



Integrated Upland Vegetation and Soils Monitoring for Bandelier National Monument

2012 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2016/1037



ON THE COVER

SCPN field crew collaborate with park fire effects crew members to monitor upland vegetation at Bandelier NM.
Photography by NPS.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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1 Introduction

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 for making decisions and working with other agencies and the public to protect park ecosystems. 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 Bandelier National Monument (BAND): the Mesa Top Pinyon-Juniper and Mixed Conifer ecological sites. For the sake of simplicity we refer to these as ecological sites, but they do not exactly conform to the concept of ecological site as described by the U.S. Natural Resource Conservation Service (NRCS). 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 sampled 31 plots in the Mixed Conifer ecological site and 6 plots in the Mesa Top Pinyon-Juniper ecological site. We will only report data for the Mixed Conifer ecological site here.

The Mixed Conifer ecological site is characterized as a high elevation forest. It faces numerous threats, including changing fire regimes, climate change, and invasion by nonnative species. In 2012 we established and sampled 31 plots in this ecological site following the Las Conchas Fire of 2011. In this report, we document monitoring activities in the Mixed Conifer ecological site of BAND during the 2012 field season. We report these data which represent baseline conditions for our monitoring of this ecological site.

2 Methods

2.1 Study area and plot establishment

Instead of establishing new plots, we took advantage of the fire effects plots that the BAND fire ecology program had established in mixed conifer forests in the park. Many of these plots had been established more than 20 years ago and therefore provided historical tree data. This also reduced the need for additional monitoring debris (rebar and tree tags) within wilderness area boundaries. Using high resolution aerial photography, we eliminated plots that had experienced high and moderately high burn severity from the Las Conchas Fire, which we defined as greater than 50% overstory tree mortality or more than 75% scorched needles. In addition, the integrated upland crew conducted a ground-based ecological site assessment, rejecting sites that (1) deviated substantially from the ecological site, (2) had moderately high or high burn severity, (3) contained another form of major disturbance, or (4) were within 100 meters of an existing plot. In establishing 31 plots (Figure 1), we rejected 16 fire effects plots—9 plots had moderately high to high burn severity and 7 plots were within 100 meters of an existing plot.

2.2 Field methods

In mid and late July, the SCPN integrated upland crew established and sampled 31 monitoring plots in the Mixed Conifer ecological site at BAND. We had planned to establish and sample plots in the site in 2011 but the Las Conchas Fire prohibited this. For the majority of the ecological sites that we monitor, we sample a subset of the plots for 3 consecutive years to quantify the annual variability of species cover and frequency, as well as other key metrics. In the Mixed Conifer ecological site, however, we established and sampled all 31 plots in the first year due to the expected post-fire response. We felt it was important to establish a solid baseline one year following the fire because annual variation due to precipitation in the three years following the fire would likely be overshadowed by the vegetative growth response to the fire.

Using the existing fire effects plots gives us access to the history of tree data that had been collected by the fire ecology program at BAND. We used a nested quadrat design to capture a more complete representation of the

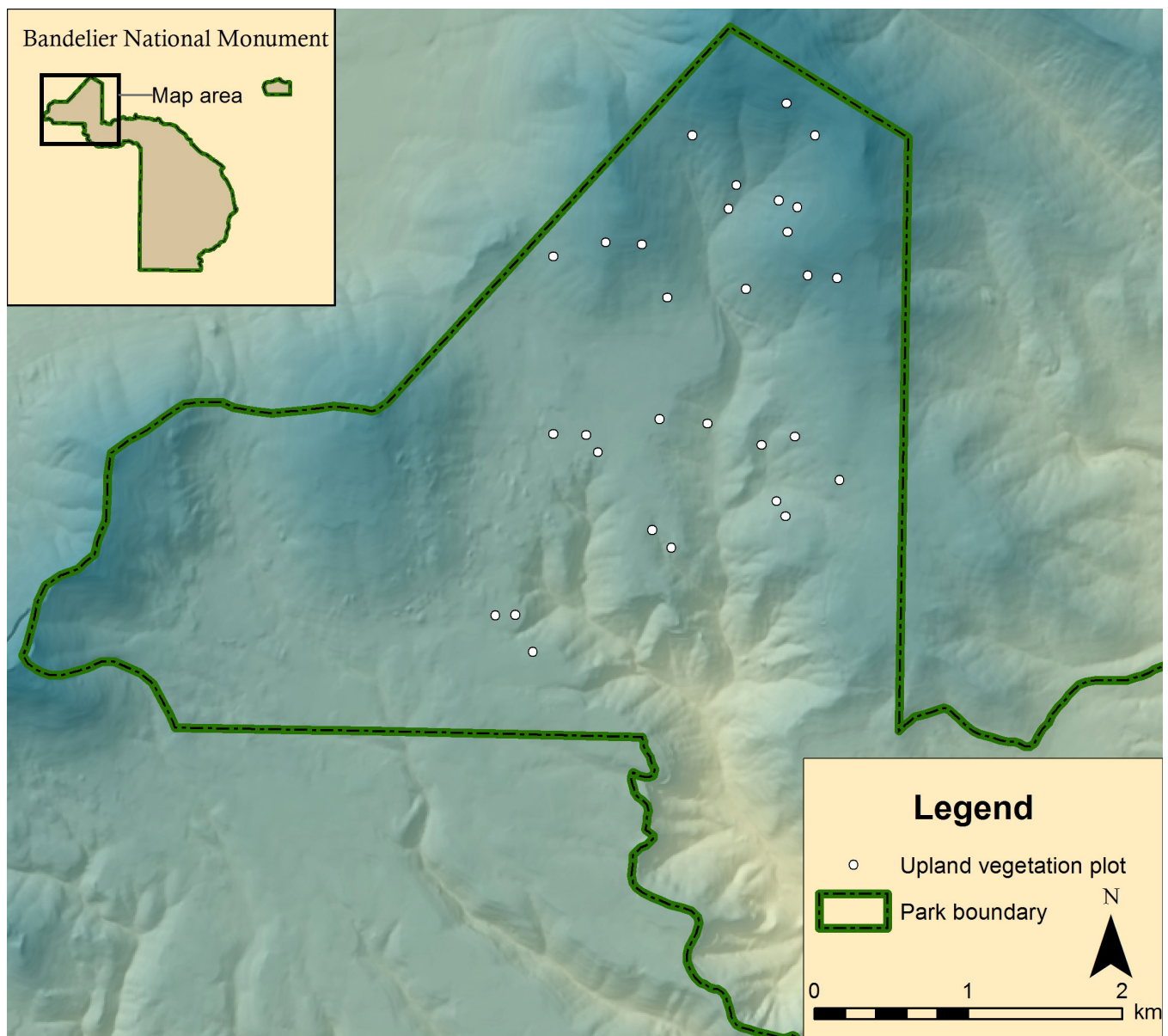


Figure 1. SCPN established 31 plots in the Mixed Conifer ecological site at Bandelier NM in 2012.

herbaceous and shrub layer. We modified our standard methodology to better integrate our sampling methods for the fire effects plots and our integrated upland plots. We conducted all sampling within the 20 x 50 m fire effects plots, rather than our standard 71 x 71 m plots. Using the two 50 m edges of the fire effects plots, we sampled only 2 transects per plot, rather than the standard 3. Otherwise, data collection for the shrub and herbaceous vegetation and soil proceeded according to the SCPN integrated upland monitoring protocol (DeCoster et al. 2012). In each transect, we collected data for shrub and herbaceous species cover and frequency, functional group cover, soil surface feature cover, and tree canopy closure. Field methodology for these procedures is provided in detail in DeCoster et al. (2012). Tree data (overstory, sapling and seedlings) were collected by the BAND fire effects crew in 2012. Field methodology for how the tree data was collected is provided in detail in the NPS Fire Monitoring Handbook (National Park Service 2003).

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 of the

2 transects. 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% to <5%, 5% to <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.

