



Plant Community Composition and Structure Monitoring for Fort Laramie National Historic Site

2012 Annual Report

Natural Resource Technical Report NPS/NGPN/NRTR—2012/648



ON THE COVER

A photograph of the B transect at a plant community site in Fort Laramie National Historic Site, 2012.
Photograph by: NGPN

Plant Community Composition and Structure Monitoring for Fort Laramie National Historic Site

2012 Annual Report

Natural Resource Technical Report NPS/NGPN/NRTR—2012/648

Isabel W. Ashton
Michael Prowatzke
Stephen K. Wilson

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

December 2012

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

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

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

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

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

Please cite this publication as:

Ashton, I. W., M. Prowatzke, and S. K. Wilson. 2012. Plant community composition and structure monitoring for Fort Laramie National Historic Site: 2012 annual report. Natural Resource Technical Report NPS/NGPN/NRTR—2012/648. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	iv
Tables.....	v
Executive Summary.....	vi
Acknowledgments.....	vii
Introduction.....	1
Methods.....	3
Sample design.....	3
Plot layout and sampling	3
Results and Discussion	8
Literature Cited	16
Appendix A: Field journal for plant community monitoring in FOLA for the 2012 season.....	17
Appendix B: List of plant species found in 2012 at FOLA	18

Figures

	Page
Figure 1. Map of Fort Laramie National Historic Site (FOLA) and plant community monitoring (PCM) plots.	2
Figure 2. Long-term monitoring plot used for sampling vegetation in Fort Laramie National Historic Site.....	4
Figure 3. The A vegetation transect at plot PCM_065 in Fort Laramie National Historic Site in 2011 (left panel) and 2012 (right panel).	8
Figure 4. Average cover by life forms in 6 plant community monitoring plots in Fort Laramie National Historic Site in 2012.	8
Figure 5. The average absolute cover of the 10 most common native (blue) and exotic (red) plants recorded at Fort Laramie National Historic Site in 2012.....	9
Figure 6. Two riparian plots at Fort Laramie National Historic Site monitored in 2012.....	13
Figure 7. The relationship between average native species richness and the relative cover of exotic species for Wyo-braska park units in 2012.....	14

Tables

	Page
Table 1. Exotic species of management concern at Fort Laramie National Historic Site and rare species that were surveyed for during the 2012 field season.....	5
Table 2. Key to the symbols used in the Natural Resource Condition Table.	7
Table 3. Natural resource condition summary table for upland plant communities in Fort Laramie National Historic Site (FOLA).....	10
Table 4. Average plant species richness at 6 plots at Fort Laramie National Historic Site in 2012..	11
Table 5. Characteristics of the plant community at 6 plots in at Fort Laramie National Historic Site in 2012 including average native species richness, exotic plant cover, cover of annual bromes, and area of disturbance.....	12

Executive Summary

Fort Laramie National Historic Site (FOLA) plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the region. The Northern Great Plains Inventory & Monitoring Network (NGPN) surveyed 6 long-term monitoring plots in FOLA in 2012 as part of an effort to better understand the condition of plant communities in the park. We measured plant diversity and cover, estimated tree and shrub density, looked for the presence of exotic species that are of concern to park management, and evaluated the amount of human and natural disturbance at all plots. This effort was the second year in a multiple-year venture to document the current status and long-term trends in plant communities in FOLA. At the end of five years, there will be an in-depth report describing the status of the plant community. In this report, we provide a simple summary of our results from sampling in 2012.

Plant cover in 2012 was extremely low due to severe drought. In this dry condition, we found the park to be characterized by low native species richness, but average richness is within a natural range of variability. There are areas of the park, particularly the northeast pasture, that fall below this range and are heavily invaded by exotic species. Some areas of the riparian forest in FOLA are healthy and contain numerous trees of all size classes, while others are more typical of old cottonwood forests where only large old trees are present and there is no significant regeneration. Exotic species such as Russian olive and tamarisk are in low abundance in the riparian corridor, but active management will be needed to maintain this condition.

Acknowledgments

We thank all the authors of the NGPN Plant Community Monitoring Protocol, particularly Amy Symstad, for outstanding guidance on data collection and reporting. We greatly appreciate the staff at FOLA, particularly Mitzi Frank, Timothy Townsend, and Sarah Bryant for providing logistical support and safety checks. The 2012 NGPN vegetation field crew of Michael Prowatzke, Timothy Pine, Lauren Baur, Daina Jackson, Ryan Manuel, and Gretchen Addington collected all the data included in this report. We thank Stephen Wilson for invaluable support and instruction on managing data in the FFI database and for assistance with the GIS data.

Introduction

During the last century, much of the prairie within the Northern Great Plains has been plowed for cropland, converted to livestock pasture, or otherwise developed, making it one of the most threatened ecosystems in the United States. The National Park Service (NPS) plays an important role in preserving and restoring some of the last pieces of intact prairies within its boundaries. The stewardship goal of the NPS is to “preserve ecological integrity and cultural and historical authenticity” (NPS 2012); however, resource managers struggle with the grim reality that there have been fundamental changes in the disturbance regimes, such as climate, fire, and 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.

Fort Laramie National Historic Site (FOLA), established in 1938 to protect and preserve the well-known military post, covers 833 acres within the northern mixed grass prairie region (Lauenroth et al. 1999). The park is a mosaic of disturbed old-fields, riparian forests, and native prairie and is host to 376 plant species (Heidel 2004). The Northern Great Plains Inventory & Monitoring Program (NGPN) began vegetation monitoring at FOLA in 2011 (Ashton et al. 2012). The long-term objectives of the NGPN plant community monitoring effort (Symstad et al. 2012b) in FOLA 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. Determine status (at 5-yr intervals) and long-term trends of tree density by species, height class, and diameter class in lowland areas near targeted perennial streams.
3. 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 FOLA in 2012, our second year of sampling. We visited 6 plots in a rotating panel design and it will take 3 more years to visit every plot in the park (Figure 1). 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.

