



Plant Community Composition and Structure Monitoring for Devils Tower National Monument

2012 Annual Report

Natural Resource Technical Report NPS/NGPN/NRTR—2013/685



ON THE COVER

Student Conservation Association intern, Dana Vesty, and biological technicians, Daina Jackson, Ryan Manuel, and Heather Rietz, surveying plant diversity at a long-term monitoring plot in Devils Tower 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

Devils Tower National Monument (DETO) protects not only the impressive rock tower, but also the ponderosa woodlands, mixed-grass prairies, and riparian plant communities within its boundaries. The Northern Great Plains Inventory & Monitoring Network and Fire Ecology Program surveyed 14 long-term monitoring plots in DETO in 2012 as part of an effort to better understand the condition of plant communities in the park. We measured plant diversity and cover, tree density, and fuel loads, 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 DETO. At the end of five years, there will be an in-depth report describing the status of the plant community. In 2013, there will be a large survey completed in the park to estimate the condition of the ponderosa and riparian forests. In this report, we provide a simple summary of our results from sampling in 2012.

We found DETO to be characterized by moderate native species richness and high exotic species cover. Of 14 sites, there were none that were less than 10% cover. Kentucky bluegrass was the most widespread and abundant exotic species. Leafy spurge was also common, but it was found in low abundance. Allowing natural disturbances such as fire, grazing, and prairie dog use may be critical to maintaining plant diversity and forest condition in DETO, 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 DETO.

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 DETO, particularly Angela Wetz for providing logistical support and safety checks. We thank DETO staff Dana Vesty, Heather Rietz, and Russell Kuhlman for help in the field. The 2012 NGPN vegetation field crew of Isabel Ashton, Daina Jackson, Ryan Manuel, 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 the Fire Ecology 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

The Black Hills is a 1.5 million hectare refuge of ponderosa pine (*Pinus ponderosa*) forest surrounded by the prairies of western South Dakota and eastern Wyoming. The ponderosa pine forest of the Black Hills is a unique ecosystem composed of species from the western Rocky Mountains, eastern deciduous forests, northern boreal forests, and the surrounding Great Plains (Larson and Johnson 2007). The National Park Service (NPS) plays an important role in preserving and restoring ponderosa woodlands 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 and fire, that have historically maintained ponderosa woodlands, and there is the continual pressure of exotic invasive species. In recent years, mountain pine beetle (*Dendroctonus ponderosae*) outbreaks have been of particular concern because they are increasing throughout the Black Hills and have caused 100% mortality of ponderosa pines in some areas (Hocking et al. 2010). Long-term monitoring in national parks is essential to sound management of ponderosa woodlands because it can provide information on environmental quality and condition, benchmarks of ecological integrity, and early warning of declines in ecosystem health.

Devils Tower National Monument (DETO) was established in 1906 as the first National Monument with a mission to protect and preserve the impressive rock tower and the lands around it. It is located in northeastern Wyoming on the edge of the Black Hills. The vegetation is a mosaic of ponderosa pine woodlands and mixed-grass prairie with a narrow riparian corridor of cottonwoods. The prevalence of exotic species in the park, changes in ponderosa pine density due to historic fire suppression, and the lack of cottonwood regeneration are of concern to park management and result in a fairly poor overall condition of native plant communities in the park (Komp et al. 2011). The Northern Great Plains Inventory & Monitoring Program (NGPN) began vegetation monitoring at DETO 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 DETO 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 park-wide status and long-term trends of tree density by species, height class, and diameter class, and of fuel loads by fuel classes.
3. Determine status (at 5-year intervals) and long-term trends of tree density by species, height class, and diameter class in lowland areas near targeted perennial streams.
4. 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 DETO in 2012, our second year of sampling. NGPN visited 8 plots and FireEP visited 6 plots (Figure 1). Not all plots are visited every year and it will take 3 more years to visit every plot in the park. A large survey of ponderosa and riparian forest condition will take place in 2013 and every 5 years thereafter. We expect to produce reports with more in-depth data analysis and interpretation when we complete 5 years of sampling and after the survey of forest condition. In the interim, reports, spatial data, and data summaries can be provided for park management and interpretation upon request.

