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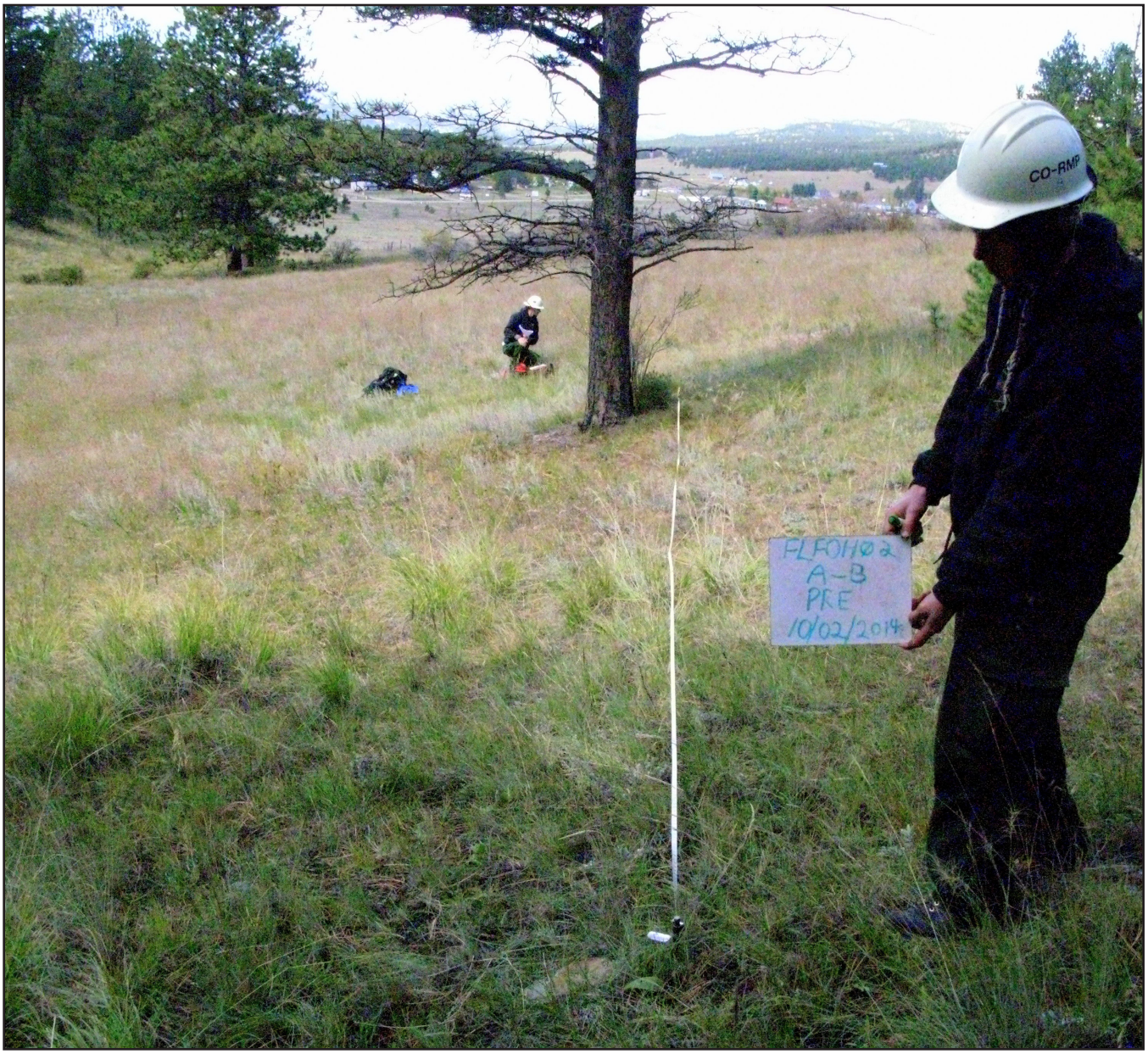
Natural Resource Stewardship and Science

Florissant Fossil Beds National Monument Upland Vegetation and Fire Effects Monitoring

2000–2014 Data Report, Revised January 13, 2020

Natural Resource Data Series NPS/ROMN/NRDS—2020/1268





ON THIS PAGE
Rocky Mountain Fire Effects Program crew sampling at Florissant Fossil Beds National Monument, October 2014.
Photograph courtesy of the National Park Service.

ON THE COVER
Inventory and monitoring transect at Florissant Fossil Beds National Monument, July 2014.
Photograph courtesy of the National Park Service.

Florissant Fossil Beds National Monument Upland Vegetation and Fire Effects Monitoring

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Authors

Borgman, E. M.[1], N. Williamson[2], I. W. Ashton [2], E. W. Schweiger [1]

[1]National Park Service
Rocky Mountain Inventory and Monitoring Network
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

[2]Rocky Mountain National Park
1000 Hwy 36
Estes Park, CO 80517

Editors

Nina Chambers
Northern Rockies Conservation Cooperative
P.O. Box 2705
Jackson, WY 83001

Sonya Daw (revision)
National Park Service
Inventory and Monitoring Division
Ashland, OR 97520

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

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Executive Summary

Scientifically credible information on the current status and long-term trends of the composition, structure, and function of the forests and grasslands in Florissant Fossil Beds National Monument (FLFO) is a key component for sound management. This report presents summary data and information from the Rocky Mountain Inventory and Monitoring Network (ROMN) and the Rocky Mountain Fire Effects Program (FireEP) monitoring between 2008 to 2013 and 2000 to 2014, respectively. In 2008, the ROMN began an effort to determine status and trends in upland vegetation structure, species composition, and soil condition in FLFO (Manier et al. 2011). A set of 32 long-term sites were established in the park using a spatially balanced probability survey design. These sites were visited from 2008 to 2013 to understand the condition of FLFO upland vegetation and soils. Prior to the implementation of the ROMN sites, the FireEP established long-term sites in FLFO. These sites were randomly selected from within specific stands scheduled for prescribed burning or thinning with the goal of better understanding management activities on fuel loads and forest structure and composition. We have incorporated both datasets into this ROMN report to provide a longer-term picture of FLFO forest condition than if reported separately.

Key results include the following:

- Upland sites in the park had a moderately diverse mixture of mostly native plants. Of the exotic species found at sites, smooth brome (*Bromus inermis*) was the most abundant.
- Forested sites contained mostly ponderosa pine (*Pinus ponderosa*) and Douglas fir (P*seudotsuga menziesii*) with a mix of mature trees, saplings, and seedlings.
- ROMN sites had generally high soil aggregate stability, high cover of litter, and moderate soil compaction, suggesting erosion potential was not of concern at those locations. Moreover, a soil quality index suggested quality of the soils at ROMN sites was above average.
- Surface fuel loading at FireEP sites was highest in the mixed conifer stands, followed by closed ponderosa pine stands and open ponderosa savannas.

This report is not an in-depth analysis of condition or trend data for either data set, nor is it a comparison of the two. ROMN upland vegetation and soils monitoring will eventually help FLFO staff understand issues such as the impact of a changing climate on the park ecosystems, the response of soils to disturbance, and changes in native and non-native species. As we collect more data and conduct additional analyses, we will look for patterns and trends that might indicate a change in the ecological integrity of FLFO vegetation and soils.

Introduction

Florissant Fossil Beds National Monument (FLFO) is a 2,427-hectare (5,998-acre) park established in 1969 to preserve and interpret one of the richest and most diverse fossil deposits in the world. FLFO lies 35 miles west of Colorado Springs in a mountain valley just west of Pikes Peak. At 2,560 meters elevation (8,400 feet), the landscape is typical of the Rocky Mountain montane zone with a mosaic of ponderosa forest, wetlands, and montane grasslands. Past agriculture use and livestock grazing, changing climate, invasive/exotic species, development, and altered fire regimes have caused changes to the landscapes. Wildfire is an integral and natural component of montane ecosystems in and near FLFO. Development, fire suppression, and land management have altered fire regimes and, consequently, ecosystem functioning. Along with fossil management and interpretation, maintaining and restoring the native plant communities in an altered fire regime, monitoring vegetation communities for future change, and promoting native species are key objectives of FLFO management (NPS 2000).

Scientifically credible information on the current status and long-term trends of the composition, structure, and function of the forests and grasslands in FLFO is a key component for sound management. In 2008, the Rocky Mountain Inventory & Monitoring Network (ROMN) began an effort to determine status and trends in upland vegetation structure, species composition, and soil condition in FLFO (Manier et al. 2011). This protocol directly addresses two high priority vital signs in ROMN small parks—(1) vegetation composition, structure, and soils and (2) invasive/exotic plants—and is linked to four other vital signs: landscape dynamics, weather and climate, wet and dry deposition, and focal species-elk (Britten et al. 2007). A set of 32 long-term sites were established in the park using a spatially balanced probability survey design (Figure 1). We report on data from these sites to understand the condition of FLFO upland vegetation from 2008 to 2013.

Prior to the establishment of the ROMN sites, the Rocky Mountain Fire Effects Program (FireEP) established 16 long-term sites in FLFO (Figure 1). These sites were randomly selected from within specific stands scheduled for prescribed burning or thinning with the goal of better understanding management activities on fuel loads and forest structure and composition. The fire and fuels management program is essential for the protection of human life, natural and cultural resources, and other properties and resources at risk and for the long-term survival and maintenance of plant and animal communities. The FireEP traditionally focuses on effectiveness monitoring (National Park Service 2003), rather than monitoring for status and trend like the ROMN. These sixteen sites were targeted primarily to the forested areas of the monument and thus estimate conditions specific to these forested areas only.

This report presents a data summary of ROMN and FireEP efforts between 2008-2013 and 2000-2014 respectively and is intended to provide only a basic, initial characterization of these data sets. In the coming years, ROMN will have sufficient data to report on trends in condition and will conduct more in-depth analysis and interpretation. Here, we have incorporated FireEP data into the ROMN report to provide a fuller, longer-term picture on the status of vegetation and soil conditions in FLFO.

