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Plant Community Composition and Structure Monitoring for Agate Fossil Beds National Monument, 2014 Annual Report

Michael Prowatzke
United States National Park Service, Northern Great Plains Inventory & Monitoring Network

Stephen K. Wilson
United States National Park Service, Northern Great Plains Inventory & Monitoring Network

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

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ON THE COVER
Long-term monitoring plot PCM-024 at Agate Fossil Beds National Monument, 2014
Photograph courtesy of the National Park Service

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Michael Prowatzke
Stephen K. Wilson

National Park Service
Northern Great Plains Inventory & Monitoring Network
231 E. St. Joseph Street
Rapid City, SD 57701

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Natural Resource Stewardship and Science
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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.

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Abstract

This report presents the results of vegetation monitoring efforts in 2014 at Agate Fossil Beds National Monument (AGFO) by the Northern Great Plains Inventory and Monitoring Network (NGPN).

During the fourth full year of field work, crew members from NGPN visited six plant community monitoring plots to collect data on the vegetation at AGFO. This is part of a long-term monitoring effort that will sample six of 15 randomly located upland plots every year, so that each plot is visited for two consecutive years and then rested for three years, on a five-year rotating basis. NGPN staff captured data relating to species richness, herb-layer height, abundance of individual native and non-native species, ground cover, and site disturbance on each of the six plots. In addition, NGPN captured an abbreviated collection of similar data at 12 sites in the riparian areas. Further data was collected at five sites using a protocol carried over from the Heartland Inventory and Monitoring Network to provide continuity of a long-term data set.

Our 2014 findings can be summarized as follows: The crew observed 172 vascular plant species in upland plots, with an average of 9.5 native species occurring within any given 1 m^2 quadrat sampled. Grasses, sedges, and shrubs made up the bulk of the plant cover, while non-native species represented about 22.6% of cover. Riparian areas seemed to be in similar condition to upland areas, though species assemble was considerably different. The mixed-grass prairies of AGFO seem to be in fair condition, though exotic plants, particularly prickly Russian thistle (*Salsola tragus*) present challenges to management.

Acknowledgments

We thank all the authors of the NGPN Plant Community Monitoring Protocol, particularly A. Symstad, for outstanding guidance on data collection and reporting. Thank you to the staff at AGFO, particularly L. Mansfield, W. Matthews, and A. Legault for providing logistical support and safety checks. We also thank the park for providing housing for our field crews and M. Benner for help in the field. With the help of the aforementioned, the 2014 NGPN vegetation field crew of M. Prowatzke, K. Legner, S. Rockwood, R. Manuel, F. Sewell, D. Pinigis, and L. Mickelson collected all the data included in this report.

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 2014, our fourth year of sampling. We visited six plots, and it will take two more years to visit every plot in the park twice (Figure 1). In addition, we surveyed vegetation in five plots that were first installed in 1997 by the Heartland Inventory & Monitoring Network. These plots are concentrated in the southeast corner of the park and represent a portion of a long-term effort to monitor native grasslands (Figure 1). We also sampled vegetation at 12 plots along the riparian corridor at AGFO for the third 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 it 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 five years of sampling. In the interim, reports, spatial data, and data summaries can be provided for park management and interpretation upon request.

