



Plant Community Composition and Structure Monitoring for Jewel Cave National Monument

2014 Annual Report

Natural Resource Data Series NPS/NGPN/NRDS—2015/768



ON THE COVER

Long-term monitoring plot PCM-007 at Jewel Cave National Monument, 2014
Photograph courtesy of the National Park Service

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

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Abstract

This report presents the results of vegetation monitoring efforts in 2014 at Jewel Cave National Monument (JECA) by the Northern Great Plains Inventory and Monitoring Network (NGPN).

During the fourth full year of field work, crew members from NGPN visited six plant community monitoring plots to collect data on the vegetation at JECA. This is part of a long-term monitoring effort that will sample six of 15 randomly located upland plots every year, so that each plot is visited for two consecutive years and then rested for three years, on a five-year rotating basis. NGPN staff captured data relating to species richness, herb-layer height, abundance of individual native and non-native species, ground cover, and site disturbance on each of the six plots.

Our 2014 findings can be summarized as follows: The crew observed 168 vascular plant species in upland plots, with an average of 10.4 native species occurring within any given 1 m² quadrat sampled. Grasses, sedges, forbs, and shrubs made up the bulk of the plant cover, while non-native species represented about 14.2% of cover. Total fuel loads were 29.5 tons/acre. Overall, JECA plant communities appear to have high native diversity and are being maintained in very good condition.

Acknowledgments

We thank all the authors of the NGPN Plant Community Monitoring Protocol, particularly A. Symstad, for outstanding guidance on data collection and reporting. We thank B. Harris, K. Sultzer, and A. Jarding for help in the field. With their assistance, the 2014 NGPN vegetation field crew of M. Prowatzke, K. Legner, S. Rockwood, R. Manuel, F. Sewell, L. Mickelson, and D. Pinigis collected all the data included in this report.

Introduction

The Black Hills is a 1.5 million ha (3.7 million acres) refuge of ponderosa pine (*Pinus ponderosa*) forest surrounded by the prairies of western South Dakota and eastern Wyoming. The ponderosa pine forest of the Black Hills is a unique ecosystem composed of species from the western Rocky Mountains, eastern deciduous forests, northern boreal forests, and the surrounding Great Plains (Larson and Johnson 2007). The National Park Service (NPS) plays an important role in preserving and restoring ponderosa woodlands within its boundaries. The stewardship goal of the NPS is to “preserve ecological integrity and cultural and historical authenticity” (NPS 2012); however, resource managers struggle with the grim reality that there have been fundamental changes in the disturbance regimes, such as climate and fire, that have historically maintained ponderosa woodlands, and there is the continual pressure of exotic invasive species. In recent years, mountain pine beetle (*Dendroctonus ponderosae*) outbreaks have been of particular concern because they are increasing throughout the Black Hills and have caused 100% mortality of ponderosa pines in some areas (Hocking et al. 2010). Long-term monitoring in national parks is essential to sound management of ponderosa woodlands because it can provide information on environmental quality and condition, benchmarks of ecological integrity, and early warning of declines in ecosystem health.

Jewel Cave National Monument (JECA) is located in the southwestern Black Hills and has a mission to preserve Jewel Cave, through management of the surface and subsurface ecosystem, while providing opportunities for the pursuit of scientific interests and public enjoyment. While this is a relatively small area (516 ha, 1274 ac), JECA contains diverse native ponderosa forest and grassland communities (Marriot and Hartment 1986, Ashton et al. 2012b). The Northern Great Plains Inventory & Monitoring Program (NGPN) began two vegetation monitoring efforts in JECA in 2011: a program to monitor understory vegetation annually (Ashton et al. 2012b) and a large survey of forest conditions that will be repeated every five years (Ashton et al. 2012a). Vegetation monitoring protocols and plot locations were chosen to represent the entire park and to coordinate efforts with the Northern Great Plains Fire Ecology Program (FireEP). The long-term objectives of the NGPN plant community monitoring effort (Symstad et al. 2012b) in JECA are to:

1. Determine park-wide status and long-term trends in vegetation species composition (e.g., exotic vs. native) and structure (e.g., cover, height) of herbaceous and shrub species.
2. Determine park-wide status (at 5-year intervals) and long-term trends of tree density by species, height class, diameter class, and fuel loads.
3. Improve our understanding of the effects of external drivers and management actions on plant community species composition and structure by correlating changes in vegetation composition and structure with changes in climate, landscape patterns, atmospheric chemical composition, fire, and invasive plant control.

This report is intended to provide a timely release of basic data sets and data summaries from our sampling efforts at JECA in 2014, our fourth year of sampling. We visited six plots, and it will take one more year to visit every plot in the park twice (Figure 1). We expect to produce reports with

more in-depth data analysis and interpretation when we complete five years of sampling. In the interim, reports, spatial data, and data summaries can be provided for park management and interpretation upon request.

