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Agate Fossil Beds National Monument Plant Community Composition and Structure Monitoring

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National Park Service
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Natural Resource Stewardship and Science

Agate Fossil Beds National Monument Plant Community Composition and Structure Monitoring

2011 Annual Report

Natural Resource Technical Report NPS/NGPN/NRTR—2011/518

ON THE COVER
A view of a plant monitoring transect at plot PCM-026 in Agate Fossil Beds National Monument, 2011
Photograph by: 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 five 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 (Gitzen et al. 2010). 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 Agate Fossil Beds National Monument (AGFO). We visited six long-term monitoring plots from June 13-16th, 2011, and recorded a total of 109 vascular plant species. This effort was the first year in a multiple-year venture to understand the status of upland plant communities in AGFO. At the end of five years, there will be an in-depth report describing the status of the plant community. In 2013, we will also revisit legacy plots that were established as part of the Prairie Cluster prototype monitoring. In this report, we provide a simple summary of our results from sampling in 2011. We found the following:

- There was considerable variation among plots, but on average bare soil was one-third of ground cover. The absolute vascular plant cover was high due to a wet spring and early summer. Grasses and sedges made up the bulk of vascular plant cover at all sites.

- The sites at AGFO had a large diversity of vascular plants. Average native species richness in the 10 m^2 plots was 15 ± 2.9 species. Forbs, or broad-leaved herbaceous plants, were more diverse than graminoids, despite making up less of the total cover.

- Exotic species occurred in all six plots we visited; however, the relative cover of exotics species was less than 10% across the plots.

- The most common disturbance in plots at AGFO was small mammal burrowing, which occurred at four of the six sites.

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 greatly appreciate the staff at AGFO for providing housing and logistical support. The 2011 NGPN vegetation field crew of Michael Bynum, Timothy Pine, Lauren Baur, and Daina Jackson, 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 the staff at AGFO and Bob Manasek for providing comments on this draft.

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 five northern Great Plains states across six ecoregions (Figure 1) and vary widely in size, amount of visitor use, and management context.

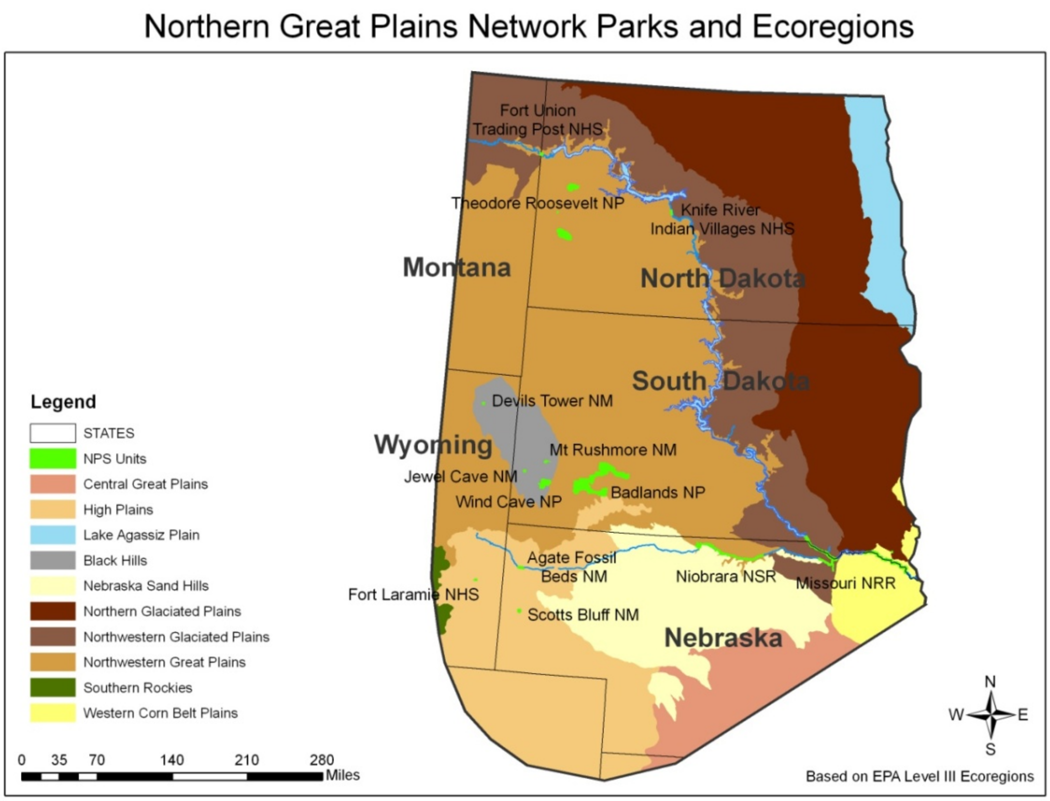

Figure 1. Parks and ecoregions of the Northern Great Plains Network (NGPN). Based on the U.S. Environmental Protection Agency's Level III ecoregions classes (Omernik 2007).