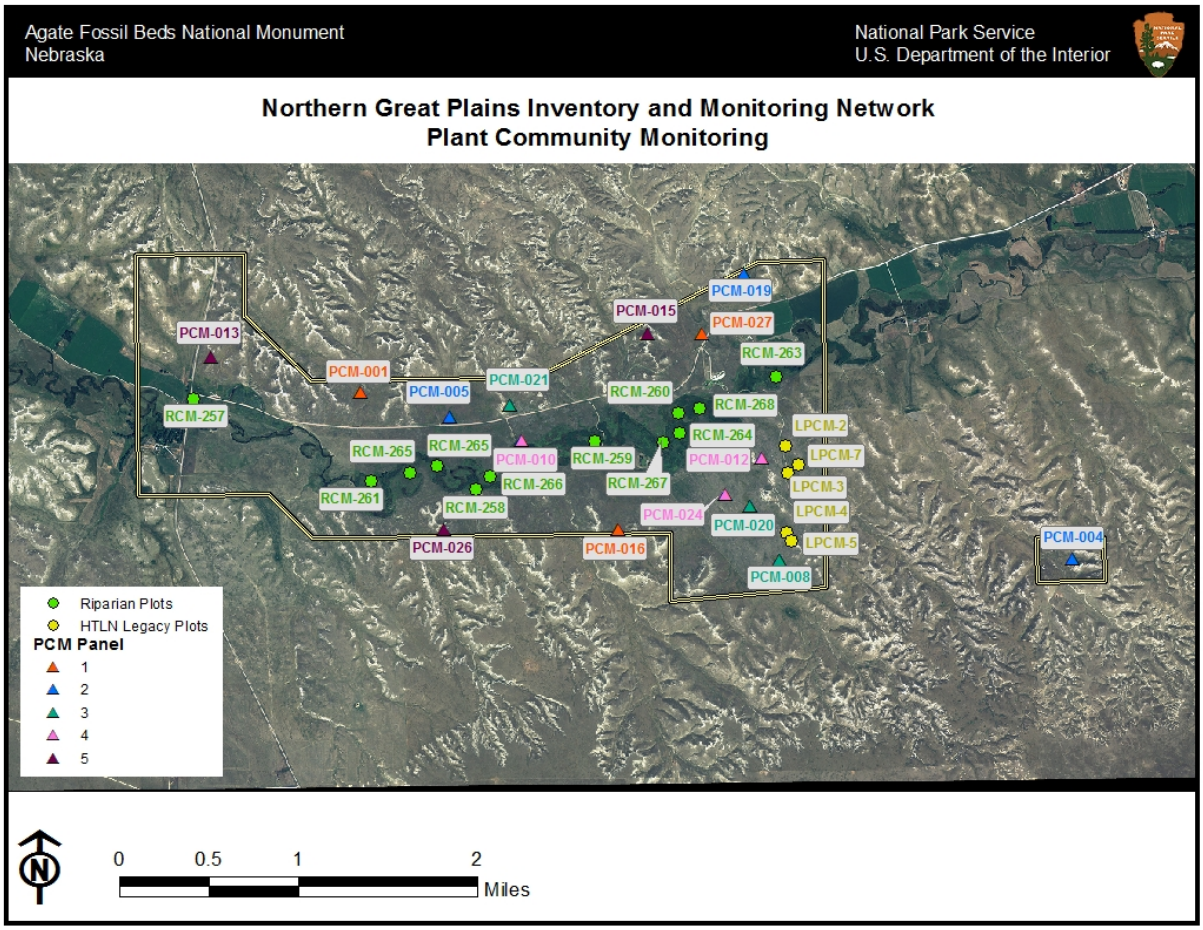


Figure 1. Map of Agate Fossil Beds National Monument and plant community monitoring (PCM) plots. Plots in panel 3 (turquoise) and panel 4 (pink), as well as riparian (green circles) and legacy (yellow circles) plots, were visited in 2014.

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. 2012a, 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 five panels with three sites each. We visit two panels (six sites) every year, and after five 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. In 2014, we visited sites in panel 3 and panel 4 during the last week of May and 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 five 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 2014, upland sampling at AGFO took NGPN crews approximately 270¼ 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 which may potentially occur in AGFO (Table 2).

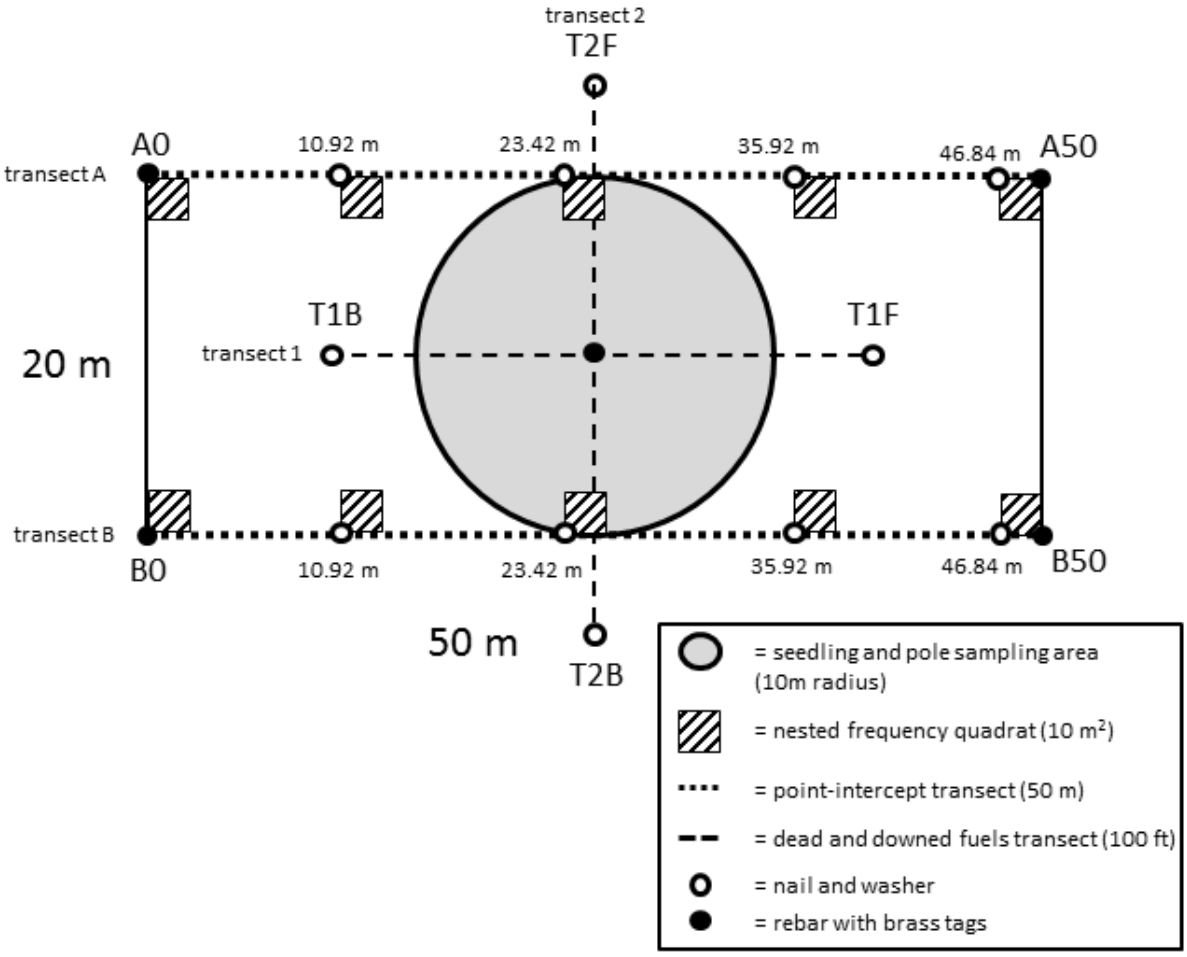


Figure 2. Long-term monitoring plot layout used for sampling vegetation in Agate Fossil Beds National Monument.

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	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 2014 field season at Agate Fossil Beds National Monument.

Scientific Name	Common Name
Astragalus barrii	Barr's milkvetch
Astragalus shortianus	Short's milkvetch
Boechera 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, five plots that were established in 1998 by the Heartland Inventory & Monitoring Program were revisited in 2014. 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 five 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 continued a pilot effort to sample vegetation in the riparian corridor in AGFO in 2014. There were three 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 2012-2014.