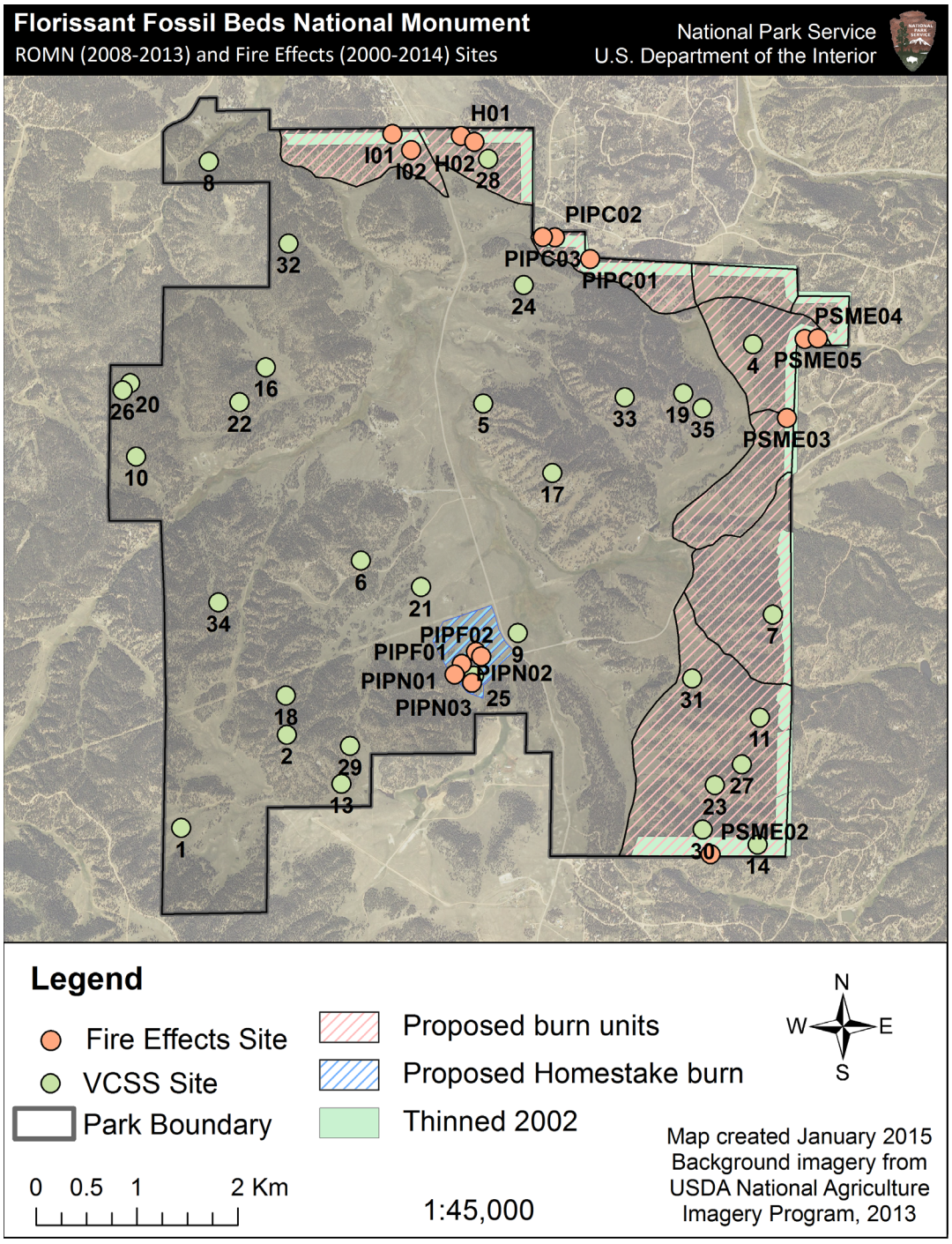


Figure 1. Thirty-two ROMN vegetation composition, structure, and soils sites (green) and 16 Rocky Mountain Fire Effect Program sites (orange) at FLFO.

Methods

ROMN VCSS Protocol

Manier et al. (2011) provides detailed descriptions of field and analytical techniques used for monitoring vegetation composition, structure, and soils (VCSS) in FLFO and other ROMN parks. The VCSS protocol used a probability ("random") sampling design (Stevens and Olsen 2004) with sites selected within five ecological sites and soil types that correspond with two general vegetation types: 7 grassland sites (in valleys) and 25 forest sites (on hills). Nine sites were visited in the first pilot year (2008) and ten sites were visited in the second pilot year (2009). Beginning in 2010, sites were visited following a paneled structure over four years, with a smaller subset visited every year to determine inter-annual variation. Between 2010 and 2013, all thirty two unique sites were visited (Figure 1; Appendix A). Within any given year, sites were drawn from across the park, including both vegetation types, facilitating (small sample sized) comparisons across years.

Vegetation Composition and Structure

VCSS sites were sampled during peak vegetation phenology, generally in July and early August (crew availability and consistency of timing from one year to the next caused some variation in the date of some sample events). Sampling during peak vegetation development facilitated identification of vegetation and corresponded to the time of year when plants were often most stressed by water availability, disturbances from herbivores, and, in some cases, local- and larger-scale anthropogenic disturbances (such as a wildfire in 2011). Sampling when vegetation was most stressed should lead to conservative assessment of condition.

Field crews measured vegetation composition using both transect and plot-based methods. Along three 36-meter transects radiating out from site center (Figure 2), crews used a point-intercept method to gather cover information on canopy and surface features. At 0.5 m intervals, the data collector dropped a pin and recorded the spe-

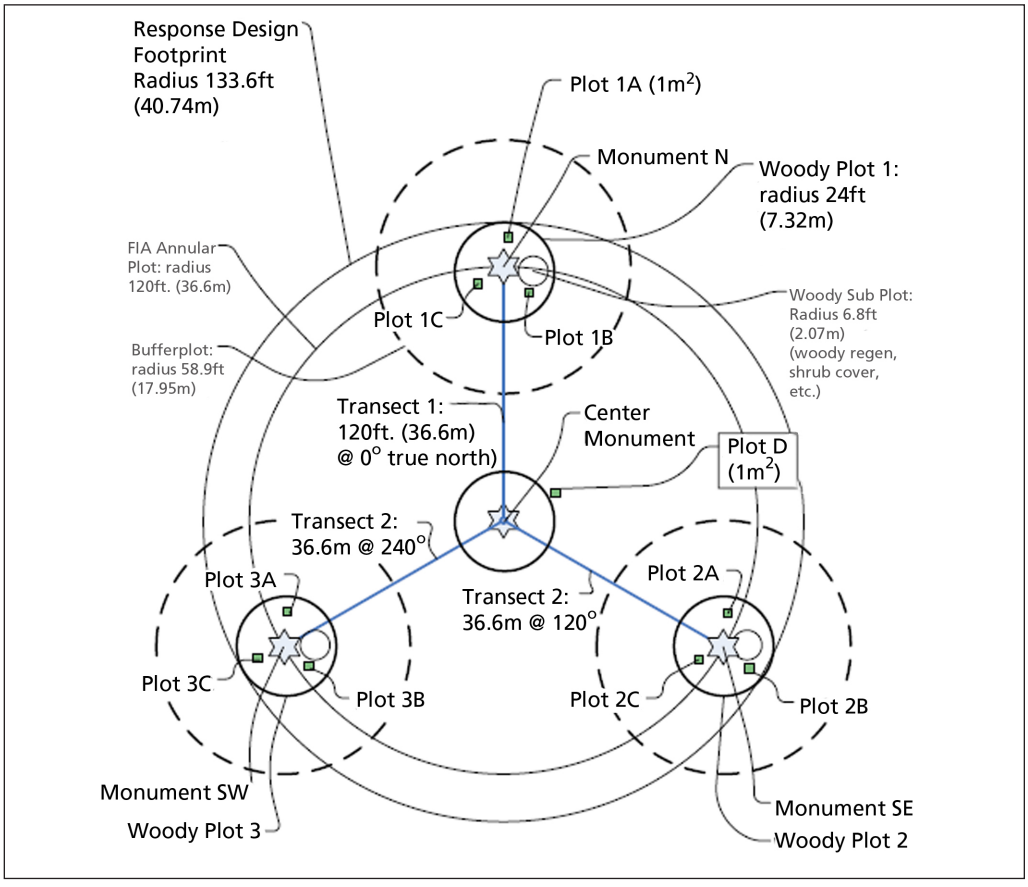


Figure 2. Rocky Mountain Network vegetation composition, structure, and soils (VCSS) site layout.

cies and surface type that touched the pin. These "hits" were later converted into percent cover. Transect sampling is a fairly objective method for estimating cover (Barbour et al. 1987) and can be used for larger areas. Crews also collected data in ten 1 m^2 plots (Figure 2). At each plot, crews used ocular estimates to record absolute percent cover of each species canopy and surface feature (e.g., coarse gravel, litter). Estimating cover in small plots complemented transect measurements by detecting lower cover species (Elzinga et al. 1998). At these same plots, crew members also documented frequency of each species in nested 0.01 m^2, 0.1 m^2, and 1 m^2 quadrats. During the first pilot year in 2008, plants were not identified to the species level. Rather, they were identified by their lifeform group, such as forb, perennial graminoid, annual graminoid, and others. Beginning in 2009, the second pilot year, all plants were identified to the species level. Nomenclature for all vegetation data followed the Integrated Species Taxonomic Information System (www.itis.gov), which can be cross-walked to multiple other nomenclature schema used in Colorado. Life and natural history attributes (i.e., nativity and lifeform), were assigned using the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) plants database (USDA NRCS 2014) and an attribute table was provided by the Colorado Natural Heritage Program (Lemly and Gilligan 2013).

When trees were present, crews set up three woody plots, one at the end of each transect (Figure 2). Crews measured tree diameter, canopy position, crown condition, and presence of any pests or diseases on mature trees >12.7 cm in diameter at breast height (DBH) and saplings between 2.5 and 12.6 cm DBH. Crews tallied the number of seedlings (<2.5 cm DBH) present by species in smaller subplots.

Soils

Collection of soil samples to estimate soil aggregate stability and susceptibility to erosion followed Herrick et al. (2005). Crews collected six surface and six subsurface soil samples from each of the three radiating transects (36 total samples per site) and submerged each in water in a field soil kit. Samples were assigned a stability class score based upon the length of time the group of soil particles cohered to one another after immersion. At the site level, crews assessed rills and gullies, pedestals, and evidence of surface flow using ratings ranging from none to extreme.

Crews also collected four soil samples along each transect (12 samples/site) for laboratory analyses. Three samples were combined for chemistry analysis while the fourth sample was kept intact and used to measure bulk density. Soil characteristics measured include texture, pH, cation exchange capacity, soil organic matter content, total nitrogen and carbon content, and the concentration of mineral nutrients.

Disturbance and Context

Crews observed and documented disturbance within and surrounding each site. Crew members rated the level of human-caused disturbance by observing features such as distance to nearest road, presence of buildings, condition of the buffer area surrounding the site, any hydrological alterations, or general physical disturbance. Crews also evaluated natural disturbance by observing signs of use and disturbance from natural processes (e.g., fire or rodent use). Field data were used to create a series of metrics including synthetic measures (indices) of Human Disturbance (HDI) and Natural Disturbance (NDI) following algorithms developed in (Rocchio 2007).

Finally, crews recorded features such as location (UTM coordinates), site description, dominant aspect, slope, topographic position, and hydrologic environment. Crews also photographed each site following set photo-point procedures for future comparison of changes in vegetation structure and land use.

ROMN Analysis Methods

The sample unit for analyses of VCSS data was the site, with all plot or transect data pooled within each sample event. Site-level data were used to calculate means and other statistics within vegetation types (forests or grasslands) or years. To understand how vegetation condition may have changed from year to year, select VCSS metrics were compared across year and site type using a generalized linear model with both independent variables treated as fixed effects. Post hoc comparisons were done using a Tukey-Kramer test (for

unequal sample sizes). Distributional assumptions were tested and appropriate transformations were included as needed. All tests of significance were based on a p-value of $p<0.05$. Where there were no significant differences in a metric between years, data were averaged across all years for each vegetation type. A more in-depth trend analysis in future years will more fully explore changes in vegetation and soils at a park level using a more statistical approach with metrics selected based on observed patterns with disturbance gradients following Schoolmaster et al. (2012, 2013a, b).

The source data and years of data included varied for each VCSS metric. Plots were used to determine species cover by lifeform, diversity, and cover of exotic species, in order to better detect less abundant species. Transects were used to summarize the relative cover of the most abundant species data because of that method's ability to detect more abundant species more objectively (Elzinga et al. 1998). Due to vegetation sampling methods changes between the first pilot year (2008) and later years, all non-woody plant-based analyses used data from 2009 to 2013. Woody plant and soil analyses used data from 2008-2013, as methods did not vary substantially between pilot and later years.

We calculated the mean number of species (species richness or Alpha diversity) and the total number of species across all sites (Gamma diversity). The measure of heterogeneity among sites (Beta diversity ($ß_w$)) was calculated as:

$$ß_w=(S_c/S)-1$$

where S_c was the number of species found at the park level, and S was the average species richness at the site level (Whittaker 1972).

