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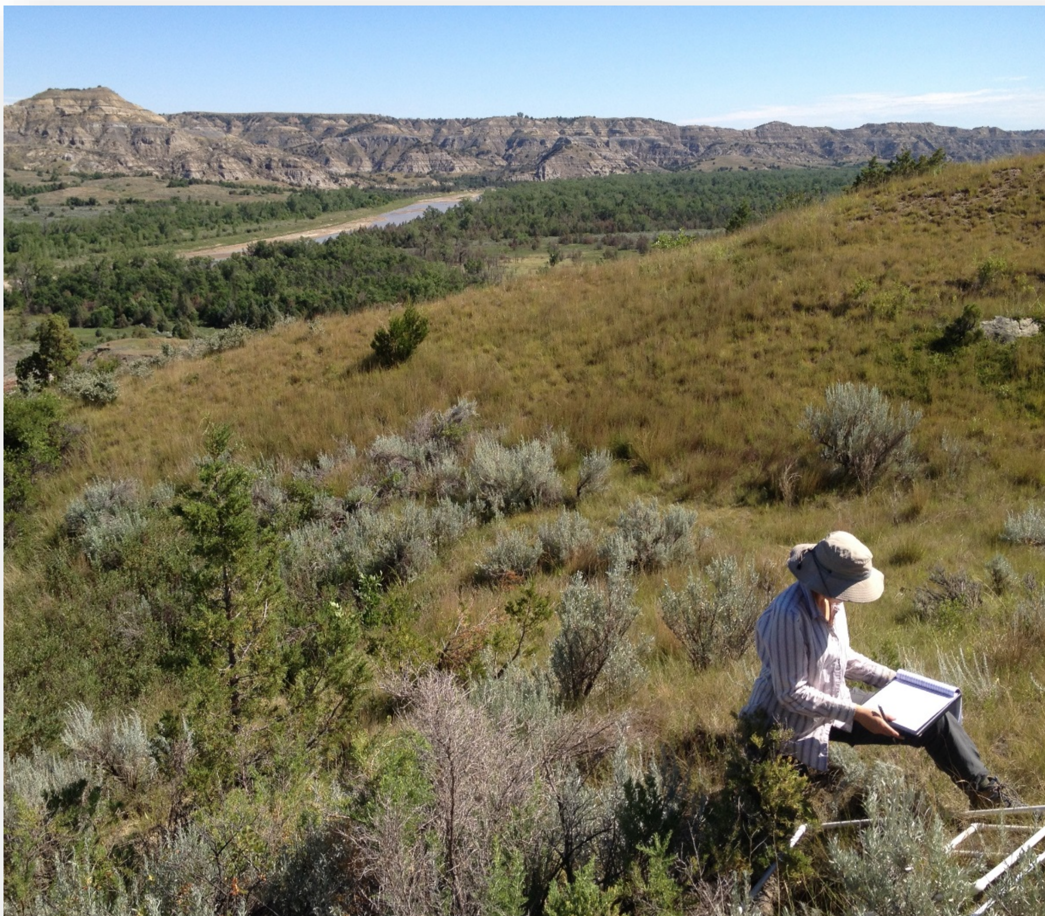
Plant Community Composition and Structure at Theodore Roosevelt National Park

2011-2016 Summary Report

Natural Resource Report NPS/NGPN/NRR—2017/1497



ON THIS PAGE
Monitoring herbaceous vegetation in Theodore Roosevelt National Park, 2015.
Photo credit: NPS

ON THE COVER
Northern Great Plains Network monitoring staff and students from Dickinson State University search for seedlings as part of efforts to monitor riparian forest structure at Theodore Roosevelt National Park, 2015.
Photo credit: NPS

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2011-2016 Summary Report

Natural Resource Report NPS/NGPN/NRR—2017/1497

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Executive Summary

This report presents the results of vegetation monitoring efforts at Theodore Roosevelt National Park (THRO) by the Northern Great Plains Inventory and Monitoring Network (NGPN) and the Northern Great Plains Fire Ecology Group from 2010-2016. Field crews captured data relating to species richness, herb-layer height, abundance of individual native and non-native species, ground cover, seedling and tree densities, and site disturbance at 81 plots in the North and South Unit and across 162 plot visits. We used these data to explore the differences across the two management units, and between riparian and upland areas. We also compared our findings to the range of natural variability seen in other grasslands and management targets to develop summaries of natural resource condition (Appendix C). In addition to annual monitoring, NGPN also surveyed riparian forest condition in 2015 at 100 randomly located plots. We collected data on tree and seedling density, tree condition, disturbance, and the presence of exotic species of management concern, such as leafy spurge and Canada thistle.

Our findings can be summarized as follows: Monitoring crews identified 361 vascular plant species, with an average of 9 native species occurring within any given 1 m^2 quadrat sampled. Grasses, sedges, and forbs make up the majority of plant cover, while non-native species comprise about 24% of plant cover. Native plant diversity in upland areas is considerably higher and exotic plant cover lower, when compared with riparian areas. There is a general trend of increasing exotic cover over time in the riparian habitat, with Kentucky bluegrass increasing in all areas of the park, and exotic plant cover significantly greater near roadways. Both units show similar patterns in herbaceous vegetation, but juniper trees are more common and forests are more dense in the North Unit. Finally, we found that North Unit riparian forests have more widespread and dense cottonwood forests, a more diverse tree assemblage, and lower cover of herbaceous exotic species compared with South Unit riparian forests. Overall, the park’s vegetation seems to be in good condition, though exotic plants pose a significant challenge to park management.

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 THRO for providing logistical support and safety checks, particularly the law enforcement team. We thank C. Whippo and his students at Dickinson State University for their help with field work. We also thank B. McCann. M. Davis, and S. Rockwood for providing comments on a draft of this manuscript. Thanks to J. Friedman for thoughtful suggestions on riparian forest monitoring and the tree vigor measurements and for reviewing the draft version of this report. The NGPN and NGP Fire Ecology field crews collected all of the data included in this report

Introduction

During the last century, much of the prairie within the Northern Great Plains has been plowed for cropland, converted to livestock pasture, or otherwise developed, making it one of the most threatened ecosystems in the United States. Within North Dakota, greater than 71% of the area of native mixed-grass prairie has been converted since European settlement (Samson and Knopf 1994). The National Park Service (NPS) plays an important role in preserving and restoring some of the last pieces of intact prairies within its boundaries. The stewardship goal of the NPS is to "preserve ecological integrity and cultural and historical authenticity" (NPS 2012). However, park resource managers struggle with fundamental changes to disturbance regimes related to climate, fire cycles, and large ungulate grazing that have historically maintained prairie, and the additional and persistent pressures of exotic invasive species. Long-term monitoring in national parks is essential to supporting sound management of prairie landscapes because it provides information on environmental quality and condition, benchmarks of ecological integrity, and early warning of declines in ecosystem health.

Located in southwestern North Dakota, Theodore Roosevelt National Park (hereafter THRO, or "the park") encompasses 70,477 acres in the Little Missouri River Badlands. THRO is composed of three discrete management units, each of which is a patchwork of mixed-grass prairie, clay buttes, bottomland forest, and open shrublands. The three park units (North, South, and Elkhorn Ranch Site) are all connected by the Little Missouri River. The park needs more information regarding the condition of native grasslands and woody draws due to the large number of exotic species and the lack of data that makes estimates of condition in these and other plant communities difficult (Amberg et al. 2014). Vegetation monitoring began in 1997 by the Northern Great Plains Fire Ecology Program (NGPFire; Wienk et al. 2010), and in 2010, THRO was incorporated into the Northern Great Plains Inventory & Monitoring Network (NGPN). At that time, vegetation monitoring protocols and plot locations were shifted to better represent the entire park and to coordinate efforts with NGPFire (Symstad et al. 2011). A total of 175 plots were established by NGPFire and NGPN in THRO and the combined sampling efforts began in 2011 (Ashton et al. 2012). In 2015, 100 additional plots were established and monitored in the riparian forest to assess forest condition, and this forest condition assessment will be repeated at 5 year intervals. In this report, we use data collected from 2012-2016 to assess the current condition of park vegetation, and we use data from 2010-2016 to look at longer-term trends.

Using 7 years of plant community monitoring data in THRO, we explore the following questions:

1. What is the current status of plant community composition and structure of THRO grasslands (species richness, exotic plant cover, and diversity)?
2. What, if any, rare plants were identified in THRO long-term monitoring plots?
3. How has plant community composition and structure changed from 2010 to 2016?
4. What is the current status of the upland forests in THRO?
5. What is the current status of the riparian forests at THRO?

Methods

The NGPN monitoring protocol (Symstad et al. 2012b, a) has been used to monitor vegetation plots in THRO since 2010. Our methods are briefly described below, and more detail can be found in the full monitoring protocol.

NGPN and NGPFire Monitoring Plots 2010-2016

The NGPN and NGPFire implemented a survey to monitor plant community structure and composition in THRO using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using the GRTS design, NGPN selected 50 randomly located sites within the North Unit (PCM plots; Figure 1) and 90 randomly located sites within the South Unit of THRO to become Plant Community Monitoring plots (Figure 2).

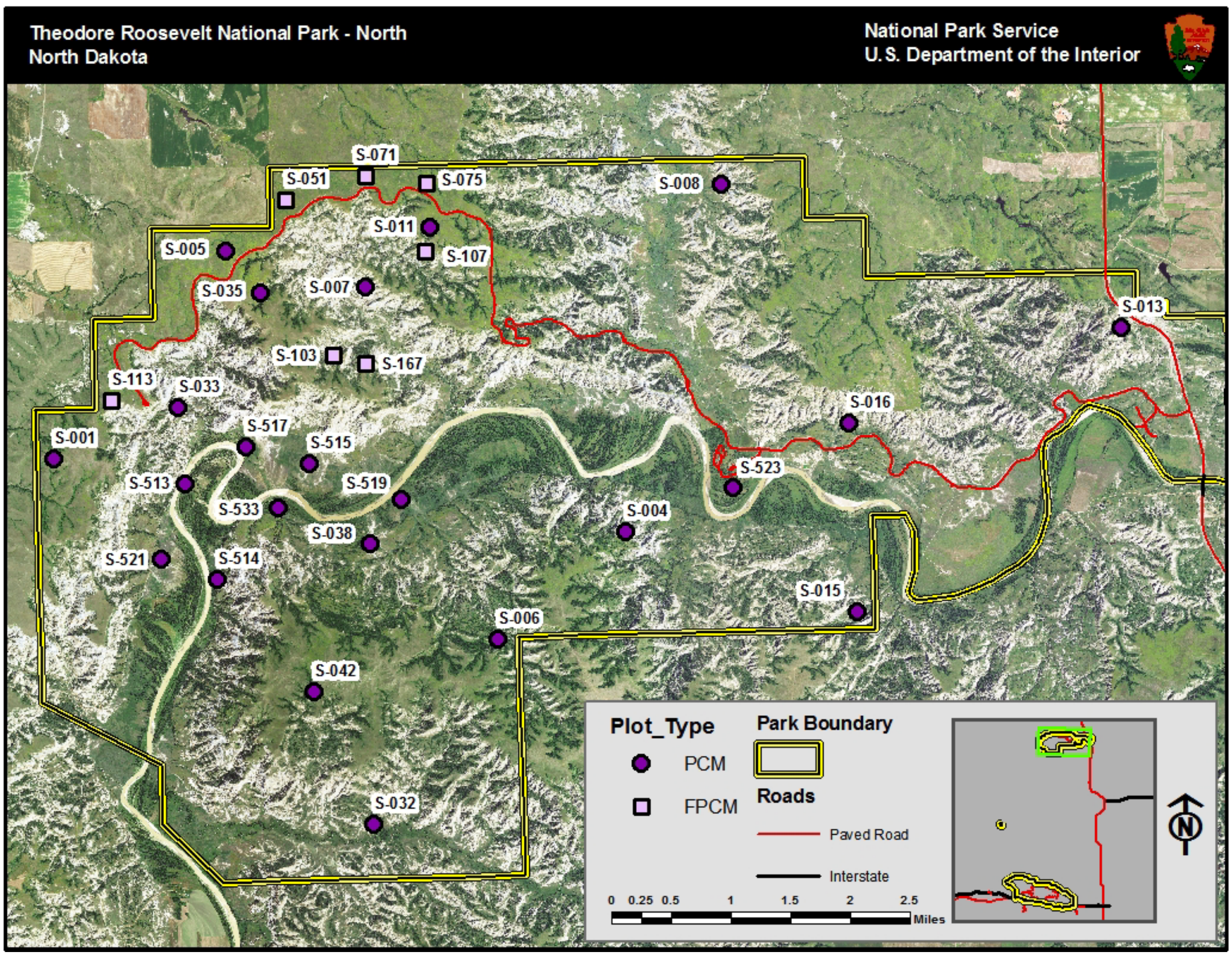

Figure 1. Map of long-term vegetation monitoring plots in the North Unit of Theodore Roosevelt National Park visited from 2010 — 2016. Twenty-three long-term plots were established by the Northern Great Plains Inventory & Monitoring Program (NGPN) and the Fire Effects Program (NGPFire) between 2010 and 2016 (circles). Seven additional plots were established to better understand the effects of prescribed fire (squares).

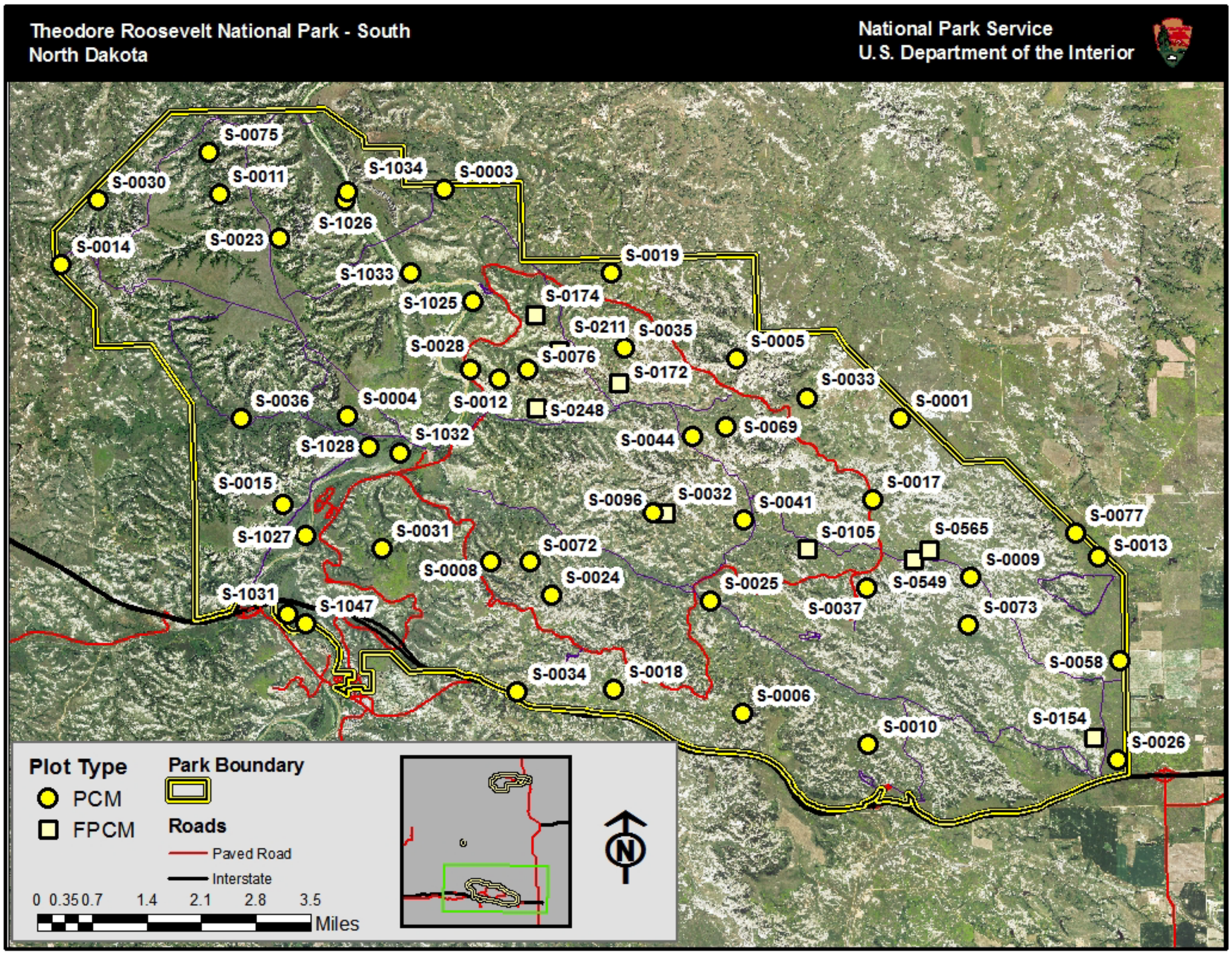

Figure 2. Map of long-term vegetation monitoring plots in the South Unit of Theodore Roosevelt National Park visited from 2010—2016. Forty-seven long-term plots were established by the Northern Great Plains Inventory & Monitoring Program (NGPN) and the Fire Effects Program (NGPFire) between 2011 and 2016 (circles). Nine additional plots were established to better understand the effects of prescribed fire (squares).

There are no monitoring sites within the Elkhorn Unit. In the North and South Units there are both riparian and upland monitoring sites. Riparian habitat extent was based on proximity to the Little Missouri River corridor and alluvial soil types. There are 20 riparian PCM plots in the North Unit and 20 riparian PCM plots within the South Unit where understory plant composition is measured.

The NGPN is scheduled to visit 28 PCM plots every year using a rotating sampling scheme where 14 sites were visited in the previous year and 14 sites are new visits. After 5 years (2011-2015), half of the PCM plots should have been visited at least twice between late July and early August. With the current sampling scheme, it will take the NGPN 20 years to monitor all 140 plots. Due to logistical, financial, and safety constraints the NGPN monitoring crew has rarely been able to monitor all 28 sites per year. Efforts ranged from 14 to 28 plots per year (Table 1). See Appendix A for a detailed list of which plots were visited in each year.

Table 1. Number of plant community monitoring (PCM) plots visited from 2010-2016. Northern Great Plains Fire Ecology Group visits are in parentheses. Only 5 plots were visited in 2010 as part of a pilot for the vegetation monitoring program. The scheduled visits did not start until 2011.

Sites	Scheduled number of plots to visit	2010	2011	2012	2013	2014	2015	2016
South Upland	14	0	10 (6)	13 (3)	9	7 (7)	12 (9)	12 (3)
South Riparian	4	0	4	4	2	3	4	2
North Upland	6	0 (5)	6	6	4	3 (4)	4	5
North Riparian	4	0	1	4	2	1	2	3
Riparian Forest Survey	100 (2015)	–	–	–	–	–	100	–
Total # of Plots Visited	28	0 (5)	21 (6)	27 (3)	17	14 (11)	22 (9)	22 (3)

When a PCM plot was located within an active burn unit, NGPFire added additional plot visits based on a 1, 2, 5, and 10 year sampling schedule. NGPFire also established and monitored a number of new sites focused on active burn units (Fire Plant Community Monitoring plots) using the same GRTS sampling schema. From 2010-2016, nine Fire Plant Community Monitoring (FPCM) plots were established in the South Unit and seven in the North Unit. Finally, using the same set of random sites, NGPN established 50 PCM plots in riparian forest corridor of the North Unit and 50 plots in the South Unit riparian corridor, and these riparian forest plots were monitored in 2015 to assess forest condition. Since 2010, NGPFire and NGPN have established 74 plots in the North Unit of THRO and 101 plots in the South Unit. Of these, we have collected herbaceous vegetation data from 81 plots during 162 site visits, and the remaining plots were included in forest structure monitoring efforts.

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 3). Data on ground cover and herb-layer (≤ 2 m) height and plant cover were collected on two 50 m transects (the long sides of the plot) using a point-intercept method (Figure 4). At 50 locations along each transect (every 1.0 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 top-most plant intercepted (Figure 4). Using this method, absolute canopy cover can be greater than 100% (particularly in wet years and at productive sites) because we record multiple layers of plants. Species richness data from the point-intercept method were supplemented in plots read by NGPN 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 3). In 2015 we omitted the 10 m^2 quadrat, and in 2016 we discontinued the use of all but the 1m^2 quadrats, which is the quadrat size most commonly used by vegetation ecologists. This was done to save time while continuing to collect species richness data at the 1 m^2 scale. In this report, we present only the data from the 1 m^2 quadrats.

