



Integrated Upland Vegetation and Soils Monitoring for Mesa Verde National Park

2010 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2013/513



ON THE COVER

Integrated upland monitoring in Mesa Verde National Park
Photography by: Karen Weber/NPS

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1 Introduction and background

The National Park Service Inventory and Monitoring (I&M) Program was designed to determine the status and monitor the conditions of park natural resources, providing park managers with a scientific foundation that informs resource management decisions. The Southern Colorado Plateau Network (SCPN) is monitoring vegetation and soils as overall indicators of upland ecosystem integrity (Thomas et al. 2006).

SCPN and park staff selected the Loamy Mesa Top Pinyon-Juniper ecological site for long-term monitoring of upland vegetation and soils at Mesa Verde National Park (MEVE). An ecological site is a landscape division with characteristic soils, hydrology, plant communities, and disturbance regimes and responses, and its classification is based on soil survey data (Butler et al. 2003). The Loamy Mesa Top Pinyon-Juniper woodland is a unique ecosystem containing old-growth pinyon-juniper woodland. It faces numerous threats, including changing fire regimes, climate change, and invasion by nonnative species.

In 2007 the SCPN integrated upland monitoring project began its work at MEVE with the installation of 10 plots in the Loamy Mesa Top Pinyon-Juniper ecological site. We sampled vegetation in nested quadrats and measured basal gaps annually for 3 years to determine the range of temporal variability for key metrics. In 2010, we established and sampled 10 new plots. The original 10 plots were not resampled. This brings our total for this ecological site to 20 established plots. In this report, we document monitoring activities in the 2010 field season and report these data in the context of the data collected in 2007, 2008 and 2009.

2 Methods

2.1 Sampling frame

We derived our base sampling frame (fig. 1) from the map of the Loamy Mesa Top Pinyon-Juniper ecological site, which was developed by the U.S. Natural Resources Conservation Service (see appendix A of DeCoster et al. 2012). The sampling frame is the area from which we randomly select our sites, and hence the area to which statistical inferences can be made. To make final adjustments to our sampling frame, we modified the map of the ecological site using Geographical Information System (GIS) technology. These modifications were necessary to avoid areas that were

- outside of the target ecological site (roads, buildings and other infrastructure)
- expected to differ substantially from the norm, such as burned areas and mechanically treated areas, because these areas would have increased ecological variation and made it more difficult to detect trends
- potentially at risk for erosion as a result of sampling (slopes $\geq 20\%$)
- overlapping with arthropod monitoring sites

We generated a set of spatially distributed sampling points using the Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). Park staff reviewed the sampling points and rejected those points that landed too close to archeological sites and other sensitive resources. The integrated upland crew visited the points in consecutive order and conducted an ecological site assessment, rejecting sites that deviated substantially from the ecological site, had a slope greater than 20%, or contained a major disturbance.

2.2 Field methods

The SCPN integrated upland crew established 10 monitoring plots in 2007, and resampled these 10 plots in 2008 and 2009. In 2010, the crew established 10 additional plots. The 10 plots established in 2007 were not sampled in 2010. In all years we conducted our field work in early to mid-August.

Integrated upland monitoring plots are 0.50 ha in size, measuring 71×71 m, and consist of 3 parallel 50 m transects spaced 25 m apart. We collected data for shrub and herbaceous species composition, soil cover and stability, tree seedling density and tree canopy on all 3 transects within each plot. We also collected overstory tree and sapling data in subplots located between 2 of the transects.

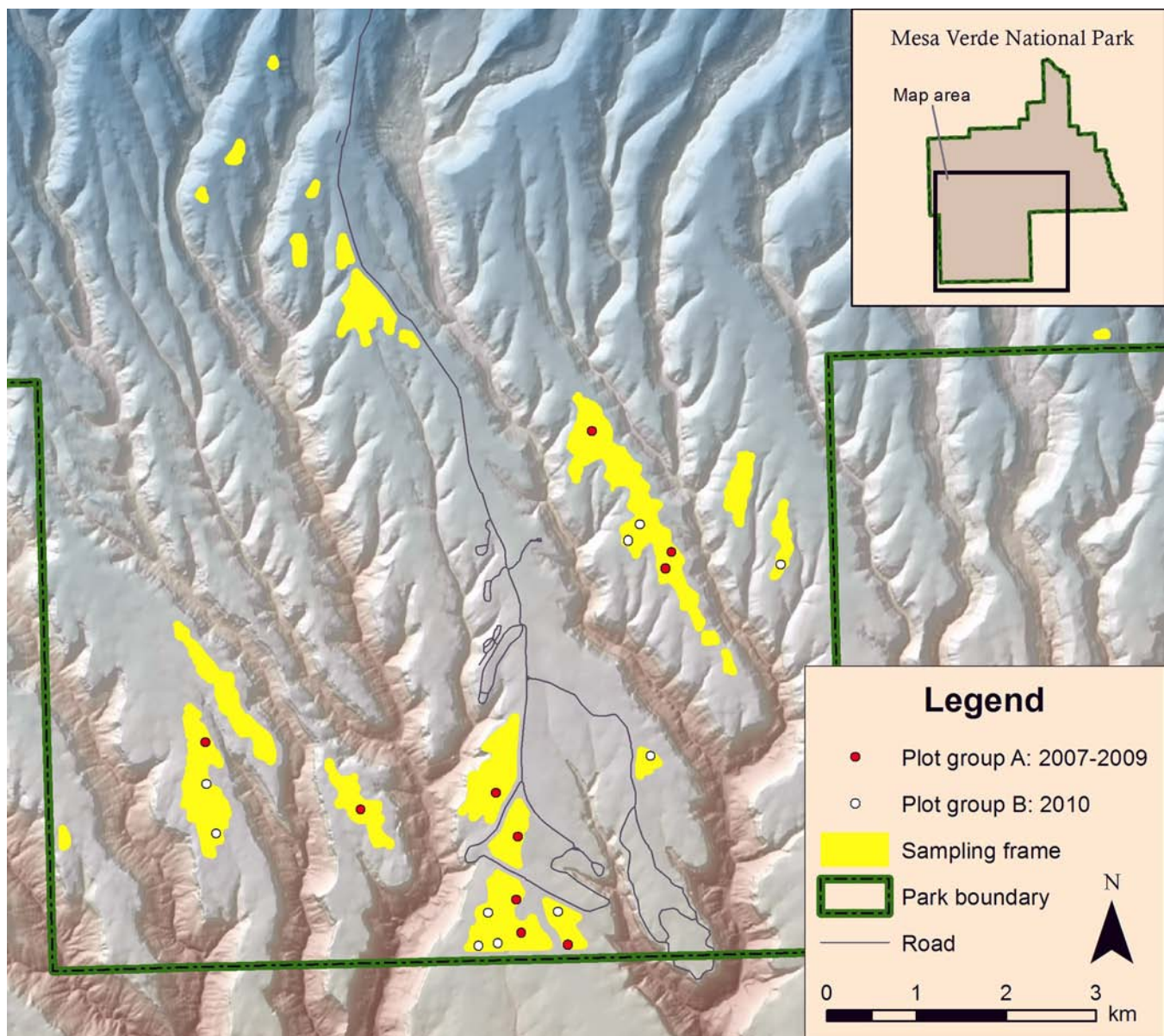


Figure 1. Sampling frame of the Loamy Mesa Top Pinyon-Juniper ecological site showing the 10 plots established in 2007 and the 10 plots established in 2010.

During plot establishment in 2007, we collected the full suite of data. In 2008 and 2009, we resampled the original 10 plots, but only collected a subset of the data: species cover and frequency, functional group cover, soil surface feature cover, and basal gaps. In 2008 and 2009 we also changed some of our methodologies. The SCPN integrated upland monitoring protocol (DeCoster et al. 2012) incorporates these latest changes. The tree measurement methods used in 2007 and 2008 are described below.

2.2.1 Shrub and herbaceous vegetation

We sampled shrub and herbaceous vegetation within 5 sets of nested quadrats at 10 m intervals along each transect. The largest quadrat size was 10 m² (2 × 5 m), with 4 smaller quadrats nested inside (0.01 m², 0.1 m², 1 m², 5 m²). We recorded the presence of each herbaceous and shrub species within each nested sub-quadrat. We estimated the percent foliar cover of each species in the 10 m² quadrat and assigned it to 1 of 12 cover classes (e.g., 2%–5%, 5%–10%, etc.). We also estimated the percent cover for functional groups (e.g., perennial grasses, forbs, shrubs) in the 10 m² quadrats and recorded the cover class. We collected these data in the initial 10 plots in 2007, 2008 and 2009, and collected the same set of data for the 10 new plots established in 2010.

2.2.2 Overstory trees, saplings, and seedlings

In 2007, we measured overstory trees in a 20 × 50 m (0.1 ha) plot located between 2 of the transects. Within this overstory tree plot, we tallied saplings by size class and species in a smaller, 10 × 25 m plot (0.25 ha). We tallied seedlings by size class and species in the fifteen 10 m² quadrats along the 3 transects. In subsequent years, we made some changes to methods, as described below.

In 2007, we measured all trees using a diameter tape: junipers were measured at the root crown, and pinyons were measured at breast height. In 2008, we remeasured all live overstory junipers using a new method. For individuals whose root crown diameter was increased by horizontal or diagonal branches, we measured the root crown of the tree using a meter stick in 2 perpendicular directions, excluding the horizontal and diagonal branches. This method does not exaggerate the size of the trees. We repeated this method for junipers in 2010.

