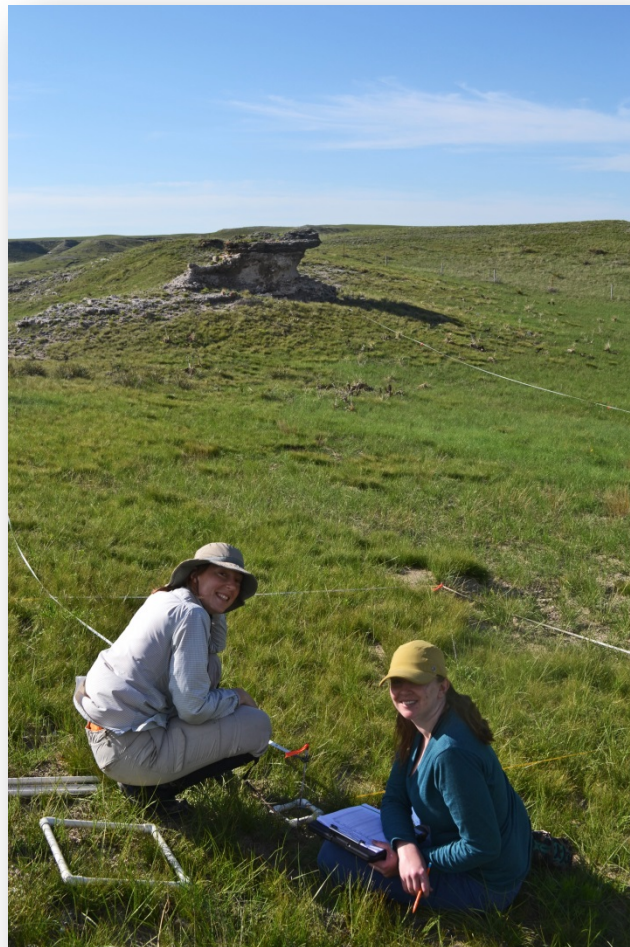




Plant Community Composition and Structure Monitoring for Agate Fossil Beds National Monument

2011-2015 Summary Report

Natural Resource Report NPS/NGPN/NRR—2016/1198





ON THIS PAGE

Photograph of riparian long-term monitoring plot 261 at Agate Fossil Beds National Monument, 2015.
Photograph courtesy of the National Park Service.

ON THE COVER

Photograph of plant community monitoring at Agate Fossil Beds National Monument, 2015.
Photograph courtesy of the National Park Service.

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

2011-2015 Summary Report

Natural Resource Report NPS/NGPN/NRR—2016/1198

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U.S. Department of the Interior
National Park Service
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Executive Summary

The Northern Great Plains Inventory & Monitoring Program and Fire Effects Program have been monitoring vegetation in Agate Fossil Beds National Monument for over 18 years. While methods have changed slightly, this report summarizes data from over 80 locations from 1998-2015. We use these data to explore status and trends in upland and riparian plant communities, the occurrence of rare plants, and the effects of the Fossil Hills trail installation on the surrounding vegetation. A summary of the current condition (2011-2015) and trends (based on 1998-2015) in plant communities at Agate Fossil Beds NM (AGFO) is found in Table ES-1 below.

1. What is the current status of plant community composition and structure of AGFO grasslands (species richness, cover, and diversity) and how has this changed from 1998 to 2015?

Native grasses, such as needle and thread, sand reed, and western wheatgrass, are abundant and the dominant component of the prairie at AGFO. Native plant diversity is at a moderate level compared to other grasslands in the region (Table 7), but diversity is spatially variable. We found no significant trends in native diversity or evenness from 1998 to 2015, but both may become threatened if cover of annual invasive brome grasses increases, as we've observed in other Northern Great Plains Inventory and Monitoring units (Figure 8).

2. How do trends in grassland condition correlate with climate and fire history?

Native species richness increased in years with more rainfall and a hot dry year in 2012 corresponded to large declines in native species richness and an increase in exotic species cover. Plots that had not burned in 5 or 6 years had a higher number of native species and a lower cover of exotics than sites that burned more recently and when compared to AGFO averages (Figure 12). This suggests that prescribed fire can benefit the mixed-grass prairie in AGFO, but it may take 5 or more years to see the positive effects following a burn.

3. What, if any, rare plants were found in AGFO long-term monitoring plots?

We identified 22 rare plant species in AGFO between 1998 and 2015; seven of these are considered critically imperiled within Nebraska. We recommend monitoring of rare plant populations and more targeted surveys of rare plant species be completed when funds are available.

4. How did installation of the AGFO Fossil Hills Trail affect the adjacent prairie?

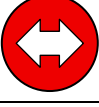
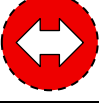
The disturbed prairie adjacent to the Fossil Hills Trail is very similar to the native prairie in other parts of AGFO. This suggests that the prairie in AGFO is resilient and can recover from a moderate level of disturbance. We suggest continued monitoring of these plots to ensure that any increase in exotic species abundance is detected so appropriate control measures can be taken.

5. What is the composition and structure of the riparian corridor at AGFO?

The riparian corridor in AGFO is a fairly diverse assemblage of riparian species such as sedges, willows, and cattails. It is, however, more invaded than the upland areas of AGFO

and threatened by high cover of Kentucky bluegrass and pale yellow iris. Since riparian monitoring began in 2012, we have not detected a significant change in the cover of pale yellow iris. Continued monitoring is necessary to determine if exotic treatment is effective over the long-term.

Table ES-1. Natural resource condition summary table for plant communities in Agate Fossil Beds National Monument (AGFO). Current values are based on data from 2011-2015 and trends are based on data from 1998-2015.

Indicator of Condition	Specific Measures	Current Value (mean $\pm$ SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Native species richness (1m ² quadrats)	7.3 $\pm$ 0.5 species	3-15 species		AGFO plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the region. The monument is characterized by moderate native species richness, but average richness is within a natural range of variability (Symstad and Jonas 2014). The lowest native diversity is found near the road. Native evenness has not changed since monitoring began in 1998.
	Evenness (native spp. point-intercept transects)	0.70 $\pm$ 0.01	To be determined		
	Relative cover of exotic species	17.6 $\pm$ 2.5%	< 10 % cover		AGFO maintains a mixed-grass prairie with moderate exotic plant cover and a fair diversity of native plants. Annual invasive bromes are not currently abundant in AGFO, but active management may be required to keep such low cover.
	Annual brome cover	7.4 $\pm$ 1.9%	< 10 % cover		
Riparian Plant Community Structure and Composition	Native species richness (50 m point-intercept transect)	9.6 $\pm$ 1.0	To be determined		The riparian areas of AGFO had levels of diversity similar to the upland areas.
	Relative cover of exotic species	28.3 $\pm$ 2.0%	$\leq$ 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. Pale yellow iris has invaded riparian areas throughout the monument. It had a patchy distribution and was absent in some sites while accounting for over 50% in others
	Relative cover of pale yellow iris	11.5 $\pm$ 2.4%	$\leq$ 10 % cover		

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Introduction

During the last century, much of the prairie within the Northern Great Plains has been plowed for cropland, planted with non-natives to maximize livestock production, 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 monument contains 2,270 acres of native mixed-grass prairie intersected by riparian vegetation along the Niobrara River. Vegetation monitoring began in AGFO in 1998 by the Heartland Inventory & Monitoring Program (James 2010a) 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 monument and to coordinate efforts with the FireEP (Symstad et al. 2012b), and sampling efforts began in 2011 (Ashton et al. 2011). In 2012, the NGPN began monitoring an additional 17 plots within the riparian corridor to assess riparian condition. In this report, we use the data from 2011-2015 to assess the current condition of AGFO vegetation and the data from 1998-2015 are used to look at longer-term trends.

Using 18 years of plant community monitoring data in AGFO, we explore the following questions:

1. What is the current status of plant community composition and structure of AGFO grasslands (species richness, exotic plant cover, and diversity) and how has this changed from 1998-2015?
2. How do trends in grassland condition correlate with climate and fire history?
3. What, if any, rare plants were found in AGFO long-term monitoring plots?
4. How did installation of the AGFO Fossil Hills Trail affect the adjacent prairie?
5. What is the composition and structure of the riparian corridor at AGFO?

Methods

Three different methods and protocols have been used to monitor long-term vegetation plots at AGFO since 1997: the NGPN monitoring protocol (Symstad et al. 2012b, a), the Fire Monitoring Handbook (NPS 2003), and the Heartland Vegetation Monitoring Protocol (James et al. 2009). Below, we briefly describe all three methods, but focus on the NGPN monitoring protocol, which is the current standard and was used to collect most of the data in this report. For more detail on any of the methods, please see the protocol publications (cited above).

NGPN and NGPFire Monitoring Plots 2011-2015

The NGPN and NGPFire 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, NGPN selected 16 randomly located sites within the upland grasslands of AGFO to become Plant Community Monitoring plots (PCM plots; Figure 1). The NGPN visits 6 PCM plots every year using a rotating sampling scheme where three sites were visited in the previous year and three sites are new visits. After five years (2011-2015), most of the PCM plots were visited at least twice during the first weeks of June. When a PCM plot fell within an active burn unit, NGPFire added additional visits based on a 1, 2, 5, and 10 year sampling schedule. NGPFire also established and monitored a number of new sites focused in active burn units (Fire FPCM plots) using the same GRTS sampling schema. From 2011-2015, 16 FPCM plots were established. Finally, using the same set of random sites, NGPN selected 17 additional plots that fell within the riparian zone along the Niobrara River. These were monitored in 2012-2015 to assess the condition of riparian condition.

At each of the grassland sites we visited, we recorded plant species cover and frequency in a rectangular, 50 m x 20 m (0.1 ha), permanent plot (Figure 2). Data on ground cover and herb-layer (≤ 2 m) height and plant cover were collected on two 50 m transects (the long sides of the plot) using a point-intercept method (Figure 3). 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 3). Using this method, absolute canopy cover can be greater than 100% (particularly in wet years and productive sites) because we record multiple layers of plants. Species richness data from the point-intercept method were supplemented in the 16 PCM plots with species presence data collected in five sets of nested square quadrats (0.01 m², 0.1 m², 1 m², and 10 m²) located systematically along each transect (Figure 2).



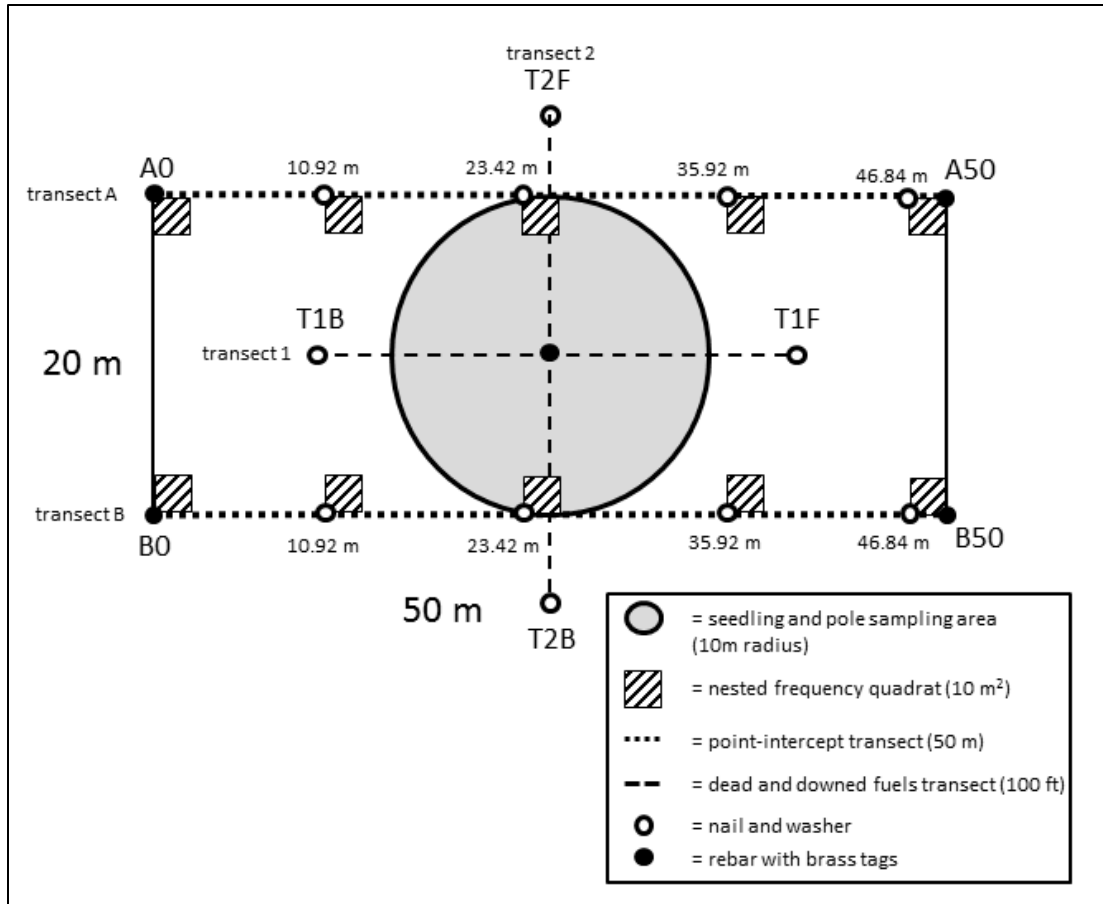


Figure 2. Long-term monitoring plot layout used for sampling vegetation in Agate Fossil Beds National Monument.

