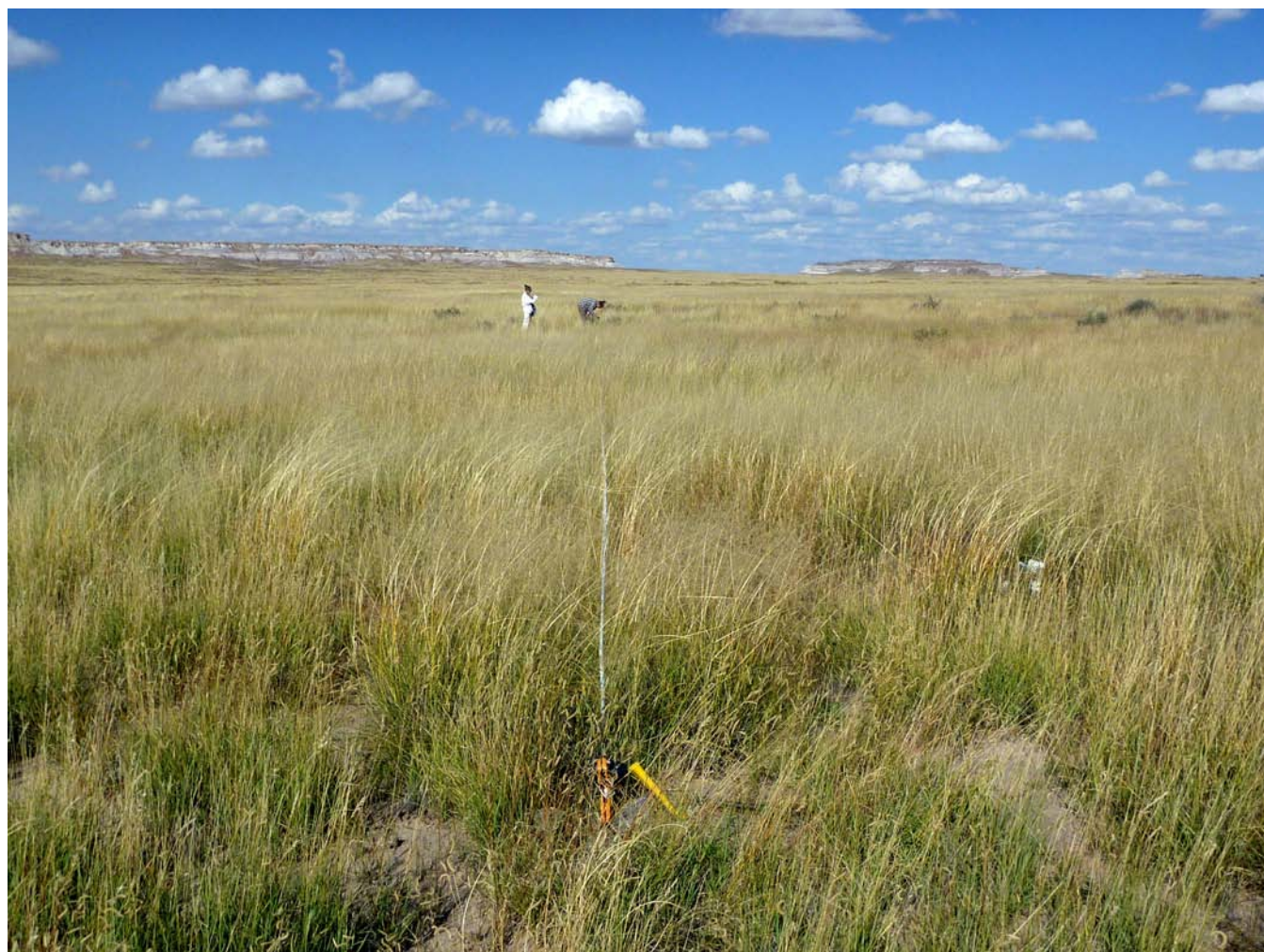




# Integrated Upland Vegetation and Soils Monitoring for Petrified Forest National Park

## *2010 Summary Report*

Natural Resource Data Series NPS/SCPN/NRDS—2013/514



**ON THE COVER**

Integrated upland monitoring in Petrified Forest National Park  
Photography by: Steven Till/NPS

# Integrated Upland Vegetation and Soils Monitoring for Petrified Forest National Park

## *2010 Summary Report*

Natural Resource Data Series NPS/SCPN/NRDS—2013/514

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July 2013

U.S. Department of the Interior  
National Park Service  
Natural Resource Stewardship and Science  
Fort Collins, Colorado

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Funding for this project was provided by the National Park Service to Northern Arizona University under Colorado Plateau Cooperative Ecosystems Study Unit agreement H1200090005 (Task NAU-331).

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Please cite this publication as:

DeCoster, J. K., and M. C. Swan. 2013. Integrated upland vegetation and soils monitoring for Petrified Forest National Park: 2010 summary report. Natural Resource Data Series NPS/SCPN/NRDS—2013/514. National Park Service, Fort Collins, Colorado.

# Contents

|                                                                                                                                                                                                                                                                                                                                         |           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| <b>Figures .....</b>                                                                                                                                                                                                                                                                                                                    | <b>iv</b> |
| <b>Tables .....</b>                                                                                                                                                                                                                                                                                                                     | <b>v</b>  |
| <b>1 Introduction and background.....</b>                                                                                                                                                                                                                                                                                               | <b>1</b>  |
| <b>2 Methods .....</b>                                                                                                                                                                                                                                                                                                                  | <b>1</b>  |
| 2.1 Sampling frame .....                                                                                                                                                                                                                                                                                                                | 1         |
| 2.2 Field methods .....                                                                                                                                                                                                                                                                                                                 | 4         |
| 2.2.1 <i>Vegetation</i> .....                                                                                                                                                                                                                                                                                                           | 4         |
| 2.2.2 <i>Soil stability and hydrologic function</i> .....                                                                                                                                                                                                                                                                               | 4         |
| 2.3 Data summary .....                                                                                                                                                                                                                                                                                                                  | 4         |
| 2.3.1 <i>Species cover and frequency</i> .....                                                                                                                                                                                                                                                                                          | 5         |
| 2.3.2 <i>Species diversity</i> .....                                                                                                                                                                                                                                                                                                    | 5         |
| 2.3.3 <i>Basal gaps</i> .....                                                                                                                                                                                                                                                                                                           | 6         |
| 2.3.4 <i>Soil stability</i> .....                                                                                                                                                                                                                                                                                                       | 6         |
| <b>3 Results .....</b>                                                                                                                                                                                                                                                                                                                  | <b>7</b>  |
| 3.1 Clayey Fan ecological site.....                                                                                                                                                                                                                                                                                                     | 7         |
| 3.1.1 <i>Vegetation</i> .....                                                                                                                                                                                                                                                                                                           | 7         |
| 3.1.2 <i>Soil</i> .....                                                                                                                                                                                                                                                                                                                 | 10        |
| 3.2 Sandy Loam ecological site .....                                                                                                                                                                                                                                                                                                    | 13        |
| 3.2.1 <i>Vegetation</i> .....                                                                                                                                                                                                                                                                                                           | 13        |
| 3.2.2 <i>Soil stability and hydrologic function</i> .....                                                                                                                                                                                                                                                                               | 17        |
| 3.3 Western Regional Climate Center precipitation data .....                                                                                                                                                                                                                                                                            | 19        |
| <b>4 Discussion .....</b>                                                                                                                                                                                                                                                                                                               | <b>21</b> |
| <b>5 Literature cited.....</b>                                                                                                                                                                                                                                                                                                          | <b>22</b> |
| <b>Appendix A: Complete species list with foliar cover and frequency values for the plots<br/>sampled between 2007 and 2009 (Plot Group A), the plots sampled in 2010 (Plot Group B),<br/>and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO. ....</b>                                                      | <b>23</b> |
| <b>Appendix B: Complete species list with foliar cover and frequency values for the plots sam-<br/>pled between 2007 and 2009 (Plot Group A), the plots sampled in 2007 only (Plot Group B),<br/>the plots sampled in 2010 (Plot Group C), and all plots (ecological site mean) in the Sandy<br/>Loam ecological site at PEFO. ....</b> | <b>28</b> |

# Figures

Figure 1. Sampling frame for the Clayey Fan ecological site at PEFO, with the 10 plots established in 2007 and the 20 plots established in 2010..... 2

Figure 2. Sampling frame for the Sandy Loam ecological site at PEFO, with the 10 plots established in 2007 and resampled twice (Plot Group A), the 7 plots established in 2007 and only sampled once (Plot Group B), and the 13 plots established in 2010 (Plot Group C). ..... 3

Figure 3. Mean percent foliar cover of functional groups for Plot Group A, Plot Group B and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO. Error bars represent one standard deviation..... 8

Figure 4. Mean percent foliar cover of the 8 most abundant shrub and herbaceous species for all plots (ecological site mean) compared to mean foliar cover for Plot Group A and Plot Group B in the Clayey Fan ecological site at PEFO. Error bars represent one standard deviation. .... 8

Figure 5. Mean percent cover of soil surface features for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site in PEFO. Biological soil crust includes moss, lichen and cyanobacteria. .... 11

Figure 6. Percentage of transect in different gap sizes for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO. Error bars represent 1 standard deviation. .... 12

Figure 7. Mean percent foliar cover of functional groups for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO. Error bars represent one standard deviation. ... 14

Figure 8. Mean percent foliar cover of the 8 most abundant shrub and herbaceous species for all plots (ecological site mean) compared to mean foliar cover for Plot Group A and Plot Group B in the Sandy Loam ecological site at PEFO. Error bars represent one standard deviation. .... 14

Figure 9. Mean percent cover of soil surface features for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site in PEFO..... 18

Figure 10. Mean percentage of transect by gap size class for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO. Error bars represent 1 standard deviation. .... 19

Figure 11. Total monthly precipitation for the 4 years of sampling. The red line represents the long term average monthly precipitation for the Petrified Forest NP (26468) AZ weather station for the period 1933–2010, collected by the Western Regional Climate Center..... 20

# Tables

|                                                                                                                                                                                                                                                                                                                       |    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Table 1. Foliar cover of functional groups for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO. ....                                                                                                                                                       | 7  |
| Table 2. Mean foliar cover and standard deviation, and mean quadrat and plot frequency of the 15 most abundant shrub and herbaceous species and all nonnative species for all plots (ecological site mean) compared with the values for Plot Group A and Plot Group B.in the Clayey Fan ecological site at PEFO. .... | 9  |
| Table 3. Species diversity metrics for all species and for native species only, for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO.....                                                                                                                   | 10 |
| Table 4. Cover of soil surface features for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO. ....                                                                                                                                                          | 11 |
| Table 5. Number of basal gaps, median gap size, and percentage of transect in different gap size classes for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO. ....                                                                                         | 12 |
| Table 6. Soil stability rating for all samples, and for samples with and without vegetative cover, in Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO. ....                                                                                                | 13 |
| Table 7. Foliar cover of functional groups for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO. ....                                                                                                                                         | 13 |
| Table 8. Mean foliar cover and standard deviation, and mean quadrat and plot frequency of the 15 most abundant shrub and herbaceous species and all nonnative species for all plots (ecological site mean) compared with the values for Plot Groups A, B, and C in the Sandy Loam ecological site at PEFO. ....       | 15 |
| Table 9. Species diversity metrics for all species and for native species only, for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO. ....                                                                                                    | 16 |
| Table 10. Cover of soil surface features for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO. ....                                                                                                                                           | 17 |
| Table 11. Number of basal gaps, median gap size, and percentage of transect in different gap size classes for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO. ....                                                                          | 18 |
| Table 12. Soil Stability rating for all samples, and for samples with and without vegetative cover, for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO. ...                                                                                 | 19 |
| Table 13. The panel design we are currently planning to use for the revisit design at PEFO. "X" represents 10 plots in an ecological site, for a total of 30 plots across 3 panels for the ecological site. ....                                                                                                      | 21 |



# 1 Introduction and background

The National Park Service Inventory and Monitoring (I&M) Program was designed to determine the status and monitor the conditions of park natural resources, providing park managers with a scientific foundation that informs resource management decisions. The Southern Colorado Plateau Network (SCPN) is monitoring vegetation and soils as overall indicators of upland ecosystem integrity (Thomas et al. 2006).

SCPN and park staff selected the Clayey Fan and Sandy Loam ecological sites for long-term monitoring of upland vegetation and soils at Petrified Forest National Park (PEFO). 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). These 2 ecological sites comprise large areas of the upland grassland ecosystems at PEFO. They face numerous threats, including climate change, soil erosion and invasion by nonnative species.

In 2007, the SCPN integrated upland monitoring project began its work at PEFO with the installation of 10 plots in the Clayey Fan ecological site and 20 plots in what we now call the Sandy Loam ecological site. We sampled vegetation in nested quadrats and measured basal gaps annually in 10 plots (10 of the original Sandy Loam plots were excluded from repeat sampling) in each ecological site for 3 years to determine the range of temporal variability for key metrics. In 2010, we established and sampled additional plots in each ecological site for a total of 30 plots. The plots established in 2007 were not resampled in 2010. In this report, we document monitoring activities in the 2010 field season and summarize the data collected between 2007 and 2010 to describe baseline conditions for the vegetation and soils of these 2 ecological sites.

## 2 Methods

### 2.1 Sampling frame

We derived our base sampling frame (figs. 1 and 2) from the maps of the ecological sites, which were developed by the U.S. Natural Resources Conservation Service (NRCS; see appendix A of DeCoster et al. 2012). The sampling frames are the areas from which we randomly select our sites, and hence the areas to which statistical inferences can be made. To make final adjustments to our sampling frames, we modified the maps of the ecological sites using Geographical Information System (GIS) technology to remove areas within 100 m of roads and exceeding 20% slope.

Development of the Sandy Loam ecological site sampling frame was complicated. We had originally planned to monitor 3 ecological sites: Clayey Fan, Sandy Loam, and Loamy Upland. After our first field season, NRCS updated the soil map and consolidated the Loamy Upland and Sandy Loam ecological sites into a single site, which kept the Sandy Loam name. As a result, we subsequently merged the sampling frames for these 2 sites.

For each ecological site, we generated a set of spatially distributed sampling points using the Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). Park staff reviewed the sampling points and rejected those points that landed too close to archeological sites and other sensitive resources. The integrated upland crew visited the points in consecutive order and conducted an ecological site assessment, rejecting sites that deviated substantially from the ecological site, had a slope greater than 20%, or contained an archeological site or major disturbance. In 2010, they revisited and accepted GRTS points in the Sandy Loam ecological site that had been rejected previously due to a combination of Sandy Loam and Loamy Upland characteristics. Since GRTS points must be sequential in order to maintain spatial balance, 3 of the original 20 plots established in 2007 had to be decommissioned. In total they rejected 58 points in the Clayey Fan ecological site: 56 points fell into areas that deviated substantially from the ecological site, and 2 points required more than 2 hours hiking time. The crew also rejected 6 points in the Sandy Loam ecological site: 3 points were in close proximity to archeological sites, one point was in close proximity to a road, one point deviated substantially from the ecological site, and one point was in close proximity to an existing plot.

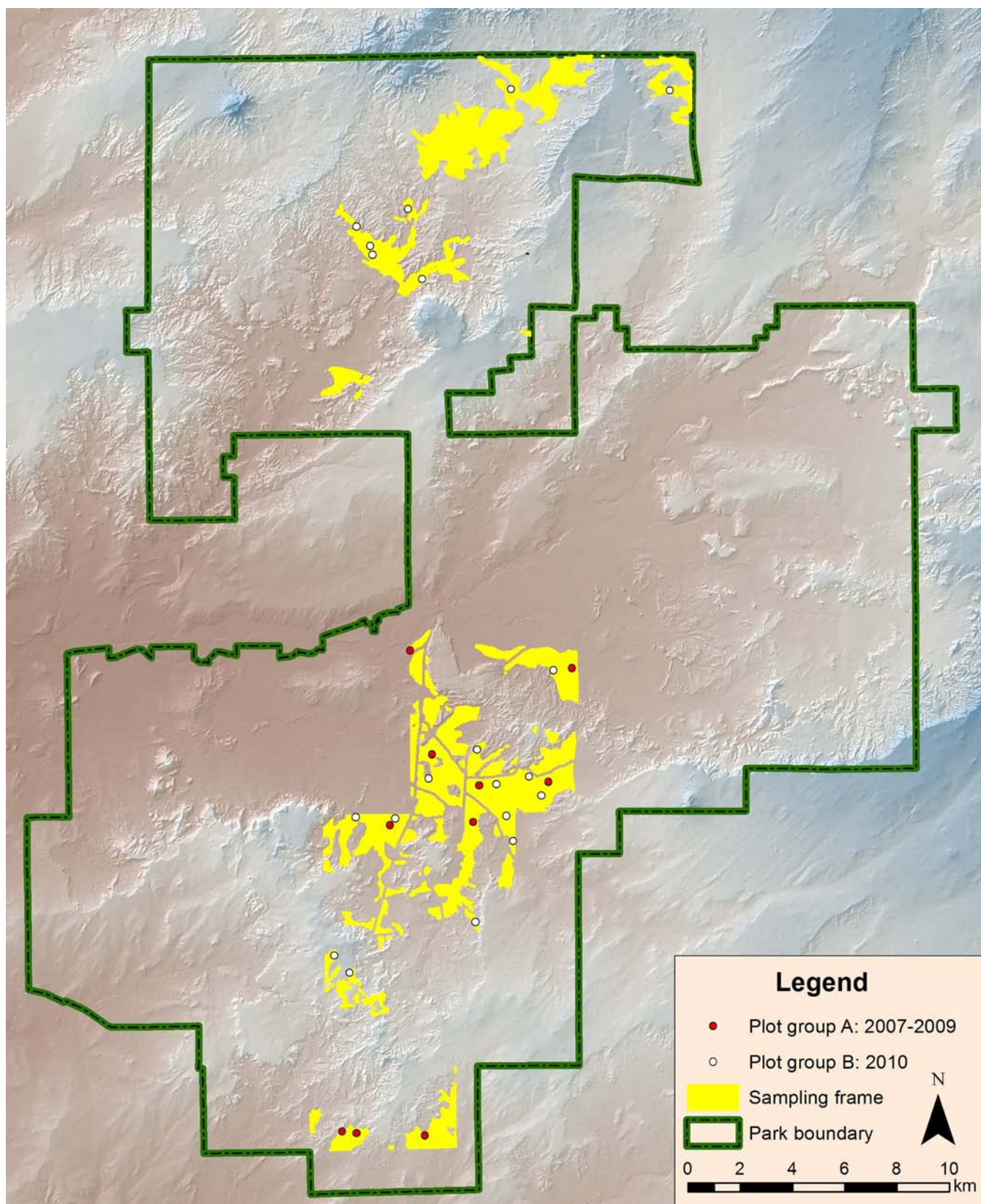


Figure 1. Sampling frame for the Clayey Fan ecological site at PEFO, with the 10 plots established in 2007 and the 20 plots established in 2010.

