National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Plant Community Composition and Structure Monitoring for Fort Union Trading Post National Historic Site

2014 Annual Report

Natural Resource Data Series NPS/NGPN/NRDS—2015/770

ON THE COVER
Long-term monitoring plot PCM-131 at Fort Union Trading Post National Historic Site, 2014
Photograph courtesy of the National Park Service

Plant Community Composition and Structure Monitoring for Fort Union Trading Post National Historic Site

2014 Annual Report

Natural Resource Data Series NPS/NGPN/NRDS—2015/770

Michael Prowatzke
Stephen K. Wilson

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

March 2015

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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

The Natural Resource 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 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.

Please cite this publication as:

Prowatzke, M. and S. K. Wilson. 2015. Plant community composition and structure monitoring for Fort Union Trading Post National Historic Site: 2014 annual report. Natural Resource Data Series NPS/NGPN/NRDS—2015/770. National Park Service, Fort Collins, Colorado.

NPS 436/128112, March 2015

Contents

Figures

Tables

Abstract

This report presents the results of vegetation monitoring efforts in 2014 at Fort Union Trading Post National Historic Site (FOUS) by the Northern Great Plains Inventory and Monitoring Network (NGPN).

During the fourth consecutive full year of field work, crew members from NGPN visited six plant community monitoring plots to collect data on the vegetation at FOUS. 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, the abundance of individual native and non-native species, ground cover, and site disturbance on each of the six plots.

Our 2014 findings can be summarized as follows: The crew observed 103 vascular plant species in upland plots, with an average of 5.9 native species occurring within any given 1 m^2 quadrat sampled. Plots in the Bodmer unit were considerably more diverse, averaging 10.6 native species per 1 m^2 quadrat, than plots near the fort, which averaged 3.5 native species per 1 m^2 quadrat. Native forbs are uncommon around the fort. Grasses and sedges made up the bulk of the plant cover in all plots, and non-native species represented about 13.3% of cover.

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 FOUS, particularly D. Carr and L. Yellow Bird, for providing logistical support (coffee!), safety checks, and interpretation of the resources. C. Boothman also provided help in the field. With the assistance of the aforementioned, the 2014 NGPN vegetation field crew of M. Prowatzke, S. Rockwood, 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 North Dakota, greater than 71% 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 the Northern Great Plains. The stewardship goal of the NPS is to "preserve ecological integrity and cultural and historical authenticity" (NPS 2012); however, resource managers struggle with the realities that 1) there have been fundamental changes to the disturbance regimes such as climate, fire, and large ungulate grazing, that have maintained prairies in the past and 2) there is the continual pressure of exotic invasive species. Long-term monitoring is essential to sound management of prairie landscapes because it can provide information on environmental quality and condition, benchmarks concerning ecological integrity, and early warning signs for declines in ecosystem health.

Fort Union Trading Post National Historic Site (FOUS) was established in 1966 with a mission to commemorate the significant role played by Fort Union as a fur trading post on the Upper Missouri River. The trading post sits on 444 acres of upland mixed-grass prairie and riparian forests. The Northern Great Plains Inventory & Monitoring Program (NGPN) began vegetation monitoring at FOUS in 2011(Ashton et al. 2012), and surveys using similar methods were done in 2010 for the vegetation management plan (Symstad 2011). Two distinct areas of grassland at FOUS are monitored: the upland terrace surrounding the fort and the Bodmer Overlook Unit to the north. The upland terrace surrounding the fort has an extensive history of agriculture and more recently has been planted with native plant species (Symstad 2011). The Bodmer Overlook Unit is a 30-acre parcel of rolling hills north of the fort comprised of relatively intact native prairie (Symstad 2011). Vegetation monitoring protocols were established, and plot locations that represent the park were chosen, to facilitate coordination of efforts with the Northern Great Plains Fire Ecology Program (FireEP). The long-term objectives of the NGPN plant community monitoring effort (Symstad et al. 2012b) at FOUS 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 FOUS in 2014. This was NGPN's fourth year of sampling, and we visited six plots (Figure 1). Not all plots are visited every year, and we expect it will take one more year to visit every plot in the park twice. 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.

