



# **Bandelier National Monument Mesa-top Pinyon-Juniper 2019 Data Summary**

## *Southern Colorado Plateau Network Integrated Upland Monitoring*

Natural Resource Data Series NPS/SCPN/NRDS—2020/1287



**ON THE COVER**

An example of a mesa-top pinyon-juniper monitoring plot at Bandelier National Monument.  
NPS photo

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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.

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## Executive Summary

This report presents a single-year snapshot of the data collected by the Southern Colorado Plateau Inventory and Monitoring Network (SCPN) in 2019 as part of integrated upland monitoring (IUM). Field crews collect data on soil stability and hydrologic function, biological soil crusts, and plant community characteristics, including abundance of functional groups, cover by species, richness and diversity, and frequency of nonnative species. In woodland and forested systems, density of seedlings, saplings and overstory tree species and canopy shading are measured. These data are summarized in a series of simple visualizations to provide a status overview for the year. Through this monitoring, SCPN seeks to increase understanding of upland systems and provide resource managers with valuable information they can use to help guide management decisions.

In 2019, IUM field crews sampled 21 plots in the mesa-top pinyon-juniper ecosystem at Bandelier National Monument. Nine additional plots were scheduled for sampling but were not able to be sampled, primarily due to logistical hurdles including the need to move camp several times to avoid construction at the campground (which took a lot of time out from sampling) and how difficult it has become to plan overnight backcountry trips with the loss of the Capulin base-camp cabin and mesa-top water cache. We may need to reconsider how many plots we can reasonably sample at Bandelier in the future.

Cheatgrass (*Bromus tectorum*) continues to increase on the mesa top. This season, it was the species with the highest average plot cover (7.89%) for the first time (surpassing snakeweed!), and it occurred in almost every plot we sampled. Cheatgrass dominance is also reflected in the overall cover of annual grass across all plots, which was high on average but variable between plots. Although there are no live overstory pinyon trees in any of the plots sampled, we are encountering seedling and sapling pinyons in various size classes. No new species were noted during sampling.

# Introduction

The National Park Service's Inventory and Monitoring (I&M) division conducts long-term ecological monitoring to provide scientifically credible, site-specific information on selected natural resources (known as "vital signs"). Each of the 32 I&M networks across the country selected a set of regionally important vital signs that are used to represent the overall health or condition of park resources. Information obtained from vital signs monitoring has applications for management decision-making, park planning, research, education, and promoting public understanding of park resources.

The Southern Colorado Plateau I&M Network (SCPN) includes 19 national park units in northern Arizona, northwestern New Mexico, southwestern Colorado, and southern Utah. Upland ecosystems, including grasslands, shrublands, pygmy conifer woodlands and high elevation forests, are an important vital sign for SCPN parks. These ecosystems are predominant across the Colorado Plateau and represent the vast majority of land area in SCPN park units (>85%) (Thomas et al. 2006). Upland ecosystems provide valuable habitat structure and contribute to species diversity. Upland vegetation (including biological soil crusts) is a major component of primary production and nutrient cycling, stabilizes and protects soils from wind and water erosion, provides energy to other trophic levels, and is a key component of wildlife habitat. Upland soils help to regulate water availability, sustain plant and animal life, filter and buffer potential pollutants, cycle nutrients, and provide physical stability.

Upland ecosystems are vulnerable to both human and natural disturbances. Even moderate disturbance can strongly affect these systems, and limited precipitation and, in most cases, limited vegetation cover can make recovery to pre-disturbance conditions slow or non-existent (Miller 2005). Common examples of disturbances that impact upland ecosystems include drought and other extreme climatic events, fire, insect and disease outbreaks, and invasion by non-native species. SCPN's integrated upland monitoring (IUM) program gathers information on the dynamics of upland ecosystems and the impacts of disturbances to increase understanding of these important systems.

IUM includes both vegetation and soil measurements. Field crews collect data on soil stability and hydrologic function, biological soil crusts, and plant community characteristics including abundance of functional groups, cover by species, richness and diversity, and frequency of nonnative species. In woodland and forested systems, density of saplings and overstory tree species and canopy shading are also measured. Through this monitoring, SCPN seeks to increase understanding of upland systems and provide resource managers with valuable information they can use to help guide management decisions. In particular, IUM monitoring seeks to understand

- What is the current condition of selected upland ecosystems in SCPN parks?
- Is the condition of selected upland ecosystems in SCPN parks changing?
- What are the important drivers of change in selected upland ecosystems?

See the Integrated Upland Protocol ([DeCoster et al. 2012](#)) for more information on the rationale behind this monitoring effort.

# Methods

## Monitoring Site Selection

The mesa-top pinyon-juniper ecosystem was selected for upland monitoring at Bandelier National Monument. SCPN worked closely with park management staff to select targeted ecosystems for monitoring, then used ecological sites to develop a sampling frame (<https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1068392>). Ecological sites are developed by the Natural Resource Conservation Service (NRCS) in conjunction with soil surveys. They describe locations based on a combination of soil characteristics, geology, landform, climate, and potential vegetation. SCPN selected map units containing significant amounts of the target ecological site from the park's soil survey. The spatial extent of the selected soil map units formed the initial sampling frame.

The sampling frame was then refined by removing areas that are not appropriate for monitoring. Excluded areas include those surrounding infrastructure (roads and buildings), heavily disturbed areas, and areas with slopes >20%. Then, using Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2004) we generated a set of spatially distributed potential sampling points within the final sampling frame.

As a final step, SCPN and park staff reviewed the potential sampling points in order and rejected points that were too close to archeological sites or other sensitive resources, contained significant disturbance, did not match the target ecological site, or were inaccessible for field crews. See Appendix A of the Integrated Upland Protocol ([DeCoster et al. 2012](#)) for park-specific details on how the sampling frame for this ecosystem was developed.

## Field Methods

Integrated upland monitoring plots are 50 m x 52 m and consist of three parallel 50 m transects spaced 25 m apart (Figure 1). Within this area, field crews collect data on shrub and herbaceous vegetation, woodland and forest trees, and selected soil attributes using quadrat and transect based sampling methods described in more detail below. Data are collected from a subset of monitoring plots every other year according to our panel revisit design and plots are sampled at approximately the same time each season and as close to maximal plant growth as possible given seasonal schedule constraints. See the integrated upland monitoring protocol for detailed explanation of the field methods ([DeCoster et al 2012](#)).

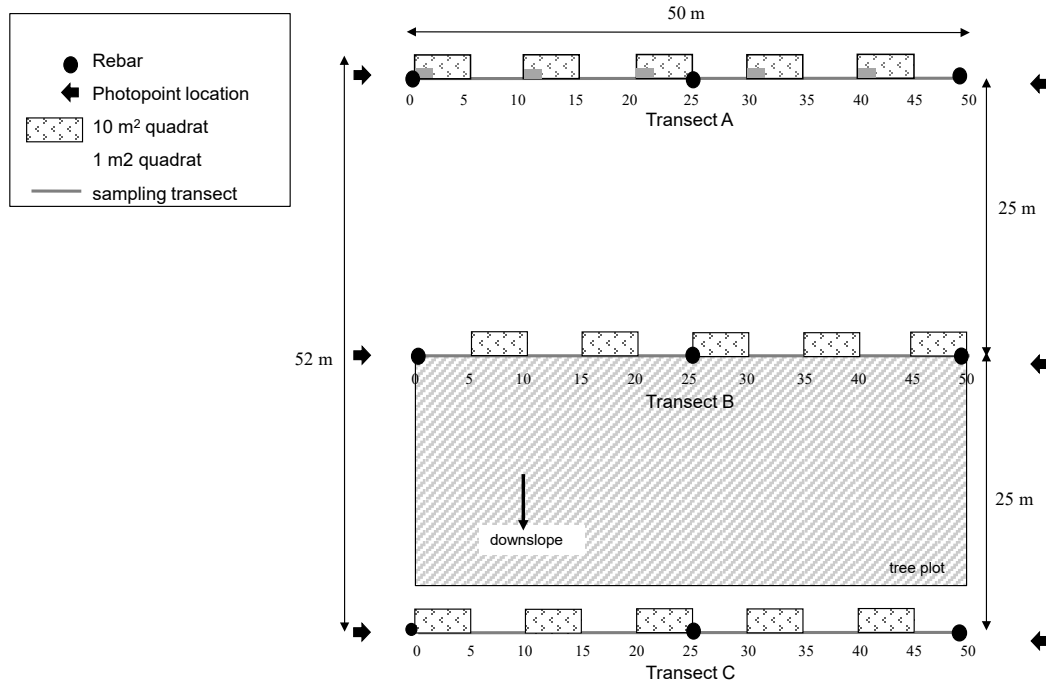


Figure 1. Basic layout of an SCPN upland monitoring plot.

### ***Herbaceous and Shrub Vegetation***

#### Species-level

Within each plot, frequency and percent foliar cover of live herbaceous and shrub vegetation was determined in 10 m<sup>2</sup> quadrats. Five quadrats were placed at 10 m intervals along each transect (Figure 1). All live vascular plants observed in each quadrat were identified to species (or the lowest taxonomic level possible). An ocular estimate of foliar cover was then made for each species detected using one of 12 cover class intervals ranging from >.01% to 75-100% (Table 1)). Plants were considered live if they were living at any point during the current growing season, even if they were dead or senescent during sampling. Plants that had foliar cover within the quadrat but were rooted outside the quadrat were assigned a cover class, but not a frequency.

Table 1. Cover classes used by the Southern Colorado Plateau Network for ocular cover estimating during upland monitoring.

| Cover Class | Range    | Midpoint |
|-------------|----------|----------|
| 0           | 0        | 0        |
| 1           | <0.1%    | 0.05%    |
| 2           | 0.1–0.5% | 0.30%    |
| 3           | >0.5–1%  | 0.75%    |
| 4           | >1–2%    | 1.50%    |
| 5           | >2–5%    | 3.50%    |
| 6           | >5–10%   | 7.50%    |

Table 1 (continued). Cover classes used by the Southern Colorado Plateau Network for ocular cover estimating during upland monitoring.

| Cover Class | Range    | Midpoint |
|-------------|----------|----------|
| 7           | >10–15%  | 12.50%   |
| 8           | >15–25%  | 20.00%   |
| 9           | >25–35%  | 30.00%   |
| 10          | >35–50%  | 42.50%   |
| 11          | >50–75%  | 62.50%   |
| 12          | >75–100% | 87.50%   |

### Functional Groups

All species present were grouped into functional categories, including perennial grass, annual grass, forb, shrub, and cacti/succulent. A cover class was recorded for each category detected in the 10 m<sup>2</sup> quadrat. A cover class was also assigned for total cover of all live shrub and herbaceous vegetation and for standing dead herbaceous and standing dead shrub vegetation within the 10 m<sup>2</sup> quadrat.

