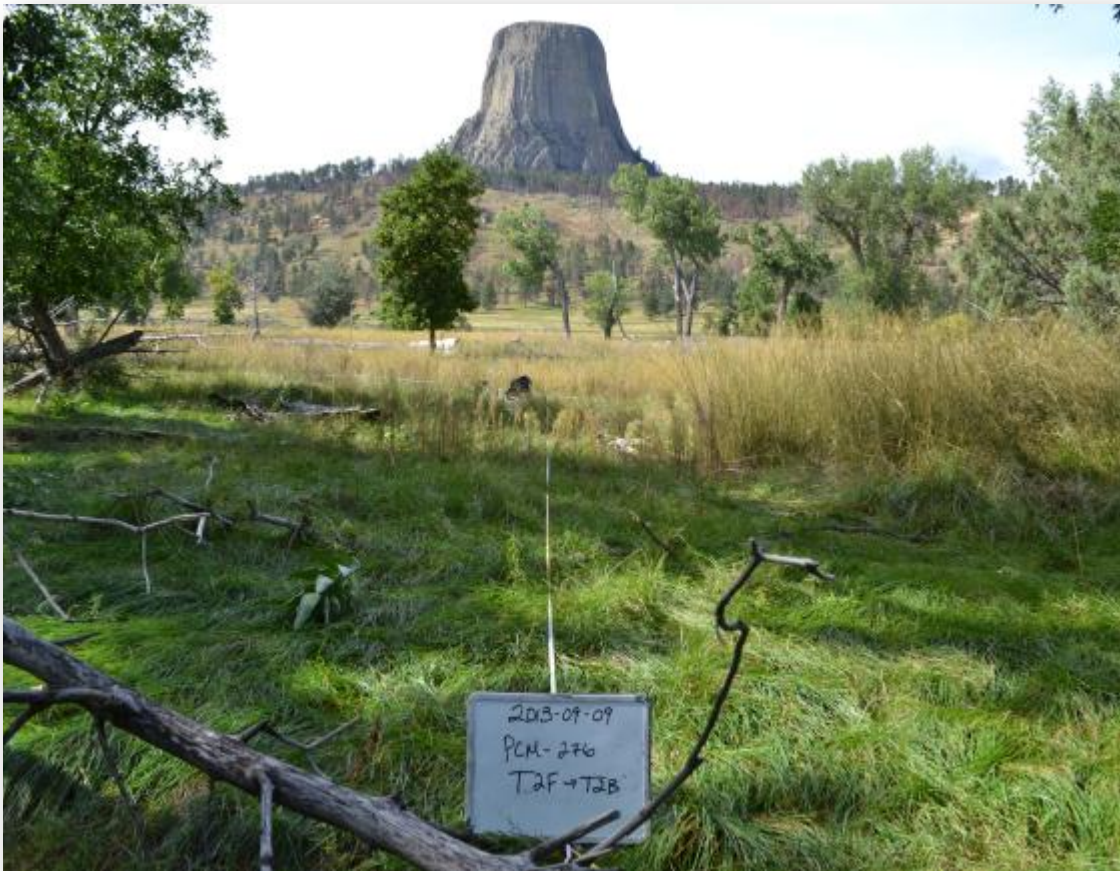




Forest Condition at Devils Tower National Monument

2013 Status Report

Natural Resource Technical Report NPS/NGPN/NRTR—2014/856



ON THE COVER

A forest monitoring plot at Devils Tower National Monument, 2013.
Photograph by: NPS

Forest Condition at Devils Tower National Monument

2013 Status Report

Natural Resource Technical Report NPS/NGPN/NRTR—2014/856

Isabel W. Ashton¹, Michael Prowatzke¹, Stephen K. Wilson¹, Daniel Swanson², Phil Graeve²

¹National Park Service
Northern Great Plains Inventory & Monitoring Network
231 East Saint Joseph Street
Rapid City, SD 57701

²National Park Service
Fire Ecology- Northern Great Plains Group
26611 U.S. Hwy 385
Hot Springs, SD 57747

March 2014

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols. This report received formal, high-level peer review based on the importance of its content, or its potentially controversial or precedent-setting nature. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Northern Great Plains website (<http://science.nature.nps.gov/im/units/ngpn/parks/deto.cfm>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Ashton, I. W., M. Prowatzke, S. K. Wilson, P. Graeve, and D. Swanson. 2014. Forest condition at Devils Tower National Monument: 2013 status report. Natural Resource Technical Report NPS/NGPN/NRTR—2014/856. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	iv
Tables.....	v
Executive Summary	vi
Acknowledgments.....	vii
Introduction.....	1
Methods.....	4
Sample design.....	4
Plot layout and sampling	6
Data Management and Analysis	8
Reporting on Natural Resource Condition	9
Results.....	10
Forest structure	10
Surface fuels	13
Disturbance and Exotic Species	15
Discussion.....	17
Literature Cited	25
Appendix A: Maps of select exotic species in DETO in 2003 and 2013.....	27

Figures

	Page
Figure 1. Devils Tower National Monument is characterized by ponderosa pine woodlands and forest (left panel) surrounding the rock tower and cottonwood woodlands in the Belle Fourche River floodplain.....	1
Figure 2. Areas within Devils Tower National Monument subject to burning and thinning operations since 1993	2
Figure 3. Map of Devils Tower National Monument and the location of 75 forest monitoring plots.	5
Figure 4. Long-term monitoring plot used for sampling forest structure and fuels in Devils Tower National Monument.	6
Figure 5. Total basal area of 9 tree species in Devils Tower National Monument.	11
Figure 6. Long-term monitoring plot PCM_030 in Devils Tower National Monument had a large number of ponderosa pine seedlings.	12
Figure 7. Surface fuels at Devils Tower National Monument in 2013.	14
Figure 8. Percent cover of nine exotic species in Devils Tower National Monument in 2013.....	16
Figure 9. Forest cover change, thinning and prescribed fire history in Devils Tower National Monument from 2000-2012.	18
Figure 10. The location of annual brome species found in Devils Tower National Monument in 2013 and 2003 (Wood and Rew 2005).....	21
Figure 11. The location of musk thistle found in Devils Tower National Monument in 2013 and 2003 (Wood and Rew 2005).	22

Tables

	Page
Table 1. Targeted exotic species of management concern at Devils Tower National Monument that were surveyed for during the 2013 field season.	7
Table 2. Exotic early detection species surveyed for at Devils Tower National Monument during the 2013 field season.	8
Table 3. Key to the symbols used in the Natural Resource Condition Table.....	9
Table 4. Tree and tall shrub species occurrence in 2013 at 75 plots in Devils Tower National Monument.	10
Table 5. Tree basal area and density by size class for ponderosa pine and deciduous trees in Devils Tower National Monument.	13
Table 6. Targeted exotic species found in 55 upland and 20 riparian forested plots in DETO in 2013.....	15
Table 7. Natural resource condition summary table for forest condition in DETO in 2013.....	24

Executive Summary

The Northern Great Plains Inventory & Monitoring Network and the Northern Great Plains Fire Ecology Program surveyed 75 forested plots in Devils Tower National Monument (DETO) in 2013. This effort will be repeated in 2018 and every 5 years thereafter to better understand status and trends in forest vegetation. We measured tree stem density, tree diameter, live and dead tree condition, fire fuel loads, cover of exotic species, and disturbance in all plots. By using a randomized survey approach, we are able to use these data to estimate the status of the forest, not just of the plots, but for the park as a whole. In this report, we provide a summary of our results from sampling in 2013.

We found that 2013 DETO's ponderosa pine forests and woodlands are in good condition but exotic species are widespread and persistent. Basal areas and tree densities are similar to historic conditions and within the range of desired conditions as outlined by the park. Surface fuels are above the targeted range and indicate the need for further treatment with prescribed fire. The condition of riparian forests and woodlands in DETO is declining due to low cottonwood recruitment and survival. Cottonwood restoration projects may be difficult due to the fundamental changes in the flow of the Belle Fourche River. DETO should focus on protecting the existing patches of hardwood forests within the riparian area and preventing further stressors such as the introduction of the emerald ash borer. Trends in forest condition are difficult to discern because few quantitative studies of past conditions were completed, but continued forest surveys will allow us to discern changes in the future.

Acknowledgments

We thank all the authors of the NGPN Plant Community Monitoring Protocol, particularly A. Symstad, for outstanding guidance on data collection and reporting. We thank the Northern Great Plains Fire Ecology Program for ongoing assistance with fieldwork and development of methods. We greatly appreciate the staff at DETO for providing logistical and field support. The 2013 NGPN vegetation, Fire Effects field crew, and DETO staff collected all the data included in this report. Data presented in this report were collected by I. Ashton, P. Graeve, V. Hoffman, D. Swanson, M. Prowatzke, M. Lund, E. Moore, M. Owen, J. Moran, S. Rockwood, C. Traft, J. Ladd, R. Kuhlman, P. Knecht, J. Shannon, C. Klinger, and K. Deweese. Comments from A. Symstad and R. Ohms improved this manuscript.

Introduction

The Black Hills contain 1.5 million hectares (ha) of discontinuous ponderosa pine (*Pinus ponderosa*) forest surrounded by the prairies of western South Dakota and eastern Wyoming. The Black Hills are a unique ecosystem composed of plant species and communities from the western Rocky Mountains, eastern deciduous forests, northern boreal forests, and the surrounding Great Plains (Larson and Johnson 2007). Natural and anthropogenic disturbances, such as fire and logging, are an integral part of the history of the ponderosa pine forests of this ecosystem (reviewed in Shepperd and Battaglia 2002). Evaluating the current status and long-term trend in forest condition is critical as climate change threatens to increase the frequency and intensity of disturbances and drought stress (Allen et al. 2010). In recent years, mountain pine beetle (*Dendroctonus ponderosae*) outbreaks have been of particular note because they are increasing throughout the Black Hills and have caused 100% mortality of ponderosa pines in some areas (Hocking et al. 2010).

Devils Tower National Monument (DETO) was established in 1906 as the first National Monument; its mission is to protect and preserve the impressive rock tower and the lands around it. It is located in northeastern Wyoming on the edge of the Black Hills and encompasses an area of 545 ha (1347 acres). The vegetation is a mosaic of ponderosa pine woodlands and mixed-grass prairie surrounding the Tower with a narrow riparian corridor of plains cottonwood (Figure 1).



Figure 1. Devils Tower National Monument is characterized by ponderosa pine woodlands and forest (left panel) surrounding the rock tower and cottonwood woodlands in the Belle Fourche River floodplain.

Historically, fires occurred at an interval of 11-32 years at DETO, which helped maintain a mosaic of open ponderosa woodlands and grassland (Fisher et al. 1987, Stambaugh et al. 2008). During the late 1800s there was a period of increased fire that coincided with a time of increased occupation and conflicts in the region (Stambaugh et al. 2008). Fire was aggressively suppressed in most forest communities starting in the late 1880s; subsequently the fire return interval lengthened to 42 years (Fisher et al. 1987). Brown (2006) found patterns of historical fires in the Bear Lodge Mountains were consistent with those of the Black Hills, where fires were often associated with periods of drought. In contrast, Stambaugh and colleagues (2008) found that past fires in DETO did not correlate with drought periods, a pattern that makes it more similar to nearby grasslands. Recently, prescribed burning has been used as a tool to restore natural ecosystem structure and function at DETO (National Park Service 2004). Since 1993, 75% of the park has been within the boundary of at

least one prescribed burn (Figure 2). The terrace north of the tower has received a significant amount of attention aimed at reducing tree density; 102 acres were thinned in 2001, with pile burns ensuing in 2002 and 2003. Significant areas that have not burned include the tower and its immediate talus field, the riparian area (including administrative areas), the prairie dog town, and an area in the north encompassing Joyner Ridge. Though the Joyner Ridge area has not had a prescribed burn, 30 acres were subject to thinning in 2010, and piles remain in this area.

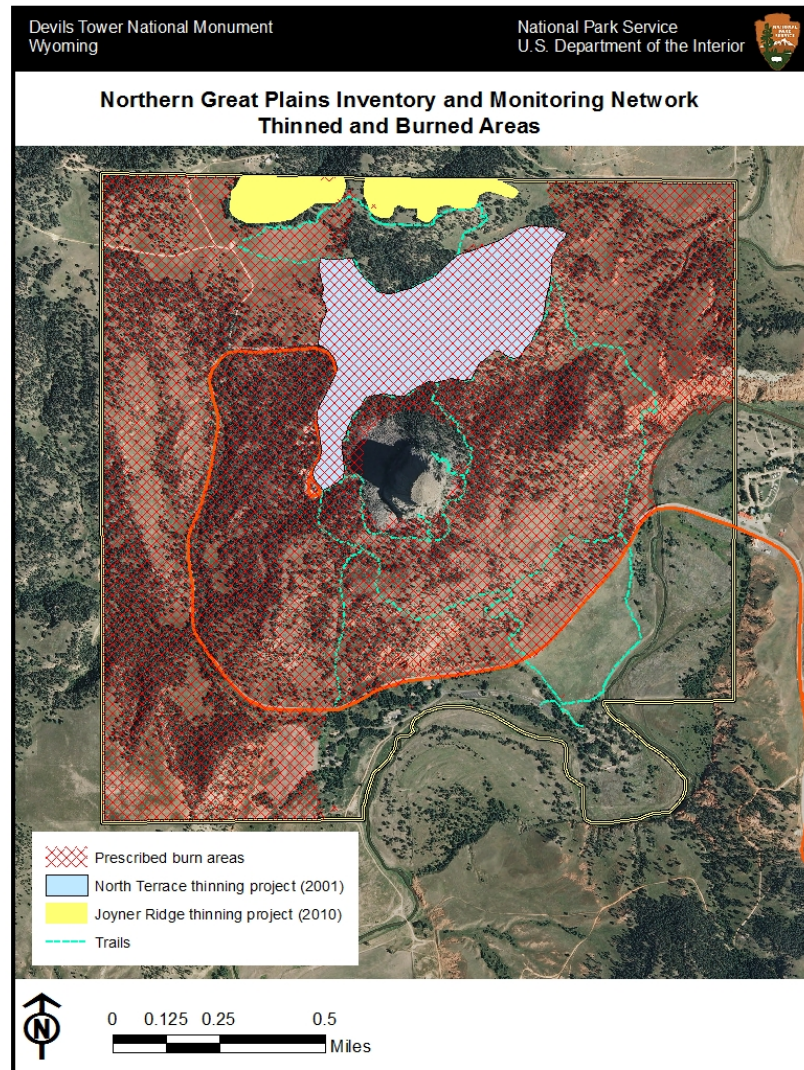


Figure 2. Areas within Devils Tower National Monument subject to burning and thinning operations since 1993.