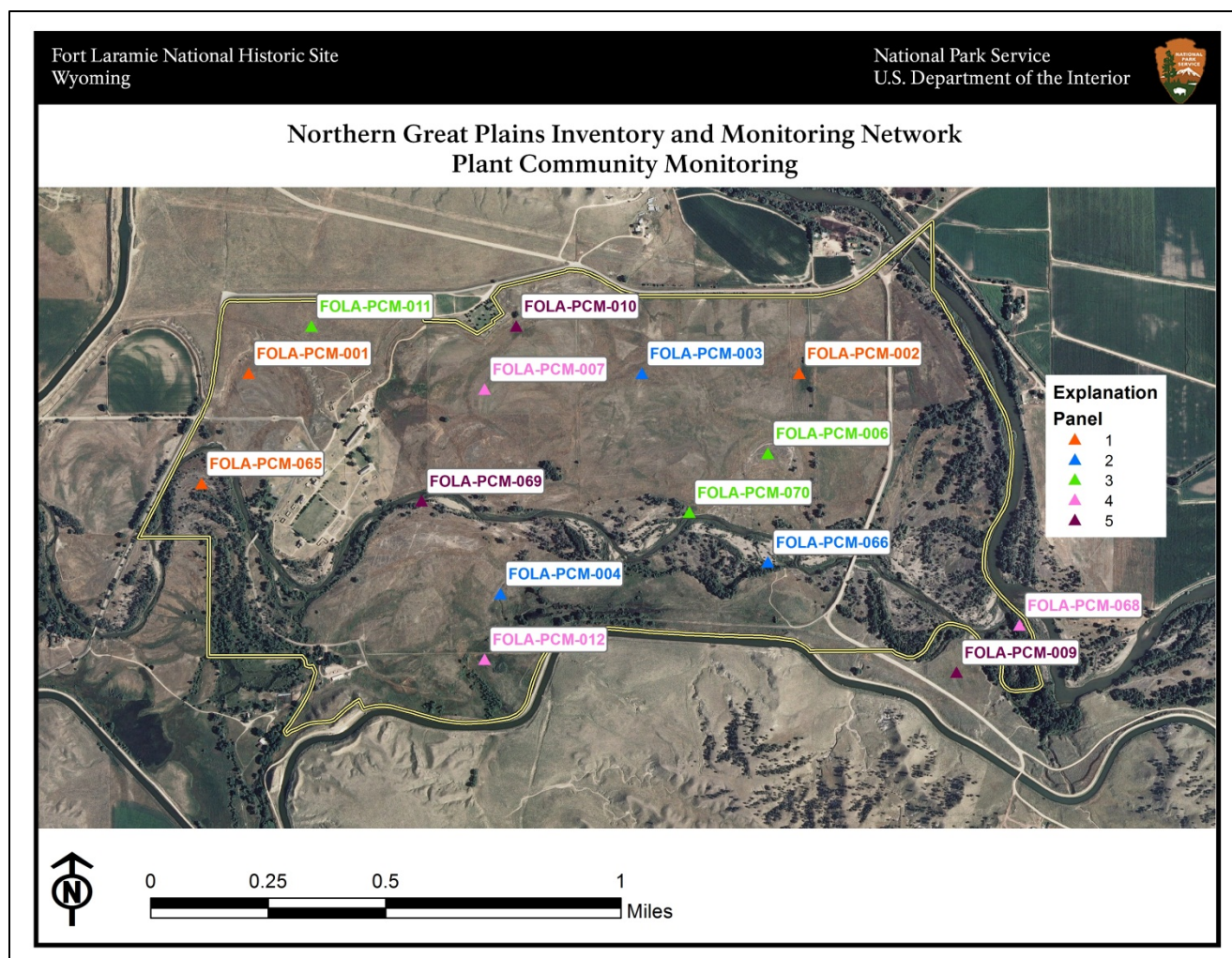


Figure 1. Map of Fort Laramie National Historic Site (FOLA) and plant community monitoring (PCM) plots. Plots in Panel 1 (orange) and Panel 2 (blue) were visited in 2012.

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/plants.cfm>.

Sample design

We implemented a survey to monitor plant community structure and composition in FOLA 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 FOLA (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 (Figure 1) during the second week of June. In 2012, we visited sites in panel 1 and panel 2 (Figure 2) during the first week of June.

When implemented successfully, probability-based survey designs allow for unbiased inference from sampled sites to un-sampled elements of the resource of interest (Hansen et al. 1983), and with repeat visits it allows for discerning trends in that resource (Larsen et al. 1995). In other words, after 5 years, we can use data from our randomly selected sites to estimate the ecological integrity of vegetation communities for the whole park.

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 m², 0.1 m², 1 m², and 10 m²) located systematically along each transect (Figure 2). In 2012, sampling at FOLA took a 4-person crew approximately 129 hours with travel time (see Appendix A for a detail of activities each day).

Plant species were identified in the field to species level and not to lower taxonomic groupings (e.g., subspecies or variety). This was a change from the data collected in 2011 by NGPN where plants were identified to the lowest taxonomic level possible. The change was made in coordination with the Northern Great Plains Fire Ecology Program because it better reflects the botanical skills of the crew, allows plants to be identified without fruits or flowers, and simplifies data management and analysis. When we were unable to identify a plant, the plant was assigned a unique identifier and collected or photographed. Most of these unknowns were subsequently identified in the office; however, in some cases identification was impossible. In these cases, the species was classified by growth form and, where possible, lifecycle (e.g., annual graminoid).