For soil aggregate stability, the 36 surface and sub-surface samples from each site were averaged to produce one estimate of stability per site. Soil chemistry parameters were averaged across all sites and all years (2008-2013) to produce a single measurement per parameter. Those measurements were then used to determine the overall soil quality. The U.S. Forest Service developed a soil quality index (SQI), compositing 19 soil parameters into an overall indicator of soil quality (Amachar et al. 2007), 14 of which the Rocky Mountain Network also collected. Each soil parameter was assigned an index value based on its level. For example, an optimal soil pH level between 5.51 and 7.2 would receive the highest possible index value while levels above or below that threshold would receive a lower index value. The SQI is calculated as:

$$SQI = \frac{\sum individual\ soil\ index\ values}{maximum\ index\ values\ possible\ for\ properties\ measured} \times 100$$

Note that this calculation takes into account that not all 19 sub metrics were measured at VCSS sites.

All VCSS metrics presented in this report were selected based on the professional opinion of ROMN ecologists in consultation with FLFO resource management staff. They were chosen based on expected utility in interpreting ecological condition and for their management relevance. All analyses were conducted in R version 3.1.2 (R Core Team 2013).

FireEP Protocol

Fire effects monitoring at FLFO used the standardized data collection procedures described in the NPS Fire Monitoring Handbook (NPS 2003). Permanently marked 1,000 m^2 (20x50 meter) monitoring sites were randomly selected within relatively homogenous vegetation associations. Within each site there are fuel sub-plots, a point intercept transect, and a shrub belt (Figure 3). These associations included mixed conifer (labeled as PSME), ponderosa pine (labeled as PIPC and PIPF), and ponderosa savanna (labeled as PIPN, H, and I) forests where fuel-reduction treatments (prescribed fire and thinning) have occurred or have been proposed (Figure 1).

FireEP sites were installed for various monitoring objectives. PIPF and PIPN sites were installed to monitor the effect of prescribed burns, PSME and PIPC of manual thinning, and H and I sites were installed to monitor a combination of thinning and prescribed fire. None of the prescribed burns have taken place as of January 2015. Only pre-treatment data are included in this report for sites where thinning occurred. Between 2000 and 2014, 16 sites were visited at FLFO by the FireEP crews (Figure 1). Sites were visited 1-2 times during the sampling period. A majority of sampling (n=19) occurred in

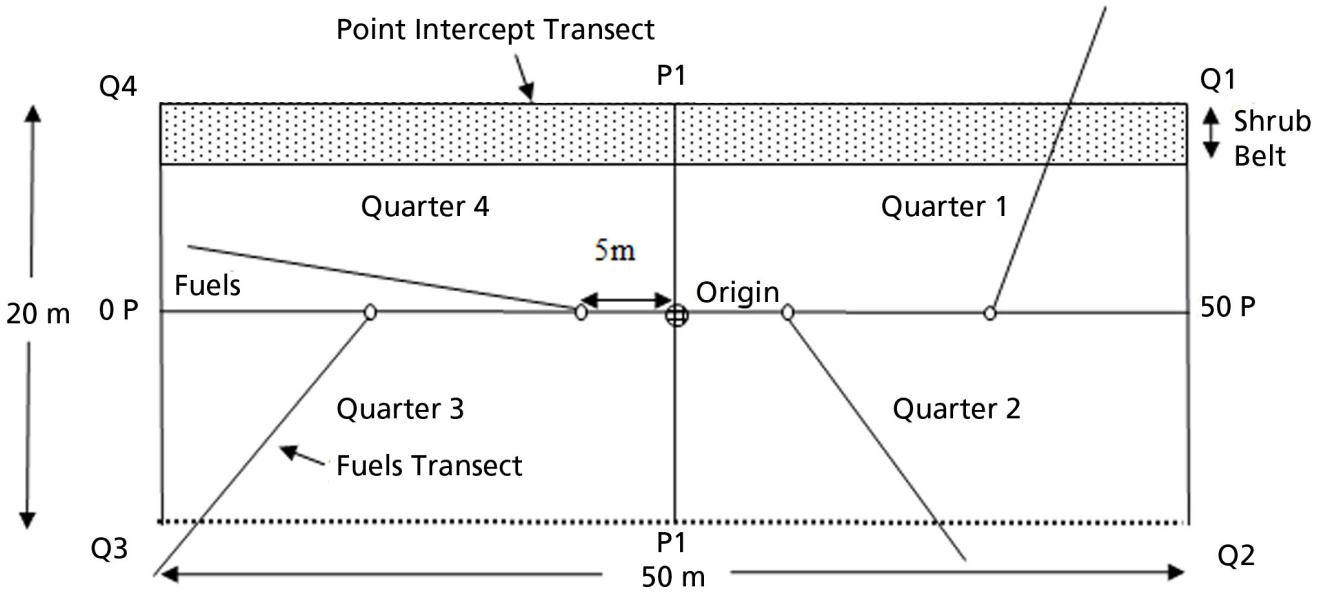


Figure 3. Layout of the Rocky Mountain Fire Effects Program monitoring sites.

2000-2004 and the H and I sites (n=4) were added in 2014.

All sites were monitored during the growing season as close to the phenological peak as possible. Within each site, herbaceous cover, shrub cover, fuel load, and stand structure were sampled. Herbaceous and shrub cover were estimated using a point-intercept method along a 50 m transect. Shrub density was estimated within the shrub belt by recording the number of individuals having >50% of their rooted base within the belt transect (Figure 3). Nomenclature followed USDA NRCS (2014).

Surface fuels based on size classes were sampled along 15 m transects in the mixed conifer monitoring type and along 30 m transects in the ponderosa and ponderosa savanna types. Surface fuel loading data included dead and down woody material, litter depth, and duff depth. Litter was considered the top layer of the forest floor consisting of freshly fallen leaves, needles, bark flakes, dead matted grass, and other vegetative parts that were little altered in structure by decomposition. Duff was defined as the fermentation and humus layer lying between the litter layer and mineral soil (NPS 2003).

To obtain overstory tree and sapling density, all trees >1.37 meters (4.5 feet) in height were tagged, mapped, identified to species, measured for diameter at breast height, and recorded as live or dead. Seedlings (<2.5 cm DBH) were tallied by species in a 25 m x 10 m subplot (quarter 1 of the monitoring site; Figure 3).

FireEP Analysis Methods

The sample unit for analyses was the site, with all transect data pooled for each sample event. Site-level data were used to calculate means and other statistics across forest monitoring types. All inferences within the results of this report are only to the sampled sites.

Point-intercept transects were used to determine percent relative cover by lifeform and cover of native and non-native species. Basal area and stem density metrics were calculated from overstory data. Fuels transects were used to determine surface fuel loading; data were pooled for each fuel category (downed woody, duff, and litter) for each forest monitoring type. Standard practice for fire management is to report fuels data in English units of tons per acre; they are reported as such here.

Where thinning occurred, only pre-treatment data are reported; a future report will investigate differences in pre- and post-thinning treatment data. Due to small sample sizes and a lack of replication between years, analyses comparing across year and site type were not run.

Since the objectives and sampling designs differed between ROMN and FireEP, results for the two are not strictly comparable. Therefore, we report results from each protocol separately.

Results

ROMN Results

Vegetation Composition and Structure

From 2008 to 2013, 176 vascular plant species (13 of which were exotic) were identified by ROMN crews (Appendix B). Of these, 40 were classified as graminoids; 11 were trees or shrubs; 109 were forbs, herbs, or subshrubs; 14 were shrubs or subshrubs; and 2 were vines.

Graminoids, which includes grasses, sedges, and rushes, were on average the lifeform with the highest percent relative understory cover in both ROMN vegetation site types (grasslands and forests) with a mean relative cover of 38% in grassland and 18% in forest sites. Shrubs, forbs, and trees were also present in varying degrees (Figure 4). There were no significant differences in lifeform cover between years.

The most abundant species found in the understory was mountain muhly (*Muhlenbergia montana*), a native perennial grass with a mean cover of 12.9±1.2% (averages and their standard deviation are taken across all sites and years). Other abundant species included Arizona fescue (*Festuca arizonica*) with a mean cover of 8.4±1.7%, Parry's oatgrass (*Danthonia parryi*) with a mean cover of 5.7±2.6%, and ponderosa pine (*Pinus ponderosa*) with a mean cover of 4.5±2.4% (Table 1).

The mean alpha diversity (species richness), was 32.92±7.66 across the two vegetation types and years. There were significant differences between 2010 and 2011 and 2010 and 2012 (p=0.02; n=50), with a higher species richness in 2010 (Table 2). In the 32 ROMN sites, the mean number of unique species found across all sampling years, or gamma diversity, was 63.9±26.15 (Table 2). Beta diversity, a measure of the heterogeneity among sites, was 0.98±0.60 across all years (Table 2). Measures of beta diversity less than 1 indicate low variation in species present among sites, while measures of beta diversity over 5 indicate high variation among sites (McCune and Grace 2002).

Exotic species recorded include smooth brome (*Bromus inermis*), and Kentucky bluegrass (*Poa pratensis*). In all ROMN sites, the relative cover of native species was greater than the cover of exotics (Figure 5).

Woody Species

The most abundant tree species in ROMN sites were ponderosa pine (*Pinus ponderosa*)and Douglas fir (*Pseudotsuga menziesii*), though quaking aspen (*Populus tremuloides*), Blue spruce (*Picea pungens*), Engelmann spruce (*Picea engelmannii*), Rocky Mountain juniper (*Juniperus scopulorum*), bristlecone pine (*Pinus aristata*), and limber pine

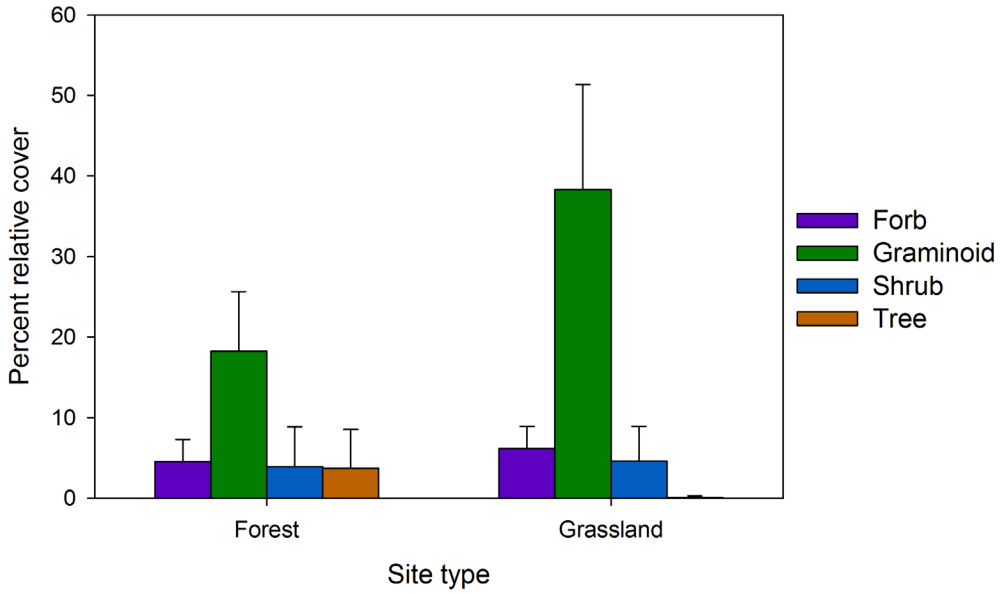


Figure 4. Mean relative understory cover by lifeform with standard deviation averaged across both ROMN site types (forests and grasslands) and years (2009-2013) (forbs: purple, graminoids:green, shrubs:blue, and trees:orange). There were no significant differences in lifeform types between years, so data were averaged across all years for each site type. Data from 2008 is omitted due to different sampling methods.

