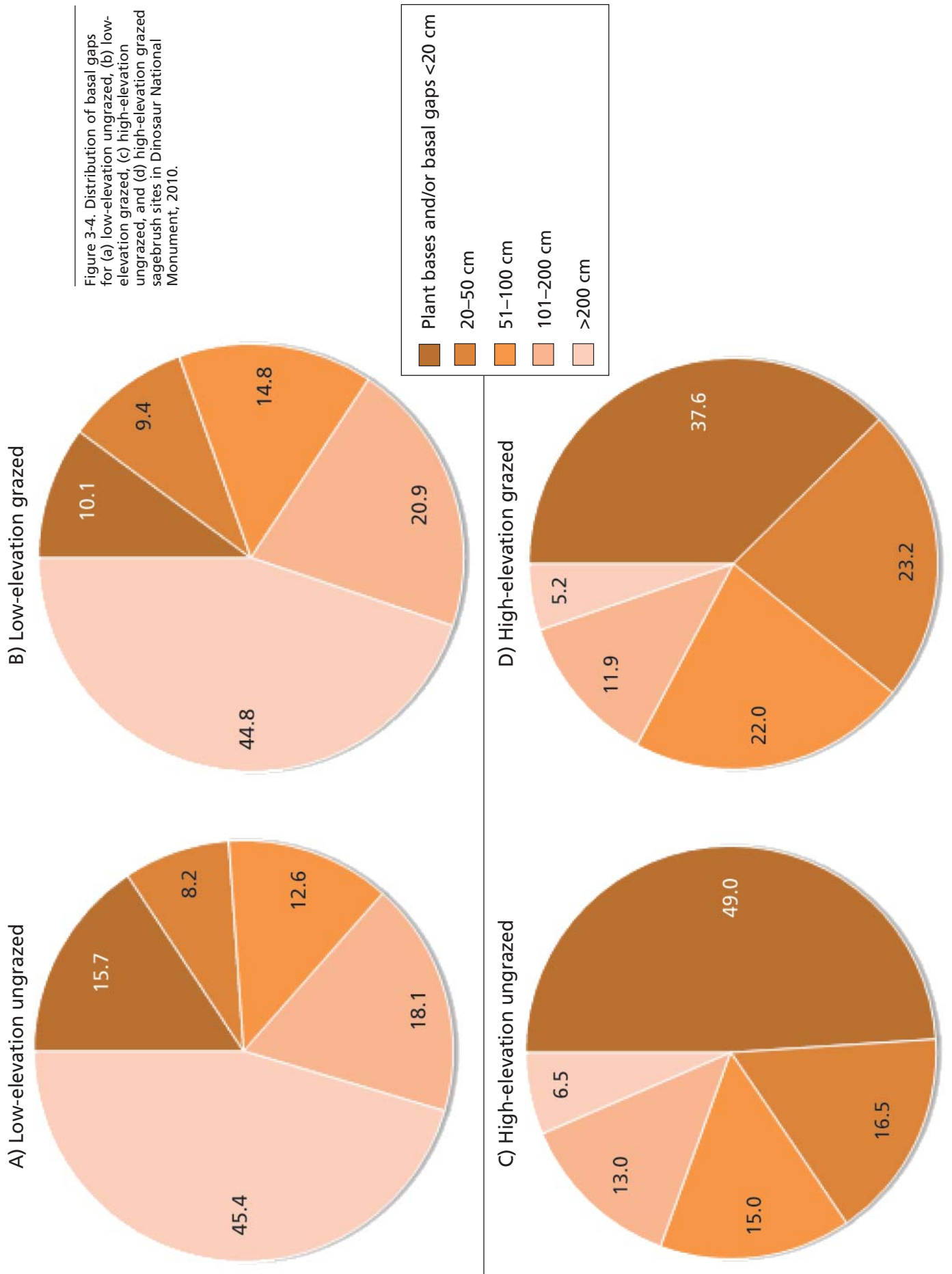


Figure 3-3. Distribution of canopy gaps for (a) low-elevation ungrazed, (b) low-elevation grazed, (c) high-elevation ungrazed, and (d) high-elevation grazed sagebrush sites in Dinosaur National Monument, 2010.