The DETO Fire Management Plan (National Park Service 2004) has outlined desired conditions for the forests in the monument including targets for tree density and reductions in exotic species cover. Periodic assessments of forest health are essential in determining whether the desired conditions of tree density and exotic species cover are being met.

Small areas of cottonwood (*Populus deltoides*) woodlands occur within DETO in the floodplain of the Belle Fourche River (Salas and Pucherelli 1998). Historically, cottonwood forests were a major

component of the floodplain supporting a diverse community of plants and wildlife. The creation of a dam and reservoir upstream of DETO in the 1950s has limited the seasonal river flow and floods that cottonwood seedlings relied on for germination and establishment. As a result, there is almost no cottonwood seedling establishment in DETO, and mature trees are in declining health (Tinker 2008). Restoration efforts have proven difficult because of recent droughts and the large shift in the Belle Fourche River hydrograph. Forest monitoring is critical to better track the demise of cottonwood forests and to target restoration efforts to areas where natural seedling establishment is still occurring.

The landscape within and surrounding DETO has an extensive history of human alterations including fire suppression, livestock grazing, agriculture, and timber production, all of which have contributed to the spread of exotic plants (Komp et al. 2011). Currently, exotic plant species are a major component of the plant community and can account for 43% of plant cover in long-term plots (Ashton and Prowatzke 2014). A large portion of exotic cover is Kentucky bluegrass (*Poa pratensis*), which to date has not been controlled by the park. Other more noxious species are also contributors to the high exotic cover. In 2003, a survey of the park estimated that between 59 and 67% of the park was infested with targeted exotic plants such as leafy spurge (*Euphorbia esula*), annual bromes (*Bromus tectorum* and *B. japonicus*), and houndstongue (*Cynoglossum officinale*) (Wood and Rew 2005). Infestations of exotic plants can threaten native plant diversity, forage availability, and habitat quality, and can drive changes in nutrient cycles and fire frequency. In the past decade, there have been significant efforts by the park and the Northern Great Plains Exotic Management Team to reduce the abundance and spread of some exotic plants (Komp et al. 2011). It is difficult to evaluate the success of these efforts because there is not a recent comprehensive survey of exotic plants in DETO.

Scientifically credible information on the current status and long-term trends of the composition, structure, and function of the forests in DETO is required for sound management. In 2013, the National Park Service Northern Great Plains Inventory & Monitoring Network (NGPN) and the Northern Great Plains Fire Ecology Program (FireEP) sampled 75 forested sites in DETO selected by a spatially balanced probability survey design (Stevens and Olsen 2004). The general goal of this monitoring effort was to better understand the condition of DETO's forest by sampling and characterizing forest structure, exotic plant prevalence, and fire and fuel dynamics (Gitzen et al. 2010). The long-term monitoring objectives are to: (1) determine status (at 5-year intervals) and long-term trends of fuel loads and tree density by species, height class, and diameter class in upland ponderosa forests, (2) determine status (at 5-year intervals) and long-term trends of tree density by species, height class, and diameter class in lowland areas near the Belle Fourche River and (3) improve our understanding of the effects of external drivers and management actions on plant community species composition and structure by correlating changes in vegetation composition and structure with changes in climate, landscape patterns, atmospheric chemical composition, fire, and invasive plant control (Symstad et al. 2012). In this report, we present the results from 2013, our first year of monitoring, which will provide a baseline against which to compare the results of our future efforts.

Methods

The NGPN Plant Community Composition and Structure Monitoring Protocol (Symstad et al. 2012) describes in detail the methods used for sampling long-term plots in DETO forests. Below, we briefly describe the general approach, sample frame, plot locations, and sampling methods. For more detail, please see Symstad et al. 2012, available at <http://science.nature.nps.gov/im/units/ngpn/monitor/plants.cfm>.

Sample design

We implemented a protocol to monitor forest structure and fuel loads in DETO using a spatially balanced probability survey design (Generalized Random Tessellation Stratified (GRTS); Stevens and Olsen 2003, 2004). A 54 x 54 m grid was overlaid on the park to create the sample frame with sampling locations at the center of a random subset of grid cells. We excluded the following areas from the sample frame: administrative areas, roads, utility lines and an appropriate buffer, areas within 10 m of a park boundary, paved trails, unpaved fire roads, and areas with little to no potential for terrestrial vegetation (e.g., large areas of bare rock). An area near the main entrance at the center of the eastern boundary was also excluded because there are plans to create a parking/shuttle lot in this area. The design consisted of 2 strata: upland and riparian. The riparian areas were defined based on topography and represent areas historically influenced by the Belle Fourche River. The final design included 75 randomly located sites, with 55 in upland areas and 20 in the riparian areas (Figure 3).

The sample frame for the woody plots in DETO was the whole park because most of the park provides suitable habitat for tree growth, particularly in the absence of fire. However, trees and tall shrubs currently do not occur or are very sparse in some areas of the park, particularly the riparian corridor. When we visited the 75 randomly located plots, the first step was to determine whether it was appropriate to conduct forest sampling in that selected location. If we found no trees or tall shrubs within 38 m of the plot center, we designated the site as “rejected” and did not sample at that site. We replaced these rejected sites with the next site drawn using the GRTS design. To save time during the 2013 season, some plots were visited and evaluated for the presence of trees in 2012. Between 2012 and 2013, we visited a total of 100 sites (66 upland and 34 riparian) to reach our target of 55 upland and 20 riparian forest plots.

The data we collect from the 75 randomly located sites can be used to estimate the condition of the entire extent of DETO forests (minus excluded areas) because probability-based survey designs allow for unbiased inference from sampled sites to un-sampled elements of the resource of interest (Hansen et al. 1983). When these sites are revisited in 2018 and every five years thereafter, we will be able report on the change in the condition of DETO forests over time.

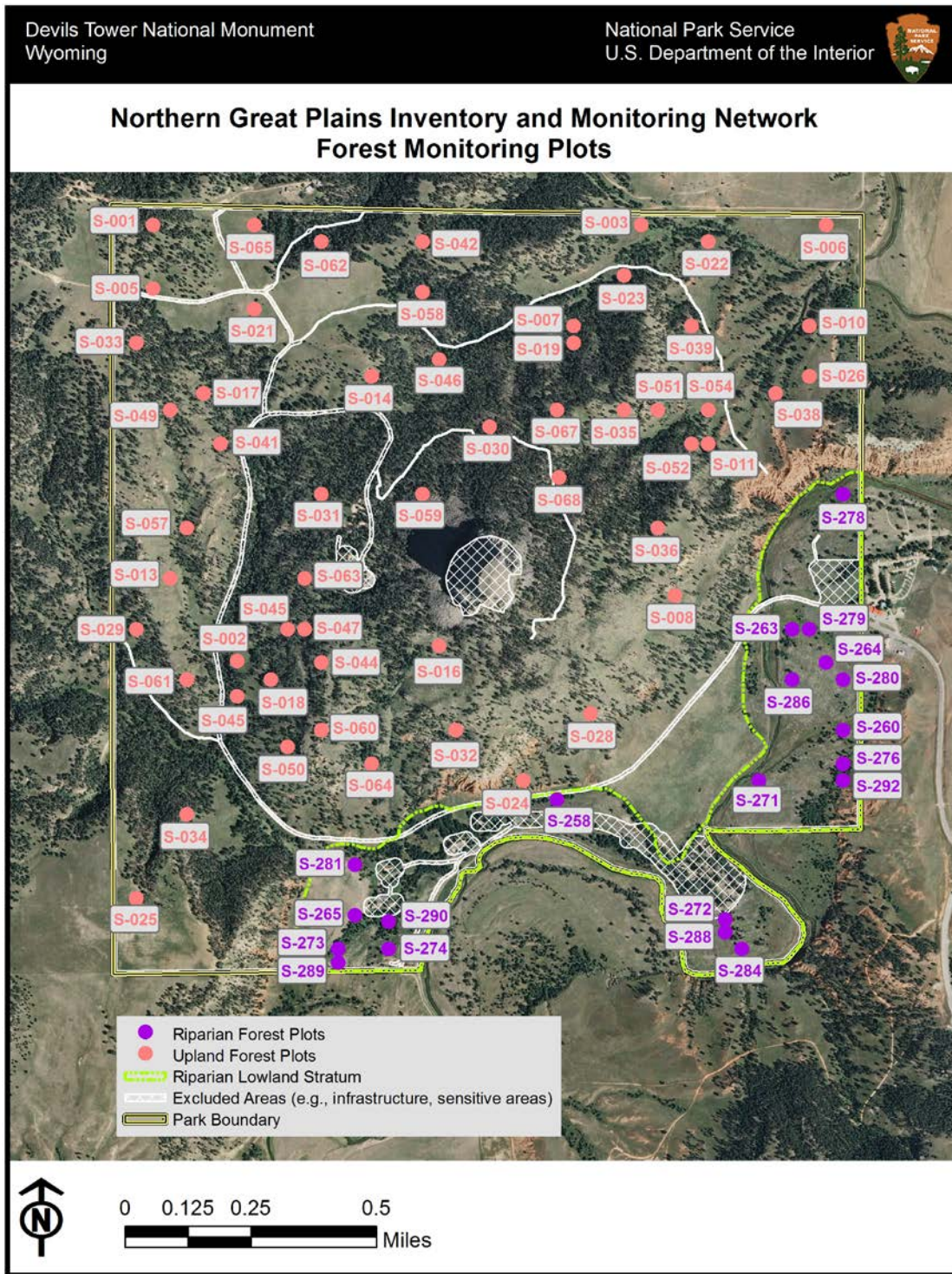


Figure 3. Map of Devils Tower National Monument and the location of 75 forest monitoring plots. Fifty-five plots are in the upland areas of the park (pink), and 20 plots fall within riparian areas (purple). The riparian plots are all within the riparian lowland strata (green). Areas excluded from the sample frame are outline in white including the tower, roads, and administrative areas.

Plot layout and sampling

At each of 75 sites, we sampled tree regeneration and density in a 10-m radius permanent plot (0.03 ha; Figure 4). Most sites were visited in the first week of September of 2013. Five of the 75 sites were visited in June 2013. Tree and targeted tall shrub species with diameter at breast height (DBH, where breast height = 137 cm) < 2.54 cm were tallied by species and classified as seedlings. For all poles ($2.54 \text{ cm} \leq \text{DBH} \leq 15 \text{ cm}$), DBH and status (live or dead) were recorded by species. Species, DBH, status, and condition (leaf-discoloration, insect-damaged, etc.) were recorded for each tree with $\text{DBH} > 15 \text{ cm}$. Dead and downed woody fuel load data were collected on two perpendicular, 100-ft (30.48 m) transects centered at the center of the plot following Brown's Line methods (Brown 1974, Brown et al. 1982).

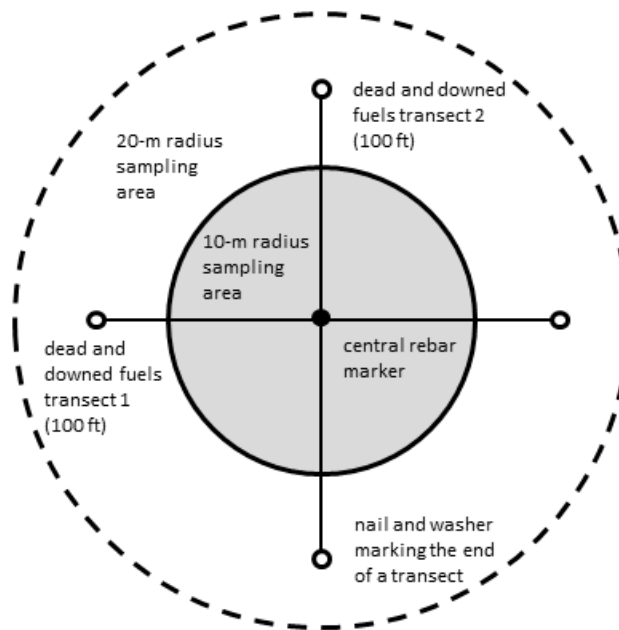


Figure 4. Long-term monitoring plot used for sampling forest structure and fuels in Devils Tower National Monument.

In a subset of 6 sites, we sampled in the 10 m radius and extended tree sampling to a 50 m x 20 m (0.1 ha) plot. In these 6 sites, trees were mapped and tagged and will be revisited two of every five years on a rotating schedule. The larger plot size and greater sampling frequency are consistent with the more comprehensive NGPN vegetation monitoring protocol (Symstad et al. 2012). In cases where we found fewer than 5 trees or poles within the sampling area, we extended the radius to 20-m and recorded all trees within the larger area. For most analyses, we include all plots that were monitored; however, in some cases we analyzed data for only plots where we found trees, seedlings, or poles within the 20-m-radius sampling area and we refer to this subset as the “forested plots”.

At all plots, we surveyed the site area defined by 15.5 m (50 ft) radius fuel transects for common disturbances and exotic species of management interest (Tables 1 and 2). The first set of species we searched for are exotic species that are known to be present in the park and are particularly concerning to park management (Table 1). The second set of plants are exotic species that have been

expanding into the Northern Great Plains and early detection will help the park target them for eradication (Table 2). Common disturbances included animal trails, fire, and erosion. The type, severity, and approximate area of the disturbances were recorded. This method was meant as a quick assessment of disturbance and typically took no more than 15 minutes in the field. Thus, the dataset focuses on large scale and obvious disturbances. For each target exotic species that was present at a site, an abundance class on a scale from 1 to 5 was assigned, where 1 = one individual, 2 = few individuals, 3 = cover 1-5% of site, 4 = cover 5-25% of site, and 5 = cover > 25% of site. For analyses, we used the midpoint of each species' cover class and at each plot we took the sum of these midpoints to estimate total exotic cover at a site.