### **Soil Attributes**

#### Soil Surface Features

Soil surface features and biological soil crust attributes were assessed in 1 m<sup>2</sup> quadrats nested within the 10 m<sup>2</sup> quadrats and located at 10 m intervals along each transect (see monitoring plot layout in Field Methods above). An ocular estimate of absolute cover was made for each of 14 categories of soil surface features, including surface gravel and rocks (characterized by size class), live and dead plant bases, duff and litter, woody debris, cyanobacteria, lichen, and moss, using 1 of 12 cover classes.

#### Indicators of Soil Erosion Potential

We use two indicators of soil erosion potential in most sites, basal gap measurement and soil aggregate stability. Both methods were adapted from standard range methodology ([Herrick, 2005](#)).

#### Basal Gaps

Basal gaps are measurements of the linear distance between the bases of perennial plants. They are assessed to the nearest centimeter along each transect using line-intercept methods.

#### Soil Aggregate Stability

Tiny samples of surface soil are collected from six random locations along each transect and tested for soil aggregate stability according to the methods described in Herrick (2005). This widely adopted rangeland procedure involves immersing the collected soil fragments repeatedly in distilled water, then rating the degree to which the soil particles hold together (Table 2). In 2007-2015 when deep litter, surface stones or exposed bedrock were encountered during sampling, the sample was not taken. In 2016, we began generating new random locations when the soil surface was obstructed at a sampling point. As a result, especially in years prior to 2016, the number of samples taken within a plot may be less than 18.

Table 2. Rating levels and descriptions used by the Southern Colorado Plateau I&M Network for soil aggregate stability monitoring.

| Rating | Description                                                                                                                 |
|--------|-----------------------------------------------------------------------------------------------------------------------------|
| 1      | 50% of structural integrity lost within 5 seconds of immersion OR soil too unstable to sample                               |
| 2      | 50% of structural integrity lost 5-30 seconds after immersion                                                               |
| 3      | 50% of structural integrity lost 30-300 seconds after immersion OR <10% of soil remains on the sieve after 5 dipping cycles |
| 4      | 10-25% of soil remains on the sieve after 5 dipping cycles                                                                  |
| 5      | 25-75% of soil remains on the sieve after 5 dipping cycles                                                                  |
| 6      | 75-100% of soil remains on the sieve after 5 dipping cycles                                                                 |

### **Trees**

Trees are assessed in one of three ways depending on the stage of growth (seedling, sapling, and overstory) as described below. Because of their irregular growth-form, species of junipers (*Juniperus*) are measured at root crown and have different size classes than other tree species at the seedling stage. All other tree species are measured at breast height (1.37 m).

#### Seedlings

Tree seedlings are tallied by species and size class in the 10m<sup>2</sup> quadrats (Table 3). Non-juniper tree species are categorized by height until they reach 137 cm (standard breast height). Once a seedling reaches 137 cm, it is then measured and categorized by diameter at breast height. Juniper seedlings are categorized by diameter at root crown regardless of height.

Table 3. Size classes used for seedlings of juniper and non-juniper trees.

| Tree Type    | Size Classes                              |
|--------------|-------------------------------------------|
| Non-junipers | 0 to <15 cm height                        |
|              | 15 to <137 cm height                      |
|              | 0 to <2.5 cm in diameter at breast height |
| Junipers     | 0 to <0.5 cm diameter at root crown       |
|              | 0.5 to <2.5 cm diameter at root crown     |

#### Saplings

Saplings are tallied by species and size class in a 10 x 25 m sub-plot nested within the overstory tree plot (see Figure 1) (Table 4). Saplings of all tree species are measured at breast height (137 cm) except for junipers, which are measured at root crown.

Table 4. Size classes used for saplings of juniper and non-juniper trees.

| Tree Type    | Size Classes                            |
|--------------|-----------------------------------------|
| Non-junipers | 2.5 to <5 cm diameter at breast height  |
|              | 5 to < 10 cm diameter at breast height  |
|              | 10 to < 15 cm diameter at breast height |
| Junipers     | 2.5 to <5 cm diameter at root crown     |
|              | 5 to < 10 cm diameter at root crown     |
|              | 10 to < 15 cm diameter at root crown    |

### Overstory

Overstory trees are assessed in a 20 x 50 m subplot located below the center transect (see Figure 1). Any tree greater than 15 cm in diameter and rooted at least 50% within the subplot area is tagged, measured and identified to species. Overstory trees are each assigned a status (Table 5) and crown health class (Table 6).

Table 5. Tree status codes used for overstory trees.

| Tree Status Code | Definition       |
|------------------|------------------|
| 1                | Live             |
| 2                | Standing dead    |
| 3                | Dead and down    |
| 4                | Cut              |
| 6                | Status unknown   |
| 7                | Consumed by fire |
| 8                | Unconfirmed      |
| 0                | Not found        |

Table 6. Crown health codes used for overstory trees.

| Crown Health Code | Definition            |
|-------------------|-----------------------|
| 1                 | >85-100% live foliage |
| 2                 | >50-85% live foliage  |
| 3                 | >15-50% live foliage  |
| 4                 | >0-15% live foliage   |

All trees except junipers are tagged and measured at breast height (137 cm). Juniper species are tagged and measured at root crown (the lowest part of the stem). For trees that are forked below the

measurement point, each stem is tagged and measured individually as a sub-part of the main stem. Status and crown health codes are updated during every visit to a plot and all live trees within a plot are remeasured every six years.

#### Tree Canopy Cover

Tree canopy cover is assessed using line-intercept methods in pinyon-juniper woodlands. Start and end of contiguous tree canopy of any height is recorded along each transect using line intercept methods. Contiguous cover is defined as a minimum 20 cm segment that has 50% or greater foliar cover.

## Data summary

This report provides a basic summary of data collected during the 2019 season for the mesa-top pinyon-juniper ecosystem at Bandelier National Monument. Data are presented at the plot level or averaged across sampled plots to provide summary values for the ecosystem for a single year. Note that data summarized at the ecosystem-level are not comparable across years because these data include different groupings of plots based on our annual revisit design. Data was summarized using R version 4.0.2 and the ggplot package (R Core Team 2020; Wickham 2009). The full reproducible code is available by request.

These reports are intended to provide a quick turnaround of data to park staff, with little interpretation. Due to the complicated methods required for analysis beyond simple summaries, comparisons between plots and years, including interpretation of change over time, will be presented in a separate report.

### **Herbaceous and Shrub Vegetation**

Ocular estimates of percent foliar cover using 1 of 12 cover classes are made at each 10m<sup>2</sup> quadrat then averaged to obtain a mean foliar cover for each plot. The midpoint of the cover class that was assigned in the field is used to represent percent cover, e.g., cover class 6 (5-10%) = 7.5%. In some cases, plants identified to species in the field were later grouped at the genus level to increase consistency through time.

### ***Cover of Functional Groups***

Average percent foliar cover (calculated as the mean of cover class midpoints) for each functional category for the ecosystem in 2019 is shown in Figure 2 below.

Functional group cover provides a coarse view of the vegetation composition of plots within the mesa-top pinyon-juniper ecosystem at Bandelier National Monument. Some functional categories, including shrubs, perennial grass and cactus, tend to be relatively stable through time, while others, such as forbs and annual grass, tend to fluctuate in response to disturbance and climate. Large values for annual grass cover may indicate a degraded site with high levels of disturbance, increased erosion potential, and altered fire regimes. Standing dead values that are much larger than those for live categories might indicate mortality or die-back related to disturbance or changing environmental conditions.

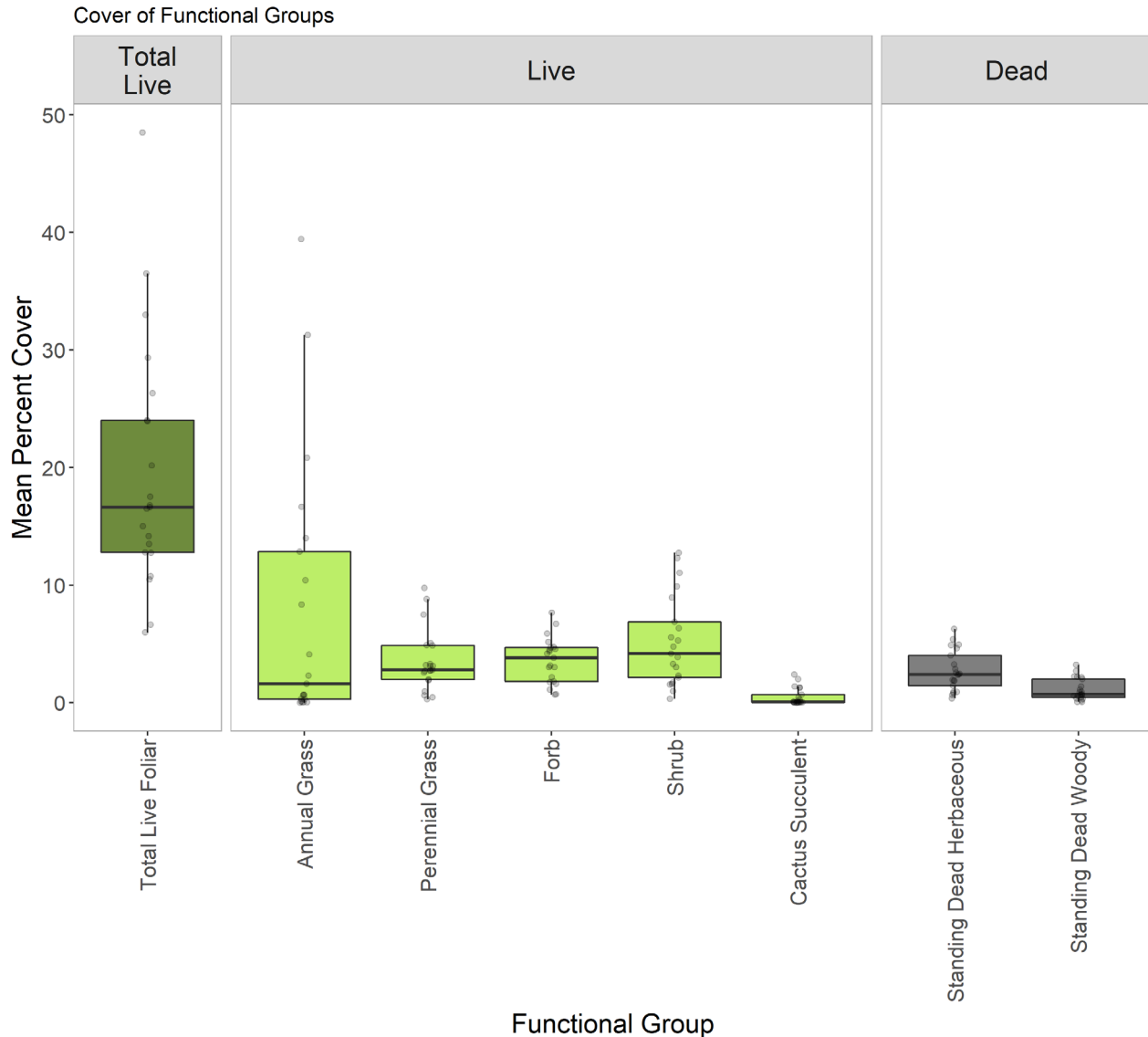


Figure 2. Average cover of functional groups across all plots sampled at Bandelier National Monument in 2019. The boxes represent the interquartile range (IQR) of plot means (i.e., when plot-level cover values were ranked from smallest to largest, the middle 50% of values were within this range). The lower box limit is the 25<sup>th</sup> percentile (25% of plot means fell below this value) and the upper box limit is the 75<sup>th</sup> percentile (25% of plot means fell above this value). The median is indicated by the horizontal line (50% of plot means fall above and below this value). The whiskers extend from the smallest to the largest values, and generally represent the full range of plot means, except in cases of outliers (values are considered outliers when the distance from the median is greater than 1.5 times the distance between the first and third quartiles). Such values are plotted as dots and are not represented in the whisker.

