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Integrated Upland Vegetation and Soils Monitoring for Mesa Verde National Park

2012 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2014/696

ON THE COVER
Integrated upland monitoring in Mesa Verde National Park
Photography by: Jim DeCoster/SCPN

Integrated Upland Vegetation and Soils Monitoring for Mesa Verde National Park

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The corresponding author and project manager for this project is Jim DeCoster (jim_decoster@nps.gov). Megan Swan is the botanist and crew leader for the project. Other contributions were made by the SCPN staff. The 2012 field crew consisted of Chris Carlson, Jesse Mike, Sean Mahoney, Maria Gaetani and Scott Massed.

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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 2 ecological sites for long-term monitoring of upland vegetation and soils at Mesa Verde National Park (MEVE): the Loamy Mesa Top Pinyon-Juniper ecological site and the Shallow Loamy Mesa Top Pinyon-Juniper ecological site. 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). In 2012 we only sampled plots in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site; hence we will not report any data for the Loamy Mesa Top Pinyon-Juniper ecological site here.

The Shallow Loamy Mesa Top Pinyon-Juniper ecological site is characterized as relatively intact old-growth pinyon-juniper woodland. It faces numerous threats, including changing fire regimes, climate change, soil erosion, and invasion by nonnative species. In 2012 we established and sampled 10 plots in the Shallow Mesa Top Pinyon-Juniper ecological site. In this report, we document monitoring activities during the 2012 field season and report these data.

2 Methods

2.1 Sampling frame

We derived our base sampling frame for the Shallow Loamy Mesa Top Pinyon-Juniper ecological site (Figure 1) from a map of the ecological site, which was developed by the U.S. Natural Resources Conservation Service (see methodology in 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 the 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, 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 ≥20%)

We generated a set of spatially distributed sampling points using the Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). Due to the relatively small size and the linear nature of the ecological site, we did not create a 50 m buffer. Instead, if a GRTS point landed close to the edge of the frame, we shifted the point away from the edge. 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 first 21 GRTS points 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.

We established 10 plots in 2012 after rejecting 11 sites: 4 sites were in close proximity to an archeological site, 5 sites deviated substantially from the ecological site (either the soil was too deep or there was too much exposed bedrock), and 2 sites were less than 200 m from plots established in the Loamy Mesa Top Pinyon-Juniper ecological site.

2.2 Field methods

In mid-August 2012, the SCPN integrated upland crew established and sampled 10 monitoring plots in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site.

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

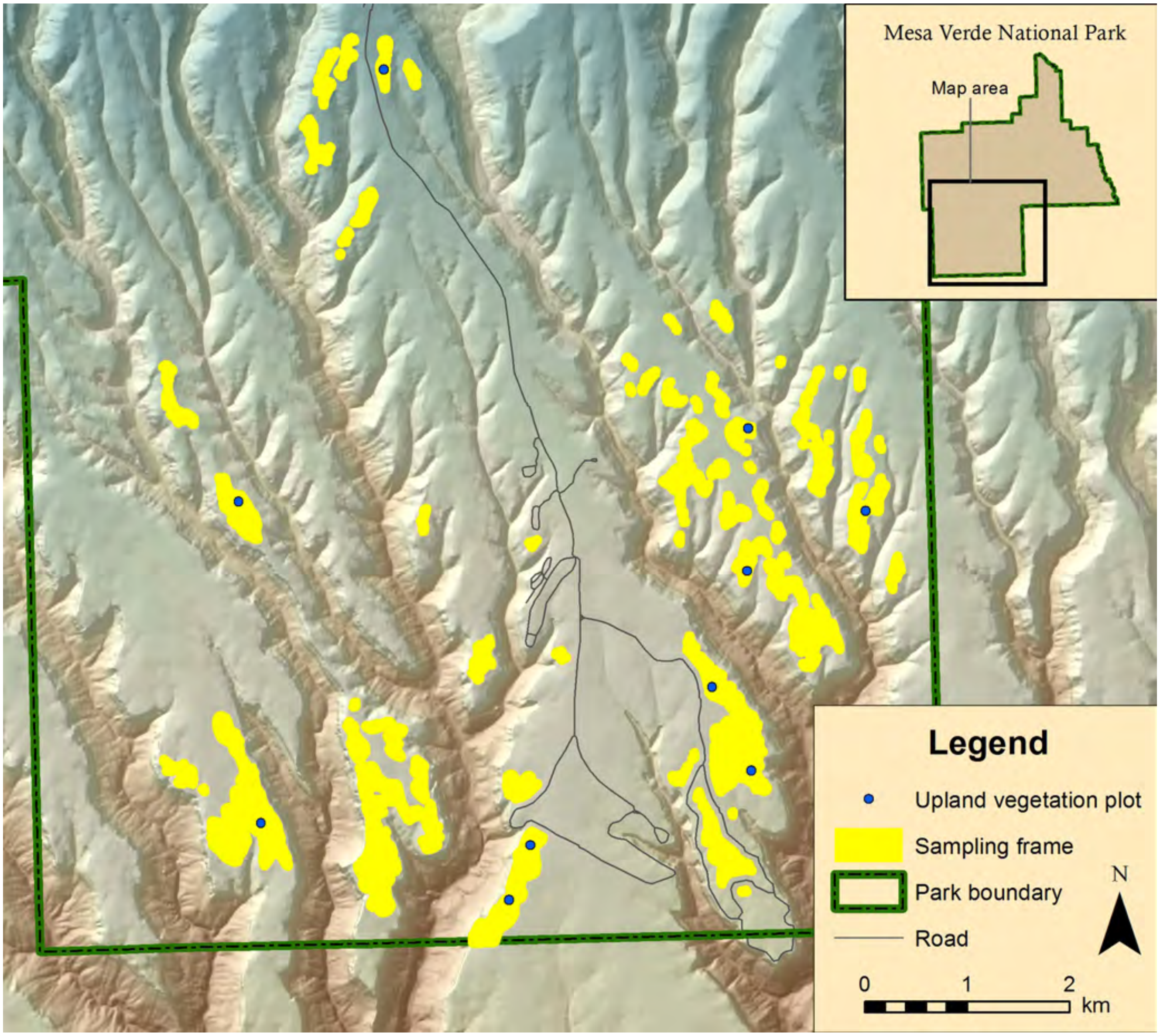


Figure 1. Sampling frame of the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE showing the 10 plots established in 2012.