In 2009 we changed the size class categories for seedlings. In this year, we also measured tree canopy cover using the line intercept method along transects. We felt that this was a more accurate representation of the canopy than the canopy closure method we used with a spherical densiometer in 2008. These new methods were used for the plots established in 2010, as well.

2.2.3 Soil stability and hydrologic function

We estimated the percent cover of soil surface features in the 1 m² quadrats along transects, and recorded the cover in 1 of 12 cover classes. We measured basal gaps as the length of bare soil between plant bases along each transect. We collected both soil surface feature and basal gap data for 3 years in the plots established in 2007, and for one year in the plots established in 2010. We also conducted a soil aggregate stability test one time in all plots established in 2007 and 2010, using 18 soil samples per plot collected along the transects. For these we noted whether there was vegetation cover over the sample point.

2.3 Data summary

In this report, we compare the data collected in the 10 new plots in 2010 to the data collected in the 10 original plots between 2007 and 2009. It must be stressed that the differences between these 2 plot groups do not represent change over time, but rather indicate differences in composition and structure resulting largely from spatial variation. We refer to these 2 groups of plots as Plot Group A for the plots established in 2007, and Plot Group B for the plots established in 2010.

The sample unit for summary and analysis is the plot; hence, we summarized data at the level of the plot. For most metrics, we then calculated the mean and standard deviation for the plot group from the plot means. (Ecological site species diversity metrics were the exception.) For Plot Group A metrics where there were 3 years of data, we calculated the mean value and a standard deviation for the 10 plots for each year, and then calculated the mean of the means and the mean of the standard deviations for the 3 years. For Plot Group B we calculated the mean and standard deviation based on a single year of data. Metrics with 3 years of data include species cover and frequency, functional group cover, soil surface features and basal gaps.

2.3.1 Species cover and frequency

For herbaceous and shrub vegetation, percent foliar cover was estimated for each species from the cover class midpoints, e.g., 7.5% for cover class 5%–10%. For each year, mean cover was calculated for each plot, and the mean and standard deviation were calculated for the ecological site from the plot means. Species frequency was calculated for quadrats (mean percentage of 10 m² quadrats per plot where the species occurs) and for plots (percentage of plots where the species occurs). For Plot Group A, we calculated the mean frequency for each year, and then calculated the mean of the 3 years.

2.3.2 Species diversity

Four diversity measures were calculated for herbaceous and shrub species for each year (Magurran 1988), first for all species and then for native species only:

- (1) Species richness (S) is the number of species at a given spatial scale. This was calculated at the level of the

plot and at the level of the ecological site.

(2) The Shannon Diversity Index (H') provides a measure of species diversity that takes into account the relative abundance of each species:

$$- \sum_{i=1}^n p_i \ln p_i$$

where p_i is the abundance of each species.

(3) Species evenness (E) is a measure of the degree to which all species are equal in abundance:

$$H' / \ln(S)$$

(4) Beta diversity (β_w) is a measure of within-ecological site heterogeneity:

$$S_e / (S_p - 1)$$

where S_e is the total number of species found in the ecological site, and S_p is the mean number of species found per plot.

For plot richness, Shannon diversity, and evenness, the mean was calculated for each plot and year, and the mean and standard deviation were then calculated for the ecological site for each year. We calculated the ecological site means for the 2 metrics, ecological site richness and beta diversity, using 10 plot values from only one year of data from plot group A—the year with the median value for Shannon diversity—combined with the remaining 10 plots from plot group B.

2.3.3 Trees

Because we were still refining tree measurement methods between 2007 and 2009, not all tree metrics from those years are directly comparable to 2010 data. In this report we compare the 2010 results with sapling and snag data from 2007, the live overstory tree data from 2008, and the seedling and canopy cover data from 2009.

Each metric was calculated for each plot, and the mean and standard deviation were then calculated for each plot group. Tree basal area (the total area of the tree cross-sections) for living trees and snags was calculated for each tree species in terms of m^2/ha . Mean diameter of living overstory trees was also calculated for each species. Tree density was calculated for all species and all size classes for overstory living trees and snags, saplings, and seedlings in terms of stems/ha. Canopy cover was calculated by first deriving the mean for each plot, and then the mean and standard deviation were calculated for the plot group.

2.3.4 Basal gaps

We calculated 5 metrics for each year of basal gap data: median basal gap size, percentage of transects comprised by gaps and plant bases, percentage of transects comprised by each gap size class, and total number of gaps. Mean and standard deviation were calculated for each metric for each year. For Plot Group A, where there are 3 years of data, we calculated the mean and standard deviation of the metrics for each year, and then calculated the mean of the means and the mean of the standard deviations for the 3 years.

2.3.5 Soil stability

We calculated the mean soil aggregate stability index for each plot and then calculated the mean and standard deviation for all plots in the plot group. This gave us a mean soil aggregate stability index for the plots established in 2007, and a separate soil aggregate stability index for the plots established in 2010. This index ranges between 1 and 6, where 1 indicates low aggregate stability and 6 indicates high aggregate stability. The index was also calculated separately for samples with vegetative cover and for samples without vegetative cover.

3 Results

3.1 Shrub and herbaceous vegetation

Perennial grasses and shrubs dominated the herbaceous/shrub vegetation of the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE, with less cover of forbs and cacti/succulents (table 1 and fig. 2). In Plot Group A—the 10 plots sampled in 2007 through 2009—perennial grasses had greater foliar cover than shrubs, but in Plot Group B—the 10 plots sampled in 2010—shrubs had greater foliar cover than perennial grasses. The cover of cacti/succulents and forbs were similar for the 2 groups of plots. Annual grasses only occurred in Plot Group A in trace amounts. Total live foliar cover was lower in the 2010 plots, but standing dead herbaceous cover and standing dead woody cover were similar for the 2 groups of plots, between 1 and 2%. Overall, the differences between the 2 groups of plots were not large, particularly in light of the large among-plot variability, as indicated by the large standard deviations.

Table 1. Foliar cover of functional groups for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Functional groups	Plot Group A 2007–2009		Plot Group B 2010	
	Mean (%)	SD	Mean (%)	SD
Total live foliar cover	11.22	5.41	8.95	3.68
Perennial grasses	4.36	2.75	2.95	2.14
Annual grasses	<0.01	<0.01	0	0
Forbs	1.02	0.63	1.00	0.49
Shrubs	2.60	2.99	4.00	3.81
Cacti/succulents	1.24	0.96	1.19	0.82
Standing dead herbaceous	1.54	0.94	1.21	0.92
Standing dead woody	1.87	1.45	1.95	1.31

Note: The live functional groups do not add up to the total live foliar cover because the calculations were made from cover class midpoints, components may overlap, and the estimations have observer error.

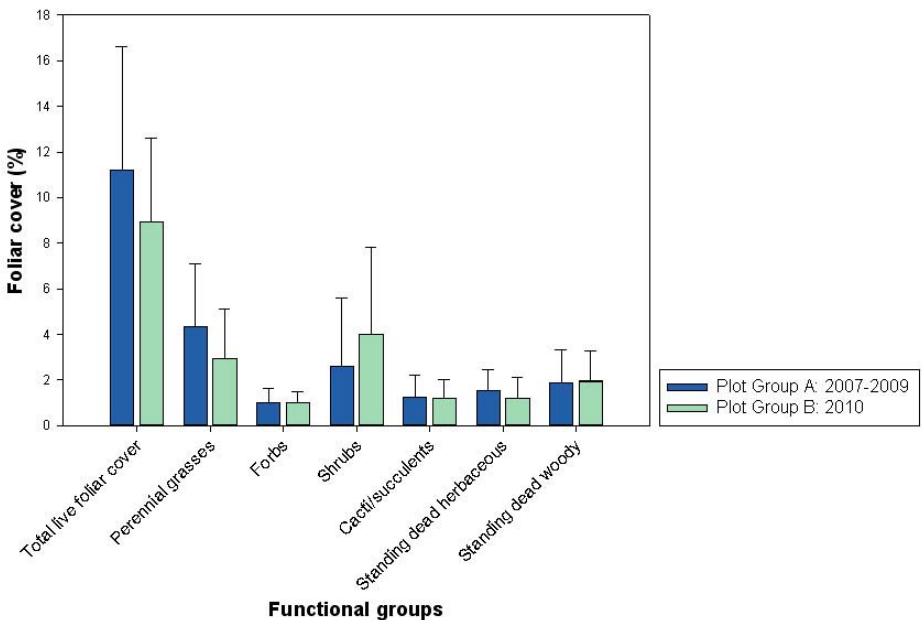


Figure 2. Mean percent foliar cover of functional groups for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Annual grasses had <0.1% foliar cover and were therefore not graphed. Error bars represent one standard deviation.

We examine species-level data for the most abundant herbs and shrubs for both plot groups in Table 2 (foliar cover and frequency) and Figure 3 (foliar cover). The dominant grass was *Poa fendleriana* (muttongrass). The dominant shrubs were *Purshia tridentata* (antelope bitterbrush), *Cercocarpus montanus* (birchleaf mountain mohagghany), and *Chrysothamnus depressus* (longflower rabbitbrush). The dominant succulents were *Opuntia* spp. (prickly pear) and *Yucca baccata* (banana yucca). The dominant forbs were *Penstemon linarioides* (toadflax penstemon) and *Petradoria pumila* (rock goldenrod). While *Artemisia tridentata* (basin big sagebrush) had relatively high foliar cover, its plot frequency was low. Its distribution was limited to plots that occur near The Glades, on the far southern end of Chapin Mesa, the site of a historic fire.