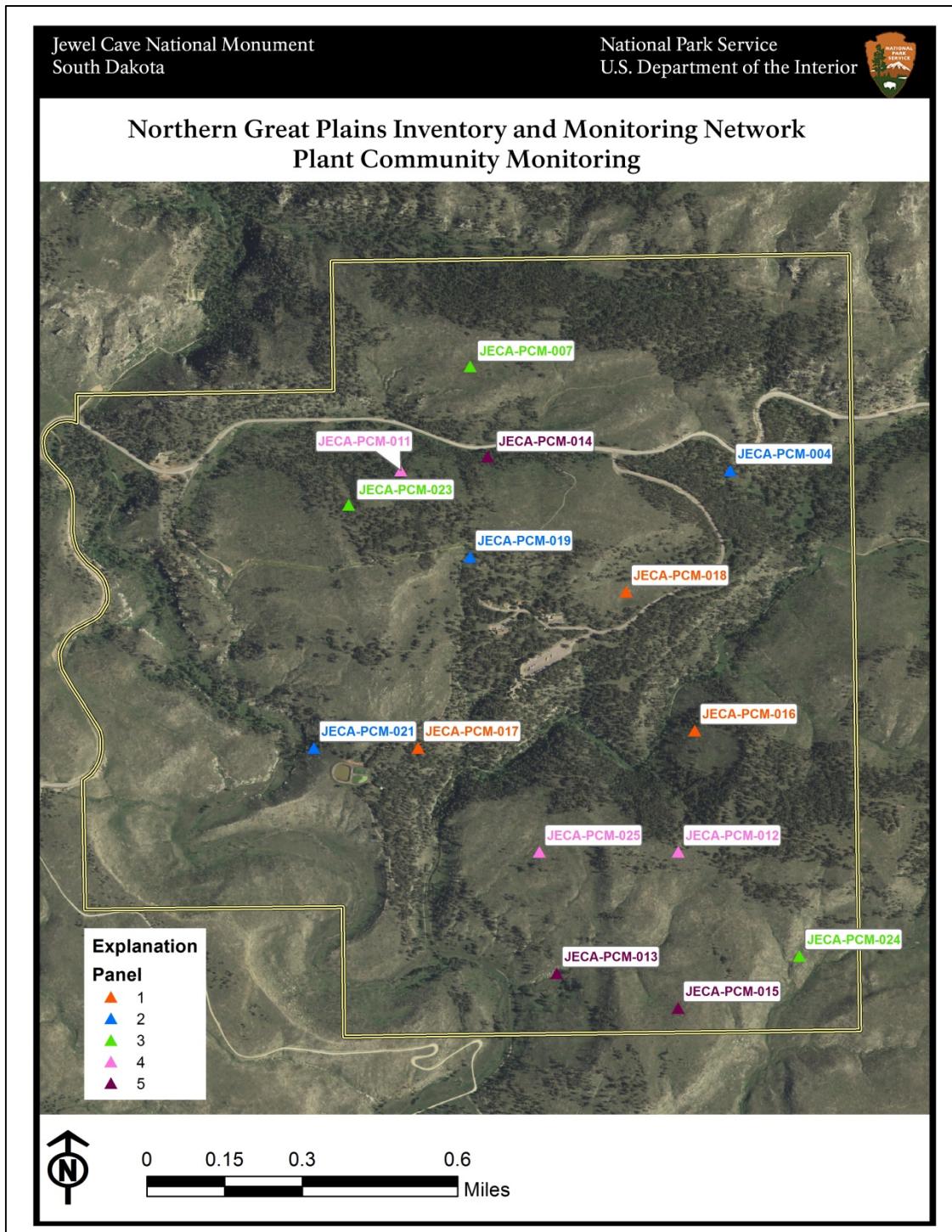


Figure 1. Map of plant community monitoring plots in Jewel Cave National Monument. Plots in panel 3 (green) and panel 4 (pink) were visited in 2014.

Methods

The NGPN Plant Community Composition and Structure Monitoring Protocol (Symstad et al. 2012b, a) describes in detail the methods used for sampling long-term plots. Below, we briefly describe the general approach. For those interested in more detail please see Symstad et al. 2012a, available at <http://science.nature.nps.gov/im/units/ngpn/monitor/plants.cfm>.

Sample Design

We implemented a survey to monitor plant community structure and composition in JECA using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, we selected 15 randomly located sites within JECA (Figure 1). We split these 15 sites into five panels with three sites each. We visit two panels (six sites) every year, and after five years (2015) we will have visited all 15 sites twice. In 2011, we visited sites in panel 1 and panel 5, and in 2012 we visited sites in panel 1 and panel 2. In 2013, we visited sites in panel 2 and panel 3. This year, we visited sites in panel 3 and panel 4 from June 30 to July 2 (Figure 1). Data from these randomly selected sites can be used to estimate condition of vegetation communities for the whole park and over time, can be used to discern trends in condition.

Plot Layout and Sampling

At each of the sites we visited, we recorded plant species cover and frequency in a rectangular, 50 m x 20 m (0.1 ha), permanent plot (Figure 2). Data on ground cover, herb-layer height ≤ 2 m, and plant cover were collected on two 50 m transects (the long sides of the plot) using a point-intercept method. Species richness data from the point-intercept method were supplemented with species presence data collected in five sets of nested square quadrats (0.01 m^2 , 0.1 m^2 , 1 m^2 , and 10 m^2) located systematically along each transect (Figure 2). In 2014, sampling at JECA took approximately 3.5 10-hour days for a nine-person crew (see Appendix A for a detail of activities each day).

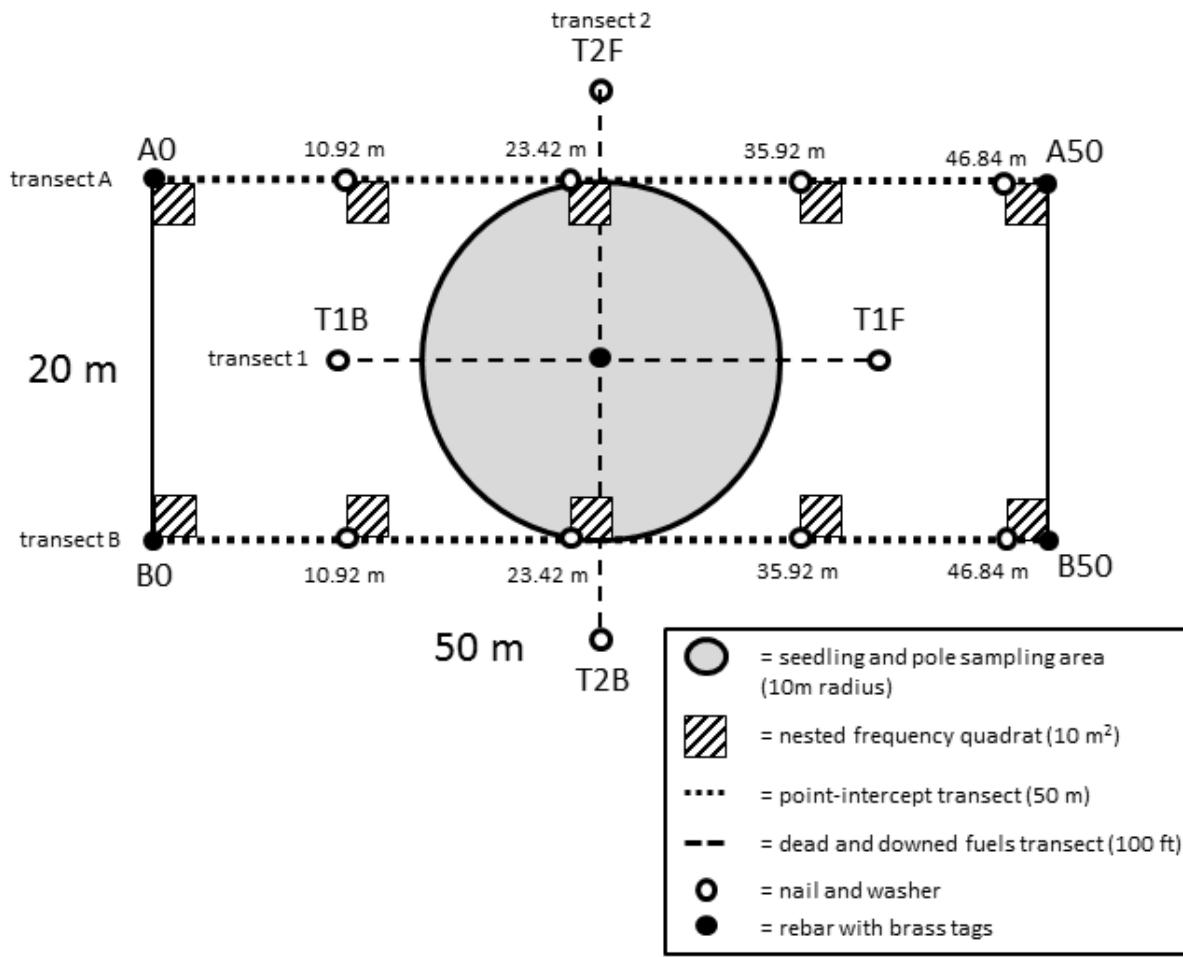


Figure 2. Long-term monitoring plot layout used for sampling vegetation in Jewel Cave National Monument.

