



Plant Community Composition and Structure Monitoring for Badlands National Park

2012 Annual Report

Natural Resource Technical Report NPS/NGPN/NRTR—2013/674



ON THE COVER

Biological technicians, Lauren Baur and Anine Smith, identifying plants at a long-term monitoring plot in Badlands National Park, 2012.

Photograph by: NGPN

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January 2013

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

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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.

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.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, D. Swanson, P. Graeve, and S. K. Wilson. 2013. Plant community composition and structure monitoring for Badlands National Park: 2012 annual report. Natural Resource Technical Report NPS/NGPN/NRTR—2013/674. National Park Service, Fort Collins, Colorado.

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Executive Summary

Badlands National Park (BADL) plays a vital role in protecting and managing one of the largest protected mixed-grass prairies in the United States. The Northern Great Plains Inventory & Monitoring Network and Fire Ecology Program surveyed 26 long-term monitoring plots in BADL in 2012 as part of an effort to better understand the condition of plant communities in the park. We measured plant diversity and cover, 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 BADL. 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.

We found BADL to be characterized by moderate native species richness that falls within a natural range of variability for northern mixed-grass prairie. There are a few areas of the park that fall below this range and others that are quite diverse. Half of the sites visited in 2012 had exotic cover at or above 10% cover. Sweet clover and annual bromes present a large challenge to BADL. More research on effective management strategies in the mixed-grass prairie is greatly needed and to retain ecological integrity it is important to continue efforts to reduce the cover of invasive plants. Allowing natural disturbances such as fire, grazing, and prairie dog use may be critical to maintaining plant diversity in BADL, 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 BADL.

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 BADL, particularly Milton Haar for providing logistical support, safety checks, and help in the field. The 2012 NGPN vegetation field crew of Isabel Ashton, Michael Prowatzke, Timothy Pine, Lauren Baur, Daina Jackson, Ryan Manuel, Anine Smith, and Gretchen Addington collected the NGPN data included in this report. The 2012 Northern Great Plains Fire Ecology Program crew of Phil Graeve, Dan Swanson, Valena Hoffman, Marcus Lund, and Ellory Watson collected data on 6 plots 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 (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 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.

Badlands National Park (BADL) was established in 1939 as a National Monument and in 1978 became a National Park with a mission to protect and preserve 242,756 acres of rugged badlands, mixed-grass prairie, and rich fossil deposits. The vegetation is a mosaic of sparsely vegetated badlands, native mixed-grass prairie, woody draws, and exotic grasslands. The Northern Great Plains Inventory & Monitoring Program (NGPN) began vegetation monitoring at BADL in 2011 (Ashton et al. 2012). Vegetation monitoring protocols and plot locations were chosen to represent the entire park and to coordinate efforts with the Northern Great Plains Fire Ecology Program (FireEP). The long-term objectives of the NGPN and FireEP plant community monitoring effort (Symstad et al. 2012b) in BADL 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 BADL in 2012, our second year of sampling. NGPN visited 20 plots and FireEP visited 6 plant community monitoring plots (Figure 1). Not all plots are visited every year and we expect it will take 7 more years to visit every plot in the park. We expect to produce reports with more in-depth data analysis and interpretation when we complete 5 and 10 years of sampling. In the interim, reports, spatial data, and data summaries can be provided for park management and interpretation upon request.

