Plant Community Composition and Structure Monitoring for Scotts Bluff National Monument, 2011-2015 Summary Report

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Natural Resource Stewardship and Science

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2011-2015 Summary Report

Natural Resource Report NPS/NGPN/NRR—2016/1145

ON THIS PAGE
Photograph of riparian cottonwood forest at Scotts Bluff National Monument, 2014.
Photograph courtesy of the National Park Service.

ON THE COVER
Photograph of Scotts Bluff National Monument, 2015.
Photograph courtesy of the National Park Service.

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National Park Service
Natural Resource Stewardship and Science
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Executive Summary

The Northern Great Plains Inventory & Monitoring Program and Fire Effects Program have been monitoring vegetation in Scotts Bluff National Monument for over 18 years. While methods have changed slightly, this report summarizes data from over 80 locations from 1998-2015. Below, we list the questions we asked using these data and provide a summarized answer. For more details see the full report. A summary of the current condition (2011-2015) and trends (based on 1988-2015) in plant communities at Scotts Bluff is found in Table ES-1 below.

1. **What is the current status of plant community composition and structure of SCBL grasslands (species richness, cover, and diversity) and how has this changed from 1998 to 2015?**

   SCBL plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the area. Native plant diversity is at a moderate level compared to other grasslands in the region (Table 10), but diversity is spatially variable. We found no significant trends in native diversity or evenness from 1998 to 2015, but both are threatened by the increasing cover of annual bromes (Figure 9). There has been an increase in annual brome abundance since the 1990s and continued control efforts will be necessary to maintain native prairie within SCBL.

2. **How do trends in grassland condition correlate with climate and fire history?**

   The large variability in SCBL's climate makes it difficult to discern strong patterns linking temperature, precipitation, and plant community structure (e.g. exotic cover, diversity). Native diversity increased in plots with longer times since burning. There is an adaptive management program planned for 2017 which should provide better guidance to the park on the role of prescribed fire in managing annual bromes.

3. **What, if any, rare plants were found in SCBL long-term monitoring plots?**

   We identified 35 rare plant species in SCBL between 1998 and 2015; eight of these are considered critically imperiled within Nebraska. These plants are found in such low abundance and in such few plots, it is unlikely that plant community monitoring will be able to detect any trends in rare plant abundance. We recommend more targeted surveys of rare plant species of concern be completed when funds are available.

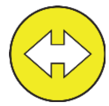
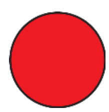
4. **Was the SCBL golf course restoration effective at creating a grassland community dominated by native species?**

   The golf course restoration project had mixed results. While some native grasses were established in one of the monitoring plots, establishment was poor in the other. To improve the rates of success and the establishment of native species, future projects should include funds to cover invasive plant control for many years (~10) after planting.

5. **What is the composition and structure of riparian forests at SCBL?**

   The riparian forest in SCBL is a fairly diverse assemblage of cottonwood, willow species, green ash, and box elder. Exotic grasses and forbs are common in the understory of the riparian forest, and continuing control efforts will be necessary to prevent their spread. The large abundance of green ash and box elder seedlings suggests that a transition to ash-dominated forests is underway.

Table ES-1. Natural resource condition summary table for plant communities in Scotts Bluff National Monument (SCBL). Current values are based on data from 2011-2015 and trends are based on data from 1998-2015.

Indicator of Condition	Specific Measures	Current Value (mean ± SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Native species richness (1m^2 quadrats)	4.6 ± 0.3 species	3-15 species		SCBL plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the region. The park is characterized by low native species richness, but average richness is within a natural range of variability (Symstad and Jonas 2014). The lowest native diversity is found in the prairie dog town and former golf course. Native evenness has not changed since monitoring began in 1998.
	Evenness (point-intercept transects)	0.67 ± 0.014	To be determined		
Exotic Plant Early Detection and Management	Relative cover of exotic species	41.2 ± 2.5%	< 10 % cover		Many areas of SCBL have a high cover of exotic species. Annual bromes: cheatgrass and Japanese brome present the largest challenge to SCBL. Exotic cover and annual brome cover has shown an increasing trend since 1998. More research on effective management strategies is greatly needed.
	Annual brome cover	37.2 ± 2.3%	< 10 % cover		
Riparian Forest	Plains cottonwood stand seral stage	Late seral stage	A mix of seral stages		The riparian forests of SCBL are currently a mosaic of areas dominated by willow, cottonwood, ash, and boxelder with an understory of many exotic plants. As cottonwood forests age in SCBL, green ash and box elder are likely to become more dominant. Only 2 of 20 plots had evidence of young cottonwoods, but more than half the riparian forest in SCBL had large densities of other native tree and shrub. Forest surveys will be repeated every 5 years in SCBL and this will allow us to detect trends in condition.
	Percent of 20 riparian plots with native deciduous seedlings	60%	To be determined		

Acknowledgments

We thank the authors of the NGPN Plant Community Monitoring Protocol, particularly A. Symstad, for outstanding guidance on data collection and reporting. Thank you to the staff at SCBL, particularly R. Manasek, for providing logistical support and performing safety checks. The NGPN and NGPFire vegetation field crews collected all the data included in this report. We thank D. Swanson for providing data on fire history and A. Weaver for helping with the maps for this report. Comments from R. Manasek, A. Symstad, D.Swanson, C. Thomsen, M. DeBacker, and T. Folts-Zettner improved this manuscript.

Introduction

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

Scotts Bluff National Monument (SCBL), established in 1919 to protect and preserve two iconic bluffs and the associated heritage of western expansion, covers 3,003 acres and is dominated by mixed-grass prairie with smaller areas of juniper woodlands, badlands, and riparian forests. Vegetation monitoring began at SCBL in 1997 by the Heartland Inventory & Monitoring Program (James 2010) and the Northern Great Plains Fire Ecology Program (NGPFire; Wienk et al. 2011). In 2010, SCBL was incorporated into the Northern Great Plains Inventory & Monitoring Network (NGPN). At that time, vegetation monitoring protocols and plot locations were shifted to better represent the entire park and to coordinate efforts with NGPFire (Symstad et al. 2012b). A total of 34 plots were established by NGPFire and NGPN in SCBL and the combined sampling efforts began in 2011 (Ashton et al. 2011). In 2014, an additional 20 plots were established in the riparian forest to assess forest condition. In this report, we use the data from 2011-2015 to assess the current condition of park vegetation and the data from 1998-2015 are used to look at longer-term trends.

Using 18 years of plant community monitoring data in SCBL, we explore the following questions:

1. What is the current status of plant community composition and structure of SCBL grasslands (species richness, exotic plant cover, and diversity) and how has this changed from 1998-2015?

2. How do trends in grassland condition correlate with climate and fire history?

3. What, if any, rare plants were found in SCBL long-term monitoring plots?

4. Was the SCBL golf course restoration effective at creating a grassland community dominated by native species?

5. What is the composition and structure of riparian forests at SCBL?

Methods

Three different methods and protocols have been used to monitor long-term vegetation plots at SCBL since 1997: the NGPN monitoring protocol (Symstad et al. 2012b, a), the Fire Monitoring Handbook (NPS 2003), and the Heartland Vegetation Monitoring Protocol (James et al. 2009). Below, we briefly describe all three methods, but focus on the NGPN monitoring protocol, which is the current standard and was used to collect most of the data in this report. For more detail on any of the methods, please see the protocol publications (cited above).

NGPN and NGPFire Monitoring Plots 2011-2015

The NGPN and NGPFire implemented a survey to monitor plant community structure and composition in SCBL using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, NGPN selected 20 randomly located sites within the upland grasslands of SCBL to become Plant Community Monitoring plots (PCM plots; Figure 1). The NGPN visits 8 PCM plots every year using a rotating sampling scheme where 4 sites were visited in the previous year and 4 sites are new visits. After 5 years (2011-2015), most of the PCM plots were visited at least twice during the last two weeks of May. When a PCM plot fell within an active burn unit, NGPFire added additional visits based on a 1, 2, 5, and 10 year sampling schedule. NGPFire also established and monitored a number of new sites focused in active burn units (Fire FPCM plots) using the same GRTS sampling schema. From 2011-2015, 14 FPCM plots were established. Finally, using the same set of random sites, NGPN selected 20 additional PCM plots that fell within the riparian forest along the North Platte River. These were monitored in 2014 to assess forest condition. A total of 34 plots were established by NGPFire and NGPN in 2011-2015.

At each of the grassland 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 and herb-layer ($\leq$ 2 m) height and plant cover were collected on two 50 m transects (the long sides of the plot) using a point-intercept method (Figure 3). At 100 locations along the transects (every 0.5 m) a pole was dropped to the ground and all species that touched the pole were recorded, along with ground cover, and the height of the canopy (Figure 3). Using this method, absolute canopy cover can be greater than 100% (particularly in wet years and productive sites) because we record multiple layers of plants. Species richness data from the point-intercept method were supplemented in the 20 NGPN plots with species presence data collected in five 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).

When woody species were also 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. This occurred at only 2 PCM plots in SCBL from 2011-2015.

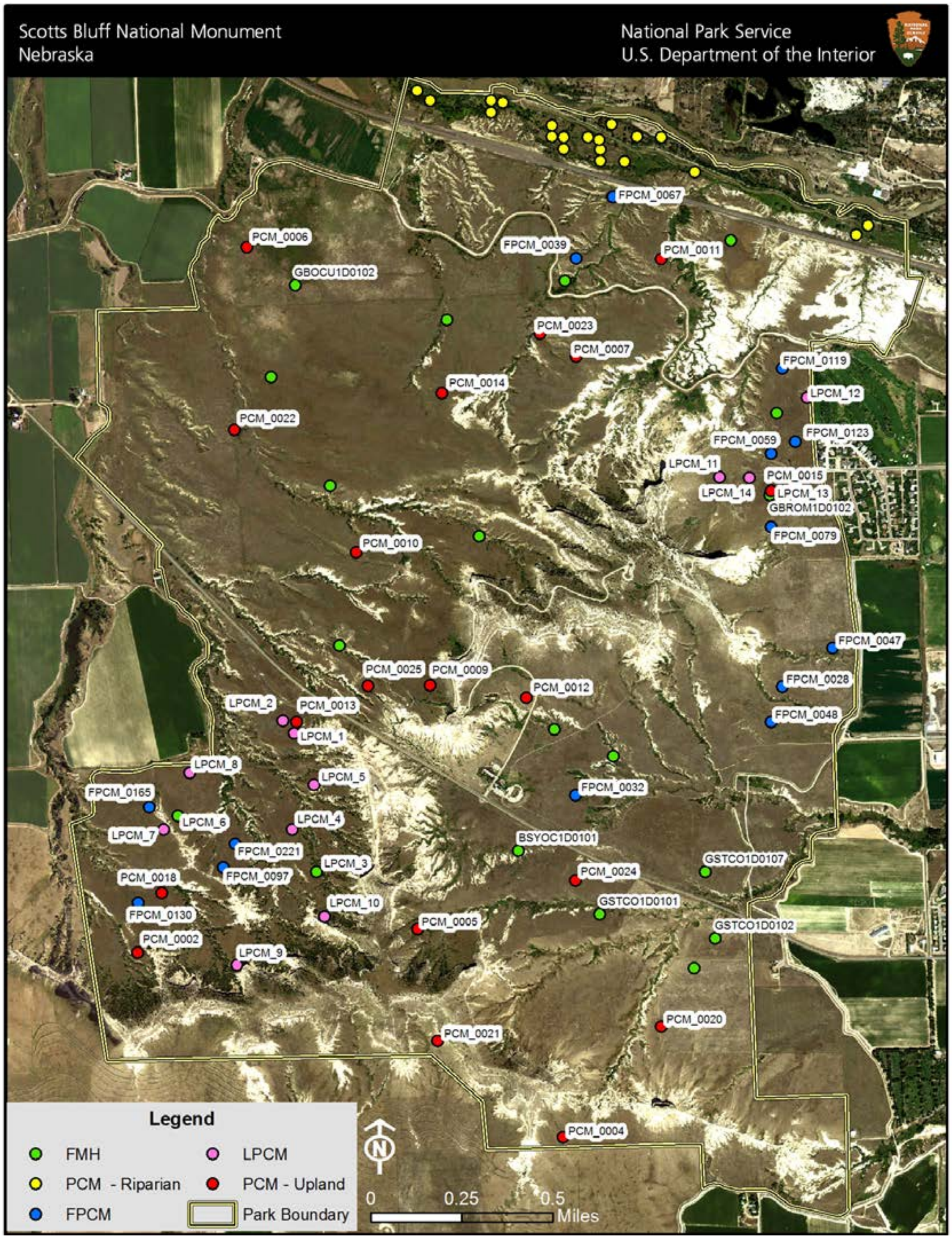


Figure 1. Map of Scotts Bluff National Monument (SCBL) plant community monitoring plots, 1997-2015. Twenty PCM plots (red) were established by the Northern Great Plains Inventory & Monitoring Program (NGPN) and 14 (blue) FPCM plots were established by the Fire Effects Program (NGPFire) between 2011 and 2015. Eleven LPCM plots were established by the Heartland Monitoring Network (pink) representing restored and native mixed-grass prairie. In 2014, 20 plots were established by the NGPN to monitor riparian forest condition (yellow). An additional 19 FMH plots (green) were monitored from 1997-2011 by NGPFire.