When woody species were present, tree regeneration and tall shrub density data were collected within a 10 m radius subplot centered in the larger 50 m x 20 m plot (Figure 2). Trees with diameter at breast height (DBH) > 15 cm, located within the entire 0.1 ha plot, were mapped and tagged. For each tree, the species, DBH, status, and condition (e.g., leaf-discoloration, insect-damaged, etc.) were recorded. Dead and downed woody fuel load data were collected on two perpendicular, 100 ft (30.49 m) transects with midpoints at the center of the plot (Figure 2), following Brown's Line methods (Brown 1974, Brown et al. 1982).

At all plots, we also surveyed the area for common disturbances and target species of interest to the park. Common disturbances included such things as roads, rodent mounds, animal trails, and fire. For all plots, the type and severity of the disturbances were recorded. We also surveyed the area for exotic species that have the potential to spread into the park and cause significant ecological impacts (Table 1). For each target species that was present at a site, an abundance class was given on a scale from 1-5 where 1 = one individual, 2 = few individuals, 3 = cover of 1-5%, 4 = cover of 5-25%, and 5 = cover > 25% of the plot. The information gathered from this procedure is critical for early

detection and rapid response to such threats. In addition, we noted the presence of plant species that are considered rare or vulnerable to loss in South Dakota, and which may potentially occur in JECA (Table 2).

Table 1. Exotic species surveyed for at Jewel Cave National Monument as part of the early detection and rapid response program within the Northern Great Plains Network.

Scientific Name	Common Name	Habitat
<i>Alliaria petiolata</i>	garlic mustard	Riparian
<i>Polygonum cuspidatum; P. sachalinense; P. x bohemicum</i>	knotweeds	Riparian
<i>Pueraria montana</i> var. <i>lobata</i>	kudzu	Riparian
<i>Iris pseudacorus</i>	yellow iris	Riparian
<i>Ailanthus altissima</i>	tree of heaven	Riparian
<i>Lepidium latifolium</i>	perennial pepperweed	Riparian
<i>Arundo donax</i>	giant reed	Riparian
<i>Rhamnus cathartica</i>	common buckthorn	Riparian
<i>Heracleum mantegazzianum</i>	giant hogweed	Riparian
<i>Centaurea solstitialis</i>	yellow star thistle	Upland
<i>Hieracium aurantiacum; H. caespitosum</i>	orange and meadow hawkweed	Upland
<i>Isatis tinctoria</i>	Dyer's woad	Upland
<i>Taeniatherum caput-medusae</i>	medusahead	Upland
<i>Chondrilla juncea</i>	rush skeletonweed	Upland
<i>Gypsophila paniculata</i>	baby's breath	Upland
<i>Centaurea virgata; C. diffusa</i>	knapweeds	Upland
<i>Linaria dalmatica; L. vulgaris</i>	toadflax	Upland
<i>Euphorbia myrsinoides & E. cyparissias</i>	myrtle spurge	Upland
<i>Dipsacus fullonum & D. laciniatus</i>	common teasel	Upland
<i>Salvia aethiopis</i>	Mediterranean sage	Upland
<i>Ventenata dubia</i>	African wiregrass	Upland

Table 2. Rare species that were surveyed for during the 2014 field season at Jewel Cave National Monument.

Scientific Name	Common Name
<i>Achnatherum robustum</i>	sleepy grass
<i>Boechara divaricarpa/ Boechara holboelli</i>	limestone rockcress
<i>Botrychium campestre</i>	prairie moonwort
<i>Botrychium lineare</i>	narrowleaf grapefern
<i>Botrychium lunaria</i>	common moonwort
<i>Erigeron ochroleucus</i>	buff fleabane
<i>Fritillaria atropurpurea</i>	spotted fritillaria
<i>Lobelia spicata</i>	palespike Lobelia
<i>Oenothera flava</i>	yellow evening primrose
<i>Oenothera lacinata</i>	cutleaf evening primrose
<i>Physaria montana</i>	mountain bladderpod
<i>Platanthera stricta</i>	slender bog orchid
<i>Thelesperma megapotamicum</i>	Hopi tea
<i>Townsendia exscapa</i>	Easter daisy
<i>Townsendia hookeri</i>	Hooker's Townsend daisy

Data Management and Analysis

We used FFI (FEAT/FIREMON Integrated; <http://frames.gov/ffi/>) as the primary software environment for managing our sampling data. FFI is used by a variety of agencies (e.g., NPS, USDA

Forest Service, U.S. Fish and Wildlife Service), has a national-level support system, and generally conforms to the Natural Resource Database Template standards established by the Inventory and Monitoring Program.

Species scientific names, codes, and common names are from the USDA Plants Database (USDA-NRCS 2012). However, nomenclature follows the Integrated Taxonomic Information System (ITIS) (<http://www.itis.gov>). In the few cases where ITIS recognizes a new name that was not in the USDA PLANTS database, the new name was used and a unique plant code was assigned.

After data for the sites were entered, 100% of records were verified to the original data sheet to minimize transcription errors. A further 10% of records were reviewed a second time. After all data were entered and verified, automated queries were developed to check for errors in the data. When errors were caught by the crew or the automated queries, changes were made to the original datasheets and the FFI database as needed.

Plant life forms (e.g., shrub, forb) were based on definitions from the USDA Plants Database (USDA-NRCS 2012). Warm-season grasses were identified primarily using a guide by Skinner (2010). Summaries were produced using the FFI reporting and query tools and statistical summaries and graphics were generated using R software (version 3.1.2).