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 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-



considered rare or vulnerable to loss in Wyoming, and may occur in FOLA. The FOLA target species list for 2012 can be found in Table 1.

Table 1. Exotic species of management concern at Fort Laramie National Historic Site and rare species that were surveyed for during the 2012 field season.

Exotic Species		Rare species	
Scientific Name	Common Name	Scientific Name	Common Name
<i>Arctium minus</i>	common burdock	<i>Agalinis tenuifolia</i>	slender flase foxglove
<i>Carduus nutans</i>	musk thistle	<i>Cyperus acuminatus</i>	short point flat sedge
<i>Centaurea stoebe</i>	spotted knapweed	<i>Cyperus bipartitus</i>	shining flatsedge
<i>Cirsium arvense</i>	Canada thistle	<i>Dalea aurea</i>	golden prairie clover
<i>Cirsium vulgare</i>	bull thistle	<i>Dalea cylindriceps</i>	Andean prairie clover
<i>Conium maculatum</i>	poison hemlock	<i>Euphorbia hexagona</i>	six-angle spurge
<i>Cynoglossum officinale</i>	houndstongue	<i>Eustoma exaltatum</i>	showy prairie gentian
<i>Elaeagnus angustifolia</i>	Russian olive	<i>Gaura neomexicana</i>	Colorado butterfly plant
<i>Hyoscyamus niger</i>	black henbane	<i>Lipocarpa drummondii</i>	dwarf bulrush
<i>Linaria dalmatica</i>	Dalmatian toadflax	<i>Lithospermum multiflorum</i>	many flowered puccoon
<i>Linaria vulgaris</i>	yellow toadflax	<i>Lobelia siphilitica</i>	great blue lobelia
<i>Onopordum acanthium</i>	Scotch thistle	<i>Oenothera flava</i>	yellow evening primrose
<i>Rhaponticum repens</i>	Russian knapweed	<i>Paronychia jamesii</i>	James's nailwort
<i>Salsola kali</i>	Russian thistle	<i>Shinnersoseris rostrata</i>	beaked skeletonweed
<i>Sonchus arvensis</i>	perennial sowthistle	<i>Sorghastrum nutans</i>	Indiangrass
<i>Tamarix spp.</i>	tamarisk	<i>Spiranthes diluvialis</i>	Ute lady's tresses
<i>Tanacetum vulgare</i>	common tansy		
<i>Verbascum thapsus</i>	common mullein		

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 datasheet 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). Pielou's Index of Evenness, J' , measures how even abundances are across taxa. It ranges between 0 and 1, where lower numbers indicate that a community is not even or that just a few species make up the majority of the total cover.

Reporting on Natural Resource Condition

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

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

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

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

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

Results and Discussion

The vegetation at FOLA suffered from a very dry winter and spring and when the NGPN field crew visited the park in June, there was not much green vegetation (Figure 3). Average canopy cover was 44% (Table 3) in 2012. The productive summer in 2011 and a dry winter and spring in 2012 contributed to a large amount of standing litter on the ground (ground cover at sites averaged 78% plant litter).



Figure 3. The A vegetation transect at plot PCM_065 in Fort Laramie National Historic Site in 2011 (left panel) and 2012 (right panel). Both photographs were taken in late spring and show the dramatic reduction in moisture available in 2012.

Despite the dry conditions, we found 103 plant species in 2012 at FOLA (Appendix B). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at FOLA, but forbs and trees were also abundant (Figure 4). The most common trees were eastern cottonwood (*Populus deltoides*), crack willow (*Salix fragilis*), and narrowleaf willow (*S. exigua*).

There was a great deal of variation in species composition across the 6 sites. Cheatgrass (*Bromus tectorum*), sand dropseed (*Sporobolus cryptandrus*), and western wheatgrass (*Pascopyrum smithii*) were found at all 6 sites. The most common species found from the point-intercept were graminoids, and most were native species (Figure 5).

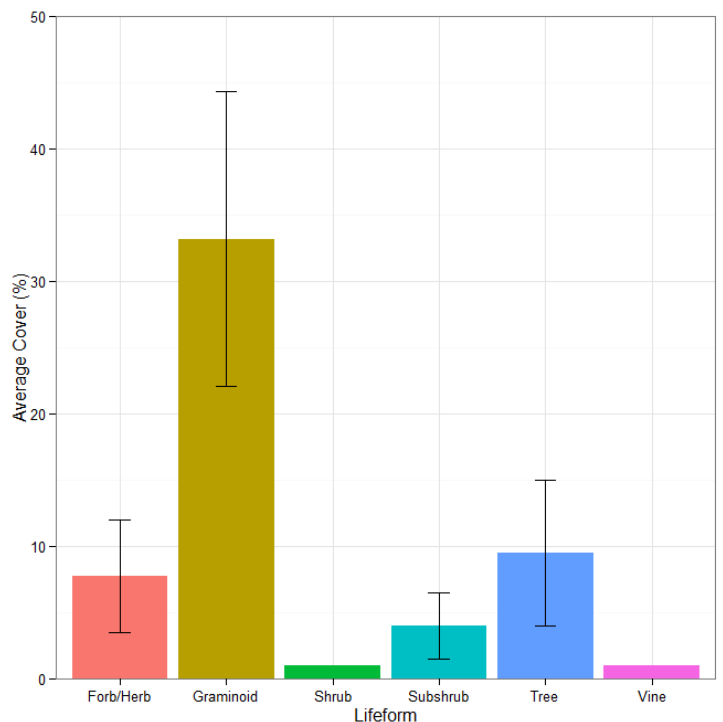


Figure 4. Average cover by life forms in 6 plant community monitoring plots in Fort Laramie National Historic Site in 2012. Bars represent means $\pm$ standard errors. Graminoids were the most abundant life-form across all the plots at FOLA.