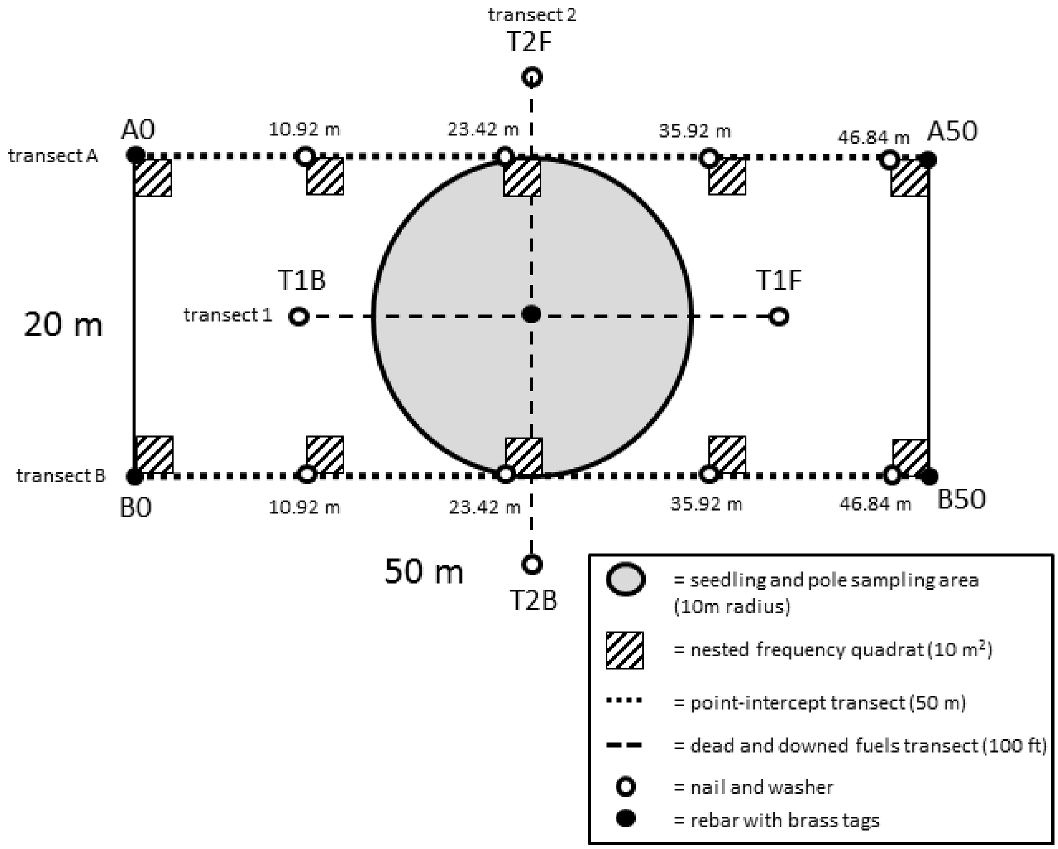


Figure 2. Long-term monitoring plot layout used for sampling vegetation in Scotts Bluff National Monument.

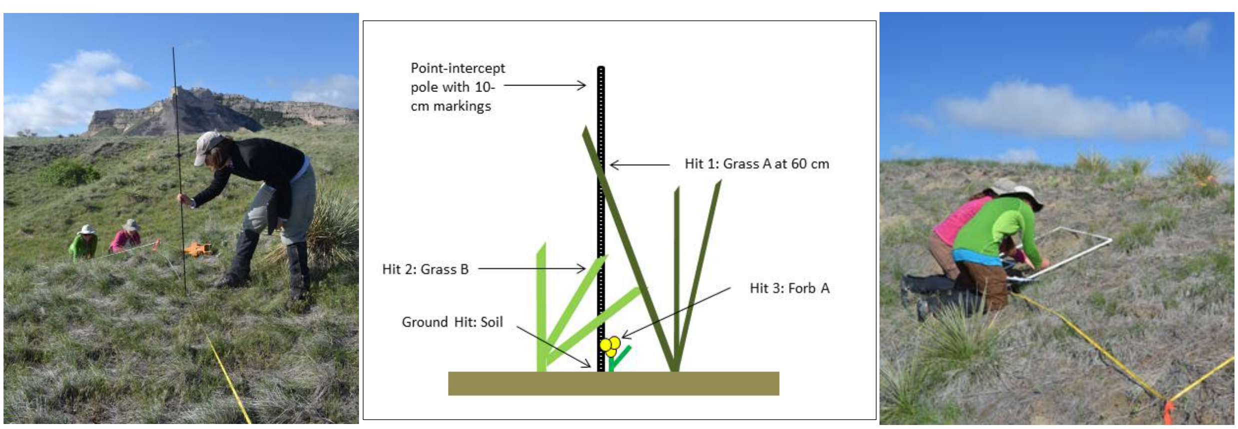


Figure 3. The Northern Great Plains Inventory & Monitoring vegetation crew used point-intercept (left and center panel) and quadrats (right panel) to document plant diversity and abundance.

NGPN completed a survey of riparian forests in SCBL in the last week of August 2014 using a set of 20 forested sites. In this case, seedlings and poles were measured as described above, but larger trees (DBH >15cm) were not tagged and only measured within the 10 m radius subplot. Dead and downed woody fuel load data were collected at these forested plots 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). These data were not reported because grasses dominated the fuel layer.

At all PCM plots, but not the FPCM plots, we also surveyed the area for common disturbances and target species of interest to the park. Common disturbances included such things as prairie dog towns, 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). These species were chosen in collaboration with the Midwest Invasive Plant Network, the Exotic Plant Management Team, park managers, and local weed experts. 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.

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

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

Other Monitoring Plots (1997-2015)

In 1997, NGPFire began monitoring plots within SCBL to evaluate the effectiveness of prescribed burns. Starting in 1998, data collection followed the NPS National Fire Ecology Program protocols (NPS 2003): in grassland plots vegetation cover and height data were collected using a point-intercept method, with 100 points evenly distributed along a single 30 m transect. In forested sites, plots are 0.1 ha (20 x 50 m) in size and point-intercept data were collected along the two 50 m sides. For each live tree with a DBH > 15 cm located within the 0.1 ha plot, the species and DBH were recorded. The densities of smaller trees (2.54 cm ≤ DBH ≤ 15 cm) were measured within a subset of the plot area. NGPFire plot locations were located randomly within major vegetation types within areas planned for prescribed burning (burn units) in the near future. The plots were then sampled 1, 2, 5, and 10 years after a prescribed burn. The data were not collected using these protocols in 1997 and 2010, so these years were excluded from analyses. Hereafter, we refer to these plots as Fire Monitoring Handbook (FMH) plots. These FMH plots are being retired after the10 year visit (e.g. the rebar will be removed) and replaced with the FPCM plots described above.

The Heartland Inventory & Monitoring Program also established a number of plots in 1997. Plant frequency was measured using circular subplots as described in the Heartland Networks' vegetation monitoring protocol (James et al. 2009). The data and a summary of results from these plots are described in detail by James (2010). In 2009, 2013 and 2014, a subset of these plots (called Legacy Plant Community Monitoring Plots, LPCMs) was revisited by NGPN and point-intercept data was also collected using the methods described above. These plots were chosen to revisit because they were established to evaluate the effectiveness of a restoration project. In 1989, Scotts Bluff NM began a restoration project in a former golf course with a goal of restoring native prairie –these areas were planted with native grasses and forbs in 1997 (Huddle et al. 2001), two plots were established within the restored area (LPCM_13 and 14) and two plots were established nearby in native prairie (LPCM_11 and 12). In this report, we present the point-intercept from the 3 survey years, but do not report frequency.

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 2015). 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. This report uses common names after the first occurrence in the text, but scientific names can be found in Appendix A.

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 used 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/or the FFI database as needed. Summaries were produced using the FFI reporting and query tools and statistical summaries, and graphics were generated using R software (version 3.2.2).

Plant life forms (e.g., shrub, forb) were based on definitions from the USDA Plants Database (USDA-NRCS 2015). The conservation status ranks of plant species in Nebraska is determined by the Nebraska Natural Heritage Program (NENHP). For the purpose of this report, a species was considered rare if its conservation status rank was S1, S2, or S3. See Table 2 for a detailed definition of each conservation status rank.

Table 2. Definitions of state and global species conservation status ranks*.

Status Rank	Category	Definition
S1/G1	Critically imperiled	Due to extreme rarity (5 or fewer occurrences) or other factor(s) making it especially vulnerable to extirpation.
S2/G2	Imperiled	Due to rarity resulting from a very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation.
S3/G3	Vulnerable	Due to a restricted range, relatively few populations (often 80 or fewer), recent widespread declines, or other factors making it vulnerable to extirpation.
S4/G4	Apparently secure	Uncommon but not rare; some cause for concern due to declines or other factors.
S5/G5	Secure	Common, widespread and abundant.
S#S#/ G#G#	Range rank (e.g. S2S3)	Used to indicate uncertainty about the status of the species or community. Ranges cannot skip more than one rank.

* Adapted from NatureServe status assessment table (http://www.natureserve.org/conservation-tools/conservation-status-assessment)

We measured diversity at the plots in two ways: species richness and Pielou's Index of Evenness. Species richness is simply a count of the species recorded in an area. Peilou'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. Plant richness was calculated for each plot using the total number of species intersected along the transects. Average height was calculated as the average height per plot using all species intersected on the transects.

Climate data from the Scottsbluff , Nebraska W.B. Heilig Field Airport weather station (GHCND:USW00024028) were downloaded from NOAA's online database (NOAA 2015). Fire history maps were compiled for the park and cross-referenced with plot locations. For each time data were collected at a plot (i.e., plot visit), we determined the number of years since the plot had burned and the number of fires recorded for that plot. For plots where no burns were recorded, we calculated the difference between the year of data collection and the oldest fire recorded in the park. This is likely an underestimate of the true time since it burned because fires were infrequent prior to the 1980s.

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 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 concern, 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”, or TBD, 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

Status & Trends in Community Composition and Structure of SCBL Prairies

There are 515 plant species on the SCBL species list and we found 250 of these in monitoring plots from 1998-2015 at SCBL (Appendix A). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at SCBL, but forbs, shrubs and subshrubs (defined as low-growing shrubs usually shorter than 0.5m) were also present (Figure 4). We found 40 exotic plant species at SCBL, all of which were forbs or graminoids. Exotic graminoids were particularly abundant (Figure 4). The shrubs and subshrubs were all native species.

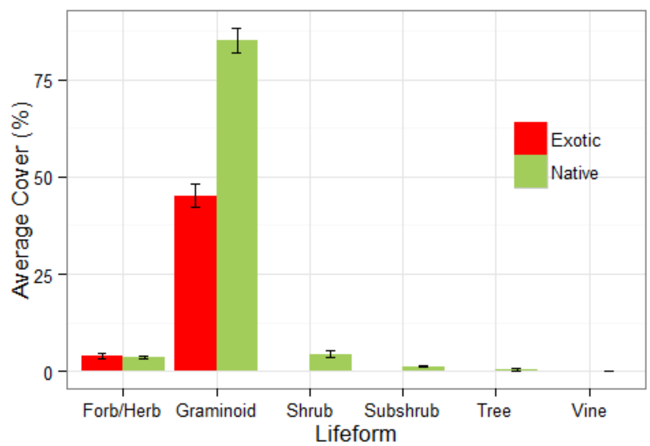


Figure 4. Average cover by lifeform of native (green) and exotic (red) plants recorded in monitoring plots in Scotts Bluff National Monument (1998-2015). Absolute cover can be greater than 100% because the point-intercept methods records layers of overlapping vegetation.

