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Natural Resource Stewardship and Science

Knife River Indian Villages National Historic Site Plant Community Composition and Structure Monitoring

2011 Annual Report

Natural Resource Technical Report NPS/NGPN/NRTR—2012/529

ON THE COVER
A view of a Knife River Indian Villages National Historic Site, 2011
Photograph by: Ryan Manuel NGPN, NPS

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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 Knife River Indian Villages National Historic Site (KNRI). We visited 8 long-term monitoring plots from July 25-28th, 2011, and recorded a total of 117 vascular plant species. This effort was the first year in a multiple-year venture to understand the status of upland plant communities in KNRI. At the end of 5 years, there will be an in-depth report describing the status of the plant community. In this report, we provide a simple summary of our results from sampling in 2011. We found the following:

- KNRI grasslands were highly productive compared to other grasslands in NGPN. The absolute vascular plant cover was very high which was likely due to a wet spring. Grasses and sedges made up the bulk of vascular plant cover at all sites. Bare soil made up a relatively low portion of ground cover

- The sites at KNRI had a low to moderate diversity of native plants compared to other grasslands in the network. Average native species richness in the 10 m^2 plots was 8.2 ± 5.23 species (mean ± standard deviation). Forbs, or broad-leaved herbaceous plants, were more diverse than grasses and sedges in these plots, despite making up less of the total cover.

- Exotic species occurred in all plots we visited and the relative cover of exotics species was 62.3 ± 30.5 % across the plots. Kentucky bluegrass and smooth brome were particularly abundant.

- In the 3 plots we visited with woody species, we found few live healthy trees. Snags and trees with considerable dieback were common. There was a high density of seedlings in 2 of these sites.

- While the majority of plant community monitoring plots at KNRI in 2011 had evidence of recent disturbance, resource management was successful at removing all target exotic species in an area that was recently seeded with native grasses. We did not document any sites in the park where an exotic target species made up greater than 5% of plant cover.

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 Management team for ongoing assistance with fieldwork and development of methods. We greatly appreciate the staff at KNRI for providing logistical support. The 2011 NGPN vegetation field crew of Kara Paintner-Green, Michael Prowatzke, Ryan Manuel, Lee Margadant, and Belinda Lo collected all the data included in this report. 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 John Moeykens 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 thirteen parks located in 5 northern Great Plains states across 6 ecoregions (Figure 1) and vary widely in size, amount of visitor use, and management context.

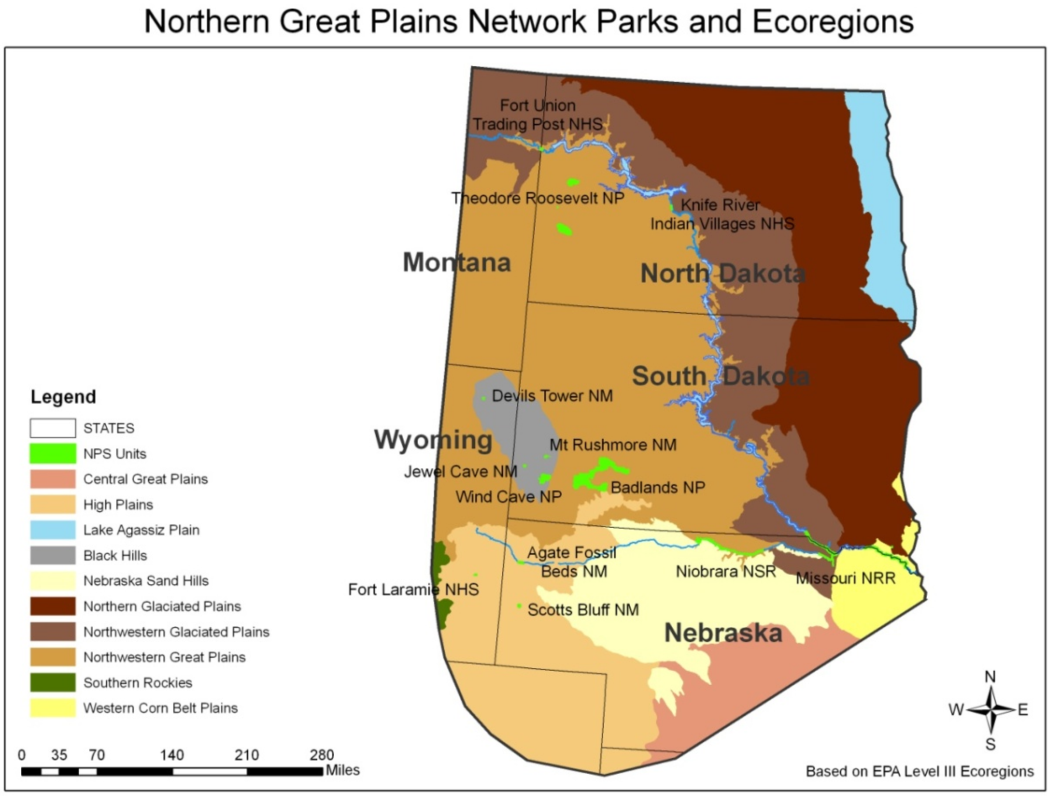

Figure 1. Parks and ecoregions of the Northern Great Plains Network. Based on the U.S. Environmental Protection Agency's Level III ecoregions classes (Omernik 2007).