Table 1. Mean relative cover with standard deviation for the five most abundant plant species found in ROMN sites each year between 2009 and 2013. Data from 2008 was omitted due to different sampling methods. Species of park concern are those FLFO staff has stated are of interest to park management.

Year	Common Name	Scientific Name	Non-native	Park Concern	Mean Cover	SD
2009	mountain muhly	*Muhlenbergia montana*	No	No	13.05	7.12
	Arizona fescue	*Festuca arizonica*	No	No	9.76	12
	Parry's oatgrass	*Danthonia parryi*	No	No	8.85	9.21
	smooth brome	*Bromus inermis*	Yes	Yes	8.08	22.67
	ponderosa pine	*Pinus ponderosa*	No	No	2.68	6.39
2010	mountain muhly	*Muhlenbergia montana*	No	No	11.78	8.31
	Arizona fescue	*Festuca arizonica*	No	No	9.94	7.93
	Parry's oatgrass	*Danthonia parryi*	No	No	7.47	5.49
	smooth brome	*Bromus inermis*	Yes	Yes	3.36	16.6
	sun sedge	*Carex inops* ssp. *heliophila*	No	No	3.09	4.98
2011	mountain muhly	*Muhlenbergia montana*	No	No	12.96	7.02
	Arizona fescue	*Festuca arizonica*	No	No	8.64	7.23
	Parry's oatgrass	*Danthonia parryi*	No	No	5.96	11.05
	ponderosa pine	*Pinus ponderosa*	No	No	5.68	7.26
	common juniper	*Juniperus communis*	No	No	4.6	6.62
2012	mountain muhly	*Muhlenbergia montana*	No	No	11.88	10.05
	ponderosa pine	*Pinus ponderosa*	No	No	7.89	6.14
	Arizona fescue	*Festuca arizonica*	No	No	7.79	7.08
	blue grama	*Bouteloua gracilis*	No	No	6.15	10.65
	common juniper	*Juniperus communis*	No	No	3.33	9.46
2013	mountain muhly	*Muhlenbergia montana*	No	No	14.74	9.46
	Arizona fescue	*Festuca arizonica*	No	No	5.82	3.46
	ponderosa pine	*Pinus ponderosa*	No	No	3.99	3.26
	Parry's oatgrass	*Danthonia parryi*	No	No	3.94	5.8
	common juniper	*Juniperus communis*	No	No	3.71	4.58

Table 2. Levels of diversity at ROMN sites for each sample year: alpha (species richness at each site averaged over all sites); gamma (total number of species found in all sites); and beta (heterogeneity among sites). There were significant differences in alpha diversity between 2010 and 2011 and 2010 and 2012 ($p=0.02$; $n=50$). Gamma and beta diversity were park-scale measurements and so were not able to be analyzed for differences between groups. Data from 2008 is omitted due to different sampling methods.

Year	Alpha Diversity ($1\ m^2$ plot scale)		Gamma Diversity (park scale)		Beta Diversity (species heterogeneity; 0-5)	
	Forest	Grassland	Forest	Grassland	Forest	Grassland
2009	36.4±7.6	26.7±9.0	88	49	1.4	0.8
2010	41.9±5.1	31.0±6.9	98	54	1.3	0.7
2011	31.3±6.4	26.0±4.2	85	32	1.7	0.2
2012	29.7±8.1	29.7±5.1	67	44	1.3	0.5
2013	33.7±5.8	23.0±NA	99	23	1.9	0.0

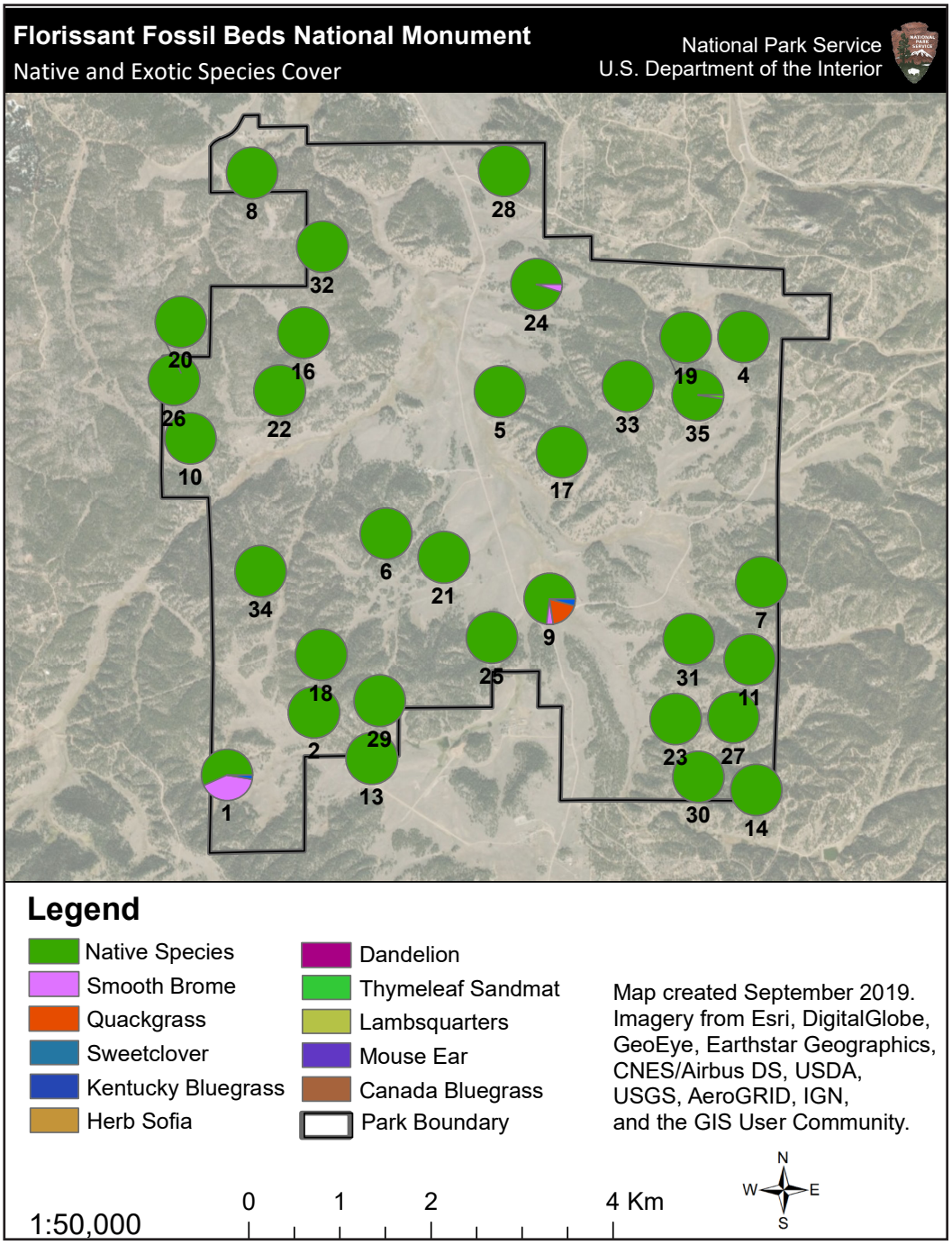


Figure 5. Native (green) and exotic (all other colors) species percent relative cover for each ROMN site in sample years 2009-2013. Where multiple years of data exist for the same site, the most recent year's data were used to provide the most current information. Data from 2008 are omitted due to different sampling methods.

(*Pinus flexilis*) were also present. The basal area at each site, a measure describing the amount of an area occupied by tree stems, ranged from 1.7 to 27.9 m^2/ha with a mean of 13.4 ± 8.2 m^2/ha (Figure 6). Woody species structure at the 29 sites with trees show a mixture of mature trees, saplings, and seedlings (Figure 7), suggesting ongoing regeneration in forest sites of all species except for bristlecone and limber pine.

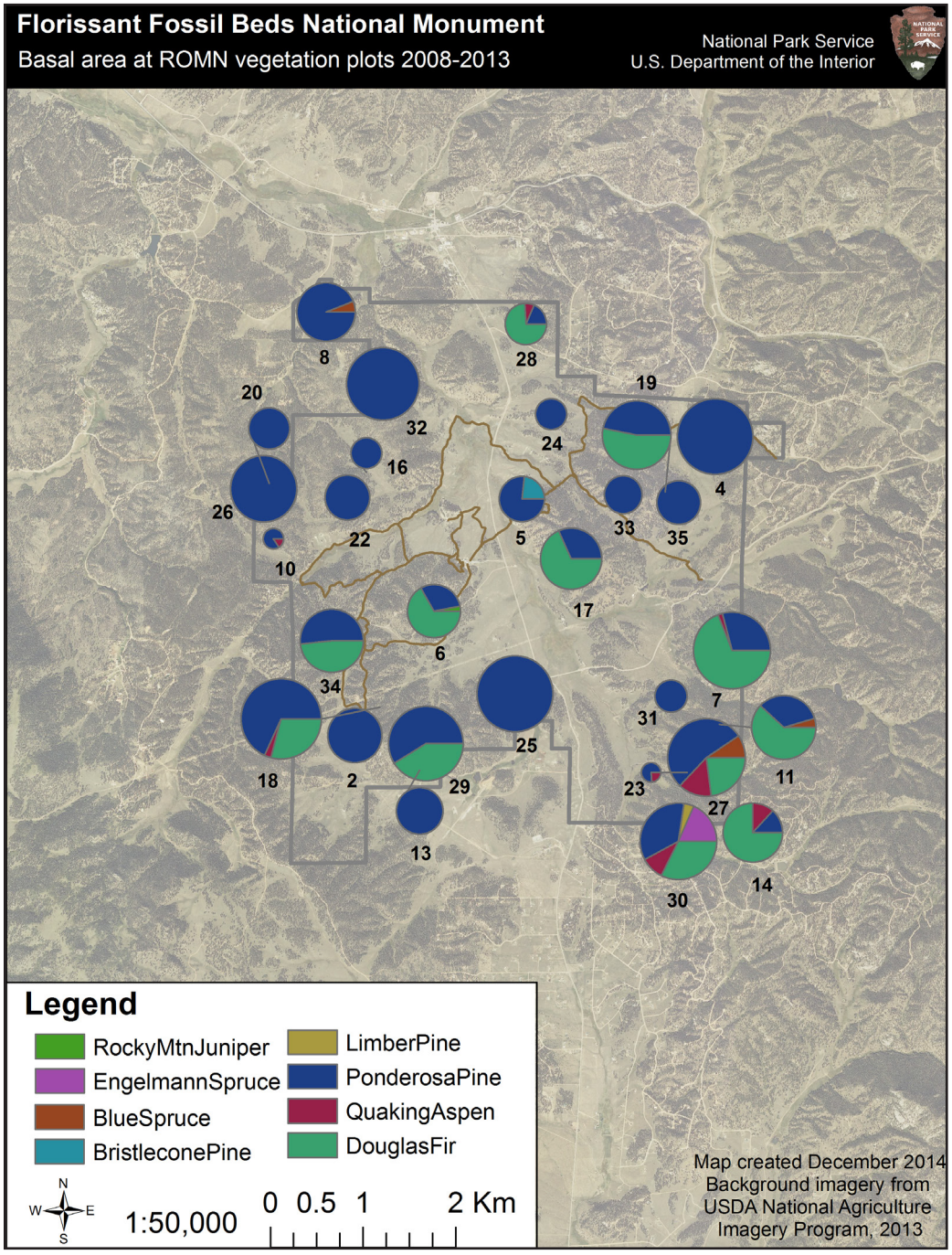


Figure 6. Tree basal area at ROMN sites averaged across all sample years (2008-2013). The size of the circle corresponds to the total basal area of all trees at the site. The color and size of each wedge of the pie charts corresponds to the species and basal area, respectively, of that species at each site. Where there is overlap, grey lines point to the location of the site.

