



Integrated Upland Vegetation and Soils Monitoring for Mesa Verde National Park

2011 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2013/517



ON THE COVER

Integrated upland monitoring in Mesa Verde National Park
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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, soil erosion 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 additional plots, and in 2011 we established another 10 plots. This brings our total for the ecological site to 30 established plots. Our power analysis suggests that this will be a sufficient sample size to detect trends in key metrics. In this report, we document monitoring activities for the 2011 field season and summarize the data collected between 2007 and 2011 to describe baseline conditions for the vegetation and soils of the Loamy Mesa Top Pinyon-Juniper ecological site.

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%, were less than 200 m from the center of an existing plot, required hiking times greater than 2 hours, or contained a major disturbance. We rejected a total of 34 points for the following reasons: the points deviated substantially from the ecological site, they were within 200 m of existing plot centers, they fell in close proximity to archeological sites, or they fell within 50 m of roads.

2.2 Field methods

The SCPN integrated upland crew established 10 monitoring plots in 2007 and resampled those 10 plots in 2008 and 2009. The crew established 10 additional plots in 2010, and then established 10 more plots in 2011. The 2010 and 2011 plots were each sampled only once. In all years we conducted our field work in early to mid-August.

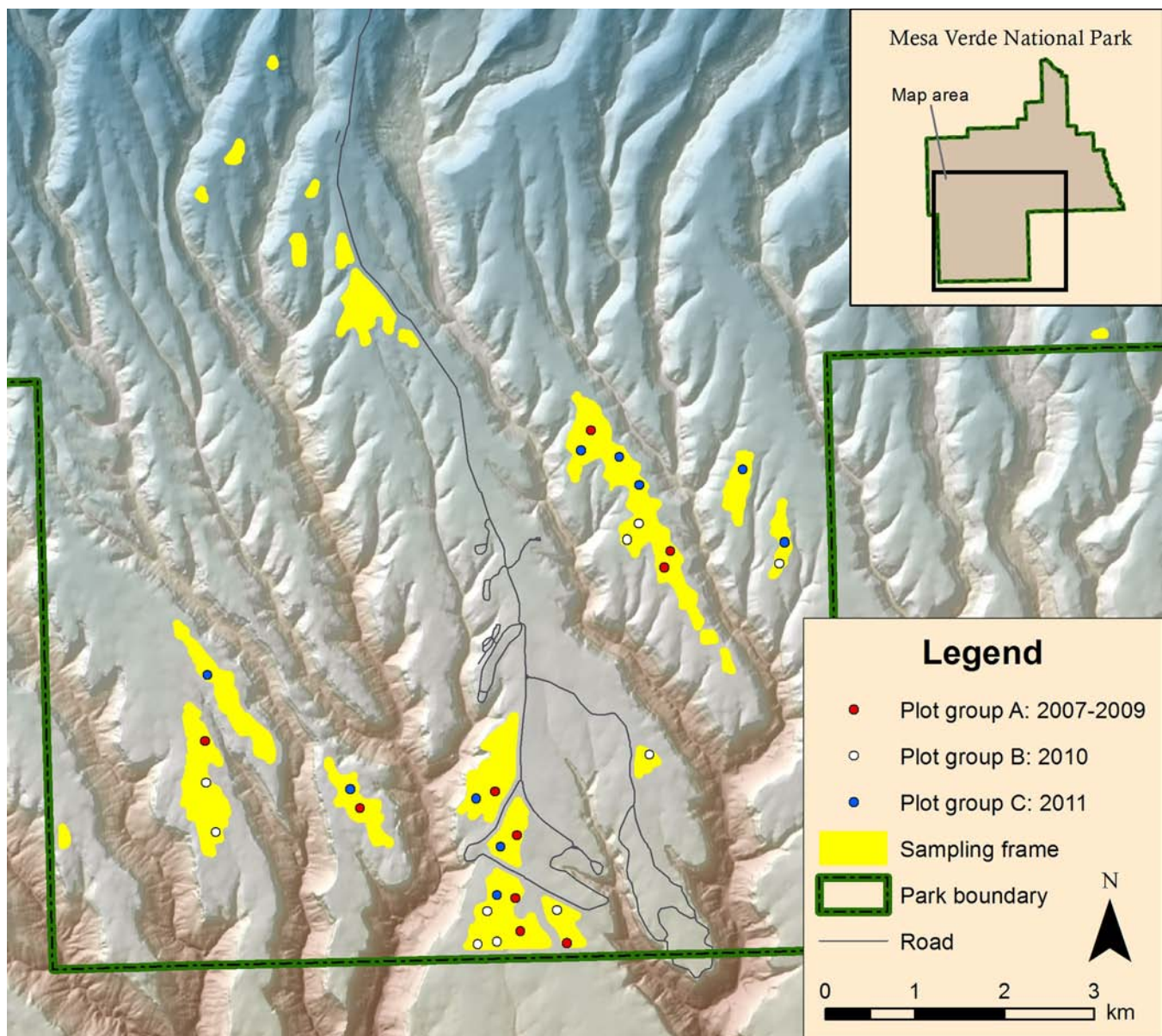


Figure 1. Sampling frame of the Loamy Mesa Top Pinyon-Juniper ecological site in MEVE, showing the 30 established plots.

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.

During plot establishment visits in 2007, 2010 and 2011, 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, cover of soil surface features, and basal gaps. In 2008 and 2009 we also refined some of our methodologies. The SCPN integrated upland monitoring protocol (DeCoster et al. 2012) incorporates the 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 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 data for the 10 plots established in 2010 and the 10 plots established in 2011.

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. We tallied saplings by size class and species in a smaller, 10 × 25 m subplot (0.025 ha), and 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 (DRC), and pinyons were measured at breast height (DBH). In 2008, we remeasured all live overstory junipers in the existing 10 plots 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 used this method for junipers in the plots established in 2010 and 2011.

In 2009 we changed the size class categories for seedlings, and began measuring 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 in 2008. These new methods were used for the plots established in 2010 and 2011.

2.2.3 Soil stability and hydrologic function

We estimated the percent cover of soil surface features in the 1 m² quadrats along the transects, and recorded the cover in 1 of 12 cover classes. We measured basal gaps as the length of bare ground 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 and 2011. We also conducted a soil aggregate stability test one time in all plots, 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 summarized data for all 30 plots as the ecological site mean. These data represent the baseline conditions for the vegetation and soils in this ecological site. We also compare the 3 plot groups to one another. It must be stressed that the differences between these 3 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 3 groups of plots as plot group A for the plots established in 2007, plot group B for the plots established in 2010, and plot group C for the plots established in 2011.

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 plot groups and for the ecological site from the plot means. For plot group A, where there were 3 years of data, we calculated the mean value and 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. Metrics with 3 years of data include species cover and frequency, functional group cover, soil surface features and basal gaps. For plot group B and plot group C, we calculated the mean and standard deviation based on a single year of data. We then calculated the ecological site means from all 30 plots, where the values for each of the 10 plots in plot group A are the average across all 3 years. Three metrics—plot frequency, ecological site richness and beta diversity—were not calculated using plot means and therefore were summarized differently. We discuss how we summarized these data below in section 2.3.1 and 2.3.2.

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%. Percent foliar cover was calculated for each plot, the 3 plot groups, and the ecological site. Mean cover and standard deviation of functional groups and surface features were calculated in a similar fashion. 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) at both the plot group and the ecological site levels. We calculated plot frequency for all 30 plots at the ecological site using a weighted mean, based on the 3 year mean value for plot group A, and the single year values for plot group B and plot group C.

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 then for the plot groups and the ecological site. For ecological site richness and beta diversity, calculations were more complicated. Plot group A values were means based on averaging across all 3 years of sampling. Plot group B and plot group C values were each based on the one year of sampling at those plots. The values for all plots combined (ecological site) were based on combining data across all 3 plot groups, using only one year of data from plot group A (the year with the median Shannon diversity value). Thus, the values for plot group B, plot group c, and the ecological site level are not means for the ecological site richness and beta diversity metrics.

2.3.3 Trees

Because we were still refining tree measurement methods between 2007 and 2009, not all tree metrics from those years are comparable to 2010 and 2011 data. In this report we compare the 2010 and the 2011 data with sapling and snag data from 2007, live overstory tree data from 2008, and seedling and canopy cover data from 2009.

Tree basal area (the total area of the tree cross-sections) for living trees and snags was calculated for each overstory tree species in terms of m²/ 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, snags, saplings,

and seedlings in terms of stems/ha. We also calculated mean percent canopy cover for trees. All metrics were calculated for each plot group, and for the 30 plots of the ecological site.

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 plot group and for the 30 plots of the ecological site.

2.3.5 Soil stability

We calculated the mean soil aggregate stability index for each plot. The index was also calculated separately for samples with vegetative cover and for samples without vegetative cover. We then calculated the mean and standard deviation for the plot groups and then for the ecological site.