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 the source of food for other 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 KNRI 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 status (at 5 year intervals) and long-term trends of tree density by species, height class, and diameter class in lowland riparian areas.

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 KNRI. We visited 8 plots in a rotating panel design and it will take 4 more years to visit every plot in the park. 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). 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 KNRI 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 KNRI, we define the target population as vegetation in the entire park and the sample frame as all vegetation. Woody riparian areas will be sampled as part of a separate effort starting in 2014 and every 5 years thereafter. 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. In KNRI, we also excluded mowed areas and high-density cultural areas. The final design includes 20 randomly located sites 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 broken down 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 1year 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 KNRI, we will visit 2 panels each with 4 sites every year and after 5 years we will have visited all sites twice (Figure 3). In 2011, we visited sites in panel 1 and panel 5 (Figure 2).

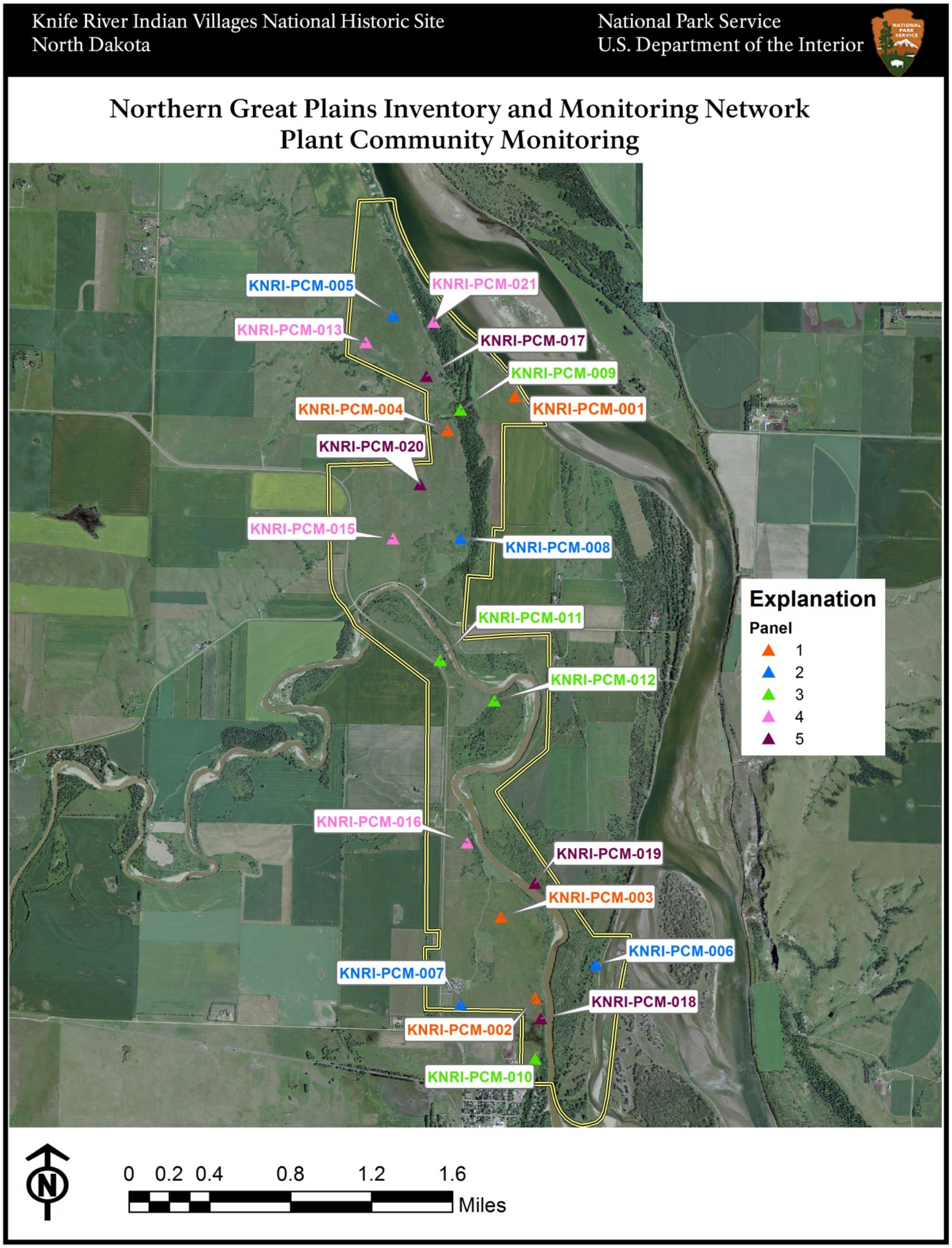

Figure 2. Map of KNRI and plant community monitoring plots. Plots in Panel 1 (orange) and Panel 5 (purple) were visited in 2011.