Erosion Potential and Soil Chemistry

Erosion potential is, in part, a function of soil aggregate stability (or the ability of particles of soil to adhere to each other) and the percent cover of bare ground. We use modified methods from Herrick et al. (2005) to create a soil aggregate stability metric. The metric ranges from 1 to 6, with lower values indicating lower stability. VCSS sites averaged 4.2±1.0 and 4.5±0.9 for sub-surface and surface soil, respectively (Figure 8). There were no significant differences between years in surface soil aggregate stability. For sub-surface stability there were differences between 2010 and 2013 ($p=0.04$; $n=59$) and between 2012 and 2013 ($p=0.01$; $n=59$), with lower soil aggregate stability in 2013.

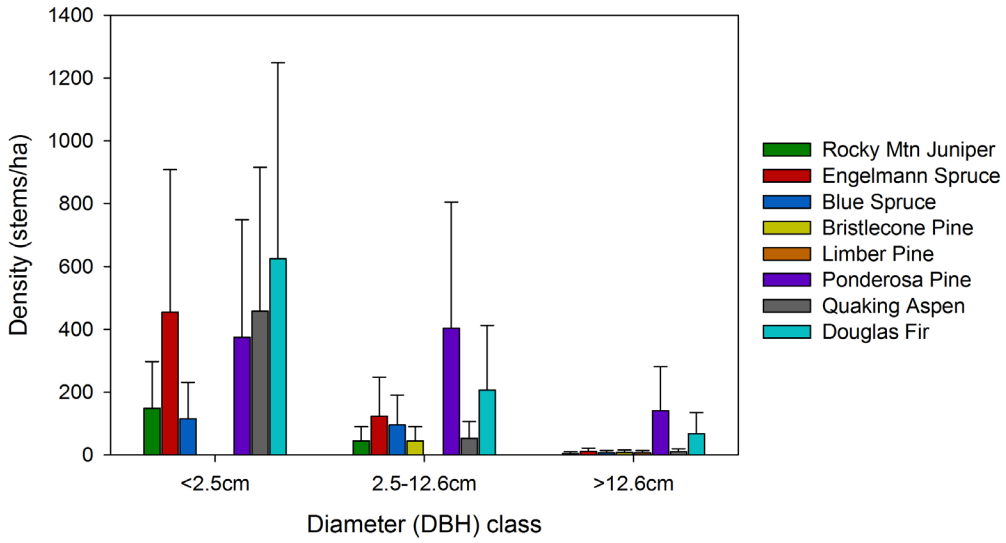


Figure 7. Mean stem density of trees in ROMN sites averaged across all years (2008-2013) with standard deviation show a mixture of seedlings (<2.5 cm in diameter at breast height; DBH), saplings (2.5-12.6 cm DBH), and trees (>12.6 cm DBH).

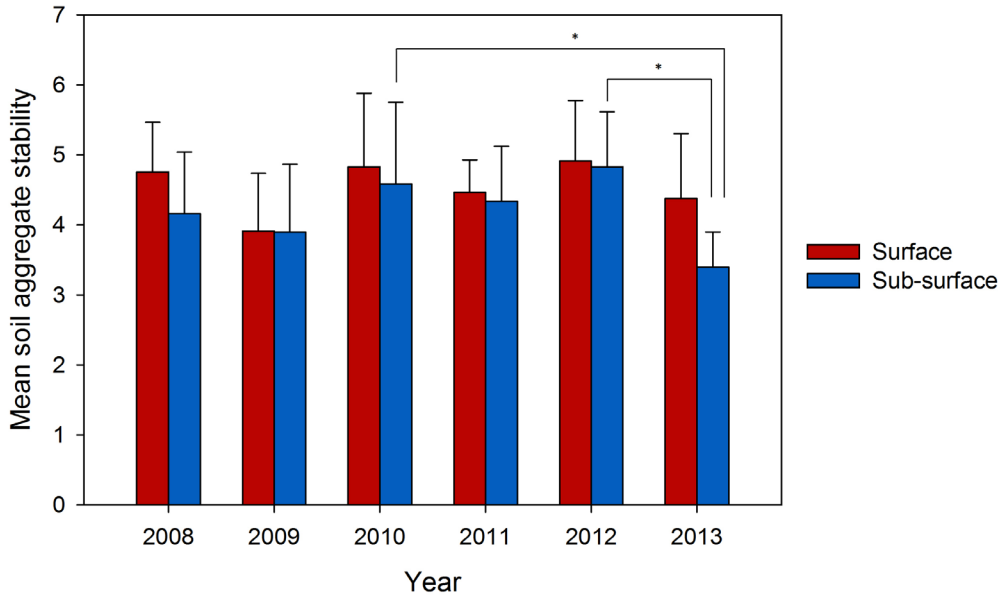


Figure 8. Soil aggregate stability (mean with standard deviation) measured in the top 1 cm of soil (surface; red) and 2 cm below the surface (sub-surface; blue) averaged across all ROMN monitoring sites from 2008-2013. Significant differences between years denoted with an asterisk ($p<0.05$; $n=59$).

Litter was the largest surface cover type at 61.2±17.5% across all sites and all years, followed by rocks and fine gravel at 12.8±21.0% and 12.1±9.4%, respectively (Table 3). High litter cover can reduce bulk density of soil, creating more space available for air and water movement (O'Neill et al. 2005). The mean bulk density at all sites across all years was 1.2±0.1 g/cm^3. Approximate bulk densities for loamy forest soils tend to be between 0.7-1.2 g/cm^3 and a bulk density greater than 1.6 g/cm^3 can impede root growth (Brady and Weil 1996).

Using the soil quality index, the overall soil quality index at FLFO was 17 out of 21 possible points, or 81% (Table 4; Amacher et al. 2007). The index is a percentage of 100, with lower values indicating lower soil quality.

Table 3. Mean surface cover with standard deviation for ROMN transects, 2008-2013.

Surface Type	Mean % Cover	SD
litter	61.2	17.5
rock, stone (>25 cm diameter)	12.8	21.0
gravel, fine (2-20 mm diameter)	12.1	9.4
plant base	9.5	6.7
bare soil	7.5	9.3
woody debris, fine (≥0.62 cm diameter	5.4	4.5
non-vascular	5.1	7.1
gravel, coarse (2.1-7.5 cm diameter)	3.4	6.0
woody debris, coarse (≥7.62 cm diameter)	2.6	2.0
scat, wild	0.9	0.6
rock, cobble (7.6-25 cm diameter)	0.6	0.3

FireEP Results

During the sampling years 2000-2014, FireEP crews found 79 total vascular plant species (6 of which were exotic) at 16 sites (Appendix B). Of these, 16 were classified as graminoids; 5 were trees or shrubs; 51 were forbs, herbs, or subshrubs; and 7 were shrubs or subshrubs.

Understory Vegetation

Understory plant composition varied between stand types. Graminoids had the highest percent cover in all stand types, with a mean cover ranging from 18.2±6.8% in mixed conifer to 74.7±10.5% in open ponderosa savanna stands (Figure 9). In mixed conifer stands, *Carex* species (sedges) were the most common graminoid (mean cover of 11.1±4.6%), followed by prairie junegrass (*Koelaria macrantha*, 6.9±4.8%) and Rocky Mountain fescue (*Festuca saximontana*, 3.9±5.3%). The most common shrub within mixed conifer stands was common juniper (*Juniperus communis*) with a mean cover of 13.6±14.9%. Wax current (*Ribes cereum*), Wood's rose (*Rosa woodsia*), and American red raspberry (*Rubus idaeus*) were also encountered in mixed conifer sites, each with a mean cover of less than 1%.

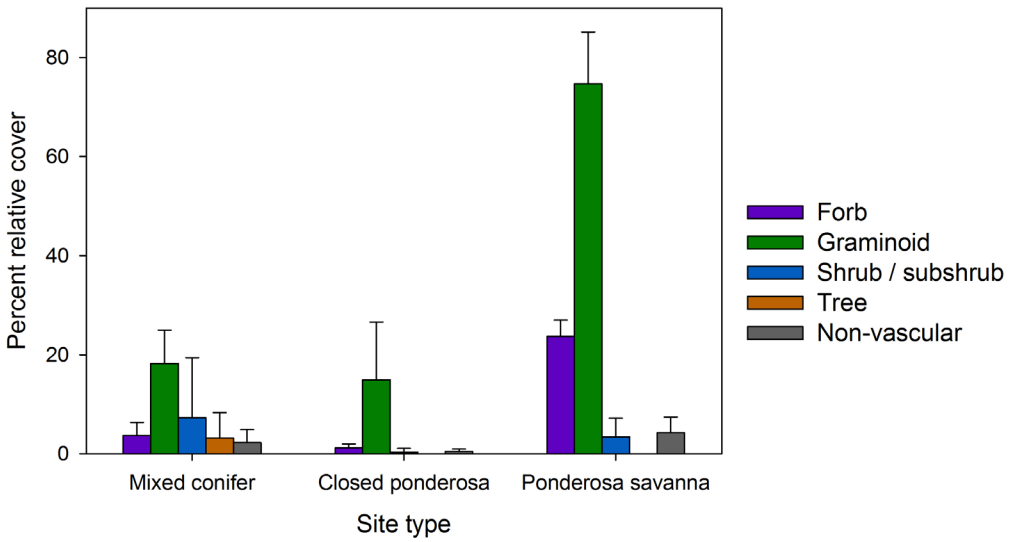


Figure 9. The mean relative understory cover by lifeform with standard deviation averaged across all FireEP sites (2000-2014) for each forest type includes forbs (purple), graminoids (green), shrubs and subshrubs (blue), trees (orange), and non-vascular (grey).

Table 4. Mean soil parameters across all ROMN sites sampled 2008-2013. Index value was assigned based on the level of each parameter. For a full list of potential index values and their interpretation, see Amacher et al. 2007.

Parameter	Mean	Standard Deviation	Level	Interpretation	Index Value	Maximum Index Value
Aluminum (mg/kg)	3.96	3.01	1 to 10	LOW - adverse effects unlikely	2	2
Bulk density (g/cm^3)	1.21	0.03	≤1.5	Adverse effects unlikely	1	1
Calcium (mg/kg)	1359.93	342.98	>1,000	HIGH - excellent reserve, probably calcareous soil	2	2
Cation exchange capacity (meq/100g)	8.72	2.44	≤15	Adverse effects unlikely	1	1
Copper (mg/kg)	0.83	NA	0.1 to 1	MODERATE - effects unknown, but adverse effects unlikely	1	1
Iron (mg/kg)	59.31	NA	>10	HIGH - effects unknown	1	1
Potassium (mg/kg)	155.77	27.05	100 to 500	MODERATE - adequate levels for most plants	1	2
Magnesium (mg/kg)	133.69	48.28	50 to 500	MODERATE - adequate levels for most plants	1	2
Manganese (mg/kg)	7.71	NA	1 to 10	LOW - adverse effects unlikely, possible deficiencies	1	1
pH	5.77	0.08	5.51 to 6.8	Slightly acid - optimum for many plant species, particularly more acid tolerant species	2	2
Soil sulfur (mg/kg)	22.66	16.93	1 to 100	MODERATE - adverse effects unlikely	1	1
Zinc (mg/kg)	2.95	NA	1 to 10	MODERATE - effects unknown, but adverse effects unlikely	1	1
Total Carbon (%)	2.77	0.56	1 to 5	MODERATE - adequate levels	1	2
Total Nitrogen (%)	0.16	0.02	0.1 to 0.5	MODERATE - adequate levels	1	2
Sum of index values	–	–	–	–	17	21
SQI (index/maximum x 100)	–	81	–	–	–	–

In closed-canopy stands dominated by ponderosa pine, *Carex* species were again the most common graminoid (5.4±6.0% mean cover). Parry's oatgrass and mountain muhly were the next most common graminoid species with a mean cover of 1.3±2.0% and 1.3±2.7%, respectively. Shrubs (0.4±0.9%) were not common in closed ponderosa stands.

