



Plant Community Composition and Structure Monitoring at Mount Rushmore National Memorial

2010-2012 Status Report

Natural Resource Technical Report NPS/NGPN/NRTR—2013/677



ON THE COVER

Field work at Mount Rushmore National Memorial, 2011

Photograph by: Belinda Lo, NGPN, NPS

Plant Community Composition and Structure Monitoring at Mount Rushmore National Memorial

2010-2012 Status Report

Natural Resource Technical Report NPS/NGPN/NRTR—2013/677

Isabel W. Ashton
Michael Prowatzke
Michael R. Bynum
Tim Shepherd
Stephen K. Wilson
Kara Paintner-Green

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

January 2013

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.

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 from Northern Great Plains Network website <http://science.nature.nps.gov/im/units/ngpn/index.cfm> and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>).

Please cite this publication as:

Ashton, I. W., M. Prowatzke, M. Bynum, T. Shepherd, S. K. Wilson, K. Paintner-Green. 2013. Plant community composition and structure monitoring at Mount Rushmore National Memorial: 2010-2012 status report. Natural Resource Technical Report NPS/NGPN/NRTR—2013/677. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	iv
Tables.....	iv
Executive Summary.....	v
Acknowledgments.....	vi
Introduction.....	1
Methods.....	3
Sample design.....	3
Plot layout and sampling	3
Data Management and Analysis	7
Reporting on Natural Resource Condition	7
Results and Discussion	9
Literature Cited	15
Appendix A: List of plant species found in 2010-2012 at MORU	17

Figures

	Page
Figure 1. Parks and ecoregions of the Northern Great Plains Network.....	2
Figure 2. Map of MORU and plant community monitoring plots.	4
Figure 3. Long-term monitoring plot used for sampling forest understory plant communities in Mount Rushmore National Memorial.	5
Figure 4. Average relative abundance and life-form of the 10 most abundant species encountered in the plant community monitoring plots in Mount Rushmore National Memorial in 2010.....	9
Figure 5. A photograph of Plot PCM_003 illustrating the understory of Mount Rushmore National Memorial.....	10
Figure 6. Average cover by life forms in 15 plant community monitoring plots in Mount Rushmore National Memorial in 2010.....	10
Figure 7. Photograph of plot PCM_018 illustrating the change from 2010 (left panel) and 2011 and 2012 (right and bottom panel).	11
Figure 8. Cumulative distribution function of relative cover of exotic species in Mount Rushmore National Memorial.	13

Tables

	Page
Table 1. Exotic species of management interest in MORU that were surveyed for during the 2010 field season.	6
Table 2. Key to the symbols used in the Natural Resource Condition Table.	8
Table 4. Species richness in Mount Rushmore National Memorial.....	11
Table 5. Natural resource condition summary table for upland plant communities in MORU.....	14

Executive Summary

The Northern Great Plains Inventory & Monitoring Network (NGPN) was established to develop and provide scientifically credible information on the current status and long-term trends of the composition, structure, and function of ecosystems in thirteen parks located in five northern Great Plains states. NGPN identified upland plant communities and exotic plant early detection as vital signs that can be used to better understand the condition of terrestrial park ecosystems.

Understory plants in 15 forested plots at Mount Rushmore National Memorial (MORU) were surveyed by NGPN in July 2010, and a subset of 6 of these plots was revisited in July 2011 and June 2012. We measured plant diversity, richness, and species cover. By using a randomized survey approach, we are able to use these data to estimate the status of the understory plant community across the park as a whole. We found the following:

- Over the two years, we recorded a total of 151 vascular plant species. The most abundant understory species was kinnikinnick (*Arctostaphylos uva-ursi*).
- We found a relatively low cover of plants on the ground and a high cover of plant litter (primarily ponderosa pine needles). A decline in plant cover between 2010 and 2012 was likely due to mechanical thinning done in the fall and winter of 2010.
- Species diversity in MORU was low. However, it is likely typically of older ponderosa forests in the Black Hills.
- Exotic species cover was very low in MORU and declined between 2010 and 2012.

The data and information in this report is summarized below in a natural resource condition table with a goal of communicating this complex park condition information in a clear and simple way. The green symbol indicates a good condition of understory plant communities in MORU. Further details about the table and its content are presented in the discussion of this paper.

Resource	Condition Status/Trend	Rationale
Understory plant community condition		MORU understory plant communities are in good condition. MORU has a low diversity of native plants and a low cover of understory plants, but this is consistent with older ponderosa forests with high conservation value. To date, MORU has maintained a low cover of exotic plants. We estimate that 60% of the park has no exotic species present. Future monitoring will allow us to determine whether thinning efforts cause a change in diversity and plant cover.