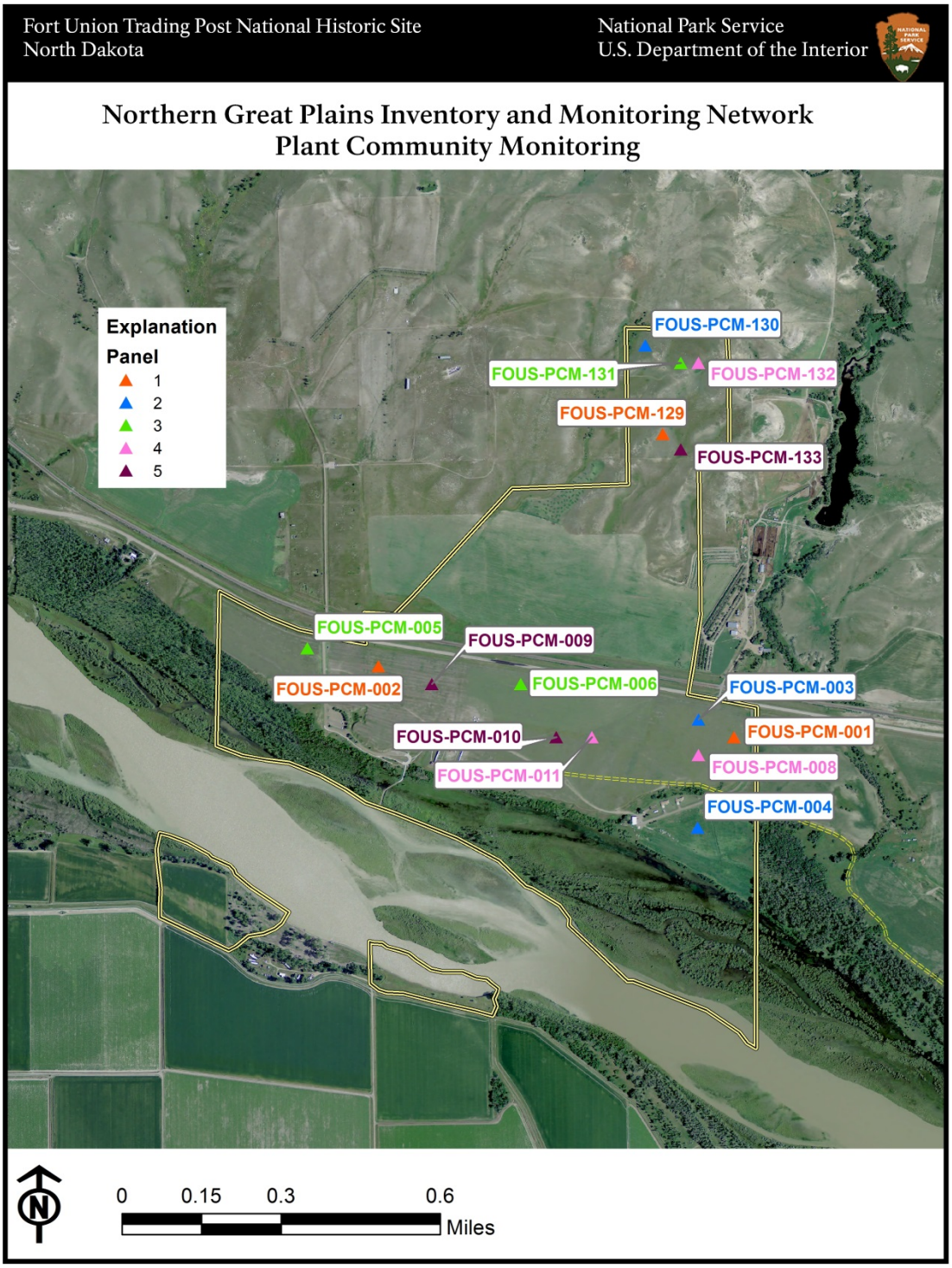


Figure 1. Map of plant community monitoring plots at Fort Union Trading Post National Historic Site (FOUS). Plant community monitoring plots in Panel 3 (green) and Panel 4 (pink) were surveyed in 2014.

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, which is 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 at FOUS 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 FOUS (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. This year, we visited sites in panel 3 and panel 4 during the last week of July. Data from these randomly selected sites can be used to estimate condition of vegetation communities for the whole park and over time 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 $\leq$ 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, sampling at FOUS took a 3-person crew three days with travel time, for a total of 101¼ hours (see Appendix A for a detail of activities each day).