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 (BADL and THRO) 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 ultimate source of food for all other organisms, but they also provide other 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 AGFO 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. 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 AGFO. We visited six plots in a rotating panel design and it will take four 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 five years of sampling (i.e., visit and sample every plot in the park twice, following a rotating panel design that stipulates two years of visitation and three years of rest per five-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 AGFO 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 five 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 AGFO, we define the target population as vegetation in the entire park and the sample frame as all vegetation. Riparian areas are small in area and therefore a randomized sample will not adequately sample them. Therefore, an additional five riparian sites will be added in the future. 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 of prohibitively difficult to access or work on, and areas that are not owned by the park. In AGFO, we also excluded mowed trails. The final design includes 15 randomly located sites representing the park where vegetation will be sampled close to peak phenology (June) (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 two consecutive years followed by three 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 one 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 AGFO, we will visit two panels each with three sites every year and after five years we will have visited all sites twice (Figure 3). In 2011, we visited sites in panel 1 and panel 5 (Figure 2).

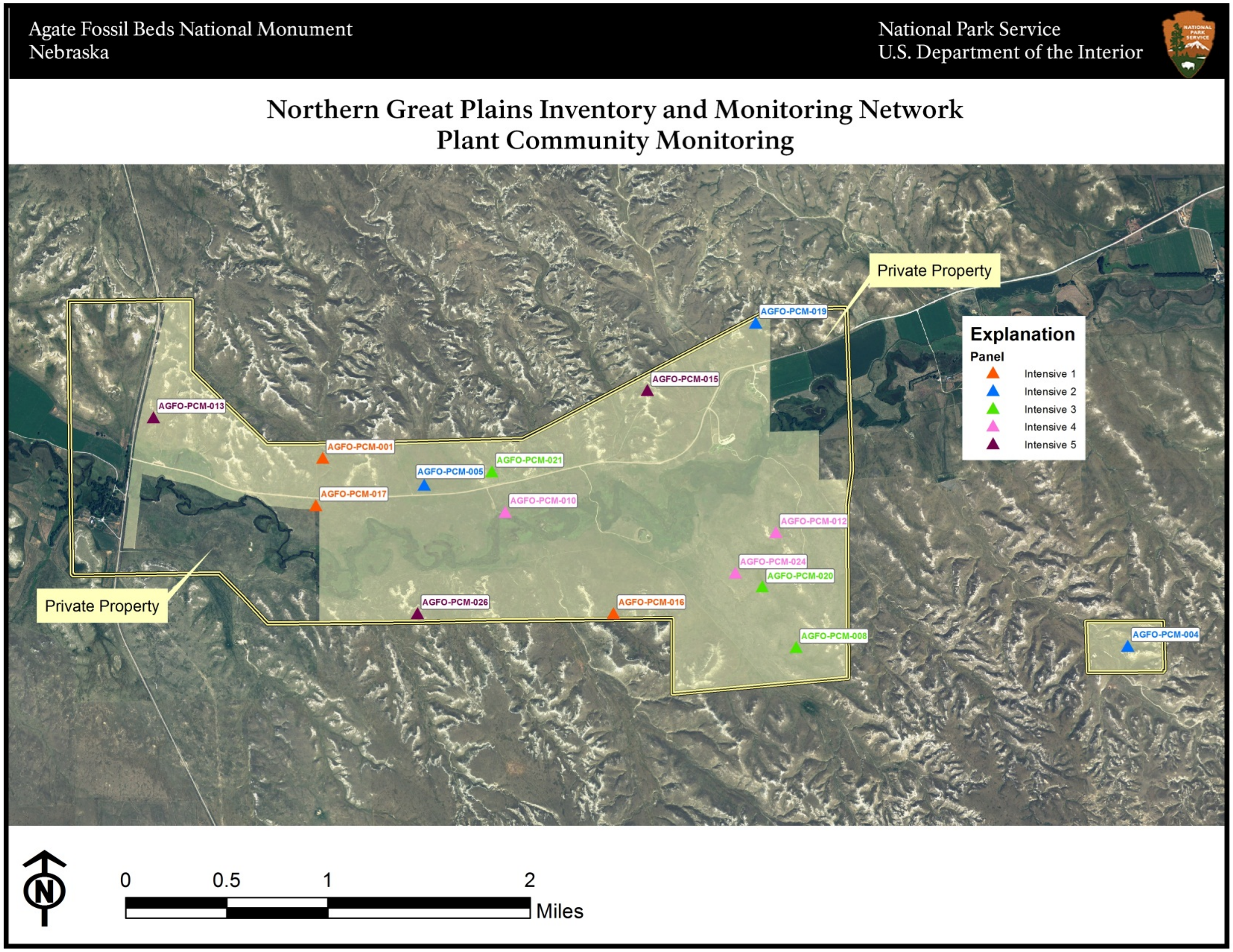

Figure 2. Map of AGFO and plant community monitoring plots. Plots in Panel 1 (orange) and Panel 5 (purple) were visited in 2011.