apart. We collected data for shrub and herbaceous species cover and frequency, functional group cover, soil surface cover, tree seedling density, tree canopy, soil stability and basal gap data on all 3 transects within each plot. We also collected overstory tree and sapling data in subplots located between 2 of the transects. Field methodology is provided in detail in the SCPN integrated upland monitoring protocol (DeCoster et al. 2012).

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 m^2 (2 × 5 m), with 4 smaller quadrats nested inside (0.01 m^2, 0.1 m^2, 1 m^2, 5 m^2). 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 m^2 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 m^2 quadrats and recorded the cover class.

2.2.2 Overstory trees, saplings, and seedlings

We measured diameters of living overstory trees and snags (standing dead trees) in a 20 × 50 m (0.1 ha) plot located between 2 of the transects. For *Pinus edulis*, diameter was measured at breast height, while for *Juniperus osteosperma* these measurements were made at crown base. Within this overstory tree plot, we tallied saplings by size class and species in a smaller, 10 × 25 m plot (0.025 ha). We tallied seedlings by size class and species in the fifteen 10 m^2 quadrats along the 3 transects. We measured tree canopy using the line intercept method along transects.

2.2.3 Soil stability and hydrologic function

We estimated the percent cover of soil surface features in the 1 m^2 quadrats along transects, and recorded cover in 1 of 12 cover classes. We also measured basal gaps as the distance between plant bases along each transect. We collected 18 soil samples along the transects and tested them for soil aggregate stability.

2.3 Data summary

The sample unit for summary and analysis is the plot; hence, we summarized data at the level of the plot. We calculated the ecological site mean and standard deviation for most metrics from the means of the 10 plots. Three metrics—plot frequency, ecological site richness and beta diversity—were calculated across all plots and were therefore not calculated by averaging plot values. We discuss how we summarized these data below in sections 2.3.1 and 2.3.2.

2.3.1 Shrub and herbaceous species, functional groups and soil surface features

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%. Mean percent foliar cover was calculated for each plot, and we then calculated the mean and standard deviation for 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 m^2 quadrats per plot in which the species occurs) and for plots (percentage of plots in which the species occurs).

2.3.2 Species diversity

Four diversity measures were calculated for herbaceous and shrub species (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 both 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.

We calculated richness, Shannon diversity, and evenness for each plot, and then calculated the mean and standard deviation for the ecological site. Ecological site richness and beta diversity, which are not based on plot means, were calculated for the ecological site.

2.3.3 Trees

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 m^2/ha. Mean diameter of living overstory trees was also calculated for each species. For *Pinus edulis,* diameter and basal area calculations were made at breast height, while for *Juniperus osteosperma,* these calculations were made at crown base. Tree density was calculated for all species and all size classes for overstory living trees, snags, saplings and seedlings in terms of stems/ha. Each metric was calculated for each plot, and the ecological site mean and standard deviation were then calculated.

Canopy cover was calculated by first deriving the mean value for each plot, and then the ecological site mean and standard deviation were calculated.

2.3.4 Basal gaps and soil stability

We calculated 4 metrics from the basal gap data for each plot: median basal gap size, percentage of transects comprised by gaps, percentage of transects comprised by each gap size class, and total number of gaps. We then calculated the ecological site mean and standard deviation for each metric.

The soil aggregate stability index ranges from 1 to 6, where 1 indicates low aggregate stability and 6 indicates high aggregate stability. We calculated the mean soil aggregate stability for each plot, and then calculated the mean and standard deviation for the ecological site. 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 co-dominated the Shallow Loamy Mesa Top Pinyon-Juniper ecological site. The mean total live foliar cover was 7.29% (Table 1 and Figure 2). The mean foliar cover of perennial grasses cover was 2.72% and the mean foliar cover of shrubs was 3.79%. Mean foliar covers of forbs, cacti/succulents and annual grasses were all less than 1%. Mean covers of standing dead herbaceous and standing dead woody were between 1 and 2%. The among-plot variability was moderately high, as indicated by large standard deviations.

Poa fendleriana (muttongrass) was the dominant perennial grass, with a mean foliar cover of 2.719% (Table 2, Figure 3). It occurred in all of the plots and 96% of the quadrats. The most abundant shrub was *Purshia tridentata* (antelope bitterbrush), which had a mean foliar cover of 1.421%. Other abundant shrubs included *Cercocarpus montanus* (birchleaf mountain mahogany), *Quercus gambelii* (Gambel oak), *Amelanchier utahensis* (Utah serviceberry), and *Fendlera rupicola* (cliff fendlerbush). The frequencies of these shrubs were variable: *Purshia tridentata* occurred in all of the plots and 63.33% of the quadrats, while *Quercus gambelii* occurred in 30% of the plots and 5.33% of the quadrats, suggesting high cover where it occurred. *Yucca baccata*

Table 1. Foliar cover of functional groups at 10 plots in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012.