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 12 plots (Figure 1) were visited over three days in August using four people (Appendix A). In addition, three plots that were co-located with existing NGPN aquatic macroinvertebrate sampling sites (Tronstad 2014) were sampled as a separate pilot study. As these three sites were neither randomly selected nor used in 2012-2013, they are neither shown on the map nor analyzed in this report.

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.

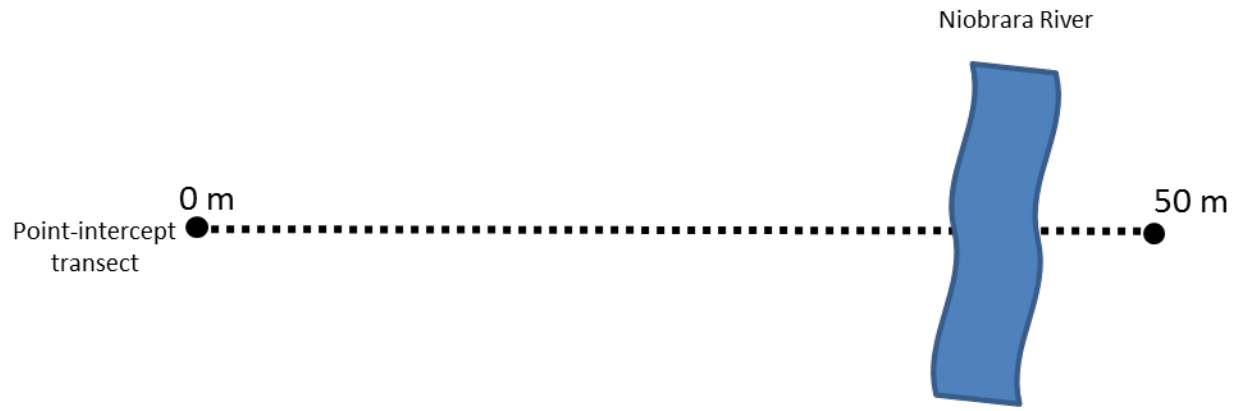


Figure 3. Survey plot used for sampling riparian vegetation in Agate Fossil Beds National Monument.

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 3.1.2).

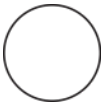
We measured diversity at the plots in three ways: species richness, the Shannon Index, and Pielou's Index of Evenness. Species richness is simply a count of the species recorded in an area. The Shannon Index, H', is a measure of the number of species in an area and how even abundances are across the 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 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 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 obtained some relief from an ongoing drought in 2014, and precipitation was slightly above average for the year (http://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00250030/detail; Figure 3). When NGPN visited the park in June, precipitation was near normal, but the park was noticeably greener than it had been in recent memory. Average canopy cover was 132% (Table 4) in 2014, which was almost three times that of the previous year (Ashton and Prowatzke 2014). There was a large amount of litter on the ground with ground cover at the sites averaging 79% plant litter.

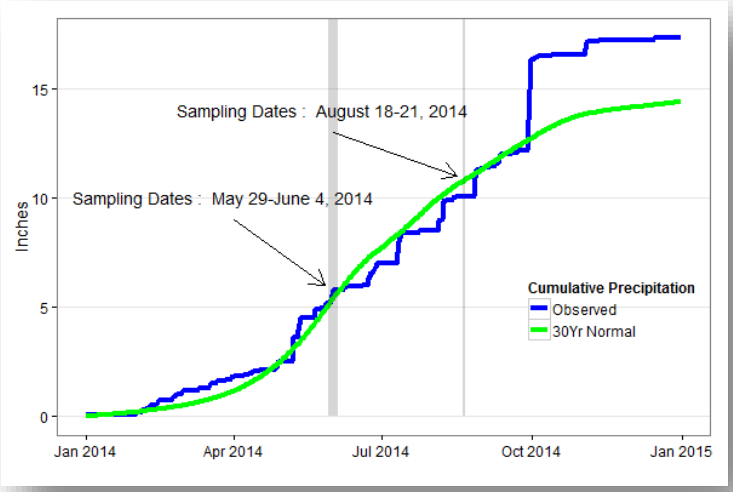


Figure 4. Observed and 30-year (1981-2010) normal precipitation near Agate Fossil Beds National Monument. Timing of NGPN visits is shown by vertical gray bars.

We found 128 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 18 exotic species in the upland areas of the park, all of which were either forbs or graminoids. No exotic target species were found at any sites in 2014.

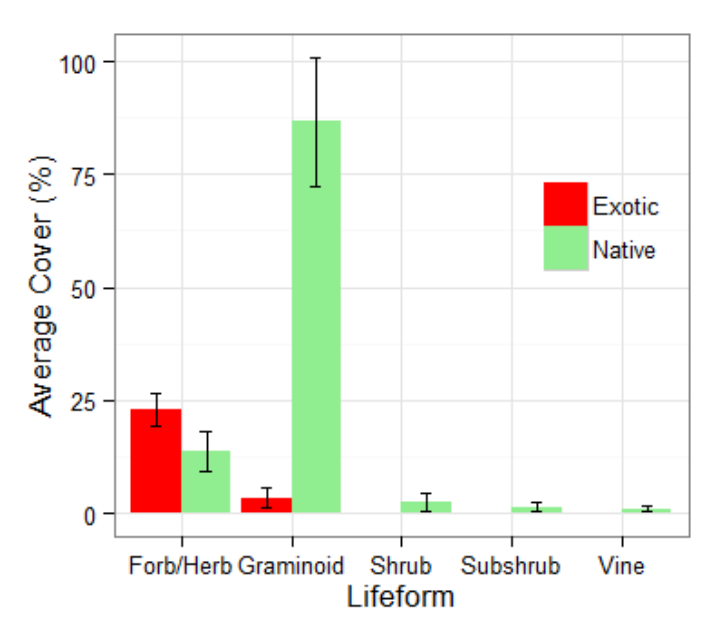


Figure 5. Average cover by lifeform in six plant community monitoring plots in Agate Fossil Beds National Monument in 2014. Graminoids and forbs were the most abundant lifeforms found in the understory across the plots. Bars represent means ± standard errors.