3 Results

We describe results generally for the ecological site mean based on all plots, but specify whenever data comes from only one of the plot groups

3.1 Shrub and herbaceous vegetation

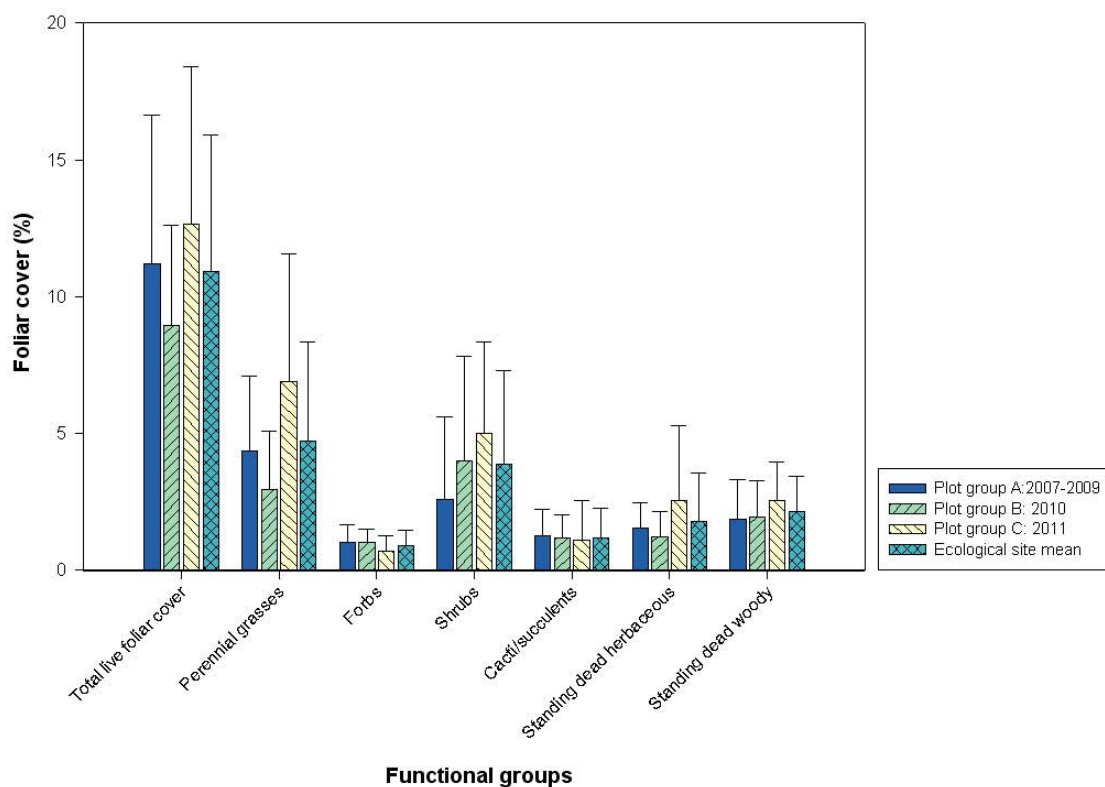
The Loamy Mesa Top Pinyon-Juniper ecological site was co-dominated by perennial grasses and shrubs. Mean foliar cover of perennial grasses was 4.73%, and mean foliar cover of shrubs was 3.86% (table 1 and fig. 2). Mean foliar covers of cacti/succulents and forbs were similar, at 1.18% and 0.90%, respectively. Mean cover of standing dead herbaceous was 1.76%, and the mean foliar cover of standing dead woody was 2.12%. (Standing dead woody only included shrubs—it did not include trees.) There were only trace amounts of annual grasses. There were differences in the functional group cover among the plot groups, but these differences were offset by moderately large standard deviations. Perennial grasses, shrubs and standing dead herbaceous had their greatest mean cover in Plot Group C.

We examine species-level data for the most abundant herbs and shrubs in Figure 3 (foliar cover) and Table 2 (foliar cover and frequency). *Poa fendleriana* (mutton grass) was the dominant perennial grass, with a mean foliar cover of 4.746%. *Purshia tridentata* was the dominant shrub, with a mean foliar cover of 2.914%. Other common shrubs included *Cercocarpus montanus* (birchleaf mountain mahogany), *Amelanchier utahensis* (Utah serviceberry) and *Quercus gambelii* (Gambel oak). *Opuntia* spp. (prickly pear) and *Yucca bacata* (banana yucca) were the dominant cacti/succulents. Common forbs included *Penstemon linarioides* (toadflax penstemon), *Petradoria pumila* (rock goldenrod), *Astragalus pattersonii* (Patterson’s milkvetch) and *Phlox hoodii* (Hood’s phlox). Some species, such as *Poa fendleriana* and *Penstemon linarioides*, showed even distributions with both high quadrat and plot frequencies. Other species showed more patchy distributions. For example, *Opuntia* spp. had a high plot frequency and a moderately low quadrat frequency, 92.50% and 44.44%, respectively. *Artemisia tridentata* had low plot and quadrat frequencies, 12.50% and 7.56%, respectively. Some species showed moderate differences in mean foliar cover among the plot groups, but the standard deviations were moderately large and the differences in frequencies tended to be small. Appendix A lists all species found in both plot groups, along with common names, families, mean foliar cover and plot frequencies by year.

Table 1. Foliar cover of functional groups for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

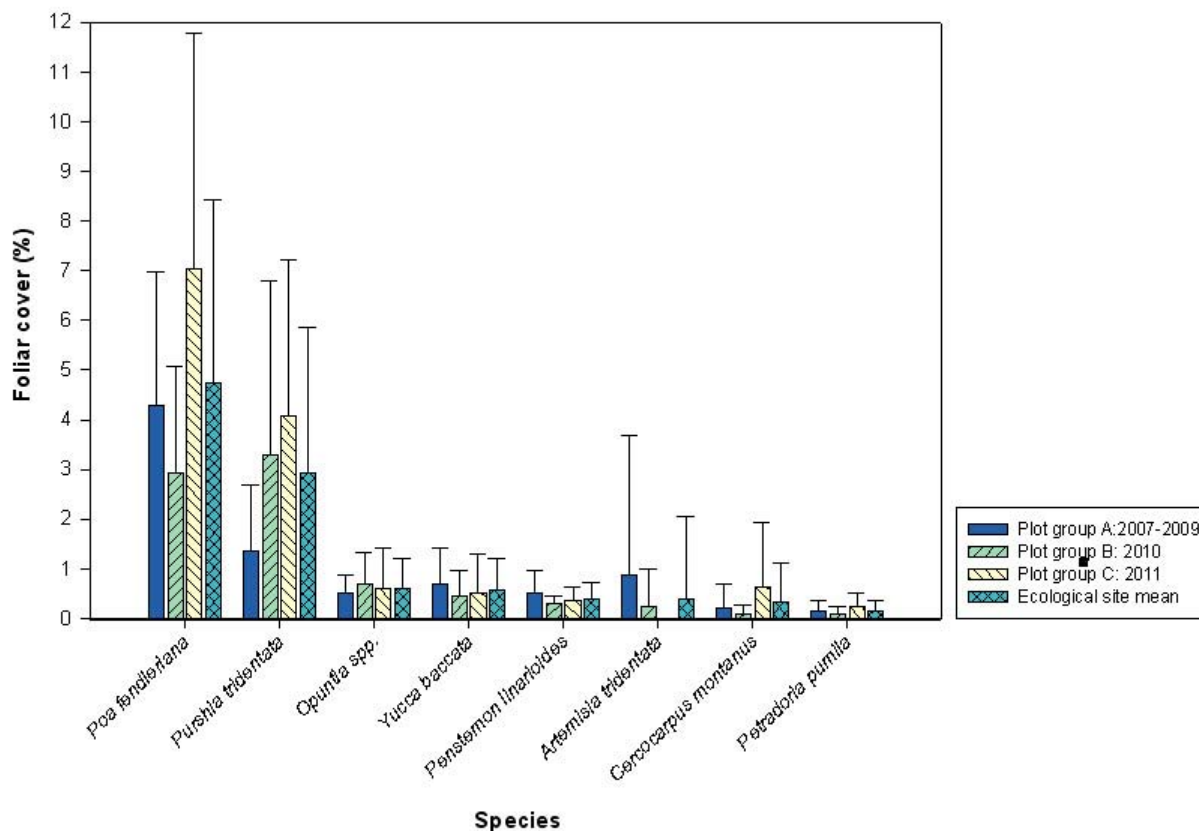
	Plot group A 2007–2009 (n = 10)		Plot group B 2010 (n = 10)		Plot group C 2011 (n = 10)		Ecological site (n = 30)	
Functional groups	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Total live foliar cover	11.22	5.41	8.95	3.68	12.65	5.76	10.94	4.99
Perennial grasses	4.36	2.75	2.95	2.14	6.89	4.66	4.73	3.60
Annual grasses	<0.01	<0.01	0	0	0	0	<0.01	<0.01
Forbs	1.02	0.63	1.00	0.49	0.69	0.55	0.90	0.55
Shrubs	2.60	2.99	4.00	3.81	4.99	3.34	3.86	3.42
Cacti/succulents	1.24	0.96	1.19	0.82	1.09	1.46	1.18	1.07
Standing dead herbaceous	1.54	0.94	1.21	0.92	2.54	2.75	1.76	1.78
Standing dead woody	1.87	1.45	1.95	1.31	2.53	1.41	2.12	1.32

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.



Functional groups

Figure 2. Mean percent foliar cover of functional groups for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Annual grasses had a mean foliar of <0.1% and were therefore not graphed. Error bars represent one standard deviation.



Species

Figure 3. Mean percent foliar cover of the 8 most abundant shrub and herbaceous species for all plots (ecological site mean), compared with the mean foliar cover for plot group A, plot group B and plot group C, in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent one standard deviation.