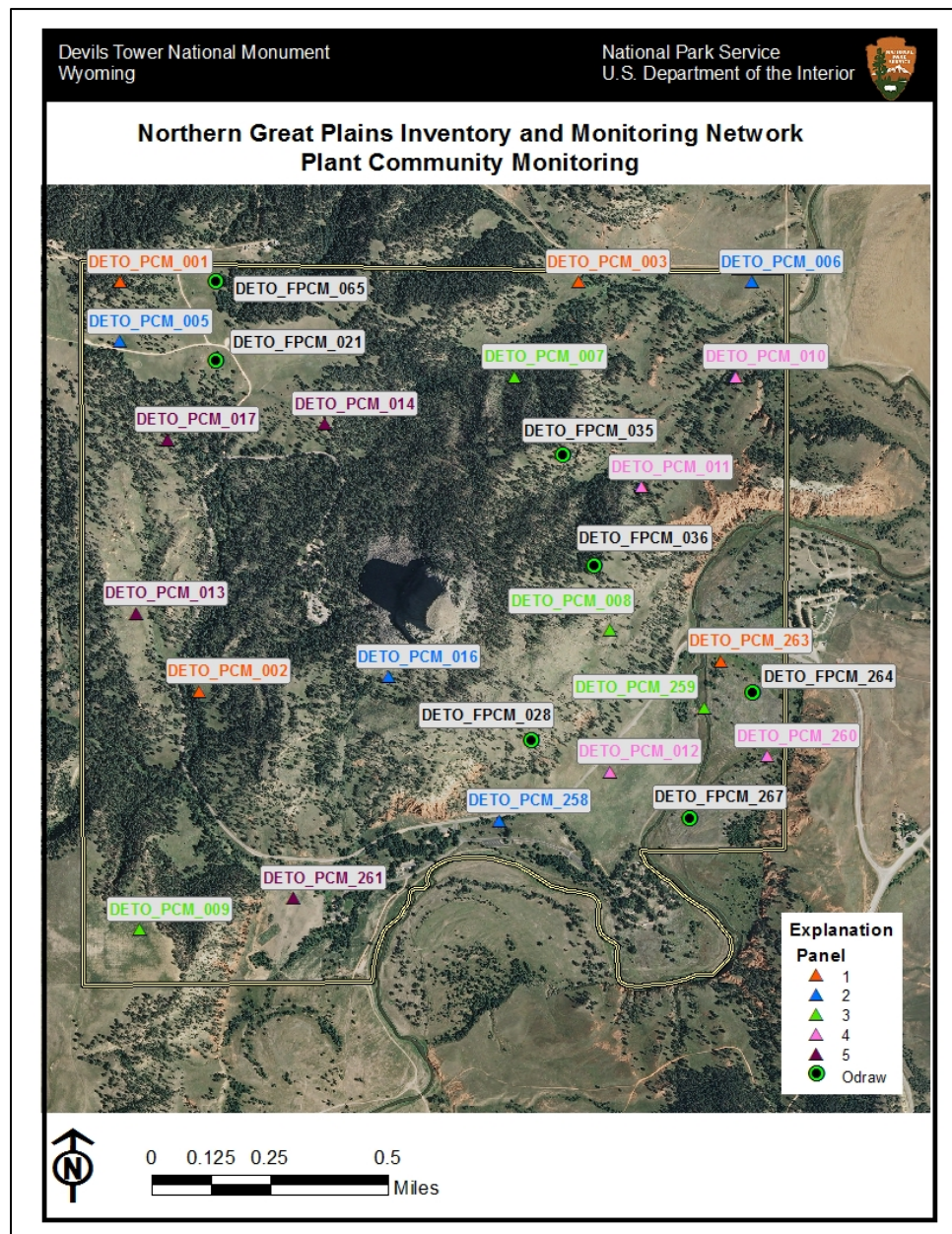


Figure 1. Map of Devils Tower National Monument (DETO) plant community monitoring (PCM) and fire community monitoring plots (FPCM). Plots from panel 1 (orange) and panel 2 (blue) and PCM_008, PCM_011, FPCM_021, FPCM_035, FPCM_036, and FPCM_065 were visited in 2012.

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.cfm>.

Sample design

NGPN and FireEP implemented a survey to monitor plant community structure and composition in DETO 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 DETO. We split these 20 sites into 5 panels with 4 sites each. We visit 2 panels (8 sites) every year, and after 5 years we will have visited all sites twice. In 2012, we visited sites in panel 1 and panel 2 (Figure 1) during the last 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.

The FireEP aims to understand how prescribed and wildland fires affect 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 first 20 plots or the scheduled visits that fall within burn units. For this reason, the initial GRTS designs included many more sites that can be visited as needed by NGPN or FireEP. These extra sites are referred to as ‘overdraws’. In 2012, FireEP visited 2 plant community monitoring sites from panel 2 and 4 (PCM_008 and PCM_011) and 4 overdraw sites (FPCM_021, FPCM_035, FPCM_036, and FPCM_065; Figure 1).

Plot layout and sampling

At each of the 14 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 8 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 the 8 plots at DETO took NGPN’s 4-person crew approximately 105 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 are mapped and tagged. For each tree, the species, DBH, status, and condition (e.g., leaf-discoloration, insect-damaged, etc.) are recorded. In ponderosa pine woodlands, dead and downed woody fuel load data are collected on two perpendicular 100 ft (30.48 m) transects centered at the center of the plot (Figure 2). Using these methods, a more thorough assessment of forest structure and health and fuel loads (75 plots) is scheduled to be conducted in 2013.

