



Plant Community Composition and Structure Monitoring for Theodore Roosevelt National Park

2013 Annual Report

Natural Resource Data Series NPS/NGPN/NRDS—2014/625



ON THE COVER

Theodore Roosevelt National Park, 2013

Photograph by: E. Moore, NPS

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

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

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

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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 North Dakota, greater than 71% of the area of native mixed-grass prairie has been lost since European settlement (Samson and Knopf 1994). The National Park Service (NPS) plays an important role in preserving and restoring some of the last pieces of intact prairies within 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.

Located in southwestern North Dakota, Theodore Roosevelt National Park (THRO) encompasses 70,477 acres in the Little Missouri River Badlands. THRO is composed of three discrete management units, each of which is a patchwork of mixed-grass prairie, clay buttes, bottomland forest, and open shrublands. The three park units (North, South, and Elkhorn Ranch Site) are connected by the Little Missouri River. The park would like more information regarding the condition of native grasslands and woody draws because of the large number of exotic species, but a lack of data makes estimates of condition in these and other plant communities difficult (Amberg et al. in review). The Northern Great Plains Inventory & Monitoring Program (NGPN) began vegetation monitoring efforts in THRO in 2011 (Ashton et al. 2012). Vegetation monitoring protocols and plot locations were chosen to represent the north and south unit and to coordinate efforts with the Northern Great Plains Fire Ecology Program (FireEP). The long-term objectives of the NGPN plant community monitoring effort (Symstad et al. 2012b) in THRO 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-year intervals) and long-term trends of tree density by species, height class, and diameter class in the riparian forest.
3. Improve our understanding of the effects of external drivers and management actions on plant community species composition and structure by correlating changes in vegetation composition and structure with changes in climate, landscape patterns, atmospheric chemical composition, fire, and invasive plant control.

This report is intended to provide a timely release of basic data sets and data summaries from our sampling efforts at THRO in 2013, our third year of sampling vegetation. NGPN visited 17 plots in the south unit and north unit (Figure 1). 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. In 2015, we will complete a comprehensive survey focused on riparian forest health at 100 sites within the park.

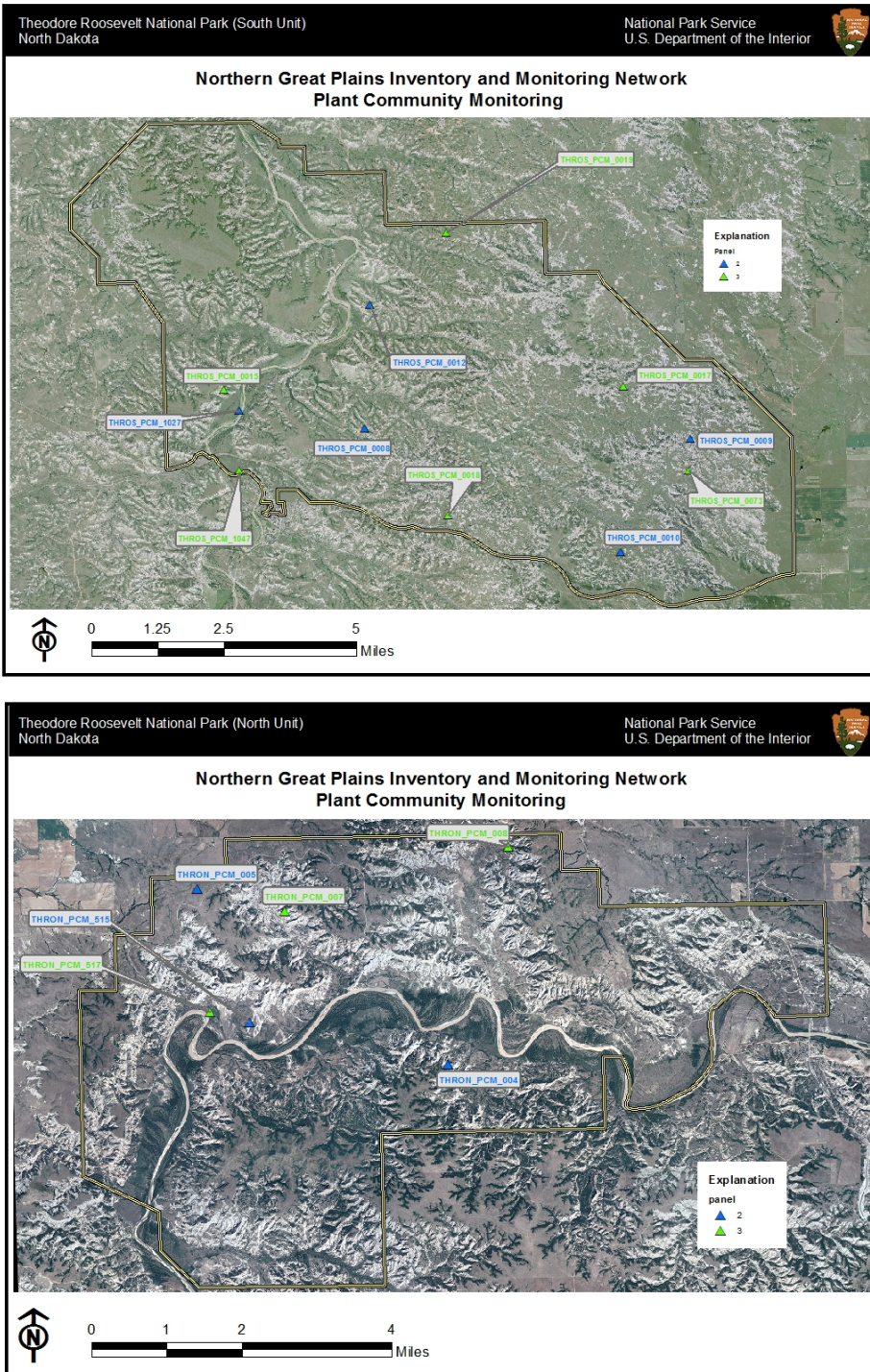


Figure 1. Map of the plant community monitoring plots surveyed in 2013 in the south (top) and north unit (bottom) of Theodore Roosevelt National Park.

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

We implemented a survey to monitor plant community structure and composition in THRO using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, we selected 50 randomly located sites within the north unit of THRO and 90 randomly located sites in the south unit. We split these 140 sites into 10 panels with 14 sites each. We hoped to visit 2 panels (28 sites) every year. In 2011, we visited sites in panel 1 and panel 5, and in 2012 we visited sites in panel 1 and panel 2 (Figure 1). Due to constraints on the NGPN and Fire Ecology Program budget and travel, we knew that we would be unable to meet the ambitious quota of 28 plots in 2013. Instead, we had planned to monitor 20 plots in panel 2 and panel 3 this year, but bad weather, high water, and safety concerns limited us to only 17 plots. We visited these sites during the last week of July and first week of August. Data from these randomly selected sites can be used to estimate condition of vegetation communities for the whole park and over time, can be used to discern trends in condition.

Plot layout and sampling

At each of the sites we visited, we recorded plant species cover and frequency in a rectangular, 50 m x 20 m (0.1 ha), permanent plot (Figure 2). Data on ground cover, herb-layer height ≤ 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 2013, sampling at THRO took an 8-person crew 12 days (see Appendix A for a detailed account of activities each day). At two plots (THRON PCM_007 and THROS PCM_0010), we did not have time to complete species presence data in the largest quadrat size and instead only surveyed up to the 1m² area.

