National Park Service
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Natural Resource Stewardship and Science

Jewel Cave National Monument Plant Community Composition and Structure Monitoring

2011 Annual Report

Natural Resource Technical Report NPS/NGPN/NRTR—2012/546

ON THE COVER
A view of a Jewel Cave National Monument, 2011
Photograph by: Daina Jackson, NGPN, NPS

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February 2012

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

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

This report is available from Northern Great Plains Network website (http://science.nature.nps.gov/im/units/ngpn/reportpubs/reports.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

Please cite this publication as:

Ashton, I. W., M. Prowatzke, M. Bynum, T. Shepherd, S. K. Wilson, K. Paintner-Green. 2012. Jewel Cave National Monument plant community composition and structure monitoring: 2011 annual report. Natural Resource Technical Report NPS/NGPN/NRTR—2012/546. National Park Service, Fort Collins, Colorado.

NPS 146/112793, February 2012

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Executive Summary

The Northern Great Plains Inventory & Monitoring Network (NGPN) was established to develop and provide scientifically credible information on the current status and long-term trends of the composition, structure, and function of ecosystems in thirteen parks located in 5 northern Great Plains states. NGPN identified upland plant communities, exotic plant early detection, and riparian lowland communities as vital signs that can be used to better understand the condition of terrestrial park ecosystems. Upland and riparian ecosystems are important targets for vegetation monitoring because the status and trends in plant communities provide critical insights into the status and trends of other biotic components within those ecosystems.

In 2011, NGPN began plant community monitoring in Jewel Cave National Monument (JECA). We sampled herbaceous vegetation at 6 long-term monitoring plots in July and recorded a total of 160 vascular plant species. This effort was the first year in a multiple-year venture to understand the status of plant communities in JECA. At the end of 5 years, there will be an in-depth report describing the status of the plant community in JECA. In collaboration with the Northern Great Plains Fire Ecology Program we visited an additional 60 plots to monitor forest health and fuels-- the results of that effort will be described in a separate report. In this report, we provide a simple summary of our results from herbaceous plant sampling in 2011. We found the following:

- Absolute vascular plant cover was high due to a wet spring, and grasses and sedges made up the bulk of vascular plant cover at all sites.

- The sites at JECA had a large diversity of vascular plants. Average native species richness in the 10 m^2 quadrats was 19 species. The relative cover of exotic species across the sites was quite low, at only 11%.

- Large ponderosa snags and other evidence of fire were present at all of the sites. Western serviceberry and black chokecherry seedlings were abundant in some areas.

- None of the 6 plots we visited had any evidence of mountain pine beetles, and only 1 live ponderosa (of 78 measured) showed evidence of dieback.

Acknowledgments

We thank all the authors of the NGPN Plant Community Monitoring Protocol, particularly Amy Symstad for outstanding guidance on data collection and reporting. We thank the Northern Great Plains Fire Ecology Program team for ongoing assistance with fieldwork and development of methods. We greatly appreciate the staff at JECA for providing logistical support. The 2011 NGPN vegetation field crew of Isabel Ashton, Kara Paintner-Green, Michael Bynum, Michael Prowatzke, Timothy Pine, Lauren Baur, Belinda Lo, Ryan Manuel, Lee Margadant, and Daina Jackson collected and entered the data included in this report. We thank Beth Burkhart and Amy Symstad for assisting in the field. We thank Timothy Shepherd for invaluable support and instruction on managing data in the FFI database and Stephen Wilson for assistance with the GIS data. We thank Rene Ohms for providing comments on an earlier draft of this report.

Introduction

One of the objectives of the National Park Service (NPS) Inventory & Monitoring (I&M) Program is to develop and provide scientifically credible information on the current status and long-term trends of the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. The Northern Great Plains I&M Network (NGPN) includes 13 parks located in 5 northern Great Plains states across 6 ecoregions (Figure 1) which vary widely in size, visitor use, and management context.

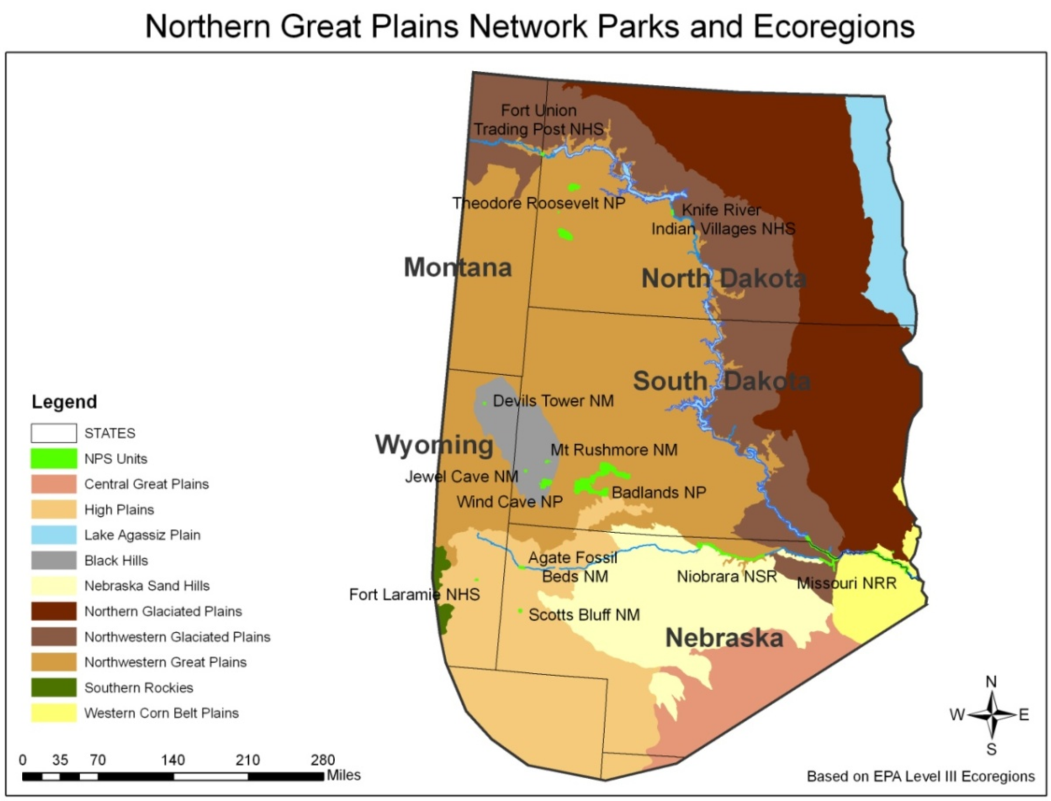

Figure 1. Parks and ecoregions of the Northern Great Plains Network. Based on the U.S. Environmental Protection Agency's Level III ecoregions classes (Omernik 2007).

NGPN identified upland plant communities, exotic plant early detection, and riparian lowland communities as vital signs that can be used to better understand the condition of terrestrial park ecosystems (Gitzen et al. 2010). Network-wide land cover is dominated by native upland grassland, but some small parks are dominated by old fields and recent prairie plantings (Symstad et al. 2011). Other major land cover types include barren or sparsely vegetated areas (Badlands and Theodore Roosevelt National Parks) and ponderosa pine forests and woodlands in Black Hills parks. Riparian hardwood forests comprise a small portion of the area but have disproportionately large ecological significance because of their value to wildlife species.