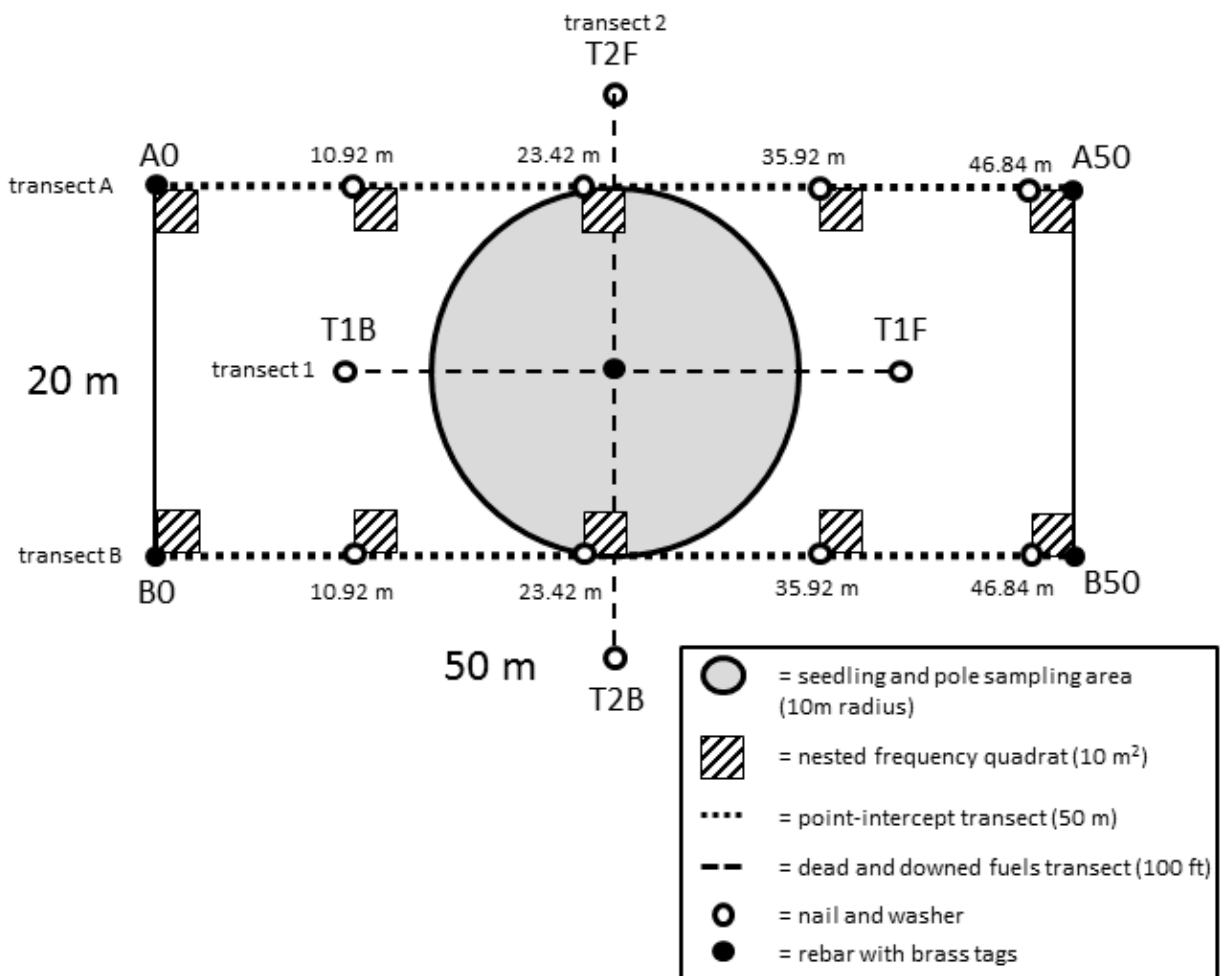


Figure 2. Long-term monitoring plot used for sampling vegetation in Devils Tower National Monument.

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 Wyoming, and may occur in DETO. The DETO target species list for 2012 can be found in Table 1.

Table 1. Exotic species of management concern at Devils Tower 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>Arctium minus</i>	common burdock	<i>Asclepias verticillata</i>	whorled milkweed
<i>Bromus tectorum</i>	cheatgrass	<i>Carex alopecoidea</i>	foxtail sedge
<i>Carduus nutans</i>	musk thistle	<i>Carex emoryi</i>	Emory's sedge
<i>Centaurea stoebe</i>	spotted knapweed	<i>Diaperia prolifera</i>	bighead pygmy cudweed
<i>Cirsium arvense</i>	Canada thistle	<i>Dichanthelium wilcoxianum</i>	fall rosette grass
<i>Cirsium vulgare</i>	bull thistle	<i>Elymus villosus</i>	hairy wildrye
<i>Convolvulus arvensis</i>	field bindweed	<i>Glandularia bipinnatifida</i>	Dakota (mock) vervain
<i>Cynoglossum officinale</i>	houndstongue	<i>Helianthemum bicknellii</i>	hoary frostweed
<i>Elaeagnus angustifolia</i>	Russian olive	<i>Oenothera laciniata</i>	cutleaf evening primrose
<i>Euphorbia esula</i>	leafy spurge	<i>Polystichum lonchitis</i>	holly fern
<i>Linaria dalmatica</i>	Dalmatian toadflax	<i>Verbesina enceliodes</i>	cowpen crownbeard
<i>Linaria vulgaris</i>	yellow toadflax		
<i>Onopordum acanthium</i>	Scotch thistle		
<i>Rhaponticum repens</i>	Russian knapweed		
<i>Poa bulbosa</i>	bulbous bluegrass		
<i>Salsola tragus</i>	Russian thistle		
<i>Tamarix</i> spp.	tamarisk		
<i>Tanacetum vulgare</i>	common tansy		
<i>Verbascum thapsus</i>	common mullein		

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, annual brome cover, fuel loads, and tree density. 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>).

Condition Status		Trend in Condition		Confidence in Assessment	
	Condition of resource warrants significant concern		Condition is Improving		High confidence in the assessment
	Condition of resource warrants moderate concern		Condition is Unchanging		Medium confidence in the assessment
	Resource is in good condition		Condition is Deteriorating		Low confidence in the assessment

Results and Discussion

Understory plant community composition and structure

The vegetation at DETO suffered from a very dry winter and spring and when the field crews visited the park in late June, there was less green vegetation than in previous years (Figure 3). Average canopy cover was 119% (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 92% plant litter). Despite the dry conditions, NGPN and FireEP found 129 plant species in 2012 at DETO (Appendix B). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at DETO, but forbs were also abundant (Figure 4).



Figure 3. A vegetation transect at plot PCM_002 in Devils Tower National Monument in 2011 (top panel) and 2012 (bottom panel). Both photographs were taken in early summer and show the dramatic reduction in moisture available in 2012.