Year↓ / Panel→	P1	P2	P3	P4	P5
2011	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 a park or stratum. Data are collected in the plots in a panel two of every five years. Blank cells indicate no plots in the panel are visited that year; at AGFO there are three plots in a panel. Thus, six plots (two 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. At AGFO, there are currently 15 monitoring plots but an additional five riparian plots could be added in the future. In addition, legacy plots established as part of the Prairie Cluster Prototype will be visited in 2013 and every five years thereafter.

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 six plots at AGFO took a four person crew approximately 40 hours with travel time (see Appendix 1 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), two 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 two additional perpendicular, 100-ft (30.49 m) transects centered at the C plot marker are marked with large nails and washers (Figure 4). One of these transects is parallel to the herb-layer transects and the second is perpendicular to that transect.

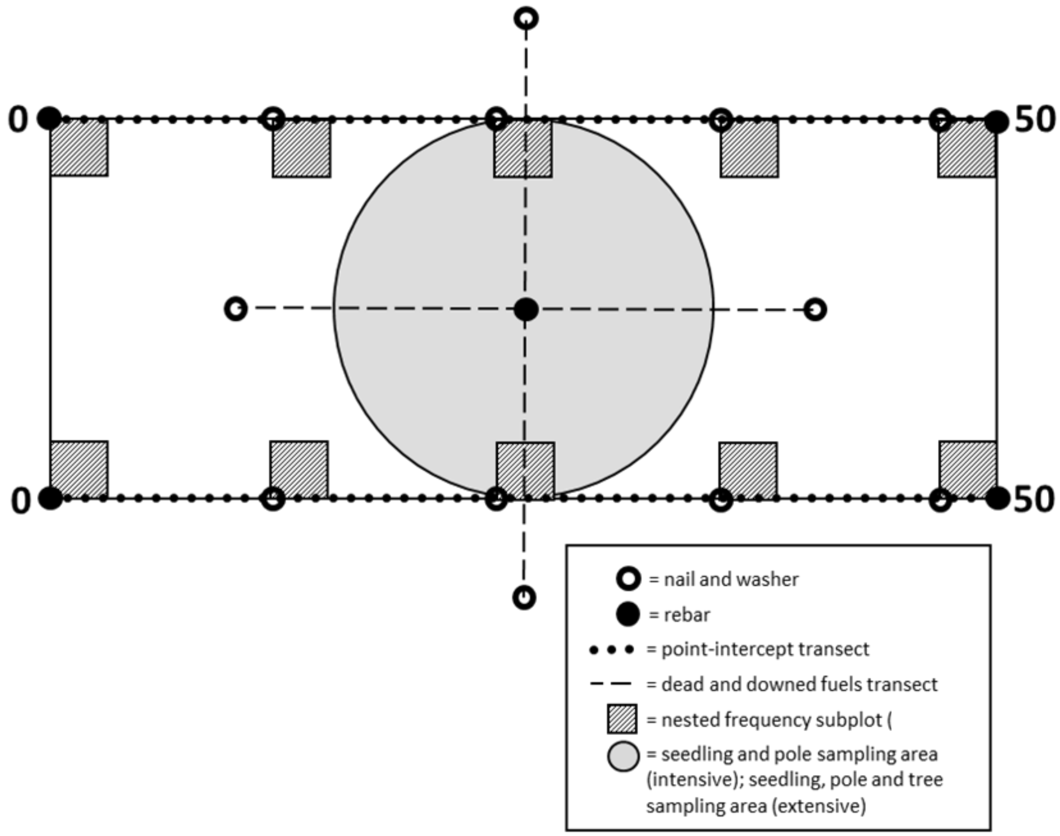

Figure 4. Layout for NGPN intensive plant community composition and structure plots.

Figure 5. A sample of the center markings 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 two 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).

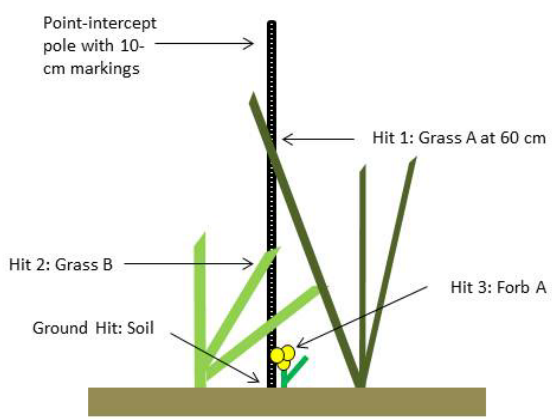

Figure 7. The NGPN point-intercept method captures multiple layers of the plant canopy.

Species richness data from this point-intercept method are supplemented with species presence data collected in five 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 go into the 20 m x 50 m plot and towards the 50 end of the transect (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).