Year↓ / Panel→	P1	P2	P3	P4	P5
2011	4				4
2012	4	4			
2013		4	4		
2014			4	4	
2015				4	4
2016	4				4
2017	4	4			
2018		4	4		
2019			4	4	
2020				4	4
2021	4				4

Figure 3. [2-3] revisit design for intensive plant community composition and structure monitoring at most NGPN parks. Five panels are used in a park or stratum. Data are collected in the plots of a given panel 2 of every 5 years. Blank cells indicate no plots in the panel are visited that year; at KNRI there are 4 plots in a panel. Thus, 8 plots (2 panels) are sampled each year and the total sample size is 20.

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. At KNRI, there are currently 20 upland monitoring plots, but an additional 20 woody riparian plots will be monitored on a separate 5 year schedule starting in 2014.

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). These are hereafter referred to as “intensive plots”. In 2011, sampling 8 plots at KNRI took a 5 person crew approximately 43 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 intensive 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.

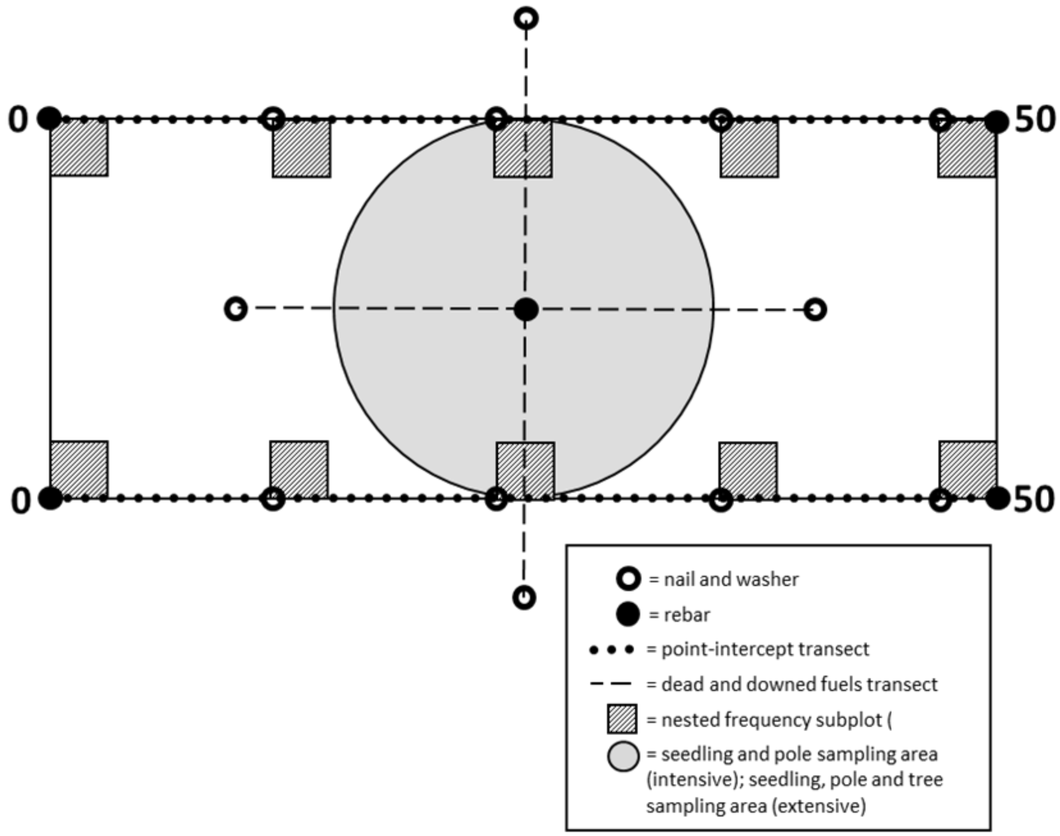

Figure 4. Layout for NGPN intensive plant community composition and structure plots.

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). This method allows absolute canopy covers that are greater than 100% because we record multiple layers of plants (Figure 7). If we hit only 1 plant at all 100 locations this would yield a cover of 100%. In wet years, it often happens that 2 or more plants are hit per location yielding an absolute cover of greater than 100%.

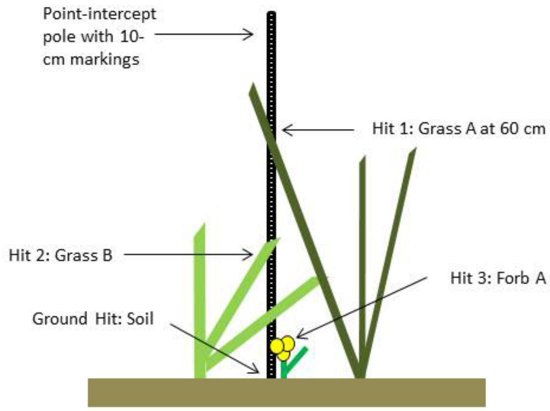

Figure 7. The NGPN point-intercept method captures multiple layers of the plant canopy.

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 (Figures 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).

