



# Integrated Upland Vegetation and Soils Monitoring for Mesa Verde National Park

## *2008 Summary Report*

Natural Resource Data Series NPS/SCPN/NRDS—2009/019



ON THE COVER

Loamy Mesa Top Pinyon-Juniper ecological site at Mesa Verde National Park  
Photograph by: Jim DeCoster

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The corresponding author and project manager for this project is Jim DeCoster ([jim\\_decoster@nps.gov](mailto:jim_decoster@nps.gov)). Megan Swan is the botanist and crew leader for the project. Other contributions were made by the SCPN staff. The 2008 field crew consisted of Jessica Erickson, Anna Lowell, and Eric Vasquez.

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# 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 strong 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 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 Integrated Upland Monitoring program of SCPN began monitoring upland sites at MEVE with the installation of 10 plots in the Loamy Mesa Top Pinyon-Juniper ecological site. We plan to sample the quadrats and gap intercept transects annually for 3-5 years to determine the range of temporal variability for key metrics. Power analysis will then be used to determine the total number of plots necessary to detect change in the key metrics. In this report, we document monitoring activities in the 2008 field season and compare these data with the data collected in 2007.

## Methods

### Sampling frame

We derived the sampling frame from the map of the Loamy Mesa Top Pinyon-Juniper ecological site, which was developed by the US Natural Resources Conservation Service (See Appendix A of De-Coster et al., in review). 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 create 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 not within the target ecological site (roads, buildings and other infrastructure)
- areas that were 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
- areas with high potential for erosion to occur as a result of sampling (slopes  $\geq 20\%$ )
- areas containing arthropod monitoring sites (fig. 1).

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 archaeological sites and other sensitive resources. Before establishing a plot, the Integrated Upland crew conducted an ecological site assessment for each sampling point and rejected the site if it did not fall within the ecological site, had a slope greater than 20%, or contained a major disturbance. Twelve points were rejected. Park staff rejected nine points that were determined to be too close to archaeological sites; the Integrated Upland crew rejected

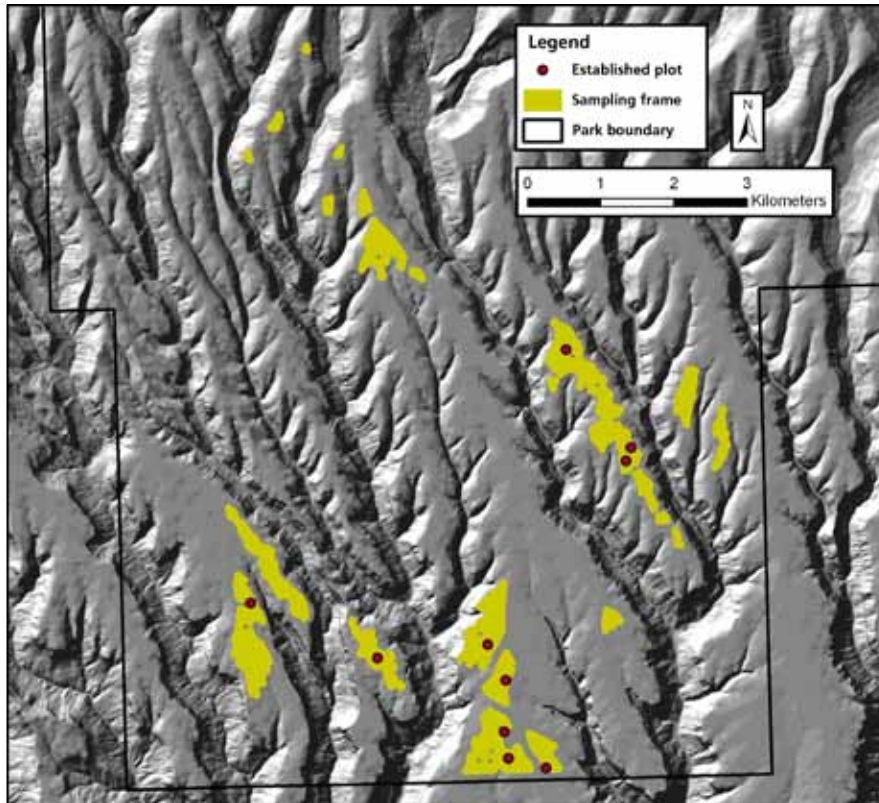


**Figure 1.** Sampling frame of Loamy Mesa Top Pinyon-Juniper ecological site with the 10 plots established in 2007.

two points located on the far north side of the ecological site which were distinctly different from the rest of the ecological site, and one point which was located in the Shallow Loamy Mesa Top Pinyon-Juniper ecological site.

### **Field methods**

The SCPN Upland Monitoring crew began monitoring at MEVE in 2007 with the establishment of 10 plots. The plots were 0.50 ha in size, measuring 71 m x 71 m. Shrub and herbaceous data and soil data were collected on three 50 m transects, spaced 25 meters apart, within each plot. Overstory tree and sapling data were collected in subplots located between two of the transects. In both years the crew collected the data from all the plots in early August. Field methodology is provided in detail in the SCPN Integrated Upland Protocol (DeCoster et al., in review).

### ***Shrub and herbaceous vegetation***

At 10 m intervals along each transect, the crew sampled shrub and herbaceous vegetation with five sets of nested quadrats. The largest quadrat size was 10 m<sup>2</sup> (2m x 5m), with four smaller quadrats nested inside (0.01 m<sup>2</sup>, 0.1 m<sup>2</sup>, 1 m<sup>2</sup>, 5 m<sup>2</sup>). The presence of individual vascular species was recorded for each nested sub-quadrat. For each herbaceous and shrub species, percent cover was then estimated in the 10 m<sup>2</sup> quadrat and recorded as one of 12 cover classes, e.g. 2-5%, 5-10%, etc. Percent cover for functional groups (e.g. perennial grasses, forbs, shrubs) was also estimated in the largest quadrat and recorded as one of 12 cover classes.

