



Plant Community Composition and Structure Monitoring for Scotts Bluff National Monument

2012 Annual Report

Natural Resource Technical Report NPS/NGPN/NRTR—2012/647



ON THE COVER

Daina Jackson, a biological technician with NGPN, measures plant diversity at Scotts Bluff National Monument, 2012.
Photograph by: NGPN

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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. 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.

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Executive Summary

Scotts Bluff National Monument (SCBL) 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 8 long-term monitoring plots in Scotts Bluff National Monument 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 SCBL. At the end of five years, there will be an in-depth report describing the status of the plant community. In 2013, we will also revisit legacy plots that were established as part of the Prairie Cluster prototype monitoring. In this report, we provide a simple summary of our results from sampling in 2012.

We found that, while some areas of the park are highly impacted and have a high cover of exotic species, there are other areas that are in good condition with a high diversity of native plants. Annual bromes present the largest challenge to SCBL, and more research on effective management strategies in the mixed-grass prairie is greatly needed. Allowing for natural disturbances such as fire, light grazing by native herbivores, and prairie dogs may be critical to maintaining plant diversity in SCBL, 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 SCBL.

Acknowledgments

We thank all the authors of the NGPN Plant Community Monitoring Protocol, particularly Dr. Amy Symstad, for outstanding guidance on data collection and reporting. We greatly appreciate the staff at SCBL, particularly Robert Manasek, for providing logistical support and safety checks. The 2012 NGPN vegetation field crew of Michael Prowatzke, Timothy Pine, Lauren Baur, Daina Jackson, Ryan Manuel, Gretchen Addington, Isabel Ashton, and Anine Smith 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. Gerry Steinauer of the Nebraska Natural Heritage Program generously provided us with a list of C-values for plants in Nebraska. Comments from Sarah Wakamiya, Robert Manasek, and Kara Paintner-Green improved this report.

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. Within Nebraska, greater than 77% of the area of native mixed grass prairie has been lost since European settlement (Samson and Knopf 1994). The National Park Service (NPS) plays an important role in preserving and restoring some of the last pieces of intact prairies within its boundaries. The stewardship goal of the NPS is to “preserve ecological integrity and cultural and historical authenticity” (NPS 2012); however, resource managers struggle with the grim reality that there have been fundamental changes in the disturbance regimes, such as climate, fire, and grazing by large, native herbivores, that have historically maintained prairies and there is the continual pressure of exotic invasive species. Long-term monitoring in national parks is essential to sound management of prairie landscapes because it can provide information on environmental quality and condition, benchmarks of ecological integrity, and early warning of declines in ecosystem health.

Scotts Bluff National Monument (SCBL), established in 1919 to protect and preserve 2 iconic bluffs and the associated heritage of western expansion, covers 3,003 acres and is dominated by mixed-grass prairie with smaller areas of juniper woodlands, badlands, and riparian forests. Vegetation monitoring began in SCBL in 1997 by the Heartland Inventory & Monitoring Program (James 2010) and the Northern Great Plains Fire Ecology Program (FireEP; Wienk et al. 2011). In 2010, SCBL 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 plant community monitoring effort in SCBL 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 in 2012 at SCBL. We visited 8 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.



Northern Great Plains Inventory and Monitoring Network Plant Community Monitoring