Functional groups	Mean (%)	SD
Total live foliar cover	7.29	2.69
Perennial grasses	2.72	2.38
Annual grasses	0.01	0.01
Forbs	0.52	0.45
Shrubs	3.79	1.87
Cacti/succulents	0.46	0.51
Standing dead herbaceous	1.22	1.03
Standing dead woody	1.84	1.08

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

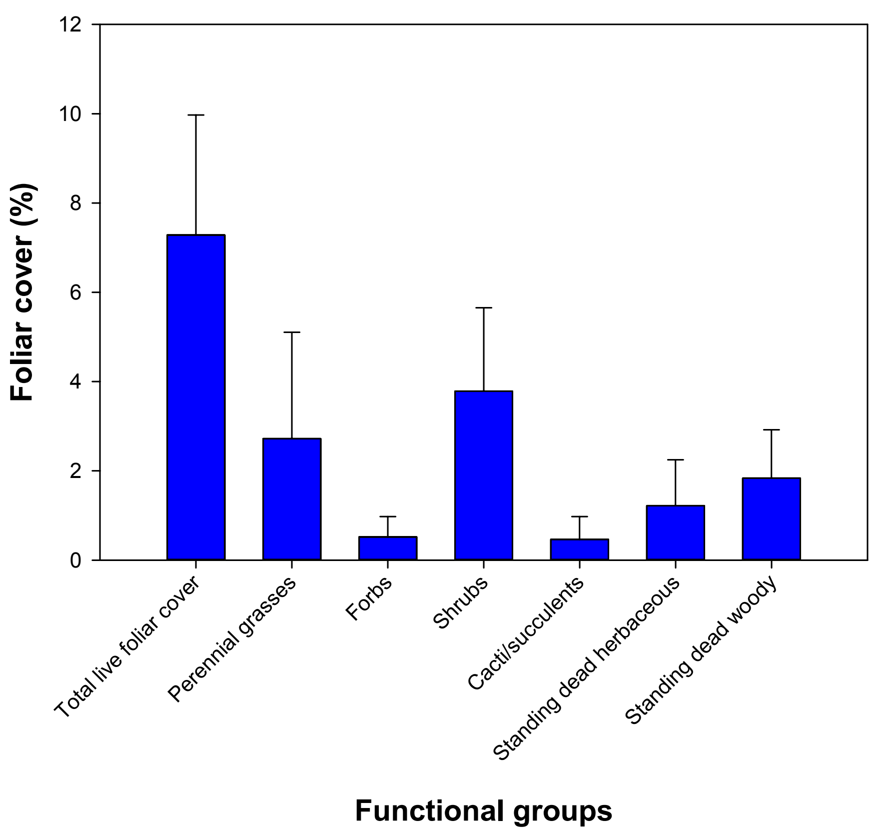


Figure 2. Mean percent foliar cover of functional groups in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012. Annual grasses had a mean foliar cover of 0.1% and therefore were not graphed. Error bars represent 1 standard deviation.

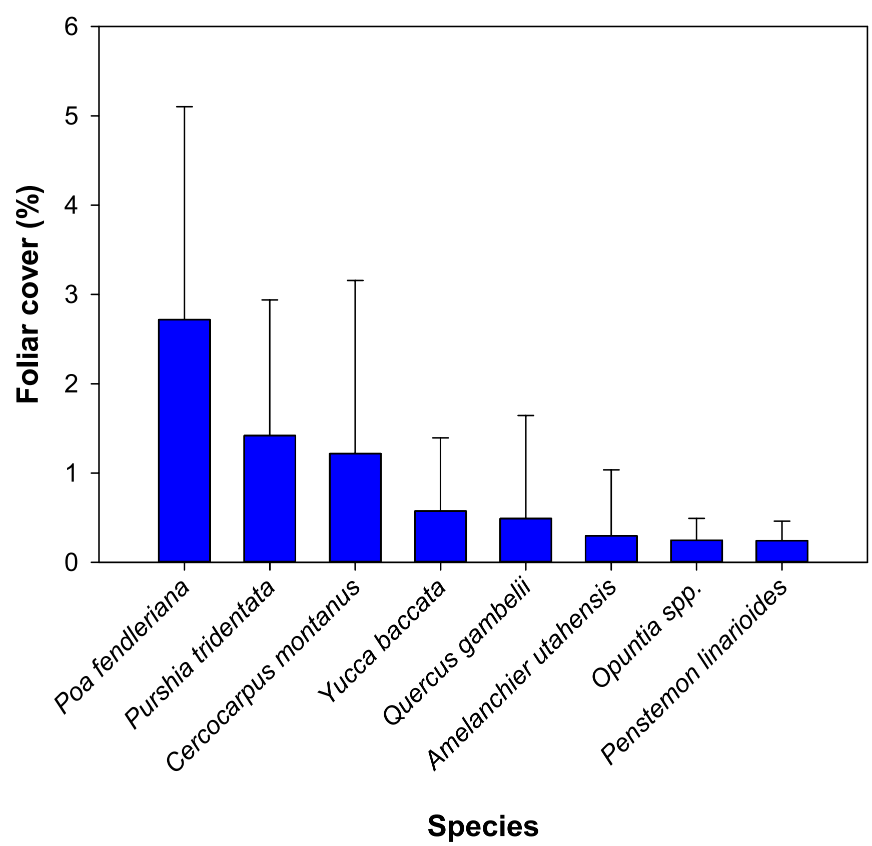
Table 2. Foliar cover and frequency of the 15 most abundant shrub and herbaceous species and all nonnative species at 10 plots in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012.