2.2.2 Overstory trees, saplings, and seedlings

In 2012, tree data were primarily collected by the fire effects crew. Diameter at breast height (dbh) was measured for all overstory trees (>15 cm) in the 20 x 50 m (0.1 ha) plots. Diameters for saplings (stems ≤ 15 cm), also referred to as “poles”, were measured in a nested sub-plot that measured 20 x 25 m (0.05 ha). Seedlings (stem < 2.5 cm) were tallied by species and height class in the 10 x 25 m sub-plot. The SCPN upland crew measured canopy closure at 5 points along each transect using a spherical densiometer.

2.2.3 Soil stability and hydrologic function

We estimated the percent cover of soil surface features in the 1 m² quadrats along transects, and recorded cover in 1 of 12 cover classes. Because erosion is generally not considered a problem in the mixed conifer ecosystem, except in areas with high severity burns, we did not collect basal gap data or soil aggregate stability data.

2.3 Data summary

We summarized data at the level of the plot, the sample unit for summary and analysis. We calculated the ecological site mean and standard deviation for most metrics from the means of the 31 plots. Plot frequency, ecological site richness and beta diversity, however, are not calculated from plot means.

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

For shrub and herbaceous vegetation, we estimated percent foliar cover for each species from the cover class midpoints; e.g., 7.5% for cover class 5% to <10%. Mean percent foliar cover was calculated for each plot, and then the mean and standard deviation were calculated for the ecological site. Mean cover and standard deviation of functional groups and soil surface features were calculated in a similar fashion. Species frequency was calculated for quadrats (mean percentage of the 10 m² quadrats per plot in which the species occurred) and for plots (percentage of plots in which the species occurred).

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 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 and generally ranges between 1.5 and 3.5:

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

where p_i is the abundance of each species.

(3) Species evenness (E) ranges from 0 to 1 and is a measure of the degree to which all species are equal in abundance:

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

(4) Beta diversity (β) is a measure of within-ecological site heterogeneity and generally ranges between 1 and 5:

$$\beta = S_e / (S_p - 1)$$

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 plot richness, Shannon diversity, and evenness for each plot. The mean and standard deviation were then calculated 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

We calculated basal area (total area of the tree cross-sections) for living trees and snags (standing dead overstory trees) for each overstory tree species in m²/ha. Mean diameter of living overstory trees was also calculated for each species and for all trees. Tree density was calculated for all species and all size classes for overstory living trees, snags (standing dead overstory trees), saplings and seedlings in stems/ha. (Note the seedling size class definition differs slightly from those we typically use). Each metric was calculated for each plot, and the mean and standard deviation were then calculated for the ecological site.

We did not include tree data for *Quercus gambelii* and *Acer glabrum*, as we considered these two species shrubs and measured them in the quadrats. At BAND we also used an expanded sapling plot and calculated sapling density based on this sapling subplot (20 x 25 m, or 0.05 ha), which is twice the size of our standard sampling plot.

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

3 Results

3.1 Shrub and herbaceous vegetation

Perennial grasses/graminoids and forbs dominated the understory of the Mixed Conifer ecological site. The mean total live foliar cover was 11.99% (Table 1 and Figure 2). Mean foliar cover of perennial grasses and graminoids was 6.28% and the mean foliar cover of forbs was 4.81%. Mean foliar cover of shrubs was 0.86%. Mean foliar cover of annual grasses was 0.01%. There were no cacti or succulents. Mean covers of standing dead herbaceous and standing dead shrubs were 2.07% and 0.13% respectively. Standard deviations were moderately large, indicating large among plot variability.

Carex spp. (sedges) was the dominant graminoid, with a mean foliar cover of 1.800% (Table 2 and Figure 3). This taxon consisted of several species that were hard to distinguish in the field, including *Carex geophila*, *Carex occidentalis* and other mesic forest species. Other abundant graminoids were the perennial grasses *Poa pratensis* (Kentucky bluegrass), *Bromus ciliatus* (fringed brome), *Koeleria macrantha* (prairie junegrass), *Danthonia parryi* (Parry's oatgrass), *Festuca thurberi* (Thurber's fescue) and *Elymus elymoides* (squirreltail). Dominant forbs included *Senecio eremophilus* (desert ragwort), *Lathyrus lanszwertii* (Nevada pea), *Achillea millefolium* (western yarrow) and *Fragaria virginiana* (Virginia strawberry). The dominant shrub was *Juniperus communis* (common juniper).

Many of the dominant perennial grasses and graminoids had high plot and quadrat frequencies, indicating they were abundant at multiple scales and were relatively evenly dispersed. The forbs and shrubs were more variable; for example, *Juniperus communis* had low frequency, despite a relatively high mean foliar cover

Table 1. Foliar cover groups for 31 plots in the Mixed Conifer ecological site at Bandelier NM, 2012. 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	Mean (%)	SD
Total live foliar cover	11.99	7.64
Perennial grasses	6.28	4.09
Annual grasses	<0.01	0.03
Forbs	4.81	3.44
Shrubs	0.86	1.52
Cacti/succulents	0	0
Standing dead herbaceous	2.07	1.73
Standing dead shrubs	0.13	0.17

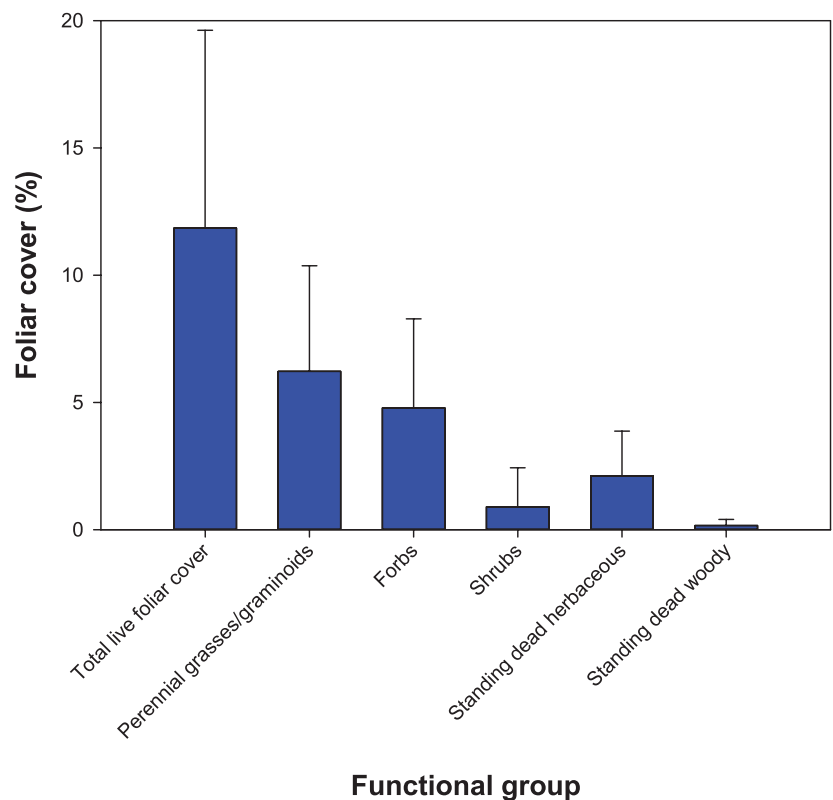


Figure 2. Mean percent foliar cover of functional groups for 31 plots in the Mixed Conifer ecological site at Bandelier NM, 2012. Annual grasses are not included. Error bars represent 1 standard deviation.

Table 2. Foliar cover and frequency of the 14 most abundant shrub and herbaceous species, and all nonnative species for 31 sites in the Mixed Conifer ecological site at Bandelier NM, 2012.