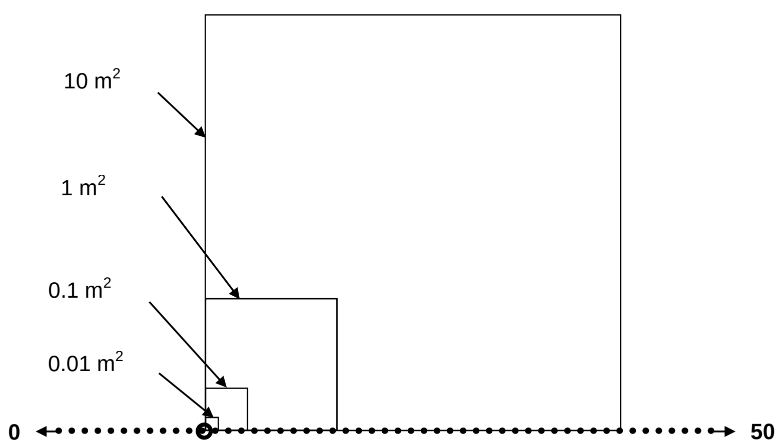

Figure 8. Arrangement of nested quadrats along tape used for point-intercept sampling. Open circle indicates permanent marker (nail and washer or, at 0 end of transect, rebar).

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 and saplings are tallied by species and size class. , Saplings are plants with a diameter at breast height (DBH, where breast height = 137 cm) < 2.54 cm. Seedlings are plants less than1.37 cm in height. Seedlings of less than 1 year are not counted because of their ephemeral nature. DBH, status (live or dead), and species are recorded for all pole-size (2.54 cm ≤ DBH ≤ 15 cm) 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.

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. The KNRI target species list for 2011 can be found in Table 1.

Table 1. Target species in KNRI for the 2011 field season.

	Invasives/noxious weeds/exotics	
Species Code	**Scientific Names**	**Common Names**
ARAB3	*Artemisia absinthium L.*	Absinth wormwood
CIAR4	*Cirsium arvense L.*	Canada thistle
CYOF	*Cynoglossum officinale L.*	Hounds tongue/gypsyflower
EUES	*Euphorbia escula L.*	Leafy spurge

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 1 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 Skinner (2010), in some rare cases they were found by searching the species name in Google scholar. Summaries were done using FFI reports and statistical summaries were done using R software (version 2.11.0).

Results

In the 8 plots we visited in KNRI during 2011, we recorded 117 vascular plant species (Appendix B). We found 1 additional forb species that could not be identified. The most common families were Asteraceae and Poaceae. Three of the plots we visited at KNRI in 2011 had trees, poles, saplings, or seedlings present.

Absolute percent and relative cover

From the point-intercept data, we found plots to average 178 ± 35.5 % (mean ± standard deviation) total herb layer cover and 22 ± 26.9 % ground layer of bare soil. The absolute canopy cover can be greater than 100% because we record multiple layers of plants (Figure 7) and because productivity was high due to a wet spring and summer.

Graminoids, which includes grasses, sedges, and rushes, had an average cover of 151 ± 23.5%. This was much higher than other plant life-forms (Figure 9). Forbs, or broad leaved plants, had an average cover of only 17.5 ± 14.0%. The only vine we recorded along the point-intercept, field bindweed (*Convolvulus arvensis*) was found at only 1 plot, PCM_003. Only 2 species, both of which were exotic graminoids were found in all 8 plots: Kentucky bluegrass (*Poa pratensis;* 45 ± 29.4 % mean absolute cover) and smooth brome (*Bromus inermis;* 53 ± 33.1 %). The most abundant forb species, or broad-leaved herbaceous plants, and shrubs varied considerably among plots. The most abundant forb was yellow sweetclover (*Melilotus officinalis*) with 13 ± 17.0 % mean absolute cover. The most abundant shrub was western snowberry (*Symphoricarpos occidentalis*) and with 13 ± 10.0% mean absolute cover and the most abundant subshrub was white sagebrush (*Artemisia ludoviciana ssp. ludoviciana*) with 7 ± 7.3% mean absolute cover.

Of the 8 plots, the average relative percent cover of exotic species was 62.3 ± 30.5 %. We found the average relative percent cover of warm season graminoids to be 23 ± 24.6 %.

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 1.7 ± 0.70. Evenness, J', averaged 0.65 ± 0.11 across the plots. When including only native species, average diversity and evenness were 1.7 ± 0.89 and 0.68 ± 0.29, 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 8 plots visited in 2011. In general, richness increases in the larger quadrat size. On average, there are about 3 exotic species found in each plot along the point-intercept (Table 2). Average graminoid richness tends to be higher than forb richness (Table 2).

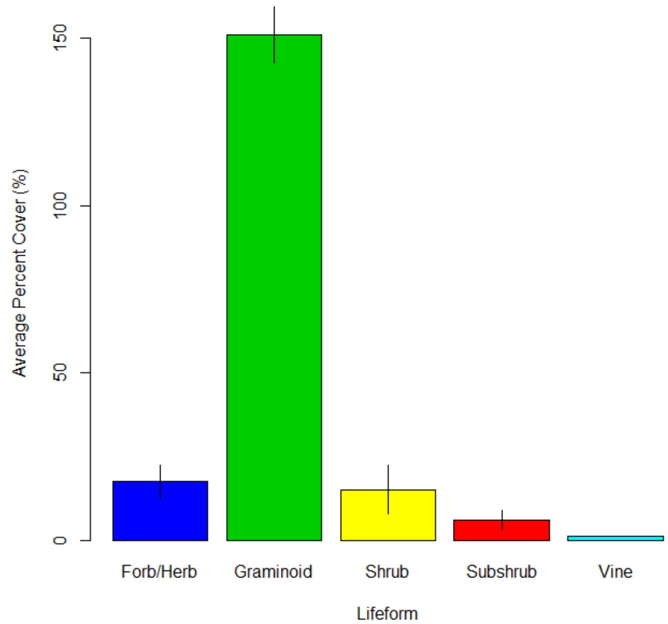

Figure 9. Absolute percent cover of different life-forms in 8 plant community monitoring plots in KNRI in 2011. Bars represent means across the 8 plots ± standard errors. Graminoids, or grasses and sedges, were the most abundant life-form across all plots at KNRI.

