



Plant Community Composition and Structure Monitoring for Fort Laramie National Historic Site

2011-2015 Summary Report

Natural Resource Report NPS/NGPN/NRR—2016/1149





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Photograph of long-term monitoring plot PCM_007 at Fort Laramie National Historic Site, 2015.
Photograph courtesy of the National Park Service.

ON THE COVER

Long-term monitoring plot PCM-070 at Fort Laramie National Historic Site, 2014
Photograph courtesy of the National Park Service

Plant Community Composition and Structure Monitoring for Fort Laramie National Historic Site

2011-2015 Summary Report

Natural Resource Data Series NPS/NGPN/NRR—2016/1149

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Executive Summary

The Northern Great Plains Inventory & Monitoring Program has been monitoring vegetation in Fort Laramie National Historic Site since 2011. This report summarizes those data from 30 locations monitored from 2011-2015. We use these data to explore status and trends in upland and riparian plant communities and the occurrence of rare plants. A summary of the current condition (2011-2015) and short-term trends in plant communities at Fort Laramie is found in Table E-1.

1. What is the current status of plant community composition and structure of FOLA grasslands (species richness, cover, and diversity) and how has this changed from 2011-2015?

FOLA plays a vital role in protecting and managing some of the last remnants of native prairie in the area. Native grasses, such western wheatgrass and needle and thread, are abundant in some sites, but many areas have a high cover of exotic plants. Native plant diversity is at a low 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 1998-2015, but both are threatened by the increasing cover of annual bromes (Table 10). Annual bromes are the most abundant exotic plant species in FOLA and present the largest challenge to FOLA. Continued control efforts will be necessary to maintain native prairie within FOLA.

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

Native diversity tended to increase in wet years. The large variability in the climate of FOLA has made 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.

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

We identified 1 rare plant species in FOLA between 2011 and 2015. This plant is found in such low abundance and in such few plots, it will take many years to determine any trends in rare plant cover. Since to our knowledge, the last rare plant survey was completed in 2004, we recommend targeted surveys of rare plant species be considered when funds are available.

4. What is the composition and structure of riparian forests at FOLA?

The riparian forest in FOLA is a fairly diverse assemblage of cottonwood, willow species, honey locust (*Gleditsia triacanthos*), and green ash. Cottonwoods of all age classes are present (Table 10). Exotic species are common in the understory of the riparian forest, and the current control measures may help reduce their abundance in the future. Young cottonwoods have successfully established in 40% of the monitoring plots. This suggests that the successional transition to green ash and box elder dominated forests may be slow.

Table E-1. Natural resource condition summary table for plant communities in Fort Laramie National Historic Site (FOLA).

Indicator of Condition	Specific Measures	2014 Value (mean $\pm$ 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)	4.3 $\pm$ 0.3 species	3-15 species ⁽¹⁾		FOLA plays a vital role in protecting and managing some of the last remnants of native prairie and riparian forests in the region. The park is characterized by low native species richness, which should be a moderate concern. Native species richness and evenness vary from year to year, but there is not a significant trend since monitoring began in 2011.
	Native evenness (point-intercept transects)	0.75 $\pm$ 0.02	To be determined		
Exotic Plant Early Detection and Management	Relative cover of exotic species	45.3 $\pm$ 4.5 %	< 10% cover		The sites in FOLA had a high cover of exotic species. None of the sites had <10% cover of exotic plants. Cheatgrass was the most abundant exotic species, and more research on effective management strategies is greatly needed.
	Annual brome cover	25.9 $\pm$ 4.4%	< 10% cover		
Riparian Forest	Plains cottonwood stand seral stage	Late-intermediate seral stage	Mixture of seral stages ⁽²⁾		The riparian forests of FOLA are currently a mosaic of areas dominated by willow, cottonwood, and ash with an understory of many exotic plants. As cottonwood forests age in FOLA, green ash and box elder are likely to become more dominant. Eight of 20 plots had evidence of young cottonwoods and a majority of plots had large densities of other native tree and shrub seedlings in the understory. Forest surveys will be repeated every 5 years in FOLA and this will allow us to detect trends in condition.
	Percent of 20 riparian plots with native deciduous seedlings	70%	To be determined		

References, Notes, and Data Sources: 1. Symstad and Jonas (2014) 2. Uresk (2015)

Acknowledgments

We thank all 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 FOLA, particularly M. Evans, for help in the field. The 2011-2015 NGPN vegetation field crews collected all the data included in this report. Thanks to A. Weaver for assistance with maps. Comments from M. Neubert, M. Evans, and J. Handley improved this report.

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. 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); 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.

Fort Laramie National Historic Site (FOLA), established in 1938 to protect and preserve the well-known military post, covers 833 acres on the boundary of the northern mixed-grass and short-grass prairie region (Lauenroth et al. 1999). The park is a mosaic of disturbed old-fields, riparian forests, and native prairie and is host to 376 plant species (Heidel 2004). The Northern Great Plains Inventory & Monitoring Program (NGPN) began vegetation monitoring at FOLA in 2011 (Ashton et al. 2012). A total of 30 plots were established in FOLA (Figure 1); 15 plots were randomly distributed throughout the park to better study herbaceous plant communities, 15 plots were established in the riparian forest to assess forest condition, and 5 plots were used to study both forest condition and herbaceous plant communities.

Using 5 years of plant community monitoring data in FOLA, we explore the following questions:

1. What is the current status of plant community composition and structure of FOLA grasslands (species richness, cover, and diversity) and how has this changed from 2011-2015?
2. How do trends in grassland condition correlate with climate?
3. What, if any, rare plants were found in FOLA long-term monitoring plots?
4. What is the composition and structure of riparian forests at FOLA?



Figure 1. Map of Fort Laramie National Historic Site and plant community monitoring plots. The blue area represents the riparian area of the park. There are three different types of monitoring plots: upland herbaceous (red), riparian woody plots (yellow)

Methods

The NGPN Plant Community Composition and Structure Monitoring Protocol (Symstad et al. 2012b, a) was used to monitor long-term vegetation plots at FOLA. Below, we briefly describe the general approach but for those interested in more detail please see Symstad et al. 2012a, 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 FOLA using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, we selected 15 randomly located sites within FOLA (Figure 1). We visited 6 sites every year, and after five years (2015) we had visited all 15 sites twice (or attempted to). Visits were made during the first week of June.

In 2014, we used the GRTS design to select 20 plots within riparian forest communities at FOLA. The riparian corridor was delineated in the field and defined as everything below the highest river terrace (Figure 1). It comprised approximately 29% of the park. Four of the previously selected plots fell within the riparian forest, so these were used (dual plots) and 16 new plots were selected (Figure 1).

Plot Layout and Sampling

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, 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 (Figure 3). Species richness data from the point-intercept method were supplemented with species presence data collected in five sets of nested square quadrats (0.01 m², 0.1 m², 1 m², and 10 m²) located systematically along each transect (Figure 2).

When woody species were also present (e.g. the plots in the riparian area), 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.

To increase the number of forested plots and our understanding of riparian forest condition, NGPN completed a survey 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 > 15 cm) 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). The fuels data were not reported because grasses dominated the fuel layer. This forest survey will be repeated every 5 years (e.g. 2019, 2024, etc.).