### ***Foliar Cover of Dominant Species***

Prevalence of dominant species within the mesa-top pinyon-juniper ecosystem is shown in Figure 3. These data are summarized at the ecosystem-level. In parks with panel revisit designs, these data are not comparable across years because different plots are sampled each year. A list of all species found in the ecosystem can be viewed in Appendix A.

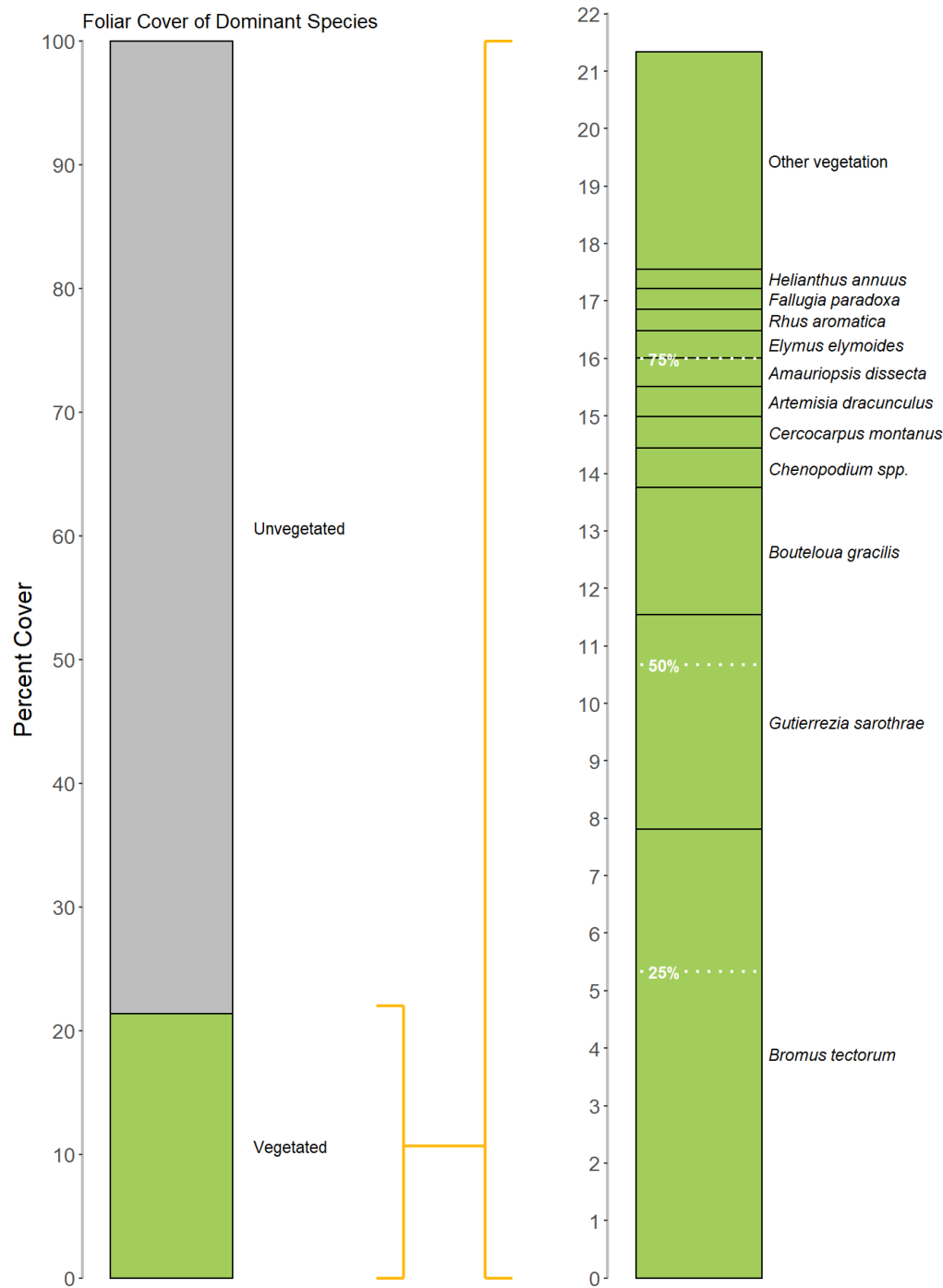


Figure 3. Mean percent vegetated cover and percent foliar cover for dominant species (over 0.5% mean percent cover) at Bandelier National Monument in 2019.

Expected values for total vegetated cover are intrinsic to each ecosystem and can also vary widely within an ecosystem. Mean percent cover of individual species can also vary widely across sampled plots. Species with large contributions to the overall cover of vegetation may be common in many or all plots, or may be present at very high cover percentages in just a few plots. In general, lower

values for shrub and herbaceous cover represent increased susceptibility to exotic plant invasion and soil erosion from wind and water.

### ***Frequency and Cover of Exotic Species***

All nonnative species detected through time in any of the plots monitored in 2019 are shown in the figure below (Figure 4). Nativity is based on the USDA plants database (<https://plants.usda.gov/java/>). Nonnative species that have high frequency (occur in many plots), high abundance in the plots in which they occur, or show increases in frequency or abundance through time may indicate degraded or invaded areas within the ecosystem.

### **Species Richness**

Species richness is the total number of distinct species detected in a plot during sampling. Species richness calculated for each plot in 2019 is shown in Figure 5. Plants that were grouped to genus or did not have a nativity in USDA Plants were assigned native status for the figure. A list of all species sampled in the ecosystem including nativity status can be viewed in the Appendix A.

Typical richness values are inherent to the ecosystem and vary through time in response to climate or disturbance, as well as spatially within an ecosystem due to plot-specific factors such as microclimate, topology and disturbance. High numbers of non-native species can indicate disturbed or invaded areas.

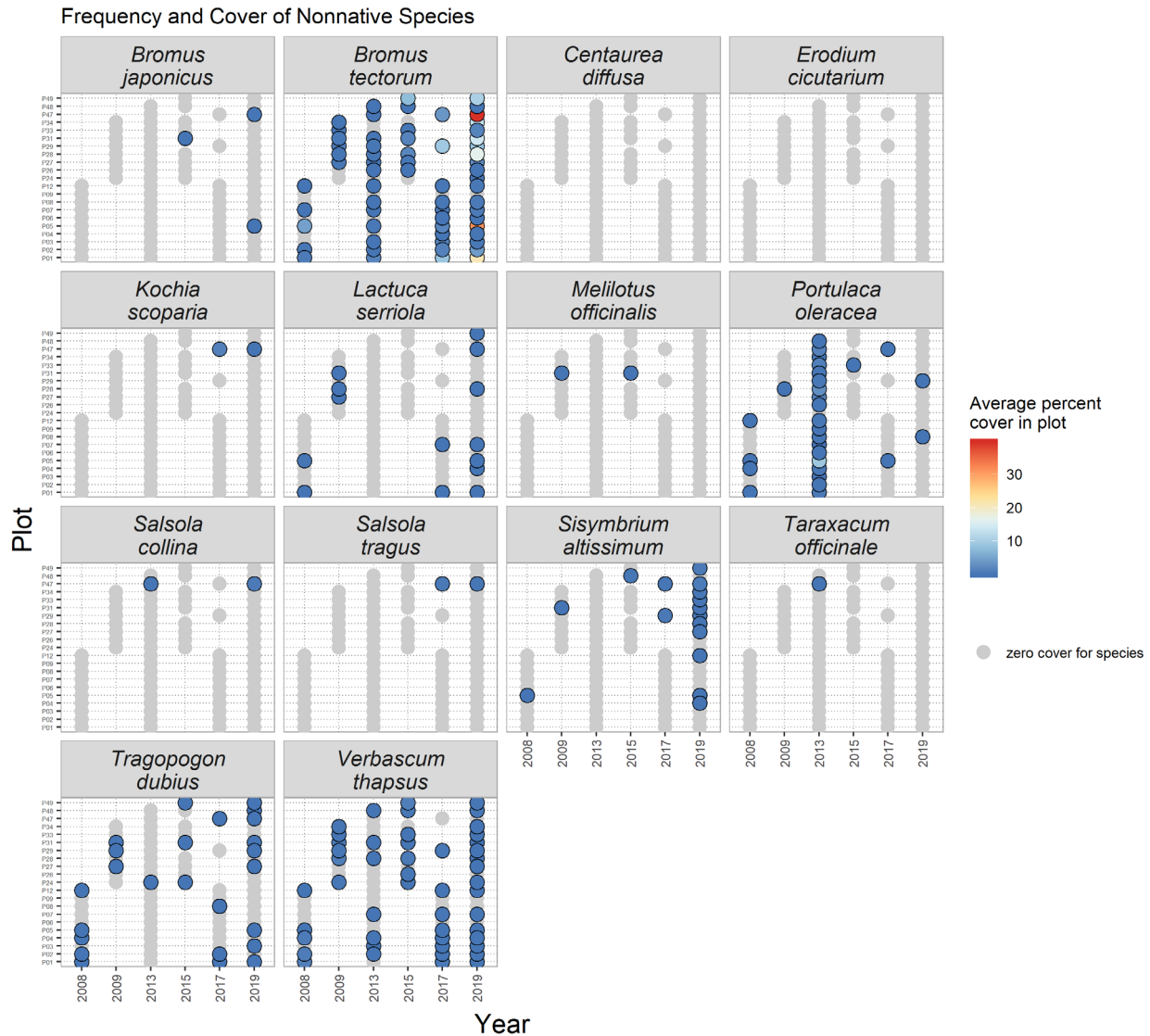


Figure 4. Chart showing mean percent foliar cover of all exotic species at Bandelier National Monument over the entire period of sampling (2008-2019). A colored (non gray) dot indicates that the given nonnative species was present in the plot and the color of the dot indicates the mean percent foliar cover (based on cover class midpoints) for a given sampling year. Gray dots indicate that the species did not occur in that plot and sampling year. The absence of any dot indicates that the plot was not sampled during that sampling year.