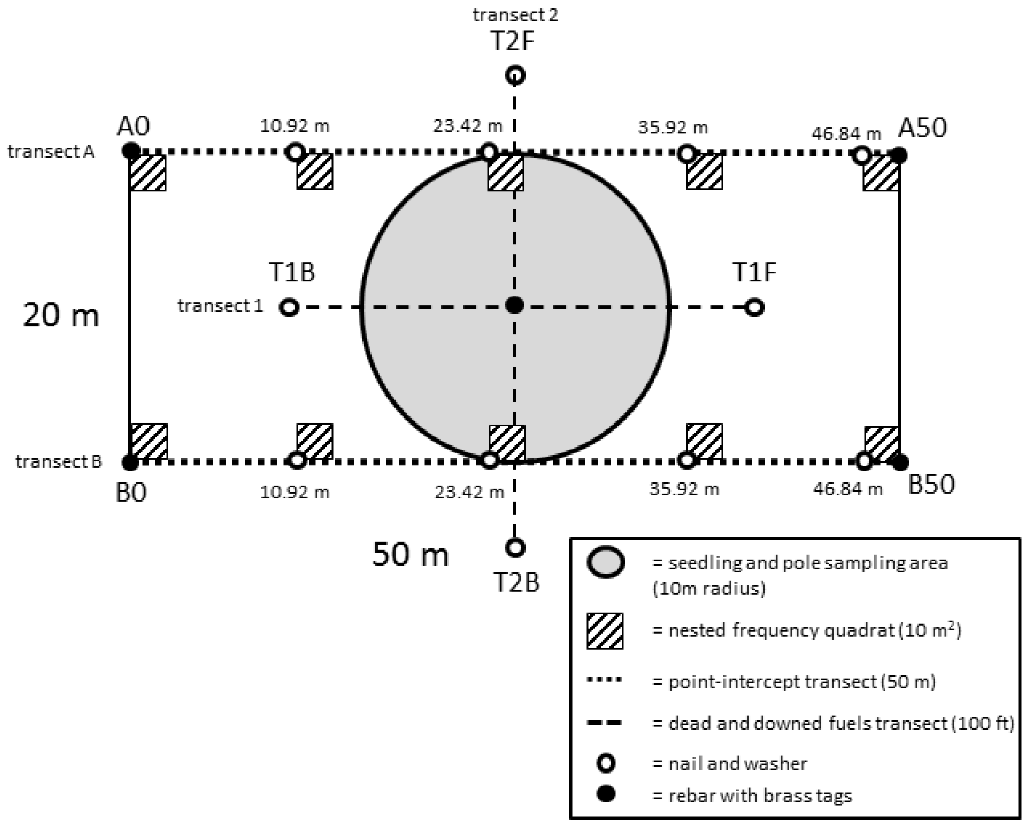

Figure 3. Long-term monitoring plot layout used for sampling vegetation in Theodore Roosevelt National Park.

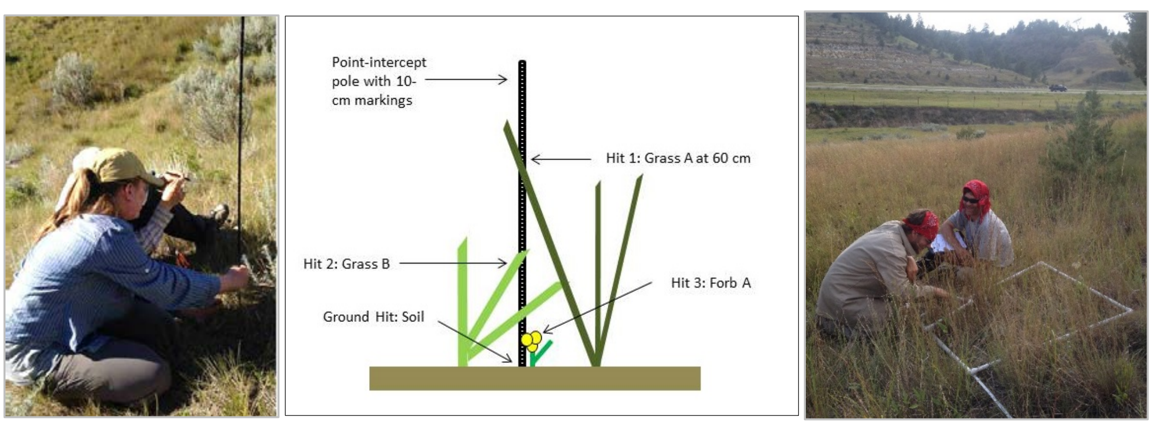

Figure 4. The Northern Great Plains Inventory & Monitoring vegetation crew used point-intercept (left and center panel) and quadrats (right panel) to document plant diversity and abundance.

When woody species were present anywhere within 38 m of the center of the plot, 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 3). 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. Juniper trees (*Juniperus scopulorum*) and tall shrubs were commonly encountered and these were measured at root collar rather than DBH. Dead and downed woody fuel load data were collected at forested plots along two perpendicular, 100 foot (30.49 m) transects with midpoints at the center of the plot (Figure 3), following Brown's Line methods (Brown 1974, Brown et al. 1982). Fuels data were only collected in plots where woody fuels from juniper or cottonwood trees were present.

At all PCM plots (but not the FPCM plots) we surveyed the area for common disturbances and target species of interest to the park. Common disturbances included rodent mounds, animal trails, prairie dogs, and fire. For all plots, the type and severity of the disturbances were recorded. We also surveyed the area for new or recent exotic species that have the potential to spread into the park and cause significant ecological impacts, otherwise known as "target species" (Table 2). These species were chosen with assistance from experts from the Midwest Invasive Plant Network, the Exotic Plant Management Team, park managers, and local weed experts. Each target species that was present at a site was assigned an abundance class 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. This information was not intended to map the common exotic species in the park. Instead, the information gathered from this procedure is critical for early detection and rapid response to new or previously undocumented exotic species invasions.

Table 2. Exotic species surveyed for at Theodore Roosevelt National Park as part of the early detection and rapid response program within the Northern Great Plains Network. ND Status of Noxious indicates the species is on North Dakota's state list of noxious weeds.

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

NGPN Riparian Forest Plots

NGPN completed a survey of riparian forests in THRO in September – October 2015 using a set of 100 forested sites. The goal of this survey was to assess status and trends in the condition of lowland forests near the Little Missouri River. The forest survey will be repeated every five years (e.g. 2015, 2020, 2025, and so on). The sites were selected from within the riparian zone (as described above) using the same GRTS sampling scheme. The PCM riparian plots described above were included in this survey if they had trees present, but additional PCM plots were added to reach the 100 total sites desired for the forest survey.

The measurements and data collected at these plots were similar to those previously described and data was collected on disturbance, target species, tree density and condition, and seedling density. However, there were some differences: (1) All plots were only included in the survey when there were trees or tall shrub species present within 38 m of the plot center; (2) Each riparian forest site was assigned a Riparian Type that was the best representation of ~ 50 m diameter area around plot center based on canopy or aerial cover (Table 3); (3) Plots were only marked with a central rebar (e.g. no nails were used to mark the tree transects shown in Figure 3) and the 10m circle was divided into quarters along North, South, East, West axes; (4) Trees were not tagged, and were only measured within the 10 m radius. If there were less than 5 trees or poles, the plot radius was extended to 20 m and all trees within the larger area were measured; (5) Additional information was collected on tree vigor.

Table 3. Riparian forest types within Theodore Roosevelt National Park. Field technicians evaluated 100 riparian forest plots in 2015 and assigned each plot to the best fit category.

Riparian type	Description
Silver sage shrubland	Mostly vegetated by shrubs <4m tall (shrub cover >10%, typically >25%). Trees may be present, but should be less than 10% canopy cover. Silver sagebrush (*Artemisia cana*) dominant, in shrub savannas within river and creek floodplains, gentle slopes, sagebrush flats, draws and depressions
Green ash woodland	Mostly vegetated by trees >4m tall (tree cover >10%, typically >25%). Green ash (*Fraxinus pennslyvanica*) dominant, with other trees/shrubs as a secondary species
Cottonwood/ juniper woodland	Mostly vegetated by trees >4m tall (tree cover >10%, typically >25%). Cottonwood (*Populus deltoides*) dominant and clearly forms an emergent layer (i.e. taller than surrounding trees), with Rocky Mountain juniper subdominant. Peachleaf willow (*Salix amygdaloides*) may also be present
Cottonwood/ willow woodland	Mostly vegetated by trees >4m tall (tree cover >10%, typically >25%). Cottonwood dominant and clearly forms an emergent layer (i.e. taller than surrounding trees), with sandbar willow (*Salix exigua*) and/or peachleaf willow subdominant in understory
Cottonwood/ herbaceous	Mostly herbaceous, grasses and forbs. If trees/shrubs present, should be <10% aerial cover. Cottonwoods generally large and mature; lacks secondary tree species and understory primarily herbaceous, though snowberry (*Symphoricarpos occidentalis*) commonly present
Sandbar willow shrubland	Mostly vegetated by shrubs <4m tall (shrub cover >10%, typically >25%). Trees may be present, but should be less than 10% canopy cover. Shrub thickets, dense, found along river and creek banks, and wet and moist drainages. Predominantly sandbar willow.
Snowberry shrubland	Mostly vegetated by shrubs <4m tall (shrub cover >10%, typically >25%). Trees may be present, but should be less than 10% canopy cover. Snowberry shrub dominant, often in oxbows, moist drainages and depressions

The crown of all trees was assessed and assigned a vigor class. Vigor class is an indicator of tree condition that varies from 0 to 100 in increments of 10 and describes the percent of the crown that is green. A tree in good condition with a green canopy would fall in the 100 class (96-100% green) and a tree falls in class 0 when less than 5% of the canopy is green; (6) In addition to early exotic invaders (Table 2), we also surveyed the area for common species of management concern (Table 4).

Table 4. Exotic species surveyed for in Theodore Roosevelt National Park during riparian forest surveys. ND Status indicates the species is on North Dakota's state list of noxious weeds, and Noxious-B and Noxious-M indicate species classified as noxious in Billings and McKenzie counties where the South and North units of THRO are located, respectively.

Scientific Name	Common Name	ND Status
Bromus inermis	smooth brome	–
Bromus japonicus	Japanese brome	–
Bromus tectorum	cheatgrass	–
Carduus nutans	musk thistle	Noxious
Centaurea stoebe	spotted knapweed	Noxious
Cirsium arvense	Canada thistle	Noxious
Cynoglossum officinale	hounds tongue	Noxious-B,M
Eleaegnus angustifolia	Russian olive	–
Euphorbia esula	leafy spurge	Noxious
Lythrum salicaria	Purple loosestrife	Noxious
Tamarix ramosissima	saltcedar	Noxious

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 NPS Inventory and Monitoring Program.

Species scientific names, codes, and common names are from the USDA Plants Database (USDA-NRCS 2017). 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 B.

After data 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. When errors were identified by the crew or automated queries, changes were made to the original datasheets and/or the FFI database as needed. Data summaries were produced using the FFI reporting and query tools. Statistical summaries and graphics were generated using the R statistics software package (version 3.3.2). 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.

Plant life forms (e.g., shrub, forb) were based on definitions from the USDA Plants Database (USDA-NRCS 2017). 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 5). Lists of noxious weeds are maintained by the North Dakota Department of Agriculture (https://www.nd.gov/ndda/program/noxious-weeds). These lists were cross-referenced with the list of species observed in THRO by NGPN. Finally, the complete list of species that NGPN observed in THRO was cross-referenced with the certified list of plant species known to occur in THRO (https://irma.nps.gov/NPSpecies/Search/SpeciesList/THRO) to identify species that are not on the certified list. When a species identified by NGPN is not on the certified park list, that species is collected and sent to botanists for independent verification and the appropriate corrections to the NGPN species list and the THRO species list are made based on the botanist's assessment.

Table 5. 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 species diversity 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 observed in ten 1 m^2 quadrats within a plot. 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 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. 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%.

Results and Discussion

Status of plant community composition and structure

There is a great deal of variation in plant community types across THRO and this was reflected in the long-term plots. Most of the monitoring plots we visited were located in upland areas, which make up a greater proportion of the land area of the park. These upland plots were often in grasslands (Figure 5), but juniper forests, badlands, and shrublands were also common. We surveyed juniper forest communities at six plots in the North Unit and four plots in the South Unit. We also visited 17 riparian plots, many of which were sagebrush communities or older cottonwood forests and grasslands (Figure 5). This variety of habitat and plant community types results in high plant species diversity in THRO. There are 680 plant species on the THRO species list, and we identified 361 species (61 of these were exotic) in monitoring plots from 2010 – 2016 (Appendix B).

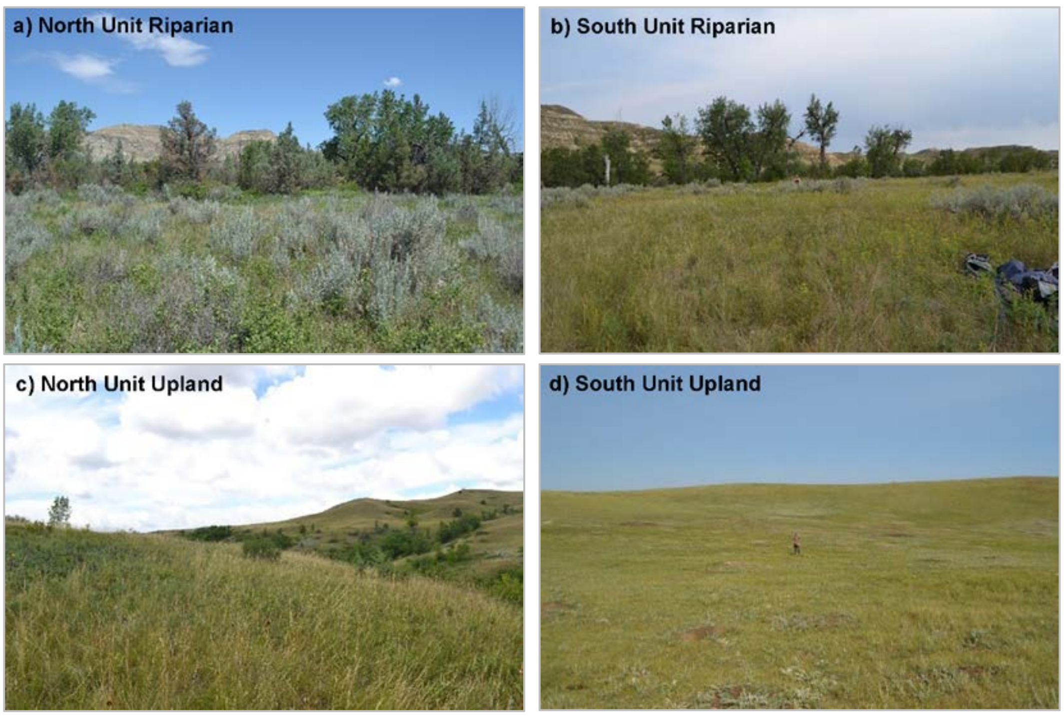

Figure 5. Photographs of the long-term monitoring plots in the a) North Unit Riparian b) South Unit Riparian c) North Unit Upland and d) South Unit Upland at Theodore Roosevelt National Park in riparian and upland areas.

While there was a great deal of variation in species diversity and plant community types across monitoring plots, graminoids (which include grass, sedge, and rush species) accounted for most of the vegetative cover at THRO (Table 6). Average relative cover of graminoid species was between 54 and 72% in monitoring plots. Forbs, vines, trees, shrubs, and subshrubs (defined as low-growing shrubs usually shorter than 0.5 m) were also present but much less abundant than graminoids. Shrubs were most abundant in riparian habitat in the North Unit with an average of 28.4% relative cover (Table 6, Figure 5).

Table 6. The average relative percent cover of graminoids, forbs, and shrubs in long-term monitoring plots within Theodore Roosevelt National Park 2012 -2016. The average percent cover is given ± 1 standard error of the mean for the North and South Unit riparian and upland areas. When the same plot was visited more than once during the time period, the values were averaged across the site visits before calculating the unit or strata average.

Strata	Unit	Number of plots	Total Graminoid Relative Cover (%)	Total Forb Relative Cover (%)	Total Shrub Relative Cover (%)	Native Graminoid Relative Cover (%)	Native Forb Relative Cover (%)	Native Shrub Relative Cover (%)
Riparian	North	8	54.0 ± 4.7	15.3 ± 5.1	28.4 ± 7.7	24.4 ± 5.6	12.3 ± 3.8	28.4 ± 7.7
Riparian	South	9	68.8 ± 4.8	18.0 ± 4.6	13.2 ± 4.4	27.9 ± 6.4	9.2 ± 3.4	13.2 ± 4.4
Upland	North	18	62.5 ± 2.5	16.1 ± 1.8	17.5 ± 2.1	43.9 ± 3.3	11.3 ± 1.2	17.5 ± 2.1
Upland	South	46	72.0 ± 2.0	13.0 ± 0.9	12.0 ± 1.3	57.1 ± 2.6	10.8 ± 0.9	12.0 ± 1.3

Exotic graminoids and forbs were common in all areas of the park. Native graminoid cover was lowest in riparian areas, averaging between 24 and 27% cover in the North and South units, respectively (Table 6). All shrub species observed in plots were native species (i.e., total shrub cover and native cover are the same in Table 6).

Western wheatgrass (*Pascopyrum smithii*), western snowberry (*Symphoricarpos occidentalis)*, and Kentucky bluegrass (*Poa pratensis*), were some of the most common species observed in the park (Figure 6). Green needlegrass (*Nassella viridula*), needle and thread grass (*Hesperostipa comata*), and blue grama (*Bouteloua gracilis*) were the most abundant species in the upland areas. Other species that were common in upland areas of both the North and South Unit included threadleaf sedge (*Carex filifolia*), fringed sagewort (*Artemisia frigida*), and prairie Junegrass (*Koeleria macrantha*).

Average relative cover of exotic species at THRO was 23.6 ± 2.4 % from 2012 – 2016 (mean ± se), which is more than twice the management target of 10% or less exotic cover (Appendix C). Riparian areas had a much higher cover of exotic species than the upland areas (Table 7) and much of this was due to two exotic grasses: Kentucky bluegrass and smooth brome (Figure 6). Kentucky bluegrass was particularly abundant in riparian areas of the South Unit and comprised more than 50% absolute cover (Figure 6 a-d), and this high Kentucky blue grass cover contributed to a very high relative cover of exotic species overall in the South unit (nearly 50%; Table 7). Smooth brome was in low abundance in the upland areas but common in the riparian areas averaging between 11 and 14 % relative cover (Table 7). Other exotic forbs, such as leafy spurge, Canada thistle, and sweet clover were common in the park but made up less of the total herbaceous cover (Table 7).

Table 7. The average relative percent cover of exotic species in long-term monitoring plots within Theodore Roosevelt National Park 2012 -2016. The average percent cover is given ± 1 standard error of the mean for the North and South Unit riparian and upland areas. When the same plot was visited more than once during the time period, the values were averaged across the site visits before calculating the unit or strata average.