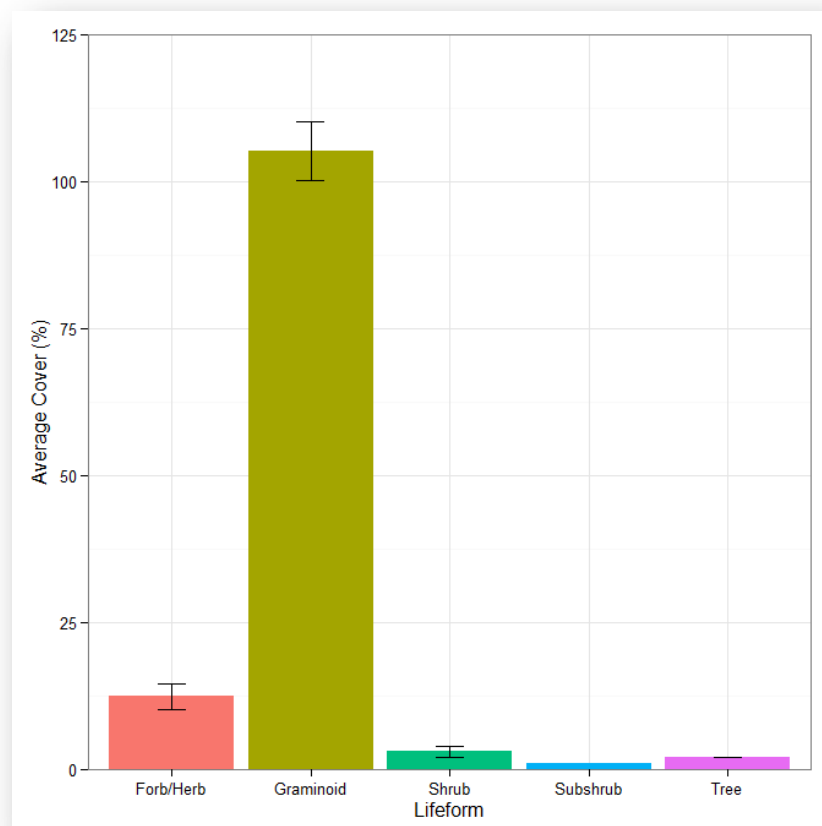
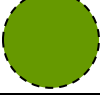
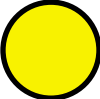
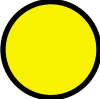
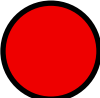
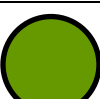


Figure 4. Average cover by life forms in 14 plant community monitoring plots in Devils Tower National Monument in 2012. Bars represent means $\pm$ standard errors. Graminoids were the most abundant life-form across all the plots at DETO.

There was a great deal of variation in species composition across the 14 sites. The most common species found from the point-intercept method were graminoids (Figure 5), with the only exception being white sagebrush (*Artemisia ludoviciana*). Kentucky bluegrass (*Poa pratensis*), an exotic grass, was found at all sites. Western wheatgrass (*Pascopyrum smithii*) and big bluestem (*Andropogon gerardii*) were the next most common, both found at 12 of 14 sites. We encountered one rare plant, fall rosette grass (*Dichanthelium wilcoxianum*) in site PCM_016 (Figure 6). This grass is fairly rare in the state, but not rare enough to be considered a species of concern by the Wyoming Natural Diversity Database (Fertig 2000).

Species richness varies with the scale on which 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).

Table 3. Natural resource condition summary table for upland plant communities in Devils Tower National Monument (DETO).

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	119 $\pm$ 5.7 %	TBD		DETO protects not only the impressive rock tower, but also the ponderosa woodlands, mixed-grass prairies and riparian plant communities within its boundaries. Dry conditions tended to reduce understory plant diversity in 2012 but it was within the natural range of variability for mixed-grass prairie. Forest density was fairly high, but varied across the park, and some areas had no trees. At this time, condition assessments for canopy cover and evenness, and forest density are 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 -18 species ⁽¹⁾		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.74 $\pm$ 0.02	TBD		
	Forest overstory density	136 $\pm$ 67 stems/ha	TBD		
Forest Insects and Disease	Percent of park with mountain pine beetle infestations >1 infested tree per hectare (%)	0	0		DETO is on the edge of the Black Hills, where mountain pine beetles have risen to epidemic levels in many areas. During 2012, we found no indication of mountain pine beetles in our plots. However, since mountain pine beetles are present in the park they are a significant concern to park managers.
Fire and Fuel Dynamics	Total fuel loads	11 $\pm$ 3.7 tons/acre	Between 2 and 10		The current fire ecology program aims to maintain fuel loads of less than 10 tons/acre. The average value seen in DETO is above this level but there was a great deal of variation across sites. Continued fire management will be necessary to maintain low fuel loads.
Exotic Plant Early Detection and Management	Relative cover of exotic species	42 $\pm$ 6.6 %	< 10 % cover		Exotic species pose a major challenge to DETO park management. Average cover of exotic species is high and there were no sites that fell below the management threshold of less than 10% cover. Kentucky bluegrass was the most widespread and abundant exotic species. Leafy spurge was also common, but it was found in low abundance.
	Annual brome cover	2.4 $\pm$ 0.9 %	< 10 % cover		

1. 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.