Mountain muhly was the most common graminoid species in open ponderosa stands with a mean cover of 31.7±25.2%. The next most abundant graminoids were prairie junegrass (17.2±19.2%) and blue grama (*Bouteloua gracilis*, 15.1±10.0%). Yellow rabbitbrush (*Chrysothamnus viscidiflorus*, 2.0±2.1%) was the only shrub encountered in open ponderosa stands (Figure 10).

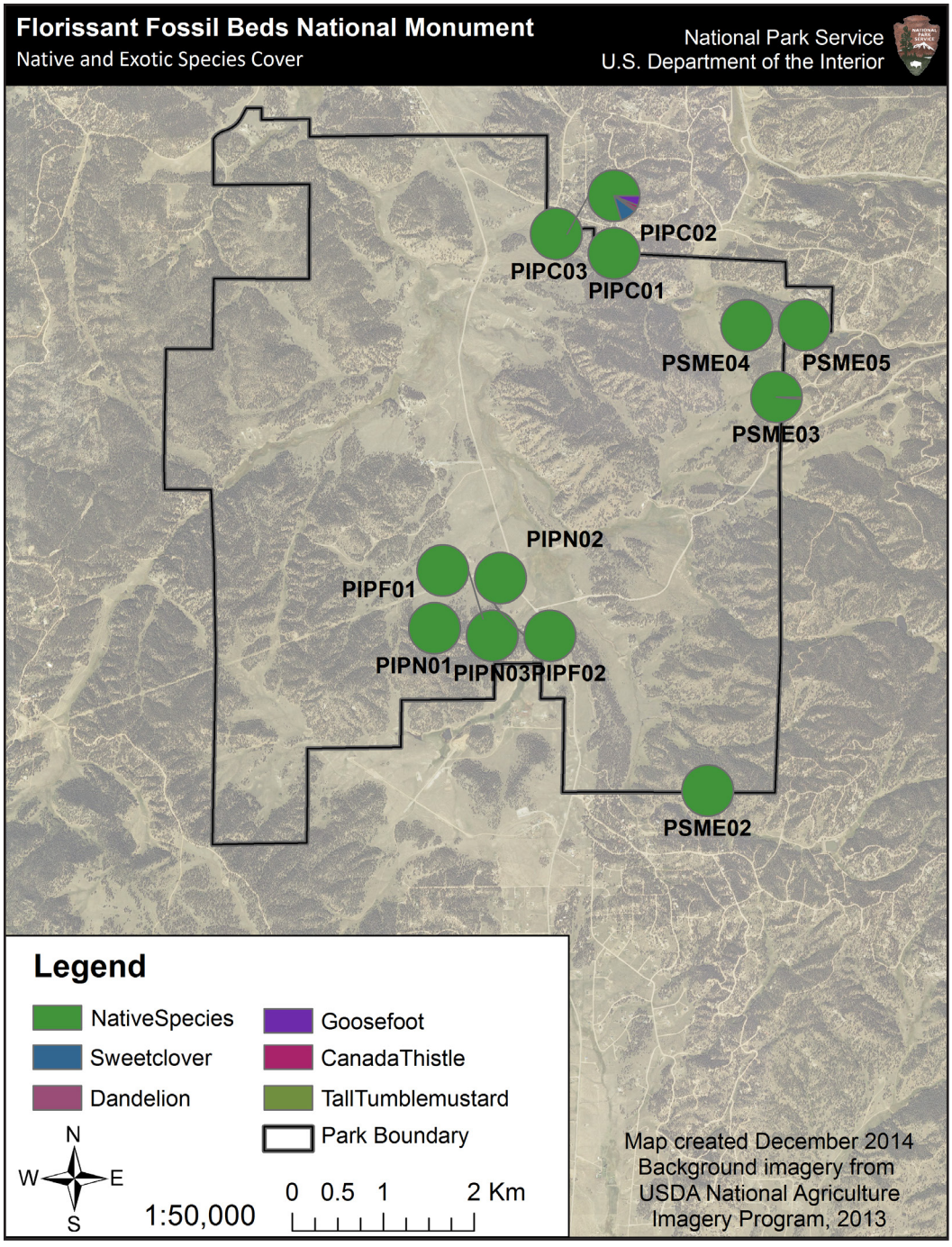


Figure 10. Native (green) and non-native (all other colors) species percent relative cover for each FireEP site in sample years 2000-2004.

All but two FireEP sites had 100% native species cover. Site PIPC02 had 10.2% relative cover of sweetclover (*Melilotus officinalis*), 6.1% cover of goosefoot (*Chenopodium* spp.), and 2.0% cover of both common dandelion (*Taraxacum officinale*) and Canada thistle (*Cirsium arvense*). Site PSEM03 had 1.6% relative cover of tall tumblemustard (*Sisymbrium altissimum*; Figure 10).

Overstory Composition and Structure

Mixed conifer stands were the most diverse forested stands in terms of both species composition and size class (Figure 11). Douglas fir was the most common species in the live mature tree size class (>12.6 cm DBH) comprising 43.6% of the overstory. Douglas fir was also the most common live, intermediate-sized tree, making up 47.7% of the sapling size class (2.5-12.6 cm DBH). Engelmann spruce comprised 63.9% of the live seedling size class (<2.5 cm DBH).

In closed-canopy stands dominated by ponderosa pine, that species made up 98.9% of the live mature tree size class, 98.8% of the live sapling size class, and 63.2% of the live seedling size class (Figure 11). In open ponderosa stands, this species was again the dominant species in all size categories comprising 100% of the live mature tree and live sapling classes and 97.2% of the live seedling class (Figure 11).

Other tree species found at sites included quaking aspen and Engelmann spruce. The basal area at each site, a measure describing the amount of an area occupied by tree stems, ranged from 1.54 m^2/ha in the open ponderosa savannas to 32.99 m^2/ha in the denser mixed conifer forests, with a mean of 18.2±11.6 m^2/ha (Figure 12).

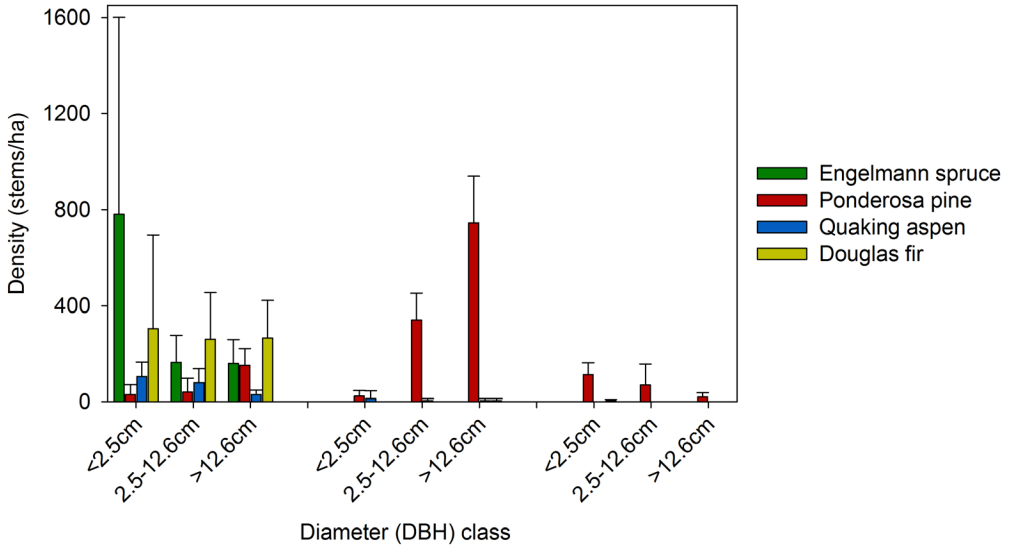


Figure 11. Stem density for FireEP sites (2000-2014) show Engelmann spruce (green), ponderosa pine (red), quaking aspen (blue), and Douglas fir (yellow) for each size diameter at breast height (DBH) class and each forest type: mixed conifer (left); ponderosa pine (center); and ponderosa savanna (right).

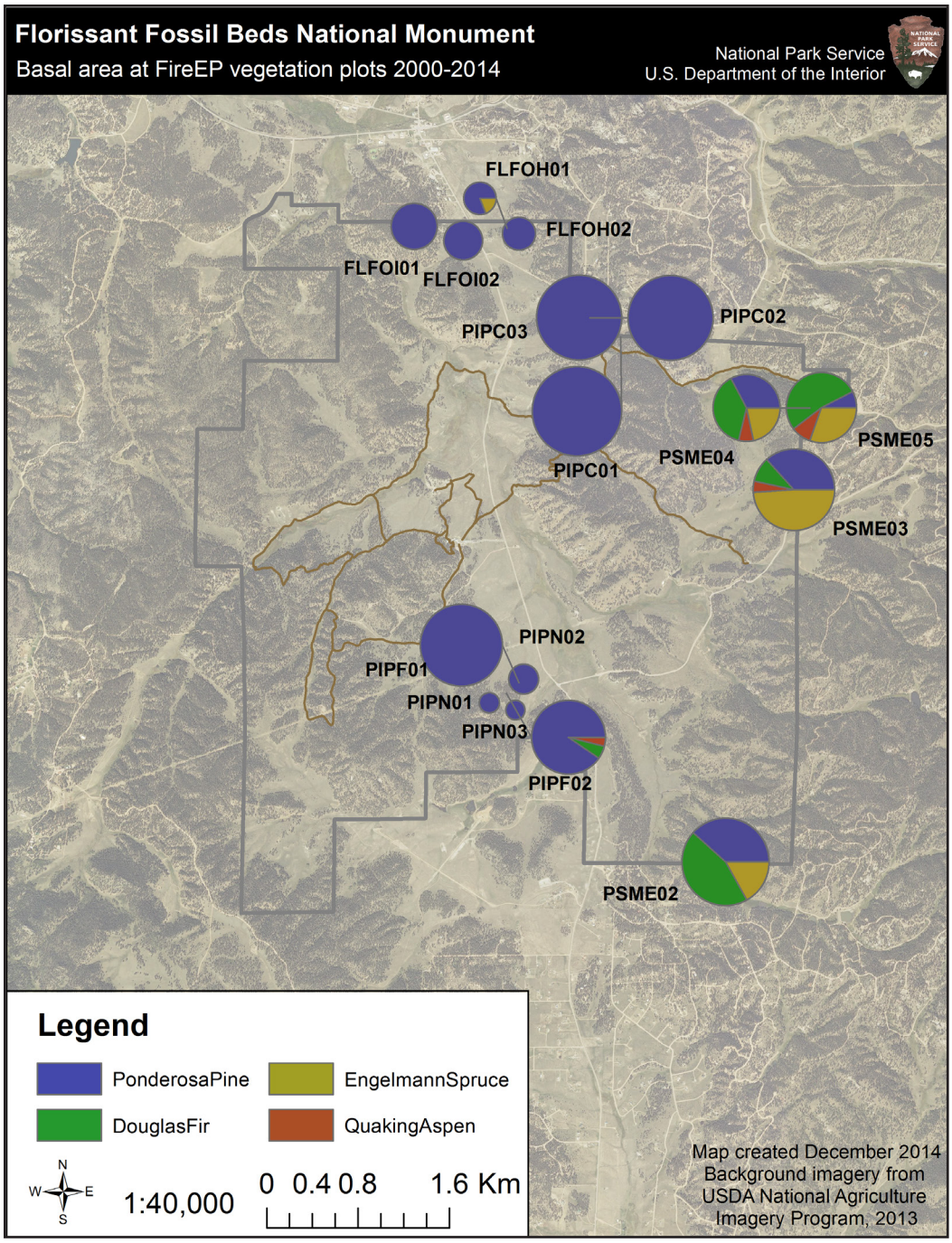


Figure 12. Tree basal area at FireEP sites averaged across all sample years (2000-2014). The size of the circle corresponds to the total basal area of all trees at the site. The color and size of each wedge of the pie charts corresponds to the species and basal area, respectively, of that species at each site. Where there is overlap, grey lines point to the location of the site.