	Foliar cover			Frequency (%)	
Species	**Mean (%)**	**SD**	**Range**	**Quadrat**	**Plot**
Poa fendleriana	2.719	2.385	0.297–7.233	96.00	100
Purshia tridentata	1.421	1.518	0.040–4.477	63.33	100
Cercocarpus montanus	1.218	1.939	0.243–6.333	37.33	70
Yucca baccata	0.573	0.821	0.003–2.653	25.33	100
Quercus gambelii	0.489	1.156	0.003–3.553	5.33	30
Amelanchier utahensis	0.296	0.740	0.023–2.380	11.33	50
Opuntia spp.	0.246	0.245	0.003–0.653	42.00	100
Penstemon linarioides	0.240	0.220	0.050–0.690	61.33	90
Petradoria pumila	0.116	0.222	0.070–0.723	19.33	50
Fendlera rupicola	0.074	0.162	0.100–0.517	4.67	30
Artemisia tridentata	0.057	0.181	0.573–0.573	4.00	10
Ephedra viridis	0.054	0.087	0.003–0.267	11.33	50
Lesquerella rectipes	0.040	0.042	0.003–0.107	28.00	70
Eriogonum umbellatum	0.040	0.058	0.017–0.157	12.00	50
Heterotheca villosa	0.038	0.106	0.040–0.337	7.33	20
Bromus tectorum[a]	0.003	0.008	0.003–0.027	3.33	30
Carduus nutans[a]	0.003	0.008	0.027–0.027	2.00	10

Note: Species are arranged in descending order by their mean foliar cover.

[a]Nonnative species.

Figure 3. Mean percent foliar cover of the 8 most abundant shrub and herbaceous species in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012. Error bars represent 1 standard deviation.



(banana yucca) and *Opuntia* spp. (prickly pear) were abundant succulents. Both species occurred in all 10 plots. The most abundant forbs were *Penstemon linarioides* (toadflax penstemon), and *Petradoria pumila* (rock goldenrod). Large standard deviations indicate large among-plot variability. Appendix A lists all species that occurred in the ecological site, along with their common names, families, mean foliar cover and plot frequencies.

We encountered 2 nonnative species in the plots: the annual grass, *Bromus tectorum* (cheatgrass), and the forb, *Carduus nutans* (nodding thistle). *Bromus tectorum* occurred in 30% of the plots, and *Carduus nutans* occurred in only 10% (1 plot). Both were sparse, with mean foliar covers of 0.003%.

Species diversity in this ecological site was low on the scale of the plot, and moderate on the scale of the ecological site. Mean plot richness was 17.6 (Table 3). Shannon diversity (which takes the relative abundance of each species into account, and generally ranges between 1.5 and 3.5) was 1.494. Evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) was 0.531. On the scale of the ecological site, species richness was 60. Beta diversity (a measure of within-ecological site heterogeneity, generally ranging between 1 and 5) was 3.614. When we calculated the metrics using only native species, all the metrics showed slight decreases except for evenness, which showed a slight increase.

Table 3. Species diversity metrics for all species and for native species only at 10 plots in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012.

	Mean	SD
Plot		
Plot richness	17.6	6.2
Shannon diversity	1.494	0.395
Evenness	0.531	0.119
Ecological site		
Ecological site richness[a]	60	
Beta diversity[a]	3.614	
Plot		
Plot richness	17.2	5.6
Shannon diversity	1.491	0.392
Evenness	0.533	0.118
Ecological site		
Ecological site richness[a]	58	
Beta diversity[a]	3.580	

[a]Ecological site richness and beta diversity values are not means.

3.2 Trees

We report tree density (stems/ha) by species for overstory trees, saplings, and seedlings. We also report basal area for overstory trees by species, grouped as living trees or snags (Table 4).

Table 4. Mean density, mean basal area, and mean diameter for trees at 10 plots in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012.

Species	Seedling[a] density (stems/ha)	Sapling[a] density (stems/ha)	Overstory[a] density (stems/ha)	Snag[a] density (stems/ha)	Overstory basal area (m^2/ha)	Snag basal area (m^2/ha)	Mean overstory diameter (cm)[b]
Juniperus osteosperma	920.0	184.0	299.0	88.0	32.64	7.42	35.7
Pinus edulis	1760.0	892.0	57.0	35.0	1.80	1.19	19.8
All species[c]	2680.0	1076.0	356.0	123.0	34.44	8.61	33.5

[a]Size 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.

[b]Mean overstory diameter is provided as DBH for *Pinus edulis* and DRC for *Juniperus osteosperma*.

[c]Values in the "All species" row 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.

There were 2 tree species in this ecological site: *Juniperus osteosperma* (Utah juniper) and *Pinus edulis* (twoneedle pinyon). *Juniperus osteosperma* was the dominant tree, with a basal area of 32.64 m^2/ha and an overstory density of 299.0 stems/ha (Figure 4). In contrast, *P. edulis* had a basal area of 1.80 m^2/ha and an overstory density of 57.0 stems/ha. *Pinus edulis* had high snag density and basal area relative to its living density and basal area: 35.0 stems/ha and 1.19 m^2/ha, respectively. *Juniperus osteosperma* had a snag density of 88.0 stems/ha and a snag basal area of 7.42 m^2/ha. The mean overstory diameter (DRC) of *J. osteosperma* was 35.7 cm, while it was 19.8 cm (DBH) for *P. edulis.* The size distribution of *J. osteosperma* showed a typical inverse relationship, with the highest density in the smallest size class and decreasing densities with size (Figure 5). *P. edulis* only occurred in the smallest 2 size classes, with more individuals in the 15–25 cm size class than the 25–35 cm size class.