We measured diversity at the plots in three ways: species richness, the Shannon Index, and Pielou's Index of Evenness. Species richness is simply a count of the species recorded in an area. The Shannon Index, H' , is a measure of the number of species in an area and how even abundances are across the community. It typically ranges between 0 (low richness and evenness) to 3.5 (high species richness and evenness). Pielou's Index of Evenness, J' , measures how even abundances are across taxa. It ranges between 0 and 1; values near 0 indicate dominance by a single species, and values near 1 indicate nearly equal abundance of all species present.

Disturbances were recorded in square meters and ranged from 0 (not present) to 2290 (the whole plot area) for each type of disturbance. We report the sum of all individual disturbances, so the value can be greater than 2290 m².

Reporting on Natural Resource Condition

Results were summarized in a Natural Resource Condition Table based on the templates from the State of the Park report series (<http://www.nps.gov/stateoftheparks/>). The goal is to improve park priority setting and to synthesize and communicate complex park condition information to the public in a clear and simple way. By focusing on specific indicators, such as exotic species cover, it will also be possible and straightforward to revisit the metric in subsequent years. The status and trend of each indicator is scored and assigned a corresponding symbol based on the key found in Table 3.

We chose a set of indicators and specific measures that can describe the condition of vegetation in the Northern Great Plains and the status of exotic plant invasions. The measures include: absolute herb-layer canopy cover, native species richness, evenness, relative cover of exotic species, and annual brome cover. Reference values were based on descriptions of historic condition and variation, past studies, and/or management targets. Current park condition was compared to a reference value,

and status was scored as good condition, warrants moderate concern, or warrants significant concern based on this comparison (Table 3). Good condition was applied to values that fell within the range of the reference value, and significant concern was applied to conditions that fell outside the bounds of the reference value. In some cases, reference conditions can be determined only after we have accumulated more years of data. When this is the case, we refer to these as “To be determined” and estimate condition based on our professional judgment.

Table 3. Key to the symbols used in the Natural Resource Condition Table. The background color represents the current status, the arrow summarizes the trend, and the thickness of the outside line represents the degree of confidence in the assessment. A symbol that does not contain an arrow indicates that there is insufficient information to assess a trend. Based on the State of the Park reports (<http://www.nps.gov/stateoftheparks/>).

Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low

Results and Discussion

Jewel Cave National Monument experienced near normal precipitation in 2014 (<http://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00094032/detail>; Figure 3). When the NGPN visited the park in early July, cumulative precipitation was slightly above average for the year.

Average herbaceous canopy cover was 118% (Table 4) in 2014, 31% more than 2013 levels (Ashton and Prowatzke 2014) and 79% greater than 2012 (Ashton et al. 2013). There was a large amount of litter on the ground with ground cover at the sites averaging 81% plant litter.

We found 168 plant species in 2014 at JECA (Appendix B). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at JECA, but trees, forbs, shrubs and subshrubs (defined as a low-growing shrub usually under 0.5m) were also present (Figure 4). We found 27 exotic species at the park, all of which were either forbs or graminoids. The shrubs, subshrubs, and trees were all native species. No exotic target species were found at any sites in 2014.

There was some variation in species composition across the six sites. The most common species in the sites we visited were graminoids, but forbs and shrubs were also abundant. Most were native species (Figure 5). We did not find any rare plants.

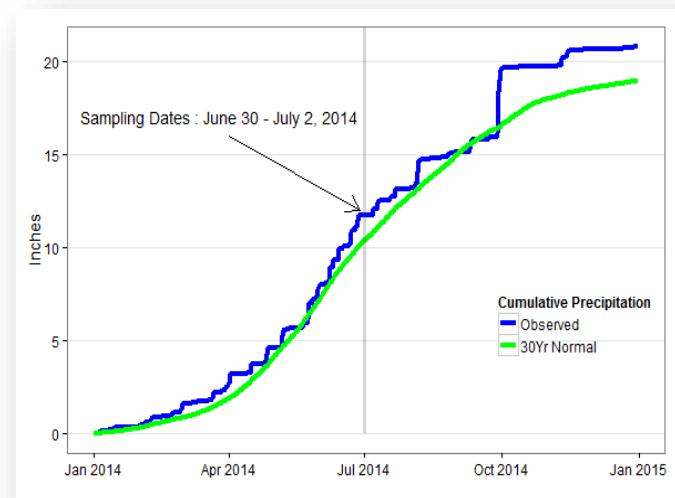


Figure 3. Observed and 30-year (1981-2010) normal precipitation near Jewel Cave National Monument. Timing of NGPN visit is shown by vertical gray bar.

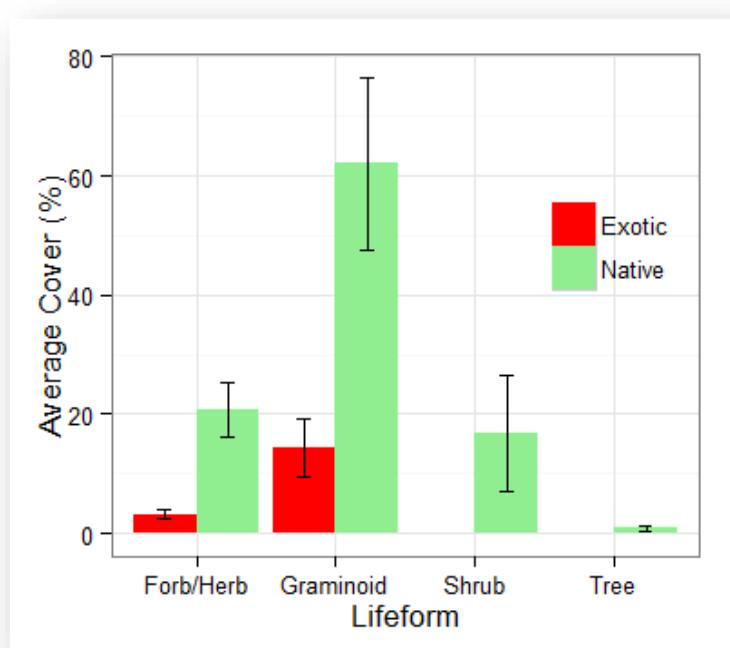


Figure 4. Average cover by lifeform and nativity in six plant community monitoring plots in Jewel Cave National Monument in 2014. Native (green) and exotic (red) graminoids were the most abundant lifeform across the plots. Bars represent means \pm standard errors.

Table 4. Natural resource condition summary table for upland plant communities in Jewel Cave National Monument (JECA).