Surface Fuels

Surface fuel loading was highest in the mixed conifer stands (mean total loading of 18.98±2.14 tons/acre), followed by closed ponderosa pine stands (mean total loading of 12.74±3.22 tons/acre). Fuel loading in ponderosa savanna stands was the lowest with a mean total loading of 5.00±1.87 tons/acre (Figure 13; note that standard practice for fire management is to report fuels data in English units of tons/acre).

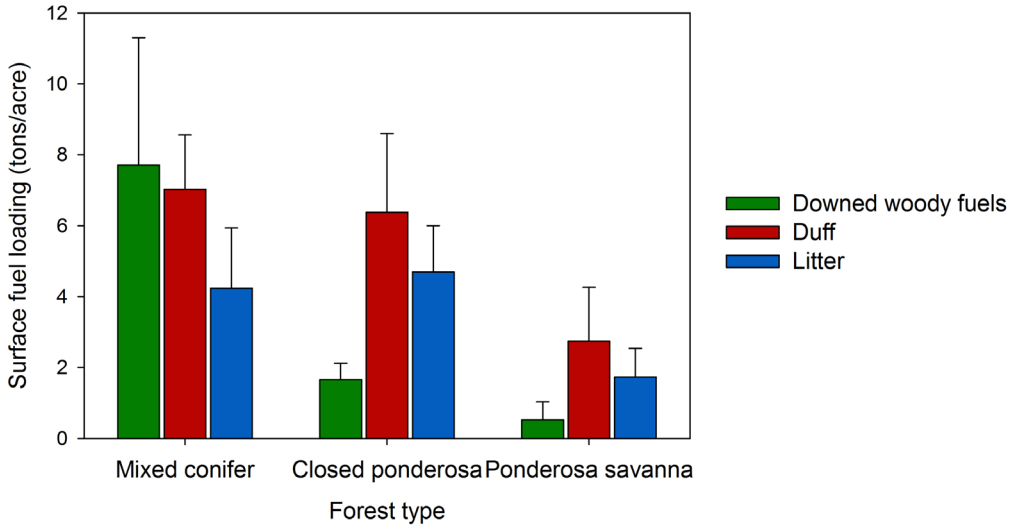


Figure 13. Fuel loads in each forest type for sites sampled 2000-2014 show downed woody fuels (green), duff (red), and litter (blue). Note that standard practice in fire management is to report fuels data in English units of tons/acre.

Discussion

The results presented here comprise a data summary report of monitoring data for ROMN VCSS and FireEP programs. We present some simple comparisons of a few vegetation and soils indicators with other published information for the region to provide context. This is not, however, a thorough analysis of the condition of FLFO vegetation and soils, and these results and interpretation are provisional. Further, since the objectives and sampling designs differ between ROMN and FireEP, results for the two are not strictly comparable.

The data summarized here suggests that within the two time periods examined, 2000-2014 and 2008-2013, FLFO had a moderately diverse mixture of mostly native plants. Measures of species richness, the number of species found in all sites, and site heterogeneity (alpha, gamma, and beta diversity, respectively) were within the range of other studies done in similar ecosystems (DeCoster and Swan 2013, Stohlgren et al. 1999).

Of the exotic species found in ROMN sites, smooth brome (*Bromus inermis*) reached its highest abundance during all sample years in the southwest part of the park at site 1 (Figure 5). Smooth brome is a perennial grass that was commonly planted to provide forage for cattle. Once it invades an area, smooth brome can out-compete native plants and can create large monocultures (Fink and Wilson 2011). Because it is currently fairly limited in extent, the park has an opportunity to remove and restore areas invaded by smooth brome. Maintaining the native understory in FLFO will involve continued efforts to prevent future invasions.

For most tree species in the two data sets, age composition (as approximated by size), followed a reverse J-shaped distribution, with many small trees and less larger ones. This size distribution is typical of montane forests and suggests a stable or steady-state (Peet 1981; Figures 7 and 11). Forests diverse in species and age composition may be more resilient to many forest stressors like beetles, rust, and others. (Thompson et al. 2009). Bristlecone and limber pine showed no recruitment at sampled sites. Both of these species grow slowly and are poor competitors; lack of regeneration of these species could be due to a lack of fire on the landscape that would reduce competition (Coop and Schoettle 2008).

Land use and fire history of FLFO likely affected plant composition and distribution. There was logging since the 1860s, intensive grazing and agriculture prior to 1984, and earthen dams constructed in the 1950s (NPS 2000). These disturbances may have assisted the introduction and establishment of exotic species. Fire can spark regeneration of native species that are adapted to the environment (Keeley et al. 2003, Coop and Schoettle 2008) but can also be a source of disturbance, promoting exotic species invasions (Keeley et al. 2003).Additionally, nine wildfires have been documented since records began in 1981. Six of those fires were less than one acre in size. A three-acre fire burned in 1999 just south of the Upper Twin Rocks Road, a 22-acre fire occurred in 1981 south of the visitor center, and a 42-acre fire burned in 2009 south of the Lower Twin Rocks Road near the eastern boundary (National Interagency Fire Center 2015).

The relatively low cover of bare ground, the high cover of litter, average soil compaction, and high soil aggregate stability suggest low erosion potential. The relatively high soil aggregate stability (Bird et al. 2007, Bestelmeyer et al. 2006) could be associated with the high cover of litter at ROMN sites. Soil was generally of high quality at FLFO compared to similar systems. Amacher et al. (2007) found a mean SQI of 66% in Forest Inventory and Analysis (FIA) plots in the Interior West between 2000 and 2004, compared to 81% found in ROMN sites between 2008 and 2013.

The patterns of fuel loading in the FireEP sites were consistent with the expectations of the FireEP's ecologist. The highest fuel loads were found in the mixed conifer forest, with less fuel in the open ponderosa savanna sites. These fuel loads are consistent with values in similar monitoring types at Rocky Mountain National Park (Nate Williamson, personal communication, January 7, 2015).

While we do not test for trend in this report, we did see some patterns in the ROMN data across years. Sub-surface soil aggregate stability was lower in 2013 than in 2010 and 2012, possibly as a result

of higher percent cover of bare ground at sites. Species richness was higher in 2010 than in 2011 or 2012. Climate patterns were generally comparable among all years in this report (USDA NRCS 2015), though ROMN site photos taken in August of 2010 and 2011 show much greener vegetation in 2010. Though many aspects of the vegetation at FLFO we summarize would not be expected to respond on an annual basis to climate drivers, the cover of annual lifeforms may have been affected by the timing of precipitation in 2010.

Conclusion

As FLFO staff plans more thinning and prescribed burning projects, the FireEP will be an integral part of effectiveness monitoring of such management actions. ROMN upland vegetation and soils monitoring will continue to help FLFO staff understand park-wide vegetation and soils relative to issues such as climate change, herbivory by elk and deer, disturbances such as fire or beetles, and change in cover or abundance of invasive species. As more data are collected over the next several years, it will be possible to recognize patterns and trends that could indicate a change in the ecological integrity of FLFO vegetation and soils.

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Appendix A: ROMN Site Schedule

Table A1. Schedule of ROMN sites visited 2008-2013.

Site	2008 (Pilot)	2009 (Pilot)	2010	2011	2012	2013
1	Yes	Yes	Yes	–	–	Yes
2	Yes	Yes	Yes	–	–	Yes
4	Yes	Yes	Yes	–	–	–
5	Yes	Yes	Yes	–	–	–
6	Yes	Yes	Yes	–	–	–
7	Yes	Yes	Yes	–	–	–
8	Yes	Yes	Yes	–	–	–
9	Yes	Yes	Yes	–	–	–
10	Yes	Yes	Yes	Yes	–	–
11	–	Yes	Yes	Yes	–	–
13	–	–	–	Yes	–	–
14	–	–	–	Yes	–	–
16	–	–	–	Yes	–	–
17	–	–	–	Yes	–	–
18	–	–	–	Yes	–	–
19	–	–	–	Yes	–	–
20	–	–	–	Yes	Yes	–
21	–	–	–	Yes	Yes	–
22	–	–	–	–	Yes	–
23	–	–	–	–	Yes	–
24	–	–	–	–	Yes	–
25	–	–	–	–	Yes	–
26	–	–	–	–	Yes	–
27	–	–	–	–	Yes	–
28	–	–	–	–	Yes	Yes
29	–	–	–	–	Yes	Yes
30	–	–	–	–	–	Yes
31	–	–	–	–	–	Yes
32	–	–	–	–	–	Yes
33	–	–	–	–	–	Yes
34	–	–	–	–	–	Yes
35	–	–	–	–	–	Yes

Appendix B: Species List

Only plants identified to species listed. Growth habit follows definition of USDA Plants Database.

Table B1. Vascular plant species identified in FLFO sites in Fire EP sites, 2000-2014 and in ROMN VCSS sites, 2008-2013 (200 total).

Growth Habit	Scientific Name	Common Name	Non-native
Graminoids (47 species)	*Achnatherum scribneri* †	Scribner needlegrass	–
	Agropyron cristatum †	crested wheatgrass	x
	Agrostis gigantea †	redtop	x
	Agrostis variabilis †	mountain bentgrass	–
	Blepharoneuron tricholepis †	pine dropseed	–
	Bouteloua gracilis * †	blue grama	–
	Bouteloua hirsuta †	hairy grama	–
	Bromus anomalus *	nodding brome	–
	Bromus ciliatus *	fringed brome	–
	Bromus inermis †	smooth brome	x
	Bromus inermis ssp. *pumpellianus* †	Pumpelly's brome	–
	Bromus porteri †	Porter brome	–
	Calamagrostis canadensis *	bluejoint	–
	Calamagrostis purpurascens * †	purple reedgrass	–
	Carex geophila †	White Mountain sedge	–
	Carex geyeri †	Geyer's sedge	–
	Carex inops ssp. *heliophila* †	sun sedge	–
	Carex obtusata †	obtuse sedge	–
	Carex rossii †	Ross' sedge	–
	Carex vernacula †	native sedge	–
	Danthonia parryi * †	Parry's oatgrass	–
	Elymus elymoides * †	squirreltail	–
	Elymus repens †	quackgrass	x
	Elymus trachycaulus †	slender wheatgrass	–
	Festuca arizonica * †	Arizona fescue	–
	Festuca brachyphylla †	alpine fescue	–
	Festuca saximontana * †	Rocky Mountain fescue	–
	Hordeum jubatum †	foxtail barley	–
	Juncus arcticus †	arctic rush	–
	Koeleria macrantha * †	prairie Junegrass	–
	Leucopoa kingii *	spike fescue	–
	Muhlenbergia andina †	foxtail muhly	–
	Muhlenbergia filiculmis * †	slimstem muhly	–

* Species found in FireEP sites

† Species found in ROMN sites

Table B1. Vascular plant species identified in FLFO sites in Fire EP sites, 2000-2014 and in ROMN VCSS sites, 2008-2013 (200 total), *continued*.