Table 1. Targeted exotic species of management concern at Devils Tower National Monument that were surveyed for during the 2013 field season.

Species Code	Scientific Name	Common Name
ARM12	<i>Arctium minus</i>	common burdock
BRTE/BRJA	<i>Bromus tectorum/B. japonicus</i>	annual bromes
CANU4	<i>Carduus nutans</i>	musk thistle
CEST8	<i>Centaurea stoebe</i>	spotted knapweed
CIAR4	<i>Cirsium arvense</i>	Canada thistle
CIVU	<i>Cirsium vulgare</i>	bull thistle
COMA2	<i>Conium maculatum</i>	poison hemlock
COAR4	<i>Convolvulus arvensis</i>	field bindweed
CYOF	<i>Cynoglossum officinale</i>	houndstongue
EUES	<i>Euphorbia esula</i>	leafy spurge
HEMA3	<i>Hesperis matronalis</i>	dame's rocket
MEOF	<i>Melilotus officinalis</i>	yellow sweetclover
ONAC	<i>Onopordum acanthium</i>	Scotch thistle
RHRE99	<i>Rhaponticum repens</i>	hardheads
SAKA	<i>Salsola kali</i>	Russian thistle
THAR5	<i>Thlaspi arvense</i>	field pennycress
VETH	<i>Verbascum thapsus</i>	common mullein

Table 2. Exotic early detection species surveyed for at Devils Tower National Monument during the 2013 field season.

Species Code	Scientific Name	Common Name
AIAL	<i>Ailanthus altissima</i>	tree of heaven
ALPE4	<i>Alliaria petiolata</i>	garlic mustard
ARDO4	<i>Arundo donax</i>	giant reed
CESO3	<i>Centaurea solstitialis</i>	yellow star thistle
CEVI; CEDI3	<i>Centaurea virgata</i> ; <i>C. diffusa</i>	knapweeds
CHJU	<i>Chondrilla juncea</i>	rush skeletonweed
DIFU2; DILA4	<i>Dipsacus fullonum</i> ; <i>D. laciniatus</i>	common teasel
ELAN	<i>Elaeagnus angustifolia</i>	Russian olive
EUMY2; EUCY2	<i>Euphorbia myrsinites</i> ; <i>E. cyperissias</i>	myrtle spurge
GYPA	<i>Gypsophila paniculata</i>	baby's breath
HEMA17	<i>Heracleum mantegazzianum</i>	giant hogweed
HIAU; HICA10	<i>Hieracium aurantiacum</i> ; <i>H. caespitosum</i>	orange and meadow hawkweed
IRPS	<i>Iris pseudacorus</i>	yellow iris
ISTI	<i>Isatis tinctoria</i>	Dyer's woad
LELA2	<i>Lepidium latifolium</i>	perennial pepperweed
LIDA/LIVU2	<i>Linaria dalmatica</i> , <i>L. vulgaris</i>	Dalmatian toadflax, yellow toadflax
POCU6; POSA4; POBO10	<i>Polygonum cuspidatum</i> ; <i>P. sachalinense</i> ; <i>P. x bohemicum</i>	knotweeds
PUMO	<i>Pueraria montana</i> var. <i>lobata</i>	kudzu
RHCA3	<i>Rhamnus cathartica</i>	common buckthorn
SAAE	<i>Salvia aethiopis</i>	Mediterranean sage
TACA8	<i>Taeniatherum caput-medusae</i>	medusahead
TAMAR2	<i>Tamarix</i> spp.	Tamarisk
TAVU	<i>Tanacetum vulgare</i>	Common tansy
VEDU	<i>Ventenata dubia</i>	African wiregrass

Data Management and Analysis

We used FFI (FEAT/FIREMON Integrated; <http://frames.gov/ffi/>) as the primary software environment for managing our sampling data. FFI is used by a variety of agencies (e.g., NPS, USDA Forest Service, U.S. Fish and Wildlife Service), has a national-level support system, and generally conforms to the Natural Resource Database Template standards established by the Inventory and Monitoring Program.

Species names, codes, and common names are from the USDA Plants Database (USDA-NRCS 2012). However, nomenclature follows the Integrated Taxonomic Information System (ITIS) (<http://www.itis.gov>). In the few cases where ITIS recognizes a new name that was not in the USDA PLANTS database, the new name was used and a unique plant code was assigned. Plant species were identified in the field to species level and not to lower taxonomic groupings (e.g., subspecies or variety). After data for the sites were entered, 100% of records were verified against the original data sheet to minimize transcription errors. Next, 10% of the records were reviewed a second time to confirm accuracy. After all data were entered and verified, automated queries were developed to

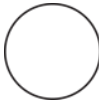
check for errors in the data (e.g., typos, duplicated species). When errors were caught by the crew or the automated queries, changes were made to the original datasheets and the FFI database as needed.

Summaries were done using FFI reports and query functions and statistical summaries were done using R software (version 3.0.2). We used the R package ‘spsurvey’ (Kincaid and Olsen 2011) to adjust the survey site weights to account for replacing non-target or non-accessible sites with overdraw samples. Fuel constants were inputted to the FFI software to calculate fuel loads. We assigned the fuel constant based on the dominant fuel species within the site. In upland plots this was ponderosa pine in all but one plot where red oak (*Quercus rubra*) was used to estimate bur oak fuels. A constant for cottonwood (*Populus balsamifera*) was used in 8 riparian sites and oak was used in 5 riparian sites. The fuel constants are available within the FFI database on the NGPN website <http://science.nature.nps.gov/im/units/ngpn/monitor/plants.cfm>).

Reporting on Natural Resource Condition

Results were summarized in a Natural Resource Condition Table based on the templates from the State of the Park report series (<http://www1.nrintra.nps.gov/im/stateoftheparks/index.cfm>). The goal is to improve park priority setting and to synthesize and communicate complex park condition information to the public in a clear and simple way. By focusing on specific indicators, such as basal area, 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 2. Reference values were based on descriptions of historic forest condition, past studies completed in the park, management targets (e.g., National Park Service 2004), or the natural resource condition assessment completed in 2011 (Komp et al. 2011).

Table 3. Key to the symbols used in the Natural Resource Condition Table. The background color represents the current status, the arrow summarizes the trend, and the thickness of the outside line represents the degree of confidence in the assessment. A symbol that does not contain an arrow indicates that there is insufficient information to assess a trend. Based on the State of the Park reports (<http://www1.nrintra.nps.gov/im/stateoftheparks/index.cfm>).

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

Results

We used a probability-based survey design that allows for unbiased inference from sampled sites (a selection of 75 grid cells) to unsampled elements of the population of interest (Figure 3; the entire sample frame or the set of grid cells that cover DETO minus the tower and select administrative areas, power line corridors, and roads). Consequently, the results we present below are estimated means (or other metrics) of forest vegetation included in this discrete sample frame. For ease of interpretation, we hereafter will refer to these means as representing the status of either the upland forests or the riparian forests in DETO, with an understanding that they do not represent administrative areas, roads, or other areas excluded from the sample frame.

Forest structure

Forest structure and composition varied across DETO in 2013. The plots we visited included open ponderosa woodlands with few trees, dense ponderosa forest, and riparian lowlands with few trees. In total, we measured the density of 11 tree and tall shrub species at 75 plots in DETO (Table 4).

Ponderosa pine was the most common mature tree found, but it was generally restricted to the upland areas (Figure 5). Bur oak and green ash were fairly common and found in both riparian and upland plots. In some cases, there were no mature trees of any species in a plot. This happened in 8 of the 20 riparian sites and 6 of the 55 upland sites. We found a larger diversity of seedlings, including many deciduous species, throughout the park, but ponderosa pine was still the most common (Table 4).

There are only 5 tree/tall shrub species on the DETO certified species list that we did not observe: *Crataegus chrysocarpa* (fireberry hawthorn), *Malus pumila* (Paradise apple) (non-native, listed as probably present), *Prunus pensylvanica* (pin cherry), *Salix lutea* (yellow willow), and *Shepherdia argentea* (silver buffaloberry). This is not surprising because none of the above species are common in the park.

Table 4. Tree and tall shrub species occurrence in 2013 at 75 plots in Devils Tower National Monument.

Species Name	Common Name	Number of plots with trees (DBH > 15 cm)	Number of plots with poles (2.5 cm ≤ DBH ≤ 15 cm)	Number of plots with seedlings (height < 137 cm)	Upland/ Riparian/ Both
<i>Pinus ponderosa</i>	ponderosa pine	48	17	25	B
<i>Quercus macrocarpa</i>	bur oak	9	3	16	B
<i>Fraxinus pennsylvanica</i>	green ash	6	4	5	B
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	5	1	6	B
<i>Populus deltoides</i>	Plains cottonwood	4	0	1	R
<i>Acer negundo</i>	boxelder	4	0	2	R
<i>Prunus americana</i>	American plum	1	1	1	U
<i>Prunus virginiana</i>	chokecherry	0	2	13	B
<i>Salix amygdaloides</i>	peachleaf willow	1	0	0	R
<i>Populus tremuloides</i>	quaking aspen	0	1	1	U
<i>Amelanchier alnifolia</i>	western serviceberry	0	0	5	U



Northern Great Plains Inventory and Monitoring Network Basal Area by Species

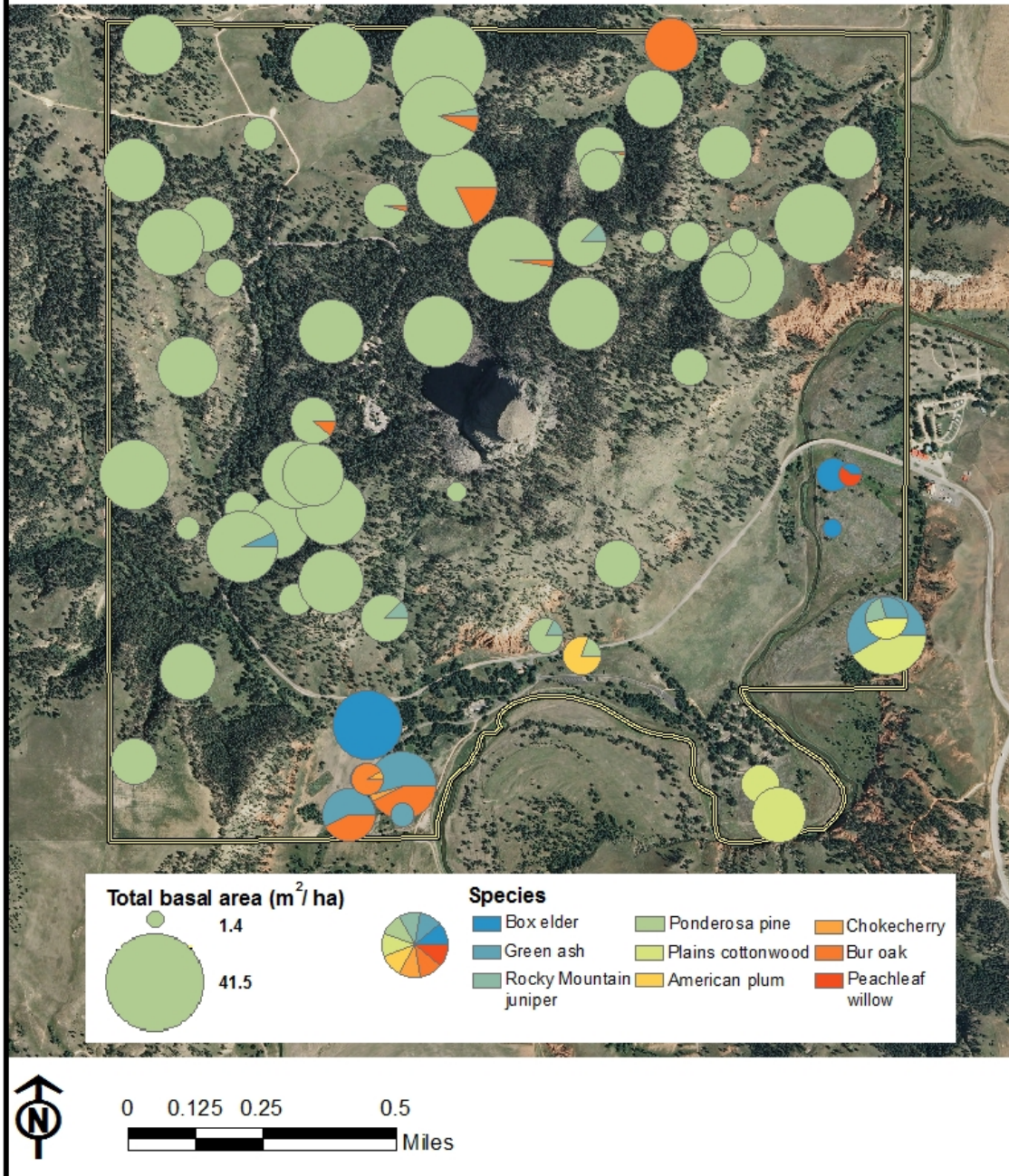


Figure 5. Total basal area of 9 tree species in Devils Tower National Monument. The size of the circle represents the total basal area at a site and each color is a different species within a site and their contribution to the total basal area.

Basal area is a measure derived from tree size and density; specifically, it describes the area that is occupied by the cross-section of stems at their “base” (here measured at 137 cm). In the upland areas of DETO, ponderosa pine basal areas averaged $13.1 \pm 1.1 \text{ m}^2/\text{ha}$ (mean $\pm$ standard error; $57 \pm 4.8 \text{ ft}^2/\text{acre}$; Table 5), and total basal area averaged $13.6 \pm 1.1 \text{ m}^2/\text{ha}$ ($59 \pm 4.8 \text{ ft}^2/\text{acre}$). When including only forested plots (those with trees, poles, or seedlings) the total basal area is higher and averages $14.9 \pm 1.1 \text{ m}^2/\text{ha}$ ($65 \pm 4.8 \text{ ft}^2/\text{acre}$). Riparian areas typically had a lower total basal areas than the upland forests, averaging only $7.0 \pm 1.6 \text{ m}^2/\text{ha}$ ($30 \pm 7.0 \text{ ft}^2/\text{acre}$). Basal area in the upland areas of the park was dominated by ponderosa pine whereas in the riparian areas forests were more diverse (Figure 5).