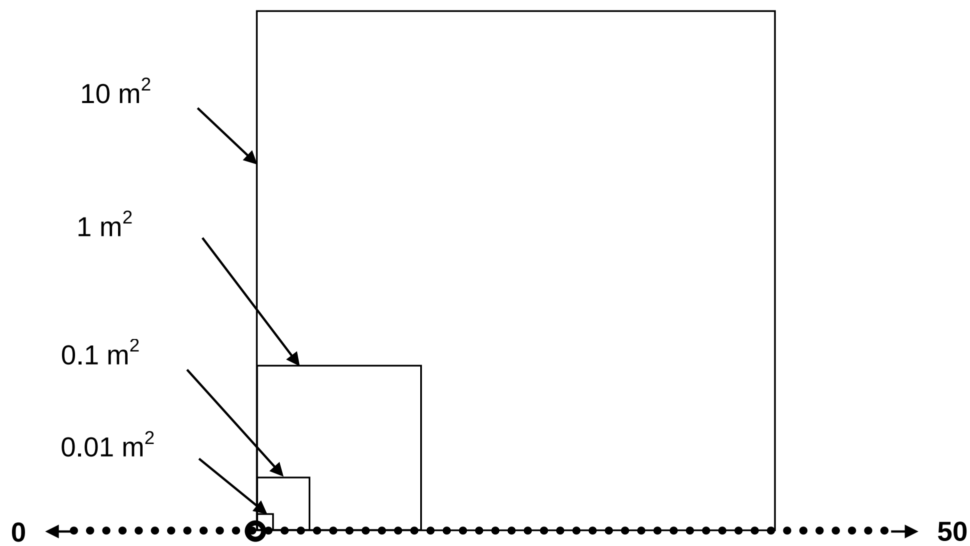

Figure 8. Arrangement of nested quadrats along tape used for point-intercept sampling. Open circle indicates permanent marker (nail and washer or, at 0 end of transect, rebar).

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, with diameter at breast height (DBH, where breast height = 137 cm) < 2.54 cm, are tallied by species; and 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 (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. In addition, this method tracks the presence of plant species that are considered rare or vulnerable to loss. The selected species occur in AGFO but are considered at-risk by the state of Nebraska (Schneider et al. 2005). The AGFO target species list for 2011 can be found in Table 1.

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

	Invasives/noxious weeds/exotics	
Species Code	**Scientific Names**	**Common Names**
BASC5	*Bassia scoparia (L.)* A.J. Scott	Kochia
BRJA	*Bromus japonicus* L.	Japanese brome, field brome
BRIN2	*Bromus inermis* Leyss.	Smooth brome
BRTE	*Bromus tectorum* L.	Cheatgrass
CANU4	*Carduus nutans* L.	Nodding plumeless (musk) thistle
CIAR4	*Cirsium arvense* L.	Canada thistle
COAR4	*Convolvulus arvensis* L.	Field bindweed
EUES	*Euphorbia esula* L.	Leafy spurge
IRPS	*Iris pseudacorus* L.	Pale yellow iris
ONAC	*Onopordum acanthium* L.	Scotch cottonthistle
POPR	*Poa pratensis* L.	Kentucky bluegrass
SAKA	*Salsola kali* L.	Russian thistle
TARA	*Tamarix ramosissima* Ledeb.	Saltcedar
	At risk/rare	
Species Code	**Scientific Name**	**Common Name**
ASBA	*Astragalus barrii* Barneby[2]	Barr's milkvetch
ASSH3	*Astragalus shortianus* Nutt.[2]	Short's milkvetch
DACY	*Dalea cylindriceps* Barneby[2]	Andean prairie clover
ERGO	*Eriogonum gordonii* Benth[2]	Gordon's (wild) buckwheat
GANEC	*Guara neomexicana* ssp. coloradensis (Rydb.) Raven & Gregory[1,2]	Colorado butterfly plant (beeblossom)
LICA36	*Linanthus caesoitosus* (Nutt)[2]	Mat prickly phlox
LONU3	*Lomatium nuttallii* (A. Gray) J.F. Macbr.[2]	Nuthall's biscuitroot
PECR	*Pedicularis crenulata* Benth.[2]	Meadow lousewort
SPDI6	*Spiranthes diluvialis* Sheviak[1,2]	Ute's lady's tresses

[1]Federally listed as threatened; [2]Considered to be globally or nationally at risk by Nebraska

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.nbii.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.

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 is 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 (Skinner 2010). Summaries were done using FFI reports and statistical summaries were done using R software (version 2.11.0).

Results

In the six plots we visited in AGFO during 2011, we recorded 109 vascular plant species (Appendix B). The most common families were Asteraceae and Poaceae. None of the plots we visited at AGFO in 2011 had trees, poles, saplings, or seedlings present, so we did not collect any data on tree regeneration or forest health.

Absolute percent and relative cover

From the point-intercept data, we found plots to average 113 ±11.1 % (mean ± standard deviation) total herb layer cover and 33 ± 11.2 % ground layer of bare soil. 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 99 ± 12.3%. This was much higher than other plant life-forms (Figure 9). The shrub, yucca (*Yucca glauca*), was found at only one plot (PCM-026) but had a relatively high cover. Likewise, two subshrubs, spreading nailwort (*Paronychia depressa*) and broom snakeweed (*Gutierrezia sarothrae*), were found only at PCM-015. The only vine encountered along the two transects, hoary pea (*Lathyrus polymorphus* var. *incanus*), was found at three plots. Only three species, all of which are graminoids, were found in all six plots: needle and thread grass (*Hesperostipa comata* ssp. *comata*; 37± 16.7 % mean absolute cover), slender wheatgrass (*Elymus trachycaulus* ssp. *trachycaulus*; 20 ± 10.2 %) and blue grama (*Bouteloua gracilis*; 3 ± 3.9 %). The most abundant forb species, or broad-leaved herbaceous plants, varied considerably among plots. The most common forbs, horseweed (*Conyza canadensis*) and fringed sagebrush (*Artemisia frigida*), were both found at five plots with 3 ± 2.8% and 2 ± 1.8 % mean absolute cover, respectively.