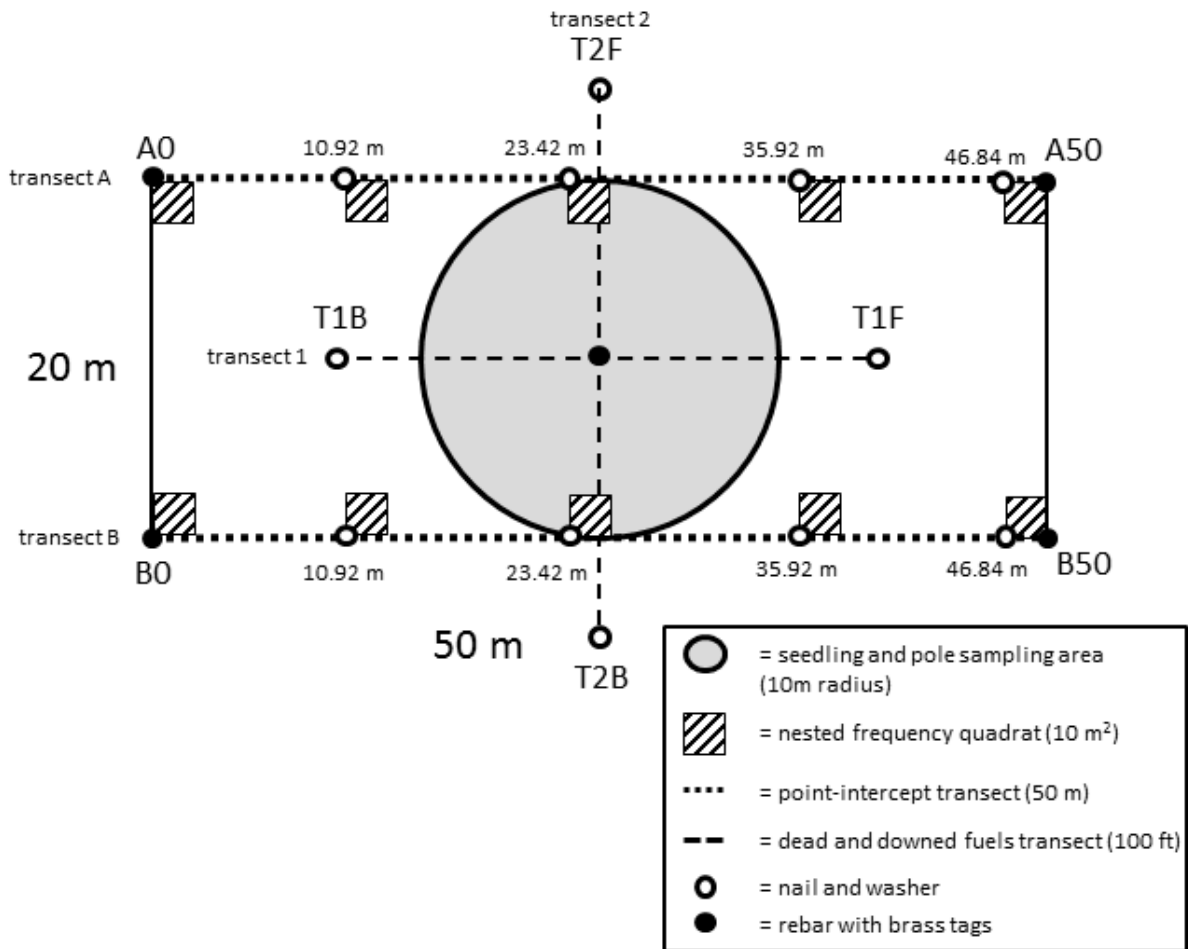


Figure 2. Long-term monitoring plot layout used for sampling vegetation in Fort Laramie National Historic Site.



Figure 3. The Northern Great Plains Inventory & Monitoring vegetation crew used point-intercept (left panel) and quadrats (right panel) to document plant diversity and abundance. These photographs were taken at Scotts Bluff National Monument, but the same methods were used at Fort Laramie NHS.

At all plots, we surveyed the area for common disturbances and target species of interest to the park. Common disturbances included such things as flooding, rodent mounds, and animal trails. 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 Fort Laramie National Historic Site 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 aethiopis</i>	Mediterranean sage	Upland
<i>Ventenata dubia</i>	African wiregrass	Upland

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., subshrub, forb) were based on definitions for each species from the USDA Plants Database (USDA-NRCS 2015). The conservation status ranks of plant species in FOLA were based on the species list maintained by the Wyoming Natural Diversity Database (WYNDD), and for the purpose of this report, a species was considered rare if it was S1, S2, or S3. See Table 2 for a detailed description of conservation ranks.

Table 2. Definitions of rare species conservation status ranks.(S: state ranks, G: global 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 from the state/province.
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.
S3G3	Vulnerable	Due to a restricted range, relatively few populations (often 80 or fewer), recent widespread declines, or other factors making it vulnerable to extirpation.
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.

We measured diversity at the plots in 2 ways: species richness and Pielou's Index of Evenness. Species richness is simply a count of the species recorded in an area. 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. 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.

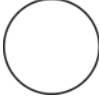
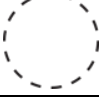
Climate data from the Old Fort Laramie, WY weather station were downloaded from NOAA's online database (NOAA 2015).

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: 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 FOLA Prairies

We found 200 plant species from 2011-2015 at FOLA (Appendix A). Graminoids, which includes grasses, sedges, and rushes, accounted for most of the vegetative cover at FOLA, but forbs, shrubs and subshrubs (defined as a low-growing shrub usually under 0.5m) were also present (Figure 4). We found 50 exotic plant species at FOLA, and exotic graminoids were particularly abundant (Figure 4). The shrubs and subshrubs were all native species.

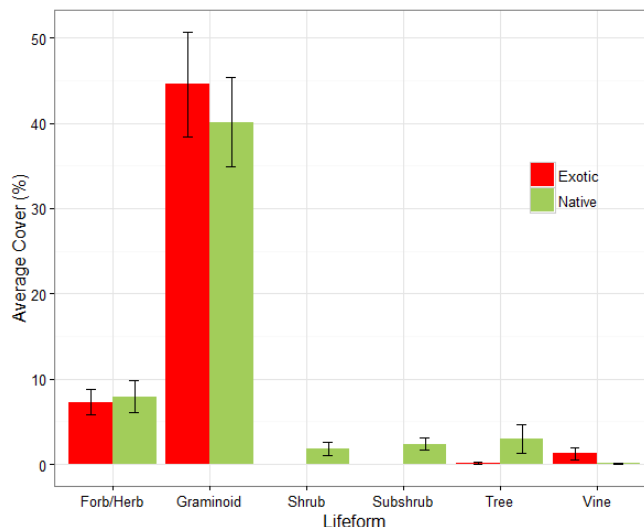


Figure 4. Average cover by lifeform of native (green) and exotic (red) plants recorded in monitoring plots in Fort Laramie National Historic Site (2011-2015).

Western wheatgrass (*Pascopyrum smithii*), needle and thread (*Heterostipa comata*), sand dropseed (*Sporobolus cryptandrus*) and blue grama (*Bouteloua gracilis*) were the most abundant native grasses and averaged between 5 and 15% absolute cover (Figure 5). Cheatgrass (*Bromus tectorum*) and smooth brome (*B. inermis*) were the most pervasive exotics at FOLA. Cheatgrass is a Eurasian, annual grass that has been a part of the Northern Great Plains landscape for more than a century, but its 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). From 2011-2015, the average relative cover of cheatgrass was $25.9 \pm 4.4\%$ (mean $\pm$ standard error; Figure 6). Smooth brome is related to cheatgrass, but differs in that it is a perennial grass that was widely planted for forage and along roads. Smooth brome can form monocultures and reduce native plant abundance and diversity, and this may be due in part to its ability alter soil nutrient dynamics (Vinton and Goergen 2006). While smooth brome and cheatgrass were the most abundant, many other exotic species were found yielding an average cover of all exotic species to be $45 \pm 4.5\%$. Maps of cheatgrass and smooth brome occurrence can be found in Appendix B.

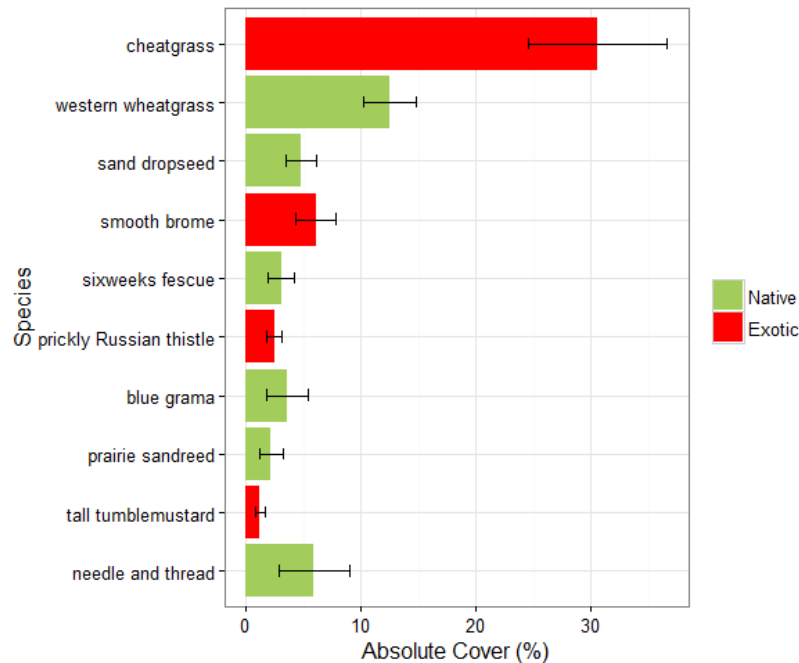


Figure 5. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded at Fort Laramie National Historic Site, 2011-2015. Bars represent means $\pm$ standard errors.

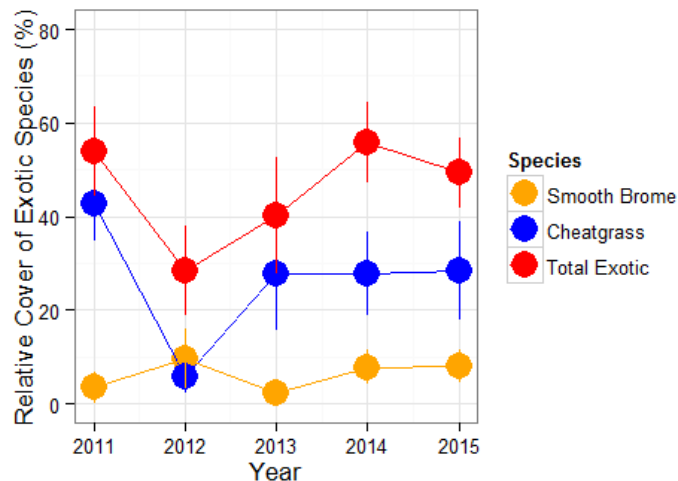


Figure 6. Trends in the relative cover of exotic plants, smooth brome, and cheatgrass in Fort Laramie National Historic Site from 2011-2015. Points represent means $\pm$ standard errors, $n=6$.

It is difficult to distinguish trends from a 5 year dataset, but historical vegetation data from FOLA can provide some evidence of whether exotic cover has changed over time. The vegetation management plan for FOLA (Jones and Tebben 2002) summarized the proportion of plots where exotic species were found in three different surveys completed in 1986 (Olmstead and Perez), 1998 (TNC), and 2000 (Fertig). Table 4 summarizes the data from Jones and Tebben (2002) and compares it to the proportion of plots where exotic species were found by NGPN. Data is represented as the proportions of plots survey with the target species, because the sample size varied across the years.