We estimated stand density for ponderosa pine trees in the upland forests to be 151 stems/ha ($61 \text{ ft}^2/\text{a}$; Table 5). For the subset of forested plots, density averaged $171 \pm 14.7 \text{ m}^2/\text{ha}$ ($69 \pm 5.9 \text{ ft}^2/\text{a}$). Ponderosa stand density ranged from 0 to 605 stems/ha. Stand densities of other common tree species were higher in riparian forests than in the upland forest (Table 5), but total tree and pole density remained low, and the riparian woodlands often had open canopies. Mature cottonwoods were present in low densities in the south east portion of the park (Figure 5).

Seedling densities were highly variable across plots and ranged from 0 to 60,948 stems per hectare. The plot with the highest density (PCM_030) had an abundance of ponderosa pine seedlings (Figure 6). Ponderosa seedlings were common and appeared in 25 of 55 upland plots (Table 4). Cottonwood seedlings were only found at one site (PCM_263, near the main entrance) in fairly low density



Figure 6. Long-term monitoring plot PCM_030 in Devils Tower National Monument had a large number of ponderosa pine seedlings.

Table 5. Tree basal area and density by size class for ponderosa pine and deciduous trees in Devils Tower National Monument. Values are estimated means and standard errors, means are computed based on the entire strata (upland/riparian).

Species	Indicator	Upland	Riparian
Ponderosa Pine	Basal Area (m ² / ha)	13.1 ± 1.1	0.1 ± 0.1
	Tree Density (stems/ha)	151 ± 14.4	1 ± 0.5
	Pole Density (stems/ha)	35 ± 8.7	0
	Seedling Density (stems/ha)	2637 ± 1124.3	0
	Snag Density (dead trees; stems/ha)	21 ± 4.7	0
Bur Oak	Tree Density (stems/ha)	9 ± 4.6	14 ± 8.5
	Pole Density (stems/ha)	4 ± 1.9	0
	Seedling Density (stems/ha)	57 ± 19.0	0
	Snag Density (dead trees; stems/ha)	1 ± 0	0
Green Ash	Tree Density (stems/ha)	1 ± 0.5	31 ± 13.4
	Pole Density (stems/ha)	2 ± 1.1	41 ± 31.9
	Seedling Density (stems/ha)	8 ± 5.9	110 ± 76.3
	Snag Density (dead trees; stems/ha)	0	3 ± 2.1
Cottonwood	Tree Density (stems/ha)	0	5 ± 1.9
	Pole Density (stems/ha)	0	0
	Seedling Density (stems/ha)	0	14 ± 12.5
	Snag Density (dead trees; stems/ha)	0	2 ± 1.2

Surface fuels

Surface fuels were measured at 65 plots in DETO; 10 plots did not have sufficient fuels to warrant measurement (i.e., there were no woody debris, pine needles or cones, or juniper needles crossing the two fuels transects). These plots were kept in the analyses, but fuels were assumed to be zero. In the upland ponderosa pine forests, total surface fuel loads averaged 16.1 ± 1.3 tons/ac (Figure 7; note that standard practice for fire management is to report fuels data in English units of tons per acre). Surface fuels within only the forested plots was 17.8 ± 1.5 tons/ac. Approximately 50% of this can be attributed to a thick duff and litter layer while the rest was woody fuels (Figure 7). Coarse woody debris totaled 5.7 ± 0.8 tons/ac. Surface fuel loads were much lower in the riparian area; the total was 5.6 ± 1.2 tons/ac with 1.7 ± 0.6 tons/ac of coarse woody debris.

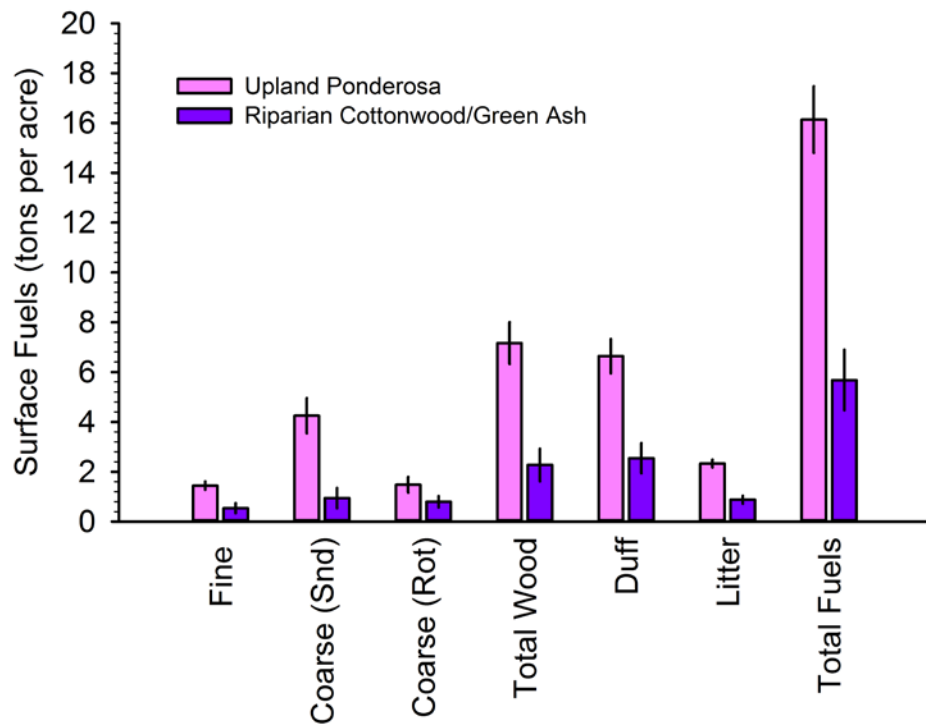


Figure 7. Surface fuels at Devils Tower National Monument in 2013. Bars represent means $\pm$ standard errors, $n = 55$ for the plots within the upland ponderosa forests (pink) and $n=20$ for the plots within the riparian areas. Fine includes 1 to 100 hour fuels, coarse sound (Snd) and rotten (Rot) refers to 1000 hour fuels.

Disturbance and Exotic Species

In 2013, the most common disturbance recorded was evidence of fire, found at 51 of 55 upland plots and 4 of 20 riparian plots. Herbicide treatment was the most common disturbance seen in the riparian area. Other disturbances were less common and included erosion, flood, storm damage, small mammal disturbance, off-road vehicle use, and mountain pine beetles. We found evidence of mountain pine beetle activity at 4 sites: PCM_007, 041, 049, and 067. All four of these sites were in the northern portion of the park (Figure 3).

We documented 11 of the targeted exotic species in DETO in 2013 (Table 6). Leafy spurge, houndstongue, and yellow sweetclover were found in the greatest number of plots and were fairly well-distributed across upland and riparian areas (Table 6). Across the park, we found an average of 3 targeted species per plot (Figure 8). The total exotic cover in plots averaged $8 \pm 1.4\%$ and $6 \pm 0.9\%$ in the upland and riparian areas, respectively. Leafy spurge had the highest cover averaging 4% in the upland and 3% in the riparian areas.

Table 6. Targeted exotic species found in 55 upland and 20 riparian forested plots in DETO in 2013.

Scientific Name	Common Name	Upland (number of plots)	Riparian (number of plots)
<i>Euphorbia esula</i>	leafy spurge	46	17
<i>Melilotus officinalis</i>	yellow sweetclover	23	13
<i>Cynoglossum officinale</i>	houndstongue	25	9
<i>Cirsium arvense</i>	Canada thistle	21	4
<i>Verbascum thapsus</i>	common mullein	18	3
<i>Bromus japonicus</i>	Japanese brome	16	5
<i>Bromus tectorum</i>	cheatgrass	7	4
<i>Thlaspi arvense</i>	field pennycress	4	3
<i>Carduus nutans</i>	musk thistle	3	0
<i>Cirsium vulgare</i>	bull thistle	3	0
<i>Onopordum acanthium</i>	Scotch thistle	1	1



Northern Great Plains Inventory and Monitoring Network Exotic Plant Cover by Plot

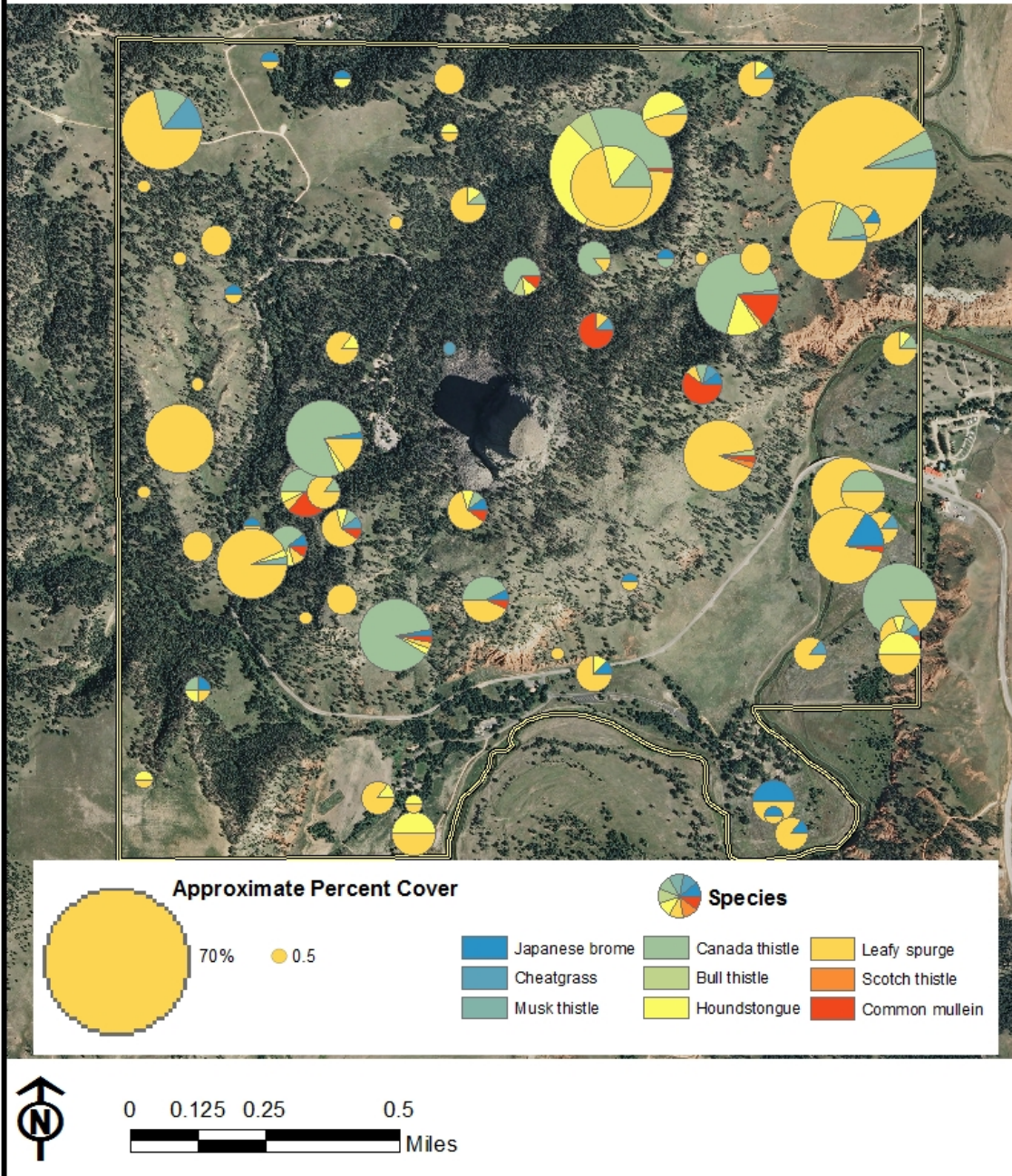


Figure 8. Percent cover of nine exotic species in Devils Tower National Monument in 2013. In this diagram, percent cover for each species (different colors) was determined by using the midpoints of cover class ranges. The size of each circle represents the sum of the cover of all species in that site.

Discussion

The forests in DETO in 2013 contained 11 species of trees or tall shrubs (Table 4) but were dominated by ponderosa pine in the uplands and deciduous trees in the riparian areas, as is typical of the Black Hills region. Average stand density (151 stems/ha) and basal areas ($13.1\text{m}^2/\text{ha}$) were similar to the reconstructed historic forest density and basal area for the northern Black Hills in 1900 (Table 7; Brown and Cook 2006). When we include only the forested plots, basal area and density increases but remains within the bounds of the reference condition. The DETO Fire management plan (National Park Service 2004) outlined desired conditions of maintaining open-canopy ponderosa pine stands with tree density in a range of 150–250 stems/ha for ponderosa pine/mixed-grass savanna. Compared to this, upland ponderosa forests overall were on the low end of the range (they averaged 151 stems/ha). The desired condition for ponderosa pine forest density is a range of 200–350 stems/ha (80–140 stems/acre). When we exclude plots that fall within the ponderosa/mixed-grass habitats, and include only the forested plots, the average density in 2013 jumps to 171 stems/ha which is still at or below the desired conditions. We found only one plot (PCM_011) that was above the desired range – it had a density of 605 stems/ha. This suggests that recent thinning activities have been effective at reducing forest density.

A recent time-series analysis of Landsat images characterizing forest extent and change (Hansen et al. 2013) highlight some of the areas where forest cover has declined between 2000–2012 in DETO (Figure 9). Forest loss has been primarily within the regions to the north and west of the tower. Loss is consistent with the history of prescribed fires and thinning treatments, but there seems to be a lagged response to treatments (Figure 9).

