2013

Plant Community Composition and Structure Monitoring for Agate Fossil Beds National Monument

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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

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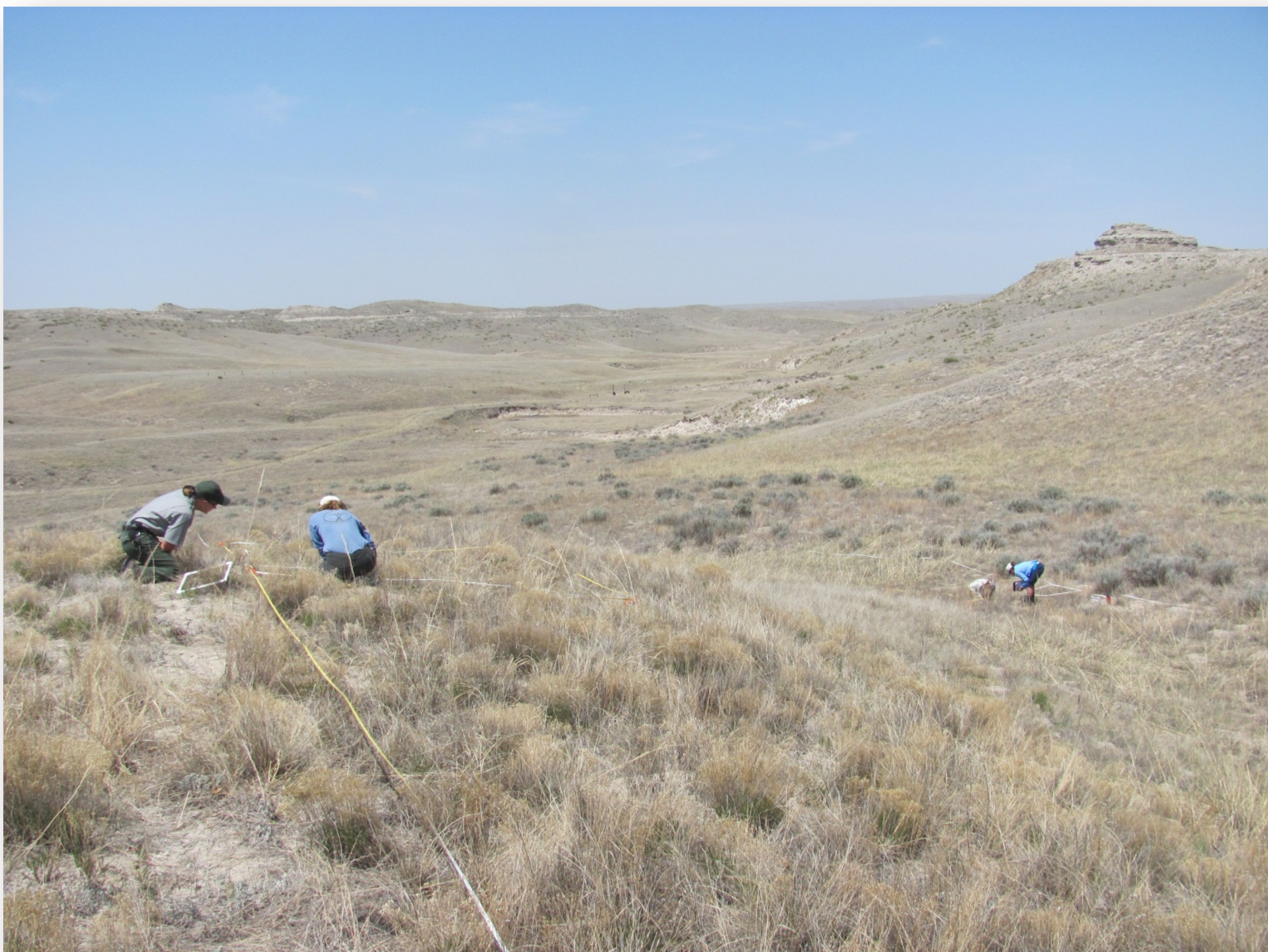
2012 Annual Report

Natural Resource Technical Report NPS/NGPN/NRTR—2013/673



ON THE COVER
Patricia Bean, Lauren Baur, Daina Jackson, and Anine Smith measuring plant diversity at Agate Fossil Beds National Monument, 2012.
Photograph by: NGPN

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National Park Service
Northern Great Plains Inventory & Monitoring Network
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U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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

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Executive Summary

Agate Fossil Beds National Monument (AGFO) plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the region. The Northern Great Plains Inventory & Monitoring Network (NGPN) and Fire Ecology Program (FireEP) surveyed 12 long-term monitoring plots in Agate Fossil Beds National Monument in 2012 as part of an effort to better understand the condition of plant communities in the park. We measured plant diversity and cover, looked for the presence of exotic species that may be newly invading the park, and evaluated the amount of human and natural disturbance at all plots. This effort was the second year in a multiple-year venture to document the current status and long-term trends in 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 addition to upland plant monitoring, we also sampled vegetation at 12 sites along the riparian corridor at AGFO as part of a pilot study to develop a long-term monitoring approach for this area. The riparian corridor is narrow and not adequately represented in our standard sampling, but is of great ecological and management importance to the park. 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 2012.

In the upland areas of the park, AGFO has maintained a mixed-grass prairie with low exotic cover and a high diversity of native plants. There was a severe drought in 2012, and as a result, we found that plant diversity and plant cover was in the low range of normal, but still higher than other parks in the region. Annual bromes, such as cheatgrass (*Bromus tectorum*), are not abundant in the park, but active management may be required to keep such low cover. For instance, off- road driving through the native prairie should be kept to a minimum. Allowing for natural disturbances such as fire may be critical to maintaining plant diversity in AGFO, but it should be balanced with the need to protect intact native communities and prevent further invasions of exotic species. Continued monitoring efforts will be critical to track changes in the condition of the vegetation communities in AGFO.

We found the riparian area to be more diverse than the upland areas of the park, but there was a high cover of exotic species, particularly pale yellow iris (*Iris pseudacorus)* and Kentucky bluegrass (*Poa pratensis*). AGFO is currently examining options for control of the iris and it will be important to consider that the patchy nature of the pale yellow iris and difficult access in the wet areas will present a challenge to control efforts. However, to retain ecological integrity it is important to pursue efforts to reduce the cover of this and other invasive plants. Since this was the first year of monitoring, it is difficult to discern trends in pale yellow iris abundance. Continued monitoring efforts in future years will be critical to track changes in the condition and the effectiveness of management activities in the riparian communities in AGFO.

Acknowledgments

We thank all the authors of the NGPN Plant Community Monitoring Protocol, particularly Dr. Amy Symstad, for outstanding guidance on data collection and reporting. We greatly appreciate the staff at AGFO, particularly Lil Mansfield, James Hill, and William Matthews, for providing logistical support and safety checks. The 2012 NGPN vegetation field crew of Michael Prowatzke, Timothy Pine, Lauren Baur, Daina Jackson, Ryan Manuel, Isabel Ashton, and Anine Smith and the FireEP crew of Phil Graeve, Valena Hoffman, Marcus Lund, and Ellery Watson collected the data included in this report. We thank Patricia Bean for assisting us with riparian and upland field work. The data presented in this report from fire monitoring plots were collected by the Northern Great Plains Fire Ecology Group led by Dan Swanson and Phil Graeve. We thank Stephen Wilson for invaluable support and instruction on managing data in the FFI database and for assistance with the GIS data.

Introduction

During the last century, much of the prairie within the Northern Great Plains has been plowed for cropland, converted to livestock pasture, or otherwise developed, making it one of the most threatened ecosystems in the United States. Within Nebraska, greater than 77% of the area of native mixed-grass prairie has been lost since European settlement (Samson and Knopf 1994). The National Park Service (NPS) plays an important role in preserving and restoring some of the last pieces of intact prairies within its boundaries. The stewardship goal of the NPS is to "preserve ecological integrity and cultural and historical authenticity" (NPS 2012); however, resource managers struggle with the grim reality that there have been fundamental changes in the disturbance regimes, such as climate, fire, and grazing by large, native herbivores, that have historically maintained prairies and there is the continual pressure of exotic invasive species. Long-term monitoring in national parks is essential to sound management of prairie landscapes because it can provide information on environmental quality and condition, benchmarks of ecological integrity, and early warning of declines in ecosystem health.