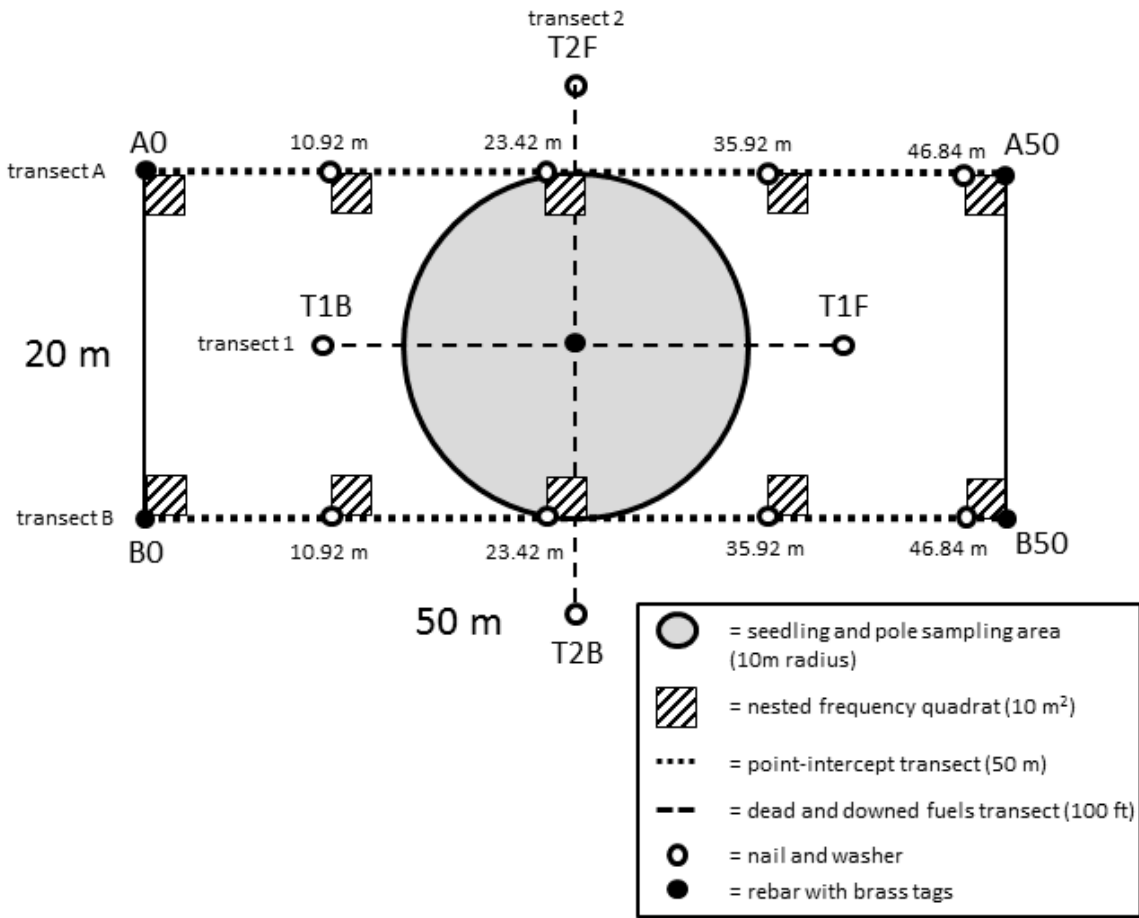


Figure 2. Long-term monitoring plot used for sampling vegetation in Theodore Roosevelt National Park.

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. For each tree, the species, DBH, status, and condition (e.g., leaf-discoloration, insect-damaged, etc.) were recorded. In juniper and cottonwood forests, dead and downed woody fuel load data were collected on two perpendicular, 100 ft (30.49 m) transects with midpoints at the center of the plot (Figure 2), following Brown's Line methods (Brown 1974, Brown et al. 1982). 2013 was the first year that NGPN collected fuels data in THRO.

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. We also surveyed the area for exotic species that have the potential to spread into the park and cause significant ecological impacts (Table 1). For each target species that was present at a site, an abundance class was given on a scale from 1-5 where 1 = one individual, 2 = few individuals, 3 = cover of 1-5%, 4 = cover of 5-25%, and 5 = cover > 25% of the plot. The information gathered from this procedure is critical for early detection and rapid response to such threats. In addition, we noted the presence of plant species that

are considered rare or vulnerable to loss in North Dakota, and may occur in THRO (Table 2) or have been documented in the park (Heidel 1990).

Table 1. Exotic species surveyed for at Theodore Roosevelt National Park as part of the early detection and rapid response program within the Northern Great Plains Network.

Scientific Name	Common Name	Habitat
<i>Alliaria petiolata</i>	garlic mustard	Riparian
<i>Polygonum cuspidatum</i> ; <i>P. sachalinense</i> ; <i>P.x bohemicum</i>	knotweeds	Riparian
<i>Pueraria montana</i> var. <i>lobata</i>	kudzu	Riparian
<i>Iris pseudacorus</i>	yellow iris	Riparian
<i>Ailanthus altissima</i>	tree of heaven	Riparian
<i>Lepidium latifolium</i>	perennial pepperweed	Riparian
<i>Arundo donax</i>	giant reed	Riparian
<i>Rhamnus cathartica</i>	common buckthorn	Riparian
<i>Heracleum mantegazzianum</i>	giant hogweed	Riparian
<i>Centaurea solstitialis</i>	yellow star thistle	Upland
<i>Hieracium aurantiacum</i> ; <i>H. caespitosum</i>	orange and meadow hawkweed	Upland
<i>Isatis tinctoria</i>	Dyer's woad	Upland
<i>Taeniatherum caput-medusae</i>	medusahead	Upland
<i>Chondrilla juncea</i>	rush skeletonweed	Upland
<i>Gypsophila paniculata</i>	baby's breath	Upland
<i>Centaurea virgata</i> ; <i>C. diffusa</i>	knapweeds	Upland
<i>Linaria dalmatica</i> ; <i>L. vulgaris</i>	toadflax	Upland
<i>Euphorbia myrsinites</i> & <i>E. cyparissias</i>	myrtle spurge	Upland
<i>Dipsacus fullonum</i> & <i>D. laciniatus</i>	common teasel	Upland
<i>Salvia aethiops</i>	Mediterranean sage	Upland
<i>Ventenata dubia</i>	African wiregrass	Upland

Table 2. Rare species that were surveyed for during the 2013 field season at Theodore Roosevelt National Park.

Scientific Name	Common Name
<i>Carex grvida</i>	heavy sedge
<i>Chenopodium subglabrum</i>	smooth goosefoot
<i>Collinsia parviflora</i>	maiden blue-eyed Mary
<i>Dalea enneandra</i>	nineanther (dalea) prairie clover
<i>Dalea villosa</i>	silky prairie clover
<i>Eriogonum cernuum</i>	nodding buckwheat
<i>Eriogonum visher</i>	Visher's buckwheat
<i>Euphorbia brachycera</i>	horned (Rocky Mountain) spurge
<i>Lobelia spicata</i>	palespike lobelia
<i>Mentzelia nuda</i>	bractless blazing star
<i>Oxytropis sericea</i>	white locoweed
<i>Phlox alyssifolia</i>	alyssumleaf phlox
<i>Physaria brassicoides</i>	double twinpod
<i>Populus x acuminata</i>	lanceleaf cottonwood
<i>Sporobolus airoides</i>	alkali sacaton
<i>Townsendia hookeri</i>	Hooker's Townsend daisy
<i>Viburnum lentago</i>	nannyberry

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). 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; values near 0 indicate dominance by a single species, and values near 1 indicate nearly equal abundance of all species present.