Table 2. Mean foliar cover and standard deviation, and mean quadrat and plot frequencies of the 15 most abundant shrub and herbaceous species for Plot Group A, and for the same species in Plot Group B, in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. All nonnative species are included from both plot groups.

Species	Plot Group A 2007–2009				Plot Group B 2010			
	Foliar cover (%)	SD	Quadrat freq. (%)	Plot freq. (%)	Foliar cover (%)	SD	Quadrat freq. (%)	Plot freq. (%)
<i>Poa fendleriana</i>	4.280	2.692	96.44	100.00	2.916	2.152	100.00	100.00
<i>Purshia tridentata</i>	1.369	1.306	48.44	90.00	3.293	3.495	61.33	90.00
<i>Artemisia tridentata</i>	0.888	2.808	10.00	10.00	0.245	0.748	12.00	20.00
<i>Yucca baccata</i>	0.697	0.722	31.56	73.33	0.460	0.496	19.33	80.00
<i>Opuntia</i> spp.	0.526	0.350	50.00	90.00	0.704	0.625	44.00	100.00
<i>Penstemon linarioides</i>	0.513	0.461	81.33	100.00	0.315	0.141	83.33	100.00
<i>Cercocarpus montanus</i>	0.209	0.468	10.00	30.00	0.103	0.180	5.33	40.00
<i>Petradoria pumila</i>	0.143	0.204	16.67	50.00	0.096	0.147	18.00	60.00
<i>Chrysothamnus depressus</i>	0.091	0.271	10.00	36.67	0.081	0.096	20.00	60.00
<i>Lupinus ammophilus</i>	0.066	0.094	19.33	63.33	0.065	0.088	27.33	60.00
<i>Cordylanthus wrightii</i>	0.056	0.068	35.56	86.67	0.107	0.123	54.67	80.00
<i>Eriogonum racemosum</i>	0.039	0.048	21.33	80.00	0.029	0.052	12.00	30.00
<i>Hesperostipa comata</i>	0.037	0.117	2.89	6.67	0	0	0	0.00
<i>Phlox hoodii</i>	0.032	0.058	13.11	40.00	0.142	0.183	46.00	70.00
<i>Comandra umbellata</i>	0.028	0.068	9.56	26.67	0.001	0.002	1.33	10.00
<i>Sisymbrium altissimum</i> ^a	0.003	0.008	4.89	16.67	0	0	0	0
<i>Bromus tectorum</i> ^a	0.003	0.005	3.56	33.33	0	0	0	0
<i>Descurainia sophia</i> ^a	0.003	0.005	3.56	13.33	0	0	0	0
<i>Ceratocephala testiculata</i> ^a	0.002	0.005	4.22	20.00	0.001	0.002	1.33	10.00
<i>Carduus nutans</i> ^a	0.001	0.001	1.56	23.33	<0.001	0.001	0.67	10.00
<i>Erodium cicutarium</i> ^a	<0.001	<0.001	0.22	3.33	0	0	0	0
<i>Taraxacum officinale</i> ^a	<0.001	<0.001	0.44	6.67	0	0	0	0
<i>Tragopogon dubius</i> ^a	<0.001	0.001	0.44	6.67	0	0	0	0
<i>Portulaca oleracea</i> ^a	0	0	0	0	0.001	0.001	1.33	20.00

Note: Species are arranged in descending order by their mean foliar cover for Plot Group A.

^aNonnative species.

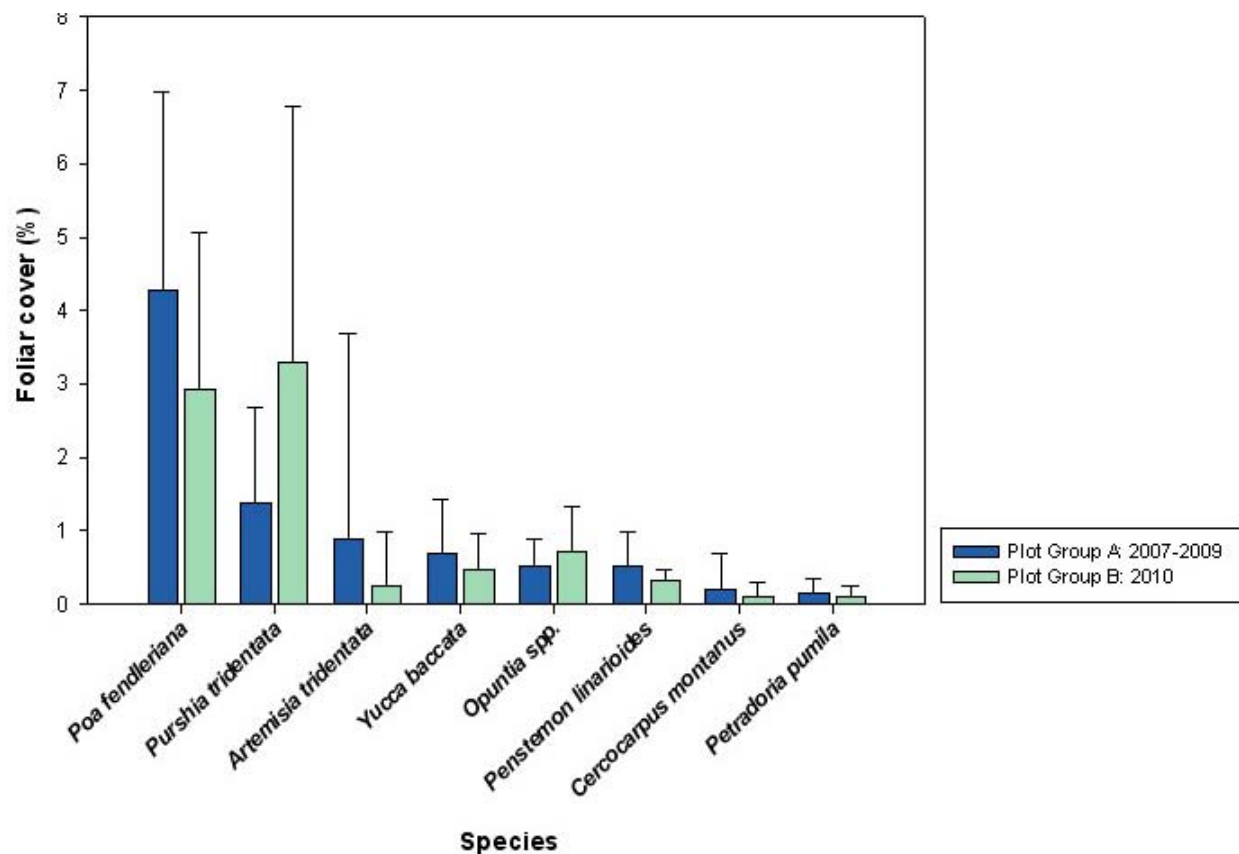


Figure 3. Mean percent foliar cover of the 8 most abundant shrub and herbaceous species for Plot Group A, compared with the foliar cover of the same species in Plot Group B, in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent one standard deviation.

For several species, there were substantial differences in the foliar cover between the 2 groups of plots. For example, foliar covers of *Poa fendleriana* and *Artemisia tridentata* were lower in Plot Group B, but foliar cover of *Purshia tridentata* was higher in Plot Group B. *Purshia tridentata* occurred in 90% of the plots in each plot group, but had much higher cover and quadrat frequency in Plot Group B. In all cases however, the standard deviations for cover were moderately large, suggesting high among-plot variability. There were generally minor differences in plot and quadrat frequencies; however, *Chrysothamnus depressus* had higher frequencies in Plot Group B, while *Hesperostipa comata* did not occur in Plot Group B. The differences in species cover and frequency between the plot groups are largely due to spatial variation, as these are 2 separate groups of plots.

Nine nonnative species were found in the plots. All had low foliar cover (0.003% or less), low quadrat frequencies, and low plot frequencies. Eight species were found in Plot Group A, while only 3 were found in Plot Group B. One species, *Portulaca oleracea* (little hogweed), was found only in Plot Group B. Appendix A lists all species found in both plot groups, along with common names, families, mean foliar cover and plot frequencies by year.

Values for diversity indices did not differ substantially between the 2 groups of plots (table 3). Plot richness, ecological site richness, and beta diversity were slightly lower in Plot Group B, while Shannon diversity and evenness were slightly higher. Mean plot species richness was 18.6 and 17.6 for Plot Group A and B, respectively. The standard deviation for plot richness was much lower for Plot Group B. Shannon diversity (which takes into account relative abundance of species, and generally ranges between 1.5 and 3.5) was 1.432 and 1.618 for Plot Group A and Plot Group B, respectively. Evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) was 0.494 and 0.566 for Plot Group A and Plot Group B, respectively. Ecological richness was 52.3 for Plot Group A and 48 for Plot Group B. Beta diversity (a measure of within site heterogeneity,

generally ranging between 1 and 5) was 2.971 for Plot Group A and 2.892 for Plot Group B. When the diversity indices were recalculated using only native species, they were slightly lower, with the exception of evenness, which was slightly higher.