Agate Fossil Beds National Monument (AGFO) was established in 1965 to protect and preserve a large concentration of ancient mammal fossils. The park contains 3,058 acres of native mixed-grass prairie intersected by riparian vegetation along the Niobrara River. Vegetation monitoring began in AGFO in 1997 by the Heartland Inventory & Monitoring Program (James 2010) and the Northern Great Plains Fire Ecology Program (FireEP; Wienk et al. 2011). In 2010, AGFO was incorporated into the Northern Great Plains Inventory & Monitoring Network (NGPN). At this time, vegetation monitoring protocols and plot locations were shifted to better represent the entire park and to coordinate efforts with the FireEP (Symstad et al. 2012b) and sampling efforts began in 2011 (Ashton et al. 2011). The long-term objectives of the NGPN and FireEP plant community monitoring effort in AGFO are to:

1. Determine park-wide status and long-term trends in vegetation species composition (e.g., exotic vs. native) and structure (e.g., cover, height) of herbaceous and shrub species.

2. Improve our understanding of the effects of external drivers and management actions on plant community species composition and structure by correlating changes in vegetation composition and structure with changes in climate, landscape patterns, atmospheric chemical composition, fire, and invasive plant control.

This report is intended to provide a timely release of basic data sets and data summaries from the NGPN and FireEP sampling efforts in 2012 at AGFO. NGPN visited 6 plots, and it will take 3 more years to visit every plot in the park to provide park-wide inference for the upland areas (Figure 1). The FireEP installed and read an additional 6 plots using the same methods to better understand the effects of fire on park vegetation. In addition to upland plant monitoring, we also sampled vegetation at 12 plots along the riparian corridor at AGFO as part of a pilot study to develop a long-term monitoring approach for this area. The riparian corridor is narrow and not adequately represented in our standard sampling, but is of great ecological and management importance to the park. NGPN will produce reports with more in-depth data analysis and interpretation when we complete 5 years of sampling, and FireEP will use these data to report on fire effects. In the interim, reports, spatial data, and data summaries can be provided for park management and interpretation upon request.

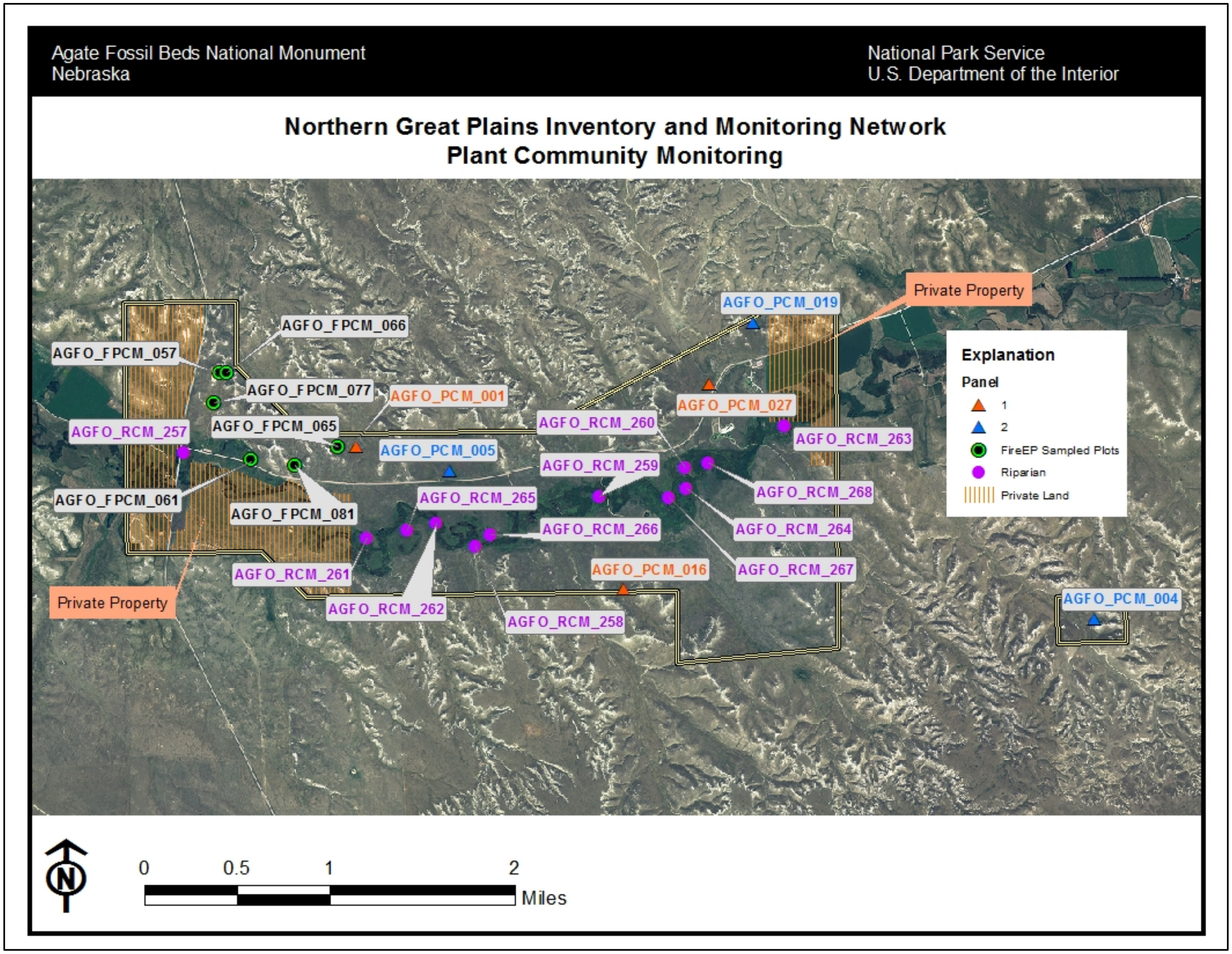


Figure 1. Map of Agate Fossil Beds National Monument (AGFO) and plant community monitoring (PCM) plots, fire effects monitoring plots (FPCM), and riparian monitoring plots (RCM). All of the sites shown were visited in 2012 by the Northern Great Plains Inventory & Monitoring Network or the Fire Ecology Program.

Methods

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

Upland vegetation monitoring sample design and plot layout

NGPN and FireEP implemented a survey to monitor plant community structure and composition in AGFO using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, we selected 15 randomly located sites within AGFO (Figure 1). We split these 15 sites into 5 panels with 3 sites each. NGPN will visit 2 panels (6 sites) every year, and after 5 years (2015) we will have visited all 15 sites twice. In 2011, we visited sites in panel 1 and panel 5 (Figure 1) during the second week of June. In 2012, we visited sites in panel 1 and panel 2 (Figure 2) during the first week of June.

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), and with repeat visits it allows for discerning trends in that resource (Larsen et al. 1995). In other words, after 5 years, we can use data from our randomly selected sites to estimate the ecological integrity of vegetation communities for the whole park.

The FireEP aims to understand how prescribed and wildland fires affects the vegetation in national park units in this region. Where possible, the same sites as above are used to assess vegetation response. However, in many cases there are not enough plots within the first 15 that fall within burn units. For this reason, the initial GRTS designs included many more sites that can be visited as needed by NGPN or FireEP. These extra sites are referred to as 'overdraws'. In 2012, FireEP installed and surveyed 6 sites during the first week of June (Figure 1) in the northwest section of the park. This section is part of the Daemonelix burn unit and was scheduled to, but did not burn in the 2012 season.

At each of the sites visited, NGPN and FireEP recorded plant species cover and frequency in a rectangular, 50 m x 20 m (0.1 ha), permanent plot (Figure 2). Data on ground cover, herb-layer (≤ 2 m height) height, and plant cover were collected on two 50 m transects (the long sides of the plot) using a point-intercept method. In the 6 plots read by NGPN, species richness data from the point-intercept method were 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) located systematically along each transect (Figure 2). In 2012, it took NGPN's 4-person crew approximately 124 hours with travel time to read 6 plots (see Appendix A for a detail of activities each day). In 2012, there were no trees or shrubs found at the 12 plots visited.

Plant species were identified in the field to species level and not to lower taxonomic groupings (e.g., subspecies or variety). This was a change from the data collected in 2011 by NGPN where plants were identified to the lowest taxonomic level possible. The change was made in coordination with the FireEP because it better reflects the botanical skills of the crew and simplifies data management and analysis. When we were unable to identify a plant, the plant was assigned a unique identifier and collected or photographed. Most of these unknowns were subsequently identified in the office; 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).