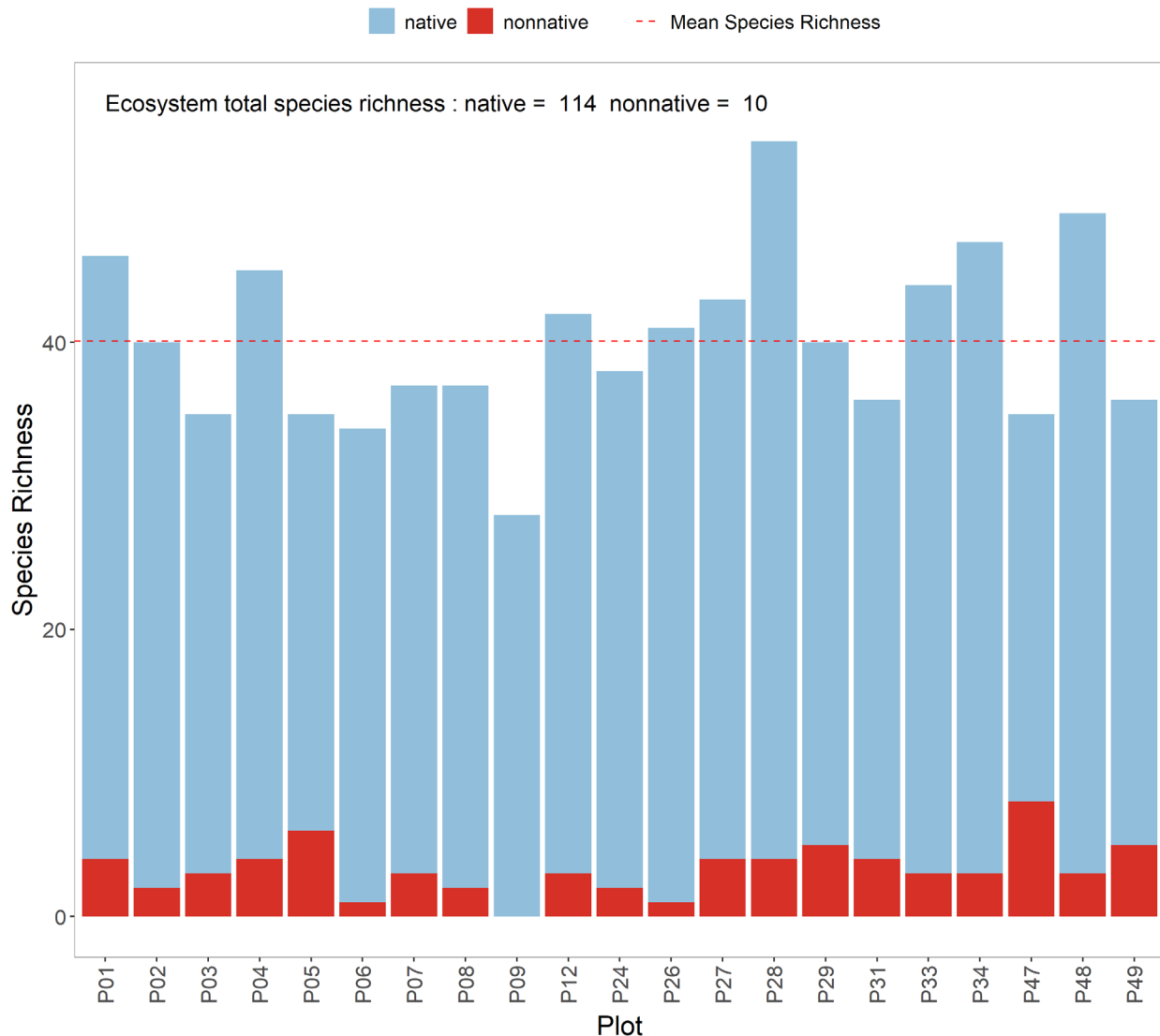


Figure 5. Species richness for each plot sampled in 2019 at Bandelier National Monument. Contribution of nonnative species to overall plot richness values are indicated in red. Mean species richness for the ecosystem is shown as the dotted line and total richness for the ecosystem is indicated at the top of the figure. Nativity status was obtained from the USDA plants database (<https://plants.usda.gov/java/>).

## Soils

Data on soil erodibility and hydrologic stability are collected at two scales. Quadrat-based cover measurements of soil surface features represent cover class midpoints and are scaled to the plot prior to summary. Transect-based measurements of aggregate stability and basal gap size (where applicable) are presented at the plot level.

### Cover of Surface Features

Ocular cover of all soil surface features were estimated within the 1 m<sup>2</sup> quadrats (see Figure 1). Cover classes are based on the midpoint of the cover class collected at the quadrat level and were scaled to the plot prior to summary. Live plant base and dead woody base includes trees stems and

areas of exposed roots. Undifferentiated crust includes both physical surface crusts and biological soil crusts that have not differentiated enough to be identified as individual biological crust components (e.g. cyanobacteria, lichen or moss). Mean percent cover of surface features is shown below (Figure 6).

Larger values for exposed bare ground suggest a system may have greater erosion potential. Biological soil crust components, plant bases, litter, woody debris and rock components reduce the amount of exposed bare ground. Typical amounts of all categories are intrinsic to the soil and plant community displayed.

### ***Soil Aggregate Stability***

Soil stability ratings for each plot in the mesa-top pinyon-juniper ecosystem are shown in Figure 7. Soil stability values closer to 6 represent stable and resilient soils with less erosion potential and intact hydrologic function, particularly in ecosystems with little bare ground and few large gaps. High stability values also are strongly correlated with healthy soil biotic communities, including biological soil crusts. Maximum soil stability values are intrinsic to the communities sampled. In some systems with coarse sandy soils or a dense layer of surface gravel, maximum possible soil stability values may be less than 6.

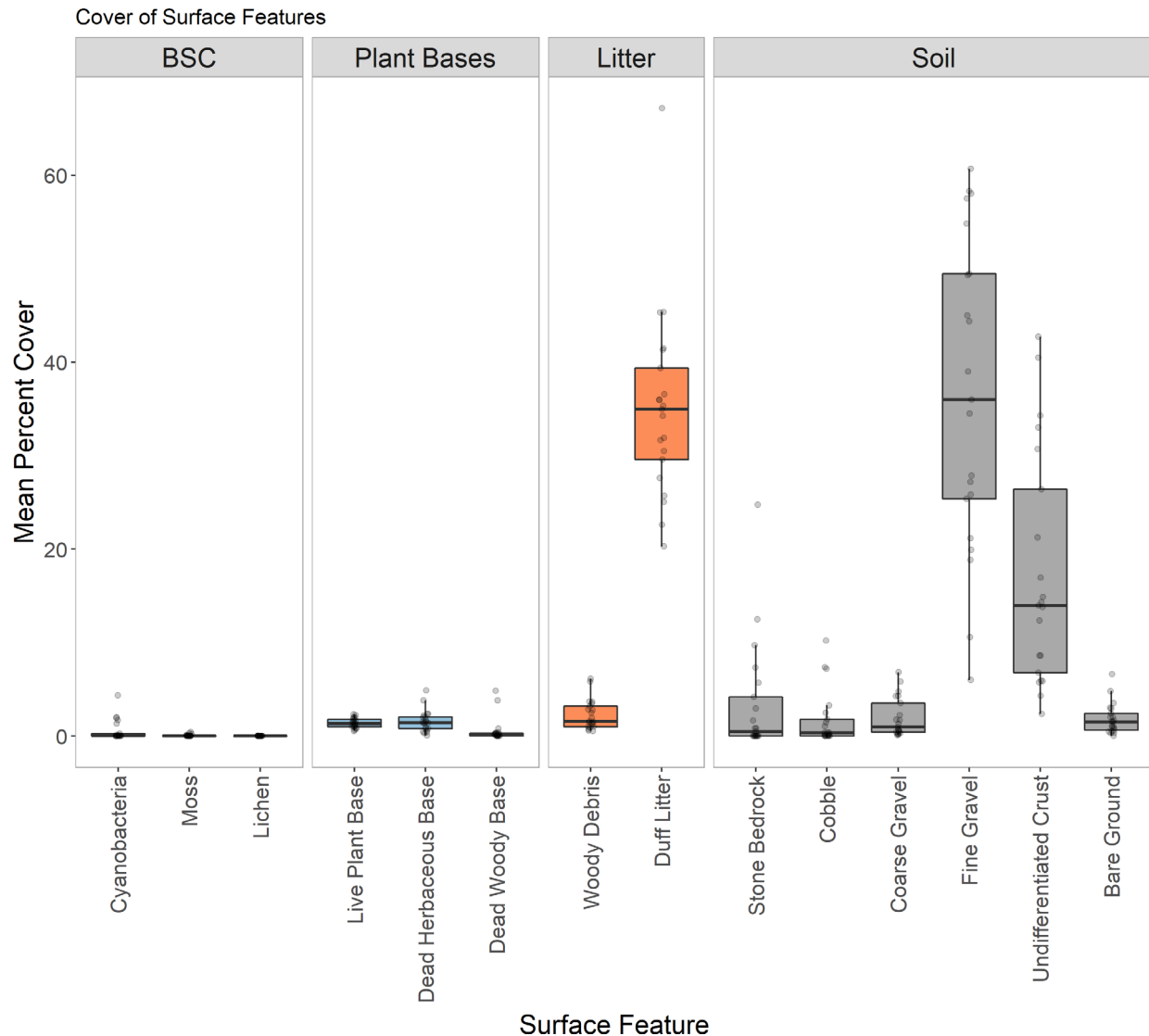


Figure 6. Mean percent cover of soil surface features Bandelier National Monument 2019. The boxes represent the interquartile range (IQR) of plot means (i.e., when plot-level cover values were ranked from smallest to largest, the middle 50% of values were within this range). The lower box limit is the 25th percentile (25% of plot means fell below this value) and the upper box limit is the 75th percentile (25% of plot means fell above this value). The median is indicated by the horizontal line (50% of plot means fall above and below this value). The whiskers extend from the smallest to the largest values, and generally represent the full range of plot means, except in cases of outliers (values are considered outliers when the distance from the median is greater than 1.5 times the distance between the first and third quartiles). Such values are plotted as dots and are not represented in the whisker.

