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

2013 Annual Report

Natural Resource Data Series NPS/NGPN/NRDS—2014/602

ON THE COVER
Rocky outcrop at Agate Fossil Beds National Monument, 2013
Photograph by: J. Ladd, NPS

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

2013 Annual Report

Natural Resource Data Series NPS/NGPN/NRDS—2014/602

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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 Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

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.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Northern Great Plains Inventory & Monitoring 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/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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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 reality that there have been fundamental changes in the disturbance regimes, such as climate, fire, and large ungulate grazing, 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 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 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 our sampling efforts at AGFO in 2013, our third year of sampling. We visited 6 plots, and it will take 2 more years to visit every plot in the park twice (Figure 1). In addition, we surveyed vegetation in 5 plots that were first installed in 1997 by the Heartland Inventory & Monitoring Network. These plots are concentrated in the southeast corner of the park to evaluate the effects of trail construction (Figure 1). We also sampled vegetation at 11 plots along the riparian corridor at AGFO for the second year in 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. We expect to produce reports with more in-depth data

analysis and interpretation when we complete 5 years of sampling. In the interim, reports, spatial data, and data summaries can be provided for park management and interpretation upon request.

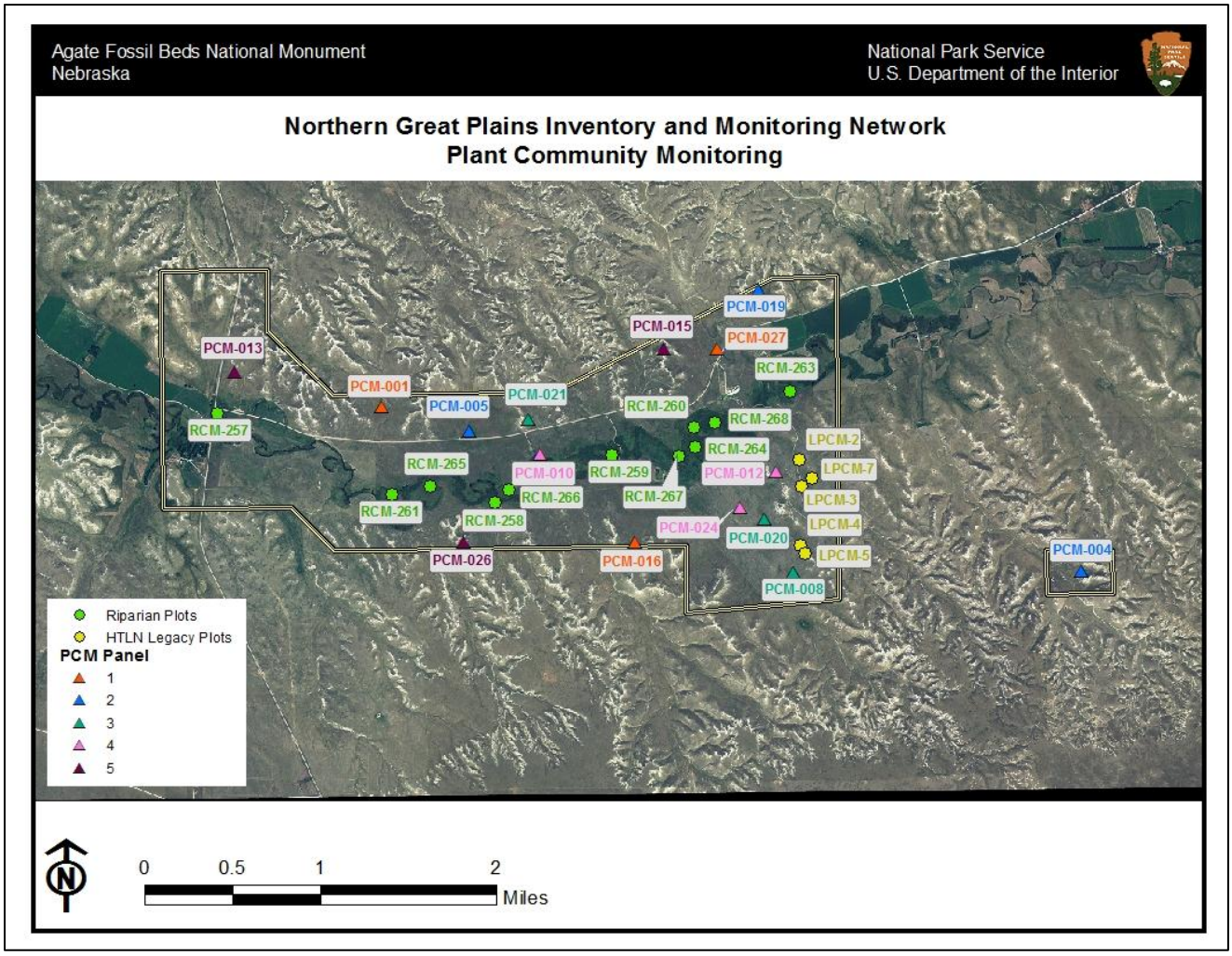


Figure 1. Map of Agate Fossil Beds National Monument (AGFO) and plant community monitoring (PCM) plots. Plots in panel 2 (blue) and panel 3 (turquoise) were visited in 2013. Legacy plant community monitoring plots (LPCM; yellow) were originally established by the Heartland Network and revisited in 2013. Riparian community monitoring plots (RCM, green) were visited in August of 2013. A total of 22 plots were monitored in 2013.

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.

Sample Design

We 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. We 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, and in 2012 we visited sites in panel 1 and panel 2 (Figure 1). In 2013, we visited sites in panel 2 and panel 3 during the first week of June. Data from these randomly selected sites can be used to estimate condition of vegetation communities for the whole park and over time, can be used to discern trends in condition.

Plot Layout and Sampling

At each of the 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, herb-layer height ≤ 2 m, and plant cover were collected on two 50 m transects (the long sides of the plot) using a point-intercept method. 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 2013, sampling at AGFO took a 6-person crew approximately 284 hours with travel time (see Appendix A for a detail of activities each day).