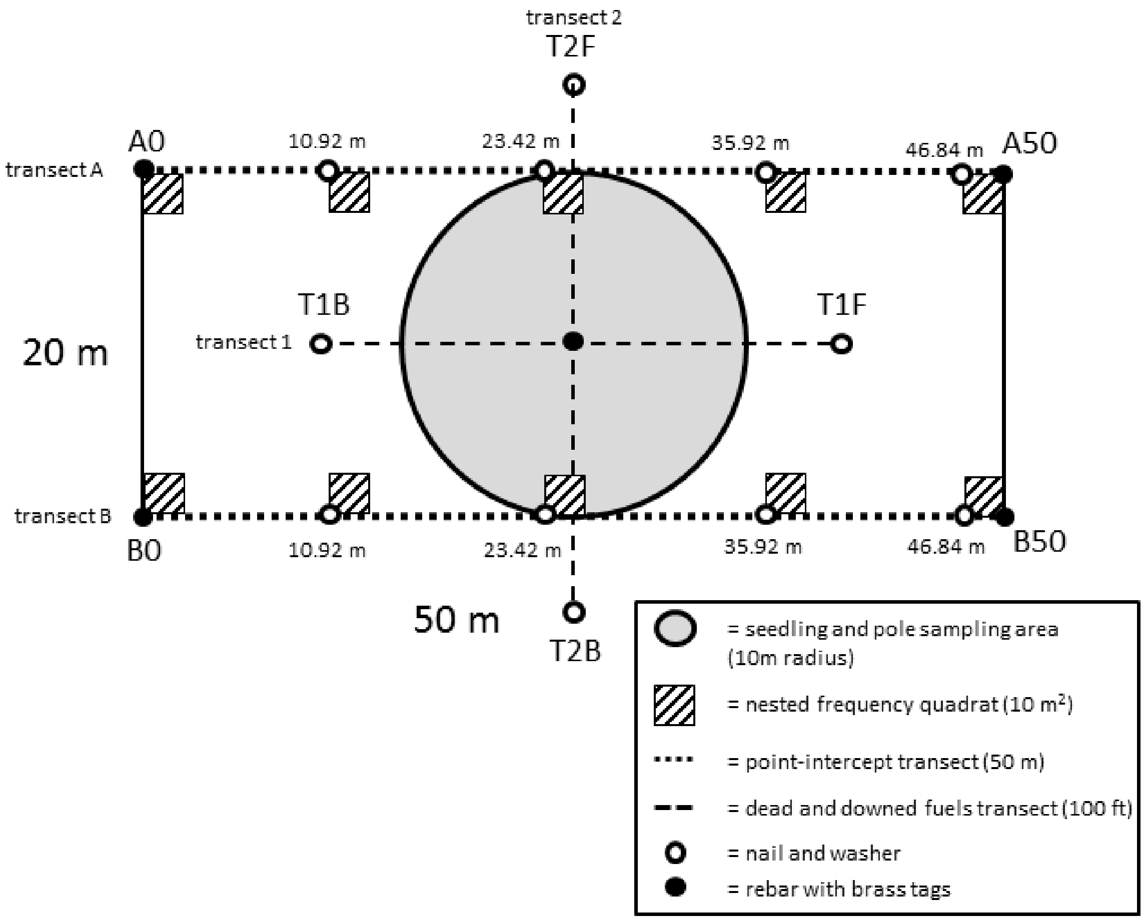


Figure 2. Long-term monitoring plot used for sampling vegetation in Agate Fossil Beds National Monument.

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 which 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 of 1-5%, 4 = cover of 5-25%, and 5 = cover > 25% of the plot. The information gathered from this procedure is critical for early detection and rapid response to such threats. In addition, this method tracks the presence of plant species that are considered rare or vulnerable to loss in Nebraska, and may occur in AGFO. The AGFO target species list for 2012 can be found in Table 1.

Table 1. Exotic species of management concern at Agate Fossil Beds National Monument and rare species that were surveyed for during the 2012 field season.

Exotic Species			**Rare species**	
Scientific Name	Common Name		**Scientific Name**	**Common Name**
Bromus inermis	smooth brome		*Astragalus barrii*	Barr's milkvetch
Carduus nutans	musk thistle		*Astragalus shortianus*	Short's milkvetch
Centaurea stoebe	spotted knapweed		*Boechara holboelli*	limestone rockcress
Cirsium arvense	Canada thistle		*Cypripedium parviflorum*	yellow lady's slipper
Cirsium vulgare	bull thistle		*Dalea cylindriceps*	Andean prairie clover
Conium maculatum	poison hemlock		*Ericameria parryi*	Parry's rabbitbrush
Convolvulus arvensis	field bindweed		*Eriogonum gordonii*	Gordon's buckwheat
Elaeagnus angustifolia	Russian olive		*Fritillaria atropurpurea*	spotted mission bells
Euphorbia esula	leafy spurge		*Gaura neomexicana*	Colorado butterfly plant
Iris pseudacorus	pale yellow iris		*Linanthus caespitosus*	matted prickly phlox
Kochia scoparia	kochia		*Paronychia sessiliflora*	stemless nailwort
Linaria dalmatica	Dalmatian toadflax		*Pedicularis crenulata*	meadow lousewort
Linaria vulgaris	yellow toadflax		*Phacelia hastata*	spearhead phacelia
Onopordum acanthium	Scotch thistle		*Physaria arenosa*	sidesaddle bladderpod
Rhaponticum repens	Russian knapweed		*Platanthera huronensis*	Huron green orchid
Poa pratensis	Kentucky bluegrass		*Spiranthes diluvialis*	Ute lady's tresses
Salsola tragus	Russian thistle			
Tamarix spp.	tamarisk			
Tanacetum vulgare	common tansy			

Riparian vegetation monitoring sample design and plot layout

We conducted a pilot effort to sample vegetation in the riparian corridor in AGFO in 2012. There were 2 objectives of this work: (1) to test field methods in the riparian area that could be used to estimate the current condition of the plant community (2) to provide some field data on the extent of pale yellow iris invasion.

We took the same general approach as the upland sampling and used a GRTS design to allocate plots randomly across the landscape. We defined the riparian area by merging a 2012 remote classification (classes equal to pale yellow iris, other lowland vegetation, and water) with the 1996-1997 USGS-NPS vegetation map (classes equal to Annual-dominated Floodplain Disturbance Herbaceous Vegetation, *Salix exigua* Shrubland, *Juncus balticus* Herbaceous Vegetation, *Pascopyrum smithii* Herbaceous Vegetation, *Typha latifolia* Western Herbaceous Vegetation, and water). This was completed because of significant overlap between the areas classified as lowland in 1996/1997 and 2012. We then used a union function to merge polygons, explode multipart polygons to single part, and select large polygons near the river (effectively eliminating small, remotely sensed areas away from the river derived from the 2012 assessment). Finally, this area was clipped to the tracts in AGFO that are owned in fee-title. In total this amounted to 156 hectares of riparian area. This was the same area for which pale yellow iris was remotely assessed (Wilson, *in preparation*) in the summer of 2012. Within this area, we visited 12 randomly located sites (Figure 1) over 2 days in August using five people (Appendix 1).

In order to sample more sites, we reduced the sampling effort and simplified the plot design used for upland sampling. Riparian sites consisted of just one 50-m transect (Figure 3). We used the randomly-generated GRTS point to determine the starting location of each transect. The direction that the transect followed was determined in the field to be roughly perpendicular to the closest water source (most often the Niobrara River; Figure 3). We used the point-intercept method to record the species that occurred every meter along the transect. All plants were identified as described above in the upland sampling methods.

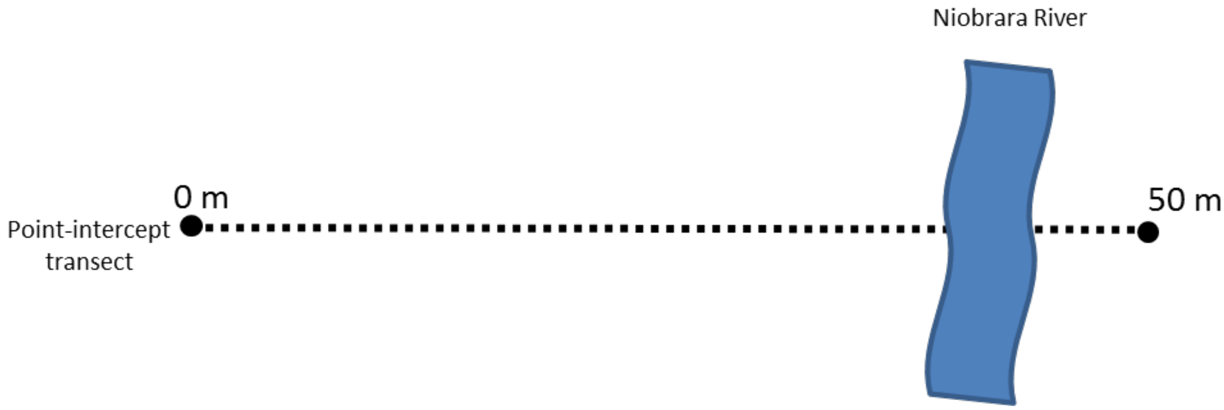


Figure 3. Survey plot used for sampling riparian vegetation in Agate Fossil Beds National Monument.