Acknowledgments

We thank all the authors of the NGPN Plant Community Monitoring Protocol, particularly Amy 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 MORU for providing logistical support. Thanks to the 2010 and 2011 NGPN vegetation field crew for collecting and entering the data included in this report. We thank Timothy Shepherd for invaluable support and instruction on managing data in the FFI database and Stephen Wilson for assistance with the GIS data.

Introduction

The Black Hills is a 1.5 million ha refuge of ponderosa pine (*Pinus ponderosa*) forest surrounded by the prairies of western South Dakota and eastern Wyoming (Figure 1). The ponderosa pine forest of the Black Hills is a unique ecosystem composed of species from the western Rocky Mountains, eastern deciduous forests, northern boreal forests, and the surrounding Great Plains (Larson and Johnson 2007). The mosaic of open and closed canopy forests maintains a relatively high diversity of vascular plants with an estimate of 1000 species in the Black Hills (Larson and Johnson 2007).

Mount Rushmore National Memorial (MORU) is located in the Black Hills (Figure 1) and has a mission to preserve and protect the sculptured visages of George Washington, Thomas Jefferson, Theodore Roosevelt, and Abraham Lincoln, as well as the land surrounding it. While this is a relatively small area (517 ha, 1278 ac), MORU contains the second-largest area of old growth ponderosa pine forest in the Black Hills (Symstad and Bynum 2007). Ponderosa pine is the dominant plant throughout the park but there are 459 vascular plant species listed on the park's certified species list (NRinfo: <https://irma.nps.gov/>). Plant diversity is highest in the small areas of the park that contain wetlands and deciduous canopy cover. There is a lower diversity of plants found under the closed-canopy of ponderosa pines, but the pristine condition of the older forest stands provides a valuable reference condition for Black Hills forests (Hoffman and Hansen 1986).

Historically, the forest has not been subject to intense management efforts, but there has been a change in fire regime. The pre-settlement (1529-1893) fire regime at MORU was characterized by low severity surface fires, about every 16 years, and larger area crown fires occurring at a period of greater than 100 years (Brown et al. 2008). Fire suppression over the last century has contributed to a change in forest structure from open to closed stands with a particular increase in small diameter trees (Brown et al. 2008). Between 1992 and 2001, there was an increase in forest cover at MORU which contributed to a decrease in landscape-scale diversity (Narumalani et al. 2009). Scientifically credible information on the current status and long-term trends of the composition and diversity of the forests in MORU is critical to increase our understanding of how changes in forest cover are impacting the understory.

The National Park Service Northern Great Plains Inventory & Monitoring Network (NGPN) sampled the understory plant communities in 15 forested sites in MORU in 2010 and revisited 6 of these sites in 2011 and another 6 sites in 2012. The sites were selected by a spatially balanced probability survey design (Stevens and Olsen 2004) which allows us to effectively sample the park and discern trends representative of the park. The general goal of this monitoring effort was to better understand the diversity and composition of MORU's forest by sampling and characterizing understory communities and exotic plant prevalence (Gitzen et al. 2010). More specifically, the long-term monitoring objectives are to: (1) determine park-wide status and long-term trends in vegetation species composition (e.g., non-native vs. native, forb vs. graminoid vs. shrub) and structure (e.g., cover, height) of herbaceous and shrub species and (2) 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. 2011).