### ***Overstory trees and saplings***

Trees were measured in 2007, but were not remeasured in 2008. In 2008, canopy closure was measured with a hemispherical densitometer in 2008 at five points along each transect.

### ***Soil stability and hydrologic function***

The crew measured the amount of bare soil by recording the length of the basal gaps (the space between plant bases) along each transect. Percent cover of ground surface features was estimated in the 1 m<sup>2</sup> quadrats in conjunction with shrub and herbaceous data and recorded in one of 12 cover classes. A soil aggregate stability test was conducted in 2007, using 18 soil samples collected along the transects. This procedure was not repeated in 2008.

### **Data summary**

The sample unit for summary and analysis is the plot; hence, we summarized data at the level of the plot. In order to calculate summary statistics for the ecological site, means and standard deviations were calculated from the plot means.

For herbaceous and shrub vegetation, cover and frequency were calculated for each species from the cover class midpoints, e.g. using 7.5% for cover class 5-10%. The mean cover was calculated for each plot, and the mean and standard deviation (SD) were calculated for the ecological site. Species frequency was calculated for quadrats (mean percentage of quadrats per plot where the species occurs) and for plots (percentage of plots where the species occurs). Mean cover and SD of functional groups and surface features were calculated in a similar fashion.

We calculated four diversity measures for herbaceous and shrub species (Magurran 1988)—first for all species in a site and then for native species only.

(1) Species richness (S) is the number of species at a given spatial scale, and it 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 (J') is a measure of the degree to which all species are equal in abundance:

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

(4) Beta diversity ( $\beta_w$ ) is a measure of within-ecological site heterogeneity (diversity among plots):

$$S_e / (S_p - 1)$$

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.

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

We made five calculations for the basal gaps data: median basal gap size, percentage of transects comprised by gaps, percentage of transects comprised by gaps  $\geq 50$  cm, number of gaps by size class and total number of gaps. Mean and SD were calculated for each metric.

# Results

## Shrub and herbaceous vegetation

Perennial grasses, shrubs, forbs, and cacti/succulents co-dominated the herbaceous/shrub vegetation of the Loamy Mesa Top Pinyon-Juniper ecological site at MEVE (table 1 and fig. 2). Total live vegetative cover was 14.17% in 2007 and decreased to 10.05% in 2008. This change, however, is largely due to slight changes in methods: in 2007, foliar cover of trees (< 2 m in height) was included in the estimation of total live vegetative cover, but trees were not included in 2008. Also, standing dead woody cover in 2007 included trees (< 2 m) and shrubs, but in 2008 standing dead woody cover included only shrubs. While there were some changes in the cover of functional groups, most of these changes were small, particularly in light of the large among-plot variability.

Cover of individual species differed between the two years, but most of these changes were quite small, especially considering the large standard deviations, which indicate high among-plot variability (fig. 3). Some species, such as the dominant grass, *Poa fenderliana* (muttongrass), decreased, while others, like the shrubs *Artemisia tridentata* (big sagebrush) and *Cercocarpus montanus* (alderleaf mountain mahogany), increased. Quadrat and plot frequencies did not change substantially between years. Appendix A lists all the species, along with common names, families, mean foliar covers, and plot frequencies.

In 2007, seven nonnative species were found in the plots. Four of these species—*Descurainia sophia* (herb sophia), *Ceratocephala testiculata* (curve-seed butterwort), *Erodium cicutarium* (stork's bill), and *Taraxacum officinale* (common dandelion)—were not found in 2008. One species, *Bromus tectorum* (cheatgrass), decreased in cover and frequency. Two nonnative species—*Sisymbrium altissimum* (tumble mustard) and *Carduus nutans* (nodding thistle)—did not change in cover, but their frequencies increased.

On the scale of the plot, species richness decreased from 19.2 to 18.2 species per plot, but Shannon diversity Shannon diversity (which takes into account relative species abundance, and generally

**Table 1. Foliar cover of functional groups for 2007 and 2008.**

| Functional group               | Foliar cover (%) |        |                  |        |
|--------------------------------|------------------|--------|------------------|--------|
|                                | 2007             |        | 2008             |        |
|                                | Mean             | (SD)   | Mean             | (SD)   |
| Total foliar cover             | 14.17            | (4.80) | 10.05            | (6.25) |
| Perennial grasses              | 4.67             | (3.12) | 4.01             | (2.38) |
| Annual grasses                 | <0.01            | (0.01) | <0.01            | (<.01) |
| Forbs                          | 0.94             | (0.77) | 1.19             | (0.66) |
| Shrubs                         | 2.30             | (2.61) | 2.82             | (3.50) |
| Cacti, succulents              | 1.29             | (0.10) | 1.17             | (0.86) |
| Understory trees (< 2m height) | 5.17             | (2.56) | n/a <sup>a</sup> | n/a    |
| Standing dead herbaceous       | 2.28             | (1.45) | 1.34             | (0.82) |
| Standing dead woody            | 2.10             | (1.02) | 2.16             | (2.18) |

*Note:* Components of total live vegetation are not strictly additive due to the fact that calculations are made from cover class midpoints, the various components may overlap, and estimations were derived independently.

<sup>a</sup> Tree cover was not measured in 2008.