Sapling and seedling densities provide measures of forest regeneration, and indicate the potential for change in species composition. Unlike the overstory, *Pinus edulis* was more abundant in the sapling and seedling layers than *Juniperus osteosperma*. Sapling density for *P. edulis* was 892.0 stems/ha, compared with 184.0 stems/ha for *J. osteosperma*. Sapling density of *P. edulis* was greatest in the smallest size class, and decreased as size class increased (Figure 6). In contrast, sapling density was fairly uniform among the size classes for *J. osteosperma*. Large standard deviations indicate large among-plot variability.

Seedling density was also much greater for *Pinus edulis* than *Juniperus osteosperma*. *Pinus edulis* had a seedling density of 1760.0 stems/ha, while *J. osteosperma* had a seedling density of 920.0 stems/ha. Seedling densities were fairly evenly distributed among size classes for both species, with the exception of the 15 to <137 cm height class for *P. edulis*. This size class had 993.3 stems/ha compared with less than 400 stems/ha in the other 2 size classes (Figure 7).

The overall size class structure of overstory and saplings combined showed an inverse distribution, where density decreased with increasing size (Figure 8). Standard deviations were large, particularly for the sapling size classes, indicating large among-plot variation. The mean plot canopy cover was 37.7% with a standard deviation of 3.3.

Figure 4. Mean basal area for living trees and snags by species in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012. Error bars represent 1 standard deviation.

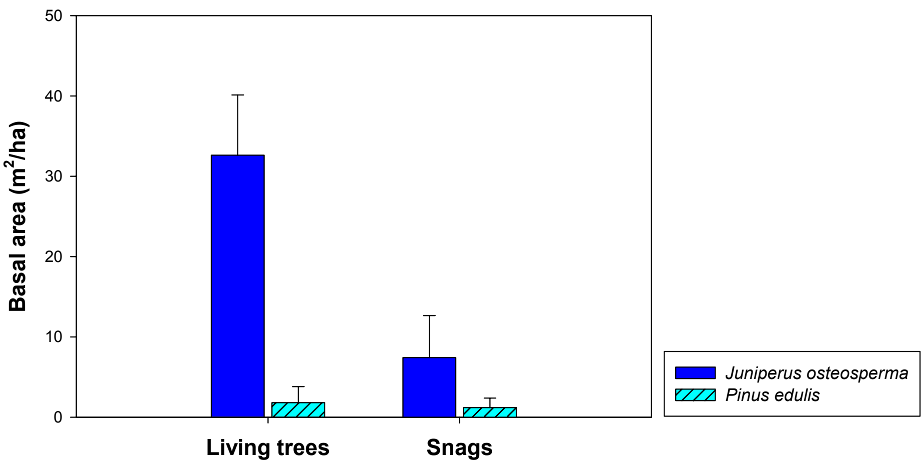
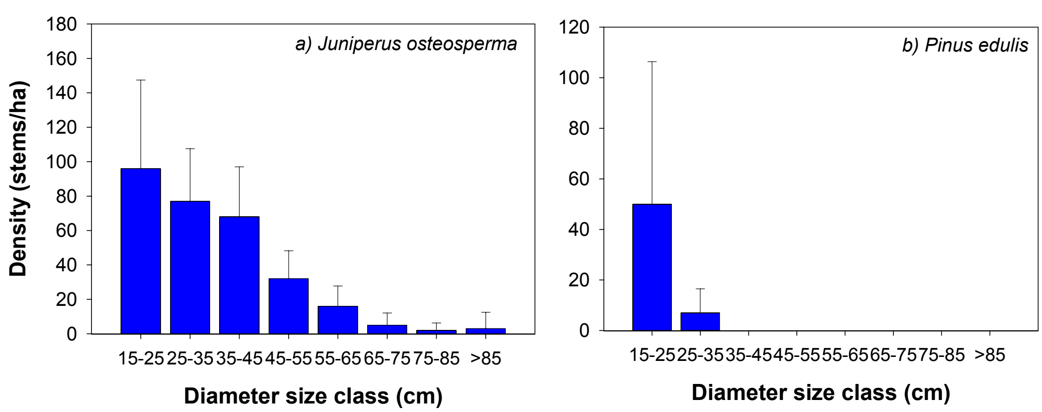


Figure 5. Size structure of living overstory trees for a) *Juniperus osteosperma* and b) *Pinus edulis* in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012. Error bars represent 1 standard deviation.