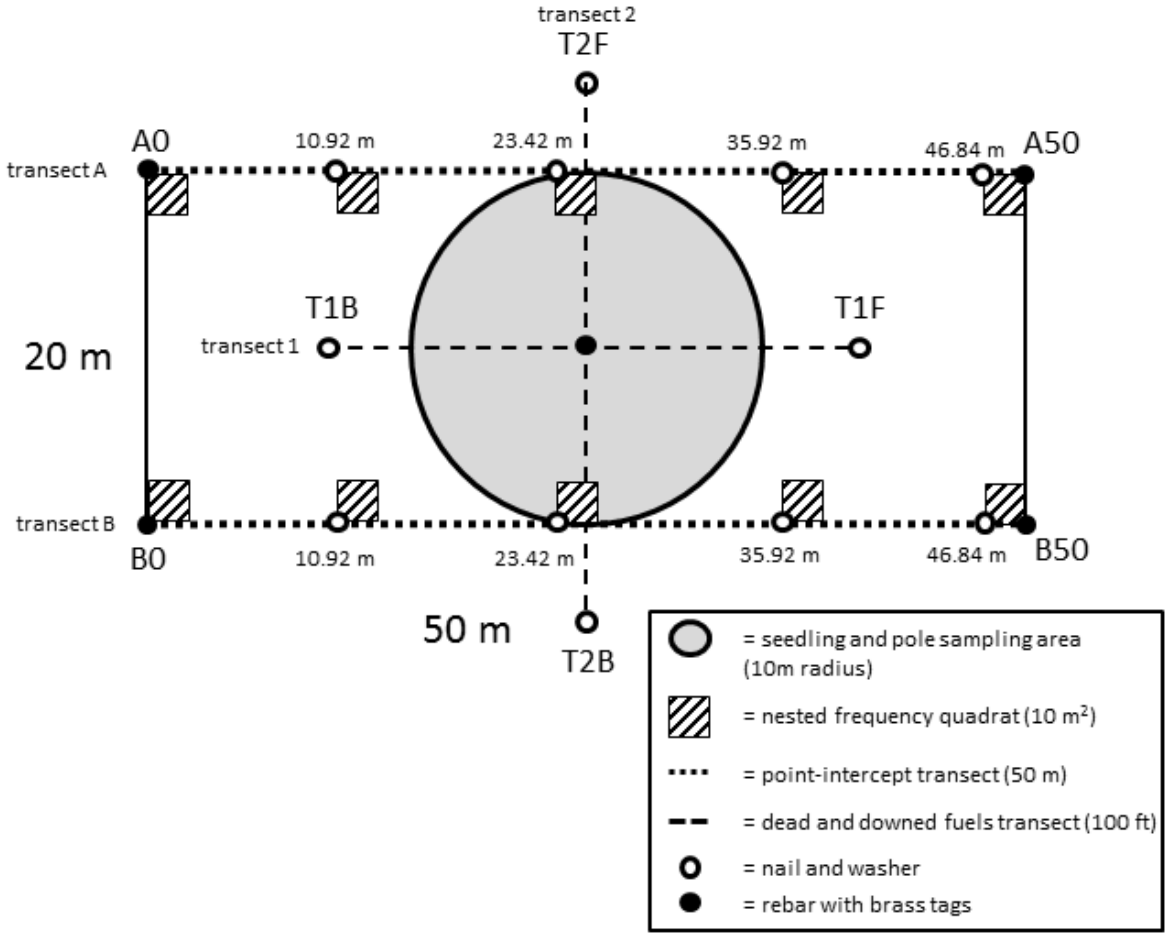


Figure 2. Long-term monitoring plot layout used for sampling vegetation in Fort Union Trading Post National Historic Site.

When woody species were present, tree regeneration and tall shrub density data were collected within a 10 m radius subplot centered in the larger 50 m x 20 m plot (Figure 2). Trees with a diameter at breast height (DBH) > 15 cm, located within the entire 0.1 ha plot, are mapped and tagged. For each tree, the species, DBH, status, and condition (e.g., leaf-discoloration, insect-damaged, etc.) are recorded. We did not find any tree or tall shrub species in any plots in 2014.

At all plots, we also surveyed the area for common disturbances and target species of interest to the park (Table 1). 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, if they were present, we noted plant

species that are considered rare or vulnerable to loss in North Dakota, and which may potentially occur in FOUS (Table 2).

Table 1. Exotic species surveyed for at Fort Union Trading Post National Historic Site 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. xbohemicum*	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 Fort Union Trading Post National Historic Site.

Scientific Name	Common Name
Oxytropis sericea	white locoweed

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; http://plants.usda.gov/). 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 against the original data sheets to minimize transcription errors. Next, 10% of the records were reviewed a second time to confirm accuracy. After all data were entered and verified, automated queries were developed to check for

errors in the data (e.g., typos, duplicated species). 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). Pielou'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.

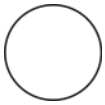
Disturbances were recorded in square meters and ranged from 0 (not present) to 2290 m^2 (the whole plot area) for each type of disturbance. We report the sum of all individual disturbances, so the value can be greater than 2290 m^2. For example, if the whole plot was burned in a prescribed fire, and half of the plot was also impacted by gophers, disturbance would be 3435 m^2 (2290 m^2 + 1145 m^2).

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, park condition can be evaluated in a consistent way 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. The current park condition was compared to a reference value, and its status was scored as one of the following: 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

Fort Union Trading Post NHS experienced below normal precipitation in 2014 (http://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00094014/detail; Figure 3). When NGPN visited the park in late July, precipitation was about three inches below normal.