The NGPN selected upland and riparian ecosystems as an important vegetation monitoring target because knowing the status and trends in plant communities of any terrestrial ecosystem is critical to understanding the status and trends in most other biotic components of that ecosystem. Not only are plants a source of food for organisms, but they also provide organisms cover from predators and the elements, structure for basic life-history processes (e.g., nest sites), and substrate on which to grow. Plant communities influence local, regional, and global climate through evapotranspiration, albedo, and greenhouse gas emissions and absorption (Smith et al. 1997). Fire regimes (D'Antonio and Vitousek 1992) and flood behavior (Anderson et al. 2006) are in part mediated by the species that comprise plant communities and the structure that they create. Plants are the major source of organic inputs into soil and aquatic systems. Finally, vegetation is a large part of the scenery that visitors to NPS units come to enjoy.

The long-term objectives of our plant community monitoring effort (Symstad et al. 2011) in JECA are to:

1. Determine park-wide status and long-term trends in vegetation species composition (e.g., non-native vs. native, forb vs. graminoid vs. shrub) 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, and diameter class and of fuel loads in Black Hills parks.

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 for our initial sampling efforts in 2011 at JECA. We sampled plant communities at 6 plots in JECA. We expect to produce reports with more in-depth data analysis and interpretation when we complete 5 years of sampling (i.e., visit and sample every plot in the park twice, following a rotating panel design that stipulates 2 years of visitation and 3 years of rest per 5-year period). In collaboration with the Northern Great Plains Fire Ecology Program, we visited an additional 60 plots to monitoring effort forest health and fuels- the results of that effort will be described in a separate report. Reports, spatial data, and data summaries can also be provided as needed for park management and interpretation.

Methods

The NGPN Plant Community Composition and Structure Monitoring Protocol (Symstad et al. 2011) describes in detail the methods used for sampling upland and riparian vegetation in 11 parks of the network. Below, we briefly describe the general approach, sample frame, plot locations, and sampling methods. For those interested in more detail, please see Symstad et al. 2011, available at http://science.nature.nps.gov/im/units/ngpn/monitor/plants/plants.cfm .

Sample design

NGPN has implemented a survey to monitor vegetation in JECA using a Generalized Random Tessellation Stratified (GRTS) sampling design (Stevens and Olsen 2003, 2004). Probability-based surveys provide unbiased estimation of both status and, with repeated visits, trend across a resource (Larsen et al. 1995). When implemented successfully, probability-based survey designs allow for unbiased inference from sampled sites to un-sampled elements of the resource of interest (Hansen et al. 1983). The goal of our probability-based design is to determine the *status* of vegetation after 5 years and from then on, the *trend* in vegetation.

The methods for the development of the survey design and site selection are described in detail in Symstad et al. 2011. In brief, a probability-based survey design consists of implementing the following steps prior to field sampling: defining a resource or target population and any subpopulations of interest, creating a sample frame within the target population, selecting sites to visit within the sample frame, and determining when to sample. For JECA, we define the target population as upland vegetation and the sample frame as the whole park. For all parks, we exclude the following areas from the sample frame: administrative areas, roads, canals, or utility lines and an appropriate buffer, areas within 10 m of a park boundary, paved trails, areas with little to no potential for terrestrial vegetation (e.g. large areas of bare rock), areas that are dangerous or prohibitively difficult to access or work on, and areas that are not owned by the park. The final design includes 15 sites randomly located in JECA representing the park where vegetation will be sampled close to peak phenology (July) (Figure 2).

An ideal revisit design would consist of a large number of sites distributed throughout a park being sampled every year. Limited resources, as well as the danger of plot wear-out (trampling and other effects of sampling), precluded this design. Instead, NGPN intensive plant community composition and structure monitoring uses a connected [2-x] rotating-panel design: every park is visited every year, but sites are grouped into panels where each panel (and the plots therein) is measured for 2 consecutive years followed by 3 or more years without sampling. Because only a subset of panels (and therefore plots) are visited each year, this allows more sites than can be visited in 1 year to be included in the sample design, while including revisitation of sites to address annual variability. Compared to the always-revisit design, connected panel designs, in which each panel is revisited periodically, sacrifice little power for detecting trend (Urquhart and Kincaid 1999) but provide much greater spatial coverage, and thus improved precision in estimates of status. At JECA, we visit 2 panels, each with 3 sites every year (Figure 3). In 2011, we visited sites in panel 1 and panel 5 (Figure 2).

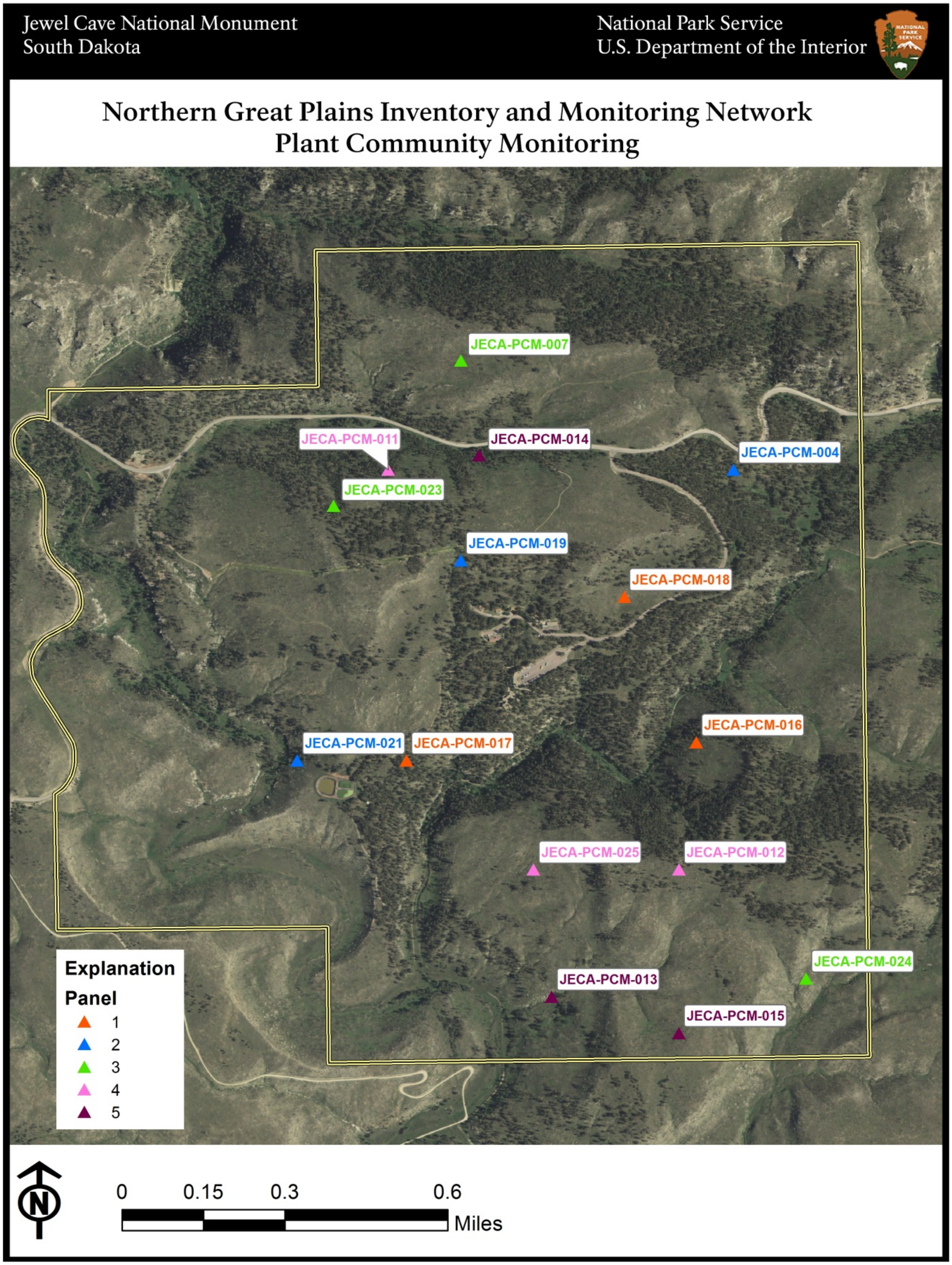

Figure 2. Map of JECA plant community monitoring plots. Plots in Panel 1 (orange) and Panel 5 (purple) were visited in 2011.

Year↓ / Panel→	P1	P2	P3	P4	P5
2011	3				3
2012	3	3			
2013		3	3		
2014			3	3	
2015				3	3
2016	3				3
2017	3	3			
2018		3	3		
2019			3	3	
2020				3	3
2021	3				3

Figure 3. [2-3] revisit design for intensive plant community composition and structure monitoring at most NGPN parks. Five panels are used in the park. Data are collected in all the plots of a given panel, 2 of every 5 years. Blank cells indicate no plots in the panel are visited that year; at JECA there are 3 plots in a panel. Thus, 6 plots (2 panels) are sampled each year and the total sample size is 15.

The number of plots allocated to each park and to strata within parks is influenced by a combination of factors, including field work logistics, statistical power estimations (see Symstad et al. 2011), and conformity to the desired revisit design. Plot numbers across parks are allocated roughly proportional to the size of the sample frame for that park, although the minimum number of plots per park was set at 15. There are currently 15 plant community monitoring plots at JECA. An additional set of forested plots (60 total) were monitored in 2011 and will be revisited every 5 years to track changes in forest structure and fuels.

Plot layout and sampling

The primary sample unit for intensive plant community composition and structure monitoring in the NGPN consists of a rectangular, 50 m x 20 m (0.1 ha), permanent plot (Figure 4). In 2011, sampling at JECA took a 5 person crew approximately 80 hours with travel time (see Appendix A for a detail of activities each day). Below, we briefly describe the methods we used for marking and sampling the plots.

Establishing, Marking, and Photographing Long-term Monitoring Plots

Locations of all plots are determined before monitoring begins in the site evaluation process. At this time, a single plot marker, marked with a metal tag identifying the plot and the marker as the center (C), is driven into the ground at the center of the plot (Figure 5). At plot establishment (which may be done prior to the first visit for data collection), 2 permanent transects are marked by driving rebar markers into the ground at the end points of each transect. A metal tag imprinted with the park code, plot ID, corner name (A0, A50, B0, or B50), and establishment date is attached to each marker. Each transect is also marked with large nails and washers sunk flush with the ground at 10.92 m, 23.42 m, 35.92 m, and 46.84 m from the 0 end of each transect. Figure 6 is a photographic sample of the tags and washers used by NGPN.

At each transect end, a photograph is taken down the length of the transect. When trees and/or tall shrub species are present in or near the plot, the ends of 2 additional perpendicular, 100-ft (30.48 m) transects centered at the C plot marker are marked with large nails and washers (Figure 4). One of these transects (T1) is parallel to the herb-layer transects and the second (T2) is perpendicular to that transect.

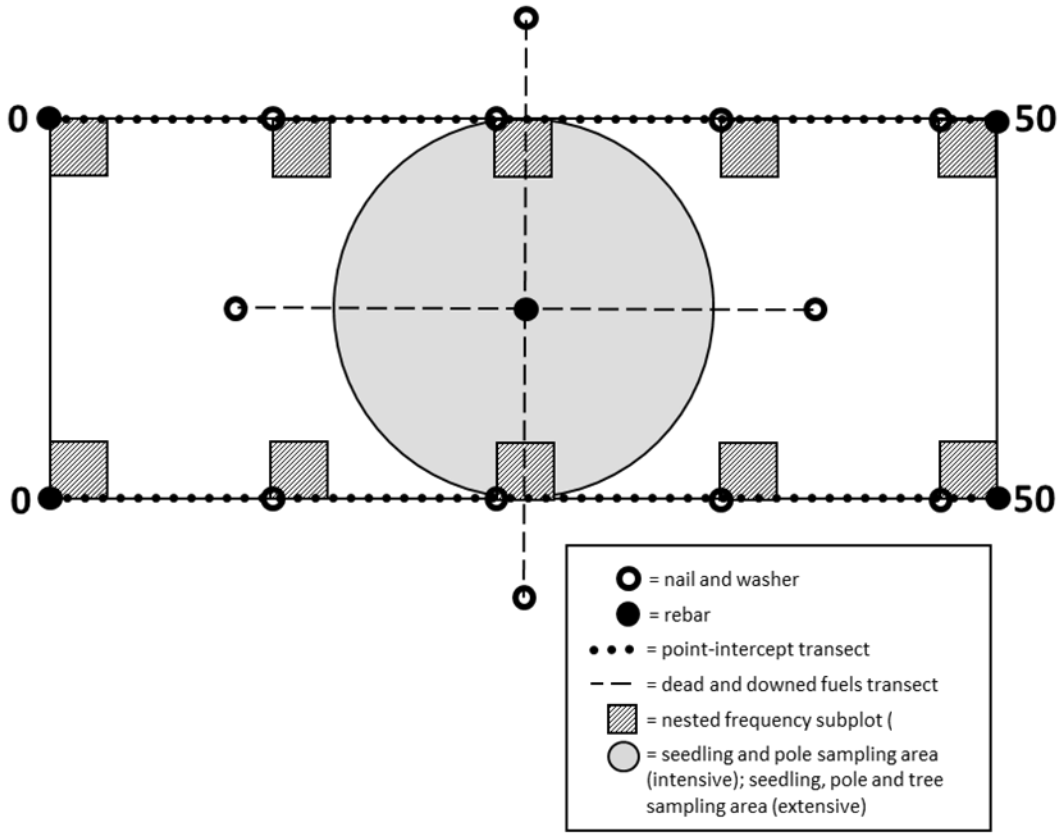

Figure 4. Layout for NGPN intensive plant community composition and structure plots.

Figure 5. A sample of the center marker at an NGPN long-term vegetation monitoring plot. The rebar is bent in the field with a brass tag noting the plot number, date of installation, and location. A compass is used for scale.

Figure 6. A sample of tags and washers used to mark long-term vegetation monitoring plots in the NGPN. From the top left and working clockwise: a center tag from PCM-08 in SCBL evaluated on May 5, 2009; a tag used to mark the end of the A transect at WICA PCM-01; a tag used to mark the center of an extensive plot in MORU; and a washer used to mark the beginning of the second tree transect. In all cases, the tags are close or flush to the ground. The brass tags are fixed to rebar with wire, and the washer is held in place by a large nail.

Plant Sampling

Data on ground cover and herb-layer (≤ 2 m height) height and foliar cover were collected on 2 50 m transects (the long sides of the plot) using a point-intercept method at each plot. Starting at the 0 end of each transect, a 50 m tape was stretched over the length of the transect, ensuring that it followed the path marked by the nails and washers (Figure 4). At 100 locations along the transects (every 0.5 m) a pole was dropped to the ground and all species that touched the pole were recorded, along with ground cover, and the height of the canopy (Figure 7).