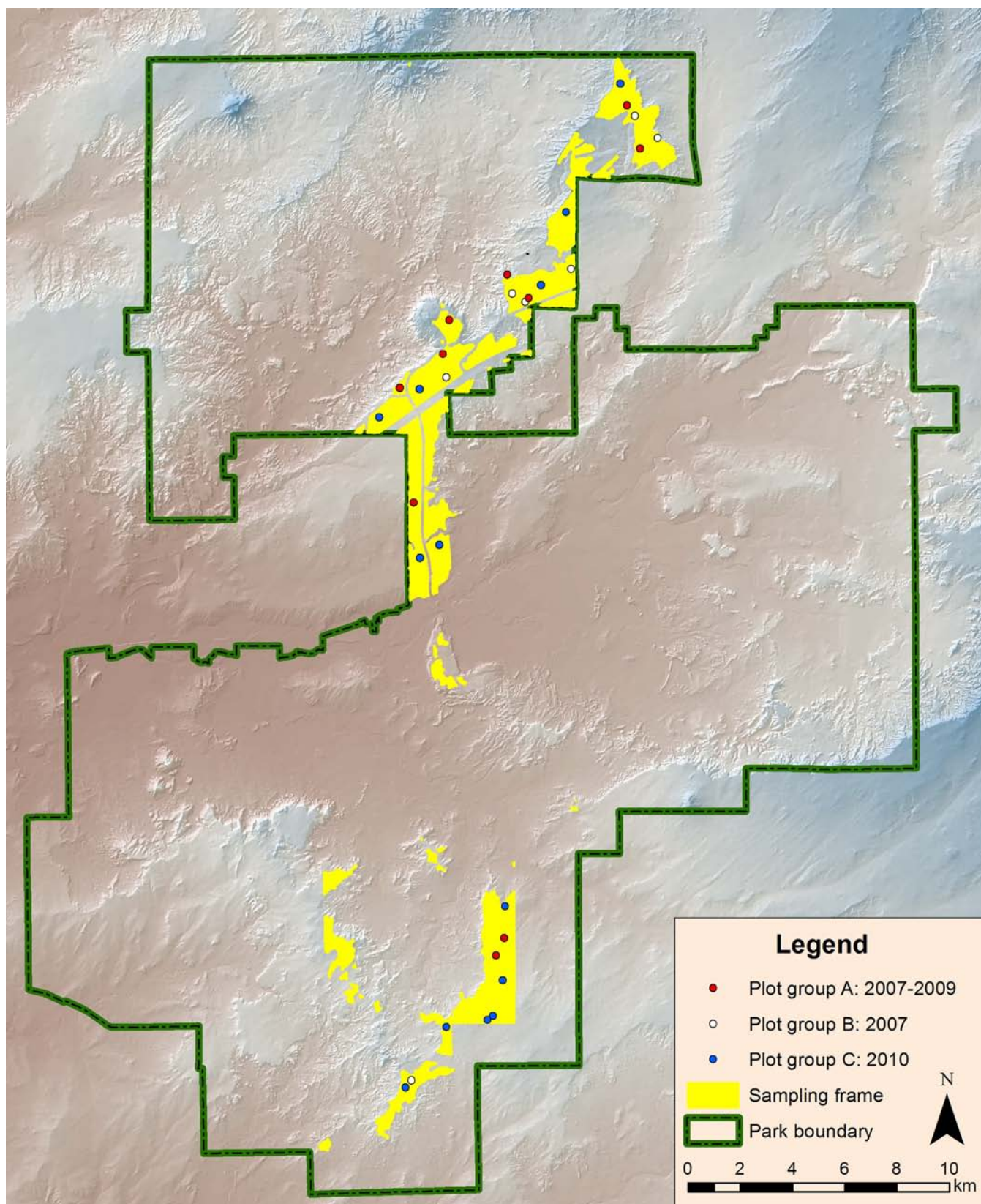


Figure 2. Sampling frame for the Sandy Loam ecological site at PEFO, with the 10 plots established in 2007 and resampled twice (Plot Group A), the 7 plots established in 2007 and only sampled once (Plot Group B), and the 13 plots established in 2010 (Plot Group C).

## 2.2 Field methods

In 2007, the SCPN integrated upland crew established 10 monitoring plots in each of 3 ecological sites: Clayey Fan, Sandy Loam, and Loamy Upland. In 2008 and 2009 we resampled the 10 Clayey Fan plots and 10 of the now combined Sandy Loam site plots (the first 5 plots in what was originally called Loamy Upland, and the first 5 original Sandy Loam plots). In 2010, we established and sampled additional plots to attain a total of 30 plots for each ecological site: 20 new Clayey Fan plots and 13 new Sandy Loam plots. None of the original 2007 plots were resampled in 2010. We conducted all sampling in mid-October, with the exception of 2007 which was sampled in late September and early October.

Integrated upland monitoring plots are 0.50 ha in size, measuring 71 × 71 m, and consist of 3 parallel 50 m transects spaced 25 m apart. We collected data for shrub and herbaceous species composition, soil cover and soil stability on all 3 transects within each plot. During establishment of new plots in 2007 and 2010, we collected the full suite of data. In 2008 and 2009, we did not collect soil stability data. Field methodology is provided in detail in the SCPN integrated upland monitoring protocol (DeCoster et al. 2012).

### 2.2.1 Vegetation

No trees occurred in our plots. We sampled shrub and herbaceous vegetation within 5 sets of nested quadrats at 10 m intervals along each transect. The largest quadrat size was 10 m<sup>2</sup> (2 × 5 m), with 4 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>). We recorded the presence of each herbaceous and shrub species within each nested sub-quadrat. We estimated the percent cover of each species in the 10 m<sup>2</sup> quadrat and assigned it to 1 of 12 cover classes (e.g., 2%–5%, 5%–10%, etc.). We also estimated the percent cover for functional groups (e.g., perennial grasses, forbs, shrubs) in the 10 m<sup>2</sup> quadrats and recorded the cover class. We collected these data in the 10 plots in each ecological site in 2007, 2008 and 2009, the 7 Sandy Loam plots established in 2007 and not subsequently resampled, and for the new plots established in 2010.

### 2.2.2 Soil stability and hydrologic function

We estimated the percent cover of soil surface features in the 1 m<sup>2</sup> quadrats along the transects, and recorded the cover in 1 of 12 cover classes. We measured basal gaps as the length of bare soil exposed between plant bases along each transect. We collected these data in the 10 plots in each ecological site in 2007, 2008 and 2009, the 7 plots established in the Sandy Loam ecological site that were not resampled, and for the new plots established in 2010. We also conducted a soil aggregate stability test one time in all plots established in 2007 and 2010, using 18 soil samples per plot collected along the transects. For these we noted whether there was vegetation cover over the sample point.

## 2.3 Data summary

For each ecological site we examine the data for all 30 plots, as these represent the baseline conditions, and report them as the ecological site means. We also compare the data collected in the plots sampled in 2010 (20 in the Clayey Fan ecological site, 13 in the Sandy Loam ecological site) to the data collected in the 10 plots sampled between 2007 and 2009. Additionally, for the Sandy Loam ecological site, we report data for the 7 plots sampled once in 2007. It must be stressed that differences among the plot groups do not represent change over time, but rather indicate differences in composition and structure resulting largely from spatial variation.

Clayey Fan plots are organized in this way:

- Plot Group A contains the 10 plots that were sampled for 3 years from 2007 to 2009
- Plot Group B contains the 20 additional plots established in 2010

Sandy Loam plots are organized in this way:

- Plot Group A contains the 10 plots that were sampled for 3 years from 2007 to 2009
- Plot Group B contains 7 plots that were sampled only once in 2007
- Plot Group C contains the 13 additional plots that were established in 2010

The sample unit for summary and analysis is the plot; hence, we summarized data at the level of the plot. For most metrics, we then calculated the mean and standard deviation for the plot group from the plot means (ecological site species diversity metrics were the exception). For Plot Group A metrics where there were 3 years of data, we calculated the mean and standard deviation for the 10 plots for each year, and then calculated the mean of the means and the mean of the standard deviations for the 3 years. Metrics with 3 years of data include species cover and frequency, functional group cover, soil surface feature cover and basal gaps. For the other plot groups where there is only one year of data, we calculated the mean and standard deviation based on a single year of data.

We also combined data for all 30 plots and calculated an ecological site mean for each ecological site. For most metrics, the ecological site mean was derived by combining the values from the plots in Plot Group B (and Plot Group C for Sandy Loam) with the 3-year mean values for the plots from Plot Group A.

### 2.3.1 Species cover and frequency

For herbaceous and shrub vegetation, percent cover was estimated for each species from the cover class midpoints, e.g., 7.5% for cover class 5%–10%. For each year, mean cover was calculated for each plot, and the mean and standard deviation were calculated for the ecological site from the plot means. 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 10 m<sup>2</sup> quadrats per plot where the species occurs) and for plots (percentage of plots where the species occurs). For Plot Group A, we calculated the quadrat and plot frequency for each year, and then calculated the 3 year means. We calculated the ecological site mean of these frequencies by using weighted means for Plot Group A and Plot Group B.

### 2.3.2 Species diversity

Four diversity measures were calculated for herbaceous and shrub species for each year (Magurran 1988), first for all species and then for native species only:

(1) Species richness (S) is the number of species at a given spatial scale. This was calculated at the level of the plot and at the level of the ecological site.

(2) The Shannon Diversity Index (H') provides a measure of species diversity that takes into account the relative abundance of each species:

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

where  $p_i$  is the abundance of each species.

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

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

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

$$S_e / (S_p - 1)$$

where  $S_e$  is the total number of species found in the ecological site, and  $S_p$  is the mean number of species found per plot.

For plot richness, Shannon diversity, and evenness within plot groups, the mean was calculated for each plot and year, and the mean and standard deviation were then calculated for the ecological site for each year. Ecological site richness and beta diversity were calculated for the ecological site for each year for each plot group.

We also calculated the ecological site mean for all metrics, using data from all 30 plots. For the ecological site richness and beta diversity we used one year of data from Plot Group A: the year that had the median value for Shannon diversity. The one-year data for these plots were combined with the other 20 plots to calculate these 2 metrics at the scale of the ecological site. For the other 3 metrics (plot richness, Shannon diversity, evenness) we took the 3-year mean for each plot in Plot Group A, and combined these with the plot means for the remaining 20 plots and calculated the mean and standard deviation for all 30 plots in the ecological site.

### ***2.3.3 Basal gaps***

We calculated 5 metrics for each year of basal gap data: median basal gap size, percentage of transects comprised by gaps and plant bases, percentage of transects comprised by each gap size class, and total number of gaps. Mean and standard deviation were calculated for each metric for each plot group and for all 30 plots in each ecological site. For Plot Group A, where there are 3 years of data, we calculated the mean and standard deviation of the metrics for each year, and then calculated the mean and of the means and the mean of the standard deviations for the 3 years.

### ***2.3.4 Soil stability***

We calculated the mean soil aggregate stability index for each plot and then calculated the mean and standard deviation for all plots in the plot group and for all plots in each ecological site. This gave us a mean soil aggregate stability index for the plots established in 2007, and a separate soil aggregate stability index for the plots established in 2010. The index was also calculated separately for samples with vegetative cover and for samples without vegetative cover. For the ecological site mean, we combined the plot means from all plot groups, and calculated the mean and standard deviation for all 30 plots.

## 3 Results

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

### 3.1 Clayey Fan ecological site

#### 3.1.1 Vegetation

Perennial grasses dominated the Clayey Fan ecological site (table 1 and fig. 3). Mean foliar cover of perennial grasses was 10.69%, while the mean total live foliar cover was 18.18%. Mean foliar cover of shrubs, forbs and annual grasses ranged between 2 and 4%. Mean foliar cover of cacti/succulents was 0.10%. Standing dead herbaceous cover was 2.92% and standing dead woody cover was 0.63%. There were large differences between the 2 plot groups. In particular, Plot Group B had much higher cover for perennial grasses, annual grasses and forbs. The large error bars indicate high variation among plots.

We present species-level data for the most abundant herbs and shrubs in the ecological site in Figure 4 (foliar cover) and Table 2 (foliar cover and frequency). *Sporobolus airoides* was the dominant species, appearing in all plots and 92% of quadrats, with a mean foliar cover of 7.127%. Other perennial grasses included *Pleuraphis jamesii* (James' galleta), *Bouteloua gracilis* (blue grama), and *Achnatherum hymenoides* (Indian ricegrass). Dominant annual grasses included *Eragrostis pectinacea* (desert lovegrass), *Sporobolus coromandelianus* (Madagascar dropseed), and *Bouteloua barbata* (sixweeks grama). The most abundant forbs included *Salsola tragus* (prickly Russian thistle), *Chamaesyce* spp. Group A (a grouping of annual sandmats based on morphological characteristics), *Xanthium strumarium* (rough cocklebur), and *Eriogonum cernuum* (nodding buckwheat). All 3 of these species are annuals. The most abundant shrubs included *Atriplex obovata* (mound saltbush), *Atriplex canescens* (fourwing saltbush), and *Gutierrezia sarothrae* (broom snakeweed). The large standard deviations indicate high variation among plots.

There were moderate differences in some of the species abundances between the 2 plot groups. Plot Group B had higher foliar cover of the dominant annual species, and higher foliar cover of *Sporobolus airoides*. The quadrat and plot frequencies for these species also tended to be higher in Plot Group B. Each plot group had species only found within that plot group. Appendix A lists all species, along with their common names, families, mean foliar cover and plot frequencies, by plot group and for the ecological site as a whole.

**Table 1. Foliar cover of functional groups for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO.**

| Functional groups        | Plot Group A<br>2007-2009 |      | Plot Group B<br>2010 |      | Ecological site |      |
|--------------------------|---------------------------|------|----------------------|------|-----------------|------|
|                          | Mean (%)                  | SD   | Mean (%)             | SD   | Mean (%)        | SD   |
| Total live foliar cover  | 12.13                     | 4.05 | 21.20                | 9.83 | 18.18           | 9.28 |
| Perennial grasses        | 8.09                      | 3.46 | 11.99                | 6.63 | 10.69           | 5.94 |
| Annual grasses           | 0.79                      | 0.94 | 3.76                 | 6.02 | 2.77            | 5.10 |
| Forbs                    | 0.67                      | 0.74 | 4.27                 | 3.63 | 3.07            | 3.43 |
| Shrubs                   | 2.64                      | 2.73 | 2.19                 | 1.71 | 2.34            | 2.07 |
| Cacti/succulents         | 0.03                      | 0.03 | 0.14                 | 0.34 | 0.10            | 0.28 |
| Standing dead herbaceous | 2.84                      | 0.93 | 2.96                 | 1.62 | 2.92            | 1.38 |
| Standing dead woody      | 0.80                      | 0.81 | 0.54                 | 0.31 | 0.63            | 0.53 |

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

Figure 3. Mean percent foliar cover of functional groups for Plot Group A, Plot Group B and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO. Error bars represent one standard deviation.

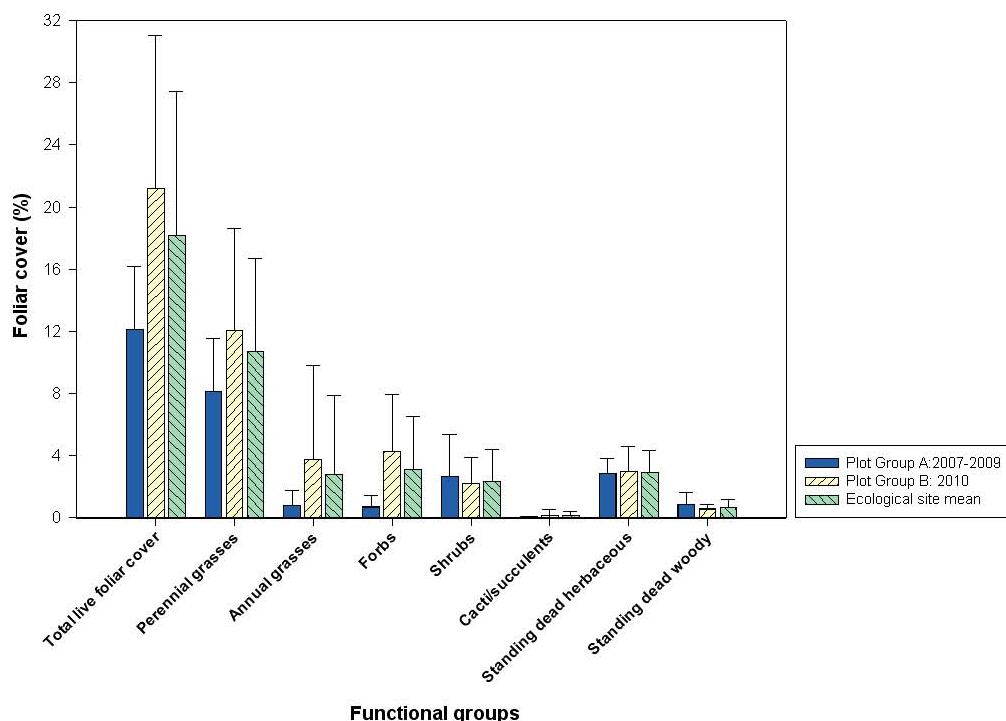
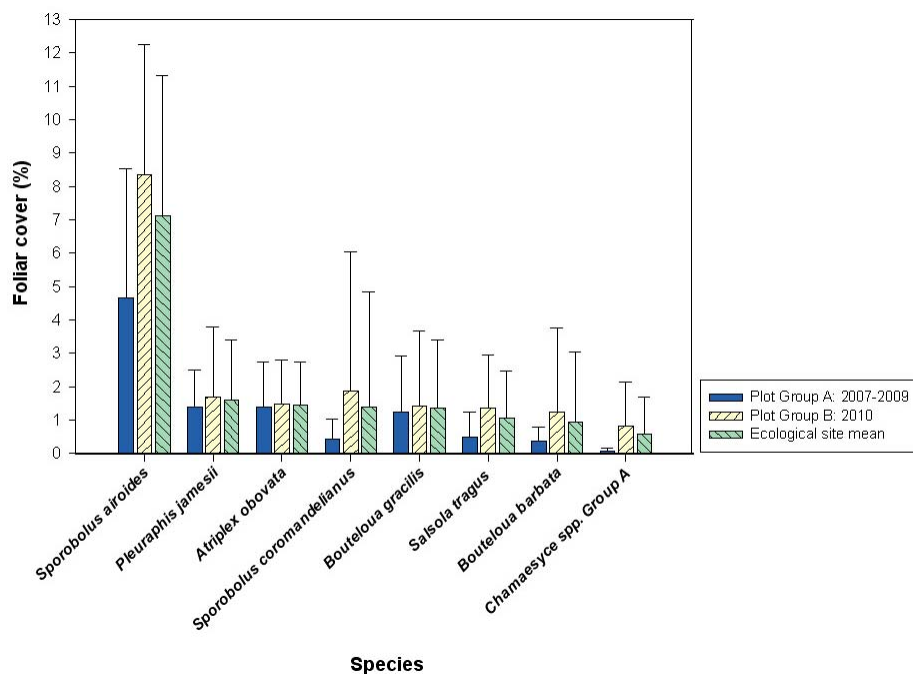


Figure 4. Mean percent foliar cover of the 8 most abundant shrub and herbaceous species for all plots (ecological site mean) compared to mean foliar cover for Plot Group A and Plot Group B in the Clayey Fan ecological site at PEFO. Error bars represent one standard deviation.



Six nonnative species were found in the plots. *Salsola tragus* was widespread and moderately abundant, with a mean foliar cover of 1.061%, a quadrat frequency of 57.56% and a plot frequency of 95.56%. The other 4 nonnative species had lower abundances. *Mollugo cerviana* (threadstem) had a mean foliar cover of 0.070% and a plot frequency of 13.33%. *Portulaca oleracea* (little hogweed) had a mean foliar cover of 0.054% and a plot frequency of 43.33%. *Bromus tectorum* (cheatgrass), *Erodium cicutarium* (stork's bill) and *Halogeton glomeratus* (saltlover) all had a mean foliar cover of 0.001% and had low plot frequencies. All of these species are annuals.