Indicator of Condition	Specific Measures	2014 Value (mean \pm SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Absolute herb-layer canopy cover	118 \pm 10.8%	TBD ⁽¹⁾		JECA has a high herbaceous canopy cover and a moderate diversity of native plants. The condition assessment for canopy cover and evenness is based on professional judgment, but as we collect more data and understand the natural range of variability our confidence in these assessments will increase. Future work is needed to determine if the reference condition for native species richness is relevant for Black Hills Parks. Forest densities are lower than historic conditions but are characterized by a mosaic of open and closed canopy sites.
	Native species richness (based on average of 10 1m ² quadrats per plot)	10.4 \pm 0.7 species	8-18 species ⁽²⁾		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.75 \pm 0.04	TBD ⁽¹⁾		
	Forest basal area (m ² /ha)	7.9 \pm 5.1	15.3 \pm 2.7 ⁽³⁾		
Exotic Plant Early Detection and Management	Relative cover of exotic species	14.2 \pm 3.2%	\leq 10 % cover		In general, the sites in JECA had a moderate cover of exotic species. Only two sites had <10% exotic cover. Annual brome cover remains low, but Kentucky bluegrass is common throughout the park.
	Annual Brome cover	0.3 \pm 0.3% (found in only one site)	\leq 10 % cover		
Fire and Fuel Dynamics	Total downed fuel loads (tons/acre)	29.5 \pm 6.2	Between 2 and 10		The current fire ecology program aims to maintain fuel loads of less than 10 tons/acre. The Jasper Fire in 2000 has led to a large amount of coarse woody debris throughout the park. Because the forest structure is open and lacking ladder and fine fuels the high total fuels is only of moderate concern.

References, Notes, and Data Sources:

1. To be determined when more data are available 2. Symstad, A. J. and J. L. Jonas. 2014. Using natural range of variation to set decision thresholds: a case study for Great Plains grasslands.in G. R. Gutenspergen, editor. Application of threshold concepts in natural resource decision making. Springer Verlag. 3. Brown, P. M. and B. Cook. 2006. Early settlement forest structure in Black Hills ponderosa pine forests. Forest Ecology and Management 223:284-290.

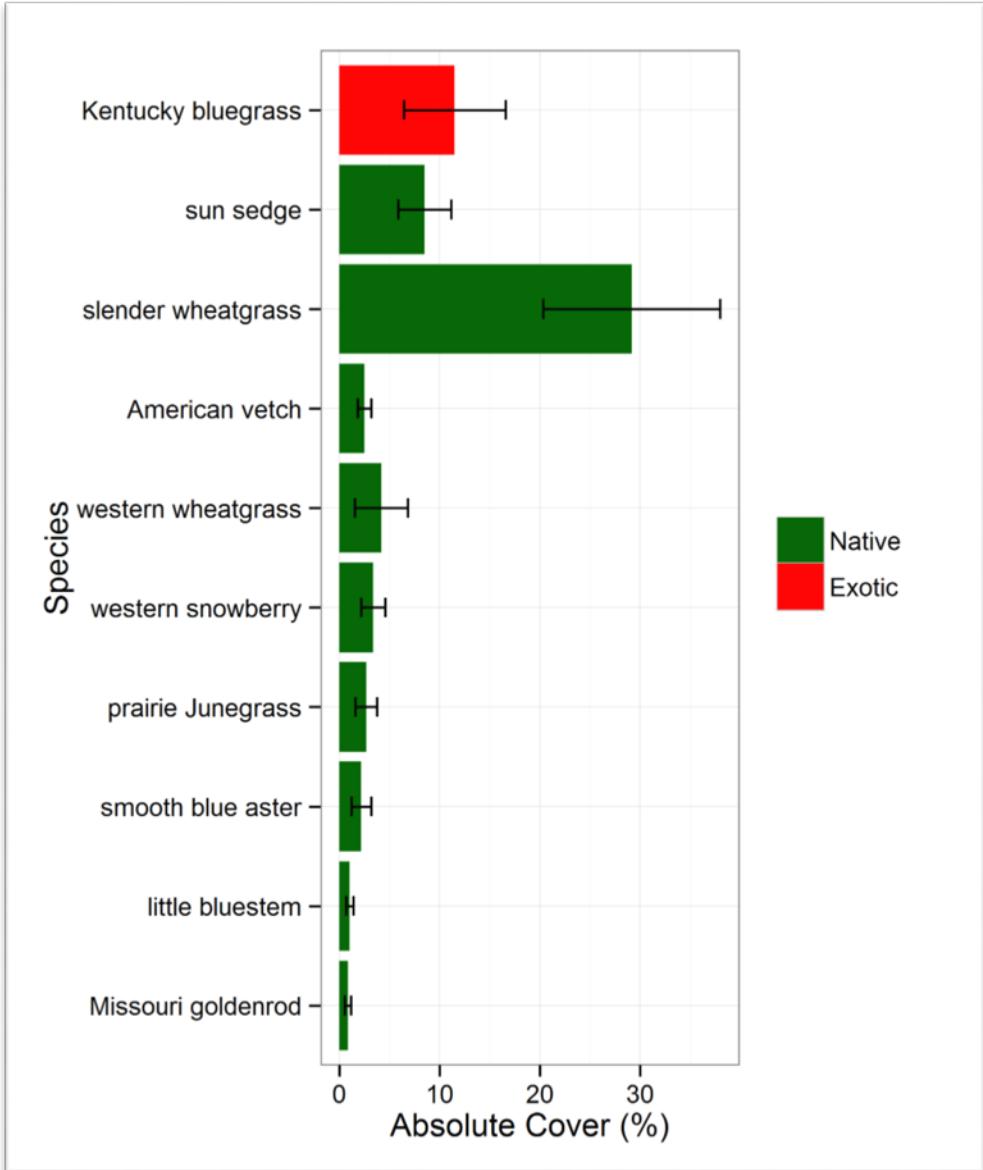


Figure 5. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded at Jewel Cave National Monument in 2014. Bars represent means \pm standard errors.

Average species richness at each of the six plots was measured by point-intercept and in 1 m² and 10 m² quadrats. On average, there are about two exotic species within the 1 m² quadrat (Table 5). From the point-intercept data, we found average plot diversity, H', to be 2.4 ± 0.18 . Evenness, J', averaged 0.75 ± 0.04 across the plots (Table 4). When including only native species, average diversity and evenness were 2.2 ± 0.19 and 0.72 ± 0.05 , respectively.

Table 5. Average plant species richness in six plots at Jewel Cave National Monument in 2014. Values represent means \pm standard errors, n=6.