Western wheatgrass (*Pascopyrum smithii*), needle and thread (*Heterostipa comata*), and threadleaf sedge (*Carex filifolia*) were the most abundant native graminoids and averaged between 15 and 30% absolute cover (Figure 5). Cheatgrass (*Bromus tectorum*) and Japanese brome (*B. japonicus*) were the most pervasive exotics at SCBL. Cheatgrass and Japanese brome are both Eurasian, annual grasses that have been a part of the NGP landscape for more than a century, but their invasion in the region has accelerated since 1950 (Schachner et al. 2008). The presence of annual bromes in mixed grass prairie is associated with decreased productivity and altered nutrient cycling (Ogle et al. 2003). There is strong evidence from regions further west that cheatgrass alters fire regimes and the persistence of native species (D'Antonio and Vitousek 2003). Our data suggest that the cover of annual bromes has been increasing over time (R^2=0.19, $F_{1,121}$ =36.5 P<0.001; Figure 6). From 1998 to 2015, the average relative cover of annual bromes was 27.5 ± 1.8% (mean ± standard error), but the average for the last 5 years was 37.2 ± 2.3%. While there are many other exotic plants within SCBL, they contribute relatively little to cover. The average cover of all exotic species in 2011-2015 was 41.2 ± 2.5 %, meaning that over 90% of exotic cover is annual bromes. Clearly, reducing the cover of annual bromes presents a major challenge for the park, as it has been for the past 15 years. We are currently studying the temporal and spatial abundance of annual bromes in greater depth with a goal of using data to help guide management actions.

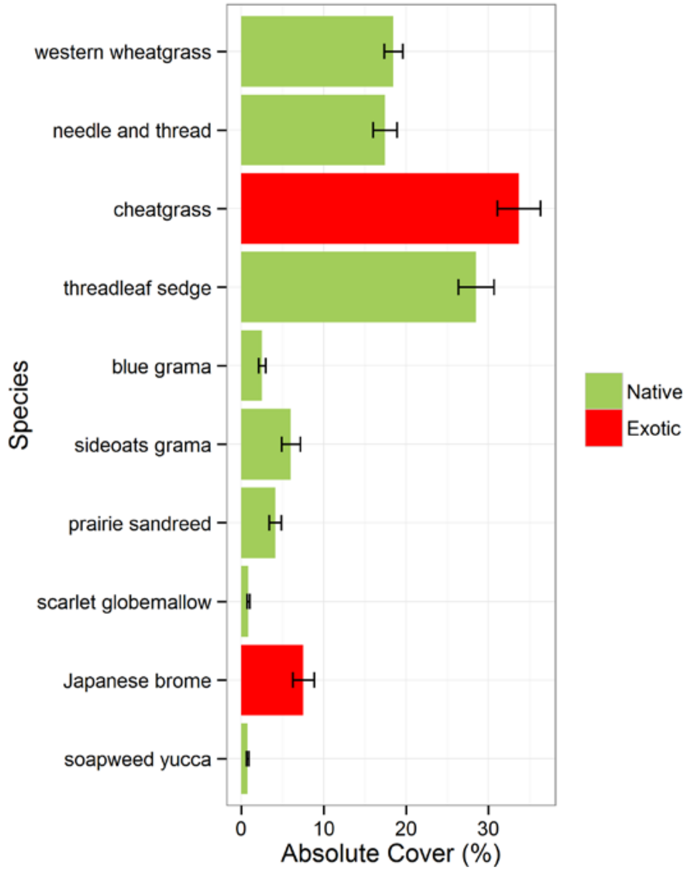


Figure 5. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded at Scotts Bluff National Monument in 1998-2015. Bars represent means ± one standard error.

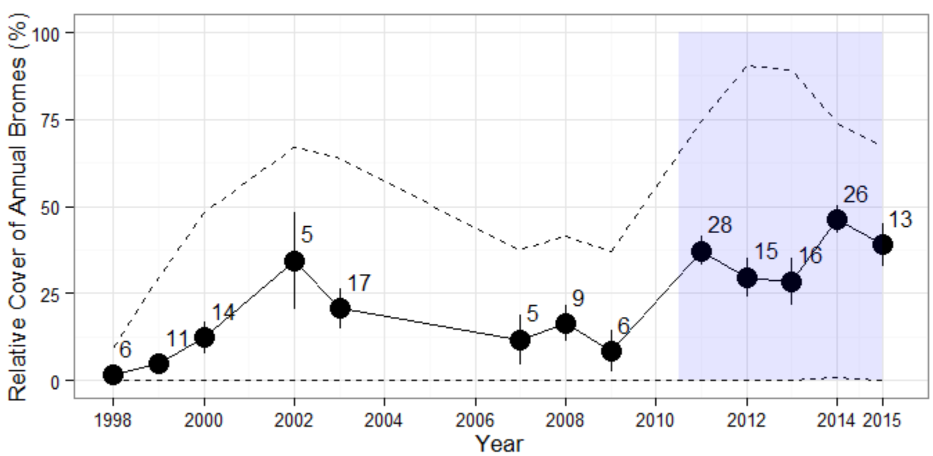


Figure 6. Trends in the relative cover of annual bromes in Scotts Bluff National Monument from 1998-2015. Points represent mean ± one standard errors and sample size is to the right of the point. Years with fewer than 3 monitoring plots were excluded from the graph. The shaded area highlights the period from 2011-2015 when sampling methods were consistent and distribution of plots was more even and consistent across years. The dashed line represents the maximum and minimum cover values for each year.

Species Richness, Diversity, and Evenness

One of the ways for the NPS to measure effectiveness of actions to achieve its mission of 'preserving ecological integrity' is to examine trends in native plant diversity and evenness within park boundaries. Average species richness has been measured by point-intercept since 1998 and in 1 m^2 and 10 m^2 quadrats since 2011 (Table 4).

Table 4. Average plant species richness in monitoring plots at Scotts Bluff National Monument from 1998 to 2015. Values represent means ± one standard error.

	Point-intercept (1998-2015; n=58)	**1 m^2 quadrats** (2011-2015, n=38)	**10 m^2 quadrats** (2011-2015, n=38)
Species richness	11.0 ± 0.6	6.3 ± 0.3	10.0 ± 0.6
Native species richness	8.6 ± 0.5	4.6 ± 0.3	7.7 ± 0.6
Exotic species richness	2.7 ± 0.2	1.6 ± 0.1	2.4 ± 0.2
Graminoid species richness	6.9 ± 0.3	3.7 ± 0.2	4.7 ± 0.2
Forb species richness	3.2 ± 0.2	2.3 ± 0.2	4.4 ± 0.4

While there was some variation across the park, the plots we visited in SCBL tended to have a low diversity of native plants compared to other mixed-grass prairies. Species richness in the mixed-grass prairie is determined by numerous factors including fire regime, grazing, prairie dog disturbance, and weather fluctuations (Symstad and Jonas 2011). In SCBL, there is also a mixed history of past land-use practices that have affected current species richness. While it is difficult to define a reference condition for species richness, which naturally varies considerably across both space and time, 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 Kansas varied between 3 and 15 species per square meter over the course of 30 years (Symstad and Jonas 2014). Compared to this, SCBL is within the natural range (5 species) but is on the low end of the range, and some sites, such as PCM_0006, 0015, and 0022 [in the northwest (0006, 0022) and northeast (0015) portions of the park; Figure 1], fall below this reference condition. In two of these plots, past and current land use can explain the degraded state: site 0006 falls within an active prairie dog town and historic feed lot, and 0015 is within the footprint of a former golf course. One of the most diverse plots, SCBL_FPCM_0039 in the north-central part of the park (Figure 1), has a mix of native shrub and grassland habitat (Figure 7).

We did not find any trends in species richness or evenness (Figure 8). Native species richness in 1m^2 quadrats was consistent from 2011 to 2015 and ranged from a low in 2012 of 4.3 ± 0.7 (a drought year) to a high of 5.2 ± 0.6 in 2014 (a wet year). In the longer record from point-intercept data (1998-2015; Figure 8: top) annual average native richness ranged between 5 and 12 species. Annual average evenness ranged from 0.58 to 0.81 during this time period, indicating the plots were not strongly dominated by a single species (Figure 8: bottom). There is a great deal of variation in species richness and evenness among sites within the park (dashed lines in Figure 8 represent the maximum and minimum values) which makes long-term trends in these metrics difficult to detect.

Figure 7. A photograph of long-term monitoring plot SCBL_FPCM_0039 which has a large diversity of native plant species.

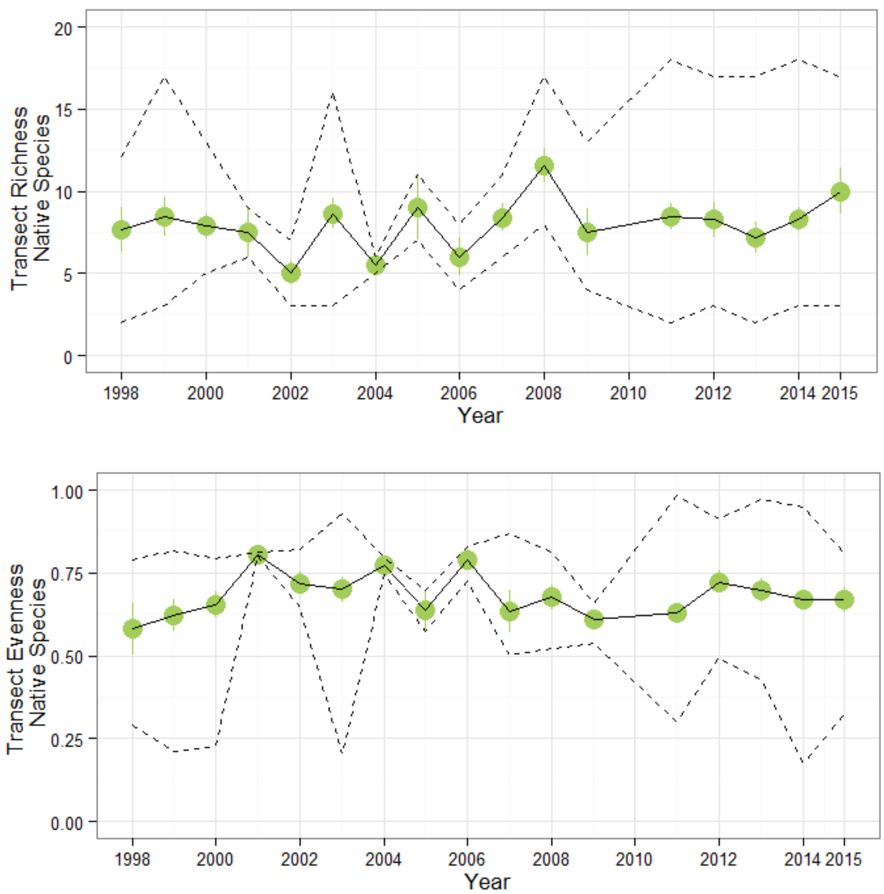


Figure 8. Trends in native species richness and evenness in Scotts Bluff National Monument, 1998-2015. Data are means ± one standard error. The dashed line indicates the maximum and minimum values for each year.

There is evidence from other regions that annual bromes can affect persistence of native species (D'Antonio and Vitousek 2003). In SCBL, there is a negative correlation between the cover of annual bromes and native species richness (Figure 9; $F_{1,162}$=19.3, P<0.0001). If the high cover of annual bromes in SCBL persists or increases, we expect there will be a corresponding decline in native species richness over time.

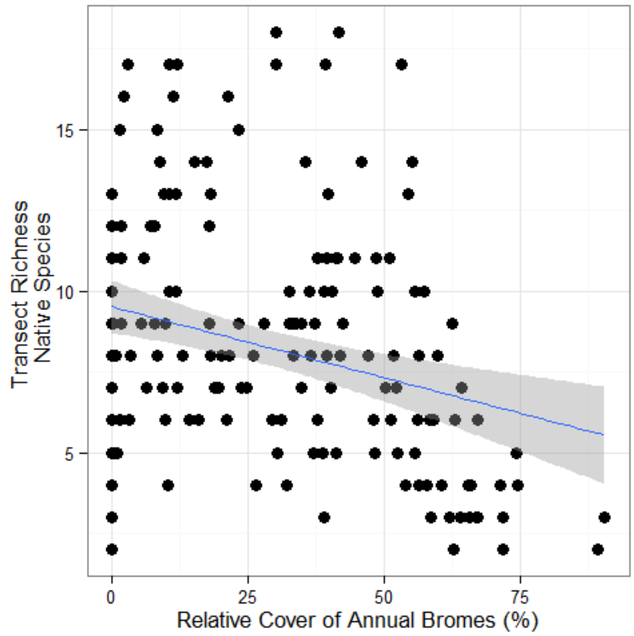


Figure 9. The relationship between native species richness and the relative cover of annual bromes in long-term monitoring plots at Scotts Bluff National Monument, 1998-2015.

Disturbance from grazing, prairie dogs, fire, and humans affects plant community structure and composition in mixed-grass prairie. We estimated the approximate area affected by natural and human disturbances at each site we visited in 2011-2015 by surveying the area for ~ 5 minutes at the end of the plot visit. The most common disturbance was from rodents (e.g. pocket gophers) and prairie dogs, but there was also evidence of deer trails and grazing. We found no correlation between native richness or exotic cover and total disturbance or small or large animal disturbance.

The Influence of Climate and Fire on Plant Community Structure and Diversity

Climate

The Northern Great Plains has a continental climate, with hot summers and very cold winters. The 30- year normal temperatures at a nearby weather station, Scottsbluff W B Heilig Field airport, ranged from average minimum monthly temperatures in December of 12.5° F to maximum monthly July temperatures of 89.8° F (based on 1981-2010). The 30-year normal annual precipitation totals 15.79 inches. Annual precipitation at SCBL in 1998-2015 was variable and ranged between 6.9 and 22.9 inches, in 2012 and 2015, respectively. There were dry years in the early 2000s, 2006-2008, and in 2012-2013 (Figure 10). The last two years have been much wetter than average. The native vegetation is adapted to this variation, and productivity responds strongly to decreases in spring and summer precipitation (Yang et al. 1998, Smart et al. 2007). Species richness and diversity in regional grasslands are also sensitive to temperature and precipitation fluctuation, but the response is complex and less predictable (Jonas et al. 2015).

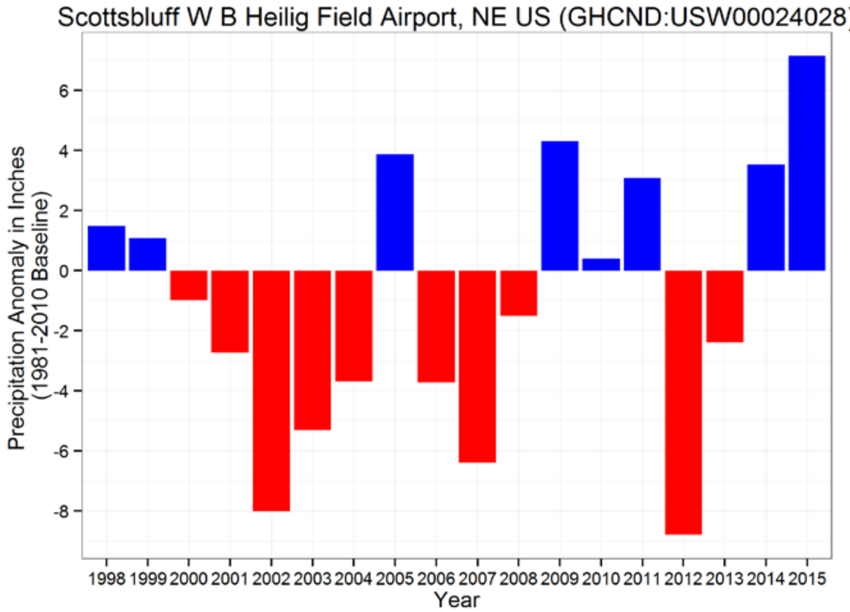


Figure 10. The total annual precipitation anomaly from 1998-2015 for Scott Bluff National Monument. Positive values (blue) represent years wetter than and negative values (red) years drier than the 1981-2010 average. The anomaly is measured in inches and based on data from a nearby weather station.

At SCBL, the average height of plants increased with increasing precipitation (R^2=0.23, *P*=0.05), but did not respond to temperature. There was a marginally significant trend for native species richness to increase in years with more precipitation (R^2=0.17, *P*=0.09), but richness did not correlate with temperature. The relative cover of annual bromes did not correlate with total annual precipitation or temperature. Because of the large variation in annual temperature and precipitation patterns at SCBL, a longer time series of vegetation data is needed to elucidate trends and correlations with climate.

Fire History

Historically, fire was a common disturbance in Northern Great Plains grasslands, with natural fire return intervals of 9-12 years (Guyette et al. 2015). Natural fires have been suppressed for most of the last century, but the use of prescribed burning in Northern Great Plains parks to mitigate the effects of the absence of natural fires has increased over time since its start at Wind Cave NP in 1973 (Wienk et al. 2011). As of 2015, there is a mosaic of recently burned and unburned areas at SCBL (Figure 11).

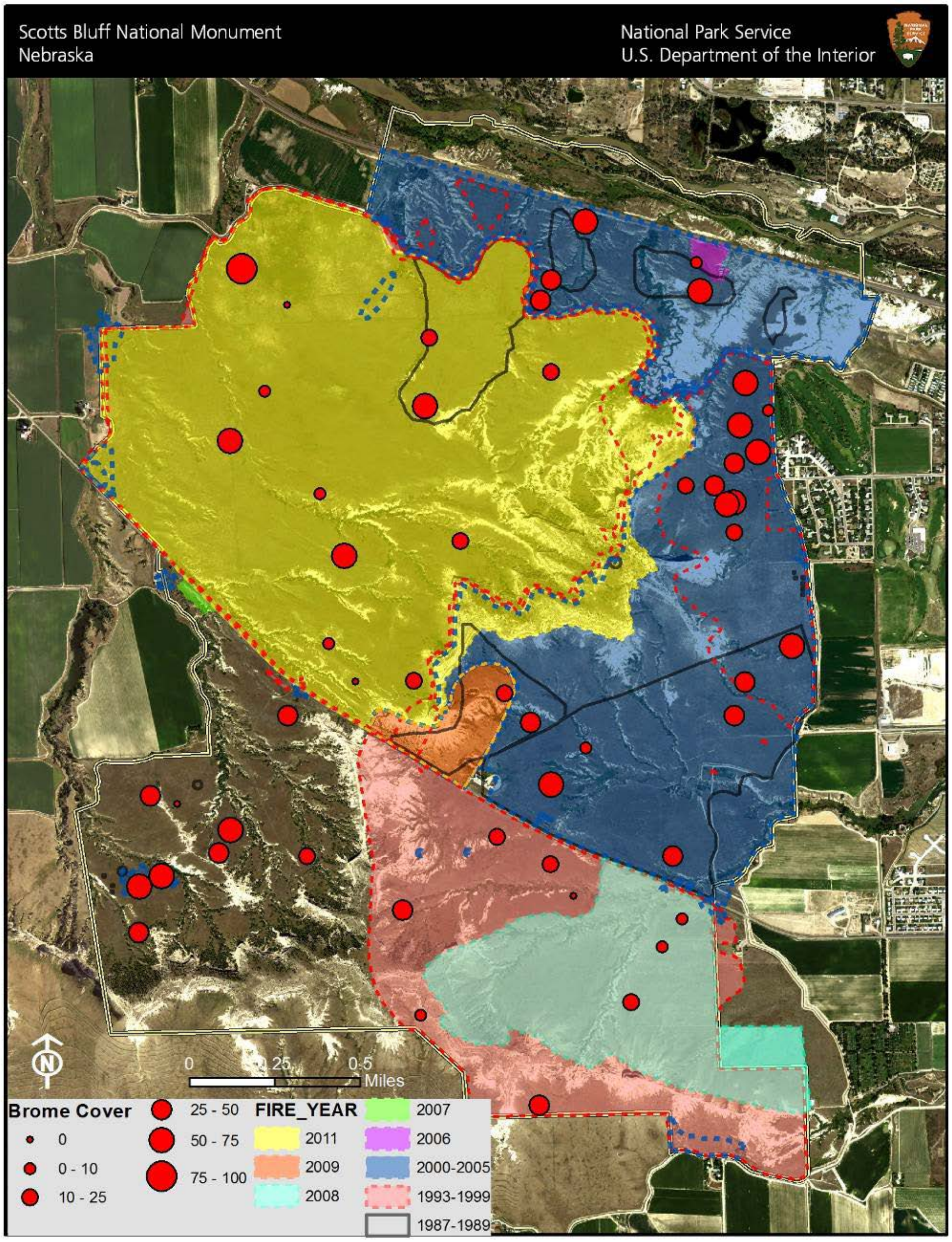


Figure 11. Map of recent fire history (polygons) and relative cover of annual bromes at long-term monitoring plots (red) at Scotts Bluff National Monument. Larger bubbles indicate higher relative cover of annual brome.

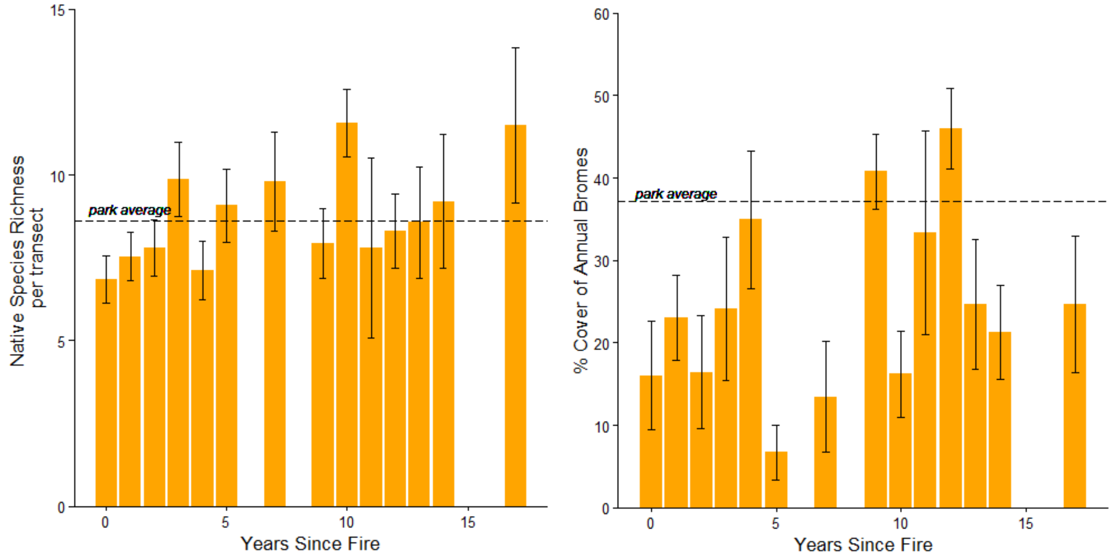


Figure 12. Native species richness and percent cover of annual bromes across plots with different fire histories.

The effects of specific prescribed burns on vegetation and fuel loads and more details about fires at SCBL can be found in past NGPFire annual reports (see http://www.nps.gov/ngpfire/docs.htm). Here, we were interested in determining the relationship between fire history and vegetation. We compared two vegetation metrics, native species richness and relative cover of annual bromes, with the length of time between the data collection at a plot and the most recent fire at that plot (years since fire). For example, a site that burned in the spring and then was visited in the summer would be 0 years since fire. We excluded plots that had not burned from this analysis, because we do not have confidence in the historical fire record (pre-1980s).

We found a positive relationship between native richness and years since fire (Figure 12; $F_{1,136}$=6.3, P=0.0135). There was a lower number of native species in sites that burned more recently. This suggests that prescribed fire may reduce native species richness in the short term, but it over time mixed-grass prairie recovers. We found no significant relationship between annual brome and years since fire (Figure 12; $F_{1,136}$=0.9, P=0.3325). This implies that in the short-term, prescribed burns are not effective at reducing brome. However, unburned plots concentrated in the southwest portion of the park had a higher cover of annual bromes than sites that burned more recently (Figure 11). Burning this unit of the park may assist in increasing native richness and reducing annual brome cover. The increasing trend in annual brome abundance across the park (Figure 6) despite fairly frequent prescribed burns suggests that burning alone may not be sufficient. The best approach to reducing annual brome abundance in SCBL will likely include burning, targeted herbicides, and seeding of native species. Ongoing research on this topic and an upcoming adaptive management initiative for annual brome control in NGPN parks should provide more data and guidance to help with these management decisions.

Rare Plants

While repeating rare plant surveys and locating rare species is not the focus of NGPN plant community monitoring, we identified 35 rare plant species in SCBL monitoring plots from 1998 to 2015. Of these species, the critically imperiled species slender wheatgrass (*Elymus trachycaulus* S1; Figure 13) was the most abundant with an average cover of 1.52%. Other critically imperiled species were observed in low frequencies and abundances, with hairy false goldenaster (*Heterotheca villosa* S1) being more common and occurring in nine plots with 0.08% average cover. Other rare species abundances are described in Table 5, and 22 vulnerable to secure (S3S5) species observations are noted in Appendix A. Most of the rare species we observed are classified as apparently secure or secure (G4 or G5) at the global scale, but are rare in Nebraska as a result of these species existing on the edge of their global range in the state.

Figure 13. Photographs of two critically imperiled species in Nebraska found in plant community monitoring plots at Scotts Bluff National Monument. *Left*: slender wheatgrass (*Elymus trachycaulus S1*). *Right*: hairy false goldenaster (*Heterotheca villosa* S1).

Table 5. Rare species occurrence in Scotts Bluff National Monument from 1998-2015. Status ranks are based on Nebraska Natural Heritage Program designations. Plot count is the number of unique plots a species was recorded in across all years. Mean cover is the average cover of that species across all years in plots where cover measurements were recorded.

Species	Common Name	State Rank	Global Rank	Plot Count	Mean Cover (%)
Hieracium umbellatum	narrow-leaf hawkweed	S1	G5	1	0.00
Pseudoroegneria spicata	bluebunch wheatgrass	S1	G5	3	0.08
Astragalus agrestis	field milk-vetch	S1	G5	2	0.01
Danthonia spicata	poverty oatgrass	S1	G5	1	0.00
Elymus lanceolatus	thickspike wheatgrass	S1	G5	2	0.01
Elymus trachycaulus	slender wheatgrass	S1	G5	44	1.52
Heterotheca villosa	hariy goldenaster	S1	G5	9	0.02
Senecio integerrimus	lambstongue ragwort	S1	G3	1	<0.01
Antennaria microphylla	little-leaf pussytoes	S2S4	G4G5	1	0.00
Fritillaria atropurpurea	leopard-lily	S2S4	G5	1	0.00
Physaria reediana	rock bladder-pod	S2S4	G4	1	0.00
Ericameria nauseosa	rubber rabbitbrush	S2S4	G5	7	0.02
Vicia americana	American vetch	S2S4	G5	13	0.08

Since it has been 20 years since the last rare plant survey was done at SCBL (Rolfsmeier 1996), we recommend a survey be redone when funds are available. A full rare plant survey will be more likely to accurately quantify the status of rare plants found on the main bluffs, an area with no monitoring plots. Any future construction efforts that could disturb native vegetation (e.g. trail building), should avoid damaging species considered rare in Nebraska.

Golf Course Restoration Project

Scotts Bluff NM acquired the property of a former golf course in 1973. Just over a decade later, the park began to restore the area by removing concrete, planting millet, spraying the area with an herbicide, and mowing. In 1997, it was planted with a mix of native grasses including western wheatgrass, junegrass (*Koeleria macrantha*), needle and thread, blue grama (*Bouteloua gracilis*), sideoats grama (*B. curtipendula*), and buffalograss (*B. dactyloides*) (Huddle et al. 2001). Sedges (*Carex filifolia*) were transplanted into the restoration area, but most died after one season due to drought and exotic species pressures (*personal communication*, M. DeBacker, B. Manasek). Two monitoring plots were established within the restored area (LPCM_13 and 14; Figure 1) and two plots were established nearby in native prairie (LPCM_11 and 12; Figure 1). An earlier evaluation of the restoration project from 1997-2009 found mixed results: this evaluation found that the park was successful at creating a community that resembled the native prairie, except that threadleaf sedge, which is difficult to seed, was absent (Huddle et al. 2001). However, the restored sites did have a higher frequency of exotic grasses than the native prairie (James 2010).

NGPN visited the native prairie and restoration sites in 2009, 2013, and 2014. In 2014, many of the species originally planted in the restoration area were present in plots LPCM-13 and 14, but only a few were common enough to contribute to the plant cover as measured by the point-intercept method (Table 6). LPCM-13 had a high cover of western wheatgrass and trace amounts of sideoats and blue grama. The native grasses in LPCM-14 were more successful and junegrass was the only species missing from the area in 2014. However, native grasses remained in low abundance and blue grama, buffalo grass, and junegrass did not establish well in either plot.

The two restored plots differ from one another (Table 6), and neither closely resembles the nearby native prairie. LPCM_13 is characterized by lower native species richness and a much higher cover of annual bromes (close to 75% cover; Figure 14) than the control plots (which in 2014 averaged 6 native species and 12.8% cover of annual brome). LPCM-14 has a high diversity of native plants, but also has a very high cover of annual bromes (close to 50% cover). To improve the rates of success and the establishment of native species, future projects should include funds to cover weed control for many years (~10) after planting.

Table 6. Original seed mixture and composition of two restoration plots in Scotts Bluff National Monument in 2009, 2013, and 2014.

	Seed (% of mix)	**% Cover in restored plot LPCM-13**			**% Cover in restored plot LPCM-14**		
	1997	*2009*	*2013*	*2014*	*2009*	*2013*	*2014*
Western wheatgrass	58	44	19	22	13	4	3
Needle and thread	23	0	0	0	51	30	36
Sideoats grama	7	0	0	0	11.5	7	5
Blue grama	6	1	0	0	1.5	0	3
Buffalo grass	5	0	0	0	0	0	0
Junegrass	trace	0	0	0	0	0	0
Native species richness	-	5	2	3	13	8	10
Relative cover of annual bromes	-	36.9	71.7	71.9	10.5	39.4	48.9

Figure 14. Cheatgrass is the dominant species at the long-term monitoring plot, LPCM_13, at Scotts Bluff National Monument.

The Status of Riparian Forests in SCBL

In 2014, the NGPN established 20 plots in the forested area along the North Platte River to monitor status and trends in lowland riparian forest condition (Figure 15). The 2014 data provide a baseline dataset for future surveys; we plan to revisit the same plots every five years (e.g. 2019, 2024, etc.). The riparian lowland forest in Scotts Bluff NM is small (~ 60 acres), and comprises only about 2% of the park. The forest is fairly open and dominated by plains cottonwood (*Populus deltoides*), peachleaf willow (*Salix amygdaloides*), and green ash (*Fraxinus pennsylvanica*) (TNC 1998). There are also large areas of shrubland (Figure 15, light green and pink) and exotic-species-dominated grassland (Figure 15, green). The 20 monitoring plots were chosen randomly within the riparian corridor and fall in all of the dominant community types with the exception of narrowleaf willow (*S. exigua*) shrubland.

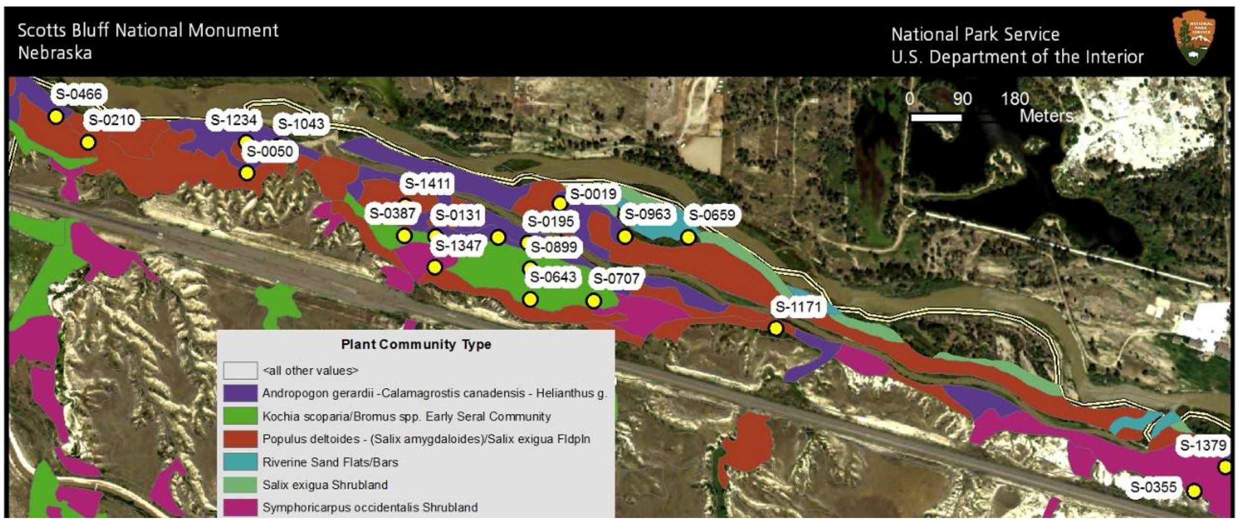


Figure 15. Map of the plant community types within the riparian area in Scotts Bluff National Monument and the location of 20 long-term monitoring plots (yellow). Vegetation classification is based on the NPS Vegetation Mapping Program report (TNC 1998).

In 2014, we found nine species of tree or tall shrub in 19 riparian forest plots at SCBL (Table 7). One plot (S-0899) did not have any tree or tall shrub species present. Our data were consistent with the 1990's vegetation map and the most common tree species were cottonwood, peachleaf willow, and green ash (Table 7). The density of large trees was similar across these three species (Table 8), but we found many fewer cottonwood seedlings compared to other species. Mature box elder (*Acer negundo*) trees occurred in only four plots (Table 7), but the average density was high (Table 8). As riparian forests along the North Platte age, cottonwood and willow forests are most often replaced with green ash and box elder forests (Johnson 1994). In 2014, we found numerous poles and seedlings of green ash and box elder but a few sites still have cottonwood and willow seedlings and poles present. Future monitoring is needed to determine if these stands will soon become dominated by green ash and box elder.

Table 7. Tree and tall shrub occurrence in 2014 at 20 plots in Scotts Bluff National Monument.

Species Name	Common Name	Number of plots with trees (DBH > 15 cm)	Number of plots with poles (2.5 cm ≤ DBH ≤ 15 cm)	Number of plots with seedlings
Salix amygdaloides	peachleaf willow	8	0	2
Populus deltoides	plains cottonwood	7	1	2
Fraxinus pennsylvanica	green ash	6	2	9
Acer negundo	boxelder	4	3	6
Juniperus scopulorum	Rocky Mountain juniper	1	1	0
Shepherdia argentea	silver buffaloberry	1	0	0
Prunus virginiana	chokecherry	0	1	4
Salix interior	sandbar willow	0	1	2
Ulmus americana	American elm	0	0	2

Table 8. Tree basal area and density by size class for dominant tree and shrub species in the riparian forest of Scotts Bluff National Monument. (Values: mean across 20 riparian forest monitoring ± standard error of the mean)

Species	Indicator	Value
Willow species	Basal Area (m^2/ ha)	3.4 ± 1.7
	Tree Density (stems/ha)	14 ± 5
	Pole Density (stems/ha)	53 ± 38
	Seedling Density (stems/ha)	5282 ± 3728
	Snag Density (stems/ha)	0
Plains cottonwood	Basal Area (m^2/ ha)	3.4 ± 1.6
	Tree Density (stems/ha)	18 ± 10
	Pole Density (stems/ha)	6 ± 6
	Seedling Density (stems/ha)	103 ± 102
	Snag Density (stems/ha)	3 ± 3
Green ash	Basal Area (m^2/ ha)	0.7 ± 0.3
	Tree Density (stems/ha)	15 ± 7
	Pole Density (stems/ha)	8 ± 6
	Seedling Density (stems/ha)	1973 ± 1070
	Snag Density (stems/ha)	5 ± 3
Box elder	Basal Area (m^2/ ha)	1.6 ± .08
	Tree Density (stems/ha)	28 ± 15
	Pole Density (stems/ha)	21 ± 14
	Seedling Density (stems/ha)	535 ± 273
	Snag Density (stems/ha)	3 ± 2

Since the mid to late 1880's, riparian forests have expanded along the North Platte as a result of the construction of dams and the resulting changes in water flow (Johnson 1994). Willows and cottonwoods have thrived because low flows in June allow for sufficient recruitment and lower peak flows and reduced ice scour reduce tree mortality. We compared our 2014 data to forest composition in the late 1850s to late 1880s (from Johnson 1994). The data from the late 1850s to late1880s encompasses a greater area, but the comparison shows large willows occurring in SCBL in 2014 but not historically, but also many more of the very smallest size classes (Figure 16, black bars). Cottonwoods also comprise a smaller proportion of the forest community (Figure 16, white bars), and there has been a decrease in the proportion of cottonwoods in smaller diameter classes and an increase in the large diameter classes (Figure 17) . This suggests that new cottonwoods are no longer being established at the same extent or rate as they were 150 years ago. A metric developed to classify cottonwood stand successional status indicates that SCBL riparian areas are primarily composed of late seral stage cottonwood stands, also suggesting a lack of cottonwood seedling recruitment (Uresk 2015). If the goal is to maintain cottonwood forests along this section of the North Platte, management interventions such as watering and fencing around existing cottonwood saplings could ensure that the young trees survive to maturity.