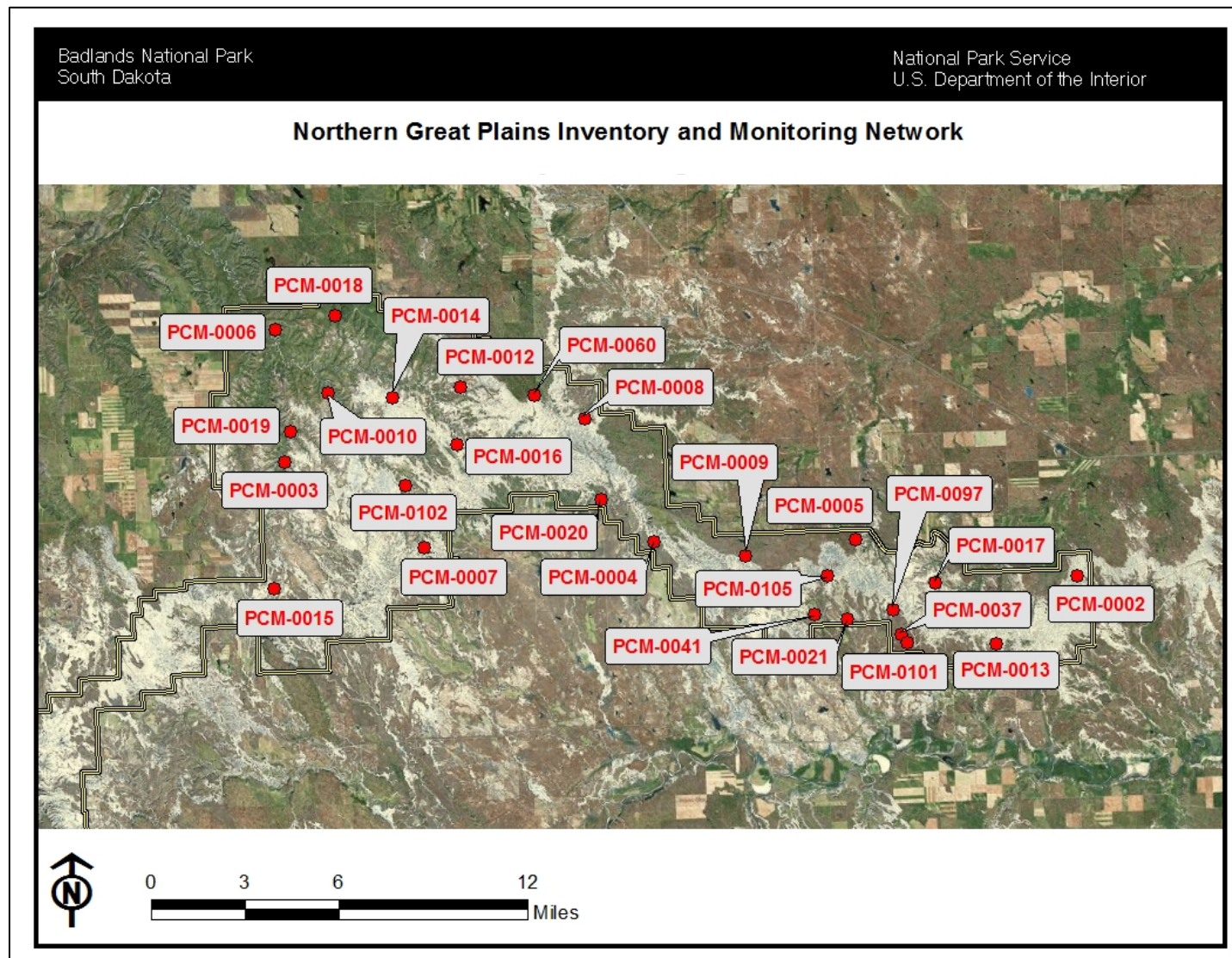


Figure 1. Map of Badlands National Park (BADL) and plant community monitoring plots surveyed in 2012.

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.cfm>.

Sample design

NGPN and FireEP implemented a survey to monitor plant community structure and composition in BADL using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, we selected 100 randomly located sites within BADL. We split these 100 sites into 10 panels with 10 sites each. We visit 2 panels (20 sites) every year, and after 10 years (2021) we will have visited all 100 sites twice. In 2012, we visited sites in panel 1 and panel 2 (Figure 1) during mid-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 and again at 10 years, we can use data from our randomly selected sites to estimate the ecological integrity of vegetation communities for the whole park.

The FireEP aims to understand how prescribed and wildland fires affects the vegetation in national park units in this region. Where possible, the same sites as above are used to assess vegetation response. However, in many cases there are not enough plots within the scheduled visits that fall within burn units. When this happens, FireEP will visit monitoring plots of interest that the NGPN crew is not scheduled to monitor. In 2012, FireEP visited 6 plant community monitoring sites during June. They visited an additional 17 plots in the Castle, Door, Interior, and Heck Table burn units.

Plot layout and sampling

At each of the sites we visited, NGPN and FireEP 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. In the 20 plots read by NGPN, species richness data from the point-intercept method were supplemented with species presence data collected in 5 sets of nested square quadrats (0.01 m^2 , 0.1 m^2 , 1 m^2 , and 10 m^2) located systematically along each transect (Figure 2). In 2012, sampling at BADL took two 4-person crews approximately 548 crew 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 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, were mapped and tagged. In 2012, we did not find any trees or tall shrubs within the plots we visited.

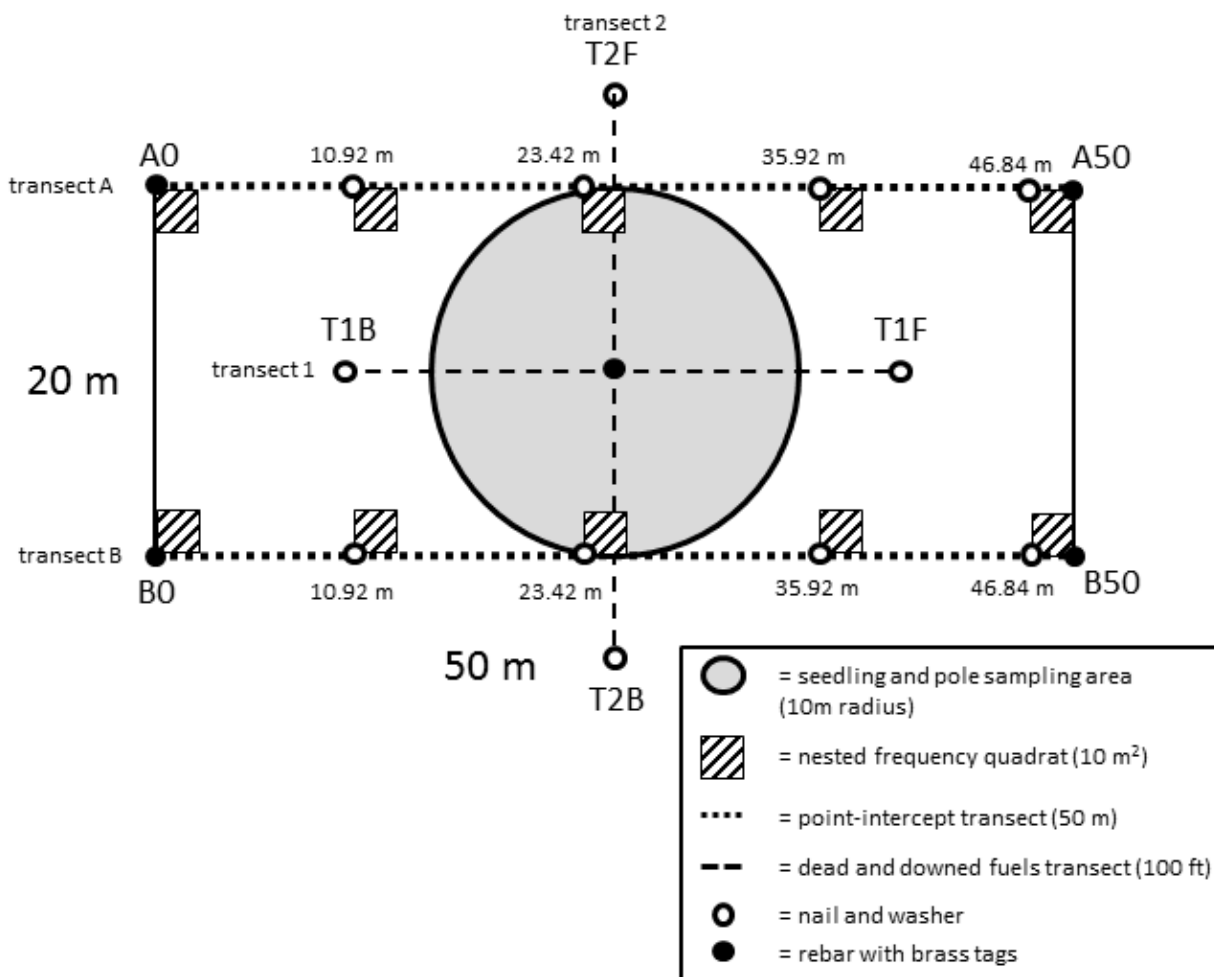


Figure 2. Long-term monitoring plot used for sampling vegetation in Badlands National Park.