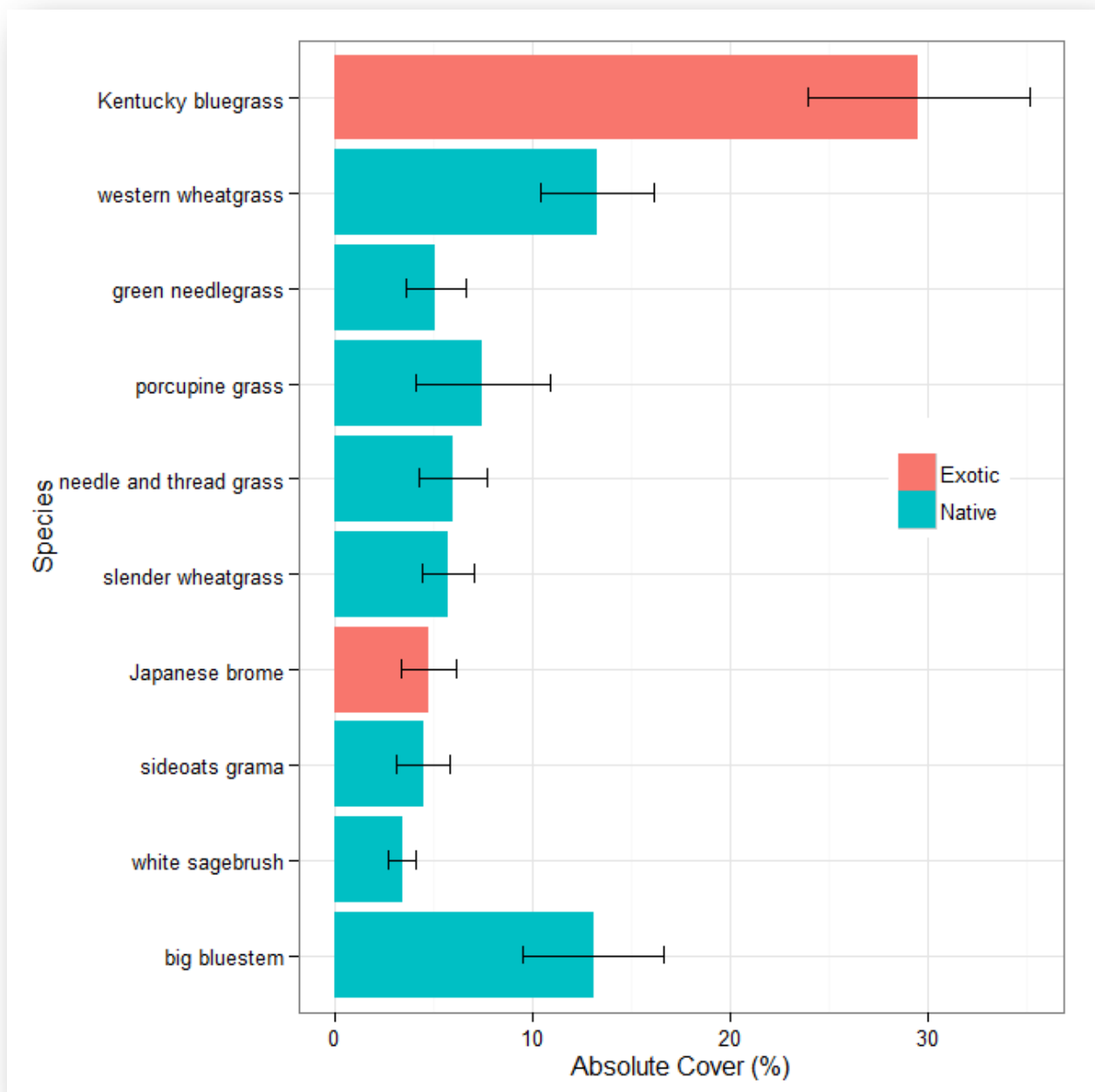


Figure 5. The average absolute cover of the 10 most common native (blue) and exotic (red) plants recorded at 14 sites at Devils Tower National Monument in 2012. Bars represent means $\pm$ standard errors.



Figure 6. The rare fall rosette grass, *Dichanthelium wilcoxianum* (left panel), found at plant community monitoring site (PCM_016; right panel) in Devils Tower National Monument, 2012.

From the point-intercept data, we found average plot diversity, H' , to be 2.1 ± 0.10 . Evenness, J' , averaged 0.74 ± 0.02 across the plots (Table 3). When including only native species, average diversity and evenness were 2.0 ± 0.12 and 0.79 ± 0.03 , respectively. 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). Along with species composition, species richness also varied across sites (Table 5). The plot with the lowest native diversity, PCM_263, was within the riparian corridor, and the lower portion was dominated by quackgrass (*Elymus repens*). Long-term records of species diversity in mixed-grass prairie in a moderately grazed site in Montana ranged between 8 and 18 species per square meter (10-90th percentile range) between 1933-1945 and the range for a relatively undisturbed site in Kansas from 1932-1972 was between 3 and 15 species per square meter (Symstad and Jonas, *in press*). Native species richness in the 1m² quadrats at DETO dropped by 2 species in 2012 compared to 2011 (Ashton et al. 2012) but was still within the range of natural variability despite dry conditions.

Table 4. Average plant species richness plant community monitoring plots at Devils Tower National Monument in 2012. Values represent means $\pm$ standard errors, n=14 for the point-intercept and n=8 for the quadrats.

	Point-intercept	1 m ² quadrats	10 m ² quadrats
Species richness	16 $\pm$ 1.3	7 $\pm$ 0.5	12 $\pm$ 1.2
Native species richness	13 $\pm$ 1.3	5 $\pm$ 0.6	9 $\pm$ 1.2
Exotic species richness	4 $\pm$ 0.4	2 $\pm$ 0.3	3 $\pm$ 0.5
Graminoid species richness	10 $\pm$ 0.7	4 $\pm$ 0.3	6 $\pm$ 0.4
Forb species richness	6 $\pm$ 0.8	3 $\pm$ 0.2	7 $\pm$ 0.5

The average relative cover of exotic species at sites in DETO was high (42%) and exotic species were present at all the sites visited (Table 5). The two sites closest to the river (PCM_258 and PCM_263) and the sites close to park boundaries (PCM_005, PCM_006, and PCM_003) had higher exotic cover than other sites. Much of the exotic cover was from Kentucky bluegrass (Table 5). 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). Overall, cover of annual bromes in DETO was fairly low at 2.4%, and there were many sites with no bromes present (Table 5). Leafy spurge is a problematic invader in DETO and was quite common. It appeared at 9 plots (Table 6), but it was found in low abundance. From the point-intercept data, we found it to average less than 1% cover across the plots.