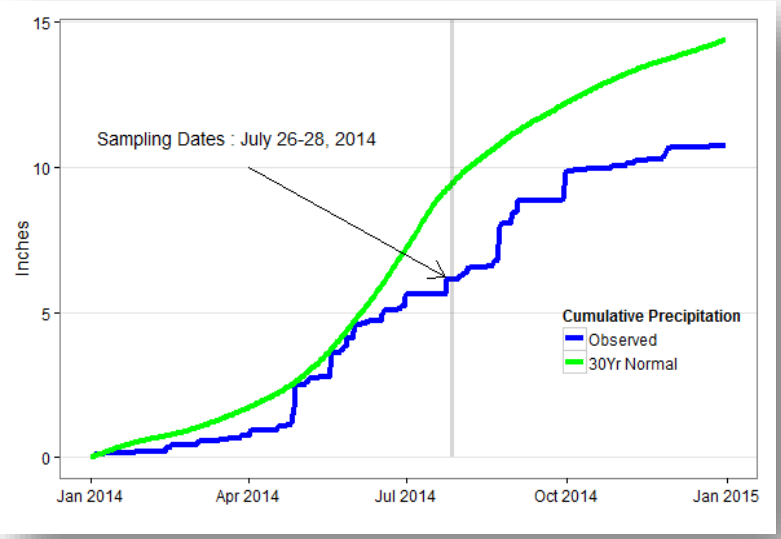


Figure 3. Observed and 30-year (1981-2010) normal precipitation near Fort Union Trading Post National Historic Site. Timing of NGPN visit is shown by vertical gray bar.

Average canopy cover was 160% (Table 4) in plots sampled in 2014, which was slightly higher than previous years (e.g. Ashton and Prowatzke 2014). (Values above 100% indicate the presence of "overlapping canopies", or more than one species above any given point on the ground.) There was a large amount of litter on the ground, with ground cover at the sites averaging 81% plant litter.

We found 103 plant species at FOUS in 2014 (Appendix B). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at FOUS. Forbs and shrubs were present, but in much lower abundance (Figure 4). We found 20 exotic species at the park.

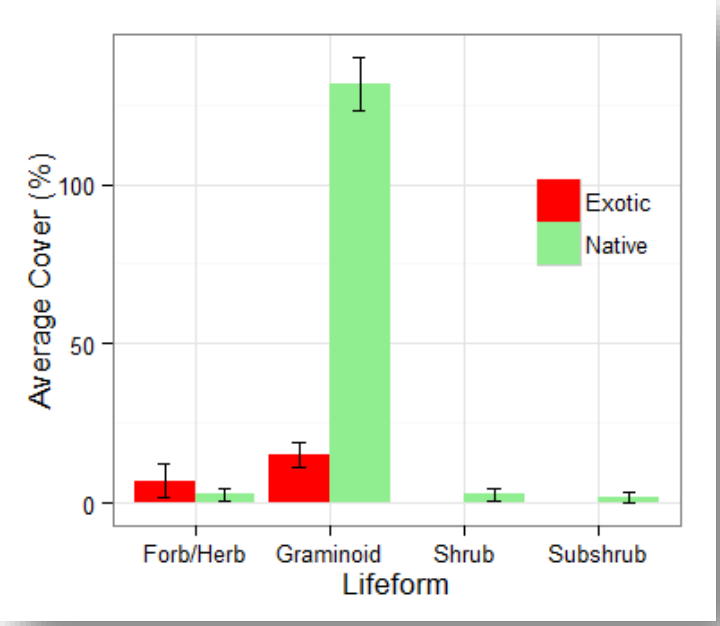


Figure 4. Average cover by lifeform and nativity in six plant community monitoring plots in Fort Union Trading Post National Historic Site in 2014. Native (green) and exotic (red) graminoids were the most abundant lifeform across the plots. Bars represent means ± standard errors.

Native graminoids accounted for most of the plant cover, and several of these species were among the most common species found at the park (Figure 5). The native western wheatgrass (*Pascopyrum smithii*) and green needlegrass (*Nassella viridula*) and the exotic crested wheatgrass (*Agropyron cristatum*) were the only species recorded at all six sites. We did not find any rare or exotic target exotic species (Table 1).

Table 4. Natural resource condition summary table for upland plant communities in Fort Union Trading Post National Historic Site (FOUS).

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	160 ±12.9%	TBD (1)		FOUS protects and manages small remnants of native mixed-grass prairie. The park is characterized by lower native species richness around the fort, which falls well below the natural range of variability for northern mixed-grass prairie. Plots in the Bodmer Overlook Unit contain more native species and are generally in good condition. The condition assessment for canopy cover and evenness is based on professional judgment, but as we collect more data and understand the natural range of variability our confidence in these assessments will increase.
	Native species richness (based on average of 10 1m^2 quadrats per plot)	5.9 ± 1.5 species	8-18 species (2)		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.77 ± 0.04	TBD (1)		
Exotic Plant Early Detection and Management	Relative cover of exotic species	13.3 ± 2.3%	≤ 10 % cover (3)		FOUS has determined that the desired condition for vegetation in upland areas comprises ≤ 10% total cover of exotic species. On average, the plots visited in 2014 had exotic cover slightly above this value. Five of six sites were above the desired threshold.

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. 3. Symstad, A. J. 2011. A vegetation management plan for Fort Union Trading Post National Historic Site: Final report for interagency agreement number F154910005 (April 2012). Natural Resource Technical Report NPS/FOUS/NRR—2012/502. National Park Service, Fort Collins, Colorado.