Strata	Unit	Number of plots	Exotic species cover (%)	Kentucky bluegrass cover (%)	Smooth brome cover (%)	Leafy spurge cover (%)	Yellow sweetclover cover (%)	Canada thistle cover (%)
Riparian	North	8	32.6 ± 8.8	15.4 ± 4.7	11.7 ± 5.8	1.4 ± 1.0	0.8 ± 0.8	0.2 ± 0.16
Riparian	South	9	49.7 ± 7.7	23.3 ± 5.2	14.4 ± 7.6	6.9 ± 2.1	0.7 ± 0.4	0.2 ± 0.14
Upland	North	18	23.3 ± 3.5	16.5 ± 2.6	1.3 ± 0.9	0	3.3 ± 1.3	0.6 ± 0.34
Upland	South	46	17.1 ± 2.7	11.1 ± 2.0	1.2 ± 0.4	0.5 ± 0.3	1.1 ± 0.2	0.1 ± 0.04

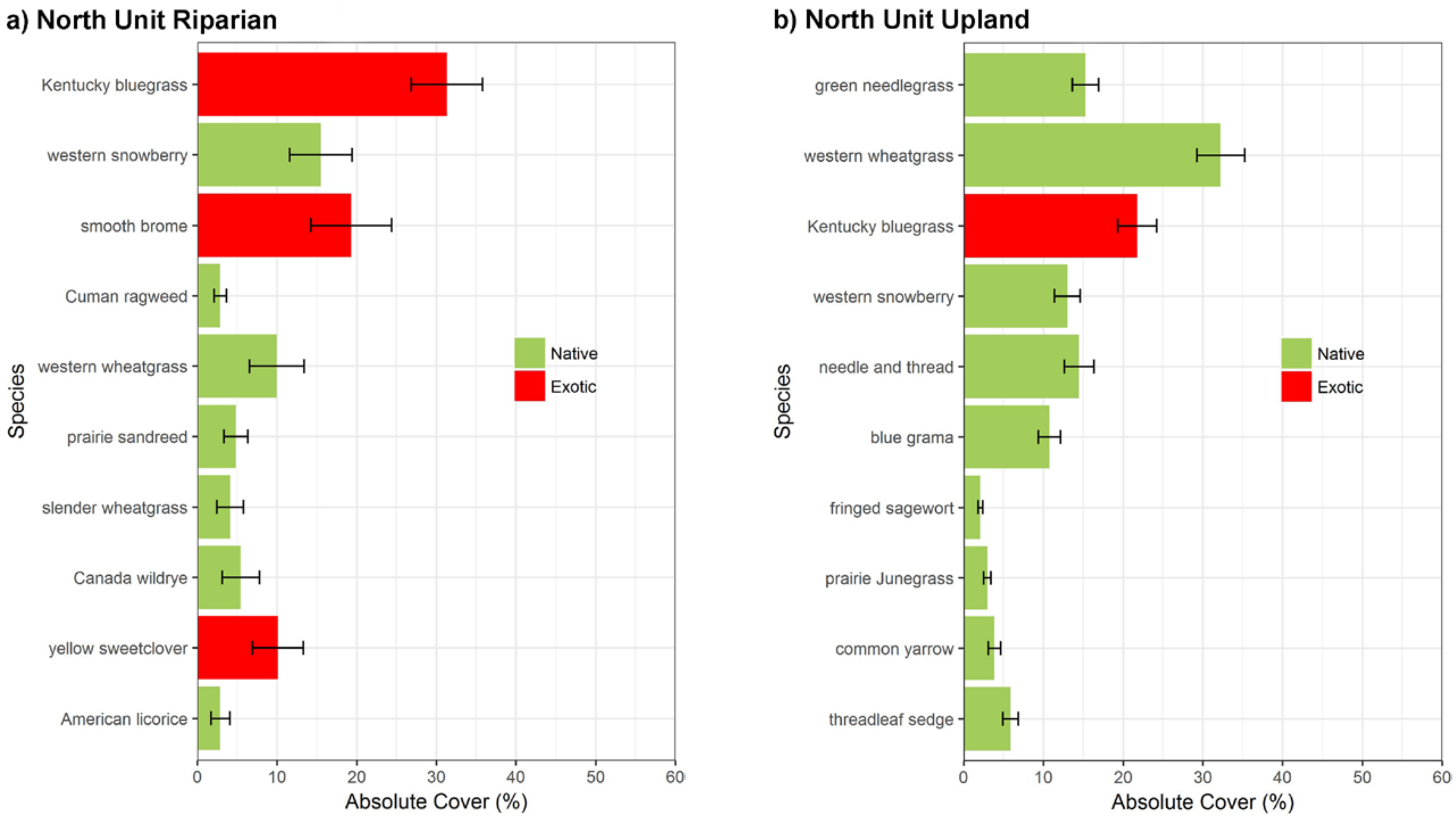

Figure 6 a-b. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded for a) North Unit Riparian and b) North Unit Upland sites at Theodore Roosevelt National Park from 2010 – 2016. Bars represent means ± one standard error.

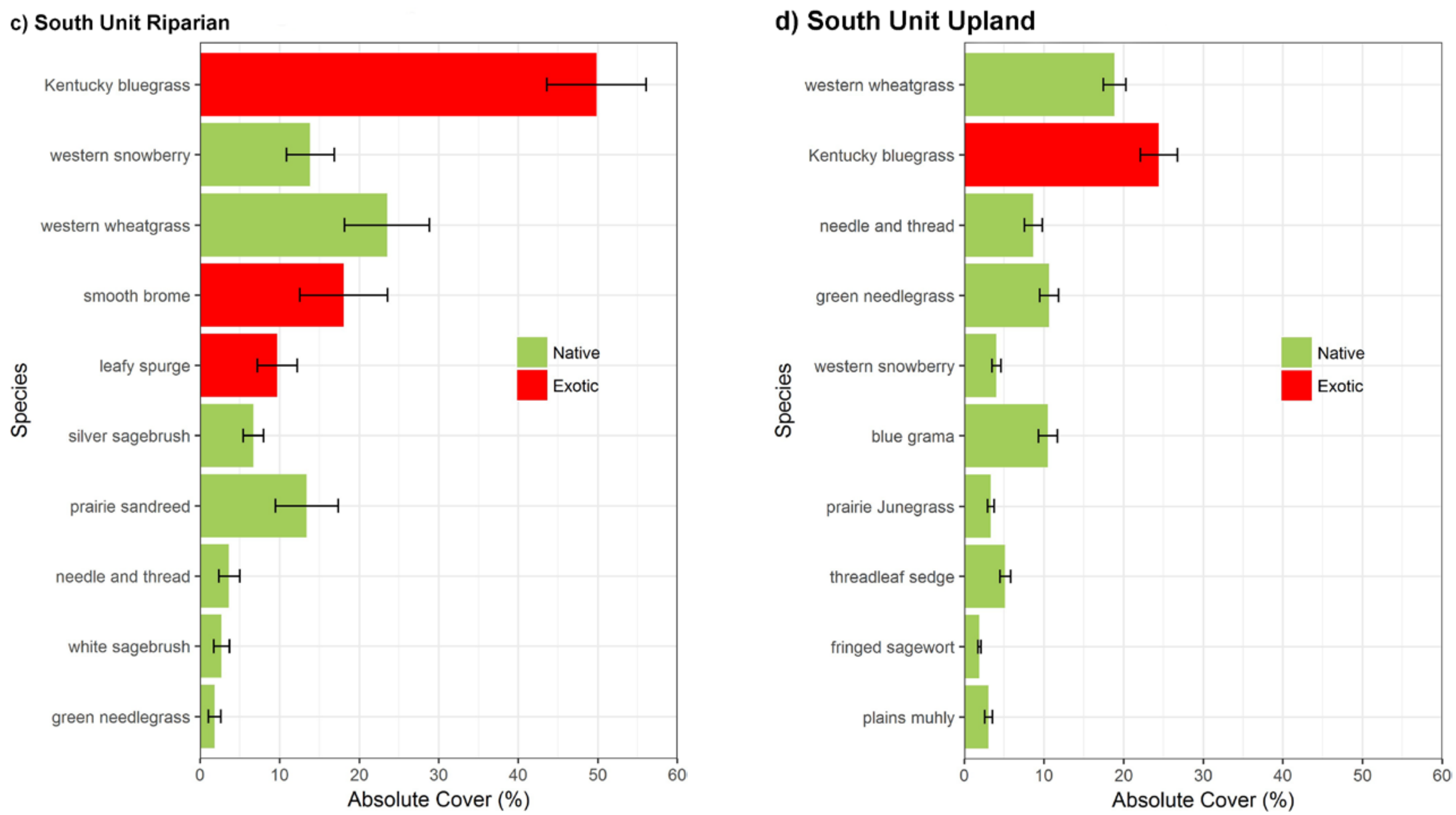

Figure 6 c-d. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded for c) South Unit Riparian and d) South Unit Upland sites at Theodore Roosevelt National Park from 2010 – 2016. Bars represent means ± one standard error.

Examining the status and trends of a park's native plant diversity and species evenness is one of the ways the NPS measures the effectiveness of management actions directed at achieving the Park Service mission of "preserving ecological integrity". Species richness in the mixed-grass prairie is determined by numerous factors, including fire regime, grazing, animal-caused disturbances, and weather fluctuations (Symstad and Jonas 2011). Average native species richness has been measured at monitoring plots throughout THRO using species presence observations in 1 m^2 quadrats (Table 8) and point-intercept measurements (Table 9). While there is no management target for species richness at THRO, richness can be compared 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 – 90^{th} percentile range) between 1933 and 1945 (Symstad and Jonas 2014). Average native species richness in upland plots at THRO (2012 – 2016) was 8.7 and 9.5 species in the North and South Unit, respectively. These richness values fall within the range of natural variability and suggests upland vegetation diversity is in good condition (Appendix C). The most diverse plot in the park (PCM_0030; Figure 7) is located in the northwest portion of the South Unit (Figure 2). In 2015, we identified an average of 18 native species per square meter at this site. Riparian plots, on average, were much less diverse than upland plots (Table 8 and Table 9).

Table 8. Average species richness in 1 m^2 quadrats in long-term monitoring plots at Theodore Roosevelt National Park 2012 -2016. The average richness is given ± 1 standard error of the mean for the North and South Unit riparian and upland areas.

Strata	Unit	Number of plots	Total Richness	Native Richness	Exotic Richness	Forb Richness	Graminoid Richness	Shrub Richness
Riparian	North	7	6.4 ± 0.6	5.0 ± 0.5	1.5 ± 0.3	2.5 ± 0.6	2.6 ± 0.4	1.0 ± 0.2
Riparian	South	9	6.0 ± 0.7	4.0 ± 0.6	2.1 ± 0.2	2.6 ± 0.6	2.6 ± 0.2	0.8 ± 0.2
Upland	North	14	9.9 ± 0.8	8.7 ± 0.8	1.2 ± 0.2	4.4 ± 0.4	3.9 ± 0.4	1.3 ± 0.1
Upland	South	35	11.0 ± 0.6	9.5 ± 0.6	1.5 ± 0.1	5.3 ± 0.5	4.5 ± 0.2	0.9 ± 0.1

Table 9. Average species richness along two 50m transects in long-term monitoring plots at Theodore Roosevelt National Park 2012 -2016. The average richness is given ± 1 standard error of the mean for the North and South Unit riparian and upland areas.

Strata	Unit	Number of plots	Total Richness	Native Richness	Exotic Richness	Forb Richness	Graminoid Richness	Shrub Richness
Riparian	North	8	16.3 ± 1.6	13.1 ± 1.4	3.2 ± 0.4	6.0 ± 1.2	6.9 ± 1.0	2.3 ± 0.6
Riparian	South	9	13.2 ± 2.0	9.0 ± 1.4	4.2 ± 0.6	5.4 ± 1.5	5.7 ± 0.7	1.9 ± 0.5
Upland	North	18	26.6 ± 1.6	23.9 ± 1.5	2.8 ± 0.3	10.6 ± 1.0	11.1 ± 0.8	3.5 ± 0.3
Upland	South	46	24.9 ± 1.1	21.9 ± 1.1	3.0 ± 0.2	9.2 ± 0.7	11.5 ± 0.4	2.9 ± 0.3

Figure 7. A photograph of the long-term monitoring plot, PCM_0030, with the highest average native species diversity found in 1m² quadrats.

We explored patterns in exotic species cover and species richness in THRO using linear mixed models and found a significant relationship between native species richness and exotic cover ($F_{1,144}$=69.2, P<0.0001). As native species richness increased, there was a corresponding decrease in relative cover of exotic species (Figure 8; left). The riparian areas tended to be less diverse and have a higher cover of exotic species than the upland areas, but the relationship between exotic cover and native species richness was the same in both areas (Figure 8; interaction term was not significant). Kentucky bluegrass, the most common exotic species, showed a similar negative relationship with native species richness ($F_{1,144}$=46.8, P<0.0001). We cannot elucidate cause and effect from these data, and the pattern could be due to diverse areas of the park resisting invasion of exotic species and/or competition from exotic species causing declines in native species richness. Our data is consistent with other studies which show that the presence of Kentucky bluegrass and smooth brome is often correlated with declines in native species richness (Miles and Knops 2009).

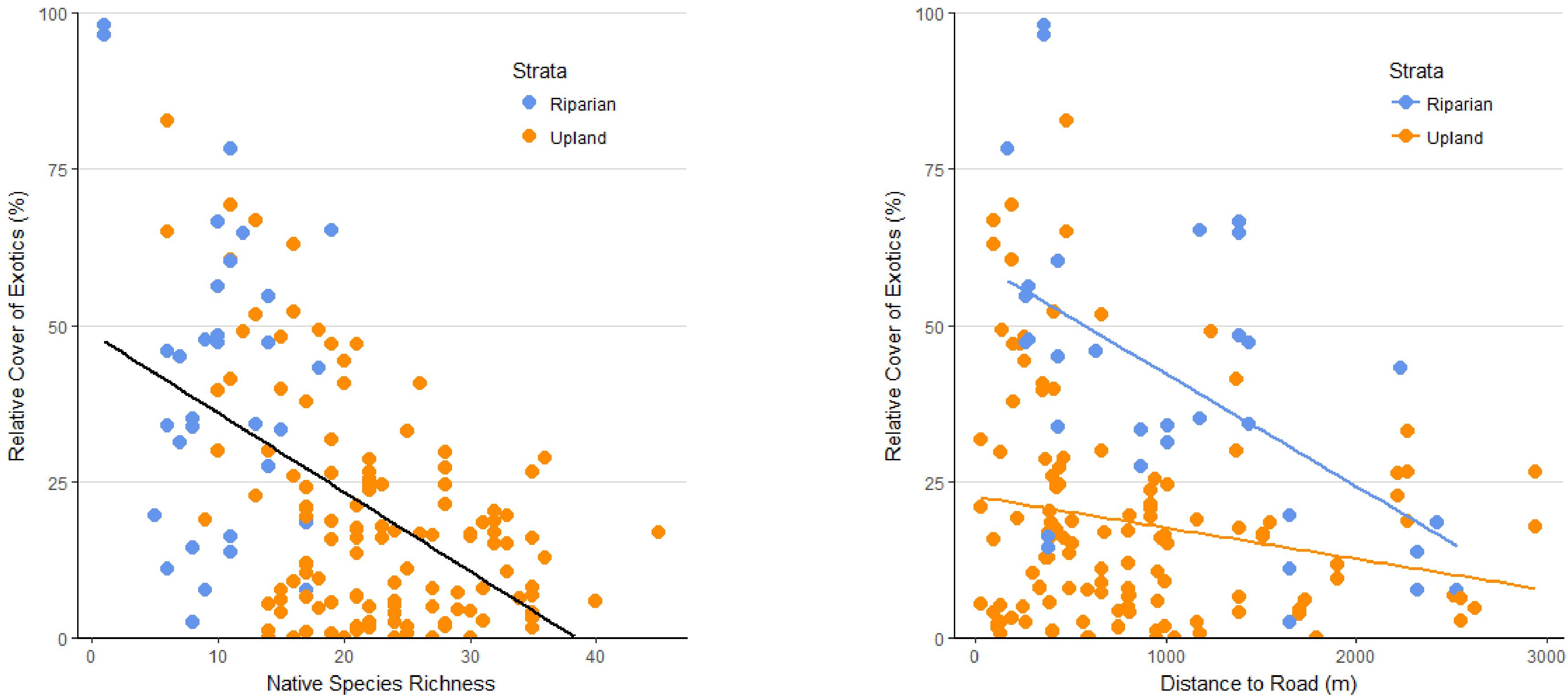

Figure 8. The relationship between the cover of exotic species in Theodore Roosevelt National park and native species richness (left) and distance to roads (right).

Disturbance is often linked to changes in native species richness and exotic species cover, but we did not find significant relationships in our dataset. We performed a brief assessment of disturbance at each plot, and have found a large variation in the amount and types of disturbance across plots. The most common sources of disturbance were animal trails and grazing, but both were only observed in approximately 25% of site visits. Over time, we hope our data can better elucidate patterns between species richness, exotic cover, and disturbance. While we did not find any significant relationships between these factors and our field measures of disturbance, we did find a significant relationship between exotic cover and distance to roads (Figure 8). Plots further from roads had lower cover of exotic species, and this relationship was strongest in riparian areas (Figure 8; significant interaction term $F_{1,133}$=6.9, P=0.0097). This suggests that targeted management actions concentrated along road corridors could be effective at reducing the overall cover of exotic species in the park. However, it is important to note that there were many exceptions to the pattern including plots located more than 2000 m from the nearest road that still had high exotic species cover (Figure 8; right).

Rare Plants

While our monitoring protocol was not designed to survey rare plants or to detect changes in their populations over time, we identified several rare plant species in long-term monitoring plots in THRO (Table 10). Smooth goosefoot (*Chenopodium subglabratum*), a critically imperiled species in North Dakota, was observed at a single plot in the North Unit of THRO in 2011. Smooth goosefoot is a small forb that is an early colonizer of disturbed soils and tends to grow in sandy areas along riverside sandbars and blowouts (Dorn 2001, FNA 2017). This plant is sparsely distributed throughout its range in North America (USDA-NRCS 2017).

Table 10. Rare plant species observed in long-term monitoring plots in Theodore Roosevelt National Park.

Scientific Name	Common Name	Status	Number of observations
Chenopodium subglabrum	Smooth goosefoot	S1/G3G4	1
*Phlox alyssifolia**	Alyssumleaf phlox	S1S2/G5	2
*Leucocrinum montanum**	Sand lily	S2/G5	3
Polygonum douglasii	Douglas' knotweed	S3/G5	2

Four remaining rare species were all observed in the South Unit of THRO. Alyssumleaf phlox (*Phlox alyssifolia*), a critically imperiled/imperiled species in North Dakota, was observed at one plot in 2009 and at a second plot in 2016. This small subshrub typically occurs on dry flats and grasslands and a distribution in the US that covers five states, but is mainly concentrated in Montana (Dorn 2001, NatureServe 2017). Sand lily (*Leucocrinum montanum*) is an imperiled forb in North Dakota and was observed in three plots in 2011. This forb is found on dry plains and in open forests, and is distributed across most of the Western US with greater concentrations in the Great Basin and Northern Rocky Mountain (Dorn 2001, USDA-NRCS 2017). Douglas' knotweed (*Polygonum douglasii*) was observed in one plot in 2011 and a different plot in 2013. This forb is commonly found growing in sandy, rocky soils that are frequently disturbed and can be distinguished from most other common knotweeds by its upright growth habit (Larson and Johnson 2007). Douglas' knotweed is more common and also less vulnerable in the states bordering North Dakota.

Alyssumleaf phlox and sand lily are not on the certified THRO species list and will be collected and sent for independent verification when (or if) they are identified again in THRO.

Trends in vegetation community composition and structure

Using the 2012-2016 dataset as a baseline for plant community conditions, we found that THRO has high species richness in upland areas and high exotic species cover park-wide (see above). We were interested in determining whether there have been changes in key metrics since data collection begain in 2010. We found that there has been a significant increase in exotic species cover in riparian areas (Figure 9, top-left; $F_{1,14}$=19.8, P<0.001) but no change over time in upland areas. Similar patterns were seen in both the North and South Unit. The increase in exotic cover in the riparian areas could be due to a number of factors including large flood events, reduced park management during that time period, or changes in fire regime. When we tested for trends in the cover of individual exotic species, we found no significnat change over time in the cover of sweet clover, leafy spurge, Canada thistle, or smooth brome. Kentucky bluegrass cover, however, has increased significantly over all areas of the park (Figure 9, top-right; $F_{1,73}$=14.0, P<0.001). While our data show that exotic species cover and Kentucky bluegrass cover are negatively correlated with native species richness (Figure 8), we did not find a corresponding decline in native richness over time. There has been a decline in species evenness in THRO (Figure 9, bottom-left; $F_{1,73}$ =8.1, P=0.0058), which suggests that there has been a shift in plant community composition.