Of the six plots, the average relative percent cover of exotic species was 8 ± 11.7 %. At AGFO, we found the average relative percent cover of warm season graminoids to be 13 ± 4.1 %.

Species richness, diversity, and evenness

We measured diversity at the plots in two 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 1.9 ± 0.23. Evenness, J', averaged 0.65 ± 0.05 across the plots. When including only native species, average diversity and evenness were 1.8 ± 0.22 and 0.65 ± 0.05, respectively. Species richness varies by the scale that it is examined. Table 2 presents average species richness for the point-intercept, 1 m^2 plots, and 10 m^2 plots for the six plots in 2011. In general, richness increases in the larger plot size. On average, there are about two exotic species found in each plot along the point-intercept (Table 2). Average forb richness tends to be higher than graminoid richness (Table 2).

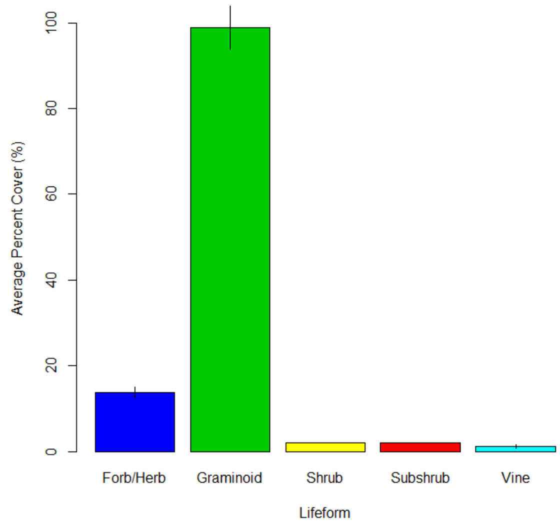

Figure 9. Absolute percent cover of different life-forms in six plant community monitoring plots in AGFO in 2011. Bars represent means across the six plots ± standard errors. Graminoids were the most abundant life-form across all plots at AGFO.

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

	Point-intercept	**1 m^2 plot**	**10 m^2 plot**
Species richness	17.8 (2.79)	10.1 (1.57)	17.3 (2.47)
Native species richness	15.8 (2.56)	9.0 (1.18)	15.1 (2.87)
Exotic species richness	2.0 (1.26)	2.6 (2.05)	2.5 (0.65)
Graminoid species richness	7.0 (1.26)	4.1 (0.86)	5.5 (0.86)
Forb species richness	9.8 (2.32)	5.8 (1.05)	10.7 (1.50)

Target species assessments and disturbance

The abundance of target species can be assessed in four ways: (1) the presence or absence in the whole plot area, (2) the abundance class in the whole plot area, (3) the frequency of the species in the nested quadrats and, (3) the % cover along the point-intercept. Only three target species appeared in our plots: Japanese brome (*Bromus japonicus*), cheatgrass (*Bromus tectorum*) and Kentucky bluegrass (*Poa pratensis*) (Table 3). Japanese brome and Kentucky bluegrass occurred in relatively few plots. From the point-intercept, relative cover of Japanese brome in plot PCM-016 was 2.1% and the field crew record seeing only a few individuals (Table 3). Japanese brome was not hit along the transects in PCM-026. Relative cover of Kentucky bluegrass in plot PCM-017 was 1.9%. Cheatgrass occurred in all six plots and varied in abundance class from just a few individuals to between 5 and 25% cover of the whole plot. The frequency of cheatgrass in the 10

m^2 plots averaged 60 ± 39.4 % across sites. Relative cover of cheatgrass in plot PCM-001, PCM-016, and PCM-017 was 1.3%, 10%, and 27.9%, respectively.

In general, the sites at AGFO showed little evidence of disturbance. Two of the six plots showed no disturbance. The most common type of disturbance was small animal burrows, appearing in four of six sites, and varying in extent from 1-10m^2 area. We also found some lumber in PCM-017 and there is a two-track road on the edge of PCM-001.