	Point-intercept	1 m ² quadrats	10 m ² quadrats
Species richness	24 \pm 2.0	12 \pm 0.8	24 \pm 1.7
Native species richness	20 \pm 2.0	10 \pm 0.7	20 \pm 1.4
Exotic species richness	4 \pm 0.6	2 \pm 0.2	4 \pm 0.4
Graminoid species richness	10 \pm 1.4	4 \pm 0.5	6 \pm 0.7
Forb species richness	12 \pm 1.4	7 \pm 0.8	15 \pm 1.7

While there was some variation across sites, the plots we visited in JECA tended to have a moderate diversity of native plants compared to other mixed-grass prairies. Species richness in the mixed-grass prairie is determined by numerous factors including fire regime, grazing, prairie dog disturbance, and weather fluctuations (Symstad and Jonas 2011). While it is difficult to define a reference condition for species richness that can vary so much spatially and temporally, the natural range of variation over long-time periods may be a good starting point (Symstad and Jonas 2014). Long-term records of species diversity in mixed-grass prairie from a relatively undisturbed site in eastern Montana vary between 8 and 18 species per square meter over the course of 13 years (Symstad and Jonas 2014). Since there are no long-term records of mixed-grass prairie diversity within the Black Hills, we are relying on these data as a reference condition. Future work is needed to develop a robust reference condition for plant communities in the Black Hills. Compared to the nearby mixed-grass prairie, JECA is within the natural range (Table 4). Among revisited sites (PCM-007, 023, and 024), average native species richness increased by 2.4 species per 1m² quadrat from 2013 (Ashton and Prowatzke 2014). The highest diversity was seen in site PCM-012 (Figure 6). This ridgeline site was characterized by a patchy tree cover.

Table 6. Characteristics of the plant community at six plots in Jewel Cave National Monument in 2014 including native species richness, exotic plant cover, average cover of annual bromes and Kentucky bluegrass, and area of disturbance.

Plot	Native species richness in 1 m ²	Exotic cover (%)	Annual brome cover (%)	Kentucky bluegrass cover (%)	Disturbance within site (m ²)
PCM-007	12	21	0	17	2290
PCM-011	9	8	0	3	2290
PCM-012	12	4	0	2	2341
PCM-023	11	16	0	4	2290
PCM-024	11	10	2	4	2290
PCM-025	8	24	0	24	2290
Park Average	10.4 \pm 0.7	14.2 \pm 3.2	0.3 \pm 0.3	8.9 \pm 3.7	-

The average relative cover of exotic species at sites in JECA was moderate (14.2 \pm 3.2%). However, cover of exotic species varied considerably among sites (Table 6). Exotic cover at sites PCM-011 and PCM-012 was below a proposed management target of 10%, but the other four sites surveyed were above this threshold. The highest cover of exotic species was 24%, found at PCM-025. Kentucky bluegrass accounted for a significant portion of the exotic cover in all plots, but other exotics were also present. Reducing the cover of annual bromes remains a major challenge for many of the parks in the region, but annual brome cover is low at JECA. Although Japanese brome (*Bromus japonicus*) was found at four of six sites, it represented less than 0.5% cover.

Disturbance from grazing, small mammals, fire, and humans affects plant community structure and composition in mixed-grass prairie. For this reason, we measured the approximate area affected by natural and human disturbances at each site we visited. In 2014, the most common disturbance was from fire, but there was also evidence of off-road travel and tree removal; both of these occurred only at site PCM-012.

Trees and/or seedlings were present in all six of the sites we visited in 2014. A more thorough



Figure 6. Photo of site PCM-012, location of highest native diversity in 2014 (11.9 species/m²).

assessment of forest structure was completed in 2011 (Ashton et al. 2012a) and will be repeated in 2016; however, the 2014 data provide a snapshot of condition at a subset of the plots. Serviceberry seedlings were very abundant (Table 7) at most sites. Plot PCM-024 and PCM-004 did not have any live ponderosa pines. Overall, basal area at the park was below estimates of historic condition (Table 4). Total downed fuel loads were high (29.5 tons/acre) due to the large amount of coarse woody debris that has remained on the ground since the Jasper Fire. Recent prescribed burns have started to reduce fuel loads; these effects may be more apparent when the forest structure assessment is repeated in 2016.

Table 7. Seedling, pole, and tree densities at six plots in Jewel Cave National Monument in 2014.

Plot	Seedling Density (seedlings/hectare)			Tree Density (trees/hectare)	
	Serviceberry	Chokecherry	Ponderosa	Ponderosa poles	Ponderosa trees
PCM-007	7,596	191	32	-	-
PCM-011	18,205	223	20,369	-	460
PCM-012	-	-	-	-	10
PCM-023	39,975	-	1,209	-	360
PCM-024	2,833	32	32	-	-
PCM-025	-	-	32	-	-

Summary

Understory plant community plots measured in 2014 in JECA had a moderate diversity of native plants, and species richness was within the range of natural variability for mixed-grass prairie. Future work is needed to develop reference conditions that are specific to the Black Hills. Forest densities

are lower than historic conditions and characterized by a mosaic of open and closed canopy sites. Exotic plant cover was higher than in past years and was greater than 10% cover at most sites. Kentucky bluegrass was the most widespread and abundant exotic species. To retain ecological integrity and the high diversity of native plants in JECA, it is important to continue efforts to reduce the cover of invasive plants. Continued monitoring efforts will be critical to track changes in the condition of the vegetation communities in JECA.

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Appendix A: Field journal for plant community monitoring in JECA for the 2014 season

Plant community composition monitoring in Jewel Cave National Monument was completed using a crew of seven people working approximately three, 10-hour days. One crew of four came back later in the season and worked a half-day to complete the tree monitoring protocol. Additionally, 15.5 hours of overtime were incurred. Two JECA employees supplemented this crew for three 7-hour days as well. Total hours worked were 287.5. Longer travel times than normal were encountered due to a road construction project within the park.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed
June 30, 2014	Monday	3.5	N/A	PCM-007 PCM-024
July 1, 2014	Tuesday	3.5	N/A	PCM-012 PCM-025
July 2, 2014	Wednesday	3.5	N/A	PCM-011 (except trees) PCM-023
September 17, 2014	Wednesday	3.5	N/A	PCM-011 (finished trees)