Disturbances were recorded in square meters and ranged from 0 (not present) to 2290 (the whole plot area) for each type of disturbance. We report the sum of all individual disturbances, so the value can be greater than 2290 m².

Reporting on Natural Resource Condition

Results were summarized in a Natural Resource Condition Table based on the templates from the State of the Park report series (<http://www.nps.gov/stateoftheparks/>). The goal is to improve park priority setting and to synthesize and communicate complex park condition information to the public in a clear and simple way. By focusing on specific indicators, such as exotic species cover, it will also be possible and straightforward to revisit the metric in subsequent years. The status and trend of each indicator is scored and assigned a corresponding symbol based on the key found in Table 3.

We chose a set of indicators and specific measures that can describe the condition of vegetation in the Northern Great Plains and the status of exotic plant invasions. The measures include: absolute

herb-layer canopy cover, native species richness, evenness, relative cover of exotic species, and annual brome cover. Reference values were based on descriptions of historic condition and variation, past studies, and/or management targets. Current park condition was compared to a reference value, and status was scored as good condition, warrants moderate caution, or warrants significant concern based on this comparison (Table 3). Good condition was applied to values that fell within the range of the reference value, and significant concern was applied to conditions that fell outside the bounds of the reference value. In some cases, reference conditions can be determined only after we have accumulated more years of data. When this is the case, we refer to these as “To be determined” and estimate condition based on our professional judgment.

Table 3. Key to the symbols used in the Natural Resource Condition Table. The background color represents the current status, the arrow summarizes the trend, and the thickness of the outside line represents the degree of confidence in the assessment. A symbol that does not contain an arrow indicates that there is insufficient information to assess a trend. Based on the State of the Park reports (<http://www.nps.gov/stateoftheparks/>).

Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low

Results and Discussion

While much of the the southern part of the region suffered from drought in 2013, Theodore Roosevelt NP experienced normal conditions, and drought conditions were not present when we visited in late July (Figure 3). Average canopy cover was 181% (Table 4) in 2013, which was much higher than the 122 % cover seen the previous year (Ashton et al. 2013). There was a large amount of standing litter on the ground with ground cover at the sites averaging 79% plant litter.

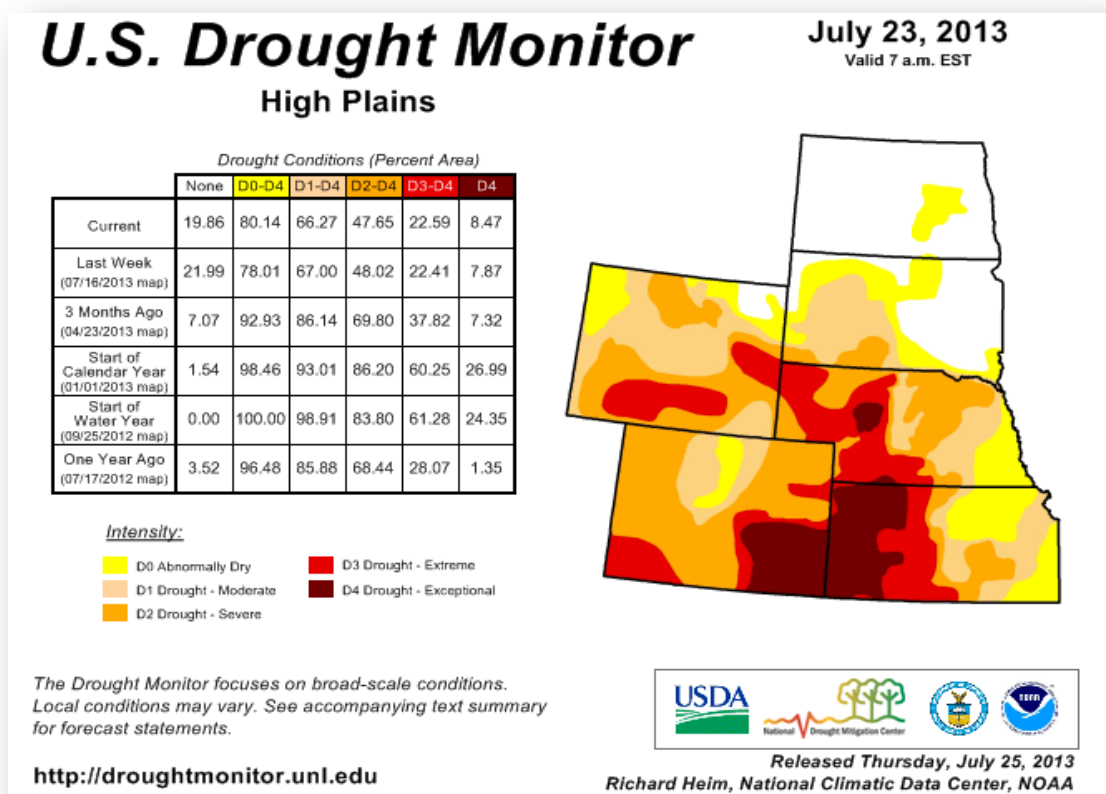


Figure 3. Drought conditions in late July 2013 in the Northern Great Plains. Theodore Roosevelt NP experienced normal conditions.

We found 234 plant species in 2013 at THRO (Appendix B). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at THRO, but trees, forbs, shrubs and subshrubs (defined as a low-growing shrub usually under 0.5m), and vines were also present (Figure 4). We found 35 exotic species at the park. We identified 2 targeted rare species in our monitoring (Figure 5): white locoweed (*Oxytropis sericea*) and double twinpod (*Physaria brassicoides*). White locoweed was seen in a few sites and the double twinpod was found in only one site in the South Unit. Neither of these species are considered rare at the global scale, but double twinpod is considered vulnerable in the state of ND (S3) and white locoweed is considered critically imperiled (S1) (Heidel 1990). THRO has a high concentration of rare plant species (Heidel 1990) and as such, the park has an important role to play in the preservation of natural processes and species diversity in North Dakota. While our monitoring is not designed to replace rare plant surveys,