Table 2. Average plant species richness at 8 plots at KNRI in 2011. Values represent means ± standard deviation.

	Point-intercept	**1 m^2 quadrat**	**10 m^2 quadrats**
Species richness	15.6 ± 8.19	7.2 ± 2.66	11.3 ± 4.61
Native species richness	12.5 ± 8.59	5.1 ± 3.21	8.2 ± 5.23
Exotic species richness	3.1 ± 0.99	2.3 ± 1.00	3.2 ± 0.86
Graminoid species richness	8.3 ± 3.92	3.3 ± 1.17	4.2 ± 1.76
Forb species richness	5.8 ± 3.77	3.3 ± 1.53	5.7 ± 2.73

Forest structure and health

In 2011, 3 of the 8 plots we visited in KNRI had woody species. We measured the density of 2 tree species, boxelder (*Acer negundo*) and green ash (*Fraxinus pennsylvanica*), and 2 tall shrub species, chokecherry (*Prunus virginiana*) and silver buffaloberry (*Shepherdia argentea*). The density of these species at each plot is given in Table 3. Tall shrub species are considered poles when their diameter 30 cm above the root collar is greater than 1 in (2.54 cm). We did not find any saplings at KNRI in these 3 plots.

Table 3. Tree and tall shrub density at 3 forested plots at KNRI in 2011.

Plot	Size Class	**Boxelder** (stems hectare^{-1})	**Green Ash** (stems hectare^{-1})	**Chokecherry** (stems hectare^{-1})	**Silver buffaloberry** (stems hectare^{-1})	**Snag** (stems hectare^{-1})
KNRI_PCM_002	Trees	-	40	-	-	50
	Poles	-	32	-	127	955
	Seedlings	32	509	-	223	-
KNRI_PCM_019	Trees	-	30	-	-	20
	Poles	-	-	-	-	32
	Seedlings	-	-	-	-	-
KNRI_PCM_020	Trees	-	-	-	-	-
	Poles	-	-	-	-	96
	Seedlings	-	-	2069	95	-

We found only 5 living trees, or tall shrubs of the pole or tree size class, across the 3 plots. Two of these 5 live trees showed evidence of greater than 10% mortality of their branches. Snags were more common across the plots (Figure 10). There was a high density of chokecherry seedlings in PCM_020 and green ash, boxelder, and silver buffaloberry seedlings were common at PCM_002.

Figure 10. A forested plot in KNRI shows evidence of tree mortality.

Target species assessments and disturbance

The abundance of target species was assessed in 2 ways: the presence or absence in the whole plot area and the abundance class in the whole plot area. All 4 target species were found in at least 1 of the 8 plots we visited in 2011 (Table4). Houndstongue and leafy spurge were relatively rare and seen in only 1 site, each in low abundances (Table 4). Canada thistle and absinth wormwood were more common and seen in the majority of plots. One plot, PCM_001, did not have any target species.

In general, the sites at KNRI showed high levels of disturbance. Four of the 8 plots showed evidence of fire from several years ago. At 3 sites (PCM_003, PCM_002, and PCM_018) there was evidence of herbicide treatment of absinth wormwood and ATV tracks. The plot with no target species, PCM_001, had recently been seeded with warm season grasses. Isolated areas of pocket gopher disturbance were seen in PCM_001, PCM-004, and PCM-020.

Table 4. Cover class of target species at 8 plots at KNRI in 2011. 1 = one individual, 2 = few individuals, 3 = cover 1-5% of site, 4 = cover 5-25% of site, 5 = cover> 25% of site, present = present at site but cover was not assessed.

Site	Target Species (abundance class)			
	Absinth wormwood	Canada Thistle	Hounds-tongue	Leafy Spurge
KNRI_PCM_001	-	-	-	-
KNRI_PCM_002	2	2	-	-
KNRI_PCM_003	3	-	-	-
KNRI_PCM_004	-	1	-	-
KNRI_PCM_017	-	2	-	-
KNRI_PCM_018	2	present	-	2
KNRI_PCM_019	-	2	-	-
KNRI_PCM_020	2	2	1	-

Discussion

The goal of our plant community monitoring efforts in KNRI 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 some variation among plots, but on average bare soil was one-fifth of ground cover. Absolute vascular plant cover averaged 178%; productivity was likely high due to a wet spring. KNRI had one of the highest vascular plant cover in the NGPN. The sites at KNRI had a fairly low diversity of vascular plants. Average native species richness in the 10 m^2 plots was 8 ± 5.2 species (Table 2). We found a greater number of species using the point-intercept method compared to the nested-quadrats. The plots at KNRI showed high levels of disturbance due to active exotic plant management and recent fires. Small mammal disturbance was found 3 plots. Moderate disturbance can contribute to diversity in grasslands (Collins and Barber 1986) and the diversity (H') at KNRI is typical of grasslands in good condition (Bai et al. 2001).