Data Management and Analysis

NGPN and the FireEP use FFI (FEAT/FIREMON Integrated; http://frames.gov/ffi/) as the primary software environment for managing our sampling data. FFI is used by a variety of agencies (e.g., NPS, USDA Forest Service, U.S. Fish and Wildlife Service), has a national-level support system, and generally conforms to the Natural Resource Database Template standards established by the Inventory and Monitoring Program.

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

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

Plant life forms (e.g., shrub, forb) were based on definitions from the USDA Plants Database (USDA-NRCS 2012). Summaries were produced using the FFI reporting, and query tools and statistical summaries and graphics were generated using R software (version 2.15.1).

We measured diversity at the plots in 3 ways: species richness, the Shannon Index, and Pielou's Index of Evenness. Species richness is simply a count of the species recorded in an area. The Shannon Index, H', is a measure of the number of species in an area and how even abundances are across the community. It typically ranges between 0 (low richness and evenness) to 3.5 (high species richness and evenness). Peilou's Index of Evenness, J', measures another aspect of diversity: how even abundances are across taxa. It ranges between 0 and 1, where lower numbers indicate that a community is not even or that just a few species make up the majority of total cover.

The riparian data were analyzed separately from the upland data. We used the R package 'spsurvey' (Kincaid and Olsen 2011) to analyze the riparian data. The data from our randomly selected riparian sites were used to estimate the ecological integrity of the riparian communities for the whole park. This method will be repeated for the upland sites after the 5 year sampling cycle is complete.

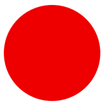
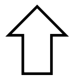
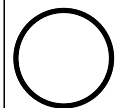
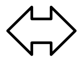
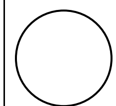
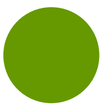
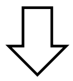
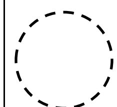
Reporting on Natural Resource Condition

Results were summarized in a Natural Resource Condition Table based on the templates from the State of the Park report series (http://www1.nrintra.nps.gov/im/stateoftheparks/index.cfm). The goal of the Natural Resource Condition Table is to improve park priority settings and to synthesize and communicate complex park condition information to the public in a clear and simple way. By focusing on specific indicators, such as exotic species cover or native diversity, it will be possible and straightforward to compare conditions in subsequent years. The status, trend, and the confidence of assessments for each indicator is scored and assigned a corresponding symbol based on the key found in Table 2.

We chose a set of indicators and specific measures that can describe the condition of vegetation in the Northern Great Plains and the status of exotic plant invasions. The measures include: absolute herb-layer canopy cover, native species richness, evenness, relative cover of exotic species, and annual brome cover. Reference values were based on descriptions of historic condition and variation, past studies, or management targets. Current park condition was compared to a reference value and status was scored as good condition, caution, or significant concern based on this comparison (Table 2). Good condition was applied to values that fell within the range of the reference value and significant concern was applied to conditions that fell outside the bounds of the reference value. Trend was scored in a similar fashion and categorized as improving, unchanging, deteriorating, or insufficient information.

Confidence in status and trend assessments within the Natural Resource Condition Table was scored as high, medium, or low. Confidence primarily reflects the quality of the data collected, rather than the quality of the reference condition. Confidence in the data summarizes three aspects of data quality: how well data represent the resource, quality of methods, and the length of the record.

Table 2. Key to the symbols used in the Natural Resource Condition Table. The background color represents the current status, the arrow summarizes the trend, and the thickness of the outside line represents the degree of confidence in the assessment. A symbol that does not contain an arrow indicates that there is insufficient information to assess a trend. Based on the State of the Park reports (http://www1.nrintra.nps.gov/im/stateoftheparks/index.cfm).

Status		**Trend**		**Confidence**	
	Significant Concern		Condition is Improving		High
	Caution		Condition is Unchanging		Medium
	Good Condition		Condition is Deteriorating		Low

Results and Discussion

Upland vegetation

The vegetation at AGFO suffered from a very dry winter and spring, and when the NGPN and FireEP field crews visited the park in June, there was not much green vegetation (Figure 4). Average canopy cover was 59% (Table 3) in 2012. The productive summer in 2011 and a dry winter and spring in 2012 contributed to a large amount of standing litter on the ground (ground cover at sites averaged 72% plant litter).

Figure 4. The A vegetation transect at plot PCM_016 in Agate Fossil Beds National Monument in 2011 (left panel) and 2012 (right panel). Both photographs were taken in early June and show the dramatic reduction in moisture available in 2012.

Despite the dry conditions, we found 87 plant species in upland sites in 2012 at AGFO (Appendix B). Graminoids, which include grasses, sedges, and rushes, accounted for most of the vegetative cover at AGFO (Figure 5). There was a great deal of variation in species composition across the 12 sites. The most common species in the sites we visited were graminoids, and most were native species (Figure 6). Needle-and-thread grass (*Heterostipa comata*) was the only species found at all sites. Slender wheatgrass (*Elymus trachycaulus*) and prairie sandreed (*Calamovilfa longifolia)* were also common. Exotic species tended to be rare in the upland areas of AGFO. Cheatgrass (*Bromus tectorum*) was the most abundant exotic (Figure 6), and it was found in half of the sites.

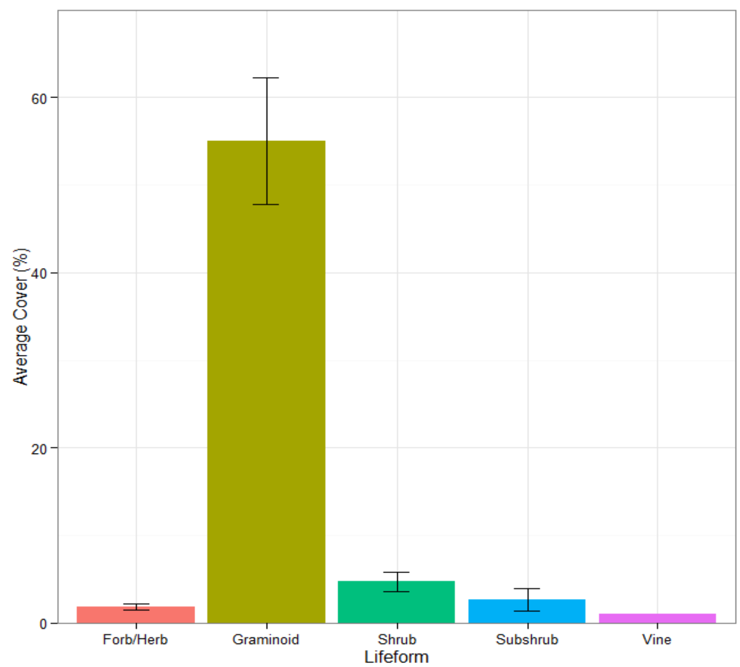


Figure 5. Average cover by life forms in 12 monitoring plots in Agate Fossil Beds National Monument (AGFO) in 2012. Bars represent means ± standard errors. Graminoids were the most abundant life-form across all the plots at AGFO.