Northern Great Plains Network Parks and Ecoregions

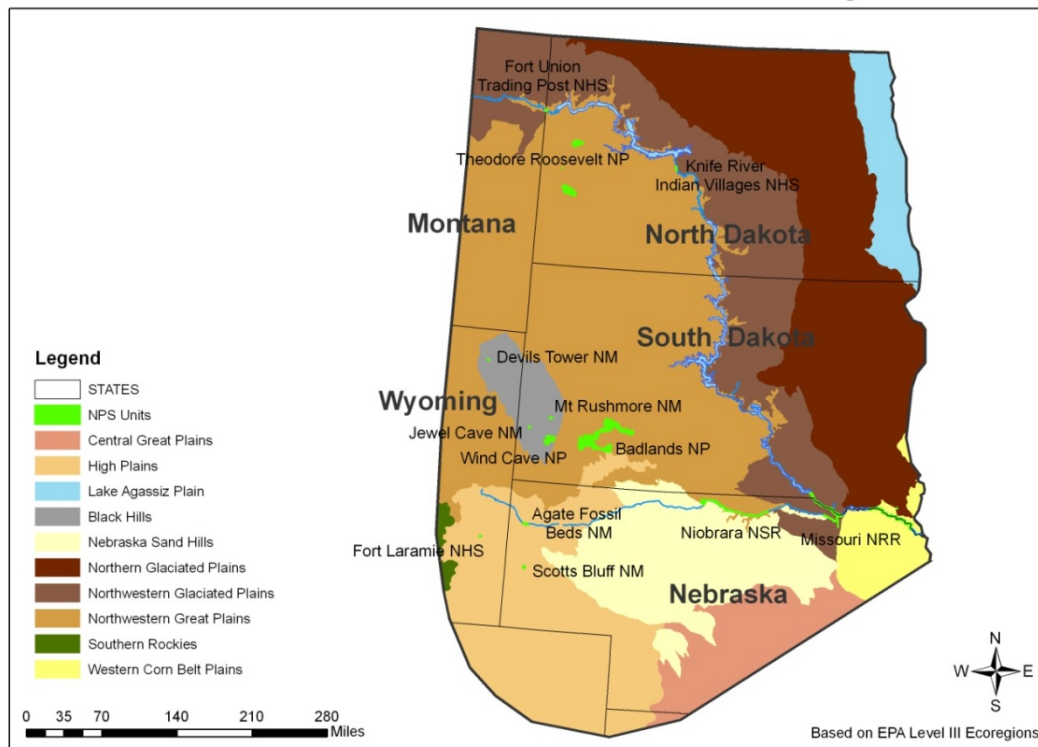


Figure 1. Parks and ecoregions of the Northern Great Plains Network. Based on the U.S. Environmental Protection Agency's Level III ecoregions classes (Omernik 2007).

This report is intended to provide a data summary for our initial sampling efforts between 2010 and 2012 at MORU. In 2010, we also conducted a large effort to examine forest structure and health in MORU which is described in a separate report (Ashton et al. 2012a).

Methods

The NGPN Plant Community Composition and Structure Monitoring Protocol (Symstad et al. 2012b, a) describes in detail the methods used for sampling long-term plots. Below, we briefly describe the general approach, sample frame, plot locations, and sampling methods. For those interested in 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 survey to monitor understory vegetation, forest structure and fuel loads in MORU using a spatially balanced probability survey design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Probability-based surveys provide unbiased estimation of both status and, with repeated visits, trend across a resource (Larsen et al. 1995). When implemented successfully, probability-based survey designs allow for unbiased inference from sampled sites to un-sampled elements of the resource of interest (Hansen et al. 1983).

Using a GRTS design, we selected 15 randomly located sites within MORU (Figure 2). As part of our pilot monitoring efforts to develop our protocol we visited all 15 plots in 2010 during the second half of July. From 2011 forward, every year we will visit 2 panels, each with 3 sites, and after 5 years we will have visited all 15 sites twice. In 2011, we visited sites in panel 1 and panel 5 (Figure 2) during the first and third week of July. In 2012, we visited sites in panel 1 and panel 2 the last week of June. We can use data from our randomly selected sites to estimate the condition of the entire extent of MORU plant communities (minus administrative areas, the firing range, etc.).

Plot layout and sampling

At each of the 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) height and foliar cover were collected on 2 50 m transects (the long sides of the plot) using a point-intercept method. Species richness data from this point-intercept method were supplemented with species presence data collected in 5 sets of nested square quadrats (0.01 m², 0.1 m², 1 m², and 10 m²) located systematically along each transect (Figure 3).

Plant species were identified in the field to species level in 2012 and not to lower taxonomic groupings (e.g., subspecies or variety). This was a change from the data collected in 2010 and 2011 by NGPN where plants were identified to the lowest taxonomic level possible. The change was made in coordination with the Fire Ecology Program because it better reflects the botanical skills of the crew and simplifies data management and analysis. When we were unable to identify a plant, the plant was assigned a unique identifier and collected or photographed. Most of these unknowns were subsequently identified in the office; however, in some cases identification was impossible. In these cases, the species was classified by growth form and, where possible, lifecycle (e.g., annual graminoid).