Our results showing such high cover of exotic species is consistent with past data from DETO. In a 2003 mapping project, it was estimated that between 59-67% of the park was infested with targeted exotic species but much of this was light densities (Wood and Rew 2005). At that time, the most abundant exotic was leafy spurge, but they did not estimate the cover of Kentucky bluegrass. Other species of management concern, including houndstongue and Canada thistle (Table 6), were found scattered across the park.

Table 5. Characteristics of the plant community in 14 plots at Devils Tower National Monument 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 (%)	Kentucky bluegrass cover (%)	Disturbance within site (m ²)
DETO_FPCM_021	-	43	3	38	-
DETO_FPCM_035	-	11	2	10	-
DETO_FPCM_036	-	15	4	10	-
DETO_FPCM_065	-	43	2	40	-
DETO_PCM_001	7	13	0	13	21
DETO_PCM_002	7	29	2	23	0
DETO_PCM_003	6	77	0	16	15
DETO_PCM_005	5	65	4	58	10
DETO_PCM_006	6	66	0	37	1145
DETO_PCM_008	-	27	2	17	-
DETO_PCM_011	-	22	0	18	-
DETO_PCM_016	6	28	12	15	2290
DETO_PCM_258	4	81	1	20	457
DETO_PCM_263	2	62	1	17	530
Site Average	5 ± 0.6	42 ± 6.5 %	2.4 ± 0.85%	24± 3.8%	

Table 6. Cover class of target species at 9 plots at DETO in 2011. 1 = one individual, 2 = few individuals, 3 = cover 1-5% of site, 4 = cover 5-25% of site, 5 = cover > 25% of site, present = present at site but cover was not assessed. We did not find target exotics at 5 plots.

Site	Canada Thistle	Cheatgrass	Houndstongue	Leafy spurge	Mullein
DETO_FPCM_036	-	-	-	present	-
DETO_PCM_002	-	-	-	present	-
DETO_PCM_005	-	-	-	2	-
DETO_PCM_006	-	-	-	present	-
DETO_PCM_008	-	-	present	present	-
DETO_PCM_011	present	-	-	present	-
DETO_PCM_016	2	present	-	3	2
DETO_PCM_258	-	present	2	3	-
DETO_PCM_263	2	present	2	3	-

Disturbance from grazing, rodents, fire, and humans affects plant community structure and composition in mixed-grass prairie and ponderosa woodlands. For this reason, we measured the approximate area affected by natural and human disturbances at each site we visited. In 2012, the type of disturbance varied and included fire, animal trails, small mammal excavations, storm damage, and off-road vehicles. PCM_016 had the largest area of disturbance because it was recently burned. In the future, when we have collected more data from the park we may be able to estimate how disturbances affect species diversity.

Tree density and fuel loads

Trees or seedlings were found in 11 of the 14 plots visited in 2012; the 3 plots without trees were PCM_005, PCM_006, and FPCM_065. Ponderosa pine was the most common tree species, appearing in 9 of the 11 forested plots (Table 7). PCM_263 was close to the river and had no trees but a high density of boxelder (13,495 stems ha⁻¹) and cottonwood seedlings (10,185 stems ha⁻¹). PCM_003 was intersected by a small grove of bur oak trees (80 stems ha⁻¹) with a good density of oak seedlings in the understory (3183 stems ha⁻¹). In most plots, all trees were healthy, but in PCM_011 and PCM_036 a number of trees showed signs of insect damage. There was no indication of mountain pine beetles in any of the sites (Table 3). When examining all the sites with trees present, we found forest density to be 136 stems ha⁻¹ (Table 3).

Table 7. Live ponderosa pine density by size class at 9 forested plots at DETO in 2012.

Plot	Ponderosa Pine (stems hectare ⁻¹)		
	Seedlings	Poles	Trees
DETO_FPCM_021	-	-	32
DETO_FPCM_035	382	-	32
DETO_FPCM_036	1464	-	65
DETO_PCM_001	95	64	180
DETO_PCM_002	95	-	100
DETO_PCM_008	32	-	-
DETO_PCM_011	573	97	548
DETO_PCM_016	-	-	20
DETO_PCM_258	-	-	10

We measured fuel loads in 7 plots in 2012 and found the average total fuel load to be 11 tons acre⁻¹. There was a large range of fuel loads from 1 ton acre⁻¹ (PCM_002) to 29 ton acre⁻¹ (PCM_008). Litter and duff depth averaged 2.3 in and 3.8 in, respectively. The average fuel load we found is slightly higher than the FireEP target of less than 10 tons acre⁻¹, suggesting forest and fire management efforts should be continued to reduce fuels. A more thorough assessment of forest structure and fuels (including 75 forested sites) will be completed in 2013 at DETO. At that time, we will have more confidence in park-wide estimates of forest density and fuel loads.

Conclusions

In conclusion, we found that dry conditions tended to reduce understory plant diversity in 2012 but species richness was within the natural range of variability for mixed-grass prairie. Forest density was fairly high, but varied across the park, and some areas had no trees. 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. Leafy spurge, annual bromes, smooth brome, and Kentucky bluegrass present a large challenge to managing DETO. We found fuel loads to be slightly above the management target, and forest densities were high in some places. Allowing natural disturbances such as fire, grazing, and prairie dog use may be critical to maintaining plant diversity in DETO, 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 DETO.