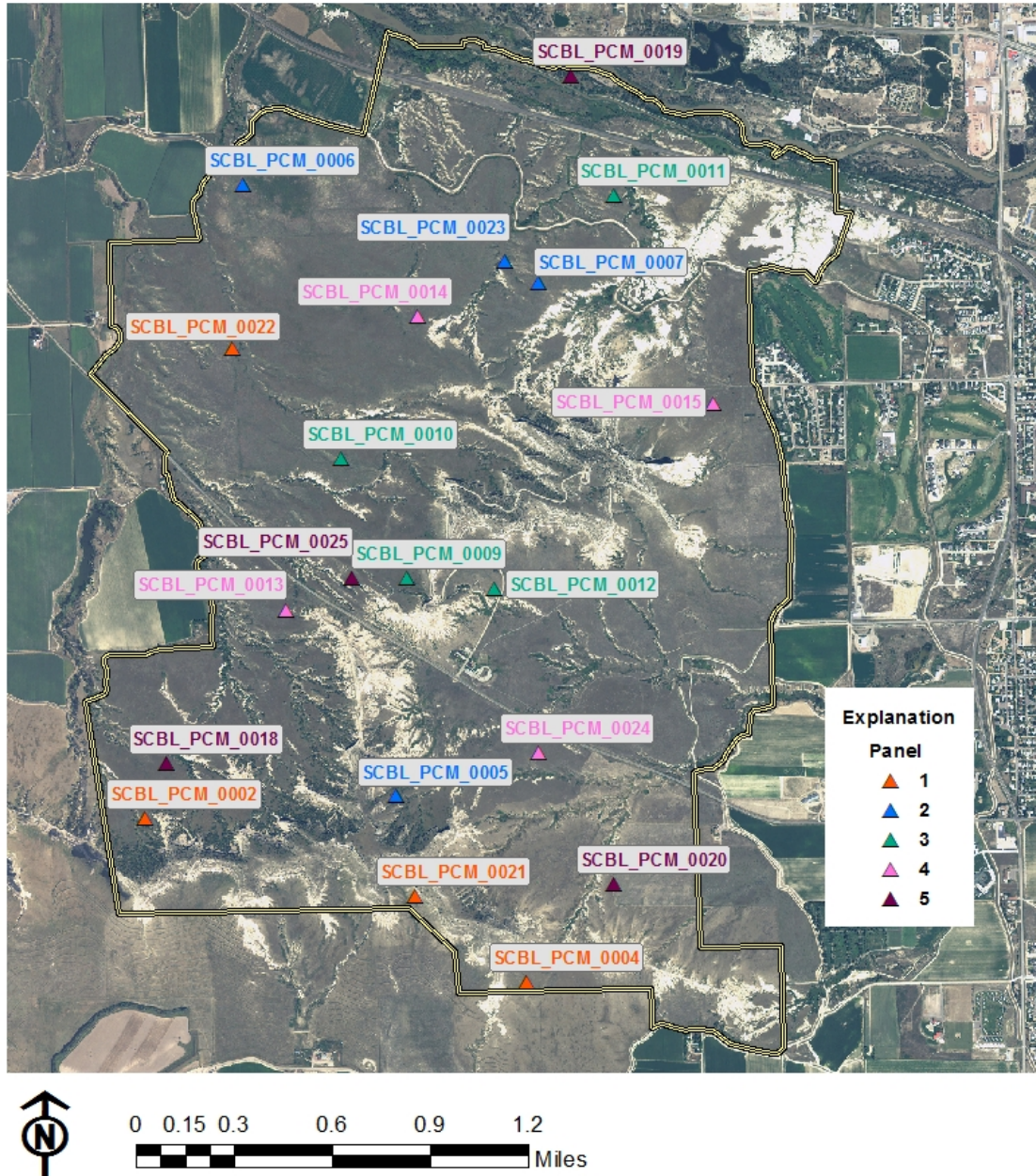


Figure 1. Map of Scotts Bluff National Monument (SCBL) and plant community monitoring (PCM) plots. Plots in Panel 1 (orange) and Panel 2 (blue) were visited in 2012.

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 SCBL using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, we selected 20 randomly located sites within SCBL (Figure 1). We split these 20 sites into 5 panels with 4 sites each. We visit 2 panels (8 sites) every year, and after 5 years (2015) we will have visited all 20 sites twice. In 2011, we visited sites in panel 1 and panel 5 (Figure 1) during the first week of June. In 2012, we visited sites in panel 1 and panel 2 (Figure 2) during the last week of May.

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 SCBL took an 8-person crew approximately 237 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 FireEP 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).

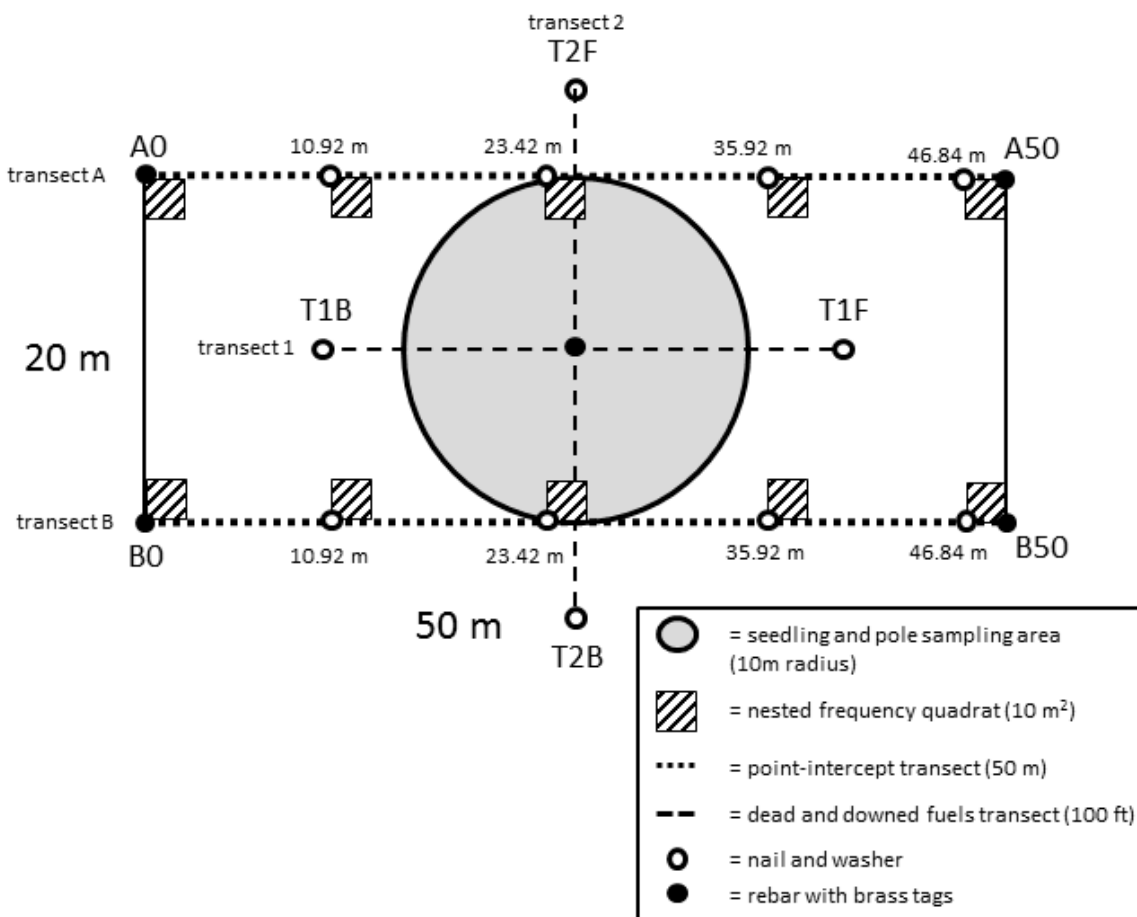


Figure 2. Long-term monitoring plot used for sampling vegetation in Scotts Bluff National Monument.