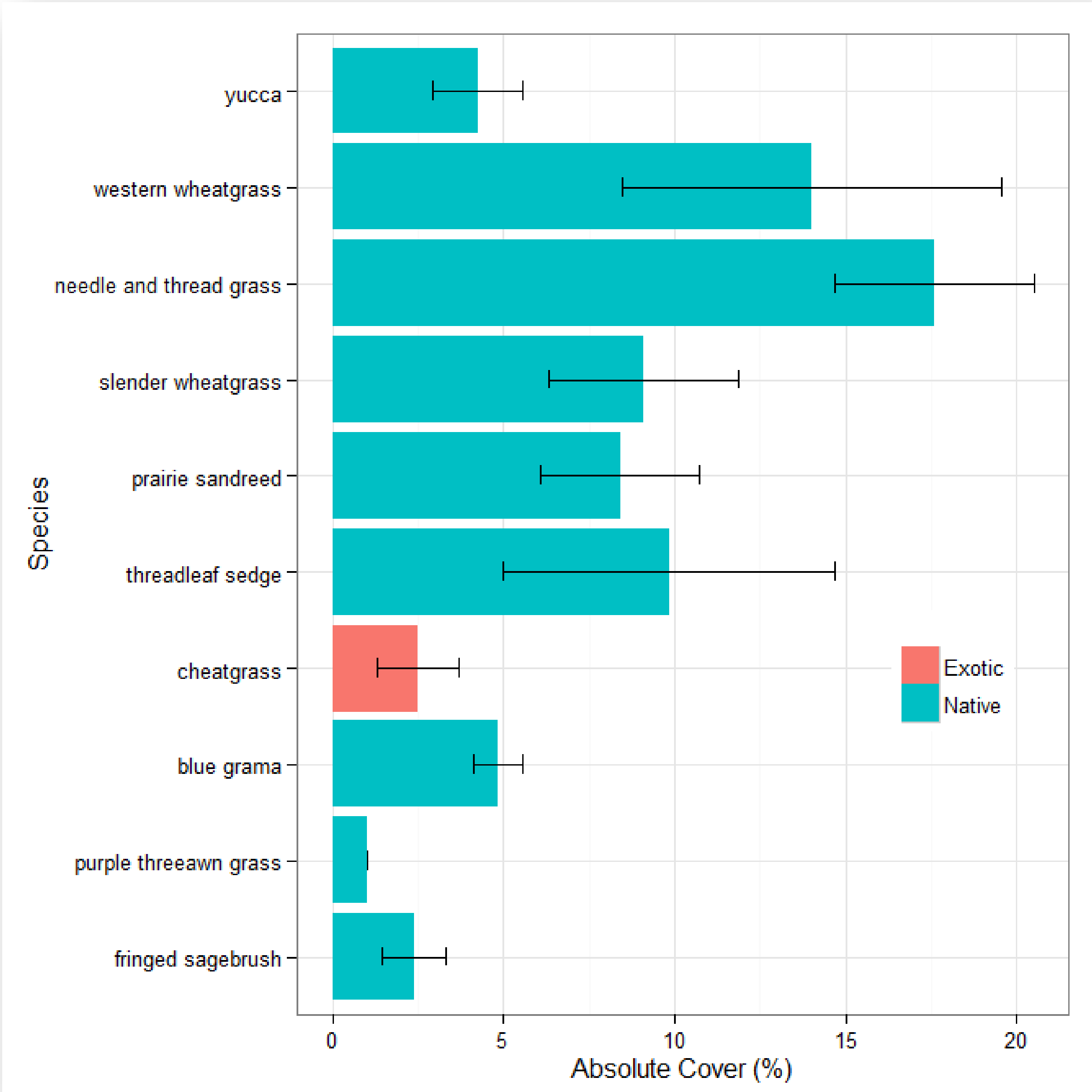
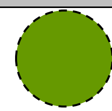
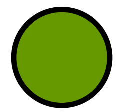
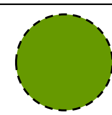
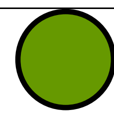
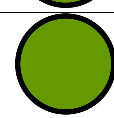


Figure 6. The average absolute cover of the 10 most common native (blue) and exotic (red) plants recorded at Agate Fossil Beds National Monument in 2012. Bars represent means ± standard errors. Cheatgrass was the only exotic species commonly found at the upland sites in Agate Fossil Beds National Monument.

Table 3. Natural resource condition summary table for upland plant communities in AGFO.

Indicator of Condition	Specific Measures	2012 Value (mean ± SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Absolute herb-layer canopy cover	59 ± 7.3 %	TBD		AGFO plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the region. The park is characterized by high native species richness. 2012 was a particularly dry year, and as a result, diversity and plant cover was in the very low range of normal. This was primarily due to a lack of forbs. At this time, the condition assessment for canopy cover and evenness is based on professional judgment, but as we collect more data and understand the natural range of variability our confidence in these assessments will increase.
	Native species richness (based on average of 10-1m^2 quadrats per plot)	5 ± 0.5 species	3-15 species [1]		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.69 ± 0.1	TBD		
Exotic Plant Early Detection and Management	Relative cover of exotic species	4 ± 1.5 %	≤ 10 % cover		AGFO has maintained a mixed-grass prairie with low exotic cover and a high diversity of native plants. Cheatgrass is not abundant in the park, but active management may be required to keep such low cover.
	Annual Brome cover	2 ± 9 %	≤10 % cover		

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1. Symstad, A. J. and J. L. Jonas*.* *in press*. Using natural range of variation to set decision thresholds: a case study for Great Plains grasslands.in G. R. Gutenspergen, editor. Application of threshold concepts in natural resource decision making. Springer Verlag.

Species richness varies by the scale that it is examined. Table 4 presents average species richness for the point-intercept, 1 m^2 quadrats, and 10 m^2 quadrats recorded in 2012. On average, there were about 2 exotic species found in each quadrat along the point-intercept (Table 4). Average forb and graminoid richness were similar in the quadrats, but the point-intercept method picked up more graminoids and fewer forbs (Table 4). From the point-intercept data, we found average plot diversity, H', to be 1.5 ± 0.09. Evenness, J', averaged 0.74 ± 0.03 across the plots (Table 3). When including only native species, average diversity and evenness were 1.4 ± 0.1 and 0.73 ± 0.04, respectively.

Table 4. Average plant species richness at monitoring plots at Agate Fossil Beds National Monument in 2012. Values represent means ± standard errors, n=12 for the point-intercept (includes both FireEP and NGPN plots) and n=6 for the quadrats (only the NGPN plots).

	Point-intercept	1 m^2 quadrats	10 m^2 quadrats
Species richness	8 ± 0.6	6 ± 0.4	10 ± 0.8
Native species richness	7 ± 0.7	5 ± 0.5	8 ± 1.0
Exotic species richness	1 ± 0.3	1 ± 0.2	2 ± 0.3
Graminoid species richness	6 ± 0.5	3 ± 0.3	4 ± 0.3
Forb species richness	1 ± 0.3	3 ± 0.2	5 ± 0.7

While there was some variation across sites, the plots we visited in AGFO tended to have a moderately low diversity of native plants compared to other mixed-grass prairies. Species richness in the mixed-grass prairie is determined by numerous factors including fire regime, grazing, prairie dog disturbance, and weather fluctuations (Symstad and Jonas 2011). While it is difficult to define a reference condition for species richness that can vary so much spatially and temporally, the natural range of variation over long-time periods may be a good starting point (Symstad and Jonas *in press*). Long-term records of species diversity in mixed-grass prairie in relatively undisturbed site in Kansas varied between 3 and 15 species per square meter over the course of 30 years (Symstad and Jonas, *in press*). Compared to this, AGFO is within the natural range (Table 4, native richness in the 1 m^2 quadrat and Table 3), but is definitely on the low end of this threshold. This is not surprising given the extreme drought and general lack of growth during the 2012 season. As a comparison, in 2011, we found an average of 9 native species within the 1 m^2 quadrats (Ashton et al. 2011), which is nearly double the average in 2012 and well within the bounds of the reference condition.

The average relative cover of exotic species at sites in AGFO was low (4 ± 1.5%; Table 3). However, cover of exotic species varied among sites (Table 5). Many sites, particularly those in the northwest corner of the park (e.g., FPCM_057 and FPCM_077) had no exotic species. The highest cover of exotic species was 13% found at PCM_027. Russian thistle was present at 6 plots, and Kentucky bluegrass was present at 2 plots, but both were found in low abundance of less than 5% cover. Two annual brome species, cheatgrass and Japanese brome (*Bromus japonicus*), account for the majority of the exotic cover (Table 5). The presence of annual bromes in mixed-grass prairie is associated with decreased productivity and altered nutrient cycling (Ogle et al. 2003), and there is strong evidence from regions further west that cheatgrass alters fire regimes and the persistence of native species (D'Antonio and Vitousek 2003). The average cover of cheatgrass is low across the park (2%, Table 5) compared to neighboring parks in the Wyo-braska region (Ashton et al. 2012a, b), but it is greater than it was in 1999 when the Heartland Inventory & Monitoring Network found annual brome cover to range between 0 and

1% (DeBacker and Miekush 2000). Focusing restoration and control efforts on the few areas that currently have high rates of exotic cover may be the most effective strategy to reduce the cover across the park as a whole.

Table 5. Characteristics of the upland plant community at 12 plots in Agate Fossil Beds National Monument in 2012 including average cover of annual bromes, exotic plant cover, and area of disturbance.