At all plots, we also surveyed the area for common disturbances and target species of interest to the park. 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. We also surveyed the area for exotic species that have the potential to spread into the park and cause significant ecological impacts (Table 1). 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, we noted the presence of plant species that are considered rare or vulnerable to loss in Nebraska, and may occur in AGFO (Table 2).

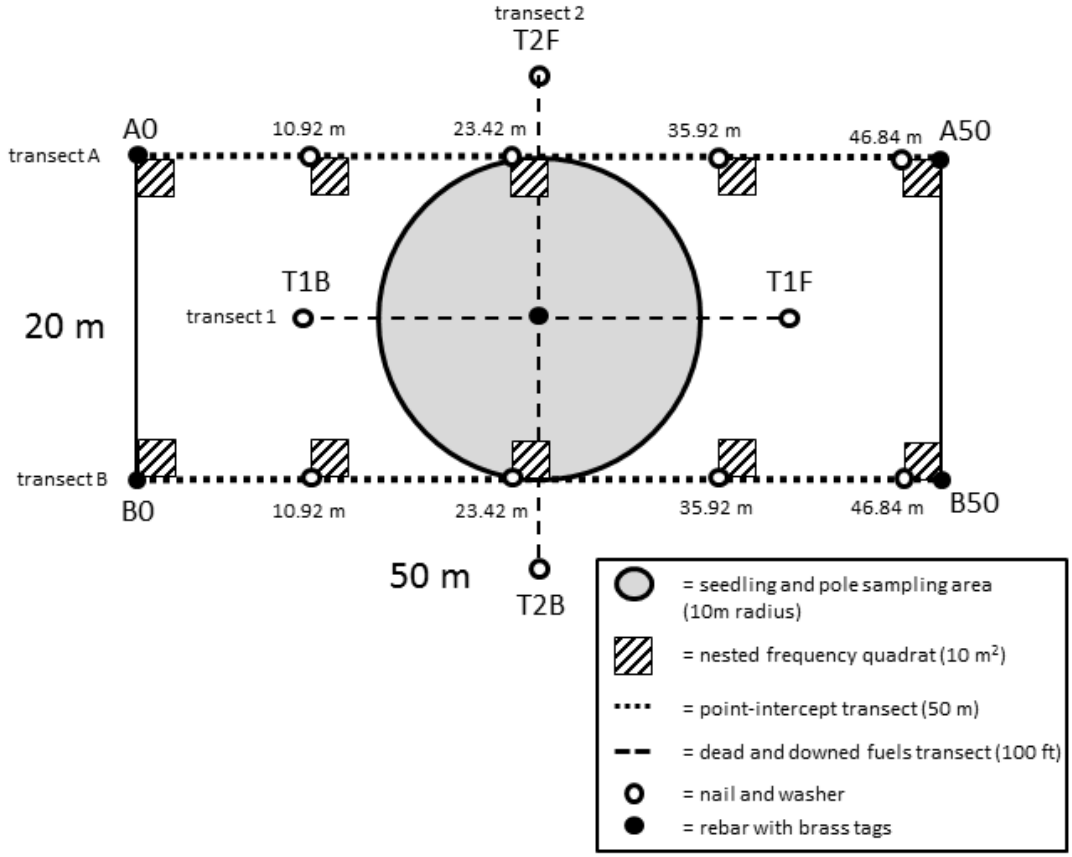


Figure 2. Long-term monitoring plot used for sampling vegetation in Agate Fossil Beds National Monument.

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

Table 2. Rare species that were surveyed for during the 2013 field season at Agate Fossil Beds National Monument.

Scientific Name	Common Name
Astragalus barrii	Barr's milkvetch
Astragalus shortianus	Short's milkvetch
Boechara holboelli	limestone rockcress
Cypripedium parviflorum	yellow lady's slipper
Dalea cylindriceps	Andean prairie clover
Ericameria parryi	Parry's rabbitbrush
Eriogonum gordonii	Gordon's buckwheat
Fritillaria atropurpurea	spotted fritillary
Gaura neomexicana	Colorado butterfly plant
Linanthus caespitosus	matted prickly phlox
Paronychia sessiliflora	stemless nailwort
Pedicularis crenulata	meadow lousewort
Phacelia hastata	silverleaf phacelia
Physaria arenosa	sidesaddle bladderpod
Platanthera huronensis	Huron green orchid
Spiranthes diluvialis	Ute lady's tresses

Legacy Monitoring

In addition to the monitoring described above, 5 plots were visited in 2013 that were established in 1998 by the Heartland Inventory & Monitoring Program. At each of these plots, point-intercept, disturbance, and target species data were collected as described above. To be consistent with prior

years of data collection, plant frequency was measured using circular subplots as described in the Heartland Networks' vegetation monitoring protocol. (James et al. 2009). The 5 plots chosen represent native mixed-grass prairie (LPCM_ 4 and 5) and an area within the same management unit impacted by construction of a paved trail to University and Carnegie Hills in 2006-2007 (LPCM_2, 3, and 7). All of these sites were impacted by a prescribed fire in May 2009 (James 2010).

Riparian Vegetation Monitoring

We conducted a pilot effort to sample vegetation in the riparian corridor in AGFO in 2013. There were 3 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 and (3) to explore the change in condition between 2012-2013.

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 in 2012. We revisited 11 of these same sites in 2013 (high water made access to the 12th site impossible). The 11 plots (Figure 1) were visited over 2 days in August using 4 people (Appendix A).

In order to sample more sites, we reduced the per-plot sampling effort by simplifying 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.