There was some variation in species composition across the six 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 six sites and continues to be one of the most abundant species at AGFO. We found two rare target plants--silverleaf phacelia (*Phacelia hastata*) at PCM-021 and limestone rockcress (*Boechera holboelli*) at LPCM-5.

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

Indicator of Condition	Specific Measures	2014 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	131.5 ± 10.9%	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. 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)	9.5 ± 0.9 species	3-15 species (2)		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.78 ± 0.02	TBD (1)		
Exotic Plant Early Detection and Management	Relative cover of exotic species	22.6 ± 7.0%	≤ 10% cover		AGFO maintains a mixed-grass prairie with moderate exotic plant cover and a fair diversity of native plants. Cheatgrass is not currently abundant in the park, but active management may be required to keep such low cover. In 2014, exotic forbs such as Russian thistle were quite abundant.
	Annual brome cover	2.7 ± 2.0%	≤10% cover		

References, Notes, and Data Sources:

1. To be determined when more data are available 2. Symstad, A. J. and J. L. Jonas. 2014. 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.

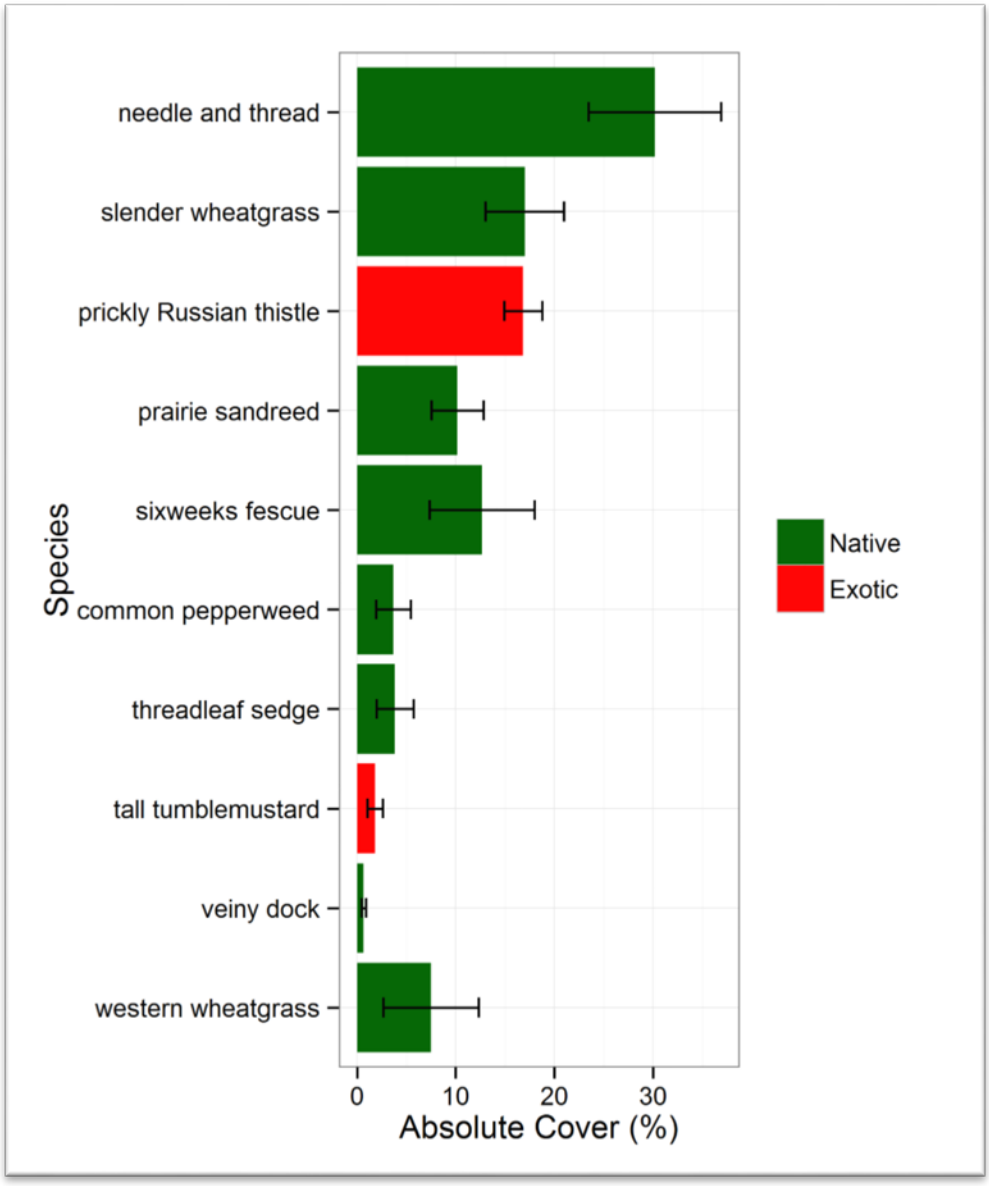


Figure 6. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded at Agate Fossil Beds National Monument in 2014. Bars represent means ± standard errors.

Average species richness at each of the six plots was measured by point-intercept and in 1 m^2 and 10 m^2 quadrats (Table 5). On average, there are about three exotic species within the 1 m^2 quadrat (Table 5). From the point-intersect data, we found average plot diversity, H', to be 2.2 ± 0.07. Evenness, J', averaged 0.78 ± 0.02 across the plots (Table 4). When including only native species, average diversity and evenness were 1.9 ± 0.15 and 0.74 ± 0.04, respectively.

Table 5. Average plant species richness in six plots at Agate Fossil Beds National Monument in 2014. Values represent means ± standard errors, n=6.