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-damaged, etc.) are recorded. In 2012, only 2 of 8 plots sampled in SCBL had trees present, PCM_002 and PCM_023. A total of 3 live and sound juniper trees (*Juniperus scopulorum*) were mapped, tagged, and measured. PCM_023 had an abundance of chokecherry (*Prunus virginiana*) seedlings, but no other seedlings, poles, or tall shrubs were found in 2012. An assessment of forest structure and health will be conducted after 5 years, when more data are available. In addition to upland sampling, NGPN is scheduled to complete a survey of riparian forests in SCBL in 2014 and every 5 years thereafter.

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. The target species lists were developed in cooperation with the park and NGPN staff during the winter and spring prior to the field season. Usually, these are invasive and/or exotic species that are not currently widespread in the park, but pose a significant threat if allowed to establish. 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, this method tracks the presence of plant species that are considered rare or vulnerable to loss in Nebraska, and may occur in SCBL. The SCBL target species list for 2012 can be found in Table 1.

Table 1. Exotic species of management concern at Scotts Bluff National Monument 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>Bromus inermis</i>	smooth brome	<i>Astragalus barrii</i>	Barr's milkvetch
<i>Bromus japonicus</i>	Japanese brome	<i>Astragalus pectinatus</i>	narrowleaf milkvetch
<i>Carduus nutans</i>	musk thistle	<i>Astragalus shortianus</i>	Short's milkvetch
<i>Centaurea stoebe</i>	spotted knapweed	<i>Boechara holboellii</i>	limestone rockcress
<i>Centaurea diffusa</i>	diffuse knapweed	<i>Dalea cylindriceps</i>	Andean prairie clover
<i>Cirsium arvense</i>	Canada thistle	<i>Ericameria parryi</i>	Parry's rabbitbrush
<i>Cirsium vulgare</i>	bull thistle	<i>Fritillaria atropurpurea</i>	spotted mission bells
<i>Conium maculatum</i>	poison hemlock	<i>Lappula cenchrusoides</i>	stickseed
<i>Convolvulus arvensis</i>	field bindweed	<i>Linanthus caespitosus</i>	matted prickly phlox
<i>Cynoglossum officinale</i>	houndstongue	<i>Lomatium nuttalli</i>	Nuttall's biscuitroot
<i>Elaeagnus angustifolia</i>	Russian olive	<i>Mentzelia albicaulis</i>	whitestem stickleaf
<i>Euphorbia esula</i>	leafy spurge	<i>Paronychia sessiliflora</i>	stemless nailwort
<i>Kochia scoparia</i>	kochia	<i>Phacelia hastata</i>	spearhead phacelia
<i>Linaria dalmatica</i>	Dalmatian toadflax	<i>Physaria arenosa</i>	sidesaddle bladderpod
<i>Linaria vulgaris</i>	yellow toadflax	<i>Physaria brassicoides</i>	double twinpod
<i>Lythrum salicaria</i>	purple loosestrife	<i>Stephanomeria runcinata</i>	desert skeletonplant
<i>Onopordum acanthium</i>	Scotch thistle		
<i>Phragmites australis</i>	common reed		
<i>Poa bulbosa</i>	bulbous bluegrass		
<i>Poa pratensis</i>	Kentucky bluegrass		
<i>Rhaponticum repens</i>	Russian knapweed		
<i>Salsola tragus</i>	Russian thistle		
<i>Tamarix spp.</i>	tamarisk		
<i>Tanacetum vulgare</i>	common tansy		

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). Conservatism values were assigned using the state list from the Nebraska Natural Heritage Program (<http://outdoornebraska.ne.gov/wildlife/programs/nongame/Heritage.asp>), and when we encountered a plant that was not on the Nebraska list, we used the score assigned in Colorado (Rocchio 2007). Every plant species is assigned a score from 0 to 10, with 10 representing plants of high conservation value that are typically the first plants to disappear from a habitat impacted by humans (Taft et al. 1997). Non-conservative species tend to dominate habitats that have had been exposed to prolonged and/or severe human impacts, resulting in a loss of ecological complexity. 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

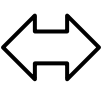
Results were summarized in a Natural Resource Condition Table based on the templates from the State of the Park report series (<http://www1.nrintra.nps.gov/im/stateoftheparks/index.cfm>).

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 SCBL suffered from a very dry winter and spring; when the NGPN field crew visited the park in May, there was not much green vegetation (Figure 3). Average canopy cover was 90% (Table 3) in 2012. Not only was there less vegetation cover than in the previous year, but the vegetation present was much shorter. The average height of the vegetation was 14 (5.5 in) in 2012 as compared to 23 cm (9 in) in the same plots in 2011. 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 B vegetation transect at plot PCM_004 in Scotts Bluff National Monument 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 95 plant species in 2012 at SCBL (Appendix B). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at SCBL, but shrubs and subshrubs were also abundant (Figure 4). Subshrubs are defined as low-growing shrub that is usually under 0.5 m (1.5 feet). Winterfat (*Krascheninnikovia lanata*) and prickly pear (*Opuntia polyacantha*) are common subshrubs in SCBL.

There was a great deal of variation in species composition across the 8 sites. Blue grama (*Bouteloua gracilis*) and cheatgrass (*Bromus tectorum*) were the only species found at all 8 sites. The most common species in the sites we visited were graminoids and most were native species (Figure 5).