Appendix B: List of plant species found in 2014 at JECA

Family	Code	Scientific Name	Common Name	Exotic
Anacardiaceae	RHTR	<i>Rhus trilobata</i>	skunkbush sumac	
	TORY	<i>Toxicodendron rydbergii</i>	western poison ivy	
Apiaceae	LOFO	<i>Lomatium foeniculaceum</i>	desert biscuitroot	
	LOOR	<i>Lomatium orientale</i>	Northern Idaho biscuitroot	
	MUTE3	<i>Musineon tenuifolium</i>	slender wildparsley	
Apocynaceae	APAN2	<i>Apocynum androsaemifolium</i>	spreading dogbane	
Asclepiadaceae	ASVE	<i>Asclepias verticillata</i>	whorled milkweed	
	ASVI	<i>Asclepias viridiflora</i>	green comet milkweed	
Asteraceae	ACMI2	<i>Achillea millefolium</i>	common yarrow	
	AGGL	<i>Agoseris glauca</i>	pale agoseris	
	ANPA4	<i>Antennaria parvifolia</i>	small-leaf pussytoes	
	ARDR4	<i>Artemisia dracunculus</i>	tarragon	
	ARFR4	<i>Artemisia frigida</i>	prairie sagewort	
	ARLU	<i>Artemisia ludoviciana</i>	white sagebrush	
	CIAR4	<i>Cirsium arvense</i>	Canada thistle	*
	CIUN	<i>Cirsium undulatum</i>	wavyleaf thistle	
	CIVU	<i>Cirsium vulgare</i>	bull thistle	*
	COCA5	<i>Conyza canadensis</i>	Canadian horseweed	
	ECAN2	<i>Echinacea angustifolia</i>	blacksamson echinacea	
	ERNA10	<i>Ericameria nauseosa</i>	rubber rabbitbrush	
	GRSQ	<i>Grindelia squarrosa</i>	curlycup gumweed	
	GUSA2	<i>Gutierrezia sarothrae</i>	broom snakeweed	
	HEPA19	<i>Helianthus pauciflorus</i>	stiff sunflower	
	LASE	<i>Lactuca serriola</i>	prickly lettuce	*
	LIPU	<i>Liatis punctata</i>	dotted blazing star	
	LOAR5	<i>Logfia arvensis</i>	field cottonrose	*
	LYJU	<i>Lygodesmia juncea</i>	rush skeletonplant	
	MUOB99	<i>Mulgedium oblongifolium</i>	blue lettuce	
	PACA15	<i>Packera cana</i>	woolly groundsel	
	PAPL12	<i>Packera plattensis</i>	prairie groundsel	
	RACO3	<i>Ratibida columnifera</i>	upright prairie coneflower	
	SOMI2	<i>Solidago missouriensis</i>	Missouri goldenrod	
	SOMO	<i>Solidago mollis</i>	velvety goldenrod	
	SONE	<i>Solidago nemoralis</i>	gray goldenrod	
	SORI2	<i>Solidago rigida</i>	stiff goldenrod	
	SYLA3	<i>Sympyotrichum laeve</i>	smooth blue aster	
	SYMPH4	<i>Sympyotrichum</i>	aster	
	SYOB	<i>Sympyotrichum oblongifolium</i>	aromatic aster	
	TAOF	<i>Taraxacum officinale</i>	common dandelion	*
	TEAC	<i>Tetraneuris acaulis</i>	stemless four-nerve daisy	
	TRDU	<i>Tragopogon dubius</i>	yellow salsify	*
Berberidaceae	BERE	<i>Berberis repens</i>	Oregon grape	
Boraginaceae	CYOF	<i>Cynoglossum officinale</i>	gypsyflower	*
	LAOC3	<i>Lappula occidentalis</i>	flatspine stickseed	
	LIIN2	<i>Lithospermum incisum</i>	narrowleaf stoneseed	
Brassicaceae	ARPY4	<i>Arabis pycnocarpa</i>	creamflower rockcress	

	BOPI99	<i>Boechera pinetorum</i>	Holboell's rockcress	
Brassicaceae	CAMI2	<i>Camelina microcarpa</i>	littlepod false flax	*
	DEPI	<i>Descurainia pinnata</i>	western tansymustard	
	DESO2	<i>Descurainia sophia</i>	herb sophia	*
	DRRE2	<i>Draba reptans</i>	Carolina draba	
	ERCA14	<i>Erysimum capitatum</i>	sanddune wallflower	
	ERCH9	<i>Erysimum cheiranthoides</i>	wormseed wallflower	*
	PHAR99	<i>Physaria arenosa</i>	Great Plains bladderpod	
	PHLU99	<i>Physaria ludoviciana</i>	foothill bladderpod	
	SIAL2	<i>Sisymbrium altissimum</i>	tall tumblemustard	*
	THAR5	<i>Thlaspi arvense</i>	field pennycress	*
Campanulaceae	CARO2	<i>Campanula rotundifolia</i>	bluebell bellflower	
Caprifoliaceae	SYAL	<i>Symphoricarpos albus</i>	common snowberry	
	SYOC	<i>Symphoricarpos occidentalis</i>	western snowberry	
Caryophyllaceae	CEAR4	<i>Cerastium arvense</i>	field chickweed	
Chenopodiaceae	CHENO	<i>Chenopodium</i> sp.	goosefoot	*
Commelinaceae	TROC	<i>Tradescantia occidentalis</i>	prairie spiderwort	
Cupressaceae	JUSC2	<i>Juniperus scopulorum</i>	Rocky Mountain juniper	
Cyperaceae	CADU6	<i>Carex duriuscula</i>	needleleaf sedge	
	CAFI	<i>Carex filifolia</i>	threadleaf sedge	
	CAIN9	<i>Carex inops</i>	long-stolon sedge	
	CAREX	<i>Carex</i> sp.	sedge	
	CARI	<i>Carex richardsonii</i>	Richardson's sedge	
	CARO5	<i>Carex rossii</i>	Ross' sedge	
Elaeagnaceae	SHCA	<i>Shepherdia canadensis</i>	russet buffaloberry	
Euphorbiaceae	EUES	<i>Euphorbia esula</i>	leafy spurge	*
	EUGL3	<i>Euphorbia glyptosperma</i>	ribseed sandmat	
Fabaceae	ASCR2	<i>Astragalus crassicarpus</i>	groundplum milkvetch	
	ASDR3	<i>Astragalus drummondii</i>	Drummond's milkvetch	
	ASF2L2	<i>Astragalus flexuosus</i>	flexile milkvetch	
	ASGI5	<i>Astragalus giliviflorus</i>	plains milkvetch	
	ASLA27	<i>Astragalus laxmannii</i>	Laxmann's milkvetch	
	ASMI10	<i>Astragalus missouriensis</i>	Missouri milkvetch	
	ASMI9	<i>Astragalus miser</i>	timber milkvetch	
	ASRA2	<i>Astragalus racemosus</i>	cream milkvetch	
	ASSP6	<i>Astragalus spatulatus</i>	tufted milkvetch	
	ASTRA	<i>Astragalus</i>	milkvetch	
	DACA7	<i>Dalea candida</i>	white prairie clover	
	DAPU5	<i>Dalea purpurea</i>	purple prairie clover	
	GLLE3	<i>Glycyrrhiza lepidota</i>	American licorice	
	LAOC2	<i>Lathyrus ochroleucus</i>	cream pea	
	LAPO2	<i>Lathyrus polymorphus</i>	manystem pea	
	LUAR3	<i>Lupinus argenteus</i>	silvery lupine	
	MELU	<i>Medicago lupulina</i>	black medick	*
	MEOF	<i>Melilotus officinalis</i>	yellow sweetclover	*
	OXCA4	<i>Oxytropis campestris</i>	field locoweed	
	OXLA3	<i>Oxytropis lambertii</i>	purple locoweed	
	OXSE	<i>Oxytropis sericea</i>	white locoweed	
	PEAR6	<i>Pediomelum argophyllum</i>	silverleaf Indian breadroot	
	PEES	<i>Pediomelum esculentum</i>	large Indian breadroot	