	Point-intercept	1 m^2 quadrats	10 m^2 quadrats
Species richness	17 ± 1.5	12 ± 0.8	19 ± 1.0
Native species richness	13 ± 1.4	9 ± 0.9	15 ± 1.2
Exotic species richness	4 ± 1.0	3 ± 0.3	4 ± 0.5
Graminoid species richness	7 ± 0.7	4 ± 0.3	6 ± 0.4
Forb species richness	9 ± 1.1	7 ± 0.5	12 ± 0.5

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 2014). 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 2014). Compared to this, AGFO is within the natural range (Table 4). The lowest diversity was seen in site PCM-010, which was close to the road and had high exotic plant cover, primarily kochia (*Kochia scoparia*), prickly Russian thistle, and cheatgrass (*Bromus tectorum*) (Table 6). The highest diversity was observed in PCM-008 (Figure 7), located in the southeastern corner of the park.

Figure 4. Long-term monitoring site PCM-008 at Agate Fossil Beds National Monument. In 2014, we found it to have higher native plant diversity than the other sites in the park.

The average relative cover of exotic species at sites in AGFO was higher than in other years, averaging 22.6 ± 7.0%. Like species richness, cover of exotic species varied considerably among sites (Table 6). Site PCM-020 had a low cover of exotic species, but site PCM-010 was over 50% exotic cover. Annual bromes were present at two of the upland plots. 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 six plots in Agate Fossil Beds National Monument in 2014 including native species richness, exotic plant cover, annual brome cover, and area of disturbance.

Plot	Native species richness in 1 m^2	Exotic cover (%)	Annual brome cover (%)	Disturbance within site (m^2)
PCM-008	12	22	0	575
PCM-010	6	55	11	3097
PCM-012	11	18	0	1000
PCM-020	10	5	0	2
PCM-021	11	22	5	15
PCM-024	8	14	0	0
Park Average	*9.5 ± 0.9*	*22.6 ± 7.0*	*2.7 ± 2.0*	-

Disturbance from grazing, prairie dogs, fire, and humans affects plant community structure and composition in mixed-grass prairie. For this reason, we measured the approximate area affected by natural and human disturbances at each site we visited. In 2014, the most common disturbance was burrowing activity of small mammals such as gophers, but there was also evidence of the recent prescribed fire and associated off-road travel.

Legacy Monitoring

Five plots that were established in 1998 by the Heartland Inventory & Monitoring Program were visited by NGPN in 2014. 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 2014.

Plot	Native species richness in 1 m^2	Exotic cover (%)	Annual brome cover (%)	Native species richness in 10 m^2
Native mixed-grass				
LPCM-4	10	26	0	18
LPCM-5	9	16	0	22
Plots adjacent to trail				
LPCM-2	-	16	2	-
LPCM-3	-	8	1	-
LPCM-7	-	30	0	-

Riparian Vegetation Monitoring

We visited 12 riparian sites in AGFO (Figure 1) to test field methods in the riparian area that could be used to estimate the current condition of the plant community and to provide some field data on the extent of pale yellow iris invasion. We can use data from our randomly selected sites to estimate the condition of the entire 156 hectare extent of AGFO riparian plant communities. We found 65 plant species in the riparian area, and 44 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 woolly sedge (*Carex pellita*), Baltic rush (*Juncus balticus*), 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 14 ± 1.3 species. On average, we recorded 11 native species along each transect (Table 8). We found average plot diversity, H', to be 2.0 ± 0.13, and when including only native species H'=1.7 ± 0.14. Evenness was similar in the riparian area and upland areas of the park. Evenness, J', averaged 0.75 ± 0.03 for all species and 0.73 ± 0.03 for native species (Table 8).

Exotic cover was high, averaging 32% across the riparian areas of the park (Table 8). Kentucky bluegrass was found at 8 of 12 sites, and averaged over 10% relative cover throughout the riparian area.

Pale yellow iris was very abundant and found at half of the sites, averaging 14% relative cover in the riparian area. It accounted for over 50% of the plant cover in two 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.