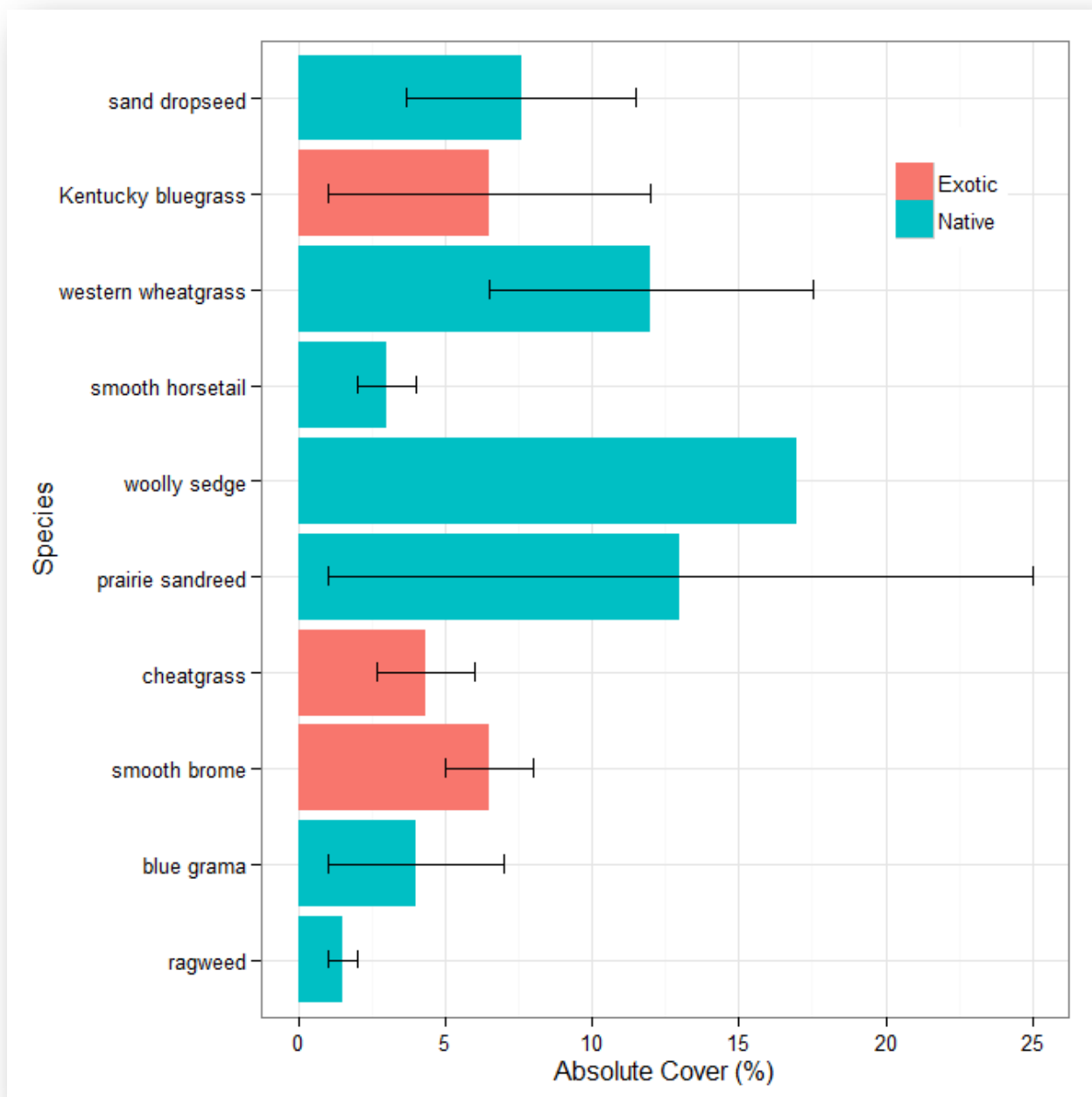
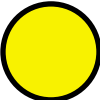
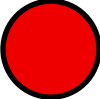
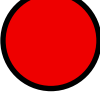
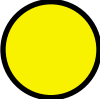


Figure 5. The average absolute cover of the 10 most common native (blue) and exotic (red) plants recorded at Fort Laramie National Historic Site in 2012. Bars represent means $\pm$ standard errors. The common native species, like western wheatgrass, accounted for greater cover than exotic species. Woolly sedge was found at only one site, but it was abundant there.

Table 3. Natural resource condition summary table for upland plant communities in Fort Laramie National Historic Site (FOLA).

Indicator of Condition	Specific Measures	2012 Value (mean $\pm$ SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Absolute herb-layer canopy cover	44 $\pm$ 13.3 %	TBD		FOLA plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie and riparian forests in the region. The park is characterized by low native species richness, but average richness is within a natural range of variability. There are areas of the park, particularly the northeast pasture, that fall below this range and are heavily invaded by exotic species.
	Native species richness (based on average of 10 1m ² quadrats per plot)	3 $\pm$ 0.7 species	3-15 species ⁽¹⁾		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.82 $\pm$ 0.02	TBD		
Exotic Plant Early Detection and Management	Relative cover of exotic species	38 $\pm$ 11 %	< 10 % cover		In general, the sites in FOLA had a high cover of exotic species. Only one site had <10% cover. However, 2012 was a very dry year, and cover of both natives and exotics was low. Annual bromes will start to present a large challenge to FOLA, and more research on effective management strategies in the mixed-grass prairie is greatly needed.
	Annual Brome cover	6 $\pm$ 4 %	< 10 % cover		
Riparian Plant Community Structure and Composition	Cottonwood seedling density	TBD	TBD		Some areas of the riparian forest in FOLA are healthy and contain numerous trees of all size classes, while others are more typical of old cottonwood forests where only large old trees are present and there is no significant regeneration. Exotic species such as Russian olive and tamarisk are in low abundance in the riparian corridor, but active management will be needed to maintain this condition.