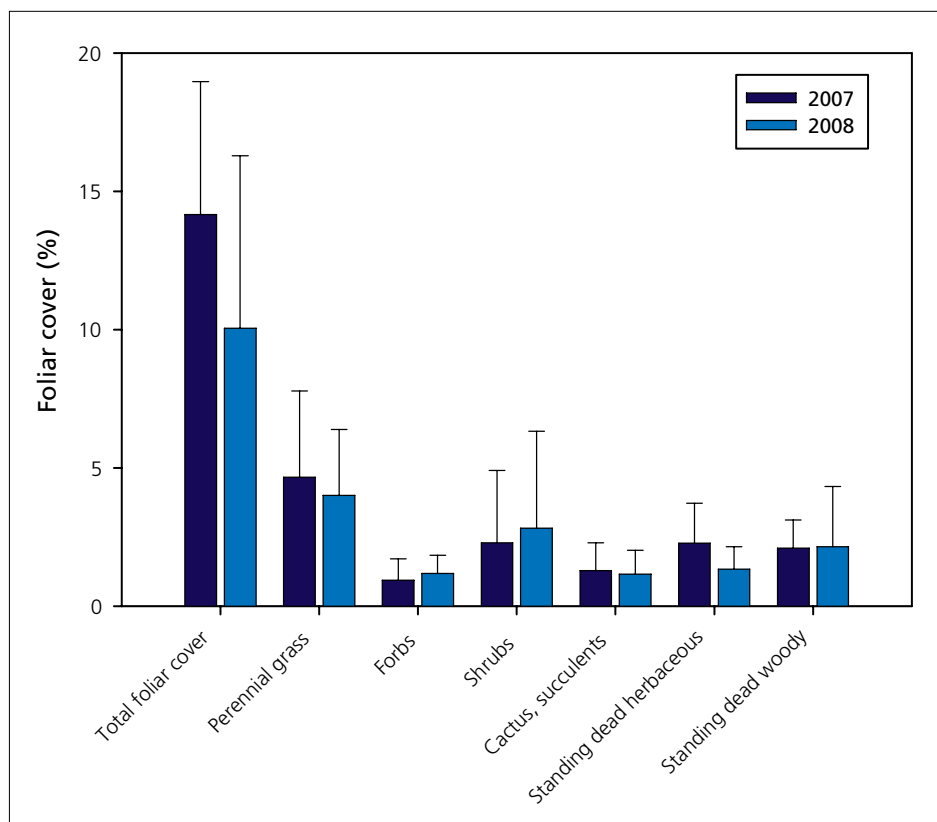


**Figure 2.** Mean cover of functional groups in 2007 and 2008. Note: means for total foliar and standing dead woody cover do not include tree components in 2007. Error bars represent one standard deviation.

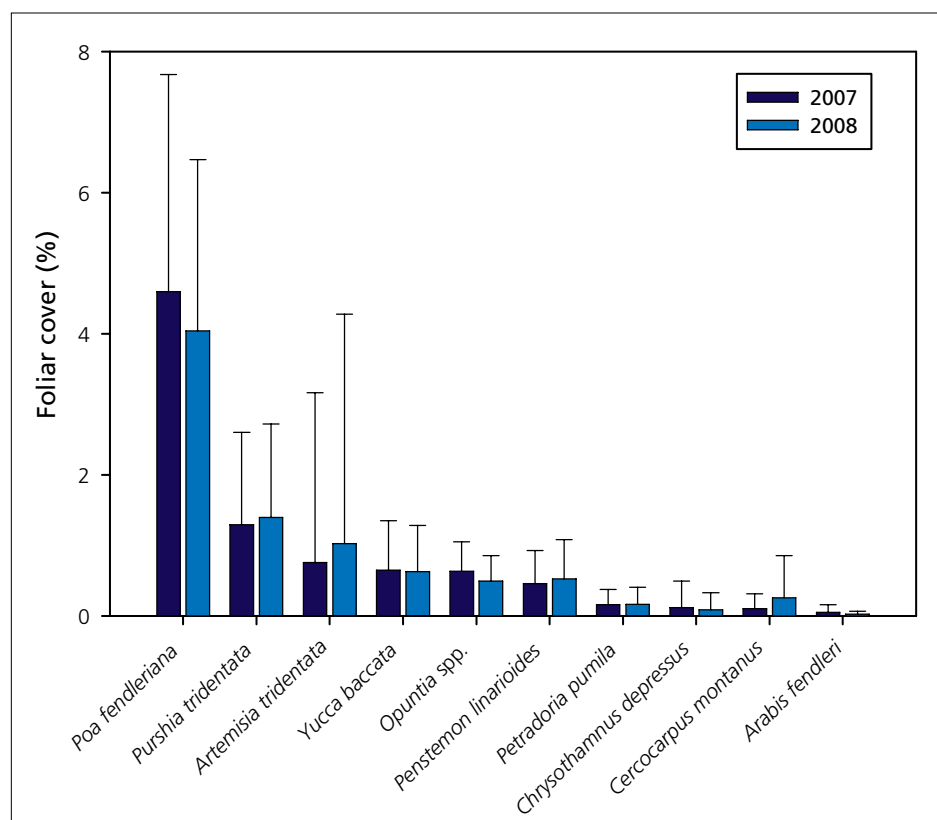


**Figure 3.** Mean foliar cover of the ten most abundant shrub and herbaceous species in 2007, as compared to 2008. Error bars represent one standard deviation.