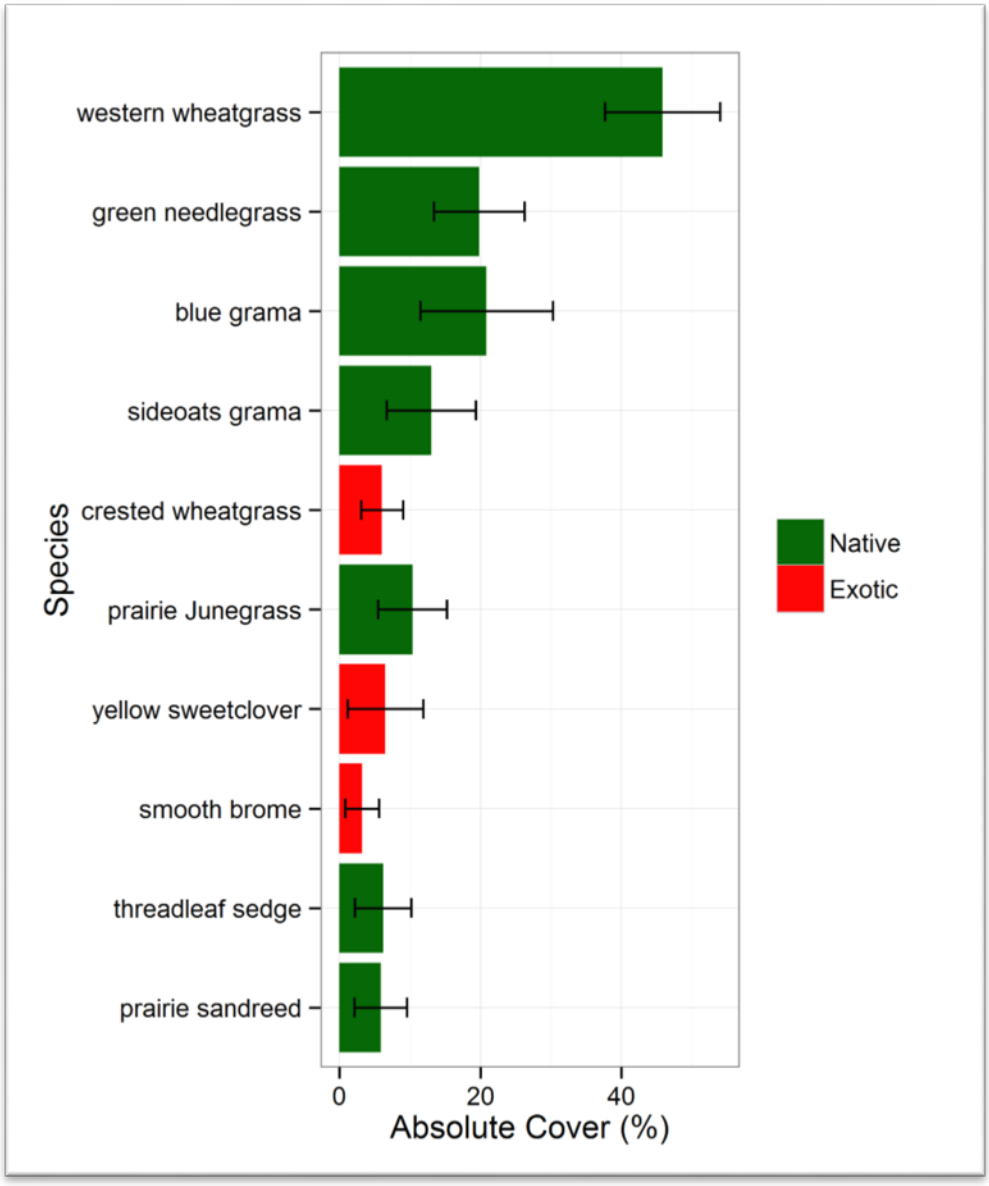


Figure 5. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded at Fort Union Trading Post National Historic Site in 2014. Bars represent means ± standard errors.

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 was about one exotic species within the 1 m^2 quadrat (Table 5). From the point-intercept data, we found average plot diversity, H', to be 1.8 ± 0.28. Evenness, J', averaged 0.77 ± 0.04 across the plots (Table 4). When including only native species, average diversity and evenness were 1.5 ± 0.30 and 0.80 ± 0.04, respectively.

Table 5. Average plant species richness in six plots at Fort Union Trading Post National Historic Site in 2014. Values represent means ± standard errors, n=6.