References and Data Sources:

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

Species richness varies by the scale that it is examined. Table 4 presents average species richness, taken from the point-intercept method, 1 m² quadrats, and 10 m² quadrats for the 6 plots in 2012. On average, there are about 2 exotic species found in each quadrat along the point-intercept (Table 4). Average forb and graminoid richness were similar in the quadrats, but the point-intercept method found more graminoids (Table 4). From the point-intercept data, we found average plot diversity, H', to be 1.6 ± 0.22 . Evenness, J', averaged 0.82 ± 0.02 across the plots (Table 3). When including only native species, average diversity and evenness were 1.2 ± 0.3 and 0.80 ± 0.05 , respectively.

Table 4. Average plant species richness at 6 plots at Fort Laramie National Historic Site in 2012. Values represent means $\pm$ standard errors, n=6.

	Point-intercept	1 m ² quadrats	10 m ² quadrats
Species richness	8 ± 2.0	5 ± 0.8	8 ± 1.7
Native species richness	6 ± 2.0	3 ± 0.7	6 ± 1.3
Exotic species richness	2 ± 0.4	2 ± 0.1	3 ± 0.4
Graminoid species richness	5 ± 1.0	3 ± 0.4	4 ± 0.6
Forb species richness	2 ± 0.9	2 ± 0.4	4 ± 0.9

While there was some variation across sites, the plots we visited in FOLA tended to have a low diversity of native plants compared to other mixed-grass prairies. Species richness in the mixed-grass prairie is determined by numerous factors including fire regime, large ungulate grazing, prairie dog disturbance, and weather fluctuations (Symstad and Jonas 2011). In FOLA, there is also a long history of human use that has affected current species richness. For instance, the sites PCM_002 and PCM_003 are in the northeastern part of the park, and according to the FOLA vegetation map, these plots lie in a matrix of upland weedy, wheatgrass, and smooth brome communities. They both have a low diversity of native plants compared to the rest of the park (Table 5). While it is difficult to define a reference condition for species richness that can vary so much spatially and temporally, the natural range of variation over long-time periods may be a good starting point (Symstad and Jonas *in press*). Long-term records of species diversity in mixed-grass prairie in 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, FOLA is within the natural range (Table 4, native richness in the 1 m² quadrat and Table 3), but is very low, and 50% of the plots fall below this reference condition of at least 3 native species per meter squared area (Table 5).

The average relative cover of exotic species at sites in FOLA was high ($29 \pm 10\%$; Table 3). However, like species richness, cover of exotic species varied considerably among sites (Table 5). Some sites such as PCM_001 had low cover. The highest cover of exotic species was 71%, found in the riparian site, PCM_065, where there was a mix of crack willow, smooth brome, and Kentucky bluegrass. Russian thistle (2 sites), Scotch thistle (1 site), Russian olive (1 site), and tamarisk (1 site) were found in low abundance of less than 5% cover throughout the park. The lone small tamarisk at site PCM_066 was pulled out by the field crew prior to leaving the site. Two annual brome species, cheatgrass and Japanese brome (*Bromus japonicus*), accounted for only a small portion of the exotic cover in 2012 (Table 4). 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). Reducing the

cover of annual bromes remains a major challenge for the parks in the region and should be prioritized by FOLA. While cover in 2012 was relatively low, this may be largely due to the fact that it was very dry and that overall there was very little plant growth of natives or exotics.

Table 5. Characteristics of the plant community in 6 plots at Fort Laramie National Historic Site in 2012 including average native species richness, exotic plant cover, cover of annual bromes, and area of disturbance.

Plot	Average native species richness 1 m ² plots	Exotic cover (%)	Annual brome cover (%)	Disturbance within site (m ²)
FOLA_PCM_001	3.4	6	0	11
FOLA_PCM_002	2	18	6	2315
FOLA_PCM_003	1.7	38	6	25
FOLA_PCM_004	5.6	14	1	95
FOLA_PCM_065	2.2	71	0	1050
FOLA_PCM_066	4.8	24	0	9
<i>Park Average</i>	3 ± 0.7	29 ± 10	6 ± 3.5	-

Disturbance from grazing, rodents, fire, and humans affects plant community structure and composition in mixed-grass prairie. For this reason, we measured the approximate area affected by natural and human disturbances at each site we visited. In 2012, the most common disturbance was from horse grazing, but there was also evidence of trails, small mammal excavations, and some flooding. The large area of disturbance in PCM_065 and PCM_002 is primarily grazing (Table 5). After 5 years of data collection and when we have more sites to compare, we hope to provide the park with a better understanding of the vegetation in grazed and ungrazed areas.

Trees and seedlings were present in only 2 of the 6 sites we visited in 2012 (PCM_065 and PCM_066). In 2014, NGPN is scheduled to complete a more thorough assessment of riparian forest structure and health in FOLA where we plan to have data from 20 locations. Still, the small data set collected in 2012 may be indicative of the variation seen in the riparian corridor at FOLA. Site PCM_065 is a typical of “living-dead” cottonwood forest where older cottonwoods are present, but there is little to no regeneration of the forest (Figure 6, top panel). Within the 50 x 20 m site, there was 1 large live eastern cottonwood and 1 crack willow, 1 dead cottonwood, no poles and only 6 seedlings. While the longevity of the forest is clearly threatened, this area may play an important role as habitat for nesting shorebirds. The field crew observed numerous killdeer (*Charadrius vociferous*) nests on the gravel bar (Figure 6, top panel). In comparison, PCM_066 was a wetter site and had a high density of seedlings, saplings, poles and trees (Figure 6, bottom panel). Boxelder (*Acer negundo*), narrowleaf cottonwood (*Populus angustifolia*), eastern cottonwood, crack willow, and peachleaf willow (*Salix amygdaloides*) were all found at this site.