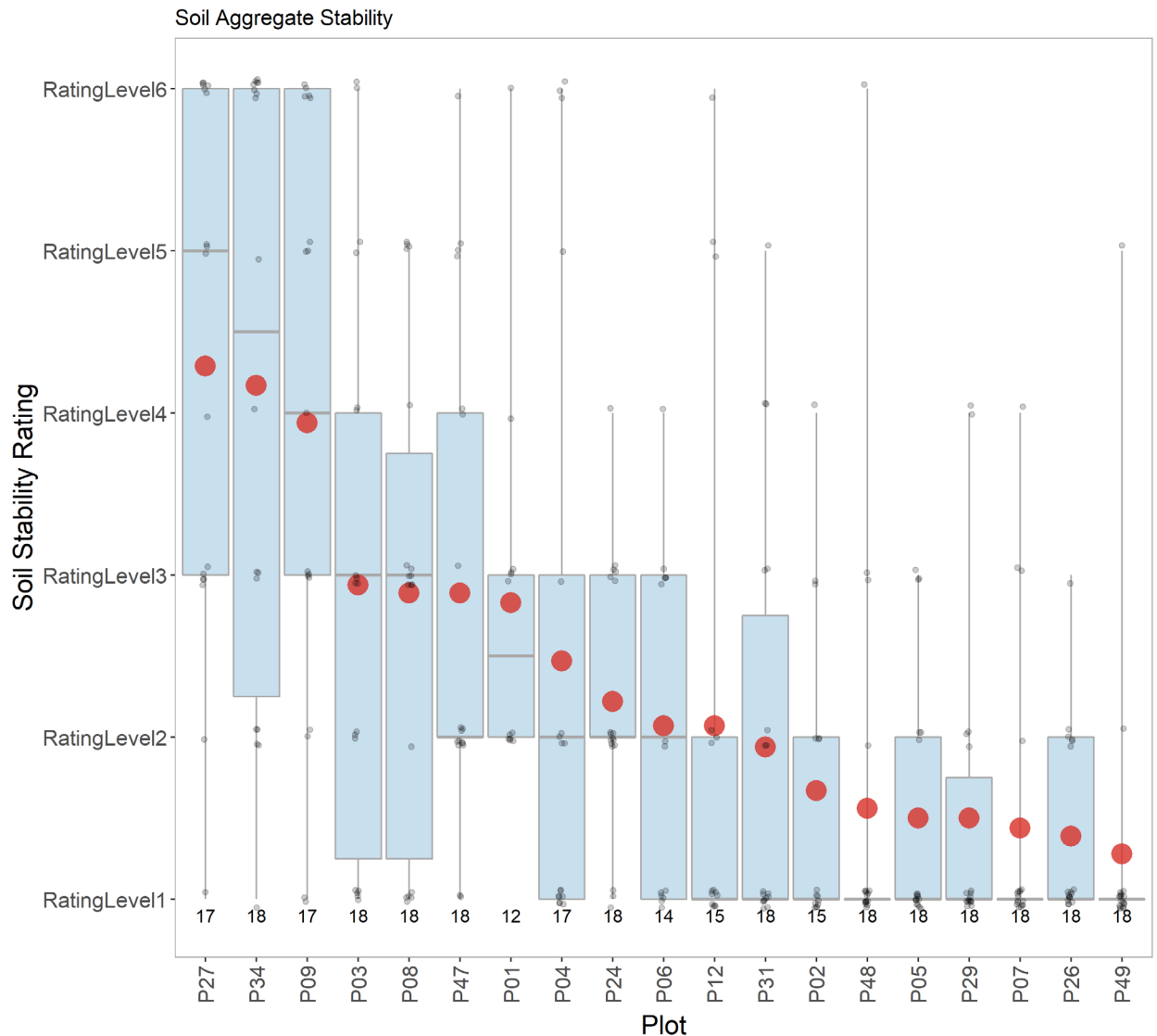


Figure 7. Soil stability rating class for each plot sampled at Bandelier National Monument in 2019. The plot mean is represented by the red circle, the median by a horizontal line, and the upper and lower bounds of the box show the 75<sup>th</sup> and 25<sup>th</sup> quartiles, respectively. The whiskers show the full range of values for the plot.

### **Basal Gap Size Distribution**

Total transect length sampled for basal gaps by plot is shown in Figure 8. Vegetation represents the aggregated length of all segments of perennial plant base recorded along the transects. Segments of basal gap are categorized by size classes (<100 cm, 100–200 cm, 200–300 cm, 300–400 cm, 400–the 500 cm, and >500 cm). In cases where an error was made in the field causing one or more gap segments to overlap, the transect was removed from the summary.

Greater proportion of large (>200 cm) basal gaps is related to increased water erosion and increased establishment of ruderal plant species, especially in areas with low litter and rock cover and low soil

aggregate stability. Note that the typical size of basal gaps is intrinsic to each ecosystem and large gaps may be expected for some vegetation communities.

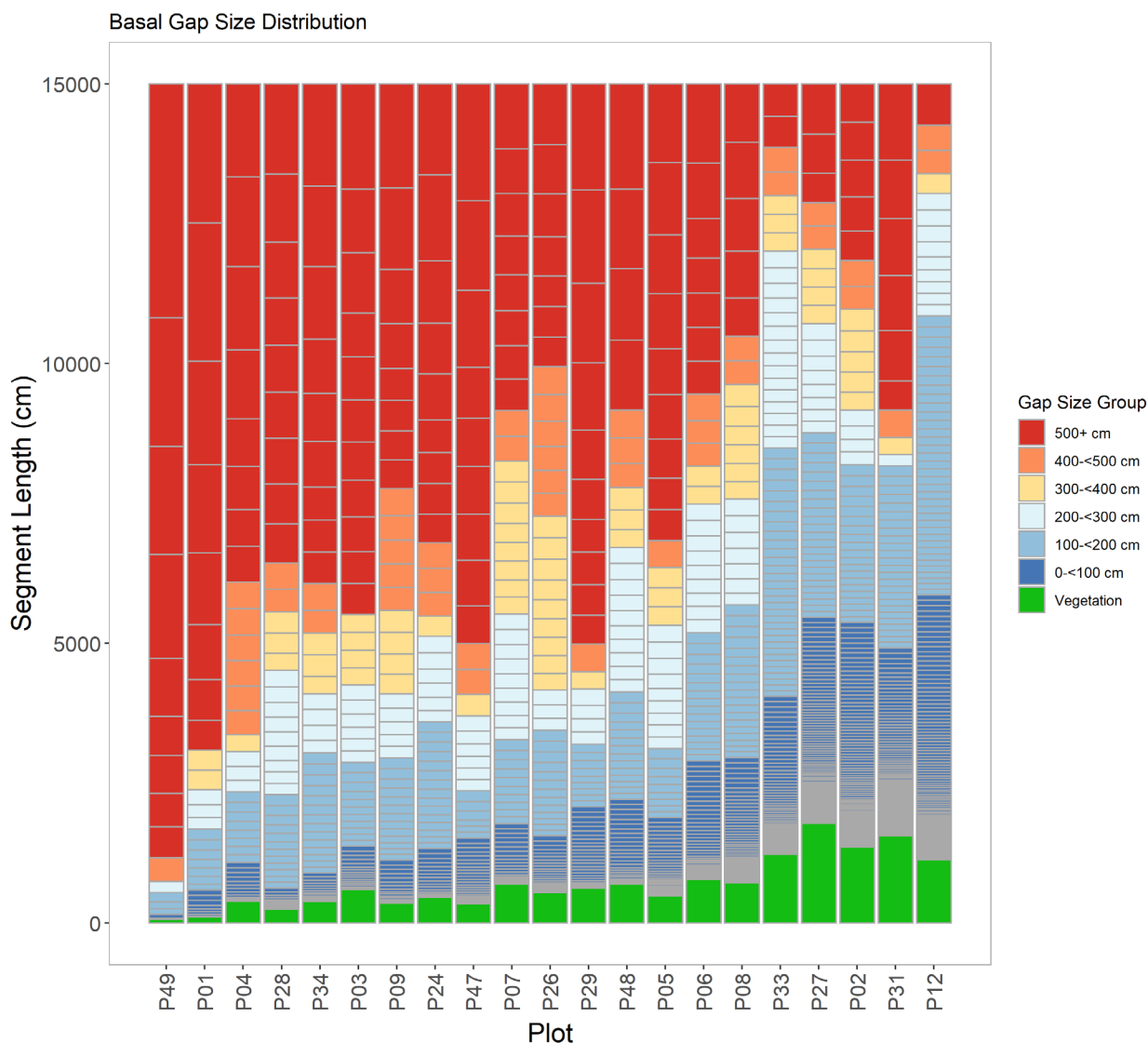


Figure 8. Size distribution of basal gaps for every plot sampled at Bandelier National Monument in 2019.

## Trees

Tree data is collected at the quadrat-level for seedlings and at plot-level for saplings and overstory and presented by hectare. For overstory trees, trees are measured every other visit. The *most recent* data are used in this summary and therefore tree measurements and status are presented for all plots and may represent data collected in different years.

## Seedlings

Number of tree seedlings per hectare in the pinyon-juniper woodland at Bandelier National Monument is shown in Figures 9 and 10. Any species of tree that occurs in any plot, regardless of life stage (seedling, sapling or overstory tree) are included in this figure, separated by size class. Juniper

species are presented separately from non-junipers because of the difference in size classes (see the Tree section under Field Methods for more details).

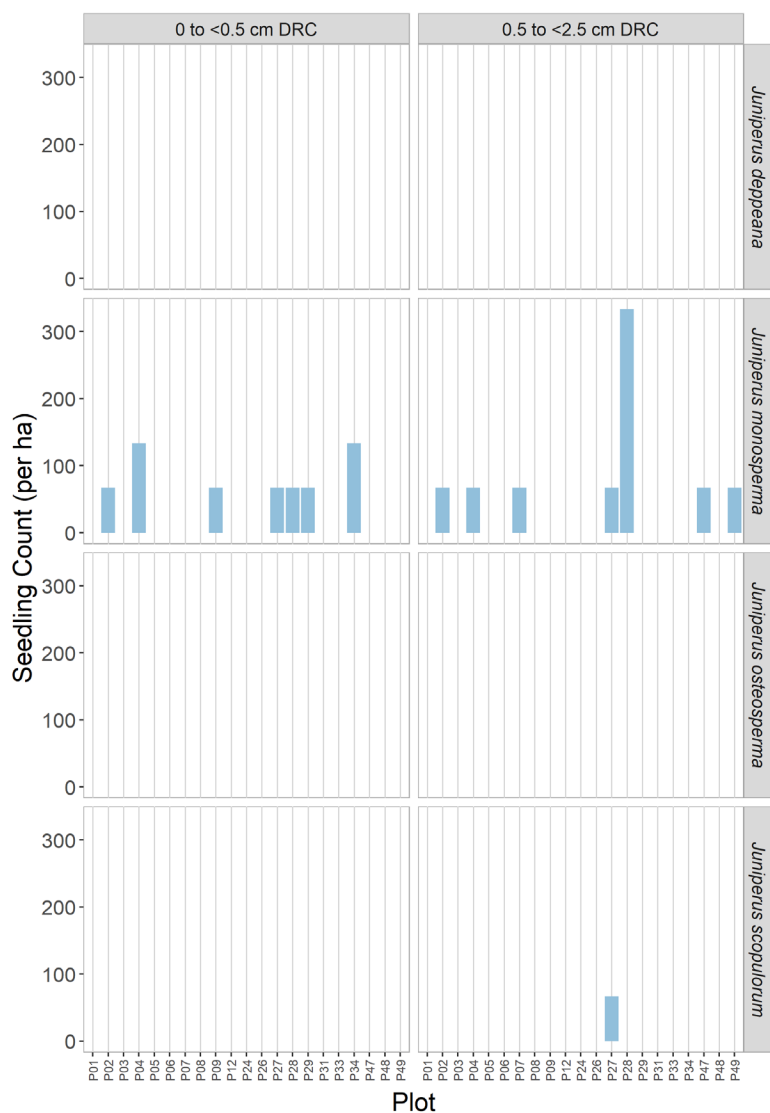


Figure 9. Number of juniper seedlings by species and size class for every plot at Bandelier National Monument in 2019.