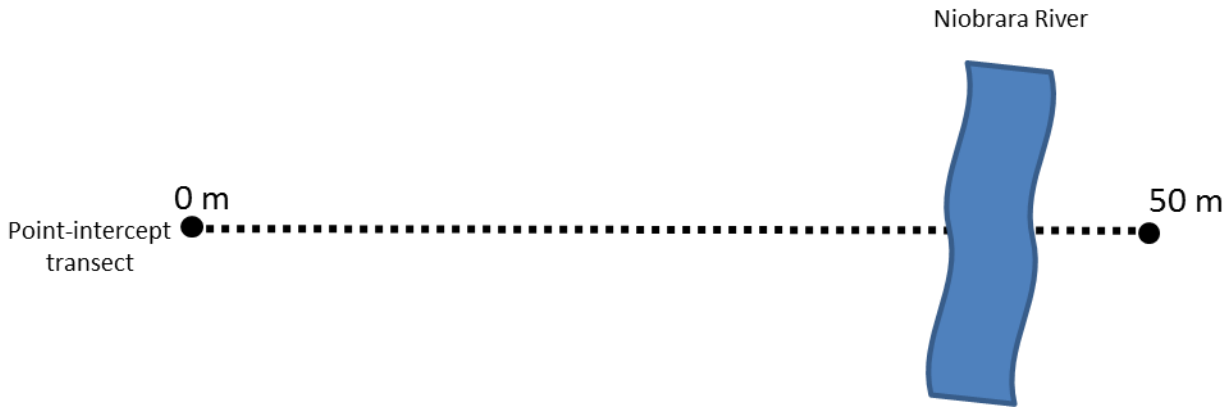


Figure 3. Survey plot used for sampling riparian vegetation in Agate Fossil Beds National Monument.

Data Management and Analysis

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 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 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 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). Warm-season grasses were identified primarily using a guide by Skinner (2010). 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 how even abundances are across taxa. It ranges between 0 and 1; values near 0 indicate dominance by a single species, and values near 1 indicate nearly equal abundance of all species present.

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://www.nps.gov/stateoftheparks/). 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.

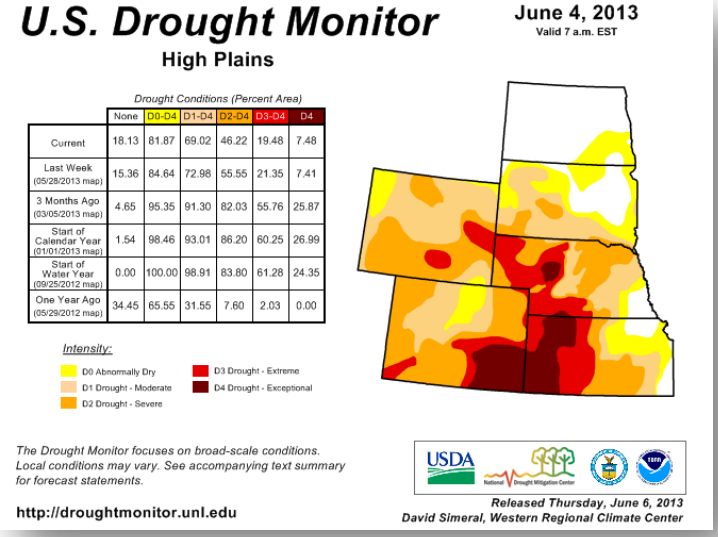
We chose a set of indicators and specific measures that can describe the condition of vegetation in the Northern Great Plains and the status of exotic plant invasions. The measures include: absolute herb-layer canopy cover, native species richness, evenness, relative cover of exotic species, and annual brome cover. Reference values were based on descriptions of historic condition and variation, past studies, and/or management targets. Current park condition was compared to a reference value, and status was scored as good condition, warrants moderate caution, 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 case, 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

Agate Fossil Beds NM experienced severe to extreme drought conditions throughout the winter and into the spring of 2013 (Figure 4). When NGPN visited the park in June, recent wet weather allowed for some green-up, but overall the park was still experiencing drought conditions. Average canopy cover was 45% (Table 4) in 2013, which was lower than the previous year (Ashton et al. 2013). There was a large amount of standing litter on the ground with ground cover at the sites averaging 78% plant litter.



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	18.13	81.87	69.02	46.22	19.48	7.48
Last Week (05/28/2013 map)	15.36	84.64	72.98	55.55	21.35	7.41
3 Months Ago (03/05/2013 map)	4.65	95.35	91.30	82.03	55.76	25.87
Start of Calendar Year (01/01/2013 map)	1.54	98.46	93.01	86.20	60.25	26.99
Start of Water Year (09/25/2012 map)	0.00	100.00	98.91	83.80	61.28	24.35
One Year Ago (05/29/2012 map)	34.45	65.55	31.55	7.60	2.03	0.00

Figure 4. Drought conditions in early June 2013 in the Northern Great Plains. Agate Fossil Beds National Monument experienced severe to extreme drought at that time.

We found 95 plant species in the upland areas of AGFO (Appendix B). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at AGFO, but forbs, shrubs and subshrubs (defined as a low-growing shrub usually under 0.5m) were also abundant (Figure 4). We found 10 exotic species in the upland areas of the park, all of which were either forbs or graminoids.

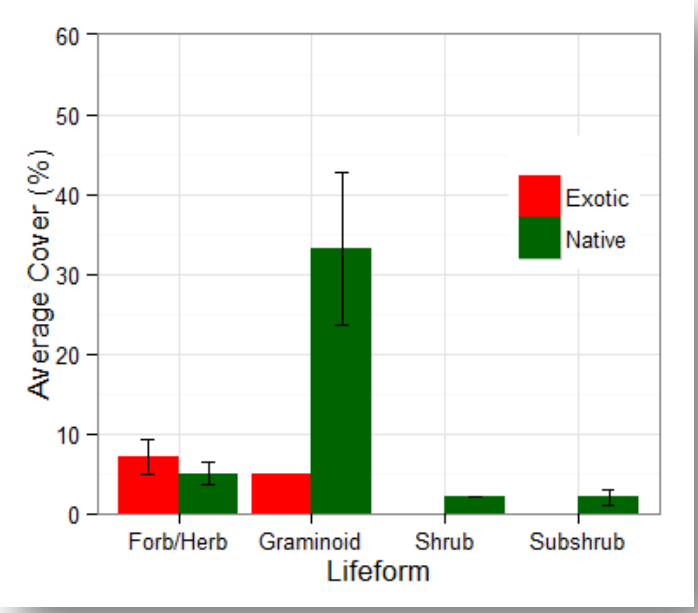


Figure 5. Average cover by lifeform and nativity in 6 plant community monitoring plots in Agate Fossil Beds National Monument in 2013. Native (green) and exotic (red) graminoids were the most abundant lifeform across the plots. Bars represent means ± standard errors.