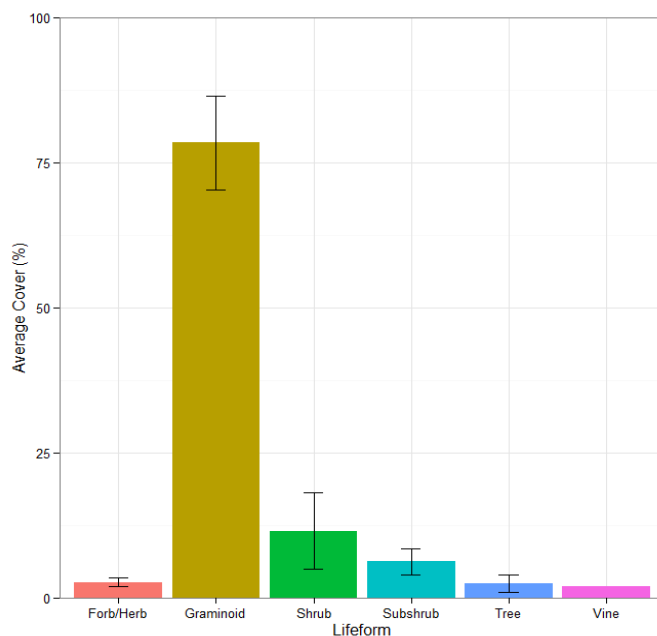


Figure 4. Average cover by life forms in 8 plant community monitoring plots in Scotts Bluff National Monument (SCBL) in 2012. Bars represent means $\pm$ standard errors. Graminoids were the most abundant life-form across all the plots at SCBL.

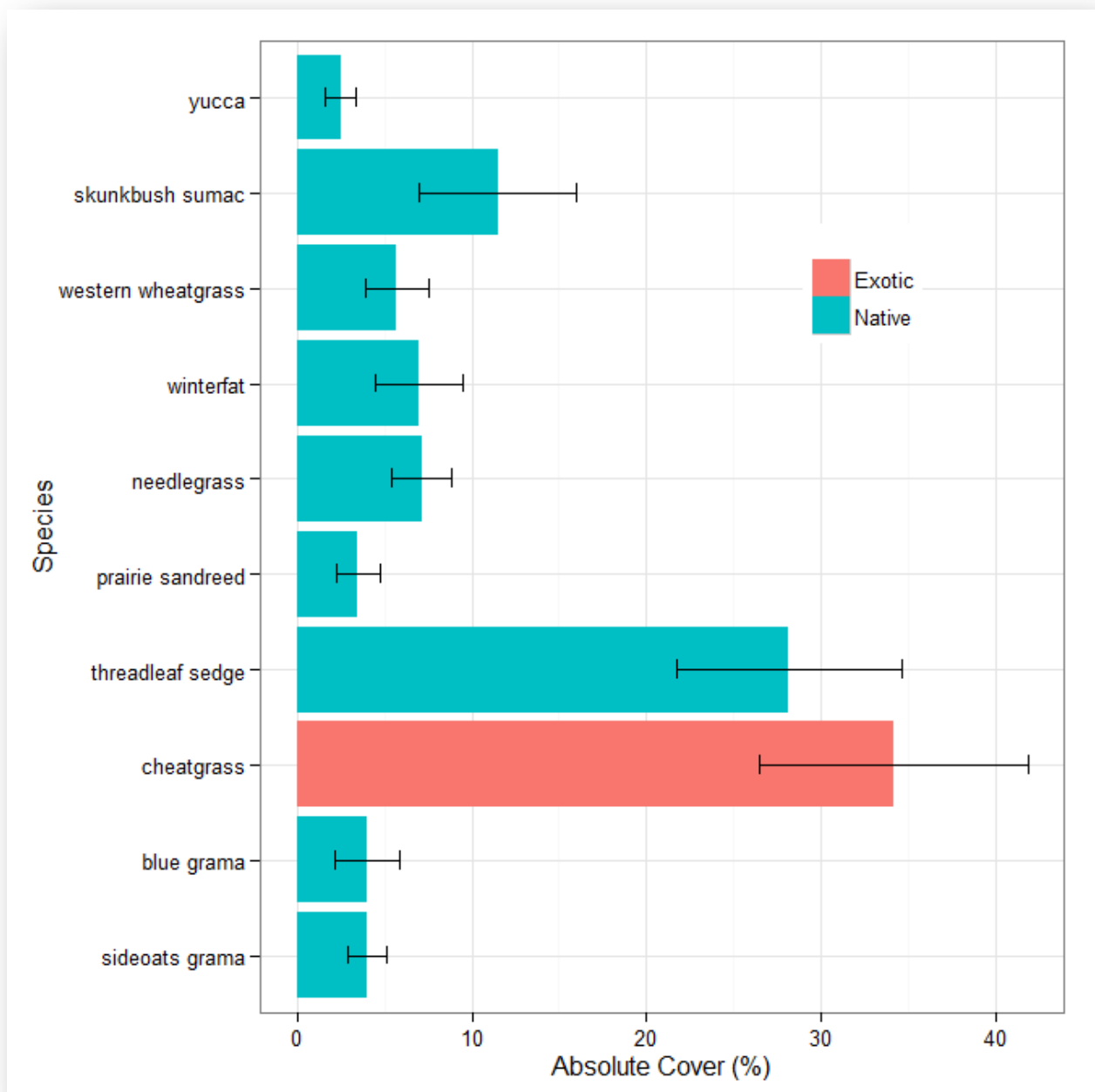
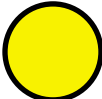
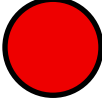
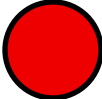


Figure 5. The average absolute cover of the 10 most common native (blue) and exotic (red) plants recorded at Scotts Bluff National Monument in 2012. Bars represent means $\pm$ standard errors. Cheatgrass, the species with the greatest average cover, was the most common exotic species.

Table 3. Natural resource condition summary table for upland plant communities in SCBL.

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	90 $\pm$ 9.2 %	TBD		SCBL 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 low native species richness, but average richness is within a natural range of variability. There are areas of the park, particularly the northwest corner, that fall below this range.
	Native species richness (based on average of 10-1m ² quadrats per plot)	4 $\pm$ 0.6 species	3-15 species ⁽¹⁾		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.69 $\pm$ 0.1	TBD		
Exotic Plant Early Detection and Management	Relative cover of exotic species	38 $\pm$ 11 %	< 10 % cover		While some areas of SCBL have a high cover of exotic species, there are other areas that have low exotic cover and a high diversity of native plants. Overall however, exotic plants are a significant concern in the park. Annual bromes present the largest challenge to SCBL and more research on effective management strategies in the mixed-grass prairie is greatly needed.
	Annual Brome cover	33 $\pm$ 9 %	< 10 % cover		
Fire and Fuel Dynamics	TBD	TBD	TBD	TBD	Prairies in Scotts Bluff that were once contiguous to massive areas of grassland likely had fire return intervals of less than 5 years. Areas of the park burned in a prescribed fire in 2011 and a wild fire in 2012. Allowing for natural disturbances such as fire and prairie dogs may be critical to maintaining plant diversity in SCBL, but it should be balanced with the need to protect intact native communities and prevent further invasions of exotic species.

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. Gutenspergen, editor. Application of threshold concepts in natural resource decision making. Springer Verlag.

Species richness varies by the scale at which it is examined. Table 4 presents average species richness, taken from the point-intercept, 1 m² quadrats, and 10 m² quadrats for the 8 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 picked up more graminoids (Table 4). From the point-intersect data, we found average plot diversity, H', to be 1.6 ± 0.22 . Evenness, J', averaged 0.69 ± 0.07 across the plots (Table 3). When including only native species, average diversity and evenness were 1.6 ± 0.2 and 0.76 ± 0.05 , respectively.

Table 4. Average plant species richness in 8 plots at Scotts Bluff National Monument in 2012. Values represent means $\pm$ standard errors, n=8.

	Point-intercept	1 m ² quadrats	10 m ² quadrats
Species richness	11 ± 2.0	6 ± 0.6	10 ± 1.3
Native species richness	9 ± 1.7	4 ± 0.6	8 ± 1.4
Exotic species richness	2 ± 0.5	1 ± 0.1	2 ± 0.2
Graminoid species richness	7 ± 0.9	4 ± 0.4	5 ± 0.6
Forb species richness	2 ± 0.6	2 ± 0.3	4 ± 0.6

While there was some variation across sites, the plots we visited in SCBL 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, grazing, prairie dog disturbance, and weather fluctuations (Symstad and Jonas 2011). In SCBL, there is also a mixed history of past land-use practices that have affected current species richness. For instance, the site PCM_006 lies in the northwestern part of the park and was once a feedlot, heavily grazed, and seeded. This plot has a low diversity of plants compared to the rest of the park. While it is difficult to define a reference condition for species richness that can vary so much spatially and temporally, the natural range of variation over long-time periods may be a good starting point (Symstad and Jonas *in press*). Long-term records of species diversity in mixed-grass prairie from a relatively undisturbed site in Kansas vary between 3 and 15 species per square meter over the course of 30 years (Symstad and Jonas, *in press*). Compared to this, SCBL is within the natural range (Table 4, native richness in the 1 m² quadrat and Table 3) but is very low, and 2 plots (PCM_006 and PCM_022) fall below this reference condition.

The average relative cover of exotic species at sites in SCBL was high ($38 \pm 11\%$; Table 3). However, like species richness, cover of exotic species varied considerably among sites (Table 5). Some sites such as PCM_0021 had no exotic species. The highest cover of exotic species was 90%, found at PCM_0006. Russian thistle (4 sites), Kentucky bluegrass (2 sites) and musk thistle (1 site) were found in low abundance of less than 5% cover. Two annual brome species, cheatgrass and Japanese brome (*Bromus japonicus*), account for a majority of the exotic cover (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 park, as it has been for the past 15 years. Some areas of the park appear to be more resistant to invasion. The variability we found in 2012 (Table 5) was similar to that seen in 1997, when the Heartland Inventory & Monitoring Network found annual brome cover to range between 1 and 34 % (DeBacker 1998). Focusing restoration efforts on the few areas that

currently have high rates of exotic cover may be the most effective strategy to reduce the cover across the park as a whole. Unfortunately, prescribed fire has not proved to be an effective strategy in reducing the cover of invasive grasses at SCBL (Swanson 2011). More research is needed to determine the best ways to reduce annual brome cover and to prevent its continued spread.

Table 5. Characteristics of the plant community at 8 plots in Scotts Bluff National Monument in 2012 including average cover of annual bromes, exotic plant cover, area of disturbance, and the mean C score of the plant community.

Plot	Exotic Cover (%)	Annual brome cover (%)	Disturbance within site (m ²)	Mean C score of the plant community
SCBL_PCM_0002	31	31	6	3.9
SCBL_PCM_0004	20	19	10	3.3
SCBL_PCM_0005	41	30	5	3.8
SCBL_PCM_0006	90	90	900	3.3
SCBL_PCM_0007	22	22	25	4.2
SCBL_PCM_0021	0	0	6	5.4
SCBL_PCM_0022	82	52	26	3.4
SCBL_PCM_0023	21	21	30	3.9
<i>Park Average</i>	<i>38 ± 11</i>	<i>33 ± 9.7</i>	-	<i>3.9 ± 0.24</i>

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 2012, the most common disturbance was from small rodents and prairie dogs, but there was also evidence of erosion, deer trails, and some light grazing. With the exception of PCM_006, which was on the edge of the prairie dog town, most plots had very little disturbance (Table 5). None of the sites visited in 2012 had evidence of recent fires, but parts of the park did burn in 2011 and 2012. We used the mean plant conservatism scores (C scores) in the site to examine how disturbance may affect plant communities across the landscape. Mean C scores can vary from 0, representing a site characterized by many weedy species, to 10, a site with many species of high conservation value. The mean C score of sites at SCBL varied (Table 5), but all of them tended to be fairly low, which is indicative of higher levels of disturbance. PCM_0021 had the highest mean C score and is a site that has no exotic cover and low disturbance (Table 5). Plant C scores vary across regions, so it will be hard to compare these values to other parks in the Northern Great Plains, but it may provide a useful metric for examining changes in plant community structure and disturbance over time at individual parks.