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 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 South Dakota, and may occur in BADL. The BADL target species list for 2012 can be found in Table 1.

Table 1. Exotic species of management concern at Badlands National Park 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>Centaurea stoebe</i>	spotted knapweed	<i>Allium drummondii</i>	Drummond's onion
<i>Centaurea diffusa</i>	diffuse knapweed	<i>Astragalus barrii</i>	Barr's milkvetch
<i>Centaurea jacea</i>	brownray knapweed	<i>Astragalus hyalinus</i>	summer orophaca
<i>Centaurea solstitialis</i>	yellow star thistle	<i>Clematis hirsutissima</i>	hairy clematis
<i>Elaeagnus angustifolia</i>	Russian olive	<i>Cryptantha cana</i>	silver-mounded candleflower
<i>Euphorbia esula</i>	leafy spurge	<i>Ericameria parryi</i>	Parry's rabbitbrush
<i>Falcaria vulgaris</i>	sickleweed	<i>Erigeron ochroleucus</i>	buff fleabane
<i>Linaria dalmatica</i>	Dalmatian toadflax	<i>Eriogonum visherii</i>	Visher's buckwheat
<i>Linaria vulgaris</i>	yellow toadflax	<i>Ipomopsis spicata</i>	spiked ipomopsis
<i>Poa bulbosa</i>	bulbous bluegrass	<i>Oenothera flava</i>	yellow evening primrose
<i>Potentilla recta</i>	sulphur cinquefoil	<i>Orobanche uniflora</i>	one-flowered broomrape
<i>Rhaponticum repens</i>	Russian knapweed	<i>Physaria arenosa</i>	sidesaddle bladderpod
<i>Sideritis montana</i>	mountain ironwort	<i>Physaria montana</i>	mountain bladderpod
<i>Tamarix</i> spp.	tamarisk	<i>Solidago velutina</i>	3-nerve goldenrod
<i>Tanacetum vulgare</i>	common tansy	<i>Thelesperma megapotamicum</i>	Hopi tea
<i>Thymelaea passerina</i>	spurge flax	<i>Townsendia exscapa</i>	Easter daisy

Data Management and Analysis

NGPN and FireEP 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). 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

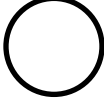
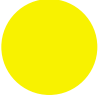
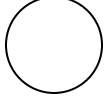
Results were summarized in a Natural Resource Condition Table based on the templates from the State of the Park report series (<http://www1.nrintra.nps.gov/im/stateoftheparks/index.cfm>).

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

Despite the dry conditions, NGPN and FireEP found 168 plant species in 2012 at BADL (Appendix B). Graminoids, which include grasses, sedges, and rushes, accounted for most of the vegetative cover at BADL, but forbs were also abundant (Figure 3). Average plant canopy cover was $82 \pm 7.0\%$ (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 62% plant litter).

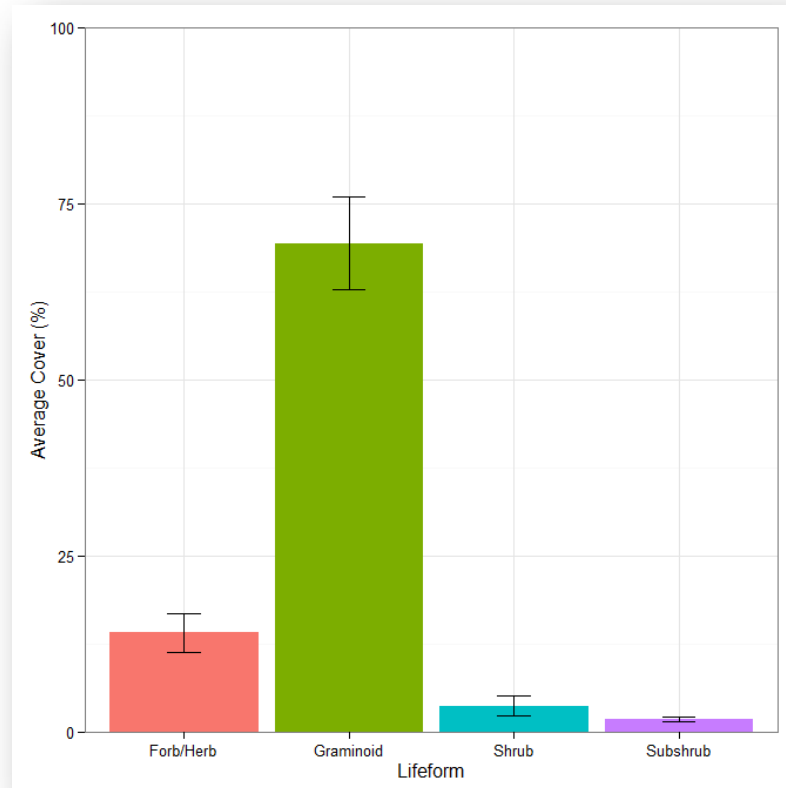


Figure 3. Average cover by life forms in 26 plant community monitoring plots in Badlands National Park in 2012. Bars represent means $\pm$ standard errors. Graminoids were the most abundant life-form across all the plots at BADL.

There was a great deal of variation in species composition across the 26 sites. The most common species found from the point-intercept were graminoids, and most were native species (Figure 4). Western wheatgrass (*Pascopyrum smithii*) was found at 22 sites and blue grama (*Boutelous gracilis*) was found at 19. We did not encounter any rare or exotic early detection target species.