The diversity and productivity of plant communities in the Northern Great Plains is affected by the dramatically shifting weather patterns of the Great Plains (Jonas et al. 2015). Although severe drought conditions existed in Billings and McKenzie Counties in the summer of 2012 and dry conditions in 2015 and 2016 (US Drought Monitor 2017), the directional trends seen in the vegetation in THRO (Figure 9) are not consistent with the cyclic changes in weather seen over the same time period. Continued long-term collection of monitoring data will be needed to better understand the complex relationships between climate and vegetation in THRO.

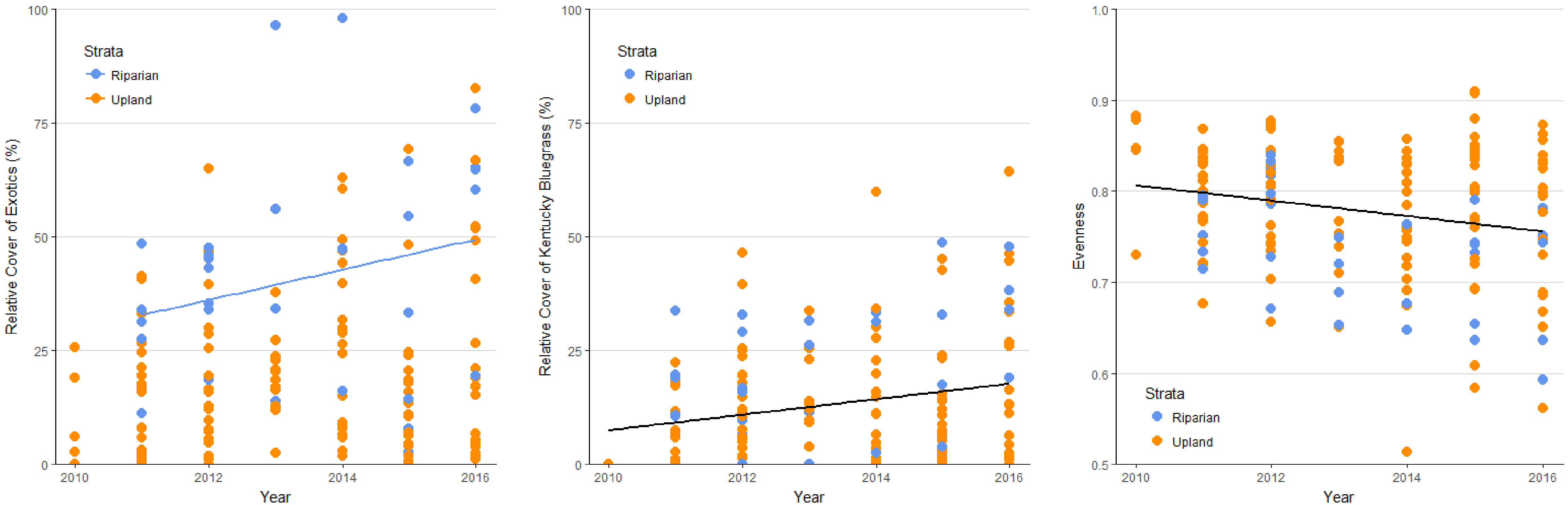

Figure 9. Scatterplots showing the changes from 2010 to 2017 at Theodore Roosevelt National Park in the cover of exotic species (top left), the relative cover of Kentucky bluegrass (top right), and species evenness (bottom left). Riparian plots visits are displayed as blue dots and upland visits are orange. The lines display significant relationships between the variables for riparian plots (blue line) or for all types of plots (black).

Upland Forest Condition

We measured tree and seedling densities in all the monitoring plots that had a tree or tall shrub within 38 m of the plot center. Many of these plots were grasslands and had few or no seedlings present but other plots were occupied by Rocky Mountain juniper, green ash, and cottonwood forests. Riparian areas with cottonwood trees were more thoroughly sampled in 2015 and results from that survey are described in the Riparian Forest Condition section of this report. Rocky Mountain juniper was the most common tree we encountered in THRO (Table 11a-b) occurring in roughly 30% of the plots visited in the South Unit and North Unit. Other species of mature trees or poles were relatively rare and were only observed in a handful of plots (Table 11a-b), and these deciduous tree and shrubs were often found growing with Rocky Mountain juniper (Figure 10). While the proportion of plots with trees present was similar across the two units, the density of trees was approximately two times greater in the North Unit (Table 12a-b). Seedlings and pole densities were similar across both units (Table 12a-b). We did not find any relationship between basal area or tree densities and relative exotic cover or native plant richness. This suggests that the patterns of exotic species abundance and species richness in THRO are similar across forested and grassland plots.

Table 11a. Live tree and tall shrub occurrence in the North Unit of Theodore Roosevelt National Park from 2010 – 2016 at 23 North Unit and 47 South Unit upland plots. (Trees: diameter at breast height (DBH) > 15 cm, poles: 2.54 cm ≤ DBH ≤ 15 cm, seedlings: DBH <2.54 cm.)

Species Name	Common Name	Number of plots with trees	Number of plots with poles	Number of plots with seedlings
Juniperus scopulorum	Rocky Mountain juniper	7	8	9
Fraxinus pennsylvanica	green ash	2	3	4
Amelanchier alnifolia	serviceberry	–	1	2
Sheperdia argentea	silver buffaloberry	–	0	0
Prunus virginana	chokecherry	–	1	9
North Unit all species		**8**	**8**	**11**

Table 11b. Live tree and tall shrub occurrence in the North Unit of Theodore Roosevelt National Park from 2010 – 2016 at 23 North Unit and 47 South Unit upland plots. (Trees: diameter at breast height (DBH) > 15 cm, poles: 2.54 cm ≤ DBH ≤ 15 cm, seedlings: DBH <2.54 cm.)

Species Name	Common Name	Number of plots with trees	Number of plots with poles	Number of plots with seedlings
Juniperus scopulorum	Rocky Mountain juniper	14	11	16
Fraxinus pennsylvanica	green ash	3	3	5
Amelanchier alnifolia	serviceberry	–	0	1
Sheperdia argentea	silver buffaloberry	–	2	5
Prunus virginana	chokecherry	–	0	9
South Unit all species		**15**	**12**	**20**

Figure 10. Long-term monitoring plot, THRON_013, had a large density of Rocky Mountain juniper and deciduous trees.

Table 12a. Tree basal area and density by size class for dominant tree and shrub species in the upland forests of the North Unit of Theodore Roosevelt National Park. Values are mean ± standard error of the mean across 11 North Unit plots and 20 South Unit plots with tree species present.

Species	Basal Area (m^2/ha)	Tree Density (stems/ha)	Pole Density (stems/ha)	Seedling Density (stems/ha)	Snag Density (stems/ha)
Rocky Mountain juniper	11.4 ± 3.1	167.3 ± 45.3	384.6 ± 159.4	84.1 ± 24.3	17.1 ± 8.9
Green ash	0.9 ± 0.6	11.3 ± 7.4	99.5 ± 64.4	46.6 ± 28.8	3.8 ± 2.6
North Unit all species	**12.4 ± 3.4**	**182.3 ± 48.8**	**488.1 ± 213.6**	**126.8 ± 59.3**	**23.3 ± 9.7**

Table 12b. Tree basal area and density by size class for dominant tree and shrub species in the upland forests of the South Unit of Theodore Roosevelt National Park. Values are mean ± standard error of the mean across 11 North Unit plots and 20 South Unit plots with tree species present.

Species	Basal Area (m^2/ha)	Tree Density (stems/ha)	Pole Density (stems/ha)	Seedling Density (stems/ha)	Snag Density (stems/ha)
Rocky Mountain juniper	5.4 ± 2.0	87.1 ± 34.2	123.8 ± 54.8	38.8 ± 11.3	15.6 ± 9.3
Green ash	0.3 ± 0.2	6.7 ± 4.0	18.3 ± 13.2	22.9 ± 11.4	1.5 ± 1.1
South Unit all species	**5.8 ± 2.0**	**93.8 ± 34.5**	**175.7 ± 58.4**	**110.8 ± 26.6**	**17.6 ± 9.1**

Riparian Forest Condition

In 2015, we visited 100 forest plots within the riparian corridor of the Little Missouri River to investigate forest and woodland condition (Figure 11 and 12). The riparian vegetation communities within THRO are diverse and include mature cottonwood forests, sagebrush shrublands, and dense willow communities (Figure 13). The vegetation types observed in the 50 plots in the North (Figure 11) and South Units (Figure 12) are indicative of this diversity. This monitoring was intended to characterize the entire range of vegetation types within the riparian corridor rather than focusing on cottonwood forests. For more specific information regarding the current condition and management of cottonwood forests in THRO, see the recent report by Friedman and Griffin (2017).

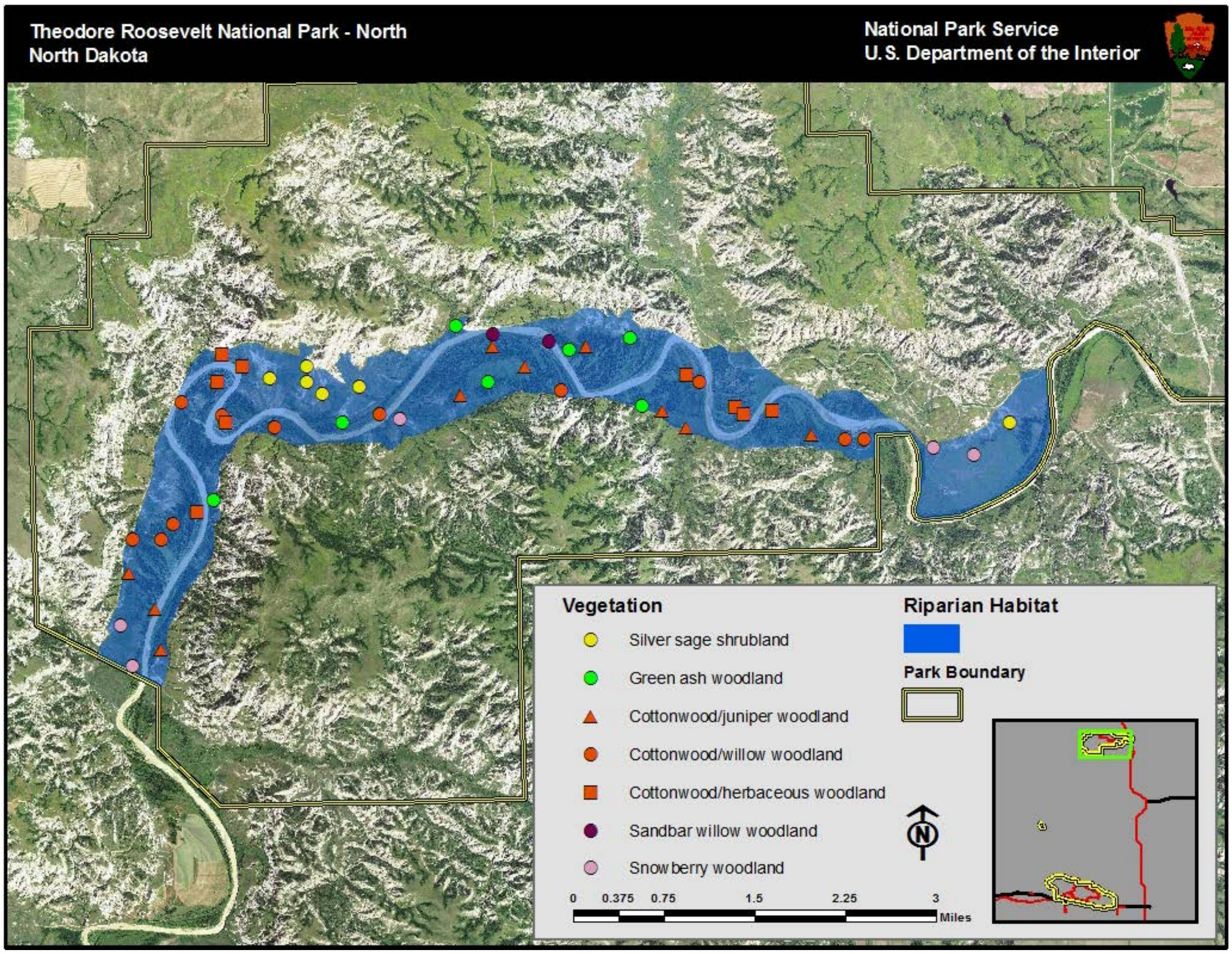

Figure 11. Map of the 50 monitoring location in the North Unit of Theodore Roosevelt National Park Service visited in 2015. The plots fall within the diverse vegetation types found in the riparian corridor.

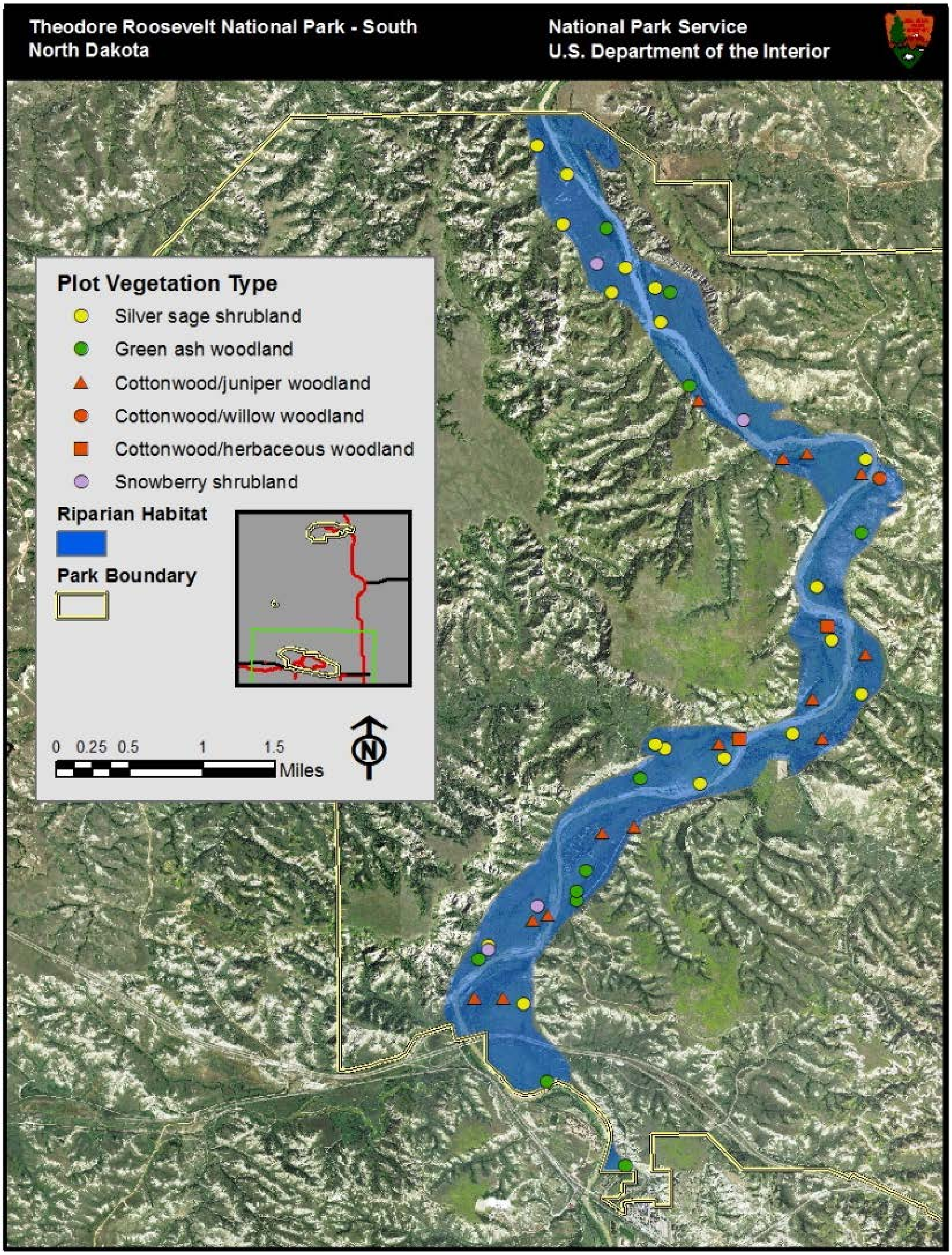

Figure 12. Map of the 50 monitoring location in the South Unit of Theodore Roosevelt National Park Service visited in 2015. The plots fall within the diverse vegetation types found in the riparian corridor.

Figure 1. Examples of several riparian forest types observed at Theodore Roosevelt National Park.

Monitoring plots were randomly located within the riparian zone but sampled only when a tree or tall shrub species was present within 38 m of plot center. This sampling approach resulted in many plots having no trees located within the sampling area since sampling is limited to a 10 or 20 m radius from plot center (rather than 38 m). This was particularly true in the South Unit where forests are less dense compared to North Unit forests. While this may limit the inferences we can make about riparian tree condition and health, this monitoring design provides a more representative sample of the riparian corridor and allows us to better track landscape-scale changes in riparian forests over time. All of the plots installed for this riparian corridor monitoring, including those with no trees, have the potential (i.e. appropriate habitat, seedlings, and nearby propagule sources) to support a least some species of trees and/or tall shrubs (e.g. juniper, ash, and chokecherry). We found 44 plots within the North unit and 32 in the South Unit that had at least one tree, seedling, or pole present. Of these plots, most had all age classes present (trees, seedlings, and poles were present in 51 plots). Seedlings were rarely found (9 plots) and poles were never found without mature trees present. This suggests that for most tree and shrub species, the spread and growth of forests will most likely be observed adjacent to existing tree stands. Cottonwoods, on the other hand, are most likely to become established on sandy point bars along the river following scouring and deposition during flood events, since seeds require wet, unvegetated soils for germination (Friedman and Griffin 2017).

Forests were primarily composed of plains cottonwood, Rocky Mountain juniper, and green ash trees in both units of THRO, though the dominant species differed between units (Tables 13-16). Cottonwood was the dominant tree species in the North Unit, where mature trees were observed in greater frequency, density, and basal area cover than other tree species (Table 13 and 15). In the South Unit, mature juniper trees were observed in greater frequency and density than other tree species, and juniper, ash, and cottonwoods occupied a similar basal area (Table 14 and 16). Overall woody riparian species richness was greater in the North Unit compared with the South Unit (10 and 7 species, respectively), and willows were only observed in North Unit plots. The establishment of cottonwood forests in THRO is driven by the flood regime of the Little Missouri River. Seedlings germinate in the fresh deposits and sand bars along the river edge, and as the river channel migrates and sediment is deposited, bands of adult trees are found at increasing distances from the main channel (Friedman and Griffin 2017). Although there were fewer cottonwoods in the South Unit, our survey data was consistent with this successional pattern. Cottonwood seedling density decreased with increasing distance from the river ($F_{1,97}$=10.0, P=0.002) and trees show the opposite pattern with densities generally increasing with distance ($F_{1,97}$=4.1, P=0.046).

Cottonwood vigor, which is the percent of the cottonwood canopy that has green foliage, was higher in the North Unit (94% green compared to 86% in the South Unit), but we could not test for a statistical difference due to the low number of plots occupied by cottonwood trees in the South Unit (eight total). Cottonwood trees were 60% less frequent and covered 61% less basal area in the South Unit. Also, mature cottonwoods, young cottonwoods (poles), and cottonwood seedlings were all at least half as dense in the South Unit (70%, 89%, and 56% less dense, respectively). Finally, the density of dead cottonwood trees (snags) was six times greater in the South Unit (Table 15 and 16). These data suggest there has been a general decline of cottonwood forest condition in the South Unit, and this is consistent with the findings of a recent study on cottonwood forest condition in THRO (Friedman and Griffin 2017).

Table 13. Tree and tall shrub occurrence in 2015 at 50 plots in Theodore Roosevelt National Park-North Unit. (Trees: diameter at breast height (DBH) > 15 cm, poles: 2.54 cm ≤ DBH ≤ 15 cm, seedlings: DBH <2.54 cm.)