Table 2. Mean foliar cover and standard deviation, and mean quadrat and plot frequencies of the 15 most abundant shrub and herbaceous species and all nonnative species at the ecological site (all plots), compared with the values for plot group A, plot group B, and plot group C in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Species	Plot group A 2007–2009 (n = 10)				Plot group B 2010 (n = 10)				Plot group C 2011 (n = 10)				Ecological site mean (n = 30)			
	Foliar cover (%)	SD	Quad. freq. (%)	Plot freq. (%)	Foliar cover (%)	SD	Quad. freq. (%)	Plot freq. (%)	Foliar cover (%)	SD	Quad. freq. (%)	Plot freq. (%)	Foliar cover (%)	SD	Quad. freq. (%)	Plot freq. (%)
<i>Poa fendleriana</i>	4.280	2.692	96.44	100.00	2.916	2.152	100.00	100.00	7.043	4.747	97.33	100.00	4.746	3.667	97.93	100.00
<i>Purshia tridentata</i>	1.369	1.306	48.44	90.00	3.293	3.495	61.33	90.00	4.080	3.148	72.00	100.00	2.914	2.953	60.59	92.50
<i>Opuntia</i> spp.	0.526	0.350	50.00	90.00	0.704	0.625	44.00	100.00	0.607	0.806	39.33	90.00	0.613	0.601	44.44	92.50
<i>Yucca baccata</i>	0.697	0.722	31.56	73.33	0.460	0.496	19.33	80.00	0.517	0.782	19.33	70.00	0.558	0.651	23.41	74.17
<i>Penstemon linarioides</i>	0.513	0.461	81.33	100.00	0.315	0.141	83.33	100.00	0.364	0.274	84.67	100.00	0.397	0.315	83.11	100.00
<i>Artemisia tridentata</i>	0.888	2.808	10.00	10.00	0.245	0.748	12.00	20.00	<0.001	0.001	0.67	10.00	0.378	1.663	7.56	12.50
<i>Cercocarpus montanus</i>	0.209	0.468	10.22	30.00	0.103	0.180	5.33	40.00	0.638	1.289	15.33	30.00	0.317	0.805	10.30	32.50
<i>Petradoria pumila</i>	0.143	0.204	16.67	50.00	0.096	0.147	18.00	60.00	0.226	0.284	30.67	80.00	0.155	0.213	21.78	60.00
<i>Amelanchier utahensis</i>	0.009	0.029	0.67	10.00	0.134	0.423	1.33	10.00	0.184	0.305	5.33	30.00	0.109	0.300	2.44	15.00
<i>Quercus gambelii</i>	0.008	0.026	0.67	10.00	0.002	0.006	1.33	20.00	0.259	0.637	4.00	30.00	0.090	0.376	2.00	17.50
<i>Astragalus pattersonii</i>	0	0	0	0	0.262	0.510	25.33	60.00	0	0	0	0	0.087	0.310	8.44	15.00
<i>Phlox hoodii</i>	0.032	0.058	13.11	40.00	0.142	0.183	46.00	70.00	0.076	0.128	29.33	50.00	0.083	0.136	29.48	50.00
<i>Chrysothamnus depressus</i>	0.091	0.271	10.00	36.67	0.081	0.096	20.00	60.00	0.020	0.036	8.00	40.00	0.064	0.164	12.67	43.33
<i>Cordylanthus wrightii</i>	0.056	0.068	35.56	86.67	0.107	0.123	54.67	80.00	0.011	0.030	9.33	50.00	0.058	0.088	33.19	75.83
<i>Lupinus ammophilus</i>	0.066	0.094	19.33	63.33	0.065	0.088	27.33	60.00	0.008	0.016	6.00	40.00	0.046	0.077	17.33	56.67
<i>Ceratocephala testiculata</i> ^a	0.002	0.005	4.22	20.00	0.001	0.002	1.33	10.00	0.001	0.003	2.67	20.00	0.001	0.003	2.67	17.50
<i>Sisymbrium altissimum</i> ^a	0.003	0.008	4.89	16.67	0	0	0	0	0	0	0	0	0.001	0.005	1.63	8.33
<i>Bromus tectorum</i> ^a	0.003	0.005	3.56	33.33	0	0	0	0	0	0	0	0	0.001	0.003	1.19	16.67
<i>Descurainia sophia</i> ^a	0.003	0.005	3.56	13.33	0	0	0	0	0	0	0	0	0.001	0.003	1.19	6.67
<i>Carduus nutans</i> ^a	0.001	0.001	1.56	23.33	<0.001	0.001	0.67	10.00	0.001	0.003	2.00	10.00	0.001	0.002	1.41	16.67
<i>Portulaca oleracea</i> ^a	0	0	0	0	0.001	0.001	1.33	20.00	0	0	0	0	<0.001	0.001	0.44	5.00
<i>Taraxacum officinale</i> ^a	<0.001	<0.001	0.44	6.67	0	0	0	0	0	0	0	0	<0.001	<0.001	0.15	3.33
<i>Tragopogon dubius</i> ^a	<0.001	0.001	0.44	6.67	0	0	0	0	0	0	0	0	<0.001	<0.001	0.15	3.33
<i>Erodium cicutarium</i> ^a	<0.001	<0.001	0.22	3.33	0	0	0	0	0	0	0	0	<0.001	<0.001	0.07	1.67

Note: Species are arranged in descending order by their mean foliar cover for the ecological site.

^aNonnative species.

Nine nonnative species were found in the plots. All had low foliar cover (0.003% or less). Three species had plot frequencies greater than 10%. Six of these species were unique to plot group A. Three species were found in plot group B, one of which was unique to that plot group. Two nonnative species were found in plot group C.

Species diversity was moderately low on the scale of the plot, and moderately high on the scale of the ecological site (table 3). On the scale of the plot, species richness was 17.6. Shannon diversity (which takes the relative abundance of each species into account, and generally ranges between 1.5 and 3.5) was only 1.435. Evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) was 0.502. On the scale of the ecological site, species richness was 71, and beta diversity (a measure of within-ecological site heterogeneity, generally ranging between 1 and 5) was 4.303. The differences in the metrics among plot groups were nominal, but the fact that ecological site richness and beta diversity were substantially larger for the ecological site mean resulted from the many unique species in each plot group and substantial differences in species composition among the plots. When we calculated the metrics using only native species, evenness increased slightly and all the other metrics decreased slightly.

Table 3. Species diversity metrics for all species and for native species only for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

	Plot group A 2007–2009 (n = 10)		Plot group B 2010 (n = 10)		Plot group C 2011 (n = 10)		Ecological site (n = 30)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All species								
Plot								
Plot richness	18.4	4.5	18.0	2.9	16.5	4.1	17.6	3.8
Shannon diversity	1.429	0.283	1.619	0.350	1.256	0.310	1.435	0.334
Evenness	0.495	0.088	0.562	0.115	0.449	0.087	0.502	0.103
Ecological site								
Ecological site richness ^a	50.3		44		49		71	
Beta diversity ^a	2.891		2.588		3.161		4.303	
Native species								
Plot								
Plot richness	17.2	4.4	17.6	2.7	16.2	3.882	17.0	3.6
Shannon diversity	1.417	0.277	1.618	0.350	1.255	0.309	1.430	0.332
Evenness	0.503	0.090	0.566	0.114	0.452	0.089	0.507	0.103
Ecological site								
Ecological site richness ^a	45.3		41		47		65	
Beta diversity ^a	2.805		2.470		3.092		4.054	

^aEcological site richness and beta diversity values are not means, except for the plot group A values which were derived from averaging across all 3 years.

3.2 Trees

The tree overstory was comprised of 2 species: *Juniperus osteosperma* (Utah juniper) and *Pinus edulis* (twoneedle pinyon). *Juniperus osteosperma* was the dominant species, with an overstory basal area of 29.54 m²/ha, and a living overstory density of 323.3 stems/ha (table 4 and fig. 4). In contrast, the basal area and overstory density of *Pinus edulis* were much lower: 1.56 m²/ha and 48.3 stems/ha, respectively. Snag densities of the 2 species were

more comparable: 61.0 stems/ha for *Juniperus osteosperma* and 40.7 stems/ha for *Pinus edulis*. The basal area of snags was much greater for *Juniperus osteosperma*, however, at 5.81 m²/ha, compared with 1.57 m²/ha for *Pinus edulis*. All individuals of *Pinus edulis* were smaller than 35 cm DBH (fig. 5). Their mean diameter was 30.0 cm. In contrast, *Juniperus osteosperma* had individuals exceeding 85 cm DRC. Its size class distribution had the highest density in the smallest size class, and decreasing density with size.

Sapling and seedling densities provide measures of forest regeneration, and indicate the potential for change in species composition. In contrast to the overstory, sapling density was higher for *Pinus edulis*, at 480.0 stems/ha, than for *Juniperus osteosperma*, at 262.7 stems/ha. For all plot groups, the size class distribution of saplings was fairly even for *Juniperus osteosperma*, and the standard deviations were moderately low (fig. 6). In contrast, for *Pinus edulis*, the plot groups showed large differences in sapling size class distributions, and the standard deviations were moderately large. The largest size class had the lowest density.

The seedling data showed a similar pattern as the sapling data. *Pinus edulis* had higher densities than *Juniperus osteosperma*, at 1762.3 stems/ha 884.4 stem/ha, respectively (fig. 7). *Juniperus osteosperma* showed a fairly even distribution, with moderately small standard deviation, and moderately small differences among the plot groups.