**Table 2. Foliar cover and frequency of the fifteen most abundant vascular species and all nonnative species in 2007 compared to 2008.**

| Species                                       | 2007           |       |           |           | 2008           |       |           |           |
|-----------------------------------------------|----------------|-------|-----------|-----------|----------------|-------|-----------|-----------|
|                                               | Mean cover (%) | SD    | Quad freq | Plot freq | Mean cover (%) | SD    | Quad freq | Plot freq |
| <i>Poa fendleriana</i>                        | 4.596          | 3.077 | 96.67     | 100       | 4.042          | 2.427 | 96.00     | 100       |
| <i>Purshia tridentata</i>                     | 1.297          | 1.306 | 48.00     | 90        | 1.398          | 1.326 | 50.67     | 90        |
| <i>Artemisia tridentata</i>                   | 0.760          | 2.404 | 10.00     | 10        | 1.028          | 3.252 | 10.00     | 10        |
| <i>Yucca baccata</i>                          | 0.651          | 0.703 | 32.00     | 80        | 0.628          | 0.654 | 32.67     | 70        |
| <i>Opuntia</i> spp.                           | 0.636          | 0.415 | 50.67     | 90        | 0.496          | 0.359 | 51.33     | 90        |
| <i>Penstemon linarioides</i>                  | 0.462          | 0.468 | 78.67     | 100       | 0.527          | 0.555 | 83.33     | 100       |
| <i>Petradoria pumila</i>                      | 0.158          | 0.217 | 14.67     | 50        | 0.165          | 0.246 | 16.67     | 50        |
| <i>Chrysothamnus depressus</i>                | 0.119          | 0.375 | 8.67      | 30        | 0.087          | 0.242 | 11.33     | 40        |
| <i>Cercocarpus montanus</i>                   | 0.104          | 0.214 | 10.00     | 30        | 0.261          | 0.596 | 10.67     | 30        |
| <i>Arabis fendleri</i>                        | 0.054          | 0.109 | 20.67     | 90        | 0.026          | 0.043 | 16.67     | 70        |
| <i>Phlox hoodii</i>                           | 0.031          | 0.062 | 10.67     | 40        | 0.030          | 0.051 | 14.00     | 40        |
| <i>Cordylanthus wrightii</i>                  | 0.029          | 0.033 | 27.33     | 80        | 0.080          | 0.087 | 33.33     | 90        |
| <i>Eriogonum racemosum</i>                    | 0.028          | 0.037 | 20.00     | 80        | 0.053          | 0.059 | 22.00     | 80        |
| <i>Gutierrezia sarothrae</i>                  | 0.021          | 0.065 | 4.00      | 10        | 0.023          | 0.073 | 4.67      | 10        |
| <i>Comandra umbellata</i>                     | 0.020          | 0.050 | 10.00     | 30        | 0.033          | 0.083 | 10.00     | 30        |
| <i>Descurainia sophia</i> <sup>a</sup>        | 0.008          | 0.016 | 10.67     | 40        | 0              | 0     | 0         | 0         |
| <i>Bromus tectorum</i> <sup>a</sup>           | 0.007          | 0.011 | 6.67      | 50        | 0.001          | 0.002 | 2.00      | 20        |
| <i>Ceratocephala testiculata</i> <sup>a</sup> | 0.005          | 0.009 | 10.00     | 50        | 0              | 0     | 0         | 0         |
| <i>Sisymbrium altissimum</i> <sup>a</sup>     | 0.002          | 0.005 | 3.33      | 10        | 0.002          | 0.006 | 4.67      | 20        |
| <i>Carduus nutans</i> <sup>a</sup>            | 0.001          | 0.002 | 2.00      | 30        | 0.001          | 0.002 | 2.67      | 40        |
| <i>Taraxacum officinale</i> <sup>a</sup>      | 0.001          | 0.001 | 1.33      | 20        | 0              | 0     | 0         | 0         |
| <i>Erodium cicutarium</i> <sup>a</sup>        | <0.001         | 0.001 | 0.67      | 10        | 0              | 0     | 0         | 0         |

Note: Species are arranged in descending order by their 2007 cover.

<sup>a</sup> Nonnative species.

ranges between 1.5 and 3.5) and evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) both increased (Margalef 1972). On the scale of the ecological site, species richness decreased from 57 to 49 species, and beta diversity (a measure of within site heterogeneity, generally ranging between 1 and 5) increased. Fourteen species observed in the plots in 2007 were not observed in 2008, while six new species were observed in the plots in 2008 (see Appendix A). When these indices were recalculated using only native species, all decreased in value, except evenness, which increased.

## Trees

Trees were not remeasured in 2008. However, canopy closure was measured for the first time. Mean canopy closure was 50.8% with a standard deviation of 15.6.

**Table 3. Species diversity metrics for all species and for native species only.**

| Metric                   | 2007  |         | 2008  |         |
|--------------------------|-------|---------|-------|---------|
|                          | Mean  | (SD)    | Mean  | (SD)    |
| <b>All species</b>       |       |         |       |         |
| <b>Plot</b>              |       |         |       |         |
| Plot richness            | 19.2  | (5.1)   | 18.2  | (4.16)  |
| Shannon diversity        | 1.346 | (0.347) | 1.506 | (0.264) |
| Evenness                 | 0.458 | (0.101) | 0.524 | (0.092) |
| <b>Ecological site</b>   |       |         |       |         |
| Ecological site richness | 57    |         | 49    |         |
| Beta diversity           | 3.132 |         | 2.849 |         |
| <b>Native species</b>    |       |         |       |         |
| <b>Plot</b>              |       |         |       |         |
| Plot richness            | 17.1  | (4.8)   | 17.3  | (4.0)   |
| Shannon diversity        | 1.324 | (0.334) | 1.500 | (0.262) |
| Evenness                 | 0.469 | (0.101) | 0.531 | (0.093) |
| <b>Ecological site</b>   |       |         |       |         |
| Ecological site richness | 50    |         | 45    |         |
| Beta diversity           | 3.106 |         | 2.761 |         |

## Soil stability and hydrologic function

The crew monitored the amount of exposed soil in two ways: cover estimates of ground surface features in quadrats and measurements of basal gaps along transects. As expected, most changes in the surface features were relatively small (table 4 and fig. 4). Two features, however, showed surprisingly large changes: undifferentiated crust increased in cover from 18.46% to 26.83%, and cyanobacteria decreased in cover from 8.65% to 3.71% (table 4 and fig. 4). The basal gap data between the two years are not comparable: In 2008, we made a slight change in the protocol to include the measurement of smaller gaps. Data from both years is presented in table 5 and figure 5. The 2008 data will be used as the baseline data to which the data of subsequent years will be compared.