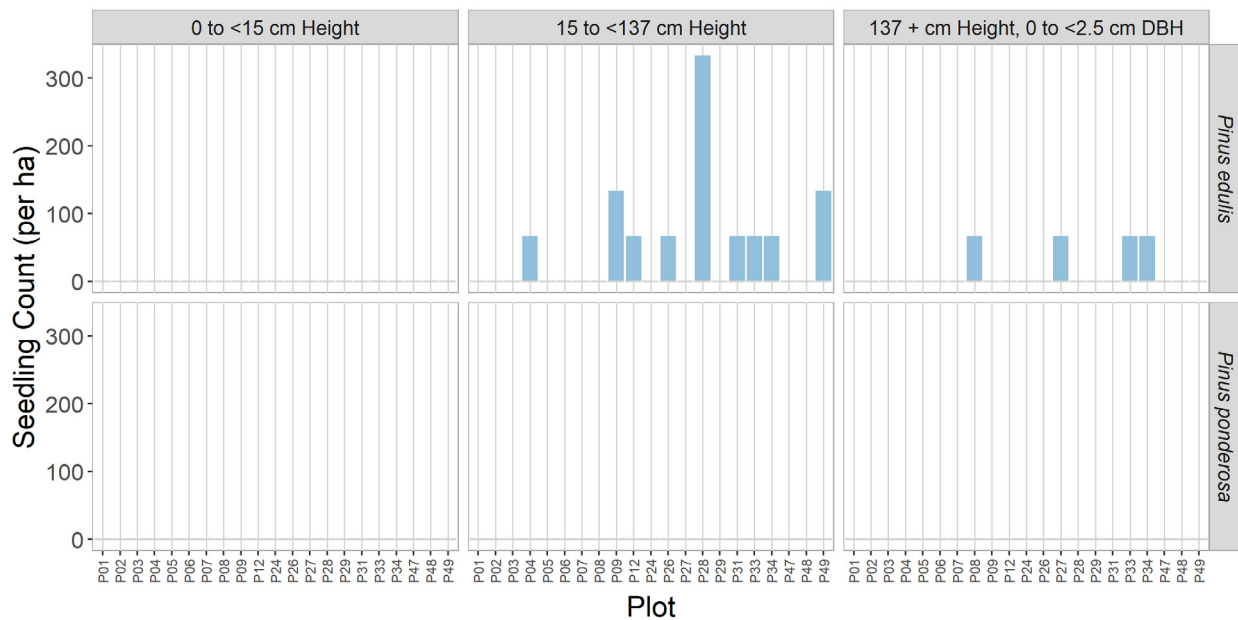


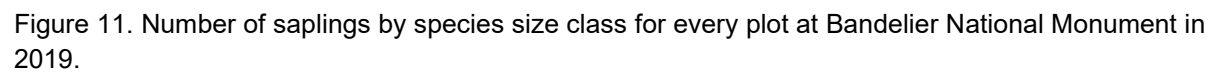
Figure 10. Number of non-juniper seedlings by species and size class for every plot at Bandelier National Monument in 2019.

## Saplings

Number of saplings per hectare, by species and size class, are displayed in Figure 11. All tree species that occurred in any plot and life stage (seedling, sapling or overstory tree) are included, separated by species and size class.

## Overstory Trees

Figure 12 shows the basal area per hectare of overstory trees by species for each plot. Basal area of live trees is shown in blue and standing dead trees in red. Due to changes in the protocol and small discrepancies through time in overstory tree measurement, this data represents the *most recent* basal area and status for overstory trees, and does not necessarily represent the data collected during 2019. Basal area does not include trees with any status other than live or standing dead. This excludes trees with status including dead and down, cut, consumed by fire and status unclear.



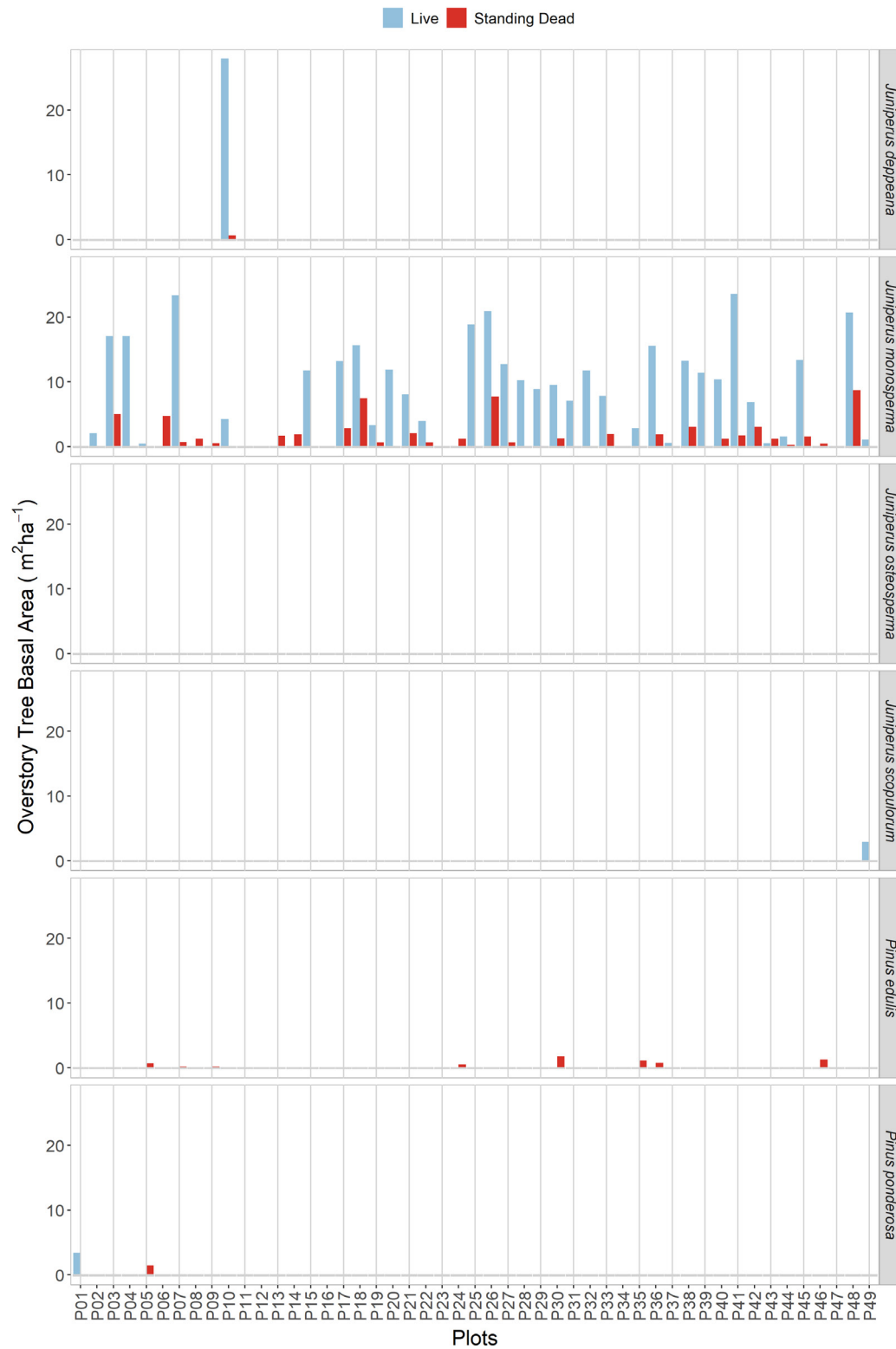


Figure 12. Basal area of overstory trees by species for every plot at Bandelier National Monument in 2019.

### Tree Canopy Cover

The percent of the total transect length that intersects tree canopy cover is shown for each plot in Figure 13. Canopy closure is not a measure of the density of the canopy, instead it represents the foliar cover of tree species within the plot. Higher proportions of tree canopy are linked to greater basal area and may influence shrub and herbaceous vegetation due to increased shading or areas of dense litter that may inhibit plant growth.

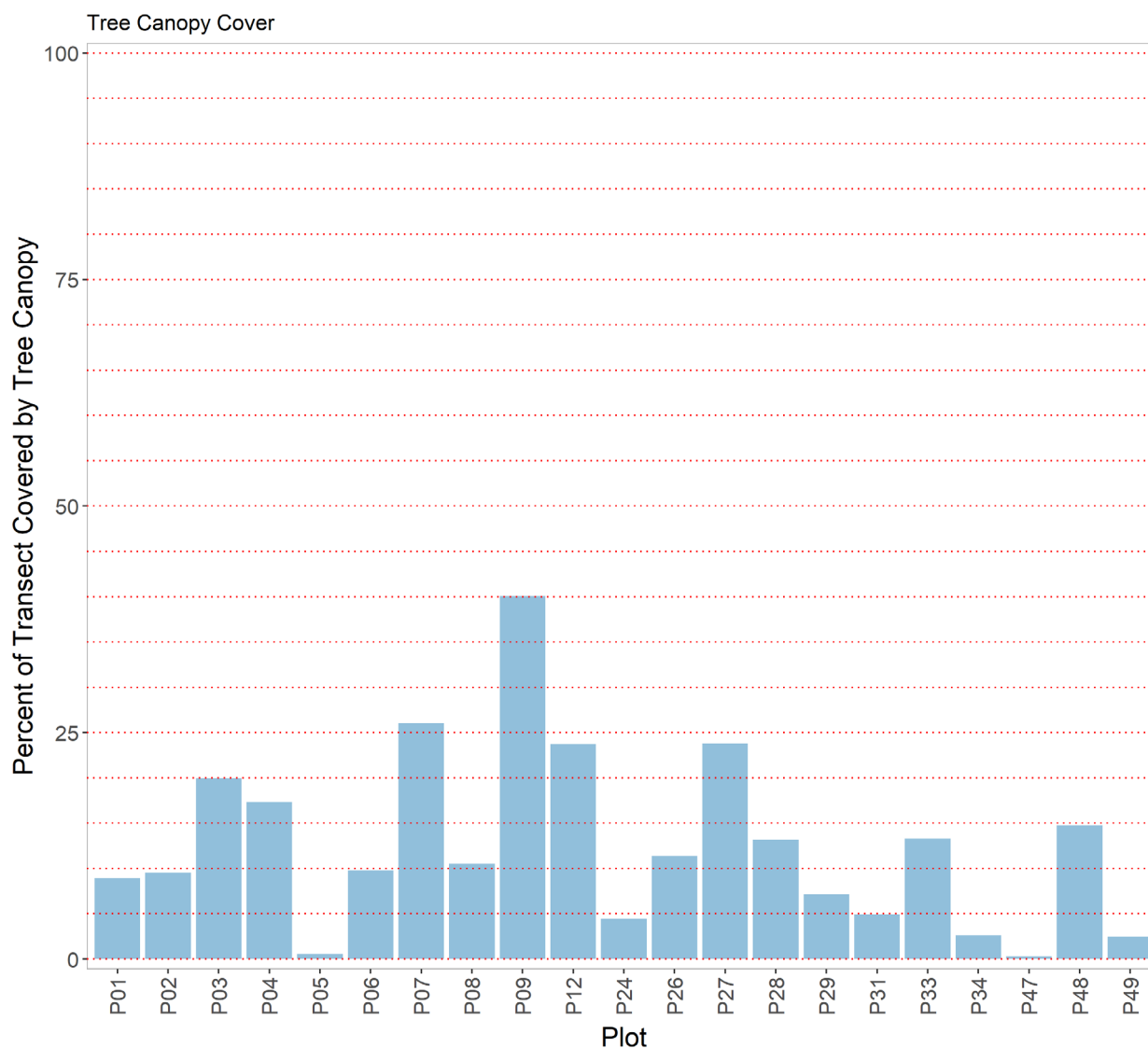


Figure 13. Percent canopy cover for every plot at Bandelier National Monument in 2019.