	VIAM	<i>Vicia americana</i>	American vetch	
Gentianaceae	FRSP	<i>Frasera speciosa</i>	elkweed	
Grossulariaceae	RICE	<i>Ribes cereum</i>	wax currant	
	RIOX	<i>Ribes oxyacanthoides</i>	Canadian gooseberry	
Iridaceae	IRMI	<i>Iris missouriensis</i>	Rocky Mountain iris	
	SIMO2	<i>Sisyrinchium montanum</i>	strict blue-eyed grass	
Lamiaceae	HEDR	<i>Hedeoma drummondii</i>	Drummond's false pennyroyal	
	MOFI	<i>Monarda fistulosa</i>	wild bergamot	
	SARE3	<i>Salvia reflexa</i>	lanceleaf sage	
Liliaceae	ALCE2	<i>Allium cernuum</i>	nodding onion	
	ALTE	<i>Allium textile</i>	textile onion	
	CANU3	<i>Calochortus nuttallii</i>	seg o lily	
	LEMO4	<i>Leucocrinum montanum</i>	common starlily	
Linaceae	LILE3	<i>Linum lewisii</i>	Lewis flax	
	LIRI	<i>Linum rigidum</i>	stiffstem flax	
Malvaceae	SPCO	<i>Sphaeralcea coccinea</i>	scarlet globemallow	
Melanthiaceae	TOVE2	<i>Toxicoscordion venenosum</i>	meadow deathcamas	
Onagraceae	OECO2	<i>Oenothera coronopifolia</i>	crownleaf evening-primrose	
	OESU99	<i>Oenothera suffrutescens</i>	scarlet beeblissom	
Pinaceae	PIPO	<i>Pinus ponderosa</i>	ponderosa pine	
Poaceae	ACRI8	<i>Achnatherum richardsonii</i>	Richardson's needlegrass	
	ANGE	<i>Andropogon gerardii</i>	big bluestem	
	ARPU9	<i>Aristida purpurea</i>	purple threeawn	
	BOCU	<i>Bouteloua curtipendula</i>	sideoats grama	
	BOGR2	<i>Bouteloua gracilis</i>	blue grama	
	BRAN	<i>Bromus anomalus</i>	nodding brome	
	BRIN2	<i>Bromus inermis</i>	smooth brome	*
	BRJA	<i>Bromus japonicus</i>	Japanese brome	*
	BRTE	<i>Bromus tectorum</i>	cheatgrass	*
	CALO	<i>Calamovilfa longifolia</i>	prairie sandreed	
	ELCA4	<i>Elymus canadensis</i>	Canada wildrye	
	ELTR7	<i>Elymus trachycaulus</i>	slender wheatgrass	
	HECO26	<i>Hesperostipa comata</i>	needle and thread	
	HESP11	<i>Hesperostipa spartea</i>	porcupinegrass	
	KOMA	<i>Koeleria macrantha</i>	prairie Junegrass	
	MUCU3	<i>Muhlenbergia cuspidata</i>	plains muhly	
	NAVI4	<i>Nassella viridula</i>	green needlegrass	
	PASM	<i>Pascopyrum smithii</i>	western wheatgrass	
	POCO	<i>Poa compressa</i>	Canada bluegrass	*
	POIN	<i>Poa interior</i>	inland bluegrass	
	POPR	<i>Poa pratensis</i>	Kentucky bluegrass	*
	POSE	<i>Poa secunda</i>	Sandberg bluegrass	
	SCSC	<i>Schizachyrium scoparium</i>	little bluestem	
	SPHE	<i>Sporobolus heterolepis</i>	prairie dropseed	
Polemoniaceae	PHAL3	<i>Phlox alyssifolia</i>	alyssumleaf phlox	
	PHAN4	<i>Phlox andicola</i>	prairie phlox	
	PHHO	<i>Phlox hoodii</i>	spiny phlox	
Polygalaceae	POAL4	<i>Polygala alba</i>	white milkwort	
Polygonaceae	FACO	<i>Fallopia convolvulus</i>	black bindweed	*
Primulaceae	ANSE4	<i>Androsace septentrionalis</i>	pygmyflower rockjasmine	

Ranunculaceae	ANCY	<i>Anemone cylindrica</i>	candle anemone	
Ranunculaceae	ANPA19	<i>Anemone patens</i>	eastern pasqueflower	
Rosaceae	AMAL2	<i>Amelanchier alnifolia</i>	Saskatoon serviceberry	
	FRVI	<i>Fragaria virginiana</i>	Virginia strawberry	
	GETR	<i>Geum triflorum</i>	old man's whiskers	
	PHMO4	<i>Physocarpus monogynus</i>	mountain ninebark	
	POCO13	<i>Potentilla concinna</i>	elegant cinquefoil	
	POHI6	<i>Potentilla hippiana</i>	woolly cinquefoil	
	PRVI	<i>Prunus virginiana</i>	chokecherry	
	ROAR3	<i>Rosa arkansana</i>	prairie rose	
	ROWO	<i>Rosa woodsii</i>	Woods' rose	
Rubiaceae	GABO2	<i>Galium boreale</i>	northern bedstraw	
Santalaceae	COUM	<i>Comandra umbellata</i>	bastard toadflax	
Scrophulariaceae	VETH	<i>Verbascum thapsus</i>	common mullein	*
Unknown family	UNKFORB	Unknown forb	unknown forb	*
	UNKFORBANN	Unknown annual forb	unknown annual forb	*
	UNKGRAMPER	Unknown perennial graminoid	unknown perennial graminoid	*
Verbenaceae	VEST	<i>Verbena stricta</i>	hoary verbena	
Violaceae	VIAD	<i>Viola adunca</i>	hookedspur violet	
	VICA4	<i>Viola canadensis</i>	Canadian white violet	
	VINU2	<i>Viola nuttallii</i>	Nuttall's violet	
	VIOLA	<i>Viola</i> sp.	violet	*

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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