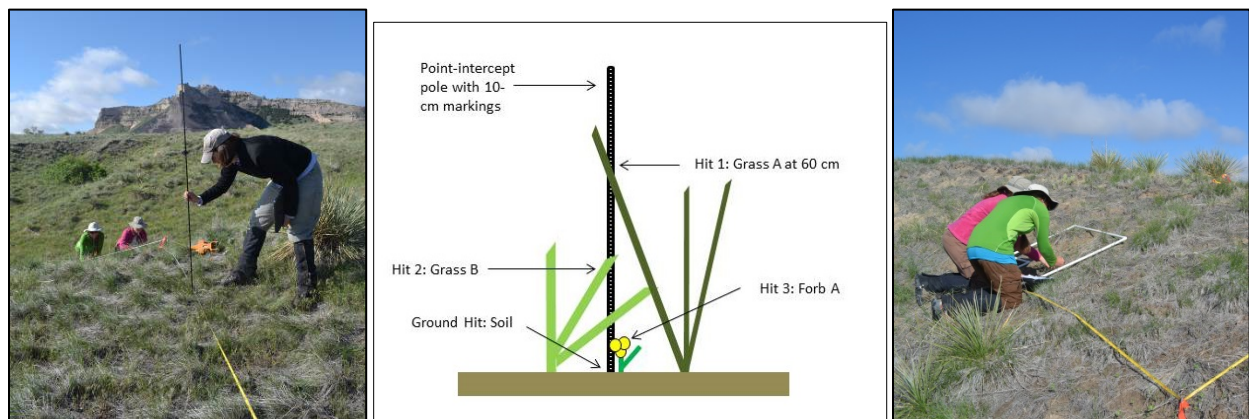


Figure 3. The Northern Great Plains Inventory & Monitoring vegetation crew used point-intercept (left and center panel) and quadrats (right panel) to document plant diversity and abundance.

NGPN completed a survey of the riparian zone in AGFO in August of 2012-2015 using a set of 17 randomly located sites. In this case, vegetation was measured using the point-intercept method, as

described above, but it was measured along only one 50 m transect that ran perpendicular to the river channel. These plots were not permanently marked and were relocated using GPS coordinates.

At all PCM plots, but not the FPCM plots, we also surveyed the area for common disturbances and target species of interest to AGFO. Common disturbances can include such things as rodent mounds, improvised and animal trails, and fire. For all plots, the type and severity of the disturbances were recorded. We also surveyed the area for exotic species that have the potential to spread into the monument and cause significant ecological impacts (Table 1). These species were chosen in collaboration with the Midwest Invasive Plant Network, the Exotic Plant Management Team, resource managers, and local weed experts. 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.

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

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

Other Monitoring Plots (1997-2015)

In 1997, NGPFire began monitoring plots within AGFO to evaluate the effectiveness of prescribed burns. Starting in 1998, data collection followed the NPS National Fire Ecology Program protocols (NPS 2003): in grassland plots vegetation cover and height data were collected using a point-intercept method, with 100 points evenly distributed along a single 30 m transect. NGPFire plot locations were located randomly within major vegetation types within areas planned for prescribed

burning (burn units) in the near future. The plots were then sampled 1, 2, 5, and 10 years after a prescribed burn. The data were not collected using these protocols in 2010, so this year was excluded from analyses. Hereafter, we refer to these plots as Fire Monitoring Handbook (FMH) plots. These FMH plots are being retired after the 10 year visit (e.g. the rebar will be removed) and replaced with the FPCM plots described above.

The Heartland Inventory & Monitoring Program also established a number of plots in 1997. Plant frequency was measured using circular subplots as described in the Heartland Networks' vegetation monitoring protocol (James et al. 2009). The data and a summary of results from these plots are described in detail by James (2010b). In 2009, 2013 and 2014, a subset of these plots (called Legacy Plant Community Monitoring Plots, LPCMs) was revisited by NGPN and point-intercept data was also collected using the methods described above. In this report, we present the point-intercept from the three survey years, but do not report frequency. These plots were chosen to revisit because they were established to evaluate the disturbance caused by a trail installation. Three plots were established adjacent to the trail in areas of prairie impacted by construction disturbance (LPCM_2, 3 and 7) and two plots were established nearby in undisturbed native prairie (LPCM_4 and 5).

Data Management and Analysis

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

Species scientific names, codes, and common names are from the USDA Plants Database (USDA-NRCS 2015). 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. This report uses common names after the first occurrence in the text, but scientific names can be found in Appendix A.

After data for the sites were entered, 100% of records were verified to the original data sheet to minimize transcription errors. A further 10% of records were reviewed a second time. After all data were entered and verified, automated queries were used 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/or the FFI database as needed. Summaries were produced using the FFI reporting and query tools and statistical summaries, and graphics were generated using R software (version 3.2.2).

Plant life forms (e.g., shrub, forb) were based on definitions from the USDA Plants Database (USDA-NRCS 2015). The conservation status ranks of plant species in Nebraska is determined by the Nebraska Natural Heritage Program (NENHP). For the purpose of this report, a species was considered rare if its conservation status rank was S1, S2, or S3. See Table 2 for a detailed definition of each conservation status rank.

Table 2. Definitions of state and global species conservation status ranks*.

Status Rank	Category	Definition
S1/G1	Critically imperiled	Due to extreme rarity (5 or fewer occurrences) or other factor(s) making it especially vulnerable to extirpation.
S2/G2	Imperiled	Due to rarity resulting from a very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation.
S3/G3	Vulnerable	Due to a restricted range, relatively few populations (often 80 or fewer), recent widespread declines, or other factors making it vulnerable to extirpation.
S4/G4	Apparently secure	Uncommon but not rare; some cause for concern due to declines or other factors.
S5/G5	Secure	Common, widespread and abundant.
S#S#/ G#G#	Range rank (e.g. S2S3)	Used to indicate uncertainty about the status of the species or community. Ranges cannot skip more than one rank.

*Adapted from NatureServe status assessment table (<http://www.natureserve.org/conservation-tools/conservation-status-assessment>)

We measured diversity at the plots in two ways: species richness and Pielou's Index of Evenness. Species richness is simply a count of the species recorded in an area. Pielou's Index of Evenness, J' , measures how even abundances are across taxa and ranges between zero and one; values near zero indicate dominance by a single species and values near one indicate nearly equal abundance of all species present. Plant richness was calculated for each plot using the total number of species intersected along the transects. Average height was calculated as the average height per plot using all species intersected on the transects.

Climate data from the Agate 3E, Nebraska weather station (GHCND:USC00250030) were downloaded from NOAA's online database (NOAA 2015). Fire history maps were compiled for AGFO and cross-referenced with plot locations. For each time data were collected at a plot (i.e., plot visit), we determined the number of years since the plot had burned and the number of fires recorded for that plot. For plots where no burns were recorded, we calculated the difference between the year of data collection and the oldest fire recorded in AGFO. This is likely an underestimate of the true time since it burned because fires were infrequent prior to the 1980s.

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 is to improve park priority setting and to synthesize and communicate complex park condition information to the public in a clear and simple way. By focusing on specific indicators, such as exotic species cover, it will also be possible and straightforward to revisit the metric in subsequent years. The status and trend of each indicator is scored and assigned a corresponding symbol based on the key found in Table 3.

We chose a set of indicators and specific measures that can describe the condition of vegetation in the Northern Great Plains and the status of exotic plant invasions. The measures include: absolute herb-layer canopy cover, native species richness, evenness, relative cover of exotic species, and annual brome cover. Reference values were based on descriptions of historic condition and variation, past studies, and/or management targets. Current park unit condition was compared to a reference value, and status was scored as good condition, warrants moderate concern, or warrants significant concern based on this comparison (Table 3). Good condition was applied to values that fell within the range of the reference value, and significant concern was applied to conditions that fell outside the bounds of the reference value. In some cases, reference conditions can be determined only after we have accumulated more years of data. When this is the case, we refer to these as “To be determined” and estimate condition based on our professional judgment.

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

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

Results and Discussion

Status & Trends in Community Composition and Structure of AGFO Prairies

There are 453 plant species on the AGFO species list and we found 277 plant species in monitoring plots from 1998-2015 at AGFO (Appendix A). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at AGFO, but forbs, shrubs and subshrubs were also present (Figure 4). We found 47 exotic plant species at AGFO, all of which were forbs or graminoids. Exotic graminoids were particularly abundant (Figure 4). The shrubs and subshrubs were all native species.

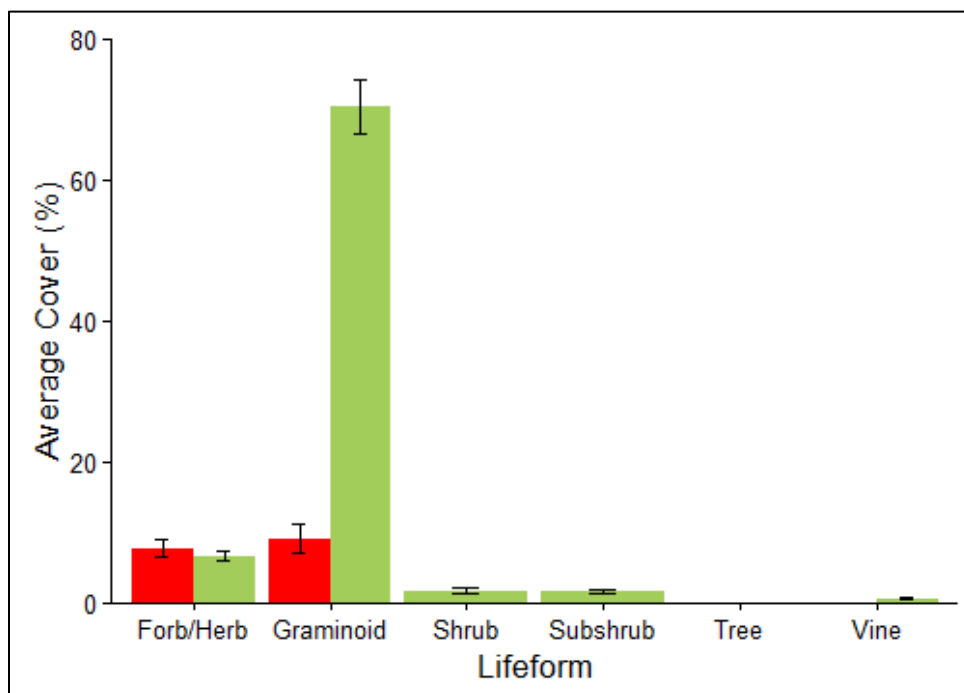


Figure 4. Average cover by lifeform of native (green) and exotic (red) plants recorded in monitoring plots in Agate Fossil Beds National Monument (1998-2015). Absolute cover can be greater than 100% because the point-intercept methods records layers of overlapping vegetation.

Needle and thread (*Heterostipa comata*), prairie sand reed (*Calamovilfa longifolia*), Western wheatgrass (*Pascopyrum smithii*), and slender wheatgrass (*Elymus trachycaulus*) were the most abundant native grasses and averaged between 8 and 25% absolute cover (Figure 5). There were no exotic species in the 10 most common plants in AGFO (Figure 5). There is also no evidence that exotic cover has increased since 1998 ($F_{1,52} = 0.65$ $P = 0.42$), but exotic species are still a concern. The cover of exotic species in 2011-2015 averaged $17.6 \pm 2.5\%$ (mean $\pm$ standard error) and it was $16.4 \pm 2.5\%$ for the entire period of record. Kentucky bluegrass (*Poa pratensis*), prickly Russian thistle (*Salsola tragus*), cheatgrass (*Bromus tectorum*) and Japanese brome (*B. japonicus*) were the most pervasive exotics at AGFO. We found no targeted early detection species (Table 1) in the upland areas of AGFO. Cheatgrass and Japanese brome are both Eurasian, annual grasses that have been a part of the NGP landscape for more than a century, but their invasion in the region has accelerated

since 1950 (Schachner et al. 2008). The presence of annual bromes in mixed grass prairie is associated with decreased productivity and altered nutrient cycling (Ogle et al. 2003). There is strong evidence from regions further west that cheatgrass alters fire regimes and the persistence of native species (D'Antonio and Vitousek 2003). From 1998 to 2015, the average relative cover of annual bromes was $5.8 \pm 1.5\%$ and the average for the last 5 years was $7.4 \pm 1.9\%$. While the cover of annual bromes has not been increasing over time in AGFO ($R^2=0.19$, $F_{1,52}=0.29$ $P=0.59$; Figure 6), there is evidence that annual bromes are increasing within other National Park units in the region (unpublished data).