In conclusion, SCBL 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 highly impacted and have a high cover of exotic species, there are other areas that have low exotic cover and a high diversity of native plants. In the Wyo-braska parks (SCBL, Agate Fossil Beds National Monument, and Fort Laramie National Historic Site), 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.

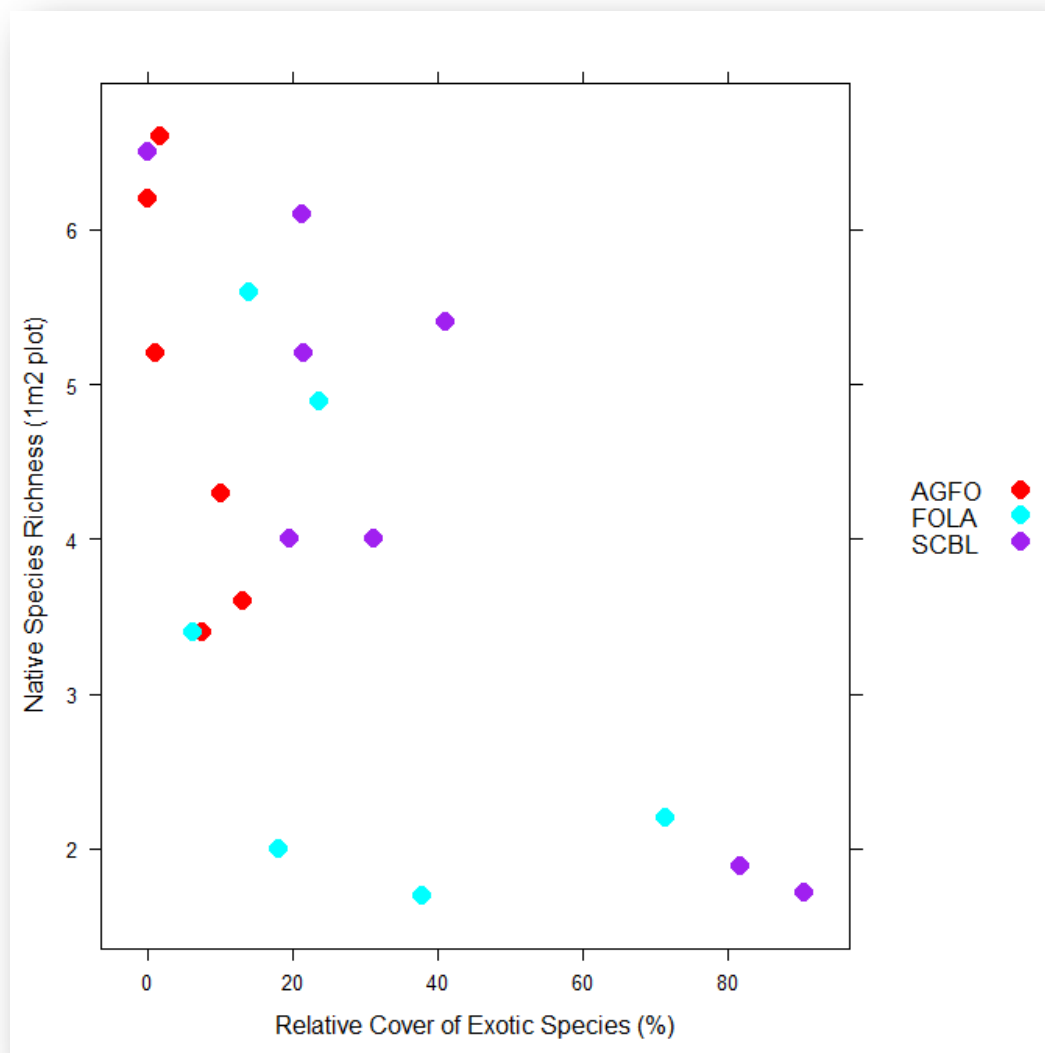


Figure 6. The relationship between average native species richness and the relative cover of exotic species for Wyo-braska park units in 2012. In general, as cover of exotic species increases there is a decline in native diversity. Scotts Bluff National Monument (SCBL) has some plots with moderate to high native species richness and low exotic cover when compared to Agate Fossil Beds National Monument (AGFO) and Fort Laramie National Historic Site (FOLA) but others with a high cover of exotic species.

Annual bromes present the largest challenge to SCBL, and more research on effective management strategies in the mixed-grass prairie is greatly needed. Allowing natural disturbances such as fire, light grazing by deer and other wildlife, and prairie dogs may be critical to maintaining plant diversity in SCBL, 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 SCBL.