Growth Habit	Scientific Name	Common Name	Non-native
Graminoids (47 species, *continued*)	*Muhlenbergia montana* * †	mountain muhly	–
	Muhlenbergia richardsonis †	mat muhly	–
	Pascopyrum smithii * †	western wheatgrass	–
	Piptatheropsis micrantha †	littleseed ricegrass	–
	Poa arida †	plains bluegrass	–
	Poa compressa †	Canada bluegrass	x
	Poa fendleriana †	muttongrass	–
	Poa glauca †	glaucous bluegrass	–
	Poa pratensis * †	Kentucky bluegrass	x
	Poa wheeleri *	Wheeler's bluegrass	–
	Schizachyrium scoparium †	little bluestem	–
	Trisetum spicatum †	spike trisetum	–
Trees/Shrubs (11 species)	*Abies lasiocarpa* *	subalpine fir	–
	Cercocarpus montanus †	alderleaf mountain mahogany	–
	Juniperus scopulorum †	Rocky Mountain juniper	–
	Picea engelmannii * †	Engelmann spruce	–
	Picea pungens †	blue spruce	–
	Pinus aristata †	bristlecone pine	–
	Pinus flexilis * †	limber pine	–
	Pinus ponderosa †	ponderosa pine	–
	Populus tremuloides * †	quaking aspen	–
	Prunus virginiana †	chokecherry	–
	Pseudotsuga menziesii * †	Douglas-fir	–
Shrub/subshrub (15 species)	*Arctostaphylos uva-ursi* * †	kinnikinnick	–
	Artemisia cana †	silver sagebrush	–
	Artemisia frigida * †	prairie sagewort	–
	Chrysothamnus viscidiflorus * †	yellow rabbitbrush	–
	Dasiphora fruticosa ssp. *floribunda* †	shrubby cinquefoil	–
	Ericameria nauseosa †	rubber rabbitbrush	–
	Ericameria parryi †	Parry's rabbitbrush	–
	Jamesia americana †	fivepetal cliffbush	–
	Juniperus communis * †	common juniper	–
	Pediocactus simpsonii †	mountain ball cactus	–
	Physocarpus monogynus †	mountain ninebark	–
	Ribes cereum * †	wax currant	–
	Ribes inerme †	whitestem gooseberry	–
	Rosa woodsii * †	Woods' rose	–
	Rubus idaeus ssp. *strigosus* *	grayleaf red raspberry	–

* Species found in FireEP sites

† Species found in ROMN sites

Table B1. Vascular plant species identified in FLFO sites in Fire EP sites, 2000-2014 and in ROMN VCSS sites, 2008-2013 (200 total), *continued*.

Growth Habit	Scientific Name	Common Name	Non-native
Forb/Herb/ Subshrubs (125 species)	*Achillea millefolium* var. *occidentalis* * †	western yarrow	–
	Aliciella pinnatifida †	sticky gilia	–
	Allium cernuum * †	nodding onion	–
	Androsace septentrionalis * †	pygmyflower rockjasmine	–
	Anemone multifida †	Pacific anemone	–
	Antennaria parvifolia * †	small-leaf pussytoes	–
	Antennaria rosea ssp. *rosea* *	rosy pussytoes	–
	Aquilegia coerulea * †	Colorado blue columbine	–
	Arabis drummondii *	Drummond's rockcress	–
	Arabis fendleri *	Fendler's rockcress	–
	Arabis holboellii †	Holboell's rockcress	–
	Arenaria fendleri * †	Fendler's sandwort	–
	Arnica fulgens †	foothill arnica	–
	Artemisia campestris †	field sagewort	–
	Artemisia carruthii †	Carruth's sagewort	–
	Artemisia dracunculus †	tarragon	–
	Artemisia ludoviciana * †	white sagebrush	–
	Artemisia scopulorum †	alpine sagebrush	–
	Astragalus alpinus †	alpine milkvetch	–
	Astragalus flexuosus * †	flexile milkvetch	–
	Astragalus hallii †	Hall's milkvetch	–
	Astragalus laxmannii * †	Laxmann's milkvetch	–
	Astragalus sparsiflorus †	Front Range milkvetch	–
	Astragalus tenellus †	looseflower milkvetch	–
	Bahia dissecta †	ragleaf bahia	–
	Besseya plantaginea * †	White River coraldrops	–
	Campanula parryi †	Parry's bellflower	–
	Campanula rotundifolia †	bluebell bellflower	–
	Castilleja integra †	wholeleaf Indian paintbrush	–
	Castilleja miniata †	giant red Indian paintbrush	–
	Cerastium arvense †	field chickweed	–
	Cerastium fontanum †	common mouse-ear chickweed	x
	Chamaesyce serpyllifolia †	thymeleaf sandmat	x
	Chamerion angustifolium * †	Fireweed	–
	Chenopodium album †	lambsquarters	x

* Species found in FireEP sites

† Species found in ROMN sites

Table B1. Vascular plant species identified in FLFO sites in Fire EP sites, 2000-2014 and in ROMN VCSS sites, 2008-2013 (200 total), *continued*.

Growth Habit	Scientific Name	Common Name	Non-native
Forb/Herb/Subshrubs (125 species, *continued*)	*Chenopodium berlandieri* †	pitseed goosefoot	–
	Chenopodium foliosum †	leafy goosefoot	x
	Chenopodium fremontii *	Fremont's goosefoot	–
	Chenopodium leptophyllum * †	narrowleaf goosefoot	–
	Cirsium arvense *	Canada thistle	x
	Cirsium canescens †	prairie thistle	–
	Cirsium scariosum †	meadow thistle	–
	Comandra umbellata †	bastard toadflax	–
	Corydalis aurea *	scrambled eggs	–
	Cryptantha gracilis †	narrowstem cryptantha	–
	Cryptantha virgata †	miner's candle	–
	Draba albertina *	slender draba	–
	Draba aurea †	golden draba	–
	Dracocephalum parviflorum *	American dragonhead	–
	Erigeron canus * †	hoary fleabane	–
	Erigeron divergens †	spreading fleabane	–
	Erigeron eximius †	sprucefir fleabane	–
	Erigeron flagellaris * †	trailing fleabane	–
	Erigeron formosissimus *	beautiful fleaban	–
	Erigeron speciosus †	aspen fleabane	–
	Erigeron subtrinervis †	threenerve fleabane	–
	Erigeron vetensis †	early bluetop fleabane	–
	Eriogonum alatum * †	winged buckwheat	–
	Erysimum capitatum †	sanddune wallflower	–
	Erysimum inconspicuum †	shy wallflower	–
	Euphorbia brachycera * †	horned spurge	–
	Fragaria vesca †	woodland strawberry	–
	Fragaria virginiana * †	Virginia strawberry	–
	Frasera speciosa †	elkweed	–
	Gaillardia aristata †	blanketflower	–
	Galium boreale * †	northern bedstraw	–
	Gentiana affinis * †	pleated gentian	–
	Gentianella amarella * †	autumn dwarf gentian	–
	Geranium caespitosum * †	pineywoods geranium	–
	Geranium richardsonii †	Richardson's geranium	–
	Grindelia inornata †	Colorado gumweed	–
	Grindelia squarrosa †	curlycup gumweed	–
	Grindelia subalpina †	subalpine gumweed	–
	Gutierrezia sarothrae †	broom snakeweed	–

* Species found in FireEP sites

† Species found in ROMN sites

Table B1. Vascular plant species identified in FLFO sites in Fire EP sites, 2000-2014 and in ROMN VCSS sites, 2008-2013 (200 total), *continued*.

Growth Habit	Scientific Name	Common Name	Non-native
Forb/Herb/Subshrubs (125 species, *continued*)	*Heterotheca fulcrata* *	rockyscree false goldenaster	–
	Heterotheca villosa * †	hairy false goldenaster	–
	Hymenoxys richardsonii * †	pingue rubberweed	–
	Ipomopsis aggregata †	scarlet gilia	–
	Iris missouriensis * †	Rocky Mountain iris	–
	Liatris punctata †	dotted blazing star	–
	Linum lewisii †	Lewis flax	–
	Lithospermum multiflorum †	manyflowered stoneseed	–
	Maianthemum racemosum †	feathery false lily of the valley	–
	Maianthemum stellatum †	starry false lily of the valley	–
	Melilotus officinalis * †	sweetclover	x
	Mertensia lanceolata †	prairie bluebells	–
	Monarda fistulosa *	wild bergamot	–
	Oligoneuron album †	prairie goldenrod	–
	Oligoneuron rigidum †	stiff goldenrod	–
	Oreochrysum parryi *	Parry's goldenrod	–
	Orthocarpus luteus †	yellow owl's-clover	–
	Oxytropis lambertii * †	purple locoweed	–
	Oxytropis parryi *	Parry's oxytrope	–
	Oxytropis splendens * †	showy locoweed	–
	Packera fendleri * †	Fendler's ragwort	–
	Penstemon barbatus †	beardlip penstemon	–
	Physaria vitulifera †	roundtip twinpod	–
	Potentilla arguta †	tall cinquefoil	–
	Potentilla concinna †	elegant cinquefoil	–
	Potentilla effusa * †	branched cinquefoil	–
	Potentilla fissa †	bigflower cinquefoil	–
	Potentilla hippiana †	woolly cinquefoil	–
	Potentilla pensylvanica †	Pennsylvania cinquefoil	–
	Potentilla plattensis †	Platte River cinquefoil	–
	Potentilla pulcherrima †	beautiful cinquefoil	–
	Pseudocymopterus montanus †	alpine false springparsley	–
	Pulsatilla patens * †	eastern pasqueflower	–
	Sedum lanceolatum * †	spearleaf stonecrop	–
	Selaginella densa †	lesser spikemoss	–
	Senecio spartioides †	broom-like ragwort	–

* Species found in FireEP sites

† Species found in ROMN sites

Table B1. Vascular plant species identified in FLFO sites in Fire EP sites, 2000-2014 and in ROMN VCSS sites, 2008-2013 (200 total), *continued*.

Growth Habit	Scientific Name	Common Name	Non-native
Forb/Herb/Subshrubs (125 species, *continued*)	*Silene drummondii* †	Drummond's campion	–
	Silene scouleri ssp. *hallii* *	simple campion	–
	Sisymbrium altissimum *	tall tumblemustard	x
	Solidago missouriensis *	Missouri goldenrod	–
	Solidago multiradiata †	Rocky Mountain goldenrod	–
	Solidago nana * †	baby goldenrod	–
	Solidago simplex ssp. *simplex* * †	Mt. Albert goldenrod	–
	Symphyotrichum foliaceum †	alpine leafybract aster	–
	Taraxacum officinale * †	common dandelion	x
	Tetraneuris acaulis †	stemless four-nerve daisy	–
	Thalictrum fendleri * †	Fendler's meadow-rue	–
	Tragopogon dubius †	yellow salsify	x
	Trifolium longipes †	longstalk clover	–
	Valeriana edulis †	tobacco root	–
	Yucca glauca †	soapweed yucca	–
Vines (2 species)	*Polygonum convolvulus* †	black bindweed	x
	Vicia americana †	American vetch	–

* Species found in FireEP sites

† Species found in ROMN sites

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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525