	Foliar cover		Frequency (%)	
	Mean (%)	SD	Quadrat	Plot
Dominant species				
<i>Carex spp.</i>	1.800	1.407	92.6	100.0
<i>Poa pratensis</i>	1.291	1.844	53.2	90.3
<i>Senecio eremophilus</i>	1.282	2.736	35.5	54.8
<i>Bromus ciliatus</i>	0.839	0.913	67.7	96.8
<i>Juniperus communis</i>	0.494	1.251	7.4	22.6
<i>Lathyrus lanszwertii</i>	0.484	0.706	77.4	96.8
<i>Koeleria macrantha</i>	0.482	0.706	54.5	96.8
<i>Danthonia parryi</i>	0.398	1.032	22.6	64.5
<i>Achillea millefolium</i>	0.390	0.538	49.4	80.6
<i>Fragaria virginiana</i>	0.375	0.804	48.1	71.0
<i>Festuca thurberi</i>	0.354	0.550	28.7	61.3
<i>Erigeron speciosus</i>	0.261	0.589	23.6	51.6
<i>Antennaria marginata</i>	0.224	0.876	13.2	22.6
<i>Elymus elymoides</i>	0.218	0.364	34.8	80.6
Nonnative species				
<i>Poa pratensis</i>	1.291	1.844	53.2	90.3
<i>Taraxacum officinale</i>	0.205	0.353	43.9	96.8
<i>Poa compressa</i>	0.045	0.176	3.6	9.7
<i>Trifolium repens</i>	0.039	0.151	5.2	22.6
<i>Phleum pratense</i>	0.014	0.068	2.6	16.1
<i>Trifolium pratense</i>	0.011	0.060	1.3	3.2
<i>Tragopogon dubius</i>	0.005	0.011	2.9	22.6
<i>Cirsium vulgare</i>	0.002	0.010	1.61	6.5
<i>Verbascum thapsus</i>	0.002	0.007	1.6	9.7
<i>Lactuca serriola</i>	<0.001	0.002	0.6	3.2
<i>Sonchus asper</i>	<0.001	0.001	0.3	3.2
<i>Capsella bursa-pastoris</i>	<0.001	0.001	0.3	3.2

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

of 0.494%. This indicates a more patchy dispersal, with high cover where the species occurs. Most species had standard deviations that were greater than their means, indicating 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 12 nonnative species in the plots (Table 2). *Poa pratensis* (Kentucky bluegrass) was the most abundant with a mean foliar cover of 1.291%, and was found in 90.3% of the plots and 53.2% of the quadrats. *Taraxacum officinale* (common dandelion) had a foliar cover of 0.205%, and was found in 96.8% of the plots and 43.9% of the quadrats. Four species had mean foliar covers between 0.01% and 0.05%. Six species had mean foliar covers less than 0.01%.

Species diversity in this ecological site was moderately high at both the plot and the ecological site scale. Mean plot richness was 35.8 (Table 3). Shannon diversity was 2.42. Evenness was 0.68. On the scale of the ecological

Table 3. Species diversity metrics for all species and for native species only in 31 plots in the Mixed Conifer ecological site at Bandelier NM, 2012.

	Mean	SD
All species		
Plot		
Plot richness	35.8	9.1
Shannon diversity	2.42	0.49
Evenness	0.68	0.11
Ecological site		
Ecological site richness ^a	133	n/a
Beta diversity ^a	3.82	n/a
Native species		
Plot		
Plot richness	33.0	9.0
Shannon diversity	2.37	0.49
Evenness	0.68	0.11
Ecological site		
Ecological site richness ^a	121	n/a
Beta diversity ^a	3.79	n/a

^aEcological site richness and beta diversity values are not means, therefore standard deviations do not apply (n/a).

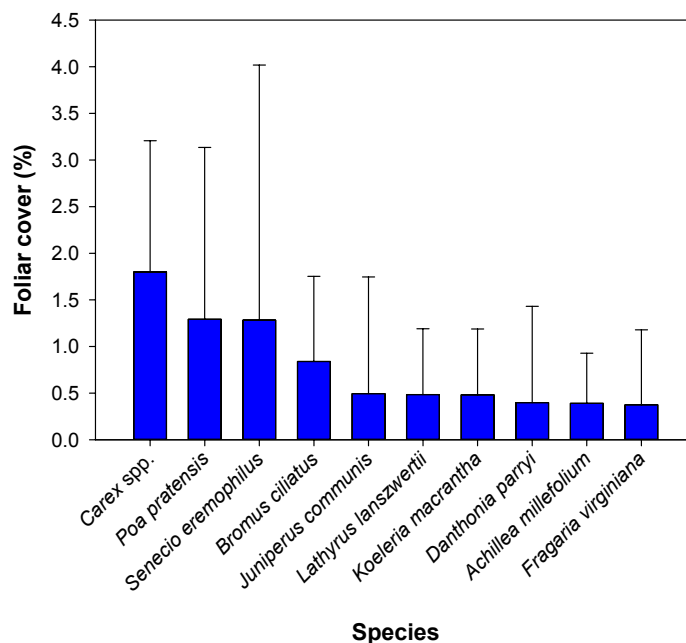


Figure 3. Mean percent foliar cover of the 10 most abundant shrub and herbaceous species for 31 plots in the Mixed Conifer ecological site at Bandelier NM in 2012. Error bars represent 1 standard deviation.

site, species richness was 133. Beta diversity was 3.82. When we calculated the metrics using only native species, all the metrics showed slight decreases except for evenness, which did not change.

3.2 Trees

We report tree density (stems/ha) by species for seedlings, saplings and overstory trees. We also report basal area for overstory trees by species, grouped as living trees or snags (Table 4). Mean plot living overstory density was 326.5 stems/ha, and mean plot overstory basal area was 32.35 m²/ha.

We found 6 tree species in the plots of the Mixed Conifer ecological site. *Pinus ponderosa* (ponderosa pine) was the most abundant with a basal area of 15.18 m²/ha and a density of 123.2 stems/ha, followed by *Pseudotsuga menziesii* (Douglas fir) which had a basal area of 9.04 m²/ha and a density of 110.3 stems/ha (Table 4 and Figure 4). *Populus tremuloides* (quaking aspen), *Abies concolor* (white fir) and *Pinus flexilis* (limber pine) were of intermediate abundance, with basal areas ranging between 1 and 4 m²/ha and densities ranging between 10 and 50 stems/ha. *Picea engelmannii* (Engelmann spruce) had low abundance with a basal area of 0.15 m²/ha and a density of 1.0 stems/ha. *Pseudotsuga menziesii* had the greatest abundance of snags with a basal area of 5.24 m²/ha and a density of 41.6 stems/ha. Standard deviations for all species were relatively large, indicating high among-plot variability.

The size distribution of the individual species revealed several patterns (Figure 5). For *Pseudotsuga menziesii* and *Abies concolor* the highest densities were in the smallest size classes and density decreased as size increased. *Populus tremuloides* and *Pinus flexilis* showed fairly even distributions. *Pinus ponderosa* had a unimodal distribution,

Table 4. Mean density, mean basal area, and mean diameter of trees in 31 plots of the Mixed Conifer ecological site at Bandelier NM, 2012 .

Species	Seedling ^a density (stems/ha)	Sapling ^a density (stems/ha)	Living 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)
<i>Abies concolor</i>	166.5	36.1	33.9	14.5	3.04	0.81	32.2
<i>Picea engelmannii</i>	1.3	0.7	1.0	0	0.15	0	36.6
<i>Pinus flexilis</i>	2.6	9.0	11.6	2.9	1.25	0.12	34.6
<i>Pinus ponderosa</i>	10.3	6.5	123.2	20.0	15.18	1.54	43.6
<i>Populus tremuloides</i>	3264.5	14.2	46.5	19.4	3.68	1.31	28.3
<i>Pseudotsuga menziesii</i>	46.5	67.7	110.3	41.6	9.04	5.24	34.4
All species	3492.9	134.2	326.5	98.4	32.35	9.02	35.2

^aSize 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.