Northern Great Plains Inventory and Monitoring Network Plant Community Monitoring

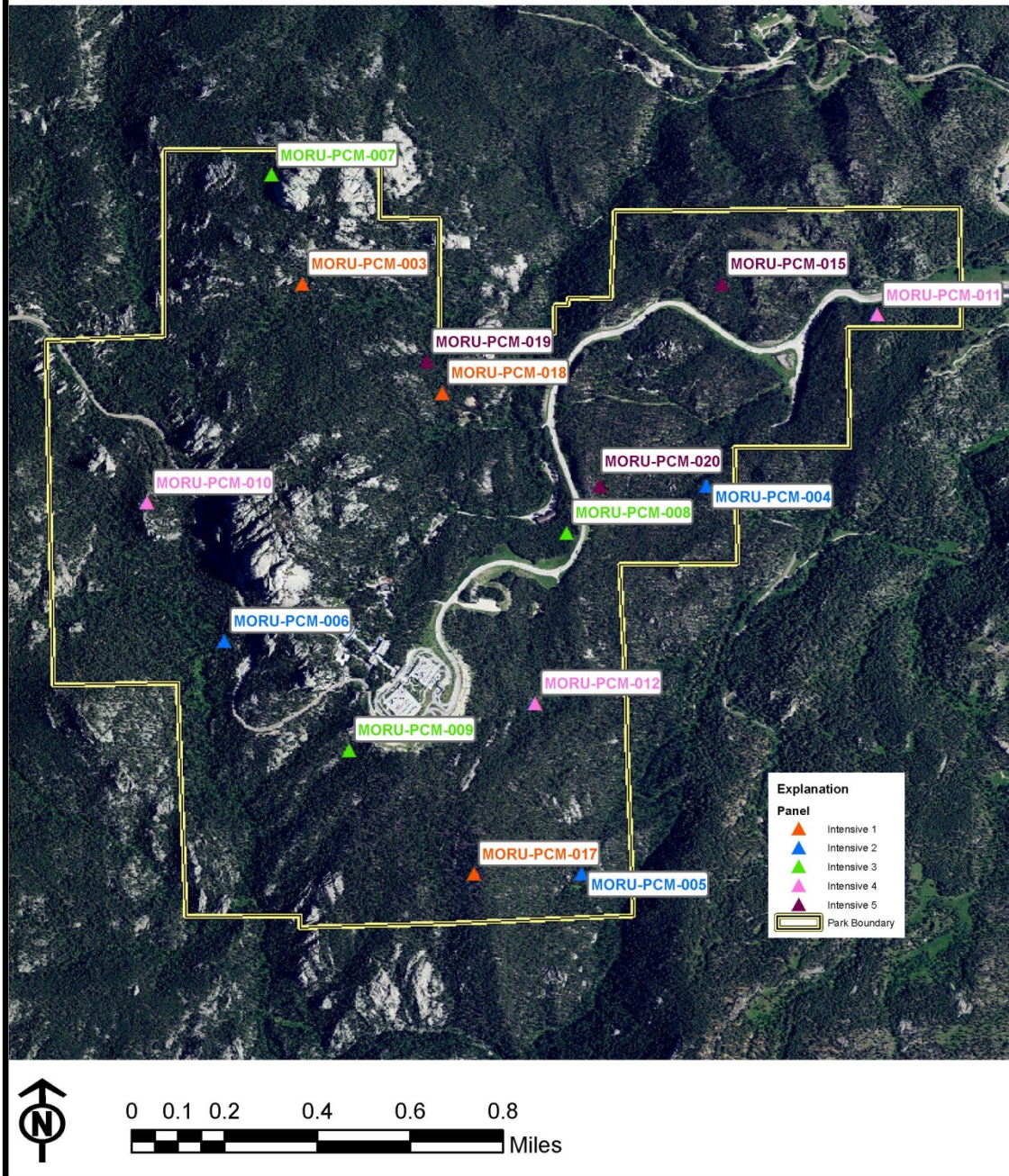


Figure 2. Map of MORU and plant community monitoring plots. Plots in Panel 1 (orange) and Panel 2 (blue) were visited in 2012, Panel 1 (orange) and Panel 5 (purple) were visited in 2011, and all plots in all panels were visited in 2010.