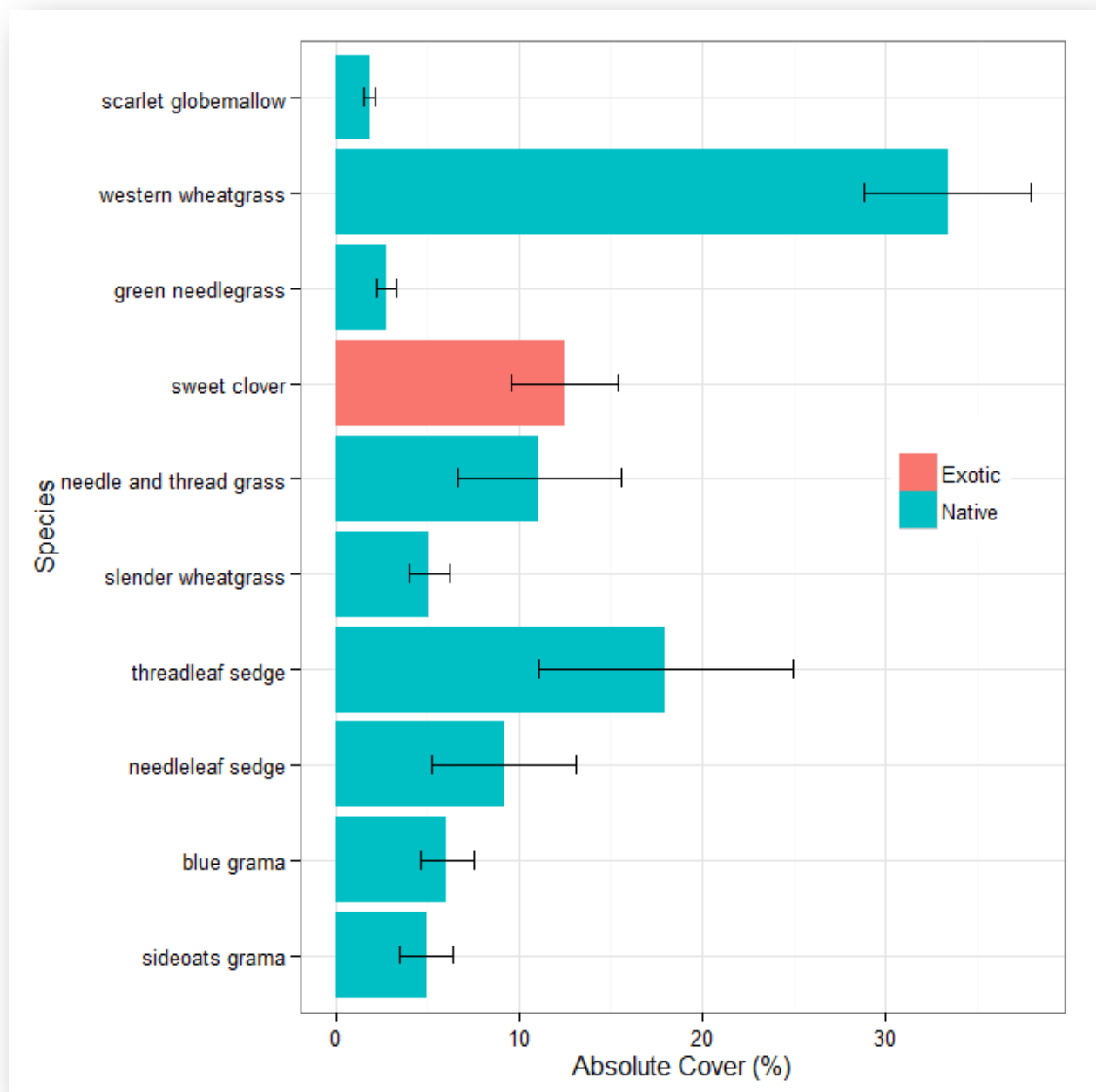
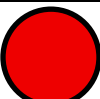
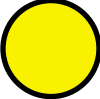


Figure 4. The average absolute cover of the 10 most common native (blue) and exotic (red) plants recorded at 26 sites at Badlands National Park in 2012. Bars represent means $\pm$ standard errors. The common native species, like western wheatgrass, accounted for greater cover than exotic species.

Table 3. Natural resource condition summary table for upland plant communities in Badlands National Park (BADL).

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	82 $\pm$ 7.0 %	TBD		BADL plays a vital role in protecting and managing some of the largest remnants of native mixed-grass prairie in the region. The park is characterized by moderate native species richness that falls within a natural range of variability. There are a few areas of the park that fall below this range and are heavily invaded by exotic species. 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 $\pm$ 0.6 species	3-15 species ⁽¹⁾		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.68 $\pm$ 0.03	TBD		
Exotic Plant Early Detection and Management	Relative cover of exotic species	19 $\pm$ 4.6 %	$\leq$ 10 % cover		In general, the sites in BADL had a high cover of exotic species. Roughly half of the sites visited in 2012 had exotic cover above 10% cover. Sweet clover and annual bromes present a large challenge to BADL, and more research on effective management strategies in the mixed-grass prairie is greatly needed.
	Annual Brome cover	1 $\pm$ 0.5 %	$\leq$ 10 % cover		

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. Guterspergen, 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 monitoring plots in 2012. On average, there are about 3 exotic species found in each 10 m² 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 1.5 ± 0.10 . Evenness, J', averaged 0.68 ± 0.03 across the plots (Table 3). When including only native species, average diversity and evenness were 1.4 ± 0.1 and 0.67 ± 0.04 , respectively.

Table 4. Average plant species richness plant community monitoring plots at Badlands National Park in 2012. Values represent means $\pm$ standard errors, n=26 for the point-intercept and n=20 for the quadrats.