We encountered several new species in this ecological site. New records for the park include one nonnative annual forb, *Mollugo cerviana*, and 3 native forbs, *Heliotropium curassavicum* (salt heliotrope), *Phemeranthus parviflorus* (sunbright), and *Portulaca pilosa* (kiss me quick).

**Table 2. Mean foliar cover and standard deviation, and mean quadrat and plot frequency of the 15 most abundant shrub and herbaceous species and all nonnative species for all plots (ecological site mean) compared with the values for Plot Group A and Plot Group B in the Clayey Fan ecological site at PEFO.**

| Species                                  | Plot Group A<br>2007-2009 |       |                       |                    | Plot Group B<br>2010 |       |                       |                    | Ecological site mean |       |                       |                    |
|------------------------------------------|---------------------------|-------|-----------------------|--------------------|----------------------|-------|-----------------------|--------------------|----------------------|-------|-----------------------|--------------------|
|                                          | Foliar cover (%)          | SD    | Quadrat frequency (%) | Plot frequency (%) | Foliar cover (%)     | SD    | Quadrat frequency (%) | Plot frequency (%) | Foliar cover (%)     | SD    | Quadrat frequency (%) | Plot frequency (%) |
| <i>Sporobolus airoides</i>               | 4.659                     | 3.874 | 91.78                 | 100.00             | 8.361                | 3.899 | 92.33                 | 100.00             | 7.127                | 4.178 | 92.15                 | 100.00             |
| <i>Pleuraphis jamesii</i>                | 1.405                     | 1.096 | 57.33                 | 100.00             | 1.698                | 2.094 | 46.33                 | 90.00              | 1.600                | 1.787 | 50.00                 | 93.33              |
| <i>Atriplex obovata</i>                  | 1.386                     | 1.360 | 56.44                 | 93.33              | 1.485                | 1.303 | 62.00                 | 90.00              | 1.452                | 1.296 | 60.15                 | 91.11              |
| <i>Sporobolus coromandelianus</i>        | 0.430                     | 0.591 | 18.22                 | 43.33              | 1.887                | 4.155 | 31.00                 | 60.00              | 1.401                | 3.450 | 26.74                 | 54.44              |
| <i>Bouteloua gracilis</i>                | 1.237                     | 1.687 | 51.33                 | 90.00              | 1.412                | 2.260 | 29.67                 | 65.00              | 1.354                | 2.050 | 36.89                 | 73.33              |
| <i>Salsola tragus</i> <sup>a</sup>       | 0.479                     | 0.773 | 49.33                 | 86.67              | 1.351                | 1.594 | 61.67                 | 100.00             | 1.061                | 1.420 | 57.56                 | 95.56              |
| <i>Bouteloua barbata</i>                 | 0.365                     | 0.437 | 25.11                 | 53.33              | 1.250                | 2.509 | 48.00                 | 90.00              | 0.955                | 2.088 | 40.37                 | 77.78              |
| <i>Chamaesyce</i> spp. Group A           | 0.067                     | 0.091 | 23.11                 | 43.33              | 0.833                | 1.295 | 58.33                 | 90.00              | 0.578                | 1.112 | 46.59                 | 74.44              |
| <i>Xanthium strumarium</i>               | 0                         | 0     | 0                     | 0                  | 0.632                | 2.126 | 8.33                  | 15.00              | 0.421                | 1.748 | 5.56                  | 10.00              |
| <i>Eragrostis pectinacea</i>             | 0.010                     | 0.033 | 1.11                  | 3.33               | 0.497                | 1.328 | 13.67                 | 30.00              | 0.335                | 1.100 | 9.48                  | 21.11              |
| <i>Atriplex canescens</i>                | 0.481                     | 0.854 | 20.00                 | 53.33              | 0.229                | 0.470 | 10.33                 | 40.00              | 0.313                | 0.620 | 13.56                 | 44.44              |
| <i>Achnatherum hymenoides</i>            | 0.256                     | 0.204 | 38.67                 | 90.00              | 0.166                | 0.252 | 19.33                 | 75.00              | 0.196                | 0.228 | 25.78                 | 80.00              |
| <i>Eriogonum cernuum</i>                 | <0.001                    | 0.001 | 0.89                  | 10.00              | 0.279                | 1.172 | 8.67                  | 25.00              | 0.186                | 0.958 | 6.07                  | 20.00              |
| <i>Chamaesyce</i> spp. Group B           | 0.007                     | 0.018 | 3.33                  | 13.33              | 0.170                | 0.510 | 11.00                 | 20.00              | 0.116                | 0.421 | 8.44                  | 17.78              |
| <i>Gutierrezia sarothrae</i>             | 0.069                     | 0.126 | 18.44                 | 46.67              | 0.097                | 0.200 | 9.00                  | 45.00              | 0.088                | 0.174 | 12.15                 | 45.56              |
| <i>Mollugo cerviana</i> <sup>a</sup>     | 0                         | 0     | 0                     | 0                  | 0.105                | 0.458 | 4.00                  | 20.00              | 0.070                | 0.374 | 2.67                  | 13.33              |
| <i>Portulaca oleracea</i> <sup>a</sup>   | 0.015                     | 0.041 | 4.00                  | 20.00              | 0.073                | 0.170 | 15.67                 | 55.00              | 0.054                | 0.142 | 11.78                 | 43.33              |
| <i>Bromus tectorum</i> <sup>a</sup>      | 0.002                     | 0.003 | 2.44                  | 20.00              | 0.001                | 0.004 | 2.00                  | 10.00              | 0.001                | 0.004 | 2.15                  | 13.33              |
| <i>Erodium cicutarium</i> <sup>a</sup>   | 0                         | 0     | 0                     | 0                  | 0.001                | 0.004 | 0.33                  | 5.00               | 0.001                | 0.004 | 0.22                  | 3.33               |
| <i>Halogeton glomeratus</i> <sup>a</sup> | 0                         | 0     | 0                     | 0                  | 0.001                | 0.004 | 0.33                  | 5.00               | 0.001                | 0.004 | 0.22                  | 3.33               |

Note: Species are arranged in descending order by the ecological site mean cover. Also, annual species of *Chamaesyce* spp. were placed into 2 groups, A and B, based on morphological characteristics.

<sup>a</sup>Nonnative species.

The species diversity metrics illustrate moderate diversity on the scale of the plot, and high diversity on the scale of the ecological site (table 3). For the entire ecological site, plot richness was 23.7 species. Shannon diversity (which takes the relative abundance of each species into account and generally ranges between 1.5 and 3.5) was 1.681. Evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) was 0.539. On the scale of the ecological site, richness was 116 species, and beta diversity was 5.103. This level of ecological site species diversity is noteworthy as beta diversity generally ranges between 1 and 5. Plot Group B generally had higher values for these diversity metrics, with the exception of evenness. This is likely the result of Plot Group B having a larger sample size: 20 plots versus 10 in Plot Group A.

When these metrics were recalculated using only native species, most values decreased while beta diversity increased.

**Table 3. Species diversity metrics for all species and for native species only, for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO.**

|                          | Plot Group A<br>2007-2009 |       | Plot Group B<br>2010 |       | Ecological site |       |
|--------------------------|---------------------------|-------|----------------------|-------|-----------------|-------|
|                          | Mean                      | SD    | Mean                 | SD    | Mean            | SD    |
| <b>All species</b>       |                           |       |                      |       |                 |       |
| <b>Plot</b>              |                           |       |                      |       |                 |       |
| Plot richness            | 19.1                      | 6.4   | 26.0                 | 9.8   | 23.7            | 9.3   |
| Shannon diversity        | 1.646                     | 0.422 | 1.699                | 0.473 | 1.681           | 0.442 |
| Evenness                 | 0.570                     | 0.105 | 0.524                | 0.099 | 0.539           | 0.098 |
| <b>Ecological site</b>   |                           |       |                      |       |                 |       |
| Ecological site richness | 57.7                      |       | 106 <sup>a</sup>     |       | 116             |       |
| Beta diversity           | 3.224                     |       | 4.240 <sup>a</sup>   |       | 5.103           |       |
| <b>Native species</b>    |                           |       |                      |       |                 |       |
| <b>Plot</b>              |                           |       |                      |       |                 |       |
| Plot richness            | 17.8                      | 6.4   | 24.1                 | 9.5   | 22.01           | 9.0   |
| Shannon diversity        | 1.597                     | 0.414 | 1.580                | 0.490 | 1.586           | 0.454 |
| Evenness                 | 0.567                     | 0.105 | 0.499                | 0.109 | 0.521           | 0.108 |
| <b>Ecological site</b>   |                           |       |                      |       |                 |       |
| Ecological site richness | 55.7                      |       | 101 <sup>a</sup>     |       | 111             |       |
| Beta diversity           | 3.337                     |       | 4.372 <sup>a</sup>   |       | 5.269           |       |

<sup>a</sup>These are not mean values.

### 3.1.2 Soil

We measured the amount of soil surface potentially subject to erosion in 2 ways: cover estimates of soil surface features in quadrats and measurements of basal gaps along transects. For soil surface features, undifferentiated crust had the greatest cover, followed by bare soil, at 69.18% and 11.36% respectively (table 4 and fig. 5). Live plant base, dead herbaceous base, duff / litter, cyanobacteria and fine gravel had mean covers that ranged between 2 and 5%. The other soil surface features had mean covers of less than 1%.

The soil surface features were similar between the 2 groups: Plot Group B had higher bare soil, and lower undifferentiated crust, but this may be attributable to slight changes in how the crew differentiated between bare soil, undifferentiated crust and cyanobacteria categories in the field.

**Table 4. Cover of soil surface features for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO.**

| Soil surface feature         | Plot Group A<br>2007–2009 |      | Plot Group B<br>2010 |       | Ecological site |       |
|------------------------------|---------------------------|------|----------------------|-------|-----------------|-------|
|                              | Mean (%)                  | SD   | Mean (%)             | SD    | Mean (%)        | SD    |
| Live plant base              | 4.69                      | 1.62 | 3.39                 | 1.94  | 3.82            | 1.88  |
| Dead woody base              | 0.25                      | 0.33 | 0.09                 | 0.18  | 0.14            | 0.22  |
| Dead herbaceous base         | 2.12                      | 0.72 | 1.94                 | 1.09  | 2.00            | 0.96  |
| Bare soil                    | 8.28                      | 4.64 | 12.90                | 9.91  | 11.36           | 8.53  |
| Duff/litter <sup>a</sup>     | 6.84                      | 4.74 | 3.77                 | 1.86  | 4.80            | 3.31  |
| Undifferentiated crust       | 74.03                     | 6.86 | 66.75                | 11.43 | 69.18           | 10.22 |
| Moss                         | 0.38                      | 0.80 | 0.57                 | 1.22  | 0.50            | 1.09  |
| Lichen                       | 0                         | 0    | 0.05                 | 0.23  | 0.04            | 0.18  |
| Cyanobacteria <sup>b</sup>   | 0.14                      | 0.38 | 4.62                 | 7.23  | 3.13            | 6.24  |
| Fine gravel (0.2 to <2 cm)   | 1.13                      | 1.83 | 3.77                 | 5.68  | 2.89            | 4.86  |
| Coarse gravel (2 to <7.5 cm) | 0.28                      | 0.75 | 0.16                 | 0.32  | 0.20            | 0.48  |
| Cobble (7.5 to <25 cm)       | 0                         | 0    | <0.01                | 0.01  | <0.01           | 0.01  |
| Stone, bedrock (>25 cm)      | 0                         | 0    | 0                    | 0     | 0               | 0     |
| Woody debris                 | 0.01                      | 0.03 | 0                    | 0     | <0.01           | 0.02  |

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

<sup>a</sup>Duff did not occur in these plots

<sup>b</sup>In 2010 we used a different method for classifying cyanobacteria.

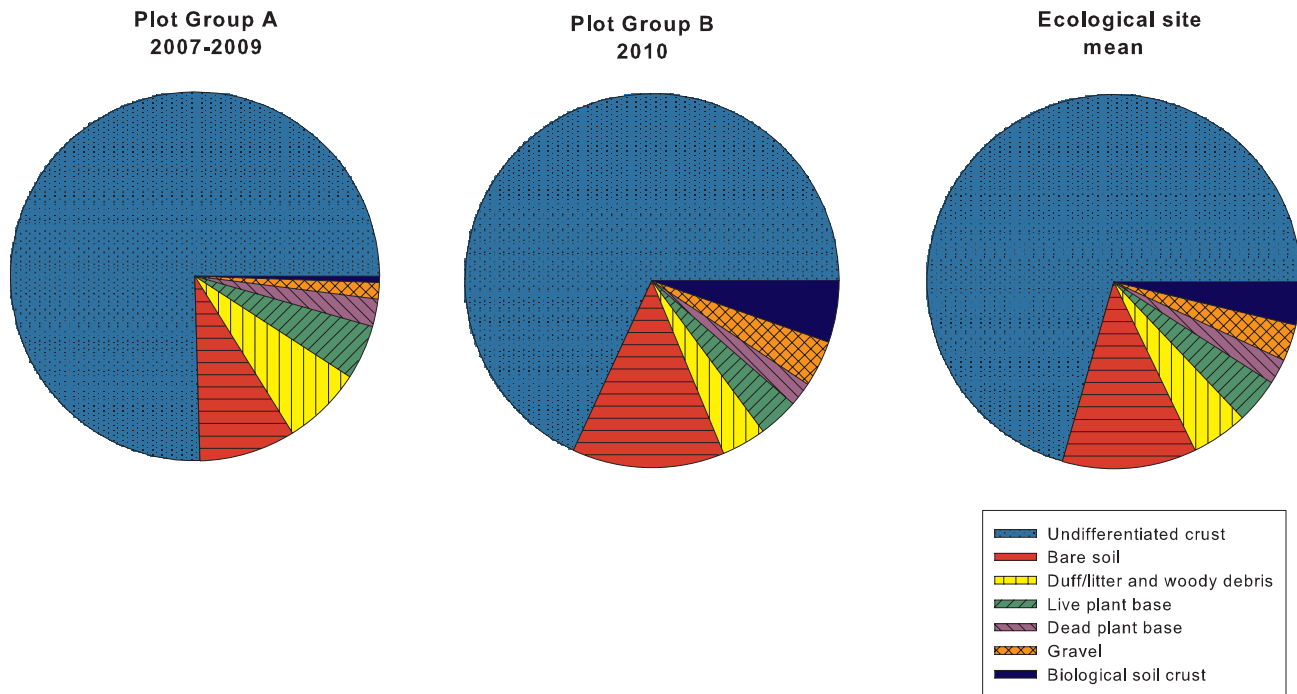


**Figure 5. Mean percent cover of soil surface features for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site in PEFO. Biological soil crust includes moss, lichen and cyanobacteria.**

The basal gap data also suggests large amounts of exposed ground. Basal gaps greater than 100 cm comprised 68.5% of the transects, while approximately 10% of the transects were comprised of gaps less than 50 cm (table 5 and fig. 6). The median gap size was 67.6 cm. The various basal gaps metrics were similar for the 2 plot groups.

Soil aggregate stability provides a measure of the erodibility of soil. The index ranges between 1 and 6, with 1 indicating low stability and 6 indicating high stability. The mean stability for the ecological site was 3.61 (table 6). Stability was higher for soil below vegetative cover. Plot Group A had slightly higher soil stability ratings than Plot Group B, but the standard deviations were large, indicating high among plot variability.

**Table 5. Number of basal gaps, median gap size, and percentage of transect in different gap size classes for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO.**

| Metric                                  | Plot Group A<br>2007–2009 |      | Plot Group B<br>2010 |      | Ecological site |      |
|-----------------------------------------|---------------------------|------|----------------------|------|-----------------|------|
|                                         | Mean                      | SD   | Mean                 | SD   | Mean            | SD   |
| Number of gaps                          | 143.1                     | 44.4 | 138.4                | 53.6 | 140.0           | 49.5 |
| Median gap size (cm)                    | 63.1                      | 25.4 | 69.8                 | 33.2 | 67.6            | 29.3 |
| Percentage of transect in gaps          | 95.2                      | 1.6  | 93.0                 | 2.8  | 93.7            | 2.6  |
| Percentage of transect in gaps 0–19 cm  | 2.2                       | 1.1  | 2.2                  | 1.4  | 2.2             | 1.3  |
| Percentage of transect in gaps 20–49 cm | 7.9                       | 3.3  | 7.7                  | 4.5  | 7.8             | 4.0  |
| Percentage of transect in gaps 50–99 cm | 14.9                      | 6.8  | 15.4                 | 7.5  | 15.2            | 7.1  |
| Percentage of transect in gaps ≥100 cm  | 70.1                      | 12.3 | 67.7                 | 15.4 | 68.5            | 14.2 |
| Percentage of transect in plant bases   | 4.8                       | 1.6  | 7.0                  | 2.8  | 6.3             | 2.6  |

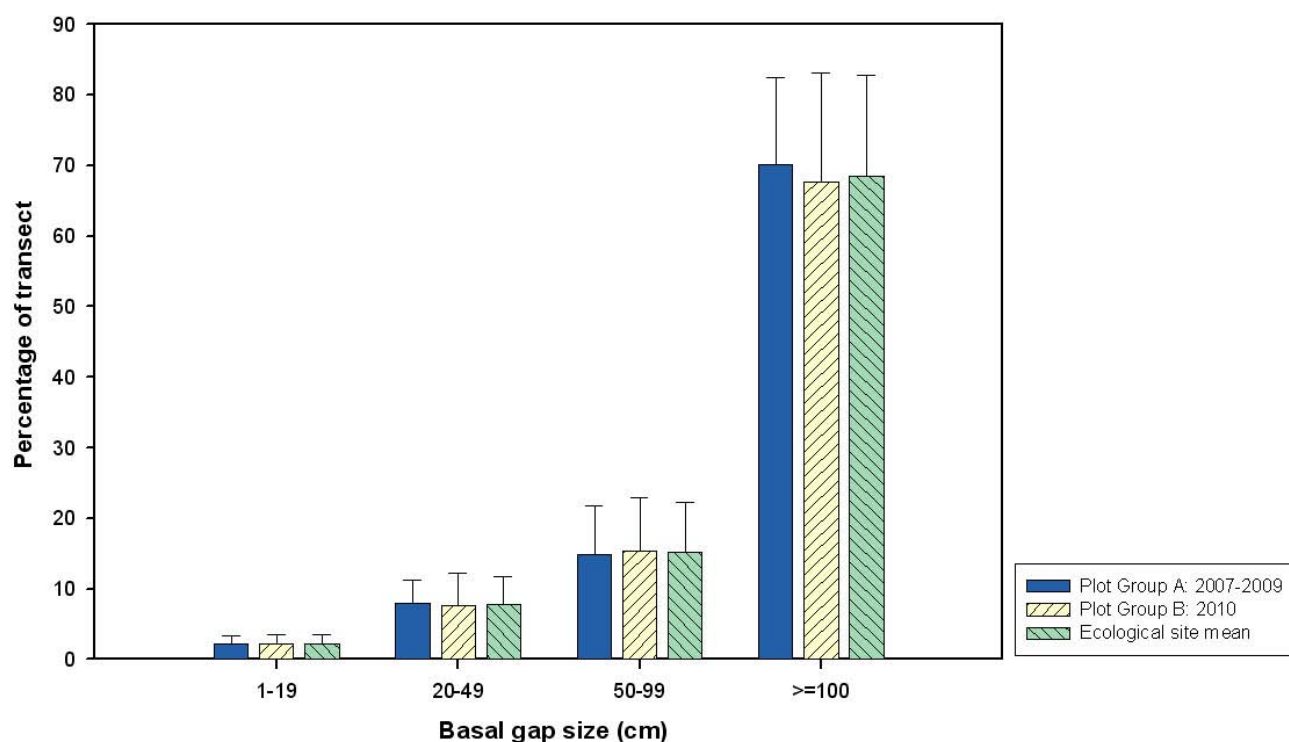


**Figure 6. Percentage of transect in different gap sizes for Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO. Error bars represent 1 standard deviation.**

**Table 6. Soil stability rating for all samples, and for samples with and without vegetative cover, in Plot Group A, Plot Group B, and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO.**

|                                    | Plot Group A<br>2007 |      | Plot Group B<br>2010 |      | Ecological site |      |
|------------------------------------|----------------------|------|----------------------|------|-----------------|------|
|                                    | Mean                 | SD   | Mean                 | SD   | Mean            | SD   |
| All samples                        | 3.96                 | 0.42 | 3.43                 | 1.16 | 3.61            | 1.00 |
| Samples under vegetative cover     | 4.41                 | 0.67 | 3.74                 | 1.23 | 3.96            | 1.11 |
| Samples not under vegetative cover | 3.67                 | 0.43 | 3.01                 | 1.42 | 3.23            | 1.22 |

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

## 3.2 Sandy Loam ecological site

### 3.2.1 Vegetation

Perennial grasses dominated the Sandy Loam ecological site. The mean foliar cover of perennial grasses was 14.18% for the ecological site, while the mean total live foliar cover was 21.09% (table 7 and fig. 7). Shrubs had a mean foliar cover of 5.15% and forbs had a mean foliar cover of 1.83%. The other living components had mean foliar covers less than 1%. Standing dead herbaceous cover was 4.42%, and standing dead woody cover was 1.89%. While there were some differences among plot groups, these differences were generally not large. Plot Group C had the highest mean values for total live foliar cover, perennial grass cover and forb cover.