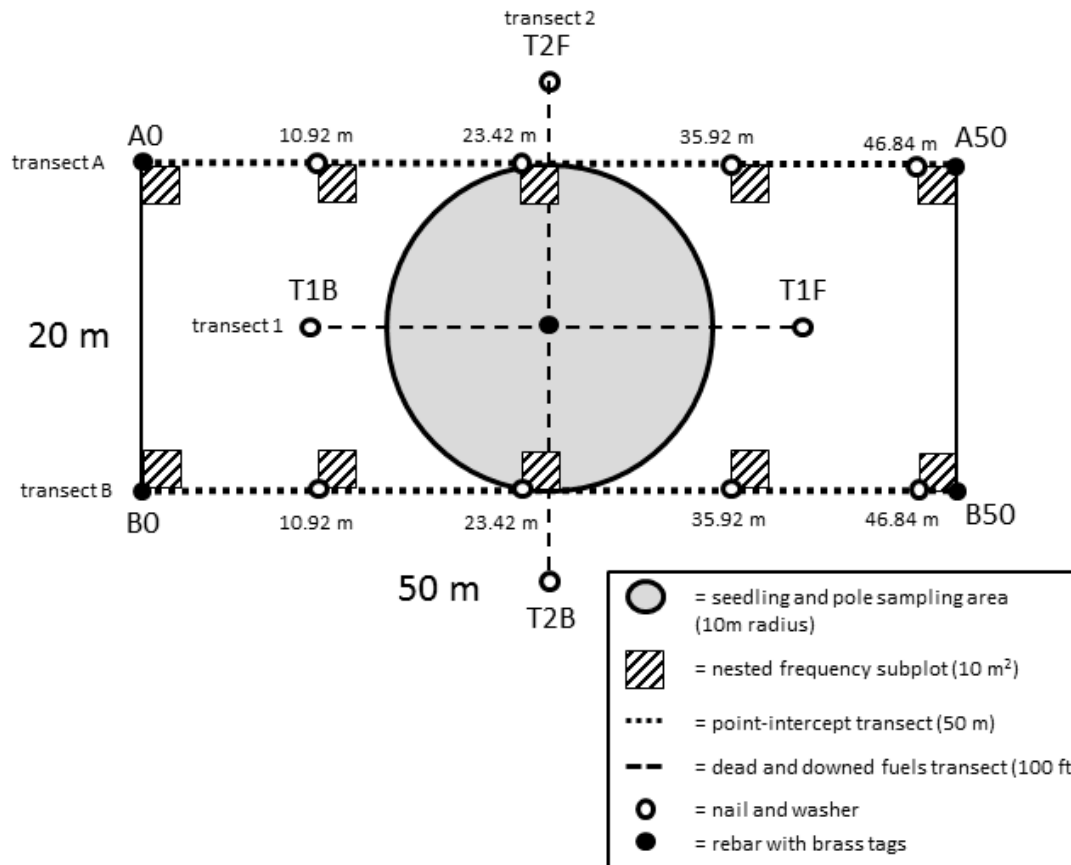


Figure 3. Long-term monitoring plot used for sampling forest understory plant communities in Mount Rushmore National Memorial.

We sampled tree health and density in the 0.1 ha permanent plot and tall shrub and seedling densities within a 10 m radius, circular subplot sharing its center with the 50 m x 20 m plot (Figure 3). Dead and downed woody fuel load data were collected on two perpendicular, 100 ft (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). These plots were a subset of 60 plots that were visited as part of a more comprehensive survey of MORU forests completed in 2010. Rather than repeat the analysis and interpretation of tree and fuel data for this subset, it is included in a more comprehensive report on the status of MORU's forests (Ashton et al. 2012a).

At all plots, we surveyed the area for common disturbances and exotic species of management interest (Table 1) in a 27 m circle around the center. Common disturbances included roads, mechanical thinning burn piles, chipping, animal trails, presence of mountain pine beetles, and evidence of fire. For all plots the type, severity, and approximate area of the disturbances were recorded. For each target species that was present at a site, an abundance class was given on a scale from 1 to 5 where 1 = one individual, 2 = few individuals, 3 = cover 1-5% of site, 4 = cover

5-25% of site, and 5 = cover > 25% of site. Where plots had more than one exotic species present, we used the maximum cover class in that plot to describe cover class of all target exotics (rather than by species). In addition, we surveyed the area for the presence of the rare species Selkirk's violet (*Viola selkirkii*) which is considered vulnerable to loss in South Dakota, (<http://gfp.sd.gov/wildlife/threatened-endangered/rare-plant.aspx>) and may occur in MORU. During the 2010-2012 surveys, we did not come across Selkirk's violet in our plots.

Table 1. Exotic species of management interest in MORU that were surveyed for during the 2010 field season.

Scientific Names	Common Names
<i>Artemisia absinthium</i>	absinth wormwood
<i>Cirsium vulgare</i>	bull thistle
<i>Cirsium arvense</i>	Canada thistle
<i>Arctium minus</i>	common burdock
<i>Verbascum thapsus</i>	common mullein
<i>Hypericum perforatum</i>	common St. Johnswort
<i>Tanacetum vulgare</i>	common tansy
<i>Cynoglossum officinale</i>	houndstongue
<i>Euphorbia esula</i>	leafy spurge
<i>Carduus nutans</i>	musk thistle
<i>Tamarix</i> ssp.	salt cedar
<i>Onopordum acanthium</i>	Scotch thistle
<i>Centaurea stoebe</i>	spotted knapweed
<i>Linaria vulgaris</i>	yellow toadflax

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.