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Appendix A: Field journal for plant community monitoring in SCBL for the 2012 season

Plant community composition monitoring in Scotts Bluff National Monument was completed using a crew of 8 people working 3.5 10-hour days. We spent 237 total crew hours.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed	Notes
May 21, 2012	Monday	3.5	Motel 6	PCM-004 PCM-022	2 plots surveyed
May 22, 2012	Tuesday	N/A	Motel 6	PCM-005 PCM-006 PCM-007 PCM-023	4 plots surveyed 4 establishments
May 23, 2012	Wednesday	N/A	Motel 6	PCM-002 PCM-005 PCM-009 PCM-010 PCM-012 PCM-021	3 plots surveyed 3 establishments
May 24, 2012	Thursday	3.5	N/A	PCM-011 PCM-014 PCM-024	No plots surveyed 3 establishments

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

Family	Code	Scientific Name	Common Name	Exotic
Agavaceae	YUGL	<i>Yucca glauca</i>	beargrass, Great Plains yucca, small soapweed, soapweed yucca, Spanish bayonet, yucca	
Anacardiaceae	RHTR	<i>Rhus trilobata</i>	Skunkbush, skunkbush sumac	
	TORY	<i>Toxicodendron rydbergii</i>	poison ivy, W. Poison ivy, western poison ivy	
Asclepiadaceae	ASPU	<i>Asclepias pumila</i>	low milkweed, plains milkweed	
	ASVI	<i>Asclepias viridiflora</i>	green antelopehorn milkweed, green comet milkweed, green milkweed	
Asteraceae	AMPS	<i>Ambrosia psilostachya</i>	Cuman ragweed, perennial ragweed, western ragweed	
	ARFI2	<i>Artemisia filifolia</i>	sand sagebrush, Sand sagebrush, sandhill sage, silvery wormwood	
	ARFR4	<i>Artemisia frigida</i>	fringed sagebrush, fringed sagewort, prairie sagewort	
	CANU4	<i>Carduus nutans</i>	chardon penche, musk thistle, nodding plumeless thistle, nodding plumeless-thistle, nodding thistle	*
	CICA11	<i>Cirsium canescens</i>	Platte thistle, prairie thistle	
	COCA5	<i>Conyza canadensis</i>	Canada horseweed, Canadian horseweed, horseweed, horseweed fleabane, mares tail,	
	ERNA10	<i>Ericameria nauseosa</i>	rubber rabbitbrush	
	ERCA4	<i>Erigeron canus</i>	hoary fleabane	
	GUSA2	<i>Gutierrezia sarothrae</i>	broom snakeweed, Broomsnakeweed, broomweed, perennial snakeweed, stinkweed, turpentine weed, yellow top	
	HEAN3	<i>Helianthus annuus</i>	annual sunflower, common sunflower, sunflower, wild sunflower	
	HEPE	<i>Helianthus petiolaris</i>	prairie sunflower	
	HEVI4	<i>Heterotheca villosa</i>	hairy false goldaster, hairy false goldenaster, hairy goldaster, hairy goldenaster	
	HIUM	<i>Hieracium umbellatum</i>	Narrowleaf hawkweed	
	LASE	<i>Lactuca serriola</i>	China lettuce, prickly lettuce, wild lettuce	*
	LIPU	<i>Liatris punctata</i>	dotted blazing star, Dotted gayfeather	
	LYJU	<i>Lygodesmia juncea</i>	rush skeleton-plant, rush skeletonplant, rush skeletonweed, skeletonplant,	
	MUOB99	<i>Mulgedium oblongifolium</i>	blue lettuce, blue wild lettuce, chicory lettuce, Russian blue lettuce	
	SOMI2	<i>Solidago missouriensis</i>	Missouri goldenrod, prairie goldenrod	
	SYER	<i>Symphotrichum ericoides</i>	white heath aster	
	TRDU	<i>Tragopogon dubius</i>	common salsify, goat's beard, goatsbeard, meadow goat's-beard, salsifis majeur, salsify, Western goat's beard, western salsify, wild oysterplant, yellow goat's beard, yellow salsify	*
Boraginaceae	LAOC3	<i>Lappula occidentalis</i>	flat-spine sheepburr, flatspine stickseed, western sticktight	
	LIIN2	<i>Lithospermum incisum</i>	fringed gromwell, Fringed puccoon, narrowleaf gromwell, narrowleaf pucoon, narrowleaf stoneseed, trumpet stoneseed	
Brassicaceae	DEPI	<i>Descurainia pinnata</i>	green tansymustard, pinnate tansy mustard,	