	Point-intercept	1 m^2 quadrats	10 m^2 quadrats
Species richness	11 ± 2.8	7 ± 1.3	11 ± 2.1
Native species richness	9 ± 2.9	6 ± 1.5	9 ± 2.5
Exotic species richness	3 ± 0.5	1 ± 0.4	2 ± 0.6
Graminoid species richness	8 ± 1.3	4 ± 0.4	6 ± 0.6
Forb species richness	3 ± 1.2	2 ± 0.7	5 ± 1.1

There was a great deal of variation in species richness across sites, and the plots found in the Bodmer Overlook Unit had more native species than the areas surrounding the fort (Table 6). Species richness in the mixed-grass prairie is determined by numerous factors including fire regime, large ungulate grazing, 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 in a moderately grazed site in Montana ranged between 8 and 18 species per square meter (10-90th percentile range) between 1933-1945 (Symstad and Jonas 2014). Species richness in the upland areas surrounding the fort falls below the natural range, but the plots in the Bodmer Overlook Unit fall within it (Table 6). The Bodmer Overlook should be managed to maintain this native prairie.

Figure 6. Photo of plot PCM-131, located near the Bodmer Overlook and typified by high native plant diversity.

The average relative cover of exotic species at sites in FOUS was moderate (13.3 ± 2.3%; Table 4). In five of the six sites, exotic cover was above the management target of 10% cover (Symstad 2011; Table 6). Smooth brome (*Bromus inermis*) and crested wheatgrass were the most troublesome exotic species in the area surrounding the fort, while crested wheatgrass and Kentucky bluegrass (*Poa pratensis*) were the most abundant exotic species in the Bodmer area. Due to the propensity of smooth brome (Nernberg and Dale 1997) and crested wheatgrass (Bakker and Wilson 2001) to form monocultures that exclude native species, the park should be proactive in treating these species while they are still at manageable levels in order to preserve native species diversity.

Table 6. Characteristics of the plant community at six plots in Fort Union Trading Post National Historic Site in 2014, including native species richness, exotic plant cover, and area of disturbance.

Management Unit	Plot	Native species richness in 1 m^2	Exotic cover (%)	Number of native forbs in 1 m^2	Smooth brome cover (%)	Disturbance within site (m^2)
Fort Area	PCM-005	5	10	1	1	5
	PCM-006	3	12	0	9	2290
	PCM-008	2	7	1	0	2290
	PCM-011	4	24	0	1	2290
	Site Average	*3.5 ± 0.5*	*13.3 ± 3.6*	*0.5 ± 0.2*	*2.9 ± 2.0*	-
Bodmer Overlook	PCM-131	11	14	5	0	5
	PCM-132	10	12	4	0	5
	Site Average	*10.6 ± 0.3*	*13.3 ± 0.9*	*4.3 ± 0.5*	*0*	-

Disturbance from grazing, 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 disturbances were from small mammal burrowing and prescribed fire. Native forb cover was very low at the sites around the historic fort, averaging 0.5 species per meter squared (Table 6). Many native forbs were seeded during the restoration effort in 2006 and 2010 (Symstad 2011); however, these species are not thriving in this area. Park management regularly mows this area, which helps meet the goal of maintaining a low vegetation stature, similar to that which would have been evident around FOUS during the most active period of the fort (Symstad 2011). However, if native plant diversity is a priority, the park may need to reseed and adjust the mowing regime to allow native forbs to establish.

Summary

FOUS protects a remnant of native northern mixed-grass prairie in the Bodmer Overlook Unit and more disturbed areas in the upland fields surrounding the fort. Most plant community plots measured in 2014 in the park have a moderate cover of exotic species. To retain ecological integrity, it is important to continue efforts to reduce the cover of invasive plants, particularly crested wheatgrass and smooth brome. Allowing for natural disturbances such as fire and for active management such as mowing may be critical to maintaining plant diversity at FOUS, but it should be balanced with the need to protect intact native communities and prevent further invasions of exotic species. Continued monitoring efforts will be critical to track changes in the condition of the vegetation communities at FOUS.

Literature Cited

Ashton, I. W and M. Prowatzke. 2014. Plant community composition and structure monitoring for Fort Union Trading Post National Historic Site: 2013 annual report. Natural Resource Data Series NPS/NGPN/NRDS—2014/610. National Park Service, Fort Collins, CO.

Ashton, I., M. Prowatzke, M. Bynum, T. Shepherd, S. K. Wilson, and K. Paintner-Green. 2012. Fort Union Trading Post National Historic Site plant community composition and structure monitoring: 2011 annual report. Natural Resource Technical Report NPS/NGPN/NRTR—2012/528. National Park Service, Fort Collins, CO.

Bakker, J. and S. Wilson. 2001. Competitive abilities of introduced and native grasses. Plant Ecology 157:119-127.

National Park Service. 2012. Revisiting Leopold: Resource stewardship in the National Parks: A report of the National Park System Advisory Board Science Committee. http://www.nps.gov/calltoaction/PDF/LeopoldReport_2012.pdf.

Nernberg, D. and M. R. T. Dale. 1997. Competition of five native prairie grasses with *Bromus inermis* under three moisture regimes. Canadian Journal of Botany 75:2140-2145.

Samson, F. B., and F. L. Knopf. 1994. Prairie conservation in North America. BioScience 44:418-421.

Skinner, Q. D. 2010. Field guide to Wyoming grasses. Education Resources Publishing, Cumming, GA.