After data for the sites were entered, 100% of records were verified to their original source to minimize transcription errors. A further 10% of records were reviewed a second time. After all data were entered and verified, automated queries were developed to check for errors in the data. When errors were caught by the crew or the automated queries, changes were made to the original datasheets and the FFI database as needed.

Growth forms were based on definitions from the USDA Plants Database (USDA-NRCS 2012). Summaries were done using FFI reports and statistical summaries were done using R software (version 2.11.0). 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.

Reporting on Natural Resource Condition

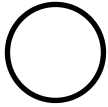
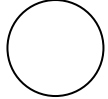
Results were summarized in a Natural Resource Condition Table based on the templates from the State of the Park report series (<http://www1.nrintra.nps.gov/im/stateoftheparks/index.cfm>). The goal is to improve park priority setting and to synthesize and communicate complex park condition information to the public in a clear and simple way. By focusing on specific metrics, such as percent cover of exotic species or evenness, it will also be possible and straightforward to revisit condition in subsequent years. The status, trend, and the confidence of assessments for each indicator is scored and assigned a corresponding symbol based on the key found in Table 2.

We chose a set of 5 indicators that can describe the condition of MORU forests and the status of exotic plant invasions. Reference values were based on descriptions of historic forest condition, past studies completed in the park, management targets, or the natural resource condition assessment completed in 2009 (Narumalani et al. 2009). Current park condition was compared to a reference value, and status was scored as good condition, caution, or significant concern based on this comparison. Good condition was applied to values that fell within the range of the reference value and significant concern was applied to conditions that fell well outside the bounds of the reference value. Trend was scored in a similar fashion and categorized as improving, unchanging, deteriorating, or insufficient information.

Confidence in status and trend assessments within the Natural Resource Condition Table was scored as high, medium, or low. Confidence primarily reflects the quality of the data collected, rather than the quality of the reference condition. Confidence in the data summarizes three

aspects of data quality: how well data represent the resource, quality of methods, and the length of the record.

Table 2. 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>).

Status		Trend		Confidence	
	Significant Concern		Condition is Improving		High
	Caution		Condition is Unchanging		Medium
	Good Condition		Condition is Deteriorating		Low

Results and Discussion

In the 15 plots we visited in MORU during 2010- 2012 we recorded 151 vascular plant species (Appendix A). The most common families were Asteraceae and Poaceae. The most abundant species in the plots was kinnikinnick (*Arctostaphylos uva-ursi*; Figure 4). Ponderosa pine was present at all plots but was included in the understory measures only when we encountered a tree or branch below 2 m of height on the transect or within one of the sampling quadrats. There was a slight variation in the most abundant species across years, but the most common across 2010-2012 included common juniper (*Juniperus communis*), Richardson's sedge (*Carex richardsonii*), and poverty oatgrass (*Danthonia spicata*).