Family	Code	Scientific Name	Common Name	Exotic
			pinnate tansymustard, tansymustard,	
	PHRE8	<i>Physaria reediana</i>	alpine bladderpod	
	SIAL2	<i>Sisymbrium altissimum</i>	Jim Hill mustard, tall hedge-mustard, tall mustard, tall tumbledustard, tumble mustard, tumbledustard, tumbleweed mustard	*
Cactaceae	OPMA2	<i>Opuntia macrorhiza</i>	grassland pricklypear, plains twistspine pricklypear, twistspine pricklypear	
	OPPO	<i>Opuntia polyacantha</i>	plains pricklypear	
Caprifoliaceae	SYOC	<i>Symphoricarpos occidentalis</i>	western snowberry, wolfberry	
Chenopodiaceae	CHENO	<i>Chenopodium</i>	goosefoot	
	CHFR3	<i>Chenopodium fremontii</i>	Fremont goosefoot, Fremont's goosefoot	
	KOSC	<i>Kochia scoparia</i>	common kochia, fireweed, kochia, Mexican burningbush, Mexican fireweed, Mexican-fireweed, mock cypress, Summer cypress	*
	KRLA2	<i>Krascheninnikovia lanata</i>	winterfat	
	SATR12	<i>Salsola tragus</i>	prickly Russian thistle	*
Commelinaceae	TROC	<i>Tradescantia occidentalis</i>	prairie spiderwort, spiderwort	
Convolvulaceae	EVNU	<i>Evolvulus nuttallianus</i>	prostrate evolvulus, shaggy dwarf morning-glory, shaggy dwarf morningglory, silver wild morningglory	
Cupressaceae	JUSC2	<i>Juniperus scopulorum</i>	rocky mountain juniper, Rocky Mountain juniper	
Cyperaceae	CAFI	<i>Carex filifolia</i>	threadleaf sedge	
	CAIN9	<i>Carex inops</i>	long-stolon sedge	
Euphorbiaceae	CRTE4	<i>Croton texensis</i>	croton, doveweed, goatweed, skunkweed, Texas croton	
	EUSE5	<i>Euphorbia serpyllifolia</i>	thymeleaf sandmat	
Fabaceae	ASGR3	<i>Astragalus gracilis</i>	Milkvetch, slender milkvetch	
	ASLA27	<i>Astragalus laxmannii</i>	Laxmann's milkvetch	
	ASMI10	<i>Astragalus missouriensis</i>	Missouri milk-vetch, Missouri milkvetch	
	DACA7	<i>Dalea candida</i>	slender white prairieclover, white dalea, white prairie clover, white prairie-clover	
	DAPU5	<i>Dalea purpurea</i>	Purple prairieclover, violet dalea, violet prairie clover, violet prairie-clover	
	LAPO2	<i>Lathyrus polymorphus</i>	manystem pea, manystem peavine	
	MESA	<i>Medicago sativa</i>	alfalfa	*
	MEOF	<i>Melilotus officinalis</i>	yellow sweet-clover, yellow sweetclover	*
	OXSE	<i>Oxytropis sericea</i>	locoweed, Silky crazyweed, silvery oxytrope, white crazyweed, white locoweed, white pointloco	
	PSTE5	<i>Psoraleidium tenuiflorum</i>	scurfpea, slimflower scurfpea	
	THRH	<i>Thermopsis rhombifolia</i>	goldenpea, prairie thermopsis	
	VIAM	<i>Vicia americana</i>	American deervetch, American vetch	
Grossulariaceae	RIAU	<i>Ribes aureum</i>	golden currant	
Malvaceae	SPCO	<i>Sphaeralcea coccinea</i>	copper mallow, orange globemallow, red falsemallow, scarlet globemallow	
Melanthiaceae	TOVE2	<i>Toxicoscordion venenosum</i>	meadow deathcamas	

Family	Code	Scientific Name	Common Name	Exotic
Onagraceae	OEBI	<i>Oenothera biennis</i>	common evening primrose, common evening-primrose, hoary eveningprimrose, king's-cureall	
	OESE3	<i>Oenothera serrulata</i>	yellow sundrops	
	OESU99	<i>Oenothera suffrutescens</i>	scarlet beeblossom	
Poaceae	ACHY	<i>Achnatherum hymenoides</i>	Indian ricegrass	
	AGCR	<i>Agropyron cristatum</i>	crested wheatgrass	*
	ANGE	<i>Andropogon gerardii</i>	big bluestem, bluejoint, turkeyfoot	
	ARPU9	<i>Aristida purpurea</i>	Purple 3-awn, purple three-awn, purple threeawn, red threeawn	
	BOCU	<i>Bouteloua curtipendula</i>	sideoats grama	
	BOGR2	<i>Bouteloua gracilis</i>	blue grama	
	BRIN2	<i>Bromus inermis</i>	awnless brome, smooth brome	*
	BRJA	<i>Bromus japonicus</i>	Japanese brome, Japanese brome grass, Japanese chess	*
	BRTE	<i>Bromus tectorum</i>	cheat grass, cheatgrass, downy brome, early chess, military grass, wild oats	*
	CALO	<i>Calamovilfa longifolia</i>	prairie sandreed	
	ELEL5	<i>Elymus elymoides</i>	bottlebrush squirreltail, squirreltail, western bottle-brush grass	
	ELTR7	<i>Elymus trachycaulus</i>	slender wheatgrass, slender wild rye	
	HECO26	<i>Hesperostipa comata</i>	Hesperostipa, Hesperostipa comata, needle and thread, needleandthread	
	KOMA	<i>Koeleria macrantha</i>	junegrass, prairie Junegrass	
	MURA	<i>Muhlenbergia racemosa</i>	green muhly, marsh muhly	
	PAVI2	<i>Panicum virgatum</i>	switchgrass	
	PASM	<i>Pascopyrum smithii</i>	pubescent wheatgrass, western wheatgrass	
	POPR	<i>Poa pratensis</i>	Kentucky bluegrass	*
	POSE	<i>Poa secunda</i>	big bluegrass, Sandberg bluegrass	
	PSSP6	<i>Pseudoroegneria spicata</i>	bluebunch wheatgrass, bluebunch-wheat grass	
	SCSC	<i>Schizachyrium scoparium</i>	little bluestem	
	SPCR	<i>Sporobolus cryptandrus</i>	sand dropseed	
	VUOC	<i>Vulpia octoflora</i>	eight-flower six-weeks grass, pullout grass, sixweeks fescue, sixweeks grass	
Polemoniaceae	PHAN4	<i>Phlox andicola</i>	prairie phlox	
	PHHO	<i>Phlox hoodii</i>	Hood's phlox, spiny phlox	
Polygonaceae	ERPA9	<i>Eriogonum pauciflorum</i>	few-flower wild buckwheat, fewflower buckwheat, manybranch eriogonum	
	POAC3	<i>Polygonum achoreum</i>	leathery knotweed, striate knotweed	
Rosaceae	PRVI	<i>Prunus virginiana</i>	chokecherry, chokecherry (common), common chokecherry, Virginia chokecherry	
	ROWO	<i>Rosa woodsii</i>	Wood's rose, woods rose, Woods' rose	
Solanaceae	PHLO4	<i>Physalis longifolia</i>	common groundcherry, long-leaf ground-cherry	
Unknown Family	UNKFORB	<i>Unknown forb</i>	Unknown forb	
Vitaceae	PAVI5	<i>Parthenocissus vitacea</i>	thicket creeper, Virginia creeper, woodbine	

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