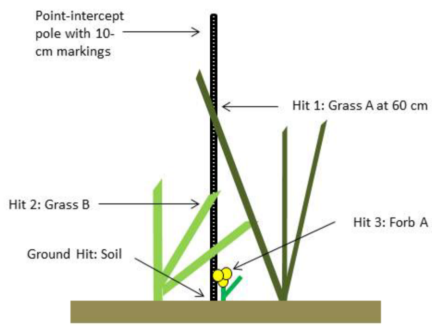

Figure 7. The NGPN point-intercept method captures multiple layers of the plant canopy.

Species richness data from this point-intercept method are supplemented with species presence data collected in 5 sets of nested square quadrats (0.01 m^2, 0.1 m^2, 1 m^2, and 10 m^2; Figure 8) located systematically along each transect. Nested quadrats are located so that they occur inside the 20 m x 50 m plot (Figure 4). Beginning with the 0.01 m^2 quadrat, all species rooted in the quadrat are identified and recorded. Once all species in this quadrat are recorded, the observer moves onto the 0.1 m^2 quadrat, listing only species not observed in the 0.01 m^2 quadrat. This is repeated in the 1.0 m^2 and 10 m^2 quadrats. Only species rooted in a quadrat are included in the species list for that quadrat.

Unknown species were recorded in the field using a unique identifier and collected or photographed. Most of these unknowns were subsequently identified by M. Bynum. However, in some cases the plant was too small or difficult to identify. In these cases, the species was classified by growth form and, where possible, lifecycle (e.g., annual graminoid).

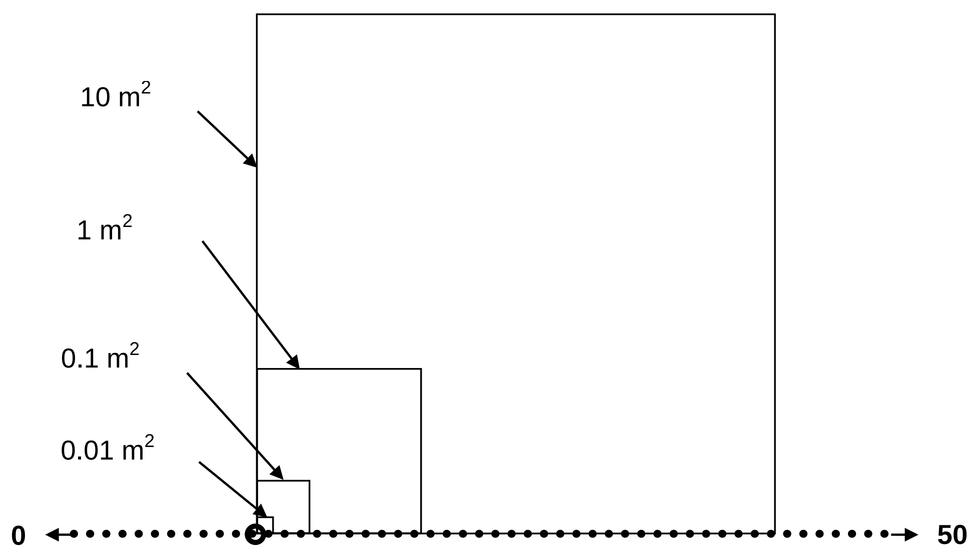

Figure 8. Arrangement of nested quadrats along tape used for point-intercept sampling. Open circle indicates permanent marker (nail and washer or, at 0 end of transect, rebar).

Where applicable, tree regeneration and tall shrub density data are collected within a 10 m-radius, circular subplot centered at the center of the 50 m x 20 m plot. In this subplot or a subset thereof, tree and targeted tall shrub seedlings are tallied by species and size class. Size classes are defined as follows. A tree has a diameter at breast height (DBH) of greater than 15 cm. A pole has a DBH of > 2.54 cm but < 15 cm. A sapling has a DBH < 2.54 cm but is > than 1.37 cm tall. A seedling is < 1.37 cm tall. DBH, status (live or dead), and species are recorded for all poles and trees and targeted tall shrubs.

Trees with DBH > 15 cm, within the entire 0.1 ha plot, are mapped and tagged, and species, DBH, status, and condition (e.g., leaf-discoloration, insect-damaged, etc.) are recorded for each tree. Where appropriate (i.e., in ponderosa pine forest or woodland in Black Hills parks), dead and downed woody fuel load data are collected on 2 perpendicular, 100 ft (30.48 m) transects centered at the center of the plot.

At all plots, we also surveyed the area for common disturbances and target species of interest. 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. The target species lists were developed in cooperation with the park and NGPN staff during the winter/spring prior to the field season. Usually these are invasive and/or exotic species that are not currently widespread in the park but pose a significant threat if allowed to establish. 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 1-5% of site, 4 = cover 5-25% of site, and 5 = cover > 25% of site. The information gathered from this procedure is critical for early detection and rapid response to such threats. In addition, this method tracks the presence of plant species that are considered rare or vulnerable to loss in South Dakota, and may occur in JECA. For example, *Botrychium lunaria* is one species that is also tracked by the South Dakota Natural Heritage Program (http://gfp.sd.gov/wildlife/threatened-endangered/rare-plant.aspx), and at the state level is considered critically imperiled because of its extreme rarity (S1). The JECA target species list for 2011 can be found in Table 1.

Table 1. Target species of concern at JECA for the 2011 field season.

Invasives/noxious weeds/exotics		
Species Code	**Scientific Name**	**Common Name**
ACRE3	*Acroptilon repens*	Russian knapweed/hardheads
CEDI3	*Centaurea diffusa*	diffuse knapweed
CEJA	*Centaurea jacea*	brownray knapweed
CESO3	*Centaurea solstitialis*	yellow star thistle
CESTM	*Centaurea biebersteinii*	spotted knapweed
TAVU	*Tanacetum vulgare* L.	common tansy
At risk/rare		
Species Code	**Scientific Name**	**Common Name**
BOLU	*Botrychium lunaria* (L.) Sw.	common moonwort

Data Management and Analysis

After the field work was completed, field sheets were scanned and stored in fire-proof cabinets, and the data were entered by the NGPN seasonal vegetation crew. FFI (FEAT/FIREMON Integrated; http://frames.gov/ffi/) is the primary software environment used for managing NGPN plant community data. NGPN uses its components for data entry, data storage, and basic summary reports. 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 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, the data were verified. This was done by comparing the entered data to the original field data sheets, and detected errors were corrected immediately. To minimize transcription errors, 100% of records were verified to their original source. A further 10% of records were reviewed a second time by I. Ashton or M. Prowatzke. When errors were found in the reviews, the entire data set was verified again. After all data were entered and verified, automated queries were developed to check for errors in the data. For instance, a query was developed that noted all plots where a species appeared twice within one nested quadrat. When errors were caught by the crew or the automated queries, changes were made to the original datasheets and the FFI database.