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 were more diverse in the 10 m^2 quadrats than graminoids (Table 2). Graminoids can be 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 is a warm season grass. At these 8 sites, 23% of the relative cover was made up of warm-season grasses. 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.

Three of the 8 plots we examined had trees present. The species and sizes classes varied considerably across plots (Table 3) across 4 species: boxelder, green ash, chockecherry, and silver buffaloberry. We found very few healthy live trees in the 3 plots, but there were a large number of seedlings. In 2014, we will visit a set of 20 woody riparian plots to better estimate the status of KNRI forests.

Exotics species occurred in all 8 plots we visited and Kentucky bluegrass and smooth brome were abundant in all sites. We found target exotic species in only 7 of the 8 plots. The plot with no target exotic species, PCM_001, had recently been seeded with warm season grasses. At the scale of the 10 m^2 quadrat, we found an average of 3.2 exotic species. We did not find any target species to be greater than 5% cover.

Results from our vegetation monitoring can be summarized in a "connect-the-dots" or a resource condition summary table (Table 5). 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 KNRI. The current value is based on sampling in 2011 and the level of inference is simply 8 sites. After 1 complete rotation in the KNRI sampling design (5 years), current values will be the average across 5 years and the level of inference will be park-wide. At that time, we will also 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 KNRI.

Table 5. Natural resource condition summary table for plant communities in KNRI.

Vital Sign	Metric	Current Value (mean ± SD)	Level of inference	Reference Value	Rationale
Exotic Plant Early Detection	% of sites where target species were encountered	87.5%	8 sites	TBD	Early detection of exotic species
	Number of sites where Canada Thistle abundance > 5%	0	8 sites	TBD	Effectiveness of exotic species management
Upland Plant Communities	Mean absolute herb-layer cover	178 ± 35.5 %	8 sites	TBD	Forage availability, climatic trends, erosion potential, habitat for small mammals and birds
	Ground-layer bare soil cover	22 ± 26.9 %	8 sites	TBD	
	Mean relative percent cover of exotic species	62.3 ± 30.5 %	8 sites	TBD	Effectiveness of exotic species management
	Percent of graminoid cover that is warm season	23 ± 24.6 %	8 sites	TBD	Climatic trends
	Mean native species richness in 10 m^2 quadrat	8.2 ± 5.23 species	8 sites	TBD	Diversity maintenance

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

Plant community composition monitoring in KNRI was completed using a crew of 5 people working 4 10-hour days with approximately 2.5 hours of overtime. The crew drove one vehicle and the total mileage for the trip was 548.5 miles. A total of 212.5 crew hours were expended in monitoring KNRI in 2011.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed
Jul 25, 2011	Monday	3.5	Roughrider, Hazen	PCM-003
Jul 26, 2011	Tuesday	N/A	Roughrider, Hazen	PCM-002 PCM-018 PCM-019
Jul 27, 2011	Wednesday	N/A	Roughrider, Hazen	PCM-001 PCM-017
Jul 28, 2011	Thursday	3.5	Roughrider, Hazen	PCM-004 PCM-020

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

Family	Code	Scientific Name	Common Names
Aceraceae	ACNE2	*Acer negundo*	ashleaf maple, box elder, boxelder, boxelder maple, california boxelder, manitoba maple, western boxelder
Amaranthaceae	AMRE	*Amaranthus retroflexus*	careless weed, Pigweed, red-root amaranth, redroot amaranth, redroot pigweed, rough pigweed
Asclepiadaceae	ASPU	*Asclepias pumila*	low milkweed, plains milkweed
	ASSP	*Asclepias speciosa*	showy milkweed
Asteraceae	ACMI2	*Achillea millefolium*	bloodwort, carpenter's weed, common yarrow, hierba de las cortaduras, milfoil, plumajillo, western yarrow, yarrow (common)
	AMPS	*Ambrosia psilostachya*	Cuman ragweed, perennial ragweed, western ragweed
	ANPA4	*Antennaria parvifolia*	little-leaf pussytoes, Rocky Mountain pussytoes, small leaf pussytoes, small-leaf pussytoes, smalleaf pussytoes, smallleaf pussytoes
	ARMI2	*Arctium minus*	bardane, beggar's button, burdock, common burdock, lesser burdock, lesser burrdock, small burdock, smaller burdock, wild burdock, wild rhubarb
	ARAB3	*Artemisia absinthium*	absinth sagewort, absinth wormwood, absinthium, common sagewort
	ARDR4	*Artemisia dracunculus*	false tarragon, green sagewort, silky wormwood, tarragon, wormwood
	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*	Californian thistle, Canada thistle, Canadian thistle, creeping thistle, field thistle
	CIFL	*Cirsium flodmanii*	Flodman thistle, Flodman's thistle
	COCA5	*Conyza canadensis*	Canada horseweed, Canadian horseweed, horseweed, horseweed fleabane, mares tail, marestail
	ECAN2	*Echinacea angustifolia*	Blacksamson, blacksamson echinacea
	ERST3	*Erigeron strigosus*	Daisy Fleabane, prairie fleabane, rough fleabane
	HEMA2	*Helianthus maximiliani*	Maximilian sunflower, Maximillian sunflower
	HEVIV	*Heterotheca villosa* var. *villosa*	hairy false golden-aster, hairy false goldenaster
	LASE	*Lactuca serriola*	China lettuce, prickly lettuce, wild lettuce
	LILI	*Liatris ligulistylis*	Rocky Mountain blazing star, Rocky Mountain gayfeather, strap-style gayfeather
	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
	RACO3	*Ratibida columnifera*	Prairie coneflower, prairie coneflower (upright), prairieconeflower, redspike Mexican hat, upright prairie coneflower
	SOMI2	*Solidago missouriensis*	Missouri goldenrod, prairie goldenrod
	SOMO	*Solidago mollis*	ashy goldenrod, soft goldenrod, velvety goldenrod, woolly goldenrod
	SORIR	*Solidago rigida* ssp. *rigida*	stiff goldenrod
	SYERE	*Symphyotrichum ericoides* var. *ericoides*	white heath aster
	SYLAH	*Symphyotrichum*	white panicle aster