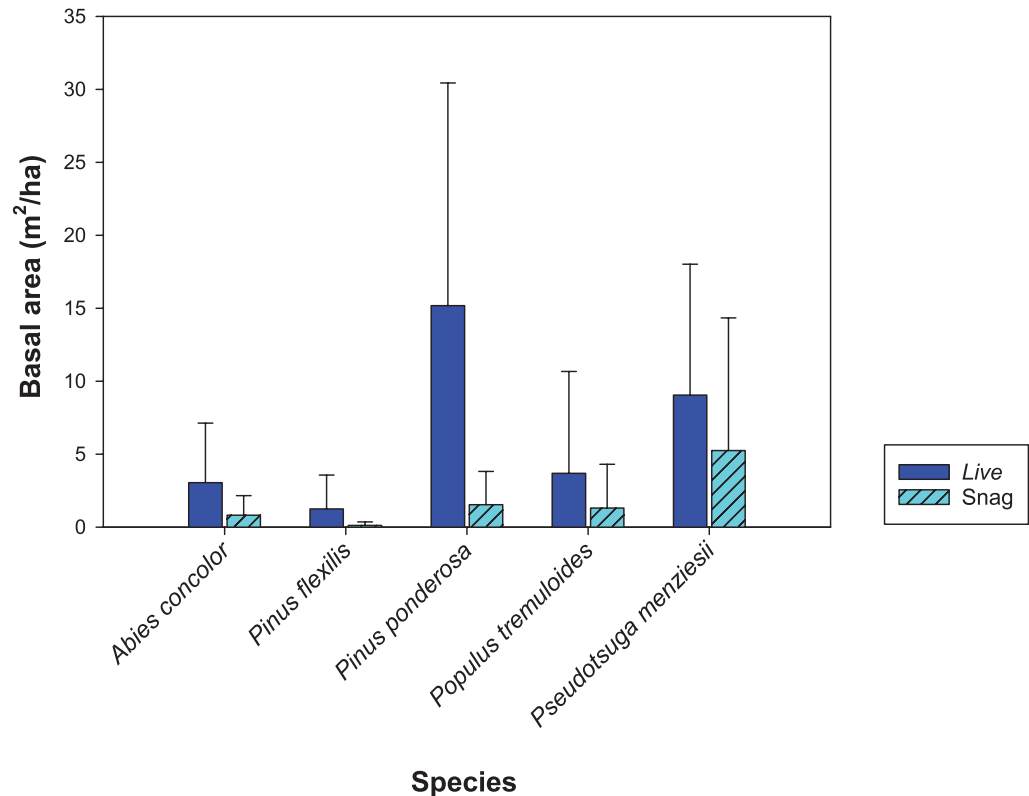


Figure 4. Mean basal area for living trees and snags, by species for 31 plots in the Mixed Conifer ecological site at Bandelier NM, 2012. Error bars represent 1 standard deviation. *Picea engelmannii* is not included.

with the greatest density in the 25–35 cm size class. *Pinus ponderosa* and *Pseudotsuga menziesii* had a few individuals greater than 75 cm in diameter. Large standard deviations indicate high among-plot variability. The mean diameters of species ranged between 43.6 for *Pinus ponderosa* and 28.3 for *Populus tremuloides* (Table 4).

Sapling and seedling densities provide measures of forest regeneration, and indicate a potential for change in species composition. The mean plot sapling density was 134.2 stems/ha (Table 4). *Pseudotsuga menziesii* had the

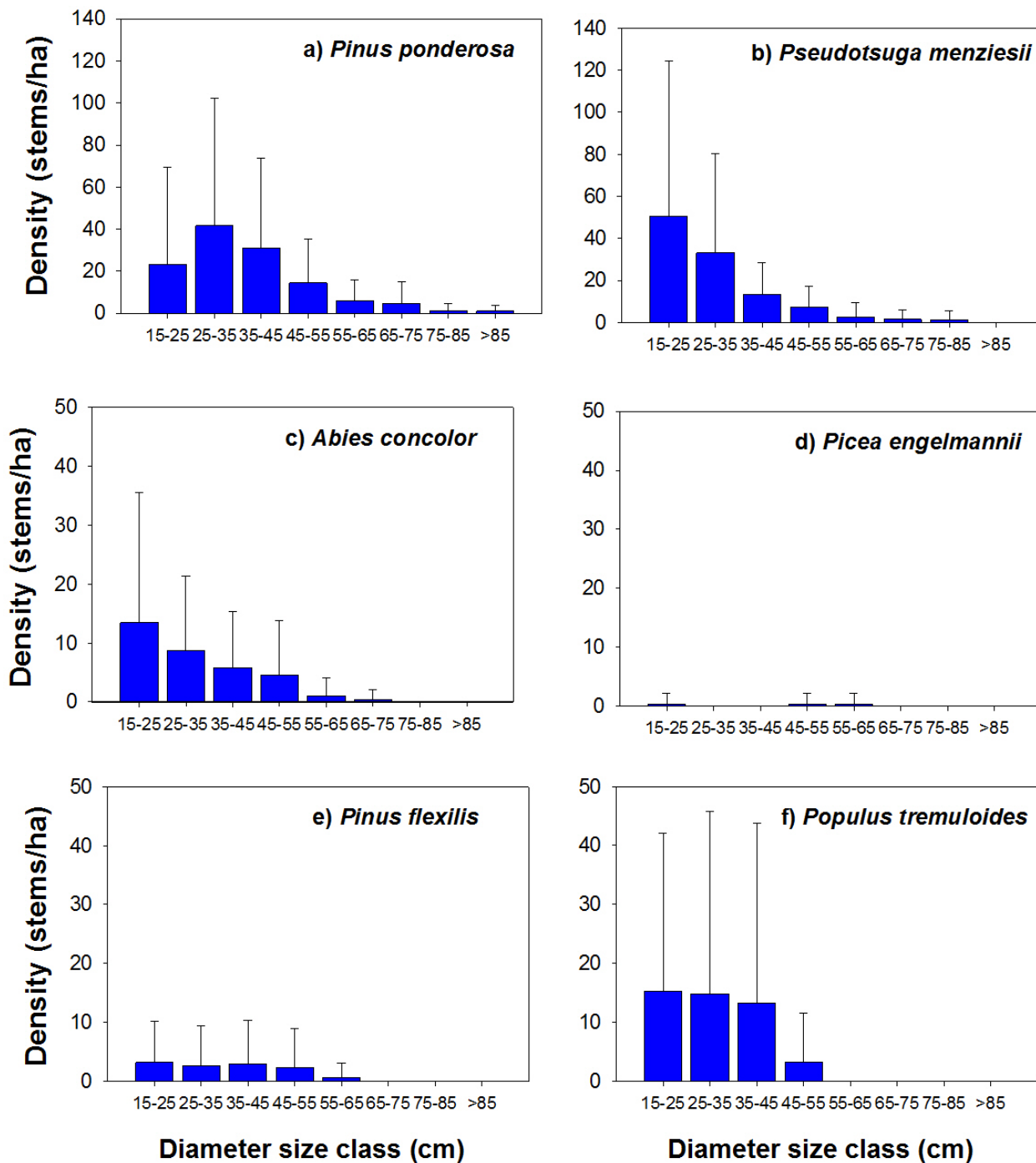


Figure 5. Size structure of living overstory tree species, by species and diameter size class for 31 plots in the Mixed Conifer ecological site at Bandelier NM, 2012. Error bars represent 1 standard deviation. Note the scales on the vertical axes vary for graphs a&b, and differ from graphs c–f.

highest sapling density followed by *Abies concolor*. *Picea engelmannii*, *Pinus flexilis*, *Pinus ponderosa*, and *Populus tremuloides* all had low densities. The distribution of saplings among size classes were fairly even among species (Figure 6). *Populus tremuloides* had no saplings in the smallest size class, and *Picea engelmannii* had low density with individuals only in the intermediate size class. The standard deviations were quite large, indicating large among-plot variability.