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

Plant community composition monitoring in DETO was completed using a crew of 4 people working 3.5 10-hour days. We spent 105 total crew hours and used 17 hours of help from DETO staff.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed
Jun 4, 2012	Monday	2.5	DETO Campground	PCM-001 PCM-005
Jun 5, 2012	Tuesday	N/A	DETO Campground	PCM-002 PCM-263
Jun 6, 2012	Wednesday	N/A	DETO Campground	PCM-003 PCM-006 PCM-258
Jun 7, 2012	Thursday	2.5	N/A	PCM-016

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

A list of species found in DETO. The species in bold do not appear on the certified plant list.

Family	Species Code	Scientific Name	Common Name	Exotic
Aceraceae	ACNE2	<i>Acer negundo</i>	box elder	
Apocynaceae	APCA	<i>Apocynum cannabinum</i>	common dogbane	
Asclepiadaceae	ASPU	<i>Asclepias pumila</i>	low milkweed	
	ASST	<i>Asclepias stenophylla</i>	slimleaf milkweed	
Asteraceae	ACMI2	<i>Achillea millefolium</i>	common yarrow	
	AMPS	<i>Ambrosia psilostachya</i>	ragweed, western ragweed	
	ANMI3	<i>Antennaria microphylla</i>	littleleaf pussytoes	
	ANPA4	<i>Antennaria parvifolia</i>	small-leaf pussytoes	
	ARCA13	<i>Artemisia cana</i>	silver sagebrush	
	ARDR4	<i>Artemisia dracunculus</i>	tarragon, wormwood	
	ARFR4	<i>Artemisia frigida</i>	fringed sagewort,	
	ARLU	<i>Artemisia ludoviciana</i>	white sagebrush	
	BREU	<i>Brickellia eupatorioides</i>	false boneset	
	CIAR4	<i>Cirsium arvense</i>	Canada thistle	*
	CIUN	<i>Cirsium undulatum</i>	wavyleaf thistle	
	COCA5	<i>Conyza canadensis</i>	horseweed	
	ECAN2	<i>Echinacea angustifolia</i>	blacksamson echinacea	
	ERCA4	<i>Erigeron canus</i>	hoary fleabane	
	ERST3	<i>Erigeron strigosus</i>	prairie fleabane	
	GRSQ	<i>Grindelia squarrosa</i>	curlycup gumweed	
	GUSA2	<i>Gutierrezia sarothrae</i>	broom snakeweed	
	HEVI4	<i>Heterotheca villosa</i>	hairy false goldenaster	
	LASE	<i>Lactuca serriola</i>	prickly lettuce, wild lettuce	*
	LYJU	<i>Lygodesmia juncea</i>	rush skeleton-plant	
	RACO3	<i>Ratibida columnifera</i>	prairie coneflower	
	SONE	<i>Solidago nemoralis</i>	gray goldenrod	
	SYER	<i>Symphyotrichum ericoides</i>	white heath aster	
	SYFA	<i>Symphyotrichum falcatum</i>	white prairie aster	
	SYOB	<i>Symphyotrichum oblongifolium</i>	aromatic aster	
	TAOF	<i>Taraxacum officinale</i>	common dandelion	*
	TEAC	<i>Tetrameuris acaulis</i>	stemless four-nerve daisy	
	TRDU	<i>Tragopogon dubius</i>	common salsify	*
	XASP99	<i>Xanthisma spinulosum</i>	lacy tansyaster	
Berberidaceae	MARE11	<i>Mahonia repens</i>	Oregon grape	

Family	Species Code	Scientific Name	Common Name	Exotic
Boraginaceae	CYOF	<i>Cynoglossum officinale</i>	houndstongue	*
	LIIN2	<i>Lithospermum incisum</i>	narrowleaf puccoon	
	ONBE	<i>Onosmodium bejariense</i>	soft-hair marbleseed	
Brassicaceae	DEPI	<i>Descurainia pinnata</i>	green tansymustard	
	HEMA3	<i>Hesperis matronalis</i>	dame's rocket	*
	LEDE	<i>Lepidium densiflorum</i>	common pepperweed	
	SIAL2	<i>Sisymbrium altissimum</i>	tumble mustard	*
	THAR5	<i>Thlaspi arvense</i>	pennycress, stinkweed	*
	TUGL	<i>Turritis glabra</i>	tower-mustard	
Cactaceae	OPFR	<i>Opuntia fragilis</i>	brittle cactus	
Caprifoliaceae	SYOC	<i>Symphoricarpos occidentalis</i>	western snowberry	
Caryophyllaceae	CEAR4	<i>Cerastium arvense</i>	field chickweed	
Cyperaceae	CAREX	<i>Carex</i>	sedge	
	CAAQ	<i>Carex aquatilis</i>	water sedge	
	CABA3	<i>Carex backii</i>	back sedge, Back's sedge	
	CABR10	<i>Carex brevior</i>	brevior sedge, fescue sedge	
	CADU6	<i>Carex duriuscula</i>	needleleaf sedge	
	CAFI	<i>Carex filifolia</i>	dry-spike sedge	
	CAFO3	<i>Carex foenea</i>	threadleaf sedge	
	CAHO5	<i>Carex hoodii</i>	hood sedge, Hood's sedge	
	CAIN9	<i>Carex inops</i>	long-stolon sedge	
Equisetaceae	EQHY	<i>Equisetum hyemale</i>	horsetail, scouringrush	
Euphorbiaceae	EUES	<i>Euphorbia esula</i>	leafy spurge	*
	EUGL3	<i>Euphorbia glyptosperma</i>	ribseed sandmat	
Fabaceae	ASTRA	<i>Astragalus</i>	milkvetch	
	ASAG2	<i>Astragalus agrestis</i>	field milkvetch	
	ASFL2	<i>Astragalus flexuosus</i>	flexile milkvetch	
	ASLA27	<i>Astragalus laxmannii</i>	Laxmann's milkvetch	
	DALEA	<i>Dalea</i>	prairie clover	
	DACA7	<i>Dalea candida</i>	slender white prairie clover	
	DAPU5	<i>Dalea purpurea</i>	purple prairie clover	
	GLLE3	<i>Glycyrrhiza lepidota</i>	licorice, wild licorice	
	LUAR3	<i>Lupinus argenteus</i>	silvery lupine	
	MELU	<i>Medicago lupulina</i>	black medic	*
	MEOF	<i>Melilotus officinalis</i>	yellow sweet-clover	*
	OXSE	<i>Oxytropis sericea</i>	white locoweed	
	PEAR6	<i>Pedimelum argophyllum</i>	silverleaf Indian breadroot	
	PSLA3	<i>Psoraleidum lanceolatum</i>	dune scurfpea	