Family	Code	Scientific Name	Common Names
		lanceolatum ssp. *hesperium*	
	SYOB	*Symphyotrichum oblongifolium*	aromatic aster
	TAOF	*Taraxacum officinale*	blowball, common dandelion, dandelion, faceclock
	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
	XASP	*Xanthisma spinulosum*	cut-leaf ironplant, lacy tansyaster, spiny goldenweed
Boraginaceae	CYOF	*Cynoglossum officinale*	gypsyflower
	LIIN2	*Lithospermum incisum*	fringed gromwell, Fringed puccoon, narrowleaf gromwell, narrowleaf pucoon, narrowleaf stoneseed, trumpet stoneseed
	ONBEO	*Onosmodium bejariense var. occidentale*	western marbleseed
Brassicaceae	BOFE	*Boechera fendleri*	Fendler's rockcress
	BOHO2	*Boechera holboellii*	Holboell rockcress, Holboell's rockcress
	DESO2	*Descurainia sophia*	flaxweed tansymustard, flixweed, flixweed tansymustard, herb sophia, herb-sophia, pinnate tansymustard, tansymustard
	HEMA3	*Hesperis matronalis*	dame rocket, dame's rocket, dames rocket, dames violet, mother-of-the-evening
Cannabaceae	HULU	*Humulus lupulus*	common hop, common hops, hops
Caprifoliaceae	SYOC	*Symphoricarpos occidentalis*	western snowberry, wolfberry
Chenopodiaceae	CHAL7	*Chenopodium album*	common lambsquarters, lambsquarters, lambsquarters goosefoot, white goosefoot
Convolvulaceae	COAR4	*Convolvulus arvensis*	creeping jenny, European bindweed, field bindweed, morningglory, perennial morningglory, smallflowered morning glory
Cyperaceae	CABR10	*Carex brevior*	shortbeak sedge
	CAFI	*Carex filifolia*	threadleaf sedge
	CAINH2	*Carex inops* ssp. *heliophila*	sun sedge
Elaeagnaceae	SHAR	*Shepherdia argentea*	silver buffaloberry
Euphorbiaceae	CHSES	*Chamaesyce serpyllifolia* ssp. *serpyllifolia*	thyme-leaf sandmat, thymeleaf sandmat, thymeleaf spurge
	EUES	*Euphorbia esula*	leafy spurge, spurge, wolf's milk, wolf's-milk
Fabaceae	ACAMA	*Acmispon americanus* var. *americanus*	American bird's-foot trefoil, American bird's-foot-trefoil, prairie trefoil, Spanish clover
	AMNA	*Amorpha nana*	dwarf false indigo, dwarf indigo, dwarf indigobush
	ASLAR	*Astragalus laxmannii* var. *robustior*	prairie milkvetch
	ASMI10	*Astragalus missouriensis*	Missouri milk-vetch, Missouri milkvetch
	DAPUP	*Dalea purpurea* var. *purpurea*	Purple prairieclover, violet dalea, violet prairie clover, violet prairie-clover, violet prairieclover
	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
	PEAR6	*Pediomelum argophyllum*	silverleaf Indian breadroot, silverleaf scurfpea
	PSLA3	*Psoralidium lanceolatum*	dune scurfpea, lemmon scurfpea, lemon scurfpea, wild lemonweed
	TRPR2	*Trifolium pratense*	red clover
	VIAM	*Vicia americana*	American deervetch, American vetch