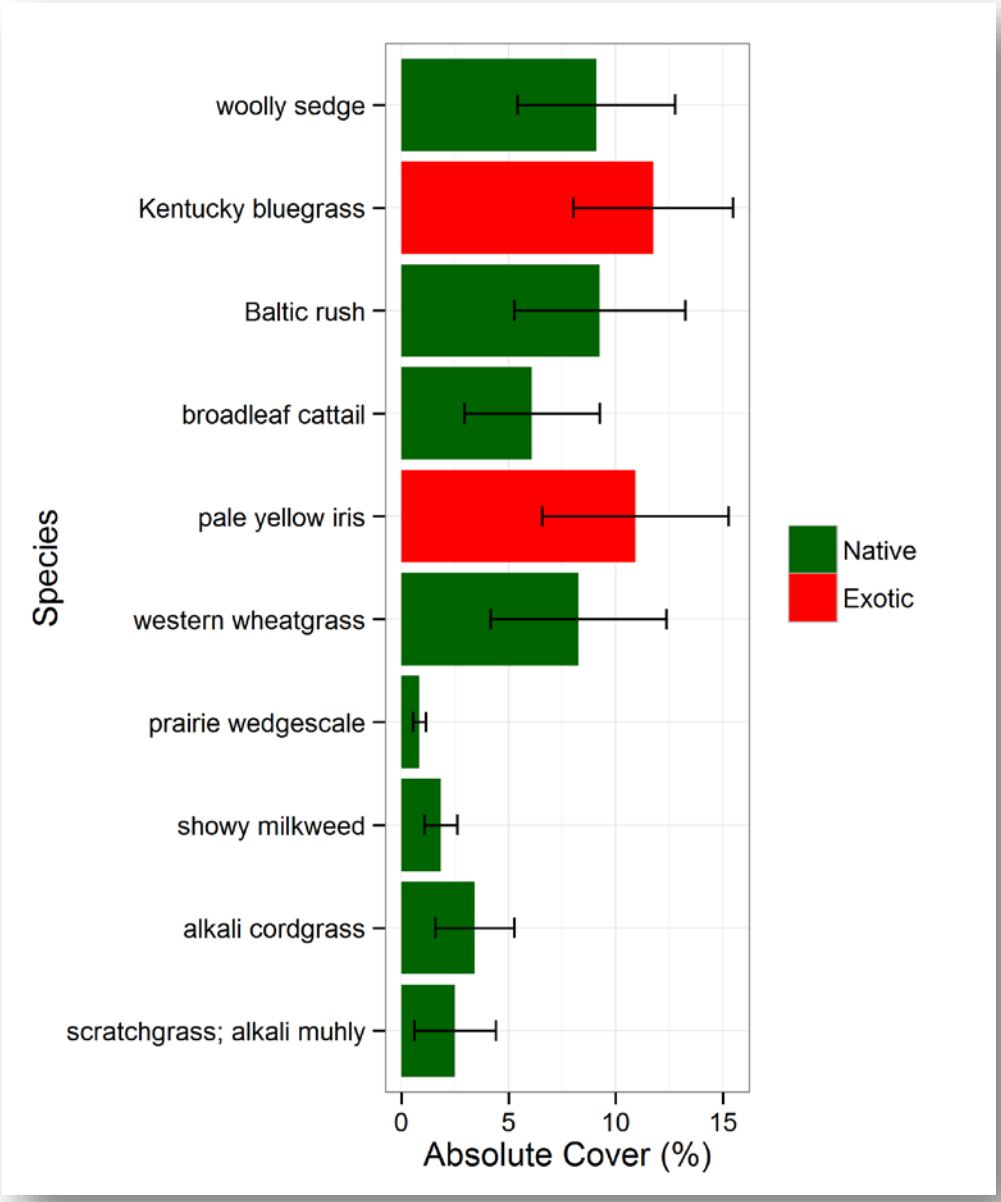
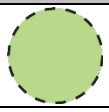
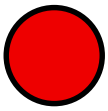
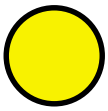


Figure 5. The average absolute cover of the 10 most common native (green) and exotic (red) riparian plants recorded at Agate Fossil Beds National Monument in 2014. Bars represent means ± standard errors. Kentucky bluegrass and pale yellow iris were the most common exotic species.

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

Indicator of Condition	Specific Measures	2014 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	98.9 ± 7.6%	TBD		The riparian areas of AGFO had levels of diversity similar to 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 on 1- 50 m point-intercept transect per plot)	11 ± 1.2 species	TBD		
	Evenness (based on 1-50m point-intercept transect per plot)	0.75 ± 0.03	TBD		
Exotic Plant Early Detection and Management	Relative cover of exotic species	31.9 ± 3.9%	≤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	14.1 ± 5.9%	≤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

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 2014. Native diversity was higher than in the two previous drought-influenced years, though both native and exotic plants have apparently benefitted from precipitation that is closer to normal levels. 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 2014 season

Plant community composition monitoring in Agate Fossil Beds National Monument was completed using a crew of six people working for two days, followed by a crew of three people working four 10-hour days (only two people worked on the last day). Additionally, 20¼ hours of overtime were incurred, for a total of 270¼ hours to complete the upland monitoring. Riparian monitoring took a team of four people three days to complete, and 15 hours of overtime were incurred. We spent a total of 135 hours to complete the riparian monitoring.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed
May 28, 2014	Wednesday	3.5	Park housing	LPCM-4 LPCM-5
May 29, 2014	Thursday	3.5	N/A	PCM-010 PCM-021
June 2, 2014	Monday	3.5	Park housing	PCM-008
June 3, 2014	Tuesday	N/A	Park housing	PCM-020 PCM-024
June 4, 2014	Wednesday	N/A	Park housing	PCM-012 LPCM-7 (point-intercept only) 2 crew members leave for wildland fire training.
June 5, 2014	Thursday	3.5	N/A	LPCM-2 (point-intercept only) LPCM-3 (point-intercept only) 1 crew member arrives from Fort Laramie crew.
August 19, 2014	Tuesday	3.5	Park housing	RCM-257 RCM-258 RCM-261
August 20, 2014	Wednesday	N/A	Park housing	RCM-259 RCM-260 RCM-262 RCM-264 RCM-265 RCM-266 RCM-267 RCM-1002
August 21, 2014	Thursday	3.5	N/A	RCM-263 RCM-268 RCM-1001 RCM-1003