Table 3. Species diversity metrics for all species and for native species only for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

	Plot Group A 2007–2009		Plot Group B 2010	
	Mean	SD	Mean	SD
All species				
Plot				
Plot richness	18.6	4.7	17.6	2.7
Shannon diversity	1.432	0.283	1.618	0.349
Evenness	0.494	0.087	0.566	0.116
Ecological site				
Ecological site richness	52.3		48 ^a	
Beta diversity	2.971		2.892 ^a	
Native species				
Plot				
Plot richness	17.4	4.6	17.2	2.5
Shannon diversity	1.420	0.277	1.616	0.349
Evenness	0.502	0.089	0.570	0.115
Ecological site				
Ecological site richness	47.3		45 ^a	
Beta diversity	2.894		2.778 ^a	

^aThese are not mean values.

3.2 Trees

The tree layer was dominated by *Juniperus osteosperma* (Utah juniper), with a smaller component of *Pinus edulis* (twoneedle pinyon). The basal area of live overstory *Juniperus osteosperma* was 27.27 and 33.28 m²/ha for Plot Groups A and B, respectively, while the basal area of live overstory *Pinus edulis* was 1.23 and 1.92 m²/ha for Plot Groups A and B, respectively (fig. 4 and table 4). The live overstory density of *Juniperus osteosperma* was 278.0 and 365.0 stems/ha for Plot Groups A and B, respectively, while the live overstory density of *Pinus edulis* was 42.0 and 59.0 stems/ha. The overstory basal area and density of *Juniperus osteosperma* snags were much lower than for the live individuals. However, snag and live overstory tree metrics were more comparable for *Pinus edulis*: snag basal area and density were slightly higher than live individuals for Plot Group A, and slightly lower for Plot Group B. The large error bars in Figure 4 indicate high among-plot variation, and suggest that the differences between the 2 plot groups are not great.

The size class distribution for both *Pinus edulis* and *Juniperus osteosperma* showed a typical pattern of decreased density with increased size (fig. 5). All individuals of *Pinus edulis* were less than 35.0 cm in diameter, while several individuals of *Juniperus osteosperma* exceeded 85.0 cm in diameter. For both species and most size classes, stem density in Plot Group B was higher than stem density in Plot Group A.

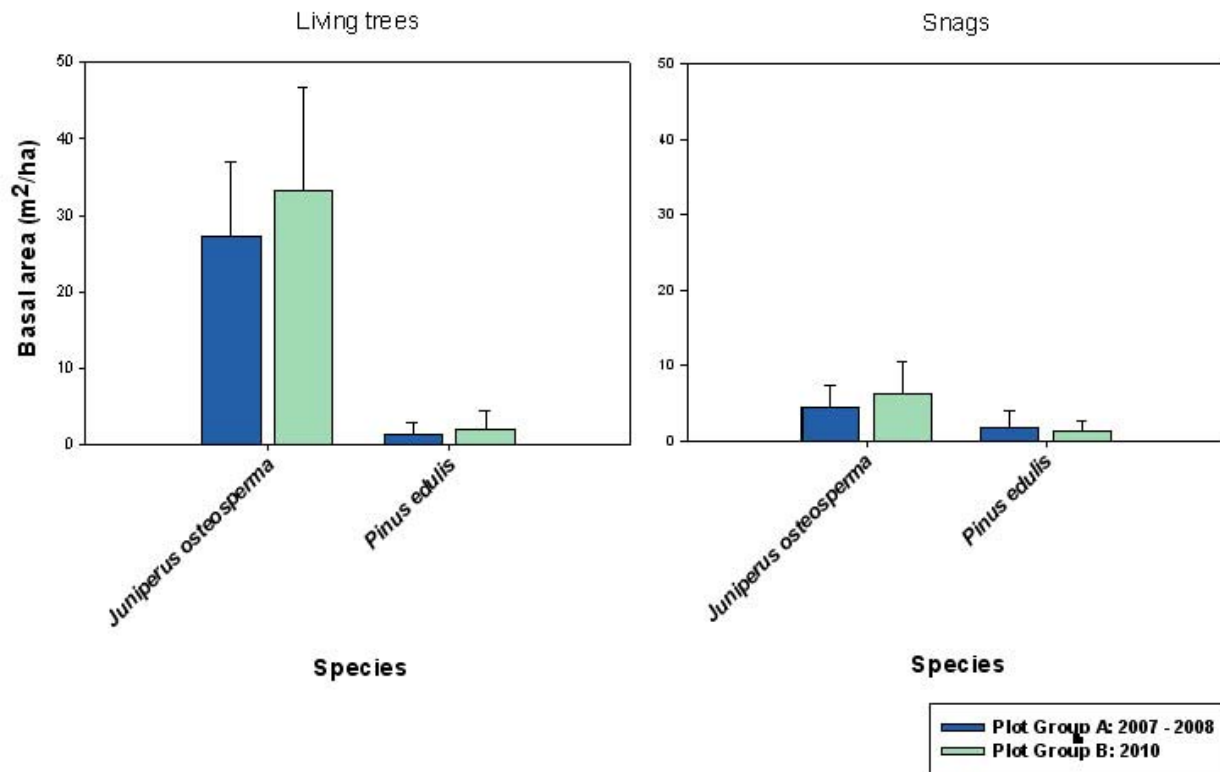


Figure 4. Mean basal area for living trees and snags, by species, for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Living trees were measured in 2008 and snags were measured in 2007. Error bars represent 1 standard deviation.

Table 4. Mean density, mean basal area and mean diameter of trees for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

	Plot group	Individual species		
		<i>Juniperus osteosperma</i>	<i>Pinus edulis</i>	All species ^a
Seedling ^b density (stems/ha)	A: 2009	686.7	1540.0	2226.7
	B: 2010	860.0	1373.3	2233.3
Sapling ^b density (stems/ha)	A: 2007	280.0	316.0	596.0
	B: 2010	220.0	456.0	676.0
Overstory ^b density (stems/ha)	A: 2008	278.0	42.0	320.0
	B: 2010	365.0	59.0	424.0
Snag ^b density (stems/ha)	A: 2007	60.0	47.0	107.0
	B: 2010	56.0	34.0	90.0
Overstory basal area (m²/ha)	A: 2008	27.27	1.23	28.53
	B: 2010	33.28	1.92	35.23
Snag basal area (m²/ha)	A: 2007	4.42	1.72	6.14
	B: 2010	6.37	1.34	7.71
Mean overstory diameter ^c (cm)	A: 2008	32.1	18.5	30.5
	B: 2010	31.1	20.1	29.5

^a"All species" density and basal area metrics are the sum of the individual species' mean values. "All species" overstory diameter is the mean diameter across both tree species.

^bSize classes: seedlings are <2.5 cm diameter, saplings are 2.5 to <15 cm diameter, overstory trees are ≥15 cm diameter, and snags are standing dead stems ≥15 cm diameter.

^cMean diameter of tree is provided as DBH for *Pinus edulis* and as DRC for *Juniperus osteosperma*.

In contrast to the overstory, *Pinus edulis* had greater sapling and seedling density than *Juniperus osteosperma* (table 4). The size structure of the *Juniperus osteosperma* saplings was fairly even, with Plot Group B having slightly lower densities (fig. 6). The size structure of the *Pinus edulis* saplings showed an inverse relationship between size and density, particularly for Plot Group B.

Juniperus osteosperma had more seedlings in the larger of the 2 size classes (based on diameter), while *Pinus edulis* had more seedlings in the intermediate size class (based on height) (fig. 7).

With the overstory trees and saplings of both species combined, the overall size structure of the trees showed an overall pattern of decreasing density with size class, although the relationship was not uniformly smooth for either plot group (fig. 8).

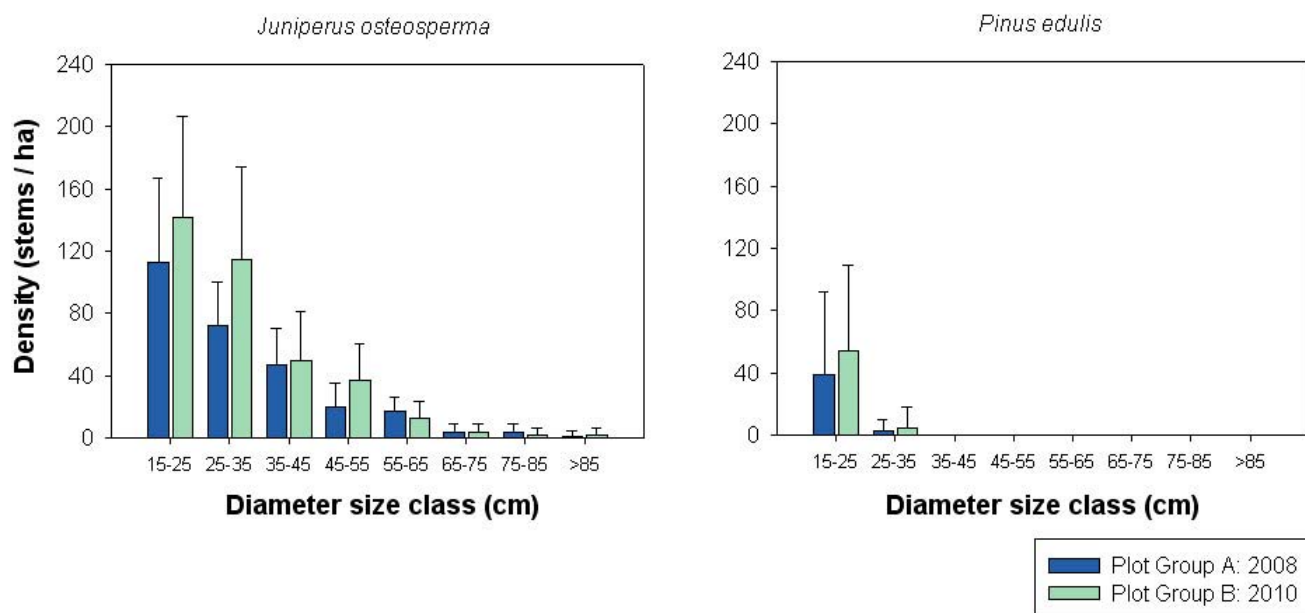


Figure 5. Size class structure of living overstory tree species for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent 1 standard deviation.