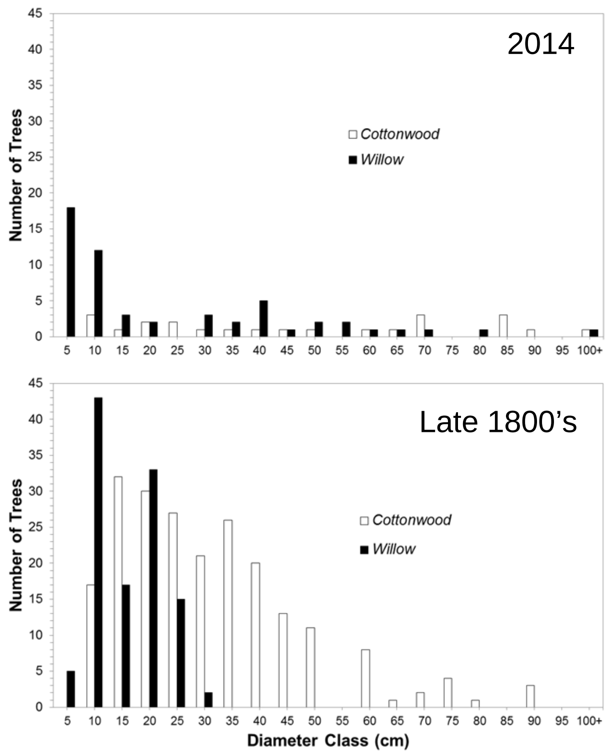


Figure 16. Diameter classes of cottonwood (*Populus*) and willow (*Salix*) trees in riparian forests along the North Platte River in Nebraska in the 1850-1880s (bottom panel; from Johnson 1994) and along the same river but only in Scotts Bluff National Monument in 2014 (top panel). Class categories indicate upper limits of each range (e.g. diameter class 10 includes individuals >5 cm and ≤10 cm).

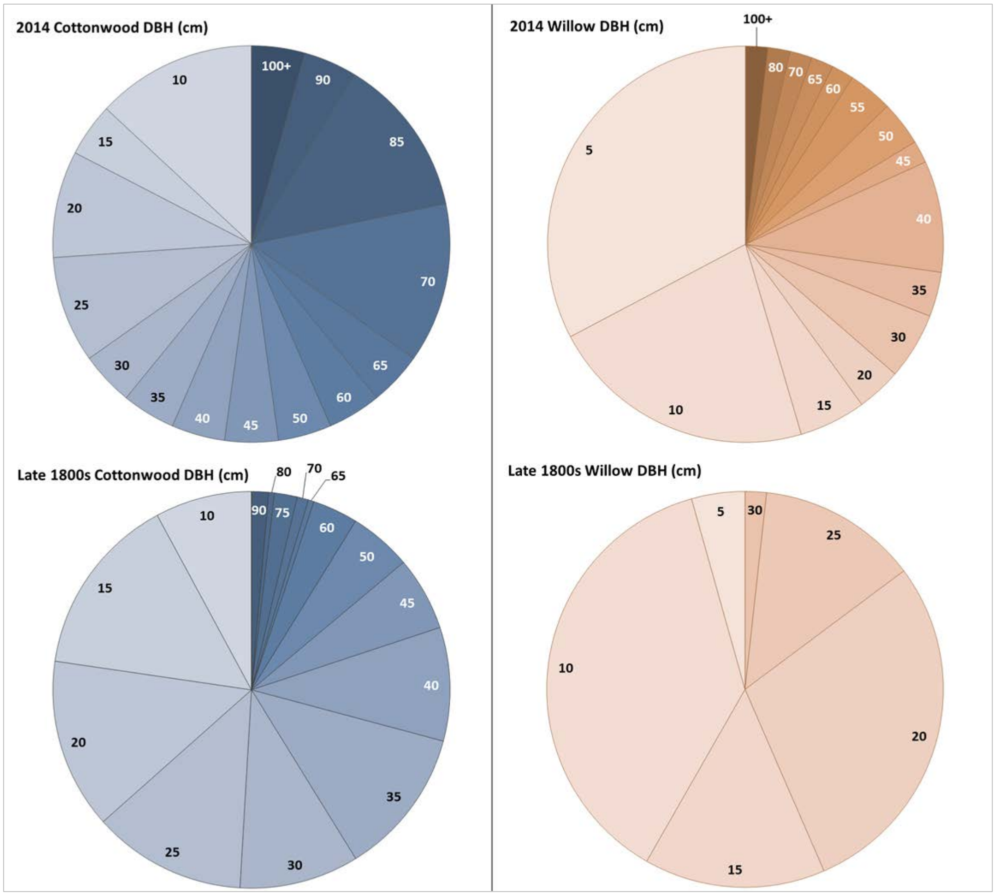


Figure 17. Size-class proportions of cottonwood (*Populus*) and willow (*Salix*) trees in riparian forests along the North Platte River in Nebraska in the 1850-1880s (bottom panels; from Johnson 1994) and along the same river but only in Scotts Bluff National Monument in 2014 (top panel). Labels in wedges indicate diameter-at-breast-height (DBH) class categories, and each number is the upper limit of that range (e.g. diameter class 10 includes individuals >5 cm and ≤10 cm).

Exotic Species in Riparian Forests

The understory of the riparian forests in SCBL is a mix of native and exotic plants. The focus of the 2014 survey was woody species, but field crews also surveyed for the presence of exotic species of management concern (e.g. musk thistle, poison hemlock) and potential early invaders (Table 1). Musk thistle and cheatgrass were found in a majority of the 20 plots (Table 9). On average, 3 exotic species were found in each plot. The only early detection we made was of perennial pepperweed (*Lepidium latifolium*); a number of plants were found in two plots in the center of the riparian corridor: SCBL_PCM_0963 and SCBL_PCM_1141 (Figure 15). Perennial pepperweed is an invasive plant that threatens wetlands, marshes, and floodplains in the Western US (Figure 18). It is common in Wyoming, but still relatively rare in Nebraska.

The NGP Exotic Plant Management Team (EMPT) is aware of the high density and cover of exotic plants in the riparian forest and much of their control efforts were concentrated in this area during the 2015 field season (Hauk 2016). The EPMT focused on the control of musk thistle (*Carduus nutans*), Canada thistle (*Cirsium arvense*), and poison hemlock (*Conium maculatum*). The NGP Exotic Management Team was notified of the perennial pepperweed, but there has not been a concerted effort at eradication. Unfortunately, the large seed bank and moist conditions will be challenging for continued control and eradication efforts of exotic species in this area. Moreover, the river continues to provide and an avenue for infestation. A more efficient use of resources may be in control efforts focused in upland areas with intact native communities (e.g. FPCM_0039, Figure 7) and rare plants (Rolfsmeier 1996).

Table 9. Exotic species detected in 20 riparian plots in Scotts Bluff National Monument and their corresponding abundance, cover class, and estimated percent cover.

Species	Common Name	Number of Plots	Average Cover Class	Estimated Cover (%)
Carduus nutans	musk thistle	17	2.4 ± 0.2	<5
Bromus tectorum	cheatgrass	12	4.3 ± 0.3	5-25
Verbascum thapsus	common mullein	8	2.0 ± 0.3	<1
Cirsium arvnese	Canada thistle	6	2.0 ± 0.0	<1
Cynoglossum officinale	houndstongue	6	1.7 ± 0.3	<1
Phalaris arundinacea	reed canarygrass	5	4.6 ± 0.4	5-25
Marrubium vulgare	horehound	4	2.0 ± 0.0	<1
Bromus inermis	smooth brome	3	3.0 ± 0.6	<5
Conium maculatum	poison hemlock	3	2.3 ± 0.3	<5
Lepidium latifolium	perennial pepperweed	2	2.0 ± 0.0	<1

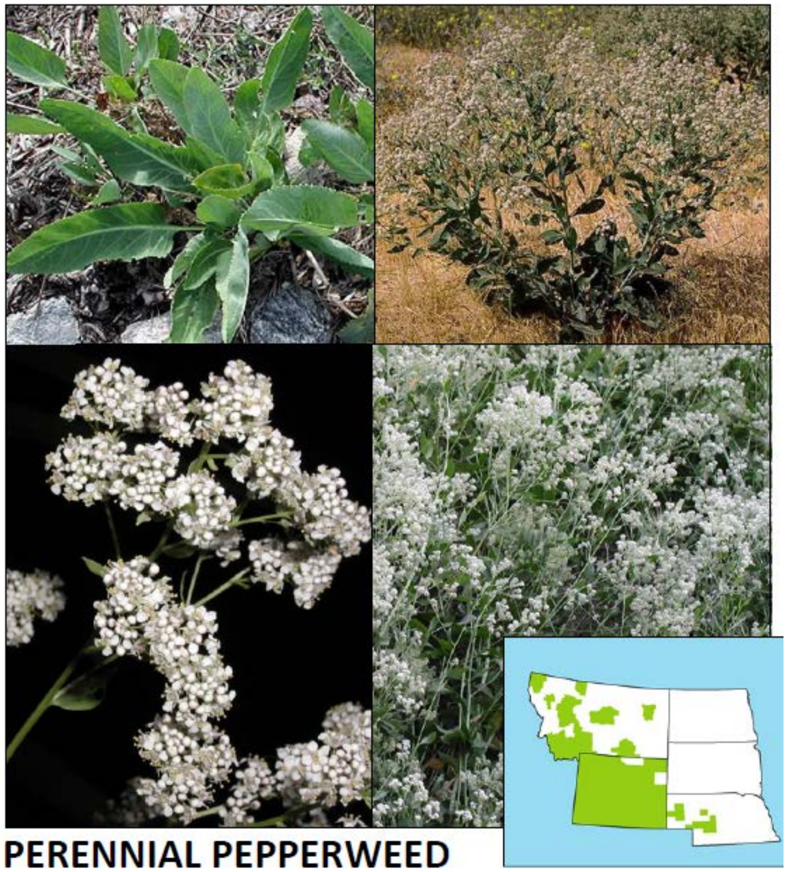


Figure 18. Perennial pepperweed, an invasive plant that threatens wetlands, marshes, and floodplains in the Western US. For more information an early detection flyer on riparian invaders can be found on the NGPN website and on the NPS IRMA Portal: https://irma.nps.gov/App/Reference/Profile/2208790/)

Conclusion

The Northern Great Plains Inventory & Monitoring Program and Fire Effects Program have been monitoring vegetation in Scotts Bluff National Monument for over 18 years. While methods have changed slightly, this report summarizes data from over 80 locations from 1998-2015. Below, we list the questions we asked and provide a summarized answer, for more details see the Results and Discussion section. We conclude with a Natural Resource Condition Table (Table 10) that summarizes the current status and trends in a few key vegetation metrics.

1. **What is the current status of plant community composition and structure of SCBL grasslands (species richness, cover, and diversity) and how has this changed from 1998 to 2015?**

   SCBL plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the area. Native grasses, such as western wheatgrass, and native sedges, such as threadleaf sedge, are abundant and still the dominant component of many sites. Native plant diversity is at a moderate level compared to other grasslands in the region (Table 10), but diversity is spatially variable. As expected, areas with historical and current disturbances, such as the prairie dog town and former golf course, have fewer native plants than other sites.