	Point-intercept	1 m ² quadrats	10 m ² quadrats
Species richness	11 $\pm$ 0.9	7 $\pm$ 0.5	11 $\pm$ 0.9
Native species richness	9 $\pm$ 0.9	5 $\pm$ 0.6	9 $\pm$ 1.0
Exotic species richness	2 $\pm$ 0.3	2 $\pm$ 0.1	3 $\pm$ 0.2
Graminoid species richness	6 $\pm$ 0.6	3 $\pm$ 0.3	5 $\pm$ 0.4
Forb species richness	4 $\pm$ 0.4	3 $\pm$ 0.3	6 $\pm$ 0.6

While there was some variation across sites (Table 5), the plots we visited in BADL tended to have a moderate diversity of native plants compared to other mixed-grass prairies. Species richness in the mixed-grass prairie is determined by numerous factors including fire regime, large ungulate grazing, prairie dog disturbance, and weather fluctuations (Symstad and Jonas 2011). While it is difficult to define a reference condition for species richness that can vary so much spatially and temporally, the natural range of variation over long-time periods may be a good starting point (Symstad and Jonas *in press*). Long-term records of species diversity in mixed-grass prairie in a relatively undisturbed site in Kansas have varied between 3 and 15 species per square meter over the course of 30 years (Symstad and Jonas, *in press*). Compared to this, BADL is within the natural range (Table 4, native richness in the 1 m² quadrat and Table 3), but one site fell below this reference condition of at least 3 native species per meter squared area (Table 5). This may be due in part to a very dry year in 2012, which tends to reduce plant diversity. Plant diversity was particularly high at PCM_0018 (Table 5, Figure 5). This site was along a grassy ridgeline and although it was close to the road, a deep woody draw separated the road from the site.

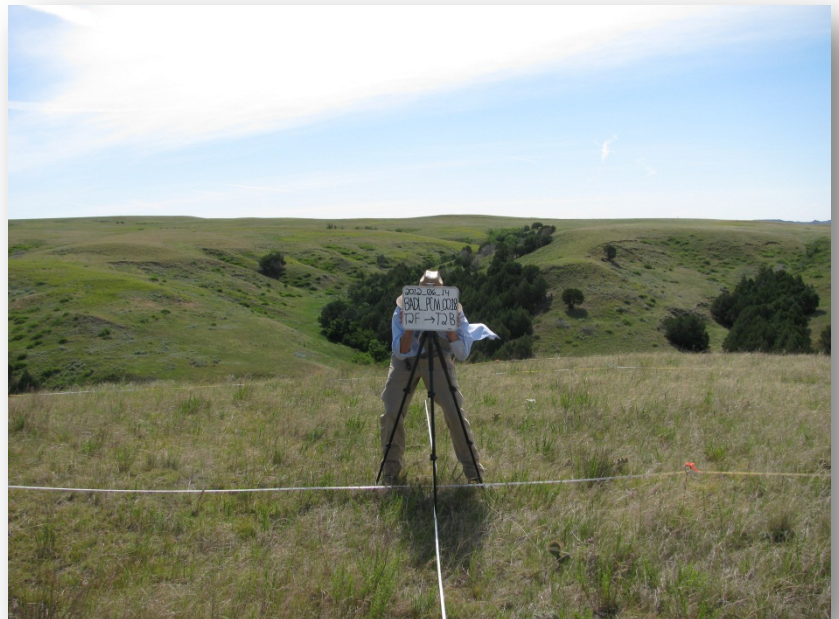


Figure 5. Photograph of long-term monitoring site PCM_0018 Badlands National Park. This site had a very high diversity of native plants in 2012.

Table 5. Characteristics of the plant community in 26 plots at Badlands National Park 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)
BADL_PCM_0010	4	86	2	4580
BADL_PCM_0002	4	59	0	2290
BADL_PCM_0060	-	54	0	-
BADL_PCM_0004	4	52	0	1145
BADL_PCM_0020	3	44	0	1
BADL_PCM_0006	2	31	2	160
BADL_PCM_0003	6	26	1	170
BADL_PCM_0012	5	26	0	45
BADL_PCM_0105	-	25	0	-
BADL_PCM_0005	8	24	0	500
BADL_PCM_0013	4	16	13	5
BADL_PCM_0008	4	14	3	750
BADL_PCM_0102	6	10	0	805
BADL_PCM_0021	-	8	0	-
BADL_PCM_0019	3	7	0	2325
BADL_PCM_0041	-	6	0	-
BADL_PCM_0007	5	4	1	1254
BADL_PCM_0015	5	4	1	1100
BADL_PCM_0009	5	2	1	1051
BADL_PCM_0017	8	1	0	0
BADL_PCM_0101	3	1	0	1
BADL_PCM_0018	14	1	1	1000
BADL_PCM_0014	4	0	0	6
BADL_PCM_0016	6	0	0	2100
BADL_PCM_0037	-	0	0	-
BADL_PCM_0097	-	0	0	-
Site Average	5 ± 0.6	19 ± 4.6 %	1 ± 0.5%	-

The average relative cover of exotic species at sites in BADL was high ($19 \pm 4.6\%$; Table 3). However, like species richness, cover of exotic species varied considerably among sites (Table 5). Some sites such as PCM_0014 had no exotic cover. The highest cover of exotic species was 89%, found at PCM_010 which had a large patch of yellow sweetclover, Canada thistle, and Russian thistle and was within an active prairie dog town (Figure 6). A major management challenge for parks in the region is to control the spread of cheatgrass and Japanese brome (annual bromes). 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). In 2012, cover of annual bromes in BADL was very low and there were many sites with no annual brome present (Table 5). Smooth brome, *Bromus inermis*, is a related perennial grass that is also invasive. It was less common in BADL, appearing in only 5 plots, but it accounted for 37 and 39% cover in plot PCM_0060 and PCM_0004.

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 grazing (primarily bison), but there was also evidence of erosion, small mammal and prairie dog use, and some off-road vehicle use (PCM_0018 and PCM_0009). While

the most invaded site was also the most disturbed, in general there was not a strong relationship between disturbances and exotic cover (Table 5).