We examine species-level data for the most abundant herbs and shrubs in Figure 8 (foliar cover) and Table 8 (foliar cover and frequency). *Bouteloua gracilis* (blue grama) was the perennial grass with the greatest mean foliar cover, at 5.547% for the ecological site. Other dominant grasses included *Pleuraphis jamesii* (James' galleta), *Sporobolus airoides* (alkali sacaton), *Bouteloua eriopoda* (black grama), *Achnatherum hymenoides* (Indian ricegrass), and *Sporobolus flexuosus* (mesa dropseed). Dominant shrubs included *Gutierrezia sarothrae* (broom snakeweed) and *Chrysothamnus greenii* (Greene's rabbitbrush). The most abundant forbs included *Salsola tragus* (prickly Russian thistle) and *Chamaesyce* spp. Group A (a grouping of annual sandmats based on morphological characteristics). Appendix B lists all species, along with their common names, families, mean foliar cover and plot frequencies, by plot group and for the Sandy Loam ecological site as a whole.

**Table 7. Foliar cover of functional groups for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO.**

| Functional groups        | Plot Group A<br>2007-2009 |      | Plot Group B<br>2007 |      | Plot Group C<br>2010 |      | Ecological site |      |
|--------------------------|---------------------------|------|----------------------|------|----------------------|------|-----------------|------|
|                          | Mean (%)                  | SD   | Mean (%)             | SD   | Mean (%)             | SD   | Mean (%)        | SD   |
| Total live foliar cover  | 16.75                     | 4.32 | 21.81                | 6.54 | 24.05                | 3.93 | 21.09           | 5.57 |
| Perennial grasses        | 10.82                     | 4.88 | 14.61                | 8.16 | 16.54                | 2.85 | 14.18           | 5.55 |
| Annual grasses           | 0.25                      | 0.70 | 0.30                 | 0.38 | 0.76                 | 1.43 | 0.48            | 1.04 |
| Forbs                    | 0.62                      | 1.08 | 0.94                 | 1.36 | 3.23                 | 1.52 | 1.83            | 1.80 |
| Shrubs                   | 4.71                      | 2.32 | 6.81                 | 4.00 | 4.60                 | 1.19 | 5.15            | 2.77 |
| Cacti/succulents         | 0.13                      | 0.15 | 0.08                 | 0.11 | 0.16                 | 0.14 | 0.13            | 0.14 |
| Standing dead herbaceous | 3.49                      | 2.10 | 5.45                 | 1.95 | 4.59                 | 1.19 | 4.42            | 1.70 |
| Standing dead woody      | 1.41                      | 0.70 | 1.16                 | 0.85 | 2.66                 | 1.54 | 1.90            | 1.31 |

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

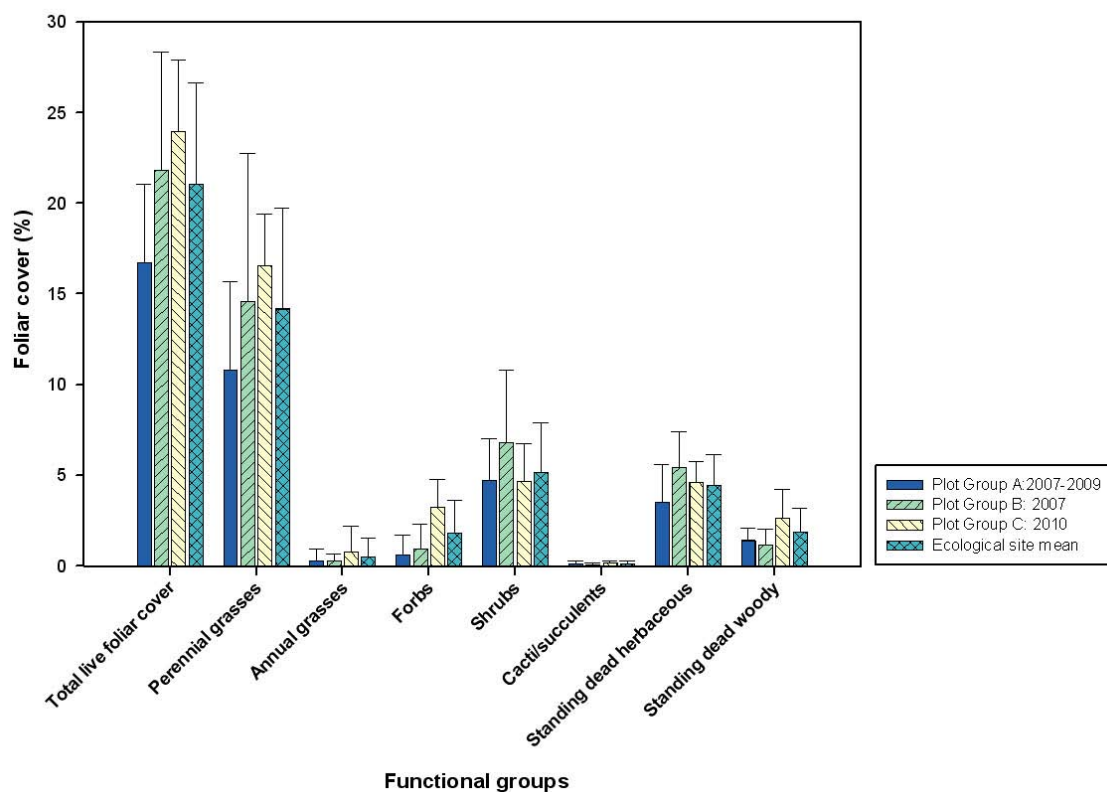


Figure 7. Mean percent foliar cover of functional groups for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO. Error bars represent one standard deviation.

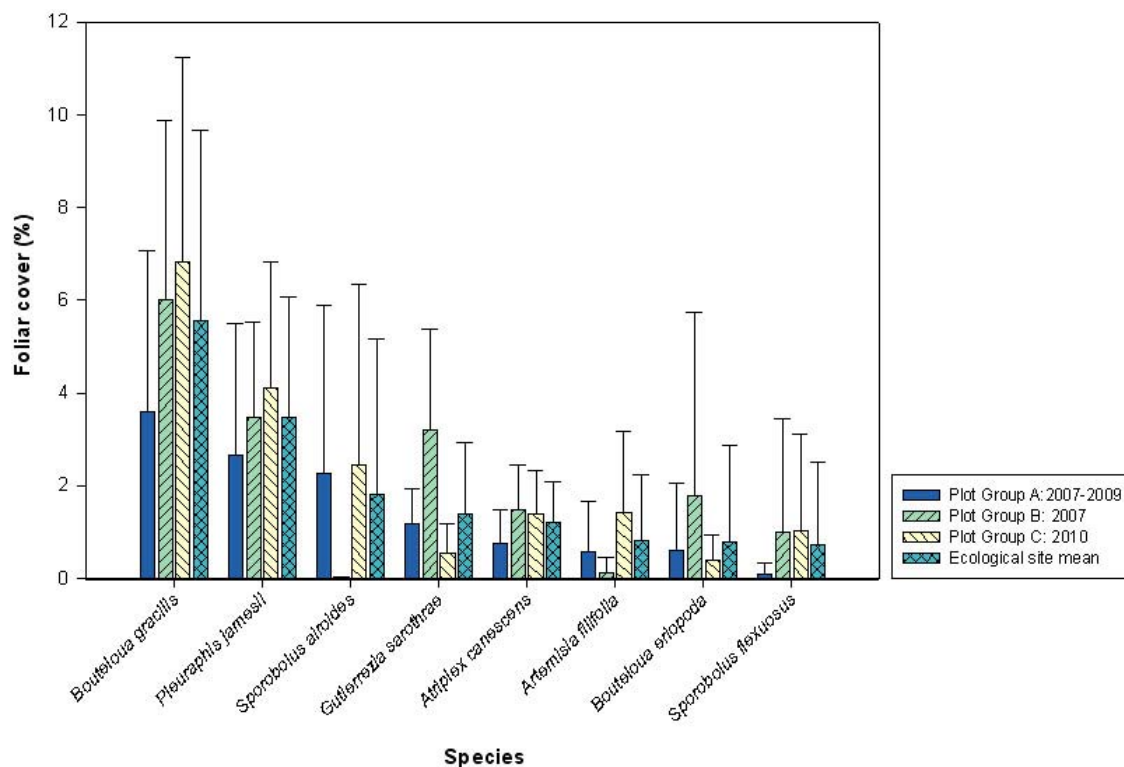


Figure 8. Mean percent foliar cover of the 8 most abundant shrub and herbaceous species for all plots (ecological site mean) compared to mean foliar cover for Plot Group A and Plot Group B in the Sandy Loam ecological site at PEFO. Error bars represent one standard deviation.

**Table 8. Mean foliar cover and standard deviation, and mean quadrat and plot frequency of the 15 most abundant shrub and herbaceous species and all nonnative species for all plots (ecological site mean) compared with the values for Plot Groups A, B, and C in the Sandy Loam ecological site at PEFO.**

| Species                                   | Plot Group A<br>2007-2009 |        |                 |                | Plot Group B<br>2007 |       |                |                | Plot Group C<br>2010 |       |                 |                | Ecological site mean |        |                 |                |
|-------------------------------------------|---------------------------|--------|-----------------|----------------|----------------------|-------|----------------|----------------|----------------------|-------|-----------------|----------------|----------------------|--------|-----------------|----------------|
|                                           | Foliar cover (%)          | SD     | Quad. freq. (%) | Plot freq. (%) | Foliar cover (%)     | SD    | Qua. freq. (%) | Plot freq. (%) | Foliar cover (%)     | SD    | Quad. freq. (%) | Plot freq. (%) | Foliar cover (%)     | SD     | Quad. freq. (%) | Plot freq. (%) |
| <i>Bouteloua gracilis</i>                 | 3.591                     | 3.469  | 65.33           | 83.33          | 5.994                | 3.893 | 87.62          | 100.00         | 6.811                | 4.428 | 74.36           | 100.00         | 5.547                | 4.116  | 74.44           | 94.44          |
| <i>Pleuraphis jamesii</i>                 | 2.641                     | 2.857  | 75.11           | 100.00         | 3.474                | 2.065 | 82.86          | 100.00         | 4.093                | 2.724 | 84.10           | 100.00         | 3.464                | 2.608  | 80.81           | 100.00         |
| <i>Sporobolus airoides</i>                | 2.265                     | 3.618  | 43.78           | 80.00          | 0.012                | 0.011 | 5.71           | 57.14          | 2.448                | 3.879 | 21.03           | 61.54          | 1.819                | 3.358  | 25.04           | 66.67          |
| <i>Gutierrezia sarothrae</i>              | 1.186                     | 0.744  | 69.56           | 90.00          | 3.205                | 2.164 | 78.10          | 100.00         | 0.542                | 0.618 | 37.95           | 92.31          | 1.378                | 1.554  | 57.85           | 93.33          |
| <i>Atriplex canescens</i>                 | 0.765                     | 0.710  | 43.33           | 90.00          | 1.488                | 0.946 | 55.24          | 85.71          | 1.391                | 0.932 | 50.26           | 100.00         | 1.205                | 0.887  | 49.11           | 93.33          |
| <i>Bouteloua eriopoda</i>                 | 0.608                     | 1.430  | 19.33           | 60.00          | 1.791                | 3.944 | 18.10          | 57.14          | 0.400                | 0.526 | 10.26           | 61.54          | 0.827                | 1.407  | 21.41           | 40.00          |
| <i>Artemisia filifolia</i>                | 0.559                     | 1.102  | 14.89           | 30.00          | 0.122                | 0.324 | 4.76           | 14.29          | 1.414                | 1.763 | 35.38           | 61.54          | 0.794                | 2.071  | 15.11           | 60.00          |
| <i>Achnatherum hymenoides</i>             | 0.649                     | 0.831  | 55.33           | 90.00          | 0.363                | 0.215 | 49.52          | 100.00         | 0.795                | 0.847 | 50.26           | 92.31          | 0.710                | 1.800  | 16.52           | 34.44          |
| <i>Sporobolus flexuosus</i>               | 0.079                     | 0.242  | 2.89            | 13.33          | 1.004                | 2.437 | 18.10          | 42.86          | 1.037                | 2.078 | 26.15           | 46.15          | 0.646                | 0.728  | 51.78           | 93.33          |
| <i>Salsola tragus</i> <sup>a</sup>        | 0.355                     | 0.897  | 26.44           | 53.33          | 0.545                | 1.441 | 13.33          | 28.57          | 0.559                | 0.594 | 40.51           | 92.31          | 0.488                | 0.910  | 29.48           | 64.44          |
| <i>Chrysothamnus Greenei</i>              | 0.790                     | 1.310  | 22.44           | 56.67          | 0                    | 0     | 0              | 0              | 0.401                | 0.929 | 12.31           | 23.08          | 0.437                | 0.988  | 12.81           | 28.89          |
| <i>Chamaesyce</i> spp. Group B            | 0.004                     | 0.006  | 4.00            | 23.33          | 0.001                | 0.003 | 1.90           | 14.29          | 1.005                | 0.847 | 82.05           | 100.00         | 0.437                | 0.743  | 37.33           | 54.44          |
| <i>Hesperostipa comata</i>                | 0.319                     | 0.533  | 25.33           | 60.00          | 0.211                | 0.272 | 20.00          | 57.14          | 0.426                | 0.686 | 27.69           | 76.92          | 0.340                | 0.547  | 25.11           | 66.67          |
| <i>Krascheninnikovia lanata</i>           | 0.100                     | 0.157  | 8.44            | 50.00          | 1.231                | 2.559 | 20.95          | 42.86          | 0.042                | 0.111 | 5.13            | 23.08          | 0.339                | 1.272  | 9.93            | 36.67          |
| <i>Ephedra torreyana</i>                  | 0.276                     | 0.373  | 11.78           | 60.00          | 0.169                | 0.273 | 7.62           | 42.86          | 0                    | 0     | 0               | 0              | 0.264                | 0.695  | 8.15            | 36.67          |
| <i>Bromus tectorum</i> <sup>a</sup>       | 0.275                     | 0.831  | 11.11           | 43.33          | 0.273                | 0.339 | 27.62          | 85.71          | 0.000                | 0.001 | 0.51            | 7.69           | 0.156                | 0.507  | 10.37           | 37.78          |
| <i>Portulaca oleracea</i> <sup>a</sup>    | 0.001                     | 0.002  | 0.22            | 3.33           | <0.001               | 0.001 | 0.95           | 14.29          | 0.118                | 0.185 | 17.95           | 53.85          | 0.051                | 0.133  | 8.07            | 27.78          |
| <i>Mollugo cerviana</i> <sup>a</sup>      | 0                         | 0      | 0               | 0              | <0.001               | 0.001 | 0.95           | 14.29          | 0.028                | 0.079 | 5.13            | 38.46          | 0.012                | 0.053  | 2.44            | 20.00          |
| <i>Kochia scoparia</i> <sup>a</sup>       | 0                         | 0      | 0               | 0              | 0                    | 0     | 0              | 0              | <0.001               | 0.001 | 0.51            | 7.69           | <0.001               | 0.001  | 0.22            | 3.33           |
| <i>Polygonum aviculare</i> <sup>a</sup>   | <0.001                    | <0.001 | 0.22            | 3.33           | 0                    | 0     | 0              | 0              | 0                    | 0     | 0               | 0              | <0.001               | <0.001 | 0.07            | 1.11           |
| <i>Sisymbrium altissimum</i> <sup>a</sup> | <0.001                    | <0.001 | 0.22            | 3.33           | 0                    | 0     | 0              | 0              | 0                    | 0     | 0               | 0              | <0.001               | <0.001 | 0.07            | 1.11           |

Note: Species are arranged in descending order by the ecological site mean cover. Also, annual species of *Chamaesyce* spp. were placed into 2 groups, A and B, based on morphological characteristics.

<sup>a</sup>Nonnative species.

There were some differences in the mean foliar covers and frequencies of species among the plot groups, but these differences were moderately small. The large error bars for mean cover values suggest high among-plot variation.

Seven nonnative species were encountered in the plots. The most abundant nonnative species was *Salsola tragus*, which occurred in 64.44% of the plots, 29.48% of the quadrats and had a mean foliar cover of 0.488%. *Bromus tectorum* (cheatgrass) was also moderately abundant, occurring in 37.78% of the plots, with a mean foliar cover of 0.156%. *Portulaca oleracea* (little hogweed) and *Mollugo cerviana* (threadstem) were less abundant, with plot frequencies of 27.78 and 20.00, respectively. *Kochia scoparia* (Mexican burning bush), *Polygonum aviculare* (prostrate knotweed) and *Sisymbrium altissima* (tumblemustard) were sparse, with trace amounts of cover.

One rare plant species already known to the park was encountered in this ecological site during the 2010 field season. *Amaranthus acanthochiton* (greenstripe) is critically imperiled in Utah and imperiled in Arizona; its Global Heritage Status Rank is G5 as defined by The Nature Conservancy. We found it in one plot, with a mean foliar cover of 0.001% for the ecological site. Two new species for the park were also detected in this ecological site, *Mollugo cerviana* and *Portulaca pilosa* (kiss me quick). The former is nonnative, and the latter is native. Both were also found in the Clayey Fan plots.

This ecological site had moderate levels of species richness at the scale of the plot, but high levels of species diversity at the scale of the ecological site (table 9). For the entire ecological site, plot richness was 26.2, Shannon diversity (which takes the relative abundance of each species into account and generally ranges from 1.5 to 3.5) was 1.934, and evenness (the degree to which all species are of equal abundance, ranging from 0 to 1) was 0.602. On the scale of the ecological site, richness was 105 species, and beta diversity (a measure of within-site heterogeneity, generally ranging between 1 and 5) was 4.134.