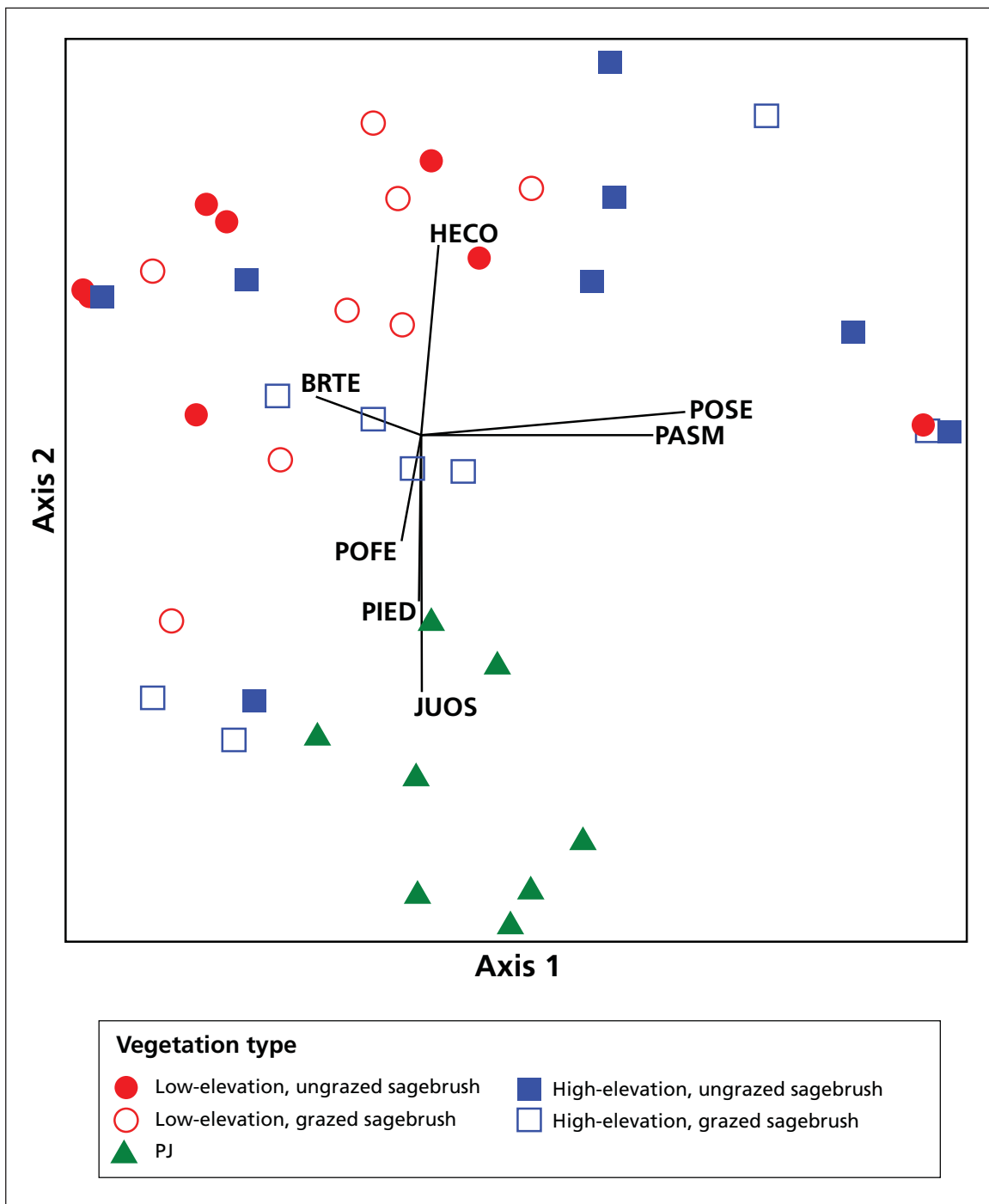


Figure 3-5a. Non-metric multidimensional scaling (NMS) ordination of plots from the five vegetation types monitored in Dinosaur National Monument in 2010 (Axes 1 and 2).

Species codes

BRTE = *Bromus tectorum* (cheatgrass)
 HECO = *Stipa comata* (needle and thread)
 JUOS = *Juniperus osteosperma* (Utah juniper)

PASM = *Elymus smithii* (western wheatgrass)
 PIED = *Pinus edulis* (two-needle pinyon pine)
 POFE = *Poa fendleriana* (muttongrass)
 POSE = *Poa secunda* (Sandberg's bluegrass)