Figure 6. Photograph of a long-term monitoring plot within an active prairie dog town in 2012 at Badlands National Park. Plot PCM_0010 is heavily invaded by exotic species such as yellow sweetclover, Canada thistle, and Russian thistle.

In conclusion, BADL plays a vital role in protecting and managing some of the largest expanses of native mixed-grass prairie in the U.S. Many areas of the park have a high cover of exotic species and to retain ecological integrity it is important to continue efforts to reduce the cover of invasive plants. Sweet clover, annual bromes, and smooth brome present a large challenge to managing grasslands in BADL, and more research on effective management strategies in the mixed-grass prairie is greatly needed. Allowing natural disturbances such as fire, grazing, and prairie dog use may be critical to maintaining plant diversity in BADL, 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 BADL.

Literature Cited

- Ashton, I., M. Prowatzke, M. Bynum, T. Shepherd, S. K. Wilson, and K. Paintner-Green. 2012. Badlands National Park plant community composition and structure monitoring: 2011 annual report. Natural Resource Technical Report NPS/NGPN/NRTR—2012/533. 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.
- 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.
- 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.
- Samson, F. and F. Knopf. 1994. Prairie conservation in North America. *BioScience* 44:418-421.
- 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. Gutespergen, 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 BADL for the 2012 season

Plant community composition monitoring in BADL was completed using a crew of 8 people working 8 10 hour days. We spent 548 total crew hours.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed
May 31, 2012	Thursday	3	N/A	PCM-0006
Jun 11, 2012	Monday	3	Ann's Motel (half of crew)	PCM-0002 PCM-0003 PCM-0009
Jun 12, 2012	Tuesday	3	Ann's Motel (half of crew)	PCM-0005 PCM-0017 PCM-0014
Jun 13, 2012	Wednesday	3	Ann's Motel (half of crew)	PCM-0007 PCM-0009 PCM-0102
Jun 14, 2012	Thursday	3	Ann's Motel (half of crew)	PCM-0012 PCM-0018 PCM-0020
Jun 18, 2012	Monday	3	Ann's Motel (half of crew)	PCM-0010 PCM-0019
Jun 19, 2012	Tuesday	3	Ann's Motel (half of crew)	PCM-0008 PCM-0013 PCM-0016
Jun 20, 2012	Wednesday	3	Ann's Motel (half of crew)	PCM-0004 PCM-0015

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

Species found in monitoring plots at Badlands National Park in 2012. Species in bold are not on the park's certified species list.

Family	Species Code	Scientific Name	Common Name	Exotic
Agavaceae	YUGL	<i>Yucca glauca</i>	yucca	
Anacardiaceae	RHTR	<i>Rhus trilobata</i>	skunkbush sumac	
	TORY	<i>Toxicodendron rydbergii</i>	poison ivy	
Apiaceae	LOFO	<i>Lomatium foeniculaceum</i>	biscuitroot, carrot-leaf desert-parsley	
	MUDI	<i>Musineon divaricatum</i>	leafy musineon, leafy wild parsley	
Asclepiadaceae	ASPU	<i>Asclepias pumila</i>	low milkweed, plains milkweed	
	ASSP	<i>Asclepias speciosa</i>	showy milkweed	
	ASVE	<i>Asclepias verticillata</i>	whorled milkweed	
	ASVI	<i>Asclepias viridiflora</i>	green comet milkweed, green milkweed	
Asteraceae	ACMI2	<i>Achillea millefolium</i>	common yarrow, western yarrow	
	ARCA13	<i>Artemisia cana</i>	silver sagebrush	
	ARDR4	<i>Artemisia dracunculus</i>	tarragon, green sagewort, wormwood	
	ARFR4	<i>Artemisia frigida</i>	fringed sagebrush, prairie sagewort	
	ARLU	<i>Artemisia ludoviciana</i>	cudweed sagewort, white sagebrush	
	BREU	<i>Brickellia eupatorioides</i>	false boneset	
	CIAR4	<i>Cirsium arvense</i>	Canada thistle	*
	CICA11	<i>Cirsium canescens</i>	Platte thistle, prairie thistle	
	CIUN	<i>Cirsium undulatum</i>	gray thistle, wavy-leaf thistle	
	COCA5	<i>Conyza canadensis</i>	Canada horseweed, horseweed	
	DYPA	<i>Dyssodia papposa</i>	dogbane dyssodia, fetid marigold	
	ECAN2	<i>Echinacea angustifolia</i>	Blacksamson, blacksamson echinacea	
	ERNA10	<i>Ericameria nauseosa</i>	rubber rabbitbrush	
	ERCA4	<i>Erigeron canus</i>	hoary fleabane	
	ERPU2	<i>Erigeron pumilus</i>	low daisy, low fleabane	
	ERST3	<i>Erigeron strigosus</i>	prairie fleabane, rough fleabane	
	GRSQ	<i>Grindelia squarrosa</i>	curleycup gumweed	
	GUSA2	<i>Gutierrezia sarothrae</i>	broom snakeweed	
	HEAN3	<i>Helianthus annuus</i>	annual sunflower, common sunflower	
	HEMA2	<i>Helianthus maximiliani</i>	Maximilian sunflower, Maximilian sunflower	
	HEVI4	<i>Heterotheca villosa</i>	hairy false goldaster	
	LASE	<i>Lactuca serriola</i>	prickly lettuce, wild lettuce	*
	LIPU	<i>Liatris punctata</i>	dotted blazing star, dotted gayfeather	
	MUOB99	<i>Mulgedium oblongifolium</i>	blue lettuce, blue wild lettuce	
	RACO3	<i>Ratibida columnifera</i>	prairie coneflower, Mexican hat	