## Discussion

The 2007 and 2008 data presented here indicate relatively minor changes in the vegetation and surface features on the Loamy Mesa Top Pinyon-Juniper ecological site. Changes in cover of functional groups and of individual species were relatively minor, especially considering the high variability, as evidenced by the large standard deviations. Of the seven nonnative species found in the plots in 2007, four species (*Ceratocephala testiculata*, *Descurainia sophia*, *Erodium cicutarium*, and *Taraxacum officinale*) were not found in 2008, and one species (*Bromus tectorum*) decreased in cover and frequency. These species are considered winter annuals, and the wet May in 2007 likely facilitated their growth that year (fig. 6). Two exotics that grow later in the year, *Sisymbrium altissimum* and *Carduus nutans*,

**Table 4. Cover of ground surface features.**

| Surface feature              | 2007             |         | 2008     |         |
|------------------------------|------------------|---------|----------|---------|
|                              | Mean (%)         | (SD)    | Mean (%) | (SD)    |
| Live plant base              | 3.02             | (1.81)  | 3.34     | (1.62)  |
| Dead woody base              | 0.28             | (0.39)  | 1.04     | (1.73)  |
| Dead herbaceous base         | n/a <sup>a</sup> | n/a     | 0.75     | (0.44)  |
| Bare soil                    | 0.84             | (0.74)  | 1.14     | (1.08)  |
| Duff and litter              | 58.16            | (13.62) | 56.72    | (9.31)  |
| Undifferentiated crust       | 18.46            | (12.86) | 26.83    | (10.27) |
| Moss                         | 2.11             | (1.69)  | 1.47     | (1.54)  |
| Lichen                       | 0.15             | (0.26)  | 0.14     | (0.19)  |
| Cyanobacteria                | 8.65             | (4.65)  | 3.71     | (4.72)  |
| Fine gravel (0.2 cm- 2cm)    | 0.01             | (0.01)  | 0.02     | (0.03)  |
| Coarse gravel (2cm – 7.5 cm) | 0.06             | (0.10)  | 0.06     | (0.11)  |
| Cobble (7.5 cm – 25 cm)      | 0.14             | (0.42)  | 0.02     | (0.04)  |
| Stone, bedrock (>25 cm)      | 0.00             | (0.00)  | 0.00     | (0.00)  |
| Woody debris                 | 1.42             | (0.76)  | 1.80     | (0.90)  |

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

<sup>a</sup> Dead herbaceous base cover was not measured in 2007.

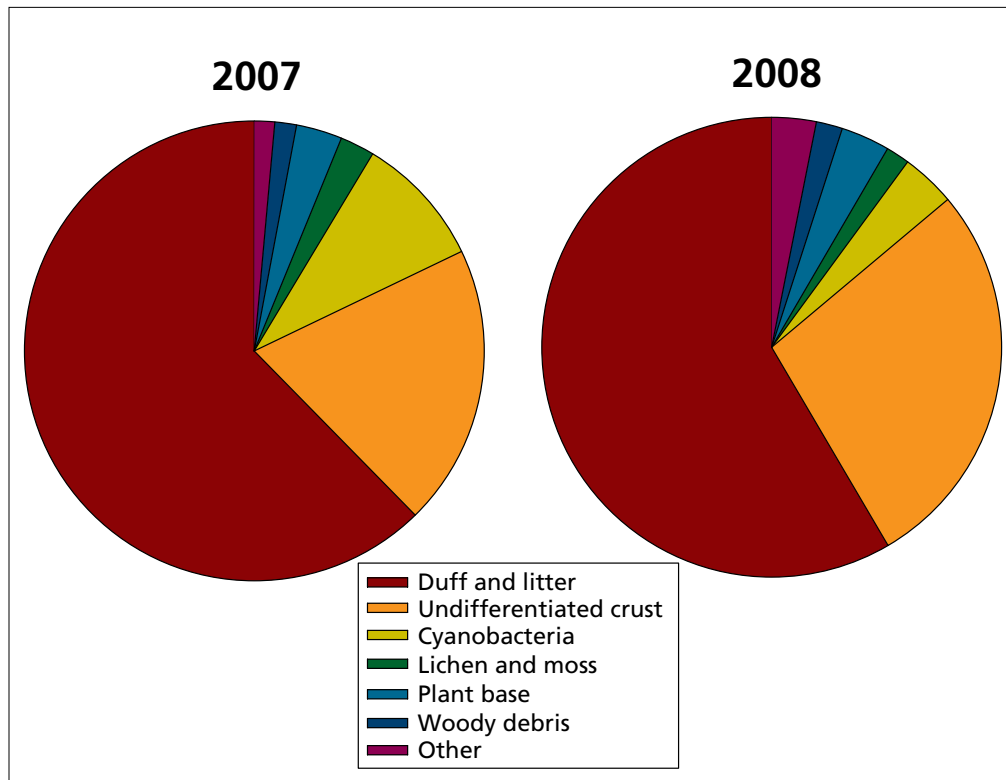


**Figure 4.** Mean cover of ground surface features in 2007 and 2008.

**Table 5. Number of basal gaps, gap size, and percentage of total transect length comprised by gaps in 2007 and 2008.**

| Metric                                   | 2007  |         | 2008  |        |
|------------------------------------------|-------|---------|-------|--------|
|                                          | Mean  | (SD)    | Mean  | (SD)   |
| Gap number                               | 52.8  | (21.2)  | 124.1 | (52.8) |
| Median gap size (cm)                     | 188.9 | (105.6) | 83.0  | (59.8) |
| Percent of transect in gaps              | 97.6  | (0.1)   | 96.7  | (1.6)  |
| Percent of transect in gaps $\geq 50$ cm | 95.6  | (0.2)   | 89.1  | (5.9)  |