For analysis of data from intensive plots, the plot is used as the unit of replication and quadrats or transects are pooled or averaged. Data from each plot are summarized for a variety of variables including: relative cover of growth forms (shrubs, grasses, forbs), absolute cover of bare soil, total herb-layer foliar cover, density and basal area of trees, species richness and diversity, relative abundance of functional groups, and proportions of foliar cover and species richness that are non-native. Growth forms were based on definitions from the USDA Plants Database. Warm-season grasses were identified primarily using a guide by Skinner (2010). Summaries were done using FFI reports and statistical summaries were done using R software (version 2.11.0).

Results

In the 6 plots where we sampled herbaceous vegetation in JECA during 2011, we recorded 160 vascular plant species (Appendix B). We found an additional 9 plants that could be identified only to genera. The most common families were Asteraceae and Poaceae.

Absolute percent and relative cover

From the point-intercept data, we found the 6 plots to average 108 ± 43.1% (mean ± standard deviation) total herb layer cover and 19 ± 11.0% bare ground. The absolute canopy cover can be greater than 100% because we record multiple layers of plants and it was a fairly wet year with abundant growth.

Graminoids, which includes grasses, sedges, and rushes, had an average cover of 62 ± 31.7%. This was much higher than other plant life-forms (Figure 9). Plant composition varied among the plots and only 3 species were found at all 6 plots: sun sedge (*Carex inops ssp. heliophila*; 8 ± 6.4 %), Kentucky bluegrass (*Poa pratensis;* 7 ± 5.3%), and American vetch (*Vicia americana;* 3 ± 1.2%). The species with the highest absolute cover were both graminoids: western wheatgrass (*Pascopyrum smithii*; 21 ± 30.6% absolute cover) and slender wheatgrass (*Elymus trachycaulus ssp. trachycaulus*; 27 ± 19.3%).

Of the 6 plots at JECA, the average relative percent cover of exotic species was 11 ± 6.2%. We found the average relative percent cover of warm season graminoids to be 15 ± 16.3%.

Species richness, diversity, and evenness

We measured diversity at the plots in 2 ways: the Shannon Index and Pielou's Index of Eveness. 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). Peilou's Index of Evenness, J', measures another aspect of diversity--how even abundances are across taxa. It ranges between 0 and 1, where higher numbers indicate that a community is not even or that just a few species make up the majority of the total cover. From the point-transect data, we found average plot diversity, H', to be 2.6 ± 0.63. Evenness, J', averaged 0.78 ± 0.13 across the plots. When including only native species, average diversity and evenness were 2.5 ± 0.66 and 0.77 ± 0.15, respectively. Species richness varies by the scale that it is examined. Table 2 presents average species richness for the point-intercept, 1 m^2 quadrats, and 10 m^2 quadrats for the 12 plots in 2011. In general, richness increases in the larger quadrat size. While graminoids have greater absolute cover, forb richness was greater than graminoid richness. On average, there are about 3 exotic species found in each plot along the point-intercept (Table 2).

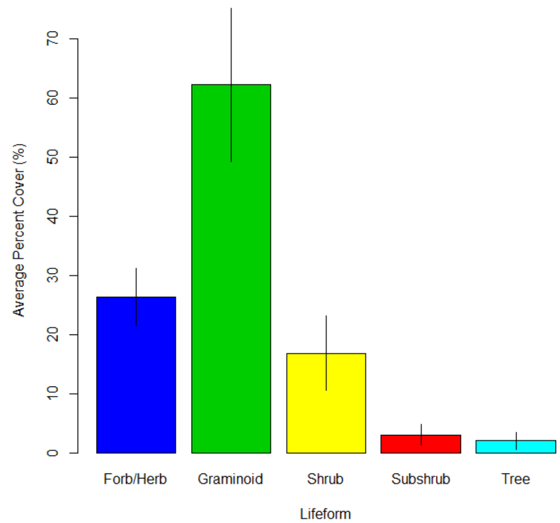

Figure 9. Absolute percent cover of different plant life-forms in 6 plant community monitoring plots in JECA in 2011. Bars represent means across the 6 plots ± standard errors. Graminoids were the most abundant plant life-form across all plots at JECA.

Table 2. Average plant species richness at 6 plots at JECA in 2011. Values represent means ± standard deviation.

	Point-intercept	**1 m^2 quadrats**	**10 m^2 quadrats**
Species richness	29.0 (8.53)	11.9 (3.54)	21.2 (5.99)
Native species richness	25.7 (7.34)	10.5 (3.20)	18.6 (5.68)
Exotic species richness	3.3 (1.51)	1.9 (0.33)	2.8 (0.41)
Graminoid species richness	9.5 (1.87)	3.5 (0.58)	5.7 (0.91)
Forb species richness	14.7 (4.55)	6.2 (2.21)	12.5 (3.25)

Forest structure and surface fuels

In 2011, we encountered and measured the density of 3 tree and tall shrub species in the plots: ponderosa pine (*Pinus ponderosa)*, black chokecherry (*Prunus virginiana var. melanocarpa*), and western serviceberry (*Amelanchier alnifolia*). The density of these species by size class at each plot is given in Table 3.

Forest structure and composition varied considerably among the plots (Table 3). Ponderosa pine seedlings were present at only 1 site, but snags were found at all 6. Only 2 plots, PCM_014 and PCM_017 had more than 5 live ponderosa trees. Of the 78 live ponderosa trees that were measured, we found evidence of dieback from insects or disease in only 1 (at site PCM_014). None of the 6 plots we visited had any evidence of mountain pine beetles.

Table 3. Average tree density at 6 forested plots at JECA in 2011.

Size Class	Ponderosa Pine (stems hectare^{-1})	Black chokecherry (stems hectare^{-1})	Western serviceberry (stems hectare^{-1})	Snag (stems hectare^{-1})
Seedlings	3132 (1 plot)	5503 (3 plots)	12752 (3 plots)	n/a
Saplings	223 (1 plot)	255 (1 plot)	-	n/a
Poles	387 (2 plots)	-	-	40 (4 plots)
Trees	195 (4 plots)	-	-	47 (6 plots)

Surface fuels were measured in all 6 plots. There was considerable variation in fuel loads across the plots. Average fuel loads for fine (1-100-hour) fuels, coarse (1000-hour) fuels, and sum of litter and duff fuels were 3.6 ± 2.87 , 14.4 ± 8.84 , and 1.4 ± 2.17 tons per acre, respectively. The average total fuel load was 21.5 ± 10.45 tons per acre.

Target species assessments and disturbance

We did not find any target exotic species or rare species in the 6 plots we assessed in 2011. However, we did find leafy spurge (*Euphorbia esula*) in PCM_013 and Canada thistle (*Cirsium arvense*) was found in 2 of the plots (PCM_016 and PCM_016).

There was evidence of fire at all the plots we sampled in 2011, and the Jasper fire had burned through all but plot PCM_017, where there was evidence of a more recent fire (likely the Lithograph prescribed burn in 2010). The only other disturbance we recorded was from game trails at PCM_016 and small mammal excavations at PCM_018.

Discussion

The goal of our plant community monitoring efforts in JECA is to determine the status and trend in vegetation composition and structure and to understand how natural and anthropogenic disturbance and management decisions influence vegetation. As of 2011, we have completed the first year of field work; while we have increased our understanding of vegetation composition and structure, we cannot yet describe park-wide status or trends. Below, we summarize the results from above and highlight some of the most interesting aspects of the plant community monitoring.

There was considerable variation among plots, but on average absolute vascular plant cover was 108 %. The absolute canopy cover can be greater than 100% because we record multiple layers of plants and productivity was high due to a wet spring. The sites at JECA had a notably large diversity of vascular plants. Average native species richness along the point-intercept was 26 species (Table 2). Richness was lower in quadrats, but still high. We found an average of 3 exotic plants in every 10 m^2 quadrat. Graminoids, which includes all grasses, sedges, and rushes, made up the bulk of cover at all sites (Figure 9). Forbs, or broad-leaved herbaceous plants, were less abundant but more diverse than graminoids at the scale of the 10 m^2 plots.

Graminoids can be further classified by their photosynthetic pathway. Warm season graminoids have a photosynthetic pathway (C4) that particularly adapts them to hot climates and an atmosphere low in carbon dioxide. These warm season graminoids grow primarily during the hot summer months and tend to be very drought tolerant. Cool season graminoids are C3 plants that tend to grow best in cooler temperatures. For example, junegrass (*Koeleria macrantha*) is a cool season grass and blue grama (*Bouteloua gracilis*) is a warm season grass. The cover of warm season graminoids in JECA was 15%. Examining the trend over time in warm-season graminoid cover and climate trends may elucidate whether warm-season grasses are increasing in abundance due to warmer and drier conditions.

Forest structure and composition varied considerably among the plots (Table 3). Not surprisingly, ponderosa pine was the most common tree species across the plots and there were large snags found in all plots. Some plots had a high density of black chokecherry and western serviceberry seedlings. Fuel loads were also high, likely due to all the downed wood following the Jasper Fire of 2000, which impacted roughly 85% of the park.

Relative cover of exotic species was quite low in JECA. We did not find target exotic species in any sites. Our sample design is limited to areas at least 10 m from roads, paved trails, or administrative buildings. It is possible that these target species exist in the park, but are restricted to these corridors or other locations outside of the surveyed areas.

Results from our vegetation monitoring can be summarized in a “connect-the-dots” or a resource condition summary table (Table 4). These tables can be used to describe the status and trend in vital signs or other indicators of ecosystem health. We chose a handful of the key metrics representing 2 vital signs, which we will continue to monitor over time at JECA. The current value is based on sampling in 2011 and the level of inference is simply the number of sites where we sampled that attribute. After 1 complete rotation in the JECA sampling design (5 years), a current value will represent a 5-year mean and the level of inference will be park-wide. At such time, we will also be able to estimate baseline reference values and begin to estimate trends in these key metrics. Over time, the vegetation data collected at these sites will greatly add to our understanding and documentation of change in the upland plant communities at JECA.

Table 4. Natural resource condition summary table for plant communities in JECA.

Vital Sign	Metric	Current Value (mean ± SD)	Level of inference	Reference Value	Rationale
Exotic Plant Early Detection	% of sites where target species were encountered	0%	6 plots	TBD	Early detection of exotic species
	Number of sites where Canada thistle > 5% cover	1	6 plots	TBD	Effectiveness of exotic species management
Upland Plant Communities	Mean absolute herb-layer cover	108 ± 43.1 %	6 plots	TBD	Forage availability, climatic trends, erosion potential, habitat for small mammals and birds
	Ground-layer bare soil cover	19 ± 11.0 %	6 plots	TBD	
	Mean relative percent cover of exotic species	11 ± 6.2 %	6 plots	TBD	Effectiveness of exotic species management
	Percent of graminoid cover that is warm season	15 ± 16.3 %	6 plots	TBD	Climatic trends
	Mean native species richness in 10 m^2 quadrats	19 ± 5.7 species	6 plots	TBD	Diversity maintenance

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Appendix A: Field journal for plant community monitoring in JECA for the 2011 season

Plant community composition monitoring in JECA was completed using a crew of 5 people working eight 10-hour days. We spent approximately 400 crew hours in JECA in 2011 to establish and sample 6 plots in panel 1 and 5. For all but 1 plot (i.e., PCM_017), we sampled herbaceous plants in July and returned in August to sample trees and fuels.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed	Notes
Jul 11, 2011	Monday	2.5	n/a	PCM_017	Full Read
Jul 12, 2011	Tuesday	2.5	n/a	PCM_015	Herbaceous
Jul 13, 2011	Wednesday	2.5	n/a	PCM_013	Herbaceous
Jul 14, 2011	Thursday	2.5	n/a	PCM_018	Herbaceous
Jul 19, 2011	Tuesday	2.5	n/a	PCM_014	Herbaceous
Jul 20, 2011	Wednesday	2.5	n/a	PCM_016	Herbaceous
Aug 24, 2011	Wednesday	2.5	n/a	PCM_014 PCM_018	Read trees and fuels
Aug 25, 2011	Thursday	2.5	n/a	PCM_013 PCM_015 PCM_016	Read trees and fuels

Appendix B: List of plant species found in 2011 at JECA

Family	Code	Scientific Name	Common Names
Anacardiaceae	RHTRT	*Rhus trilobata* var. *trilobata*	ill-scented sumac, skunkbush, skunkbush sumac
	TORY	*Toxicodendron rydbergii*	poison ivy, W. Poison ivy, western poison ivy, western poison-ivy
Apiaceae	MUTE3	*Musineon tenuifolium*	slender wildparsley
Apocynaceae	APAN2	*Apocynum androsaemifolium*	bitterroot, flytrap dogbane, spreading dogbane
Asclepiadaceae	ASPU	*Asclepias pumila*	low milkweed, plains milkweed
Asteraceae	ACMI2	*Achillea millefolium*	bloodwort, carpenter's weed, common yarrow, hierba de las cortaduras, milfoil, plumajillo, western yarrow, yarrow (common)
	AGGLG	*Agoseris glauca* var. *glauca*	pale agoseris
	ANMI3	*Antennaria microphylla*	littleleaf pussytoes
	ANPA4	*Antennaria parvifolia*	little-leaf pussytoes, Rocky Mountain pussytoes, small leaf pussytoes, small-leaf pussytoes, smalleaf pussytoes, smallleaf pussytoes
	ARFR4	*Artemisia frigida*	fringed sagebrush, fringed sagewort, prairie sagewort
	ARLUL2	*Artemisia ludoviciana* ssp. *ludoviciana*	cudweed sagewort, foothill sagewort, Louisiana sagewort, white sagebrush
	CIAR4	*Cirsium arvense*	Canada thistle, Canadian thistle
	CIUN	*Cirsium undulatum*	gray thistle, wavy-leaf thistle, wavyleaf thistle
	COCA5	*Conyza canadensis*	Canada horseweed, Canadian horseweed, horseweed, horseweed fleabane, mares tail, marestail
	ECAN2	*Echinacea angustifolia*	Blacksamson, blacksamson echinacea
	ERIGE2	*Erigeron*	fleabane
	ERFO3	*Erigeron formosissimus*	beautiful fleabane
	ERSTS2	*Erigeron strigosus* var. *strigosus*	prairie fleabane
	ERSU2	*Erigeron subtrinervis*	three-nerve fleabane, threenerve fleabane, threeveined fleabane
	HEPAS	*Helianthus pauciflorus* ssp. *subrhomboideus*	stiff sunflower
	LASE	*Lactuca serriola*	China lettuce, prickly lettuce, wild lettuce
	LIPU	*Liatris punctata*	dotted blazing star, Dotted gayfeather
	LYJU	*Lygodesmia juncea*	rush skeleton-plant, rush skeletonplant, rush skeletonweed, skeletonplant, skeletonweed
	MUOB	*Mulgedium oblongifolium*	blue lettuce
	PACA15	*Packera cana*	woolly groundsel
	PAPL12	*Packera plattensis*	prairie groundsel
	RUHI2	*Rudbeckia hirta*	blackeyed Susan, blackeyedsusan
	SOLID	*Solidago*	goldenrod, goldenrod species
	SOCA6	*Solidago canadensis*	Canada goldenrod, Canadian goldenrod, common goldenrod
	SOMI2	*Solidago missouriensis*	Missouri goldenrod, prairie goldenrod
	SONED	*Solidago nemoralis* ssp. *decemflora*	gray goldenrod
	SORIH2	*Solidago rigida* ssp. *humilis*	hardleaf goldenrod, stiff goldenrod
	SYERE	*Symphyotrichum ericoides* var. *ericoides*	white heath aster

Family	Code	Scientific Name	Common Names
	SYLAG	*Symphyotrichum laeve* var. *geyeri*	Geyer's aster
	SYOB	*Symphyotrichum oblongifolium*	aromatic aster
	TAOF	*Taraxacum officinale*	blowball, common dandelion, dandelion, faceclock
	TEACA2	*Tetraneuris acaulis* var. *acaulis*	stemless actinea, stemless bitterweed, stemless four-nerve daisy, stemless four-nerve-daisy, stemless hymenoxys
	TRDU	*Tragopogon dubius*	common salsify, goat's beard, goatsbeard, meadow goat's-beard, salsifis majeur, salsify, Western goat's beard, western salsify, wild oysterplant, yellow goat's beard, yellow salsify
Boraginaceae	CYOF	*Cynoglossum officinale*	common houndstongue, gypsy-flower, gypsyflower, hound's tongue, houndstongue
	LIIN2	*Lithospermum incisum*	fringed gromwell, Fringed puccoon, narrowleaf gromwell, narrowleaf pucoon, narrowleaf stoneseed, trumpet stoneseed
	ONBEO	*Onosmodium bejariense* var. *occidentale*	soft-hair marbleseed, western marbleseed, western onosmodium
Brassicaceae	ARABI2	*Arabis*	rockcress
	ARPY9	*Arabis pycnocarpa* var. *pycnocarpa*	creamflower rockcress, hairy rockcress
	BOPI4	*Boechera pinetorum*	Holboell's rockcress
	CAMI2	*Camelina microcarpa*	false flax, little-pod false flax, littlepod false flax, littlepod falseflax, littleseed falseflax, small fruited falseflax, smallseed falseflax
	DRABA	*Draba*	draba
	ERCA14	*Erysimum capitatum*	coast wallflower, sand-dune wallflower, sanddune wallflower, western wallflower
	SIAL2	*Sisymbrium altissimum*	tumble mustard, tumblemustard
	THAR5	*Thlaspi arvense*	fanweed, field pennycress, Frenchweed, pennycress, stinkweed
Campanulaceae	CARO2	*Campanula rotundifolia*	bluebell, bluebell bellflower, bluebell-of-Scotland, roundleaf harebell
Caprifoliaceae	SYAL	*Symphoricarpos albus*	common snowberry, snowberry (common)
	SYOC	*Symphoricarpos occidentalis*	western snowberry, wolfberry
Caryophyllaceae	SINO	*Silene noctiflora*	nightflowering silene
Chenopodiaceae	CHAL7	*Chenopodium album*	common lambsquarters, lambsquarters, lambsquarters goosefoot, white goosefoot
	CHBEZ	*Chenopodium berlandieri* var. *zschackii*	pit-seed goosefoot, Zschack goosefoot, Zschack's goosefoot
	CHPR5	*Chenopodium pratericola*	desert goosefoot
Cyperaceae	CAREX	*Carex*	carex, sedge
	CABA3	*Carex backii*	back sedge, Back's sedge
	CADU6	*Carex duriuscula*	needleleaf sedge, spike-rush sedge
	CAFI	*Carex filifolia*	threadleaf sedge
	CAINH2	*Carex inops* ssp. *heliophila*	sun sedge
	CARI	*Carex richardsonii*	Richardson sedge, Richardson's sedge
Elaeagnaceae	SHCA	*Shepherdia canadensis*	russet buffalo-berry, russet buffaloberry
Ericaceae	ARUV	*Arctostaphylos uva-ursi*	bearberry, bearberry manzanita, kinnikinnick, mealberry
Euphorbiaceae	EUES	*Euphorbia esula*	leafy spurge
Fabaceae	ASTRA	*Astragalus*	astragalus spp., locoweed, locoweed species, milkvetch
	ASAG2	*Astragalus agrestis*	cocks-head, field milkvetch, purple milkvetch

Family	Code	Scientific Name	Common Names
	ASDR3	*Astragalus drummondii*	Drummond milkvetch, Drummond's milk-vetch, Drummond's milkvetch
	ASFL2	*Astragalus flexuosus*	flexile milkvetch, pliant milk-vetch, pliant milkvetch
	ASGR3	*Astragalus gracilis*	slender milkvetch
	ASLAR	*Astragalus laxmannii* var. *robustior*	prairie milkvetch
	ASMID	*Astragalus miser* var. *decumbens*	prostrate milkvetch
	ASMI10	*Astragalus missouriensis*	Missouri milkvetch
	ASSP6	*Astragalus spatulatus*	tufted milk-vetch, tufted milkvetch
	DACAO	*Dalea candida* var. *oligophylla*	white dalea, white prairie clover, white prairie-clover, white prairieclover
	DAPUP	*Dalea purpurea* var. *purpurea*	Purple prairieclover, violet dalea, violet prairie clover, violet prairie-clover, violet prairieclover
	GLLE3	*Glycyrrhiza lepidota*	American licorice, licorice, wild licorice
	HEAL	*Hedysarum alpinum*	alpine sweetvetch
	LUAR3	*Lupinus argenteus*	silvery lupine
	MELU	*Medicago lupulina*	black medic, black medic clover, black medick, hop clover, hop medic, nonesuch, yellow trefoil
	MEOF	*Melilotus officinalis*	yellow sweet-clover, yellow sweetclover
	OXSES	*Oxytropis sericea* var. *sericea*	silvery oxytrope, white locoweed
	PEAR6	*Pediomelum argophyllum*	silverleaf Indian breadroot, silverleaf scurfpea
	PEES	*Pediomelum esculentum*	breadroot scurfpea, Indian breadroot, large Indian breadroot
	PSTE5	*Psoralidium tenuiflorum*	scurfpea, slimflower scurfpea
	VIAM	*Vicia americana*	American deervetch, American vetch
Gentianaceae	FRSP	*Frasera speciosa*	deer ears, elkweed, green gentian, monument plant, monument-plant, showy frasera
Grossulariaceae	RIBES	*Ribes*	currant
	RIOX	*Ribes oxyacanthoides*	Canadian gooseberry
Iridaceae	IRMI	*Iris missouriensis*	Rocky Mountain iris, western blue flag, wild iris, wildiris
	SIMO2	*Sisyrinchium montanum*	mountain blue eyedgrass, mountain blueeyed grass, strict blue-eyed grass, strict blue-eyed-grass
Lamiaceae	MOFI	*Monarda fistulosa*	mintleaf beebalm, Oswego-tea, wild bergamot, wildbergamot beebalm, wildbergamot horsemint
Liliaceae	ALCE2	*Allium cernuum*	nodding onion
	ALTE	*Allium textile*	prairie onion, textile onion, wild onion
	CALOC	*Calochortus*	mariposa lily
	CAGU	*Calochortus gunnisonii*	Gunnison mariposa lily, Gunnison's mariposa lily
	MAST4	*Maianthemum stellatum*	false Solomons seal, starry false lily of the vally, starry false Solomon's seal, Starry false solomon's-seal, starry Solomon's-seal
Linaceae	LICO3	*Linum compactum*	Wyoming flax
	LILEL2	*Linum lewisii* var. *lewisii*	prairie flax
Malvaceae	SPCO	*Sphaeralcea coccinea*	copper mallow, orange globemallow, red falsemallow, scarlet globemallow
Melanthiaceae	ANELE	*Anticlea elegans* var. *elegans*	mountain deathcamas
	TOVEV	*Toxicoscordion venenosum* var. *venenosum*	death camas, meadow deathcamas
Monotropaceae	PTAN2	*Pterospora andromedea*	woodland pinedrops