Table 4. Mean density, mean basal area, and mean diameter of trees for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

	Species	Plot group A 2007–2009 ^a (n = 10)	Plot group B 2010 (n = 10)	Plot group C 2011 (n = 10)	Ecological site (n = 30)
Seedling ^b density (stems/ha)	<i>Juniperus osteosperma</i>	686.7	860.0	1106.7	884.4
	<i>Pinus edulis</i>	1540.0	1373.3	2373.3	1762.2
	All species	2226.7	2233.3	3480.0	2646.6
Sapling ^b density (stems/ha)	<i>Juniperus osteosperma</i>	280.0	220.0	288.0	262.7
	<i>Pinus edulis</i>	316.0	456.0	668.0	480.0
	All species	596.0	676.0	956.0	742.7
Overstory ^b density (stems/ha)	<i>Juniperus osteosperma</i>	278.0	365.0	327.0	323.3
	<i>Pinus edulis</i>	42.0	59.0	44.0	48.3
	All species	320.0	424.0	371.0	371.6
Snag ^b density (stems/ha)	<i>Juniperus osteosperma</i>	60.0	56.0	67.0	61.0
	<i>Pinus edulis</i>	47.0	34.0	41.0	40.7
	All species	107.0	90.0	108.0	101.7
Overstory basal area (m ² /ha)	<i>Juniperus osteosperma</i>	27.27	33.28	28.06	29.54
	<i>Pinus edulis</i>	1.23	1.92	1.53	1.56
	All species	28.50	35.20	29.59	31.10
Snag basal area (m ² /ha)	<i>Juniperus osteosperma</i>	4.42	6.37	6.64	5.81
	<i>Pinus edulis</i>	1.72	1.34	1.66	1.57
	All species	6.14	7.71	8.30	7.38
Mean overstory diameter (cm) ^c	<i>Juniperus osteosperma</i>	32.1	31.1	31.2	31.5
	<i>Pinus edulis</i>	18.5	20.1	20.3	19.7
	All species	30.5	29.5	30.0	30.0

Note: Values in the “All species” rows represent both *Juniperus osteosperma* and *Pinus edulis*, combined. “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.

^aFor plot group A, data from 2007 were used for sapling density, snag density and snag basal area; data from 2008 were used for living overstory density, living overstory basal area and mean living overstory diameter; data from 2009 were used for seedling density.

^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*.

Pinus edulis seedlings had moderately large standard deviations, and moderately large differences among the plot groups (with the highest density in the intermediate size class).

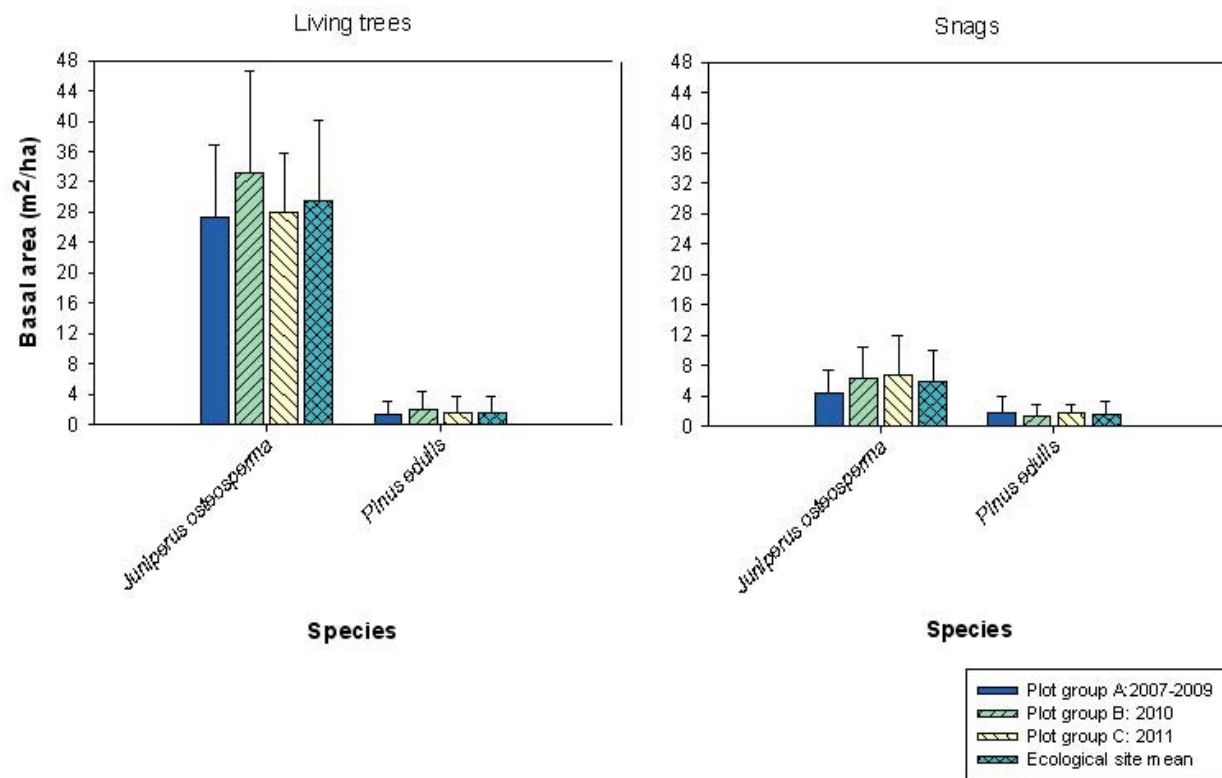


Figure 4. Mean basal area for living trees and snags, by species, for plot group A, plot group B, plot group C and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Living trees were measured in 2008 and snags were measured in 2007. Error bars represent 1 standard deviation.

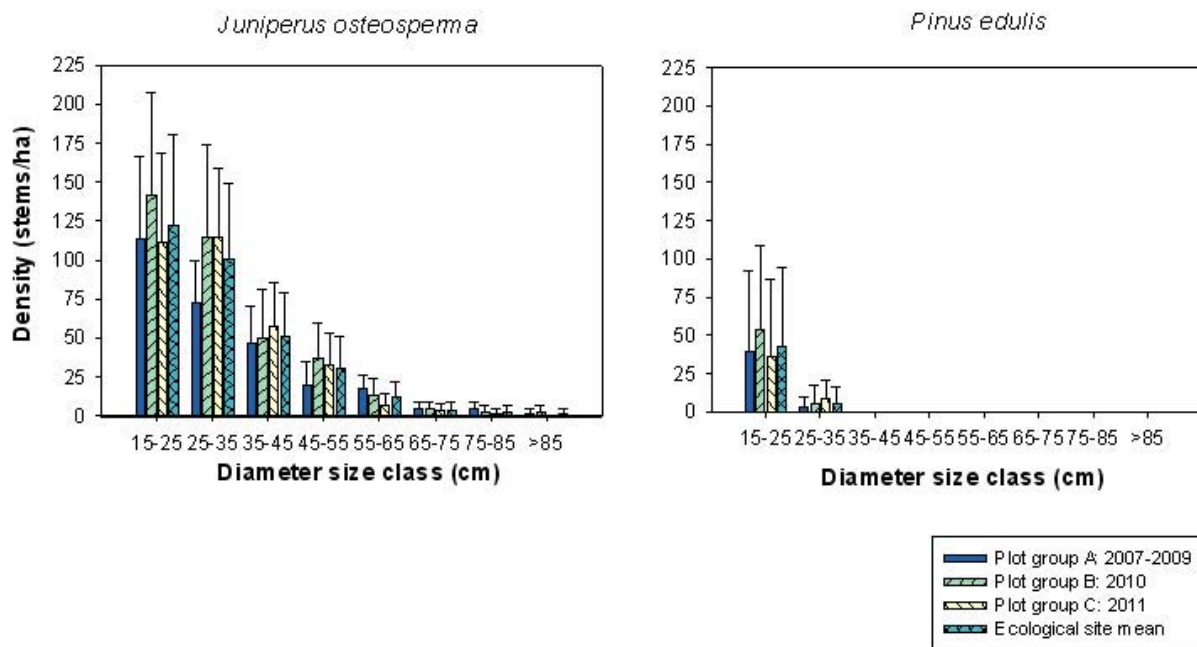


Figure 5. Size structure of living overstory tree species for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent 1 standard deviation.

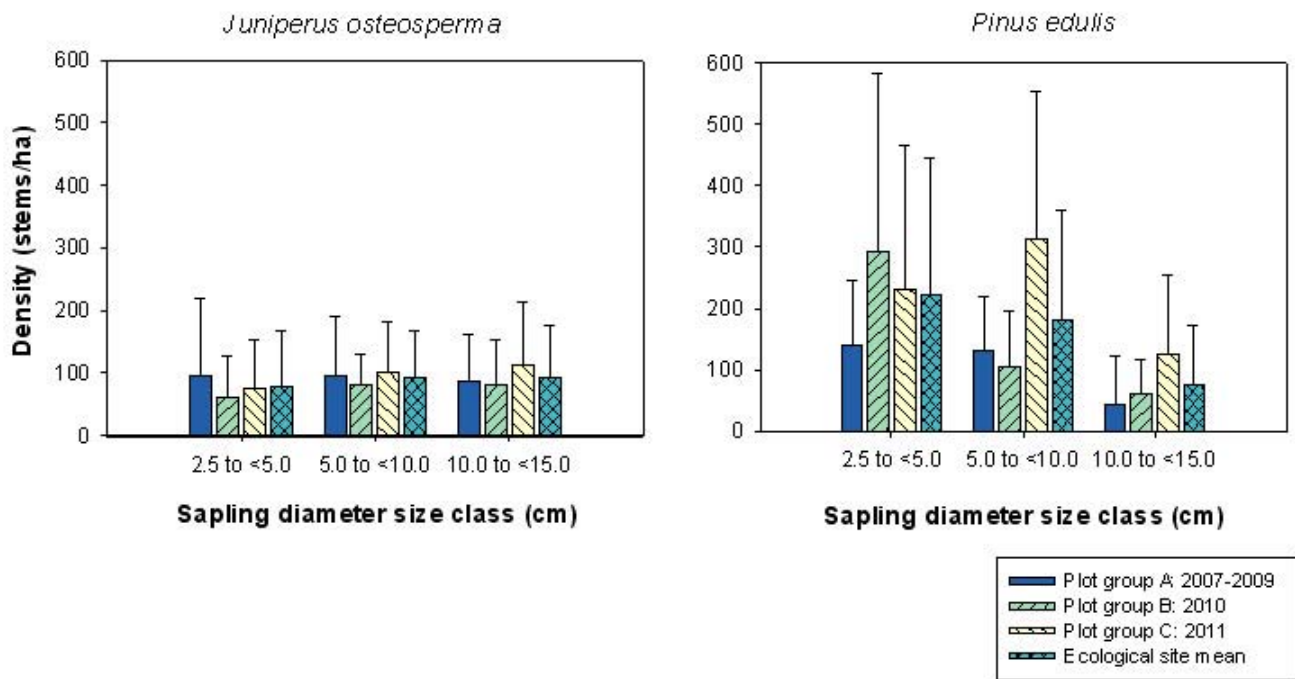


Figure 6. Mean density of saplings in different diameter size classes, by species, for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent 1 standard deviation.