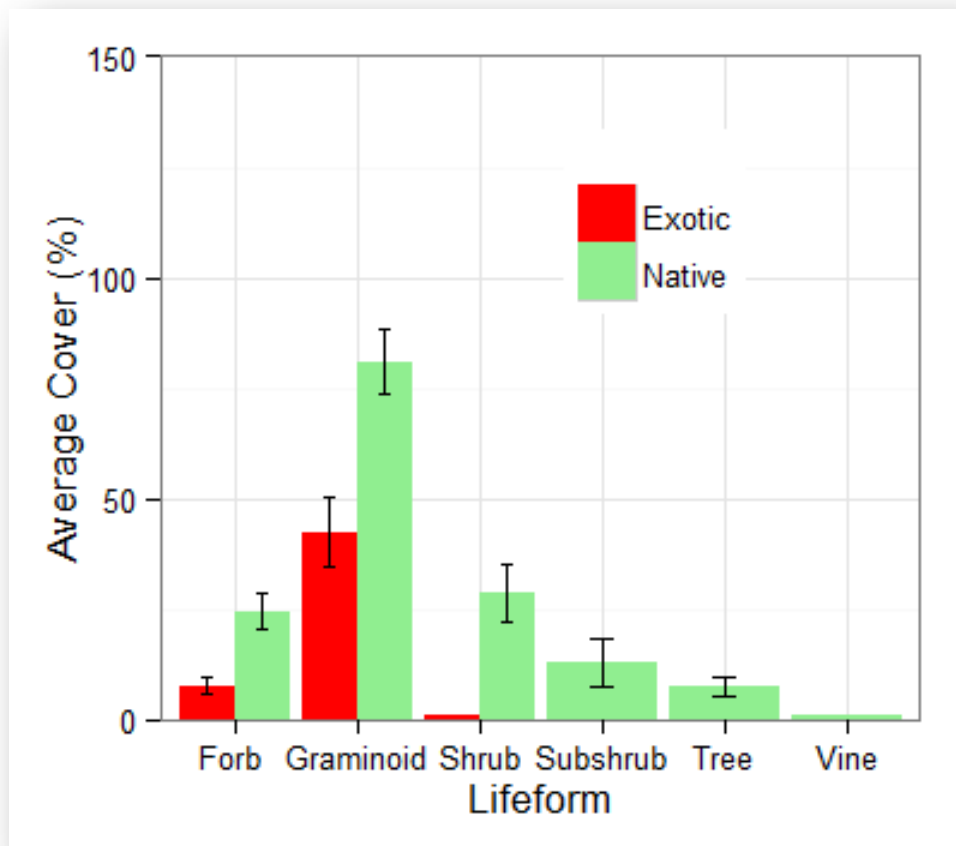


Figure 4. Average cover by lifeform and nativity in 17 plant community monitoring plots in Theodore Roosevelt National Park in 2013. Native (green) and exotic (red) graminoids were the most abundant lifeform across the plots. Bars represent means $\pm$ standard errors.



Figure 5. Two rare plants found in Theodore Roosevelt National Park in 2013. Double twinpod (left) and white locoweed (right) were identified in long-term monitoring plots.

it can provide some additional data on the distribution and abundance of these species in the park. The most common species in the sites we visited were graminoids, and most were native species (Figure 6). Western wheatgrass (*Pascopyrum smithii*) was particularly abundant. Smooth brome (*Bromus inermis*) was not as common as some other species (it was found in only 8 of 17 plots), but where it occurred it was often a large component of the plant cover.

Table 4. Natural resource condition summary table for plant communities in Theodore Roosevelt National Park (THRO).

Indicator of Condition	Specific Measures	2013 Value (mean $\pm$ SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Plant Community Structure and Composition	Absolute herb-layer canopy cover	181 $\pm$ 19 %	TBD ⁽¹⁾		THRO has a high herbaceous canopy cover and a high diversity of native plants. Native species richness is lower in the riparian areas of the park. 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)	9 $\pm$ 0.2 species	8-18 species ⁽²⁾		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.77 $\pm$ 0.02	TBD ⁽¹⁾		
Exotic Plant Early Detection and Management	Relative cover of exotic species	27 $\pm$ 5.3 %	$\leq$ 10 % cover		In general, the sites in THRO had a high cover of exotic species. Only one site of 17 had <10% exotic cover. Annual brome cover remains low, but Kentucky bluegrass and smooth brome are common.
	Leafy spurge cover	<1%	$\leq$ 10 % cover		

References, Notes, and Data Sources:

1. To be determined when more data are available. 2. Symstad, A. J. and J. L. Jonas. 2014. Using natural range of variation to set decision thresholds: a case study for Great Plains grasslands.in G. R. Gutzenspergen, editor. Application of threshold concepts in natural resource decision making. Springer Verlag.

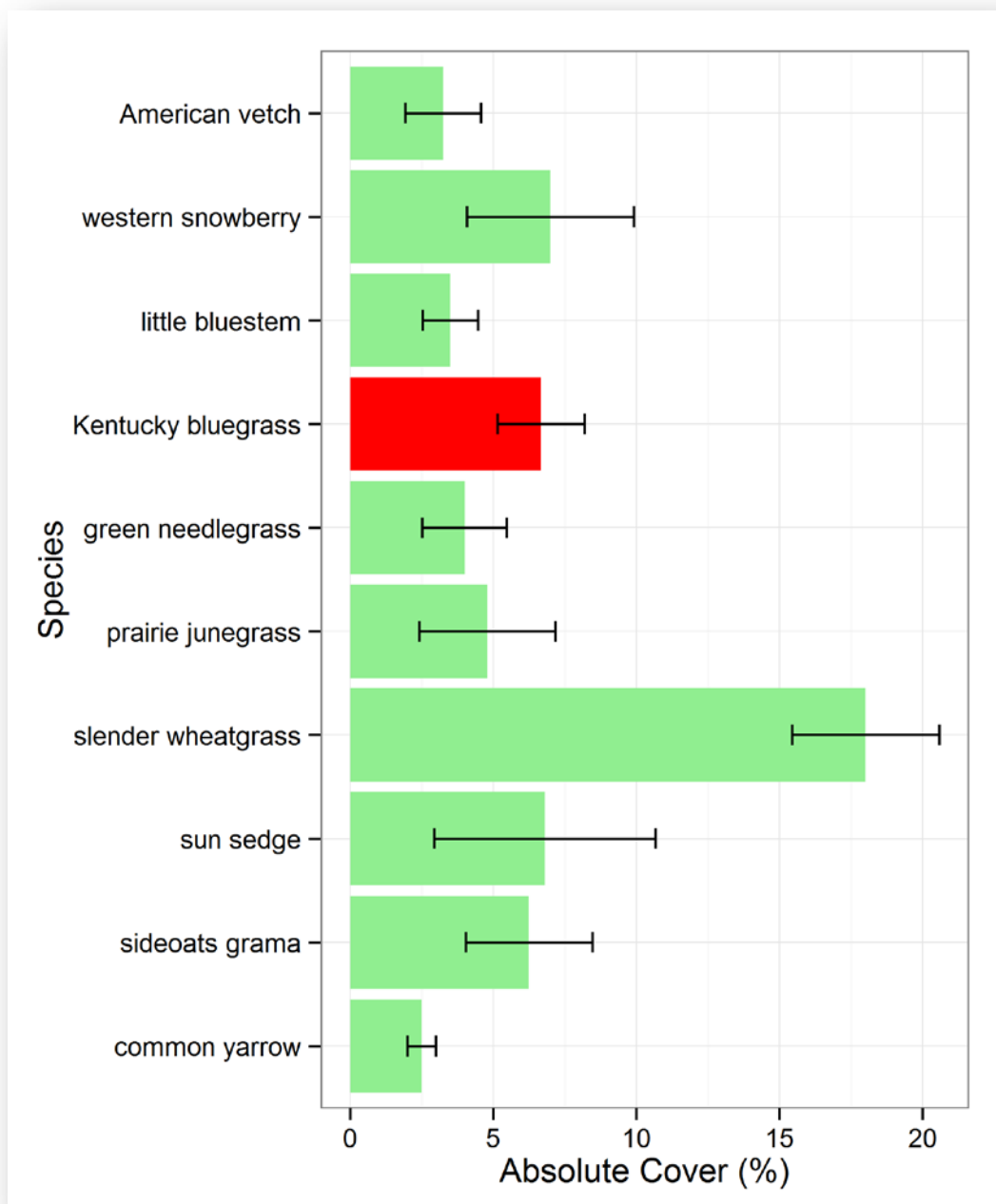


Figure 6. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded at Theodore Roosevelt National Park in 2013. Bars represent means $\pm$ standard errors.