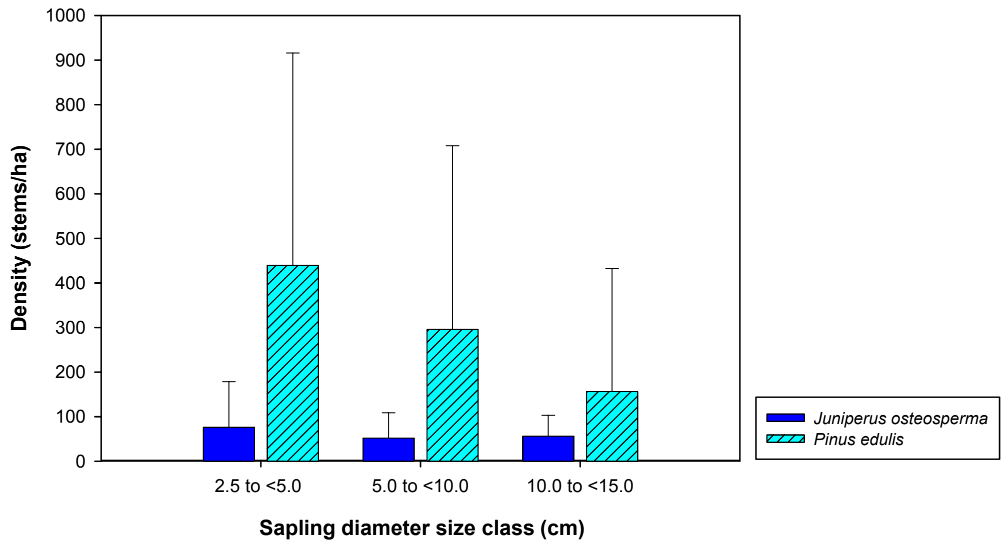


Figure 6. Mean density of saplings in different diameter size classes, by species, in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012. Error bars represent 1 standard deviation. Sapling diameter is measured at root crown for *Juniperus osteosperma*, and at breast height for *Pinus edulis*.

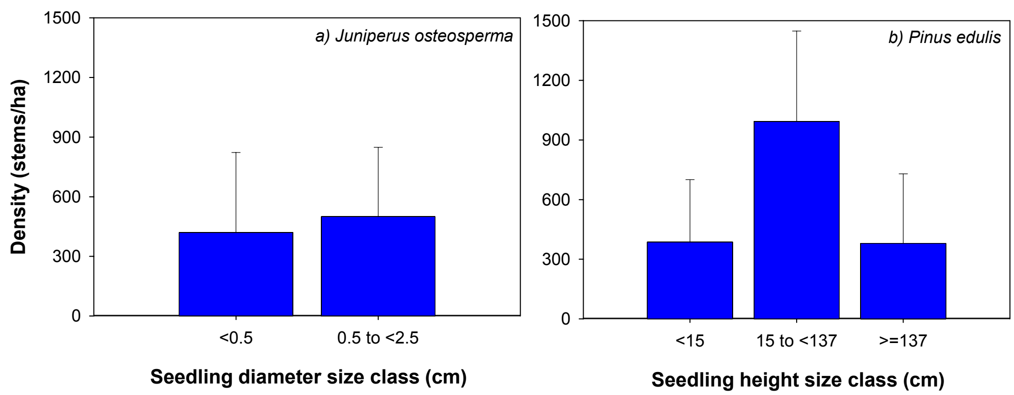


Figure 7. Mean density of seedlings in different size classes for a) *Juniperus osteosperma* and b) *Pinus edulis*, in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012. Error bars represent 1 standard deviation. Seedling diameter is measured at root crown for *Juniperus osteosperma*.

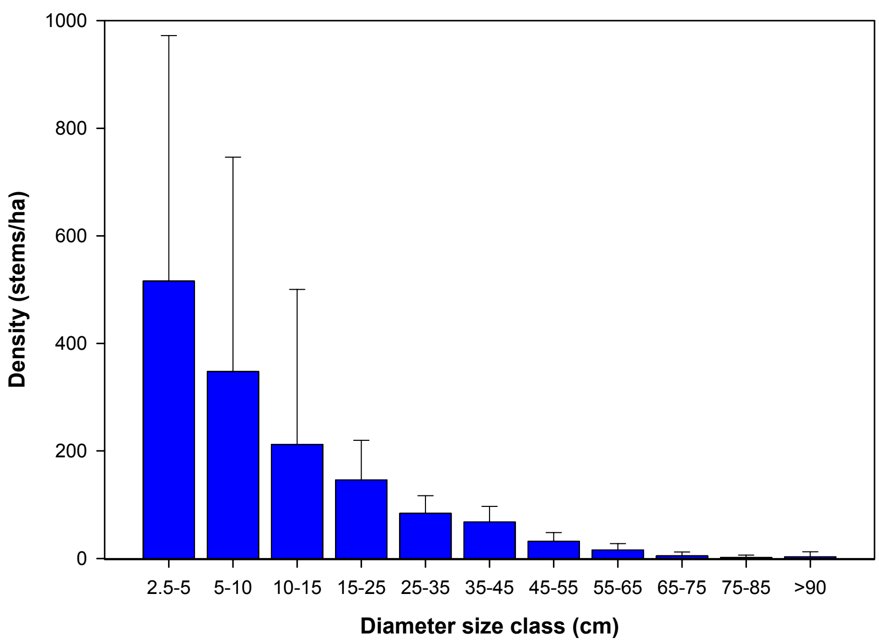


Figure 8. Size structure of all living overstory trees and saplings in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012. Error bars represent 1 standard deviation. Overstory tree and sapling diameter is measured at root crown for *Juniperus osteosperma*, and at breast height for *Pinus edulis*.

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, with a mean cover of 60.82% (Table 5 and Figure 9). Other important features included undifferentiated crust (12.92%), bare soil (7.10%) and stone/bedrock (5.06%). Live plant base, moss, fine gravel, coarse gravel, cobble and woody debris had mean covers between 1 and 3%. All the other features had mean covers less than 1%. The standard deviations were moderately large, indicating large among-plot variability.

Table 5. Cover of soil surface features at 10 plots in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012.