Table 3. Cover class of target species at six plots at AGFO 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)		
	Japanese Brome	Cheatgrass	Kentucky bluegrass
AGFO_PCM_001		3	
AGFO_PCM_013		2	
AGFO_PCM_015		2	
AGFO_PCM_016	2	3	
AGFO_PCM_017		4	1
AGFO_PCM_026	Present	Present	

Discussion

The goal of our plant community monitoring efforts in AGFO 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 bare soil was one-third of ground cover. Absolute vascular plant cover averaged over 100%; productivity was high due to a wet spring and early summer. The sites at AGFO had a large diversity of vascular plants. Average native species richness in the 10 m^2 plots was 15 ± 2.9 species (Table 2). We found a very similar number of native species using the point-intercept method as the nested-quadrats. The most common disturbance in plots at AGFO was small mammal burrowing, which occurred at four of the six sites. Small mammal disturbance likely contributes to the relatively high cover of bare soil. One of the two sites with no disturbance (PCM_026) also had the lowest cover of exotic plants. Moderate disturbance can contribute to diversity in grasslands (Collins and Barber 1986) and the diversity (H') at AGFO 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 than graminoids. From the 10 m^2 plots, we found nearly double the number of forbs compared to graminoids (Table 2). Shrubs, vines, and subshrubs were not a large component of the cover at the sites we visited (Figure 9). 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 is a warm season grass. At these six sites, only 13% 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.

Exotics species occurred in all six plots we visited; however, the relative cover of exotics species was less than 10% across the plots. At the scale of the 10 m^2 plot, we found an average of 2.5 exotic species. We found only three of the target species (Table 3), and cheatgrass was the most ubiquitous, occurring at all six sites.

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 two vital signs, which we will continue to monitor over time at AGFO. The current value is based on sampling in 2011 and the level of inference is simply six sites. After one complete rotation in the AGFO sampling design (five years), current values will be the average across five years and the level of inference will be park-wide. After a minimum of five years of data collection, or one complete rotation in the AGFO panel sampling design, 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 AGFO.

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

Vital Sign	Metric	Current Value (mean ± SD)	Level of inference	Reference Value	Rationale
Exotic Plant Early Detection	% of sites where target species were encountered	100%	6 sites	TBD	Early detection of exotic species
	Number of sites where *Bromus tectorum* abundance > 5%	1	6 sites	TBD	Effectiveness of exotic species management
Upland Plant Communities	Mean absolute herb-layer graminoid cover	99 ± 12.3 %	6 sites	TBD	Forage availability, climatic trends, erosion potential, habitat for small mammals and birds
	Ground-layer bare soil cover	33 ± 11.2 %	6 sites	TBD	
	Mean relative percent cover of exotic species	8 ± 11.7 %	6 sites	TBD	Effectiveness of exotic species management
	Percent of graminoid cover that is warm season	13 ± 4.1 %	6 sites	TBD	Climatic trends
	Mean native species richness in 10 m^2 plots	15 ± 2.9 species	6 sites	TBD	Diversity maintenance

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

Plant community composition monitoring in AGFO was completed using a crew of 4 people working four 10-hour days with approximately 1 hour of overtime. The crew drove one vehicle and the total mileage for the trip was 347 miles. We spent a total of 164 crew hours in AGFO in 2011.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed	Notes
Jun 13, 2011	Monday	3.5	Park housing	PCM-013	1 establishment
Jun 14, 2011	Tuesday	N/A	Park housing	PCM-001	
				PCM-017	1 establishment
Jun 15, 2011	Wednesday	N/A	Park housing	PCM-026	
				PCM-016	1 establishment
Jun 16, 2011	Thursday	3.5	N/A	PCM-015	

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

Family	Code	Scientific Name	Common Names
Agavaceae	YUGL	*Yucca glauca*	beargrass, Great Plains yucca, small soapweed, soapweed yucca, Spanish bayonet, yucca
Apiaceae	LOOR	*Lomatium orientale*	eastern lomatium, Northern Idaho biscuitroot, oriental desert-parsley
	MUTE3	*Musineon tenuifolium*	slender wildparsley
Asteraceae	AMPS	*Ambrosia psilostachya*	Cuman ragweed, perennial ragweed, western ragweed
	ARDR4	*Artemisia dracunculus*	false tarragon, green sagewort, silky wormwood, tarragon, wormwood
	ARFR4	*Artemisia frigida*	fringed sagebrush, fringed sagewort, prairie sagewort
	BREUC	*Brickellia eupatorioides* var. *corymbulosa*	false boneset
	CICA11	*Cirsium canescens*	Platte thistle, prairie thistle
	COCA5	*Conyza canadensis*	Canada horseweed, Canadian horseweed, horseweed, horseweed fleabane, mares tail, marestail
	ERBE2	*Erigeron bellidiastrum*	western daisy fleabane, western fleabane
	ERPU2	*Erigeron pumilus*	low daisy, low fleabane, shaggy fleabane
	GUSA2	*Gutierrezia sarothrae*	broom snakeweed, Broomsnakeweed, broomweed, perennial snakeweed, stinkweed, turpentine weed, yellow top
	HEPE	*Helianthus petiolaris*	prairie sunflower
	HEVIV	*Heterotheca villosa* var. *villosa*	hairy false golden-aster, hairy false goldenaster
	LASE	*Lactuca serriola*	prickly 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, blue wild lettuce, chicory lettuce, Russian blue lettuce
	PACA15	*Packera cana*	woolly groundsel
	RACO3	*Ratibida columnifera*	Prairie coneflower, prairie coneflower (upright), prairieconeflower, redspike Mexican hat, upright prairie coneflower
	SERI2	*Senecio riddellii*	riddell groundsel, Riddell ragwort, Riddell's ragwort, Sand groundsel
	SOCA6	*Solidago canadensis*	Canada goldenrod, Canadian goldenrod, common goldenrod
	SOMI2	*Solidago missouriensis*	Missouri goldenrod, prairie goldenrod
	SYERP2	*Symphyotrichum ericoides* var. *pansum*	manyflowered aster
	TEAC	*Tetraneuris acaulis*	stemless actinea, 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
	XAGR2	*Xanthisma grindelioides*	rayless tansyaster
Boraginaceae	CRCA8	*Cryptantha cana*	mountain cryptantha
	CRFE3	*Cryptantha fendleri*	Fendlers cryptantha, sand-dune catseye, sanddune catseye, sanddune cryptantha
	CRMI5	*Cryptantha minima*	little catseye, little cryptantha, small cryptantha
	LAOCO	*Lappula occidentalis* var. *occidentalis*	desert stickseed, flat-spine sheepburr, flatspine stickseed, western stickseed
	LICA13	*Lithospermum caroliniense*	Carolina puccoon
	LIIN2	*Lithospermum incisum*	fringed gromwell, Fringed puccoon, narrowleaf gromwell, narrowleaf