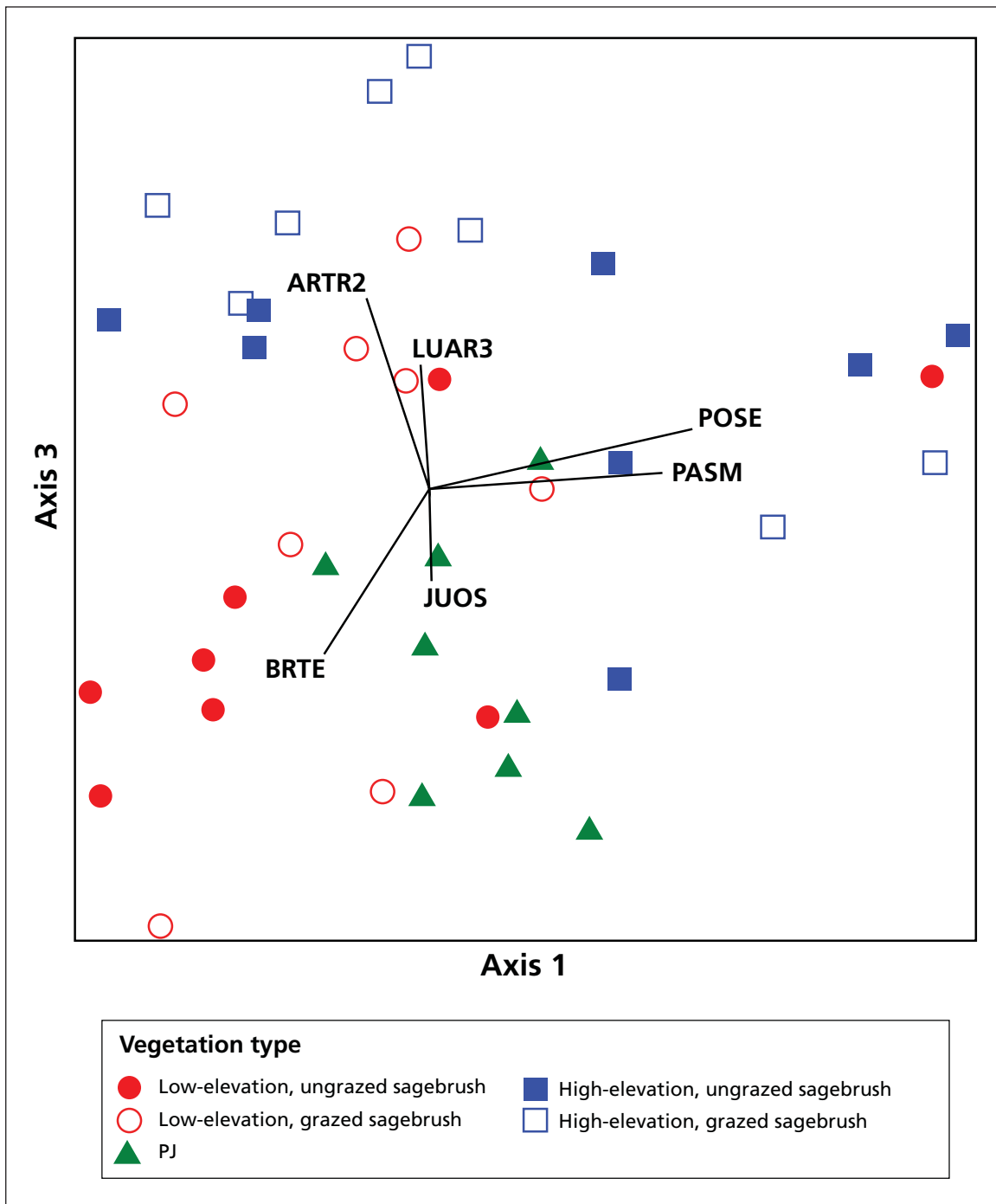


Figure 3-5b. Non-metric multidimensional scaling (NMS) ordination of plots from the five vegetation types monitored in Dinosaur National Monument in 2010 (Axes 1 and 3).