Many of the exotic species we encountered were present in the park in 1986, including cheatgrass, quackgrass, and kochia, at a similar rate as seen in 2011-2015. Since 1986 and 1998, the proportion of plots infested with smooth brome, crested wheatgrass, Canada thistle, prickly lettuce, and prickly Russian thistle has close to doubled. Future monitoring will allow us to better quantify these increases and determine whether they are statistically significant.

Table 4. Exotic plant species found in vegetation monitoring plots in 1986, 1998, 2000, and 2011-2015. The historic data were copied from Jones and Tebben 2002. The 2011-2015 data were from the NGPN monitoring plots. The values represent the percent of plots where the exotic species was present. An “X” indicates presence within the park.

Common name	Scientific Name	1986 (n=16)	1998 (n=32)	2000 (based on species list for park)	2011-2015 (n=15 or * 30 plots)
crested wheatgrass †	<i>Agropyron cristatum</i>		6		13
creeping bentgrass	<i>Agrostis stolonifera</i>			X	
pale madwort	<i>Alyssum alyssoides</i>		6		
desert madwort	<i>Alyssum desertorum</i>				47
mat amaranth	<i>Amaranthus blitoides</i>				13
Absinthium *	<i>Artemisia absinthium</i>				3
biennial wormwood	<i>Artemisia biennis</i>				20
smooth brome †	<i>Bromus inermis</i>		34	X	67
Japanese brome *	<i>Bromus japonicus</i>		22	X	27
Cheatgrass *	<i>Bromus tectorum</i>	56	53	X	57
littlepod false flax †	<i>Camelina microcarpa</i>		9		47
shepard's purse	<i>Capsella bursa-pastoris</i>	X			
musk thistle	<i>Carduus nutans</i>			X	
lambsquarters	<i>Chenopodium album</i>				7
Canada thistle * †	<i>Cirsium arvense</i>		16	X	30
bull thistle	<i>Cirsium vulgare</i>				7
field bindweed	<i>Convolvulus arvensis</i>			X	27
gypsyflower*	<i>Cynoglossum officinale</i>				20
herb sophia	<i>Descurainia sophia</i>			X	67
barnyardgrass	<i>Echinochloa crus-galli</i>				13
Russian olive*	<i>Elaeagnus angustifolia</i>			X	7
quackgrass	<i>Elymus repens</i>	38	6	X	33
stinkgrass	<i>Eragrostis cilianensis</i>			X	
roundfruit rush	<i>Juncus compressus</i>				13
burningbush, kochia * †	<i>Kochia scoparia</i>	19		X	33
prickly lettuce †	<i>Lactuca serriola</i>	19	6	X	80

* Indicates 2011-2015 species that were surveyed in 30 plots (15 plots were typically searched).

† Those species, also in bold, that appear in a substantially greater proportion of plots in recent years.

Table 4 (continued). Exotic plant species found in vegetation monitoring plots in 1986, 1998, 2000, and 2011-2015. The historic data were copied from Jones and Tebben 2002. The 2011-2015 data were from the NGPN monitoring plots. The values represent the percent of plots where the exotic species was present. An "X" indicates presence within the park.

Common name	Scientific Name	1986 (n=16)	1998 (n=32)	2000 (based on species list for park)	2011-2015 (n=15 or * 30 plots)
field pepperweed	<i>Lepidium campestre</i>				7
clasping pepperweed	<i>Lepidium perfoliatum</i>	X			
butter and eggs	<i>Linaria vulgaris</i>	X			
perennial ryegrass	<i>Lolium perenne</i>	X			
black medick	<i>Medicago lupulina</i>			X	27
alfalfa	<i>Medicago sativa</i>				13
yellow sweetclover* †	<i>Melilotus officinalis</i>		6	X	43
catnip	<i>Nepeta cataria</i>		3	X	20
Scotch cottonthistle *	<i>Onopordum acanthium</i>			X	37
pearl millet	<i>Pennisetum glaucum</i>			X	
spotted ladythumb	<i>Persicaria maculosa</i>			X	7
reed canarygrass *	<i>Phalaris arundinacea</i>				10
timothy	<i>Phleum pratense</i>	25			13
common plantain	<i>Plantago major</i>	X			
Canada bluegrass	<i>Poa compressa</i>				13
Kentucky bluegrass †	<i>Poa pratensis</i>	25	19	X	40
curlytop knotweed	<i>Polygonum lapathifolium</i>			X	
annual rabbitsfoot grass	<i>Polypogon monspeliensis</i>			X	
purslane	<i>Portulaca oleracea</i>			X	
curly dock	<i>Rumex crispus</i>			X	13
narrowleaf dock	<i>Rumex stenophyllus</i>			X	
crack willow	<i>Salix fragilis</i>				7
slender Russian thistle	<i>Salsola collina</i>	X			13
prickly Russian thistle * †	<i>Salsola tragus</i>	31		X	70
green bristlegrass	<i>Setaria viridis</i>	13		X	7
tall tumbled mustard * †	<i>Sisymbrium altissimum</i>		9	X	47
field sowthistle	<i>Sonchus arvensis</i>			X	
five-stamen tamarisk *	<i>Tamarix chinensis</i>			X	3
common dandelion †	<i>Taraxacum officinale</i>	6	6		60
field pennycress	<i>Thlaspi arvense</i>		9		13
yellow salsify †	<i>Tragopogon dubius</i>		38		73

* Indicates 2011-2015 species that were surveyed in 30 plots (15 plots were typically searched).

† Those species, also in bold, that appear in a substantially greater proportion of plots in recent years.

Table 4 (continued). Exotic plant species found in vegetation monitoring plots in 1986, 1998, 2000, and 2011-2015. The historic data were copied from Jones and Tebben 2002. The 2011-2015 data were from the NGPN monitoring plots. The values represent the percent of plots where the exotic species was present. An "X" indicates presence within the park.

Common name	Scientific Name	1986 (n=16)	1998 (n=32)	2000 (based on species list for park)	2011-2015 (n=15 or * 30 plots)
puncture vine	<i>Tribulus terrestris</i>			X	
strawberry clover	<i>Trifolium fragiferum</i>			X	20
narrowleaf cattail	<i>Typha angustifolia</i>				7
common mullein *	<i>Verbascum thapsus</i>	X			30

* Indicates 2011-2015 species that were surveyed in 30 plots (15 plots were typically searched).

† Those species, also in bold, that appear in a substantially greater proportion of plots in recent years.

Species Richness, Diversity, and Evenness

One of the ways for the NPS to measure effectiveness at the mission to ‘preserve ecological integrity’ is to examine trends in native plant diversity and evenness within their boundaries. Average species richness has been measured by point-intercept and in 1 m² and 10 m² quadrats since 2011 (Table 5).

Table 5. Average plant species richness in monitoring plots at Fort Laramie National Historic Site from 2011 to 2015. Values represent means ± standard errors.

Attribute	Point-intercept	1 m ² quadrats	10 m ² quadrats
Species richness	14 ± 1.4	7 ± 0.4	12 ± 0.7
Native species richness	9 ± 1.1	4 ± 0.3	7 ± 0.6
Exotic species richness	5 ± 0.6	3 ± 0.2	4 ± 0.3
Graminoid species richness	6 ± 0.5	3 ± 0.2	4 ± 0.2
Forb species richness	6 ± 0.8	3 ± 0.3	6 ± 0.5

While there was some variation across sites, the plots we visited in FOLA 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 FOLA, 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 vary between 3 and 15 species per square meter over the course of 30 years (Symstad and Jonas 2014). Compared to this, FOLA is within the natural range (4 species) but is on the low end of the range. Some sites, such as PCM_002, 003, 070, and 068 (Figure 1), fall below this

reference condition. In contrast, the most diverse plots, FOLA_PCM_069, 011, 09 (Figure 7) have greater than 7 native species per square meter.



Figure 7. A photograph of long-term monitoring plot FOLA_PCM_009 which has a moderate diversity of native plant species.

We did not find any trends in species richness or evenness over time (Figure 8). Native species richness in 1m² quadrats was consistent from 2011 to 2015 and ranged from a low in 2012 of 3.2 ± 0.64 (a drought year) to a high of 4.8 ± 1.02 in 2011 (a wet year). From 2011-2015, we recorded between 1 and 20 native species along the point-intercept transects (Figure 8: top). There was no trend in Peilou's Index of Evenness, J' , which measures how even abundances are across taxa (Figure 8). There is a great deal of variation in species richness and evenness across sites within the park (dashed lines in Figure 8 represent the maximum and minimum values) which makes detecting long-term trends difficult.