**Table 9. Species diversity metrics for all species and for native species only, for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO.**

|                          | Plot Group A<br>2007-2009 |       | Plot Group B<br>2007 |       | Plot Group C<br>2010 |       | Ecological site |       |
|--------------------------|---------------------------|-------|----------------------|-------|----------------------|-------|-----------------|-------|
|                          | Mean                      | SD    | Mean                 | SD    | Mean                 | SD    | Mean            | SD    |
| <b>All species</b>       |                           |       |                      |       |                      |       |                 |       |
| <b>Plot</b>              |                           |       |                      |       |                      |       |                 |       |
| Plot richness            | 20.3                      | 5.2   | 20.1                 | 4.5   | 34.0                 | 5.5   | 26.2            | 8.5   |
| Shannon diversity        | 1.798                     | 0.491 | 1.769                | 0.157 | 2.128                | 0.360 | 1.934           | 0.401 |
| Evenness                 | 0.604                     | 0.122 | 0.595                | 0.056 | 0.604                | 0.090 | 0.602           | 0.091 |
| <b>Ecological site</b>   |                           |       |                      |       |                      |       |                 |       |
| Ecological site richness | 52.7                      |       | 45 <sup>a</sup>      |       | 87 <sup>a</sup>      |       | 105             |       |
| Beta diversity           | 2.722                     |       | 2.351 <sup>a</sup>   |       | 2.636 <sup>a</sup>   |       | 4.134           |       |
| <b>Native species</b>    |                           |       |                      |       |                      |       |                 |       |
| <b>Plot</b>              |                           |       |                      |       |                      |       |                 |       |
| Plot richness            | 19.2                      | 5.0   | 18.7                 | 4.1   | 32.0                 | 5.4   | 24.6            | 8.1   |
| Shannon diversity        | 1.768                     | 0.495 | 1.702                | 0.160 | 2.061                | 0.359 | 1.880           | 0.399 |
| Evenness                 | 0.605                     | 0.123 | 0.586                | 0.050 | 0.595                | 0.091 | 0.596           | 0.091 |
| <b>Ecological site</b>   |                           |       |                      |       |                      |       |                 |       |
| Ecological site richness | 49.7                      |       | 41 <sup>a</sup>      |       | 82 <sup>a</sup>      |       | 99              |       |
| Beta diversity           | 2.715                     |       | 2.315 <sup>a</sup>   |       | 2.645 <sup>a</sup>   |       | 4.160           |       |

<sup>a</sup>These are not mean values.

There were some differences among the plot groups. Plot Group C had higher diversity than the other 2 groups for all metrics except evenness was similar to the other 2 groups, which may have been the result of having a slightly larger sample size.

When we recalculated the metrics using only native species, beta diversity generally increased while the other metrics generally decreased.

### 3.2.2 Soil stability and hydrologic function

The amount of exposed soil was measured in 2 ways: cover estimates of soil surface features in quadrats and measurements of basal gaps along transects. Undifferentiated crust and bare soil were the 2 dominant soil surface features, with mean covers of 63.25% and 17.33%, respectively (table 10 and fig. 9). Litter, live plant base and dead herbaceous base had mean cover values which ranged between 3 and 9%. The remainder of the features had mean covers of less than 1%. Biological soil crusts components (cyanobacteria, lichen, and moss) had a combined mean cover of 0.20%. Differences in the cover of soil surface features among the plot groups were generally small; the features with the greatest differences were bare soil and undifferentiated crust, but this may be attributable to slight changes in how the crew differentiated between bare soil, undifferentiated crust and cyanobacteria categories in the field.

The basal gap data also showed a large amount of exposed ground. Basal gaps greater than 100 cm comprised 52.2% of the transects (table 11 and fig. 10). The median gap size was 50.6 cm. There were some differences in the gap structure among the plot groups. In contrast to the other 2 plot groups, Plot Group C had smaller gaps overall. A smaller percentage of the transects was comprised of gaps greater than 100 cm. Also, the median gap size for Plot Group C was 36.9 cm, compared to the ecological site mean of 50.6 cm.

**Table 10. Cover of soil surface features for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO.**

| Soil surface feature         | Plot Group A<br>2007–2009 |       | Plot Group B<br>2007 |       | Plot Group C<br>2010 |       | Ecological site |       |
|------------------------------|---------------------------|-------|----------------------|-------|----------------------|-------|-----------------|-------|
|                              | Mean (%)                  | SD    | Mean (%)             | SD    | Mean (%)             | SD    | Mean (%)        | SD    |
| Live plant base              | 6.21                      | 2.63  | 8.65                 | 3.76  | 4.16                 | 1.08  | 5.89            | 2.90  |
| Dead woody base              | 0.31                      | 0.33  | 0.62                 | 0.77  | 0.34                 | 0.35  | 0.40            | 0.46  |
| Dead herbaceous base         | 2.40                      | 1.33  | 3.14                 | 1.66  | 3.82                 | 1.33  | 3.19            | 1.47  |
| Bare soil                    | 9.06                      | 8.29  | 25.56                | 23.76 | 19.25                | 19.11 | 17.33           | 18.05 |
| Duff/litter <sup>a</sup>     | 9.37                      | 3.54  | 8.00                 | 2.11  | 7.65                 | 3.00  | 8.31            | 2.77  |
| Undifferentiated crust       | 68.88                     | 13.09 | 52.55                | 25.55 | 64.67                | 21.14 | 63.25           | 19.61 |
| Moss                         | 0.08                      | 0.23  | 0.09                 | 0.23  | 0.01                 | 0.03  | 0.05            | 0.17  |
| Lichen                       | 0.02                      | 0.05  | 0                    | 0     | 0                    | 0     | 0.01            | 0.03  |
| Cyanobacteria <sup>b</sup>   | 0.17                      | 0.54  | 0                    | 0     | 0.19                 | 0.51  | 0.14            | 0.45  |
| Fine gravel (0.2 to <2 cm)   | 2.18                      | 6.53  | 0.04                 | 0.09  | 0.10                 | 0.19  | 0.78            | 3.78  |
| Coarse gravel (2 to <7.5 cm) | 0.08                      | 0.23  | 0.03                 | 0.09  | 0.03                 | 0.07  | 0.05            | 0.14  |
| Cobble (7.5 to <25 cm)       | 0                         | 0     | 0.03                 | 0.05  | 0.00                 | 0.00  | 0.01            | 0.03  |
| Stone, bedrock (>25 cm)      | 0                         | 0     | 0                    | 0     | 0                    | 0     | 0               | 0     |
| Woody debris                 | 0.19                      | 0.48  | <0.01                | 0.01  | 0.12                 | 0.40  | 0.12            | 0.37  |

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

<sup>a</sup>Duff did not occur in these plots.

<sup>b</sup>In 2010 we used a different method for classifying cyanobacteria.

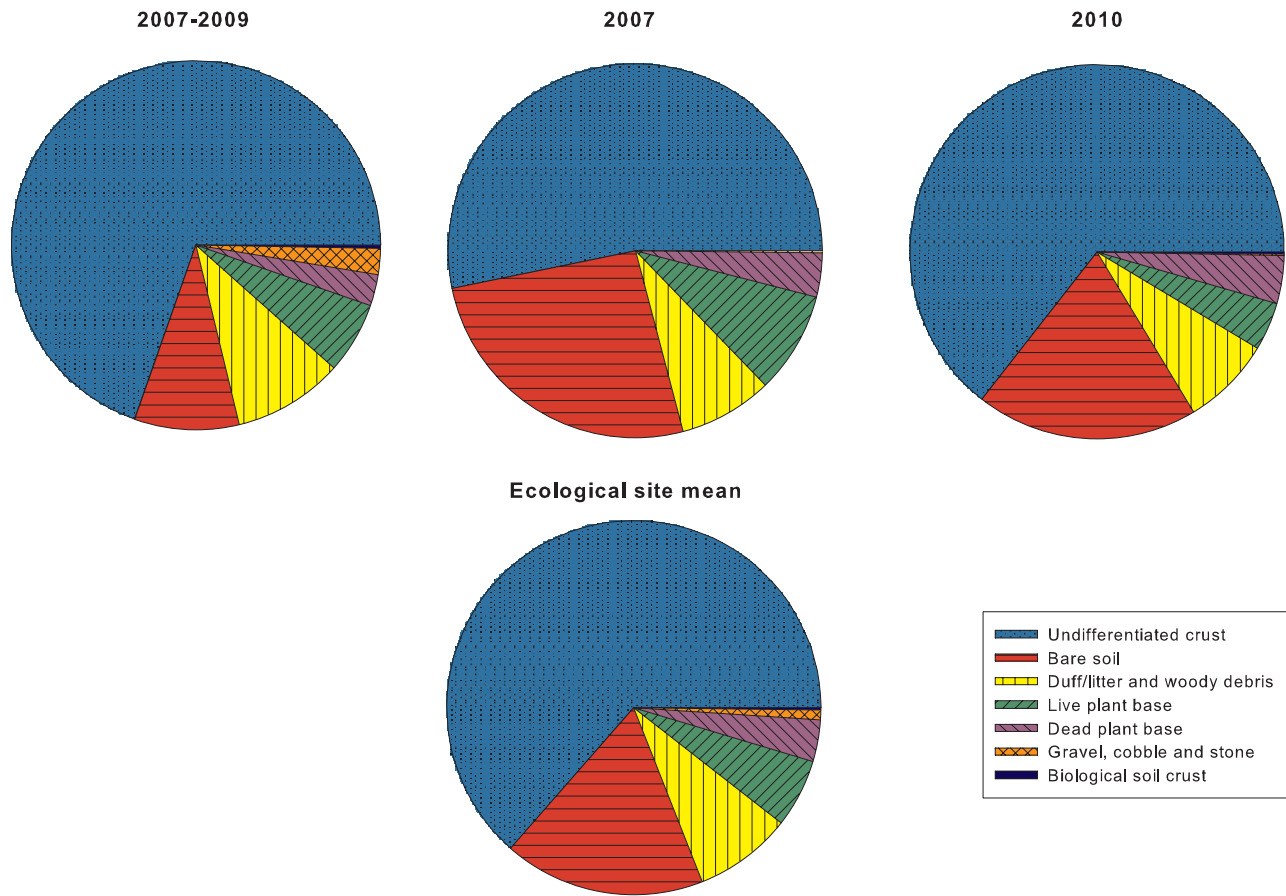


Figure 9. Mean percent cover of soil surface features for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site in PEFO.

Table 11. Number of basal gaps, median gap size, and percentage of transect in different gap size classes for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO.

| Metric                                  | Plot Group A<br>2007–2009 |      | Plot Group B<br>2007 |      | Plot Group C<br>2010 |      | Ecological site |      |
|-----------------------------------------|---------------------------|------|----------------------|------|----------------------|------|-----------------|------|
|                                         | Mean                      | SD   | Mean                 | SD   | Mean                 | SD   | Mean            | SD   |
| Number of gaps                          | 187.2                     | 71.0 | 168.4                | 52.3 | 241.3                | 68.3 | 206.3           | 69.8 |
| Median gap size (cm)                    | 63.0                      | 45.9 | 58.2                 | 18.9 | 36.9                 | 12.2 | 50.6            | 30.4 |
| Percentage of transect in gaps          | 92.5                      | 2.9  | 94.1                 | 3.4  | 87.2                 | 3.8  | 90.6            | 4.5  |
| Percentage of transect in gaps 0–19 cm  | 3.5                       | 2.2  | 2.9                  | 2.0  | 5.8                  | 3.1  | 4.3             | 2.8  |
| Percentage of transect in gaps 20–49 cm | 11.5                      | 6.4  | 10.1                 | 5.2  | 15.5                 | 5.6  | 12.9            | 5.9  |
| Percentage of transect in gaps 50–99 cm | 20.1                      | 8.0  | 19.1                 | 5.8  | 23.0                 | 2.1  | 21.1            | 5.3  |
| Percentage of transect in gaps ≥100 cm  | 57.4                      | 18.4 | 62.1                 | 15.1 | 42.9                 | 12.2 | 52.2            | 16.4 |
| Percentage of transect in plant bases   | 7.5                       | 2.9  | 5.9                  | 3.4  | 12.8                 | 3.8  | 9.4             | 4.5  |

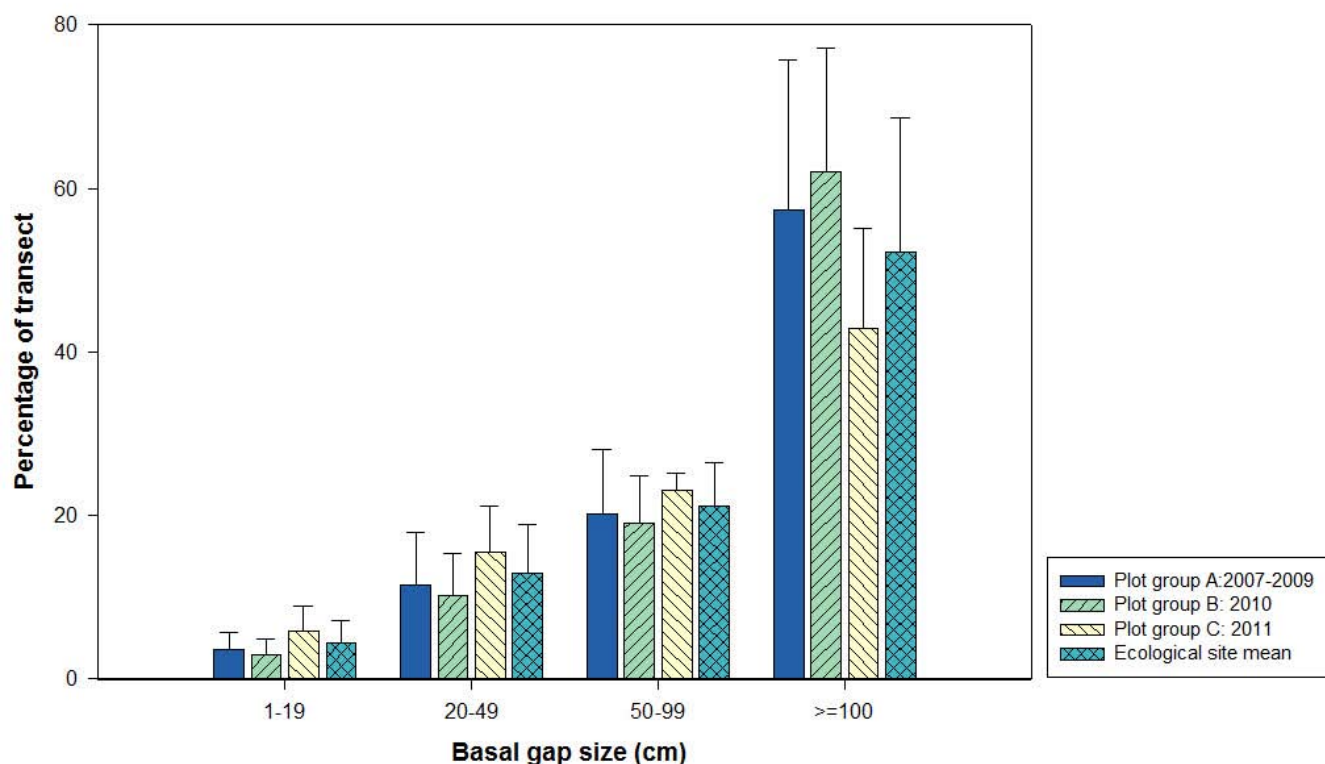


Figure 10. Mean percentage of transect by gap size class for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO. Error bars represent 1 standard deviation.

Soil aggregate stability provides a measure of the erodibility of soil. The index ranges between 1 and 6, with 1 indicating low stability and 6 indicating high stability. The mean stability for the ecological site was 3.08 (table 12). Stability was higher for soil below vegetative cover. There was variation in the soil stability ratings among the plot groups, although the large standard deviations indicate large among plot variability.

Table 12. Soil Stability rating for all samples, and for samples with and without vegetative cover, for Plot Group A, Plot Group B, Plot Group C, and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO.

|                                    | Plot Group A<br>2007 |      | Plot Group B<br>2007 |      | Plot Group C<br>2010 |      | Ecological site |      |
|------------------------------------|----------------------|------|----------------------|------|----------------------|------|-----------------|------|
|                                    | Mean                 | SD   | Mean                 | SD   | Mean                 | SD   | Mean            | SD   |
| All samples                        | 3.10                 | 0.83 | 3.44                 | 0.40 | 2.86                 | 0.93 | 3.08            | 0.81 |
| Samples under vegetative cover     | 3.66                 | 1.08 | 3.83                 | 0.34 | 3.32                 | 1.00 | 3.55            | 0.92 |
| Samples not under vegetative cover | 2.70                 | 0.96 | 2.72                 | 0.33 | 2.07                 | 1.00 | 2.43            | 0.91 |

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

### 3.3 Western Regional Climate Center precipitation data

Precipitation records for PEFO are available from the Western Regional Climate Center (2012). Figure 11 shows the total monthly precipitation for each of the 4 years of monitoring described in this report, compared with the long term average precipitation by month for the period 1933–2010.

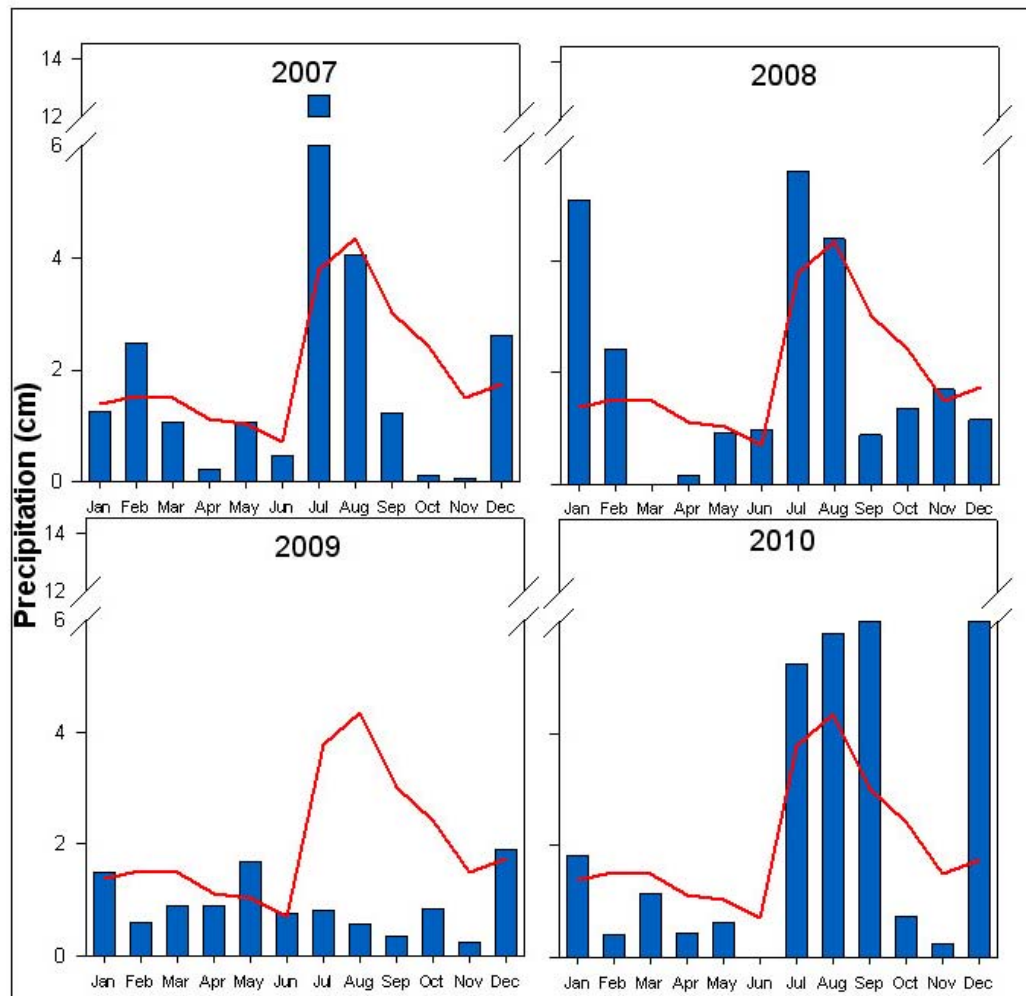


Figure 11. Total monthly precipitation for the 4 years of sampling. The red line represents the long term average monthly precipitation for the Petrified Forest NP (26468) AZ weather station for the period 1933–2010, collected by the Western Regional Climate Center.