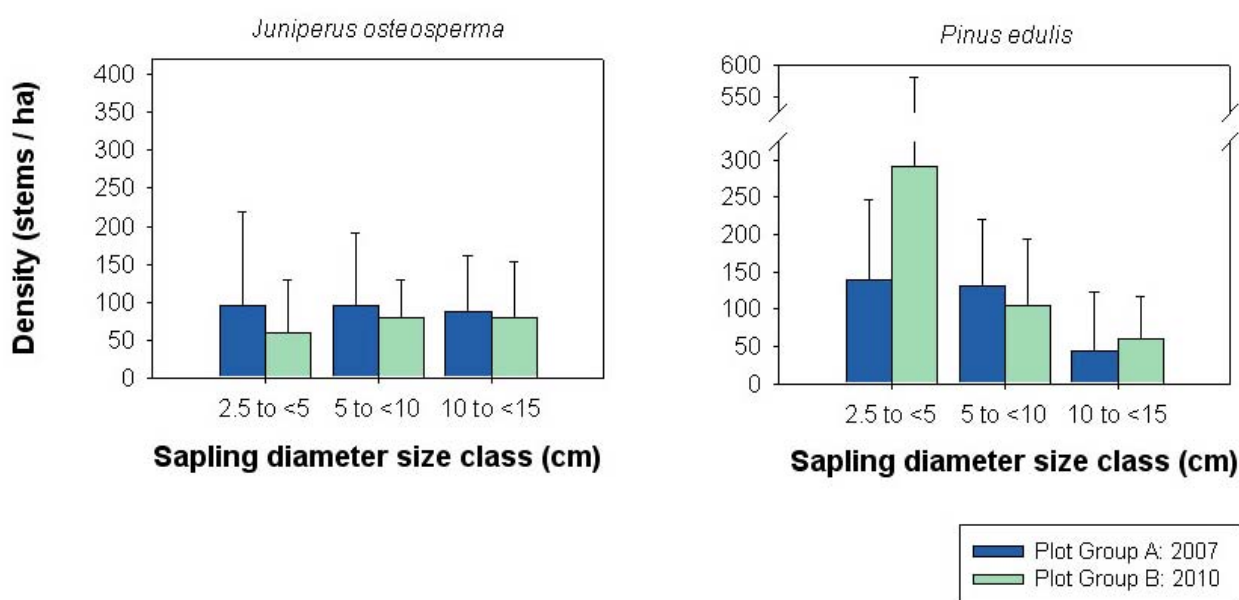


Figure 6. Mean density of saplings in different size classes, by species, for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent 1 standard deviation.

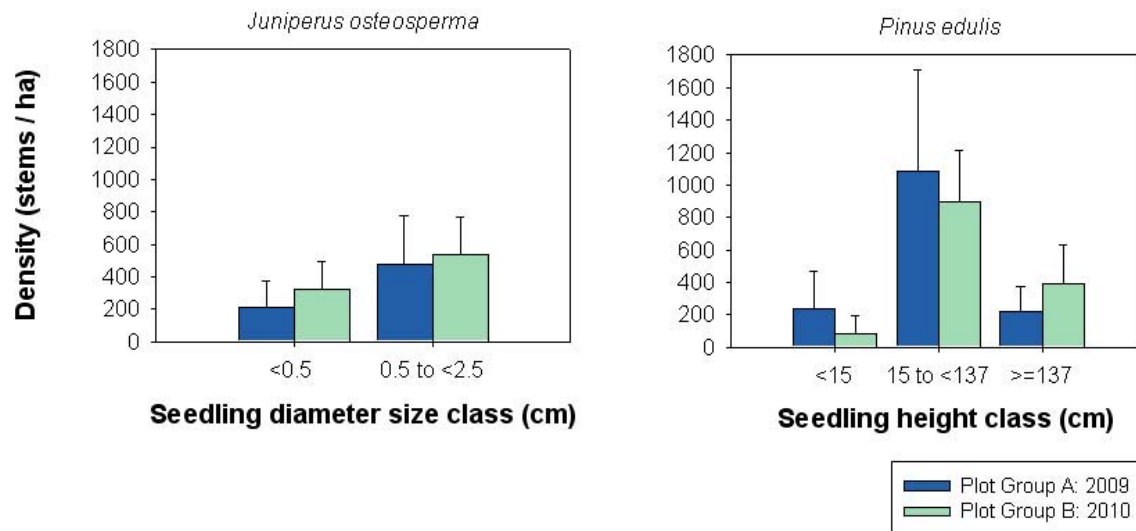


Figure 7. Mean density of seedlings in different size classes by species for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent 1 standard deviation. The seedling category includes all trees <2.5 cm diameter.

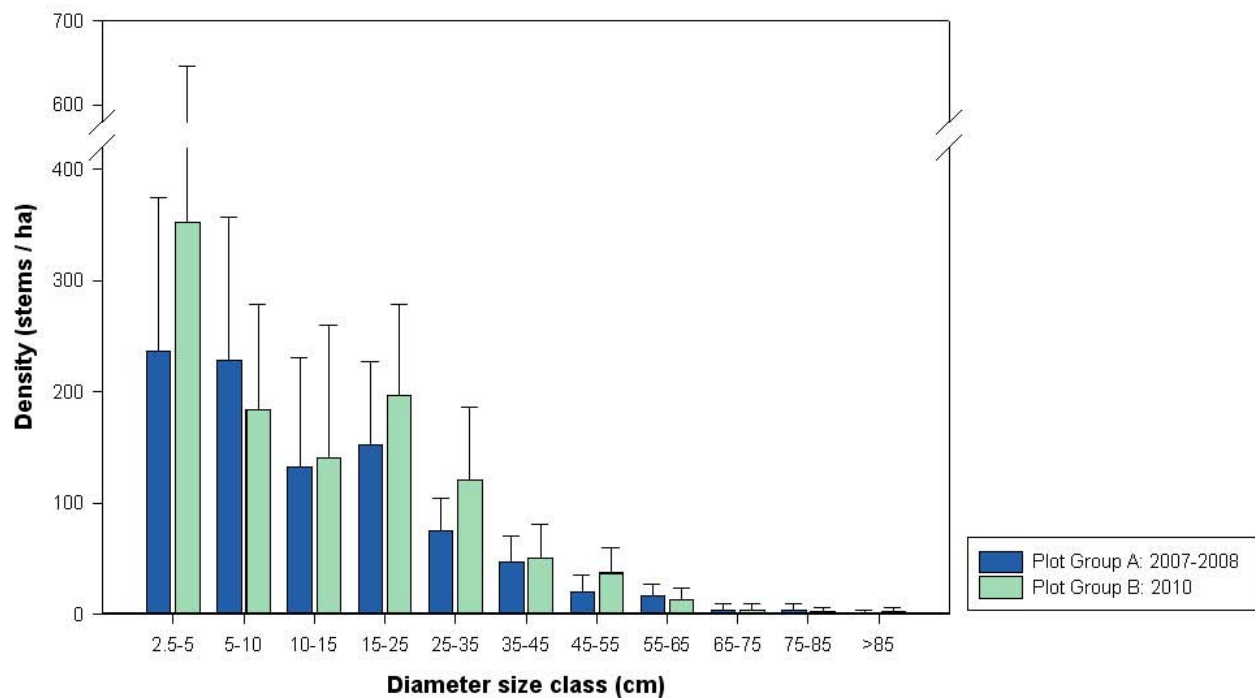
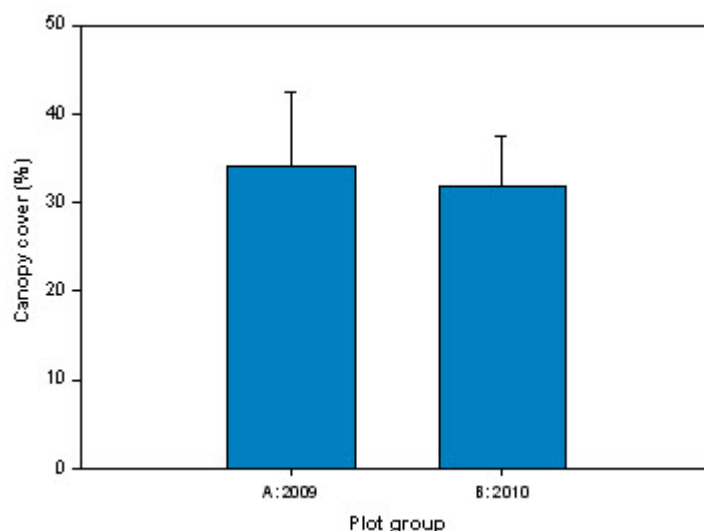


Figure 8. Size class structure of living overstory trees and saplings for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent 1 standard deviation.