Family	Code	Scientific Name	Common Names
			pucoon, narrowleaf stoneseed, trumpet stoneseed
Brassicaceae	DEPI	*Descurainia pinnata*	green tansymustard, pinnate tansy mustard, pinnate tansymustard, tansymustard, western tansymustard
	DRRE2	*Draba reptans*	Carolina draba, Carolina whitlow-grass, Carolina whitlowgrass, creeping draba
	ERCAC	*Erysimum capitatum* var. *capitatum*	plains wallflower, prairie rocket, sanddune wallflower, western wallflower
	LEDE	*Lepidium densiflorum*	common pepperweed, greenflower pepperweed, miner's pepperwort, miners pepperweed, peppergrass, pepperweed, prairie pepperweed
	PHLU6	*Physaria ludoviciana*	foothill bladderpod, Louisiana bladderpod, silver bladderpod
	PHRE8	*Physaria reediana*	alpine bladderpod
	SIAL2	*Sisymbrium altissimum*	tumble mustard
Cactaceae	OPFR	*Opuntia fragilis*	brittle cactus, brittle pricklypear, fragile cactus, jumping cactus, little pricklypear, little pricklypear cactus
	OPMAM3	*Opuntia macrorhiza* var. *macrorhiza*	bigflower pricklypear, twistspine pricklypear
	OPPOP	*Opuntia polyacantha* var. *polyacantha*	hair-spine prickly-pear, hairspine pricklypear
Caryophyllaceae	ARHO4	*Arenaria hookeri*	Hooker sandwort, Hooker's sandwort
	PADE4	*Paronychia depressa*	spreading nailwort
Chenopodiaceae	CHPR5	*Chenopodium pratericola*	desert goosefoot
	SATR12	*Salsola tragus*	prickly Russian thistle
Commelinaceae	TROC	*Tradescantia occidentalis*	prairie spiderwort, spiderwort
Cyperaceae	CADU6	*Carex duriuscula*	needleleaf sedge, spike-rush sedge
	CAFI	*Carex filifolia*	threadleaf sedge
Fabaceae	ASMI10	*Astragalus missouriensis*	Missouri milk-vetch, Missouri milkvetch
	ASMO7	*Astragalus mollissimus*	purple locoweed, Woolly loco, woolly locoweed, woolly milkvetch, wooly loco, wooly locoweed
	ASSP6	*Astragalus spatulatus*	tufted milk-vetch, tufted milkvetch
	DACA7	*Dalea candida*	slender white prairieclover, white dalea, white prairie clover, white prairie-clover, white prairieclover
	DAPU5	*Dalea purpurea*	Purple prairieclover, violet dalea, violet prairie clover, violet prairie-clover
	LAPOI2	*Lathyrus polymorphus* var. *incanus*	hoary pea
	LUPL	*Lupinus plattensis*	Nebraska lupine, Platt lupine, Platte lupine
	LUPU	*Lupinus pusillus*	low lupine, rusty lupine, small lupine
	MESA	*Medicago sativa*	alfalfa
	MEOF	*Melilotus officinalis*	yellow sweetclover
	OXSE	*Oxytropis sericea*	locoweed, Silky crazyweed, silvery oxytrope, white crazyweed, white locoweed, white pointloco
	PSLA3	*Psoralidium lanceolatum*	dune scurfpea, lemmon scurfpea, lemon scurfpea, wild lemonweed
	PSTE5	*Psoralidium tenuiflorum*	scurfpea, slimflower scurfpea
	THRH	*Thermopsis rhombifolia*	goldenpea, prairie thermopsis
Hydrophyllaceae	ELNY	*Ellisia nyctelea*	Aunt Lucy, ellisia, false babyblueeyes, waterpod
Lamiaceae	HEHI	*Hedeoma hispida*	false pennyroyal, falsepennyroyal, rough false pennyroyal, rough falsepennyroyal, rough pennyroyal
Liliaceae	ALTE	*Allium textile*	prairie onion, textile onion, wild onion