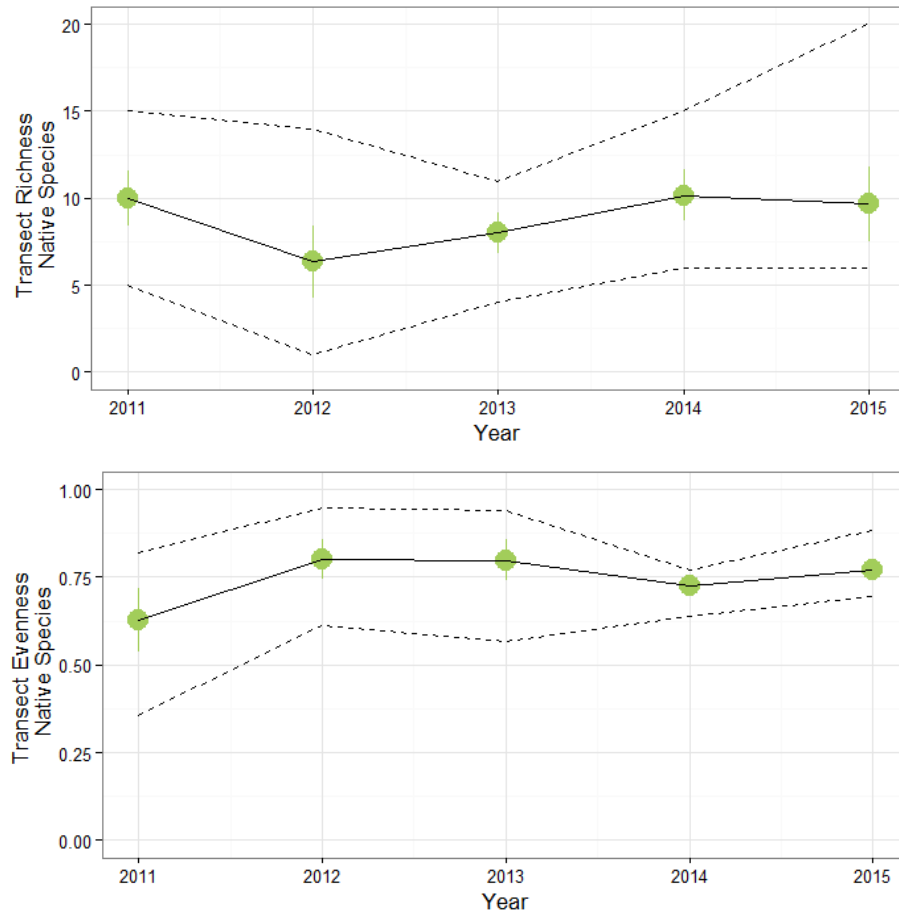


Figure 8. Trends in native species richness and evenness in Fort Laramie National Historic Site, 2011-2015. Data are means $\pm$ one standard error. The dashed line indicates the range of values across the entire data set.

There is evidence from other regions that annual bromes can affect persistence of native species (D'Antonio and Vitousek 2003). In the Northern Great Plains Parks, there is a negative correlation between the cover of annual bromes and native species richness (Figure 9; $F_{1,551}=36.5$, $P<0.0001$). If the high cover of annual bromes in FOLA persists or increases, we expect there will be a corresponding decline in native species richness over time.

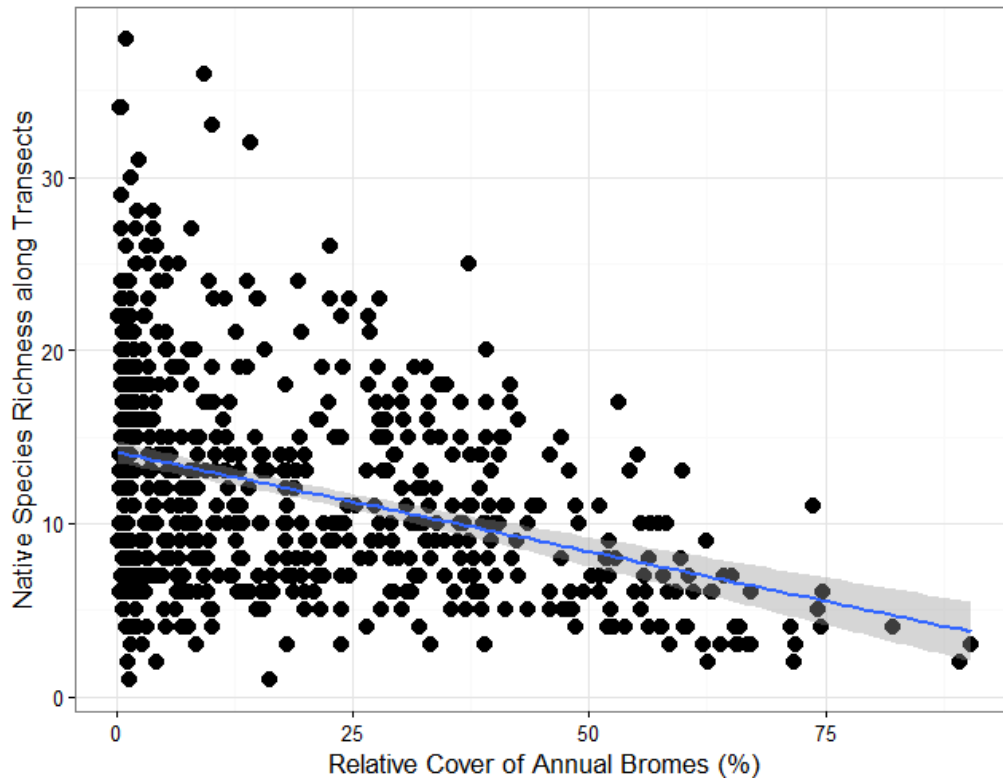


Figure 9. The relationship between native species richness and the relative cover of annual bromes in long-term monitoring plots in national park units of the Northern Great Plains, 1998-2015.

Disturbance from grazing, flooding, and humans can affect plant community structure and composition in prairie. We measured the approximate area affected by natural and human disturbances at each site we visited between 2011-2015. The most common disturbance was from small rodents, but there was also evidence of deer trails, grazing, and flooding. We found no correlation with total disturbance, small or large animal disturbance and native richness or exotic cover. As more monitoring data are collected in future years, we may be able to better explore the statistical relationship between these metrics and disturbance.

The Influence of Climate on Plant Community Structure and Diversity

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, Old Fort Laramie, ranged from average minimum monthly temperatures in December of 10.8° F to maximum monthly July temperatures of 88.4° F (based on 1981-2010). The 30-year normal annual precipitation totals 15.79 inches. Annual precipitation at FOLA in 2011-2015 was variable and ranged between 6.2 and 17.0 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 increases in summer precipitation (Yang et al. 1998). 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).

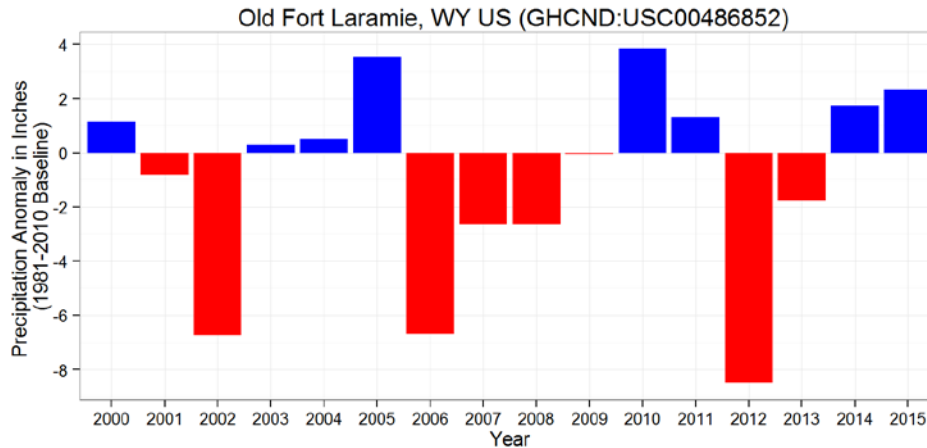


Figure 10. The total annual precipitation anomaly from 2000-2015 for Fort Laramie National Historic Site. Positive values (blue) represent years wetter than and negative values (red) are drier than the 1981-2010 normal. The anomaly is measured in inches and based on data from a nearby weather station.

A longer time series of vegetation data is needed to elucidate trends and correlations with climate because of the large variation in annual temperature and precipitation patterns at FOLA. It is very likely that the large drought in 2012 contributed to the declines in both native species richness (Figure 8) and exotic species cover seen in that year (Figure 6). Native species richness and exotic cover increased in the subsequent wetter years.

Rare Plants

A review of rare plant observations in FOLA was completed in 2000 (Fertig 2000) and a floristic inventory of FOLA was conducted in 2004 (Heidel 2004). While repeating a floristic inventory and locating rare species was not the focus of this study, two rare plant species were observed within vegetation monitoring plots at FOLA.

We identified one rare sedge species, Emory's sedge (*Carex emoryi*; Figure 11) in FOLA between 1998 and 2015 (Table 6). Emory's sedge was observed once in 2013 in a single plot. It is critically imperiled (S1) in the state of Wyoming, but is globally secure (G5); the result of the species existing on the edge of their global distribution range in Fort Laramie National Historic Site.



Figure 11. Photograph of Emory's sedge (*Carex emoryi*), a critically imperiled (S1) species in Wyoming found in plant community monitoring plots at Fort Laramie National Historic Site.

Table 6. Rare species occurrence in Fort Laramie National Historic Site from 1998-2015. Status ranks are based on Wyoming Natural Diversity Database 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 (%)
<i>Carex emoryi</i>	Emory's sedge	S1	G5	1	0.05

The Status of Riparian Forests in FOLA

In 2014, the NGPN established 20 plots in the forested area along the Laramie River to monitor status and trends in lowland riparian forest condition (Figure 12). 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 Fort Laramie NHS is small (~234 acres), and comprises about 28% of the park. The forest is fairly open and dominated by plains cottonwood (*Populus deltoides*), narrowleaf willow (*Salix exiqua*), and bare sand flats (TNC 1998) The 20 monitoring plots were chosen randomly within the riparian corridor and most fall within the cottonwood community type.

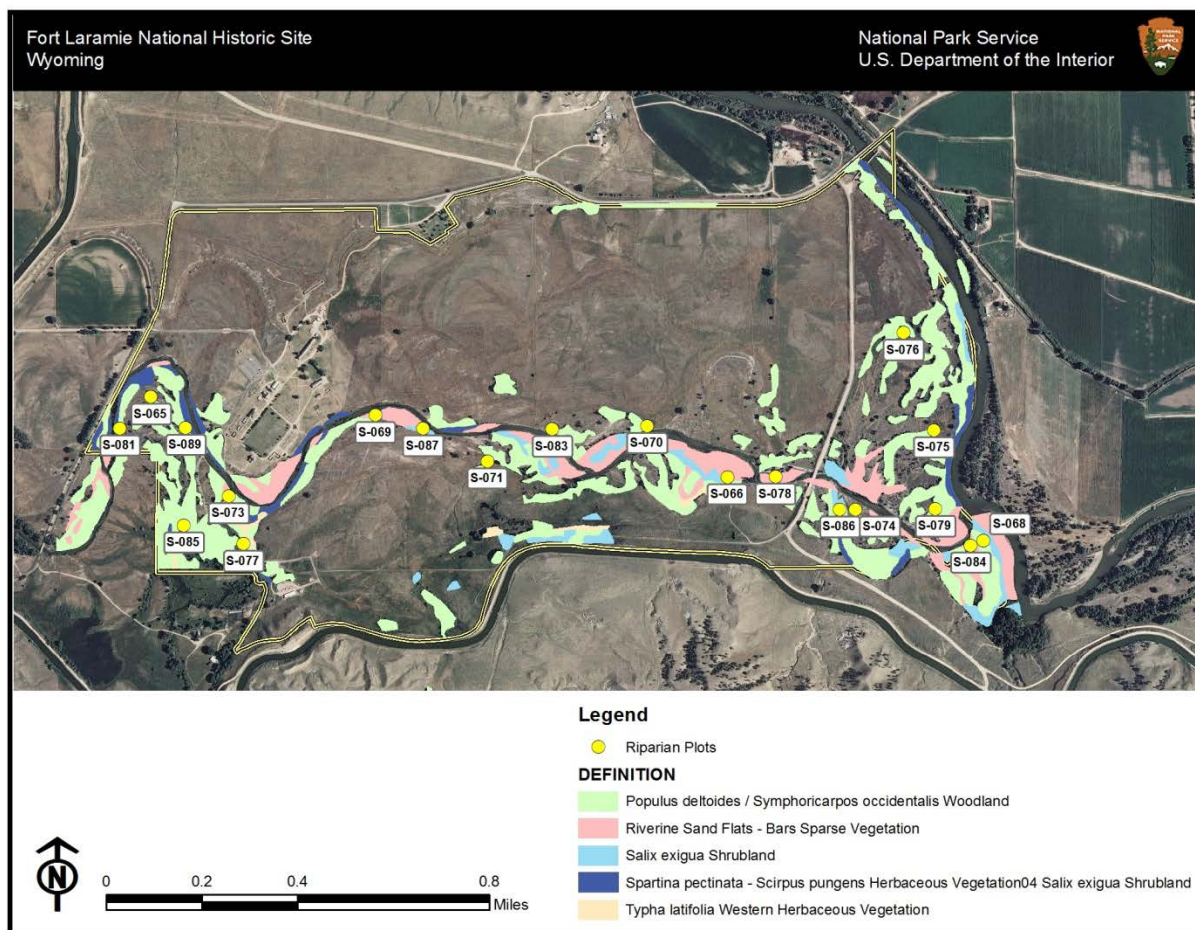


Figure 12. Map of the plant community types within the riparian area in Fort Laramie National Historic Site and the location of 20 long-term monitoring plots (red). Vegetation classification is based on the NPS Vegetation Mapping Program report (TNC 1998).

In 2014, we found 9 species of tree or tall shrub in 18 riparian forest plots at FOLA (Table 7); 2 plots (PCM-083 and 074) 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). Mature cottonwood trees were found in higher average densities than other species (Table 8). Younger cottonwood trees were also fairly common, but seedlings were found in only 4 sites (Table 7; Sites: 066, 069, 073, 087). Mature green ash (*Fraxinus pennsylvanica*) trees were found in only 5 sites (Table 7), and the average density was less than half that of cottonwood trees (Table 8). As riparian forests along the North Platte age, cottonwood and willow forests are most often replaced with green ash and box elder (*Acer negundo*) forests (Johnson 1994). In 2014, we found numerous poles and seedlings of green ash, but box elder is still uncommon. Future monitoring is needed to determine if these cottonwood and willow stands will soon become dominated by green ash.

Table 7. Tree and tall shrub occurrence in 2014 at 20 plots in Fort Laramie National Historic Site.

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 (height < 137 cm)
<i>Populus deltoides</i>	plains cottonwood	12	8	4
<i>Salix amygdaloides</i>	peachleaf willow	6	2	2
<i>Fraxinus pennsylvanica</i>	green ash	5	3	9
<i>Gleditsia triacanthos</i>	honey locust	1	1	3
<i>Salix fragilis</i> (exotic)	crack willow	1	0	1
<i>Acer negundo</i>	boxelder	0	1	1
<i>Prunus virginiana</i>	chokecherry	0	1	3
<i>Salix exigua</i>	narrowleaf willow	0	4	6
<i>Shepherdia argentea</i>	silver buffaloberry	0	2	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 (copied from Johnson 1994). The data from the 1850s to late 1880s encompasses a greater area and thus a greater number of total trees, but the shape of the histogram reveals that cottonwood and willow age structure in 2014 is fairly similar to the past (Figure 13). This suggests that new cottonwoods are being established. There were relatively fewer willow trees in the 10 cm size class in 2014 than the past. It is unclear, however, if the establishment of young cottonwoods is sufficient to maintain a cottonwood forest in this area. Jones (2007) conducted a survey of riparian forests in Fort Laramie NHS in 2006. He mapped cottonwood seedling and sapling patches along the entire length of the riparian corridor. He found 33 seedlings patches and numerous saplings, but many of the seedlings were root sprouts and it was unclear if these patches were being established frequently enough to maintain cottonwood forests (Jones 2007). Since 2006, there have been a few flood years (e.g. 2010 and 2014) that have likely allowed cottonwood seedlings to germinate and persist. A metric developed to classify cottonwood stand successional status indicates that FOLA riparian areas are primarily composed of late-intermediate seral stage cottonwood stands, indicating at least some cottonwood seedling recruitment is occurring in these plots (Uresk 2015). We plan to resurvey the FOLA riparian plots in 2019 and at that time, we may be able to determine whether cottonwoods are persisting and document effects of the large flood event in 2015.

If the goal is to maintain cottonwood forests and willows along this section of the Laramie and Platte Rivers, management interventions such as watering, bank stabilization, and fencing could ensure that the young trees which are currently present survive to maturity.

Table 8. Tree basal area and density by size class for dominant tree and shrub species in the riparian forest of Fort Laramie National Historic Site. (Values: mean across 20 riparian forest monitoring $\pm$ standard error of the mean)

Species	Indicator	Value
Plains cottonwood	Basal Area (m ² / ha)	7.18 $\pm$ 2.15
	Tree Density (stems/ha)	87.54 $\pm$ 30.73
	Pole Density (stems/ha)	28.66 $\pm$ 11.06
	Seedling Density (stems/ha)	784.53 $\pm$ 544.99
	Snag Density (stems/ha)	20.90 $\pm$ 14.78
Green ash	Basal Area (m ² / ha)	5.86 $\pm$ 4.52
	Tree Density (stems/ha)	33.94 $\pm$ 21.20
	Pole Density (stems/ha)	15.92 $\pm$ 9.94
	Seedling Density (stems/ha)	36.60 $\pm$ 11.14
	Snag Density (stems/ha)	20.70 $\pm$ 14.29
Willow species	Basal Area (m ² / ha)	3.89 $\pm$ 2.70
	Tree Density (stems/ha)	19.24 $\pm$ 10.47
	Pole Density (stems/ha)	35.03 $\pm$ 15.65
	Seedling Density (stems/ha)	4048.38 $\pm$ 1618.05
	Snag Density (stems/ha)	9.55 $\pm$ 5.71
Honey locust	Basal Area (m ² / ha)	0.01 $\pm$ 0.01
	Tree Density (stems/ha)	7.96 $\pm$ 7.96
	Pole Density (stems/ha)	7.96 $\pm$ 7.96
	Seedling Density (stems/ha)	224.38 $\pm$ 159.38
	Snag Density (stems/ha)	4.78 $\pm$ 3.48
Deciduous shrubs	Basal Area (m ² / ha)	0.09 $\pm$ 0.06
	Tree Density (stems/ha)	0.00 $\pm$ 0.00
	Pole Density (stems/ha)	35.03 $\pm$ 28.76
	Seedling Density (stems/ha)	1940.38 $\pm$ 1537.88
	Snag Density (stems/ha)	4.78 $\pm$ 3.48
Boxelder	Basal Area (m ² / ha)	0.45 $\pm$ 0.45
	Tree Density (stems/ha)	0.00 $\pm$ 0.00
	Pole Density (stems/ha)	1.59 $\pm$ 1.59
	Seedling Density (stems/ha)	1.59 $\pm$ 1.59
	Snag Density (stems/ha)	0.00 $\pm$ 0.00
Crack willow (exotic)	Basal Area (m ² / ha)	0.03 $\pm$ 0.03
	Tree Density (stems/ha)	0.40 $\pm$ 0.40
	Pole Density (stems/ha)	0.00 $\pm$ 0.00
	Seedling Density (stems/ha)	7.96 $\pm$ 7.96
	Snag Density (stems/ha)	0.00 $\pm$ 0.00

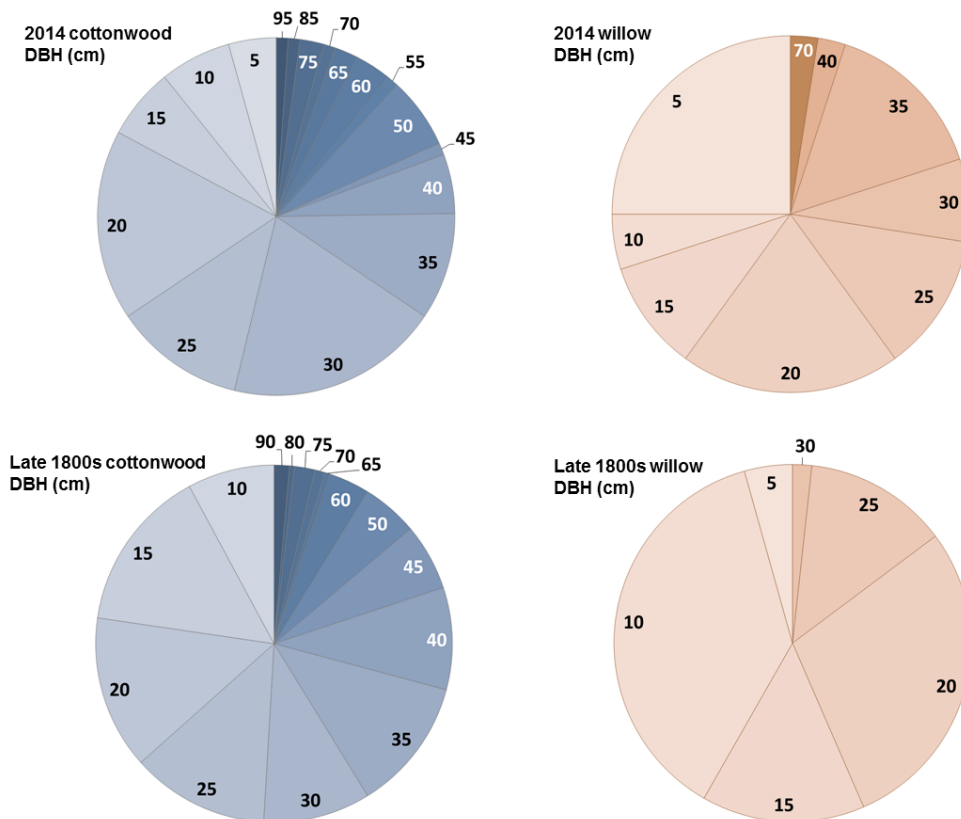


Figure 13. Size-class proportions of cottonwood (*Populus*) and willow (*Salix*) trees in riparian forests along the North Platte River in Nebraska in the 1850-1880s (bottom panels; from Johnson 1994) and along the Laramie and North Platte River in Fort Laramie National Historic Site (top panel). Labels 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 FOLA is a mix of native and exotic grasses and shrubs. 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, Russian olive) and potential early invaders (Table 1). Smooth brome (*B. inermis*) is widespread in this area, but the 2014 survey did not include it, probably because it was assumed to be abundant. Canada thistle and prickly Russian thistle were each found in half of the 20 plots (Table 9). On average, 2 exotic species were found in each plot. We did not find any early detection species. Where Japanese brome, reed canarygrass, and yellow sweetclover were found, they were in very high abundance (>25% cover)

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, Canada thistle, and Scotch cottonthistle. They have also continued to remove Russian olive and tamarisk as they are found to keep their spread under control.

Table 9. Exotic species detected in 20 riparian plots in Fort Laramie National Historic Site and their corresponding abundance, cover class, and estimated percent cover.

Species	Common Name	Number of Plots	Average Cover Class	Estimated Cover (%)
<i>Cirsium arvense</i>	Canada thistle	10	2.50 ± 0.17	1-5
<i>Salsola tragus</i>	prickly Russian thistle	10	3.20 ± 0.39	1-5
<i>Onopordum acanthium</i>	Scotch cottonthistle	8	2.25 ± 0.25	<5
<i>Verbascum thapsus</i>	common mullein	8	2.00 ± 0.19	<1
<i>Cynoglossum officinale</i>	houndstongue	5	2.20 ± 0.37	<5
<i>Bromus japonicus</i>	Japanese brome	3	5.00 ± 0.00	>25%
<i>Bromus tectorum</i>	cheatgrass	3	4.34 ± 0.67	5-25
<i>Elaeagnus angustifolia</i>	Russian olive	2	2.00 ± 0.00	<1
<i>Kochia scoparia</i>	burningbush; kochia	2	2.50 ± 0.50	<5
<i>Artemisia absinthium</i>	absinth wormwood	1	2.00 ± 0.00	<1
<i>Melilotus officinalis</i>	yellow sweetclover	1	5.00 ± 0.00	>25%
<i>Phalaris arundinacea</i>	reed canarygrass	1	5.00 ± 0.00	>25%
<i>Sisymbrium altissimum</i>	tall tumbled mustard	1	3.00 ± 0.00	1-5
<i>Tamarix chinensis</i>	five-stamen tamarisk	1	1.00 ± 0.00	<1

Conclusion

The Northern Great Plains Inventory & Monitoring Program has been monitoring vegetation in Fort Laramie National Historic Site for 5 years. This report summarizes data from 30 locations from 2011-2015. 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 FOLA grasslands (species richness, cover, and diversity) and how has this changed from 2011-2015?

FOLA plays a vital role in protecting and managing some of the last remnants of native prairie in the area. Native grasses, such western wheatgrass and needle and thread, are abundant in some sites, but many areas have a high cover of exotic plants. Native plant diversity is at a low 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 1998-2015, but both are threatened by the increasing cover of annual bromes (Table 10). Annual bromes are the most abundant exotic plant species in FOLA and present the largest challenge to FOLA. Continued control efforts will be necessary to maintain native prairie within FOLA.

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

Native diversity tended to increase in wet years. The large variability in FOLA's climate has made 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.

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

We identified 1 rare plant species in FOLA between 2011 and 2015. This plant is found in such low abundance and in such few plots, it will take many years to determine any trends in rare plant cover. Since to our knowledge, the last rare plant survey was completed in 2004, we recommend targeted surveys of individual rare plant species be considered when funds are available.

4. What is the composition and structure of riparian forests at FOLA?

The riparian forest in FOLA is a fairly diverse assemblage of cottonwood, willow species, honey locust (*Gleditsia triacanthos*), and green ash. Cottonwoods of all age classes are present (Table 10). Exotic species are common in the understory of the riparian forest, and the current control measures may help reduce their abundance in the future. Young cottonwoods have successfully established in 40% of the monitoring plots. This suggests that the successional transition to green ash and box elder dominated forests may be slow.

Table 10. Natural resource condition summary table for plant communities in Fort Laramie National Historic Site (FOLA).

Indicator of Condition	Specific Measures	2014 Value (mean $\pm$ 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)	4.3 $\pm$ 0.3 species	3-15 species		FOLA plays a vital role in protecting and managing some of the last remnants of native prairie and riparian forests in the region. The park is characterized by low native species richness which should be a moderate concern. Native species richness and evenness vary from year to year, but there is not a significant trend since monitoring began in 2011.
	Native evenness (point-intercept transects)	0.75 $\pm$ 0.02	To be determined		
Exotic Plant Early Detection and Management	Relative cover of exotic species	45.3 $\pm$ 4.5 %	< 10% cover		The sites in FOLA had a high cover of exotic species. None of the sites had <10% cover of exotic plants. Cheatgrass was the most abundant exotic species, and more research on effective management strategies is greatly needed.
	Annual brome cover	25.9 $\pm$ 4.4%	< 10% cover		
Riparian Forest	Plains cottonwood stand seral stage	Late-intermediate seral stage	Mixture of seral stages ⁽²⁾		The riparian forests of FOLA are currently a mosaic of areas dominated by willow, cottonwood, and ash with an understory of many exotic plants. As cottonwood forests age in FOLA, green ash and box elder are likely to become more dominant. Eight of 20 plots had evidence of young cottonwoods and a majority of plots had large densities of other native tree and shrub seedlings in the understory. Forest surveys will be repeated every 5 years in FOLA and this will allow us to detect trends in condition.
	Percent of 20 riparian plots with native deciduous seedlings	70%	To be determined		

References, Notes, and Data Sources: 1. Symstad and Jonas (2014) 2. Uresk (2015)

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Appendix A: List of plant species found in 2011-2015 at FOLA

Family	Code	Scientific Name	Common Name	Exotic	Rare
Aceraceae	ACNE2	<i>Acer negundo</i>	boxelder		
Agavaceae	YUGL	<i>Yucca glauca</i>	soapweed yucca		
Amaranthaceae	AMBL	<i>Amaranthus blitoides</i>	mat amaranth	X	
Anacardiaceae	RHTR	<i>Rhus trilobata</i>	skunkbush sumac		
	TORY	<i>Toxicodendron rydbergii</i>	western poison ivy		
Apiaceae	LOFO	<i>Lomatium foeniculaceum</i>	desert biscuitroot		
Apocynaceae	APCA	<i>Apocynum cannabinum</i>	Indianhemp		
Asclepiadaceae	ASSP	<i>Asclepias speciosa</i>	showy milkweed		
	ASVI	<i>Asclepias viridiflora</i>	green comet milkweed		
Asteraceae	AMPS	<i>Ambrosia psilostachya</i>	Cuman ragweed		
	AMTO3	<i>Ambrosia tomentosa</i>	skeletonleaf burr ragweed		
	ARAB3	<i>Artemisia absinthium</i>	absinth wormwood	X	
	ARBI2	<i>Artemisia biennis</i>	biennial sagewort	X	
	ARCA12	<i>Artemisia campestris</i>	field sagewort		
	ARDR4	<i>Artemisia dracunculus</i>	tarragon		
	ARFI2	<i>Artemisia filifolia</i>	sand sagebrush		
	ARFR4	<i>Artemisia frigida</i>	fringed sagewort		
	ARLU	<i>Artemisia ludoviciana</i>	white sagebrush		
	BIFR	<i>Bidens frondosa</i>	devil's beggartick		
	BITR	<i>Bidens tripartita</i>	threelobe beggarticks		
	CIAR4	<i>Cirsium arvense</i>	Canada thistle	X	
	CICA11	<i>Cirsium canescens</i>	prairie thistle	X	
	CIFL	<i>Cirsium flodmanii</i>	Flodman's thistle		
	CIVU	<i>Cirsium vulgare</i>	bull thistle	X	
	COCA5	<i>Conyza canadensis</i>	horseweed		
	CYXA	<i>Cyclachaena xanthifolia</i>	giant sumpweed		
	ERIGE2	<i>Erigeron</i> spp.	fleabane		
	EUOC4	<i>Euthamia occidentalis</i>	western goldentop		
	GNPA	<i>Gnaphalium palustre</i>	western marsh cudweed		
	GRSQ	<i>Grindelia squarrosa</i>	curlycup gumweed		
	HEAN3	<i>Helianthus annuus</i>	common sunflower		
	HELIA3	<i>Helianthus</i> spp.	sunflower		
	HEPE	<i>Helianthus petiolaris</i>	prairie sunflower		
	HEVI4	<i>Heterotheca villosa</i>	hairy false goldenaster		
	LASE	<i>Lactuca serriola</i>	prickly lettuce	X	
	LYJU	<i>Lygodesmia juncea</i>	rush skeletonplant		
	MATA2	<i>Machaeranthera tanacetifolia</i>	tanseyleaf tansyaster		
	MUOB99	<i>Mulgedium oblongifolium</i>	blue lettuce		

Family	Code	Scientific Name	Common Name	Exotic	Rare
	ONAC	<i>Onopordum acanthium</i>	Scotch cottonthistle	X	
	PACA15	<i>Packera cana</i>	woolly groundsel		
	PAPL12	<i>Packera plattensis</i>	prairie groundsel		
	RACO3	<i>Ratibida columnifera</i>	upright prairie coneflower		
	SERI2	<i>Senecio riddellii</i>	Riddell's ragwort		
	SYER	<i>Symphyotrichum ericoides</i>	white heath aster		
	SYLA6	<i>Symphyotrichum lanceolatum</i>	white panicle aster		
	TAOF	<i>Taraxacum officinale</i>	common dandelion	X	
	THME	<i>Thelesperma megapotamicum</i>	Hopi tea greenthread		
	TRDU	<i>Tragopogon dubius</i>	yellow salsify	X	
	XAST	<i>Xanthium strumarium</i>	rough cocklebur		
Boraginaceae	CRCE	<i>Cryptantha celosioides</i>	buttecandle		
	CRM15	<i>Cryptantha minima</i>	little cryptantha		
	CYOF	<i>Cynoglossum officinale</i>	houndstongue	X	
	LAOC3	<i>Lappula occidentalis</i>	flatspine stickseed		
	LIIN2	<i>Lithospermum incisum</i>	narrowleaf stoneseed		
Brassicaceae	ALDE	<i>Alyssum desertorum</i>	desert madwort	X	
	CAMI2	<i>Camelina microcarpa</i>	littlepod false flax	X	
	DEPI	<i>Descurainia pinnata</i>	western tansymustard		
	DESO2	<i>Descurainia sophia</i>	herb sophia	X	
	DRRE2	<i>Draba reptans</i>	Carolina draba		
	LECA5	<i>Lepidium campestre</i>	field pepperweed	X	
	LEDE	<i>Lepidium densiflorum</i>	common pepperweed		
	SIAL2	<i>Sisymbrium altissimum</i>	tall tumbledmustard	X	
	THAR5	<i>Thlaspi arvense</i>	field pennycress	X	
Cactaceae	ESVI2	<i>Escobaria vivipara</i>	spiny star		
	OPFR	<i>Opuntia fragilis</i>	brittle pricklypear		
	OPMA2	<i>Opuntia macrorhiza</i>	twistspine pricklypear		
	OPPO	<i>Opuntia polyacantha</i>	plains pricklypear		
Capparaceae	PODO3	<i>Polanisia dodecandra</i>	redwhisker clammyweed		
Caprifoliaceae	SYOC	<i>Symphoricarpos occidentalis</i>	western snowberry		
Chenopodiaceae	CHAL7	<i>Chenopodium album</i>	lambsquarters	X	
	CHBE4	<i>Chenopodium berlandieri</i>	pitseed goosefoot	X	
	CHENO	<i>Chenopodium</i> spp.	goosefoot	X	
	CHFR3	<i>Chenopodium fremontii</i>	Fremont's goosefoot		
	KOSC	<i>Kochia scoparia</i>	burningbush, kochia	X	
	KRLA2	<i>Krascheninnikovia lanata</i>	winterfat		
	SACO8	<i>Salsola collina</i>	slender Russian thistle	X	
	SATR12	<i>Salsola tragus</i>	prickly Russian thistle	X	
Commelinaceae	TROC	<i>Tradescantia occidentalis</i>	prairie spiderwort		

Family	Code	Scientific Name	Common Name	Exotic	Rare
Convolvulaceae	COAR4	<i>Convolvulus arvensis</i>	field bindweed	X	
	IPLE	<i>Ipomoea leptophylla</i>	bush morning-glory		
Cyperaceae	CADU6	<i>Carex duriuscula</i>	needleleaf sedge		
	CAEM2	<i>Carex emoryi</i>	Emory's sedge		S1
	CAFI	<i>Carex filifolia</i>	threadleaf sedge		
	CAHY4	<i>Carex hystericina</i>	bottlebrush sedge		
	CAIN9	<i>Carex inops</i>	sun sedge		
	CANE2	<i>Carex nebrascensis</i>	Nebraska sedge		
	CAPE42	<i>Carex pellita</i>	woolly sedge		
	CAPR5	<i>Carex praegracilis</i>	clustered field sedge		
	CAREX	<i>Carex</i> spp.	sedge		
	CYSQ	<i>Cyperus squarrosus</i>	bearded flatsedge		
	ELAC	<i>Eleocharis acicularis</i>	needle spikerush		
	ELPA3	<i>Eleocharis palustris</i>	common spikerush		
	SCPU10	<i>Schoenoplectus pungens</i>	common threesquare		
	SCTA2	<i>Schoenoplectus tabernaemontani</i>	softstem bulrush		
Elaeagnaceae	ELAN	<i>Elaeagnus angustifolia</i>	Russian olive	X	
	SHAR	<i>Shepherdia argentea</i>	silver buffaloberry		
Equisetaceae	EQLA	<i>Equisetum laevigatum</i>	smooth horsetail		
Euphorbiaceae	CRTE4	<i>Croton texensis</i>	Texas croton		
	EUPHO	<i>Euphorbia</i> spp.	spurge, sandmat	X	
	EUGL3	<i>Euphorbia glyptosperma</i>	ribseed sandmat		
	EUSE5	<i>Euphorbia serpyllifolia</i>	thymeleaf sandmat		
Fabaceae	AMFR	<i>Amorpha fruticosa</i>	desert false indigo		
	DACA7	<i>Dalea candida</i>	white prairie clover		
	GLLE3	<i>Glycyrrhiza lepidota</i>	American licorice		
	GLTR	<i>Gleditsia triacanthos</i>	honeylocust		
	LAPO2	<i>Lathyrus polymorphus</i>	manystem pea		
	LUPU	<i>Lupinus pusillus</i>	rusty lupine		
	MELU	<i>Medicago lupulina</i>	black medick	X	
	MEOF	<i>Melilotus officinalis</i>	yellow sweetclover	X	
	MESA	<i>Medicago sativa</i>	alfalfa	X	
	PEES	<i>Pedimelum esculentum</i>	large Indian breadroot		
	PSTE5	<i>Psoralidium tenuiflorum</i>	slimflower scurfpea		
	TRFR2	<i>Trifolium fragiferum</i>	strawberry clover	X	
Fumariaceae	COCU2	<i>Corydalis curvisiliqua</i>	curvedpod fumewort		
Grossulariaceae	RIAU	<i>Ribes aureum</i>	golden currant		
	RICE	<i>Ribes cereum</i>	wax currant		
Hydrophyllaceae	ELNY	<i>Ellisia nyctelea</i>	Aunt Lucy		

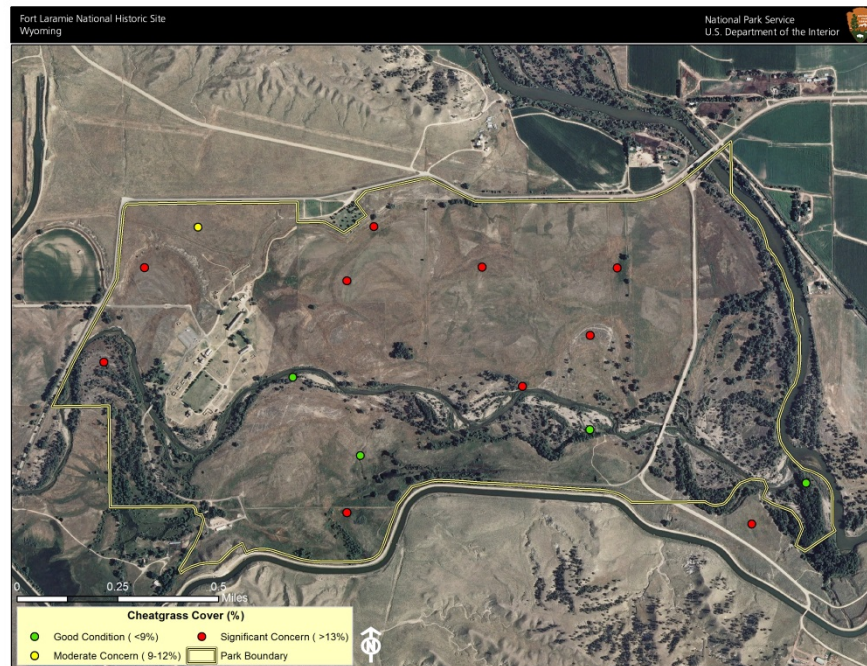
Family	Code	Scientific Name	Common Name	Exotic	Rare
Juncaceae	JUBA	<i>Juncus balticus</i>	Baltic rush		
	JUCO	<i>Juncus compressus</i>	roundfruit rush	X	
Lamiaceae	LYAM	<i>Lycopus americanus</i>	American water horehound		
	LYAS	<i>Lycopus asper</i>	rough bugleweed		
	MEAR4	<i>Mentha arvensis</i>	wild mint		
	NECA2	<i>Nepeta cataria</i>	catnip	X	
	TECA3	<i>Teucrium canadense</i>	Canada germander		
Lemnaceae	LETU2	<i>Lemna turionifera</i>	turion duckweed		
Liliaceae	ALTE	<i>Allium textile</i>	textile onion		
Loasaceae	MEDE2	<i>Mentzelia decapetala</i>	tenpetal blazingstar		
Malvaceae	SPCO	<i>Sphaeralcea coccinea</i>	scarlet globemallow		
Nyctaginaceae	MIHI	<i>Mirabilis hirsuta</i>	hairy four o'clock		
	MILI3	<i>Mirabilis linearis</i>	narrowleaf four o'clock		
Oleaceae	FRPE	<i>Fraxinus pennsylvanica</i>	green ash		
Onagraceae	OEAL	<i>Oenothera albicaulis</i>	whitest evening-primrose		
	OECU2	<i>Oenothera curtiflora</i>	velvetweed		
	OENOT	<i>Oenothera</i> spp.	evening-primrose		
	OESE3	<i>Oenothera serrulata</i>	yellow sundrops		
	OESU99	<i>Oenothera suffrutescens</i>	scarlet beeblossom		
	OEVI	<i>Oenothera villosa</i>	hairy evening primrose		
Papaveraceae	ARPO2	<i>Argemone polyanthemus</i>	crested pricklypoppy		
Plantaginaceae	PLMA2	<i>Plantago major</i>	common plantain		
	PLPA2	<i>Plantago patagonica</i>	woolly plantain		
Poaceae	ACHY	<i>Achnatherum hymenoides</i>	Indian ricegrass		
	AGCR	<i>Agropyron cristatum</i>	crested wheatgrass	X	
	AGST2	<i>Agrostis stolonifera</i>	creeping bentgrass		
	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	X	
	BRJA	<i>Bromus japonicus</i>	Japanese brome	X	
	BRTE	<i>Bromus tectorum</i>	cheatgrass	X	
	CALO	<i>Calamovilfa longifolia</i>	prairie sandreed		
	ECCR	<i>Echinochloa crus-galli</i>	barnyardgrass	X	
	ELCA4	<i>Elymus canadensis</i>	Canada wildrye		
	ELRE4	<i>Elymus repens</i>	quackgrass	X	
	ELTR7	<i>Elymus trachycaulus</i>	slender wheatgrass		
	HECO26	<i>Hesperostipa comata</i>	needle and thread		
	HOBR2	<i>Hordeum brachyantherum</i>	meadow barley		

Family	Code	Scientific Name	Common Name	Exotic	Rare
	KOMA	<i>Koeleria macrantha</i>	prairie Junegrass		
	MUPA99	<i>Muhlenbergia paniculata</i>	tumblegrass		
	NAVI4	<i>Nassella viridula</i>	green needlegrass		
	PACA6	<i>Panicum capillare</i>	witchgrass		
	PASM	<i>Pascopyrum smithii</i>	western wheatgrass		
	PAVI2	<i>Panicum virgatum</i>	switchgrass		
	PHAR3	<i>Phalaris arundinacea</i>	reed canarygrass	X	
	PHPR3	<i>Phleum pratense</i>	timothy	X	
	POCO	<i>Poa compressa</i>	Canada bluegrass	X	
	POPR	<i>Poa pratensis</i>	Kentucky bluegrass	X	
	PSSP6	<i>Pseudoroegneria spicata</i>	bluebunch wheatgrass		
	SCSC	<i>Schizachyrium scoparium</i>	little bluestem		
	SEVI4	<i>Setaria viridis</i>	green bristlegrass	X	
	SPCR	<i>Sporobolus cryptandrus</i>	sand dropseed		
	SPPE	<i>Spartina pectinata</i>	prairie cordgrass		
	VUOC	<i>Vulpia octoflora</i>	sixweeks fescue		
Polygonaceae	ERAN4	<i>Eriogonum annuum</i>	annual buckwheat		
	EREF	<i>Eriogonum effusum</i>	spreading buckwheat		
	PEAM8	<i>Persicaria amphibia</i>	longroot smartweed		
	PEMA24	<i>Persicaria maculosa</i>	spotted ladythumb	X	
	PERSI99	<i>Persicaria</i> spp.	smartweed	X	
	PELA22	<i>Persicaria lapathifolia</i>	curlytop knotweed		
	RUCR	<i>Rumex crispus</i>	curly dock	X	
	RUMEX	<i>Rumex</i> spp.	dock	X	
Ranunculaceae	RACY	<i>Ranunculus cymbalaria</i>	alkali buttercup		
Rosaceae	POSU25	<i>Potentilla supina</i>	Paradox cinquefoil		
	PRAM	<i>Prunus americana</i>	American plum		
	PRVI	<i>Prunus virginiana</i>	chokecherry		
	ROAR3	<i>Rosa arkansana</i>	prairie rose		
Rubiaceae	GAAP2	<i>Galium aparine</i>	stickywilly		
	GATR3	<i>Galium triflorum</i>	fragrant bedstraw		
Salicaceae	POAN3	<i>Populus angustifolia</i>	narrowleaf cottonwood		
	PODE3	<i>Populus deltoides</i>	eastern cottonwood		
	SAAM2	<i>Salix amygdaloides</i>	peachleaf willow		
	SAEX	<i>Salix exigua</i>	narrowleaf willow		
	SAFR	<i>Salix fragilis</i>	crack willow	X	
Scrophulariaceae	VEAN2	<i>Veronica anagallis-aquatica</i>	water speedwell		
	VETH	<i>Verbascum thapsus</i>	common mullein	X	
Solanaceae	PHLO4	<i>Physalis longifolia</i>	longleaf groundcherry		

Family	Code	Scientific Name	Common Name	Exotic	Rare
	SORO	<i>Solanum rostratum</i>	buffalobur nightshade		
Tamaricaceae	TACH2	<i>Tamarix chinensis</i>	five-stamen tamarisk	X	
Typhaceae	TYAN	<i>Typha angustifolia</i>	narrowleaf cattail	X	
Urticaceae	PAPE5	<i>Parietaria pensylvanica</i>	Pennsylvania pellitory		
Verbenaceae	PHCU3	<i>Phyla cuneifolia</i>	wedgeleaf		
	VEBR	<i>Verbena bracteata</i>	bigbract verbena		
	VEHA2	<i>Verbena hastata</i>	swamp verbena		
Vitaceae	PAVI5	<i>Parthenocissus vitacea</i>	woodbine		
	VIRI	<i>Vitis riparia</i>	riverbank grape		

Appendix B: Natural Resource Condition Maps of Exotic Species at FOLA

The maps below illustrate the abundance of cheatgrass (*Bromus tectorum*) and smooth brome (*B. inermis*) in monitoring plots at Fort Laramie National Historic Site. Red indicates relative cover of >13 % and is a significant concern.



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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U.S. Department of the Interior



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