Soil surface feature	Mean (%)	SD
Live plant base	2.27	1.34
Dead woody base	0.51	0.61
Dead herbaceous base	0.70	0.71
Bare soil	7.10	4.74
Duff/litter	60.82	11.46
Undifferentiated crust	12.92	9.78
Moss	1.20	1.78
Lichen	0.01	0.03
Cyanobacteria	0.47	0.96
Fine gravel (0.2 to <2 cm)	2.12	2.60
Coarse gravel (2 to <7.5 cm)	1.47	1.39
Cobble (7.5 to <25 cm)	1.22	1.19
Stone, bedrock (≥25 cm)	5.06	9.08
Woody debris	2.74	1.66

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

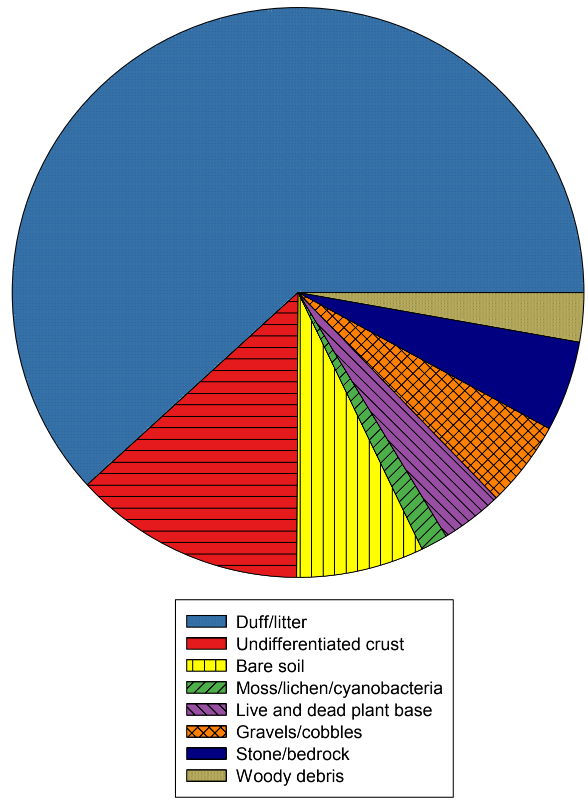


Figure 9. Mean percent cover of soil surface features in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012.

The basal gap data showed large distances between the plant bases. A mean of 82.2% of the transect lengths were comprised of gaps of 100 cm or greater (Table 6 and Figure 10). Gaps less than 20 cm comprised only 1.1% of the transect lengths. The median gap size was 132.1 cm.

Soil stability was moderately high, with a mean rating of 4.60 (Table 7). Ratings range from 1 (low stability) to 6 (high stability). Samples collected under vegetative cover were higher (4.82) than those without vegetative cover (4.17). Standard deviations indicate a moderate amount of among-plot variability.

Table 6. Number of basal gaps, median gap size, and percentage of transect in different gap size classes at 10 plots in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012.

Metric	Mean	SD
Number of gaps	86.3	57.1
Median gap size (cm)	132.1	78.0
Percentage of transect in gaps	95.6	2.7
Percentage of transect in gaps 0 to <20 cm	1.1	1.4
Percentage of transect in gaps 20 to <50 cm	3.9	3.5
Percentage of transect in gaps 50 to <100 cm	8.4	7.5
Percentage of transect in gaps ≥100 cm	82.2	14.2

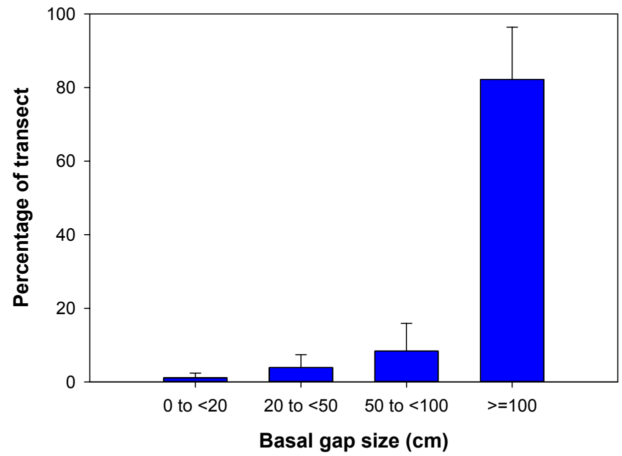


Figure 10. Mean percentage of transect by gap size class in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012. Error bars represent 1 standard deviation.

Table 7. Soil stability rating for all samples, and for samples with and without vegetative cover at 10 plots in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012.

	Mean	SD
All samples	4.60	0.57
Samples under vegetative cover	4.82	0.77
Samples not under vegetative cover	4.17	0.60

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

4 Discussion

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

The shrub/herbaceous vegetation was co-dominated by shrubs and perennial grasses. Dominant shrubs included *Purshia tridentata*, *Cercocarpus montanus*, *Quercus gambelii*, *Amelanchier utahensis*, and *Fendlera rupicola*. *Poa fendleriana* was the dominant perennial grass. *Yucca baccata* and *Opuntia* spp. were abundant cacti/succulents. Two nonnative species – *Bromus tectorum* and *Carduus nutans* – occurred with low cover and frequency. The low abundance of these nonnative species suggests that these are currently not a threat to the ecosystem. However, these and many other nonnative species are annuals, which have the ability to dramatically increase with increases in precipitation. Species diversity was moderately low on the scale of the plot, and moderate on the scale of the ecological site.

The tree overstory was dominated by *Juniperus osteosperma*, with a lower abundance of *Pinus edulis*. The low abundance of *P. edulis* was the result of drought-induced mortality in the previous decade, as evidenced by the relatively high number of snags. Many dead individuals, however, had fallen to the ground, and hence were not sampled. *Pinus edulis* was well represented in the seedling and sapling layers, suggesting a potential for this species to increase in the overstory in the future.

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 soil surface was mostly composed of duff and litter. The soil aggregate stability was moderately high, in part due to the high cover of duff and litter.