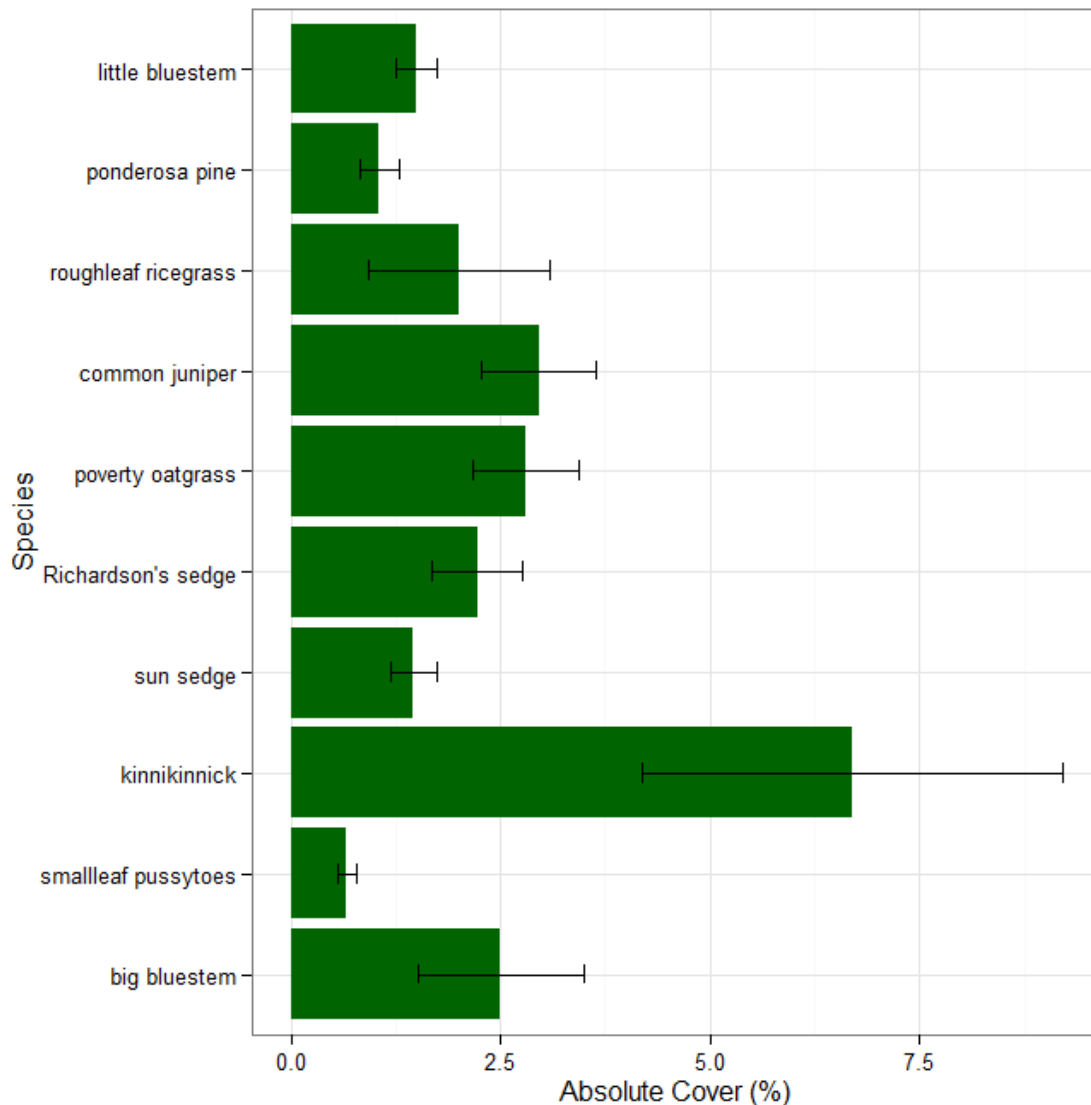


Figure 4. Average relative abundance of the 10 most abundant species encountered in the plant community monitoring plots in Mount Rushmore National Memorial in 2010. All of the most common species are native.



Figure 5. A photograph of plot PCM_003 illustrating the Mount Rushmore National Memorial understory, typified by herbaceous plants, small ponderosa pines, and large areas of pine litter and bare rock.

In most plots, we found a relatively low cover of plants on the ground and a high cover of plant litter (primarily ponderosa pine needles). Litter covered a large proportion of the area in our plots (ranging from 61%-78%), and total understory plant cover was low, averaging 22% in 2010, 11% in 2011, and 19% in 2012 (Figure 5). Understory cover is typically a mix of forbs, graminoids, shrubs, and young trees, with graminoids and shrubs accounting for most of the cover (Figure 6). The majority of the plants encountered in a plot were native species. From the point-intercept data, we found an average of 12, 8, and 8 species per plot in 2010, 2011 and 2012, respectively (Table 3). On average, we recorded 4 native species in a 1 m² area (Table 3).

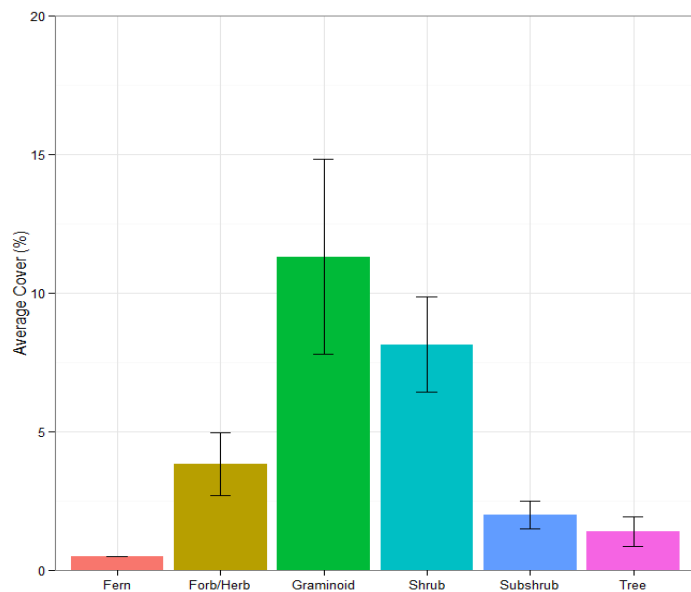


Figure 6. Average cover by life forms in 15 plant community monitoring plots in Mount Rushmore National Memorial in 2010. Bars represent means $\pm$ standard errors. The total canopy cover in the understory was low, and graminoids were the most abundant life-form across all the plots.