### Data Requests

The data used to generate this annual data summary is available from SCPN. Please submit a detailed request through the SCPN Upland Project Manager [Megan Swan](#), or the current project contact at the bottom of the [SCPN Upland Project](#) webpage.

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## Appendix A.

Table A1. Mean percent cover and plot frequency for every plant species sampled in 2019.

| Species                         | Family        | Common Name                 | Nativity  | Mean | Plot Frequency |
|---------------------------------|---------------|-----------------------------|-----------|------|----------------|
| <i>Achnatherum hymenoides</i>   | Poaceae       | Indian ricegrass            | native    | 0.01 | 28.57          |
| <i>Amaranthus</i> spp.          | Amaranthaceae | NA                          | NA        | 0.04 | 38.1           |
| <i>Amauriopsis dissecta</i>     | Asteraceae    | ragleaf bahia               | native    | 0.50 | 95.24          |
| <i>Andropogon gerardii</i>      | Poaceae       | big bluestem                | native    | 0.00 | 4.76           |
| <i>Aristida purpurea</i>        | Poaceae       | purple threeawn             | native    | 0.10 | 61.9           |
| <i>Artemisia campestris</i>     | Asteraceae    | field sagewort              | native    | 0.18 | 80.95          |
| <i>Artemisia carruthii</i>      | Asteraceae    | Carruth's sagewort          | native    | 0.27 | 57.14          |
| <i>Artemisia dracunculus</i>    | Asteraceae    | tarragon                    | native    | 0.51 | 57.14          |
| <i>Artemisia frigida</i>        | Asteraceae    | prairie sagewort            | native    | 0.01 | 19.05          |
| <i>Artemisia ludoviciana</i>    | Asteraceae    | white sagebrush             | native    | 0.02 | 66.67          |
| <i>Asclepias</i> spp.           | Apocynaceae   | NA                          | NA        | 0.00 | 9.52           |
| <i>Astragalus</i> spp.          | Fabaceae      | NA                          | NA        | 0.00 | 14.29          |
| <i>Boechera</i> spp.            | Brassicaceae  | NA                          | NA        | 0.00 | 9.52           |
| <i>Bouteloua curtipendula</i>   | Poaceae       | sideoats grama              | native    | 0.00 | 4.76           |
| <i>Bouteloua eriopoda</i>       | Poaceae       | black grama                 | native    | 0.04 | 19.05          |
| <i>Bouteloua gracilis</i>       | Poaceae       | blue grama                  | native    | 2.22 | 100            |
| <i>Brickellia eupatorioides</i> | Asteraceae    | false boneset               | native    | 0.06 | 23.81          |
| <i>Brickellia</i> spp.          | Asteraceae    | NA                          | NA        | 0.00 | 4.76           |
| <i>Bromus japonicus</i>         | Poaceae       | Japanese brome              | nonnative | 0.01 | 9.52           |
| <i>Bromus tectorum</i>          | Poaceae       | cheatgrass                  | nonnative | 7.81 | 95.24          |
| <i>Castilleja integra</i>       | Orobanchaceae | wholeleaf Indian paintbrush | native    | 0.00 | 4.76           |
| <i>Cercocarpus montanus</i>     | Rosaceae      | alderleaf mountain mahogany | native    | 0.55 | 42.86          |
| <i>Chaetopappa ericoides</i>    | Asteraceae    | rose heath                  | native    | 0.01 | 14.29          |
| <i>Chenopodium</i> spp.         | Amaranthaceae | NA                          | NA        | 0.68 | 100            |
| <i>Cirsium neomexicanum</i>     | Asteraceae    | New Mexico thistle          | native    | 0.00 | 9.52           |

| Species                      | Family        | Common Name             | Nativity | Mean | Plot Frequency |
|------------------------------|---------------|-------------------------|----------|------|----------------|
| <i>Cirsium</i> spp.          | Asteraceae    | NA                      | NA       | 0.00 | 4.76           |
| <i>Conyza canadensis</i>     | Asteraceae    | Canadian horseweed      | native   | 0.00 | 19.05          |
| <i>Cordylanthus wrightii</i> | Orobanchaceae | Wright's bird's beak    | native   | 0.23 | 61.9           |
| <i>Croton texensis</i>       | Euphorbiaceae | Texas croton            | native   | 0.14 | 52.38          |
| <i>Cryptantha cinerea</i>    | Boraginaceae  | James' cryptantha       | native   | 0.02 | 66.67          |
| <i>Cryptantha</i> spp.       | Boraginaceae  | NA                      | NA       | 0.00 | 14.29          |
| <i>Dalea candida</i>         | Fabaceae      | white prairie clover    | native   | 0.00 | 9.52           |
| <i>Dalea polygonoides</i>    | Fabaceae      | sixweeks prairie clover | native   | 0.01 | 14.29          |
| <i>Descurainia pinnata</i>   | Brassicaceae  | western tansymustard    | native   | 0.05 | 66.67          |
| <i>Dieteria</i> spp.         | Asteraceae    | NA                      | NA       | 0.02 | 52.38          |
| <i>Dysphania graveolens</i>  | Amaranthaceae | fetid goosefoot         | native   | 0.01 | 38.1           |
| <i>Echinocereus</i> spp.     | Cactaceae     | NA                      | NA       | 0.00 | 19.05          |
| <i>Elymus elymoides</i>      | Poaceae       | squirreltail            | native   | 0.47 | 100            |
| <i>Ericameria nauseosa</i>   | Asteraceae    | rubber rabbitbrush      | native   | 0.01 | 4.76           |
| <i>Erigeron divergens</i>    | Asteraceae    | spreading fleabane      | native   | 0.03 | 76.19          |
| <i>Erigeron flagellaris</i>  | Asteraceae    | trailing fleabane       | native   | 0.00 | 33.33          |
| <i>Eriogonum cernuum</i>     | Polygonaceae  | nodding buckwheat       | native   | 0.00 | 4.76           |
| <i>Eriogonum jamesii</i>     | Polygonaceae  | James' buckwheat        | native   | 0.02 | 28.57          |
| <i>Eriogonum polycladon</i>  | Polygonaceae  | sorrel buckwheat        | native   | 0.00 | 9.52           |
| <i>Eriogonum racemosum</i>   | Polygonaceae  | redroot buckwheat       | native   | 0.00 | 9.52           |
| <i>Erysimum capitatum</i>    | Brassicaceae  | sanddune wallflower     | native   | 0.01 | 47.62          |
| <i>Escobaria</i> spp.        | Cactaceae     | NA                      | NA       | 0.00 | 19.05          |
| <i>Euphorbia fendleri</i>    | Euphorbiaceae | Fendler's sandmat       | native   | 0.03 | 61.9           |
| <i>Euphorbia</i> spp.        | Euphorbiaceae | NA                      | NA       | 0.01 | 61.9           |
| <i>Fallugia paradoxa</i>     | Rosaceae      | Apache plume            | native   | 0.36 | 19.05          |
| <i>Forestiera pubescens</i>  | Oleaceae      | stretchberry            | native   | 0.01 | 4.76           |
| <i>Geranium caespitosum</i>  | Geraniaceae   | pineywoods geranium     | native   | 0.00 | 4.76           |
| <i>Gilia</i> spp.            | Polemoniaceae | NA                      | NA       | 0.00 | 9.52           |

| Species                             | Family        | Common Name                 | Nativity  | Mean | Plot Frequency |
|-------------------------------------|---------------|-----------------------------|-----------|------|----------------|
| <i>Gutierrezia sarothrae</i>        | Asteraceae    | broom snakeweed             | native    | 3.73 | 95.24          |
| <i>Hedeoma drummondii</i>           | Lamiaceae     | Drummond's false pennyroyal | native    | 0.00 | 9.52           |
| <i>Hedeoma</i> spp.                 | Lamiaceae     | NA                          | NA        | 0.00 | 4.76           |
| <i>Helianthus annuus</i>            | Asteraceae    | common sunflower            | native    | 0.33 | 57.14          |
| <i>Heliomeris multiflora</i>        | Asteraceae    | showy goldeneye             | native    | 0.01 | 14.29          |
| <i>Hesperidanthus linearifolius</i> | Brassicaceae  | slimleaf plainsmustard      | native    | 0.01 | 47.62          |
| <i>Hesperostipa comata</i>          | Poaceae       | needle and thread           | native    | 0.04 | 23.81          |
| <i>Heterotheca villosa</i>          | Asteraceae    | hairy false goldenaster     | native    | 0.09 | 42.86          |
| <i>Hilaria jamesii</i>              | Poaceae       | galleta                     | native    | 0.13 | 42.86          |
| <i>Hymenopappus filifolius</i>      | Asteraceae    | fineleaf hymenopappus       | native    | 0.02 | 61.9           |
| <i>Hymenoxys richardsonii</i>       | Asteraceae    | pingue rubberweed           | native    | 0.00 | 4.76           |
| <i>Ipomopsis aggregata</i>          | Polemoniaceae | scarlet gilia               | native    | 0.00 | 19.05          |
| <i>Ipomopsis longiflora</i>         | Polemoniaceae | flaxflowered ipomopsis      | native    | 0.04 | 42.86          |
| <i>Ipomopsis</i> spp.               | Polemoniaceae | NA                          | NA        | 0.00 | 4.76           |
| <i>Kochia scoparia</i>              | Amaranthaceae | burningbush                 | nonnative | 0.00 | 4.76           |
| <i>Koeleria macrantha</i>           | Poaceae       | prairie Junegrass           | native    | 0.04 | 28.57          |
| <i>Lactuca serriola</i>             | Asteraceae    | prickly lettuce             | nonnative | 0.01 | 33.33          |
| <i>Lappula occidentalis</i>         | Boraginaceae  | flatspine stickseed         | native    | 0.03 | 95.24          |
| <i>Linum lewisii</i>                | Linaceae      | Lewis flax                  | native    | 0.00 | 9.52           |
| <i>Linum neomexicanum</i>           | Linaceae      | New Mexico yellow flax      | native    | 0.00 | 9.52           |
| <i>Linum</i> spp.                   | Linaceae      | NA                          | NA        | 0.00 | 4.76           |
| <i>Lotus wrightii</i>               | Fabaceae      | Wright's deervetch          | native    | 0.06 | 85.71          |
| <i>Lupinus kingii</i>               | Fabaceae      | King's lupine               | native    | 0.09 | 71.43          |
| <i>Mentzelia albicaulis</i>         | Loasaceae     | whitestem blazingstar       | native    | 0.09 | 57.14          |
| <i>Mentzelia</i> spp.               | Loasaceae     | NA                          | NA        | 0.17 | 61.9           |