Average species richness at each of the 17 plots was measured by point-intercept and in 1 m² and 10 m² quadrats (Table 5). On average, there are about 2 exotic species within the 1 m² quadrat (Table 5). From the point-intersect data, we found average plot diversity, H' , to be 2.4 ± 0.16 . Evenness, J' , averaged 0.77 ± 0.02 across the plots (Table 4). When including only native species, average diversity and evenness were 2.3 ± 0.19 and 0.78 ± 0.02 , respectively.

Table 5. Average plant species richness in 17 plots at Theodore Roosevelt National Park in 2013. Values represent means $\pm$ standard errors, $n=17$ for point-intercept and 1 m^2 quadrats; $n=15$ for the 10m^2 quadrats.

	Point-intercept	1 m^2 quadrats	10 m^2 quadrats
Species richness	26 ± 2.9	11 ± 1.1	19 ± 2.2
Native species richness	22 ± 2.7	9 ± 1.0	16 ± 1.9
Exotic species richness	4 ± 0.4	2 ± 0.1	4 ± 0.3
Graminoid species richness	10 ± 0.9	4 ± 0.4	6 ± 0.6
Forb species richness	11 ± 1.5	6 ± 0.6	11 ± 1.3

While there was some variation across sites, the plots we visited in THRO tended to have a high 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). While it is difficult to define a reference condition for species richness that can vary so much spatially and temporally, the natural range of variation over long-time periods may be a good starting point (Symstad and Jonas 2014). Long-term records of species diversity in mixed-grass prairie from a relatively undisturbed site in eastern Montana vary between 8 and 18 species per square meter over the course of 13 years. Compared to the nearby mixed-grass prairie, THRO is within the natural range (Table 4, native richness in the 1 m^2 quadrat and Table 5). The highest diversity was seen in site PCM_0015 in the South Unit (Figure 7). This site was characterized by a mix of habitat types including rocky outcrops, deciduous woodland, a juniper draw, grasslands, and shrublands areas.



Figure 7. Long-term monitoring site PCM_0015 at Theodore Roosevelt National Park. In 2013, we found it to have a high native plant diversity and low exotic cover relative to the other sites in the park.

The average relative cover of exotic species at sites in THRO was high ($27 \pm 5\%$; Table 4). However, like species richness, cover of exotic species varied considerably among sites (Table 6). Exotic cover ranged from less than 5% to greater than 95% across the park. In all but one plot, exotic cover was above 10%. The two riparian plots in the South Unit were particularly invaded, primarily by smooth brome (*Bromus inermis*). Park-wide, Kentucky bluegrass accounted for a majority of the exotic cover in the plots (Table 6). Reducing the cover of cheatgrass (*B. tectorum*) and Japanese brome (*B. japonicus*) is a major challenge for many of the parks in Nebraska and South Dakota, but annual brome cover is low at THRO ($\sim 2\%$). These annual bromes, however, contributed to the plant cover in 8 of the 17 plots suggesting that it will be important to monitor and manage for them in the future to

maintain such low abundance. Kentucky bluegrass is common throughout North Dakota and management has proved challenging. Recent work suggests that controlled-burning is the most effective control (<http://www.fws.gov/midwest/news/nativeprairies.html>).

Disturbance from grazing, prairie dogs, bison, 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 2013, the most common disturbance was from animal trails and erosion, but there was also evidence of grazing and small mammal activity.

Table 6. Characteristics of the plant community in 27 plots at Theodore Roosevelt National Park in 2012 including average native species richness, exotic plant cover, leafy spurge cover, Kentucky bluegrass cover, and area of disturbance.

Plot	Average native species richness 1 m ² plots	Exotic cover (%)	Leafy spurge cover (%)	Kentucky bluegrass cover (%)	Disturbance within site (m ²)
THRON_PCM_004	10	16	0	14	30
THRON_PCM_005	10	38	0	34	35
THRON_PCM_007	7	3	0	0	60
THRON_PCM_008	10	27	0	25	100
Average North Unit Upland	9 ± 0.8 species	21 ± 7.5%	0%	18 ± 7.3%	
THROS_PCM_0008	11	13	0	10	20
THROS_PCM_0009	9	12	0	4	55
THROS_PCM_0010	9	24	0	23	535
THROS_PCM_0012	12	20	0	0	15
THROS_PCM_0015	13	17	0	10	2590
THROS_PCM_0017	9	21	0	4	250
THROS_PCM_0018	15	19	0	9	0
THROS_PCM_0019	17	19	0	13	40
THROS_PCM_0073	10	23	0	12	20
Average South Unit Upland	12 ± 1.0 species	19 ± 1.4%	0%	9 ± 2.2%	
THRON_PCM_515	3	14	0	12	2340
THRON_PCM_517	4	34	1	32	0
Average North Unit Riparian	4 ± 0.5 species	24 ± 10%	<1%	22 ± 10%	
THROS_PCM_1027	5	56	7	0	2291
THROS_PCM_1047	1	96	0	26	0
Average South Unit Riparian	3 ± 2 species	76 ± 20%	3.5 ± 3.5%	13 ± 13%	

Trees and/or seedlings were present in many of the sites we visited in 2013. A more thorough assessment of forest structure in the riparian areas will be conducted in 2015; it will include 50 plots in each of the north and south units. The 2013 data provide a much smaller snapshot of condition. Rocky Mountain juniper (*Juniperus scopulorum*) was the most common woody species we found (Table 7). Chokecherry (*Prunus virginiana*) seedlings were very common and abundant (Table 7). Green ash (*Fraxinus pennsylvanica*) was found at only 3 plots, but where it was found seedlings were quite dense. The 7 plots where junipers were abundant were characterized by a diverse age structure where seedlings, saplings, poles, and trees were present.

Table 7. Tree and tall shrub density in Theodore Roosevelt National Park in 2013.

Size Class	Juniper (7 plots; stems hectare ⁻¹)	Green Ash (3 plots; stems hectare ⁻¹)	Cottonwood (2 plots; stems hectare ⁻¹)	Chokecherry (9 plots; stems hectare ⁻¹)	Buffaloberry (2 plots; stems hectare ⁻¹)
Seedlings	550.1	2058.1	111.4	1725.7	318.3
Saplings	222.8	286.4	n/a	180.4	n/a
Poles	85.9	12.9	n/a	206.2*	12.9*
Trees	41.8	18.2	89.0*	n/a	n/a
Snags	45.2	11.3	8.1*	n/a	n/a

* Density of mature cottonwood, buffaloberry, and chokecherry are based on only 1 plot.

We measured surface fuels in 7 sites within the park; one of these sites (THRON_PCM_517) was within a cottonwood forest, and 6 were juniper woodlands. In the juniper woodlands, total downed fuel loads were fairly high (Table 8), driven mainly by high litter and duff loads. We found the average total litter and duff depth to be 0.9 inches and 0.3 inches, respectively.

Table 8. Surface fuels loads in 6 juniper woodlands in Theodore Roosevelt National Park in 2013.

Fine Woody Debris	Course Woody Debris (sound)	Course Woody Debris (rotten)	Duff	Litter	Total
2.3 ± 1.0 tons acre ⁻¹	1.2 ± 1.2 tons acre ⁻¹	0.3 ± 0.3 tons acre ⁻¹	6.1 ± 1.2 tons acre ⁻¹	7.0 ± 1.8 tons acre ⁻¹	17.0 ± 3.2 tons acre ⁻¹

Summary

In conclusion, Theodore Roosevelt National Park has a high diversity of native plants that appears to be within the range of natural variability for northern mixed-grass prairie. The mixed-grass prairie sites had higher diversity than those in riparian areas. Average cover of exotic species was high, particularly in the riparian areas, which were dominated by smooth brome. Kentucky bluegrass was the most widespread and abundant exotic species. Juniper woodlands are common throughout the park and characterized by fairly high surface fuel loads. To retain ecological integrity and the high diversity of native plants in THRO, it is important to continue efforts to reduce the cover of invasive plants. Continued monitoring efforts will be critical to track changes in the condition of the vegetation communities in THRO.