There was some variation in species composition across the 6 sites. The most common species in the sites we visited were graminoids, and most were native species (Figure 5). Russian thistle (*Salsola tragus*), an exotic forb, was found at all 6 sites and was more abundant in 2013 than it had been in previous years. Goosefoot species (*Chenopodium* sp.) were also abundant, and some of these species are exotic. The species were difficult to distinguish from one another during our visit to AGFO because they lacked flowers. For this report, we considered the group to be exotic. We found two rare target plants. Silverleaf phacelia (*Phacelia hastate*) was seen at one site and spotted fritillary (*Fritillaria atropurpurea*) at two sites.

Table 4. Natural resource condition summary table for upland plant communities in Agate Fossil Beds National Monument (AGFO).

Indicator of Condition	Specific Measures	2013 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	45 ± 9.8 %	TBD [1]		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 moderate native species richness. 2013 was a particularly dry year, and as a result, diversity and plant cover was in the 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)	6 ± 1.0 species	3-15 species [2]		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.83 ± 0.03	TBD [1]		
Exotic Plant Early Detection and Management	Relative cover of exotic species	14 ± 5.3 %	≤ 10 % cover		AGFO has maintained a mixed-grass prairie with low exotic cover and a moderate diversity of native plants. Cheatgrass is not abundant in the park, but active management may be required to keep such low cover. In 2013, exotic forbs such as Russian thistle were quite abundant.
	Annual Brome cover	1.5 ± 1.5 %	≤10 % cover		

References and Data Sources:

1. To be determined when more data are available. 2. 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.

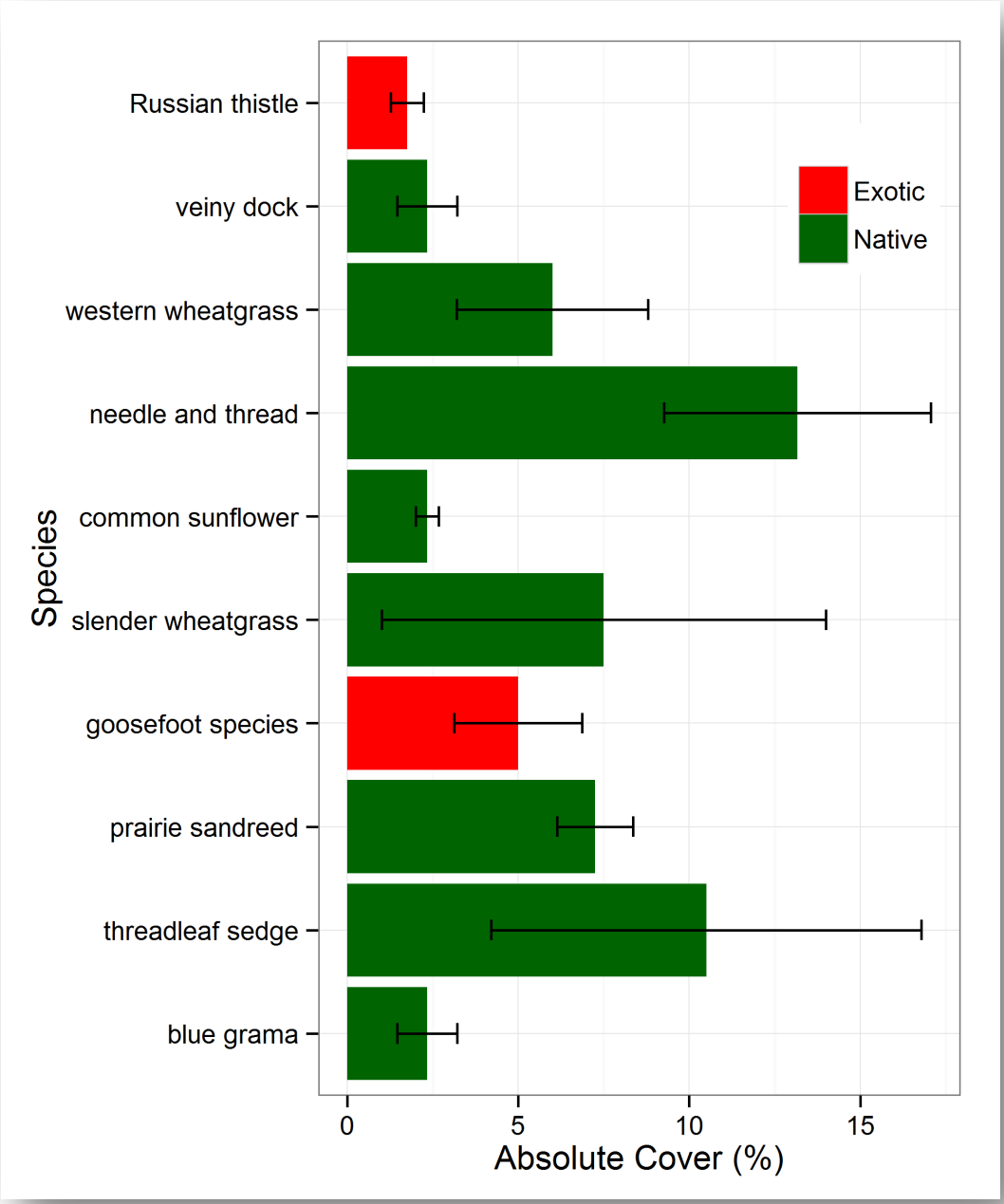


Figure 6. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded at Agate Fossil Beds National Monument in 2013. Bars represent means ± standard errors.