Mountain pine beetles have been spreading throughout the Black Hills (USDA 2013) and may be an increasing management concern to the park in areas where maintaining ponderosa pine is desired or where affected trees may become hazardous (e.g., around the Visitor Center) (Ambourn and Allen 2013). Pine beetles are endemic to the park, but when there is greater than 1 infested tree per hectare infestations are considered to be at epidemic levels (Schmid et al. 2007). High ponderosa stand density and basal area can increase susceptibility to attack by mountain pine beetles (Negrón et al. 2008). Less than 12% of the upland forest in DETO has basal areas that are considered high enough to have an increased risk of mountain pine beetle infestation based on density ($> 27.6\text{ m}^2$ per hectare) (Schmid et al. 1994). In 2013, we found 5 plots in the park that had some evidence of mountain pine beetles (PCM_007, 041, 042, 049, and 067). These plots were not clustered, and they were generally in the northern areas of the park. Despite the predictions of increased risk, the plots with mountain pine beetle did not all have high basal areas. Our finding is consistent with a 2012 assessment done by the U.S. Forest Service that stated current levels of mountain pine beetle activity in DETO is low to moderate (Ambourn and Allen 2013).



Global Forest Change Forest Loss from 2000 to 2012

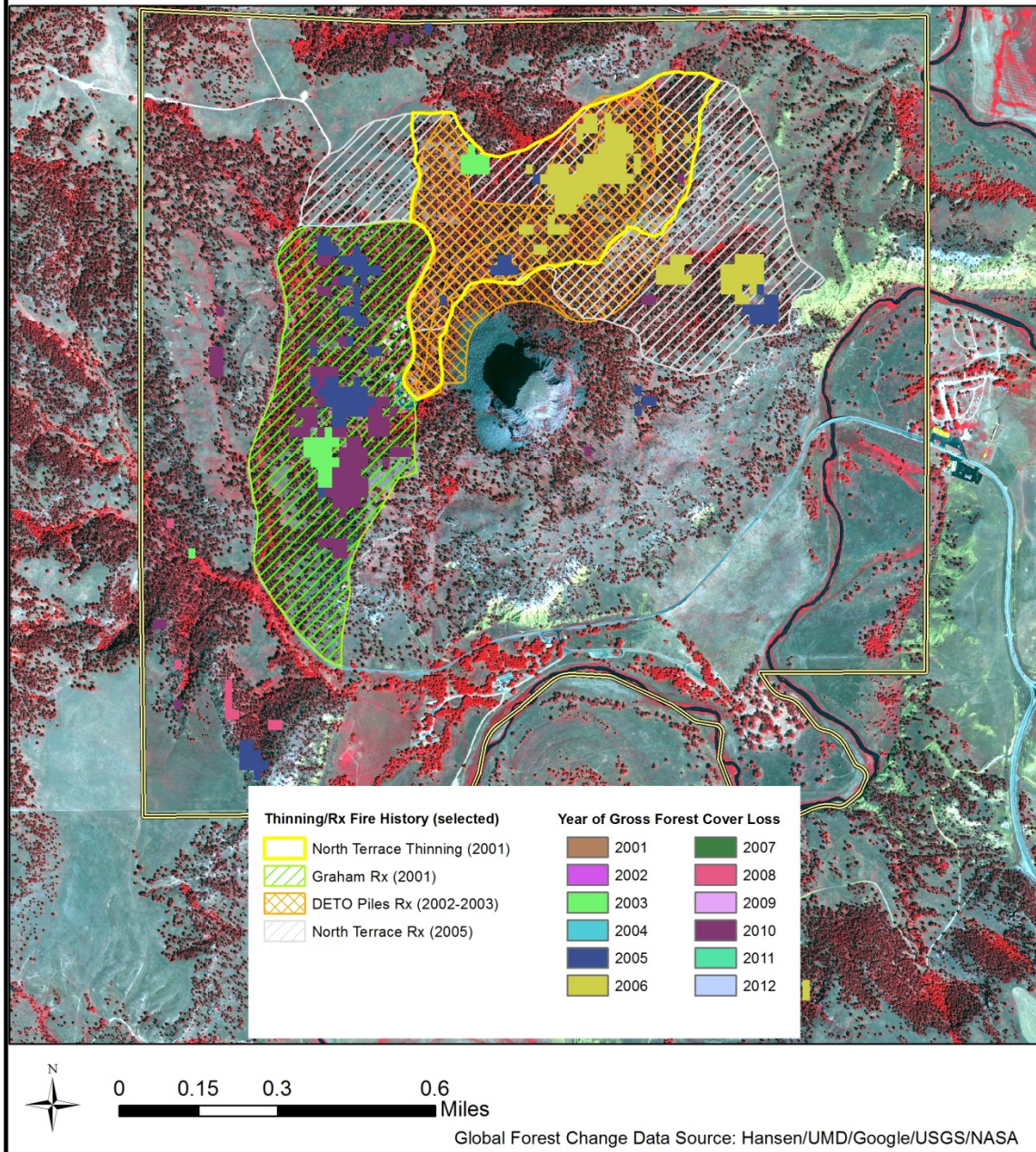


Figure 9. Forest cover change, thinning and prescribed fire history in Devils Tower National Monument from 2000-2012. Forest cover change data are from Hansen et al. 2014.

Forests in the Black Hills National Forest are generally managed to keep an initial basal area of < 14 m² per hectare to allow pine seedlings to establish in the understory and to maximize understory productivity to sustain periodic timber harvests (Shepperd and Battaglia 2002). Between 55 and 60% of the park met this criterion, suggesting that seedling recruitment will not be limited by reduced light penetration to the understory. Seedling densities were spatially variable, and there were a number of plots with a high density of ponderosa seedlings. Ponderosa pine pole density was also variable across the park. Site PCM_058 has the maximum density of 350 stems/ha. In five years, when this survey is repeated, we may be able to discern changes in forest structure.

Downed wood and surface fuels provide foraging habitat and refugia for small wildlife species, as well as substrate for mosses and fungi. Downed wood also sometimes provide “nursery” logs for vascular plant establishment. However, when surface fuels are too abundant in a forest they can increase the risk of high intensity fires. Ideally, a healthy forest will have a mosaic of conditions that range from open areas with low fuel loads to denser areas. The Northern Great Plains FireEP has developed a management target for surface fuels: the goal is to keep a range between 2 and 10 tons per acre within the Black Hills parks. In 2013, we found that surface fuels at DETO were above this management target (Table 7). Brown and colleagues (2003) defined an optimum range of coarse woody debris for warm and dry ponderosa forests of 5 to 20 tons per acre. This optimum range of coarse woody debris is thought to provide an acceptable risk of fire hazard while still providing benefit to wildlife and soils. Within DETO, coarse woody debris averaged 5.7 tons per acre in the ponderosa forest. This suggests there is a good balance between fire hazard and providing optimal benefit to forest soils and wildlife. The high total surface fuel loads was driven instead by a significant duff and litter layer on the forest floor. The thick litter and duff layer is most likely a result of changes to the natural fire frequency. We expect that when (and if) a more natural fire frequency is established through a prescribed burning program, the litter and duff layer will be reduced and total surface fuel loads will decline. Reducing the litter and duff loading through prescribed fire will also lead to more suitable ponderosa pine regeneration conditions due to increased areas of bare soil and nutrient recycling.

The riparian cottonwood forests in DETO are not in good condition (Table 7). A healthy forest stand should have a mixed-age structure with mature trees, poles, and seedlings present. In 2013, we found only one cottonwood seedling and only 4 mature trees in the 20 plots we examined in the riparian zone. The lack of regeneration is because dams upstream on the Belle Fourche River have greatly reduced flood events and their associated moisture and bare ground conditions, which cottonwood seedling establishment requires (Tinker 2008, Komp et al. 2011). Restoration efforts to reestablish cottonwoods will likely require intensive and active management and include planting, watering, and fencing (for protection from browse) (Anderson 2013). We did find seedlings and mature trees of other hardwood species, such as green ash and boxelder, within the riparian area (Figure 5). Protecting and, where possible, managing for a healthy hardwood forest may provide a more realistic goal for park management. Planting green ash trees will likely be one of the most-cost effective strategies (Anderson 2013), but as green ash increases in dominance the park may be more susceptible to emerald ash borer. Emerald ash borer (*Agrilus planipennis*) is a beetle that is highly destructive to ash trees and, while it is not yet found in Wyoming, it has been spreading rapidly in

neighboring states (<https://sites.google.com/a/wyo.gov/forest-health/>). Green ash is a dominant component of the riparian forest in DETO and its loss would be devastating to the park's riparian forest. Efforts to monitor and prevent the spread of the beetle into the park (via firewood) should be prioritized.

DETO has a long history of human alterations to the landscape and exotic species are prevalent throughout the park. The cover of exotic target species has been fairly stable over the past decade (based on the 2003 (Wood and Rew 2005) and this 2013 survey; Appendix A). Some species, such as the annual bromes, were found in a greater number of locations in 2013 than ten years ago (Figure 9). Other species, such as musk thistle, have been effectively controlled and are now found in fewer areas of the park than in 2003 (Figure 10). Overall, there has not been a significant decline in the cover of exotic target species, and leafy spurge has remained the most prevalent exotic species. (Table 7). This analysis, however, is coarse, and a more thorough analysis that incorporates park and Exotic Plant Management Team data might yield different results. Ideally, the mapping project done in 2003 could be repeated, but that is beyond the scope of the NGPN or FireEP. In five years, when this forest survey is repeated, we will have a higher confidence in the status and trend of exotic cover in DETO.

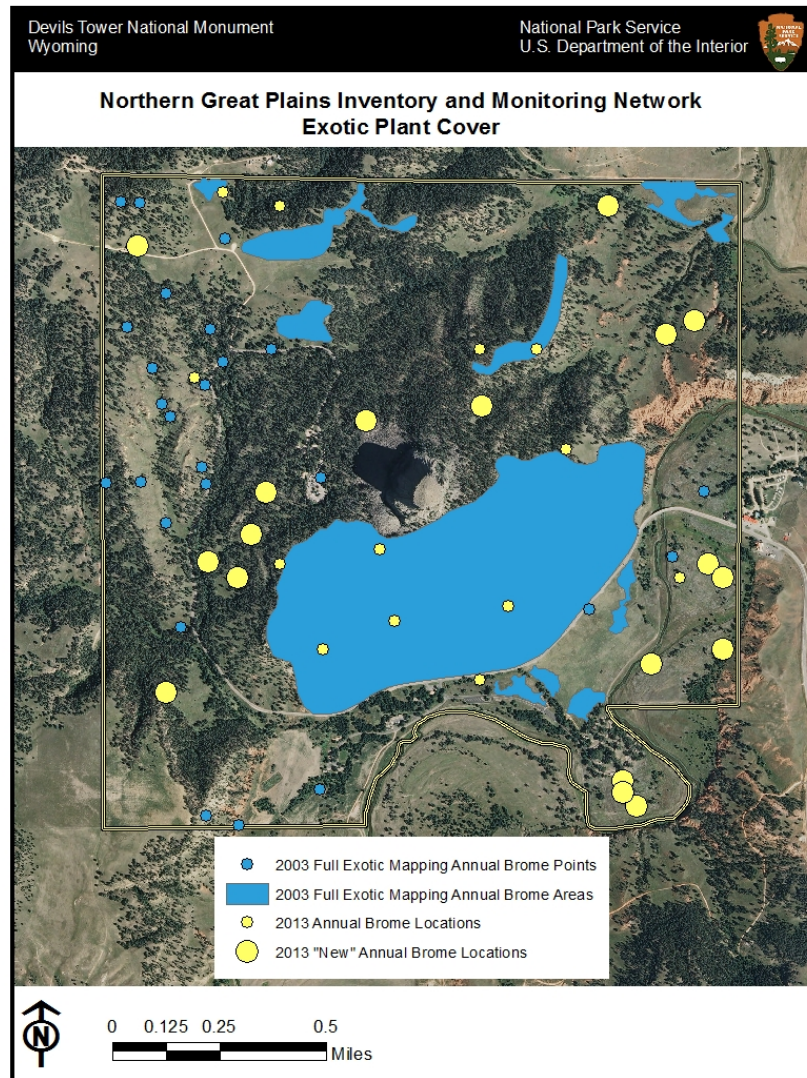


Figure 10. The location of annual brome species found in Devils Tower National Monument in 2013 and 2003 (Wood and Rew 2005). The plots where annual bromes were found in 2013 that are more than 100m from 2003 documented locations are highlighted with larger circles.

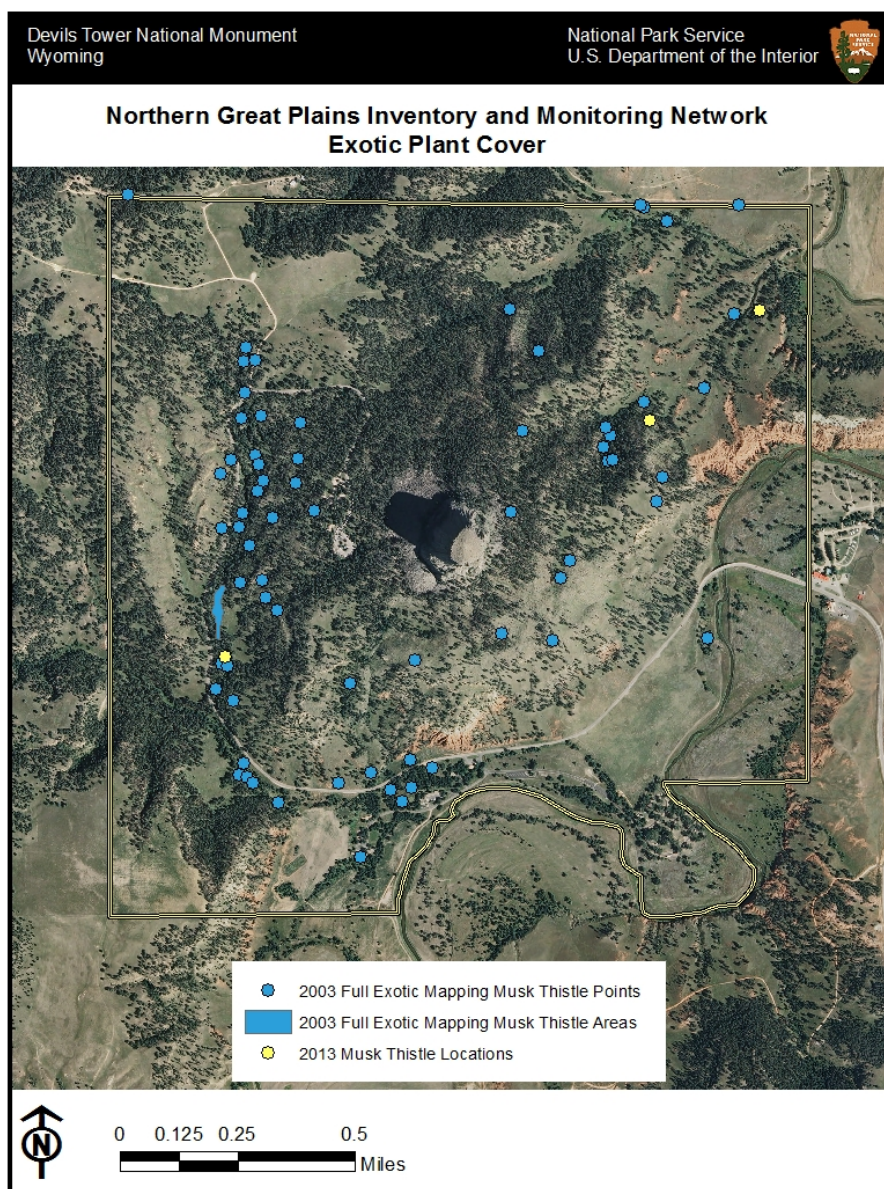


Figure 11. The location of musk thistle found in Devils Tower National Monument in 2013 and 2003 (Wood and Rew 2005). The plots where thistles were found in 2013 that are more than 100m from 2003 documented locations are highlighted with larger circles.