Species Name	Common Name	Number of plots with trees	Number of plots with poles	Number of plots with seedlings
Populus deltiodes	plains cottonwood	26	8	8
Juniperus scopulorum	Rocky Mountain juniper	18	20	22
Fraxinus pennsylvanica	green ash	9	14	33
Salix lucida	shining willow	2	5	6
Sheperdia argentea	silver buffaloberry	1	4	4
Acer negundo	boxelder	0	0	1
Prunus virginana	chokecherry	0	8	18
Salix eriocephala	Missouri river willow	0	1	5
Salix exigua	narrowleaf willow	0	3	7
Ulmus americana	American elm	0	1	3

Table 14. Tree and tall shrub occurrence in 2015 at 50 plots in Theodore Roosevelt National Park-South Unit. (Trees: diameter at breast height (DBH) > 15 cm, poles: 2.54 cm ≤ DBH ≤ 15 cm, seedlings: DBH <2.54 cm.)

Species Name	Common Name	Number of plots with trees	Number of plots with poles	Number of plots with seedlings
Juniperus scopulorum	Rocky Mountain juniper	13	19	13
Fraxinus pennsylvanica	green ash	11	11	22
Populus deltiodes	plains cottonwood	8	2	4
Amelanchier alnifolia	serviceberry	0	0	3
Sheperdia argentea	silver buffaloberry	0	5	2
Acer negundo	boxelder	0	0	1
Prunus virginana	chokecherry	0	5	18

Table 15. Tree basal area and density by size class for dominant tree and shrub species in the riparian forest of Theodore Roosevelt National Park-North Unit. (Values: mean across 20 riparian forest monitoring ± standard error of the mean)

Species	Basal Area (m^2/ha)	Tree Density (stems/ha)	Pole Density (stems/ha)	Seedling Density (stems/ha)	Snag Density (stems/ha)
Populus deltiodes	7.1 ± 1.4	64.1 ± 17.2	35 ± 14.7	11.5 ± 4.8	0.6 ± 0.6
Juniperus scopulorum	2.0 ± 0.5	37.5 ± 10.5	84.1 ± 26	27.4 ± 5.5	4.8 ± 2.2
Fraxinus pennsylvanica	1.4 ± 0.7	23.2 ± 12.2	70.1 ± 29.4	77.9 ± 10.3	3.2 ± 2.1
Salix species	0.6 ± 0.3	2.5 ± 2	415.3 ± 305.7	31.7 ± 14.6	0.6 ± 0.6
Other tree species	0 ± 0	0 ± 0	0.6 ± 0.6	5.1 ± 3.2	0 ± 0
Other tall shrub species	0.1+0.0	0.6+0.6	45.8 ± 27.3	37.8 ± 9.6	0 ± 0

Table 16. Tree basal area and density by size class for dominant tree and shrub species in the riparian forest of Theodore Roosevelt National Park-South Unit. (Values: mean across 20 riparian forest monitoring ± standard error of the mean)

Species	Basal Area (m^2/ha)	Tree Density (stems/ha)	Pole Density (stems/ha)	Seedling Density (stems/ha)	Snag Density (stems/ha)
Populus deltiodes	2.8 ± 1.2	19.6 ± 9	3.8 ± 2.7	5.1 ± 2.6	3.7 ± 1.9
Juniperus scopulorum	2.1 ± 0.7	33.8 ± 12.3	61.8 ± 28.4	18.5 ± 5.2	0.6 ± 0.6
Fraxinus pennsylvanica	1.2 ± 0.4	22.6 ± 7.7	56.1 ± 19.8	57.3 ± 11.5	6.1 ± 2.2
Salix species	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Other tree species	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.6 ± 0.6	0.0 ± 0.0
Other tall shrub species	0.2 ± 0.1	2.7 ± 1.8	25.5 ± 14.4	38.2 ± 11.7	0.8 ± 0.7

One of the threats to the herbaceous component of riparian forests in the Missouri River watershed is the spread of exotic species (Johnson et al. 2012). Preventing the spread and persistence of exotic plants can be challenging and exotic plant management activities, such as widespread herbicide application, can affect the survival and health of tree species (Friedman and Griffin 2017). The establishment of invasive trees, such as saltcedar, are particularly problematic because these species can alter water tables, fire frequency, and animal and plant diversity (Di Tomaso 1998). One of the first steps to managing exotic species is to map their current extent. Although a full exotic plant map of the riparian forests is beyond the scope of our monitoring study, we recorded the cover of exotic target species within all 100 plots (Table 15). Maps in Appendix D show cover classes for the 3 species most commonly recorded (leafy spurge, smooth brome, and Canada thistle) at each plot in the North and South Unit. We did not find either invasive tree species, saltcedar or Russian olive, in our plots at THRO.

Generally, exotic species were more abundant in the South Unit (Table 17, total target species). Leafy spurge and smooth brome were significantly more abundant in the South Unit, while cover of Canada thistle was similar in both units (Table 17). Japanese brome was recorded only in the South

Unit. We did not find a statistically significant relationship between exotic cover (for individual species and total cover) and the distance to road or trails. This is in contrast to upland plots where exotic cover declined further from roads (Figure 8). The difference may be due to the narrow corridor the riparian plots fell within in, the lower sample size, and/or the more qualitative measures of target species abundance in the riparian survey (cover class versus point-intercept).

Table 17. Differences in target species cover in the North and South units of Theodore Roosevelt National Park.

Species	North Unit (# plots)	South Unit (# plots)	North Unit Average cover	South Unit Average cover	Den DF	F	*p*
Leafy spurge	20	38	1.5 ± 0.3	2.8 ± 0.3	98	11.18	**<0.01**
Canada thistle	18	19	0.8 ± 0.2	1.1 ± 0.2	98	1.13	0.28
Smooth brome	15	33	1.6 ± 0.3	2.8 ± 0.3	98	6.92	**>0.01**
Japanese brome	0	1	n/a	>0.1 ± 0.0	n/a	n/a	n/a
Total target species	**35**	**42**	**1.0 ± 0.1**	**1.7 ± 0.1**	**98**	**13.32**	**<<0.01**

To explore whether exotic species are reducing native tree seedling establishment, we examined the relationship between seedling densities and exotic cover class. Contrary to our expectation, we found a positive relationship between cottonwood seedling and tree density and exotic cover class ($F_{1,97}$=14.8, P<0.001 and $F_{1,97}$=8.8, P=0.004, respectively) and green ash seedling density and exotic cover class ($F_{1,97}$=6.1, P=0.015). There are a few potential explanations for this pattern. First, one of the management tools used to reduce the spread and abundance of exotic species in THRO has been aerial herbicide application. Helicopter spraying has been focused in areas where cottonwoods are not present to avoid potential damage to adult trees (Friedman and Griffin 2017). It could therefore be that exotic cover is significantly higher in forested areas where there are not as many effective treatment options. Alternatively, disturbed areas which promote seedling establishment could also promote weedy species and the growth and germination of both trees and exotic species could be responding positively to increased nutrients or moisture. Finally, it is likely that forest conditions in THRO are being more severely impacted by changes in flood frequency and intensity, exotic pests and diseases, and invasive tree species rather than by direct competition from herbaceous exotic species (J.M. Freidman, personal communication).

In summary, 2015 was the first visit to 100 riparian plots in THRO and can provide a glimpse of forest condition at that time. In general, we found that the North Unit has more cottonwood forest, a more diverse tree assemblage, and lower exotic species cover in the understory than the South Unit. Because this monitoring is unique and includes a range of forest types, it is not directly comparable to past work in THRO. However, these data will be used as a baseline and when the sites are revisited in 2020 and every five years thereafter, we will be able to determine how these forest are changing over time.

Conclusions

The Northern Great Plains Inventory and Monitoring Network (NGPN) and the Northern Great Plains Fire Ecology Group (FireEP) have monitored vegetation at randomly located plots in THRO from 2010-2016. Field crews captured data relating to species richness, herb-layer height, and abundance of individual native and non-native species, ground cover, seedling and tree densities, and site disturbance at 81 plots in the North and South Unit and across 162 plot visits. In addition to annual monitoring, NGPN also surveyed riparian forest condition in 2015 at 100 randomly located plots. We collected data on tree and seedling density, tree condition, disturbance, and the presence of exotic species of management concern, such as leafy spurge and Canada thistle.

Monitoring crews identified 361 vascular plant species over that time period, with an average of 9 native species occurring within any given 1 m^2 quadrat. This species richness is comparable to species richness found in native prairie in the region, indicating that the park upland vegetation is in good condition. Grasses, sedges, and forbs make up the majority of plant cover, while non-native species comprise about 24% of cover. Native plant diversity in upland areas is considerably higher and exotic plant cover lower, when compared with riparian areas. There is a general trend of increasing exotic cover over time in riparian habitat, while Kentucky bluegrass is increasing in all areas of the park, and exotic plant cover is significantly greater closer to roadways. Both units show similar patterns in herbaceous vegetation, but juniper trees are more common and forests are denser in the North Unit. Finally, we found that North Unit riparian forests have denser and more widespread cottonwood forests, a more diverse tree assemblage, and lower herbaceous exotic species when compared with South Unit riparian forests. The South Unit has a much larger density of cottonwood snags, suggesting recent declines in forest condition. Overall, the park's vegetation seems to be in good condition, though exotic plants and declines in cottonwood forests in the South Unit pose a significant challenge to park management.

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Appendix A: Monitoring visits at Plant Community Plots in Theodore Roosevelt National Park

A table of monitoring activities in the North Unit of THRO at Plant Community Monitoring Plots from 2010-206. Reads are designated as FS= Forest Structure, PC= Plant Community, FX= Fire Effects

North Unit Plot	2010	2011	2012	2013	2014	2015	2016
THRON_FPCM_051	–	–	–	–	FX	–	–
THRON_FPCM_071	–	–	–	–	FX	–	–
THRON_FPCM_075	–	–	–	–	FX	–	–
THRON_FPCM_103	FX	–	–	–	–	–	–
THRON_FPCM_107	FX	–	–	–	–	–	–
THRON_FPCM_113	–	–	–	–	FX	–	–
THRON_FPCM_167	FX	–	–	–	–	–	–
THRON_PCM_001	–	PC	PC	–	–	–	PC
THRON_PCM_004	–	–	PC	PC	–	–	–
THRON_PCM_005	–	–	PC	PC	–	–	–
THRON_PCM_006	–	–	PC	–	–	–	–
THRON_PCM_007	FX	–	–	PC	–	–	–
THRON_PCM_008	–	–	–	PC	PC	–	–
THRON_PCM_011	–	–	–	–	PC	PC	–
THRON_PCM_013	–	PC	–	–	–	–	–
THRON_PCM_015	–	PC	–	–	–	PC	PC
THRON_PCM_016	–	–	–	–	–	–	PC
THRON_PCM_032	–	PC	PC	–	–	–	PC
THRON_PCM_033	FX	PC	PC	–	–	–	–
THRON_PCM_035	–	–	–	–	PC	PC	–
THRON_PCM_038	–	PC	–	–	–	PC	–
THRON_PCM_042	–	–	–	–	–	–	PC
THRON_PCM_513	–	FS	PC	–	–	FS	PC
THRON_PCM_514	–	–	PC	–	–	FS	–
THRON_PCM_515	–	–	PC	PC	–	FS	–
THRON_PCM_517	–	–	–	PC	PC	FS	–
THRON_PCM_518	–	–	–	–	–	FS	–
THRON_PCM_519	–	–	–	–	–	PC	–
THRON_PCM_520	–	–	–	–	–	FS	–
THRON_PCM_521	–	PC	–	–	–	PC	PC
THRON_PCM_522	–	–	–	–	–	FS	–
THRON_PCM_523	–	–	–	–	–	FS	PC
THRON_PCM_524	–	–	–	–	–	FS	–
THRON_PCM_525	–	–	–	–	–	FS	–
THRON_PCM_527	–	–	–	–	–	FS	–
THRON_PCM_529	–	–	–	–	–	FS	–
THRON_PCM_531	–	–	–	–	–	FS	–

North Unit Plot	2010	2011	2012	2013	2014	2015	2016
THRON_PCM_532	–	–	–	–	–	FS	–
THRON_PCM_533	–	–	PC	–	–	FS	–
THRON_PCM_534	–	–	–	–	–	FS	–
THRON_PCM_535	–	–	–	–	–	FS	–
THRON_PCM_536	–	–	–	–	–	FS	–
THRON_PCM_537	–	–	–	–	–	FS	–
THRON_PCM_538	–	–	–	–	–	FS	–
THRON_PCM_539	–	–	–	–	–	FS	–
THRON_PCM_541	–	–	–	–	–	FS	–
THRON_PCM_542	–	–	–	–	–	FS	–
THRON_PCM_544	–	–	–	–	–	FS	–
THRON_PCM_545	–	–	–	–	–	FS	–
THRON_PCM_546	–	–	–	–	–	FS	–
THRON_PCM_547	–	–	–	–	–	FS	–
THRON_PCM_548	–	–	–	–	–	FS	–
THRON_PCM_549	–	–	–	–	–	FS	–
THRON_PCM_551	–	–	–	–	–	FS	–
THRON_PCM_552	–	–	–	–	–	FS	–
THRON_PCM_555	–	–	–	–	–	FS	–
THRON_PCM_556	–	–	–	–	–	FS	–
THRON_PCM_557	–	–	–	–	–	FS	–
THRON_PCM_558	–	–	–	–	–	FS	–
THRON_PCM_559	–	–	–	–	–	FS	–
THRON_PCM_560	–	–	–	–	–	FS	–
THRON_PCM_561	–	–	–	–	–	FS	–
THRON_PCM_562	–	–	–	–	–	FS	–
THRON_PCM_563	–	–	–	–	–	FS	–
THRON_PCM_564	–	–	–	–	–	FS	–
THRON_PCM_565	–	–	–	–	–	FS	–
THRON_PCM_566	–	–	–	–	–	FS	–
THRON_PCM_568	–	–	–	–	–	FS	–
THRON_PCM_569	–	–	–	–	–	FS	–
THRON_PCM_570	–	–	–	–	–	FS	–
THRON_PCM_571	–	–	–	–	–	FS	–
THRON_PCM_572	–	–	–	–	–	FS	–

Plant community monitoring activities in the South Unit of THRO, 2011-2016. Reads are designated as FS= Forest Structure, PC= Plant Community, FX= Fire Effects

South Unit Plot	2011	2012	2013	2014	2015	2016
THROS_FPCM_0096	–	–	–	–	FX	–
THROS_FPCM_0105	–	–	–	–	FX	–
THROS_FPCM_0154	–	–	–	FX	–	FX
THROS_FPCM_0172	FX	–	–	FX	FX	–
THROS_FPCM_0174	FX	–	–	–	–	–
THROS_FPCM_0211	FX	–	–	FX	FX	–
THROS_FPCM_0248	FX	–	–	FX	FX	–
THROS_FPCM_0549	–	FX	–	–	–	–
THROS_FPCM_0565	–	FX	–	–	–	–
THROS_PCM_0001	PC	PC	–	–	–	PC
THROS_PCM_0003	PC	PC	–	–	–	PC
THROS_PCM_0004	PC	PC	–	–	–	–
THROS_PCM_0005	PC	PC	–	–	–	–
THROS_PCM_0006	PC	PC	–	–	–	–
THROS_PCM_0008	–	PC	PC	–	–	–
THROS_PCM_0009	–	PC	PC	–	–	–
THROS_PCM_0010	–	PC	PC	–	–	–
THROS_PCM_0011	–	PC	–	–	–	–
THROS_PCM_0012	FX	PC	PC	–	–	–
THROS_PCM_0013	–	PC	–	–	–	FX
THROS_PCM_0014	–	PC	–	–	–	–
THROS_PCM_0015	–	–	PC	–	–	–
THROS_PCM_0017	–	FX	PC	PC	–	–
THROS_PCM_0018	–	–	PC	PC	–	–
THROS_PCM_0019	–	–	PC	–	–	–
THROS_PCM_0023	–	–	–	PC	PC	–
THROS_PCM_0024	–	–	–	PC	PC	–
THROS_PCM_0025	–	–	–	–	PC	–
THROS_PCM_0026	–	–	–	PC	PC	–
THROS_PCM_0028	–	–	–	–	PC	–
THROS_PCM_0030	PC	–	–	–	PC	–
THROS_PCM_0031	PC	–	–	–	PC	PC
THROS_PCM_0032	–	–	–	–	PC	PC
THROS_PCM_0033	PC	–	–	–	PC	PC
THROS_PCM_0034	PC	–	–	–	PC	PC
THROS_PCM_0035	PC	–	–	–	PC	PC
THROS_PCM_0036	–	–	–	–	–	PC
THROS_PCM_0037	–	–	–	–	–	PC

South Unit Plot	2011	2012	2013	2014	2015	2016
THROS_PCM_0041	–	–	–	–	FX	PC
THROS_PCM_0044	–	–	–	–	FX	–
THROS_PCM_0058	–	–	–	FX	–	FX
THROS_PCM_0069	–	–	–	–	FX	–
THROS_PCM_0072	–	PC	–	–	–	PC
THROS_PCM_0073	–	–	PC	PC	–	–
THROS_PCM_0074	–	–	–	–	–	–
THROS_PCM_0075	–	–	–	PC	PC	–
THROS_PCM_0076	FX	–	–	FX	FX/PC	–
THROS_PCM_0077	–	–	–	FX	–	PC
THROS_PCM_1025	PC	PC	–	–	FS	PC
THROS_PCM_1026	PC	PC	–	–	–	–
THROS_PCM_1027	–	PC	PC	–	FS	–
THROS_PCM_1028	–	PC	–	–	FS	–
THROS_PCM_1030	–	–	–	–	FS	–
THROS_PCM_1031	–	–	–	PC	PC	–
THROS_PCM_1032	–	–	–	PC	PC	–
THROS_PCM_1033	PC	–	–	–	PC	PC
THROS_PCM_1034	PC	–	–	–	PC	–
THROS_PCM_1035	–	–	–	–	FS	–
THROS_PCM_1037	–	–	–	–	FS	–
THROS_PCM_1040	–	–	–	–	FS	–
THROS_PCM_1041	–	–	–	–	FS	–
THROS_PCM_1042	–	–	–	–	FS	–
THROS_PCM_1043	–	–	–	–	FS	–
THROS_PCM_1044	–	–	–	–	FS	–
THROS_PCM_1047	–	–	PC	PC	FS	–
THROS_PCM_1048	–	–	–	–	FS	–
THROS_PCM_1050	–	–	–	–	FS	–
THROS_PCM_1051	–	–	–	–	FS	–
THROS_PCM_1052	–	–	–	–	FS	–
THROS_PCM_1054	–	–	–	–	FS	–
THROS_PCM_1055	–	–	–	–	FS	–
THROS_PCM_1057	–	–	–	–	FS	–
THROS_PCM_1058	–	–	–	–	FS	–
THROS_PCM_1059	–	–	–	–	FS	–
THROS_PCM_1060	–	–	–	–	FS	–
THROS_PCM_1061	–	–	–	–	FS	–
THROS_PCM_1062	–	–	–	–	FS	–
THROS_PCM_1064	–	–	–	–	FS	–

South Unit Plot	2011	2012	2013	2014	2015	2016
THROS_PCM_1066	–	–	–	–	FS	–
THROS_PCM_1067	–	–	–	–	FS	–
THROS_PCM_1068	–	–	–	–	FS	–
THROS_PCM_1070	–	–	–	–	FS	–
THROS_PCM_1071	–	–	–	–	FS	–
THROS_PCM_1072	–	–	–	–	FS	–
THROS_PCM_1073	–	–	–	–	FS	–
THROS_PCM_1074	–	–	–	–	FS	–
THROS_PCM_1076	–	–	–	–	FS	–
THROS_PCM_1077	–	–	–	–	FS	–
THROS_PCM_1079	–	–	–	–	FS	–
THROS_PCM_1080	–	–	–	–	FS	–
THROS_PCM_1081	–	–	–	–	FS	–
THROS_PCM_1083	–	–	–	–	FS	–
THROS_PCM_1084	–	–	–	–	FS	–
THROS_PCM_1085	–	–	–	–	FS	–
THROS_PCM_1086	–	–	–	–	FS	–
THROS_PCM_1088	–	–	–	–	FS	–
THROS_PCM_1089	–	–	–	–	FS	–
THROS_PCM_1090	–	–	–	–	FS	–
THROS_PCM_1091	–	–	–	–	FS	–

Appendix B: List of plant species found at Theodore Roosevelt National Park

Below is a list of all the plant species found in THRO long-term plant community monitoring plots. This includes all the species found since 1997 in NGPN monitoring plots and the species found in plots monitored by the Fire Ecology Program. 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. An ND indicates the species is on North Dakota's state list of noxious weeds, and ND-B and ND-M indicate species classified as noxious in Billings and McKenzie counties where the South and North units of THRO are located, respectively. Rare species are indicated with their NatureServe conservancy score (S1-S3). The species with an asterisk (*) are not on the THRO certified species list.