Family	Species Code	Scientific Name	Common Name	Exotic
Fabaceae	THRH	<i>Thermopsis rhombifolia</i>	goldenpea	
	VIAM	<i>Vicia americana</i>	American vetch	
Fagaceae	QUMA2	<i>Quercus macrocarpa</i>	bur oak	
Grossulariaceae	RIAU	<i>Ribes aureum</i>	golden currant	
Iridaceae	SIMO2	<i>Sisyrinchium montanum</i>	mountain blue-eyed grass	
Lamiaceae	HEHI	<i>Hedeoma hispida</i>	false pennyroyal	
	MEAR4	<i>Mentha arvensis</i>	field mint, wild mint	
Liliaceae	ALTE	<i>Allium textile</i>	prairie onion, textile onion	
Malvaceae	SPCO	<i>Sphaeralcea coccinea</i>	scarlet globemallow	
Melanthiaceae	TOVE2	<i>Toxicoscordion venenosum</i>	meadow deathcamas	
Oleaceae	FRPE	<i>Fraxinus pennsylvanica</i>	green ash	
Onagraceae	OESU99	<i>Oenothera suffrutescens</i>	scarlet beeblossom	
Pinaceae	PIPO	<i>Pinus ponderosa</i>	ponderosa pine	
Plantaginaceae	PLPA2	<i>Plantago patagonica</i>	woolly plantain	
Poaceae	AGCR	<i>Agropyron cristatum</i>	crested wheatgrass	*
	ANGE	<i>Andropogon gerardii</i>	big bluestem	
	ARPU9	<i>Aristida purpurea</i>	purple threeawn	
	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>	smooth brome	*
	BRJA	<i>Bromus japonicus</i>	Japanese brome	*
	BRTE	<i>Bromus tectorum</i>	cheatgrass, downy brome	*
	CALO	<i>Calamovilfa longifolia</i>	prairie sandreed	
	DASP2	<i>Danthonia spicata</i>	poverty oatgrass	
	DIWI5	<i>Dichanthelium wilcoxianum</i>	fall panicum, fall rosette grass	
	ELYMU	<i>Elymus</i>	wildrye	*
	ELGL	<i>Elymus glaucus</i>	blue wild rye, blue wildrye	
	ELRE4	<i>Elymus repens</i>	quackgrass	*
	ELTR7	<i>Elymus trachycaulus</i>	slender wheatgrass	
	FEID	<i>Festuca idahoensis</i>	Idaho fescue	
	FESA	<i>Festuca saximontana</i>	mountain fescue	
	HECO26	<i>Hesperostipa comata</i>	needle-and-thread grass	
	HESP11	<i>Hesperostipa spartea</i>	porcupinegrass	
	KOMA	<i>Koeleria macrantha</i>	junegrass, prairie Junegrass	
	MUCU3	<i>Muhlenbergia cuspidata</i>	plains muhly	
	NAVI4	<i>Nassella viridula</i>	green needlegrass	
	PASM	<i>Pascopyrum smithii</i>	western wheatgrass	

Family	Species Code	Scientific Name	Common Name	Exotic
Poaceae	POPR	<i>Poa pratensis</i>	Kentucky bluegrass	*
	PSSP6	<i>Pseudoroegneria spicata</i>	bluebunch-wheat grass	
	SCSC	<i>Schizachyrium scoparium</i>	little bluestem	
	SPCR	<i>Sporobolus cryptandrus</i>	sand dropseed	
	VUOC	<i>Vulpia octoflora</i>	sixweeks fescue	
Polemoniaceae	COLI2	<i>Collomia linearis</i>	slenderleaf collomia	
	PHAN4	<i>Phlox andicola</i>	prairie phlox	
	PHHO	<i>Phlox hoodii</i>	Hood's phlox, spiny phlox	
Ranunculaceae	ANCY	<i>Anemone cylindrica</i>	candle anemone	
	ANPA	<i>Anemone parviflora</i>	smallflowered anemone	
Rosaceae	PRAM	<i>Prunus americana</i>	American plum	
	ROAR3	<i>Rosa arkansana</i>	Arkansas rose, prairie rose	
Rubiaceae	GABO2	<i>Galium boreale</i>	northern bedstraw	
Salicaceae	PODE3	<i>Populus deltoides</i>	plains cottonwood	
Scrophulariaceae	PEGR5	<i>Penstemon gracilis</i>	lilac penstemon	
	SYWY99	<i>Synthyris wyomingensis</i>	Wyoming kittentails	
	VETH	<i>Verbascum thapsus</i>	common mullein	*
	VEPE2	<i>Veronica peregrina</i>	purslane speedwell	
Unknown Family	UNKFORB	<i>Unknown forb</i>	Unknown forb	*
Urticaceae	PAPE5	<i>Parietaria pensylvanica</i>	Pennsylvania pellitory	
Violaceae	VIOLA	<i>Viola</i>	violet	*
	VINU2	<i>Viola nuttallii</i>	Nuttall's violet	

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