In conclusion, as of 2013 DETO's ponderosa pine forests and woodlands are in good condition but exotic species are widespread and persistent. Basal areas and tree densities are similar to historic conditions and within the range of desired conditions as outlined by the park. Surface fuels are above the targeted range and indicate the need for further treatment with prescribed fire. Most units have had only one entry of prescribed fire and an appropriate prescribed fire return interval between 10 and 20 years for each prescribed burn unit would be desired as park management continues the restoration phase of the forest ecosystem. The condition of riparian forests and woodlands in DETO is declining due to low cottonwood recruitment and survival. Exotic species are also abundant in this corridor. As suggested by others, restoration projects may be difficult due to the fundamental

changes in the flow of the Belle Fourche River. Trends in forest condition are difficult to discern because few quantitative studies of past conditions were completed, but continued forest surveys will allow us to discern changes in the future.

Table 7. Natural resource condition summary table for forest condition in DETO in 2013.

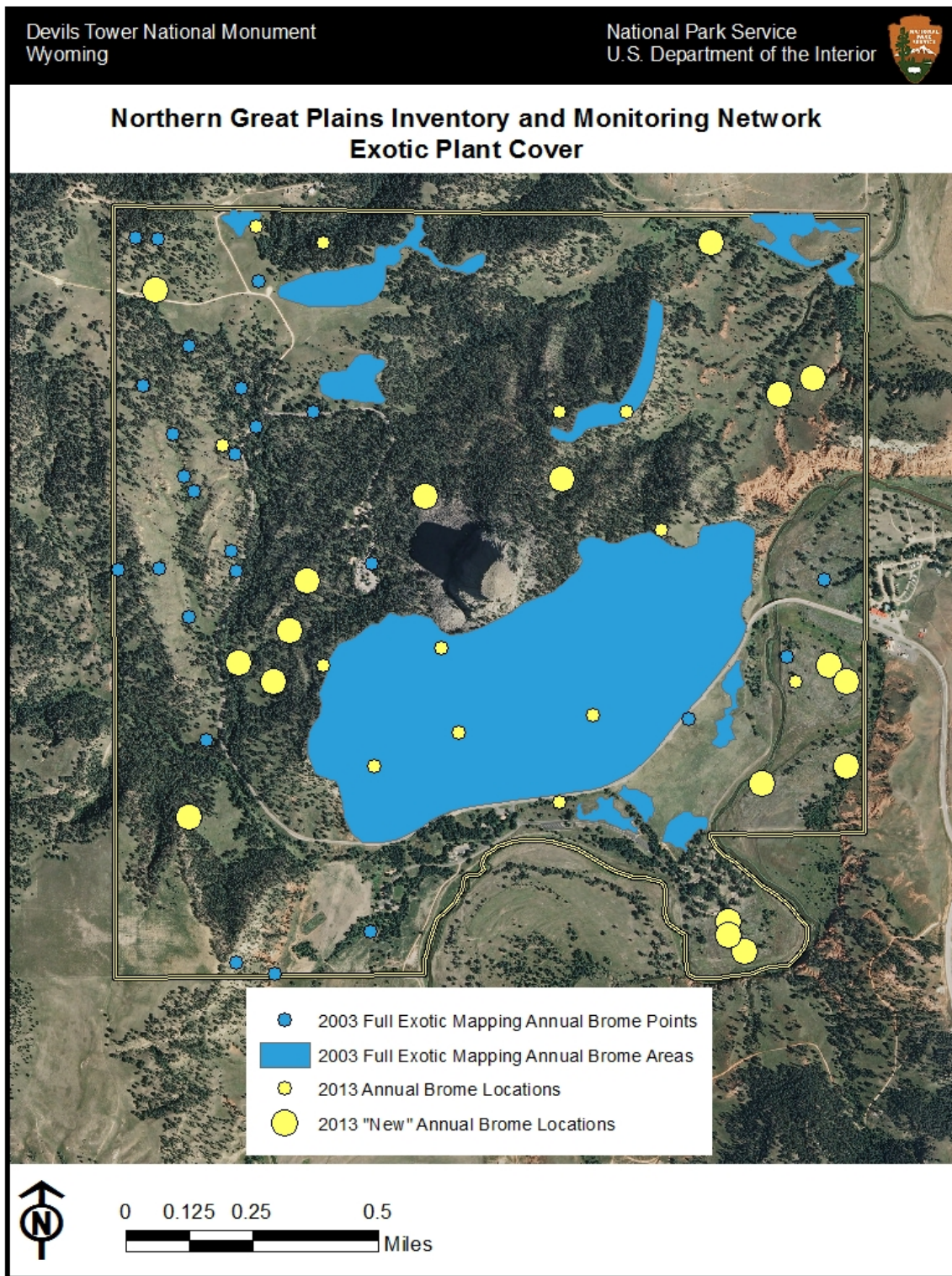
Indicators of Condition	Specific Measures	2013 Value (mean $\pm$ SE)	Reference Value	Condition Status/Trend	Rationale
Upland Plant Communities	Ponderosa pine basal area	13.1 $\pm$ 1.3 m ² ha ⁻¹	10.7 $\pm$ 3.1 m ² ha ⁻¹		Basal area in the park is similar to historic conditions of the Northern Back Hills (Brown and Cook 2006). When we include only the forested plots, basal area increases but remains within the bounds of the reference condition. Our confidence in this assessment is reduced because data used to derive the reference condition were not available from the Bear Lodge mountains.
	Ponderosa pine density	151 $\pm$ 14.4 stems ha ⁻¹	150 - 350 stems ha ⁻¹		The current forest density is on the low end of the desired conditions outlined by the DETO Fire Management Plan (National Park Service 2004). This suggests that recent thinning activities have been effective at reducing forest density.
Fire and Fuel Dynamics	Total surface fuel loads	16.1 $\pm$ 1.3 tons per acre	Between 2 and 10		The current fire ecology program aims to maintain fuel loads of less than 10 tons per acre. The ponderosa pine woodlands of DETO have fuel loads above this management threshold. When the mixed-grass prairie sites are excluded, the average fuel loads are increased to 18 tons per acre. A large amount of surface fuels can increase the chance of high severity fires.
Riparian Plant Communities	Percent of riparian plots with deciduous poles or seedlings	35%	TBD		In the absence of cottonwood regeneration, DETO riparian forests may be dominated by species such as green ash and box elder. We found seedlings and poles of deciduous trees in 35% of the riparian plots. Future monitoring is needed to determine whether these will continue to support a hardwood forest in DETO.
Riparian Plant Communities	Cottonwood stand structure	1 seedling and dominated by old growth	Healthy mixed-age structure		Cottonwood forests within DETO consist of a large number of standing dead and old trees with little to no regeneration. This forest structure is a result of alterations in the flow of the Belle Fourche River. Without the return of a natural hydroperiod, it is unlikely that cottonwoods will thrive in DETO (Anderson 2013).
Exotic Plant Cover	Upland average cover of exotic target species	8 $\pm$ 1.4%	A decline in the cover of exotic target species		DETO has a long history of human alterations to the landscape and exotic species are prevalent throughout the park. Based on a comparison of exotic target species cover in 2003 (Wood and Rew 2005) and 2013, there is no indication that exotic cover is declining. Our confidence in this assessment is low because the methods differ across these studies. In five years, when this forest survey is repeated, we will have a higher confidence in the status and trend.
	Riparian average cover of exotic target species	6 $\pm$ 0.9%	A decline in the cover of exotic target species		

Literature Cited

- Allen, C. D., A. K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D. D. Breshears, E. H. Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J.-H. Lim, G. Allard, S. W. Running, A. Semerci, and N. Cobb. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* 259:660-684.
- Ambourn, A. and K. Allen. 2013. Evaluation of MPB activity at Devils Tower National Monument, Wyoming. USDA Forest Service. Rocky Mountain Region Forest Health Management.
- Anderson, J. M. 2013. The decline of a riparian gallery forest in Devils Tower, Wyoming: causation and management techniques for restoration. Montana State University, Bozeman, Montana.
- Ashton, I. and M. Prowatzke. 2014. Plant community composition and structure monitoring for Devils Tower National Monument: 2013 annual report. Natural Resource Data Series NPS/NGPN/NRDS—2014/612. National Park Service, Fort Collins, Colorado.
- Brown, J. K. 1974. Handbook for inventorying downed material. General Technical Report INT-16. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.
- Brown, J. K., R. D. Oberhue, and C. M. Johnston. 1982. Inventorying surface fuels and biomass in the Interior West. General Technical Report INT-129. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.
- Brown, J. K., E. D. Reinhardt, and K. A. Kramer. 2003. Coarse woody debris: managing benefits and fire hazard in the recovering forest. Gen. Tech. Rep. RMRS-GTR-105 U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.
- Brown, P. M. 2006. Climate effects on fire regimes and tree recruitment in Black Hills ponderosa pine forests. *Ecology* 87:2500-2510.
- Brown, P. M. and B. Cook. 2006. Early settlement forest structure in Black Hills ponderosa pine forests. *Forest Ecology and Management* 223:284-290.
- Fisher, R. F., M. J. Jenkins, and W. F. Fisher. 1987. Fire and the prairie-forest mosaic of Devils Tower National Monument. *American Midland Naturalist* 117:250-257.
- Gitzen, R. A., M. Wilson, J. Brumm, M. Bynum, J. Wrede, J. J. Millspaugh, and K. J. Paintner. 2010. Northern Great Plains Network vital signs monitoring plan. Natural Resource Report NPS/NGPN/ NRR-2010/186.
- Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science* 342:850-853.
- Hansen, M. H., W. G. Madow, and B. J. Tepping. 1983. An evaluation of model-dependent and probability-sampling inferences in sample-surveys. *Journal Of The American Statistical Association* 78:776-793.
- Hocking, C. M., E. L. Krantz, and G. J. Josten. 2010. South Dakota statewide assessment of forest resources. South Dakota Department of Agriculture. <http://sdda.sd.gov/forestry/current-news/assessment.aspx>.
- Kincaid, T. M. and A. R. Olsen. 2011. spsurvey: Spatial survey desing and Analysis. R package version 2.2.
- Komp, M. R., K. J. Stark, A. J. Nadeau, S. Amberg, E. Iverson, and B. Drazkowski. 2011. Devils Tower National Monument: Natural resource condition assessment. Natural Resource Report NPS/DETO/NRR—2011/479. National Park Service, Fort Collins, Colorado.
- Larson, G. E. and J. R. Johnson. 2007. Plants of the Black Hills and Bear Lodge Mountains, 2nd edition. South Dakota State University, Brookings, SD.
- National Park Service. 2004. Devils Tower National Monument fire management plan: 2004. Devils Tower National Monument, WY.