# 4 Discussion

The data summarized in this report represents baseline conditions for monitoring vegetation and soils of these 2 ecological sites at PEFO. The Clayey Fan and Sandy Loam ecological sites represent 2 distinct ecosystems with a number of similarities. The Clayey Fan ecological site is a grassland, dominated by *Sporobolus airoides* and other perennial grasses, with smaller amounts of shrubs, forbs and annual grasses. The Sandy Loam ecological site is also dominated by perennial grasses, including *Bouteloua gracilis*, *Pleuraphis jamesii* and *Sporobolus airoides*. It had a larger shrub component, and smaller forb and annual grass components. Both sites had a number of nonnative species: the 2 most abundant were *Salsola tragus* and *Bromus tectorum*. Both ecological sites had moderate levels of species diversity at the plot scale, and high levels of species diversity at the landscape scale.

The soil data demonstrates that both ecological sites had large areas of exposed soil, suggesting a potential for soil erosion. The soil surface of both sites was dominated by undifferentiated crust and bare soil. Biological crusts, cyanobacteria in particular, had greater cover in the Clayey Fan ecological site. The size structure of the basal gaps showed gaps greater than 100 cm dominated transects of both ecological sites. The potential for soil erosion is moderated in the Clayey Fan ecological site by higher soil stability.

We would expect minor differences in species composition and soil characteristics between the plot groups in each ecological site, particularly for the groups with small sample sizes, due to random spatial variation. The groups represent different plots in different locations. Due to endogenous and exogenous factors, the species composition and structure and soil characteristics naturally vary. While spatial variability likely accounts for the majority of the differences between the 2 plot groups, additional variation may result from annual climatic variation. Variation in precipitation has been associated with changes in cover and frequency of herbaceous plants, particularly annual species and forbs—both of which are abundant in these ecological sites. Precipitation records for PEFO gathered by the Western Regional Climate Center indicate that 2010 had above average precipitation from July through September at PEFO. The years 2007 and 2008 only had strong monsoons. This likely may have accounted for the higher cover and frequency of some of the herbaceous, and particularly the annual, species in the plot groups sampled in 2010. These differences in precipitation, however, likely are a relatively minor factor contributing to the differences between the plot groups.

Now that we have completed our baseline monitoring of these 2 ecological sites, we will begin to implement the revisit design. Our power analysis indicates that sample sizes of 30 plots should provide a large enough sample size to detect trends in key metrics.

We will implement a 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 every re-visit, and monitoring a new set of sites with each revisit, there are designs that provide some balance between repeated visits to individual plots and the total number of sites visited. Our general revisit design is a connected design in both spatial and temporal aspects that balances the allocation of effort between addressing temporal (year to year) variability and spatial variability within the ecological site. We will split the 30 plots in each ecological site into 3 panels, and sample 2 of the panels every other year (table 13). We will alternate years that we sample each ecological site.

**Table 13. The panel design we are currently planning to use for the revisit design at PEFO. “X” represents 10 plots in an ecological site, for a total of 30 plots across 3 panels for the ecological site.**

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

## 5 Literature cited

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# Appendix A: Complete species list with foliar cover and frequency values for the plots sampled between 2007 and 2009 (Plot Group A), the plots sampled in 2010 (Plot Group B), and all plots (ecological site mean) in the Clayey Fan ecological site at PEFO.

| Species                             | Common name          | Family         | Plot Group A<br>2007–2009 |                    |                  | Plot Group B<br>2010 |                  |                    | Ecological site mean |                    |
|-------------------------------------|----------------------|----------------|---------------------------|--------------------|------------------|----------------------|------------------|--------------------|----------------------|--------------------|
|                                     |                      |                | Foliar cover (%)          | Plot frequency (%) | Foliar cover (%) | Plot frequency (%)   | Foliar cover (%) | Plot frequency (%) | Foliar cover (%)     | Plot frequency (%) |
| <i>Achnatherum hymenoides</i>       | Indian ricegrass     | Poaceae        | 0.256                     | 90.00              | 0.166            | 75.00                | 0.196            | 80.00              |                      |                    |
| <i>Allium macropetalum</i>          | largeflower onion    | Liliaceae      | 0                         | 0                  | <0.001           | 10.00                | <0.001           | 6.67               |                      |                    |
| <i>Amaranthus</i> sp.               | pigweed              | Amaranthaceae  | 0                         | 0                  | 0.001            | 10.00                | 0.001            | 6.67               |                      |                    |
| <i>Aristida adscensionis</i>        | sixweeks threearwn   | Poaceae        | <0.001                    | 3.33               | 0.006            | 5.00                 | 0.004            | 4.44               |                      |                    |
| <i>Aristida purpurea</i>            | Fendler's threearwn  | Poaceae        | <0.001                    | 10.00              | 0.030            | 25.00                | 0.020            | 20.00              |                      |                    |
| <i>Artemisia bigelovii</i>          | Bigelow sage         | Asteraceae     | 0.002                     | 10.00              | 0.064            | 15.00                | 0.043            | 13.33              |                      |                    |
| <i>Artemisia filifolia</i>          | sand sagebrush       | Asteraceae     | 0.007                     | 10.00              | 0.094            | 15.00                | 0.065            | 13.33              |                      |                    |
| <i>Astragalus</i> spp.              | milkvetch            | Fabaceae       | 0.006                     | 36.67              | 0.001            | 30.00                | 0.003            | 32.22              |                      |                    |
| <i>Astragalus amphioxys</i>         | Crescent milkvetch   | Fabaceae       | 0                         | 0                  | 0.019            | 55.00                | 0.012            | 36.67              |                      |                    |
| <i>Astragalus ceramicus</i>         | painted milkvetch    | Fabaceae       | 0                         | 0                  | 0.001            | 10.00                | 0.001            | 6.67               |                      |                    |
| <i>Astragalus mollissimus</i>       | woolly locoweed      | Fabaceae       | 0                         | 0                  | 0.001            | 5.00                 | 0.001            | 3.33               |                      |                    |
| <i>Atriplex canescens</i>           | fourwing saltbush    | Chenopodiaceae | 0.481                     | 53.33              | 0.229            | 40.00                | 0.313            | 44.44              |                      |                    |
| <i>Atriplex confertifolia</i>       | shadscale saltbush   | Chenopodiaceae | 0.118                     | 56.67              | 0.026            | 25.00                | 0.056            | 35.56              |                      |                    |
| <i>Atriplex obovata</i>             | mound saltbush       | Chenopodiaceae | 1.386                     | 93.33              | 1.485            | 90.00                | 1.452            | 91.11              |                      |                    |
| <i>Atriplex saccaria</i>            | sack saltbush        | Chenopodiaceae | 0                         | 0                  | 0.006            | 10.00                | 0.004            | 6.67               |                      |                    |
| <i>Bouteloua barbata</i>            | sixweeks grama       | Poaceae        | 0.365                     | 53.33              | 1.250            | 90.00                | 0.955            | 77.78              |                      |                    |
| <i>Bouteloua eriopoda</i>           | black grama          | Poaceae        | 0.037                     | 10.00              | 0                | 0                    | 0.012            | 3.33               |                      |                    |
| <i>Bouteloua gracilis</i>           | blue grama           | Poaceae        | 1.237                     | 90.00              | 1.412            | 65.00                | 1.354            | 73.33              |                      |                    |
| <i>Bromus tectorum</i> <sup>a</sup> | cheatgrass           | Poaceae        | 0.002                     | 20.00              | 0.001            | 10.00                | 0.001            | 13.33              |                      |                    |
| <i>Calochortus aureus</i>           | golden mariposa lily | Liliaceae      | <0.001                    | 3.33               | 0                | 0                    | <0.001           | 1.11               |                      |                    |
| <i>Chaetopappa ericoides</i>        | rose heath           | Asteraceae     | 0.007                     | 50.00              | 0.004            | 25.00                | 0.005            | 33.33              |                      |                    |
| <i>Chamaesaracha coronopus</i>      | greenleaf five eyes  | Solanaceae     | 0.005                     | 13.33              | 0.050            | 45.00                | 0.035            | 34.44              |                      |                    |
| <i>Chamaesyce</i> spp. Group A      | annual sandmats      | Euphorbiaceae  | 0.067                     | 43.33              | 0.833            | 90.00                | 0.578            | 74.44              |                      |                    |
| <i>Chamaesyce</i> spp. Group B      | annual sandmats      | Euphorbiaceae  | 0.007                     | 13.33              | 0.170            | 20.00                | 0.116            | 17.78              |                      |                    |
| <i>Chamaesyce albomarginata</i>     | whitemargin sandmat  | Euphorbiaceae  | 0                         | 0                  | 0.001            | 5.00                 | 0.001            | 3.33               |                      |                    |
| <i>Chamaesyce fendleri</i>          | Fendler's sandmat    | Euphorbiaceae  | 0                         | 0                  | 0.025            | 30.00                | 0.017            | 20.00              |                      |                    |

**Appendix A (continued)**

| Species                                | Common name          | Family           | Plot Group A<br>2007–2009 |                    |                  | Plot Group B<br>2010 |                  |                    | Ecological site mean |                    |
|----------------------------------------|----------------------|------------------|---------------------------|--------------------|------------------|----------------------|------------------|--------------------|----------------------|--------------------|
|                                        |                      |                  | Foliar cover (%)          | Plot frequency (%) | Foliar cover (%) | Plot frequency (%)   | Foliar cover (%) | Plot frequency (%) | Foliar cover (%)     | Plot frequency (%) |
| <i>Chenopodium</i> spp.                | goosefoot            | Chenopodiaceae   | 0                         | 0                  | 0.006            | 15.00                | 0.004            | 10.00              |                      |                    |
| <i>Chenopodium fremontii</i>           | Fremont's goosefoot  | Chenopodiaceae   | <0.001                    | 3.33               | 0                | 0                    | <0.001           | 1.11               |                      |                    |
| <i>Chenopodium leptophyllum</i>        | narrowleaf goosefoot | Chenopodiaceae   | <0.001                    | 3.33               | 0.092            | 15.00                | 0.061            | 11.11              |                      |                    |
| <i>Chrysothamnus Greenei</i>           | Greene's rabbitbrush | Asteraceae       | 0                         | 0                  | 0.023            | 20.00                | 0.016            | 13.33              |                      |                    |
| <i>Comandra umbellata</i>              | bastard toadflax     | Santalaceae      | 0                         | 0                  | 0.004            | 5.00                 | 0.002            | 3.33               |                      |                    |
| <i>Cordylanthus wrightii</i>           | Wright's bird's beak | Scrophulariaceae | 0.001                     | 3.33               | 0.001            | 10.00                | 0.001            | 7.78               |                      |                    |
| <i>Corispermum americanum</i>          | shiny bugseed        | Chenopodiaceae   | 0                         | 0                  | 0.013            | 10.00                | 0.009            | 6.67               |                      |                    |
| <i>Cryptantha</i> spp.                 | cryptantha           | Boraginaceae     | <0.001                    | 3.33               | 0.007            | 35.00                | 0.004            | 24.44              |                      |                    |
| <i>Dalea candida</i>                   | white prairieclover  | Fabaceae         | 0.010                     | 13.33              | 0.005            | 5.00                 | 0.007            | 7.78               |                      |                    |
| <i>Descurainia pinnata</i>             | western tansymustard | Brassicaceae     | 0                         | 0                  | <0.001           | 5.00                 | <0.001           | 3.33               |                      |                    |
| <i>Dimorphocarpa wislizeni</i>         | spectacle pod        | Brassicaceae     | <0.001                    | 3.33               | 0.004            | 15.00                | 0.003            | 11.11              |                      |                    |
| <i>Draba cuneifolia</i>                | wedgeleaf draba      | Brassicaceae     | 0                         | 0                  | 0.003            | 15.00                | 0.002            | 10.00              |                      |                    |
| <i>Elymus elymoides</i>                | squirreltail         | Poaceae          | 0.015                     | 33.33              | <0.001           | 5.00                 | 0.005            | 14.44              |                      |                    |
| <i>Erneapogon desvauxii</i>            | nineawn pappusgrass  | Poaceae          | 0                         | 0                  | <0.001           | 5.00                 | <0.001           | 3.33               |                      |                    |
| <i>Ephedra cutleri</i>                 | Cutler's jointfir    | Ephedraceae      | 0.066                     | 16.67              | 0                | 0                    | 0.022            | 5.56               |                      |                    |
| <i>Ephedra torreyana</i>               | Torrey's jointfir    | Ephedraceae      | 0.041                     | 23.33              | 0.012            | 5.00                 | 0.021            | 11.11              |                      |                    |
| <i>Ephedra viridis</i>                 | mormon tea           | Ephedraceae      | 0.050                     | 10.00              | 0                | 0                    | 0.017            | 3.33               |                      |                    |
| <i>Eragrostis pectinacea</i>           | desert lovegrass     | Poaceae          | 0.010                     | 3.33               | 0.497            | 30.00                | 0.335            | 21.11              |                      |                    |
| <i>Eriastrum diffusum</i>              | miniature woollystar | Polemoniaceae    | <0.001                    | 3.33               | 0                | 0                    | <0.001           | 1.11               |                      |                    |
| <i>Ericameria nauseosa</i>             | rubber rabbitbrush   | Asteraceae       | 0.079                     | 40.00              | 0.031            | 15.00                | 0.047            | 23.33              |                      |                    |
| <i>Erigeron</i> spp.                   | fleabane             | Asteraceae       | 0                         | 0                  | 0.011            | 15.00                | 0.007            | 10.00              |                      |                    |
| <i>Erigeron concinnus</i>              | Navajo fleabane      | Asteraceae       | <0.001                    | 6.67               | 0.001            | 5.00                 | 0.001            | 5.56               |                      |                    |
| <i>Erigeron divergens</i>              | spreading fleabane   | Asteraceae       | 0.004                     | 16.67              | 0.020            | 5.00                 | 0.015            | 8.89               |                      |                    |
| <i>Eriogonum</i> sp.                   | buckwheat            | Polygonaceae     | <0.001                    | 6.67               | 0                | 0                    | <0.001           | 2.22               |                      |                    |
| <i>Eriogonum cernuum</i>               | nodding buckwheat    | Polygonaceae     | <0.001                    | 10.00              | 0.279            | 25.00                | 0.186            | 20.00              |                      |                    |
| <i>Eriogonum deflexum</i>              | flatcrown buckwheat  | Polygonaceae     | 0.010                     | 26.67              | <0.001           | 5.00                 | 0.003            | 12.22              |                      |                    |
| <i>Eriogonum divaricatum</i>           | divergent buckwheat  | Polygonaceae     | 0.003                     | 36.67              | 0.016            | 55.00                | 0.012            | 48.89              |                      |                    |
| <i>Eriogonum leptoclodon</i>           | sand buckwheat       | Polygonaceae     | 0                         | 0                  | 0.029            | 10.00                | 0.019            | 6.67               |                      |                    |
| <i>Erodium cicutarium</i> <sup>a</sup> | stork's bill         | Geraniaceae      | 0                         | 0                  | 0.001            | 5.00                 | 0.001            | 3.33               |                      |                    |

**Appendix A (continued)**

| Species                                       | Common name                | Family          | Plot Group A<br>2007–2009 |                    |                  | Plot Group B<br>2010 |                  |                    | Ecological site mean |                    |
|-----------------------------------------------|----------------------------|-----------------|---------------------------|--------------------|------------------|----------------------|------------------|--------------------|----------------------|--------------------|
|                                               |                            |                 | Foliar cover (%)          | Plot frequency (%) | Foliar cover (%) | Plot frequency (%)   | Foliar cover (%) | Plot frequency (%) | Foliar cover (%)     | Plot frequency (%) |
| <i>Escobaria vivipara</i>                     | spiny star                 | Cactaceae       | <0.001                    | 3.33               | <0.001           | 5.00                 | <0.001           | 5.00               | <0.001               | 4.44               |
| <i>Evolvulus nuttallianus</i>                 | shaggy dwarf morning-glory | Convolvulaceae  | 0                         | 0                  | 0.017            | 10.00                | 0.017            | 10.00              | 0.011                | 6.67               |
| <i>Gallardia pinnatifida</i>                  | red dome blanketflower     | Asteraceae      | <0.001                    | 3.33               | 0                | 0                    | 0                | 0                  | <0.001               | 1.11               |
| <i>Gutierrezia sarothrae</i>                  | broom snakeweed            | Asteraceae      | 0.069                     | 46.67              | 0.097            | 45.00                | 0.097            | 45.00              | 0.088                | 45.56              |
| <i>Halogeton glomeratus</i> <sup>a</sup>      | saltlover                  | Chenopodiaceae  | 0                         | 0                  | 0.001            | 5.00                 | 0.001            | 5.00               | 0.001                | 3.33               |
| <i>Helianthus annuus</i>                      | common sunflower           | Asteraceae      | 0                         | 0                  | <0.001           | 5.00                 | <0.001           | 5.00               | <0.001               | 3.33               |
| <i>Heliomeris multiflora</i>                  | showy goldeneye            | Asteraceae      | <0.001                    | 6.67               | 0.001            | 5.00                 | 0.001            | 5.00               | 0.001                | 5.56               |
| <i>Heliotropium curassavicum</i> <sup>b</sup> | salt heliotrope            | Boraginaceae    | 0                         | 0                  | <0.001           | 5.00                 | <0.001           | 5.00               | <0.001               | 3.33               |
| <i>Hesperostipa comata</i>                    | needle and thread          | Poaceae         | 0.007                     | 13.33              | 0.027            | 20.00                | 0.027            | 20.00              | 0.020                | 17.78              |
| <i>Hymenopappus filifolius</i>                | fineleaf hymenopappus      | Asteraceae      | 0                         | 0                  | 0.001            | 15.00                | 0.001            | 15.00              | 0.001                | 10.00              |
| <i>Hymenopappus flavescens</i>                | collegeflower              | Asteraceae      | 0.001                     | 3.33               | 0                | 0                    | 0                | 0                  | <0.001               | 1.11               |
| <i>Hymenoxys richardsonii</i>                 | Colorado rubberweed        | Asteraceae      | 0                         | 0                  | 0.001            | 5.00                 | 0.001            | 5.00               | 0.001                | 3.33               |
| <i>Ipomopsis gunnisonii</i>                   | sanddune ipomopsis         | Polemoniaceae   | <0.001                    | 6.67               | 0.002            | 10.00                | 0.002            | 10.00              | 0.001                | 8.89               |
| <i>Ipomopsis longiflora</i>                   | whiteflower ipomopsis      | Polemoniaceae   | 0                         | 0                  | 0.007            | 15.00                | 0.007            | 15.00              | 0.005                | 10.00              |
| <i>Isocoma rusbyi</i>                         | Rusby's goldenbush         | Asteraceae      | 0.022                     | 20.00              | 0.029            | 5.00                 | 0.029            | 5.00               | 0.027                | 10.00              |
| <i>Kallstroemia parviflora</i>                | warty caltrop              | Zygophyllaceae  | 0                         | 0                  | 0.001            | 5.00                 | 0.001            | 5.00               | 0.001                | 3.33               |
| <i>Krascheninnikovia lanata</i>               | winterfat                  | Chenopodiaceae  | 0.015                     | 23.33              | 0                | 0                    | 0                | 0                  | 0.005                | 7.78               |
| <i>Lappula occidentalis</i>                   | flatspine stickseed        | Boraginaceae    | 0                         | 0                  | 0.003            | 5.00                 | 0.003            | 5.00               | 0.002                | 3.33               |
| <i>Linum lewisii</i>                          | prairie flax               | Linaceae        | 0                         | 0                  | 0.001            | 20.00                | 0.001            | 20.00              | 0.001                | 13.33              |
| <i>Machaeranthera canescens</i>               | hoary tansyaster           | Asteraceae      | 0.001                     | 10.00              | 0.019            | 10.00                | 0.019            | 10.00              | 0.013                | 10.00              |
| <i>Menodora scabra</i>                        | rough menodora             | Oleaceae        | 0                         | 0                  | <0.001           | 5.00                 | <0.001           | 5.00               | <0.001               | 3.33               |
| <i>Mentzelia albicaulis</i>                   | whitestem blazingstar      | Loasaceae       | 0.001                     | 13.33              | 0.008            | 5.00                 | 0.008            | 5.00               | 0.006                | 7.78               |
| <i>Mentzelia multiflora</i>                   | Adonis blazingstar         | Loasaceae       | 0                         | 0                  | 0.004            | 15.00                | 0.004            | 15.00              | 0.002                | 10.00              |
| <i>Mollugo cerviana</i> <sup>a, b</sup>       | threadstem carpetweed      | Molluginaceae   | 0                         | 0                  | 0.105            | 20.00                | 0.105            | 20.00              | 0.070                | 13.33              |
| <i>Monroa squarrosa</i>                       | false buffalograss         | Poaceae         | 0.012                     | 36.67              | 0.054            | 75.00                | 0.054            | 75.00              | 0.040                | 62.22              |
| <i>Muhlenbergia pungens</i>                   | sandhill muhly             | Poaceae         | 0.010                     | 20.00              | 0.013            | 5.00                 | 0.013            | 5.00               | 0.012                | 10.00              |
| <i>Nama hispida</i>                           | bristly nama               | Hydrophyllaceae | 0                         | 0                  | 0.002            | 30.00                | 0.002            | 30.00              | 0.001                | 20.00              |
| <i>Oenothera</i> spp.                         | evening primrose           | Onagraceae      | 0.007                     | 16.67              | 0.004            | 10.00                | 0.004            | 10.00              | 0.005                | 12.22              |
| <i>Oenothera albicaulis</i>                   | whitest evening-primrose   | Onagraceae      | 0                         | 0                  | 0.126            | 50.00                | 0.126            | 50.00              | 0.084                | 33.33              |