Canopy cover was similar for the 2 groups of plots. Live canopy cover was 34.2% for Plot Group A, and 32.0% for Plot Group B (fig. 9). (We report the canopy cover for Plot Group A as 37.4% in the 2009 report, however, dead branches were included.)

Figure 9. Mean percent canopy cover for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars indicate 1 standard deviation.



3.3 Soil stability and hydrologic function

We measured the amount of soil surface potentially subject to erosion in 2 ways: cover estimates of soil surface features in quadrats, and measurements of basal gaps along transects.

Duff/litter was the dominant soil surface feature in both plot groups (table 5 and fig. 10), and the majority of the features had less than 5% cover. For most features, there were small differences in the cover between the 2 groups of plots. The exceptions were undifferentiated crust and cyanobacteria. Undifferentiated crust had covers of 22.03% and 6.61% for Plot Group A and Plot Group B, respectively, while cyanobacteria had covers of 5.21% and 26.60%, respectively. These relatively large differences were likely the result of a change in the way biological soil crusts were classified in 2010.

Table 5. Cover of soil surface features for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Soil surface feature	Plot Group A 2007–2009		Plot Group B 2010	
	Mean (%)	SD	Mean (%)	SD
Live plant base	3.20	1.70	1.29	0.53
Dead woody base	0.59	0.93	0.84	1.81
Dead herbaceous base	0.43	0.25	0.58	0.28
Bare soil	2.47	2.16	1.92	1.85
Duff/litter	58.51	10.19	55.44	12.78
Undifferentiated crust	22.03	11.45	6.61	11.96
Moss	1.43	1.30	0.73	0.98
Lichen	0.15	0.23	0.04	0.09
Cyanobacteria ^a	5.21	4.46	26.60	15.44
Fine gravel (0.2 to <2 cm)	0.01	0.02	0.01	0.02
Coarse gravel (2 to <7.5 cm)	0.06	0.10	0.06	0.09
Cobble (7.5 to <25 cm)	0.06	0.16	0.09	0.14
Stone, bedrock (≥25 cm)	0.04	0.11	0.11	0.34
Woody debris	1.76	0.89	2.82	2.01

Note: The soil surface feature components do not add up to 100% because the calculations were made from cover class midpoints, and the estimations have observer error.

^aIn 2010 we used a different method for classifying cyanobacteria.

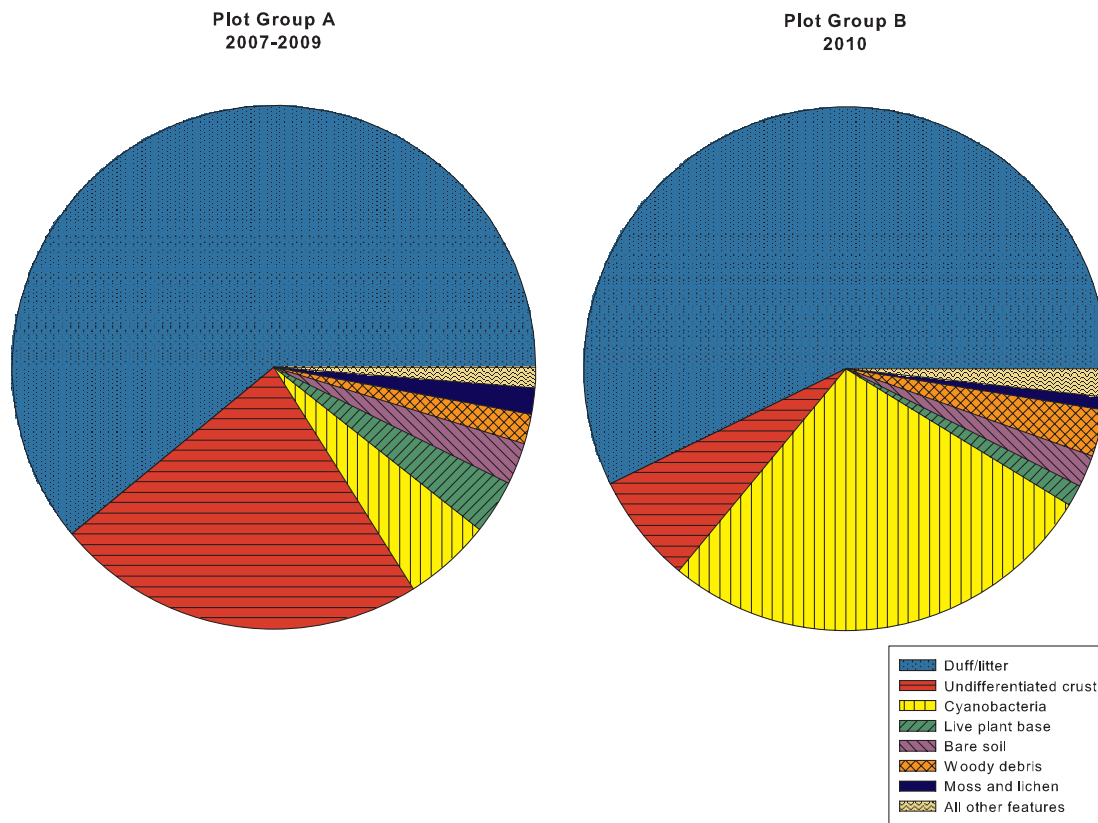


Figure 10. Mean percent cover of soil surface features for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

The ecological site was dominated by basal gaps in the largest size class, indicating large amounts of bare ground that may be subject to erosion (table 6 and fig. 11). There were moderate differences in some of the basal gap metrics between the 2 groups of plots. In particular, the number of gaps and the median gap size differed between the 2 groups of plots. The percentage of the transect in the various size classes of gaps, however, showed no large differences.

Table 6. Number of basal gaps, median gap size, and percentage of transect in different gap size classes for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Metric	Plot Group A 2008–2009 ^a		Plot Group B 2010	
	Mean	SD	Mean	SD
Number of gaps	109.1	48.3	87.7	38.8
Median gap size (cm)	88.9	48.7	118.0	61.8
Percentage of transect in gaps	96.7	1.7	97.1	1.4
Percentage of transect in gaps 0–19 cm	1.5	1.1	0.9	0.6
Percentage of transect in gaps 20–49 cm	5.1	3.2	3.9	2.2
Percentage of transect in gaps 50–99 cm	10.8	6.2	8.2	4.7
Percentage of transect in gaps ≥100 cm	79.3	11.3	84.2	8.7
Percentage of transect in plant bases	3.3	1.7	2.9	1.4

^aThe mean for Plot Group A does not include data collected in 2007 because it was collected using slightly different methods than in the other 2 years.

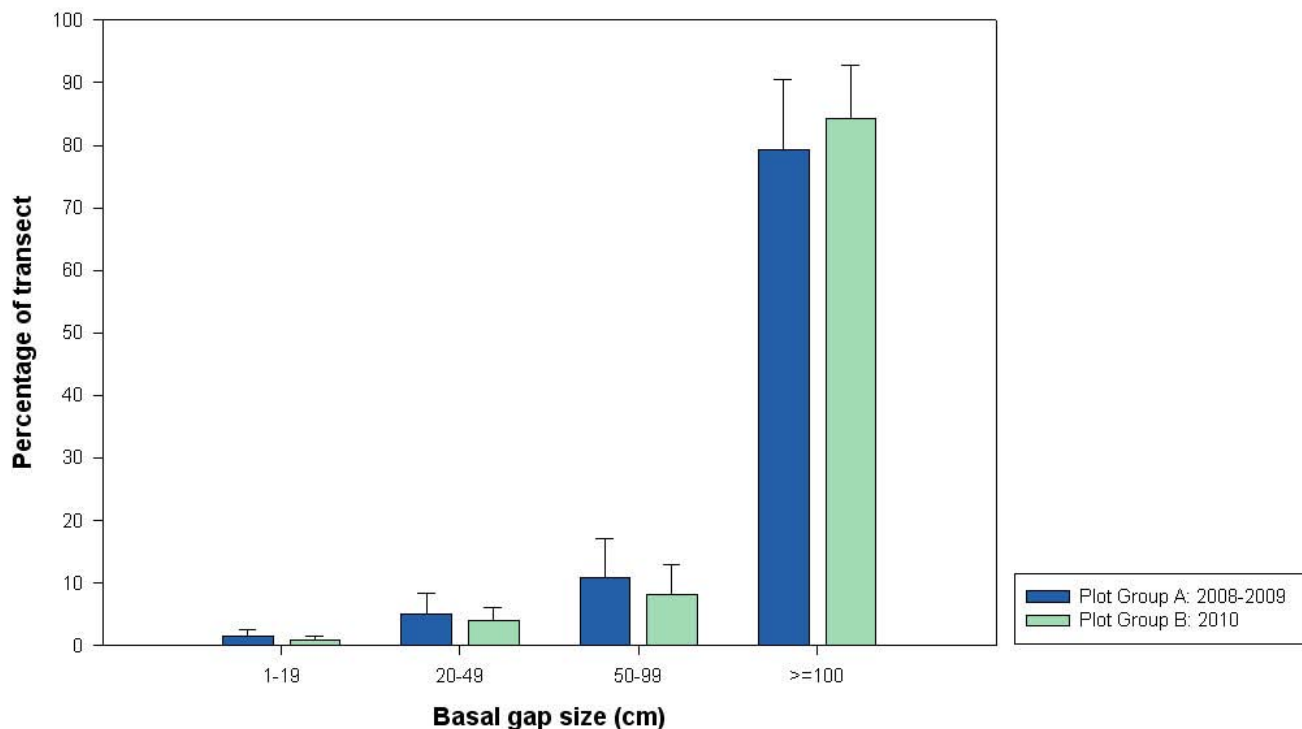


Figure 11. Mean percentage of transect by gap size class for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent 1 standard deviation. Data from 2007 was not included in Plot Group A for this metric.

Soil stability ratings were fairly consistent between the 2 plot groups (table 7). Ratings range from 1 to 6, with 1 indicating low stability and 6 indicating high stability. The mean rating for Plot Group A was 4.43, and the mean rating for plot group B was 4.62. Plot group B showed greater differences than Plot Group A between the samples collected under vegetative cover and those collected with no cover.

While the basal gap data suggests large amounts of area not covered by plant bases, the potential for erosion is moderated by the high soil stability and the large amount of area covered by litter.

Table 7. Soil stability rating for all samples, and for samples with and without vegetative cover, in Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

	Plot Group A 2007		Plot Group B 2010	
	Mean	SD	Mean	SD
All samples	4.43	0.71	4.62	0.52
Samples under vegetative cover	4.51	0.75	4.90	0.53
Samples not under vegetative cover	4.27	0.94	4.02	0.71

Note: Ratings ranged from 1–6, with 1 being the lowest stability and 6 being the highest.

3.4 Western Regional Climate Center precipitation data

Precipitation records for MEVE are available from the Western Regional Climate Center (2012). Figure 12 shows the total monthly precipitation for each of the 4 years of monitoring described in this report, compared with the long term average precipitation by month for the period 1948–2012.

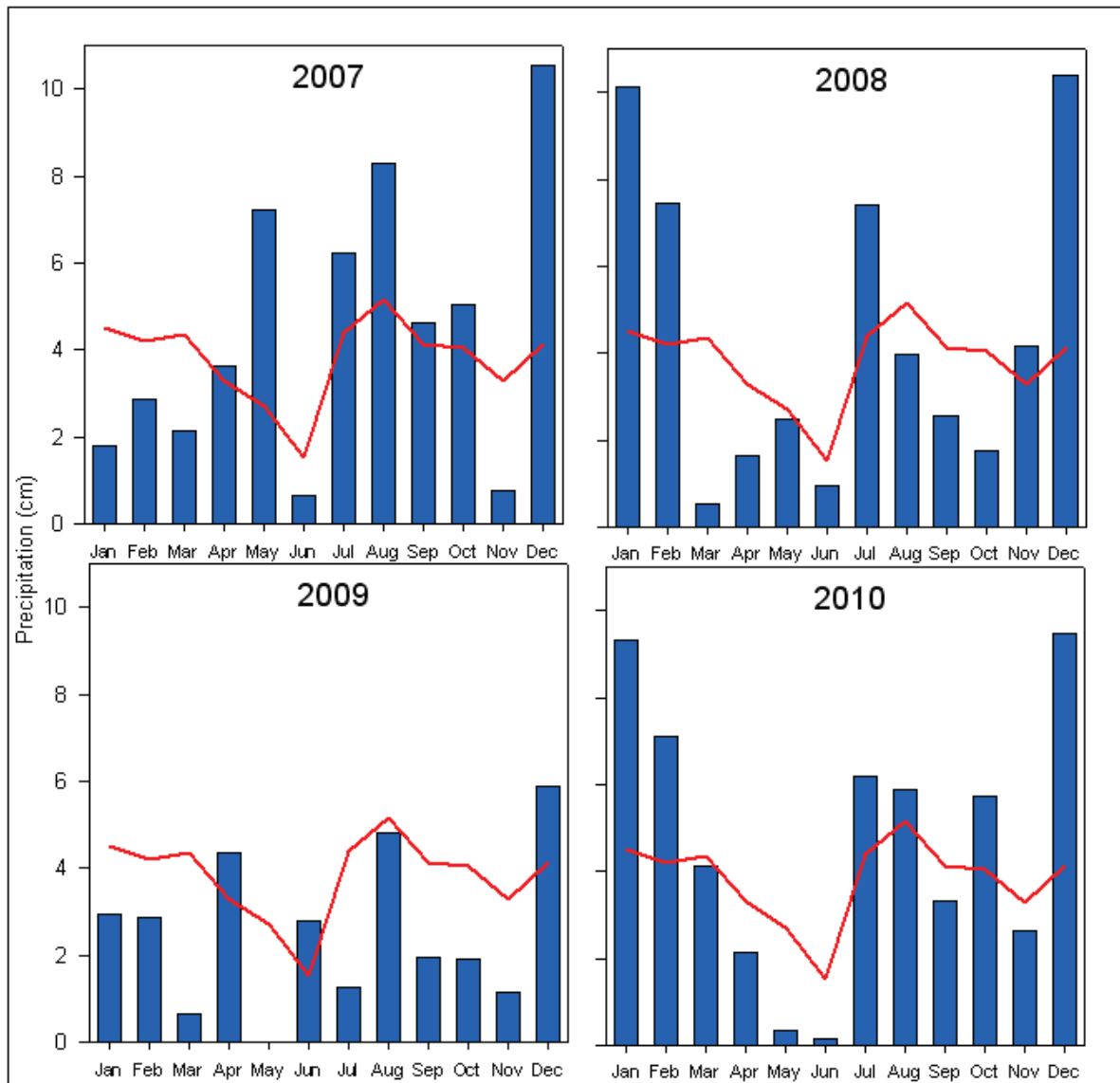


Figure 12. Total monthly precipitation for the 4 years of sampling. The red line represents the long term average precipitation for the Mesa Verde (55531) weather station for the period 1948 through 2012, collected by the Western Regional Climate Center.

4 Discussion

The data presented here indicates that the second set of plots established in 2010 in the Loamy Mesa Top Pinyon-Juniper ecological site were quite similar to the first set of plots established in 2007 in terms of vegetation composition and structure, and soil characteristics. Plot Group B had less perennial grass cover but more shrub cover, fewer nonnative species, overall greater density and basal areas of trees, greater canopy cover of trees, larger basal gaps, and some different species. We would expect minor differences in species composition and structure and soil characteristics between the 2 groups, particularly for groups with small sample sizes, due to random spatial variation. The groups represent different plots in different locations. Due to endogenous and exogenous factors, the species composition and structure and soil characteristics naturally vary. For example, *Purshia tridentata* occurred in 90% of the plots in each plot group, but had much high cover and plot frequency in Plot Group B.

While spatial variability likely accounts for the majority of the differences between the 2 plot groups, additional variation may result from annual climatic variation. We have associated variation in precipitation with changes in cover and frequency of herbaceous plants, particularly annual species, but to a lesser extent, perennial forbs. Precipitation records for MEVE gathered by the Western Regional Climate Center (2010) indicate that 2009 was a particularly dry year, which may have reduced cover and frequency of herbaceous species. These differences in precipitation, however, likely are a minor factor contributing to the differences between the plot groups.

Variability may also be attributable to sampling error. Although we strive to reduce sampling error through training and being diligent while collecting data, sampling error is inevitable. Cover estimation may vary among individuals (and crews), species may be misidentified, slight differences among observers in applying sampling methods may go unnoticed, and the location of transects and quadrats vary slightly from year to year. We minimize this source of error by ensuring that transect lines are as straight as possible, quadrats are placed correctly, and field crews are thoroughly trained on methods and species identification and remain calibrated on cover estimation.

In 2011, we installed and sampled an additional 10 plots in the Loamy Mesa Top Pinyon-Juniper ecological site. These data will be reported once they have been verified, validated and summarized. Power analysis indicates that a total of 30 plots should provide a large enough sample size to detect trends in key metrics. Data from these 30 plots will be used to describe the baseline conditions of the vegetation and soils of this ecological site and to monitor long term change.

5 Literature cited

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Appendix A: Complete species list for plots sampled in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Table A1. Herbaceous and shrub species with mean foliar cover and mean plot frequency for Plot Group A and Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Species	Common name	Family	Plot Group A 2007–2009		Plot Group B 2010	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Achnatherum hymenoides</i>	Indian ricegrass	Poaceae	0.014	16.67	0.002	20.00
<i>Amelanchier utahensis</i>	Utah serviceberry	Rosaceae	0.010	13.33	0.134	10.00
<i>Androsace septentrionalis</i>	pygmy rock jasmine	Primulaceae	<0.001	3.33	<0.001	10.00
<i>Antennaria parvifolia</i>	small leaf pussytoes	Asteraceae	0	0	0.002	10.00
<i>Antennaria rosea</i>	rosy pussytoes	Asteraceae	<0.001	10.00	0	0
<i>Arabis</i> spp.	rockcress	Brassicaceae	0.005	20.00	0	0
<i>Arabis fendleri</i>	Fendler's rockcress	Brassicaceae	0.027	53.33	0.013	50.00
<i>Arabis holboellii</i>	Holboell's rockcress	Brassicaceae	<0.001	6.67	0	0
<i>Artemisia bigelovii</i>	Bigelow sage	Asteraceae	0	0	0.105	50.00
<i>Artemisia tridentata</i>	basin big sagebrush	Asteraceae	0.888	10.00	0.245	20.00
<i>Astragalus</i> spp.	milkvetch	Fabaceae	0.027	63.33	0.011	20.00
<i>Astragalus pattersonii</i>	Patterson's milkvetch	Fabaceae	0.003	6.67	0.265	60.00
<i>Bromus tectorum</i> ^a	cheatgrass	Poaceae	0.003	33.33	0	0
<i>Calochortus</i> spp.	mariposa lily	Liliaceae	0.001	6.67	0.002	50.00
<i>Carduus nutans</i> ^a	nodding thistle	Asteraceae	0.001	23.33	<0.001	10.00
<i>Carex rossii</i>	Ross' sedge	Cyperaceae	<0.001	3.33	0	0
<i>Ceratocephala testiculata</i> ^a	curvseed butterwort	Ranunculaceae	0.002	20.00	0.001	10.00
<i>Cercocarpus montanus</i>	birchleaf mountain mahogany	Rosaceae	0.209	30.00	0.103	40.00
<i>Chaenactis douglasii</i>	Douglas dustymaiden	Asteraceae	0	0	0.001	20.00
<i>Chenopodium</i> spp.	goosefoot	Chenopodiaceae	0	0	0.006	50.00
<i>Chenopodium album</i>	lambsquarters	Chenopodiaceae	0.002	40.00	0	0
<i>Chenopodium fremontii</i>	Fremont's goosefoot	Chenopodiaceae	0	0	<0.001	10.00
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0.001	10.00	<0.001	10.00
<i>Chrysothamnus depressus</i>	longflower rabbitbrush	Asteraceae	0.091	36.67	0.081	60.00
<i>Comandra umbellata</i>	bastard toadflax	Santalaceae	0.028	26.67	0.001	10.00

Table A1 (continued)

Species	Common name	Family	Plot Group A 2007–2009		Plot Group B 2010	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Cordylanthus wrightii</i>	Wright's bird's beak	Scrophulariaceae	0.056	86.67	0.107	80.00
<i>Cryptantha</i> sp.	cryptantha	Boraginaceae	<0.001	3.33	0.003	10.00
<i>Dalea</i> sp.	prairie clover	Fabaceae	<0.001	3.33	0	0
<i>Delphinium scaposum</i>	barestem larkspur	Ranunculaceae	<0.001	3.33	0	0
<i>Descurainia sophia</i> ^a	herb sophia	Brassicaceae	0.003	13.33	0	0
<i>Draba reptans</i>	Carolina draba	Brassicaceae	0.006	23.33	0	0
<i>Echinocereus</i> sp.	hedgehog cactus	Cactaceae	<0.001	3.33	0	0
<i>Elymus elymoides</i>	squirreltail	Poaceae	0.017	43.33	0.018	50.00
<i>Erigeron divergens</i>	spreading fleabane	Asteraceae	0.006	20.00	0	0
<i>Eriogonum alatum</i>	winged buckwheat	Polygonaceae	0	0	0.009	20.00
<i>Eriogonum racemosum</i>	redroot buckwheat	Polygonaceae	0.039	80.00	0.029	30.00
<i>Eriogonum umbellatum</i>	sulpher-flowered buckwheat	Polygonaceae	0.005	26.67	0.017	60.00
<i>Erodium cicutarium</i> ^a	stork's bill	Geraniaceae	<0.001	3.33	0	0
<i>Escobaria vivipara</i>	spinystar	Cactaceae	<0.001	10.00	0	0
<i>Erysimum capitatum</i>	sanddune wallflower	Brassicaceae	0	0	0.007	10.00
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	0.020	16.67	0.031	10.00
<i>Hesperostipa comata</i>	needle and thread	Poaceae	0.037	6.67	0	0
<i>Heterotheca villosa</i>	hairy false goldenaster	Asteraceae	0.002	13.33	0	0
<i>Ipomopsis aggregata</i>	scarlet gilia	Polemoniaceae	<0.001	3.33	0	0
<i>Koeleria macrantha</i>	prairie junegrass	Poaceae	0.018	30.00	0.002	10.00
<i>Lappula occidentalis</i>	flatspine stickseed	Boraginaceae	<0.001	3.33	0	0
<i>Lepidium latifolium</i>	broadleaved pepperweed	Brassicaceae	0	0	0.002	10.00
<i>Lepidium montanum</i>	mountain pepperweed	Brassicaceae	<0.001	3.33	0	0
<i>Lesquerella rectipes</i>	straight bladderpod	Brassicaceae	0.007	20.00	0.019	30.00
<i>Lithospermum incisum</i>	narrowleaf gromwell	Boraginaceae	0	0	0.001	10.00
<i>Lupinus</i> sp.	lupine	Fabaceae	<0.001	6.67	0.001	10.00
<i>Lupinus ammophilus</i>	sand lupine	Fabaceae	0.066	63.33	0.065	60.00
<i>Lupinus argenteus</i>	silvery lupine	Fabaceae	0.002	13.33	0	0
<i>Lupinus caudatus</i>	tailcup lupine	Fabaceae	0	0	0.018	20.00

Table A1 (continued)

Species	Common name	Family	Plot Group A 2007–2009		Plot Group B 2010	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Machaeranthera bigelovii</i>	Bigelow's tansy-aster	Asteraceae	0	0	0.001	10.00
<i>Machaeranthera canescens</i>	hoary tansyaster	Asteraceae	0.012	70.00	0.004	20.00
<i>Opuntia</i> spp.	prickly pear	Cactaceae	0.526	90.00	0.704	100.00
<i>Packera multilobata</i>	lobeleaf groundsel	Asteraceae	<0.001	10.00	0	0
<i>Pedicularis centranthera</i>	dwarf lousewort	Scrophulariaceae	0.023	30.00	0	0
<i>Penstemon</i> spp.	penstemon	Scrophulariaceae	0	0	0.026	40.00
<i>Penstemon barbatus</i>	beardlip penstemon	Scrophulariaceae	0.016	63.33	0	0
<i>Penstemon linarioides</i>	toadflax penstemon	Scrophulariaceae	0.513	100.00	0.315	100.00
<i>Peraphyllum ramosissimum</i>	squaw apple	Rosaceae	0.004	10.00	0	0
<i>Petroradia pumila</i>	rock goldenrod	Asteraceae	0.143	50.00	0.096	60.00
<i>Phlox gracilis</i>	slender phlox	Polemoniaceae	0.005	10.00	0	0
<i>Phlox hoodii</i>	Hood's phlox	Polemoniaceae	0.032	40.00	0.142	70.00
<i>Phlox longifolia</i>	longleaf phlox	Polemoniaceae	0.003	20.00	0	0
<i>Phoradendron juniperinum</i>	juniper mistletoe	Viscaceae	0.001	3.33	0.010	10.00
<i>Poa fendleriana</i>	muttongrass	Poaceae	4.280	100.00	2.916	100.00
<i>Polygonum douglasii</i> ^a	Douglas' knotweed	Polygonaceae	0.015	100.00	0.025	100.00
<i>Portulaca oleracea</i> ^a	little hogweed	Portulacaceae	0	0	0.001	20.00
<i>Purshia tridentata</i>	antelope bitterbrush	Rosaceae	1.369	90.00	3.293	90.00
<i>Quercus gambelii</i>	Gambel oak	Fagaceae	0.008	10.00	0.002	20.00
<i>Sisymbrium altissimum</i> ^a	tumblemustard	Brassicaceae	0.003	16.67	0	0
<i>Sphaeralcea coccinea</i>	scarlet globemallow	Malvaceae	0.003	10.00	0	0
<i>Sporobolus cryptandrus</i>	sand dropseed	Poaceae	<0.001	3.33	0	0
<i>Streptanthus cordatus</i>	heartleaf twistflower	Brassicaceae	<0.001	6.67	0	0
<i>Taraxacum officinale</i> ^a	common dandelion	Asteraceae	<0.001	6.67	0	0
<i>Tragopogon dubius</i> ^a	yellow salsify	Asteraceae	<0.001	6.67	0	0
<i>Yucca baccata</i>	banana yucca	Agavaceae	0.697	73.33	0.460	80.00
unknownMEV20070803_1			<0.001	3.33	0	0
unknownMEV20070803_2			<0.001	3.33	0	0

^aNonnative species

Table A2. Tree species with mean basal area and plot frequency for Plot Group A and for Plot Group B in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Species	Common name	Family	Plot Group A 2007–2008		Plot Group B 2010	
			Basal area (m ² /ha) ^a	Plot frequency (%) ^b	Basal area (m ² /ha) ^a	Plot frequency (%) ^b
<i>Juniperus osteosperma</i>	Utah juniper	Cupressaceae	27.27	100.00	33.28	100.00
<i>Pinus edulis</i>	twoneedle pinyon	Pinaceae	1.23	100.00	1.92	100.00

^aBasal area measures only overstory trees.

^bPlot frequency includes overstory trees, saplings, and seedlings.