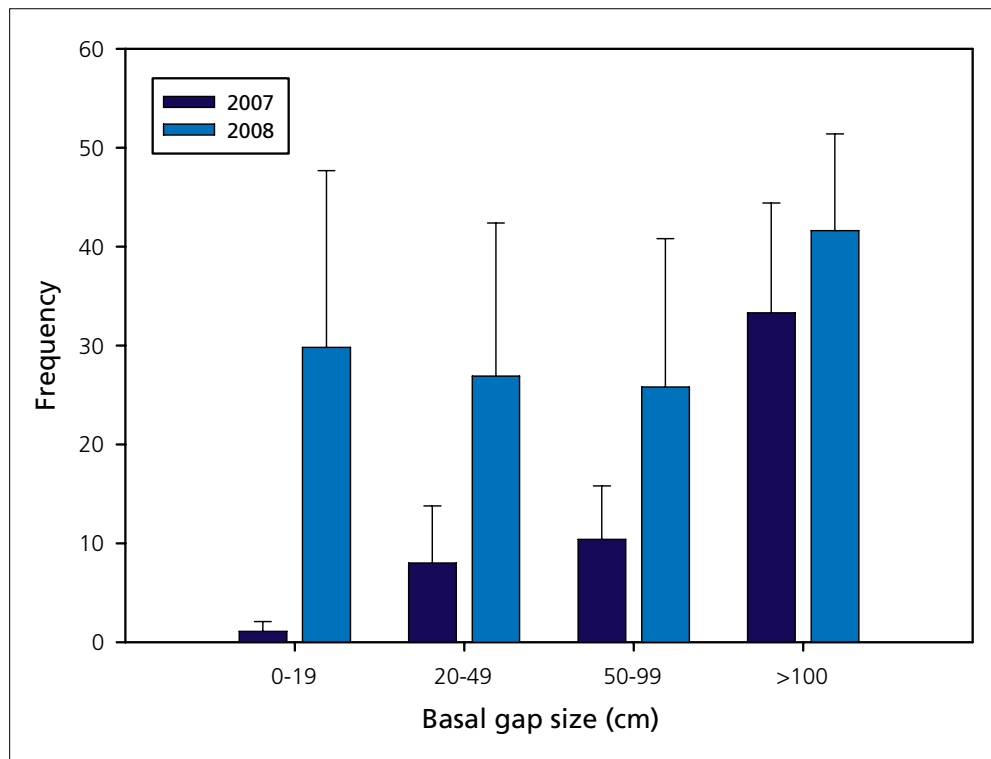


**Figure 5.** The frequency distribution of basal gap sizes in 2007 and 2008. Error bars represent one standard deviation.

did not change in cover between years, but they increased in frequency.

Plot richness, ecological site richness, and beta diversity decreased, but Shannon diversity and evenness increased slightly. The increase in Shannon diversity and evenness probably resulted from the disappearance of several species with low cover, thus making cover slightly more equal among species. The decrease in plot richness and beta diversity suggests that the mean loss of the species per plot made the plots slightly more similar to one another in composition.

Cover of undifferentiated crust cover increased substantially while mean cyanobacteria cover decreased. These changes may be attributable to how ground surface features appear in wet conditions versus dry conditions. When the ground surface is wet, cyanobacteria are much more visible, and undifferentiated crust becomes more difficult to distinguish from bare soil. Because of the strong

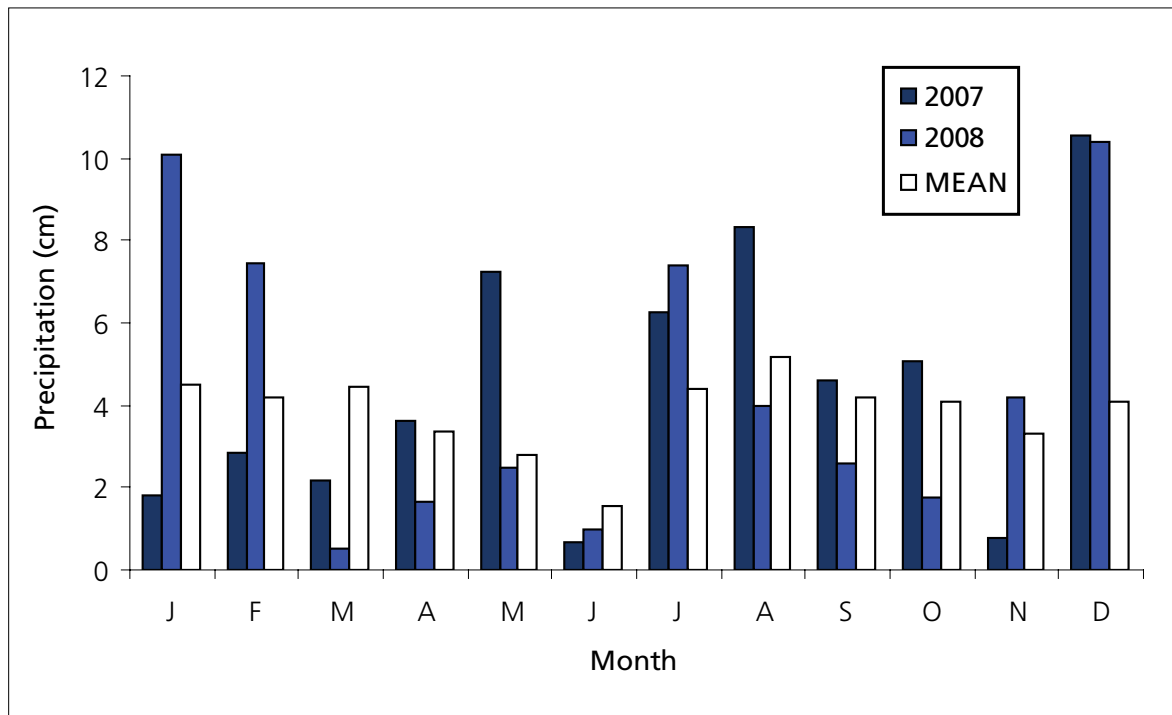


**Figure 6.** Monthly precipitation in 2007 and 2008 and the average precipitation (1922-2009) at Mesa Verde National Park (WRCC 2009).