**Appendix A (continued)**

| Species                                      | Common name                  | Family          | Plot Group A<br>2007–2009 |                       | Plot Group B<br>2010 |                       | Ecological site mean |                       |
|----------------------------------------------|------------------------------|-----------------|---------------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|
|                                              |                              |                 | Foliar cover<br>(%)       | Plot frequency<br>(%) | Foliar cover<br>(%)  | Plot frequency<br>(%) | Foliar cover<br>(%)  | Plot frequency<br>(%) |
| <i>Oenothera caespitosa</i>                  | tufted evening-primrose      | Onagraceae      | 0                         | 0                     | 0.001                | 10.00                 | 0.001                | 6.67                  |
| <i>Opuntia</i> spp.                          | prickly pear                 | Cactaceae       | 0.009                     | 36.67                 | 0.011                | 45.00                 | 0.010                | 42.22                 |
| <i>Opuntia whipplei</i>                      | Whipple's cholla             | Cactaceae       | 0.008                     | 23.33                 | 0.048                | 35.00                 | 0.034                | 31.11                 |
| <i>Panicum hirticaule</i>                    | Mexican panicgrass           | Poaceae         | <0.001                    | 3.33                  | 0                    | 0                     | <0.001               | 1.11                  |
| <i>Parryella filifolia</i>                   | common dunebroom             | Fabaceae        | 0.024                     | 10.00                 | 0.020                | 15.00                 | 0.021                | 13.33                 |
| <i>Pascopyrum smithii</i>                    | western wheatgrass           | Poaceae         | 0.002                     | 3.33                  | 0                    | 0                     | 0.001                | 1.11                  |
| <i>Pectis angustifolia</i>                   | lemonscent                   | Asteraceae      | 0.003                     | 13.33                 | 0.108                | 30.00                 | 0.073                | 24.44                 |
| <i>Phacelia</i> sp.                          | scorpionweed                 | Hydrophyllaceae | 0                         | 0                     | 0.001                | 15.00                 | <0.001               | 10.00                 |
| <i>Phemeranthus parviflorus</i> <sup>b</sup> | sunbright                    | Portulacaceae   | 0                         | 0                     | 0.002                | 5.00                  | 0.001                | 3.33                  |
| <i>Plantago patagonica</i>                   | woolly plantain              | Plantaginaceae  | 0.011                     | 40.00                 | 0.017                | 75.00                 | 0.015                | 63.33                 |
| <i>Pleuraphis jamesii</i>                    | James' galleta               | Poaceae         | 1.405                     | 100.00                | 1.698                | 90.00                 | 1.600                | 93.33                 |
| <i>Portulaca oleracea</i> <sup>a</sup>       | little hogweed               | Portulacaceae   | 0.015                     | 20.00                 | 0.073                | 55.00                 | 0.054                | 43.33                 |
| <i>Portulaca pilosa</i> <sup>b</sup>         | kiss me quick                | Portulacaceae   | 0                         | 0                     | 0.090                | 15.00                 | 0.060                | 10.00                 |
| <i>Psilostrophe tagetina</i>                 | woolly paperflower           | Asteraceae      | <0.001                    | 10.00                 | 0                    | 0                     | <0.001               | 3.33                  |
| <i>Quincula lobata</i>                       | Chinese lantern              | Solanaceae      | 0                         | 0                     | 0.003                | 10.00                 | 0.002                | 6.67                  |
| <i>Salsola tragus</i> <sup>s</sup>           | prickly Russian thistle      | Chenopodiaceae  | 0.479                     | 86.67                 | 1.351                | 100.00                | 1.061                | 95.56                 |
| <i>Sanvitalia abertii</i>                    | Abert's creeping zinnia      | Asteraceae      | 0.004                     | 13.33                 | 0.010                | 10.00                 | 0.008                | 11.11                 |
| <i>Sarcobatus vermiculatus</i>               | greasewood                   | Chenopodiaceae  | 0.207                     | 10.00                 | 0.007                | 5.00                  | 0.074                | 6.67                  |
| <i>Schkuhria multiflora</i>                  | many-flower false threadleaf | Asteraceae      | <0.001                    | 6.67                  | 0.003                | 20.00                 | 0.002                | 15.56                 |
| <i>Sclerocactus papyracanthus</i>            | paperspine fishhook cactus   | Cactaceae       | 0                         | 0                     | <0.001               | 5.00                  | <0.001               | 3.33                  |
| <i>Senecio flaccidus</i>                     | threadleaf ragwort           | Asteraceae      | 0.003                     | 10.00                 | 0                    | 0                     | 0.001                | 3.33                  |
| <i>Senecio spartioides</i>                   | broomlike ragwort            | Asteraceae      | 0.001                     | 3.33                  | 0                    | 0                     | <0.001               | 1.11                  |
| <i>Sphaeralcea</i> spp.                      | globemallow                  | Malvaceae       | 0.002                     | 16.67                 | 0.102                | 100.00                | 0.069                | 72.22                 |
| <i>Sphaeralcea hastulata</i>                 | spear globemallow            | Malvaceae       | 0.032                     | 56.67                 | 0                    | 0                     | 0.011                | 18.89                 |
| <i>Sporobolus airoides</i>                   | alkali sacaton               | Poaceae         | 4.659                     | 100.00                | 8.361                | 100.00                | 7.127                | 100.00                |
| <i>Sporobolus contractus</i>                 | spike dropseed               | Poaceae         | 0.026                     | 13.33                 | 0.075                | 40.00                 | 0.058                | 31.11                 |
| <i>Sporobolus coromandelianus</i>            | Madagascar dropseed          | Poaceae         | 0.430                     | 43.33                 | 1.887                | 60.00                 | 1.401                | 54.44                 |
| <i>Sporobolus cryptandrus</i>                | sand dropseed                | Poaceae         | 0.028                     | 33.33                 | 0.047                | 50.00                 | 0.041                | 44.44                 |
| <i>Sporobolus flexuosus</i>                  | mesa dropseed                | Poaceae         | 0.091                     | 20.00                 | 0.080                | 10.00                 | 0.084                | 13.33                 |

**Appendix A (continued)**

| Species                          | Common name            | Family      | Plot Group A<br>2007–2009 |                       | Plot Group B<br>2010 |                       | Ecological site mean |                       |
|----------------------------------|------------------------|-------------|---------------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|
|                                  |                        |             | Foliar cover<br>(%)       | Plot frequency<br>(%) | Foliar cover<br>(%)  | Plot frequency<br>(%) | Foliar cover<br>(%)  | Plot frequency<br>(%) |
| <i>Stephanomeria pauciflora</i>  | brownplume wirelettuce | Asteraceae  | 0                         | 0                     | 0.001                | 5.00                  | 0.001                | 3.33                  |
| <i>Thelesperma megapotamicum</i> | Hopi tea greenthread   | Asteraceae  | <0.001                    | 3.33                  | 0.008                | 15.00                 | 0.005                | 11.11                 |
| <i>Thinopyrum ponticum</i>       | tall wheatgrass        | Poaceae     | 0                         | 0                     | 0.017                | 5.00                  | 0.011                | 3.33                  |
| <i>Townsendia annua</i>          | annual Townsend daisy  | Asteraceae  | 0                         | 0                     | 0.025                | 70.00                 | 0.016                | 46.67                 |
| <i>Verbena bracteata</i>         | bigbract verbena       | Verbenaceae | 0                         | 0                     | 0.020                | 10.00                 | 0.013                | 6.67                  |
| <i>Verbesina encelioides</i>     | golden crownbeard      | Asteraceae  | 0                         | 0                     | <0.001               | 5.00                  | <0.001               | 3.33                  |
| <i>Vulpia octoflora</i>          | sixweeks fescue        | Poaceae     | 0.002                     | 20.00                 | 0                    | 0                     | 0.001                | 6.67                  |
| <i>Xanthium strumarium</i>       | rough cocklebur        | Asteraceae  | 0                         | 0                     | 0.632                | 15.00                 | 0.421                | 10.00                 |
| <i>Yucca angustissima</i>        | narrowleaf yucca       | Agavaceae   | 0.008                     | 43.33                 | 0.013                | 30.00                 | 0.011                | 34.44                 |
| <i>Yucca baccata</i>             | banana yucca           | Agavaceae   | 0                         | 0                     | <0.001               | 5.00                  | <0.001               | 3.33                  |
| unknownPEFO20081021_1            |                        |             | 0.001                     | 3.33                  | 0                    | 0                     | <0.001               | 1.11                  |
| unknownPEFO20070917_1            |                        |             | <0.001                    | 3.33                  | 0                    | 0                     | <0.001               | 1.11                  |
| unknownPEFO20070927_2            |                        |             | 0.002                     | 3.33                  | 0                    | 0                     | 0.001                | 1.11                  |
| unknownPEFO20071001_1            |                        |             | <0.001                    | 3.33                  | 0                    | 0                     | <0.001               | 1.11                  |
| unknownPEFO20071002_2            |                        |             | 0.001                     | 3.33                  | 0                    | 0                     | <0.001               | 1.11                  |
| unknownPEFO20071002_3            |                        |             | <0.001                    | 3.33                  | 0                    | 0                     | <0.001               | 1.11                  |
| unknownPEFO20071004_2            |                        |             | <0.001                    | 3.33                  | 0                    | 0                     | <0.001               | 1.11                  |

<sup>a</sup>Nonnative species.

<sup>b</sup>New species record.

**Appendix B: Complete species list with foliar cover and frequency values for the plots sampled between 2007 and 2009 (Plot Group A), the plots sampled in 2007 only (Plot Group B), the plots sampled in 2010 (Plot Group C), and all plots (ecological site mean) in the Sandy Loam ecological site at PEFO.**

| Species                                      | Common name              | Family         | Plot Group A<br>2007–2009 |                    |  | Plot Group B<br>2007 |                    |  | Plot Group C<br>2010 |                    |  | Ecological site mean |                    |
|----------------------------------------------|--------------------------|----------------|---------------------------|--------------------|--|----------------------|--------------------|--|----------------------|--------------------|--|----------------------|--------------------|
|                                              |                          |                | Foliar cover (%)          | Plot frequency (%) |  | Foliar cover (%)     | Plot frequency (%) |  | Foliar cover (%)     | Plot frequency (%) |  | Foliar cover (%)     | Plot frequency (%) |
| <i>Achnatherum hymenoides</i>                | Indian ricegrass         | Poaceae        | 0.649                     | 90.00              |  | 0.363                | 100.00             |  | 0.795                | 92.31              |  | 0.646                | 93.33              |
| <i>Amaranthus</i> spp.                       | Pigweed                  | Amaranthaceae  | <0.001                    | 3.33               |  | 0                    | 0                  |  | 0.048                | 23.08              |  | 0.021                | 11.11              |
| <i>Amaranthus acanthochiton</i> <sup>a</sup> | greenstripe              | Amaranthaceae  | 0                         | 0                  |  | 0                    | 0                  |  | 0.003                | 7.69               |  | 0.001                | 3.33               |
| <i>Aristida purpurea</i>                     | Fendler's threeawn       | Poaceae        | 0.049                     | 46.67              |  | 0.041                | 57.14              |  | 0.022                | 46.15              |  | 0.035                | 48.89              |
| <i>Artemisia bigelovii</i>                   | Bigelow sage             | Asteraceae     | 0.377                     | 33.33              |  | 0.224                | 28.57              |  | 0.061                | 15.38              |  | 0.204                | 24.44              |
| <i>Artemisia filifolia</i>                   | sand sagebrush           | Asteraceae     | 0.559                     | 30.00              |  | 0.122                | 14.29              |  | 1.414                | 61.54              |  | 0.827                | 40.00              |
| <i>Asclepias involucreata</i>                | dwarf milkweed           | Asclepiadaceae | 0                         | 0                  |  | 0                    | 0                  |  | 0.002                | 7.69               |  | 0.001                | 3.33               |
| <i>Asclepias subverticillata</i>             | western whorled milkweed | Asclepiadaceae | <0.001                    | 6.67               |  | 0                    | 0                  |  | 0                    | 0                  |  | <0.001               | 2.22               |
| <i>Astragalus</i> spp.                       | milkvetch                | Fabaceae       | 0.001                     | 20.00              |  | 0.001                | 14.29              |  | 0.003                | 30.77              |  | 0.002                | 23.33              |
| <i>Astragalus amphioxys</i>                  | Crescent milkvetch       | Fabaceae       | 0                         | 0                  |  | 0                    | 0                  |  | 0.024                | 53.85              |  | 0.010                | 23.33              |
| <i>Astragalus ceramicus</i>                  | painted milkvetch        | Fabaceae       | 0                         | 0                  |  | 0                    | 0                  |  | 0.001                | 15.38              |  | <0.001               | 6.67               |
| <i>Astragalus mollissimus</i>                | woolly locoweed          | Fabaceae       | 0                         | 0                  |  | 0                    | 0                  |  | 0.076                | 69.23              |  | 0.033                | 30.00              |
| <i>Atriplex canescens</i>                    | fourwing saltbush        | Chenopodiaceae | 0.765                     | 90.00              |  | 1.488                | 85.71              |  | 1.391                | 100.00             |  | 1.205                | 93.33              |
| <i>Atriplex confertifolia</i>                | shadscale saltbush       | Chenopodiaceae | 0.121                     | 20.00              |  | 0                    | 0                  |  | 0                    | 0                  |  | 0.040                | 6.67               |
| <i>Atriplex obovata</i>                      | mound saltbush           | Chenopodiaceae | 0.200                     | 10.00              |  | 0                    | 0                  |  | 0                    | 0                  |  | 0.067                | 3.33               |
| <i>Bouteloua barbata</i>                     | sixweeks grama           | Poaceae        | 0.002                     | 13.33              |  | 0                    | 0                  |  | 0.099                | 84.62              |  | 0.043                | 41.11              |
| <i>Bouteloua eriopoda</i>                    | black grama              | Poaceae        | 0.608                     | 60.00              |  | 1.791                | 57.14              |  | 0.400                | 61.54              |  | 0.794                | 60.00              |
| <i>Bouteloua gracilis</i>                    | blue grama               | Poaceae        | 3.591                     | 83.33              |  | 5.994                | 100.00             |  | 6.811                | 100.00             |  | 5.547                | 94.44              |
| <i>Bromus tectorum</i> <sup>b</sup>          | cheatgrass               | Poaceae        | 0.275                     | 43.33              |  | 0.273                | 85.71              |  | <0.001               | 7.69               |  | 0.156                | 37.78              |
| <i>Pomaria jamesii</i>                       | James' holdback          | Fabaceae       | 0                         | 0                  |  | 0                    | 0                  |  | 0.009                | 23.08              |  | 0.004                | 10.00              |
| <i>Chaetopappa ericoides</i>                 | rose heath               | Asteraceae     | 0.069                     | 86.67              |  | 0.125                | 100.00             |  | 0.092                | 92.31              |  | 0.092                | 92.22              |
| <i>Chamaesaracha coronopus</i>               | greenleaf five eyes      | Solanaceae     | <0.001                    | 3.33               |  | <0.001               | 14.29              |  | 0.065                | 69.23              |  | 0.028                | 34.44              |
| <i>Chamaesyce</i> spp. Group A               | annual sandmats          | Euphorbiaceae  | 0.014                     | 33.33              |  | 0.012                | 28.57              |  | 0                    | 0                  |  | 0.008                | 17.78              |