Average species richness at each of the 6 plots was measured by point-intercept and in 1 m^2 and 10 m^2 quadrats (Table 5). On average, there are about 2 exotic species within the 1 m^2 quadrat (Table 5). From the point-intersect data, we found average plot diversity, H', to be 1.7 ± 0.24. Evenness, J',

averaged 0.83 ± 0.03 across the plots (Table 4). When including only native species, average diversity and evenness were 1.5 ± 0.2 and 0.84 ± 0.03, respectively.

Table 5. Average plant species richness in 6 plots at Agate Fossil Beds National Monument in 2013. Values represent means ± standard errors, n=6.

	Point-intercept	**1 m^2 quadrats**	**10 m^2 quadrats**
Species richness	9 ± 1.7	8 ± 1.3	12 ± 1.9
Native species richness	7 ± 1.2	6 ± 1.0	10 ± 1.6
Exotic species richness	2 ± 0.7	2 ± 0.2	3 ± 0.4
Graminoid species richness	4 ± 0.5	3 ± 0.4	4 ± 0.5
Forb species richness	4 ± 1.1	4 ± 0.8	7 ± 1.3

While there was some variation across sites, 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, 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 from a relatively undisturbed site in Kansas vary 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 5) but two years of drought have driven diversity lower than in previous years (Ashton et al. 2011). The lowest diversity was seen in site PCM_005 (Figure 7), which was close to the road, very dry, and had a large amount of small mammal disturbance (Table 6).

Figure 7. Long-term monitoring site PCM_005 at Agate Fossil Beds National Monument. In 2013, we found it to have a low native plant diversity and low plant cover relative to the other sites in the park.

The average relative cover of exotic species at sites in AGFO was high (14 ± 5%; Table 4) compared to 2012 (Ashton et al. 2013) but similar to the cover found in 2011(Ashton et al. 2011). Like species richness, cover of exotic species varied considerably among sites (Table 6). Site PCM_020 and PCM_005 had a low cover of exotic species. The highest cover of exotic species was 31%, found at

PCM_004. With the exception of site PCM_021, annual bromes did not contribute to exotic cover. 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). Active management may be required to keep annual bromes in such low abundance.

Table 6. Characteristics of the plant community at 6 plots in Agate Fossil Beds National Monument in 2013 including average cover of annual bromes, exotic plant cover, and area of disturbance.

Plot	Native species richness in 1 m^2	Exotic cover (%)	Annual brome cover (%)	Disturbance within site (m^2)
AGFO_PCM_004	9	31	0	900
AGFO_PCM_005	2	0	0	2290
AGFO_PCM_008	6	29	0	500
AGFO_PCM_019	4	9	0	3290
AGFO_PCM_020	8	3	0	1100
AGFO_PCM_021	7	15	9	510
Park Average	*6 ± 1.0*	*14 ± 5.3*	*1.5 ± 1.5*	-

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 2013, the most common disturbance was borrowing activity of small rodents, but there was also evidence of the recent prescribed fire and ungulate animal trails. The average area of small mammal disturbance (likely pocket gophers) was much larger in 2013 than in past years, this is likely an effect of such dry conditions.

Legacy Monitoring

Five plots that were established in 1998 by the Heartland Inventory & Monitoring Program were visited by NGPN in 2013. The three plots that were adjacent to University and Carnegie Hills Trail Construction had similar exotic cover compared to nearby control plots in mixed-grass prairie (Table 7). Species diversity was much higher in the native mixed-grass prairie than in the disturbed sites.

Table 7. Characteristics of the plant community adjacent to trail construction and in mixed-grass prairie plots in Agate Fossil Beds National Monument in 2013.

Plot	Native species richness in 1 m^2	Exotic cover (%)	Annual brome cover (%)	Species richness in 10 m^2
Native mixed-grass				
AGFO_LPCM_4	8	13	0.5	18
AGFO_LPCM_5	8	3	0	22
Plots adjacent to trail				
AGFO_LPCM_2	5	14	0	12
AGFO_LPCM_3	6	5	0	12
AGFO_LPCM_7	4	0	0	12

Riparian Vegetation Monitoring

We visited 11 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 (180%; Table 8). We found 50 plant species in the riparian area, and 43 of these were unique and not seen in the upland plots (Appendix B). Many of the most common species were native graminoids (Figure 8) including western wheatgrass (*Pascopyrum smithii*), Baltic rush (*Juncus balticus*), and woolly sedge (*Carex pellita*). Common exotic species included Kentucky bluegrass (*Poa pratensis*), pale yellow iris (*Iris pseudacorus*), and Canada thistle (*Cirsium arvense*). Species richness in the riparian areas was generally higher than in the upland areas. Total species richness averaged 12 ± 1.9 species. On average, we recorded 9 native species along each transect (Table 8). We found average plot diversity, H', to be 1.9 ± 0.13, and when including only native species H'=1.7 ± 0.13. Evenness was similar in the riparian area and upland areas of the park. Evenness, J', averaged 0.80 ± 0.02 for all species and 0.79 ± 0.02 for native species (Table 8).

Exotic cover was high, averaging 31% across the riparian areas of the park (Table 8). Kentucky bluegrass was found at 7 of 12 sites, at over 30% absolute cover (Figure 8), and a relative cover of 10% throughout the riparian area. Canada thistle was found at 5 of the sites visited and overall had a relative cover of 3%. 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 5 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.