August monsoon in 2007 (fig. 6), many of the plots that year were sampled during or shortly after precipitation events. The crew may have underestimated the cover of undifferentiated crust during the wet conditions of 2007, and underestimated the cover of cyanobacteria during the drier conditions in 2008.

We stress that the differences noted between years are not indicative of any trend, since trends cannot be determined with only two years of sampling, nor should they be interpreted as being ecologically significant. Differences are due to ecological variability, such as annual climatic fluctuations, or sampling errors inherent in the field sampling process. Cover estimation may vary among individuals (and crews), similar species may occasionally be mis-identified, and the location of the quadrats will vary slightly from year to year. We strive to minimize these errors by ensuring that transect lines are as straight as possible, quadrats are placed correctly, and field crews are trained continuously on species identification and cover estimation.

The SCPN Upland Crew plans to sample the quadrats and gap intercept transects annually for 3-5 years to determine the range of variability for key metrics. Power analysis will then be used to determine the total number of plots necessary to detect change in the key metrics. A temporal sampling design will then be implemented, with the installation of additional plots in subsequent years. Each year's data will be compared to the previously collected data to analyze changes through time in vegetation composition and structure and in soil stability and hydrologic function. Trend analyses will be conducted once sufficient data have been collected.

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## Appendix A

Complete species list with foliar cover and frequency values for 2007 and 2008.

| Species                                       | Common name                 | Family           | 2007             |                    | 2008             |                    |
|-----------------------------------------------|-----------------------------|------------------|------------------|--------------------|------------------|--------------------|
|                                               |                             |                  | Foliar cover (%) | Plot frequency (%) | Foliar cover (%) | Plot frequency (%) |
| <i>Achnatherum hymenoides</i>                 | Indian ricegrass            | Poaceae          | 0.009            | 10                 | 0.017            | 20                 |
| <i>Amelanchier utahensis</i>                  | Utah serviceberry           | Rosaceae         | 0.002            | 10                 | 0.002            | 10                 |
| <i>Androsace septentrionalis</i>              | pygmy rock jasmine          | Primulaceae      | <.001            | 10                 | 0                | 0                  |
| <i>Antennaria rosea</i>                       | rosy pussytoes              | Asteraceae       | 0.001            | 10                 | 0.001            | 10                 |
| <i>Arabis fendleri</i>                        | Fendler's rockcress         | Brassicaceae     | 0.054            | 90                 | 0.026            | 70                 |
| <i>Arabis holboellii</i>                      | Holboell's rockcress        | Brassicaceae     | 0.001            | 10                 | 0.001            | 10                 |
| <i>Artemisia tridentata</i>                   | basin big sagebrush         | Asteraceae       | 0.760            | 10                 | 1.028            | 10                 |
| <i>Astragalus</i> sp.                         | milkvetch                   | Fabaceae         | 0.008            | 50                 | 0.044            | 70                 |
| <i>Bromus tectorum</i> <sup>a</sup>           | cheatgrass                  | Poaceae          | 0.007            | 50                 | 0.001            | 20                 |
| <i>Carduus nutans</i> <sup>a</sup>            | nodding thistle             | Asteraceae       | 0.001            | 30                 | 0.001            | 40                 |
| <i>Ceratocephala testiculata</i> <sup>a</sup> | curvseed butterwort         | Ranunculaceae    | 0.005            | 50                 | 0                | 0                  |
| <i>Cercocarpus montanus</i>                   | birchleaf mountain mahogany | Rosaceae         | 0.104            | 30                 | 0.261            | 30                 |
| <i>Chenopodium album</i>                      | lambquarters                | Chenopodiaceae   | 0.004            | 50                 | 0.002            | 40                 |
| <i>Chenopodium leptophyllum</i>               | narrowleaf goosefoot        | Chenopodiaceae   | 0                | 0                  | 0.001            | 10                 |
| <i>Chrysothamnus depressus</i>                | longflower rabbitbrush      | Asteraceae       | 0.119            | 30                 | 0.087            | 40                 |
| <i>Comandra umbellata</i>                     | bastard toadflax            | Santalaceae      | 0.020            | 30                 | 0.033            | 30                 |
| <i>Cordylanthus wrightii</i>                  | Wright's bird's beak        | Scrophulariaceae | 0.029            | 80                 | 0.080            | 90                 |
| <i>Dalea</i> sp.                              |                             | Fabaceae         | 0.001            | 10                 | 0                | 0                  |
| <i>Descurainia sophia</i> <sup>a</sup>        | herb sophia                 | Brassicaceae     | 0.008            | 40                 | 0                | 0                  |
| <i>Draba reptans</i>                          | Carolina draba              | Brassicaceae     | 0.017            | 60                 | 0                | 0                  |
| <i>Echinocereus</i> sp.                       | hedgehog cactus             | Cactaceae        | 0.001            | 10                 | 0                | 0                  |
| <i>Elymus elymoides</i>                       | squirreltail                | Poaceae          | 0.019            | 40                 | 0.022            | 40                 |
| <i>Erigeron divergens</i>                     | spreading fleabane          | Asteraceae       | 0.006            | 10                 | 0.011            | 20                 |
| <i>Eriogonum racemosum</i>                    | redroot buckwheat           | Polygonaceae     | 0.028            | 80                 | 0.053            | 80                 |