Stevens, D. L. and A. R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. Environmetrics 14:593-610.

Stevens, D. L. and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal Of The American Statistical Association 99:262-278.

Symstad, A. J. 2011. A vegetation management plan for Fort Union Trading Post National Historic Site: Final report for interagency agreement number F154910005 (April 2012). Natural Resource Technical Report NPS/FOUS/NRR—2012/502. National Park Service, Fort Collins, CO.

Symstad, A. J., R.A. Gitzen, C. L. Wienk, M. R. Bynum, D. J. Swanson, A. D. Thorstenson, and K. J. Paintner. 2012a. Plant community composition and structure monitoring protocol for the Northern Great Plains I&M Network-Standard Operating Procedures: version 1.01. Natural Resource Report NPS/NGPN/ NRR-2012/489.1.

Symstad, A. J., R.A. Gitzen, C. L. Wienk, M. R. Bynum, D. J. Swanson, A. D. Thorstenson, and K. J. Paintner. 2012b. Plant community composition and structure monitoring protocol for the Northern Great Plains I&M Network: version 1.01. Natural Resource Report NPS/NGPN/NRR-2012/489.

Symstad, A. J. and J. L. Jonas. 2011. Incorporating biodiversity into rangeland health: plant species richness and diversity in Great Plains grasslands. Rangeland Ecology & Management 64:555-572.

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.

USDA-NRCS. 2012. The PLANTS Database (http://plants.usda.gov, 24 January 2012). National Plant Data Team, Greensboro, NC 27401-4901 USA.

Appendix A: Field journal for plant community monitoring in FOUS for the 2014 season

Plant community composition monitoring in Fort Union National Historic Site was completed using a crew of three people working three 10-hour days, plus 11¼ hours of overtime. Total hours spent were 101¼ .

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Visited/Notes
July 26, 2014	Saturday	1.25	Marquis Inn and Suites, Williston, ND	PCM-005 PCM-006 PCM-131
July 27, 2014	Sunday	1.25	Marquis Inn and Suites, Williston, ND	PCM-008 PCM-132 PCM-011 (installed plot only)
July 28, 2014	Monday	8	N/A	PCM-011 Travel to Rapid City, SD

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

Family	Code	*Scientific Name*	Common Name	Exotic
Amaranthaceae	AMAL	*Amaranthus albus*	prostrate pigweed	
	AMRE	*Amaranthus retroflexus*	redroot amaranth	
Asclepiadaceae	ASOV	*Asclepias ovalifolia*	oval-leaf milkweed	
	ASSP	*Asclepias speciosa*	showy milkweed	
Asteraceae	ANMI3	*Antennaria microphylla*	littleleaf pussytoes	
	ARDR4	*Artemisia dracunculus*	tarragon	
	ARFR4	*Artemisia frigida*	prairie sagewort	
	ARLU	*Artemisia ludoviciana*	white sagebrush	
	BREU	*Brickellia eupatorioides*	false boneset	
	CIAR4	*Cirsium arvense*	Canada thistle	*
	CIUN	*Cirsium undulatum*	wavyleaf thistle	
	COCA5	*Conyza canadensis*	Canadian horseweed	
	ECAN2	*Echinacea angustifolia*	blacksamson echinacea	
	GAAR	*Gaillardia aristata*	common gaillardia	
	GRSQ	*Grindelia squarrosa*	curlycup gumweed	
	GUSA2	*Gutierrezia sarothrae*	broom snakeweed	
	HEVI4	*Heterotheca villosa*	hairy false goldenaster	
	HYFI	*Hymenopappus filifolius*	fineleaf hymenopappus	
	LIPU	*Liatris punctata*	dotted blazing star	
	LYJU	*Lygodesmia juncea*	rush skeletonplant	
	MUOB99	*Mulgedium oblongifolium*	blue lettuce	
	RACO3	*Ratibida columnifera*	upright prairie coneflower	
	SOMI2	*Solidago missouriensis*	Missouri goldenrod	
	SOMO	*Solidago mollis*	velvety goldenrod	
	SYER	*Symphyotrichum ericoides*	white heath aster	
	SYMPH4	*Symphyotrichum*	aster	
	SYOB	*Symphyotrichum oblongifolium*	aromatic aster	
	TAOF	*Taraxacum officinale*	common dandelion	*
	TEAC	*Tetraneuris acaulis*	stemless four-nerve daisy	
	TRDU	*Tragopogon dubius*	yellow salsify	*
Boraginaceae	LIIN2	*Lithospermum incisum*	narrowleaf stoneseed	
Brassicaceae	ALDE	*Alyssum desertorum*	desert madwort	*
	CAMI2	*Camelina microcarpa*	littlepod false flax	*
	DESO2	*Descurainia sophia*	herb sophia	*
	DRRE2	*Draba reptans*	Carolina draba	
	ERCA14	*Erysimum capitatum*	sanddune wallflower	
	LEDE	*Lepidium densiflorum*	common pepperweed	
	PHLU99	*Physaria ludoviciana*	foothill bladderpod	
	SIAL2	*Sisymbrium altissimum*	tall tumblemustard	*
	THAR5	*Thlaspi arvense*	field pennycress	*
Cactaceae	OPFR	*Opuntia fragilis*	brittle pricklypear	
Caprifoliaceae	SYOC	*Symphoricarpos occidentalis*	western snowberry	
Chenopodiaceae	CHENO	*Chenopodium*	goosefoot	*
	KOSC	*Kochia scoparia*	burningbush, kochia	*
	KRLA2	*Krascheninnikovia lanata*	winterfat	
Cyperaceae	CADU6	*Carex duriuscula*	needleleaf sedge	
	CAFI	*Carex filifolia*	threadleaf sedge	