Family	Code	Scientific Name	Common Names
Onagraceae	GACO5	*Gaura coccinea*	scarlet beeblossom, scarlet gaura, Scarlet guara
Pinaceae	PIPO	*Pinus ponderosa*	ponderosa pine
Poaceae	ACRI8	*Achnatherum richardsonii*	Richardson needlegrass, Richardson's needlegrass
	ANGE	*Andropogon gerardii*	big bluestem, bluejoint, turkeyfoot
	BOCUC2	*Bouteloua curtipendula* var. *curtipendula*	side-oats grama, sideoats grama
	BOGR2	*Bouteloua gracilis*	blue grama
	BRAN	*Bromus anomalus*	nodding brome, nodding bromegrass
	BRCI2	*Bromus ciliatus*	fringed brome
	BRIN2	*Bromus inermis*	awnless brome, smooth brome
	BRJA	*Bromus japonicus*	Japanese brome, Japanese bromegrass, Japanese chess
	DAIN	*Danthonia intermedia*	timber oatgrass
	DASP2	*Danthonia spicata*	poverty danthonia, poverty oatgrass, poverty wild oat grass
	ELTRS	*Elymus trachycaulus* ssp. *subsecundus*	bearded wheatgrass, slender wheatgrass, slender wild rye
	ELTRT	*Elymus trachycaulus* ssp. *trachycaulus*	slender wheatgrass
	ELVI3	*Elymus virginicus*	Virginia wildrye
	HECOC8	*Hesperostipa comata* ssp. *comata*	needle and thread, needleandthread
	HECU9	*Hesperostipa curtiseta*	shortbristle needle and thread
	HESP11	*Hesperostipa spartea*	porcupinegrass
	KOMA	*Koeleria macrantha*	junegrass, prairie Junegrass
	LEIN6	*Leymus innovatus*	downy ryegrass
	MUCU3	*Muhlenbergia cuspidata*	plains muhly
	MURA	*Muhlenbergia racemosa*	green muhly, marsh muhly
	NAVI4	*Nassella viridula*	green needlegrass
	PASM	*Pascopyrum smithii*	pubescent wheatgrass, western wheatgrass
	POCO	*Poa compressa*	Canada bluegrass, flat-stem blue grass
	POPA2	*Poa palustris*	fowl blue grass, fowl bluegrass
	POPR	*Poa pratensis*	Kentucky bluegrass
	PSSPS	*Pseudoroegneria spicata* ssp. *spicata*	bluebunch wheatgrass, bluebunch-wheat grass
	SCSCS	*Schizachyrium scoparium* var. *scoparium*	little bluestem
Polemoniaceae	PHAL3	*Phlox alyssifolia*	alyssum-leaf phlox, alyssumleaf phlox, phlox
	PHHO	*Phlox hoodii*	Hood's phlox, spiny phlox
Polygalaceae	POAL4	*Polygala alba*	milkwoart (White), white milkwort
Polygonaceae	POAC3	*Polygonum achoreum*	leathery knotweed, striate knotweed
Primulaceae	ANSE4	*Androsace septentrionalis*	northern rockjasmine, pygmy-flower rock-jasmine, pygmyflower rockjasmine
	LYCI	*Lysimachia ciliata*	fringed loosestrife, fringed yellow-loosestrife
Pteridaceae	PEAT2	*Pellaea atropurpurea*	purple cliffbrake, purple-stem cliffbrake
Ranunculaceae	ANCY	*Anemone cylindrica*	candle anemone, cottonweed
	ANMUM3	*Anemone multifida* var. *multifida*	Pacific anemone

Family	Code	Scientific Name	Common Names
	ANPAM	*Anemone patens* var. *multifida*	cutleaf anemone, eastern pasqueflower
Rosaceae	AMAL2	*Amelanchier alnifolia*	juneberry, pacific serviceberry, saskatoon serviceberry, Saskatoon serviceberry, western serviceberry, western shadbush
	CEMO2	*Cercocarpus montanus*	alderleaf cercocarpus, alderleaf mountain mahogany, birchleaf mountainmahogany, mountainmahogany, true mountain mahogany, true mountainmahogany
	FRVIG2	*Fragaria virginiana* ssp. *glauca*	blueleaf strawberry, Virginia strawberry
	GETR	*Geum triflorum*	old man's whiskers, prairie smoke, prairiesmoke
	PHMO4	*Physocarpus monogynus*	mountain ninebark
	POCOC3	*Potentilla concinna* var. *concinna*	elegant cinquefoil, red cinquefoil
	POGLP	*Potentilla glandulosa ssp. pseudorupestris*	sticky cinquefoil
	POGR9	*Potentilla gracilis*	graceful cinquefoil, northwest cinquefoil, slender cinquefoil
	PRVIM	*Prunus virginiana* var. *melanocarpa*	black chokecherry
	ROACS	*Rosa acicularis* ssp. *sayi*	prickly rose
	ROAR3	*Rosa arkansana*	Arkansas rose, prairie rose, prairie wildrose, wild rose, wildrose (prairie)
	ROWO	*Rosa woodsii*	Wood's rose, woods rose, Woods' rose
Rubiaceae	GABO2	*Galium boreale*	northern bedstraw
Santalaceae	COUMP	*Comandra umbellata* ssp. *pallida*	bastard toadflax, bastard-toadflax, common toadflax, pale bastard toadflax, pine bastard toadflax
Saxifragaceae	HERI	*Heuchera richardsonii*	alumroot, Richardson's alumroot
Scrophulariaceae	BEWY	*Besseya wyomingensis*	Wyoming besseya, Wyoming kittentail
	CASU12	*Castilleja sulphurea*	sulphur Indian paintbrush, sulphur Indianpaintbrush
	VETH	*Verbascum thapsus*	big taper, common mullein, flannel mullein, flannel plant, great mullein, mullein, velvet dock, velvet plant, woolly mullein
Solanaceae	PHVI5	*Physalis virginiana*	Virginia groundcherry
Unknown Family	UNKFORB	*Unknown forb*	Unknown forb
	UNKGRAM	*Unknown graminoid*	Unknown graminoid
Verbenaceae	VEBR	*Verbena bracteata*	bigbract verbena, bracted vervain, carpet vervain, prostrate verbena, prostrate vervain
Violaceae	VIOLA	*Viola*	violet
	VIAD	*Viola adunca*	blue violet, hook violet, hookedspur violet
	VINU2	*Viola nuttallii*	Nuttall violet, Nuttall's violet, yellow prairie violet

NPS 146/112793, February 2012

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