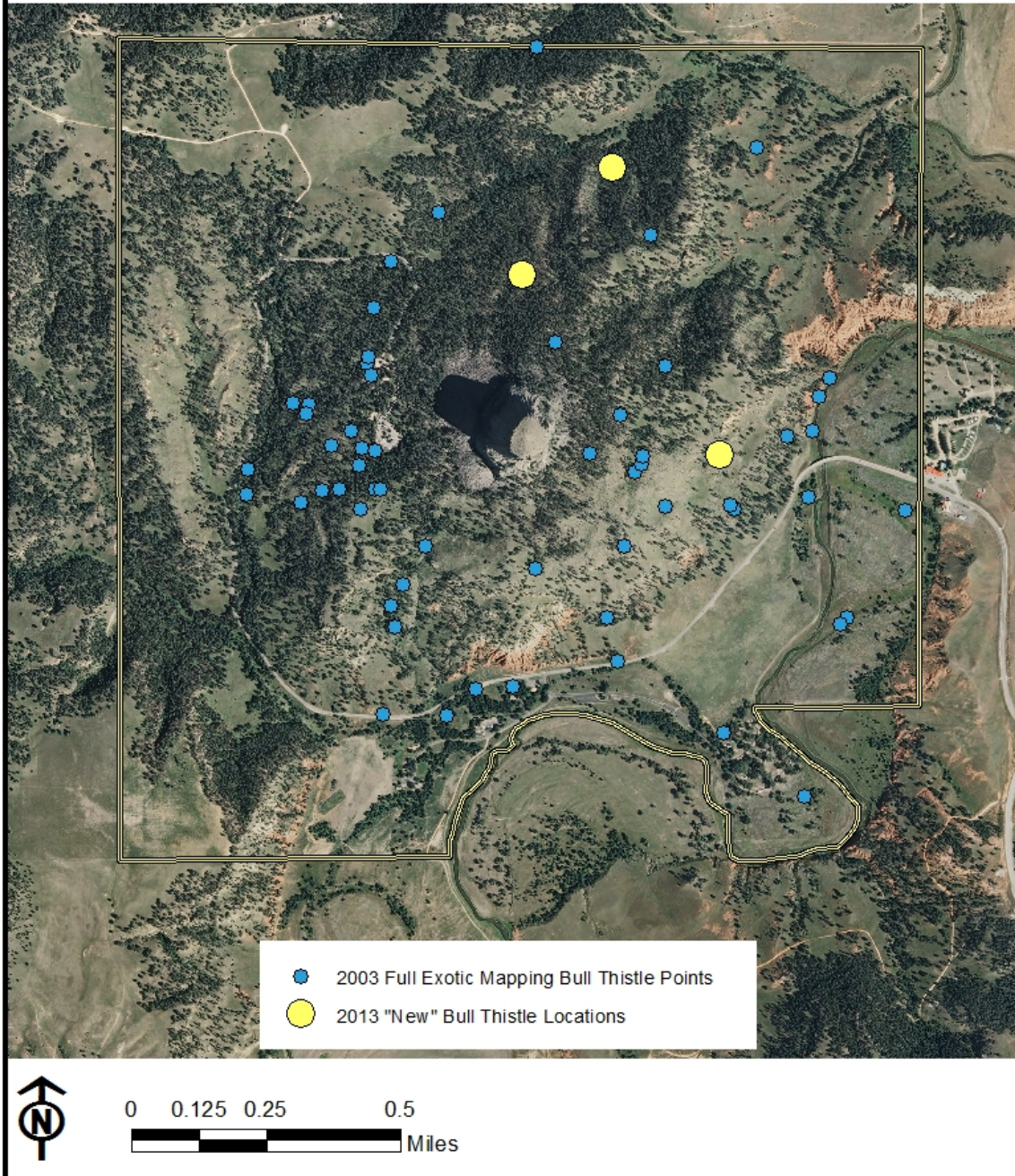
- Negrón, J. F., K. Allen, B. Cook, and J. R. Withrow Jr. 2008. Susceptibility of ponderosa pine, *Pinus ponderosa* (Dougl. ex Laws.), to mountain pine beetle, *Dendroctonus ponderosae* Hopkins, attack in uneven-aged stands in the Black Hills of South Dakota and Wyoming USA. *Forest Ecology and Management* 254:327-334.
- Salas, D. E. and M. J. Pucherelli. 1998. USGS-NPS Vegetation Mapping Devils Tower National Monument, Wyoming. USDI Bureau of Reclamation. Denver, CO.
- Schmid, J. M., S. A. Mata, R. R. Kessler, and J. B. Popp. 2007. The influence of partial cutting on mountain pine beetle-caused tree mortality in Black Hills ponderosa pine stands. Res. Pap. RMRS-RP-68 Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
- Schmid, J. M., S. A. Mata, and R. A. Obedzinski. 1994. Hazard rating ponderosa pine stands for mountain pine beetles in the Black Hills. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Note RM-529.
- Shepperd, W. D. and M. A. Battaglia. 2002. Ecology, silviculture, and management of Black Hills ponderosa pine. *in* USDA, editor. Rocky Mountain Research Station General Technical Report RMS-GTR-97.
- Stambaugh, M. C., R. P. Guyette, E. R. McMurry, J. M. Marschall, and G. Willson. 2008. Six centuries of fire history at Devils Tower National Monument with comments on regionwide temperature influence. *Great Plains Research* 18:177-187.
- Stevens, D. L. and A. R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. *Environmetrics* 14:593-610.
- Stevens, D. L. and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal Of The American Statistical Association* 99:262-278.
- Symstad, A. J., R.A. Gitzen, C. L. Wienk, M. R. Bynum, D. J. Swanson, A. D. Thorstenson, and K. J. Paintner. 2012. Plant community composition and structure monitoring protocol for the Northern Great Plains I&M Network: version 1.01. Natural Resource Report NPS/NGPN/ NRR-2012/489.
- Tinker, D. B. 2008. Riparian habitat restoration in Devil's Tower National Monument. Final Report. University of Wyoming, Laramie, WY.
- USDA-NRCS. 2012. The PLANTS Database (<http://plants.usda.gov>, 24 January 2012). National Plant Data Team, Greensboro, NC 27401-4901 USA.
- USDA. 2013. Forest and Grassland Health- Aerial Detection Survey 2012 Results: <http://www.fs.usda.gov/detail/r2/forest-grasslandhealth/?cid=stelprdb5408531>.
- Wood, S. D. and L. J. Rew. 2005. Non-native plant survey at Devils Tower National Monument. Montana State University, Bozeman.