| Species                           | Family         | Common Name              | Nativity  | Mean | Plot Frequency |
|-----------------------------------|----------------|--------------------------|-----------|------|----------------|
| <i>Mirabilis linearis</i>         | Nyctaginaceae  | narrowleaf four o'clock  | native    | 0.00 | 19.05          |
| <i>Mirabilis multiflora</i>       | Nyctaginaceae  | Colorado four o'clock    | native    | 0.05 | 38.1           |
| <i>Muhlenbergia alopecuroides</i> | Poaceae        | bristly wolfstail        | native    | 0.02 | 23.81          |
| <i>Muhlenbergia montana</i>       | Poaceae        | mountain muhly           | native    | 0.01 | 38.1           |
| <i>Muhlenbergia wrightii</i>      | Poaceae        | spike muhly              | native    | 0.00 | 4.76           |
| <i>Munroa squarrosa</i>           | Poaceae        | false buffalograss       | native    | 0.00 | 4.76           |
| <i>Oenothera caespitosa</i>       | Onagraceae     | tufted evening primrose  | native    | 0.00 | 4.76           |
| <i>Oenothera</i> spp.             | Onagraceae     | NA                       | NA        | 0.00 | 4.76           |
| <i>Oenothera suffrutescens</i>    | Onagraceae     | scarlet beeblossom       | native    | 0.00 | 4.76           |
| <i>Opuntia</i> spp.               | Cactaceae      | NA                       | NA        | 0.25 | 76.19          |
| <i>Orobanche</i> spp.             | Orobanchaceae  | NA                       | NA        | 0.00 | 4.76           |
| <i>Orthocarpus purpureoalbus</i>  | Orobanchaceae  | purplewhite owl's-clover | native    | 0.02 | 14.29          |
| <i>Penstemon</i> spp.             | Plantaginaceae | NA                       | NA        | 0.00 | 19.05          |
| <i>Phacelia</i> spp.              | Boraginaceae   | NA                       | NA        | 0.00 | 4.76           |
| <i>Phoradendron juniperinum</i>   | Santalaceae    | juniper mistletoe        | native    | 0.00 | 14.29          |
| <i>Physalis hederifolia</i>       | Solanaceae     | ivyleaf groundcherry     | native    | 0.01 | 33.33          |
| <i>Piptatherum micranthum</i>     | Poaceae        | littleseed ricegrass     | native    | 0.05 | 47.62          |
| <i>Plantago patagonica</i>        | Plantaginaceae | woolly plantain          | native    | 0.00 | 28.57          |
| <i>Poa fendleriana</i>            | Poaceae        | muttongrass              | native    | 0.21 | 85.71          |
| <i>Polanisia dodecandra</i>       | Cleomaceae     | redwhisker clammyweed    | native    | 0.00 | 9.52           |
| <i>Polygonum sawatchense</i>      | Polygonaceae   | knotweed                 | native    | 0.00 | 23.81          |
| <i>Polygonum</i> spp.             | Polygonaceae   | NA                       | NA        | 0.00 | 4.76           |
| <i>Portulaca oleracea</i>         | Portulacaceae  | little hogweed           | nonnative | 0.00 | 9.52           |
| <i>Quercus</i> spp.               | Fagaceae       | NA                       | NA        | 0.20 | 28.57          |

| Species                         | Family           | Common Name             | Nativity  | Mean | Plot Frequency |
|---------------------------------|------------------|-------------------------|-----------|------|----------------|
| <i>Rhus aromatica</i>           | Anacardiaceae    | fragrant sumac          | native    | 0.38 | 38.1           |
| <i>Ribes cereum</i>             | Grossulariaceae  | wax currant             | native    | 0.00 | 4.76           |
| <i>Salsola collina</i>          | Amaranthaceae    | slender Russian thistle | nonnative | 0.03 | 4.76           |
| <i>Salsola tragus</i>           | Amaranthaceae    | prickly Russian thistle | nonnative | 0.01 | 4.76           |
| <i>Schizachyrium scoparium</i>  | Poaceae          | little bluestem         | native    | 0.02 | 28.57          |
| <i>Senecio spartioides</i>      | Asteraceae       | broom-like ragwort      | native    | 0.01 | 52.38          |
| <i>Silene antirrhina</i>        | Caryophyllaceae  | sleepy silene           | native    | 0.00 | 4.76           |
| <i>Sisymbrium altissimum</i>    | Brassicaceae     | tall tumbled mustard    | nonnative | 0.11 | 52.38          |
| <i>Solanum jamesii</i>          | Solanaceae       | wild potato             | native    | 0.00 | 4.76           |
| <i>Sphaeralcea</i> spp.         | Malvaceae        | NA                      | NA        | 0.00 | 4.76           |
| <i>Sporobolus</i> spp.          | Poaceae          | NA                      | NA        | 0.22 | 90.48          |
| <i>Stephanomeria pauciflora</i> | Asteraceae       | brownplume wirelettuce  | native    | 0.01 | 28.57          |
| <i>Streptanthus cordatus</i>    | Brassicaceae     | heartleaf twistflower   | native    | 0.00 | 4.76           |
| <i>Tetraneuris ivesiana</i>     | Asteraceae       | Ives' fournerved daisy  | native    | 0.01 | 14.29          |
| <i>Thelesperma filifolium</i>   | Asteraceae       | stiff green thread      | native    | 0.03 | 61.9           |
| <i>Thelypodium wrightii</i>     | Brassicaceae     | Wright's thelypod       | native    | 0.00 | 4.76           |
| <i>Tragopogon dubius</i>        | Asteraceae       | yellow salsify          | nonnative | 0.01 | 42.86          |
| <i>Verbascum thapsus</i>        | Scrophulariaceae | common mullein          | nonnative | 0.05 | 76.19          |
| <i>Vulpia octoflora</i>         | Poaceae          | sixweeks fescue         | native    | 0.04 | 66.67          |
| <i>Xanthisma gracile</i>        | Asteraceae       | slender goldenweed      | native    | 0.00 | 9.52           |
| <i>Yucca angustissima</i>       | Asparagaceae     | narrowleaf yucca        | native    | 0.03 | 23.81          |
| <i>Yucca baccata</i>            | Asparagaceae     | banana yucca            | native    | 0.12 | 19.05          |

## Appendix B.

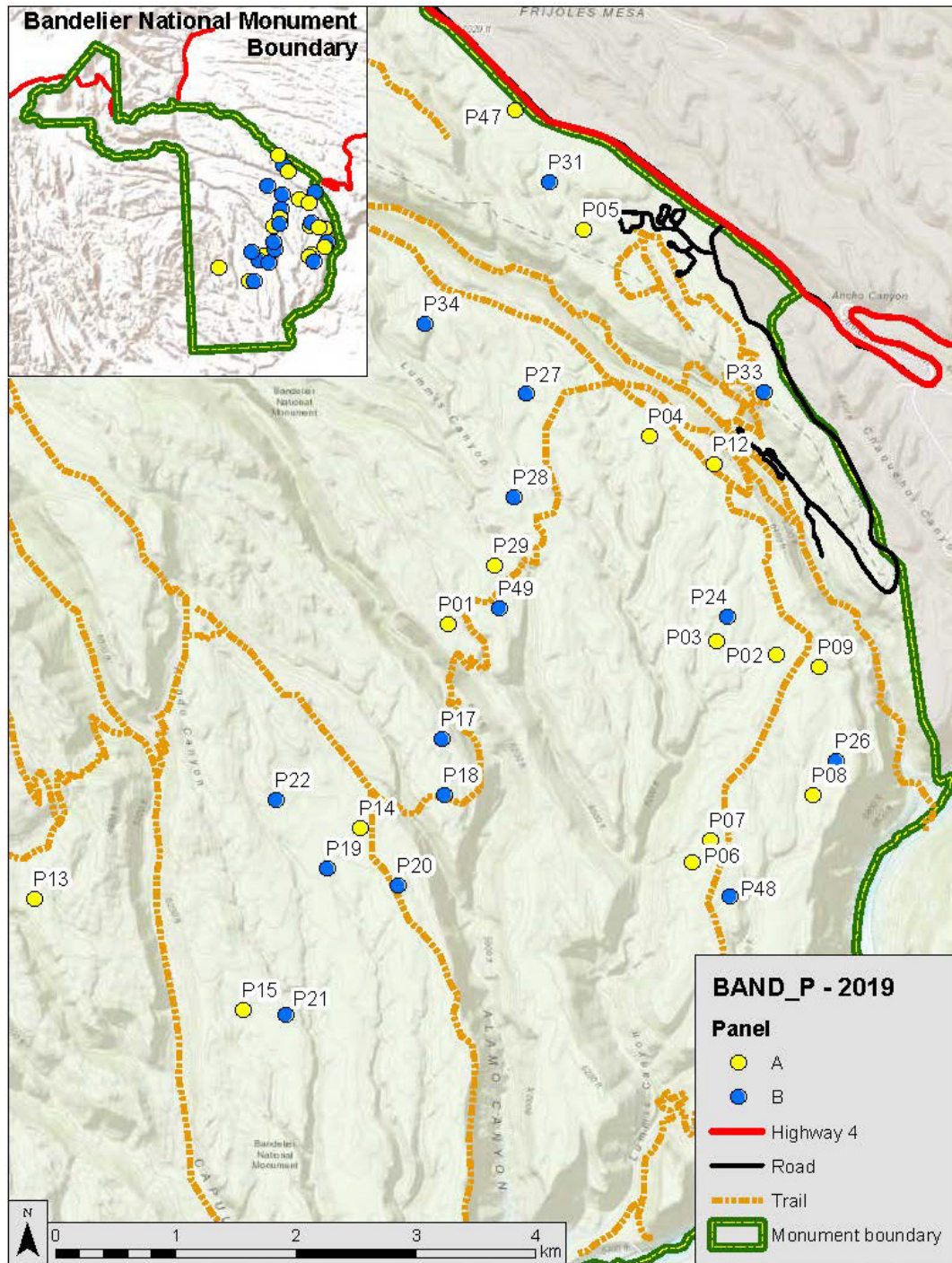


Figure B1. Location of plots sampled in 2019. Note: due to time constraints 9 of these plots were not sampled in 2019. These plots include: 13, 14, 15, 17, 18, 19, 20, 21, 22.

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NPS 315/173730, September 2020

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