Plot	**Exotic Cover (%)**	**Annual brome cover (%)**	**Disturbance within site (m^2)**
AGFO_PCM_001	1	0	1001
AGFO_PCM_004	0	0	150
AGFO_PCM_005	8	8	50
AGFO_PCM_016	1	1	95
AGFO_PCM_019	10	10	2890 (fire)
AGFO_PCM_027	13	5	2310 (fire)
AGFO_FPCM_057	0	0	-
AGFO_FPCM_061	12	1	-
AGFO_FPCM_065	3	3	-
AGFO_FPCM_066	0	0	-
AGFO_FPCM_077	0	0	-
AGFO_FPCM_081	0	0	-
Park Average	**4 ± 1.5**	**2 ± 1.0**	-

Disturbance from grazing, prairie dogs, fire, and humans affects plant community structure and composition in mixed-grass prairie. For this reason, we measured the approximate area affected by natural and human disturbances at each site we visited. In 2012, the most common disturbance was from small mammal activity, off-road vehicle use (off of established roads), and fire. Small mammal activity was seen at all plots but was confined to small areas (usually less than 50 m^2). Two of the sites with high exotic cover (PCM_019 and PCM_027) had recently burned (Table 5). Off-road vehicle use was present at many of our sites, presumably because of preparations for prescribed burning. At this time, there is no evidence that these disturbances are linked to declines in diversity or increased exotic cover. However, as a general practice these disturbances should be kept to a minimum in intact mixed-grass prairie to prevent the spread of exotic species.

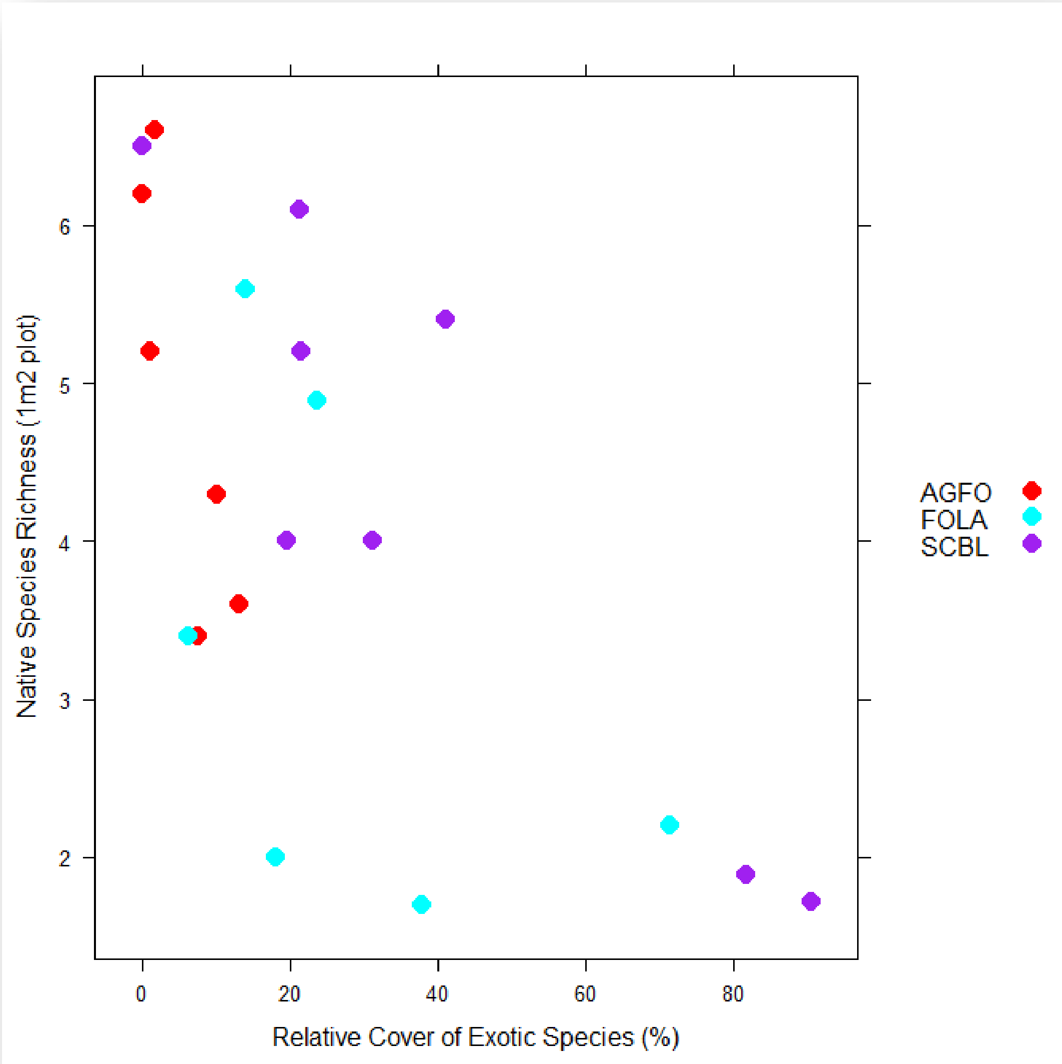


Figure 7. The relationship between average native species richness and the relative cover of exotic species for selected park units in the Northern Great Plains. In general, as cover of exotic species increases there is a decline in native diversity. The upland prairie of Agate Fossil Beds National Monument (AGFO, red) is characterized by sites with moderate diversity and low cover of exotic species compared to Scotts Bluff National Monument (SCBL, purple) and Fort Laramie National Historic Site (FOLA, teal).

In conclusion, AGFO plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the area. The park maintained a moderate diversity of native plants, even in a drought year, and a low cover of exotic species. In the Northern Great Plains, the cover of exotic species is correlated with decreases in native species richness (Figure 7), and to retain ecological integrity it is important to continue efforts to reduce the cover of invasive plants and keep human disturbance to a minimum. Continued monitoring efforts will be critical to track changes in the condition of the vegetation communities in AGFO.

Riparian vegetation

We visited 12 riparian sites in AGFO (Figure 1) to test field methods in the riparian area that could be used to estimate the current condition of the plant community and to provide some field data on the extent of pale yellow iris invasion. We can use data from our randomly selected sites to estimate the condition of the entire 156 hectare extent of AGFO riparian plant communities. Unlike the drier upland areas, we found that average plant cover was very high (165%; Figure 8, Table 6). Sites closer to the main channel of the Niobrara often had a high cover of cattails (*Typha* spp.) and/or pale yellow iris, while areas further from water were dominated by graminoids (Figure 8).

Figure 8. Photographs of two riparian monitoring sites at Agate Fossil Beds National Monument. Site RCM_259 (top panel) was characteristic of the wetter cattail and iris dominated sites. Site RCM_267 (bottom panel) was more typical of drier riparian sites with a mixture of upland and riparian plants.

It was a dry year, and we visited the park in August. As a result we found that only 5% of the ground cover was standing water. The dominant ground cover was plant litter, 87%.

We found 52 plant species in the riparian area, and 36 of these were unique and not seen in the upland plots (Appendix B). Many of the most common species were native graminoids (Figure 9) including western wheatgrass (*Pascopyrum smithii*), Baltic rush (*Juncus balticus*), and woolly sedge (*Carex pellita*). Common exotic species included Kentucky bluegrass, pale yellow iris, and Canada thistle (*Cirsium arvense*). Species richness in the riparian areas was generally higher than in the upland areas. Total species richness averaged 11 ± 1.6 species (point-intercept richness, Table 4). On average, we recorded 9 native species along each transect (Table 6). We found average plot diversity, H', to be 1.8 ± 0.14, and when including only native species H'=1.5 ± 0.17. Evenness was similar in the riparian area and upland areas of the park. Evenness, J', averaged 0.76 ± 0.02 for all species and 0.71 ± 0.04 for native species (Table 6).