**Appendix A, continued.**

|                                        |                           |                  |       |     |       |     |
|----------------------------------------|---------------------------|------------------|-------|-----|-------|-----|
| <i>Eriogonum umbellatum</i>            | sulfur-flowered buckwheat | Polygonaceae     | 0.002 | 30  | 0.007 | 30  |
| <i>Erodium cicutarium</i> <sup>a</sup> | stork's bill              | Geraniaceae      | <.001 | 10  | 0     | 0   |
| <i>Escobaria vivipara</i>              | spiny star                | Cactaceae        | <.001 | 10  | <.001 | 10  |
| <i>Gutierrezia sarothrae</i>           | broom snakeweed           | Asteraceae       | 0.021 | 10  | 0.023 | 10  |
| <i>Hesperostipa comata</i>             | needle and thread         | Poaceae          | 0     | 0   | 0.013 | 10  |
| <i>Heterotheca villosa</i>             | hairy false goldenaster   | Asteraceae       | 0.001 | 20  | 0.002 | 10  |
| <i>Ipomopsis aggregata</i>             | scarlet gilia             | Polemoniaceae    | <.001 | 10  | 0     | 0   |
| <i>Iris missouriensis</i>              | western blue flag         | Iridaceae        | 0     | 0   | <.001 | 10  |
| <i>Koeleria macrantha</i>              | prairie junegrass         | Poaceae          | 0.013 | 30  | 0.035 | 40  |
| <i>Lappula occidentalis</i>            | flatspine stickseed       | Boraginaceae     | 0.001 | 10  | 0     | 0   |
| <i>Lepidium montanum</i>               | mountain pepperweed       | Brassicaceae     | 0.001 | 10  | 0     | 0   |
| <i>Lesquerella rectipes</i>            | straight bladderpod       | Brassicaceae     | 0.004 | 10  | 0.011 | 20  |
| <i>Lupinus ammophilus</i>              | sand lupine               | Fabaceae         | 0.002 | 40  | 0.165 | 70  |
| <i>Lupinus argenteus</i>               | silvery lupine            | Fabaceae         | <.001 | 10  | 0.006 | 40  |
| <i>Machaeranthera canescens</i>        | hoary tansyaster          | Asteraceae       | 0.009 | 60  | 0.020 | 70  |
| <i>Opuntia</i> spp.                    | prickly pear              | Cactaceae        | 0.636 | 90  | 0.496 | 90  |
| <i>Packera multilobata</i>             | lobeleaf groundsel        | Asteraceae       | <.001 | 10  | <.001 | 10  |
| <i>Pedicularis centranthera</i>        | dwarf lousewort           | Scrophulariaceae | 0.001 | 20  | 0.024 | 30  |
| <i>Penstemon barbatus</i>              | beardlip penstemon        | Scrophulariaceae | 0.017 | 60  | 0.016 | 70  |
| <i>Penstemon linarioides</i>           | toadflax penstemon        | Scrophulariaceae | 0.462 | 100 | 0.527 | 100 |
| <i>Peraphyllum ramosissimum</i>        | squaw apple               | Rosaceae         | <.001 | 10  | 0.002 | 10  |
| <i>Petradoria pumila</i>               | rock goldenrod            | Asteraceae       | 0.158 | 50  | 0.165 | 50  |
| <i>Phlox gracilis</i>                  | slender phlox             | Polemoniaceae    | 0.009 | 20  | 0     | 0   |
| <i>Phlox hoodii</i>                    | Hood's phlox              | Polemoniaceae    | 0.031 | 40  | 0.030 | 40  |
| <i>Phlox longifolia</i>                | longleaf phlox            | Polemoniaceae    | 0.002 | 10  | 0.003 | 20  |
| <i>Phoradendron juniperinum</i>        | juniper mistletoe         | Viscaceae        | 0     | 0   | 0.002 | 10  |
| <i>Poa fendleriana</i>                 | muttongrass               | Poaceae          | 4.596 | 100 | 4.042 | 100 |
| <i>Polygonum douglasii</i>             | Douglas' knotweed         | Polygonaceae     | 0.013 | 100 | 0.019 | 100 |
| <i>Purshia tridentata</i>              | antelope bitterbrush      | Rosaceae         | 1.297 | 90  | 1.398 | 90  |

*Appendix A, continued.*

|                                          |                       |              |       |    |       |    |
|------------------------------------------|-----------------------|--------------|-------|----|-------|----|
| <i>Quercus gambelii</i>                  | Gambel oak            | Fagaceae     | 0.005 | 10 | 0.010 | 10 |
| <i>Sisymbrium albisimum</i> <sup>a</sup> | tumblemustard         | Brassicaceae | 0.002 | 10 | 0.002 | 20 |
| <i>Sphaeralcea coccinea</i>              | scarlet globemallow   | Malvaceae    | 0.001 | 10 | 0.003 | 10 |
| <i>Sporobolus cryptandrus</i>            | sand dropseed         | Poaceae      | 0     | 0  | <.001 | 10 |
| <i>Streptanthus cordatus</i>             | heartleaf twistflower | Brassicaceae | <.001 | 10 | <.001 | 10 |
| <i>Taraxacum officinale</i> <sup>a</sup> | common dandelion      | Asteraceae   | 0.001 | 20 | 0     | 0  |
| <i>Tragopogon dubius</i> <sup>a</sup>    | yellow salsify        | Asteraceae   | 0     | 0  | <.001 | 10 |
| <i>Yucca baccata</i>                     | banana yucca          | Agavaceae    | 0.651 | 80 | 0.628 | 70 |
| Unknown MEVE08032007-1                   |                       |              | <.001 | 10 | 0     | 0  |
| Unknown MEVE08032007-2                   |                       |              | <.001 | 10 | 0     | 0  |

<sup>a</sup> Nonnative species.