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Appendix A: Field journal for plant community monitoring in THRO for the 2013 season

Plant community composition monitoring in Theodore Roosevelt National Park was completed using a crew of 8 people working 12, 10-hour days with some overtime.

Date	Day of week	Approximate Travel Time (hrs)	Housing	Sites Completed/Notes
July 22, 2013	Monday	5	Juniper Campground	THRON PCM-005 Dropped off Chevy Tahoe in Belfield for FOUS
July 23, 2013	Tuesday	N/A	Juniper Campground	THRON PCM-005 (finished plot) THRON PCM-007 (partial install; only read to 1 m ²)
July 24, 2013	Wednesday	N/A	Juniper Campground	THRON PCM-517
July 25, 2013	Thursday	N/A	Juniper Campground	THRON PCM-008 THRON PCM-004 (set up tapes)
July 26, 2013	Friday	2	Sully Creek State Park Campground	THRON PCM-004 (finished plot; team departed to FOUS) THROS PCM-0008 (team arrived from KNRI)
July 27, 2013	Saturday	3	Sully Creek State Park Campground	THRON PCM-515
July 28, 2013	Sunday	1	Sully Creek State Park Campground	THROS PCM-0015 THROS PCM-1027
July 29, 2013	Monday	4	N/A	Thunderstorms/drove back to Rapid City early
August 5, 2013	Monday	4	Sully Creek State Park Campground	THROS PCM-0073 (2 crews) Attempted THROS PCM_009 but bison were territorial
August 6, 2013	Tuesday	1	Sully Creek State Park Campground	THROS PCM-1047 (installed and read) THROS PCM-0018 THROS PCM-009 (bison had left) THROS PCM-0017
August 7, 2013	Wednesday	1	Sully Creek State Park Campground	THROS PCM_0018 (finished plot) THROS PCM_0019 THROS PCM_0012 Attempted THROS PCM_0011 but bison were blocking all approach routes Attempted THROS PCM_1028 but Little Missouri was too high to cross safely
August 8, 2013	Thursday	4	N/A	THROS PCM_0010 (only read to 1m ²) THROS PCM_0012 (finished plot) Both crews returned to Rapid City, SD

Appendix B: List of plant species found in 2013 at THRO

Family	Code	Scientific Name	Common Name	Exotic
Agavaceae	YUGL	<i>Yucca glauca</i>	soapweed yucca	
Anacardiaceae	RHTR	<i>Rhus trilobata</i>	skunkbush sumac	
	TORY	<i>Toxicodendron rydbergii</i>	western poison ivy	
Asclepiadaceae	ASPU	<i>Asclepias pumila</i>	plains milkweed	
	ASSP	<i>Asclepias speciosa</i>	showy milkweed	
	ASVE	<i>Asclepias verticillata</i>	whorled milkweed	
	ASVI	<i>Asclepias viridiflora</i>	green comet milkweed	
Asteraceae	ACMI2	<i>Achillea millefolium</i>	common yarrow	
	AMAR2	<i>Ambrosia artemisiifolia</i>	annual ragweed	*
	AMPS	<i>Ambrosia psilostachya</i>	Cuman ragweed	
	ANMI3	<i>Antennaria microphylla</i>	littleleaf pussytoes	
	ANPA4	<i>Antennaria parvifolia</i>	small-leaf pussytoes	
	ARM2	<i>Arctium minus</i>	lesser burdock	*
	ARAB3	<i>Artemisia absinthium</i>	absinthium	*
	ARCA12	<i>Artemisia campestris</i>	field sagewort	
	ARCA13	<i>Artemisia cana</i>	silver sagebrush	
	ARDR4	<i>Artemisia dracunculus</i>	tarragon	
	ARFR4	<i>Artemisia frigida</i>	prairie sagewort	
	ARLO7	<i>Artemisia longifolia</i>	longleaf wormwood	
	ARLU	<i>Artemisia ludoviciana</i>	white sagebrush	
	ARTR2	<i>Artemisia tridentata</i>	big sagebrush	
	BREU	<i>Brickellia eupatorioides</i>	false boneset	
	CIAR4	<i>Cirsium arvense</i>	Canada thistle	*
	CIFL	<i>Cirsium flodmanii</i>	Flodman's thistle	
	COCA5	<i>Conyza canadensis</i>	Canadian horseweed	
	DYPA	<i>Dyssodia papposa</i>	fetid marigold	
	ECAN2	<i>Echinacea angustifolia</i>	blacksamson echinacea	
	ERNA10	<i>Ericameria nauseosa</i>	rubber rabbitbrush	
	ERIGE2	<i>Erigeron</i> species	fleabane	
	ERCA4	<i>Erigeron canus</i>	hoary fleabane	
	ERST3	<i>Erigeron strigosus</i>	prairie fleabane	
	ERSU2	<i>Erigeron subtrinervis</i>	threenerve fleabane	
	GRSQ	<i>Grindelia squarrosa</i>	curlycup gumweed	
	GUSA2	<i>Gutierrezia sarothrae</i>	broom snakeweed	
	HEAN3	<i>Helianthus annuus</i>	common sunflower	
	HEMA2	<i>Helianthus maximiliani</i>	Maximilian sunflower	
	HEPA19	<i>Helianthus pauciflorus</i>	stiff sunflower	
	HEPE	<i>Helianthus petiolaris</i>	prairie sunflower	
	HEVI4	<i>Heterotheca villosa</i>	hairy false goldenaster	
	LASE	<i>Lactuca serriola</i>	prickly lettuce	*
	LIPU	<i>Liatris punctata</i>	dotted blazing star	
	LYJU	<i>Lygodesmia juncea</i>	rush skeletonplant	
	MUOB99	<i>Mulgedium oblongifolium</i>	blue lettuce	