Family	Code	Scientific Name	Common Names
Iridaceae	SIMO2	*Sisyrinchium montanum*	strict blue-eyed grass
Juncaceae	JUBA	*Juncus balticus*	Baltic rush
Lamiaceae	HEHI	*Hedeoma hispida*	false pennyroyal, falsepennyroyal, rough false pennyroyal, rough falsepennyroyal, rough pennyroyal
	NECA2	*Nepeta cataria*	catmint, catnip, catwort, field balm
	STPIP5	*Stachys pilosa* var. *pilosa*	hairy hedgenettle
Liliaceae	ASOF	*Asparagus officinalis*	asparagus, garden asparagus, garden-asparagus
	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	LILEL2	*Linum lewisii* var. *lewisii*	Lewis' flax, prairie flax
	LIRI	*Linum rigidum*	orange flax, Stiff flax, stiffstem flax
Malvaceae	SPCO	*Sphaeralcea coccinea*	copper mallow, orange globemallow, red falsemallow, scarlet globemallow
Oleaceae	FRPE	*Fraxinus pennsylvanica*	green ash
Onagraceae	CASE12	*Calylophus serrulatus*	halfshrub calylophus, halfshrub sundrop, serrateleaf eveningprimrose, yellow sundrops
	GACO5	*Gaura coccinea*	scarlet beeblossom, scarlet gaura, Scarlet guara
Oxalidaceae	OXST	*Oxalis stricta*	common yellow oxalis, erect woodsorrel, sheep sorrel, sourgrass, toad sorrel, upright yellow wood-sorrel, upright yellow woodsorrel, yellow woodsorrel
Plantaginaceae	PLPA2	*Plantago patagonica*	woolly Indianwheat, woolly plantain, woolly plantian, wooly Indianwheat, wooly plantain
Poaceae	AGCR	*Agropyron cristatum*	crested wheatgrass
	ANGE	*Andropogon gerardii*	big bluestem, bluejoint, turkeyfoot
	ARPUL	*Aristida purpurea* var. *longiseta*	Fendler threeawn, Fendler's threeawn, red threeawn, red threeawn (Fendler)
	BOCU	*Bouteloua curtipendula*	sideoats grama
	BOGR2	*Bouteloua gracilis*	blue grama
	BRIN2	*Bromus inermis*	awnless brome, smooth brome
	CALO	*Calamovilfa longifolia*	prairie sandreed
	DIWI5	*Dichanthelium wilcoxianum*	fall panicum, fall rosette grass
	ELCA4	*Elymus canadensis*	Canada wildrye
	ELCA11	*Elymus caninus*	bearded wheatgrass, bearded wild rye
	ELTR7	*Elymus trachycaulus*	slender wheatgrass, slender wild rye
	HECOC8	*Hesperostipa comata* ssp. *comata*	needle and thread, needleandthread
	HOJU	*Hordeum jubatum*	foxtail barley
	KOMA	*Koeleria macrantha*	junegrass, prairie Junegrass
	MUCU3	*Muhlenbergia cuspidata*	plains muhly
	MURA	*Muhlenbergia racemosa*	green muhly, marsh muhly
	NAVI4	*Nassella viridula*	green needlegrass
	PACA6	*Panicum capillare*	annual witchgrass, common panic grass, common witchgrass, panicgrass, ticklegrass, tumble panic, tumbleweed grass, witches hair, witchgrass
	PASM	*Pascopyrum smithii*	pubescent wheatgrass, western wheatgrass
	PEGL2	*Pennisetum glaucum*	pearl millet

Family	Code	Scientific Name	Common Names
	POPR	*Poa pratensis*	Kentucky bluegrass
	SCSCS	*Schizachyrium scoparium* var. *scoparium*	little bluestem
	SONU2	*Sorghastrum nutans*	Indiangrass
	SPCR	*Sporobolus cryptandrus*	sand dropseed
	THIN6	*Thinopyrum intermedium*	intermediate wheatgrass
Polygalaceae	POAL4	*Polygala alba*	milkwoart (White), white milkwort
	POVE	*Polygala verticillata*	whorled milkwort
Polygonaceae	PORA3	*Polygonum ramosissimum*	bushy knotweed, tall knotweed, yellow knotweed, yellow-flower knotweed
Ranunculaceae	ANCY	*Anemone cylindrica*	candle anemone, cottonweed
	THDA	*Thalictrum dasycarpum*	purple meadow-rue, purple meadowrue
Rhamnaceae	RHCA3	*Rhamnus cathartica*	carolina buckthorn, common buckthorn, European buckthorn, European waythorn, Hart's thorn, nerprun cathartique
Rosaceae	PRVI	*Prunus virginiana*	chokecherry, chokecherry (common), common chokecherry, Virginia chokecherry
	ROAR3	*Rosa arkansana*	Arkansas rose, prairie rose, prairie wildrose, wild rose, wildrose (prairie)
Rubiaceae	GABO2	*Galium boreale*	northern bedstraw
Scrophulariaceae	COPA3	*Collinsia parviflora*	blue-eyed Mary, littleflower collinsia, maiden blue eyed Mary, small-flower blue-eyed mary, smallflower blue eyed Mary
Solanaceae	PHVI5	*Physalis virginiana*	ground cherry (Virginia), lanceleaf groundcherry, Virginia ground-cherry, Virginia groundcherry
Unknown Family	UNKFORB	*Unknown forb*	Unknown forb
Urticaceae	PAPE5	*Parietaria pensylvanica*	Pennsylvania pellitory
Verbenaceae	VEBR	*Verbena bracteata*	bigbract verbena
Violaceae	VINU2	*Viola nuttallii*	Nuttall violet, Nuttall's violet, yellow prairie violet
Vitaceae	PAVI5	*Parthenocissus vitacea*	thicket creeper, Virginia creeper, woodbine

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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