Figure 6. Two riparian plots at Fort Laramie National Historic Site monitored in 2012. Plot PCM_065 (top panel) is typical of older cottonwood forests where there is little regeneration. PCM_66 (bottom panel) is a healthy riparian forest site with many seedlings, saplings, poles, and trees.

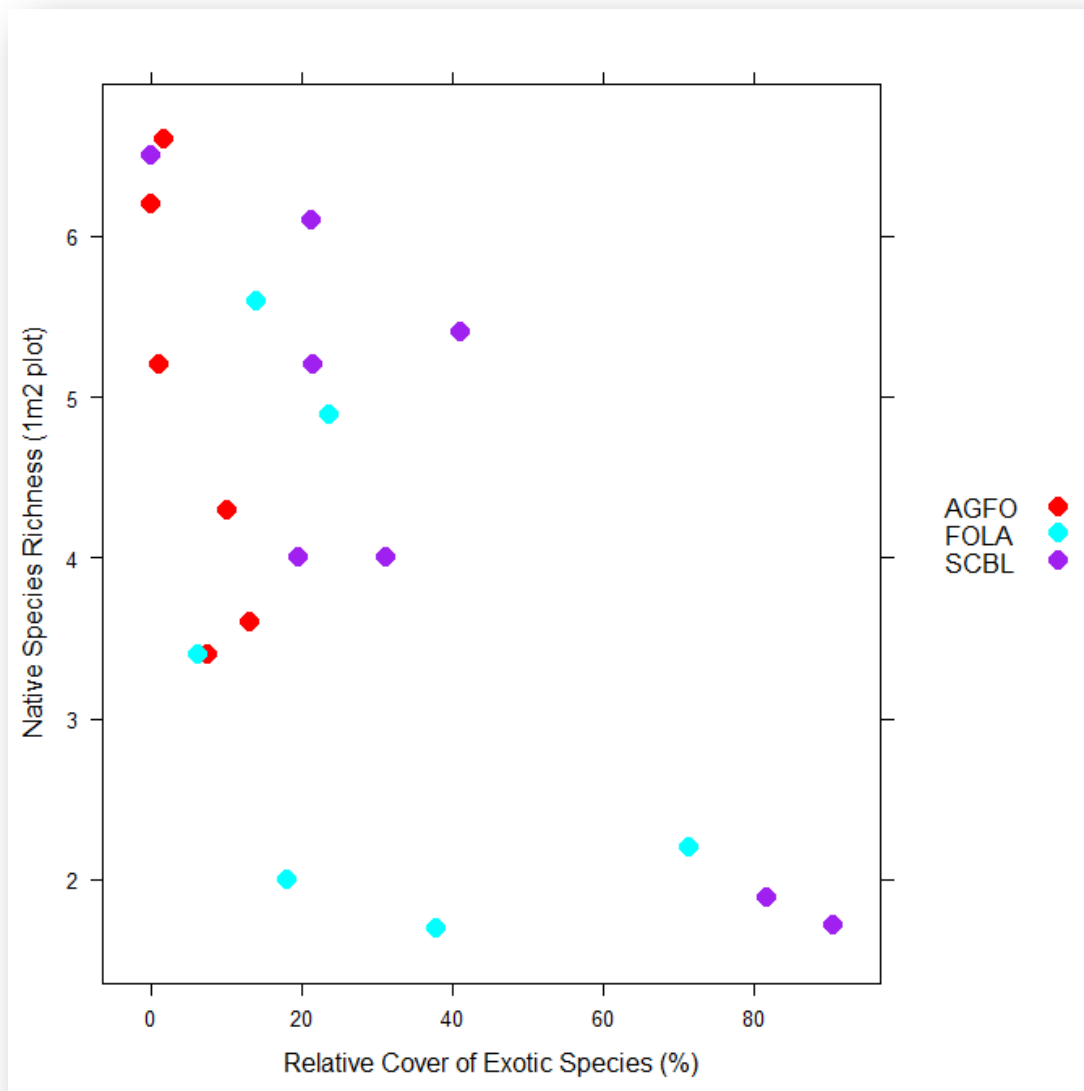


Figure 7. The relationship between average native species richness and the relative cover of exotic species for Wyo-braska park units in 2012. In general, as cover of exotic species increases there is a decline in native diversity. Fort Laramie National Historic Site (FOLA) has some plots with moderate native species richness compared to Scotts Bluff (SCBL) and Agate Fossil Beds (AGFO) National Monuments, but others with a high cover of exotic species.

In conclusion, FOLA plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie and riparian forests in the area. However, a long history of human disturbance has resulted in many areas of the park having a high cover of exotic species. In the Wyo-braska parks (FOLA, Scotts Bluff and Agate Fossil Beds National Monuments), the cover of exotic species is correlated with decreases in native species richness (Figure 6), and to retain ecological integrity it is important to continue efforts to reduce the cover of invasive plants. Annual bromes and smooth bromes present a large challenge to managing upland areas in FOLA, and more research on effective management strategies in the mixed-grass prairie is

greatly needed. In addition, the park will need to continue monitoring and removing populations of the Russian olive and tamarisk in the riparian corridor. Allowing natural disturbances such as fire and light grazing may be critical to maintaining plant diversity in FOLA, but it should be balanced with the need to protect intact native communities and prevent further invasions of exotic species. Continued monitoring efforts will be critical to track changes in the condition of the vegetation communities in FOLA.