   We found no significant trends in native diversity or evenness from 1998 to 2015, but both are threatened by the increasing cover of annual bromes (Figure 9). Annual bromes are the most abundant exotic plant species in SCBL and present the largest challenge to SCBL. There has been an increase in annual brome abundance since the 1990s and continued control efforts will be necessary to maintain native prairie within SCBL.

2. **How do trends in grassland condition correlate with climate and fire history?**

   Native diversity tended to increase in wet years. The large variability in SCBL's climate makes it difficult to discern strong patterns linking temperature, precipitation, and plant community structure (e.g. exotic cover, diversity). A longer time series of vegetation data will make it easier to elucidate trends in the future.

   SCBL has been using prescribed burning as a management tool since the 1980s. There was a lower number of native species in sites that burned more recently suggesting that prescribed fire can benefit the mixed-grass prairie in SCBL, but it may take time to see the positive effects. We found no significant relationship between annual brome and years since fire. There is an adaptive management program planned for 2017 which should provide better guidance to the park on how to manage annual bromes. Ongoing research is looking at treating areas with a range of annual brome abundance with a combination of prescribed fire, herbicide, and native grass drill seeding to see which combination of treatments is most effective in reducing annual brome cover.

3. **What, if any, rare plants were found in SCBL long-term monitoring plots?**

   We identified 35 rare plant species in SCBL between 1998 and 2015; eight of these are considered critically imperiled within Nebraska. These plants are found in such low abundance and in such few plots, it is unlikely that plant community monitoring will be able to detect any trends in rare plant abundance. We recommend more targeted surveys of rare plant species of concern be completed when funds are available.

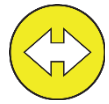
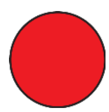
4. **Was the SCBL golf course restoration effective at creating a grassland community dominated by native species**?

   The golf course restoration project had mixed results. While some native grasses were established in one of the monitoring plots, establishment was poor in the other. The project area now has a very high relative cover of annual bromes (>45%). To improve the rates of success and the establishment of native species, future projects should include funds to cover invasive plant control for many years (~10) after planting.

5. **What is the composition and structure of riparian forests at SCBL**?

   The riparian forest in SCBL is a fairly diverse assemblage of cottonwood, willow species, green ash, and box elder. Seedlings are common (Table 10) and cottonwoods of all age classes are present. Exotic grasses and forbs are common in the understory of the riparian forest, and continuing control efforts will be necessary to prevent their spread. While there are fewer young cottonwood trees compared to surveys done in the late 1800s, some young cottonwoods have successfully established. However, the large abundance of green ash and box elder seedlings suggests that a transition to ash-dominated forests is underway.

Table 10. Natural resource condition summary table for plant communities in Scotts Bluff National Monument (SCBL). Current values are based on data from 2011-2015 and trends are based on data from 1998-2015.

Indicator of Condition	Specific Measures	Current Value (mean ± SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Native species richness (1m^2 quadrats)	4.6 ± 0.3 species	3-15 species		SCBL plays a vital role in protecting and managing some of the last remnants of native mixed-grass prairie in the region. The park is characterized by low native species richness, but average richness is within a natural range of variability (Symstad and Jonas 2014). The lowest native diversity is found in the prairie dog town and former golf course. Native evenness has not changed since monitoring began in 1998.
	Evenness (point-intercept transects)	0.67 ± 0.014	To be determined		
Exotic Plant Early Detection and Management	Relative cover of exotic species	41.2 ± 2.5%	< 10 % cover		Many areas of SCBL have a high cover of exotic species. Annual bromes: cheatgrass and Japanese brome present the largest challenge to SCBL. Exotic cover and annual brome cover has shown an increasing trend since 1998. More research on effective management strategies is greatly needed.
	Annual brome cover	37.2 ± 2.3%	< 10 % cover		
Riparian Forest	Plains cottonwood stand seral stage	Late seral stage	Mix of seral stages		The riparian forests of SCBL are currently a mosaic of areas dominated by willow, cottonwood, ash, and boxelder with an understory of many exotic plants. As cottonwood forests age in SCBL, green ash and box elder are likely to become more dominant. Only 2 of 20 plots had evidence of young cottonwoods, but more than half the riparian forest in SCBL had large densities of other native tree and shrub. Forest surveys will be repeated every 5 years in SCBL and this will allow us to detect trends in condition.
	Percent of 20 riparian plots with native deciduous seedlings	60%	To be determined		

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Appendix A: List of plant species found at SCBL 1998-2015

Below is a list of all the plant species found in SCBL long-term plant community monitoring plots. The species are grouped by plant family. An "X" in the exotic column means that species is not native to the park or, in the case where only the genus was identified, there are some species within that genus that are exotic. Species considered to be rare in Nebraska are marked in the final column and the state conservation ranks are provided. Conservation rank definitions are in Table 2 of the report.

Family	Code	Scientific Name	Common Name	Exotic	Rare
Aceraceae	ACNE2	*Acer negundo*	boxelder		S3S5
Agavaceae	YUGL	*Yucca glauca*	soapweed yucca		
Amaranthaceae	AMARA	*Amaranthus*	pigweed	X	
	AMRE	*Amaranthus retroflexus*	redroot amaranth		
Anacardiaceae	RHAR4	*Rhus aromatica*	fragrant sumac		
	RHTR	*Rhus trilobata*	skunkbush sumac		
	TORA2	*Toxicodendron radicans*	eastern poison ivy		
	TORY	*Toxicodendron rydbergii*	western poison ivy		
Apiaceae	COMA2	*Conium maculatum*	poison hemlock	X	
	CYGL99	*Cymopterus glomeratus*	plains springparsley		
	PASA2	*Pastinaca sativa*	wild parsnip	X	
Asclepiadaceae	ASCLE	*Asclepias* spp.	milkweed		
	ASPU	*Asclepias pumila*	plains milkweed		
	ASSP	*Asclepias speciosa*	showy milkweed		
	ASVE	*Asclepias verticillata*	whorled milkweed		
	ASVI	*Asclepias viridiflora*	green comet milkweed		
Asteraceae	AGGL	*Agoseris glauca*	pale agoseris		S1
	AMPS	*Ambrosia psilostachya*	Cuman ragweed		
	ANMI3	*Antennaria microphylla*	littleleaf pussytoes		S2S4
	ANTEN	*Antennaria* spp.	pussytoes		
	ARCA12	*Artemisia campestris*	field sagewort		S3S5
	ARDR4	*Artemisia dracunculus*	tarragon		
	ARFI2	*Artemisia filifolia*	sand sagebrush		
	ARFR4	*Artemisia frigida*	fringed sagewort		
	ASTER	*Aster* spp.	aster		
	BREU	*Brickellia eupatorioides*	false boneset		
	CANU4	*Carduus nutans*	musk thistle	X	
	CIAR4	*Cirsium arvense*	Canada thistle	X	
	CICA11	*Cirsium canescens*	prairie thistle		
	CIOC2	*Cirsium ochrocentrum*	yellowspine thistle		
	CIRSI	*Cirsium* spp.	thistle	X	
	COCA5	*Conyza canadensis*	horseweed		
	DICA18	*Dieteria canescens*	hoary tansyaster		S2S4
	DYPA	*Dyssodia papposa*	fetid marigold		
	ERCA4	*Erigeron canus*	hoary fleabane		
	ERFL	*Erigeron flagellaris*	trailing fleabane		S3

Family	Code	Scientific Name	Common Name	Exotic	Rare
	ERNA10	*Ericameria nauseosa*	rubber rabbitbrush		S2S4
	GRSQ	*Grindelia squarrosa*	curlycup gumweed		S1
	GUSA2	*Gutierrezia sarothrae*	broom snakeweed		
	HEAN3	*Helianthus annuus*	common sunflower		
	HELIA3	*Helianthus* spp.	sunflower		
	HEPE	*Helianthus petiolaris*	prairie sunflower		
	HEVI4	*Heterotheca villosa*	hairy false goldenaster		S1
	HIUM	*Hieracium umbellatum*	narrowleaf hawkweed		S1
	HYFI	*Hymenopappus filifolius*	fineleaf hymenopappus		
	HASP3	*Haplopappus spinulosus*	lacy tansyaster	X	
	LASE	*Lactuca serriola*	prickly lettuce	X	
	LIPU	*Liatris punctata*	dotted blazing star		
	LOAR5	*Logfia arvensis*	field cottonrose	X	
	LYJU	*Lygodesmia juncea*	rush skeletonplant		
	MAPI	*Machaeranthera pinnatifida*	lacy tansyaster		
	MUOB99	*Mulgedium oblongifolium*	blue lettuce		
	NOCU	*Nothocalais cuspidata*	prairie false dandelion		
	PACA15	*Packera cana*	woolly groundsel		
	PAPL12	*Packera plattensis*	prairie groundsel		
	RACO3	*Ratibida columnifera*	upright prairie coneflower		
	SEIN2	*Senecio integerrimus*	lambstongue ragwort		S1
	SENEC	*Senecio* spp.	ragwort		
	SERI2	*Senecio riddellii*	Riddell's ragwort		
	SOCA6	*Solidago canadensis*	Canada goldenrod		S3S5
	SOLID	*Solidago* spp.	goldenrod		
	SOMI2	*Solidago missouriensis*	Missouri goldenrod		
	SOMO	*Solidago mollis*	velvety goldenrod		
	SONCH	*Sonchus* spp.	sowthistle	X	
	SONE	*Solidago nemoralis*	gray goldenrod		
	SYER	*Symphyotrichum ericoides*	white heath aster		S3S5
	SYMPH4	*Symphyotrichum*	aster		
	TAOF	*Taraxacum officinale*	common dandelion	X	
	THME	*Thelesperma megapotamicum*	Hopi tea greenthread		
	TRDU	*Tragopogon dubius*	yellow salsify	X	
	XASP99	*Xanthium spinulosum*	lacy tansyaster		
Boraginaceae	CRCA8	*Cryptantha cana*	mountain cryptantha		
	CRCE	*Cryptantha celosioides*	buttecandle		
	CRTH	*Cryptantha thyrsiflora*	calcareous cryptantha		S3S5
	CYOF	*Cynoglossum officinale*	houndstongue	X	
	LAOC3	*Lappula occidentalis*	flatspine stickseed		
	LIIN2	*Lithospermum incisum*	narrowleaf stoneseed		
Brassicaceae	ALDE	*Alyssum desertorum*	desert madwort	X	
	BRASS2	*Brassica*	mustard	X	
	CAMI2	*Camelina microcarpa*	littlepod false flax	X	
	DEPI	*Descurainia pinnata*	western tansymustard		S3S5
	DESCU	*Descurainia* spp.	tansymustard	X	