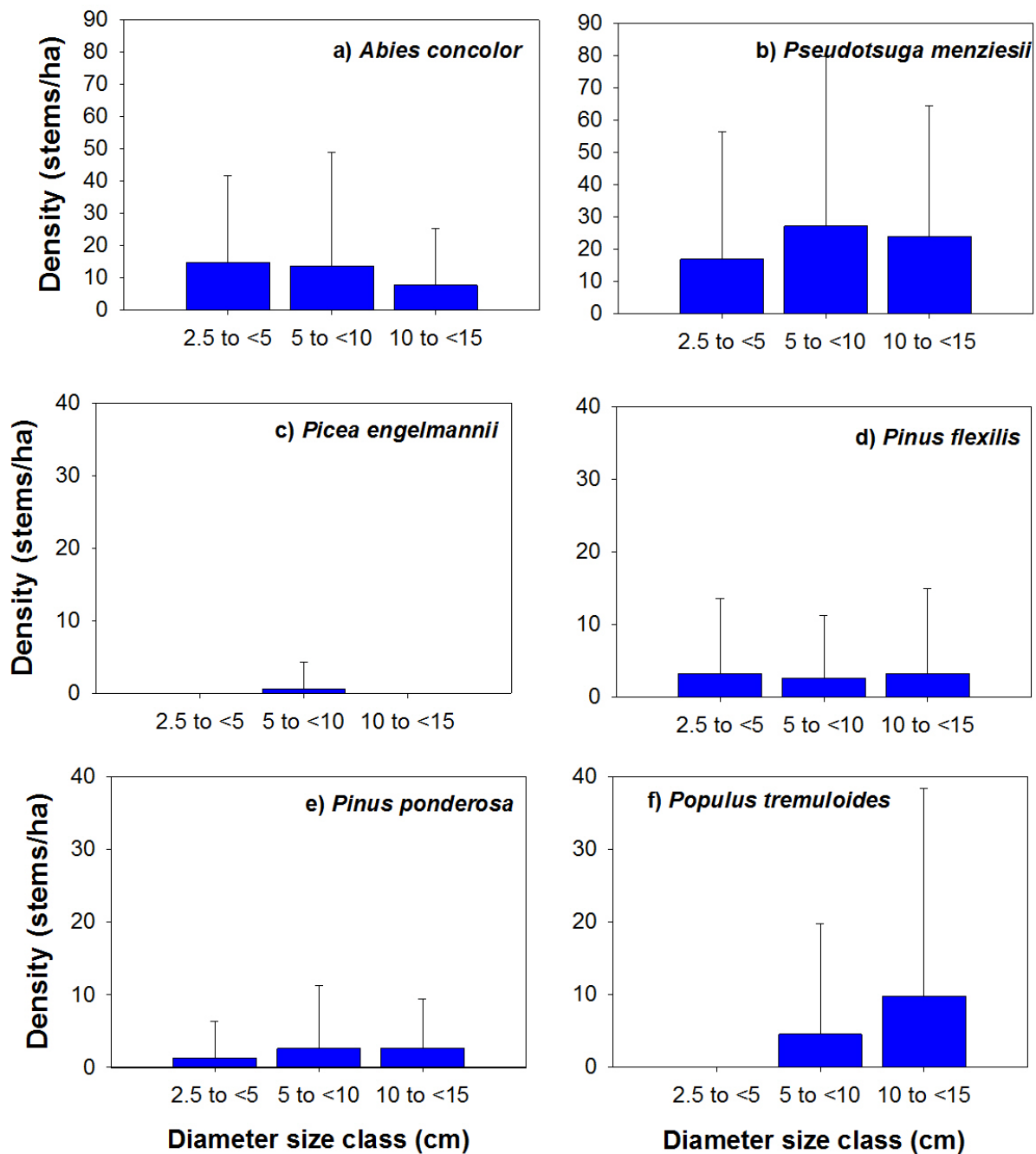


Figure 6. Mean density of saplings by diameter size class for the species in the 31 plots of the Mixed Conifer ecological site at Bandelier NM, 2012. Error bars represent 1 standard deviation. *Note the scales on the vertical axes vary.*

The seedling layer was dominated by *Populus tremuloides* with a mean density of 3264.5 stems /ha (Table 4). *Abies concolor* and *Pseudotsuga menziesii* had moderate seedling densities; *Picea engelmannii*, *Pinus flexilis*, and *Pinus ponderosa* had very low densities. The three most abundant species had the highest seedling densities in the intermediate size class (Figure 7). It is interesting to note that the seedling densities of *Pseudotsuga menziesii* and *Pinus flexilis* were smaller than their sapling densities. Large standard deviations indicate large among plot variability.

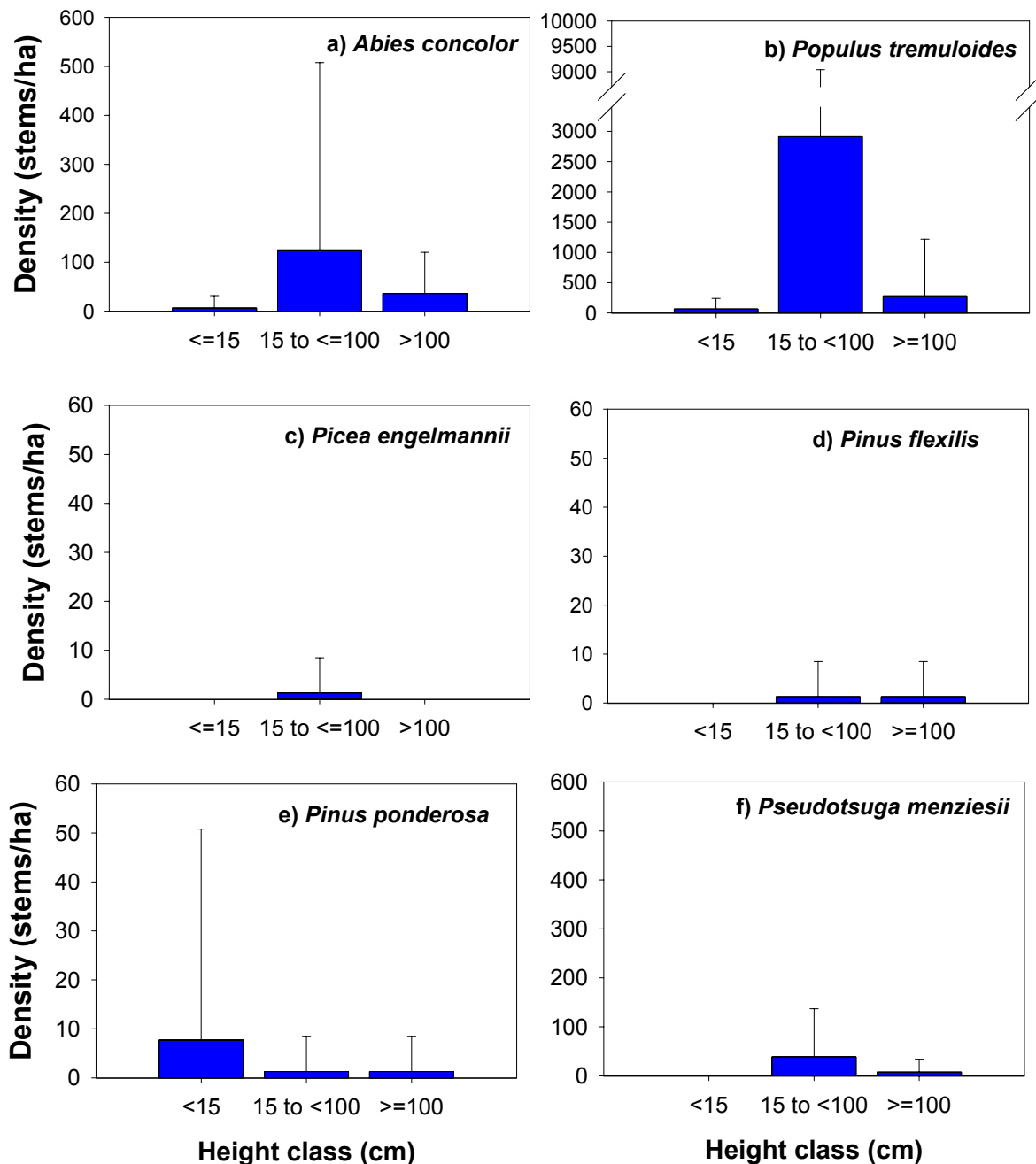


Figure 7. Mean density of seedlings in by height class for each species in the 31 plots of the Mixed Conifer ecological site at Bandelier NM, 2012. Error bars represent 1 standard deviation. *Note the scales on the vertical axes vary.*

The size structure of the overstory and saplings of all species demonstrates a unimodal distribution, with the classes between 15 cm and 35 cm having the highest densities (Figure 8). Sapling densities are much lower than would be found in an inverse distribution. Standard deviations are quite large, indicating large among-plot variability. Mean canopy closure was 45.0% with a standard deviation of 18.0.