Literature Cited

- Ashton, I., M. Prowatzke, M. Bynum, T. Shepherd, S. K. Wilson, and K. Paintner-Green. 2012. Fort Laramie National Historic Site plant community composition and structure monitoring: 2011 annual report. Natural Resource Technical Report NPS/NGPN/NRTR—2012/536. National Park Service, Fort Collins, Colorado.
- D'Antonio, C. M. and P. M. Vitousek. 2003. Biological invasions by exotic grasses, the grass/fire cycle, and global change. *Annual Review of Ecology and Systematics* 23:63-87.
- Hansen, M. H., W. G. Madow, and B. J. Tepping. 1983. An evaluation of model-dependent and probability-sampling inferences in sample-surveys. *Journal Of The American Statistical Association* 78:776-793.
- Heidel, B. 2004. Floristic inventory of Fort Laramie National Historic Site. prepared for the Northern Great Plains Inventory Program and Fort Laramie National Historic Site. Wyoming Natural Diversity Database, Laramie, WY.
- Larsen, D. P., N. S. Urquhart, and D. L. Kugler. 1995. Regional-scale trend monitoring of indicators of trophic condition of lakes. *Water Resources Bulletin* 31:117-140.
- Lauenroth, W., I. Burke, and M. Gutman. 1999. The structure and function of ecosystems in the central North American grassland region. *Great Plains Research* 9:223-259.
- NPS. 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.
- Ogle, S. M., W. A. Reiners, and K. G. Gerow. 2003. Impacts of exotic annual brome grasses (*Bromus spp.*) on ecosystem properties of northern mixed grass prairie. *The American Midland Naturalist* 149:46-58.
- 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. 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. *in press*. Using natural range of variation to set decision thresholds: a case study for Great Plains grasslands. *in* G. R. Gutsenspergen, editor. Application of threshold concepts in natural resource decision making. Springer Verlag.
- 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.
- 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 FOLA for the 2012 season

Plant community composition monitoring in FOLA was completed using a crew of 4 people working 3.5 10-hour days. We spent 129 total crew hours. An additional 2 days (Sept 11-12, 2012) were spent establishing plots that will be monitored in future years.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed	Notes
Jun 04, 2012	Monday	4.5	Holiday Inn Torrington, WY	PCM-001 PCM-004	2 plots surveyed
Jun 05, 2012	Tuesday	1	Holiday Inn Torrington, WY	PCM-002 PCM-003	2 plots surveyed
Jun 06, 2012	Wednesday	1	Holiday Inn Torrington, WY	PCM-065	1 plot surveyed
Jun 07, 2012	Thursday	4.5	Holiday Inn Torrington, WY	PCM-066	1 plot surveyed

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

Family	Code	Scientific Name	Common Name	Exotic
Aceraceae	ACNE2	<i>Acer negundo</i>	boxelder	
Anacardiaceae	TORY	<i>Toxicodendron rydbergii</i>	western poison ivy	
Asclepiadaceae	ASVI	<i>Asclepias viridiflora</i>	green comet milkweed	
Asteraceae	AMPS	<i>Ambrosia psilostachya</i>	Cuman ragweed	
	AMTO3	<i>Ambrosia tomentosa</i>	skeletonleaf burr ragweed	
	ARCA12	<i>Artemisia campestris</i>	field sagewort	
	ARFR4	<i>Artemisia frigida</i>	prairie sagewort	
	ARLU	<i>Artemisia ludoviciana</i>	white sagebrush	
	CIAR4	<i>Cirsium arvense</i>	Canada thistle	*
	CICA11	<i>Cirsium canescens</i>	prairie thistle	
	COCA5	<i>Conyza canadensis</i>	Canadian horseweed	
	GRSQ	<i>Grindelia squarrosa</i>	curlycup gumweed	
	HEAN3	<i>Helianthus annuus</i>	common sunflower	
	HEVI4	<i>Heterotheca villosa</i>	hairy false goldenaster	
	LASE	<i>Lactuca serriola</i>	prickly lettuce	*
	MUOB99	<i>Mulgedium oblongifolium</i>	blue lettuce	
	ONAC	<i>Onopordum acanthium</i>	Scotch cottonthistle	*
	PACA15	<i>Packera cana</i>	woolly groundsel	
	SYER	<i>Symphyotrichum ericoides</i>	white heath aster	
	TAOF	<i>Taraxacum officinale</i>	common dandelion	*
	TRDU	<i>Tragopogon dubius</i>	yellow salsify	*
Boraginaceae	CRMI5	<i>Cryptantha minima</i>	little cryptantha	
	LAOC3	<i>Lappula occidentalis</i>	flatspine stickseed	
	LIIN2	<i>Lithospermum incisum</i>	narrowleaf stoneseed	
Brassicaceae	ALDE	<i>Alyssum desertorum</i>	desert madwort	*
	CAMI2	<i>Camelina microcarpa</i>	littlepod false flax	*
	DEPI	<i>Descurainia pinnata</i>	western tansymustard	
	DESO2	<i>Descurainia sophia</i>	herb sophia	*
	LEDE	<i>Lepidium densiflorum</i>	common pepperweed	
	SIAL2	<i>Sisymbrium altissimum</i>	tall tumbledmustard	*
Cactaceae	OPFR	<i>Opuntia fragilis</i>	brittle pricklypear	
	OPMA2	<i>Opuntia macrorhiza</i>	twistspine pricklypear	
	OPPO	<i>Opuntia polyacantha</i>	plains pricklypear	
Capparaceae	PODO3	<i>Polanisia dodecandra</i>	redwhisker clammyweed	
Caprifoliaceae	SYOC	<i>Symphoricarpos occidentalis</i>	western snowberry	
Chenopodiaceae	CHAL7	<i>Chenopodium album</i>	lambsquarters	*
	CHBE4	<i>Chenopodium berlandieri</i>	pitseed goosefoot	
	SATR12	<i>Salsola tragus</i>	prickly Russian thistle	*