Family	Code	Scientific Name	Common Name	Exotic
Asteraceae	PAPL12	<i>Packera plattensis</i>	prairie groundsel	
	RACO3	<i>Ratibida columnifera</i>	upright prairie coneflower	
	RUHI2	<i>Rudbeckia hirta</i>	blackeyed Susan	
	SOCA6	<i>Solidago canadensis</i>	Canada goldenrod	
	SOGI	<i>Solidago gigantea</i>	giant goldenrod	
	SOMI2	<i>Solidago missouriensis</i>	Missouri goldenrod	
	SONE	<i>Solidago nemoralis</i>	gray goldenrod	
	SOPT4	<i>Solidago ptarmicoides</i>	prairie goldenrod	
	SORI2	<i>Solidago rigida</i>	stiff goldenrod	
	SOAR2	<i>Sonchus arvensis</i>	field sowthistle	*
	SYER	<i>Symphyotrichum ericoides</i>	white heath aster	
	SYLA3	<i>Symphyotrichum laeve</i>	smooth blue aster	
	SYOB	<i>Symphyotrichum oblongifolium</i>	aromatic aster	
	TAOF	<i>Taraxacum officinale</i>	common dandelion	*
	TEAC	<i>Tetraneuris acaulis</i>	stemless four-nerve daisy	
	TRDU	<i>Tragopogon dubius</i>	yellow salsify	*
	XASP99	<i>Xanthisma spinulosum</i>	lacy tansyaster	
	XAST	<i>Xanthium strumarium</i>	rough cocklebur	
Boraginaceae	CRCE	<i>Cryptantha celosioides</i>	buttecandle	
	LAOC3	<i>Lappula occidentalis</i>	flatspine stickseed	
	LIIN2	<i>Lithospermum incisum</i>	narrowleaf stoneseed	
	MELA3	<i>Mertensia lanceolata</i>	prairie bluebells	
	ONBE	<i>Onosmodium bejariense</i>	soft-hair marbleseed	
Brassicaceae	ALDE	<i>Alyssum desertorum</i>	desert madwort	*
	CAMI2	<i>Camelina microcarpa</i>	littlepod false flax	*
	DEPI	<i>Descurainia pinnata</i>	western tansymustard	
	DESO2	<i>Descurainia sophia</i>	herb sophia	*
	DRABA	<i>Draba species</i>	draba	
	DRRE2	<i>Draba reptans</i>	Carolina draba	
	ERYSI	<i>Erysimum species</i>	wallflower	*
	ERCA14	<i>Erysimum capitatum</i>	sanddune wallflower	
	ERCH9	<i>Erysimum cheiranthoides</i>	wormseed wallflower	*
	ERIN7	<i>Erysimum inconspicuum</i>	shy wallflower	
	LEDE	<i>Lepidium densiflorum</i>	common pepperweed	
	PHAR99	<i>Physaria arenosa</i>	Great Plains bladderpod	
	PHBR5	<i>Physaria brassicoides</i>	double twinpod	
	PHLU99	<i>Physaria ludoviciana</i>	foothill bladderpod	
	THAR5	<i>Thlaspi arvense</i>	field pennycress	*
Cactaceae	OPPO	<i>Opuntia polyacantha</i>	plains pricklypear	
Campanulaceae	CARO2	<i>Campanula rotundifolia</i>	bluebell bellflower	
Capparaceae	PODO3	<i>Polanisia dodecandra</i>	redwhisker clammyweed	
Caprifoliaceae	SYOC	<i>Symphoricarpos occidentalis</i>	western snowberry	
Caryophyllaceae	CEAR4	<i>Cerastium arvense</i>	field chickweed	
	SIAN2	<i>Silene antirrhina</i>	sleepy silene	
Chenopodiaceae	ATRIP	<i>Atriplex</i>	saltbush	*
	ATCA2	<i>Atriplex canescens</i>	fourwing saltbush	

Family	Code	Scientific Name	Common Name	Exotic
Chenopodiaceae	ATCO	<i>Atriplex confertifolia</i>	shadscale saltbush	
	CHENO	<i>Chenopodium</i> species	goosefoot	*
	CHFR3	<i>Chenopodium fremontii</i>	Fremont's goosefoot	
	CHGL3	<i>Chenopodium glaucum</i>	oakleaf goosefoot	*
	CHPR5	<i>Chenopodium pratericola</i>	desert goosefoot	
	CHSI2	<i>Chenopodium simplex</i>	mapleleaf goosefoot	
	KOSC	<i>Kochia scoparia</i>	burningbush, kochia	*
	KRLA2	<i>Krascheninnikovia lanata</i>	winterfat	
	SATR12	<i>Salsola tragus</i>	prickly Russian thistle	*
	SAVE4	<i>Sarcobatus vermiculatus</i>	greasewood	
Convolvulaceae	COAR4	<i>Convolvulus arvensis</i>	field bindweed	*
Cornaceae	COSE16	<i>Cornus sericea</i>	redosier dogwood	
Cupressaceae	JUCO6	<i>Juniperus communis</i>	common juniper	
	JUHO2	<i>Juniperus horizontalis</i>	creeping juniper	
	JUSC2	<i>Juniperus scopulorum</i>	Rocky Mountain juniper	
Cyperaceae	CAREX	<i>Carex</i> species	sedge	
	CABR10	<i>Carex brevior</i>	shortbeak sedge	
	CAEB2	<i>Carex eburnea</i>	bristleleaf sedge	
	CAFI	<i>Carex filifolia</i>	threadleaf sedge	
	CAIN9	<i>Carex inops</i>	sun sedge	
Dryopteridaceae	WOOR	<i>Woodsia oregana</i>	Oregon cliff fern	
Elaeagnaceae	SHAR	<i>Shepherdia argentea</i>	silver buffaloberry	
Equisetaceae	EQAR	<i>Equisetum arvense</i>	field horsetail	
Euphorbiaceae	EUPHO	<i>Euphorbia</i> species	spurge, sandmat	*
	EUES	<i>Euphorbia esula</i>	leafy spurge	*
	EUGL3	<i>Euphorbia glyptosperma</i>	ribseed sandmat	
	EUSE4	<i>Euphorbia serpens</i>	matted sandmat	
	EUSP	<i>Euphorbia spathulata</i>	warty spurge	
Fabaceae	ASTRA	<i>Astragalus</i>	milkvetch	
	ASAG2	<i>Astragalus agrestis</i>	purple milkvetch	
	ASFL2	<i>Astragalus flexuosus</i>	flexile milkvetch	
	ASGI5	<i>Astragalus gilviflorus</i>	plains milkvetch	
	ASGR3	<i>Astragalus gracilis</i>	slender milkvetch	
	ASLA27	<i>Astragalus laxmannii</i>	Laxmann's milkvetch	
	ASLO4	<i>Astragalus lotiflorus</i>	lotus milkvetch	
	ASMI10	<i>Astragalus missouriensis</i>	Missouri milkvetch	
	ASPE5	<i>Astragalus pectinatus</i>	narrowleaf milkvetch	
	DAPU5	<i>Dalea purpurea</i>	purple prairie clover	
	GLLE3	<i>Glycyrrhiza lepidota</i>	American licorice	
	MELU	<i>Medicago lupulina</i>	black medick	*
	MESA	<i>Medicago sativa</i>	alfalfa	*
	MEOF	<i>Melilotus officinalis</i>	yellow sweetclover	*
	OXLA3	<i>Oxytropis lambertii</i>	purple locoweed	
	OXSE	<i>Oxytropis sericea</i>	white locoweed	
	PEAR6	<i>Pedimelum argophyllum</i>	silverleaf Indian breadroot	
	PEES	<i>Pedimelum esculentum</i>	large Indian breadroot	