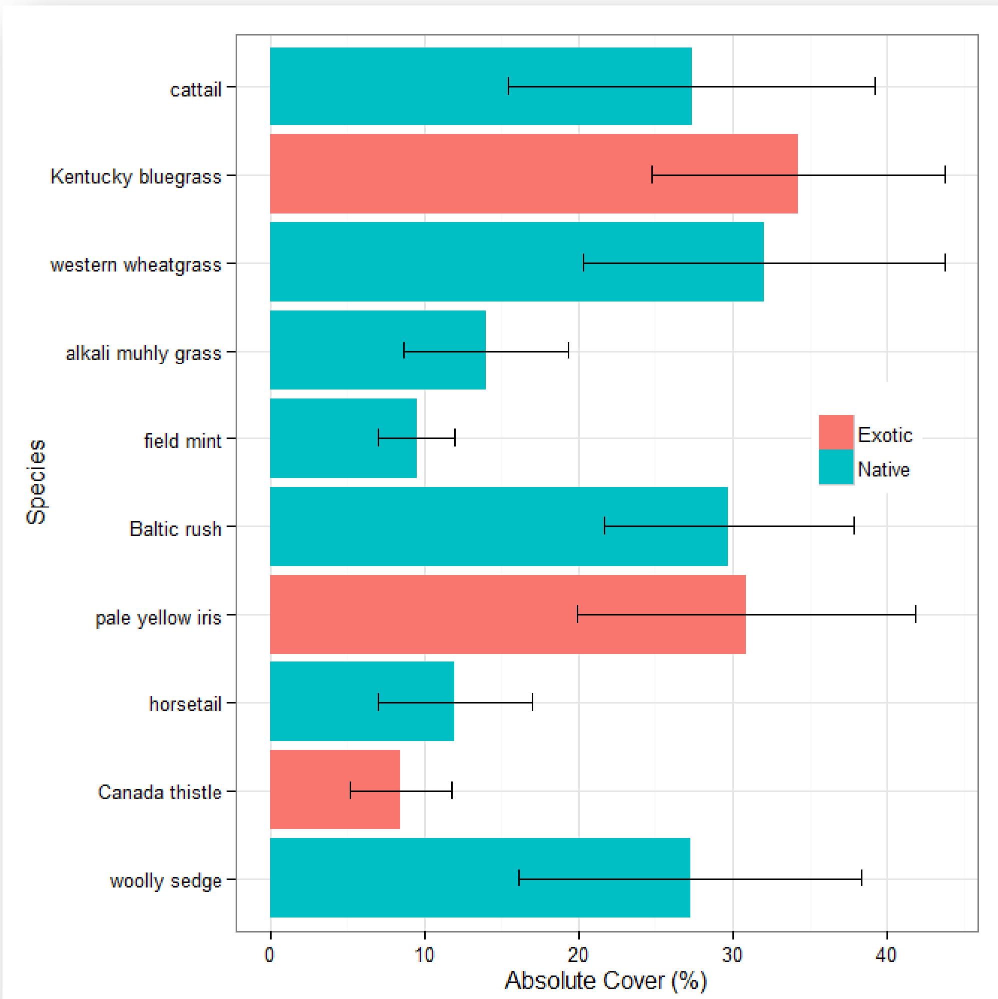
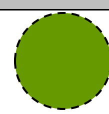
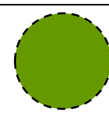
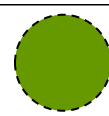
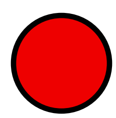
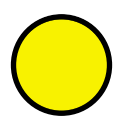


Figure 9. The average absolute cover of the 10 most common native (blue) and exotic (red) riparian plants recorded at Agate Fossil Beds National Monument in 2012. Bars represent means ± standard errors. Kentucky bluegrass, pale yellow iris, and Canada thistle were the most common exotic species. Note this figure displays absolute cover. The relative cover of each species is lower because of the high total plant cover in these sites.

Exotic cover was high and averaged 29% across the riparian areas of the park (Table 6). The most abundant exotic species was Kentucky bluegrass found at 8 of 12 sites, at over 30% absolute cover (Figure 9), and a relative cover of 12% throughout the riparian area. Canada thistle was found at 1/3 of the sites visited and overall had a relative cover of 2%. It was most abundant at RCM_257 and RCM_266 where it accounted for close to 10% of plant cover.

The pale yellow iris was very abundant and found at 7 sites with 11% relative cover in the riparian area. It accounted for close to 50% of the plant cover in 2 sites (RCM_259 and RCM_268). The distribution of the pale yellow iris is not continuous (i.e., it is not in high abundance at neighboring sites); instead it appears to be patchy across the riparian area, most often appearing in the wetter sites with the cattails. This patchiness may present a challenge to future control efforts.

Table 6. Natural resource condition summary table for riparian plant communities in AGFO.

Indicator of Condition	Specific Measures	2012 Value (mean ± SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Riparian Plant Community Structure and Composition	Absolute herb-layer canopy cover	165 ± 13.5 %	TBD		The riparian areas of AGFO were more diverse and had higher plant cover than the upland areas. Our condition assessment is based on professional judgment, but as we collect more data and understand the natural range of variability our confidence in these assessments will increase
	Native species richness (based 1-50 m transect per plot)	9 ± 1.4 species	TBD		
	Evenness (based on point-intercept of 1-50m transects per plot)	0.76 ± 0.02	TBD		
Exotic Plant Early Detection and Management	Relative cover of exotic species	29 ± 3.8%	≤10 % cover		The relative cover of exotic species in the riparian areas of AGFO was very high. Exotic control efforts should be focused in this area to restore native plant diversity and ecological integrity.
	Relative cover of pale yellow iris	11 ± 4.6%	≤10 % cover		Pale yellow iris has invaded riparian areas throughout the park. It had a patchy distribution and was absent in some sites while accounting for close to 50% cover in others.

In conclusion, our initial year of riparian monitoring at AGFO was successful. We encountered many plant assemblages and species that we have not seen in upland plots. We found the riparian area to be more diverse than the upland areas of the park, but there was a high cover of exotic species, particularly pale yellow iris and Kentucky bluegrass. The patchy nature of the pale yellow iris and difficult access in the wet areas will present a challenge to control efforts. However to retain ecological integrity it is important to pursue efforts to reduce the cover of this and other invasive plants. Since this was the first year of monitoring, it is difficult to discern trends in pale yellow iris abundance. Continued monitoring efforts in future years will be critical to track changes in the condition and the effectiveness of management activities in the riparian communities in AGFO.

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Appendix A: Field journal for plant community monitoring in AGFO for the 2012 season

The upland portion of the plant community composition monitoring in AGFO was completed using a crew of 4 people working 3.5 10-hour days. The riparian sampling took a 4-person crew 2 additional 10-hour days. We spent a total of 204 crew hours.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed	Notes
Jun 4, 2012	Monday	3	Park Housing	PCM-001 PCM-019	1 plot surveyed 1 plot established
Jun 5, 2012	Tuesday	N/A	Park Housing	PCM-005 PCM-016	2 plots surveyed
Jun 6, 2012	Wednesday	N/A	Park Housing	PCM-004	1 plot surveyed 1 plot established
Jun 7, 2012	Thursday	3	N/A	PCM-027	1 plot established
Aug 22, 2012	Wednesday	3	Park housing	RCM_257 RCM_258 RCM_259 RCM_260	4 plots surveyed
Aug 23, 2012	Thursday	3	N/A	RCM_261 RCM_262 RCM_263 RCM_264 RCM_265 RCM_266 RCM_267 RCM_268	8 plots surveyed

Appendix B: List of plant species found in 2012 at AGFO

Plant species found in NGPN and FireEP upland and NGPN riparian monitoring plots in 2012. The species that are not on the certified park list are in bold. The species found *only* in riparian sites are highlighted in gray, but many species were found in both upland and riparian areas.

Family	Code	Scientific Name	Common Name	Exotic
Agavaceae	YUGL	*Yucca glauca*	beargrass, yucca	
Anacardiaceae	RHTR	*Rhus trilobata*	skunkbush, skunkbush sumac	
Apiaceae	CIMA2	*Cicuta maculata*	common water hemlock, poison parsnip	
Asclepiadaceae	ASSP	*Asclepias speciosa*	showy milkweed	
Asteraceae	AMPS	*Ambrosia psilostachya*	Cuman ragweed, western ragweed	
	ARDR4	*Artemisia dracunculus*	false tarragon, green sagewort	
	ARFR4	*Artemisia frigida*	fringed sagebrush, fringed sagewort	
	CIAR4	*Cirsium arvense*	Canada thistle	*
	CICA11	*Cirsium canescens*	Platte thistle, prairie thistle	
	CIFL	*Cirsium flodmanii*	Flodman thistle, Flodman's thistle	
	COCA5	*Conyza canadensis*	Canada horseweed, horseweed	
	DYPA	*Dyssodia papposa*	dogbane dyssodia, fetid marigold	
	GUSA2	*Gutierrezia sarothrae*	broom snakeweed	
	HEAN3	*Helianthus annuus*	annual sunflower, common sunflower	
	HEPE	*Helianthus petiolaris*	prairie sunflower	
	HEVI4	*Heterotheca villosa*	hairy false goldaster	
	LASE	*Lactuca serriola*	prickly lettuce	*
	LYJU	*Lygodesmia juncea*	rush skeleton-plant, skeletonweed	
	MUOB99	*Mulgedium oblongifolium*	blue lettuce, blue wild lettuce	
	SERI2	*Senecio riddellii*	riddell groundsel, Riddell ragwort	
	SOGI	*Solidago gigantea*	giant goldenrod	
	SOAR2	*Sonchus arvensis*	field sowthistle	*
	SYER	*Symphyotrichum ericoides*	white heath aster	
	SYLA6	*Symphyotrichum lanceolatum*	white panicle aster	
	TAOF	*Taraxacum officinale*	common dandelion	*
	TRDU	*Tragopogon dubius*	common salsify, goat's beard	*
Boraginaceae	CRCA8	*Cryptantha cana*	mountain cryptantha	
	LAOC3	*Lappula occidentalis*	flatspine stickseed	
Brassicaceae	DEPI	*Descurainia pinnata*	green tansymustard	
	LEDE	*Lepidium densiflorum*	common pepperweed, peppergrass	
	PHLU99	*Physaria ludoviciana*	foothill bladderpod, silver bladderpod	
	SIAL2	*Sisymbrium altissimum*	tumble mustard	*
Cactaceae	OPFR	*Opuntia fragilis*	brittle pricklypear, fragile cactus	
Caprifoliaceae	SYOC	*Symphoricarpos occidentalis*	western snowberry, wolfberry	
Caryophyllaceae	SIDR	*Silene drummondii*	Drummond cockle	