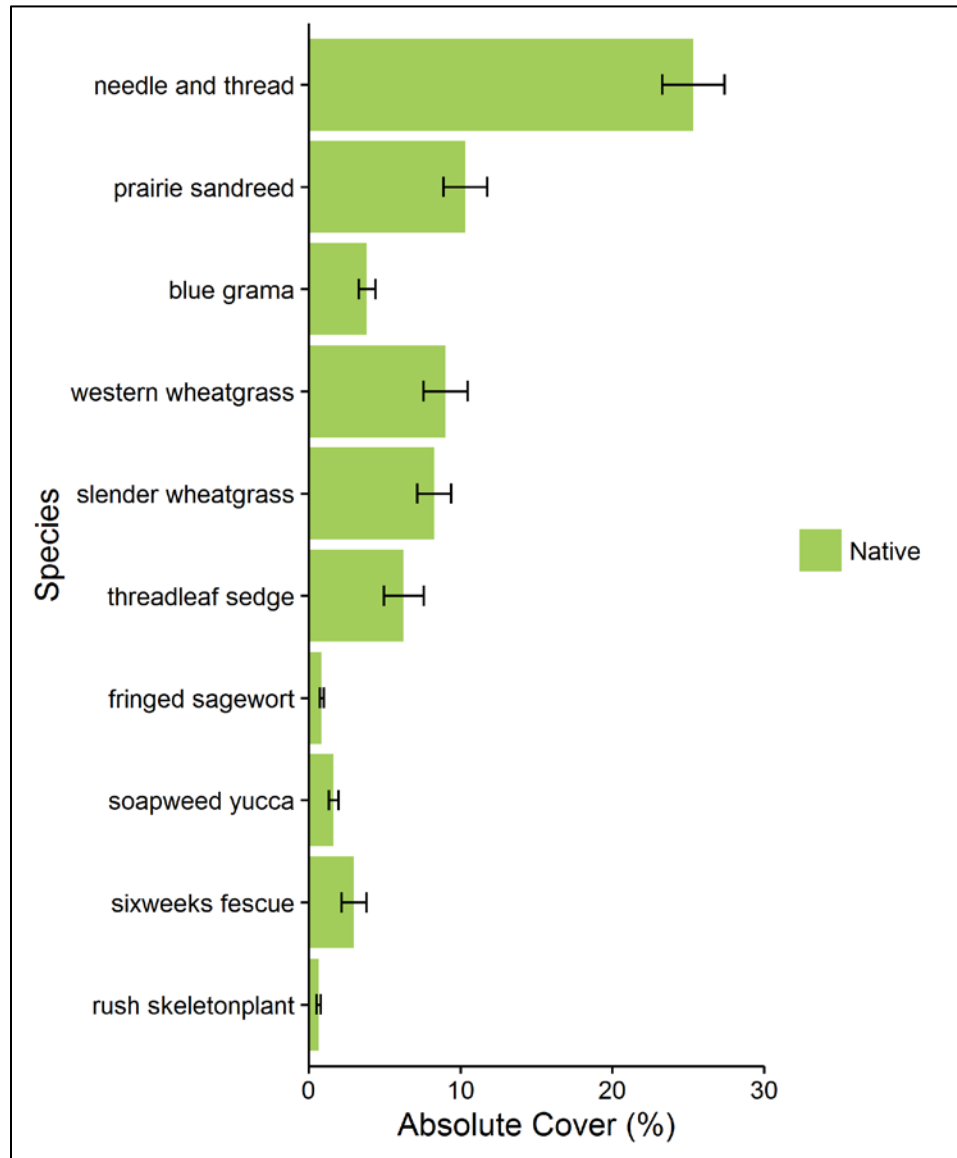


Figure 5. The average absolute cover of the 10 most common native plants recorded at Agate Fossil Beds National Monument in 1998-2015. Bars represent means $\pm$ one standard error. All of the 10 most common plants were native species.

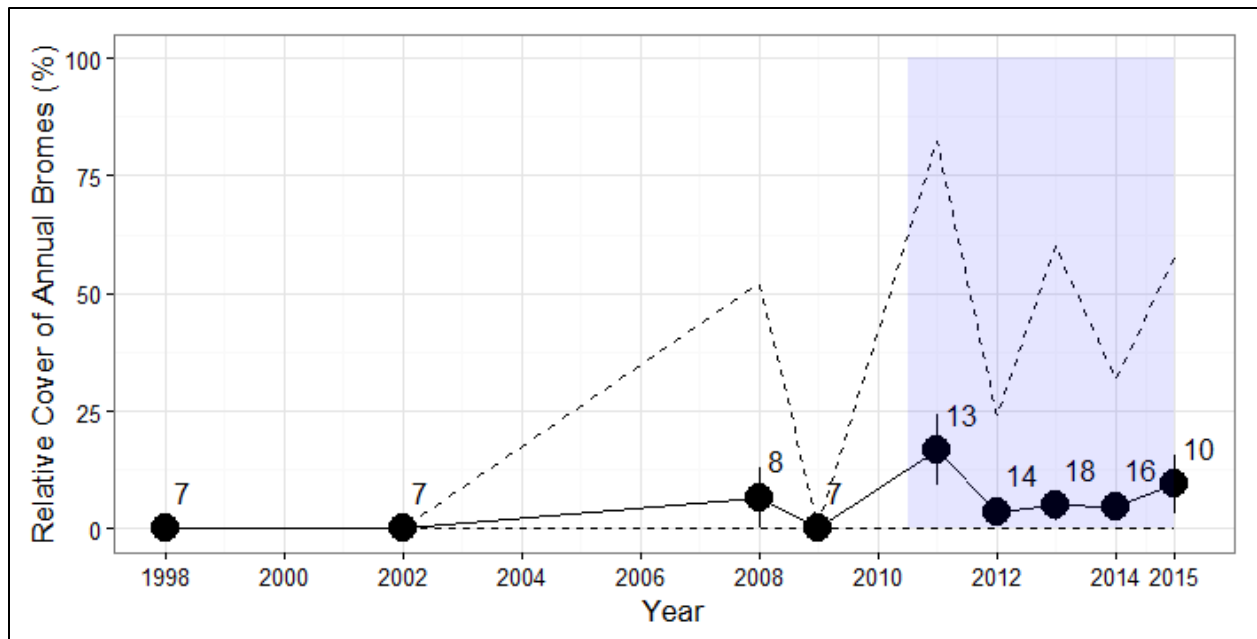


Figure 6. Trends in the relative cover of annual bromes in Agate Fossil Beds National Monument from 1998-2015. Points represent mean $\pm$ one standard errors and sample size is to the right of the point. Years with fewer than three monitoring plots were excluded from the graph. The shaded area highlights the period from 2011-2015 when sampling methods were consistent and distribution of plots was more even and consistent across years. The dashed line represents the maximum and minimum cover values for each year.

Species Richness, Diversity, and Evenness

One of the ways for the NPS to measure effectiveness of actions to achieve its mission of ‘preserving ecological integrity’ is to examine trends in native plant diversity and evenness within park unit boundaries. Average species richness has been measured by point-intercept since 1998 and in 1 m² and 10 m² quadrats since 2011 (Table 4).

Table 4. Average plant species richness in monitoring plots at Agate Fossil Beds National Monument from 1998 to 2015. Values represent means $\pm$ one standard error.

	Point-intercept (1998-2015; n=47)	1 m ² quadrats (2011-2015, n=31)	10 m ² quadrats (2011-2015, n=31)
Species richness	11.8 $\pm$ 0.6	8.7 $\pm$ 0.6	14.8 $\pm$ 0.9
Native species richness	9.8 $\pm$ 0.6	7.3 $\pm$ 0.5	12.2 $\pm$ 0.8
Exotic species richness	2.8 $\pm$ 0.2	1.4 $\pm$ 0.2	2.5 $\pm$ 0.3
Graminoid species richness	6.0 $\pm$ 0.2	3.6 $\pm$ 0.2	4.7 $\pm$ 0.2
Forb species richness	5.0 $\pm$ 0.4	4.5 $\pm$ 0.4	8.9 $\pm$ 0.6

While there was some variation across the monument, the plots we visited in AGFO tended to have a moderate diversity of native plants compared to other mixed-grass prairies. Species richness in the mixed-grass prairie is determined by numerous factors including fire regime, grazing, disturbance, and weather fluctuations (Symstad and Jonas 2011). While it is difficult to define a reference

condition for species richness, which naturally varies considerably across both space and time, the natural range of variation over long-time periods may be a good starting point (Symstad and Jonas 2014). Long-term records of species diversity in mixed-grass prairie from a relatively undisturbed site in Kansas varied between 3 and 15 species per square meter over the course of 30 years (Symstad and Jonas 2014). Compared to this, AGFO is within the natural range (7 species). Only one site, PCM_005 (Figure 1; middle) fell below this reference condition. This site is very close to the road and was likely impacted by construction. The most diverse plot, AGFO_PCM_012 (Figure 1; southeast), averaged 10.2 species.

We did not find any directional change in species richness or evenness over time (Figure 8). Native species richness in 1m² quadrats was consistent from 2011 to 2015; it ranged from a low in 2012 of 4.5 ± 0.6 (a drought year) to a high of 9.5 ± 0.9 in 2014 (a wet year). In the longer record from point-intercept data (1998-2015; Figure 7: top) annual average native richness ranged between 7 and 14 species. Annual average evenness of native species ranged from 0.62 to 0.72 during this time period, indicating the plots were not strongly dominated by a single species (Figure 7: bottom). There is a great deal of variation in species richness and evenness among sites within AGFO (dashed lines in Figure 7 represent the maximum and minimum values) which makes long-term trends in these metrics difficult to detect.

There is evidence from other regions that annual bromes can affected persistence of native species (D'Antonio and Vitousek 2003). In AGFO and other nearby Northern Great Plains parks, there is a negative correlation between the cover of annual bromes and native species richness (Figure 9; $F_{1,551}=36.5$, $P<0.0001$). If the cover of annual bromes in AGFO increases over time, we expect there will be a corresponding decline in native species richness.

Disturbance from grazing, fire, and humans affects plant community structure and composition in mixed-grass prairie. We estimated the approximate area affected by natural and human disturbances at each site we visited in 2011-2015 by surveying the area for ~ 5 minutes at the end of the plot visit. The most common disturbance was from rodents (e.g. pocket gophers) and it was widespread, occurring in 21 plots. There was also evidence of prescribed fires and off-road use, but this occurred in fewer plots (7 and 6 plots, respectively). We found no correlation with total disturbance, small or large animal disturbance and native richness or exotic cover. As more monitoring data are collected in future years, we may be able to better explore the statistical relationship between these metrics and disturbance.

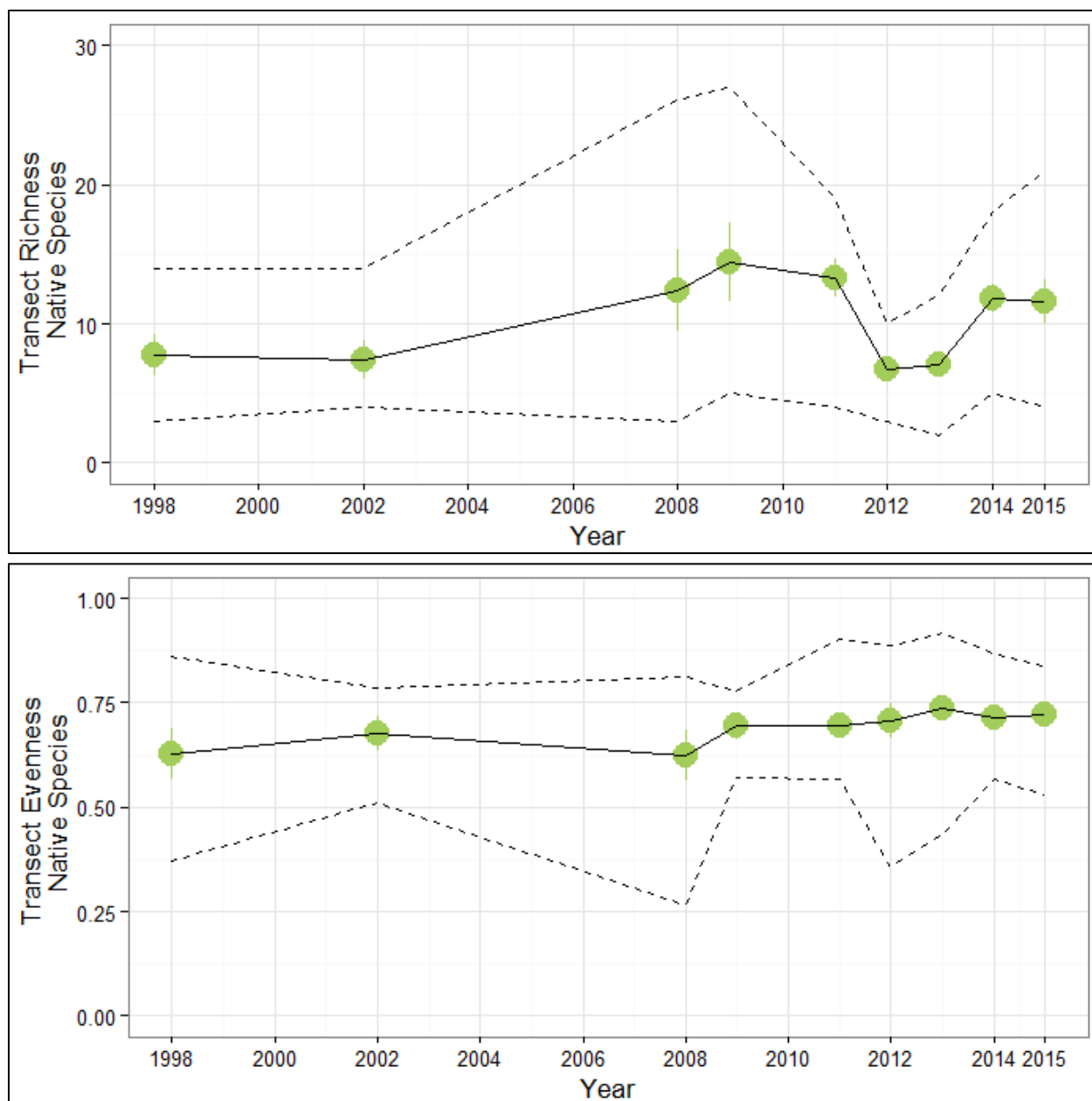


Figure 7. Trends in native species richness and evenness in Agate Fossil Beds National Monument, 1998-2015. Data are means $\pm$ one standard error. The dashed line indicates the maximum and minimum values for each year.

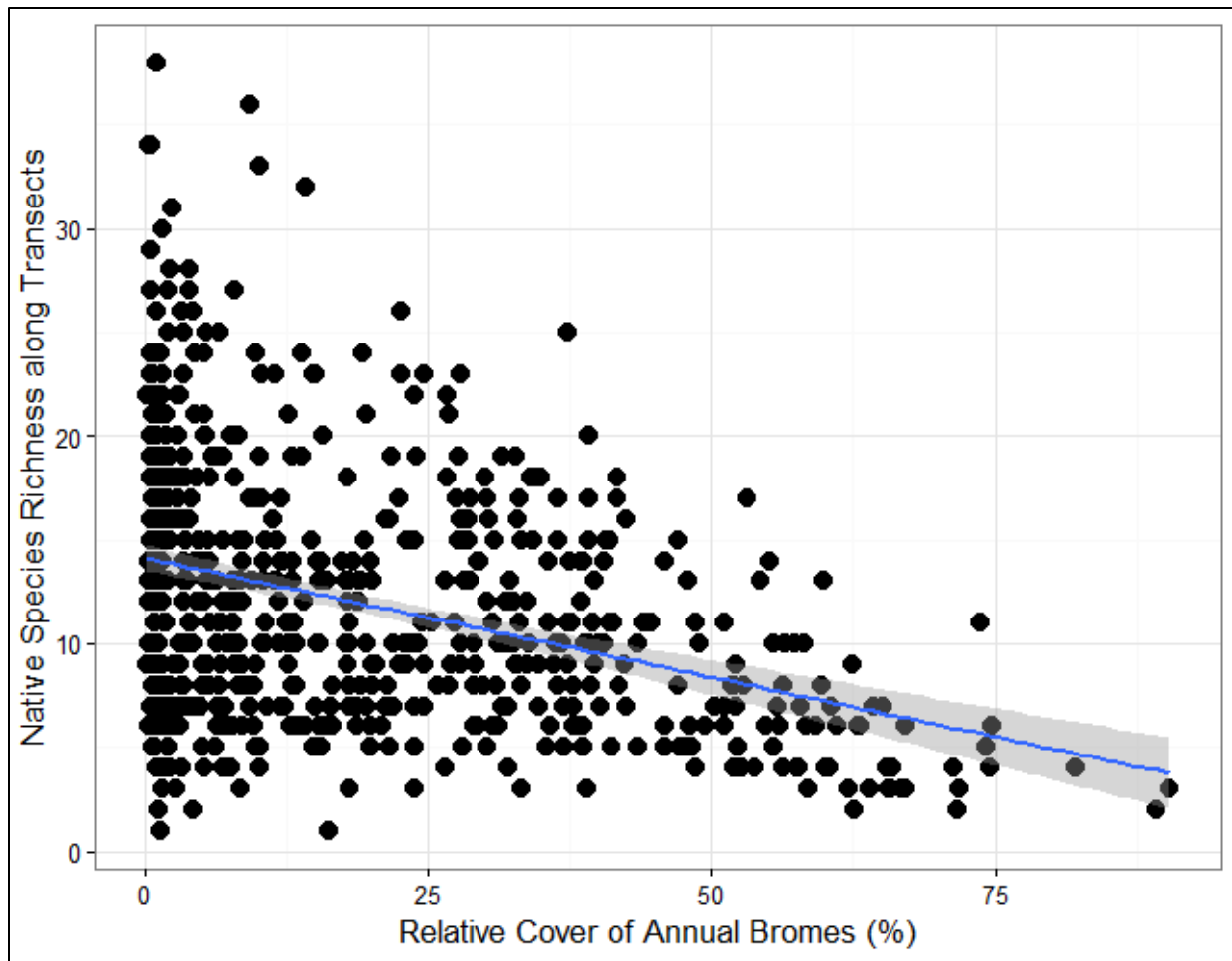


Figure 8. The relationship between native species richness and the relative cover of annual bromes in long-term monitoring plots in National Park units of the Northern Great Plains, 1998-2015.

The Influence of Climate and Fire on Plant Community Structure and Diversity

Climate

The Northern Great Plains has a continental climate, with hot summers and very cold winters. The 30-year normal temperatures at a nearby weather station, Agate 3E, Nebraska ranged from average minimum monthly temperatures in December of 7.8° F to maximum monthly July temperatures of 88.7° F (based on 1980-2010). The 30-year normal annual precipitation totals 14.37 inches. Annual precipitation at AGFO in 1998-2015 was variable and ranged between 4.5 and 21.3 inches, in 2012 and 2009, respectively. There were dry years in the early 2000s, 2006-2008, and in 2012 (Figure 10). The last two years have been much wetter than average. The native vegetation is adapted to this variation, and productivity responds strongly to decreases in spring and summer precipitation (Yang et al. 1998, Smart et al. 2007). Species richness and diversity in regional grasslands are also sensitive to temperature and precipitation fluctuation, but the response is complex and less predictable (Jonas et al. 2015).

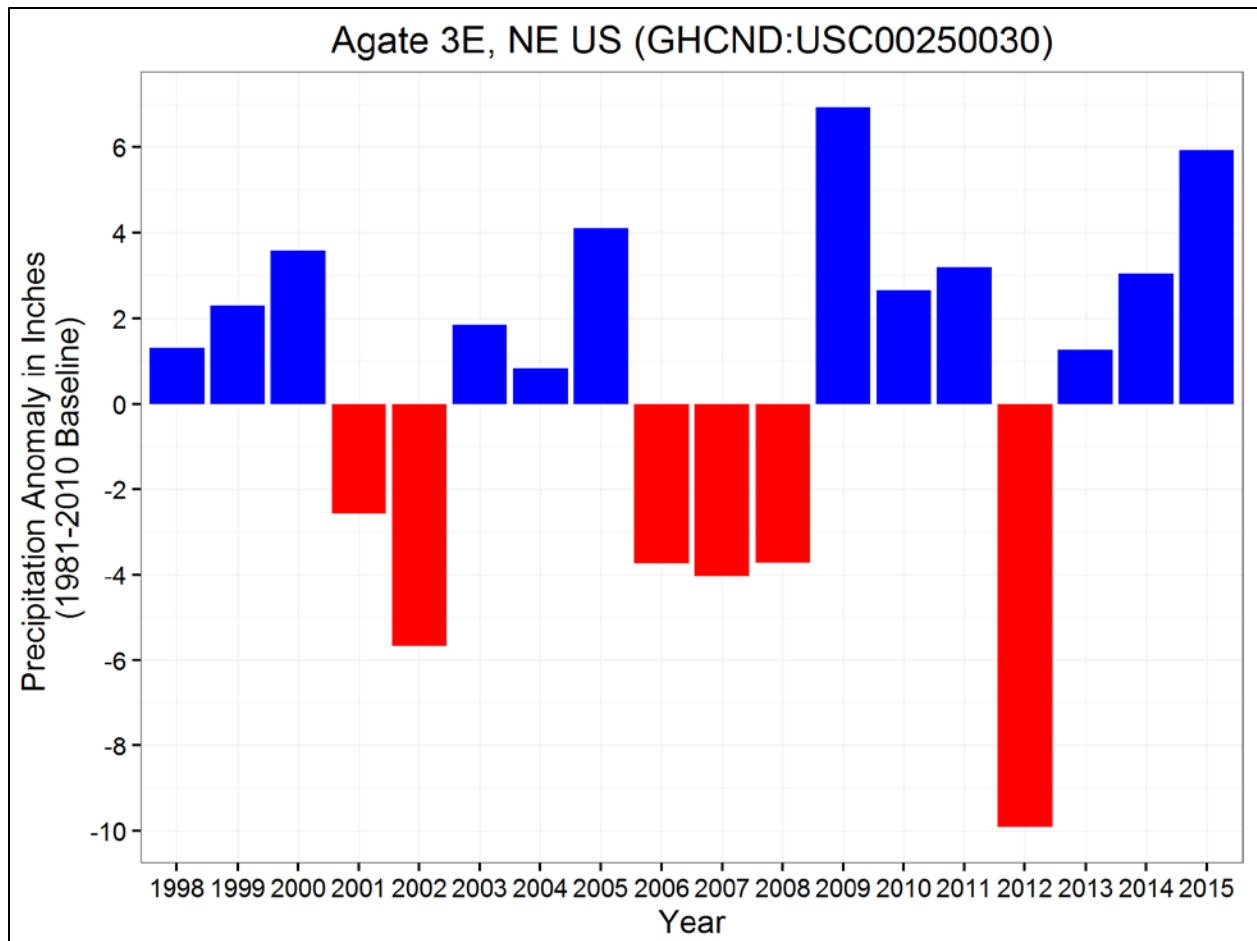


Figure 9. The total annual precipitation anomaly from 1998-2015 for Agate Fossil Beds National Monument. Positive values (blue) represent years wetter than and negative values (red) years drier than the 1981-2010 average. The anomaly is measured in inches and based on data from a nearby weather station.

We found that native species richness increased in response to increasing precipitation ($F_{1,52}=11.1$, $P<0.001$). Plant height and exotic cover also responded to precipitation ($F_{1,52}=4.2$, $P=0.047$, $F_{1,52}=6.2$, $P=0.016$, for height and cover respectively) and maximum temperature ($F_{1,52}=7.8$, $P=0.007$, $F_{1,52}=13.8$, $P<0.001$). However, the response was driven by 2012, an extremely hot and dry year (Figure 10). When 2012 was excluded from analysis neither height nor exotic cover showed a significant response to temperatures or precipitation. Similarly, native species richness declined in 2012 when average maximum temperatures were very hot, but otherwise there was no significant response over this time period. Continued monitoring and a longer time series of vegetation data and climate will allow us to determine whether the response to the 2012 drought is typical.



Figure 10. A long-term monitoring plot in Agate Fossil Beds National Monument in 2012, during a severe drought, and 2014 a wet year.

Fire History

Historically, fire was a common disturbance in Northern Great Plains grasslands, with natural fire return intervals of 9-12 years (Guyette et al. 2015). Natural fires have been suppressed for most of the last century, but the use of prescribed burning in Northern Great Plains parks to mitigate the effects of the absence of natural fires has increased over time since its start at Wind Cave NP in 1973 (Wienk et al. 2011). As of 2015, there is a mosaic of recently burned and unburned areas at AGFO (Figure 11).

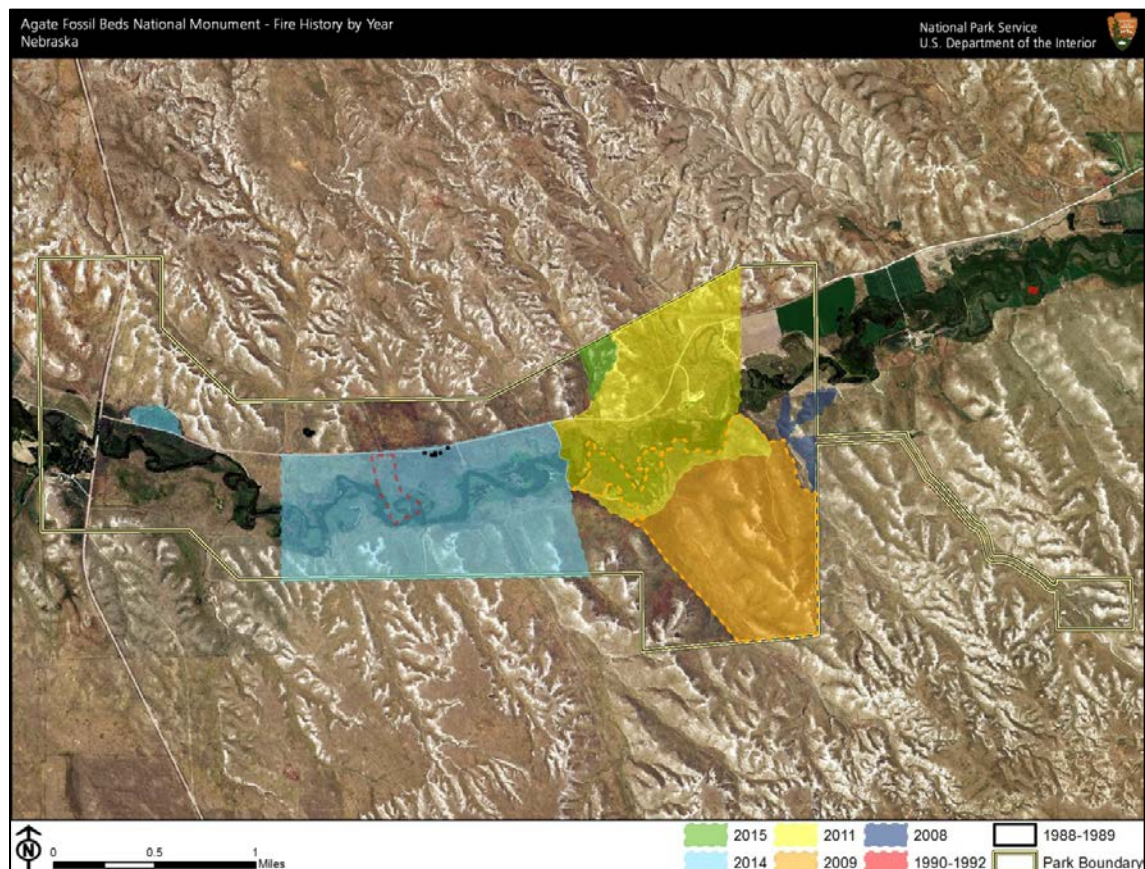


Figure 11. Map of recent fire history at Agate Fossil Beds National Monument.

The effects of specific prescribed burns on vegetation and fuel loads and more details about fires at AGFO can be found in past NGPFire annual reports (see <http://www.nps.gov/ngpfire/docs.htm>). Here, we were interested in determining the relationship between fire history and vegetation. We compared two vegetation metrics, native species richness and relative cover of exotic plants, with the length of time between the data collection at a plot and the most recent fire at that plot (years since fire). For example, a site that burned in the spring and then was visited in the summer would be 0 years since fire. We excluded plots that had not burned from this analysis, because we do not have confidence in the historical fire record (pre-1980s).

We found a strong positive relationship between native richness and years since fire (Figure 12; $F_{1,32}=32.6$, $P<0.0001$). Exotic species cover declined significantly as years since fire increased (Figure 12; $F_{1,32}=4.8$, $P=0.036$). Annual bromes show a similar pattern, but it is not significant. Plots that had not burned in 5 or 6 years had a higher number of native species and a lower cover of exotics than sites that burned more recently and when compared to AGFO averages. This suggests that prescribed fire can benefit the mixed-grass prairie in AGFO, but it may take 5 or more years to see the positive effects.

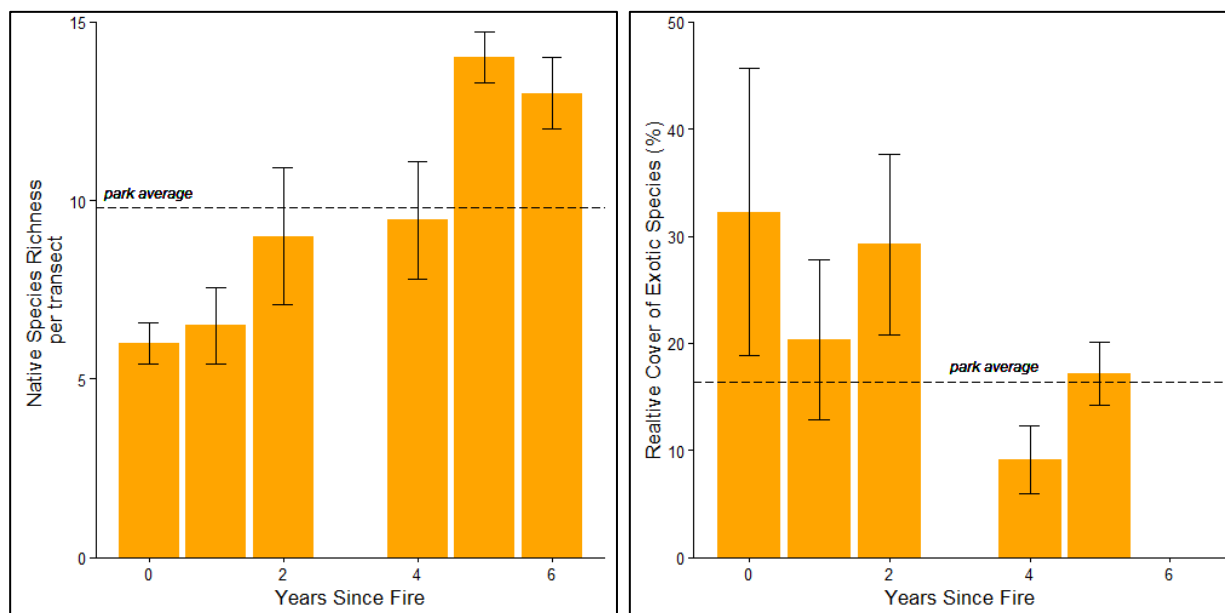


Figure 12. Native species richness (left panel) and relative percent cover of exotic plants (right panel) across plots with different fire histories. Observations vary between plots that have recently burned (0 years since fire) and plots that had burned 6 years previously (6 years since fire). Bars represent means $\pm$ one standard error and sample sizes range from 3 to 9 plots. The dashed line indicates the average native species richness and relative percent cover of exotic species of all plots in AGFO.

The best approach to reducing exotic species abundance in AGFO will likely include burning; however there may also be a need for targeted herbicides and seeding of native species. Ongoing research on this topic and an upcoming adaptive management initiative for annual brome control in NGPN units should provide more data and guidance to help with these management decisions.

Rare Plants

While repeating rare plant surveys and locating rare species is not the focus of NGPN plant community monitoring, we identified 40 rare plant species in AGFO from 1998 to 2015. Of these species, 22 were S3S5 species (vulnerable to secure) whose vulnerability rank is low and uncertain and won't be discussed here (see Appendix A for S3S5 species). Seven critically imperiled (S1) species were observed mostly in very low frequencies and abundances with the exception of slender wheatgrass (*Elymus trachycaulus*), which was observed in 42 plots with 8% mean cover (Table 5). Other more commonly observed rare species included aridland goosefoot (*Chenopodium desiccatum*, S2S4), longbracted plantain (*Plantago patagonica* S2S4), and hairy goldenaster (*Heterotheca villosa*, S1). Most rare species we observed were in fewer than 5 plots and had less than 0.01% mean cover (Table 5; Figure 13). All rare species we observed in AGFO are classified as apparently secure or secure (G4 or G5) at the global scale, but are rare in Nebraska, generally because these species exist on the edge of their global range in the state.

Table 5. Rare species occurrence in Agate Fossil Beds National Monument sampling plots from 1998-2015. Status ranks are based on Nebraska Natural Heritage Program designations. Plot count is the number of unique plots a species was recorded in across all years. Mean cover is the average cover of that species across all years in plots where cover measurements were recorded.

Species	Common Name	State Rank	Global Rank	Plot Count	Mean Cover (%)
<i>Astragalus agrestis</i>	purple milkvetch	S1	G5	1	0.00
<i>Elymus lanceolatus</i>	thickspike wheatgrass	S1	G5	1	0.00
<i>Elymus trachycaulus</i>	slender wheatgrass	S1	G5	42	8.00
<i>Eriogonum cernuum</i>	nodding buckwheat	S1	G5	3	<0.01
<i>Heterotheca villosa</i>	hairy goldenaster	S1	G5	7	0.01
<i>Symphoricarpos albus</i>	common snowberry	S1	G5	1	0.00
<i>Symphyotrichum falcatum</i>	white prairie aster	S1	G5	1	<0.01
<i>Euphorbia missurica</i>	prairie sandmat	S1S3	G5	1	0.00
<i>Erigeron ochroleucus</i>	buff fleabane	S2	G5	3	0.00
<i>Fritillaria atropurpurea</i>	spotted fritillary	S2	G5	2	0.00
<i>Phacelia hastata</i>	silverleaf phacelia	S2S3	G5	1	0.00
<i>Dieteria canescens</i>	hoary tansyaster	S2S4	G5	1	0.00
<i>Carex hallii</i>	deer sedge	S2S4	G4	5	0.00
<i>Chenopodium desiccatum</i>	aridland goosefoot	S2S4	G5	13	0.29
<i>Cryptantha fendleri</i>	sanddune cryptantha	S2S4	G5	4	0.00
<i>Physaria reediana</i>	Reed's twinpod	S2S4	G4	2	0.00
<i>Plantago patagonica</i>	longbracted plantain	S2S4	G5	14	0.03
<i>Sphenopholis obtusata</i>	prairie wedgescale	S2S4	G5	10	0.00



Figure 13. Photographs of two rare species found in plant community monitoring plots at Agate Fossil Beds National Monument. *Left:* purple milkvetch (*Astragalus agrestis* S1); *Right:* spotted fritillary (*Fritillaria atropurpurea* S2). Both species were observed in very low frequencies.

We recommend monitoring of known rare plant populations and a formal rare plant survey be conducted when funds are available. A full rare plant survey will be more likely to thoroughly and accurately quantify the status of rare plants found in AGFO. Any future construction efforts that could disturb native vegetation (e.g. trail building), should avoid damaging species considered rare in Nebraska.

Fossil Hills Trail Paving Project

Fossil Hills Trail is a paved walkway that connects the AGFO visitor center with University and Carnegie Hills. Construction work on the trail was completed in 2007 and resulted in areas of disturbance to native mixed-grass prairie along the trail corridor. We collected data from three plots installed in disturbed prairie habitat and two plots in nearby undisturbed native prairie to evaluate the recovery of the disturbed sites. All of the monitoring sites were impacted by a prescribed fire in May 2009 (James 2009).

There was no statistically significant difference in native species richness (Figure 14; $F_{2,6}=0.11$, $P=0.898$) or exotic species relative cover (Figure 14; $F_{1,6}=0.70$, $P=0.533$) between disturbed and undisturbed native prairie habitat from 2009-2014. Native species richness in both disturbed and undisturbed habitat was typically equal to, or greater than, the 18-year average native species richness across all plots in AGFO, except in disturbed prairie plots in 2013, which followed a drought year (Figure 9; Figure 15). Exotic species relative cover was less than, or equal to, the average exotic species relative cover across the entire monument. Litter cover was greater in disturbed prairie plots from 2009-2014 (Figure 14; $F_{1,6}=8.2$, $P=0.029$), and was greater than the 18-year average litter cover in AGFO in 2013 and 2014 in disturbed prairie plots.

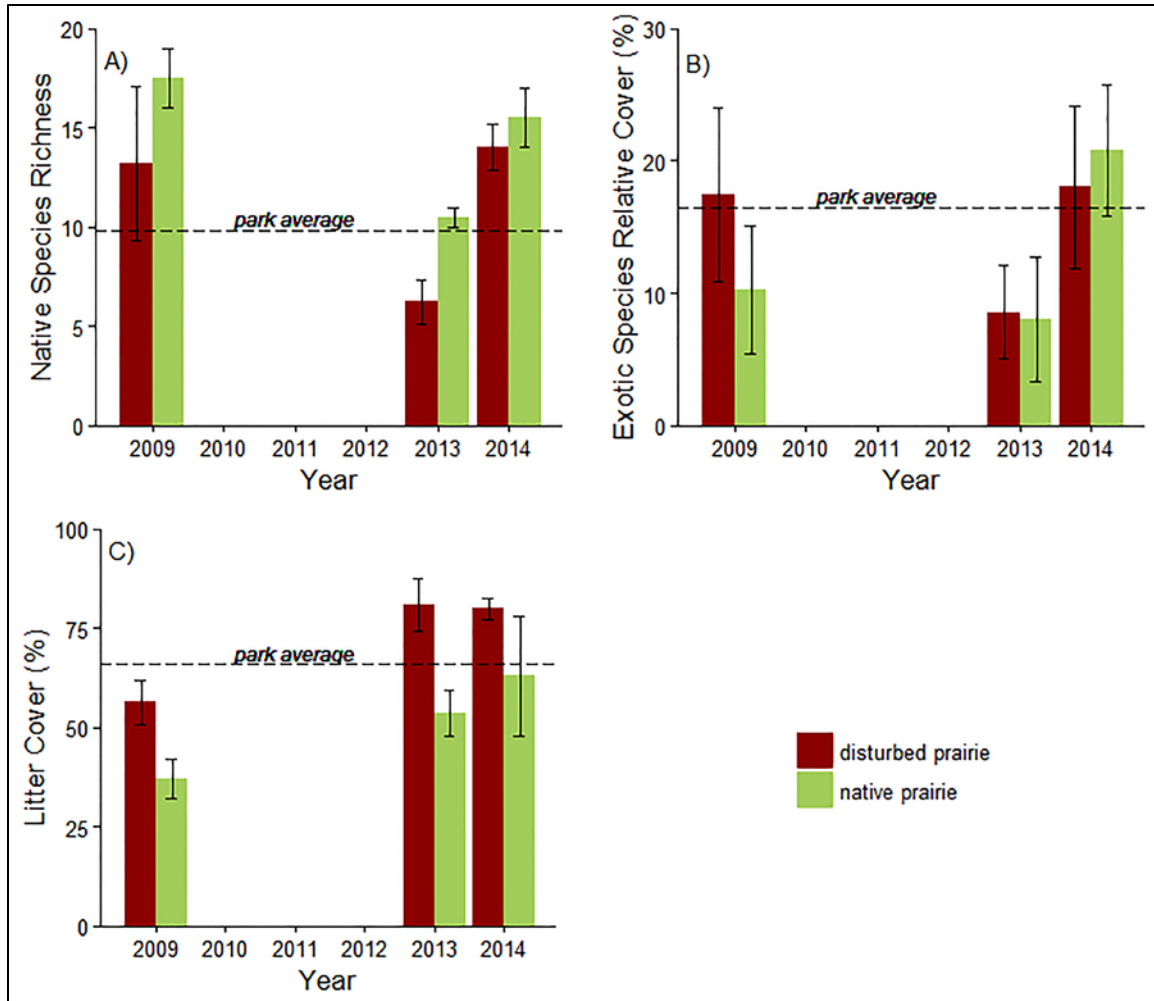


Figure 14. Native species richness (A), exotic species relative cover (B), and litter cover (C) in intact native mixed-grass prairie and disturbed prairie along the Fossil Hill Trail at Agate Fossil Beds National Monument (mean $\pm$ standard error of the mean). The dashed line indicates the average value for each respective table's attribute across all plots in the park.

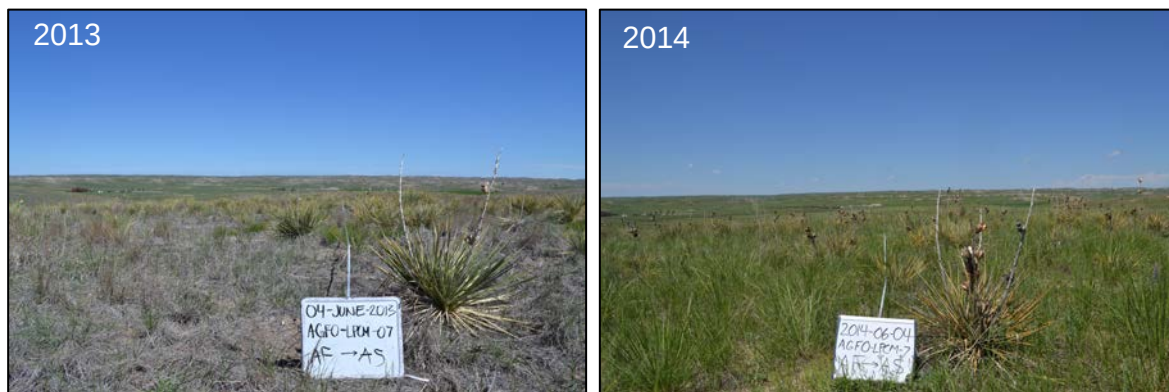


Figure 15. Native species richness and exotic species relative cover in disturbed prairie plots were lower in 2013 but had returned to levels similar to 18-year AGFO averages by 2014. This variation was likely in response to drought conditions in 2012, and comparing images of plot LPCM_07 in 2013 and 2014 clearly shows the difference in plant community condition in those years.

Native plant richness is similar in both disturbed and undisturbed plot types and is generally higher in those plots than the AGFO average; however, there are exotic species present in both plot types and there is greater litter cover in disturbed prairie plots. Increased litter cover is associated with a greater risk of exotic brome invasion in Northern Great Plains National Park units (unpublished data), and we suggest continued monitoring of these plots to ensure that any increase in exotic species abundance is detected so appropriate control measures can be taken.

The Status of Riparian Vegetation in AGFO

Wetlands along the Niobrara River cover approximately 234 acres within AGFO, or 8% of the monument (Gitzen et al. 2010). We visited 17 riparian monitoring plots in AGFO between 2012 and 2015 (Figure 16) to estimate the current condition of the plant community and to provide some field data on the extent of pale yellow iris (*Iris pseudacorus*) invasion.

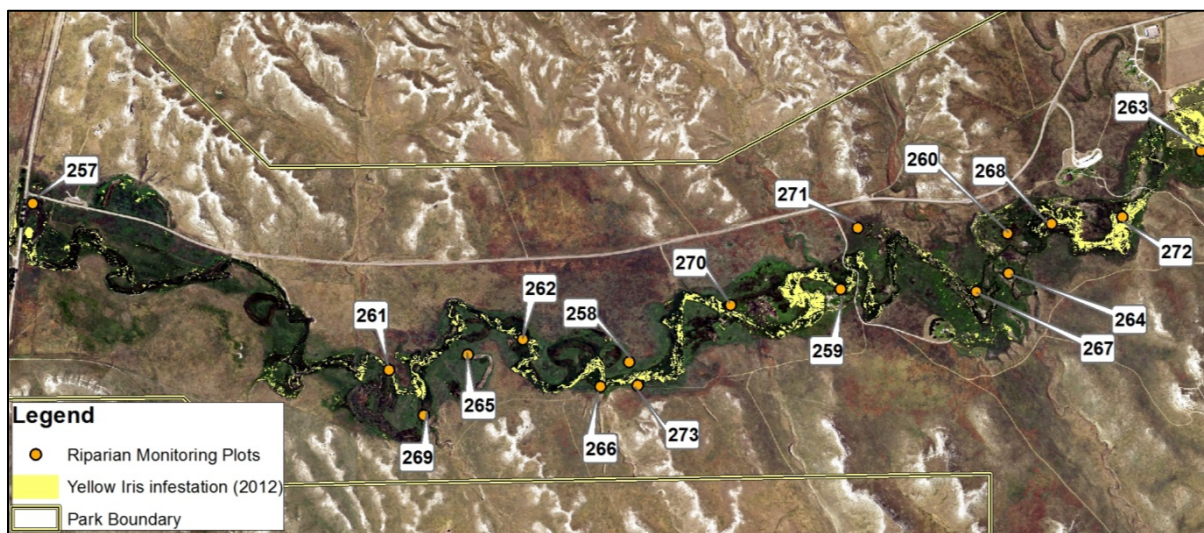


Figure 16. Location of 17 riparian monitoring plots in Agate Fossil Beds National Monument, 2012-2015 and estimated pale yellow iris infestation in 2012. The land cover classification was developed by the NGPN in 2012 from 0.6 meter, WorldView-2 satellite imagery collected on June 4, 2012 and refined using field training data sets acquired on June 21, 2012.

We found 88 plant species in the riparian area, and 15 of these were exotic species. Many of the most common species were native graminoids (Figure 17) including woolly sedge (*Carex pellita*), Baltic rush (*Juncus balticus*), broadleaf cattail (*Typha latifolia*) and western wheatgrass (*Pascopyrum smithii*). Common exotic species included Kentucky bluegrass (*Poa pratensis*) and pale yellow iris (*Iris pseudacorus*). Species richness in the riparian areas was comparable to that of the upland areas. Total species richness averaged 12.2 ± 1.2 species. On average, we recorded 9.6 ± 1.0 native species on each transect. Exotic cover was high, averaging 28.3 ± 2.0 % across the riparian areas of the monument from 2012 to 2015 (Table 8). Kentucky bluegrass occurred in 12 of 17 plots and averaged over 10.0 ± 1.6 % relative cover throughout the riparian area (Table 8).

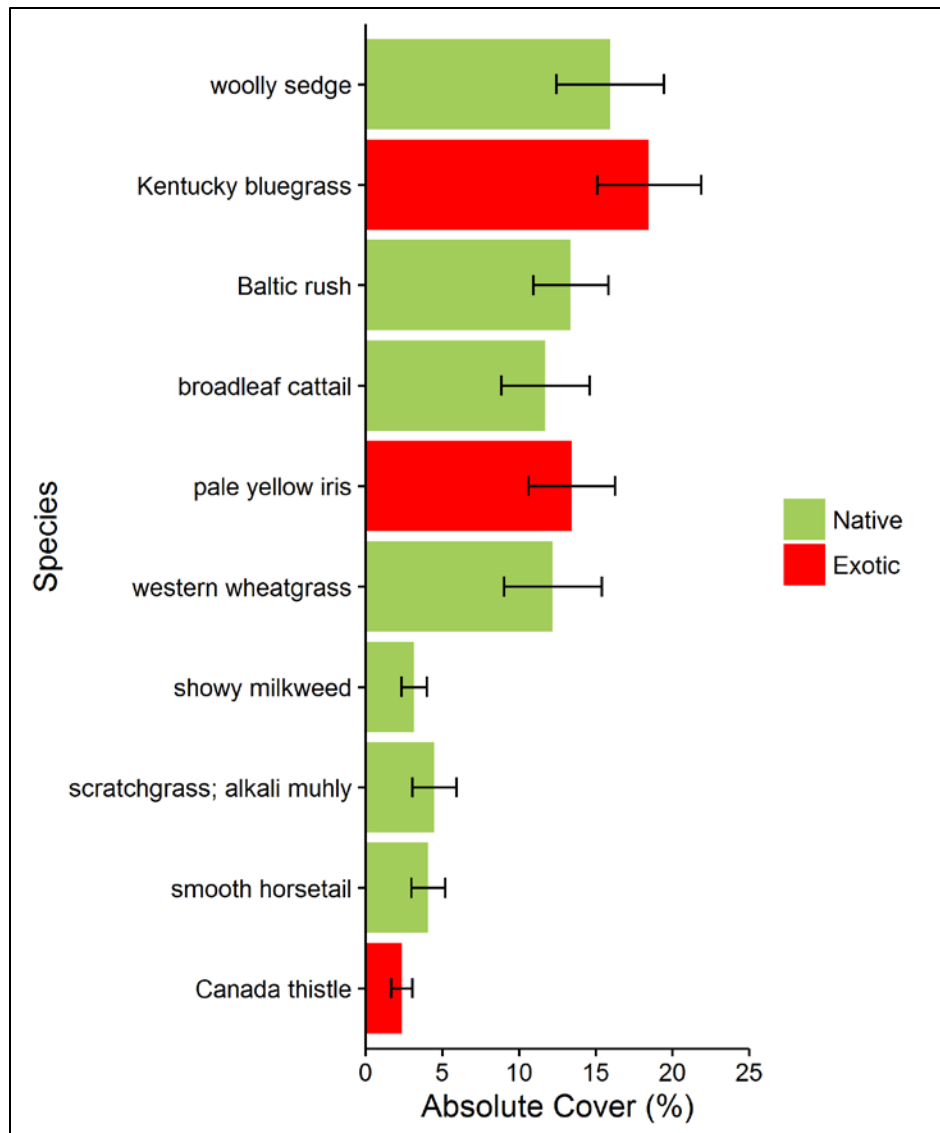


Figure 17. The average absolute cover of the 10 most common native (green) and exotic (red) riparian plants recorded at Agate Fossil Beds National Monument in 2015. Bars represent means $\pm$ standard errors. Kentucky bluegrass and pale yellow iris were the most common exotic species.

In 2012, it was estimated that 57 acres of the riparian corridor were infested with pale yellow iris (Figure 16). Pale yellow iris is an Eurasian species that typically grows in temperate freshwater and brackish marsh communities (Sutherland 1990). Its showy flower has made it a favorite ornamental plant and it is now considered invasive across much of North America. Pale yellow iris has the potential to uplift sediments, alter habitat, reduce diversity of native species, and these changes favor its continued spread (Thomas 1980). It was first introduced in the Niobrara basin in 1906 upstream of AGFO in a manmade, spring fed pond on Agate Springs Ranch.

Pale yellow iris was very abundant and found in 11 of 17 sites, averaging $11.5 \pm 2.4\%$ relative cover in the riparian area. 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 (Figure 16), most often appearing in the wetter sites with the cattails. This patchiness may present a challenge to future control efforts. The abundance of pale yellow iris has stayed fairly constant over the 4 year monitoring period (Table 8), despite some control efforts in 2015. Future monitoring will be necessary to determine the effectiveness of the treatment program over time.

Table 6. The relative percent cover of pale yellow iris in monitoring plots at Agate Fossil Beds National Monument 2012-2015.

Year	Number of plots	Relative cover of exotic species (% mean $\pm$ se)	Relative cover of Kentucky bluegrass (% mean $\pm$ se)	Relative cover of yellow iris (% mean $\pm$ se)	Minimum relative cover of yellow iris (%)	Maximum relative cover of yellow iris (%)
2012	12	28.1 $\pm$ 4.7	11.9 $\pm$ 3.6	11.4 $\pm$ 5.1	0	48.2
2013	11	31.0 $\pm$ 5.0	9.8 $\pm$ 3.9	10.6 $\pm$ 6.0	0	57.1
2014	12	31.9 $\pm$ 3.9	10.1 $\pm$ 3.2	14.1 $\pm$ 5.9	0	54.3
2015	17	24.2 $\pm$ 3.3	8.7 $\pm$ 2.8	10.1 $\pm$ 3.3	0	40.4

Conclusion

The Northern Great Plains Inventory & Monitoring Program and Fire Effects Program have been monitoring vegetation in Agate Fossil Beds National Monument for over 18 years. While methods have changed slightly, this report summarizes data from over 64 locations from 1998-2015. Below, we list the questions we asked and provide a summarized answer, for more details see the Results and Discussion section. We conclude with a Natural Resource Condition Table (Table 9) that summarizes the current status and trends in a few key vegetation metrics.

1. What is the current status of plant community composition and structure of AGFO grasslands (species richness, cover, and diversity) and how has this changed from 1998 to 2015?

Native grasses, such as needle and thread, sand reed, and western wheatgrass, are abundant and the dominant component of the prairie at AGFO. Native plant diversity is at a moderate level compared to other grasslands in the region (Table 7), but diversity is spatially variable. We found no significant trends in native diversity or evenness from 1998 to 2015, but both may become threatened if cover of annual invasive brome grasses increases, as we've observed in other Northern Great Plains Inventory and Monitoring units (Figure 8).

2. How do trends in grassland condition correlate with climate and fire history?

Native species richness increased in years with more rainfall and a hot dry year in 2012 corresponded to large declines in native species richness and an increase in exotic species cover. Plots that had not burned in 5 or 6 years had a higher number of native species and a lower cover of exotics than sites that burned more recently and when compared to AGFO averages (Figure 12). This suggests that prescribed fire can benefit the mixed-grass prairie in AGFO, but it may take 5 or more years to see the positive effects following a burn.

3. What, if any, rare plants were found in AGFO long-term monitoring plots?

We identified 22 rare plant species in AGFO between 1998 and 2015; seven of these are considered critically imperiled within Nebraska. We recommend monitoring of rare plant populations and more targeted surveys of rare plant species be completed when funds are available.

4. How did installation of the AGFO Fossil Hills Trail affect the adjacent prairie?

The disturbed prairie adjacent to the Fossil Hills Trail is very similar to the native prairie in other parts of AGFO. This suggests that the prairie in AGFO is resilient and can recover from a moderate level of disturbance. We suggest continued monitoring of these plots to ensure that any increase in exotic species abundance is detected so appropriate control measures can be taken.

5. What is the composition and structure of the riparian corridor at AGFO?

The riparian corridor in AGFO is a fairly diverse assemblage of riparian species such as sedges, willows, and cattails. It is, however, more invaded than the upland areas of AGFO and threatened by high cover of Kentucky bluegrass and pale yellow iris. Since riparian

monitoring began in 2012, we have not detected a significant change in the cover of pale yellow iris. Continued monitoring is necessary to determine if exotic treatment is effective over the long-term.

Table 7. Natural resource condition summary table of plant communities in Agate Fossil Beds National Monument (AGFO). Current values are based on data from 2011-2015 and trends are based on data from 1998-2015.

Indicator of Condition	Specific Measures	Current Value (mean $\pm$ SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Native species richness (1m ² quadrats)	7.3 $\pm$ 0.5 species	3-15 species		AGFO plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the region. The monument is characterized by moderate native species richness, but average richness is within a natural range of variability (Symstad and Jonas 2014). The lowest native diversity is found near the road. Native evenness has not changed since monitoring began in 1998.
	Evenness (native spp. point-intercept transects)	0.70 $\pm$ 0.01	To be determined		
	Relative cover of exotic species	17.6 $\pm$ 2.5%	< 10 % cover		AGFO maintains a mixed-grass prairie with moderate exotic plant cover and a fair diversity of native plants. Annual invasive bromes are not currently abundant in AGFO, but active management may be required to keep such low cover.
	Annual brome cover	7.4 $\pm$ 1.9%	< 10 % cover		
Riparian Plant Community Structure and Composition	Native species richness (50 m point-intercept transect)	9.6 $\pm$ 1.0	To be determined		The riparian areas of AGFO had levels of diversity similar to the upland areas.
	Relative cover of exotic species	28.3 $\pm$ 2.0%	$\leq$ 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. Pale yellow iris has invaded riparian areas throughout the monument. It had a patchy distribution and was absent in some sites while accounting for over 50% in others
	Relative cover of pale yellow iris	11.5 $\pm$ 2.4%	$\leq$ 10 % cover		

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Appendix A: List of plant species found at AGFO 1998-2015

Below is a list of all the plant species found in AGFO long-term plant community monitoring plots. The species are grouped by plant family. An “X” in the exotic column means that species is not native to the park or, in the case where only the genus was identified, there are some species within that genus that are exotic. Species considered to be rare in Nebraska are marked in the final column and the state conservation ranks are provided. Conservation rank definitions are in Table 2 of the report.

Family	Code	Scientific Name	Common Name	Exotic	Rare
Agavaceae	YUGL	<i>Yucca glauca</i>	soapweed yucca		
Alismataceae	SACU	<i>Sagittaria cuneata</i>	arumleaf arrowhead		
Amaranthaceae	AMAR	<i>Amaranthus arenicola</i>	sandhill amaranth		
Anacardiaceae	RHTR	<i>Rhus trilobata</i>	skunkbush sumac		
Apiaceae	CIMA2	<i>Cicuta maculata</i>	spotted water hemlock		S3S5
	CYGL99	<i>Cymopterus glomeratus</i>	plains springparsley		
	LOOR	<i>Lomatium orientale</i>	Northern Idaho biscuitroot		
	MUTE3	<i>Musineon tenuifolium</i>	slender wildparsley		
Asclepiadaceae	ASIN	<i>Asclepias incarnata</i>	swamp milkweed		
	ASSP	<i>Asclepias speciosa</i>	showy milkweed		
	ASVI	<i>Asclepias viridiflora</i>	green comet milkweed		
Asteraceae	AMAC2	<i>Ambrosia acanthicarpa</i>	flatspine burr ragweed		
	AMBRO	<i>Ambrosia</i> spp.	ragweed	X	
	AMPS	<i>Ambrosia psilostachya</i>	Cuman ragweed		
	AMTR	<i>Ambrosia trifida</i>	great ragweed		
	ARDR4	<i>Artemisia dracunculus</i>	tarragon		
	ARFR4	<i>Artemisia frigida</i>	fringed sagewort		
	BIFR	<i>Bidens frondosa</i>	devil's beggartick		
	BREU	<i>Brickellia eupatorioides</i>	false boneset		
	CIAR4	<i>Cirsium arvense</i>	Canada thistle	X	
	CICA11	<i>Cirsium canescens</i>	prairie thistle		
	CIFL	<i>Cirsium flodmanii</i>	Flodman's thistle		
	CIRSI	<i>Cirsium</i> spp.	thistle	X	
	COCA5	<i>Conyza canadensis</i>	horseweed		
	CYXA	<i>Cyclachaena xanthifolia</i>	giant sumpweed		
	DICA18	<i>Dieteria canescens</i>	hoary tansyaster		S2S4
	DYPA	<i>Dyssodia papposa</i>	fetid marigold		
	ERBE2	<i>Erigeron bellidiastrum</i>	western daisy fleabane		
	EROC	<i>Erigeron ochroleucus</i>	buff fleabane		S2
	ERPU2	<i>Erigeron pumilus</i>	shaggy fleabane		
	ERST3	<i>Erigeron strigosus</i>	prairie fleabane		

Family	Code	Scientific Name	Common Name	Exotic	Rare
	GUSA2	<i>Gutierrezia sarothrae</i>	broom snakeweed		
	HEAN3	<i>Helianthus annuus</i>	common sunflower		
	HELIA3	<i>Helianthus</i> spp.	sunflower	X	
	HEPE	<i>Helianthus petiolaris</i>	prairie sunflower		
	HEVI4	<i>Heterotheca villosa</i>	hairy false goldenaster		S1
	HYFI	<i>Hymenopappus filifolius</i>	fineleaf hymenopappus		
	LASE	<i>Lactuca serriola</i>	prickly lettuce	X	
	LAPU	<i>Lactuca pulchella</i>	blue lettuce	X	
	LIPU	<i>Liatris punctata</i>	dotted blazing star		
	LYJU	<i>Lygodesmia juncea</i>	rush skeletonplant		
	MATA2	<i>Machaeranthera tanacetifolia</i>	tanseyleaf tansyaster		S3S5
	MUOB99	<i>Mulgedium oblongifolium</i>	blue lettuce		
	PACA15	<i>Packera cana</i>	woolly groundsel		
	RACO3	<i>Ratibida columnifera</i>	upright prairie coneflower		
	SERI2	<i>Senecio riddellii</i>	Riddell's ragwort		
	SOAR2	<i>Sonchus arvensis</i>	field sowthistle	X	
	SOCA6	<i>Solidago canadensis</i>	Canada goldenrod		S3S5
	SOGI	<i>Solidago gigantea</i>	giant goldenrod		
	SOMI2	<i>Solidago missouriensis</i>	Missouri goldenrod		
	SOMO	<i>Solidago mollis</i>	velvety goldenrod		
	SYER	<i>Symphyotrichum ericoides</i>	white heath aster		S3S5
	SYFA	<i>Symphyotrichum falcatum</i>	white prairie aster		S1
	SYLA6	<i>Symphyotrichum lanceolatum</i>	white panicle aster		
	SYMPH4	<i>Symphyotrichum</i> spp.	aster		
	TAOF	<i>Taraxacum officinale</i>	common dandelion	X	
	TEAC	<i>Tetrameuris acaulis</i>	stemless four-nerve daisy		
	TOEX2	<i>Townsendia exscapa</i>	stemless Townsend daisy		S3S5
	TOGR	<i>Townsendia grandiflora</i>	largeflower Townsend daisy		S3S5
	TRDU	<i>Tragopogon dubius</i>	yellow salsify	X	
	XAGR99	<i>Xanthisma grindelioides</i>	rayless tansyaster		
	XASP99	<i>Xanthisma spinulosum</i>	lacy tansyaster		
Boraginaceae	CRCA8	<i>Cryptantha cana</i>	mountain cryptantha		
	CRCE	<i>Cryptantha celosioides</i>	buttecandle		
	CRFE3	<i>Cryptantha fendleri</i>	sanddune cryptantha		S2S4
	CRMI5	<i>Cryptantha minima</i>	little cryptantha		
	CRTN	<i>Cryptantha thyrsoflora</i>	calcareous cryptantha		S3S5
	LAOC3	<i>Lappula occidentalis</i>	flatspine stickseed		
	LASQ	<i>Lappula squarrosa</i>	European stickseed	X	

Family	Code	Scientific Name	Common Name	Exotic	Rare
	LICA13	<i>Lithospermum caroliniense</i>	Carolina puccoon		
	LIIN2	<i>Lithospermum incisum</i>	narrowleaf stoneseed		
Brassicaceae	ALDE	<i>Alyssum desertorum</i>	desert madwort	X	
	ARHO2	<i>Arabis holboellii</i>	Holboell's rockcress		
	BOHO99	<i>Boechera holboellii</i>	Holboell's rockcress		
	BRASS2	<i>Brassica</i> spp.	mustard	X	
	BOCO4	<i>Boechera collinsii</i>	Collins' rockcress		
	CAMI2	<i>Camelina microcarpa</i>	littlepod false flax	X	
	DEPI	<i>Descurainia pinnata</i>	western tansymustard		S3S5
	DESO2	<i>Descurainia sophia</i>	herb sophia	X	
	DRRE2	<i>Draba reptans</i>	Carolina draba		
	ERCA14	<i>Erysimum capitatum</i>	sanddune wallflower		
	LEDE	<i>Lepidium densiflorum</i>	common pepperweed		
	PHLU99	<i>Physaria ludoviciana</i>	foothill bladderpod		
	PHRE8	<i>Physaria reediana</i>	alpine bladderpod		S2S4
	SIAL2	<i>Sisymbrium altissimum</i>	tall tumbled mustard	X	
	THAR5	<i>Thlaspi arvense</i>	field pennycress	X	
Cactaceae	ESVI2	<i>Escobaria vivipara</i>	spiny star		
	MAHEM2	<i>Mammillaria heyderi</i> var. <i>meiacantha</i>	little nipple cactus		
	OPFR	<i>Opuntia fragilis</i>	brittle pricklypear		
	OPMA2	<i>Opuntia macrorhiza</i>	twistspine pricklypear		
	OPPO	<i>Opuntia polyacantha</i>	plains pricklypear		
Capparaceae	PODO3	<i>Polanisia dodecandra</i>	redwhisker clammyweed		
Caprifoliaceae	SYAL	<i>Symphoricarpos albus</i>	common snowberry		S1
	SYOC	<i>Symphoricarpos occidentalis</i>	western snowberry		
Caryophyllaceae	ERHO13	<i>Eremogone hookeri</i>	Hooker's sandwort		S3S5
	PADE4	<i>Paronychia depressa</i>	spreading nailwort		
	SIDR	<i>Silene drummondii</i>	Drummond's campion	X	
	SILEN	<i>Silene</i> spp.	catchfly		
Chenopodiaceae	CHAL7	<i>Chenopodium album</i>	lambsquarters	X	
	CHBE4	<i>Chenopodium berlandieri</i>	pitseed goosefoot		
	CHDE	<i>Chenopodium desiccatum</i>	aridland goosefoot		S2S4
	CHENO	<i>Chenopodium</i> spp.	goosefoot	X	
	CHFR3	<i>Chenopodium fremontii</i>	Fremont's goosefoot		
	CHPR5	<i>Chenopodium pratericola</i>	desert goosefoot		
	CHSI2	<i>Chenopodium simplex</i>	mapleleaf goosefoot		
	CORIS	<i>Corispermum</i> spp.	bugseed	X	
	KOSC	<i>Kochia scoparia</i>	burningbush, kochia	X	

Family	Code	Scientific Name	Common Name	Exotic	Rare
	KRLA2	<i>Krascheninnikovia lanata</i>	winterfat		S3S5
	SALSO	<i>Salsola</i> spp.	Russian thistle	X	
	SATR12	<i>Salsola tragus</i>	prickly Russian thistle	X	
Cleomaceae	PESE99	<i>Peritoma serrulata</i>	Rocky Mountain beeplant		
Commelinaceae	TRBR	<i>Tradescantia bracteata</i>	longbract spiderwort		
	TROC	<i>Tradescantia occidentalis</i>	prairie spiderwort		
Cucurbitaceae	ECLO	<i>Echinocystis lobata</i>	wild cucumber		
Cyperaceae	CADU6	<i>Carex duriuscula</i>	needleleaf sedge		
	CAFI	<i>Carex filifolia</i>	threadleaf sedge		
	CAHA3	<i>Carex hallii</i>	deer sedge		S2S4
	CAHY4	<i>Carex hystericina</i>	bottlebrush sedge		
	CAIN9	<i>Carex inops</i>	sun sedge		
	CANE2	<i>Carex nebrascensis</i>	Nebraska sedge		
	CAPE42	<i>Carex pellita</i>	woolly sedge		
	CAPR5	<i>Carex praegracilis</i>	clustered field sedge		
	CAREX	<i>Carex</i> spp.	sedge		
	ELER	<i>Eleocharis erythropoda</i>	bald spikerush		
	SCPU10	<i>Schoenoplectus pungens</i>	common threesquare		
	SCTA2	<i>Schoenoplectus tabernaemontani</i>	softstem bulrush		
Equisetaceae	EQLA	<i>Equisetum laevigatum</i>	smooth horsetail		
Euphorbiaceae	CHGL13	<i>Chamaesyce glyptosperma</i>	ribseed sandmat	X	
	EUGL3	<i>Euphorbia glyptosperma</i>	ribseed sandmat	X	
	EURO5	<i>Euphorbia robusta</i>	horned spurge	X	
	EUSE4	<i>Euphorbia serpens</i>	matted sandmat		
	CRTE4	<i>Croton texensis</i>	Texas croton		
	EUBR	<i>Euphorbia brachycera</i>	horned spurge		
	EUMI5	<i>Euphorbia missurica</i>	prairie sandmat		S1S3
	EUPHO	<i>Euphorbia</i> spp.	spurge, sandmat	X	
Fabaceae	ASAD11	<i>Astragalus adsurgens</i>	prairie milkvetch		
	ASAG2	<i>Astragalus agrestis</i>	purple milkvetch		S1
	ASCE	<i>Astragalus ceramicus</i>	painted milkvetch		
	ASCR2	<i>Astragalus crassicaupus</i>	groundplum milkvetch		
	ASLA27	<i>Astragalus laxmannii</i>	Laxmann's milkvetch		
	ASLO4	<i>Astragalus lotiflorus</i>	lotus milkvetch		
	ASMI10	<i>Astragalus missouriensis</i>	Missouri milkvetch		
	ASMO7	<i>Astragalus mollissimus</i>	woolly locoweed		
	ASSE5	<i>Astragalus sericoleucus</i>	silky milkvetch		
	ASSP6	<i>Astragalus spatulatus</i>	tufted milkvetch		

Family	Code	Scientific Name	Common Name	Exotic	Rare
	ASTRA	<i>Astragalus</i> spp.	milkvetch		
	DACA7	<i>Dalea candida</i>	white prairie clover		
	DAEN	<i>Dalea enneandra</i>	nineanther prairie clover		
	DALEA	<i>Dalea</i> spp.	prairie clover		
	DAPU5	<i>Dalea purpurea</i>	purple prairie clover		S3S5
	GLLE3	<i>Glycyrrhiza lepidota</i>	American licorice		
	LAPO2	<i>Lathyrus polymorphus</i>	manystem pea		
	LUAR3	<i>Lupinus argenteus</i>	silvery lupine		
	LUPIN	<i>Lupinus</i> spp.	lupine		
	LUPL	<i>Lupinus plattensis</i>	Nebraska lupine		
	LUPU	<i>Lupinus pusillus</i>	rusty lupine		
	MELU	<i>Medicago lupulina</i>	black medick	X	
	MEOF	<i>Melilotus officinalis</i>	yellow sweetclover	X	
	MESA	<i>Medicago sativa</i>	alfalfa	X	
	OXLA3	<i>Oxytropis lambertii</i>	purple locoweed		
	OXSE	<i>Oxytropis sericea</i>	white locoweed		
	PEAR6	<i>Pedimelum argophyllum</i>	silverleaf Indian breadroot		
	PEES	<i>Pedimelum esculentum</i>	large Indian breadroot		
	PSLA3	<i>Psoralegium lanceolatum</i>	lemon scurfpea		
	PSTE5	<i>Psoralegium tenuiflorum</i>	slimflower scurfpea		
	THRH	<i>Thermopsis rhombifolia</i>	golden pea		
Grossulariaceae	RIAM2	<i>Ribes americanum</i>	American black currant		
Hydrophyllaceae	ELNY	<i>Ellisia nyctelea</i>	Aunt Lucy		
	PHHA	<i>Phacelia hastata</i>	silverleaf phacelia		S2S4
Iridaceae	IRPS	<i>Iris pseudacorus</i>	pale yellow iris	X	
Juncaceae	JUBA	<i>Juncus balticus</i>	Baltic rush		
	JUNCU	<i>Juncus</i> spp.	rush	X	
Lamiaceae	HEDR	<i>Hedeoma drummondii</i>	Drummond's false pennyroyal		
	HEHI	<i>Hedeoma hispida</i>	rough false pennyroyal		
	LYAM	<i>Lycopus americanus</i>	American water horehound		
	LYAS	<i>Lycopus asper</i>	rough bugleweed		
	MEAR4	<i>Mentha arvensis</i>	wild mint		
	SCLA2	<i>Scutellaria lateriflora</i>	blue skullcap		
Lemnaceae	LEMI3	<i>Lemna minor</i>	common duckweed		S3S5
Lentibulariaceae	UTRIC	<i>Utricularia</i> spp.	bladderwort		
Liliaceae	ALTE	<i>Allium textile</i>	textile onion		
	CANU3	<i>Calochortus nuttallii</i>	sego lily		
	FRAT	<i>Fritillaria atropurpurea</i>	spotted fritillary		S2
	MAST4	<i>Maianthemum stellatum</i>	starry false lily of the valley		
Linaceae	LIRI	<i>Linum rigidum</i>	stiffstem flax		

Family	Code	Scientific Name	Common Name	Exotic	Rare
Loasaceae	MEDE2	<i>Mentzelia decapetala</i>	tenpetal blazingstar		
Malvaceae	SPCO	<i>Sphaeralcea coccinea</i>	scarlet globemallow		
Melanthiaceae	TOVE2	<i>Toxicoscordion venenosum</i>	meadow deathcamas		
Nyctaginaceae	ABFR2	<i>Abronia fragrans</i>	snowball sand verberna		
	MIHI	<i>Mirabilis hirsuta</i>	hairy four o'clock		
	MILI3	<i>Mirabilis linearis</i>	narrowleaf four o'clock		
Onagraceae	EPLE2	<i>Epilobium leptophyllum</i>	bog willowherb		
	GAPA6	<i>Gaura parviflora</i>	velvetweed	X	
	OEAL	<i>Oenothera albicaulis</i>	whitest evening primrose		
	OENU	<i>Oenothera nuttallii</i>	Nuttall's evening-primrose		
	OESE3	<i>Oenothera serrulata</i>	yellow sundrops		
	OESU99	<i>Oenothera suffrutescens</i>	scarlet beeblossom		
Orobanchaceae	ORFA	<i>Orobanche fasciculata</i>	clustered broomrape		
Papaveraceae	ARPO2	<i>Argemone polyanthemos</i>	crested pricklypoppy		
Pinaceae	PIPU	<i>Picea pungens</i>	blue spruce		
Plantaginaceae	PLER	<i>Plantago eriopoda</i>	redwool plantain		S3S5
	PLPA2	<i>Plantago patagonica</i>	woolly plantain		S2S4
Poaceae	ACHY	<i>Achnatherum hymenoides</i>	Indian ricegrass		
	ANGE	<i>Andropogon gerardii</i>	big bluestem		
	ANHA	<i>Andropogon hallii</i>	sand bluestem		
	ARPU9	<i>Aristida purpurea</i>	purple threeawn		S3S5
	BOCU	<i>Bouteloua curtipendula</i>	sideoats grama		
	BOGR2	<i>Bouteloua gracilis</i>	blue grama		
	BRIN2	<i>Bromus inermis</i>	smooth brome	X	
	BRJA	<i>Bromus japonicus</i>	Japanese brome	X	
	BROMU	<i>Bromus</i> spp.	brome	X	
	BRTE	<i>Bromus tectorum</i>	cheatgrass	X	
	CALO	<i>Calamovilfa longifolia</i>	prairie sandreed		
	CAST36	<i>Calamagrostis stricta</i>	slimstem reedgrass		
	DISP	<i>Distichlis spicata</i>	saltgrass		
	ELEL5	<i>Elymus elymoides</i>	squirreltail		
	ELLA3	<i>Elymus lanceolatus</i>	thickspike wheatgrass		S1
	ELRE4	<i>Elymus repens</i>	quackgrass	X	
	ELTR7	<i>Elymus trachycaulus</i>	slender wheatgrass		S1
	ELYMU	<i>Elymus</i> spp.	wildrye	X	
	FEOC	<i>Festuca occidentalis</i>	western fescue		
	GLST	<i>Glyceria striata</i>	fowl mannagrass		
	HECO26	<i>Hesperostipa comata</i>	needle and thread		
	HOJU	<i>Hordeum jubatum</i>	foxtail barley		

Family	Code	Scientific Name	Common Name	Exotic	Rare
	KOMA	<i>Koeleria macrantha</i>	prairie Junegrass		
	LEOR	<i>Leersia oryzoides</i>	rice cutgrass		
	MUAS	<i>Muhlenbergia asperifolia</i>	scratchgrass, alkali muhly		
	MUCU3	<i>Muhlenbergia cuspidata</i>	plains muhly		
	MUHLE	<i>Muhlenbergia</i> spp.	muhly		
	MUME2	<i>Muhlenbergia mexicana</i>	Mexican muhly		
	MUPA99	<i>Muhlenbergia paniculata</i>	tumblegrass		
	MUPU2	<i>Muhlenbergia pungens</i>	sandhill muhly		
	MURA	<i>Muhlenbergia racemosa</i>	marsh muhly		
	NAVI4	<i>Nassella viridula</i>	green needlegrass		
	PACA6	<i>Panicum capillare</i>	witchgrass		S3S5
	PANIC	<i>Panicum</i> spp.	panicgrass	X	
	PASM	<i>Pascopyrum smithii</i>	western wheatgrass		
	PAVI2	<i>Panicum virgatum</i>	switchgrass		
	POCO	<i>Poa compressa</i>	Canada bluegrass	X	
	POPA2	<i>Poa palustris</i>	fowl bluegrass		
	POPR	<i>Poa pratensis</i>	Kentucky bluegrass	X	
	POSE	<i>Poa secunda</i>	Sandberg bluegrass		
	SCSC	<i>Schizachyrium scoparium</i>	little bluestem		
	SONU2	<i>Sorghastrum nutans</i>	Indiangrass		
	SPCR	<i>Sporobolus cryptandrus</i>	sand dropseed		
	SPGR	<i>Spartina gracilis</i>	alkali cordgrass		
	SPOB	<i>Sphenopholis obtusata</i>	prairie wedgescale		S2S4
	SPPE	<i>Spartina pectinata</i>	prairie cordgrass		
	THIN6	<i>Thinopyrum intermedium</i>	intermediate wheatgrass	X	
	VUOC	<i>Vulpia octoflora</i>	sixweeks fescue		
Polemoniaceae	PHAN4	<i>Phlox andicola</i>	prairie phlox		
	PHHO	<i>Phlox hoodii</i>	spiny phlox		
Polygonaceae	ERAN4	<i>Eriogonum annuum</i>	annual buckwheat		
	ERCE2	<i>Eriogonum cernuum</i>	nodding buckwheat		S1
	ERFL4	<i>Eriogonum flavum</i>	alpine golden buckwheat		
	ERPA9	<i>Eriogonum pauciflorum</i>	fewflower buckwheat		S3S5
	FACO	<i>Fallopia convolvulus</i>	black bindweed	X	
	PEAM8	<i>Persicaria amphibia</i>	longroot smartweed		S3S5
	PELA22	<i>Persicaria lapathifolia</i>	curlytop knotweed		
	POAV	<i>Polygonum aviculare</i>	prostrate knotweed	X	
	PORA3	<i>Polygonum ramosissimum</i>	bushy knotweed		
	RUVE2	<i>Rumex venosus</i>	veiny dock		
Potamogetonaceae	POTAM	<i>Potamogeton</i>	pondweed		
Rosaceae	ROWO	<i>Rosa woodsii</i>	Woods' rose		

Family	Code	Scientific Name	Common Name	Exotic	Rare
Rubiaceae	GATI	<i>Galium tinctorium</i>	stiff marsh bedstraw		
Salicaceae	SAER	<i>Salix eriocephala</i>	Missouri River willow		S3S5
	SAIN3	<i>Salix interior</i>	sandbar willow		
	SALIX	<i>Salix</i> spp.	willow		
Santalaceae	COUM	<i>Comandra umbellata</i>	bastard toadflax		
Scrophulariaceae	CASE5	<i>Castilleja sessiliflora</i>	Great Plains Indian paintbrush		
	PEAL2	<i>Penstemon albidus</i>	white penstemon		
	PEAN4	<i>Penstemon angustifolius</i>	broadbeard beardtongue		
	PEER	<i>Penstemon eriantherus</i>	fuzzytongue penstemon		S3S5
	VEAN2	<i>Veronica anagallis-aquatica</i>	water speedwell		
	VETH	<i>Verbascum thapsus</i>	common mullein	X	
Solanaceae	PHHI8	<i>Physalis hispida</i>	prairie groundcherry		
	PHVI5	<i>Physalis virginiana</i>	Virginia groundcherry		
	PHYSA	<i>Physalis</i> spp.	groundcherry		
	SOTR	<i>Solanum triflorum</i>	cutleaf nightshade		S3S5
Sparganiaceae	SPEU	<i>Sparganium eurycarpum</i>	broadfruit bur-reed		
Typhaceae	TYAN	<i>Typha angustifolia</i>	narrowleaf cattail		
	TYLA	<i>Typha latifolia</i>	broadleaf cattail		
Urticaceae	PAPE5	<i>Parietaria pensylvanica</i>	Pennsylvania pellitory		
	URDI	<i>Urtica dioica</i>	stinging nettle		
Verbenaceae	VEHA2	<i>Verbena hastata</i>	swamp verbena		
Violaceae	VINU2	<i>Viola nuttallii</i>	Nuttall's violet, yellow prairie violet		

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

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