Family	Code	Scientific Name	Common Names
	CANU3	*Calochortus nuttallii*	sego lily, sego-lily
Linaceae	LIRIR	*Linum rigidum* var. *rigidum*	large-flower yellow flax, largeflower yellow flax, stiffstem flax
Loasaceae	MEDE2	*Mentzelia decapetala*	evening starflower, gumbo-lily, tenpetal blazingstar, tenpetal mentzelia, tenpetal stickleaf
Malvaceae	SPCO	*Sphaeralcea coccinea*	copper mallow, orange globemallow, red falsemallow, scarlet globemallow
Melanthiaceae	TOVEG	*Toxicoscordion venenosum* var. *gramineum*	deathcamas, grassy deathcamas
Nyctaginaceae	MIHI	*Mirabilis hirsuta*	hairy four o clock, hairy four o'clock, hairy four-o'clock
Onagraceae	CASE12	*Calylophus serrulatus*	halfshrub calylophus, halfshrub sundrop, serrateleaf eveningprimrose, yellow sundrops
	GACO5	*Gaura coccinea*	scarlet beeblossom, scarlet gaura, Scarlet guara
	OEAL	*Oenothera albicaulis*	halfshrub sundrop, white-stem evening-primrose, whitest evening-primrose, whitest eveningprimrose
Orobanchaceae	ORFA	*Orobanche fasciculata*	clustered broom-rape, clustered broomrape, purple broomrape, tufted broomrape
Papaveraceae	ARPO2	*Argemone polyanthemos*	annual pricklepoppy, bluestem pricklepoppy, bluestem prickly poppy, crested pricklypoppy, pricklypoppy, thistle poppy, white prickly poppy, White pricklypoppy
Plantaginaceae	PLPA2	*Plantago patagonica*	woolly Indianwheat, woolly plantain, woolly plantian, wooly Indianwheat, wooly plantain
Poaceae	ACHY	*Achnatherum hymenoides*	Indian ricegrass
	ARPUF	*Aristida purpurea* var. *fendleriana*	Fendler's threeawn
	BOGR2	*Bouteloua gracilis*	blue grama
	BRJA	*Bromus japonicus*	Japanese brome, Japanese bromegrass, Japanese chess
	BRTE	*Bromus tectorum*	cheat grass, cheatgrass, downy brome, early chess, military grass, wild oats
	CALO	*Calamovilfa longifolia*	prairie sandreed
	ELELB2	*Elymus elymoides* ssp. *brevifolius*	squirreltail
	ELTRT	*Elymus trachycaulus* ssp. *trachycaulus*	slender wheatgrass
	HECOC8	*Hesperostipa comata* ssp. *comata*	needle and thread, needleandthread
	KOMA	*Koeleria macrantha*	junegrass, prairie Junegrass
	MUCU3	*Muhlenbergia cuspidate*	Plains muhly
	MUPU2	*Muhlenbergia pungens*	sandhill muhly
	PASM	*Pascopyrum smithii*	pubescent wheatgrass, western wheatgrass
	POPR	*Poa pratensis*	Kentucky bluegrass
	POSE	*Poa secunda*	big bluegrass, Sandberg bluegrass, Sandberg's bluegrass
	SCSC	*Schizachyrium scoparium*	little bluestem
	SPCR	*Sporobolus cryptandrus*	sand dropseed
	VUOC	*Vulpia octoflora*	eight-flower six-weeks grass, pullout grass, sixweeks fescue, sixweeks grass
Polemoniaceae	PHAN4	*Phlox andicola*	prairie phlox
	PHHO	*Phlox hoodii*	Hood's phlox, spiny phlox
Polygonaceae	ERAN4	*Eriogonum annuum*	annual buckwheat, annual eriogonum, annual wild buckwheat, annual wildbuckwheat, umbrella plant, wild buckwheat
	ERFL4	*Eriogonum flavum*	alpine golden buckwheat, yellow eriogonum

Family	Code	Scientific Name	Common Names
	PORA3	*Polygonum ramosissimum*	bushy knotweed, tall knotweed, yellow knotweed, yellow-flower knotweed
	RUVE2	*Rumex venosus*	veiny dock
Santalaceae	COUM	*Comandra umbellata*	bastard toadflax
Scrophulariaceae	CASE5	*Castilleja sessiliflora*	downy paintedcup, Great Plains Indian paintbrush, Indianpaintbrush
	PEANA2	*Penstemon angustifolius* var. *angustifolius*	broad-beard beardtongue, broadbeard beardtongue
	PEERE	*Penstemon eriantherus* var. *eriantherus*	fuzzytongue penstemon
Solanaceae	PHHI8	*Physalis hispida*	groundcherry, prairie ground-cherry, prairie groundcherry
Violaceae	VINU2	*Viola nuttallii*	Nuttall violet, Nuttall's violet, yellow prairie violet

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