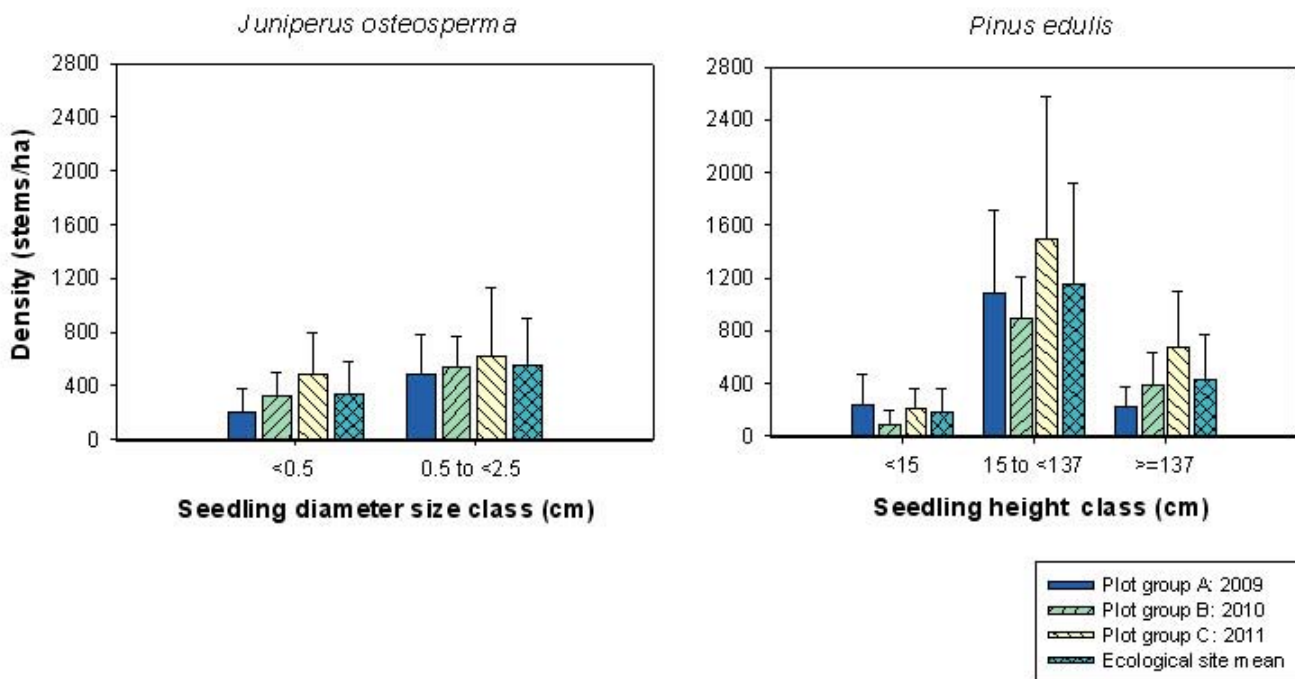


Figure 7. Mean density of seedlings in different size classes, by species, for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent 1 standard deviation. Seedling diameter for *Juniperus osteosperma* is measured at root crown.

Combining living overstory trees and saplings across all species, the size class distribution showed a typical inverse relationship, where density decreased with increasing size (fig. 8). The standard deviations were large, particularly for the sapling size classes. The plot groups showed moderate differences, particularly in the smaller size classes. Mean canopy cover was 34.1% for the ecological site (fig. 9). The standard deviations for canopy cover were moderate, and the differences among plot groups were small.

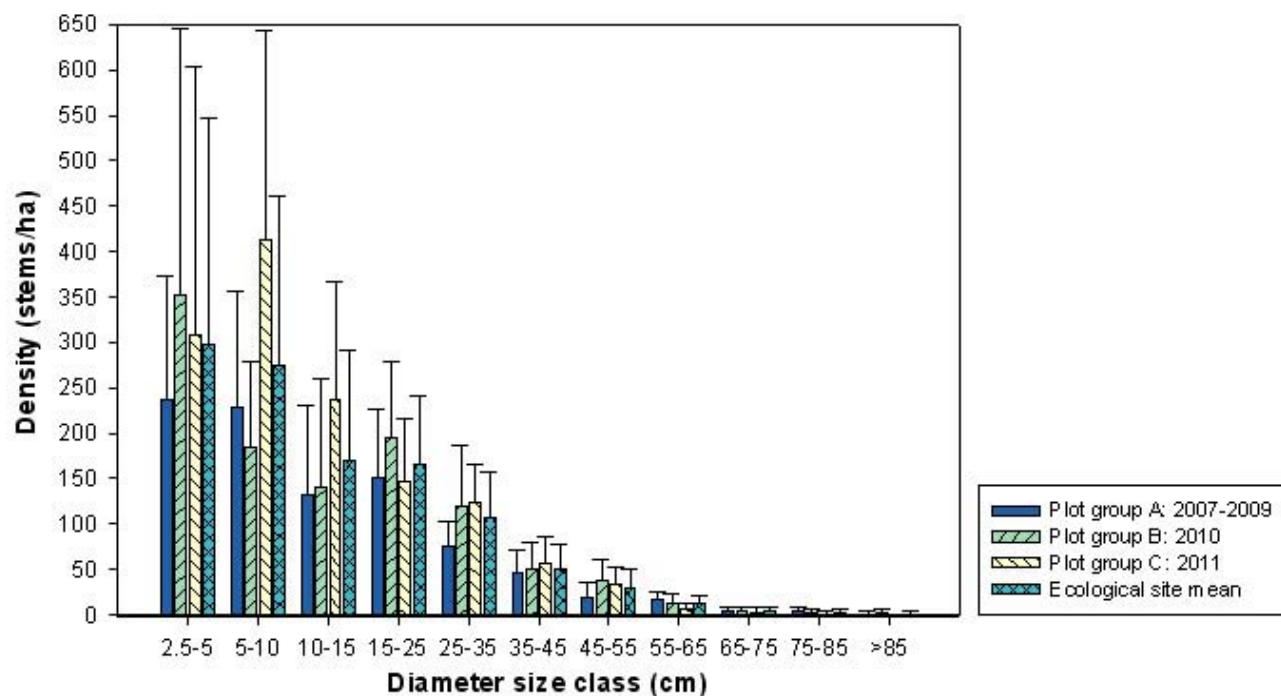


Figure 8. Size structure of all living overstory trees and saplings for plot group A, plot group B, plot group C and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent 1 standard deviation.

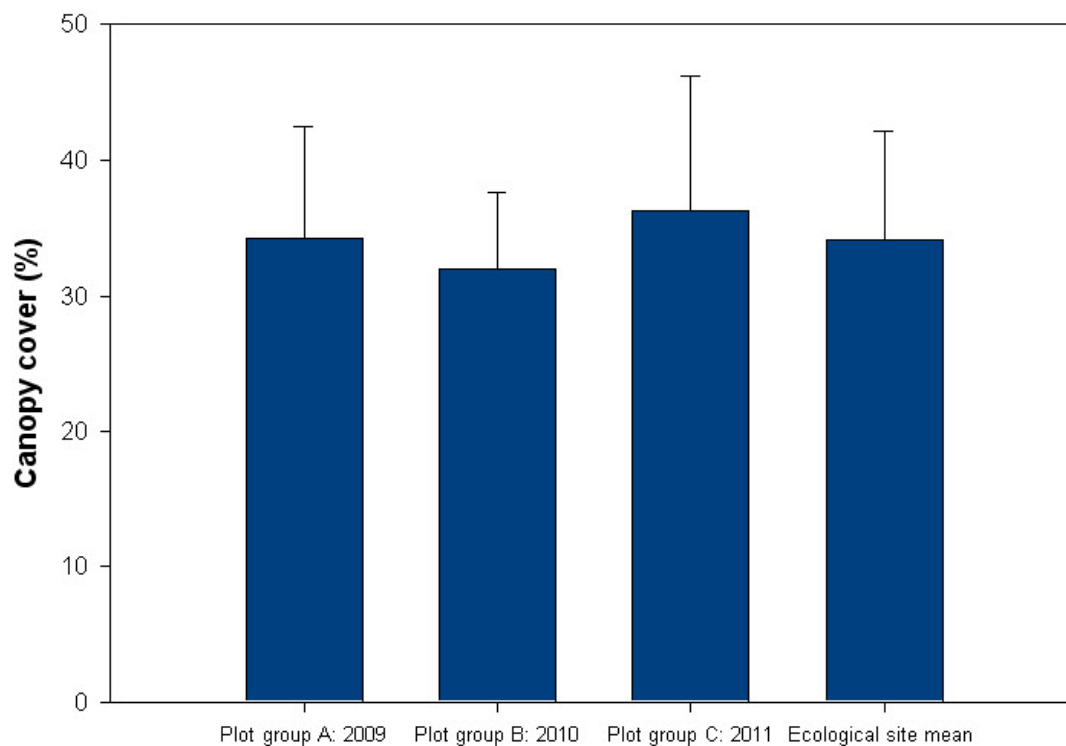


Figure 9. Mean percent canopy cover for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Canopy cover was measure only once for plot group A in 2009. Error bars indicate 1 standard deviation.