3.3 Soil surface features

We used cover estimates of soil surface features in quadrats to characterize the soil surface environment.

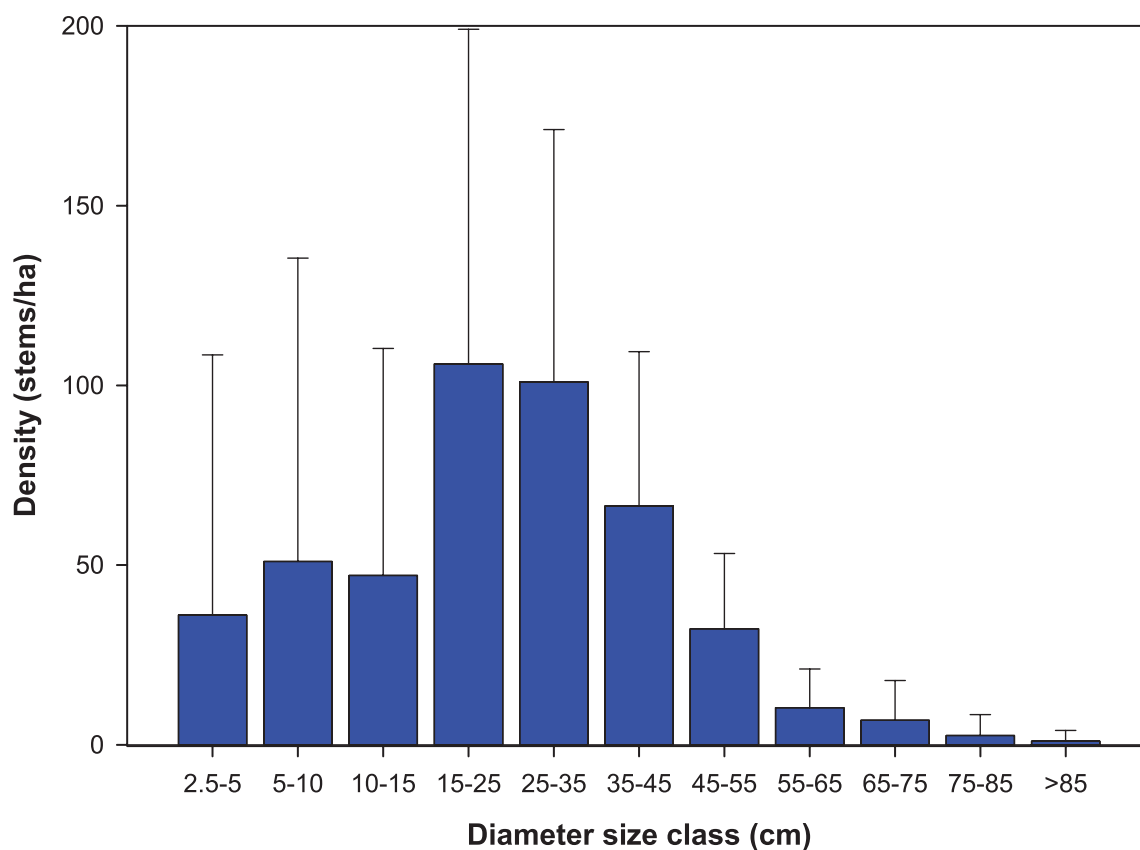


Figure 8. Mean density of living overstory trees and saplings by diameter size class in the 31 plots of the Mixed Conifer ecological site at Bandelier NM, 2012. Error bars represent 1 standard deviation.

Table 5. Cover of soil surface features for 31 plots in the Mixed Conifer ecological site at Bandelier NM, 2012.

Soil surface feature	Mean (%)	SD
Live plant base	2.32	2.41
Dead woody base	0.56	1.00
Dead herbaceous base	0.68	0.67
Bare soil	6.45	6.51
Duff/litter	76.46	9.67
Undifferentiated crust	0.28	1.57
Moss	1.11	1.99
Lichen	0.03	0.07
Cyanobacteria	0.02	0.13
Fine gravel (0.2 to <2 cm)	0.75	1.32
Coarse gravel (2 to <7.5 cm)	0.69	0.96
Cobble (7.5 to <25 cm)	1.79	2.80
Stone/bedrock (>25 cm)	2.46	2.37
Woody debris	2.62	1.92

Note: The soil surface features do not add up to 100% because the calculations were made from cover class midpoints.

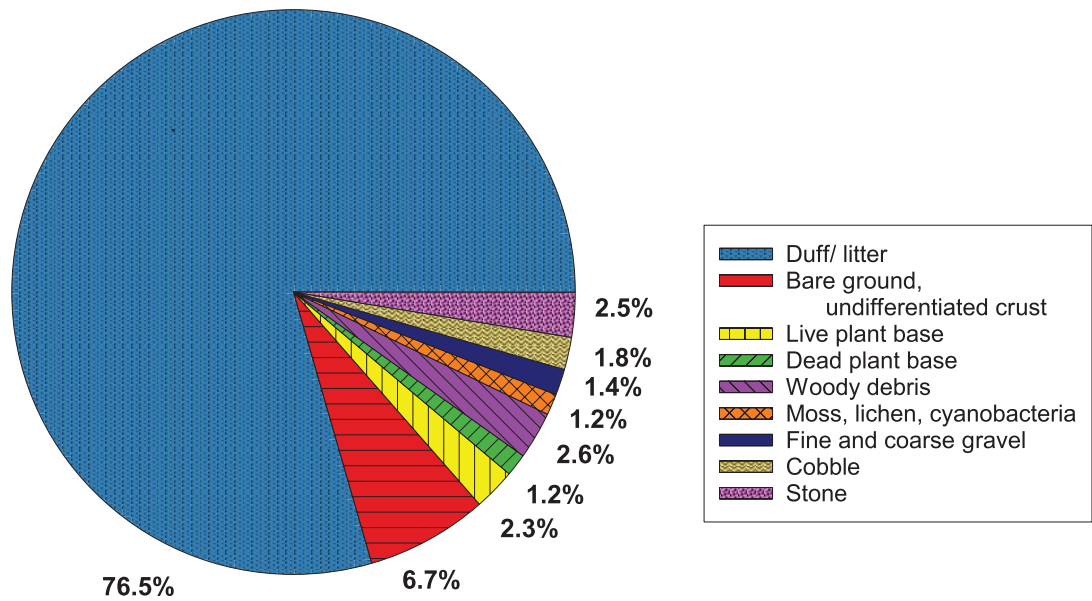


Figure 9. Mean percent cover of soil surface features in 31 plots of the Mixed Conifer ecological site at Bandelier NM in 2012. Several features have been combined for greater readability.

(continued from page 11) Duff/litter was the dominant soil surface feature with a mean cover of 76.46% (Table 5). Bare soil had a mean cover of 6.45%. Live plant base, moss, cobble, stone/bedrock and woody debris had mean covers between 1 and 3%. All other soil surface features had mean covers of less than 1%. There was moderate variation in the cover of many of the features. The mean percent cover of the categories is summarized in Figure 9. Some of the categories have been combined.

4 Discussion

The data summarized in this report represent the first year of baseline conditions for monitoring vegetation and soils in the Mixed Conifer ecological site at BAND.

The shrub/herbaceous vegetation was co-dominated by perennial grasses/graminoids and forbs. Dominant perennial grasses/graminoids included *Carex* spp., *Poa pratensis*, *Bromus ciliatus*, *Koeleria macrantha*, *Festuca thurb-eri* and *Elymus elymoides*. Dominant forbs included *Senecio eremophilus*, *Lathyrus lanszwertii*, *Achillea millefolium* and *Fragaria virginica*. The most abundant shrub was *Juniperus communis*. Twelve nonnative species occurred in the plots. *Poa pratensis* was the most abundant and *Taraxacum officinale* was moderately abundant. Species diversity was moderately high both on the scale of the plot and on the scale of the ecological site.