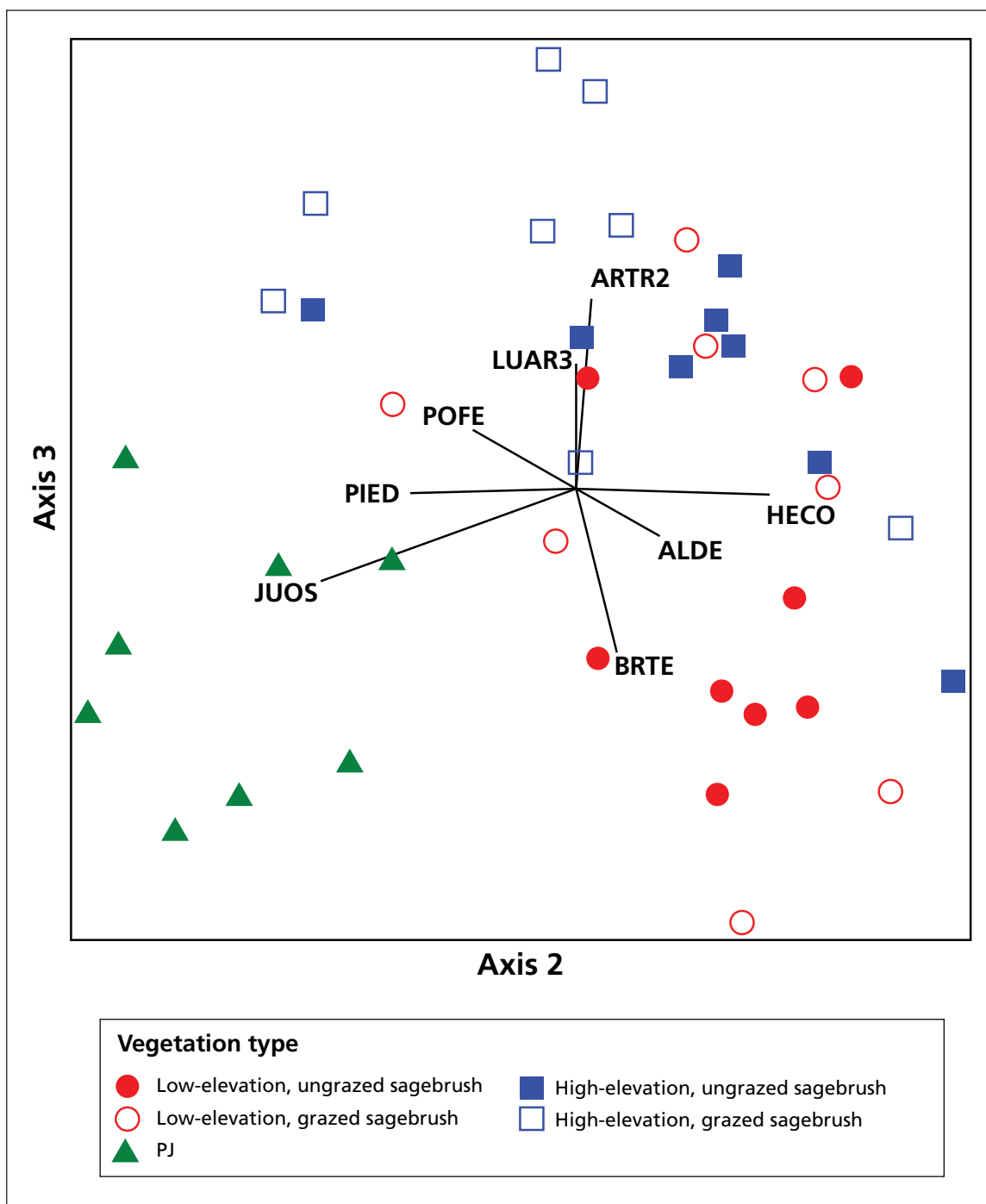


Figure 3-5c. Non-metric multidimensional scaling (NMS) ordination of plots from the five vegetation types monitored in Dinosaur National Monument in 2010 (Axes 2 and 3).

Species codes

ALDE = *Alyssum desertorum* (desert madwort)
 ARTR2 = *Artemisia tridentata* (big sagebrush)
 BRTE = *Bromus tectorum* (cheatgrass)
 HECO = *Stipa comata* (needle and thread)

JUOS = *Juniperus osteosperma* (Utah juniper)
 LUAR3 = *Lupinus argenteus* (silvery lupine)
 PIED = *Pinus edulis* (two-needle pinyon pine)
 POFE = *Poa fendleriana* (muttongrass)

4 Discussion

One goal of monitoring sagebrush at Dinosaur NM was to compare grazed and ungrazed areas in the park units. Our initial sampling detected little difference between grazed and ungrazed sagebrush for most measurements. Differences between low- and high-elevation sagebrush sites provided a much more dramatic contrast. High-elevation sagebrush had smaller canopy and basal gaps and a higher cover of perennial grasses. Low-elevation sagebrush, with lower plant cover, larger gaps, and a higher surface cover of biological soil crust, had a higher risk of soil erosion. In addition, low-elevation sagebrush was more invaded by exotic-plant species. Cheatgrass, in particular, was found at more than 10 times higher percent cover in low-elevation than in high-elevation sagebrush.

There were few differences between years at sagebrush sites, and most of the differences were likely due to the different seasons when plots were sampled (September and October in 2009 vs. June and July in 2010). PJ plots were not compared between years because only three plots were sampled in 2009, and any differences were probably attributable to the small sample size. Two-to-seven more species, primarily forbs, were detected in 2010. Live cover was also higher in

2010, primarily due to an increase in perennial grass cover at all site types, but also due to an increase in forb cover at high-elevation sagebrush sites. It appears that the field crew had trouble distinguishing Sandberg's bluegrass (*Poa secunda*) from muttongrass (*Poa fendleriana*), and these species may have been mistaken for one another at some plots. There were few differences in shrub density, exotics species cover, surface cover, basal and canopy gaps, and soil stability between years. In the future, all upland monitoring plots at Dinosaur NM will be visited in June and July to minimize seasonal differences.

In 2011, we plan to revisit the 40 established plots. In winter 2011–2012, two-to-three years of 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, as well as potential revisit designs. Recommendations for an operational survey design will be presented to Dinosaur NM resource staff for discussion and approval in spring 2012. After five full years of monitoring, 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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