Family	Symbol	Scientific Name	Common Name	Exotic	Rare
Aceraceae	ACNE2	*Acer negundo*	boxelder	–	–
Agavaceae	YUGL	*Yucca glauca*	soapweed yucca	–	–
Anacardiaceae	RHTR	*Rhus trilobata*	skunkbush sumac	–	–
	TORY	*Toxicodendron rydbergii*	western poison ivy	–	–
Apiaceae	CYGL99	*Cymopterus glomeratus*	plains springparsley	–	–
	LOFO	*Lomatium foeniculaceum*	desert biscuitroot	–	–
Apocynaceae	APAN2	*Apocynum androsaemifolium*	spreading dogbane	–	–
	APCA	*Apocynum cannabinum*	common dogbane	–	–
Asclepiadaceae	ASCLE	*Asclepias spp.*	milkweed	–	–
	ASOV*	*Asclepias ovalifolia**	oval-leaf milkweed*	–	–
	ASPU	*Asclepias pumila*	plains milkweed	–	–
	ASSP	*Asclepias speciosa*	showy milkweed	–	–
	ASVE	*Asclepias verticillata*	whorled milkweed	–	–
	ASVI	*Asclepias viridiflora*	green comet milkweed	–	–
Asteraceae	ACMI2	*Achillea millefolium*	common yarrow	–	–
	AMAR2	*Ambrosia artemisiifolia*	common ragweed	X	–
	AMPS	*Ambrosia psilostachya*	Cuman ragweed	–	–
	AMTR	*Ambrosia trifida*	great ragweed	–	–
	ANMI3	*Antennaria microphylla*	littleleaf pussytoes	–	–
	ANPA4	*Antennaria parvifolia*	small-leaf pussytoes	–	–
	ANPA9	*Antennaria parlinii*	Parlin's pussytoes	–	–
	ANTEN	*Antennaria spp.*	pussytoes	–	–
	ARAB3	*Artemisia absinthium*	absinth wormwood	ND	–
	ARBI2	*Artemisia biennis*	biennial sagewort	X	–
	ARCA12	*Artemisia campestris*	field sagewort	–	–
	ARCA13	*Artemisia cana*	silver sagebrush	–	–
	ARDR4	*Artemisia dracunculus*	tarragon	–	–
	ARFR4	*Artemisia frigida*	fringed sagewort	–	–
	ARLO7	*Artemisia longifolia*	longleaf sagebrush	–	–
	ARLU	*Artemisia ludoviciana*	white sagebrush	–	–
	ARMI2	*Arctium minus*	common burdock	ND-B,M	–
	ARTR2	*Artemisia tridentata*	big sagebrush	–	–

Family	Symbol	Scientific Name	Common Name	Exotic	Rare
	BREU	*Brickellia eupatorioides*	false boneset	–	–
Asteraceae (continued)	CIAR4	*Cirsium arvense*	Canada thistle	ND	–
	CIFL	*Cirsium flodmanii*	Flodman's thistle	–	–
	CIRSI	*Cirsium spp.*	thistle	X	–
	CIUN	*Cirsium undulatum*	wavyleaf thistle	–	–
	COCA5	*Conyza canadensis*	horseweed	–	–
	CORA4	*Conyza ramosissima*	dwarf horseweed	–	–
	CRRU3	*Crepis runcinata*	fiddleleaf hawksbeard	–	–
	CYXA	*Cyclachaena xanthifolia*	giant sumpweed	–	–
	DICA18	*Dieteria canescens*	hoary tansyaster	–	–
	DYPA	*Dyssodia papposa*	fetid marigold	–	–
	ECAN2	*Echinacea angustifolia*	blacksamson echinacea	–	–
	ERCA4	*Erigeron canus*	hoary fleabane	–	–
	ERGL2	*Erigeron glabellus*	streamside fleabane	–	–
	ERIGE2	*Erigeron spp.*	fleabane	–	–
	ERNA10	*Ericameria nauseosa*	rubber rabbitbrush	–	–
	ERST3	*Erigeron strigosus*	prairie fleabane	–	–
	ERSU2	*Erigeron subtrinervis*	threenerve fleabane	–	–
	GRSQ	*Grindelia squarrosa*	curlycup gumweed	–	–
	GUSA2	*Gutierrezia sarothrae*	broom snakeweed	–	–
	HEAN3	*Helianthus annuus*	common sunflower	–	–
	HELIA3	*Helianthus spp.*	sunflower	–	–
	HEMA2	*Helianthus maximiliani*	Maximilian sunflower	–	–
	HEPA19	*Helianthus pauciflorus*	stiff sunflower	–	–
	HEPE	*Helianthus petiolaris*	prairie sunflower	–	–
	HEVI4	*Heterotheca villosa*	hairy false goldenaster	–	–
	HYFI	*Hymenopappus filifolius*	fineleaf hymenopappus	–	–
	IVAX	*Iva axillaris*	povertyweed	–	–
	LASE	*Lactuca serriola*	prickly lettuce	X	–
	LIPU	*Liatris punctata*	dotted blazing star	–	–
	LOAR5*	*Logfia arvensis**	field cottonrose*	X	–
	LYJU	*Lygodesmia juncea*	rush skeletonplant	–	–
	MUOB99	*Mulgedium oblongifolium*	blue lettuce	–	–
	PACA15	*Packera cana*	woolly groundsel	–	–
	PAPL12	*Packera plattensis*	prairie groundsel	–	–
	RACO3	*Ratibida columnifera*	upright prairie coneflower	–	–
	RUHI2	*Rudbeckia hirta*	blackeyed Susan	–	–
	SENEC	*Senecio spp.*	ragwort	X	–
	SOAR2	*Sonchus arvensis*	field sowthistle	X	–
	SOCA6	*Solidago canadensis*	Canada goldenrod	–	–
	SOGI	*Solidago gigantea*	giant goldenrod	–	–
	SOLID	*Solidago spp.*	goldenrod	–	–
	SOMI2	*Solidago missouriensis*	Missouri goldenrod	–	–
	SOMO	*Solidago mollis*	velvety goldenrod	–	–

Family	Symbol	Scientific Name	Common Name	Exotic	Rare
	SONE	*Solidago nemoralis*	gray goldenrod	–	–
Asteraceae (continued)	SOPT4	*Solidago ptarmicoides*	prairie goldenrod	–	–
	SORI2	*Solidago rigida*	stiff goldenrod	–	–
	SOSP2*	*Solidago speciose**	showy goldenrod*	–	–
	SYER	*Symphyotrichum ericoides*	white heath aster	–	–
	SYLA3	*Symphyotrichum laeve*	smooth blue 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	–
	XASP99	*Xanthisma spinulosum*	lacy tansyaster	–	–
	XAST	*Xanthium strumarium*	cocklebur	–	–
Betulaceae	OSVI*	*Ostrya virginiana**	Hophornbeam*	–	–
Boraginaceae	CRCE	*Cryptantha celosioides*	buttecandle	–	–
	CYOF	*Cynoglossum officinale*	houndstongue	ND-B	–
	HADE	*Hackelia deflexa*	nodding stickseed	–	–
	LAOC3	*Lappula occidentalis*	flatspine stickseed	–	–
	LIIN2	*Lithospermum incisum*	narrowleaf stoneseed	–	–
	MELA3	*Mertensia lanceolata*	prairie bluebells	–	–
	ONBE	*Onosmodium bejariense*	soft-hair marbleseed	–	–
Brassicaceae	ALDE	*Alyssum desertorum*	desert madwort	X	–
	ARDR*	*Arabis drummondii**	Drummond's rockcress*	–	–
	ARHI	*Arabis hirsuta*	hairy rockcress	–	–
	BODI4	*Boechera divaricarpa*	spreadingpod rockcress	–	–
	BOHO99	*Boechera holboellii*	Holboell's rockcress	–	–
	CAMI2	*Camelina microcarpa*	littlepod false flax	X	–
	DEPI	*Descurainia pinnata*	western tansymustard	–	–
	DESO2	*Descurainia sophia*	herb sophia	X	–
	DRABA	*Draba spp.*	draba	–	–
	DRRE2	*Draba reptans*	Carolina draba	–	–
	ERCA14	*Erysimum capitatum*	sanddune wallflower	–	–
	ERCH9	*Erysimum cheiranthoides*	wormseed wallflower	X	–
	ERIN7	*Erysimum inconspicuum*	shy wallflower	–	–
	ERRE4*	*Erysimum repandum**	spreading wallflower*	X	–
	ERYSI	*Erysimum spp.*	wallflower	X	–
	LEDE	*Lepidium densiflorum*	common pepperweed	–	–
	PHAR99	*Physaria arenosa*	Great Plains bladderpod	–	–
	PHBR5	*Physaria brassicoides*	double twinpod	–	–
	PHLU99	*Physaria ludoviciana*	foothill bladderpod	–	–
	PHRE8	*Physaria reediana*	alpine bladderpod	–	–
	PHYSA2	*Physaria spp.*	twinpod	–	–
	SIAL2	*Sisymbrium altissimum*	tall tumblemustard	X	–

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	THAR5	*Thlaspi arvense*	field pennycress	X	–
Cactaceae	ESCOB	*Escobaria spp.*	foxtail cactus, beehive cactus	–	–
	ESVI2	*Escobaria vivipara*	spinystar	–	–
	OPFR	*Opuntia fragilis*	brittle pricklypear	–	–
	OPPO	*Opuntia polyacantha*	plains pricklypear	–	–
Campanulaceae	CARO2	*Campanula rotundifolia*	bluebell bellflower	–	–
	TRLE3	*Triodanis leptocarpa*	slimpod Venus' looking-glass	–	–
Capparaceae	PODO3	*Polanisia dodecandra*	redwhisker clammyweed	–	–
Caprifoliaceae	SYOC	*Symphoricarpos occidentalis*	western snowberry	–	–
Caryophyllaceae	CEAR4	*Cerastium arvense*	field chickweed	–	–
	CEBR3	*Cerastium brachypodum*	shortstalk chickweed	–	–
	CENU2	*Cerastium nutans*	nodding chickweed	–	–
	SIAN2	*Silene antirrhina*	sleepy silene	–	–
	SILA21	*Silene latifolia*	bladder campion	X	–
Celastraceae	CESC	*Celastrus scandens*	American bittersweet	–	–
Chenopodiaceae	ATCA2	*Atriplex canescens*	fourwing saltbush	–	–
	ATCO	*Atriplex confertifolia*	shadscale saltbush	–	–
	ATRIP	*Atriplex spp.*	saltbush	X	–
	CHAL7	*Chenopodium album*	lambsquarters	X	–
	CHBE4	*Chenopodium berlandieri*	pitseed goosefoot	–	–
	CHDE	*Chenopodium desiccatum*	aridland goosefoot	–	–
	CHENO	*Chenopodium spp.*	goosefoot	X	–
	CHFR3	*Chenopodium fremontii*	Fremont's goosefoot	–	–
	CHGL3	*Chenopodium glaucum*	oakleaf goosefoot	X	–
	CHPR5	*Chenopodium pratericola*	desert goosefoot	–	–
	CHSI2	*Chenopodium simplex*	mapleleaf goosefoot	–	–
	CHSU2	*Chenopodium subglabrum*	smooth goosefoot	–	S1
	KOSC	*Kochia scoparia*	burningbush, kochia	X	–
	KRLA2	*Krascheninnikovia lanata*	winterfat	–	–
	MONU	*Monolepis nuttalliana*	Nuttall's povertyweed	–	–
	SATR12	*Salsola tragus*	prickly Russian thistle	X	–
	SAVE4	*Sarcobatus vermiculatus*	greasewood	–	–
	SUCA2	*Suaeda calceoliformis*	Pursh seepweed	–	–
Commelinaceae	TRBR	*Tradescantia bracteata*	longbract spiderwort	–	–
Convolvulaceae	COAR4	*Convolvulus arvensis*	field bindweed	ND-B	–
Cornaceae	COSE16	*Cornus sericea*	redosier dogwood	–	–
Cupressaceae	JUCO6	*Juniperus communis*	common juniper	–	–
	JUHO2	*Juniperus horizontalis*	creeping juniper	–	–
	JUNIP	*Juniperus spp.*	juniper	–	–
	JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper	–	–
Cyperaceae	CABR10	*Carex brevior*	shortbeak sedge	–	–
	CADU6	*Carex duriuscula*	needleleaf sedge	–	–

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	CAEB2	*Carex eburnea*	bristleleaf sedge	–	–
Cyperaceae (continued)	CAFI	*Carex filifolia*	threadleaf sedge	–	–
	CAIN9	*Carex inops*	sun sedge	–	–
	CAREX	*Carex spp.*	sedge	–	–
	CASA9	*Carex saximontana*	Rocky Mountain sedge	–	–
	CASP7	*Carex sprengelii*	Sprengel's sedge	–	–
	CATO3	*Carex torreyi*	Torrey's sedge	–	–
	SCPU10	*Schoenoplectus pungens*	common threesquare	–	–
Dryopteridaceae	CYFR2	*Cystopteris fragilis*	brittle bladderfern	–	–
	WOOR	*Woodsia oregana*	Oregon cliff fern	–	–
Elaeagnaceae	SHAR	*Shepherdia argentea*	silver buffaloberry	–	–
Equisetaceae	EQAR	*Equisetum arvense*	field horsetail	–	–
	EQHY	*Equisetum hyemale*	scouringrush horsetail	–	–
	EQLA	*Equisetum laevigatum*	smooth horsetail	–	–
Euphorbiaceae	EUES	*Euphorbia esula*	leafy spurge	ND	–
	EUGL3	*Euphorbia glyptosperma*	ribseed sandmat	–	–
	EUMA7	*Euphorbia maculata*	spotted sandmat	–	–
	EUPHO	*Euphorbia spp.*	spurge, sandmat	X	–
	EUSE4	*Euphorbia serpens*	matted sandmat	–	–
	EUSP	*Euphorbia spathulata*	warty spurge	–	–
Fabaceae	ACAM99	*Acmispon americanus*	American bird's-foot trefoil	–	–
	ASAG2	*Astragalus agrestis*	purple milkvetch	–	–
	ASCI4*	*Astragalus cicer**	cicer milkvetch*	X	–
	ASFL2	*Astragalus flexuosus*	flexile milkvetch	–	–
	ASGI5	*Astragalus gilviflorus*	plains milkvetch	–	–
	ASGR3	*Astragalus gracilis**	slender milkvetch*	–	–
	ASLA27	*Astragalus laxmannii*	Laxmann's milkvetch	–	–
	ASLO4	*Astragalus lotiflorus*	lotus milkvetch	–	–
	ASMI10	*Astragalus missouriensis*	Missouri milkvetch	–	–
	ASPE5	*Astragalus pectinatus*	narrowleaf milkvetch	–	–
	ASRA2	*Astragalus racemosus*	cream milkvetch	–	–
	ASTRA	*Astragalus spp.*	milkvetch	–	–
	DACA7	*Dalea candida*	white prairie clover	–	–
	DAPU5	*Dalea purpurea*	purple prairie clover	–	–
	GLLE3	*Glycyrrhiza lepidota*	American licorice	–	–
	HEBO	*Hedysarum boreale*	Utah sweetvetch	–	–
	LAOC2*	*Lathyrus ochroleucus**	cream pea*	–	–
	LAPO2*	*Lathyrus polymorphus**	manystem pea*	–	–
	MELU	*Medicago lupulina*	black medick	X	–
	MEOF	*Melilotus officinalis*	yellow sweetclover	X	–
	MESA	*Medicago sativa*	alfalfa	X	–
	OXCA4	*Oxytropis campestris*	field locoweed	–	–
	OXLA3	*Oxytropis lambertii*	purple locoweed	–	–
	OXSE	*Oxytropis sericea*	white locoweed	–	–

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	OXYTR	*Oxytropis spp.*	locoweed	–	–
Fabaceae (continued)	PEAR6	*Pediomelum argophyllum*	silverleaf Indian breadroot	–	–
	PEES	*Pediomelum esculentum*	large Indian breadroot	–	–
	PSLA3	*Psoralidium lanceolatum*	lemon scurfpea	–	–
	PSTE5	*Psoralidium tenuiflorum*	slimflower scurfpea	–	–
	THRH	*Thermopsis rhombifolia*	golden pea	–	–
	VIAM	*Vicia americana*	American vetch	–	–
	VICIA	*Vicia spp.*	vetch	X	–
Fagaceae	QUMA2	*Quercus macrocarpa*	bur oak	–	–
Fumariaceae	COAU2*	*Corydalis aurea**	scrambled eggs*	–	–
Gentianaceae	GEAM3	*Gentianella amarella*	autumn dwarf gentian	–	–
Grossulariaceae	RIAU	*Ribes aureum*	golden currant	–	–
	RIOX	*Ribes oxyacanthoides*	Canadian gooseberry	–	–
Hydrophyllaceae	ELNY*	*Ellisia nyctelea**	Aunt Lucy*	–	–
	PHHA	*Phacelia hastata*	silverleaf phacelia	–	–
Iridaceae	SIAN3	*Sisyrinchium angustifolium*	narrowleaf blue-eyed grass	–	–
	SIMO2	*Sisyrinchium montanum*	strict blue-eyed grass	–	–
Juncaceae	JUBA	*Juncus balticus*	Baltic rush	–	–
Lamiaceae	AGFO	*Agastache foeniculum*	blue giant hyssop	–	–
	HEDR	*Hedeoma drummondii*	Drummond's false pennyroyal	–	–
	HEHI	*Hedeoma hispida*	rough false pennyroyal	–	–
	MOFI	*Monarda fistulosa*	wild bergamot	–	–
	NECA2	*Nepeta cataria*	catnip	X	–
Liliaceae	ALTE	*Allium textile*	textile onion	–	–
	CANU3	*Calochortus nuttallii*	sego lily	–	–
	LEMO4*	*Leucocrinum montanum**	common starlily*	–	S2
	MAST4	*Maianthemum stellatum*	starry false lily of the valley	–	–
	PRTR4	*Prosartes trachycarpa*	roughfruit fairybells	–	–
Linaceae	LILE3	*Linum lewisii*	Lewis flax	–	–
	LINUM	*Linum spp.*	flax	X	–
	LIRI	*Linum rigidum*	stiffstem flax	–	–
Loasaceae	MEDE2	*Mentzelia decapetala*	tenpetal blazingstar	–	–
Malvaceae	SPCO	*Sphaeralcea coccinea*	scarlet globemallow	–	–
Melanthiaceae	TOVE2	*Toxicoscordion venenosum*	meadow deathcamas	–	–
Nyctaginaceae	MIAL4	*Mirabilis albida*	white four o'clock	–	–
	MILI3	*Mirabilis linearis*	narrowleaf four o'clock	–	–
Oleaceae	FRPE	*Fraxinus pennsylvanica*	green ash	–	–
Onagraceae	EPBR3	*Epilobium brachycarpum*	tall annual willowherb	–	–
	OEBI	*Oenothera biennis*	common evening primrose	–	–
	OECE2	*Oenothera cespitosa*	tufted evening primrose	–	–
	OENU	*Oenothera nuttallii*	Nuttall's evening primrose	–	–
	OESE3	*Oenothera serrulata*	yellow sundrops	–	–
	OESU99	*Oenothera suffrutescens*	scarlet beeblossom	–	–