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 revisit, and monitoring a new set of plots with each revisit, there are designs that provide some balance between repeated visits 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 plots into 3 panels, and sample 2 of the panels every other year (Table 8).

The Shallow Loamy Mesa Top Pinyon-Juniper adds a second ecological site to SCPN's integrated upland monitoring at MEVE. The original ecological site, Loamy Mesa Top Pinyon-Juniper, will be sampled in odd years, and this newer site, Shallow Loamy Mesa Top, will be sampled in even years.

Table 8. The panel design we are currently planning to use for the revisit design in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE. "X" represents 10 plots, for a total of 30 plots across 3 panels for the ecological site.

	Year											
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
A	X				X		X				X	
B	X		X				X		X			
C			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 10 plots sampled in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE in 2012.

Table A1. Shrub and herbaceous species with mean foliar cover and plot frequency in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Species	Common name	Family	Foliar cover (%)	Plot frequency (%)
Achnatherum hymenoides	Indian ricegrass	Poaceae	0.002	20
Amelanchier utahensis	Utah serviceberry	Rosaceae	0.296	50
Antennaria parvifolia	small leaf pussytoes	Asteraceae	<0.001	10
Arceuthobium divaricatum	pinyon dwarf mistletoe	Viscaceae	0.009	10
Artemisia tridentata	basin big sagebrush	Asteraceae	0.057	10
Boechera spp.	rockcress	Brassicaceae	0.013	60
Bromus tectorum[a]	cheatgrass	Poaceae	0.003	30
Carduus nutans[a]	nodding thistle	Asteraceae	0.003	10
Cercocarpus montanus	birchleaf mountain mahogany	Rosaceae	1.218	70
Chaenactis douglasii	Douglas dustymaiden	Asteraceae	0.002	20
Chaetopappa ericoides	rose heath	Asteraceae	<0.001	10
Chamaesyce fendleri	Fendler's sandmat	Euphorbiaceae	0.003	20
Chenopodium fremontii	Fremont's goosefoot	Chenopodiaceae	<0.001	10
Chrysothamnus depressus	longflower rabbitbrush	Asteraceae	0.012	10
Collinsia parviflora	blue-eyed Mary	Scrophulariaceae	<0.001	10
Comandra umbellata	bastard toadflax	Santalaceae	0.028	10
Cordylanthus wrightii	Wright's bird's beak	Scrophulariaceae	<0.001	10
Cryptantha sp.	cryptantha	Boraginaceae	0.012	30
Descurainia pinnata	western tansymustard	Brassicaceae	0.001	10
Echinocereus sp.	hedgehog cactus	Cactaceae	<0.001	10
Elymus elymoides	squirreltail	Poaceae	0.010	60
Ephedra viridis	mormon tea	Ephedraceae	0.054	50
Erigeron flagellaris	trailing fleabane	Asteraceae	0.005	10
Eriogonum alatum	winged buckwheat	Polygonaceae	0.023	30
Eriogonum racemosum	redroot buckwheat	Polygonaceae	0.025	10
Eriogonum umbellatum	sulphur-flowered buckwheat	Polygonaceae	0.040	50
Fendlera rupicola	cliff fendlerbush	Hydrangeaceae	0.074	30
Hedysarum boreale	Utah sweetvetch	Fabaceae	0.003	30
Hesperidanthus linearifolius	slimleaf plains mustard	Brassicaceae	0.018	60
Heterotheca villosa	hairy false goldenaster	Asteraceae	0.038	20
Hymenopappus filifolius	fineleaf hymenopappus	Asteraceae	<0.001	10
Hymenoxys richardsonii	Colorado rubberweed	Asteraceae	<0.001	10
Ipomopsis aggregata	scarlet gilia	Polemoniaceae	0.002	10
Krascheninnikovia lanata	winterfat	Chenopodiaceae	0.002	10
Lesquerella rectipes	straight bladderpod	Brassicaceae	0.040	70
Lithospermum multiflorum	many flowered puccoon	Boraginaceae	0.002	10
Lupinus sp.	lupine	Fabaceae	0.001	10
Machaeranthera bigelovii	Bigelow's tansy-aster	Asteraceae	0.001	10
Machaeranthera canescens	hoary tansyaster	Asteraceae	0.007	30
Opuntia spp.	prickly pear	Cactaceae	0.246	100

Table A1 (*continued*)

Species	Common name	Family	Foliar cover (%)	Plot frequency (%)
Packera neomexicana	New Mexico groundsel	Asteraceae	<0.001	10
Penstemon barbatus	beardlip penstemon	Scrophulariaceae	0.004	30
Peraphyllum ramosissimum	squaw apple	Rosaceae	0.002	10
Phlox hoodii	Hood's phlox	Polemoniaceae	0.008	30
Physaria acutifolia	sharpleaf twinpod	Brassicaceae	0.015	20
Purshia tridentata	antelope bitterbrush	Rosaceae	1.421	100
Stenotus armerioides	thrift mock goldenweed	Asteraceae	0.033	30
Streptanthus cordatus	heartleaf twistflower	Brassicaceae	0.011	30
Tetraneuris ivesiana	Ives' fournerved daisy	Asteraceae	0.005	10

[a]Nonnative species.

Table A2. Tree species, with mean basal area and plot frequency in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site at MEVE.

Species	Common name	Family	Basal area (m^2/ha)[a]	Plot frequency (%)[b]
Juniperus osteosperma	Utah juniper	Cuppressaceae	32.64	100
Pinus edulis	twoneedle pinyon	Pinaceae	1.80	100

[a]Basal area measurements only include overstory trees.

[b]Plot frequency includes overstory trees, saplings, and seedlings.

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