The overstory was dominated by *Pseudotsuga menziesii* and *Pinus ponderosa*, with moderate abundance of *Populus tremuloides*, *Abies concolor* and *Pinus flexilis*, and low abundance of *Picea engelmannii*. Sapling density and seedling density were low, with the exception of *Populus tremuloides* seedlings. The surface feature data indicate litter and duff dominated the soil surface.

In 2011, the Las Conchas Fire impacted large portions of the forests and woodlands across BAND, with high severity impacts in many areas. Although we did not sample in sites of high or moderately high severity many of our plots were directly impacted by the fire at a low or moderately low severity. Wildland fire, including prescribed fire, is not an uncommon occurrence in mixed conifer forests of the Jemez Mountains, and many of these plots had previously burned.

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 plots with each revisit, there are designs that provide some balance between repeated visit to individual plots and the total number of site 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 mixed conifer plots into 3 panels, and sample 2 of the panels every other year (Table 6). We will begin using our panel design in 2014, sampling panels A and B. In 2016 we will sample plots in panels B and C.

Table 6. Proposed panel revisit design for the Mixed Conifer ecological site at Bandelier NM, with number of plots visited in each panel for each year. There are 10 plots in each of the panels for a total of 30 plots in the ecological site. A “-” indicates no revisit planned.

Panel	Year											
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
A	10	-	-	-	10	-	10	-	-	-	10	-
B	10	-	10	-	-	-	10	-	10	-	-	-
C	-	-	10	-	10	-	-	-	10	-	10	-
Sum/yr	20	0	20	0	20	0	20	0	20	0	20	0

5 Literature cited

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Appendix A: Complete species list for plots sampled in the Mixed Conifer ecological site at Bandelier National Monument

Table A1. Shrub and herbaceous species with mean foliar cover and plot frequency for plots in the Mixed Conifer ecological site at BAND.

Species	Common name	Family	Mean foliar cover (%)	Mean plot frequency (%)
<i>Acer glabrum</i>	Rocky Mountain maple	Aceraceae	0.002	12.90
<i>Achillea millefolium</i>	western yarrow	Asteraceae	0.390	80.65
<i>Agoseris aurantiaca</i>	orange agoseris	Asteraceae	0.001	6.45
<i>Agoseris glauca</i>	pale agoseris	Asteraceae	<0.001	3.23
<i>Agrostis scabra</i>	rough bentgrass	Poaceae	0.025	38.71
<i>Allium cernuum</i>	nodding onion	Liliaceae	0.014	58.06
<i>Amaranthus</i> sp.	pigweed	Amaranthaceae	<0.001	3.23
<i>Androsace septentrionalis</i>	pygmy rock jasmine	Primulaceae	0.015	38.71
<i>Anticlea elegans</i>	mountain deathcamas	Liliaceae	0.003	12.90
<i>Antennaria marginata</i>	white margin pussytoes	Asteraceae	0.224	22.58
<i>Antennaria parvifolia</i>	small leaf pussytoes	Asteraceae	0.134	74.19
<i>Arceuthobium divaricatum</i>	pinyon dwarf mistletoe	Viscaceae	0.001	3.23
<i>Arctostaphylos uva-ursi</i>	kinnikinnick	Ericaceae	0.015	9.68
<i>Arenaria lanuginosa</i>	spreading sandwort	Caryophyllaceae	0.013	41.94
<i>Artemisia franserioides</i>	ragweed sagebrush	Asteraceae	0.069	19.35
<i>Artemisia ludoviciana</i>	white sagewort	Asteraceae	0.009	25.81
<i>Boechera</i> sp.	rockcress	Brassicaceae	0.006	12.90
<i>Bromus</i> sp.	brome	Poaceae	<0.001	3.23
<i>Bromus ciliatus</i>	fringed brome	Poaceae	0.839	96.77
<i>Bromus porteri</i>	Porter brome	Poaceae	<0.001	3.23
<i>Calamagrostis stricta</i>	slimstem reedgrass	Poaceae	<0.001	3.23
<i>Campanula rotundifolia</i>	bluebell bellflower	Campanulaceae	0.076	70.97
<i>Capsella bursa-pastoris</i>	shepherd's purse	Brassicaceae	<0.001	3.23
<i>Carex</i> spp.	sedge	Cyperaceae	1.788	100.00
<i>Castilleja miniata</i>	giant red Indian paintbrush	Scrophulariaceae	0.002	9.68
<i>Cerastium arvense</i>	field chickweed	Caryophyllaceae	0.030	51.61
<i>Chamerion angustifolium</i>	fireweed	Onagraceae	0.007	6.45
<i>Chenopodium</i> spp.	goosefoot	Chenopodiaceae	0.050	51.61
<i>Chenopodium capitatum</i>	blite goosefoot	Chenopodiaceae	0.015	35.48
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0.001	6.45
<i>Cirsium</i> spp.	thistle	Asteraceae	0.002	6.45
<i>Cirsium pallidum</i>	pale thistle	Asteraceae	0.008	19.35
<i>Cirsium vulgare</i>	bull thistle	Asteraceae	0.002	6.45
<i>Clematis columbiana</i>	rock clematis	Ranunculaceae	0.035	32.26
<i>Conyza canadensis</i>	Canadian horseweed	Asteraceae	0.001	19.35
<i>Corydalis aurea</i>	golden corydalis	Fumariaceae	0.165	58.06

Table A1. (continued) Shrub and herbaceous species with mean foliar cover and plot frequency for plots in the Mixed Conifer ecological site at BAND.

Species	Common name	Family	Mean foliar cover (%)	Mean plot frequency (%)
<i>Cystopteris reevesiana</i>	Reeves' bladderfern	Dryopteridaceae	0.001	6.45
<i>Danthonia parryi</i>	Parry's oatgrass	Poaceae	0.392	64.52
<i>Descurainia incana</i>	mountain tansymustard	Brassicaceae	0.003	12.90
<i>Draba reptans</i>	Carolina draba	Brassicaceae	<0.001	3.23
<i>Dracocephalum parviflorum</i>	American dragonhead	Lamiaceae	0.002	9.68
<i>Elymus elymoides</i>	squirreltail	Poaceae	0.215	80.65
<i>Elymus glaucus</i>	blue wildrye	Poaceae	0.051	45.16
<i>Eragrostis spectabilis</i>	purple lovegrass	Poaceae	0.001	3.23
<i>Erigeron</i> spp.	fleabane	Asteraceae	0.005	3.23
<i>Erigeron divergens</i>	spreading fleabane	Asteraceae	<0.001	3.23
<i>Erigeron flagellaris</i>	trailing fleabane	Asteraceae	0.010	16.13
<i>Erigeron philadelphicus</i>	Philadelphia fleabane	Asteraceae	0.067	41.94
<i>Erigeron speciosus</i>	aspen fleabane	Asteraceae	0.261	51.61
<i>Erysimum capitatum</i>	sanddune wallflower	Brassicaceae	<0.001	6.45
<i>Festuca</i> spp.	fescue	Poaceae	0.030	16.13
<i>Festuca arizonica</i>	Arizona fescue	Poaceae	0.008	16.13
<i>Festuca sororia</i>	ravine fescue	Poaceae	0.103	19.35
<i>Festuca thurberi</i>	Thurber's fescue	Poaceae	0.354	61.29
<i>Fragaria vesca</i>	woodland strawberry	Rosaceae	0.098	45.16
<i>Fragaria virginiana</i>	Virginia strawberry	Rosaceae	0.375	70.97
<i>Fraseria speciosa</i>	elkweed	Gentianaceae	0.001	3.23
<i>Galium aparine</i>	stickywilly	Rubiaceae	0.125	38.71
<i>Galium boreale</i>	northern bedstraw	Rubiaceae	0.023	16.13
<i>Geranium caespitosum</i>	piney-woods geranium	Geraniaceae	0.027	35.48
<i>Geranium richardsonii</i>	Richardson's geranium	Geraniaceae	0.131	51.61
<i>Goodyera oblongifolia</i>	western rattlesnake plantain	Orchidaceae	0.003	16.13
<i>Hackelia floribunda</i>	manyflower stickseed	Boraginaceae	0.001	3.23
<i>Heterotheca villosa</i>	hairy false goldenaster	Asteraceae	<0.001	3.23
<i>Heuchera parviflora</i>	little-leaf alumroot	Saxifragaceae	0.002	3.23
<i>Hieracium fendleri</i>	yellow hawkweed	Asteraceae	0.010	32.26
<i>Holodiscus dumosus</i>	rockspirea	Rosaceae	0.012	6.45
<i>Iris missouriensis</i>	western blue flag	Iridaceae	0.051	48.39
<i>Juniperus communis</i>	common juniper	Cupressaceae	0.490	22.58
<i>Koeleria macrantha</i>	prairie junegrass	Poaceae	0.480	96.77
<i>Lactuca serriola</i> ^a	prickly lettuce	Asteraceae	<0.001	3.23
<i>Lathyrus lanszwertii</i>	Nevada pea	Fabaceae	0.479	96.77
<i>Lithospermum incisum</i>	narrowleaf gromwell	Boraginaceae	0.002	3.23
<i>Maianthemum racemosum</i>	feathery false lily of the valley	Liliaceae	0.019	35.48
<i>Mertensia lanceolata</i>	lanceleaf bluebells	Boraginaceae	0.047	74.19
<i>Monarda fistulosa</i>	wild bergamot	Lamiaceae	0.006	9.68
<i>Muhlenbergia montana</i>	mountain muhly	Poaceae	0.133	19.35
<i>Muhlenbergia tricholepis</i>	pine dropseed	Poaceae	0.002	6.45
<i>Noccaea fendleri</i>	Fendler's pennycress	Brassicaceae	0.005	12.90