Appendix B: List of plant species found in 2014 at AGFO

Family	Code	Scientific Name	Common Name	2014 Habitat	Exotic
Agavaceae	YUGL	*Yucca glauca*	soapweed yucca	Upland	
Alismataceae	SACU	*Sagittaria cuneata*	arumleaf arrowhead	Riparian	
Anacardiaceae	RHTR	*Rhus trilobata*	skunkbush sumac	Upland	
Apiaceae	CIMA2	*Cicuta maculate*	spotted water hemlock	Riparian	
	CYGL99	*Cymopterus glomeratus*	plains springparsley	Upland	
	MUTE3	*Musineon tenuifolium*	slender wildparsley	Upland	
Asclepiadaceae	ASIN	*Asclepias incarnata*	swamp milkweed	Riparian	
	ASSP	*Asclepias speciosa*	showy milkweed	Both	
Asteraceae	AMPS	*Ambrosia psilostachya*	Cuman ragweed	Upland	
	ARFR4	*Artemisia frigida*	prairie sagewort	Both	
	BIFR	*Bidens frondosa*	devil's beggartick	Riparian	
	CIAR4	*Cirsium arvense*	Canada thistle	Riparian	*
	CIFL	*Cirsium flodmanii*	Flodman's thistle	Both	
	COCA5	*Conyza canadensis*	Canadian horseweed	Both	
	CYXA	*Cyclachaena xanthifolia*	giant sumpweed	Riparian	
	EROC	*Erigeron ochroleucus*	buff fleabane	Upland	
	ERPU2	*Erigeron pumilus*	shaggy fleabane	Upland	
	GUSA2	*Gutierrezia sarothrae*	broom snakeweed	Upland	
	HEAN3	*Helianthus annuus*	common sunflower	Both	
	HEVI4	*Heterotheca villosa*	hairy false goldenaster	Upland	
	HYFI	*Hymenopappus filifolius*	fineleaf hymenopappus	Upland	
	LASE	*Lactuca serriola*	prickly lettuce	Both	*
	LIPU	*Liatris punctate*	dotted blazing star	Upland	
	LYJU	*Lygodesmia juncea*	rush skeletonplant	Upland	
	MATA2	*Machaeranthera tanacetifolia*	tanseyleaf tansyaster	Upland	
	MUOB99	*Mulgedium oblongifolium*	blue lettuce	Both	
	PACA15	*Packera cana*	woolly groundsel	Upland	
	SERI2	*Senecio riddellii*	Riddell's ragwort	Upland	
	SOAR2	*Sonchus arvensis*	field sowthistle	Riparian	*
	SOGI	*Solidago gigantea*	giant goldenrod	Riparian	
	SOMI2	*Solidago missouriensis*	Missouri goldenrod	Upland	
	SOMO	*Solidago mollis*	velvety goldenrod	Upland	
	SYFA	*Symphyotrichum falcatum*	white prairie aster	Upland	
	SYLA6	*Symphyotrichum lanceolatum*	white panicle aster	Riparian	
	SYMPH4	*Symphyotrichum* sp.	aster	Upland	
	TEAC	*Tetraneuris acaulis*	stemless four-nerve daisy	Upland	
	TRDU	*Tragopogon dubius*	yellow salsify	Upland	*
	XAGR99	*Xanthisma grindelioides*	rayless tansyaster	Upland	
	XASP99	*Xanthisma spinulosum*	lacy tansyaster	Upland	
Boraginaceae	CRCE	*Cryptantha celosioides*	buttecandle	Upland	
	LAOC3	*Lappula occidentalis*	flatspine stickseed	Upland	
	LIIN2	*Lithospermum incisum*	narrowleaf stoneseed	Upland	

Brassicaceae	ALDE	*Alyssum desertorum*	desert madwort	Upland	*
	BOHO99	*Boechera holboellii*	Holboell's rockcress	Upland	
	CAMI2	*Camelina microcarpa*	littlepod false flax	Upland	*
	DEPI	*Descurainia pinnata*	western tansymustard	Upland	
	DESO2	*Descurainia sophia*	herb sophia	Upland	*
	DRRE2	*Draba reptans*	Carolina draba	Upland	
	ERCA14	*Erysimum capitatum*	sanddune wallflower	Upland	
	LEDE	*Lepidium densiflorum*	common pepperweed	Upland	
	PHLU99	*Physaria ludoviciana*	foothill bladderpod	Upland	
	SIAL2	*Sisymbrium altissimum*	tall tumblemustard	Both	*
Cactaceae	ESVI2	*Escobaria vivipara*	spinystar	Upland	
	OPFR	*Opuntia fragilis*	brittle pricklypear	Upland	
	OPMA2	*Opuntia macrorhiza*	twistspine pricklypear	Upland	
	OPPO	*Opuntia polyacantha*	plains pricklypear	Upland	
Caprifoliaceae	SYOC	*Symphoricarpos occidentalis*	western snowberry	Riparian	
Caryophyllaceae	PADE4	*Paronychia depressa*	spreading nailwort	Upland	
Chenopodiaceae	CHBE4	*Chenopodium berlandieri*	pitseed goosefoot	Riparian	
	CHENO	*Chenopodium*	goosefoot	Both	*
	KOSC	*Kochia scoparia*	burningbush, kochia	Both	*
	SATR12	*Salsola tragus*	prickly Russian thistle	Both	*
Cleomaceae	PESE99	*Peritoma serrulata*	Rocky Mountain beeplant	Riparian	
Commelinaceae	TROC	*Tradescantia occidentalis*	prairie spiderwort	Upland	
Cucurbitaceae	ECLO	*Echinocystis lobata*	wild cucumber	Upland	
Cyperaceae	CADU6	*Carex duriuscula*	needleleaf sedge	Riparian	
	CAFI	*Carex filifolia*	threadleaf sedge	Upland	
	CAHA3	*Carex hallii*	deer sedge	Riparian	
	CAHY4	*Carex hystericina*	bottlebrush sedge	Riparian	
	CAIN9	*Carex inops*	long-stolon sedge	Upland	
	CAPE42	*Carex pellita*	woolly sedge	Riparian	
	CAREX	*Carex*	sedge	Both	
	ELER	*Eleocharis erythropoda*	bald spikerush	Riparian	
	SCPU10	*Schoenoplectus pungens*	common threesquare	Riparian	
	SCTA2	*Schoenoplectus tabernaemontani*	softstem bulrush	Riparian	
Equisetaceae	EQLA	*Equisetum laevigatum*	smooth horsetail	Both	
Euphorbiaceae	EUBR	*Euphorbia brachycera*	horned spurge	Upland	
Fabaceae	ASCE	*Astragalus ceramicus*	painted milkvetch	Upland	
	ASLA27	*Astragalus laxmannii*	Laxmann's milkvetch	Upland	
	ASLO4	*Astragalus lotiflorus*	lotus milkvetch	Upland	
	ASMI10	*Astragalus missouriensis*	Missouri milkvetch	Upland	
	ASMO7	*Astragalus mollissimus*	woolly locoweed	Upland	
	ASTRA	*Astragalus* sp.	milkvetch	Upland	
	DACA7	*Dalea candida*	white prairie clover	Upland	
	GLLE3	*Glycyrrhiza lepidota*	American licorice	Both	
	LAPO2	*Lathyrus polymorphus*	manystem pea	Upland	