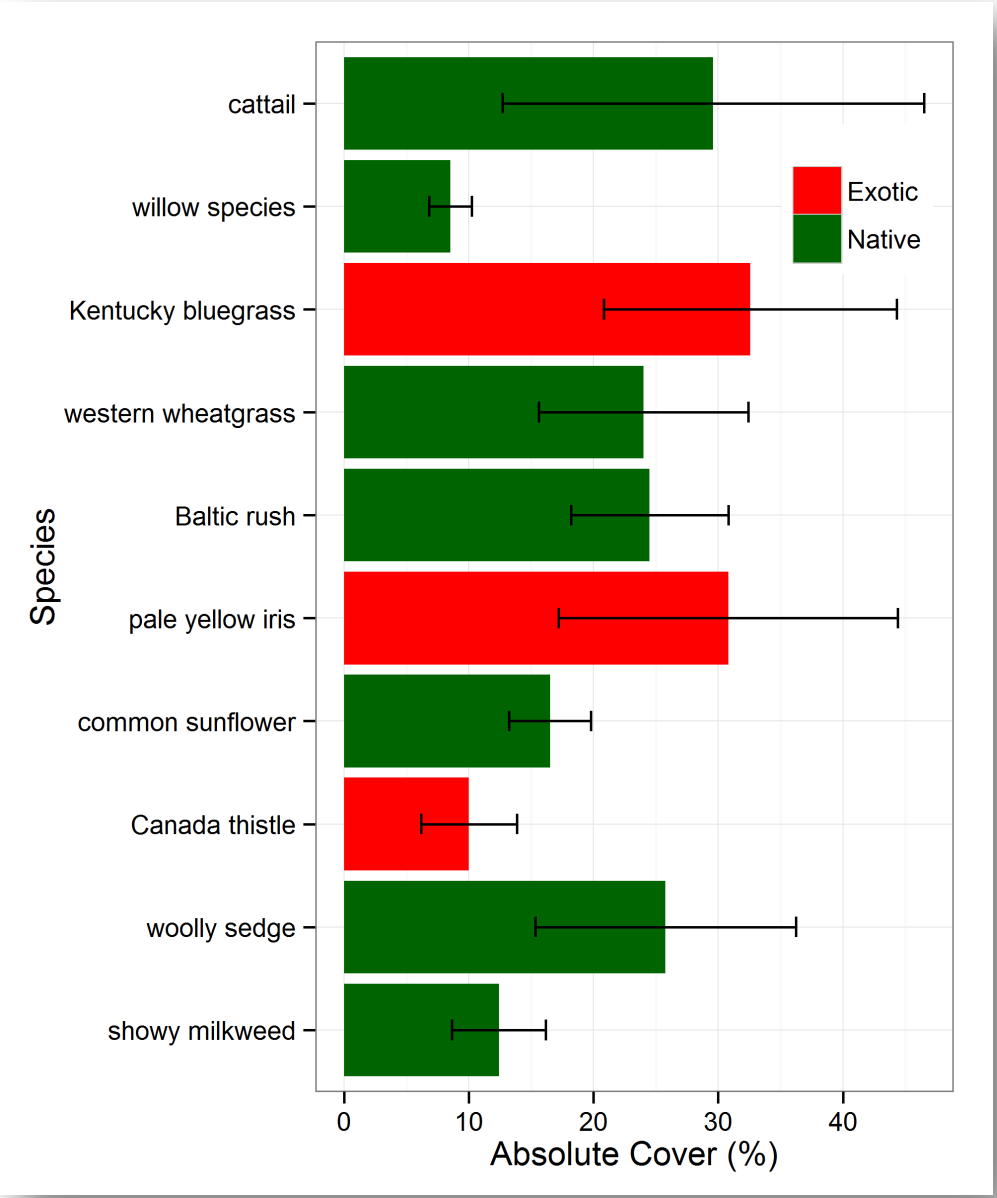


Figure 8. The average absolute cover of the 10 most common native (green) and exotic (red) riparian plants recorded at Agate Fossil Beds National Monument in 2013. Bars represent means ± standard errors. Kentucky bluegrass, pale yellow iris, and Canada thistle were the most common exotic species. Note this figure displays absolute cover. The relative cover of each species is lower because of the high total plant cover in these sites.

Table 8. Natural resource condition summary table for riparian plant communities in AGFO.

Indicator of Condition	Specific Measures	2013 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	180 ± 15.8 %	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)	0.80 ± 0.02	TBD		
Exotic Plant Early Detection and Management	Relative cover of exotic species	31 ± 5.0%	≤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 ± 5.4%	≤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 over 50% cover in others.

Summary

In conclusion, AGFO plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the area. While some areas of the park are impacted and have a high cover of exotic species, there are other areas that have relatively low exotic cover and a high diversity of native plants. We found two rare upland plant species in the park during 2013. After two dry years in a row, there has been a decline in native diversity. There has also been an increase in small mammal disturbance. To retain ecological integrity it is important to continue efforts to reduce the cover of invasive plants, particularly in the riparian corridor. Continued monitoring efforts will be critical to track changes in the condition of the vegetation communities in AGFO.

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Appendix A: Field journal for plant community monitoring in AGFO for the 2013 season

Plant community composition monitoring in Agate Fossil Beds National Monument was completed using a crew of 4 people working 4, 10-hour days and a crew of 6 people working for 2 days. We spent 284 total crew hours to complete the upland monitoring. Riparian monitoring took a team of 4 people 2 days to complete. We spent a total of 84 hours to complete the riparian monitoring.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed
May 29, 2013	Tuesday	3.5	Park housing	PCM-005 PCM-021
May 30, 2013	Wednesday	N/A	N/A	PCM-019 PCM-020
June 3, 2013	Monday	3.5	Park housing	PCM-020 PCM-008
June 4, 2013	Tuesday	N/A	N/A	LPCM-2 LPCM-3 LPCM-4 LPCM-7
June 5, 2013	Wednesday	N/A	Park housing	PCM-004 LPCM_5
June 6, 2013	Thursday	3.5	N/A	N/A
August 14, 2013	Wednesday	3.5	Park housing	RCM-257 RCM-258 RCM-261 RCM-265 RCM-266
August 15, 2013	Thursday	3.5	N/A	RCM-259 RCM-260 RCM-263 RCM-264 RCM-267 RCM-268