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	OEVI	*Oenothera villosa*	hairy evening primrose	–	–
Orobanchaceae	ORFA	*Orobanche fasciculata*	clustered broomrape	–	–
	ORLU	*Orobanche ludoviciana*	Louisiana broomrape	–	–
Oxalidaceae	OXST	*Oxalis stricta*	common yellow woodsorrel	–	–
Plantaginaceae	PLEL	*Plantago elongata*	prairie plantain	–	–
	PLPA2	*Plantago patagonica*	woolly plantain	–	–
Poaceae	ACHY	*Achnatherum hymenoides*	Indian ricegrass	–	–
	AGCR	*Agropyron cristatum*	crested wheatgrass	X	–
	AGSC5	*Agrostis scabra*	rough bentgrass	–	–
	ANGE	*Andropogon gerardii*	big bluestem	–	–
	ARPU9	*Aristida purpurea*	purple threeawn	–	–
	BOCU	*Bouteloua curtipendula*	sideoats grama	–	–
	BODA2	*Bouteloua dactyloides*	buffalograss	–	–
	BOGR2	*Bouteloua gracilis*	blue grama	–	–
	BOHI2	*Bouteloua hirsuta*	hairy grama	–	–
	BRCI2	*Bromus ciliatus*	fringed brome	–	–
	BRIN2	*Bromus inermis*	smooth brome	X	–
	BRJA	*Bromus japonicus*	Japanese brome	X	–
	BROMU	*Bromus spp.*	brome	X	–
	BRTE	*Bromus tectorum*	cheatgrass	X	–
	CALO	*Calamovilfa longifolia*	prairie sandreed	–	–
	CELO3*	*Cenchrus longispinus**	mat sandbur*	–	–
	DASP2	*Danthonia spicata*	poverty oatgrass	–	–
	DIOL	*Dichanthelium oligosanthes*	Heller's rosette grass	–	–
	DISP	*Distichlis spicata*	saltgrass	–	–
	DIWI5	*Dichanthelium wilcoxianum*	fall rosette grass	–	–
	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	–	–
	FESA	*Festuca saximontana*	Rocky Mountain fescue	–	–
	FESTU	*Festuca spp.*	fescue	X	–
	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	–	–
	MURA	*Muhlenbergia racemosa*	marsh muhly	–	–
	MUSQ3	*Munroa squarrosa*	false buffalograss	X	–
	NAVI4	*Nassella viridula*	green needlegrass	–	–
	PACA6	*Panicum capillare*	witchgrass	–	–

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	PASM	*Pascopyrum smithii*	western wheatgrass	–	–
Poaceae (continued)	PAVI2	*Panicum virgatum*	switchgrass	–	–
	POCO	*Poa compressa*	Canada bluegrass	X	–
	POIN	*Poa interior*	inland bluegrass	–	–
	POPA2	*Poa palustris*	fowl bluegrass	–	–
	POPR	*Poa pratensis*	Kentucky bluegrass	X	–
	POSE	*Poa secunda*	Sandberg bluegrass	–	–
	PSSP6	*Pseudoroegneria spicata*	bluebunch wheatgrass	–	–
	PUNU2	*Puccinellia nuttalliana*	Nuttall's alkaligrass	–	–
	SCSC	*Schizachyrium scoparium*	little bluestem	–	–
	SEVI4	*Setaria viridis*	green foxtail	X	–
	SPCR	*Sporobolus cryptandrus*	sand dropseed	–	–
	SPGR	*Spartina gracilis*	alkali cordgrass	–	–
	SPHE*	*Sporobolus heterolepis**	prairie dropseed*	–	–
	SPPE	*Spartina pectinata*	prairie cordgrass	–	–
	THIN6*	*Thinopyrum intermedium**	intermediate wheatgrass*	X	–
	VUOC	*Vulpia octoflora*	sixweeks fescue	–	–
Polemoniaceae	COLI2	*Collomia linearis*	tiny trumpet	–	–
	PHAL3*	*Phlox alyssifolia**	alyssumleaf phlox*	–	S1
	PHAN4*	*Phlox andicola**	prairie phlox*	–	–
	PHHO	*Phlox hoodii*	spiny phlox	–	–
Polygalaceae	POAL4	*Polygala alba*	white milkwort	–	–
	POVE*	*Polygala verticillata**	whorled milkwort*	–	–
Polygonaceae	ERFL4	*Eriogonum flavum*	alpine golden buckwheat	–	–
	ERPA9	*Eriogonum pauciflorum*	fewflower buckwheat	–	–
	FACO	*Fallopia convolvulus*	black bindweed	X	–
	POAV	*Polygonum aviculare*	prostrate knotweed	X	–
	PODO4	*Polygonum douglasii*	Douglas' knotweed	–	S3
	POER2	*Polygonum erectum*	erect knotweed	–	–
	PORA3*	*Polygonum ramosissimum**	bushy knotweed*	–	–
	RUCR	*Rumex crispus*	curly dock	X	–
	RUMEX	*Rumex spp.*	dock	X	–
Portulacaceae	POOL	*Portulaca oleracea*	little hogweed	X	–
Primulaceae	ANOC2	*Androsace occidentalis*	western rockjasmine	–	–
	LYCI	*Lysimachia ciliata*	fringed loosestrife	–	–
Ranunculaceae	ANCA8	*Anemone canadensis*	Canadian anemone	–	–
	ANCY	*Anemone cylindrica*	candle anemone	–	–
	ANEMO	*Anemone spp.*	anemone	–	–
	ANMU*	*Anemone multifida**	cutleaf anemone*	–	–
	ANPA19	*Anemone patens*	eastern pasqueflower	–	–
	AQCA	*Aquilegia canadensis*	red columbine	–	–
	CLLI2	*Clematis ligusticifolia*	western white clematis	–	–
	DEBI	*Delphinium bicolor*	little larkspur	–	–
	THDA	*Thalictrum dasycarpum*	purple meadow-rue	–	–

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	THVE	*Thalictrum venulosum*	veiny meadow-rue	–	–
Rosaceae	AMAL2	*Amelanchier alnifolia*	Saskatoon serviceberry	–	–
	DAFR6	*Dasiphora fruticosa*	shrubby cinquefoil	–	–
	DRAR8	*Drymocallis arguta*	tall cinquefoil	–	–
	DRFI3*	*Drymocallis fissa**	bigflower cinquefoil*	–	–
	FRVE	*Fragaria vesca*	woodland strawberry	–	–
	FRVI	*Fragaria virginiana*	Virginia strawberry	–	–
	GETR	*Geum triflorum*	prairie smoke	–	–
	PONO3	*Potentilla norvegica*	Norwegian cinquefoil	–	–
	POPE8	*Potentilla pensylvanica*	Pennsylvania cinquefoil	–	–
	POTEN	*Potentilla spp.*	cinquefoil	X	–
	PRAM	*Prunus americana*	American plum	–	–
	PRPE2	*Prunus pensylvanica*	pin cherry	–	–
	PRVI	*Prunus virginiana*	chokecherry	–	–
	ROAR3	*Rosa arkansana*	prairie rose	–	–
	ROSA5	*Rosa spp.*	rose	–	–
	ROWO	*Rosa woodsii*	Woods' rose	–	–
Rubiaceae	GAAP2	*Galium aparine*	stickywilly	–	–
	GABO2	*Galium boreale*	northern bedstraw	–	–
Salicaceae	PODE3	*Populus deltoides*	eastern cottonwood	–	–
	POTR5	*Populus tremuloides*	quaking aspen	–	–
	SAAM2	*Salix amygdaloides*	peachleaf willow	–	–
	SAER	*Salix eriocephala*	Missouri River willow	–	–
	SAEX	*Salix exigua*	narrowleaf willow	–	–
	SALIX	*Salix spp.*	willow	–	–
	SALU2	*Salix lutea*	yellow willow	–	–
Santalaceae	COUM	*Comandra umbellata*	bastard toadflax	–	–
Saxifragaceae	HERI	*Heuchera richardsonii*	Richardson's alumroot	–	–
Scrophulariaceae	CASE5	*Castilleja sessiliflora*	Great Plains Indian paintbrush	–	–
	ORLU2	*Orthocarpus luteus*	yellow owl's-clover	–	–
	PEAL2	*Penstemon albidus*	white penstemon	–	–
	PEGR5	*Penstemon gracilis*	lilac penstemon	–	–
	PENST	*Penstemon spp.*	beardtongue	–	–
	SYWY99 *	*Synthyris wyomingensis**	Wyoming kittentails*	–	–
Selaginellaceae	SEDE2	*Selaginella densa*	lesser spikemoss	–	–
Smilacaceae	SMHE	*Smilax herbacea*	smooth carrionflower	–	–
	SMLA3	*Smilax lasioneura*	Blue Ridge carrionflower	–	–
Solanaceae	PHHE5	*Physalis heterophylla*	clammy groundcherry	–	–
	PHVI5	*Physalis virginiana*	Virginia groundcherry	–	–
	SORO	*Solanum rostratum*	buffalobur nightshade	–	–
Typhaceae	TYLA	*Typha latifolia*	broadleaf cattail	–	–
Ulmaceae	ULAM	*Ulmus americana*	American elm	–	–
Unknown family	unkforb	*Unknown forb*	unknown forb	X	–

Family	Symbol	Scientific Name	Common Name	Exotic	Rare
	unkgram	*Unknown graminoid*	unknown graminoid	X	–
Unknown family (continued)	unkshrub	*Unknown shrub*	unknown shrub	X	–
	unkvine	*Unknown vine*	unknown vine	X	–
Urticaceae	PAPE5	*Parietaria pensylvanica*	Pennsylvania pellitory	–	–
Verbenaceae	PHCU3*	*Phyla cuneifolia**	wedgeleaf*	–	–
	VEST	*Verbena stricta*	hoary verbena	–	–
Violaceae	VIAD	*Viola adunca*	hookedspur violet	–	–
	VICA4	*Viola canadensis*	Canadian white violet	–	–
	VINU2	*Viola nuttallii*	Nuttall's violet	–	–
	VIOLA	*Viola spp.*	violet	X	–
Vitaceae	PAQU2	*Parthenocissus quinquefolia*	Virginia creeper	–	–
	PAVI5	*Parthenocissus vitacea*	woodbine	–	–

Appendix C. Natural Resource Condition Tables for Theodore Roosevelt National Park

Results were summarized in a Natural Resource Condition Table based on the templates from the State of the Park report series (Appendix C). 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 5.

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 relative cover of Kentucky bluegrass and smooth 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 the reference value, and status was scored as “good condition”, “warrants moderate concern”, or “warrants significant concern” (Table 5). “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. 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. For instance, many of the riparian forest metrics were measured for the first time in 2015 and we do not have comparable data to use as reference conditions. We plan to use 2015 as a baseline year and future surveys will use these data as the reference.

Table 18. 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.

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

Table 19. Natural resource condition summary table for plant communities in the North Unit of Theodore Roosevelt National Park (THRO). Current values are based on data from 2012-2016 and trends are based on data from 2010-2016.

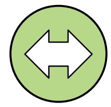
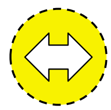
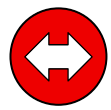
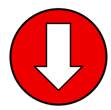
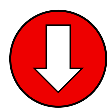
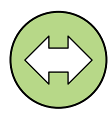
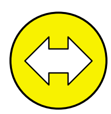
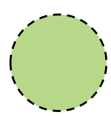
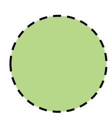
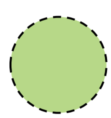
Indicator of Condition	Specific Measures	Current Value (mean ± SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Plant Community Structure and Composition	Native species richness (1m2 quadrats) in upland areas	8.7 ± 0.8 species	8-18 species		Native species richness in upland areas of the park fall within the natural range of variation for mixed grass prairie. Long-term diversity studies in riparian areas are lacking, making it difficult to find reference conditions, but these areas are much less species rich than upland areas of the park.
	Native species richness (1m2 quadrats) in riparian areas	5.0 ± 0.5 species	To be determined		
Exotic Plant Early Detection and Management	Relative cover of exotic species in upland areas	23.3 ± 3.5%	≤ 10 % cover		Exotic species are a management concern in THRO, particularly in the riparian corridor where they make up about a third of the plant community. Kentucky bluegrass and smooth brome are particularly abundant. Kentucky bluegrass has been increasing in abundance since 2010.
	Relative cover of Kentucky bluegrass in upland areas	16.5 ± 2.6%	≤ 10 % cover		
	Relative cover of exotic species in riparian areas	32.6 ± 8.8%	A reduction in exotic cover over time		
	Leafy spurge average relative cover in riparian areas	1.5 ± 1.0%	≤ 10 % cover		
	Smooth brome average relative cover in riparian areas	11.7 ± 5.8%	≤ 10 % cover		
Upland Forest	Juniper stem density	167.3 ± 45.3 stems/ha	To be determined		Upland juniper forests are common in THRO. Continued monitoring is necessary to learn more about the change over time in these forests.
	Seedlings stem density at plots with trees present (all species)	126.8 ± 59.3 stems/ha	To be determined		
Riparian Forest	Mature cottonwood stem density	64.1 ± 17.2 stems/ha	To be determined		Riparian forests in the North Unit of THRO are dominated by cottonwood stands, but many other species are present. We will repeat forest surveys in 5 year intervals to document any changes over time in condition.

Table 19 (continued). Natural resource condition summary table for plant communities in the North Unit of Theodore Roosevelt National Park (THRO). Current values are based on data from 2012-2016 and trends are based on data from 2010-2016.

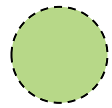
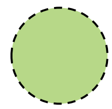
Indicator of Condition	Specific Measures	Current Value (mean ± SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Riparian Forest (continued)	Percent of 50 riparian plots with live trees or poles present	80%	To be determined		Riparian forests in the North Unit of THRO are dominated by cottonwood stands, but many other species are present. We will repeat forest surveys in 5 year intervals to document any changes over time in condition.
	Percent of 50 riparian plots with seedlings present	84%	To be determined		

Table 20. Natural resource condition summary table for plant communities in the South Unit of Theodore Roosevelt National Park (THRO). Current values are based on data from 2012-2016 and trends are based on data from 2010-2016.

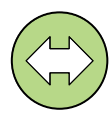
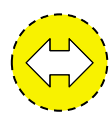
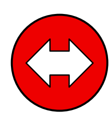
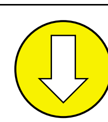
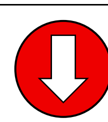
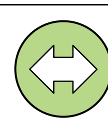
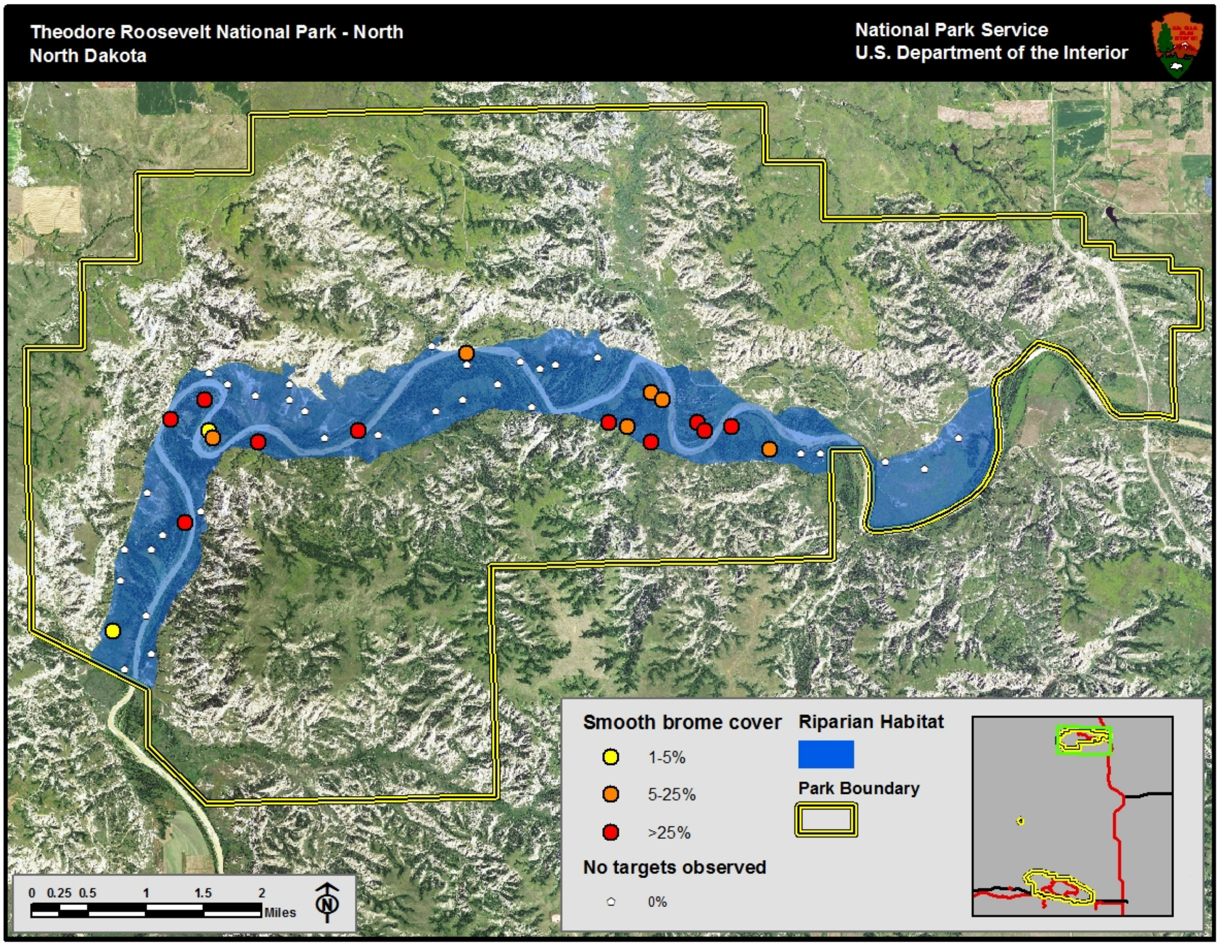
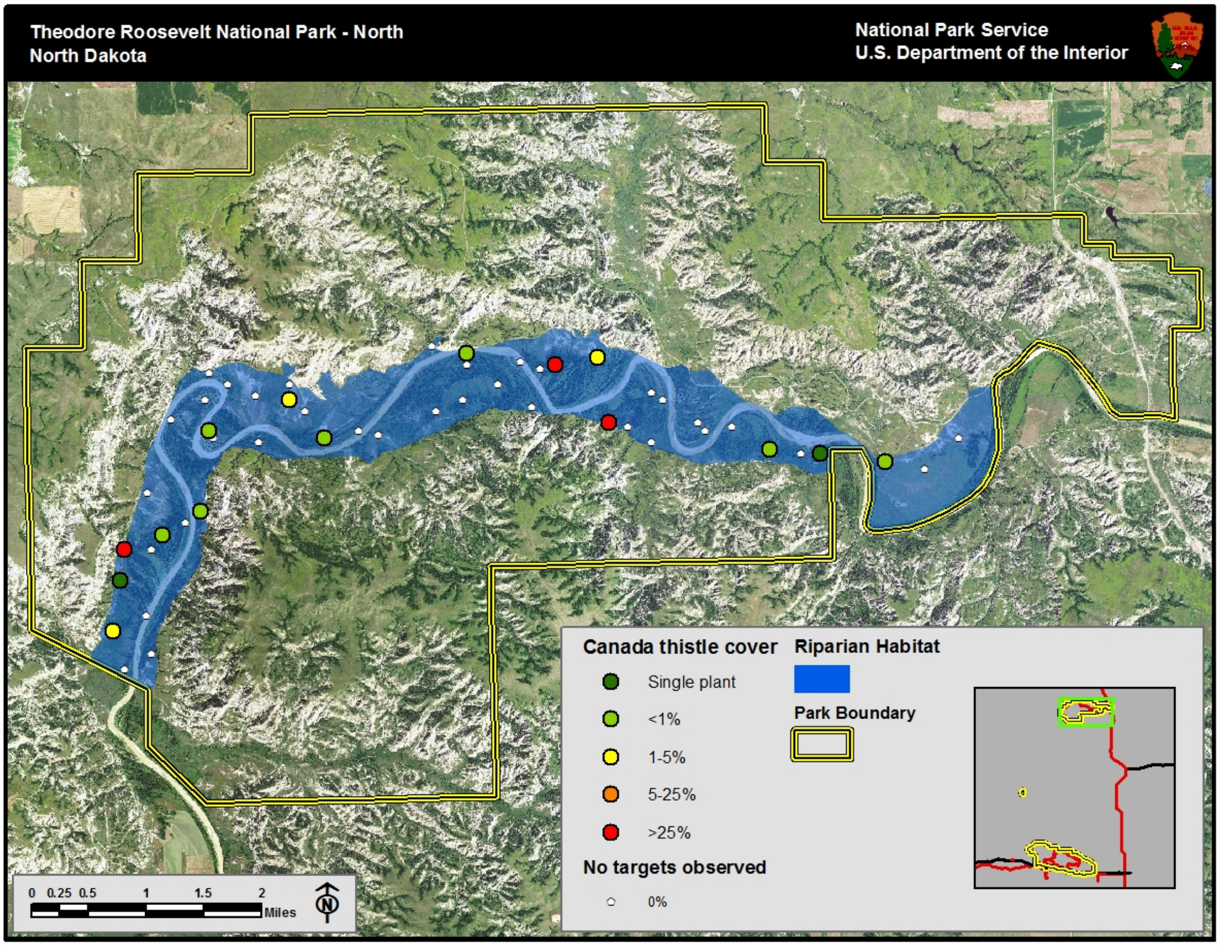
Indicator of Condition	Specific Measures	Current Value (mean ± SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Plant Community Structure and Composition	Native species richness (1m2 quadrats) in upland areas	9.5 ± 0.6 species	8-18 species		Native species richness in upland areas of the park fall within the natural range of variation for mixed grass prairie. Long-term diversity studies in riparian areas are lacking, making it difficult to find reference conditions, but these areas are much less species rich than upland areas of the park.
	Native species richness (1m2 quadrats) in riparian areas	4.0 ± 0.6 species	To be determined		
Exotic Plant Early Detection and Management	Relative cover of exotic species in upland areas	17.1 ± 2.7%	≤ 10 % cover		Exotic species are a management concern in THRO, particularly in the riparian corridor where they make up about a third of the plant community. Kentucky bluegrass and smooth brome are particularly abundant. Kentucky bluegrass has been increasing in abundance since 2010.
	Relative cover of Kentucky bluegrass in upland areas	11.1 ± 2.0%	≤ 10 % cover		
	Relative cover of exotic species in riparian areas	49.7 ± 7.7%	A reduction in exotic cover over time		
	Leafy spurge average relative cover in riparian areas	6.9 ± 2.1%	≤ 10 % cover		