Family	Species Code	Scientific Name	Common Name	Exotic
	SOMI2	<i>Solidago missouriensis</i>	Missouri goldenrod, prairie goldenrod	
	SONE	<i>Solidago nemoralis</i>	dyersweed goldenrod, gray goldenrod	
	SORI2	<i>Solidago rigida</i>	stiff goldenrod	
	SYER	<i>Symphyotrichum ericoides</i>	white heath aster	
	SYOB	<i>Symphyotrichum oblongifolium</i>	aromatic aster	
	TAOF	<i>Taraxacum officinale</i>	common dandelion, dandelion	*
	TEAC	<i>Tetraneuris acaulis</i>	stemless four-nerve-daisy	
	TRDU	<i>Tragopogon dubius</i>	common salsify, goat's beard	*
	XASP99	<i>Xanthisma spinulosum</i>	lacy tansyaster, spiny goldenweed	
	XAST	<i>Xanthium strumarium</i>	cocklebur	
Boraginaceae	CRCE	<i>Cryptantha celosioides</i>	buttecandle, minerscandle	
	LAOC3	<i>Lappula occidentalis</i>	flatspine stickseed, western sticktight	
	LASQ	<i>Lappula squarrosa</i>	bristly sheepburr, European stickseed	*
	LIIN2	<i>Lithospermum incisum</i>	fringed gromwell, fringed puccoon	
Brassicaceae	ARHI	<i>Arabis hirsuta</i>	hairy rockcress	
	ERAS2	<i>Erysimum asperum</i>	western wallflower	
	ERIN7	<i>Erysimum inconspicuum</i>	shy wallflower, smallflower wallflower	
	LEDE	<i>Lepidium densiflorum</i>	common pepperweed	
	PHLU99	<i>Physaria ludoviciana</i>	foothill bladderpod, silver bladderpod	
	SIAL2	<i>Sisymbrium altissimum</i>	tumblemustard, tumbleweed mustard	*
	THAR5	<i>Thlaspi arvense</i>	pennycress, stinkweed	*
Cactaceae	ESMI3	<i>Escobaria missouriensis</i>	Missouri foxtail cactus	
	OPFR	<i>Opuntia fragilis</i>	brittle cactus, brittle pricklypear	
	OPMA2	<i>Opuntia macrorhiza</i>	grassland pricklypear	
	OPPO	<i>Opuntia polyacantha</i>	plains pricklypear	
Caprifoliaceae	SYOC	<i>Symphoricarpos occidentalis</i>	western snowberry, wolfberry	
Caryophyllaceae	SIAN2	<i>Silene antirrhina</i>	catchfly, sleepy campion	
Chenopodiaceae	ATAR2	<i>Atriplex argentea</i>	silverscale, silverscale saltbush	
	ATCA2	<i>Atriplex canescens</i>	fourwing saltbush	
	CHAL7	<i>Chenopodium album</i>	lambsquarters, white goosefoot	*
	CHFR3	<i>Chenopodium fremontii</i>	Fremont goosefoot	
	HAGL	<i>Halogeton glomeratus</i>	barilla, halogeton, saltlover	*
	MONU	<i>Monolepis nuttalliana</i>	Nuttall's poverty-weed	
	SATR12	<i>Salsola tragus</i>	prickly Russian thistle	*
Commelinaceae	TRBR	<i>Tradescantia bracteata</i>	bracted spiderwort	
	TROC	<i>Tradescantia occidentalis</i>	prairie spiderwort, spiderwort	
Convolvulaceae	COAR4	<i>Convolvulus arvensis</i>	field bindweed, morningglory	*
Cyperaceae	CABR10	<i>Carex brevior</i>	fescue sedge, shortbeak sedge	
	CADU6	<i>Carex duriuscula</i>	needleleaf sedge, spike-rush sedge	

Family	Species Code	Scientific Name	Common Name	Exotic
	CAFI	<i>Carex filifolia</i>	threadleaf sedge	
	CAIN9	<i>Carex inops</i>	long-stolon sedge, sun sedge	
	CAPR5	<i>Carex praegracilis</i>	clustered field sedge, slim sedge	
	ELCO2	<i>Eleocharis compressa</i>	flat-stem spike-rush	
Euphorbiaceae	EUMA7	<i>Euphorbia maculata</i>	spotted sandmat	
	EUMA8	<i>Euphorbia marginata</i>	smoke-on-the-prairie, variegated spurge	
	EUMI5	<i>Euphorbia missurica</i>	prairie sandmat	
	EUSE4	<i>Euphorbia serpens</i>	matted sandmat	
	EUSE5	<i>Euphorbia serpyllifolia</i>	thymeleaf sandmat	
	EUST4	<i>Euphorbia stictospora</i>	slimseed sandmat	
Fabaceae	AMCA6	<i>Amorpha canescens</i>	leadplant, leadplant amorpha	
	ASGI5	<i>Astragalus gilviflorus</i>	plains milk-vetch, plains milkvetch	
	ASMI10	<i>Astragalus missouriensis</i>	Missouri milk-vetch, Missouri milkvetch	
	ASMO7	<i>Astragalus mollissimus</i>	purple locoweed, wooly locoweed	
	ASMU99	<i>Astragalus multiflorus</i>	loose-flower milk-vetch	
	ASPL2	<i>Astragalus plattensis</i>	Platte milkvetch	
	ASRA2	<i>Astragalus racemosus</i>	alkali poisonvetch, cream milk-vetch	
	DAAU	<i>Dalea aurea</i>	golden dalea, golden prairie clover	
	DACA7	<i>Dalea candida</i>	slender white prairieclover, white dalea	
	DAPU5	<i>Dalea purpurea</i>	purple prairieclover, violet dalea	
	GLLE3	<i>Glycyrrhiza lepidota</i>	American licorice, licorice, wild licorice	
	LAPO2	<i>Lathyrus polymorphus</i>	manystem pea, manystem peavine	
	LUPU	<i>Lupinus pusillus</i>	low lupine, rusty lupine, small lupine	
	MESA	<i>Medicago sativa</i>	alfalfa	*
	MEOF	<i>Melilotus officinalis</i>	yellow sweet-clover, yellow sweetclover	*
	OXLA3	<i>Oxytropis lambertii</i>	Lambert crazyweed	
	PEAR6	<i>Pedimelum argophyllum</i>	Indian breadroot, silverleaf scurfpea	
	PEES	<i>Pedimelum esculentum</i>	breadroot scurfpea, Indian breadroot	
	PSTE5	<i>Psoralidium tenuiflorum</i>	scurfpea, slimflower scurfpea	
	VIAM	<i>Vicia americana</i>	American deervetch, American vetch	
Iridaceae	SIAN3	<i>Sisyrinchium angustifolium</i>	narrowleaf blue-eyed grass	
Lamiaceae	HEHI	<i>Hedeoma hispida</i>	false pennyroyal	
	NECA2	<i>Nepeta cataria</i>	catmint, catnip, catwort, field balm	*
	SARE3	<i>Salvia reflexa</i>	blue sage, lambsleaf sage	
Liliaceae	ALTE	<i>Allium textile</i>	prairie onion, textile onion, wild onion	
Linaceae	LIRI	<i>Linum rigidum</i>	orange flax, stiff flax, stiffstem flax	
Malvaceae	SPCO	<i>Sphaeralcea coccinea</i>	scarlet globemallow	
Melanthiaceae	TOVE2	<i>Toxicoscordion venenosum</i>	meadow deathcamas	
Nyctaginaceae	MILI3	<i>Mirabilis linearis</i>	linearleaf four-o'clock	
Onagraceae	OEBI	<i>Oenothera biennis</i>	common evening primrose	