Appendix B: List of plant species found in 2013 at AGFO

Family	Code	Scientific Name	Common Name	2013 Habitat	Exotic
Agavaceae	YUGL	*Yucca glauca*	soapweed yucca	Upland	
Anacardiaceae	RHTR	*Rhus trilobata*	skunkbush sumac	Upland	
Apiaceae	MUTE3	*Musineon tenuifolium*	slender wildparsley	Upland	
Asclepiadaceae	ASIN	*Asclepias incarnata*	swamp milkweed	Riparian	
	ASSP	*Asclepias speciosa*	showy milkweed	Riparian	
	ASVI	*Asclepias viridiflora*	green comet milkweed	Upland	
Asteraceae	AMPS	*Ambrosia psilostachya*	Cuman ragweed	Riparian	
	AMTR	*Ambrosia trifida*	great ragweed	Riparian	
	ARFR4	*Artemisia frigida*	prairie sagewort	Upland	
	CIAR4	*Cirsium arvense*	Canada thistle	Riparian	*
	CICA11	*Cirsium canescens*	prairie thistle	Upland	
	CIFL	*Cirsium flodmanii*	Flodman's thistle	Upland	
	COCA5	*Conyza canadensis*	Canadian horseweed	Both	
	GUSA2	*Gutierrezia sarothrae*	broom snakeweed	Upland	
	HEAN3	*Helianthus annuus*	common sunflower	Both	
	HEPE	*Helianthus petiolaris*	prairie sunflower	Upland	
	HEVI4	*Heterotheca villosa*	hairy false goldenaster	Upland	
	LASE	*Lactuca serriola*	prickly lettuce	Riparian	*
	LIPU	*Liatris punctata*	dotted blazing star	Upland	
	LYJU	*Lygodesmia juncea*	rush skeletonplant	Upland	
	SERI2	*Senecio riddellii*	Riddell's ragwort	Upland	
	SOGI	*Solidago gigantea*	giant goldenrod	Riparian	
	SOMO	*Solidago mollis*	velvety goldenrod	Upland	
	SOAR2	*Sonchus arvensis*	field sowthistle	Riparian	*
	SYER	*Symphyotrichum ericoides*	white heath aster	Riparian	
	SYLA6	*Symphyotrichum lanceolatum*	white panicle aster	Riparian	
	TEAC	*Tetraneuris acaulis*	stemless four-nerve daisy	Upland	
	TRDU	*Tragopogon dubius*	yellow salsify	Both	*
Boraginaceae	CRCA8	*Cryptantha cana*	mountain cryptantha	Upland	
	CRCE	*Cryptantha celosioides*	buttecandle	Upland	
	LAOC3	*Lappula occidentalis*	flatspine stickseed	Upland	
	LIIN2	*Lithospermum incisum*	narrowleaf stoneseed	Upland	
Brassicaceae	ALDE	*Alyssum desertorum*	desert madwort	Upland	*
	CAMI2	*Camelina microcarpa*	littlepod false flax	Upland	*

Family	Code	Scientific Name	Common Name	2013 Habitat	Exotic
	DEPI	*Descurainia pinnata*	western tansymustard	Upland	
Brassicaceae	DESO2	*Descurainia sophia*	herb sophia	Riparian	*
	LEDE	*Lepidium densiflorum*	common pepperweed	Upland	
	SIAL2	*Sisymbrium altissimum*	tall tumblemustard	Upland	*
Cactaceae	OPFR	*Opuntia fragilis*	brittle pricklypear	Upland	
	OPMA2	*Opuntia macrorhiza*	twistspine pricklypear	Upland	
	OPPO	*Opuntia polyacantha*	plains pricklypear	Upland	
Capparaceae	PODO3	*Polanisia dodecandra*	redwhisker clammyweed	Riparian	
Caprifoliaceae	SYOC	*Symphoricarpos occidentalis*	western snowberry	Riparian	
Caryophyllaceae	PADE4	*Paronychia depressa*	spreading nailwort	Upland	
Chenopodiaceae	CHENO	*Chenopodium*	goosefoot	Both	*
	CHBE4	*Chenopodium berlandieri*	pitseed goosefoot	Riparian	
	CHFR3	*Chenopodium fremontii*	Fremont's goosefoot	Riparian	
	CORIS	*Corispermum*	bugseed	Upland	*
	KRLA2	*Krascheninnikovia lanata*	winterfat	Upland	
	SALSO	*Salsola*	Russian thistle	Upland	*
	SATR12	*Salsola tragus*	prickly Russian thistle	Both	*
Commelinaceae	TROC	*Tradescantia occidentalis*	prairie spiderwort	Upland	
Cyperaceae	CAFI	*Carex filifolia*	threadleaf sedge	Upland	
	CAHA3	*Carex hallii*	deer sedge	Riparian	
	CAPE42	*Carex pellita*	woolly sedge	Riparian	
	SCPU10	*Schoenoplectus pungens*	common threesquare	Riparian	
	SCTA2	*Schoenoplectus tabernaemontani*	softstem bulrush	Riparian	
Equisetaceae	EQLA	*Equisetum laevigatum*	smooth horsetail	Riparian	
Euphorbiaceae	CRTE4	*Croton texensis*	Texas croton	Upland	
	EUPHO	*Euphorbia*	spurge	Upland	*
	EUBR	*Euphorbia brachycera*	horned spurge	Upland	
	EUSE4	*Euphorbia serpens*	matted sandmat	Upland	
Fabaceae	ASCR2	*Astragalus crassicarpus*	groundplum milkvetch	Upland	
	ASMI10	*Astragalus missouriensis*	Missouri milkvetch	Upland	
	ASMO7	*Astragalus mollissimus*	woolly locoweed	Upland	
	DALEA	*Dalea*	prairie clover	Upland	
	DACA7	*Dalea candida*	white prairie clover	Upland	
	GLLE3	*Glycyrrhiza lepidota*	American licorice	Riparian	
	LAPO2	*Lathyrus polymorphus*	manystem pea	Upland	
	LUPL	*Lupinus plattensis*	Nebraska lupine	Upland	
	LUPU	*Lupinus pusillus*	rusty lupine	Upland	

Family	Code	Scientific Name	Common Name	2013 Habitat	Exotic
Fabaceae	MEOF	*Melilotus officinalis*	yellow sweetclover	Riparian	*
	PEAR6	*Pediomelum argophyllum*	silverleaf Indian breadroot	Upland	
Fabaceae	PEES	*Pediomelum esculentum*	large Indian breadroot	Upland	
	PSTE5	*Psoralidium tenuiflorum*	slimflower scurfpea	Upland	
	THRH	*Thermopsis rhombifolia*	prairie thermopsis	Upland	
Hydrophyllaceae	ELNY	*Ellisia nyctelea*	Aunt Lucy	Upland	
	PHHA	*Phacelia hastata*	silverleaf phacelia	Upland	
Iridaceae	IRPS	*Iris pseudacorus*	pale yellow iris	Riparian	*
Lamiaceae	LYAM	*Lycopus americanus*	American water horehound	Riparian	
	LYAS	*Lycopus asper*	rough bugleweed	Riparian	
	MEAR4	*Mentha arvensis*	wild mint	Riparian	
Lemnaceae	LEMI3	*Lemna minor*	common duckweed	Riparian	
Liliaceae	ALTE	*Allium textile*	textile onion	Upland	
	FRAT	*Fritillaria atropurpurea*	spotted fritillary	Upland	
Loasaceae	MEDE2	*Mentzelia decapetala*	tenpetal blazingstar	Upland	
Malvaceae	SPCO	*Sphaeralcea coccinea*	scarlet globemallow	Upland	
Nyctaginaceae	ABFR2	*Abronia fragrans*	snowball sand verbena	Upland	
	MIHI	*Mirabilis hirsuta*	hairy four o'clock	Upland	
Onagraceae	EPLE2	*Epilobium leptophyllum*	bog willowherb	Riparian	
Papaveraceae	ARPO2	*Argemone polyanthemos*	crested pricklypoppy	Upland	
Plantaginaceae	PLPA2	*Plantago patagonica*	woolly plantain	Upland	
Poaceae	ACHY	*Achnatherum hymenoides*	Indian ricegrass	Upland	
	ANGE	*Andropogon gerardii*	big bluestem	Upland	
	ARPU9	*Aristida purpurea*	purple threeawn	Upland	
	BOCU	*Bouteloua curtipendula*	sideoats grama	Upland	
	BOGR2	*Bouteloua gracilis*	blue grama	Upland	
	BRTE	*Bromus tectorum*	cheatgrass	Upland	*
	CAST36	*Calamagrostis stricta*	slimstem reedgrass	Riparian	
	CALO	*Calamovilfa longifolia*	prairie sandreed	Upland	
	DISP	*Distichlis spicata*	saltgrass	Riparian	
	ELEL5	*Elymus elymoides*	squirreltail	Upland	
	ELTR7	*Elymus trachycaulus*	slender wheatgrass	Both	
	HECO26	*Hesperostipa comata*	needle and thread	Upland	
	HOJU	*Hordeum jubatum*	foxtail barley	Riparian	
	KOMA	*Koeleria macrantha*	prairie Junegrass	Upland	
	MUAS	*Muhlenbergia asperifolia*	scratchgrass	Riparian	

Family	Code	Scientific Name	Common Name	2013 Habitat	Exotic
	MUME2	*Muhlenbergia mexicana*	Mexican muhly	Riparian	
	MUPU2	*Muhlenbergia pungens*	sandhill muhly	Upland	
	MURA	*Muhlenbergia racemosa*	marsh muhly	Riparian	
	PAVI2	*Panicum virgatum*	switchgrass	Riparian	
Poaceae	PASM	*Pascopyrum smithii*	western wheatgrass	Both	
	POPR	*Poa pratensis*	Kentucky bluegrass	Riparian	*
	POSE	*Poa secunda*	Sandberg bluegrass	Upland	
	SCSC	*Schizachyrium scoparium*	little bluestem	Upland	
	SPGR	*Spartina gracilis*	alkali cordgrass	Riparian	
	SPPE	*Spartina pectinata*	prairie cordgrass	Riparian	
	SPCR	*Sporobolus cryptandrus*	sand dropseed	Upland	
	VUOC	*Vulpia octoflora*	sixweeks fescue	Upland	
Polemoniaceae	PHAN4	*Phlox andicola*	prairie phlox	Upland	
	PHHO	*Phlox hoodii*	spiny phlox	Upland	
Polygonaceae	ERAN4	*Eriogonum annuum*	annual buckwheat	Upland	
	ERCE2	*Eriogonum cernuum*	nodding buckwheat	Upland	
	ERFL4	*Eriogonum flavum*	alpine golden buckwheat	Upland	
	RUVE2	*Rumex venosus*	veiny dock	Upland	
Salicaceae	SALIX	*Salix species*	willow species	Riparian	
Santalaceae	COUM	*Comandra umbellata*	bastard toadflax	Upland	
Scrophulariaceae	CASE5	*Castilleja sessiliflora*	downy paintedcup	Upland	
	PEAL2	*Penstemon albidus*	white penstemon	Upland	
	PEAN4	*Penstemon angustifolius*	broadbeard beardtongue	Upland	
Solanaceae	PHHI8	*Physalis hispida*	prairie groundcherry	Riparian	
	PHVI5	*Physalis virginiana*	Virginia groundcherry	Upland	
Typhaceae	TYLA	*Typha latifolia*	broadleaf cattail	Riparian	
Urticaceae	URDI	*Urtica dioica*	stinging nettle	Riparian	
Verbenaceae	VEHA2	*Verbena hastata*	swamp verbena	Riparian	
Violaceae	VINU2	*Viola nuttallii*	Nuttall's violet	Upland	