Appendix A: Maps of select exotic species in DETO in 2003 and 2013



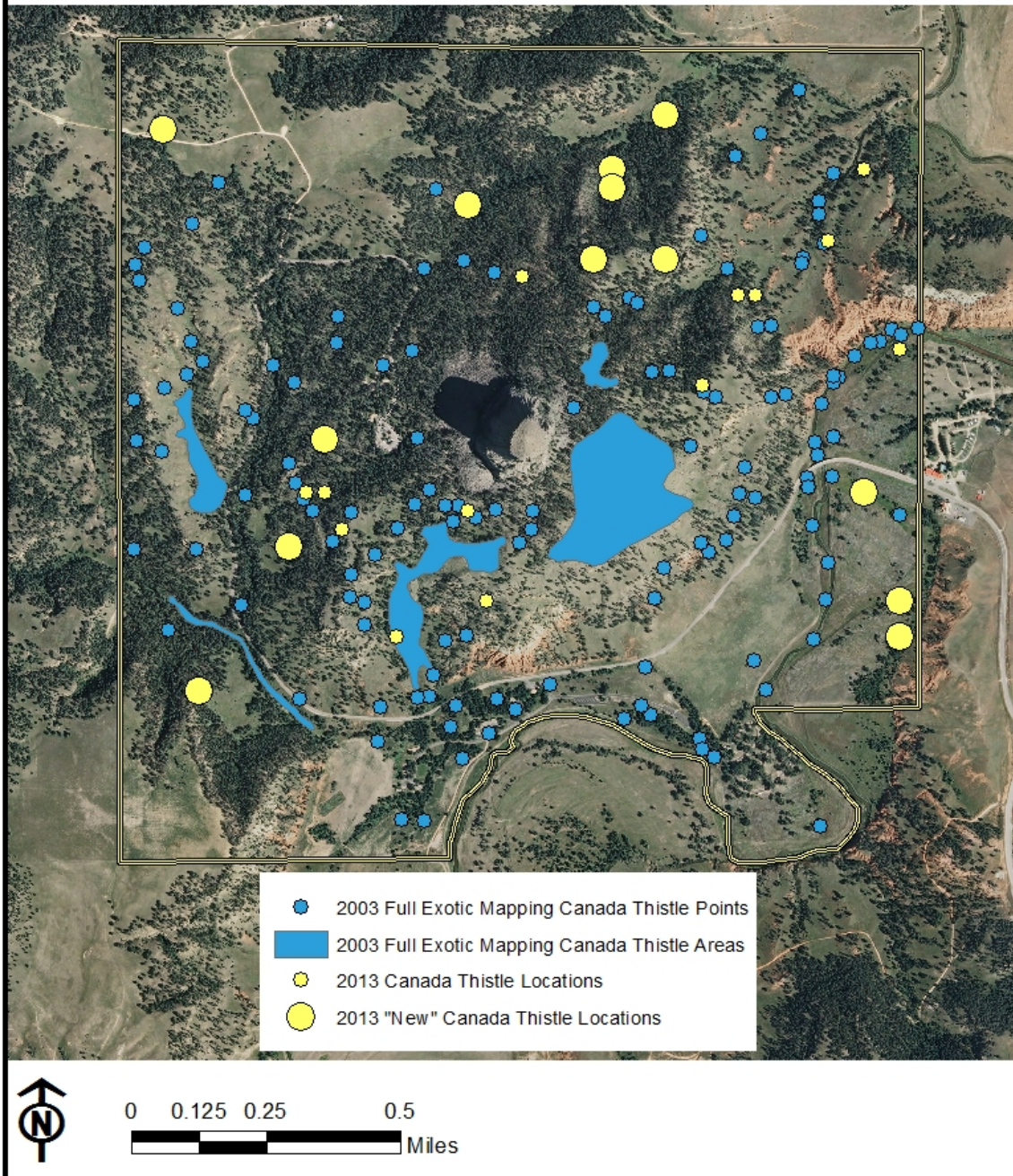


Northern Great Plains Inventory and Monitoring Network Exotic Plant Cover



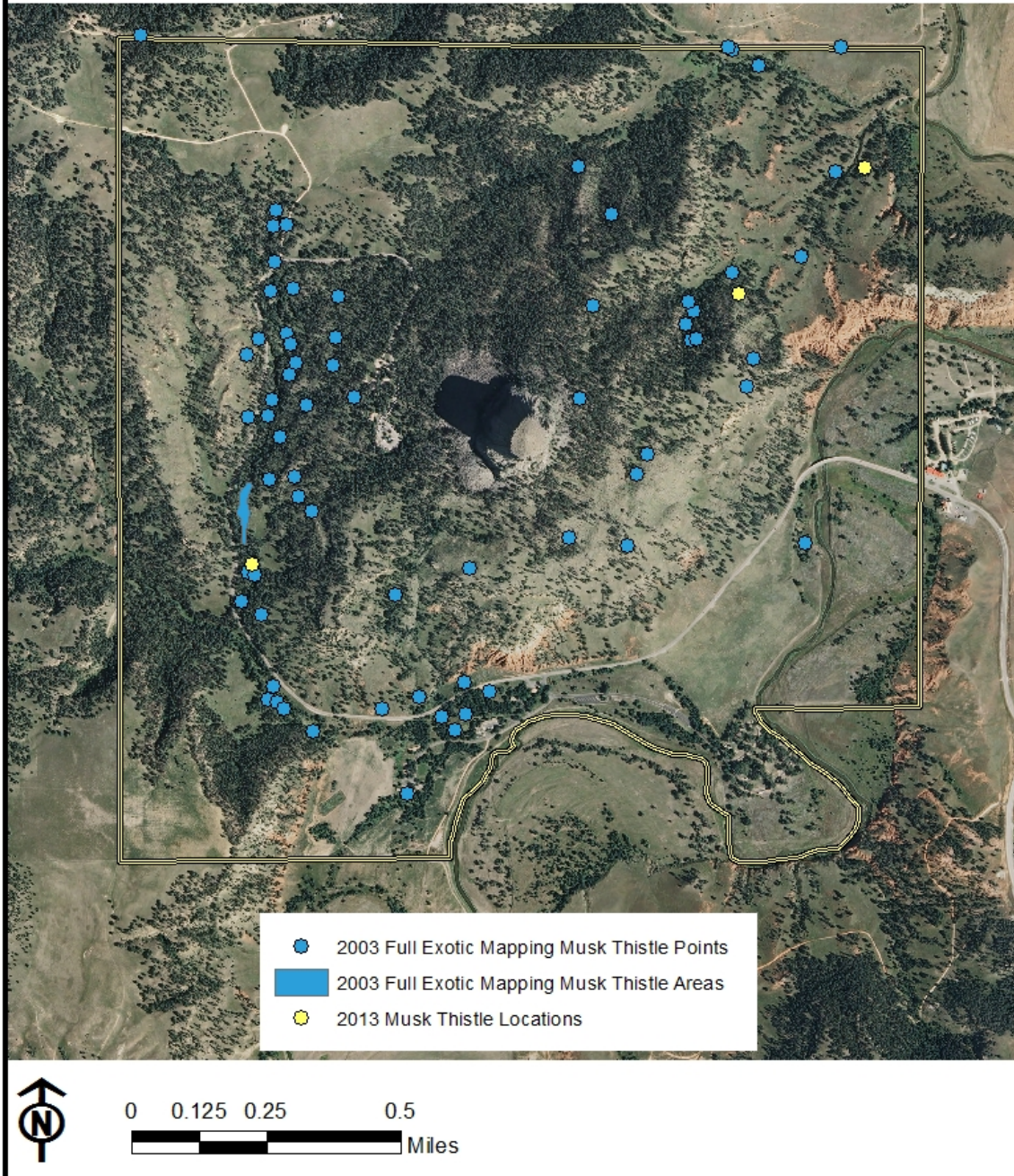


Northern Great Plains Inventory and Monitoring Network Exotic Plant Cover



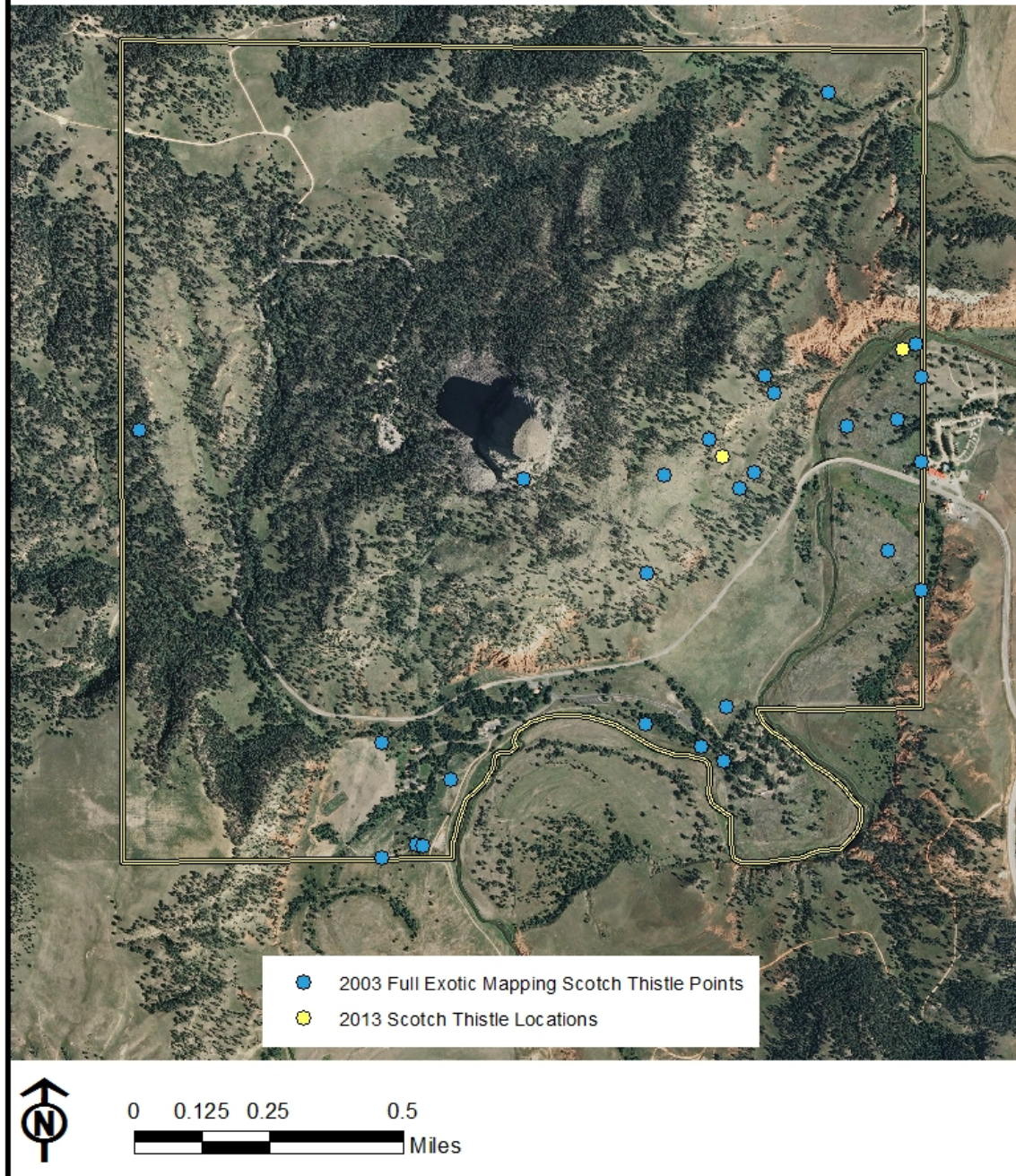


Northern Great Plains Inventory and Monitoring Network Exotic Plant Cover



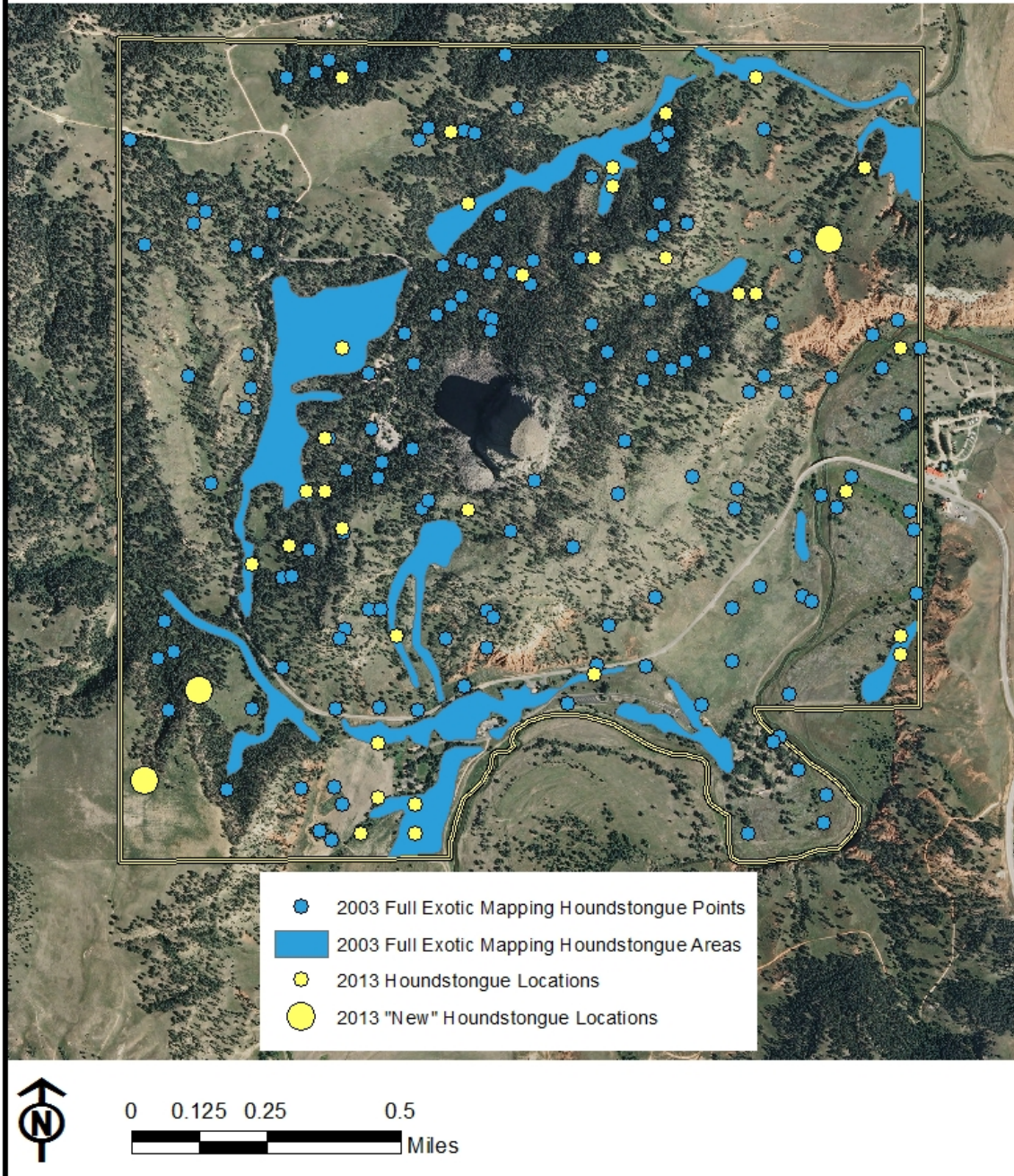


Northern Great Plains Inventory and Monitoring Network Exotic Plant Cover



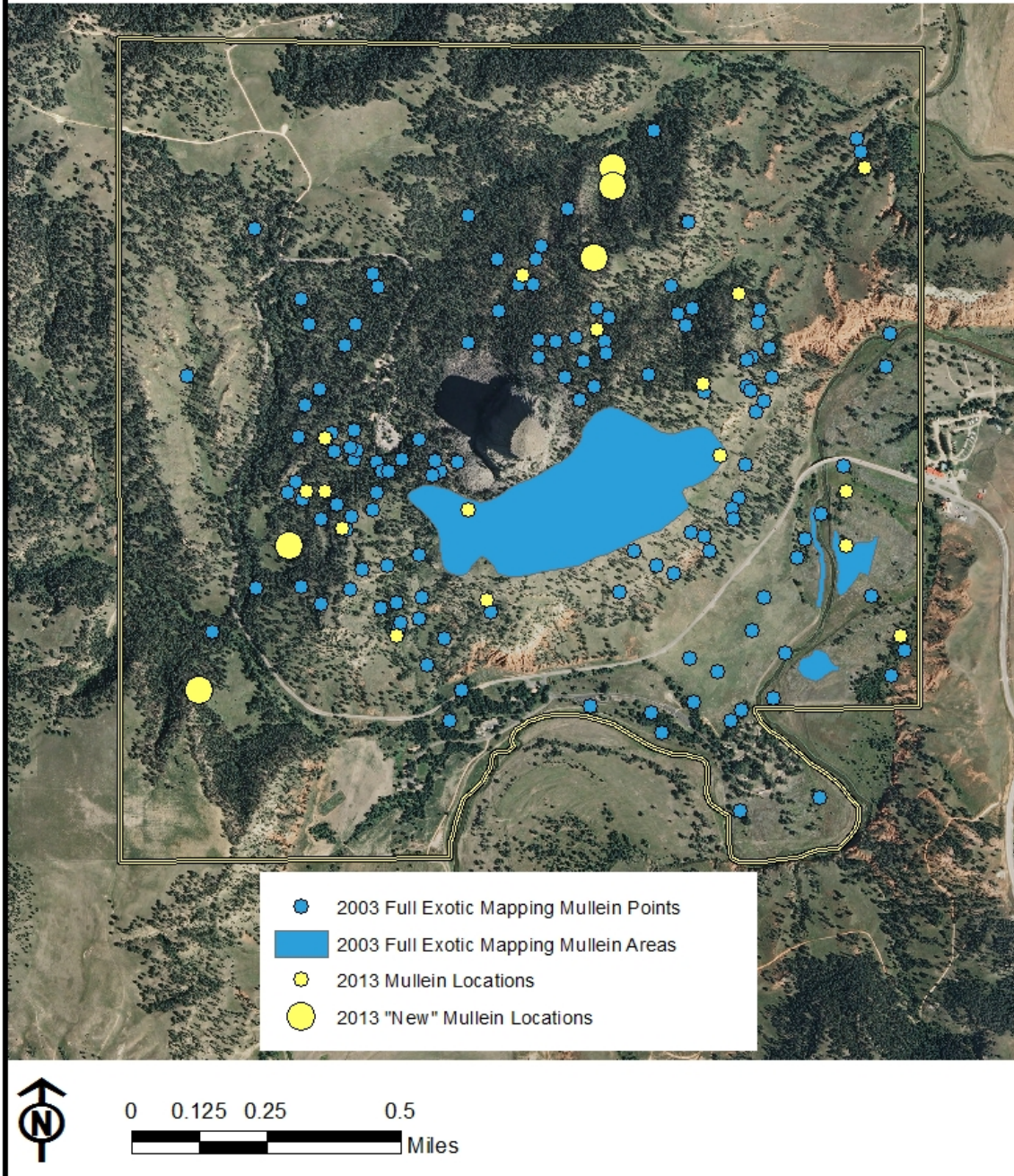


Northern Great Plains Inventory and Monitoring Network Exotic Plant Cover



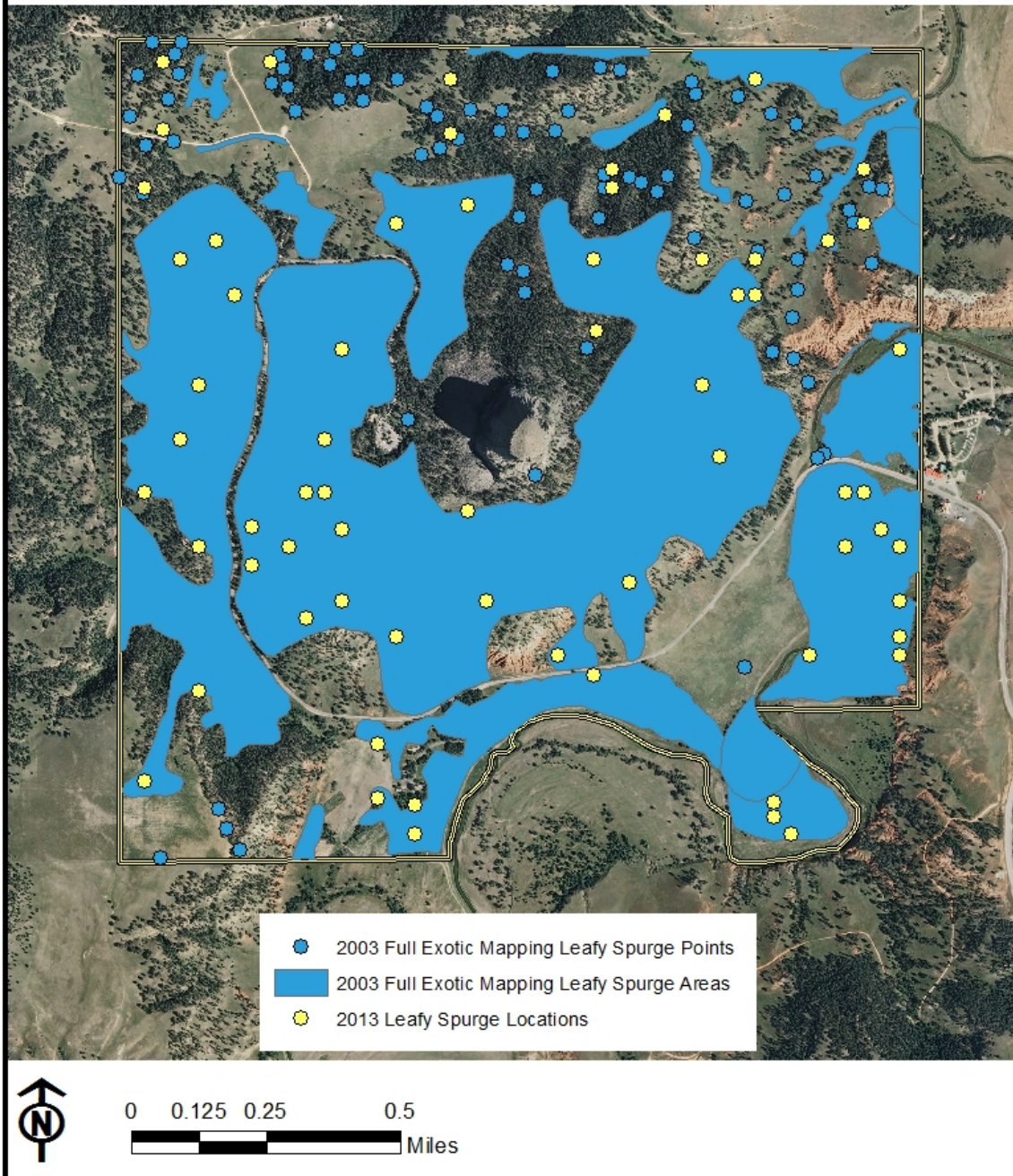


Northern Great Plains Inventory and Monitoring Network Exotic Plant Cover





Northern Great Plains Inventory and Monitoring Network Exotic Plant Cover



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

NPS 109/124158, March 2014

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™