Family	Code	Scientific Name	Common Name	Exotic	Rare
	DESO2	*Descurainia sophia*	herb sophia	X	
	DRRE2	*Draba reptans*	Carolina draba		
	ERAS2	*Erysimum asperum*	western wallflower		
	ERCA14	*Erysimum capitatum*	sanddune wallflower		
	LEDE	*Lepidium densiflorum*	common pepperweed		
	LELA2	*Lepidium latifolium*	broadleaved pepperweed	X	
	LEPID	*Lepidium* spp.	pepperweed	X	
	LESQU	*Lesquerella* spp.	bladderpod		
	PHLU99	*Physaria ludoviciana*	foothill bladderpod		
	PHRE8	*Physaria reediana*	alpine bladderpod		S2S4
	ROSI2	*Rorippa sinuata*	spreading yellowcress		
	SIAL2	*Sisymbrium altissimum*	tall tumblemustard	X	
	THAR5	*Thlaspi arvense*	field pennycress	X	
Cactaceae	ESMI3	*Escobaria missouriensis*	Missouri foxtail cactus		
	ESVI2	*Escobaria vivipara*	spinystar		
	OPFR	*Opuntia fragilis*	brittle pricklypear		
	OPMA2	*Opuntia macrorhiza*	twistspine pricklypear		
	OPPO	*Opuntia polyacantha*	plains pricklypear		
	OPUNT	*Opuntia* spp.	pricklypear		
Caprifoliaceae	LOTA	*Lonicera tatarica*	Tatarian honeysuckle	X	
	SYOC	*Symphoricarpos occidentalis*	western snowberry		
Caryophyllaceae	PADE4	*Paronychia depressa*	spreading nailwort		
Chenopodiaceae	ATCA2	*Atriplex canescens*	fourwing saltbush		S3S5
	CHAL7	*Chenopodium album*	lambsquarters	X	
	CHBE4	*Chenopodium berlandieri*	pitseed goosefoot		
	CHENO	*Chenopodium* spp.	goosefoot	X	
	CHFR3	*Chenopodium fremontii*	Fremont's goosefoot		
	CHPR5	*Chenopodium pratericola*	desert goosefoot		
	KOSC	*Kochia scoparia*	burningbush, kochia	X	
	KRLA2	*Krascheninnikovia lanata*	winterfat		S3S5
	SAKA	*Salsola kali*	Russian thistle	X	
	SALSO	*Salsola* spp.	Russian thistle	X	
	SATR12	*Salsola tragus*	prickly Russian thistle	X	
Commelinaceae	TRADE	*Tradescantia* spp.	spiderwort		
	TRBR	*Tradescantia bracteata*	longbract spiderwort		
	TROC	*Tradescantia occidentalis*	prairie spiderwort		
Convolvulaceae	COAR4	*Convolvulus arvensis*	field bindweed	X	
	EVNU	*Evolvulus nuttallianus*	shaggy dwarf morning-glory		
	IPLE	*Ipomoea leptophylla*	bush morning-glory		
Cupressaceae	JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper		
Cyperaceae	CADU6	*Carex duriuscula*	needleleaf sedge		
	CAFI	*Carex filifolia*	threadleaf sedge		
	CAIN9	*Carex inops*	sun sedge		
	CAREX	*Carex* spp.	sedge		
Elaeagnaceae	SHAR	*Shepherdia argentea*	silver buffaloberry		
	SHCA	*Shepherdia canadensis*	russet buffaloberry		

Family	Code	Scientific Name	Common Name	Exotic	Rare
Euphorbiaceae	CRTE4	*Croton texensis*	Texas croton		
	EUMA8	*Euphorbia marginata*	snow on the mountain		
	EUGL3	*Euphorbia glyptosperma*	ribseed sandmat		
	EUSE5	*Euphorbia serpyllifolia*	thymeleaf sandmat	X	
	EUPHO	*Euphorbia* spp.	spurge, sandmat	X	
Fabaceae	ASAG2	*Astragalus agrestis*	purple milkvetch		S1
	ASBI2	*Astragalus bisulcatus*	twogrooved milkvetch		S3S5
	ASGR3	*Astragalus gracilis*	slender milkvetch		
	ASLA27	*Astragalus laxmannii*	Laxmann's milkvetch		
	ASMI10	*Astragalus missouriensis*	Missouri milkvetch		
	ASMO7	*Astragalus mollissimus*	woolly locoweed		
	ASTRA	*Astragalus*	milkvetch		
	DACA7	*Dalea candida*	white prairie clover		
	DAPU5	*Dalea purpurea*	purple prairie clover		S3S5
	DAVI	*Dalea villosa*	silky prairie clover		
	GLLE3	*Glycyrrhiza lepidota*	American licorice		
	LAPO2	*Lathyrus polymorphus*	manystem pea		
	LUPIN	*Lupinus* spp.	lupine		
	MELIL	*Melilotus* spp.	sweetclover	X	
	MELU	*Medicago lupulina*	black medick	X	
	MEOF	*Melilotus officinalis*	yellow sweetclover	X	
	MESA	*Medicago sativa*	alfalfa		
	OXLA3	*Oxytropis lambertii*	purple locoweed		
	OXSE	*Oxytropis sericea*	white locoweed		
	PEAR6	*Pediomelum argophyllum*	silverleaf Indian breadroot		
	PEES	*Pediomelum esculentum*	large Indian breadroot		
	PSLA3	*Psoralidium lanceolatum*	lemon scurfpea		
	PSTE5	*Psoralidium tenuiflorum*	slimflower scurfpea		
	THRH	*Thermopsis rhombifolia*	golden pea		
	VIAM	*Vicia americana*	American vetch		S2S4
Grossulariaceae	RIAU	*Ribes aureum*	golden currant		
	RIBES	*Ribes* spp.	currant		
	RICE	*Ribes cereum*	wax currant		
Hydrophyllaceae	ELNY	*Ellisia nyctelea*	Aunt Lucy		
Lamiaceae	HEDR	*Hedeoma drummondii*	Drummond's false pennyroyal		
	HEHI	*Hedeoma hispida*	rough false pennyroyal		
	MAVU	*Marrubium vulgare*	horehound	X	
	MEAR4	*Mentha arvensis*	wild mint		
	MOFI	*Monarda fistulosa*	wild bergamot		
	MOPE	*Monarda pectinata*	pony beebalm		
	NECA2	*Nepeta cataria*	catnip	X	
	TECA3	*Teucrium canadense*	Canada germander		
Liliaceae	ALTE	*Allium textile*	textile onion		
	ASOF	*Asparagus officinalis*	garden asparagus	X	
	FRAT	*Fritillaria atropurpurea*	spotted fritillary		S2

Family	Code	Scientific Name	Common Name	Exotic	Rare
	LEMO4	*Leucocrinum montanum*	common starlily		
	MAST4	*Maianthemum stellatum*	starry false lily of the valley		
	ZIVE	*Zigadenus venenosus*	meadow deathcamas		
Loasaceae	MEDE2	*Mentzelia decapetala*	tenpetal blazingstar		
Malvaceae	SPCO	*Sphaeralcea coccinea*	scarlet globemallow		
Melanthiaceae	TOVE2	*Toxicoscordion venenosum*	meadow deathcamas		
Nyctaginaceae	MIAL4	*Mirabilis albida*	white four o'clock		
	MIHI	*Mirabilis hirsuta*	hairy four o'clock		
	MILI3	*Mirabilis linearis*	narrowleaf four o'clock		
Oleaceae	FRPE	*Fraxinus pennsylvanica*	green ash		
Onagraceae	OEBI	*Oenothera biennis*	common evening primrose		
	OECE2	*Oenothera cespitosa*	Tufted evening primrose		S2S4
	OECU99	*Oenothera curtiflora*	velvetweed		
	OESE3	*Oenothera serrulata*	yellow sundrops		
	OESU99	*Oenothera suffrutescens*	scarlet beeblossom		
Orobanchaceae	ORFA	*Orobanche fasciculata*	clustered broomrape		
Papaveraceae	ARPO2	*Argemone polyanthemos*	crested pricklypoppy		
Pinaceae	PIPO	*Pinus ponderosa*	ponderosa pine		
Poaceae	ACHY	*Achnatherum hymenoides*	Indian ricegrass		
	AGCR	*Agropyron cristatum*	crested wheatgrass	X	
	ANGE	*Andropogon gerardii*	big bluestem		
	ARPU9	*Aristida purpurea*	purple threeawn		S3S5
	BOCU	*Bouteloua curtipendula*	sideoats grama		
	BODA2	*Bouteloua dactyloides*	buffalograss		
	BOGR2	*Bouteloua gracilis*	blue grama		
	BOHI2	*Bouteloua hirsuta*	hairy grama		
	BRHOH	*Bromus hordeaceus ssp. hordeaceus*	soft brome	X	
	BRIN2	*Bromus inermis*	smooth brome	X	
	BRJA	*Bromus japonicus*	Japanese brome	X	
	BROMU	*Bromus* spp.	brome	X	
	BRTE	*Bromus tectorum*	cheatgrass	X	
	CALO	*Calamovilfa longifolia*	prairie sandreed		
	DASP2	*Danthonia spicata*	poverty oatgrass		S1
	DISP	*Distichlis spicata*	saltgrass		
	ELCA4	*Elymus canadensis*	Canada wildrye		
	ELEL5	*Elymus elymoides*	squirreltail		
	ELLA3	*Elymus lanceolatus*	thickspike wheatgrass		S1
	ELTR7	*Elymus trachycaulus*	slender wheatgrass		S1
	ELYMU	*Elymus* spp.	wildrye		
	HECO26	*Hesperostipa comata*	needle and thread		
	HESP11	*Hesperostipa spartea*	porcupinegrass		
	HOJU	*Hordeum jubatum*	foxtail barley		
	KOMA	*Koeleria macrantha*	prairie Junegrass		
	MUCU3	*Muhlenbergia cuspidata*	plains muhly		
	MURA	*Muhlenbergia racemosa*	marsh muhly		

Family	Code	Scientific Name	Common Name	Exotic	Rare
	NAVI4	*Nassella viridula*	green needlegrass		
	PACA6	*Panicum capillare*	witchgrass		S3S5
	PASM	*Pascopyrum smithii*	western wheatgrass		
	PAVI2	*Panicum virgatum*	switchgrass		
	PHAR3	*Phalaris arundinacea*	reed canarygrass	X	
	PIMI7	*Piptatherum micranthum*	littleseed ricegrass		
	POPR	*Poa pratensis*	Kentucky bluegrass	X	
	POSE	*Poa secunda*	Sandberg bluegrass		
	PSSP6	*Pseudoroegneria spicata*	bluebunch wheatgrass		S1
	SCSC	*Schizachyrium scoparium*	little bluestem		
	SEVI4	*Setaria viridis*	green foxtail		
	SONU2	*Sorghastrum nutans*	Indiangrass		
	SPCR	*Sporobolus cryptandrus*	sand dropseed		
	BUDA	*Buchloe dactyloides*	buffalograss		
	FEOC3	*Festuca octoflora*	sixweeks fescue	X	
	THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	X	
	VUOC	*Vulpia octoflora*	sixweeks fescue		
Polemoniaceae	IPCO5	*Ipomopsis congesta*	ballhead ipomopsis		S2S4
	PHAN4	*Phlox andicola*	prairie phlox		
	PHHO	*Phlox hoodii*	spiny phlox		
Polygonaceae	ERFL4	*Eriogonum flavum*	alpine golden buckwheat		
	ERPA9	*Eriogonum pauciflorum*	fewflower buckwheat		S3S5
	POAC3	*Polygonum achoreum*	leathery knotweed		
	FACO	*Fallopia convolvulus*	black bindweed	X	
	RUSA	*Rumex salicifolius*	willow dock		
Ranunculaceae	CLHI	*Clematis hirsutissima*	hairy clematis		S1
Rosaceae	PRVI	*Prunus virginiana*	chokecherry		
	ROAR3	*Rosa arkansana*	prairie rose		
	ROSA5	*Rosa* spp.	rose		
	ROWO	*Rosa woodsii*	Woods' rose		
Rubiaceae	GAAP2	*Galium aparine*	stickywilly		
Salicaceae	PODE3	*Populus deltoides*	eastern cottonwood		
	SAAM2	*Salix amygdaloides*	peachleaf willow		
	SAIN3	*Salix interior*	sandbar willow		
Santalaceae	COUM	*Comandra umbellata*	bastard toadflax		
Scrophulariaceae	BEWY	*Besseya wyomingensis*	Wyoming kittentails		
	PEAL2	*Penstemon albidus*	white penstemon		
	PEGR5	*Penstemon gracilis*	lilac penstemon		
	PENST	*Penstemon* spp.	beardtongue		
	VEAM2	*Veronica americana*	American speedwell		
	VETH	*Verbascum thapsus*	common mullein	X	
Solanaceae	PHHE4	*Physalis hederifolia*	ivyleaf groundcherry		S3S5
	PHHE5	*Physalis heterophylla*	clammy groundcherry		
	PHHI8	*Physalis hispida*	prairie groundcherry		
	PHLO4	*Physalis longifolia*	longleaf groundcherry		
	PHVI5	*Physalis virginiana*	Virginia groundcherry		

Family	Code	Scientific Name	Common Name	Exotic	Rare
Ulmaceae	CEOC	*Celtis occidentalis*	common hackberry		
	ULAM	*Ulmus americana*	American elm		
Urticaceae	PAPE5	*Parietaria pensylvanica*	Pennsylvania pellitory		
Verbenaceae	VEBR	*Verbena bracteata*	bigbract verbena		
	VEST	*Verbena stricta*	hoary verbena		
Violaceae	VINU2	*Viola nuttallii*	Nuttall's violet		
Vitaceae	PAVI5	*Parthenocissus vitacea*	woodbine		

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