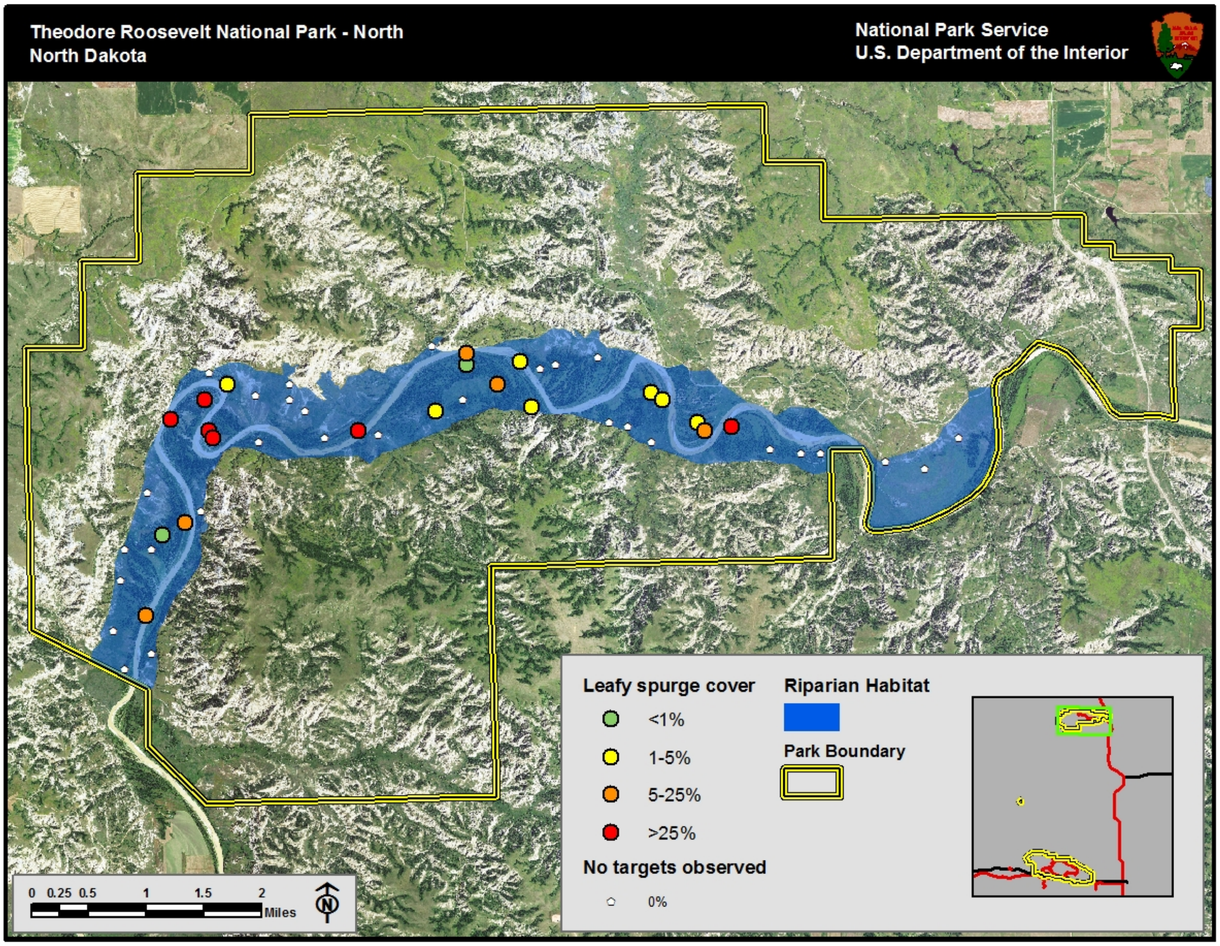
Table 20 (continued). Natural resource condition summary table for plant communities in the South Unit of Theodore Roosevelt National Park (THRO). Current values are based on data from 2012-2016 and trends are based on data from 2010-2016.

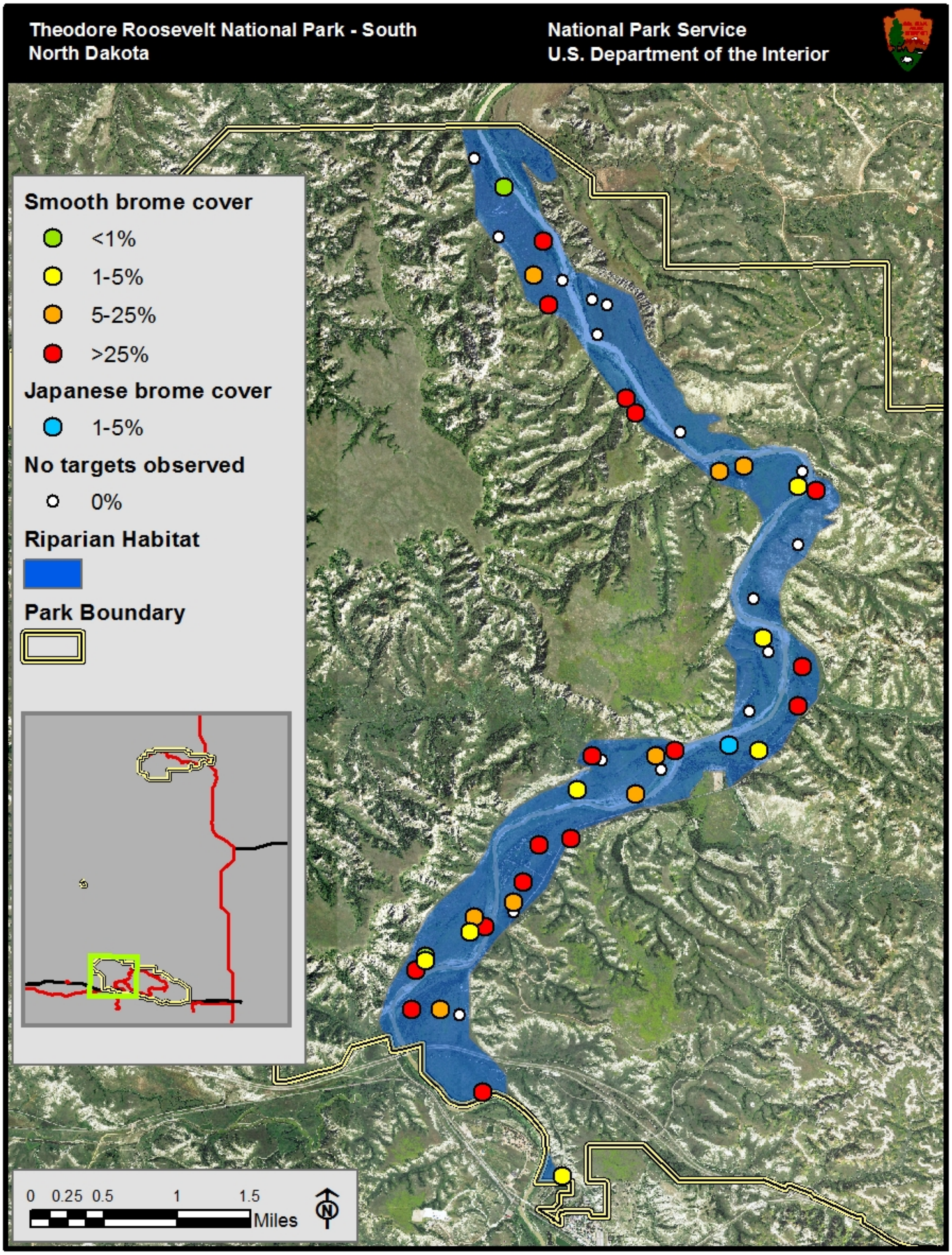
Indicator of Condition	Specific Measures	Current Value (mean ± SE)	Reference Condition and Data Source	Condition Status/Trend	Rationale for Resource Condition
Exotic Plant Early Detection and Management (continued)	Smooth brome average relative cover in riparian areas	14.4 ± 7.6%	≤ 10 % cover		Exotic species are a management concern in THRO, particularly in the riparian corridor where they make up about a third of the plant community. Kentucky bluegrass and smooth brome are particularly abundant. Kentucky bluegrass has been increasing in abundance since 2010.
Upland Forest	Juniper stem density	87.1 ± 34.2 stems/ha	To be determined		Upland juniper forests are common in THRO. Continued monitoring is necessary to learn more about the change over time in these forests
	Seedlings stem density at plots with trees present (all species)	110.8 ± 26.6 stems/ha	To be determined		
Riparian Forest	Mature cottonwood stem density	19.6 ± 9 stems/ha	To be determined		Riparian forests in the South Unit have fewer trees, species, and cottonwoods than the North Unit. We will repeat forest surveys in 5 year intervals to document any changes over time in condition
	Percent of 50 riparian plots with live trees or poles present	54%	To be determined		
	Percent of 50 riparian plots with seedlings present	58%	To be determined		

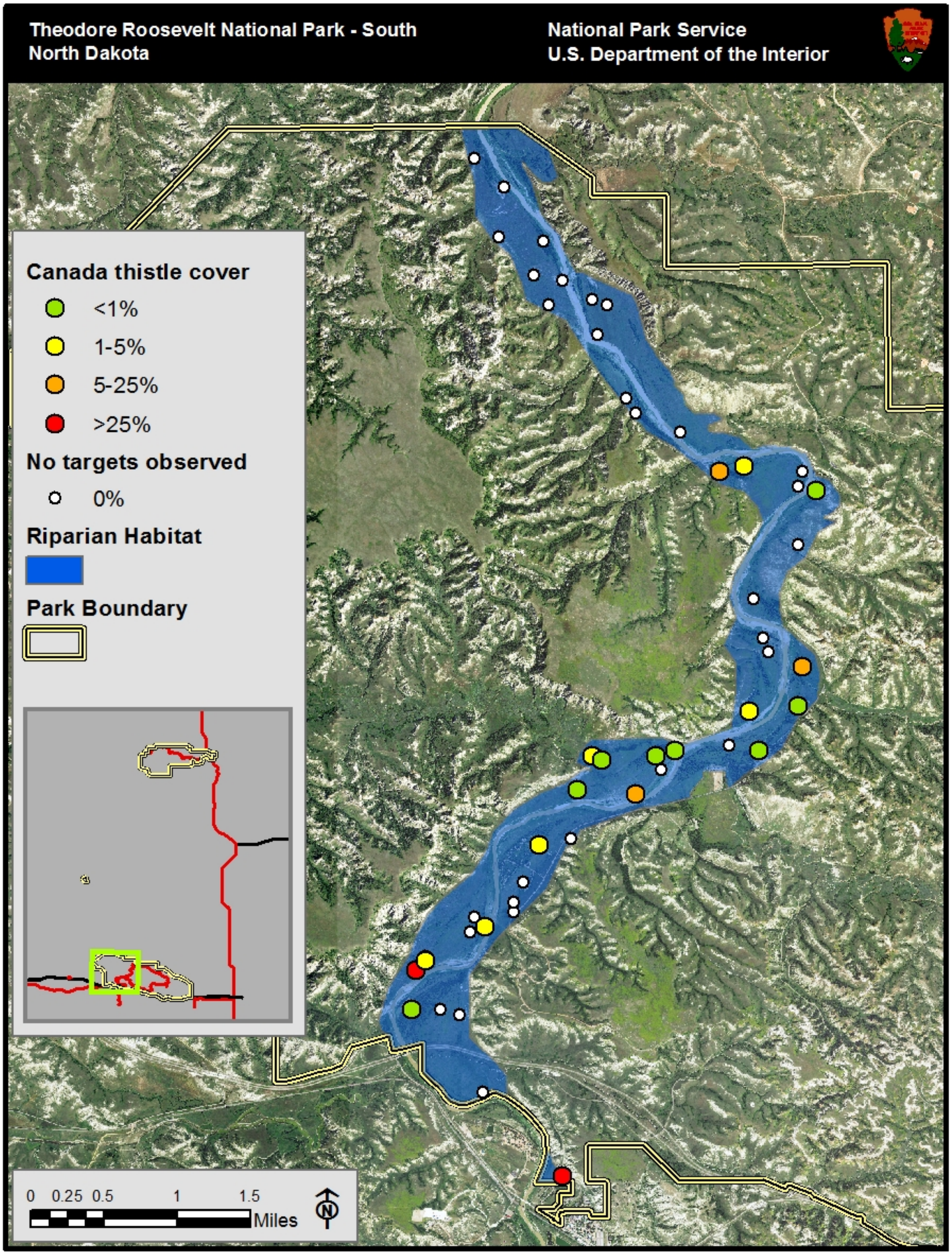
Appendix D. Maps of exotic species in the riparian areas of Theodore Roosevelt National Park

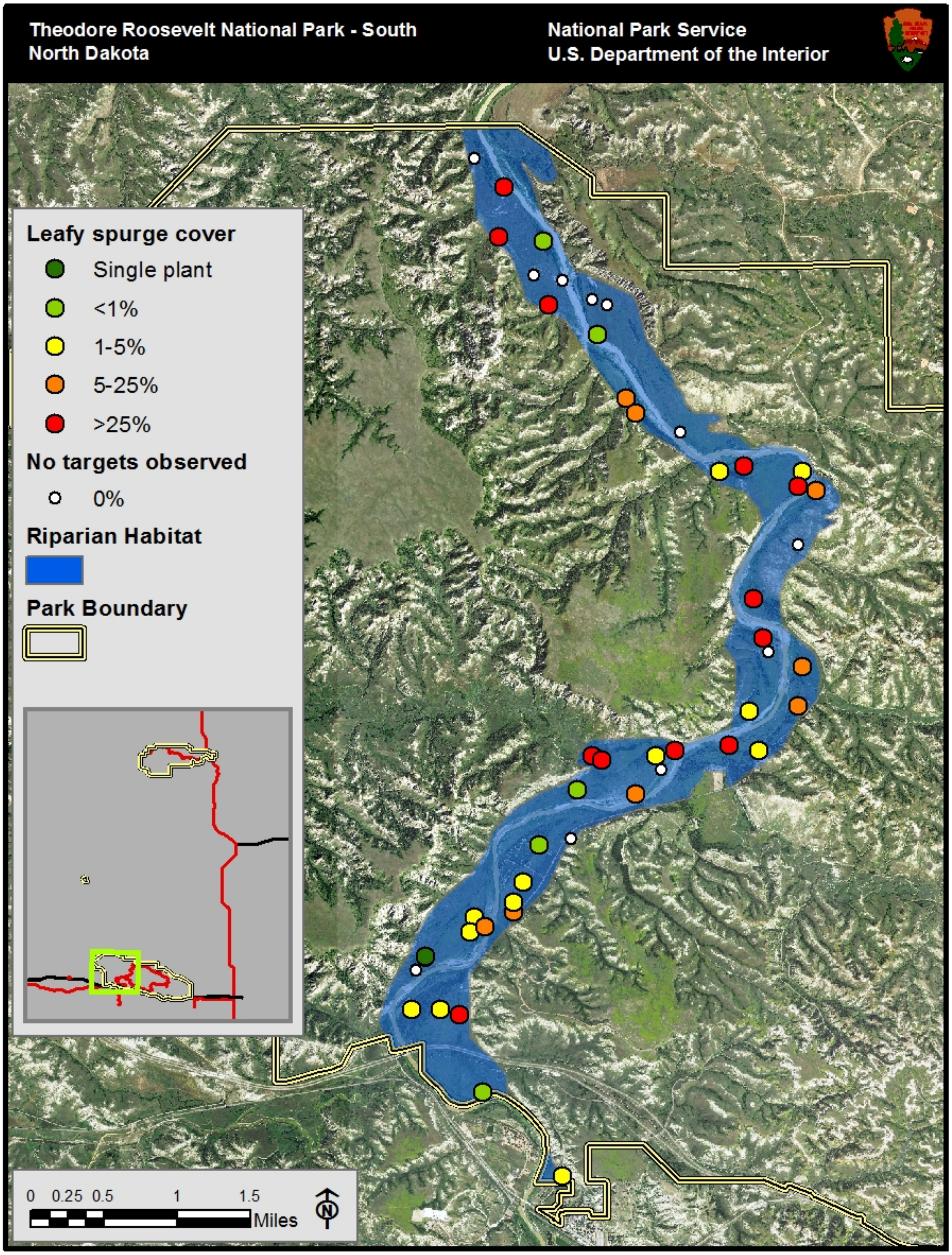



Theodore Roosevelt National Park - North
North Dakota
National Park Service
U.S. Department of the Interior
Canada thistle cover
Single plant
<1%
1-5%
5-25%
>25%
No targets observed
0%
Riparian Habitat
Park Boundary
0 0.25 0.5 1 1.5 2
Miles
N


Theodore Roosevelt National Park - North
North Dakota
National Park Service
U.S. Department of the Interior
Leafy spurge cover
<1%
1-5%
5-25%
>25%
No targets observed
0%
Riparian Habitat
Park Boundary
0 0.25 0.5 1 1.5 2
Miles
N


Theodore Roosevelt National Park - South
North Dakota
National Park Service
U.S. Department of the Interior
Smooth brome cover
<1%
1-5%
5-25%
>25%
Japanese brome cover
1-5%
No targets observed
0%
Riparian Habitat
Park Boundary
0 0.25 0.5 1 1.5
Miles
N


Theodore Roosevelt National Park - South
North Dakota
National Park Service
U.S. Department of the Interior
Canada thistle cover
<1%
1-5%
5-25%
>25%
No targets observed
0%
Riparian Habitat
Park Boundary
0 0.25 0.5 1 1.5
Miles
N


Theodore Roosevelt National Park - South
North Dakota
National Park Service
U.S. Department of the Interior
Leafy spurge cover
Single plant
<1%
1-5%
5-25%
>25%
No targets observed
0%
Riparian Habitat
Park Boundary
0 0.25 0.5 1 1.5
Miles
N

NPS 387/139810, August 2017

National Park Service
U.S. Department of the Interior

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