**Appendix B (continued)**

| Species                             | Common name          | Family         | Plot Group A<br>2007–2009 |                    | Plot Group B<br>2007 |                    | Plot Group C<br>2010 |                    | Ecological site mean |                    |
|-------------------------------------|----------------------|----------------|---------------------------|--------------------|----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
|                                     |                      |                | Foliar cover (%)          | Plot frequency (%) | Foliar cover (%)     | Plot frequency (%) | Foliar cover (%)     | Plot frequency (%) | Foliar cover (%)     | Plot frequency (%) |
| <i>Chamaesyce</i> spp. Group B      | annual sandmats      | Euphorbiaceae  | 0.004                     | 23.33              | 0.001                | 14.29              | 1.005                | 100.00             | 0.437                | 54.44              |
| <i>Chamaesyce</i> spp.              | Sandmat              | Euphorbiaceae  | <0.001                    | 3.33               | 0                    | 0                  | 0                    | 0                  | <0.001               | 1.11               |
| <i>Chamaesyce fendleri</i>          | Fendler's sandmat    | Euphorbiaceae  | 0                         | 0                  | 0                    | 0                  | 0.091                | 15.38              | 0.040                | 6.67               |
| <i>Chenopodium</i> spp.             | goosefoot            | Chenopodiaceae | 0                         | 0                  | 0                    | 0                  | 0.230                | 76.92              | 0.100                | 33.33              |
| <i>Chenopodium leptophyllum</i>     | narrowleaf goosefoot | Chenopodiaceae | 0.001                     | 3.33               | 0.003                | 14.29              | 0.113                | 30.77              | 0.050                | 17.78              |
| <i>Chrysothamnus Greenei</i>        | Greene's rabbitbrush | Asteraceae     | 0.790                     | 56.67              | 0                    | 0                  | 0.401                | 23.08              | 0.437                | 28.89              |
| <i>Comandra umbellata</i>           | bastard toadflax     | Santalaceae    | 0                         | 0                  | 0                    | 0                  | 0.058                | 38.46              | 0.025                | 16.67              |
| <i>Cryptantha</i>                   | cryptantha           | Boraginaceae   | <0.001                    | 10.00              | 0                    | 0                  | 0.021                | 46.15              | 0.009                | 23.33              |
| <i>Dalea candida</i>                | white prairieclover  | Fabaceae       | 0                         | 0                  | 0                    | 0                  | 0.007                | 30.77              | 0.003                | 13.33              |
| <i>Dalea lanata</i>                 | woolly prairieclover | Fabaceae       | 0                         | 0                  | 0                    | 0                  | 0.002                | 7.69               | 0.001                | 3.33               |
| <i>Dasyochloa pulchella</i>         | low woollygrass      | Poaceae        | <0.001                    | 6.67               | 0                    | 0                  | 0                    | 0                  | <0.001               | 2.22               |
| <i>Dimorphocarpa wislizeni</i>      | spectacle pod        | Brassicaceae   | 0                         | 0                  | 0                    | 0                  | 0.008                | 30.77              | 0.003                | 13.33              |
| <i>Echinocereus triglochidiatus</i> | kingcup cactus       | Cactaceae      | <0.001                    | 3.33               | 0                    | 0                  | 0                    | 0                  | <0.001               | 1.11               |
| <i>Elymus elymoides</i>             | squirreltail         | Poaceae        | 0.046                     | 76.67              | 0.010                | 42.86              | 0.032                | 46.15              | 0.032                | 55.56              |
| <i>Ephedra cutleri</i>              | Cutler's jointfir    | Ephedraceae    | 0.073                     | 10.00              | 0                    | 0                  | 0.208                | 7.69               | 0.114                | 6.67               |
| <i>Ephedra torreyana</i>            | Torrey's jointfir    | Ephedraceae    | 0.276                     | 60.00              | 0.169                | 42.86              | 0.306                | 15.38              | 0.264                | 36.67              |
| <i>Ephedra viridis</i>              | mormon tea           | Ephedraceae    | 0                         | 0                  | 0.088                | 14.29              | 0                    | 0                  | 0.021                | 3.33               |
| <i>Eragrostis pectinacea</i>        | desert lovegrass     | Poaceae        | 0                         | 0                  | 0                    | 0                  | 0.327                | 23.08              | 0.142                | 10.00              |
| <i>Ericameria nauseosa</i>          | rubber rabbitbrush   | Asteraceae     | 0.041                     | 20.00              | 0                    | 0                  | 0                    | 0                  | 0.014                | 6.67               |
| <i>Erigeron divergens</i>           | spreading fleabane   | Asteraceae     | 0.002                     | 6.67               | 0                    | 0                  | 0.020                | 15.38              | 0.009                | 8.89               |
| <i>Eriogonum cernuum</i>            | nodding buckwheat    | Polygonaceae   | 0                         | 0                  | 0                    | 0                  | 0.016                | 15.38              | 0.007                | 6.67               |
| <i>Eriogonum corymbosum</i>         | crispleaf buckwheat  | Polygonaceae   | 0.001                     | 10.00              | 0                    | 0                  | 0                    | 0                  | <0.001               | 3.33               |
| <i>Eriogonum divaricatum</i>        | divergent buckwheat  | Polygonaceae   | 0                         | 0                  | 0                    | 0                  | 0.011                | 23.08              | 0.005                | 10.00              |
| <i>Eriogonum ericifolium</i>        | Yavapai buckwheat    | Polygonaceae   | 0.002                     | 10.00              | 0                    | 0                  | 0                    | 0                  | 0.001                | 3.33               |
| <i>Eriogonum jamesii</i>            | James' buckwheat     | Polygonaceae   | 0.002                     | 10.00              | 0                    | 0                  | 0                    | 0                  | 0.001                | 3.33               |
| <i>Eriogonum leptoclodon</i>        | sand buckwheat       | Polygonaceae   | <0.001                    | 6.67               | 0                    | 0                  | 0.005                | 15.38              | 0.002                | 8.89               |
| <i>Escobaria vivipara</i>           | spiny star           | Cactaceae      | 0.001                     | 6.67               | 0.001                | 14.29              | <0.001               | 7.69               | 0.001                | 8.89               |

# Appendix B (continued)

| Species                                | Common name                | Family          | Plot Group A<br>2007–2009 |                    | Plot Group B<br>2007 |                    | Plot Group C<br>2010 |                    | Ecological site mean |                    |
|----------------------------------------|----------------------------|-----------------|---------------------------|--------------------|----------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
|                                        |                            |                 | Foliar cover (%)          | Plot frequency (%) | Foliar cover (%)     | Plot frequency (%) | Foliar cover (%)     | Plot frequency (%) | Foliar cover (%)     | Plot frequency (%) |
| <i>Evolvulus nuttallianus</i>          | shaggy dwarf morning-glory | Convolvulaceae  | 0.006                     | 16.67              | 0.023                | 28.57              | 0.012                | 46.15              | 0.012                | 32.22              |
| <i>Gutierrezia sarothrae</i>           | broom snakeweed            | Asteraceae      | 1.186                     | 90.00              | 3.205                | 100.00             | 0.542                | 92.31              | 1.378                | 93.33              |
| <i>Hesperostipa comata</i>             | needle and thread          | Poaceae         | 0.319                     | 60.00              | 0.211                | 57.14              | 0.426                | 76.92              | 0.340                | 66.67              |
| <i>Hymenopappus filifolius</i>         | fineleaf hymenopappus      | Asteraceae      | 0                         | 0                  | 0                    | 0                  | 0.005                | 23.08              | 0.002                | 10.00              |
| <i>Hymenopappus flavescens</i>         | collegeflower              | Asteraceae      | 0.001                     | 6.67               | 0.006                | 14.29              | 0                    | 0                  | 0.002                | 5.56               |
| <i>Ipomopsis gunnisonii</i>            | sanddune ipomopsis         | Polemoniaceae   | 0                         | 0                  | 0                    | 0                  | 0.001                | 7.69               | <0.001               | 3.33               |
| <i>Ipomopsis longiflora</i>            | whiteflower ipomopsis      | Polemoniaceae   | 0.020                     | 26.67              | 0.011                | 28.57              | 0.055                | 61.54              | 0.033                | 42.22              |
| <i>Kochia scoparia</i> <sup>b</sup>    | Mexican burningbush        | Chenopodiaceae  | 0                         | 0                  | 0                    | 0                  | <0.001               | 7.69               | <0.001               | 3.33               |
| <i>Krascheninnikovia lanata</i>        | winterfat                  | Chenopodiaceae  | 0.100                     | 50.00              | 1.231                | 42.86              | 0.042                | 23.08              | 0.339                | 36.67              |
| <i>Linum lewisii</i>                   | prairie flax               | Linaceae        | 0                         | 0                  | 0                    | 0                  | <0.001               | 7.69               | <0.001               | 3.33               |
| <i>Lycium pallidum</i>                 | pale desert-thorn          | Solanaceae      | 0                         | 0                  | 0                    | 0                  | <0.001               | 7.69               | <0.001               | 3.33               |
| <i>Machaeranthera canescens</i>        | hoary tansyaster           | Asteraceae      | 0.006                     | 20.00              | 0.002                | 42.86              | 0.117                | 46.15              | 0.053                | 36.67              |
| <i>Machaeranthera gracilis</i>         | slender goldenweed         | Asteraceae      | <0.001                    | 3.33               | 0.009                | 14.29              | 0                    | 0                  | 0.002                | 4.44               |
| <i>Machaeranthera pinnatifida</i>      | lacy tansyaster            | Asteraceae      | 0                         | 0                  | 0                    | 0                  | 0.032                | 23.08              | 0.014                | 10.00              |
| <i>Mentzelia albicaulis</i>            | whitestem blazingstar      | Loasaceae       | 0.001                     | 3.33               | 0                    | 0                  | <0.001               | 7.69               | <0.001               | 4.44               |
| <i>Mentzelia multiflora</i>            | Adonis blazingstar         | Loasaceae       | 0                         | 0                  | 0                    | 0                  | 0.002                | 15.38              | 0.001                | 6.67               |
| <i>Mollugo cerviana</i> <sup>b c</sup> | threadstem carpetweed      | Molluginaceae   | 0                         | 0                  | <0.001               | 14.29              | 0.028                | 38.46              | 0.012                | 20.00              |
| <i>Monroa squarrosa</i>                | false buffalograss         | Poaceae         | 0.007                     | 16.67              | 0.001                | 28.57              | 0.090                | 92.31              | 0.041                | 52.22              |
| <i>Muhlenbergia pungens</i>            | sandhill muhly             | Poaceae         | 0.035                     | 20.00              | 0                    | 0                  | 0.019                | 7.69               | 0.020                | 10.00              |
| <i>Muhlenbergia torreyi</i>            | ring muhly                 | Poaceae         | 0.064                     | 60.00              | 0.105                | 57.14              | 0.025                | 23.08              | 0.057                | 43.33              |
| <i>Nama dichotomum</i>                 | wishbone fiddleleaf        | Hydrophyllaceae | 0                         | 0                  | 0                    | 0                  | 0.002                | 7.69               | 0.001                | 3.33               |
| <i>Nama hispidium</i>                  | bristly nama               | Hydrophyllaceae | 0                         | 0                  | 0                    | 0                  | 0.018                | 53.85              | 0.008                | 23.33              |
| <i>Oenothera</i> sp.                   | evening primrose           | Onagraceae      | 0                         | 0                  | 0                    | 0                  | 0.001                | 23.08              | <0.001               | 10.00              |
| <i>Oenothera albicaulis</i>            | whitest evening-primrose   | Onagraceae      | 0                         | 0                  | 0                    | 0                  | 0.060                | 76.92              | 0.026                | 33.33              |
| <i>Oenothera caespitosa</i>            | tufted evening-primrose    | Onagraceae      | 0.001                     | 3.33               | 0                    | 0                  | 0                    | 0                  | <0.001               | 1.11               |
| <i>Oenothera pallida</i>               | pale evening-primrose      | Onagraceae      | 0                         | 0                  | 0                    | 0                  | 0.034                | 15.38              | 0.015                | 6.67               |
| <i>Opuntia</i> spp.                    | prickly pear               | Cactaceae       | 0.014                     | 56.67              | 0.020                | 85.71              | 0.015                | 46.15              | 0.016                | 58.89              |

**Appendix B (continued)**

| Species                                   | Common name                     | Family          | Plot Group A<br>2007–2009 |                          | Plot Group B<br>2007 |                          | Plot Group C<br>2010 |                          | Ecological site mean |                          |
|-------------------------------------------|---------------------------------|-----------------|---------------------------|--------------------------|----------------------|--------------------------|----------------------|--------------------------|----------------------|--------------------------|
|                                           |                                 |                 | Foliar<br>cover (%)       | Plot<br>frequency<br>(%) | Foliar<br>cover (%)  | Plot<br>frequency<br>(%) | Foliar<br>cover (%)  | Plot<br>frequency<br>(%) | Foliar<br>cover (%)  | Plot<br>frequency<br>(%) |
| <i>Opuntia whipplei</i>                   | Whipple's cholla                | Cactaceae       | 0.080                     | 60.00                    | 0.010                | 28.57                    | 0.089                | 61.54                    | 0.068                | 53.33                    |
| <i>Parryella filifolia</i>                | common dunebroom                | Fabaceae        | 0                         | 0                        | 0                    | 0                        | 0.077                | 15.38                    | 0.033                | 6.67                     |
| <i>Pectis angustifolia</i>                | lemonscent                      | Asteraceae      | 0                         | 0                        | 0                    | 0                        | 0.004                | 30.77                    | 0.002                | 13.33                    |
| <i>Phacelia integrifolia</i>              | gypsum phacelia                 | Hydrophyllaceae | 0                         | 0                        | 0                    | 0                        | 0.002                | 7.69                     | 0.001                | 3.33                     |
| <i>Phacelia ivesiana</i>                  | Ives' phacelia                  | Hydrophyllaceae | 0                         | 0                        | 0                    | 0                        | 0.001                | 7.69                     | <0.001               | 3.33                     |
| <i>Plantago patagonica</i>                | woolly plantain                 | Plantaginaceae  | 0.013                     | 36.67                    | 0.020                | 85.71                    | 0.003                | 30.77                    | 0.010                | 45.56                    |
| <i>Pleuraphis jamesii</i>                 | James' galleta                  | Poaceae         | 2.641                     | 100.00                   | 3.474                | 100.00                   | 4.093                | 100.00                   | 3.464                | 100.00                   |
| <i>Polygonum aviculare</i> <sup>b</sup>   | prostrate knotweed              | Polygonaceae    | <0.001                    | 3.33                     | 0.001                | 14.29                    | 0                    | 0                        | <0.001               | 1.11                     |
| <i>Polygonum douglasii</i>                | Douglas' knotweed               | Polygonaceae    | 0.001                     | 3.33                     | 0                    | 0                        | 0                    | 0                        | <0.001               | 1.11                     |
| <i>Portulaca oleracea</i> <sup>b</sup>    | little hogweed                  | Portulacaceae   | 0.001                     | 3.33                     | 0                    | 0                        | 0.118                | 53.85                    | 0.051                | 27.78                    |
| <i>Portulaca pilosa</i> <sup>c</sup>      | kiss me quick                   | Portulacaceae   | 0                         | 0                        | 0                    | 0                        | 0.006                | 15.38                    | 0.002                | 6.67                     |
| <i>Salsola tragus</i> <sup>b</sup>        | prickly Russian thistle         | Chenopodiaceae  | 0.355                     | 53.33                    | 0.545                | 28.57                    | 0.559                | 92.31                    | 0.488                | 64.44                    |
| <i>Sanvitalia abertii</i>                 | Abert's creeping zinnia         | Asteraceae      | 0                         | 0                        | 0.015                | 14.29                    | 0.074                | 23.08                    | 0.036                | 13.33                    |
| <i>Schkuhria multiflora</i>               | many-flower false<br>threadleaf | Asteraceae      | <0.001                    | 3.33                     | 0                    | 0                        | 0.005                | 7.69                     | 0.002                | 4.44                     |
| <i>Senecio flaccidus</i>                  | threadleaf ragwort              | Asteraceae      | <0.001                    | 3.33                     | 0                    | 0                        | 0                    | 0                        | <0.001               | 1.11                     |
| <i>Sisymbrium altissimum</i> <sup>b</sup> | tumblemustard                   | Brassicaceae    | <0.001                    | 3.33                     | 0                    | 0                        | 0                    | 0                        | <0.001               | 1.11                     |
| <i>Solanum jamesii</i>                    | wild potato                     | Solanaceae      | 0                         | 0                        | 0                    | 0                        | 0.002                | 7.69                     | 0.001                | 3.33                     |
| <i>Sphaeralcea</i>                        | globemallow                     | Malvaceae       | 0.002                     | 13.33                    | 0.001                | 28.57                    | 0.287                | 100.00                   | 0.125                | 54.44                    |
| <i>Sphaeralcea hastulata</i>              | spear globemallow               | Malvaceae       | 0.072                     | 50.00                    | 0.075                | 71.43                    | 0                    | 0                        | 0.041                | 33.33                    |
| <i>Sporobolus</i> sp.                     | dropseed                        | Poaceae         | 0.002                     | 6.67                     | 0                    | 0                        | 0                    | 0                        | 0.001                | 2.22                     |
| <i>Sporobolus airoides</i>                | alkali sacaton                  | Poaceae         | 2.265                     | 80.00                    | 0.012                | 57.14                    | 2.448                | 61.54                    | 1.819                | 66.67                    |
| <i>Sporobolus contractus</i>              | spike dropseed                  | Poaceae         | 0.024                     | 10.00                    | 0.053                | 28.57                    | 0.163                | 61.54                    | 0.091                | 36.67                    |
| <i>Sporobolus coromandelianus</i>         | Madagascar dropseed             | Poaceae         | 0.012                     | 10.00                    | 0                    | 0                        | 0.193                | 46.15                    | 0.088                | 23.33                    |
| <i>Sporobolus cryptandrus</i>             | sand dropseed                   | Poaceae         | 0.062                     | 23.33                    | 0.164                | 42.86                    | 0.274                | 92.31                    | 0.178                | 57.78                    |
| <i>Sporobolus flexuosus</i>               | mesa dropseed                   | Poaceae         | 0.079                     | 13.33                    | 1.004                | 42.86                    | 1.037                | 46.15                    | 0.710                | 34.44                    |
| <i>Stephanomeria pauciflora</i>           | brownplume wirelettuce          | Asteraceae      | 0                         | 0                        | 0                    | 0                        | 0.007                | 15.38                    | 0.003                | 6.67                     |

## Appendix B (continued)

| Species                    | Common name           | Family      | Plot Group A<br>2007–2009 |                          | Plot Group B<br>2007 |                          | Plot Group C<br>2010 |                          | Ecological site mean |                          |
|----------------------------|-----------------------|-------------|---------------------------|--------------------------|----------------------|--------------------------|----------------------|--------------------------|----------------------|--------------------------|
|                            |                       |             | Foliar<br>cover (%)       | Plot<br>frequency<br>(%) | Foliar<br>cover (%)  | Plot<br>frequency<br>(%) | Foliar<br>cover (%)  | Plot<br>frequency<br>(%) | Foliar<br>cover (%)  | Plot<br>frequency<br>(%) |
| <i>Townsendia annua</i>    | annual Townsend daisy | Asteraceae  | 0                         | 0                        | 0                    | 0                        | 0.015                | 53.85                    | 0.006                | 23.33                    |
| <i>Verbena bracteata</i>   | bigbract verbena      | Verbenaceae | 0.008                     | 6.67                     | 0                    | 0                        | 0                    | 0                        | 0.003                | 2.22                     |
| <i>Vulpia octoflora</i>    | sixweeks fescue       | Poaceae     | 0.006                     | 23.33                    | 0.064                | 71.43                    | 0                    | 0                        | 0.017                | 24.44                    |
| <i>Xanthium strumarium</i> | rough cocklebur       | Asteraceae  | 0                         | 0                        | 0                    | 0                        | <0.001               | 7.69                     | <0.001               | 3.33                     |
| <i>Yucca angustissima</i>  | narrowleaf yucca      | Agavaceae   | 0.034                     | 46.67                    | 0.024                | 42.86                    | 0.050                | 84.62                    | 0.039                | 62.22                    |
| <i>Yucca baccata</i>       | banana yucca          | Agavaceae   | 0.003                     | 10.00                    | 0.029                | 14.29                    | 0.008                | 7.69                     | 0.011                | 10.00                    |
| <i>Zinnia grandiflora</i>  | Rocky Mountain zinnia | Asteraceae  | 0.042                     | 30.00                    | 0                    | 0                        | 0                    | 0                        | 0.014                | 10.00                    |
| unknownPEFO20070912_2      |                       |             | <0.001                    | 3.33                     | 0                    | 0                        | 0                    | 0                        | <0.001               | 1.11                     |
| unknownPEFO20101001_1      |                       |             | 0                         | 0                        | 0                    | 0                        | 0.001                | 7.69                     | <0.001               | 3.33                     |

<sup>a</sup>Rare species.

<sup>b</sup>Nonnative species.

<sup>c</sup>New species record.