Family	Code	Scientific Name	Common Name	Exotic
Chenopodiaceae	CHENO	*Chenopodium* spp.	goosefoot	*
	CHBE4	*Chenopodium berlandieri*	netseed lambsquarters, goosefoot	
	CHPR5	*Chenopodium pratericola*	desert goosefoot	
	KRLA2	*Krascheninnikovia lanata*	winterfat	
	SATR12	*Salsola tragus*	prickly Russian thistle	*
Cleomaceae	PESE99	*Peritoma serrulata*	Rocky Mountain beeplant	
Commelinaceae	TROC	*Tradescantia occidentalis*	prairie spiderwort, spiderwort	
Cyperaceae	CAREX	*Carex* spp.	carex, sedge, sedge species, sedges	
	CAFI	*Carex filifolia*	threadleaf sedge	
	CAHA3	*Carex hallii*	deer sedge	
	CANE2	*Carex nebrascensis*	Nebraska sedge	
	CAPE42	*Carex pellita*	woolly sedge	
	CAPR5	*Carex praegracilis*	clustered field sedge, slim sedge	
	ELER	*Eleocharis erythropoda*	bald spike-rush, bald spikerush	
	SCPU10	*Schoenoplectus pungens*	common threesquare	
	SCTA2	*Schoenoplectus tabernaemontani*	great bulrush, soft-stem bulrush	
Equisetaceae	EQLA	*Equisetum laevigatum*	horsetail, smooth horsetail	
Euphorbiaceae	CRTE4	*Croton texensis*	croton, doveweed, Texas croton	
Fabaceae	ASMO7	*Astragalus mollissimus*	purple locoweed, woolly locoweed	
	GLLE3	*Glycyrrhiza lepidota*	American licorice, licorice, wild licorice	
	LAPO2	*Lathyrus polymorphus*	manystem pea, manystem peavine	
	LUPU	*Lupinus pusillus*	low lupine, rusty lupine, small lupine	
	MEOF	*Melilotus officinalis*	yellow sweetclover	*
	PSTE5	*Psoralidium tenuiflorum*	scurfpea, slimflower scurfpea	
	THRH	*Thermopsis rhombifolia*	goldenpea, prairie thermopsis	
Iridaceae	IRPS	*Iris pseudacorus*	pale yellow iris, yellow flag	*
Juncaceae	JUBA	*Juncus balticus*	Baltic rush	
Lamiaceae	LYAS	*Lycopus asper*	rough bugleweed	
	MEAR4	*Mentha arvensis*	field mint, wild mint	
	SARE3	***Salvia reflexa***	**blue sage, lambsleaf sage**	
	SCLA2	*Scutellaria lateriflora*	blue skullcap, mad dog skullcap	
Lemnaceae	LEMI3	*Lemna minor*	common duckweed, least duckweed	
Liliaceae	CANU3	*Calochortus nuttallii*	sego lily, sego-lily	
Loasaceae	MEDE2	*Mentzelia decapetala*	evening starflower, tenpetal blazingstar	
Malvaceae	SPCO	*Sphaeralcea coccinea*	scarlet globemallow	
Melanthiaceae	TOVE2	*Toxicoscordion venenosum*	death camas	
Nyctaginaceae	MILI3	*Mirabilis linearis*	narrow-leaf four-o'clock	
Onagraceae	OESE3	*Oenothera serrulata*	yellow sundrops	
	OESU99	*Oenothera suffrutescens*	scarlet beeblossom	
Papaveraceae	ARPO2	*Argemone polyanthemos*	annual pricklepoppy, thistle poppy	

Family	Code	Scientific Name	Common Name	Exotic
Plantaginaceae	PLPA2	*Plantago patagonica*	woolly Indianwheat, woolly plantain	
Poaceae	ACHY	*Achnatherum hymenoides*	Indian ricegrass	
	ANGE	*Andropogon gerardii*	big bluestem, bluejoint, turkeyfoot	
	ARPU9	*Aristida purpurea*	purple threeawn, red threeawn	
	BOGR2	*Bouteloua gracilis*	blue grama	
	BRIN2	*Bromus inermis*	awnless brome, smooth brome	*
	BRJA	*Bromus japonicus*	Japanese brome, Japanese bromegrass	*
	BRTE	*Bromus tectorum*	cheat grass,downy brome	*
	CAST36	*Calamagrostis stricta*	narrowspike reedgrass	
	CALO	*Calamovilfa longifolia*	prairie sandreed	
	DISP	*Distichlis spicata*	desert saltgrass, inland saltgrass	
	ELLA3	*Elymus lanceolatus*	thickspike wheatgrass	
	ELRE4	*Elymus repens*	quackgrass	*
	ELTR7	*Elymus trachycaulus*	slender wheatgrass, slender wild rye	
	HECO26	*Hesperostipa comata*	needle and thread	
	HOJU	*Hordeum jubatum*	foxtail barley	
	KOMA	*Koeleria macrantha*	junegrass, prairie Junegrass	
	MUAS	*Muhlenbergia asperifolia*	alkali muhly, scratchgrass	
	MUCU3	*Muhlenbergia cuspidata*	plains muhly	
	MUPA99	*Muhlenbergia paniculata*	tumblegrass	
	MUPU2	*Muhlenbergia pungens*	sandhill muhly	
	MURA	*Muhlenbergia racemosa*	green muhly, marsh muhly	
	NAVI4	***Nassella viridula***	**green needlegrass**	
	PAVI2	*Panicum virgatum*	switchgrass	
	PASM	*Pascopyrum smithii*	western wheatgrass	
	POPR	*Poa pratensis*	Kentucky bluegrass	*
	SCSC	*Schizachyrium scoparium*	little bluestem	
	SPGR	*Spartina gracilis*	alkali cordgrass	
	SPPE	*Spartina pectinata*	prairie cordgrass	
	SPCR	*Sporobolus cryptandrus*	sand dropseed	
	VUOC	*Vulpia octoflora*	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	
	ERPA9	***Eriogonum pauciflorum***	**few-flower wild buckwheat**	
	PEAM8	*Persicaria amphibia*	smartweed	*
	PORA3	*Polygonum ramosissimum*	bushy knotweed, tall knotweed	
	RUVE2	*Rumex venosus*	veiny dock	
Salicaceae	SARU3	*Salix ×rubens*	hybrid crack willow	*
Solanaceae	PHVI5	*Physalis virginiana*	ground cherry (Virginia)	

Family	Code	Scientific Name	Common Name	Exotic
	SOTR	*Solanum triflorum*	cut-leaf nightshade, cutleaf nightshade	
Typhaceae	TYAN	*Typha angustifolia*	narrow-leaf cat-tail, narrowleaf cattail	
	TYLA	*Typha latifolia*	broadleaf cattail, common cattail	
Unknown family	UNKFORB	*Unknown forb*	unknown forb	*
	UNKFORB PER	*Unknown perennial forb*	unknown perennial forb	*
Urticaceae	URDI	*Urtica dioica*	stinging nettle	
Verbenaceae	VEHA2	*Verbena hastata*	blue verbena, blue vervain	
Violaceae	VINU2	*Viola nuttallii*	Nuttall's violet, yellow prairie violet	

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