Family	Species Code	Scientific Name	Common Name	Exotic
	OECE2	<i>Oenothera cespitosa</i>	tufted evening primrose	
	OESU99	<i>Oenothera suffrutescens</i>	scarlet beeblossom	
Oxalidaceae	OXDI2	<i>Oxalis dillenii</i>	slender yellow woodsorrel	
	OXST	<i>Oxalis stricta</i>	common yellow oxalis	
Plantaginaceae	PLPA2	<i>Plantago patagonica</i>	woolly Indianwheat, woolly plantain	
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 three-awn	
	BOCU	<i>Bouteloua curtipendula</i>	sideoats grama	
	BODA2	<i>Bouteloua dactyloides</i>	buffalograss	
	BOGR2	<i>Bouteloua gracilis</i>	blue grama	
	BRIN2	<i>Bromus inermis</i>	awnless brome, smooth brome	*
	BRJA	<i>Bromus japonicus</i>	Japanese brome	*
	BRTE	<i>Bromus tectorum</i>	cheat grass, downy brome	*
	CALO	<i>Calamovilfa longifolia</i>	prairie sandreed	
	DASP2	<i>Danthonia spicata</i>	poverty danthonia, poverty oatgrass	
	DISP	<i>Distichlis spicata</i>	desert saltgrass, inland saltgrass	
	ELEL5	<i>Elymus elymoides</i>	bottlebrush squirreltail, squirreltail	
	ELRE4	<i>Elymus repens</i>	quackgrass	*
	ELTR7	<i>Elymus trachycaulus</i>	slender wheatgrass, slender wild rye	
	HECO26	<i>Hesperostipa comata</i>	needle-and-thread grass	
	HOJU	<i>Hordeum jubatum</i>	foxtail barley	
	HOPU	<i>Hordeum pusillum</i>	little barley, little wildbarley	
	KOMA	<i>Koeleria macrantha</i>	junegrass, prairie Junegrass	
	MUCU3	<i>Muhlenbergia cuspidata</i>	plains muhly	
	MUPA99	<i>Muhlenbergia paniculata</i>	tumblegrass	
	NAVI4	<i>Nassella viridula</i>	green needlegrass	
	PACA6	<i>Panicum capillare</i>	annual witchgrass, common panic grass	
	PAVI2	<i>Panicum virgatum</i>	switchgrass	
	PASM	<i>Pascopyrum smithii</i>	western wheatgrass	
	POCO	<i>Poa compressa</i>	Canada bluegrass, flat-stem blue grass	*
	POPR	<i>Poa pratensis</i>	Kentucky bluegrass	*
	POSE	<i>Poa secunda</i>	big bluegrass, Sandberg bluegrass	
	SCSC	<i>Schizachyrium scoparium</i>	little bluestem	
	SPCO16	<i>Sporobolus compositus</i>	composite dropseed	
	SPCR	<i>Sporobolus cryptandrus</i>	sand dropseed	
Polemoniaceae	PHAN4	<i>Phlox andicola</i>	prairie phlox	
	PHHO	<i>Phlox hoodii</i>	Hood's phlox, spiny phlox	
Polygalaceae	POAL4	<i>Polygala alba</i>	white milkwort	

Family	Species Code	Scientific Name	Common Name	Exotic
Polygonaceae	ERPA9	<i>Eriogonum pauciflorum</i>	few-flower wild buckwheat	
	POAV	<i>Polygonum aviculare</i>	prostrate knotweed, yard knotweed	*
Ranunculaceae	DECA3	<i>Delphinium carolinianum</i>	Carolina larkspur	
Rosaceae	PRVI	<i>Prunus virginiana</i>	chokecherry	
	ROAR3	<i>Rosa arkansana</i>	Arkansas rose, prairie rose	
	ROBL	<i>Rosa blanda</i>	smooth rose	
Santalaceae	COUM	<i>Comandra umbellata</i>	bastard toadflax	
Scrophulariaceae	PEER	<i>Penstemon eriantherus</i>	fuzzytongue penstemon	
	SYWY99	<i>Synthyris wyomingensis</i>	Wyoming besseya	
Solanaceae	PHLO4	<i>Physalis longifolia</i>	common groundcherry	
	PHVI5	<i>Physalis virginiana</i>	lanceleaf groundcherry	
	SOTR	<i>Solanum triflorum</i>	cut-leaf nightshade, cutleaf nightshade	
Unknown Family	UNKFORB	Unknown forb	unknown forb	*
Verbenaceae	VEBR	<i>Verbena bracteata</i>	bigbract verbena, bracted vervain,	
	VEST	<i>Verbena stricta</i>	hoary verbena, woolly 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 137/119660, January 2013

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