Table A1. (continued) Shrub and herbaceous species with mean foliar cover and plot frequency for plots in the Mixed Conifer ecological site at BAND.

Species	Common name	Family	Mean foliar cover (%)	Mean plot frequency (%)
<i>Oreochrysum parryi</i>	Parry's goldenrod	Asteraceae	0.089	41.94
<i>Orthilia secunda</i>	sidebells wintergreen	Pyrolaceae	0.001	6.45
<i>Oryzopsis asperifolia</i>	roughleaf ricegrass	Poaceae	0.037	22.58
<i>Osmorhiza depauperata</i>	blunt-fruit sweet-cicely	Apiaceae	0.028	45.16
<i>Oxalis violacea</i>	violet woodsorrel	Oxalidaceae	.001	12.90
<i>Packera fendleri</i>	Fendler's ragwort	Asteraceae	0.013	29.03
<i>Packera neomexicana</i>	New Mexico groundsel	Asteraceae	0.006	6.45
<i>Pedicularis grayi</i>	giant lousewort	Scrophulariaceae	0.001	3.23
<i>Penstemon barbatus</i>	beardlip penstemon	Scrophulariaceae	0.002	3.23
<i>Phleum pratense</i>	timothy	Poaceae	0.014	16.13
<i>Physocarpus monogynus</i>	mountain ninebark	Rosaceae	0.020	9.68
<i>Poa compressa</i>	Canada bluegrass	Poaceae	0.044	9.68
<i>Poa fendleriana</i>	muttongrass	Poaceae	0.146	87.10
<i>Poa pratensis</i>	Kentucky bluegrass	Poaceae	1.279	90.32
<i>Potentilla gracilis</i>	slender cinquefoil	Rosaceae	0.004	9.68
<i>Potentilla hippiana</i>	woolly cinquefoil	Rosaceae	0.119	77.42
<i>Potentilla norvegica</i>	Norwegian cinquefoil	Rosaceae	0.001	3.23
<i>Potentilla pulcherrima</i>	beautiful cinquefoil	Rosaceae	0.005	6.45
<i>Prunella vulgaris</i>	common selfheal	Lamiaceae	0.001	6.45
<i>Pseudocymopterus montanus</i>	alpine false springparsley	Apiaceae	0.042	74.19
<i>Pseudognaphalium</i> spp.	cudweed	Asteraceae	0.006	25.81
<i>Pteridium aquilinum</i>	western bracken fern	Dennstaedtiaceae	0.150	22.58
<i>Pterospora andromedea</i>	woodland pinedrops	Monotropaceae	<0.001	3.23
<i>Pyrola chlorantha</i>	green flowered wintergreen	Pyrolaceae	0.001	6.45
<i>Quercus gambelii</i>	Gambel oak	Fagaceae	0.082	45.16
<i>Rhus aromatica</i>	skunkbush sumac	Anacardiaceae	0.001	3.23
<i>Ribes inerme</i>	whitestem gooseberry	Grossulariaceae	0.003	6.45
<i>Ribes montigenum</i>	gooseberry currant	Grossulariaceae	<0.001	3.23
<i>Ribes wolfii</i>	Wolf's currant	Grossulariaceae	<0.001	3.23
<i>Robinia neomexicana</i>	New Mexico locust	Fabaceae	0.187	25.81
<i>Rosa woodsii</i>	Woods' rose	Rosaceae	0.052	54.84
<i>Rubus idaeus</i>	western red raspberry	Rosaceae	0.011	22.58
<i>Rubus parviflorus</i>	thimbleberry	Rosaceae	0.026	16.13
<i>Sambucus racemosa</i>	red elderberry	Caprifoliaceae	0.001	3.23
<i>Senecio bigelovii</i>	nodding ragwort	Asteraceae	0.002	3.23
<i>Senecio eremophilus</i>	desert ragwort	Asteraceae	1.282	54.84
<i>Senecio wootonii</i>	Wooton's ragwort	Asteraceae	0.152	38.71
<i>Silene scouleri</i>	simple campion	Caryophyllaceae	0.008	29.03
<i>Solidago</i> sp.	goldenrod	Asteraceae	0.005	3.23
<i>Solidago simplex</i>	Mount Albert goldenrod	Asteraceae	0.043	22.58
<i>Solidago speciosa</i>	showy goldenrod	Asteraceae	0.002	3.23
<i>Sonchus asper</i>	spiny sowthistle	Asteraceae	<0.001	3.23
<i>Symphyotrichum laeve</i>	smooth blue aster	Asteraceae	0.001	3.23

Table A1. (continued) Shrub and herbaceous species with mean foliar cover and plot frequency for plots in the Mixed Conifer ecological site at BAND.

Species	Common name	Family	Mean foliar cover (%)	Mean plot frequency (%)
<i>Taraxacum officinale</i> ^a	common dandelion	Asteraceae	0.205	96.77
<i>Thalictrum fendleri</i>	meadow-rue	Ranunculaceae	0.189	38.71
<i>Thermopsis montana</i>	mountain goldenbanner	Fabaceae	0.015	16.13
<i>Tragopogon dubius</i> ^a	yellow salsify	Asteraceae	0.005	22.58
<i>Trifolium pratense</i>	red clover	Fabaceae	0.011	3.23
<i>Trifolium repens</i>	white clover	Fabaceae	0.039	22.58
<i>Trisetum montanum</i>	Rocky Mountain trisetum	Poaceae	0.063	19.35
<i>Trisetum spicatum</i>	spike trisetum	Poaceae	0.001	3.23
<i>Verbascum thapsus</i> ^a	common mullein	Scrophulariaceae	0.002	9.68
<i>Vicia americana</i>	American vetch	Fabaceae	0.089	87.10
<i>Viola canadensis</i>	Canadian white violet	Violaceae	0.057	41.94

a nonnative species

Table A2. Tree species with mean basal area and plot frequency for plots in the Mixed Conifer ecological site at BAND.

Species	Common name	Family	Basal area (m ² /ha)	Plot frequency
<i>Abies concolor</i>	white fir	Pinaceae	3.05	70.97
<i>Picea engelmannii</i>	Engelmann spruce	Pinaceae	0.15	6.45
<i>Pinus flexilis</i>	limber pine	Pinaceae	1.25	38.71
<i>Pinus ponderosa</i>	ponderosa pine	Pinaceae	15.18	80.64
<i>Populus tremuloides</i>	quaking aspen	Salicaceae	3.68	64.52
<i>Pseudotsuga menziesii</i>	Douglas fir	Pinaceae	9.04	87.10

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