Family	Code	Scientific Name	Common Name	Exotic
Convolvulaceae	COAR4	<i>Convolvulus arvensis</i>	field bindweed	*
Cyperaceae	CAREX	<i>Carex</i>	sedge	
	CADU6	<i>Carex duriuscula</i>	needleleaf sedge	
	CAFI	<i>Carex filifolia</i>	threadleaf sedge	
	CAIN9	<i>Carex inops</i>	long-stolon sedge	
	CAPE42	<i>Carex pellita</i>	woolly sedge	
	CAPR5	<i>Carex praegracilis</i>	clustered field sedge	
	CARI	<i>Carex richardsonii</i>	Richardson's sedge	
	ELAC	<i>Eleocharis acicularis</i>	needle spikerush	
	ELPA3	<i>Eleocharis palustris</i>	common spikerush	
	SCPU10	<i>Schoenoplectus pungens</i>	common threesquare	
Elaeagnaceae	ELAN	<i>Elaeagnus angustifolia</i>	Russian olive	*
Equisetaceae	EQLA	<i>Equisetum laevigatum</i>	smooth horsetail	
Euphorbiaceae	EUPHO	<i>Euphorbia</i>	spurge	*
Fabaceae	GLLE3	<i>Glycyrrhiza lepidota</i>	American licorice	
	MELU	<i>Medicago lupulina</i>	black medick	*
	MESA	<i>Medicago sativa</i>	alfalfa	*
	MEOF	<i>Melilotus officinalis</i>	yellow sweetclover	*
	TRFR2	<i>Trifolium fragiferum</i>	strawberry clover	*
Lemnaceae	LETU2	<i>Lemna turionifera</i>	turion duckweed	
Malvaceae	SPCO	<i>Sphaeralcea coccinea</i>	scarlet globemallow	
Nyctaginaceae	MILI3	<i>Mirabilis linearis</i>	linearleaf four-o'clock, narrow-leaf four-o'clock	
Oleaceae	FRPE	<i>Fraxinus pennsylvanica</i>	green ash	
Onagraceae	OESU99	<i>Oenothera suffrutescens</i>	scarlet beeblossom	
Papaveraceae	ARPO2	<i>Argemone polyanthemus</i>	crested pricklypoppy	
Plantaginaceae	PLMA2	<i>Plantago major</i>	common plantain	
Poaceae	AGST2	<i>Agrostis stolonifera</i>	creeping bentgrass	
	BODA2	<i>Bouteloua dactyloides</i>	buffalograss	
	BOGR2	<i>Bouteloua gracilis</i>	blue grama	
	BRIN2	<i>Bromus inermis</i>	smooth brome	*
	BRJA	<i>Bromus japonicus</i>	Japanese brome	*
	BRTE	<i>Bromus tectorum</i>	cheatgrass	*
	CALO	<i>Calamovilfa longifolia</i>	prairie sandreed	
	ELCA4	<i>Elymus canadensis</i>	Canada wildrye	
	HECO26	<i>Hesperostipa comata</i>	needle and thread	
	HOBR2	<i>Hordeum brachyantherum</i>	meadow barley	
	NAVI4	<i>Nassella viridula</i>	green needlegrass	
	PAVI2	<i>Panicum virgatum</i>	switchgrass	
	PASM	<i>Pascopyrum smithii</i>	western wheatgrass	
	POCO	<i>Poa compressa</i>	Canada bluegrass	*

Family	Code	Scientific Name	Common Name	Exotic
Poaceae	POPR	<i>Poa pratensis</i>	Kentucky bluegrass	*
	PSSP6	<i>Pseudoroegneria spicata</i>	bluebunch wheatgrass	
	SCSC	<i>Schizachyrium scoparium</i>	little bluestem	
	SPPE	<i>Spartina pectinata</i>	prairie cordgrass	
	SPCR	<i>Sporobolus cryptandrus</i>	sand dropseed	
	VUOC	<i>Vulpia octoflora</i>	sixweeks fescue	
Polygonaceae	ERAN4	<i>Eriogonum annuum</i>	annual buckwheat	
	PEMA24	<i>Persicaria maculosa</i>	spotted ladythumb	*
	RUCR	<i>Rumex crispus</i>	curly dock	*
Ranunculaceae	RACY	<i>Ranunculus cymbalaria</i>	alkali buttercup	
Rosaceae	POSU25	<i>Potentilla supina</i>	bushy cinquefoil	
Salicaceae	POAN3	<i>Populus angustifolia</i>	narrowleaf cottonwood	
	PODE3	<i>Populus deltoides</i>	eastern cottonwood	
	SAAM2	<i>Salix amygdaloides</i>	peachleaf willow	
	SAEX	<i>Salix exigua</i>	narrowleaf willow	
	SAFR	<i>Salix fragilis</i>	crack willow	*
Scrophulariaceae	VEAN2	<i>Veronica anagallis-aquatica</i>	water speedwell	
	VETH	<i>Verbascum thapsus</i>	common mullein	*
Solanaceae	PHLO4	<i>Physalis longifolia</i>	longleaf groundcherry	
Tamaricaceae	TACH2	<i>Tamarix chinensis</i>	five-stamen tamarisk	*
Typhaceae	TYAN	<i>Typha angustifolia</i>	narrowleaf cattail	
Unknown Family	UNKFORB	Unknown forb	Unknown forb	
Verbenaceae	PHCU3	<i>Phyla cuneifolia</i>	wedgeleaf	
Verbenaceae	VEBR	<i>Verbena bracteata</i>	bigbract verbena	
Vitaceae	PAVI5	<i>Parthenocissus vitacea</i>	woodbine	

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 375/118215, December 2012

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

EXPERIENCE YOUR AMERICA™