Cyperaceae	CAIN9	*Carex inops*	long-stolon sedge	
Euphorbiaceae	EUES	*Euphorbia esula*	leafy spurge	*
	EUGL3	*Euphorbia glyptosperma*	ribseed sandmat	
Fabaceae	ASFL2	*Astragalus flexuosus*	flexile milkvetch	
	ASGI5	*Astragalus gilviflorus*	plains milkvetch	
	ASPE5	*Astragalus pectinatus*	narrowleaf milkvetch	
	ASTRA	*Astragalus* sp.	milkvetch	
	DACA7	*Dalea candida*	white prairie clover	
	DAPU5	*Dalea purpurea*	purple prairie clover	
	LAPO2	*Lathyrus polymorphus*	manystem pea	
	MEOF	*Melilotus officinalis*	yellow sweetclover	*
	MESA	*Medicago sativa*	alfalfa	*
	PEES	*Pediomelum esculentum*	large Indian breadroot	
	VIAM	*Vicia americana*	American vetch	
Lamiaceae	HEHI	*Hedeoma hispida*	rough false pennyroyal	
Liliaceae	ALTE	*Allium textile*	textile onion	
Linaceae	LILE3	*Linum lewisii*	Lewis flax	
	LIRI	*Linum rigidum*	stiffstem flax	
Malvaceae	SPCO	*Sphaeralcea coccinea*	scarlet globemallow	
Onagraceae	OESE3	*Oenothera serrulata*	yellow sundrops	
	OESU99	*Oenothera suffrutescens*	scarlet beeblossom	
Poaceae	AGCR	*Agropyron cristatum*	crested wheatgrass	*
	AGSC5	*Agrostis scabra*	rough bentgrass	
	ANGE	*Andropogon gerardii*	big bluestem	
	ARPU9	*Aristida purpurea*	purple threeawn	
	BOCU	*Bouteloua curtipendula*	sideoats grama	
	BOGR2	*Bouteloua gracilis*	blue grama	
	BRIN2	*Bromus inermis*	smooth brome	*
	BRJA	*Bromus japonicus*	Japanese brome	*
	CALO	*Calamovilfa longifolia*	prairie sandreed	
	ELTR7	*Elymus trachycaulus*	slender wheatgrass	
	HECO26	*Hesperostipa comata*	needle and thread	
	HESP11	*Hesperostipa spartea*	porcupinegrass	
	KOMA	*Koeleria macrantha*	prairie Junegrass	
	MUCU3	*Muhlenbergia cuspidata*	plains muhly	
	NAVI4	*Nassella viridula*	green needlegrass	
	PACA6	*Panicum capillare*	witchgrass	
	PASM	*Pascopyrum smithii*	western wheatgrass	
	POPR	*Poa pratensis*	Kentucky bluegrass	*
	SCSC	*Schizachyrium scoparium*	little bluestem	
	SEVI4	*Setaria viridis*	green bristlegrass	*
Polemoniaceae	PHAL3	*Phlox alyssifolia*	alyssumleaf phlox	
	PHHO	*Phlox hoodii*	spiny phlox	
Polygalaceae	POAL4	*Polygala alba*	white milkwort	
Polygonaceae	ERFL4	*Eriogonum flavum*	alpine golden buckwheat	
	ERPA9	*Eriogonum pauciflorum*	fewflower buckwheat	
	FACO	*Fallopia convolvulus*	black bindweed	*
Ranunculaceae	ANCY	*Anemone cylindrica*	candle anemone	
	ANPA19	*Anemone patens*	eastern pasqueflower	
Rosaceae	POPE8	*Potentilla pensylvanica*	Pennsylvania cinquefoil	

Rosaceae	ROAC	*Rosa acicularis*	prickly rose	
	ROAR3	*Rosa arkansana*	prairie rose	
Scrophulariaceae	ORLU2	*Orthocarpus luteus*	yellow owl's-clover	
	PEGR7	*Penstemon grandiflorus*	large beardtongue	
Unknown Family	UNKFORB	Unknown forb	unknown forb	*
Verbenaceae	VEST	*Verbena stricta*	hoary verbena	

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.

NPS 436/128112, March 2015

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