Fabaceae	LUPL	*Lupinus plattensis*	Nebraska lupine	Upland	
	LUPU	*Lupinus pusillus*	rusty lupine	Upland	
	MELU	*Medicago lupulina*	black medick	Upland	*
	MEOF	*Melilotus officinalis*	yellow sweetclover	Both	*
	PEES	*Pediomelum esculentum*	large Indian breadroot	Upland	
	PSLA3	*Psoralidium lanceolatum*	lemon scurfpea	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*	paleyellow iris	Riparian	*
Juncaceae	JUBA	*Juncus balticus*	Baltic rush	Riparian	
Lamiaceae	HEDR	*Hedeoma drummondii*	Drummond's false pennyroyal	Upland	
	HEHI	*Hedeoma hispida*	rough false pennyroyal	Upland	
	LYAS	*Lycopus asper*	rough bugleweed	Riparian	
	MEAR4	*Mentha arvensis*	wild mint	Riparian	
	SCLA2	*Scutellaria lateriflora*	blue skullcap	Riparian	
Lemnaceae	LEMI3	*Lemna minor*	common duckweed	Riparian	
Liliaceae	ALTE	*Allium textile*	textile onion	Upland	
	CANU3	*Calochortus nuttallii*	sego lily	Upland	
Linaceae	LIRI	*Linum rigidum*	stiffstem flax	Upland	
Malvaceae	SPCO	*Sphaeralcea coccinea*	scarlet globemallow	Upland	
Nyctaginaceae	MIHI	*Mirabilis hirsuta*	hairy four o'clock	Upland	
Onagraceae	EPLE2	*Epilobium leptophyllum*	bog willowherb	Riparian	
	OEAL	*Oenothera albicaulis*	whitest evening-primrose	Upland	
	OENU	*Oenothera nuttallii*	Nuttall's evening-primrose	Upland	
	OESE3	*Oenothera serrulata*	yellow sundrops	Upland	
	OESU99	*Oenothera suffrutescens*	scarlet beeblossom	Upland	
Papaveraceae	ARPO2	*Argemone polyanthemos*	crested pricklypoppy	Upland	
Plantaginaceae	PLPA2	*Plantago patagonica*	woolly plantain	Upland	
Poaceae	ACHY	*Achnatherum hymenoides*	Indian ricegrass	Upland	
	ARPU9	*Aristida purpurea*	purple threeawn	Upland	
	BOCU	*Bouteloua curtipendula*	sideoats grama	Upland	
	BOGR2	*Bouteloua gracilis*	blue grama	Upland	
	BRIN2	*Bromus inermis*	smooth brome	Upland	*
	BRJA	*Bromus japonicus*	Japanese brome	Riparian	*
	BRTE	*Bromus tectorum*	cheatgrass	Upland	*
	CALO	*Calamovilfa longifolia*	prairie sandreed	Both	
	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	

Poaceae	KOMA	*Koeleria macrantha*	prairie Junegrass	Upland	
	LEOR	*Leersia oryzoides*	rice cutgrass	Riparian	
	MUAS	*Muhlenbergia asperifolia*	scratchgrass	Riparian	
	MUPA99	*Muhlenbergia paniculata*	tumblegrass	Upland	
	MUPU2	*Muhlenbergia pungens*	sandhill muhly	Upland	
	PACA6	*Panicum capillare*	witchgrass	Riparian	
	PASM	*Pascopyrum smithii*	western wheatgrass	Both	
	PAVI2	*Panicum virgatum*	switchgrass	Riparian	
	POPA2	*Poa palustris*	fowl bluegrass	Upland	
	POPR	*Poa pratensis*	Kentucky bluegrass	Both	*
	POSE	*Poa secunda*	Sandberg bluegrass	Upland	
	SCSC	*Schizachyrium scoparium*	little bluestem	Upland	
	SPCR	*Sporobolus cryptandrus*	sand dropseed	Upland	
	SPGR	*Spartina gracilis*	alkali cordgrass	Riparian	
	SPOB	*Sphenopholis obtusata*	prairie wedgescale	Riparian	
	SPPE	*Spartina pectinata*	prairie cordgrass	Riparian	
	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	
	ERFL4	*Eriogonum flavum*	alpine golden buckwheat	Upland	
	FACO	*Fallopia convolvulus*	black bindweed	Riparian	*
	RUVE2	*Rumex venosus*	veiny dock	Upland	
Rosaceae	ROWO	*Rosa woodsii*	Woods' rose	Upland	
Salicaceae	SAIN3	*Salix interior*	sandbar willow	Riparian	
	SALIX	*Salix* sp.	willow	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	
	VEAN2	*Veronica anagallis-aquatica*	water speedwell	Riparian	
Solanaceae	PHHI8	*Physalis hispida*	prairie groundcherry	Both	
	PHVI5	*Physalis virginiana*	Virginia groundcherry	Upland	
Typhaceae	TYAN	*Typha angustifolia*	narrowleaf cattail	Riparian	
	TYLA	*Typha latifolia*	broadleaf cattail	Riparian	
Unknown family	UNKFORB	Unknown forb	unknown forb	Upland	*
	UNKFORBANN	Unknown annual forb	unknown annual forb	Upland	*
	UNKFORBPER	Unknown perennial forb	unknown perennial forb	Upland	*
	UNKGRAM	Unknown graminoid	unknown graminoid	Upland	*
	UNKGRAMANN	Unknown annual graminoid	unknown annual graminoid	Riparian	*
Urticaceae	URDI	*Urtica dioica*	stinging nettle	Both	
Verbenaceae	VEHA2	*Verbena hastata*	swamp verbena	Riparian	
Violaceae	VINU2	*Viola nuttallii*	Nuttall's violet	Upland	

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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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov