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Plant Community Composition and Structure at Fort Union Trading Post National Historic Site

2010 – 2016 Summary Report

Natural Resource Report NPS/NGPN/NRR—2017/1406

ON THE COVER
Long-term monitoring plot PCM-010 at Fort Union Trading Post National Historic Site, 2016
Photograph courtesy of the National Park Service

Plant Community Composition and Structure at Fort Union Trading Post National Historic Site

2010 – 2016 Summary Report

Natural Resource Report NPS/NGPN/NRR—2017/1406

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Executive Summary

The National Park Service's Northern Great Plains Inventory & Monitoring Program and Fire Effects Program have been monitoring vegetation in Fort Union Trading Post National Historic Site (FOUS) for over 18 years. While the monitoring methods used have changed slightly during those years, this report summarizes the data collected from 22 locations between 1999 and 2016. We used these data to compare current conditions to the desired conditions outlined in the FOUS Vegetation Management Plan (Symstad 2012). Our results are focused on two areas: the Bodmer Unit, an area north of the highway that is native prairie, and the Upland Terrace area surrounding the fort that has been planted. A summary of our results can be found in the Natural Resource Conditions Table for the Upland Terrace (Table 7) and Bodmer Unit (Table 8).

After restoration efforts in the late 1990s through 2010 in the Upland Terrace, there was a large reduction in the cover of exotic grasses. However, Kentucky bluegrass, smooth brome, and crested wheatgrass are now contributing to a higher cover of exotic species than desired. Efforts to control these grasses and noxious weeds should be made a priority, before they continue to spread and conditions decline. There is also a much lower cover and diversity of forb species than desired. To improve the condition of the Upland Terrace, efforts should be made to increase the number of forb species through continued seeding projects.

The Bodmer Unit is a fairly diverse mixed-grass prairie. The vegetation communities in the Bodmer Unit at Fort Union are generally in good condition, particularly the hill top plots. There is a large diversity of native plants, and the current graminoid, forb, and shrub cover match the desired conditions. There is a moderate cover of exotic species that is above the desired conditions. There are no noxious weeds in the area, but Kentucky bluegrass is abundant in the unit. This is of concern because in other areas of North Dakota, an increase in Kentucky bluegrass has been correlated with reductions in native plant diversity.

Acknowledgments

We thank all the authors of the Northern Great Plains Network (NGPN) Plant Community Monitoring Protocol, particularly A. Symstad, for outstanding guidance on data collection and reporting. Thank you to the staff at FOUS, particularly A. Banta for providing logistical support and safety checks. The NGPN and Northern Great Plains Fire Ecology vegetation field crews and A. Symstad collected all the data included in this report. Thanks to D. Swanson and his staff for allowing ongoing collaboration between the Fire Ecology and Inventory & Monitoring Programs. Comments from S. Rockwood, M. Davis, A. Banta, F. MacVaugh, and A. Symstad improved this report.

Introduction

During the last century, much of the prairie within the Northern Great Plains was 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 North Dakota, greater than 71% of the area of native mixed-grass prairie has been lost since European settlement in the 1800s (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 the Northern Great Plains. The NPS's stewardship goal is to "preserve ecological integrity and cultural and historical authenticity" (NPS 2012). However, resource managers struggle with the realities that: (1) there have been fundamental changes to disturbance regimes such as climate, fire, and large ungulate grazing that formerly maintained prairie habitat, and (2) there is continual pressure from exotic invasive species. Long-term monitoring is essential to sound management of prairie landscapes because it can provide information on environmental quality and condition, benchmarks concerning ecological integrity, and early warning signs for declines in ecosystem health.

Fort Union Trading Post National Historic Site (FOUS) was established in 1966 with a mission to commemorate the significant role played by Fort Union as a fur trading post on the Upper Missouri River. The trading post sits on 444 acres of upland mixed-grass prairie and riparian forests. Vegetation monitoring at FOUS was initiated by the Northern Great Plains Fire Ecology Program in 1997 (NGPFire; Wienk et al. 2010). In 2011, the Northern Great Plains Inventory & Monitoring Network (NGPN) and NGPFire combined their efforts to establish a coordinated vegetation monitoring protocol and shifted plot locations to better represent the entire park (Symstad et al. 2011) and the goals of the FOUS vegetation management plan (Symstad 2012). Combined sampling efforts began in 2011 (Ashton et al. 2012).

Two distinct areas of grassland at FOUS are monitored: the Upland Terrace surrounding the reconstructed fort, and the Bodmer Overlook Unit (hereafter the Bodmer Unit), which is north of the fort and terrace. The Upland Terrace has an extensive history of agricultural use that predates the park's creation. More recently, it was planted with native species (Symstad 2012). The Bodmer Unit is a 30-acre parcel of rolling hills north of the fort comprised of relatively intact native prairie (Symstad 2012). In this report, we use the 2012–2016 data to assess the current condition of vegetation in the Bodmer Unit and the Upland Terrace. The 2010–2016 data are used to look at longer-term trends. We compared the conditions to desired conditions for vegetation outlined in the FOUS vegetation management plan (Symstad 2012). Finally, we explore how vegetation has changed in the Upland Terrace since the restoration efforts.

Methods

Two different methods and protocols have been used to monitor long-term vegetation plots at FOUS since 1999: the NGPN monitoring protocol (Symstad et al. 2012b, a), and the Fire Monitoring Handbook (NPS 2003). Although we briefly describe both methods below, the focus is on the NGPN monitoring protocol, which is the current standard method used to collect most of the data presented in this report. For more detail on any of the methods, please see the protocol publications cited above.

NGPN and NGPFire Monitoring Plots 2011–2016

The NGPN and NGPFire implemented a survey to monitor plant community structure and composition in FOUS using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, NGPN selected 15 randomly located sites within FOUS to become Plant Community Monitoring plots (PCM plots; Figure 1). The NGPN visits six PCM plots during late July every year, using a rotating sampling scheme that consists of three sites visited the previous year and three sites that have not been visited for five years. Two of the sites monitored each year were located in the Bodmer Unit. After five years (2011 – 2015), all of the PCM plots were visited at least twice. The original sampling design developed in 2010 included areas south of the Missouri River (Symstad et al. 2012a), but these were excluded when the vegetation management plan was completed in 2012 (Symstad 2012) and active management in these areas was not recommended. Instead, monitoring plots were restricted to the Bodmer Unit and the Upland Terrace surrounding the fort (Symstad 2012).

At each of the sites visited, NGPN teams recorded plant species cover in a rectangular, 50 m x 20 m (0.1 ha), permanent plot (Figure 2). Data on ground cover, herb-layer height ($\leq$ 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). At 50 locations along each transect (every 1 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 tallest/first plant intercepted (Figure 3). Using this method, absolute canopy cover can be greater than 100% (particularly in wet years and productive sites) because team members record multiple layers of plants. Species richness data from the point-intercept method were supplemented 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). In 2016, NGPN discontinued the use of nested quadrats and replaced this with 1m^2 quadrats. This was done to save time while continuing to collect diversity data at the 1m^2 scale, which is more commonly used by vegetation ecologists. In this report, only the data from the 1m^2 and 10m^2 quadrats is presented. A journal of which plots were visited in which year is provided in Appendix A.

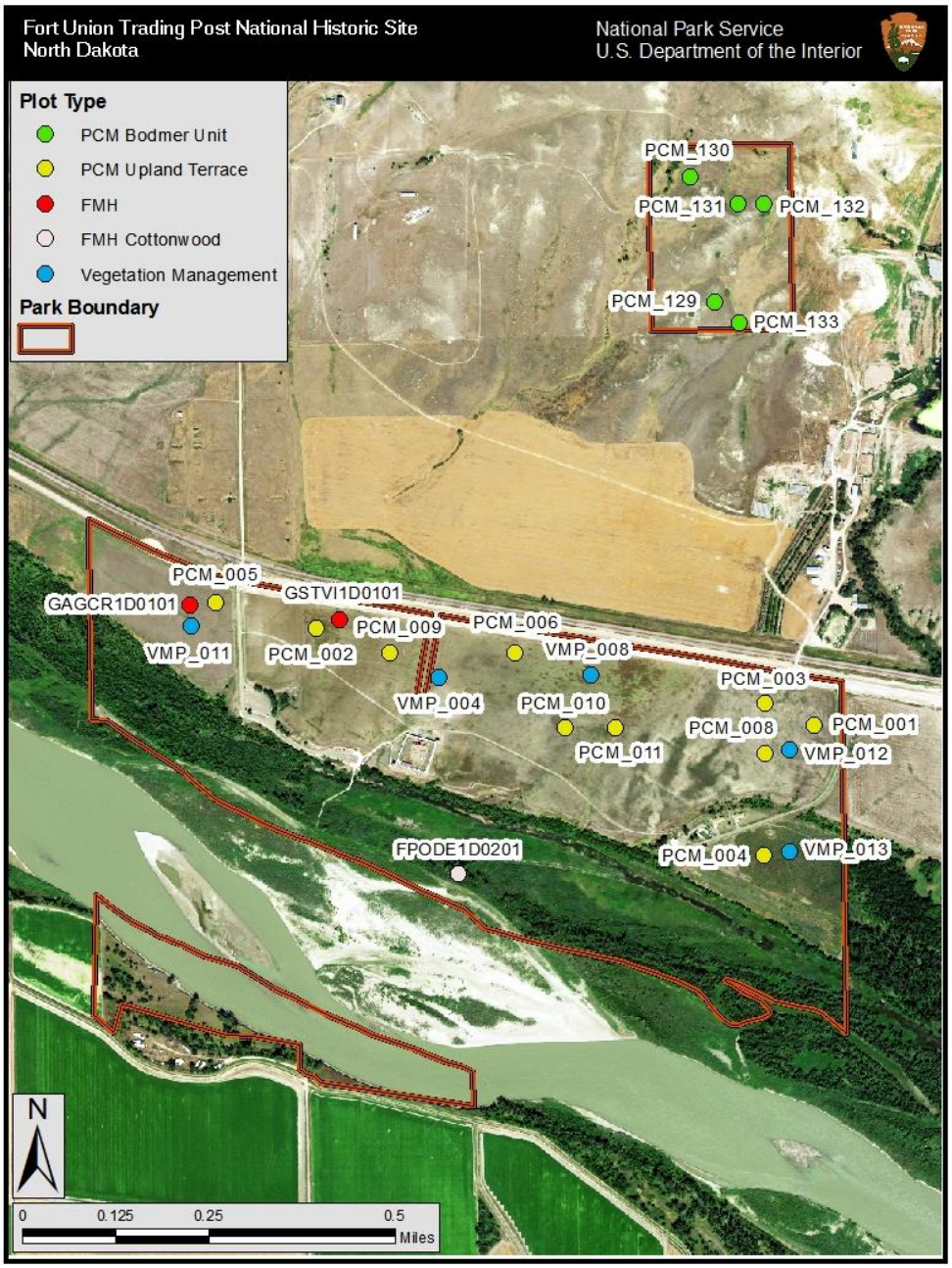


Figure 1. Map of Fort Union Trading Post National Historic Site (FOUS) plant community monitoring plots, 1999 – 2016. Fifteen PCM plots were established by the Northern Great Plains Inventory & Monitoring Program (NGPN) and the Fire Effects Program (NGPFire) between 2011 and 2016. Five of these plots are within the Bodmer Unit (green plots) and 10 are in the Upland Terrace (yellow plots). Three Fire Monitoring Handbook plots (FMH; white and red) plots were monitored from 1997 – 2011 by NGPFire. Data from the two FMH plots in the Upland Terrace were used in this report. Five plots were monitored in 2010 as part of the Vegetation Management Planning process (VMP; blue plots).

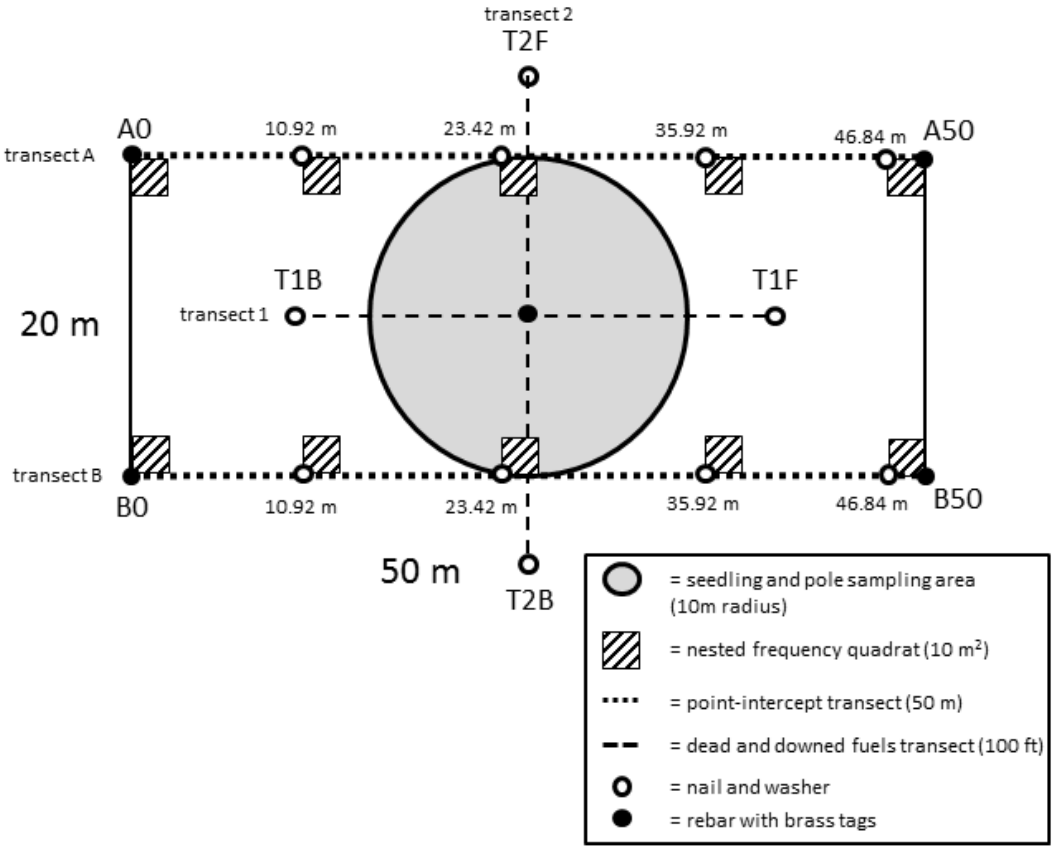


Figure 2. Long-term monitoring plot layout used for sampling vegetation in Fort Union Trading Post National Historic Site.

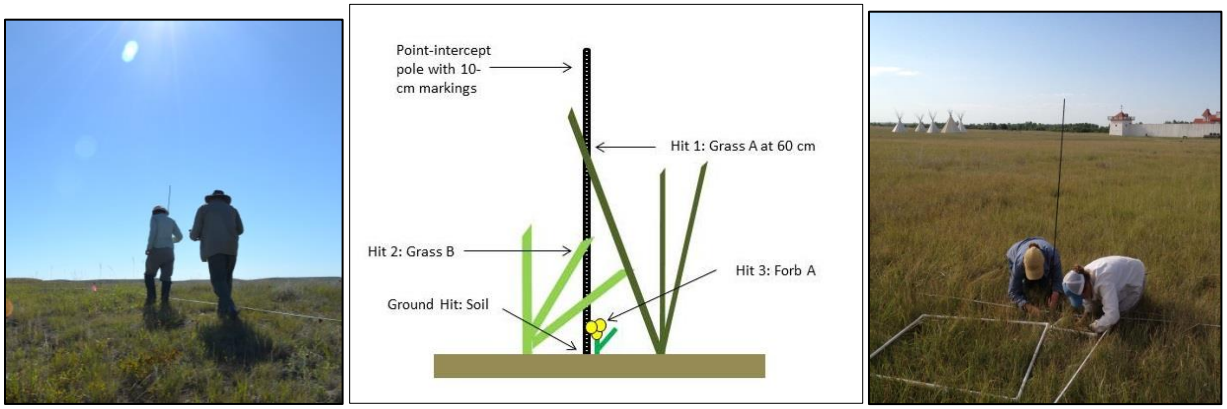


Figure 3. The Northern Great Plains Inventory & Monitoring vegetation crew used point-intercept (left and center panel) and quadrats (right panel) to document plant diversity and abundance.

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 (live or dead), and condition (e.g., leaf-discoloration, insect-damaged, etc.) were recorded. Mean values included zeroes for plots where no trees were present.

Tree data were collected for three plots: PCM_129, PCM_130, and PCM_131. A single green ash (*Fraxinus pennsylvanica*) seedling was identified in 2012 and 2013 at PCM_130. Chokecherry (*Prunus virginia*) and serviceberry (*Amelanchier alnifolia*) were located within 38 m of the remaining two plots, but not within the appropriate 0.1 ha plot or 10 m radius subplot boundaries. Due to the very low density of trees and tall shrubs in the area sampled (1 seedling) we performed no analyses and report no further on this metric.

At the 15 PCM plots visited by NGPN, team members surveyed the area for common disturbances and target exotic species of interest to the park. Common disturbances included such things as rodent mounds, animal trails, mowing, and fire, and the approximate area (m^2) and severity of each disturbance was recorded. NGPN also surveyed the area for target exotic species that have the potential to spread into the park and cause significant ecological impacts (Table 1).

Table 1. Exotic species included in the Northern Great Plains Network's early detection and rapid response program. The State Noxious Species column indicates species included on the Montana (MT) or North Dakota (ND) state list of noxious weeds. ND-M indicates species considered noxious in McKenzie County, ND.

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

These target 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 to 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 the early detection and rapid response to exotic species presence.

Other Monitoring Plots (1999 – 2016)

In 1997, NGPFire began monitoring three plots within FOUS to evaluate the effectiveness of prescribed burns. Starting in 1999, 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.

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 sampled prior to a burn, and then 1, 2, 5, and 10 years after a prescribed burn (See Appendix A for a list of when plots were visited). Hereafter, we refer to these plots as Fire Monitoring Handbook (FMH) plots. These FMH plots will be retired and permanent plot markers removed after the 10-year visit. The FMH plots will be replaced with the PCM plots described above. This report does not include data from one of the three FMH plots (FPODE1D0201) because it was in a forested area and is dissimilar to all the other data collected.

In 2010, ten plots were visited to collect data for the FOUS Vegetation Management Plan (Symstad 2012). These Vegetation Management Plots (VMP, Figure 1) were measured following the NGPN protocol with two exceptions: the plots were chosen to represent the restoration fields, and the point-intercept pole was a smaller diameter (Symstad 2012). Data from seven of these plots were included in this report and three plots were excluded. One of the excluded plots had no location associated with it and the raw data have not been entered into the FFI database for the two others. The two plots that were sampled in the Bodmer Unit (PCM_129 and PCM_130) were incorporated into the NGPN sample design and will continue to be visited.

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, U.S. Department of Agriculture (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). 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; scientific names can be found in Appendix B.

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 identified during data checks or automated queries, the original datasheets and/or the FFI database were corrected.

Data summaries were produced using the FFI reporting and query tools. Statistical summaries and graphics were generated using the R statistics software package (version 3.2.2). Trends were tested using a linear mixed model with plots nested within years as a random factor using R software. Models were considered significant when the P value was <0.05. Trends were examined over the period of consistent sampling (2010-2016). Data from the earlier time period are presented but not included in graphs or statistical analyses because of low sample sizes and a change in monitoring methods.

Plant life forms (e.g., shrub, forb) were based on definitions from the USDA Plants Database (USDA-NRCS 2015). The conservation status rank of plant species in North Dakota was determined by cross-referencing the list of species observed by NGPN with the NatureServe conservation status list. For the purpose of this report, a species was considered rare if its global conservation status rank was considered critically imperiled (G1), imperiled (G2), or vulnerable (G3), or if it was considered rare in North Dakota and had a conservation status rank of S1, S2, or S3 (Table 2). Lists of noxious weeds are maintained by the North Dakota Department of Agriculture (https://www.nd.gov/ndda/program/noxious-weeds) and the Montana Department of Agriculture (http://agr.mt.gov/Weeds). These lists were cross-referenced with the list of species observed in FOUS by NGPN.

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)

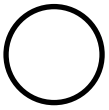
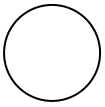
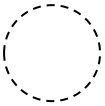
We calculated diversity in the plots in two ways: species richness and Pielou's Evenness Index. Species richness is simply a count of the species recorded in an area, and is reported as the number of species intercepted along two 50 m transects and the average number of species identified in ten quadrats within a plot from both a 1 m^2 and 10 m^2 area. Pielou's Evenness Index, J', measures how

even abundances are across taxa, and J' values range 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. This was only calculated only from the point-intercept method. Plant richness was calculated for each plot using the total number of species intersected along the two transects. Average height for the plot was calculated as the average of the 100 heights recorded (1 per point) along the transects. Absolute cover was calculated from the point-intercept method and is the total number of vegetation intercepts. This is often greater than 100% because more than one species can be intercepted per point due to overlapping vegetation. Relative cover is calculated by dividing the absolute cover of the species or grouping of interest by the total absolute cover. Relative cover is therefore constrained between 0 and 100%.

Reporting on Natural Resource Condition

Results were summarized in a Natural Resource Condition Table based on the templates created for the State of the Park report series. The goal of the Natural Resource Condition Table is to improve the setting of park priorities and to synthesize and communicate complex park condition information to the public in a clear and simple way. Focusing on specific indicators such as exotic species cover also makes it 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.

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. This template is based on the one created for the State of the Park reports (http://www.nps.gov/stateoftheparks/).

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

We chose a set of indicators that align with the desired conditions outlined in the FOUS Vegetation Management Plan (Symstad 2012). The indicators include measures of composition (e.g., percent graminoid and forb cover), the relative cover of exotic species, vegetation height, and absolute bare ground cover. Reference values were the desired condition or management targets. Current park condition was compared to the reference value, and status was scored as "good condition", "warrants

moderate concern", or "warrants significant concern" (Table 3). "Good condition" was applied to values that fell within the range of the reference value, and "warrants significant concern" was applied to conditions that fell outside the bounds of the reference value. Indicators were classified as "warrants moderate concern" when the average value was near the threshold of significant concern but the variation associated with that value (e.g. 1 standard error) fell within both good condition and significant concern.

Results and Discussion

Status and Trends in Plant Community Composition and Structure

There are 386 vascular plant species on the FOUS species list and we identified 190 species in monitoring plots from 1999 to 2016 at FOUS (Appendix A). Western wheatgrass (*Pascopyrum smithii*), green needlegrass (*Nassella viridula*), and blue grama (*Bouteloua gracilis*) were the most abundant species in the Upland Terrace and averaged between 15 and 35% absolute cover (Figure 4, left). Although present, green needlegrass was less abundant in the Bodmer Unit, while threadleaf sedge (*Carex filifolia*) and prairie Junegrass (*Koeleria macrantha*) were more abundant (Figure 4, right). We identified 44 exotic plant species at FOUS. Exotic grasses were common in both areas. Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), and crested wheatgrass (*Agropyron cristatum*) averaged between 5 and 10% cover.

Figure 4. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded at Fort Union Trading Post National Historic Site from 1999 – 2016 in the Upland Terrace (left) and Bodmer Unit (right). Bars represent means ± one standard error.

Graminoid, Forb, and Shrub Cover

Graminoids, which include grasses, sedges, and rushes, accounted for most of the vegetative cover at FOUS, but forbs, shrubs, and subshrubs (defined as low-growing shrubs usually shorter than 0.5 m) were also present (Figure 5). Exotic graminoids were particularly abundant in both the Upland

Terrace and Bodmer Unit (Figure 5), while exotic forbs and vines were only abundant in the Upland Terrace. The shrubs and subshrubs were all native species and were found primarily in the Bodmer Unit.

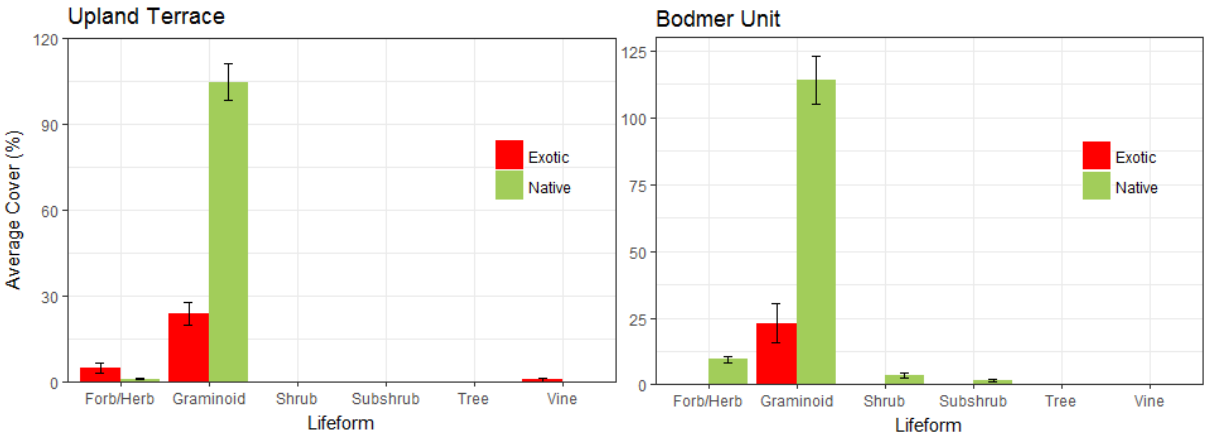


Figure 5. Average cover by lifeform of native (green) and exotic (red) plants recorded in monitoring plots in Fort Union Trading Post National Historic Site (1999 – 2016) in the Upland Terrace (left) and Bodmer Unit (right). Absolute cover can be greater than 100% because the point-intercept methods records layers of overlapping vegetation.

The FOUS Vegetation Management Plan includes desired conditions for the relative cover of lifeforms within the Upland Terrace and Bodmer Unit (Symstad 2012). In the Upland Terrace, the desired conditions include 55 – 90 % relative cover of graminoids, 10 – 20 % forbs, and 0 – 15 % shrubs. The desired conditions in the Bodmer Unit include 75 – 93% relative cover of graminoids, 5 – 20% forbs, and 1 – 10% shrubs. Shrub cover in the Bodmer Unit is expected to be greater on hilltops and upper slopes (2 – 10%) than in lower slopes and valleys (1 – 5%), but the coverage for this analysis is grouped as one range (1 – 10%).

When the 2012 – 2016 data is averaged, the results show that the desired conditions for the Bodmer Unit are being met, and relative cover of each vegetation growth form falls within the recommended ranges (Table 4). The Upland Terrace, however, has a higher graminoid cover (97.3 ± 1.1 %) and much lower forb cover than desired (2.6 ± 1.0 %). To date, restoration projects in the Upland Terrace have included efforts to seed native forb and grass species (see Restoration section below). Forbs have not been established in sufficient numbers to reach the desired 10 – 20% cover; seeding efforts have, however, been successful at establishing native grasses. The native graminoid cover in the Upland Terrace is 82.7 ± 2.9%, which is within the range of the desired condition, and the condition has been improving over time.

In the Upland Terrace and Bodmer Unit, forb and graminoid cover has not significantly changed since 2010 (upland graminoids: $F_{1,5}$=1.9, P=0.230, upland forbs:$F_{1,5}$=0.8, P=0.412, Bodmer graminoids: $F_{1,5}$=2.5, P=0.172, Bodmer forbs: $F_{1,5}$=0.8, P=0.414). Shrubs make up a very small proportion of the plant community in FOUS (Table 4) and this has not changed over time in the Upland Terrace ($F_{1,5}$=2.38, P=0.188) or Bodmer Unit ($F_{1,5}$=0.8, P=0.410). Nor has there been a

change in the relative cover of native graminoids in the Upland Terrace since 2010 ($F_{1,5}$=0.06, *P*=0.814). However, the average cover of native graminoids in 1999, 2000, and 2001 was about 40%, and after restoration efforts, cover has consistently been between 81% and 83%. While statistical tests are inappropriate because the sample sizes were small in those years and plots were not randomly distributed, it does suggest that the effort to restore native grasses at FOUS has been largely successful.

Table 4. The current (2012 – 2016 average) and desired conditions of relative cover of graminoids (total and native), shrubs, and forbs in Fort Union Trading Post National Historic Site.

	Upland Terrace		Bodmer Unit	
Specific Measures	**Current Value (2012 – 2016; mean ± SE)**	**Desired Condition**	**Current Value (2012 – 2016; mean ± SE)**	**Desired Condition**
Relative cover of graminoids	97.3 ± 1.1 %	55 – 90%	89.5 ± 1.2 %	75 – 93%
Relative cover of forbs	2.6 ± 1.0 %	10 – 20%	6.8 ± 1.0 %	5 – 20%
Relative cover of shrubs	0 ± 0 %	0 – 15%	3.7 ± 1.0 %	1 – 10%
Relative cover of native graminoids	82.7 ± 2.9%	≥ 70%	–	No desired condition

Exotic Species Cover

The park would like to maintain relative cover of all exotic species at 10% or less (Symstad 2012). The average relative cover of exotic species from 2012 to 2016 was above this target in both the Upland Terrace (17 ± 2.8%) and Bodmer Unit (16.5 ± 6.2 %) (Table 5). There has been no significant change in exotic cover since 2010 in the Bodmer Unit ($F_{1,5}$=1.6, *P*=0.258) or the Upland Terrace ($F_{1,5}$=0.01, *P*=0.92). From 2010 to 2016, the relative cover of exotic species in the Upland Terrace has been remarkably consistent, and ranged from 16.4 ± 3.8% in 2014 to 18.0 ± 8.1% in 2016 (Figure 6). The average exotic cover was substantially higher in 1999 and 2001 (>50%), suggesting restoration efforts did succeed in reducing exotic cover.

Table 5. The current (2012 – 2016 average) and desired conditions for relative cover of exotic, native, and noxious weed species in Fort Union Trading Post National Historic Site.

	Upland Terrace		Bodmer Unit	
Specific Measures	**Current Value (2012 – 2016; mean ± SE)**	**Desired Condition**	**Current Value (2012 – 2016; mean ± SE)**	**Desired Condition**
Relative cover of exotic species	17 ± 2.8%	≤ 10%	16.5 ± 6.2 %	≤ 10%
Relative cover federal, state, or county noxious weeds	0.02 ± 0.02%	<1%	0 ± 0 %	<1%
Relative cover of native species		No desired condition	83.4 ± 6.2 %	≥ 80%

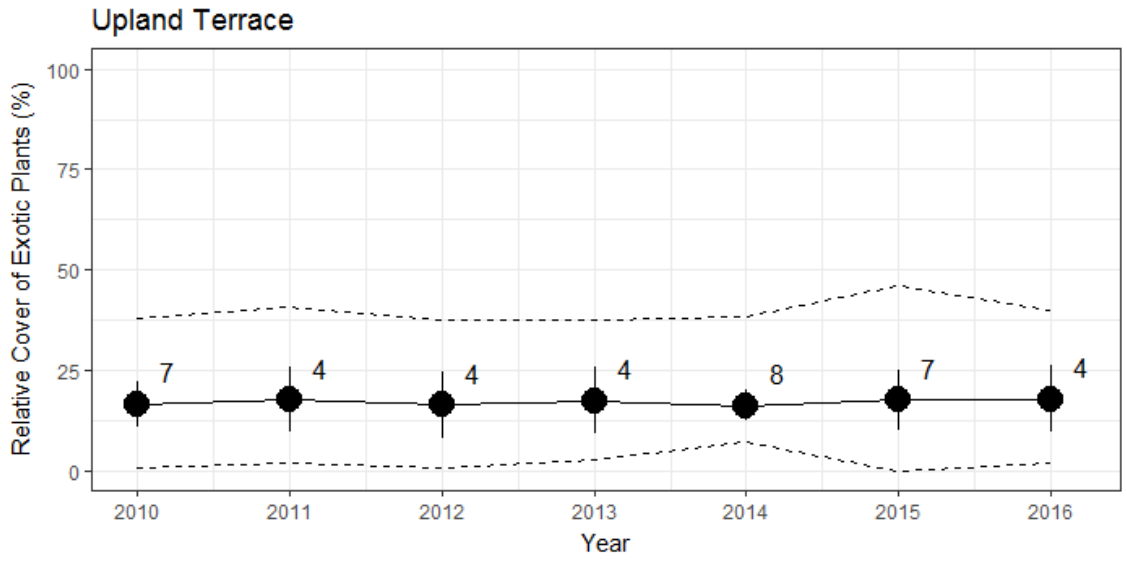


Figure 6. Trends in the relative cover of exotic species in the Upland Terrace of Fort Union Trading Post National Historic Site from 2010 to 2016. Points indicate means, and sample size is to the right of the point. Error bars indicate ± one standard error. The dashed lines represent the maximum and minimum cover values for each year.

The two state noxious weeds that we encountered, Canada thistle (*Cirsium arvense*) and leafy spurge (*Euphorbia esula)*, were observed in very low abundance (Table 5; <1 % average cover). The high cover of exotic species was instead driven primarily by exotic grasses, particularly Kentucky bluegrass, smooth brome, and crested wheatgrass (Figure 4). Kentucky bluegrass and smooth brome are cool-season perennial grasses that have recently been increasing in abundance in the Northern Great Plains (DeKeyser et al. 2013), and their presence is often correlated with declines in native species richness (Miles and Knops 2009). It is likely that the native plant community at FOUS would benefit from efforts to control these three exotic grasses.

Species Richness, Diversity, and Evenness

One of the ways the NPS measures the effectiveness of actions intended to achieve the mission of "preserving ecological integrity" is to examine trends in native plant diversity and evenness within park boundaries. Average species richness at monitoring plots has been measured in FOUS using point-intercept measurements since 1999. Since 2010, species richness has also been recorded in1 m^2 and 10 m^2 quadrats within the long-term monitoring plots (Table 6).

Species richness in the mixed-grass prairie is determined by numerous factors, including fire regime, grazing, ground squirrel disturbance, and weather fluctuations (Symstad and Jonas 2011). In the Upland Terrace of FOUS, a long history of agriculture and more recent restoration efforts have determined current species richness. There is no desired condition of native plant diversity outlined in the FOUS Vegetation Management Plan, in part because native diversity in the Upland Terrace is mainly determined by historic land-use history and the species that have been seeded into the area (Symstad 2012).

Table 6. Average plant species richness in monitoring plots at Fort Union Trading Post National Historic Site from 1999 to 2016. Values represent means ± one standard error.

	Upland Terrace			Bodmer Unit		
Method	**Point-intercept (2012 – 2016, n=20)**	**1 m2 quadrats (2012 – 2016 n=20)**	**10 m2 quadrats (2011 – 2015, n=20)**	**Point-intercept (2012 – 2016, n=10)**	**1 m2 quadrats (2012 – 2016 n=10)**	**10 m2 quadrats (2011 – 2015, n=10)**
Species richness	7.5 ± 1.1	5.1 ± 0.5	8.4 ± 0.9	19.3 ± 1.9	10.1 ± 0.9	16.4 ± 1.3
Native species richness	4.7 ± 0.8	3.7 ± 0.3	5.3 ± 0.6	17.3 ± 2.3	9.4 ± 1.0	15.1 ± 1.5
Exotic species richness	2.9 ± 0.4	1.4 ± 0.2	3.1 ± 0.4	1.8 ± 0.3	0.7 ± 0.2	1.3 ± 0.3
Graminoid species richness	6.5 ± 0.8	4.0 ± 0.3	5.5 ± 0.5	11.3 ± 0.9	5.3 ± 0.3	7.0 ± 0.4
Forb species richness	1.8 ± 0.3	1.0 ± 0.2	2.7 ± 0.4	5.7 ± 0.8	3.9 ± 0.5	7.4 ± 0.8

It can be useful, however, to compare the current status of FOUS species richness to the natural range of variation seen in other mixed-grass prairies. Long-term records of species diversity in mixed-grass prairie in a moderately grazed site in Montana ranged between 8 and 18 species per square meter (10 – 90th percentile range) between 1933 and 1945 (Symstad and Jonas 2014). The average native richness of the plots within the Bodmer Unit (2012 – 2016) is 9.4 species, which falls within this range (Table 6). Native richness in Upland Terrace plots averaged only 3.7 native species per square meter, falling well below the natural range of variation. The most diverse plot in the park (PCM_129) is on the hill-top in the Bodmer Unit (Figure 7). In 2016, we observed an average of 13.9 native species per square meter at this site.

Figure 7. Long-term monitoring plot FOUS_PCM_129 is on a hilltop in the Bodmer Unit and has a large diversity of native plant species.

We did not identify any significant trends in species richness or evenness (Figure 8). Native species richness in $1m^2$ quadrats was consistent from 2012 to 2016. In the Bodmer Unit, it ranged from a low of 7.7 ± 2.6 species m^2 in 2015 to a high of 11.3 ± 2.7 species m^2 in 2010. The Upland Terrace ranged between 3.1 ± 0.3 species m^2 in 2013 to 4.5 ± 1.3 species m^2 in 2011. In the longer record from point-intercept data in the Upland Terrace, annual average native richness (2002 – 2016; Figure 8: top) ranged between 4 and 8.6 species. Annual average evenness in the Upland Terrace (2002 – 2016; Figure 8: bottom) ranged from 0.66 to 0.80 during this time period, indicating the plots were not strongly dominated by a single species.

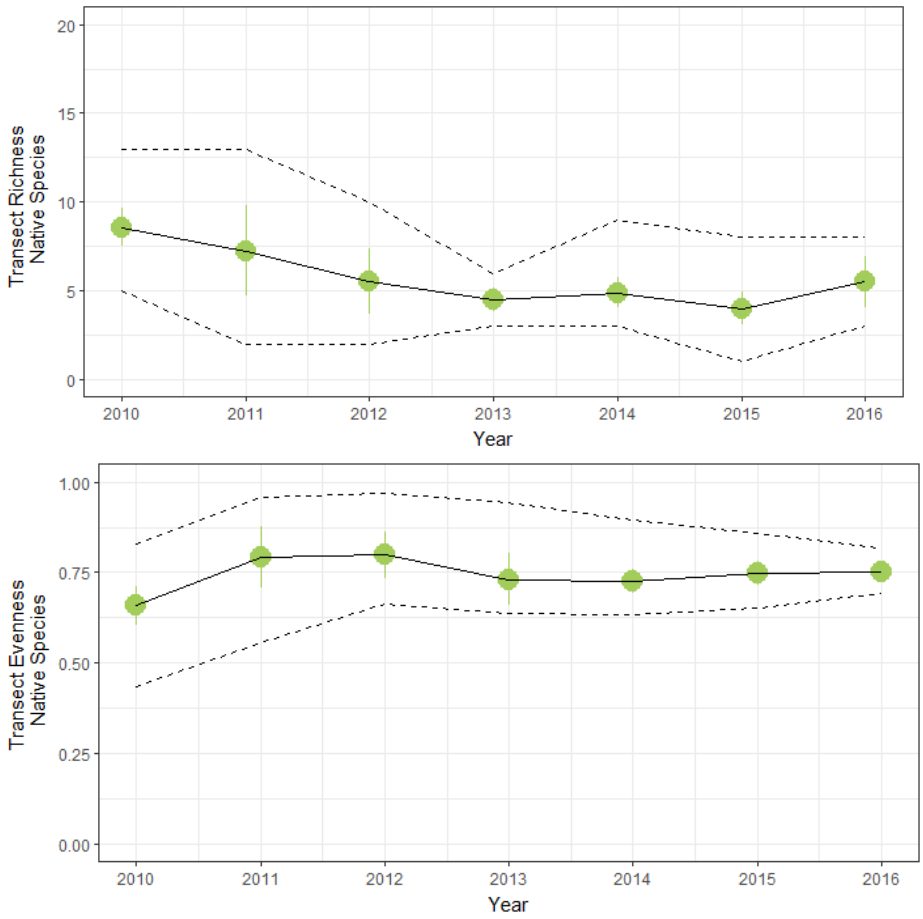


Figure 8. Trends in native species richness (top) and evenness (bottom) in the Upland Terrace Section of Fort Union Trading Post National Historic Site, 2002 – 2016. Data are means ± one standard error. The dashed line indicates the maximum and minimum values for each year.

Disturbance and Bare Ground

Disturbance from grazing, small rodents, fire, and humans affects plant community structure and composition in the mixed-grass prairie. We estimated the approximate area affected by natural and human disturbances at each site we visited in 2011 – 2016 by surveying the area for ~ five minutes at the end of the plot visit. In the Bodmer Unit, we found small mammal activity (e.g., gopher holes) in all five plots. These disturbances were usually small and ranged from 1–20 m^2 in area. There was also some scattered evidence of light grazing and several cow patties from trespassing cattle. In contrast, the actively managed Upland Terrace had widespread signs of mowing operations and prescribed fires, as well as less frequent natural disturbances such as small mammal activity (five plots).

Many disturbances, particularly small mammal activity, can result in patches of bare ground where new plants can become established. The FOUS Vegetation Management Plan outlines desired conditions for the amount of bare ground present in the Bodmer Unit and Upland Terrace (Symstad 2012). In the Bodmer Unit from 2012 to 2016, bare ground cover averaged 6.1 ± 2.2 %, which is

within the desired condition of < 5 – 10%. Upland Terrace plots had more bare ground, with an average of 19.6 ± 4.7% cover during the same period, which is greater than the desired condition of 5 – 15%. The amount of bare ground has not significantly changed over time in either area of the park. While the best way to limit bare ground in the Upper Terrace is not obvious, less mowing and/or reseeding with more forb species could increase vegetation cover on non-vegetated soils.

Climate and Vegetation Height

The Northern Great Plains has a continental climate, with hot summers and very cold winters. 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). In FOUS, there were dry years from 2002 to 2008, and again in 2012 (Figure 9). The most extreme drought was in 2008 (Figure 9). It is likely that the peak in native richness seen in 2010 (Figure 8) was influenced by wetter conditions during that time.

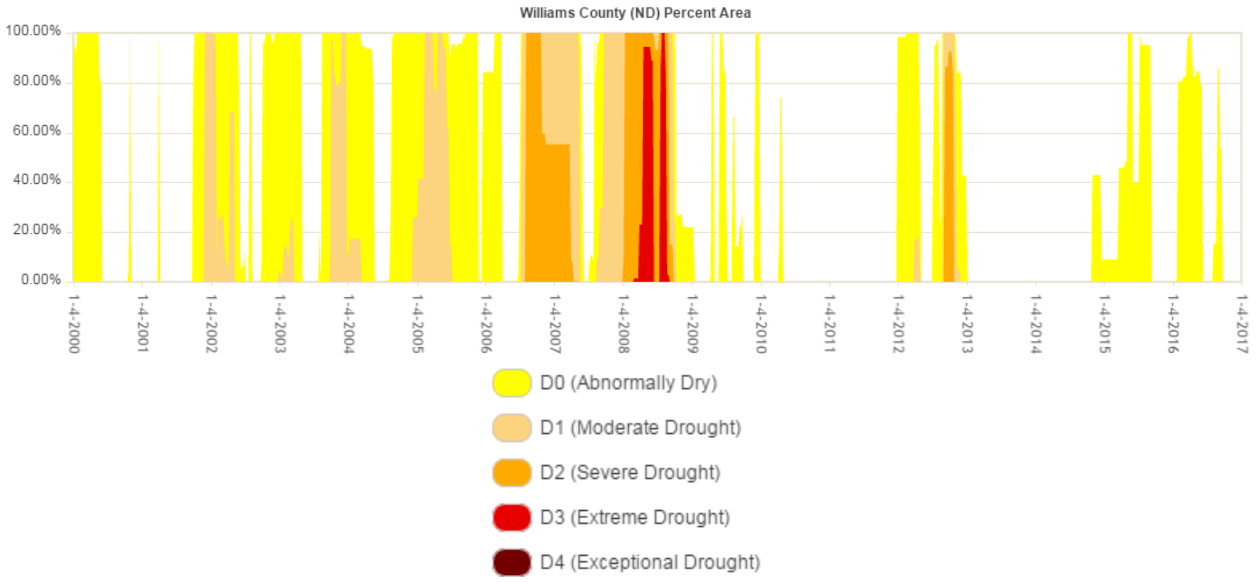


Figure 9. The percent of area in Williams County, ND experiencing drought conditions from 2000 to 2016. The most severe droughts are indicated in dark orange, red, and brown. Dates with 0% drought indicate normal or wet conditions during those periods. Graph courtesy of the US Drought Monitor http://droughtmonitor.unl.edu/home/regionaldroughtmonitor.aspx?high_plains.

Vegetation height tends to increase in wet years in the mixed-grass prairie, and the desired conditions at FOUS include a range of heights to incorporate this variability. During the historic active period of the fort, however, the vegetation canopy height was low due to continued human use (e.g., grazing). The desired condition for the Bodmer Unit can range from less than 15 cm in dry years to as much as 60 cm. The current condition of 18.3 ± 1.2 cm (average from 2012 – 2016) is within the desired condition. The current condition of the Upland Terrace is 21.6 ± 2.1 cm. The desired condition is generally less than 10 cm with occasional taller forbs and shrubs. The current condition is higher than

desired and has been maintained by mowing (see Appendix C). It is unlikely the desired condition would be met in the absence of the mowing efforts. Over time, height has been variable, but there has been no significant directional change in the Upland Terrace ($F_{1,11}$=0.02, P=0.882) or the Bodmer Unit ($F_{1,5}$=0.01, P=0.948). In 2011, a wet year, the average vegetation height in the Bodmer Unit reached its tallest point of 30.5 cm.

Rare Plants

Alyssum-leaf phlox (*Phlox alyssifolia*; S1S2) was observed in two plots in 2010 through 2016, and white locoweed (*Oxytropis sericea*; S1) was observed in a single plot in 2005 (Figure 10). Both of these forb species are more common in Montana and Wyoming and reach the limit of their eastern distribution in western North Dakota. Our vegetation monitoring protocol is not designed to locate small or highly dispersed plant populations, and a full rare plant survey would be more likely to accurately quantify the status of rare plants found throughout the park, particularly in areas with no monitoring plots.

Figure 10. *Left image*: Alyssum-leaf phlox (*Phlox alyssifolia*; pink flower,right), a species of conservation concern observed in Fort Union Trading Post National Historic Site, is compared with the common Hood's phlox (*Phlox hoodii*; white flower, left). *Right image*: White locoweed (*Oxytropis sericea*), another species of conservation concern observed in Fort Union Trading Post National Historic Site.

Restoration

During the time Fort Union was closed, from 1867 until 1966 when it was acquired by the NPS, the upland terrace area of the fort was primarily used for pasture and agriculture, which resulted in dramatic changes to native plant communities. Also, between 1869 and 1884, a dissident band of Hidatsa led by Chief Crow Flies High established and inhabited a village on the southeast section of the park's upland terrace (restoration fields 7 and 8 in Figure 11). Two decades later, in 1903, European American settlers established the town of Mondak, which occupied portions of the fields north and west of the fort site until 1928. These two former town sites and the agricultural fields, some terraced in the mid-1900s, were planted with perennial grass species, most likely non-native smooth brome and crested wheatgrass, after the fort site was purchased by the NPS (Symstad 2012).

Once reconstruction of the fort was completed in 1991, management efforts to return the exotic-grass-dominated prairie to its pre-agricultural state began. Restoration actions have included a variety of mechanical seedbed preparation methods, prescribed burns, herbicide applications (e.g. Round-Up), and several seeding and overseeding efforts (Symstad 2012). The upland terrace fields are also regularly mowed. These management actions were not implemented uniformly across the terrace, resulting in a mosaic of fields that have been managed using different combinations of techniques over three decades (Figure 11; see Appendix C for a list of management actions by year).

Figure 11. Fort Union Trading Post National Historic Site upland terrace restoration fields (Adapted from Symstad 2012).

We summarized vegetation data from long-term monitoring plots located in three of these fields (Figure 12) to determine if there were any notable changes in plant communities following restoration efforts. The fields included in this analysis—2, 8, and 9—had more than a single long-term monitoring plot located within their boundaries.

The results presented in this section are intended to provide a rough characterization of the effects of restoration actions in these fields. Our monitoring design is not intended for thoroughly evaluating restoration effectiveness, and we recommend implementation of a monitoring study specifically designed to assess restoration success to accurately monitor restoration effects in these fields.

While all three fields were burned, treated with herbicide, and seeded at various intervals, the combination of management actions used in each field was considerably different. Field 2 was burned frequently, Field 8 had extensive seedbed preparation and soil decompaction with less frequent burning, and Field 9 was burned frequently and treated several times with the herbicide glyphosate. All three fields were mowed at similar intervals. Plant communities in all three fields were almost entirely dominated by grasses (>95% relative cover) in all years, which is similar to what we observed across the Upland Terrace as a whole (Figure 5).

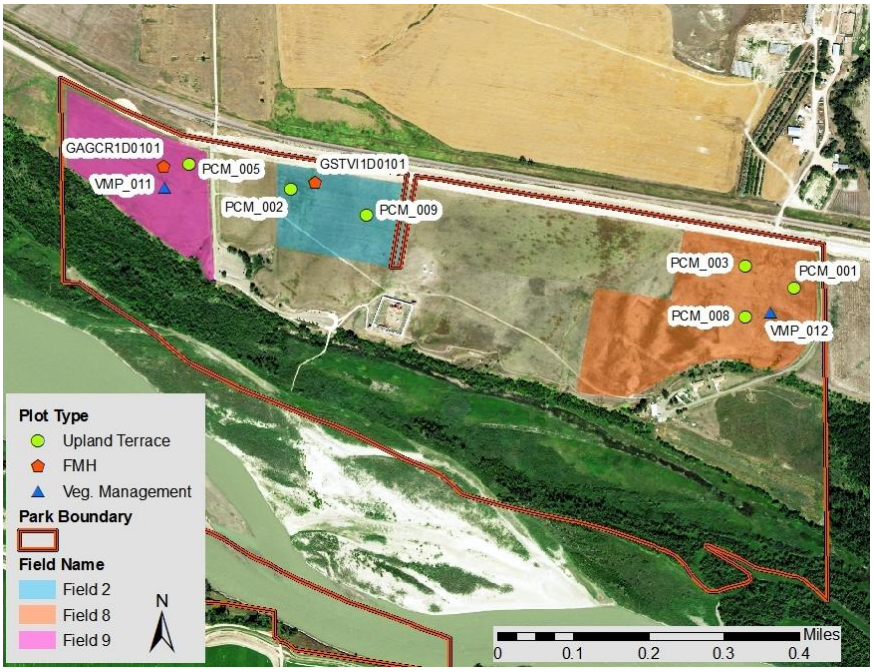


Figure 12. Map of long-term monitoring plots located in selected restoration fields (polygons) at Fort Union Trading Post National Historic Site.

Field 2

Management in Field 2 included prescribed burns in the spring of 2001, 2002, 2006, 2010, and 2011, and seeding in 1990 and the spring of 2006 and 2011 (Figure 13). The seed mix used in 1990 was primarily composed of Western wheatgrass and green needlegrass. In addition to those two species, the 2006 and 2011 mixes contained big bluestem, sideoats grama (*Bouteloua curtipendula*), blue grama, prairie sandreed (*Calamovilfa longifolia*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum vigatum*), along with small percentages of several other grasses and forbs.

The relative cover of native graminoids in Field 2 was 75% by 2016 (Fig.13), which was lower than in other fields. Of the seeded species, big bluestem (14%) and sideoats grama (18%) were the most abundant in 2016. Big bluestem and sideoats grama each represented 25% of the seed mix used for seeding in 2011, and their abundance may be evidence for the success of that seeding effort. Exotic species cover was primarily Kentucky bluegrass (8%), smooth brome (6%), and yellow sweetclover (*Melilotus officianalis*, 8%). Bare ground in Field 2 was reduced from 47% absolute cover in 2007 to 1% in 2016.

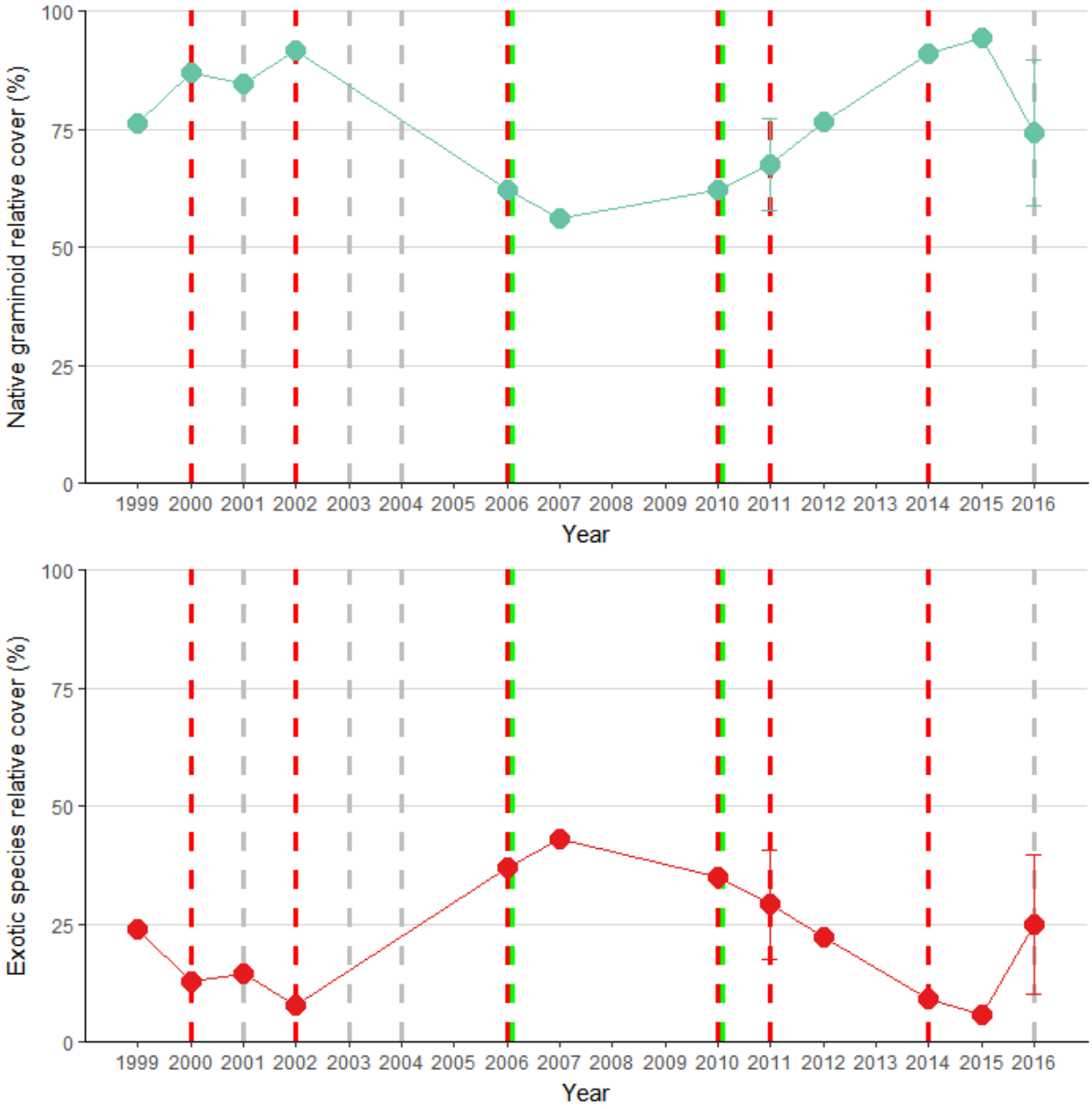


Figure 13. Relative percent cover of native graminoid species (top) and exotic species (bottom) in monitoring plots located in restoration Field 2. Dashed lines indicate prescribed burn events (red), mowing (gray) and seeding applications (green).

Field 8

There were no historic monitoring plots located in Field 8, so data were only available from 2011 onward. There was extensive seedbed preparation in Field 8 from 1996 to 1998, with a total of 12 treatments (disking or sweeping with a tractor) applied to break up sod and soil clumps. The field was also seeded in 2000 and 2006 and burned in 2002 and 2011. The seed mix used in 2000 was primarily composed of Western wheatgrass, blue grama, sideoats grama, and green needlegrass. In

addition to those species, the 2006 seed mix contained big bluestem, prairie Indiangrass, and switchgrass, along with small percentages of several other grasses and forbs.

Native graminoid cover in Field 8 was 98% by 2016 (Fig.14), the highest of the three fields, and graminoid cover was dominated by two species: Western wheatgrass (49%) and green needlegrass (47%). Exotic species cover was 2% in 2016, with smooth brome and crested wheatgrass each comprising 1% of the exotic cover. Exotic cover was higher in 2015 due to one plot, PCM_003, having high crested wheatgrass cover (35%). There has been a general reduction in bare ground in Field 8 plots as well, with bare ground cover decreasing from a high of 80% absolute cover in 2014 to 10% in 2016.

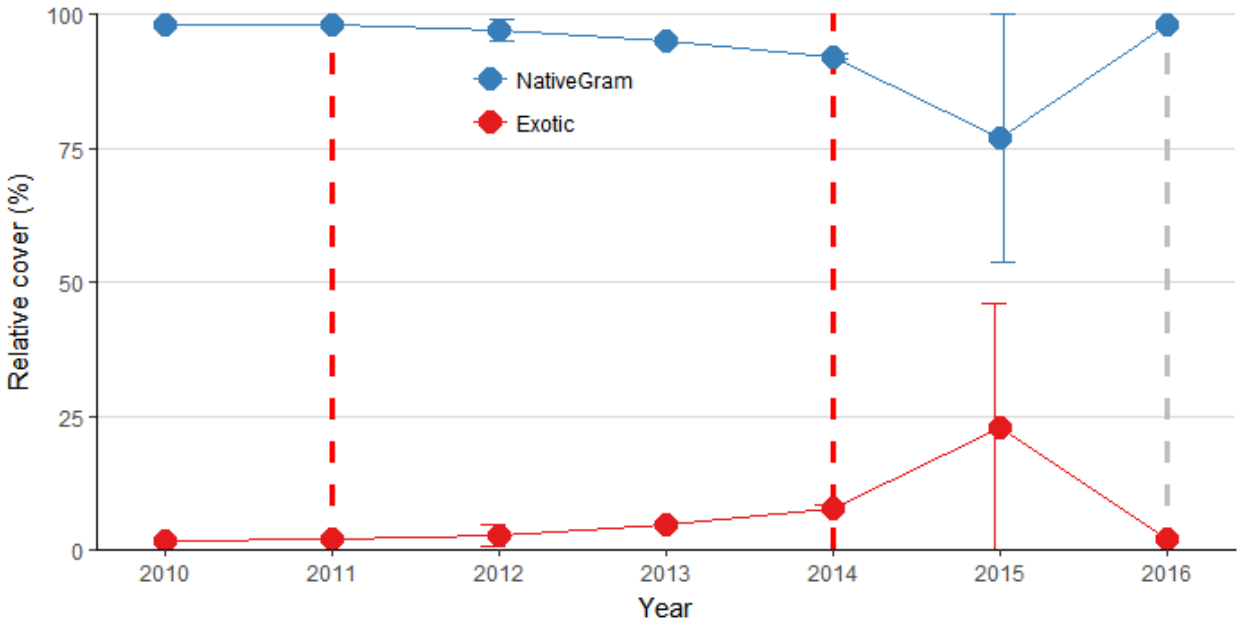


Figure 14. Relative percent cover of native graminoid species (blue) and exotic species (red) in monitoring plots located in restoration Field 8. Dashed lines indicate prescribed burn events (red), and mowing (gray).

Field 9

Field 9 was intensively managed, with four burns, three herbicide applications, and two seedings, occurring between 1999 and 2011 (Fig. 15). The seed mix used in 2000 was primarily composed of Western wheatgrass, blue grama, sideoats grama, and green needlegrass. The 2006 seed mix contained Western Wheatgrass, green needlegrass, big bluestem, prairie Indiangrass, and switchgrass, along with small percentages of several other grasses and forbs.

Native graminoid cover increased dramatically in Field 9 from 0% in 2001 to 90% by 2014. This appears to be in response to herbicide application and subsequent seeding of this site. Prior to herbicide application, this field was dominated by exotic smooth brome and crested wheatgrass. Following herbicide and seeding treatments, the combined cover of these exotic grasses was 8%.

Native graminoid cover in Field 9 was composed primarily of Western wheatgrass (32%), green needlegrass (27%), and *Bouteloua* species (13%), all of which were the main components of seed mixes used to revegetate this field. Exotic species relative cover was 19% in 2016, a dramatic reduction from an average 97% cover from 1999 to 2001. This is likely the result of annual herbicide applications in this field from 2000 to 2002.

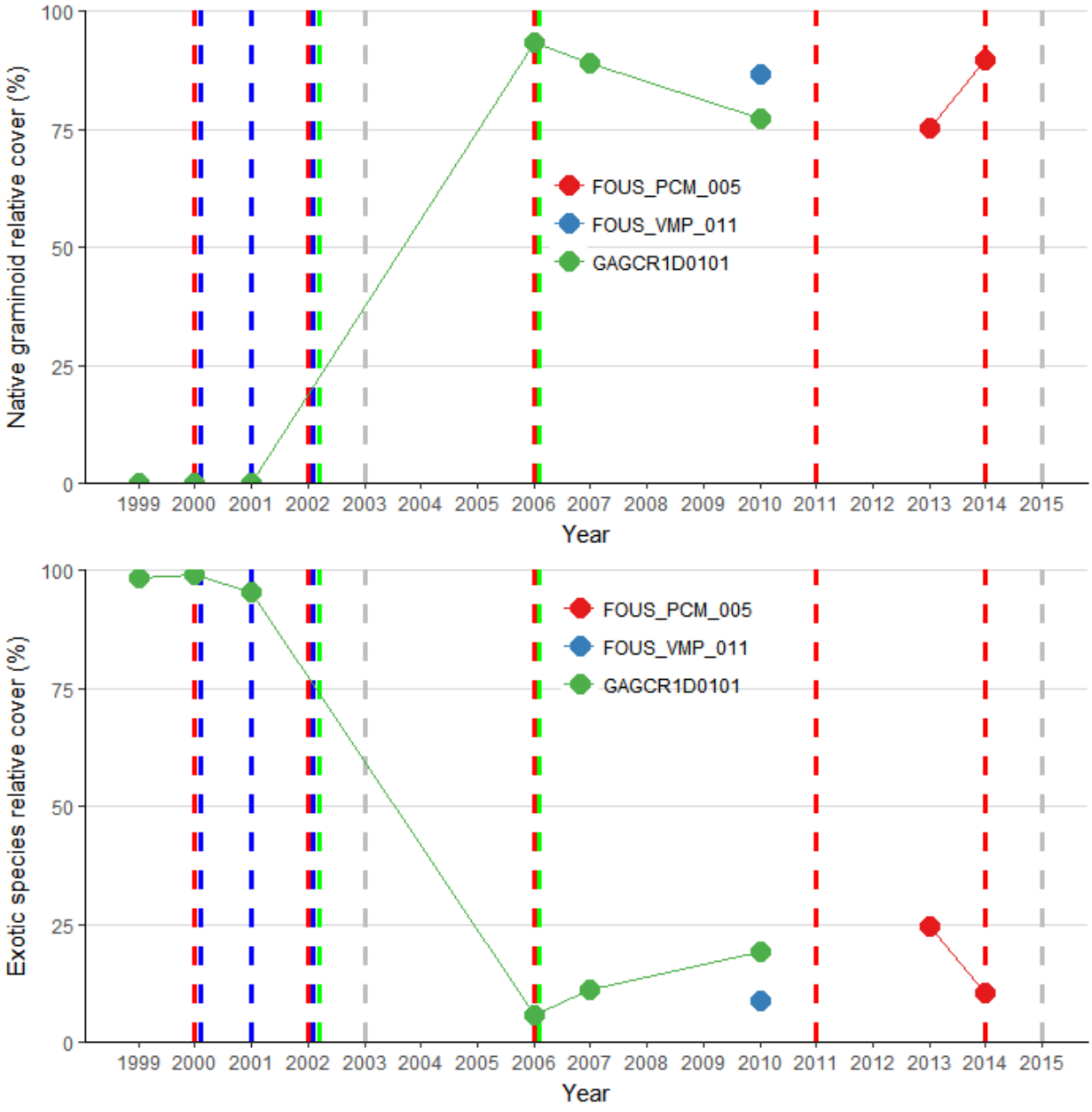


Figure 15. Relative percent cover of native graminoid species (top) and exotic species (bottom) in monitoring plots located in restoration Field 9. Dashed lines indicate prescribed burn events (red), seeding applications (green), mowing (gray), and herbicide applications (blue).

In general, exotics management and grass reseeding efforts appear to have been mostly effective in all three fields. Grasses made up the large majority of seed mixes used for all seeding in these plots, and are now the dominant lifeform in these sites. Also, the grass species that comprised the largest proportion of seed mixes applied to each field tended to be the dominant grass species we observed in those fields. Three grass species seem to have been especially effective in revegetating these sites: Western wheatgrass, green needlegrass, and big bluestem. The two *Bouteloua* species (*B. curtipendula* and *B. gracilis*) were also moderately effective. Indiangrass, prairie sandreed, and switchgrass were less successful at becoming established, in spite of being included in seed mixes at similar rates to the other grass species. Although forbs were included in all seed mixes at rates as high as 25% of the seed volume, there has been little to no apparent establishment of forbs in these fields. It is unclear why the effort to establish forbs was not more successful, but a stretch of dry years following the seeding efforts (Figure 9) may have played a role. Further revegetation effort will likely be required to increase forb abundance in these sites to achieve the 10–20% forb cover recommended in the Fort Union Vegetation Management Plan. Continued exotic species treatment will also be needed to further reduce exotic species abundance in areas that exceed the 10% relative cover reference condition described in the vegetation management plan.

Conclusion

The Northern Great Plains Inventory & Monitoring Program and Fire Effects Program have been monitoring vegetation in Fort Union Trading Post National Historic Site for over 18 years. While methods have changed slightly, this report summarizes data from 22 locations from 1999 to 2016. We conclude with the Natural Resource Condition Tables that were presented in the Executive Summaries (Table 7 and 8). These summarize the current status and trends in a few key vegetation metrics and compare these to the desired conditions from the FOUS Vegetation Management Plan (Symstad 2012).

Overall, we found that the condition of the Upper Terrace of FOUS warrants moderate concern. The efforts to replace exotic grasses with native grasses have been very successful. Native graminoids account for over 80% of the cover. While native grasses dominate this area, there are still exotic grasses present. Moreover, the restoration has not yet seen the same success with native forbs as it has with native grasses. Native forb cover is quite low and so is the overall native plant diversity. To reduce exotic plant cover and increase forb diversity in the Upper Terrace, active management efforts will be needed (see below).

The Bodmer Overlook Unit of FOUS is in good condition. There is a high diversity of native plants, particularly on the hilltops, and most of the desired conditions are being met. However, exotic species cover is higher than desired, and Kentucky bluegrass is particularly abundant. At this point, the exotic species cover seems to be stable; there has been little change since 2010. Preventing the further spread of these species may be necessary to protect the intact native prairie within the Bodmer Unit.

Specifically, to meet the desired conditions outlined in the FOUS Vegetation Management Plan, we recommend the following list of actions, in priority order:

1) Focus efforts on reducing the spread of invasive grasses, particularly smooth brome, crested wheatgrass, and Kentucky bluegrass in the Upland Terrace and Bodmer Unit. This can be accomplished by first mapping the areas affected by these species and then using herbicide to remove them.
2) Seed the Upland Terrace with native forbs. Past restoration efforts included native forbs, but very few have established. Despite those failures, seeding in wetter years or in areas cleared of invasive grasses could provide an increase in native forbs in the future.
3) Maintain natural disturbance regimes (grazing and fire) or, in their absence, continue mowing operations and prescribed burning. Ideally, both smooth brome and Kentucky bluegrass will decrease in abundance with frequent disturbance (DeKeyser et al. 2013). Mowing will also allow park managers to meet the desired condition of low-stature vegetation that mimics historic condition.
4) Increase efforts to monitoring the effectiveness of the management actions. The long-term monitoring program is not designed to test success of a specific action. Rather, small studies can be done to document the condition of vegetation before and after the treatment, and these data can be compared to untreated areas of the unit.

5) Conduct a vegetation inventory to document rare species within the park (or determine if there are any) and to update the existing park species list.

Table 7. Natural resource condition summary table for plant communities in the upland terrace area of Fort Union Trading Post National Historic Site (FOUS). Current values are based on data from 2012 – 2016, and trends are based on data from 2010 – 2016. Reference conditions are based on the desired conditions outlined in the Vegetation Management Plan (Symstad 2012)

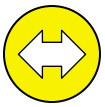
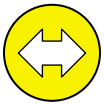
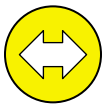
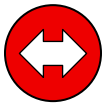
Indicator of Condition	Specific Measures	Current Value (2012 – 2016; mean ± SE)	Reference Condition	Condition Status/Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Relative cover of graminoids	97.3 ± 1.1 %	55 – 90%		The vegetation communities in the Upland Terrace of FOUS are a result of a decade's worth of restoration efforts. Some of these efforts, such as planting native grasses, have been very successful. Unfortunately, cover and diversity of forb species is still much lower than is desired. To improve the condition of the Upland Terrace, efforts should be made to increase the number of forb species through continued seeding projects.
	Relative cover of forbs	2.6 ± 1.0 %	10 – 20%		
	Relative cover of shrubs	0 ± 0 %	0 – 15%		
	Relative cover of native graminoids	82.7 ± 2.9%	≥ 70%		
	Vegetation height	21.6 ± 2.1 cm	Most often < 10 cm, occasionally up to 35 cm		
	Bare ground	19.6 ± 4.7%	5 – 15%		
Exotic Plant Early Detection and Management	Relative cover of exotic species	17 ± 2.8%	≤ 10%		Around 2001, after the restoration efforts, there was a large reduction in the cover of exotic grasses. However, Kentucky bluegrass, smooth brome, and crested wheatgrass are contributing to a higher cover of exotic species than desired. Efforts to control these grasses and noxious weeds are needed.
	Relative cover federal, state, or county noxious weeds	0.02 ± 0.02%	<1%		

Table 8. Natural resource condition summary table for plant communities in the Bodmer Unit of Fort Union Trading Post National Historic Site (FOUS). Current values are based on data from 2012 – 2016, and trends are based on data from 2010 – 2016. Reference conditions are based on the desired conditions outlined in the Vegetation Management Plan (Symstad 2012).

Indicator of Condition	Specific Measures	Current Value (mean ± SE)	Reference Condition	Condition Status/Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Relative cover of graminoids	89.5 ± 1.2 %	75 – 93%		The vegetation communities in the Bodmer Unit at FOUS are generally in good condition, particularly the hill top plots. There is a large diversity of native plants and the current graminoid, forb, and shrub covers match the desired conditions. We found no directional trends, meaning that these conditions have been stable over the last 6 years.
	Relative cover of forbs	6.8 ± 1.0 %	5 – 20%		
	Relative cover of shrubs	3.7 ± 1.0 %	1 – 10%		
	Vegetation height	18.3 ± 1.2 cm	< 15 – 60 cm		
	Bare ground	6.1 ± 2.2 %	< 5 – 10%		
Exotic Plant Early Detection and Management	Relative cover of native species	83.4 ± 6.2 %	≥ 80%		The Bodmer Unit has a moderate cover of exotic species, which is above the desired conditions. There are no noxious weeds in the area, but Kentucky bluegrass is abundant in the unit. This is concerning because in other areas of North Dakota, Kentucky bluegrass has been correlated with reductions in native plant diversity.
	Relative cover of exotic species	16.5 ± 6.2 %	≤ 10%		
	Relative cover federal, state, or county noxious weeds	0 ± 0 %	<1%		

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Appendix A: List of monitoring plots and years monitored

Plot Name	Unit	Years monitored	Notes
FOUS_PCM_001	Upland Terrace	2011 – 2012, 2016	In 2015, corner rebar was replaced with nails and stamped washers. In 2016, changed protocol to only read 1 m quadrats
FOUS_PCM_002	Upland Terrace	2011 – 2012, 2016	In 2015, corner rebar was replaced with nails and stamped washers. In 2016, changed protocol to only read 1 m quadrats
FOUS_PCM_003	Upland Terrace	2012 – 2015	In 2015, corner rebar was replaced with nails and stamped washers.
FOUS_PCM_004	Upland Terrace	2012 – 2015	In 2015, corner rebar was replaced with nails and stamped washers.
FOUS_PCM_005	Upland Terrace	2013 – 2014	In 2015, corner rebar was replaced with nails and stamped washers.
FOUS_PCM_006	Upland Terrace	2013 – 2015	In 2015, corner rebar was replaced with nails and stamped washers.
FOUS_PCM_008	Upland Terrace	2014 – 2015	In 2015, corner rebar was replaced with nails and stamped washers.
FOUS_PCM_009	Upland Terrace	2011, 2014 – 2016	In 2015, corner rebar was replaced with nails and stamped washers. In 2016, changed protocol to only read 1 m quadrats
FOUS_PCM_010	Upland Terrace	2011, 2014 – 2016	In 2015, corner rebar was replaced with nails and stamped washers. In 2016, changed protocol to only read 1 m quadrats
FOUS_PCM_011	Upland Terrace	2014 – 2015	In 2015, corner rebar was replaced with nails and stamped washers.
FOUS_PCM_129	Bodmer Unit	2010 – 2012, 2016	In 2016, changed protocol to only read 1 m quadrats
FOUS_PCM_130	Bodmer Unit	2010, 2012 – 2013, 2016	In 2016, changed protocol to only read 1 m quadrats
FOUS_PCM_131	Bodmer Unit	2013 – 2014, 2016	
FOUS_PCM_132	Bodmer Unit	2014 – 2015	
FOUS_PCM_133	Bodmer Unit	2011, 2015 – 2016	
FPODE1D0201	Lower Terrace	2000, 2006 – 2007, 2010	FMH plot, Not included in this report, Retired but rebar is still present
GAGCR1D0101	Upland Terrace	1997, 1999 – 2001, 2006 - 2007, 2010	FMH plot, Retired but rebar is still present
GSTVI1D0101	Upland Terrace	1997, 1999 – 2002, 2006 – 2007, 2010	FMH plot, Retired but rebar is still present
FOUS_VMP_004	Upland Terrace	2010	Plot removed in 2011?
FOUS_VMP_008	Upland Terrace	2010	Plot removed in 2011?
FOUS_VMP_011	Upland Terrace	2010	Plot removed in 2011?
FOUS_VMP_012	Upland Terrace	2010	Plot removed in 2011?
FOUS_VMP_013	Upland Terrace	2010	Plot removed in 2011?

Appendix B: List of plant species identified at FOUS 1999 – 2016

Below is a list of all the plant species identified in FOUS 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. "State Noxious Species" indicates the species is on the Montana (MT) or North Dakota (ND) state list of noxious weeds. ND-M indicates species considered noxious in McKenzie County, ND and ND-B indicates species considered noxious in Billings County, ND.

Family	Symbol	Scientific Name	Common Name	Exotic	Rare
Agavaceae	YUGL	*Yucca glauca*	soapweed yucca		
Amaranthaceae	AMAL	*Amaranthus albus*	prostrate pigweed		
	AMBL	*Amaranthus blitoides*	mat amaranth	X	
	AMRE	*Amaranthus retroflexus*	redroot amaranth		
Anacardiaceae	TORY	*Toxicodendron rydbergii*	western poison ivy		
Apocynaceae	APCA	*Apocynum cannabinum*	common dogbane		
Asclepiadaceae	ASOV	*Asclepias ovalifolia*	oval-leaf milkweed		
	ASSP	*Asclepias speciosa*	showy milkweed		
	ASVE	*Asclepias verticillata*	whorled milkweed		
Asteraceae	ACMI2	*Achillea millefolium*	common yarrow		
	ANMI3	*Antennaria microphylla*	littleleaf pussytoes		
	ARCA13	*Artemisia cana*	silver sagebrush		
	ARDR4	*Artemisia dracunculus*	tarragon		
	ARFR4	*Artemisia frigida*	fringed sagewort		
	ARLU	*Artemisia ludoviciana*	white sagebrush		
	BREU	*Brickellia eupatorioides*	false boneset		
	CIAR4	*Cirsium arvense*	Canada thistle	MT,ND	
	CIUN	*Cirsium undulatum*	wavyleaf thistle		
	COCA5	*Conyza canadensis*	horseweed		
	ECAN2	*Echinacea angustifolia*	blacksamson echinacea		
	ERPU2	*Erigeron pumilus*	shaggy fleabane		
	GAAR	*Gaillardia aristata*	common gaillardia		
	GRSQ	*Grindelia squarrosa*	curlycup gumweed		
	GUSA2	*Gutierrezia sarothrae*	broom snakeweed		
	HEAN3	*Helianthus annuus*	common sunflower		
	HELIA3	*Helianthus* spp.	sunflower		
	HEMA2	*Helianthus maximiliani*	Maximilian sunflower		

Family	Symbol	Scientific Name	Common Name	Exotic	Rare
	HENU	*Helianthus nuttallii*	Nuttall's sunflower		
	HEPA19	*Helianthus pauciflorus*	stiff sunflower		
	HEPE	*Helianthus petiolaris*	prairie sunflower		
	HEVI4	*Heterotheca villosa*	hairy false goldenaster		
	HYFI	*Hymenopappus filifolius*	fineleaf hymenopappus		
	LASE	*Lactuca serriola*	prickly lettuce	X	
	LIPU	*Liatris punctata*	dotted blazing star		
	LYJU	*Lygodesmia juncea*	rush skeletonplant		
	MUOB99	*Mulgedium oblongifolium*	blue lettuce		
	PACA15	*Packera cana*	woolly groundsel		
	RACO3	*Ratibida columnifera*	upright prairie coneflower		
	RUHI2	*Rudbeckia hirta*	blackeyed Susan		
	SOAR	*Solidago arguta*	Atlantic goldenrod		
	SOAR2	*Sonchus arvensis*	field sowthistle	X	
	SOAS	*Sonchus asper*	spiny sowthistle	X	
	SOCA6	*Solidago canadensis*	Canada goldenrod		
	SOGI	*Solidago gigantea*	giant goldenrod		
	SOMI2	*Solidago missouriensis*	Missouri goldenrod		
	SOMO	*Solidago mollis*	velvety goldenrod		
	SOOL	*Sonchus oleraceus*	common sowthistle	X	
	SYER	*Symphyotrichum ericoides*	white heath aster		
	SYLA6	*Symphyotrichum lanceolatum*	white panicle aster		
	SYMPH4	*Symphyotrichum* spp.	aster		
	SYOB	*Symphyotrichum oblongifolium*	aromatic aster		
	TAOF	*Taraxacum officinale*	common dandelion	X	
	TEAC	*Tetraneuris acaulis*	stemless four-nerve daisy		
	TRDU	*Tragopogon dubius*	yellow salsify	X	
	XAGR99	*Xanthisma grindelioides*	rayless tansyaster		
	XASP99	*Xanthisma spinulosum*	lacy tansyaster		
	XAST	*Xanthium strumarium*	cocklebur		
Boraginaceae	LIIN2	*Lithospermum incisum*	narrowleaf stoneseed		
	MELA3	*Mertensia lanceolata*	prairie bluebells		
Brassicaceae	ALAL3	*Alyssum alyssoides*	pale madwort	X	
	ALDE	*Alyssum desertorum*	desert madwort	X	
	ARABI2	*Arabis* spp.	rockcress		

Family	Symbol	Scientific Name	Common Name	Exotic	Rare
	CAMI2	*Camelina microcarpa*	littlepod false flax	X	
	DEPI	*Descurainia pinnata*	western tansymustard		
	DESO2	*Descurainia sophia*	herb sophia	X	
	DRNE	*Draba nemorosa*	woodland draba		
	DRRE2	*Draba reptans*	Carolina draba		
	ERCA14	*Erysimum capitatum*	sanddune wallflower		
	ERCH9	*Erysimum cheiranthoides*	wormseed wallflower	X	
	LEDE	*Lepidium densiflorum*	common pepperweed		
	LEPID	*Lepidium* spp.	pepperweed	X	
	PHLU99	*Physaria ludoviciana*	foothill bladderpod		
	SIAL2	*Sisymbrium altissimum*	tall tumblemustard	X	
	THAR5	*Thlaspi arvense*	field pennycress	X	
Cactaceae	ESVI2	*Escobaria vivipara*	spinystar		
	OPFR	*Opuntia fragilis*	brittle pricklypear		
	OPPO	*Opuntia polyacantha*	plains pricklypear		
Campanulaceae	CARO2	*Campanula rotundifolia*	bluebell bellflower		
Caprifoliaceae	SYOC	*Symphoricarpos occidentalis*	western snowberry		
Chenopodiaceae	CHAL7	*Chenopodium album*	lambsquarters	X	
	CHBE4	*Chenopodium berlandieri*	pitseed goosefoot		
	CHENO	*Chenopodium* spp.	goosefoot	X	
	CHPR5	*Chenopodium pratericola*	desert goosefoot		
	KOSC	*Kochia scoparia*	burningbush, kochia	X	
	KRLA2	*Krascheninnikovia lanata*	winterfat		
	SAKA	*Salsola kali*	Russian thistle	X	
Convolvulaceae	COAR4	*Convolvulus arvensis*	field bindweed	MT,ND-B	
Cornaceae	COSE16	*Cornus sericea*	redosier dogwood		
Cyperaceae	CADU6	*Carex duriuscula*	needleleaf sedge		
	CAFI	*Carex filifolia*	threadleaf sedge		
	CAIN9	*Carex inops*	sun sedge		
	CAREX	*Carex* spp.	sedge		
Elaeagnaceae	ELAN	*Elaeagnus angustifolia*	Russian olive	MT	
Equisetaceae	EQAR	*Equisetum arvense*	field horsetail		
Euphorbiaceae	EUES	*Euphorbia esula*	leafy spurge	MT,ND	
	EUGL3	*Euphorbia glyptosperma*	ribseed sandmat		
	EUPHO	*Euphorbia* spp.	spurge, sandmat	X	

Family	Symbol	Scientific Name	Common Name	Exotic	Rare
	EUSE5	*Euphorbia serpyllifolia*	thymeleaf sandmat		
Fabaceae	ASFL2	*Astragalus flexuosus*	flexile milkvetch		
	ASGI5	*Astragalus gilviflorus*	plains milkvetch		
	ASLA27	*Astragalus laxmannii*	Laxmann's milkvetch		
	ASMI10	*Astragalus missouriensis*	Missouri milkvetch		
	ASPE5	*Astragalus pectinatus*	narrowleaf milkvetch		
	ASTRA	*Astragalus* spp.	milkvetch		
	DACA7	*Dalea candida*	white prairie clover		
	DAPU5	*Dalea purpurea*	purple prairie clover		
	GLLE3	*Glycyrrhiza lepidota*	American licorice		
	LAPO2	*Lathyrus polymorphus*	manystem pea		
	MELU	*Medicago lupulina*	black medick	X	
	MEOF	*Melilotus officinalis*	yellow sweetclover	X	
	MESA	*Medicago sativa*	alfalfa	X	
	OXSE	*Oxytropis sericea*	white locoweed		
	PEES	*Pediomelum esculentum*	large Indian breadroot		
	PSLA3	*Psoralidium lanceolatum*	lemon scurfpea		
	SEVA4	*Securigera varia*	crownvetch	X	
	VIAM	*Vicia americana*	American vetch		
Lamiaceae	HEHI	*Hedeoma hispida*	rough false pennyroyal		
	MOFI	*Monarda fistulosa*	wild bergamot		
Liliaceae	ALTE	*Allium textile*	textile onion		
	MAST4	*Maianthemum stellatum*	starry false lily of the valley		
Linaceae	LILE3	*Linum lewisii*	Lewis flax		
	LIRI	*Linum rigidum*	stiffstem flax		
Malvaceae	SPCO	*Sphaeralcea coccinea*	scarlet globemallow		
Nyctaginaceae	MILI3	*Mirabilis linearis*	narrowleaf four o'clock		
Oleaceae	FRPE	*Fraxinus pennsylvanica*	green ash		
Onagraceae	OEBI	*Oenothera biennis*	common evening primrose		
	OESE3	*Oenothera serrulata*	yellow sundrops		
	OESU99	*Oenothera suffrutescens*	scarlet beeblossom		
Plantaginaceae	PLPA2	*Plantago patagonica*	woolly plantain		
Poaceae	AGCR	*Agropyron cristatum*	crested wheatgrass	X	
	AGROP2	*Agropyron* spp.	wheatgrass	X	
	AGSC5	*Agrostis scabra*	rough bentgrass		

Family	Symbol	Scientific Name	Common Name	Exotic	Rare
	ANGE	*Andropogon gerardii*	big bluestem		
	ARPU9	*Aristida purpurea*	purple threeawn		
	BOCU	*Bouteloua curtipendula*	sideoats grama		
	BOGR2	*Bouteloua gracilis*	blue grama		
	BOHI2	*Bouteloua hirsuta*	hairy grama		
	BRIN2	*Bromus inermis*	smooth brome	X	
	BRJA	*Bromus japonicus*	Japanese brome	X	
	CALO	*Calamovilfa longifolia*	prairie sandreed		
	ELCA4	*Elymus canadensis*	Canada wildrye		
	ELEL5	*Elymus elymoides*	squirreltail		
	ELLA3	*Elymus lanceolatus*	thickspike wheatgrass		
	ELRE4	*Elymus repens*	quackgrass	X	
	ELTR7	*Elymus trachycaulus*	slender wheatgrass		
	ELVI3	*Elymus virginicus*	Virginia 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		
	MUPA99	*Muhlenbergia paniculata*	tumblegrass		
	MUSQ3	*Munroa squarrosa*	false buffalograss		
	NAVI4	*Nassella viridula*	green needlegrass		
	PACA6	*Panicum capillare*	witchgrass		
	PASM	*Pascopyrum smithii*	western wheatgrass		
	PAVI2	*Panicum virgatum*	switchgrass		
	PEGL2	*Pennisetum glaucum*	pearl millet	X	
	PHAR3	*Phalaris arundinacea*	reed canarygrass	X	
	PHAU7	*Phragmites australis*	common reed		
	PHPR3	*Phleum pratense*	timothy	X	
	POPR	*Poa pratensis*	Kentucky bluegrass	X	
	POSE	*Poa secunda*	Sandberg bluegrass		
	PSSP6	*Pseudoroegneria spicata*	bluebunch wheatgrass		
	SCSC	*Schizachyrium scoparium*	little bluestem		
	SEVI4	*Setaria viridis*	green foxtail	X	
	SONU2	*Sorghastrum nutans*	Indiangrass		
	SPCR	*Sporobolus cryptandrus*	sand dropseed		

Family	Symbol	Scientific Name	Common Name	Exotic	Rare
Polemoniaceae	PHAL3	*Phlox alyssifolia*	alyssumleaf phlox		
	PHHO	*Phlox hoodii*	spiny phlox		
Polygalaceae	POAL4	*Polygala alba*	white milkwort		
	ERFL4	*Eriogonum flavum*	alpine golden buckwheat		
	ERPA9	*Eriogonum pauciflorum*	fewflower buckwheat		
	FACO	*Fallopia convolvulus*	black bindweed	X	
Primulaceae	ANOC2	*Androsace occidentalis*	western rockjasmine		
Ranunculaceae	ANCY	*Anemone cylindrica*	candle anemone		
	ANMU	*Anemone multifida*	cutleaf anemone		
	ANPA19	*Anemone patens*	eastern pasqueflower		
Rosaceae	CRATA	*Crataegus* spp.	hawthorn	X	
	POPE8	*Potentilla pensylvanica*	Pennsylvania cinquefoil		
	POTEN	*Potentilla* spp.	cinquefoil	X	
	PRVI	*Prunus virginiana*	chokecherry		
	ROAC	*Rosa acicularis*	prickly rose		
	ROAR3	*Rosa arkansana*	prairie rose		
	ROSA5	*Rosa* spp.	rose		
	ROWO	*Rosa woodsii*	Woods' rose		
Salicaceae	PODE3	*Populus deltoides*	eastern cottonwood		
	SAER	*Salix eriocephala*	Missouri River willow		
	SAEX	*Salix exigua*	narrowleaf willow		
	SALIX	*Salix* spp.	willow		
Santalaceae	COUM	*Comandra umbellata*	bastard toadflax		
Scrophulariaceae	ORLU2	*Orthocarpus luteus*	yellow owl's-clover		
	PEAL2	*Penstemon albidus*	white penstemon		
	PEGR5	*Penstemon gracilis*	lilac penstemon		
	PEGR7	*Penstemon grandiflorus*	large beardtongue		
Unknown Family	UNKFORB	Unknown forb	unknown forb	X	
	UNKGRAM	Unknown graminoid	unknown graminoid	X	
	UNKTREE	Unknown tree	unknown tree	X	
Verbenaceae	VEBR	*Verbena bracteata*	bigbract verbena		
	VEST	*Verbena stricta*	hoary verbena		
Violaceae	VINU2	*Viola nuttallii*	Nuttall's violet		
Vitaceae	VIRI	*Vitis riparia*	riverbank grape		

Appendix C: Vegetation Management Activities at FOUS

Below is a list of management activities recorded by Fort Union Trading Post from 1987-2016 for each vegetation management unit (restoration field). The fields within the Upland terrace are shown in Figure 11. Further descriptions and maps can be found in the Fort Union Trading Post Vegetation Management Plan (Symstad 2012)

	Restoration Field (acres)								
Year	1 (6.167)	2 (12.068)	3 (4.611)	4 (6.750)	5 (0.719)	6 (20.328)	7 15.99	8 (27.546)	9 (24.000)
1987		Disk?							
1988	Burn?	Burn?	Burn?	Burn?		Burn?	Burn?	Burn?	
1990		Seed							
1993	Disk		Disk						
1994				Seed		Disk			
1995	Burn	Burn	Burn				Disk		
1996	Seed		Seed					Disk	
1998						Seed			
1999							Seed		
2000	Burn	Burn	Burn	Burn	Burn	Burn		Seed	Burn + Round-up
2001	Hay	Hay	Hay	Hay	Hay	Hay	Hay		Round-up
2002	Burn	Burn	Burn	Burn	Burn	Burn	Burn	Burn	Round-up + Seed
2003	Hay	Hay	Hay	Hay	Hay	Hay	Hay	Hay	Hay
2004	Hay	Hay	Hay	Hay	Hay	Hay	Hay	Hay	
2006	Burn + Seed	Burn + Seed	Burn + Seed	Burn + Seed	Burn + Seed	Burn + Seed	Burn + Seed	Burn + Seed	Burn + Seed
2010	Burn + Seed	Burn + Seed	Burn + Seed	Burn + Seed					
2014	Burn	Burn	Burn	Burn	Burn	Burn	Burn	Burn	Burn
2015									mowed
2016	Mow (partial)	Mow (partial)	Mow (partial)	Mow (partial)	Mow (partial)	Mow (partial)	Mow (partial)	Mow (partial)	

Description or Year	Restoration Field (acres)									
	10 (19.00)	**11 (6.50)**	**12 (4.00)**	**13 (3.00)**	**14 (0.00)**	**15 (13.00)**	**16 (10.32)**	**17 (10.65)**	**18 (30.00)**	**19 (0.00)**
Description	East of shop	So-side Herdt	Niles; So-side, west end	Roadsides	ND State	Paschke-private	Maurer-so-side east end	Gunder-son	Bodmer Overlook	State Land Mt and ND
1995			Purchased?							
1996		Initial purchase, Seed with green needle grass								
1998		Plant trees w/ tree spade								
2003		Burn	Burn							
2004	Round-up	Plant trees		Round-up						
2005	Round-up	Plant trees		Round-up						
2006	Seed	Plant trees		Seed						
2007		Plant trees								
2008		Plant trees/ monitoring wells	Clear					Cleared		
2009			Herbicide					Herbicide		
2010	Burn + Seed		Seed					Seed		
2014	Burn									
2015		Canal Failure, significant bank loss.								

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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