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 dominated the soil surface, with a mean cover of 59.42% (table 5 and fig. 10). Undifferentiated crust and cyanobacteria were also important, with mean covers of 13.23% and 11.91%, respectively. Mean cover of cyanobacteria appears much higher in 2010 and undifferentiated crust much lower, but this is likely a result of

Table 5. Cover of soil surface features for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Soil surface feature	Plot group A 2007–2009 (n = 10)		Plot group B 2010 (n = 10)		Plot group C 2011 (n = 10)		Ecological site (n = 30)	
	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Live plant base	3.20	1.70	1.29	0.53	2.19	0.98	2.23	1.31
Dead woody base	0.59	0.93	0.84	1.81	0.50	0.63	0.64	1.14
Dead herbaceous base	0.43	0.25	0.58	0.28	0.57	0.46	0.53	0.34
Bare soil	2.47	2.16	1.92	1.85	5.55	5.86	3.31	3.89
Duff/litter	58.51	10.19	55.44	12.78	64.31	12.35	59.42	11.89
Undifferentiated crust	22.03	11.45	6.61	11.96	11.05	7.50	13.23	11.66
Moss	1.43	1.30	0.73	0.98	3.25	3.10	1.81	2.21
Lichen	0.15	0.23	0.04	0.09	0.06	0.09	0.08	0.13
Cyanobacteria ^a	5.21	4.46	26.60	15.44	3.92	5.93	11.91	14.21
Fine gravel (0.2 to <2 cm)	0.01	0.02	0.01	0.02	0.14	0.20	0.06	0.13
Coarse gravel (2 to <7.5 cm)	0.06	0.10	0.06	0.09	0.13	0.13	0.08	0.11
Cobble (7.5 to <25 cm)	0.06	0.16	0.09	0.14	0.13	0.20	0.09	0.16
Stone, bedrock (≥25 cm)	0.04	0.11	0.11	0.34	0.37	0.62	0.17	0.42
Woody debris	1.76	0.89	2.82	2.01	3.68	2.61	2.75	2.06

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.

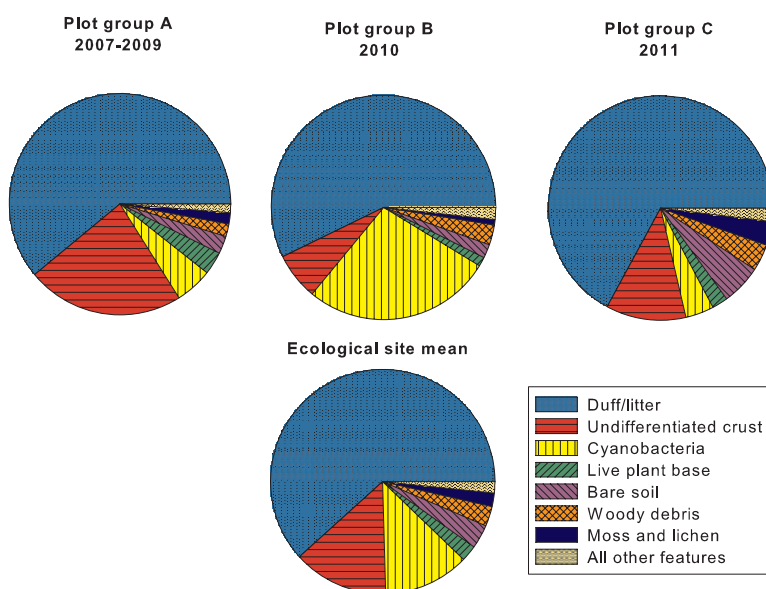


Figure 10. Mean percent cover of soil surface features for plot group A, plot group B, plot group C and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

differences in classification by the crew that year. All other surface features had mean covers of less than 4%. There were only moderate differences in soil surface feature cover among the plot groups.

The basal gap data showed that the soil surface was dominated by basal gaps in the largest size class, indicating large areas of bare ground. Basal gaps greater than 100 cm comprised 81.7% of the transects (table 6 and fig. 11). Basal gaps between 50 and 100 cm comprised 9.4% of the transects. The 2 smallest basal gap size classes and plant bases each comprised less than 5% of the transects. The median gap size was 108.2 cm. The differences in the basal gap metrics among the plot groups were generally small.

Table 6. Number of basal gaps, median gap size, and percentage of transect in different gap size classes for plot group A, plot group B, plot group C and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Metric	Plot group A 2008–2009 ^a (n = 10)		Plot group B 2010 (n = 10)		Plot group C 2011 (n = 10)		Ecological site (n = 30)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of gaps	109.1	48.3	87.7	38.8	97.5	46.7	98.1	44.02
Median gap size (cm)	88.9	48.7	118.0	61.8	117.7	74.8	108.2	61.3
Percentage of transect in gaps	96.7	1.7	97.1	1.4	96.4	2.2	96.7	1.7
Percentage of transect in gaps 0 to <20 cm	1.5	1.1	0.9	0.6	1.3	0.8	1.2	0.9
Percentage of transect in gaps 20 to <50 cm	5.1	3.2	3.9	2.2	4.2	2.9	4.4	2.7
Percentage of transect in gaps 50 to <100 cm	10.8	6.2	8.2	4.7	9.4	6.5	9.4	5.6
Percentage of transect in gaps ≥100 cm	79.3	11.3	84.2	8.7	81.5	11.8	81.7	10.5
Percentage of transect in plant bases	3.3	1.7	2.9	1.4	3.6	2.2	3.3	1.7

^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.

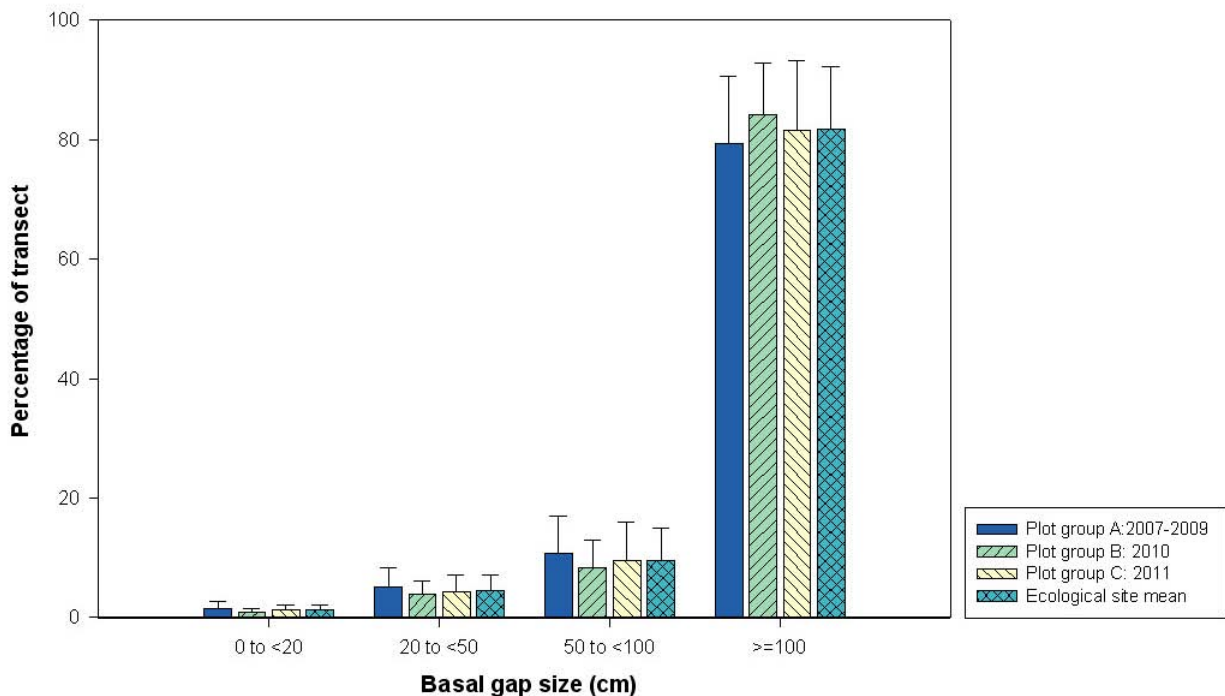


Figure 11. Mean percentage of transect by gap size class for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. Error bars represent 1 standard deviation. Data from 2007 were not included in plot group A for this metric.

The mean soil stability rating for the ecological site was 4.61, which is moderately high (table 7). Ratings range from 1 to 6, with 1 representing low stability and 6 representing high stability. Stability was higher for samples collected under vegetation. There were only small differences in the soil stability ratings among the plot groups.

Table 7. Soil stability rating for all samples, and for samples with and without vegetative cover, for plot group A, plot group B, plot group C, and all plots (ecological site mean) in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

	Plot group A 2007 (n = 10)		Plot group B 2010 (n = 10)		Plot group C 2011 (n = 10)		Ecological site (n = 30)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All samples	4.43	0.71	4.62	0.52	4.78	0.40	4.61	0.56
Samples under vegetative cover	4.51	0.75	4.90	0.53	5.05	0.33	4.82	0.59
Samples not under vegetative cover	4.27	0.94	4.02	0.71	4.18	0.77	4.16	0.79

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 (2013). Figure 12 shows the total monthly precipitation for each of the 5 years of monitoring described in this report, compared with the long term average precipitation by month for the period 1948–2011.

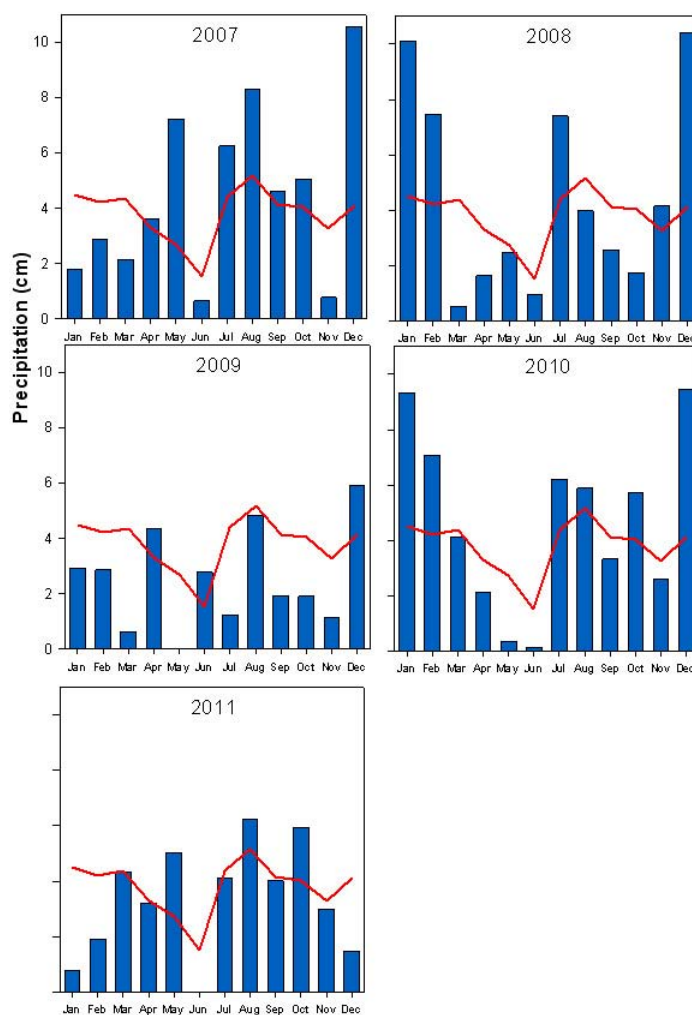


Figure 12. Total monthly precipitation for the 5 years of sampling. The red line represents the long-term mean monthly precipitation for the Mesa Verde NP (5531) CO weather station for the period 1948 through 2011, collected by the Western Regional Climate Center.

4 Discussion

The data summarized in this report represent baseline conditions for monitoring vegetation and soils in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

The vegetation represents an example of an intact old-growth pinyon-juniper woodland. The tree canopy was dominated by *Juniperus osteosperma* with a small component of *Pinus edulis*. The sapling and seedling layers had a much larger representation of *Pinus edulis*. The herbaceous/shrub vegetation was co-dominated by perennial grasses, such as *Poa fendleriana*, and shrubs, such as *Purshia tridentata* and *Cercocarpus montanus*. Cacti/succulents and forbs were less abundant. Common cacti/succulents included *Opuntia* spp. and *Yucca bacata*. Common forbs included *Penstemon linarioides* and *Petradoria pumila*. Nine nonnative species occurred in the plots, although all of them occurred with low foliar covers and frequencies. Species diversity was moderately low on the scale of the plot, but moderately high on the scale of the landscape.

The soils data indicated that there is not a large potential for erosion. While the basal gap data showed that there were large distances between plant bases, the majority of the area was mostly composed of duff and litter. Moreover, the cover of well-developed biological crusts was relatively large compared to other pinyon-juniper woodlands we monitor in the Southern Colorado Plateau. The soil stability ratings were also quite high, partially due to the high cover of biological crusts and the large areas of thick litter and duff (which receive the highest stability rating).

The different plot groups demonstrated variability in species composition and structure, and in soil characteristics. We would expect such differences as a result of random spatial variation, especially for sample sizes of only 10 plots. The plot groups represented different plots in different locations. Due to endogenous factors such as soils and topography, and exogenous factors such as climate and disturbance, species composition and soil characteristics naturally vary. Spatial variability accounts for the majority of the differences among the plot groups, but additional variation may result from annual climatic variation, particularly for the herbaceous/shrub layer. Variation in precipitation has been associated with changes in cover and frequency of herbaceous plants, particularly for annual species and forbs. Many of the nonnative species are annuals, so their presence or absence in a given year may be associated with the amount of rainfall in the weeks prior to sampling. Two of the plot groups were sampled only once, making their species composition more influenced by that year's precipitation regime than the plot group with 3 years of data.

Precipitation records for MEVE gathered by the Western Regional Climate Center show variation in precipitation regimes during the 5 years of sampling. In particular, 2009 had below average precipitation for all but 2 months, and 3 of the years—2007, 2009 and 2011—had low precipitation in January and February, which may have influenced species composition and abundance. Given that the herbaceous/shrub data from 2009 data was averaged in with the 2007 and 2008 data, however, the variation attributable to climatic factors was probably small.

Now that we have completed our baseline monitoring for this ecological site, we will begin to implement the revisit design. Our power analysis indicates that a sample size of 30 plots should provide a large enough sample size to detect trends in key metrics.

We will implement the revisit design using a panel design. Panel designs describe the temporal plan for revisiting monitoring plots through time. Between the extremes of monitoring the same set of plots with each re-visit, and monitoring a new set of sites with each revisit, there are designs that provide some balance between repeated visit to individual plots and the total number of sites visited. Our general revisit design is a connected design in both spatial and temporal aspects that balances the allocation of effort between addressing temporal (year to year) variability and spatial variability within the ecological site. We will split the 30 plots into 3 panels, and sample 2 of the panels every other year (table 8).

Table 8. Panel design for the revisit design at MEVE. "X" represents 10 plots, for a total of 30 plots across 3 panels for the ecological site.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	X				X		X				X	
2	X		X				X		X			
3			X		X				X		X	
Sum/yr	2X	0	2X	0	2X	0	2X	0	2X	0	2X	0

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, plot group B, plot group C, and all plots in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Species	Common name	Family	Plot group A 2007–2009		Plot group B 2010		Plot group C 2011		All plots	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Achnatherum hymenoides</i>	Indian ricegrass	Poaceae	0.014	16.67	0.002	20.00	0.001	20.00	0.006	18.33
<i>Amelanchier utahensis</i>	Utah serviceberry	Rosaceae	0.009	10.00	0.134	10.00	0.184	30.00	0.109	15.00
<i>Androsace septentrionalis</i>	pygmy rock jasmine	Primulaceae	<0.001	3.33	<0.001	10.00	0	0	<0.001	4.17
<i>Antennaria parvifolia</i>	small leaf pussytoes	Asteraceae	<0.001	10.00	0.002	10.00	0	0	0.001	7.50
<i>Artemisia bigelovii</i>	Bigelow sage	Asteraceae	0	0	0.105	50.00	0.004	10.00	0.036	15.00
<i>Artemisia tridentata</i>	basin big sagebrush	Asteraceae	0.888	10.00	0.245	20.00	<0.001	10.00	0.378	12.50
<i>Astragalus</i> spp.	milkvetch	Fabaceae	0.031	70.00	0.014	60.00	0.007	60.00	0.017	65.00
<i>Astragalus pattersonii</i>	Patterson's milkvetch	Fabaceae	0	0	0.262	60.00	0	0	0.087	15.00
<i>Boechea</i> sp.	rockress	Brassicaceae	0.032	73.33	0.013	50.00	0.005	80.00	0.017	69.17
<i>Boechea holboellii</i>	Holboell's rockress	Brassicaceae	<0.001	6.67	0	0	0	0	<0.001	3.33
<i>Bromus tectorum</i> ^a	cheatgrass	Poaceae	0.003	33.33	0	0	0	0	0.001	16.67
<i>Calochortus</i> sp.	mariposa lily	Liliaceae	0.001	6.67	0.002	50.00	0	0	0.001	15.83
<i>Carduus nutans</i> ^a	nodding thistle	Asteraceae	0.001	23.33	<0.001	10.00	0.001	10.00	0.001	16.67
<i>Carex rossii</i>	Ross' sedge	Cyperaceae	<0.001	3.33	0	0	0.006	30.00	0.002	9.17
<i>Ceratocephala testiculata</i> ^a	curveseed butterwort	Ranunculaceae	0.002	20.00	0.001	10.00	0.001	20.00	0.001	17.50
<i>Cercocarpus montanus</i>	birchleaf mountain mahogany	Rosaceae	0.209	30.00	0.103	40.00	0.638	30.00	0.317	32.50
<i>Chaenactis douglasii</i>	Douglas dustymaiden	Asteraceae	0	0	0.001	20.00	<0.001	10.00	<0.001	7.50
<i>Chenopodium</i> spp.	goosefoot	Chenopodiaceae	0.004	40.00	0.007	70.00	0.001	20.00	0.004	42.50
<i>Chrysothamnus depressus</i>	longflower rabbitbrush	Asteraceae	0.091	36.67	0.081	60.00	0.020	40.00	0.064	43.33
<i>Comandra umbellata</i>	bastard toadflax	Santalaceae	0.028	26.67	0.001	10.00	0.002	20.00	0.010	20.83
<i>Cordylanthus wrightii</i>	Wright's bird's beak	Scrophulariaceae	0.056	86.67	0.107	80.00	0.011	50.00	0.058	75.83
<i>Cryptantha</i> spp.	cryptantha	Boraginaceae	<0.001	3.33	0.003	10.00	0.003	10.00	0.002	6.67
<i>Delphinium scaposum</i>	barestem larkspur	Ranunculaceae	<0.001	3.33	0	0	0	0	<0.001	1.67
<i>Descurainia sophia</i> ^a	herb sophia	Brassicaceae	0.003	13.33	0	0	0	0	0.001	6.67
<i>Draba reptans</i>	Carolina draba	Brassicaceae	0.006	23.33	0	0	0.001	10.00	0.002	14.17

Table A1 (continued)

Species	Common name	Family	Plot group A 2007–2009		Plot group B 2010		Plot group C 2011		All plots	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Echinocereus</i> sp.	hedgehog cactus	Cactaceae	<0.001	3.33	0	0	0	0	<0.001	1.67
<i>Elymus elymoides</i>	squirreltail	Poaceae	0.017	43.33	0.018	50.00	0.063	40.00	0.033	44.17
<i>Erigeron divergens</i>	spreading fleabane	Asteraceae	0.006	20.00	0	0	0	0	0.002	10.00
<i>Eriogonum alatum</i>	winged buckwheat	Polygonaceae	0	0	0.009	20.00	0	0	0.003	5.00
<i>Eriogonum jamesii</i>	James' buckwheat	Polygonaceae	0	0	0	0	0.007	10.00	0.002	2.50
<i>Eriogonum racemosum</i>	redroot buckwheat	Polygonaceae	0.039	80.00	0.029	30.00	0.011	20.00	0.026	52.50
<i>Eriogonum umbellatum</i>	sulphur-flowered buckwheat	Polygonaceae	0.005	26.67	0.017	60.00	0.012	30.00	0.011	35.83
<i>Erodium cicutarium</i> ^a	stork's bill	Geraniaceae	<0.001	3.33	0	0	0	0	<0.001	1.67
<i>Erysimum capitatum</i>	sandlune wallflower	Brassicaceae	0	0	0.007	10.00	0	0	0.002	2.50
<i>Escobaria vivipara</i>	spiny star	Cactaceae	<0.001	10.00	0	0	0	0	<0.001	5.00
<i>Gutierrezia sarothrae</i>	broom snakeweed	Asteraceae	0.020	16.67	0.031	10.00	0	0	0.017	10.83
<i>Hesperidanthus linearifolius</i>	slimleaf plains mustard	Brassicaceae	0	0	0	0	0.002	10.00	0.001	2.50
<i>Hesperostipa comata</i>	needle and thread	Poaceae	0.037	6.67	0	0	0	0	0.012	3.33
<i>Heterotheca villosa</i>	hairy false goldenaster	Asteraceae	0.002	13.33	0	0	<0.001	10.00	0.001	9.17
<i>Hymenopappus filifolius</i>	fineleaf hymenopappus	Asteraceae	0	0	0	0	0.002	10.00	0.001	2.50
<i>Ipomopsis aggregata</i>	scarlet gilia	Polemoniaceae	<0.001	3.33	0	0	0	0	<0.001	1.67
<i>Koeleria macrantha</i>	prairie junegrass	Poaceae	0.011	30.00	0.002	10.00	0.018	20.00	0.010	22.50
<i>Lappula occidentalis</i>	flatspine stickseed	Boraginaceae	<0.001	3.33	0	0	0	0	<0.001	1.67
<i>Lepidium latifolium</i>	broad-leaved pepperweed	Brassicaceae	<0.001	3.33	0.002	10.00	0	0	0.001	4.17
<i>Lesquerella rectipes</i>	straight bladderpod	Brassicaceae	0.007	20.00	0.019	30.00	0.015	40.00	0.014	27.50
<i>Lithospermum incisum</i>	narrowleaf gromwell	Boraginaceae	0	0	0.001	10.00	0	0	<0.001	2.50
<i>Lupinus ammophilus</i>	sand lupine	Fabaceae	0.066	63.33	0.065	60.00	0.008	40.00	0.046	56.67
<i>Lupinus caudatus</i>	tailcup lupine	Fabaceae	0.002	20.00	0.019	30.00	0	0	0.007	17.50
<i>Machaeranthera bigelovii</i>	Bigelow's tansy-aster	Asteraceae	0	0	0	0	0.001	20.00	<0.001	5.00
<i>Machaeranthera canescens</i>	hoary tansyaster	Asteraceae	0.012	73.33	0.004	30.00	0.011	50.00	0.009	56.67
<i>Mahonia repens</i>	creeping barberry	Berberidaceae	0	0	0	0	<0.001	10.00	<0.001	2.50
<i>Opuntia</i> spp.	prickly pear	Cactaceae	0.526	90.00	0.704	100.00	0.607	90.00	0.613	92.50
<i>Orthocarpus purpureoalbus</i>	purple owllover	Scrophulariaceae	0	0	0	0	0.001	10.00	<0.001	2.50

Table A1 (continued)

Species	Common name	Family	Plot group A 2007–2009		Plot group B 2010		Plot group C 2011		All plots	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Packera multilobata</i>	lobeleaf groundsel	Asteraceae	<0.001	10.00	0	0	0	0	<0.001	5.00
<i>Packera neomexicana</i>	New Mexico groundsel	Asteraceae	0	0	0	0	0.002	20.00	0.001	5.00
<i>Pedicularis centranthera</i>	dwarf lousewort	Scrophulariaceae	0.023	30.00	0	0	0.004	20.00	0.009	20.00
<i>Penstemon</i> spp.	penstemon	Scrophulariaceae	0	0	0.026	40.00	0.002	10.00	0.010	12.50
<i>Penstemon barbatus</i>	beardlip penstemon	Scrophulariaceae	0.016	63.33	0	0	0.001	10.00	0.005	34.17
<i>Penstemon linarioides</i>	toadflax penstemon	Scrophulariaceae	0.513	100.00	0.315	100.00	0.364	100.00	0.397	100.00
<i>Penstemon strictus</i>	Rocky Mountain penstemon	Scrophulariaceae	0	0	0	0	0.030	10.00	0.010	2.50
<i>Peraphyllum ramosissimum</i>	squaw apple	Rosaceae	0.004	10.00	0	0	0.002	10.00	0.002	7.50
<i>Petradoria pumila</i>	rock goldenrod	Asteraceae	0.143	50.00	0.096	60.00	0.226	80.00	0.155	60.00
<i>Phlox gracilis</i>	slender phlox	Polemoniaceae	0.005	10	0	0	0	0	0.002	5.00
<i>Phlox hoodii</i>	Hood's phlox	Polemoniaceae	0.032	40.00	0.142	70.00	0.076	50.00	0.083	50.00
<i>Phlox longifolia</i>	longleaf phlox	Polemoniaceae	0.003	20.00	0	0	0	0	0.001	10.00
<i>Phoradendron juniperinum</i>	juniper mistletoe	Viscaceae	0.001	3.33	0.010	10.00	0.019	70.00	0.010	21.67
<i>Physaria acutifolia</i>	sharpleaf twinpod	Brassicaceae	0	0	0	0	0.002	10.00	0.001	2.50
<i>Poa fendleriana</i>	muttongrass	Poaceae	4.280	100.00	2.916	100.00	7.043	100.00	4.746	100.00
<i>Polygonum douglasii</i>	Douglas' knotweed	Polygonaceae	0.015	100.00	0.025	100.00	0.012	80.00	0.017	95.00
<i>Portulaca oleracea</i> ^a	little hogweed	Portulacaceae	0	0	0.001	20.00	0	0	<0.001	5.00
<i>Purshia tridentata</i>	antelope bitterbrush	Rosaceae	1.369	90.00	3.293	90.00	4.080	100.00	2.914	92.50
<i>Quercus gambelii</i>	Gambel oak	Fagaceae	0.008	10.00	0.002	20.00	0.259	30.00	0.090	17.50
<i>Sisymbrium altissimum</i> ^a	tumblemustard	Brassicaceae	0.003	16.67	0	0	0	0	0.001	8.33
<i>Sphaeralcea coccinea</i>	scarlet globemallow	Malvaceae	0.003	10.00	0	0	0	0	0.001	5.00
<i>Sporobolus cryptandrus</i>	sand dropseed	Poaceae	<0.001	3.33	0	0	0	0	<0.001	1.67
<i>Streptanthus cordatus</i>	heartleaf twistflower	Brassicaceae	<0.001	6.67	0	0	<0.001	10.00	<0.001	5.83
<i>Taraxacum officinale</i> ^a	common dandelion	Asteraceae	<0.001	6.67	0	0	0	0	<0.001	3.33
<i>Tragopogon dubius</i> ^a	yellow salsify	Asteraceae	<0.001	6.67	0	0	0	0	<0.001	3.33
<i>Yucca baccata</i>	banana yucca	Agavaceae	0.697	73.33	0.460	80.00	0.517	70.00	0.558	74.17

^aNonnative species

Table A2. Tree species with mean basal area and plot frequency for plots sampled in plot group A, plot group B, plot group C, and for all plots in the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Species	Common name	Family	Plot group A 2007–2008		Plot group B 2010		Plot group C 2011		All plots	
			Basal area (m ² /ha) ^a	Plot frequency (%) ^b	Basal area (m ² /ha) ^a	Plot frequency (%) ^b	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	28.06	100	29.54	100.00
<i>Pinus edulis</i>	two-needle pinyon	Pinaceae	1.23	100.00	1.92	100.00	1.53	100	1.56	100.00

^aBasal area measurements only include overstory trees.

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