Family	Code	Scientific Name	Common Name	Exotic
Fabaceae	PSLA3	<i>Psoralea lanceolata</i>	lemon scurfpea	
	PSTE5	<i>Psoralea tenuiflora</i>	slimflower scurfpea	
	THRH	<i>Thermopsis rhombifolia</i>	prairie thermopsis	
	VIAM	<i>Vicia americana</i>	American vetch	
Grossulariaceae	RIAU	<i>Ribes aureum</i>	golden currant	
	RIOX	<i>Ribes oxycanthoides</i>	Canadian gooseberry	
Hydrophyllaceae	ELNY	<i>Ellisia nyctelea</i>	Aunt Lucy	
Iridaceae	SIAN3	<i>Sisyrinchium angustifolium</i>	narrowleaf blue-eyed grass	
Lamiaceae	HEHI	<i>Hedeoma hispida</i>	rough false pennyroyal	
Lamiaceae	MOFI	<i>Monarda fistulosa</i>	wild bergamot	
Liliaceae	ALTE	<i>Allium textile</i>	textile onion	
	CANU3	<i>Calochortus nuttallii</i>	sego lily	
	MAST4	<i>Maianthemum stellatum</i>	starry false lily of the valley	
Linaceae	LILE3	<i>Linum lewisii</i>	Lewis flax	
	LIRI	<i>Linum rigidum</i>	stiffstem flax	
Loasaceae	MEDE2	<i>Mentzelia decapetala</i>	tenpetal blazingstar	
Malvaceae	SPCO	<i>Sphaeralcea coccinea</i>	scarlet globemallow	
Oleaceae	FRPE	<i>Fraxinus pennsylvanica</i>	green ash	
Onagraceae	EPBR3	<i>Epilobium brachycarpum</i>	tall annual willowherb	
	OENU	<i>Oenothera nuttallii</i>	Nuttall's evening-primrose	
	OESE3	<i>Oenothera serrulata</i>	yellow sundrops	
	OESU99	<i>Oenothera suffrutescens</i>	scarlet beeblossom	
Orobanchaceae	ORLU	<i>Orobanche ludoviciana</i>	Louisiana broomrape	
Oxalidaceae	OXST	<i>Oxalis stricta</i>	common yellow oxalis	
Plantaginaceae	PLEL	<i>Plantago elongata</i>	prairie plantain	
	PLPA2	<i>Plantago patagonica</i>	woolly plantain	
Poaceae	ACHY	<i>Achnatherum hymenoides</i>	Indian ricegrass	
	AGSC5	<i>Agrostis scabra</i>	rough bentgrass	
	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	*
	CALO	<i>Calamovilfa longifolia</i>	prairie sandreed	
	CELO3	<i>Cenchrus longispinus</i>	mat sandbur	
	DASP2	<i>Danthonia spicata</i>	poverty oatgrass	
	DIOL	<i>Dichanthelium oligosanthos</i>	Heller's rosette grass	
	DIWI5	<i>Dichanthelium wilcoxianum</i>	fall rosette grass	
	DISP	<i>Distichlis spicata</i>	saltgrass	
	ELCA4	<i>Elymus canadensis</i>	Canada wildrye	
	ELEL5	<i>Elymus elymoides</i>	squirreltail	
	ELRE4	<i>Elymus repens</i>	quackgrass	*
	ELTR7	<i>Elymus trachycaulus</i>	slender wheatgrass	
	HECO26	<i>Hesperostipa comata</i>	needle and thread	
	HESP11	<i>Hesperostipa spartea</i>	porcupinegrass	
	HOJU	<i>Hordeum jubatum</i>	foxtail barley	

Family	Code	Scientific Name	Common Name	Exotic
Poaceae	KOMA	<i>Koeleria macrantha</i>	prairie Junegrass	
	MUCU3	<i>Muhlenbergia cuspidata</i>	plains muhly	
	MUPA99	<i>Muhlenbergia paniculata</i>	tumblegrass	
	MURA	<i>Muhlenbergia racemosa</i>	marsh muhly	
	NAVI4	<i>Nassella viridula</i>	green needlegrass	
	PACA6	<i>Panicum capillare</i>	witchgrass	
	PASM	<i>Pascopyrum smithii</i>	western wheatgrass	
	PIMI7	<i>Piptatherum micranthum</i>	littleseed ricegrass	
	POCO	<i>Poa compressa</i>	Canada bluegrass	*
	POPR	<i>Poa pratensis</i>	Kentucky bluegrass	*
	PSSP6	<i>Pseudoroegneria spicata</i>	bluebunch wheatgrass	
	SCSC	<i>Schizachyrium scoparium</i>	little bluestem	
	SEVI4	<i>Setaria viridis</i>	green bristlegrass	*
	SPCR	<i>Sporobolus cryptandrus</i>	sand dropseed	
	VUOC	<i>Vulpia octoflora</i>	sixweeks fescue	
Polemoniaceae	COLI2	<i>Collomia linearis</i>	tiny trumpet	
	PHHO	<i>Phlox hoodii</i>	spiny phlox	
Polygalaceae	POAL4	<i>Polygala alba</i>	white milkwort	
	POVE	<i>Polygala verticillata</i>	whorled milkwort	
Polygonaceae	ERFL4	<i>Eriogonum flavum</i>	alpine golden buckwheat	
	ERPA9	<i>Eriogonum pauciflorum</i>	fewflower buckwheat	
	FACO	<i>Fallopia convolvulus</i>	black bindweed	*
	POAV	<i>Polygonum aviculare</i>	prostrate knotweed	*
	PODO4	<i>Polygonum douglasii</i>	Douglas' knotweed	
	RUCR	<i>Rumex crispus</i>	curly dock	*
Ranunculaceae	ANCY	<i>Anemone cylindrica</i>	candle anemone	
	ANPA19	<i>Anemone patens</i>	eastern pasqueflower	
	CLLI2	<i>Clematis ligusticifolia</i>	western white clematis	
	DEBI	<i>Delphinium bicolor</i>	little larkspur	
	THDA	<i>Thalictrum dasycarpum</i>	purple meadow-rue	
	THVE	<i>Thalictrum venulosum</i>	veiny meadow-rue	
Rosaceae	AMAL2	<i>Amelanchier alnifolia</i>	Saskatoon serviceberry	
	DAFR6	<i>Dasiphora fruticosa</i>	shrubby cinquefoil	
	DRAR8	<i>Drymocallis arguta</i>	tall cinquefoil	
	GETR	<i>Geum triflorum</i>	old man's whiskers	
	POTEN	<i>Potentilla</i>	cinquefoil	*
	PONO3	<i>Potentilla norvegica</i>	Norwegian cinquefoil	
	POPE8	<i>Potentilla pensylvanica</i>	Pennsylvania cinquefoil	
	PRVI	<i>Prunus virginiana</i>	chokecherry	
	ROAR3	<i>Rosa arkansana</i>	prairie rose	
	ROWO	<i>Rosa woodsii</i>	Woods' rose	
Rubiaceae	GAAP2	<i>Galium aparine</i>	stickywilly	
	GABO2	<i>Galium boreale</i>	northern bedstraw	
Salicaceae	PODE3	<i>Populus deltoides</i>	eastern cottonwood	
	SAAM2	<i>Salix amygdaloides</i>	peachleaf willow	
Santalaceae	COUM	<i>Comandra umbellata</i>	bastard toadflax	
Saxifragaceae	HERI	<i>Heuchera richardsonii</i>	Richardson's alumroot	

Family	Code	Scientific Name	Common Name	Exotic
Scrophulariaceae	CASE5	<i>Castilleja sessiliflora</i>	downy paintedcup	
	ORLU2	<i>Orthocarpus luteus</i>	yellow owl's-clover	
	PEGR5	<i>Penstemon gracilis</i>	lilac penstemon	
	SYWY99	<i>Synthyris wyomingensis</i>	Wyoming kittentails	
Selaginellaceae	SEDE2	<i>Selaginella densa</i>	lesser spikemoss	
Solanaceae	PHHE5	<i>Physalis heterophylla</i>	clammy groundcherry	
	PHVI5	<i>Physalis virginiana</i>	Virginia groundcherry	
Unknown family	UNKFORB	<i>Unknown forb</i>	unknown forb	*
Unknown family	UNKGRAM	<i>Unknown graminoid</i>	unknown graminoid	*
Urticaceae	PAPE5	<i>Parietaria pensylvanica</i>	Pennsylvania pellitory	
Verbenaceae	VEST	<i>Verbena stricta</i>	hoary verbena	
Violaceae	VIOLA	<i>Viola</i>	violet	
	VIAD	<i>Viola adunca</i>	hookedspur violet	
	VINU2	<i>Viola nuttallii</i>	Nuttall's violet	