The tendency for a reduction in plant cover and diversity and the increase in litter cover across the two years was likely a result of the thinning that had been completed in the park during the fall and winter of 2010-2011. For 4 plots that were revisited in 2011, plant cover and diversity was reduced by about half compared to no change in the 2 plots that had not been thinned (Figure 7). The small sample size and large variation across plots meant that these changes were not statistically significant. From the 2010 data, there was no difference in plant cover or diversity among plots that had been thinned in the past decade and plots that had not. Moreover, we found an increase of plant canopy cover between 2011 and 2012, despite a dry year. This suggests that while there may be a short-term effect of thinning on plant cover at MORU, it is likely that thinning will not affect plant and litter cover over longer time periods.

Table 3. Species richness in Mount Rushmore National Memorial. Means and standard deviations are shown, $n=15$ for 2010 and $n=6$ plots for 2011 and 2012, estimates are adjusted to account for GRTS design.

Year	Species richness (point-intercept)	Evenness (point intercept)	Native species richness (10 m ² quadrats)	Native species richness (1 m ² quadrats)
2010	11.9 ± 1.8	0.86 ± 0.02	9.2 ± 0.8	3.6 ± 0.4
2011	8.3 ± 2.6	0.86 ± 0.02	10.3 ± 1.3	4.2 ± 0.6
2012	8.3 ± 2.8	0.90 ± 0.02	8.9 ± 1.9	3.7 ± 0.9



Figure 7. Photograph of plot PCM_018 illustrating the change from 2010 (left panel) and 2011 and 2012 (right and bottom panel). The plot was thinned between the 2010 and 2011 sampling dates, and this thinning reduced plant diversity and cover.

In addition to species richness, we measured diversity using the Shannon Index and Pielou's Index of Evenness. The Shannon Index, H' , is a measure of the number of species in an area and how even abundances are across the community. It typically ranges between 0 (low richness and evenness) to 3.5 (high species richness and evenness). Pielou's Index of Evenness, J' , measures another aspect of diversity—how even abundances are across taxa. It ranges between 0 and 1, where lower numbers indicate that a community is not even or that just a few species make up the majority of the total cover. From the point-transect data, we found average diversity, H' , to be 1.9 ± 0.14 in 2010, 1.6 ± 0.24 in 2011, and 1.5 ± 0.33 in 2012. Evenness, J' , was the same in 2010 and 2011, averaging 0.86 ± 0.02 but increased slightly in 2012 to 0.90 ± 0.02 (Table 3).

Understory plant diversity and cover values are low compared to neighboring park units with a larger grassland component. For instance, Wind Cave National Park had an average diversity (H') of 2.4 and averaged 12 native species per square meter (Ashton et al. 2012b). Despite a low diversity of plant species, the forest stands in MORU are prime examples of late-stage ponderosa forest that are of high conservation value (Hoffman 1986). While we do not yet have defined reference conditions for upland plant communities in MORU, we choose to interpret the 2010-2012 values as representative of a forest in good condition (Table 4). Future monitoring efforts may use the values measured here as a baseline reference condition to track changes in plant diversity and cover.

Compared to many park units in the region, MORU has few exotic species. The most common target species (Table 1) we encountered were houndstongue, Canada thistle, and common mullein. Canada thistle was the only species we found with an estimated cover of greater than 5% at any plot (they were abundant in plot PCM_017 and PCM_015 in 2010). Including all exotic species, we recorded an average of 3% relative cover of exotic species in the plots in 2010, and fewer exotic species (<1%) in 2011 and 2012. It is unclear whether this decline in exotic species cover is explained by the normal variation expected across years, caused by thinning and chipping in plots, or is merely an artifact of the larger sample size in 2010.

From a cumulative distribution function of the data in 2010, it is clear that a large portion of the park has no exotic species present (Figure 8). About 60% of the park has no exotic species, and over 80% of the park area has an exotic species cover of less than 5% (Figure 8). The 5% represents a management target that we feel is reasonable and achievable for the park. Exotic species are often concentrated in developed areas such as park housing, administrative areas, and roads. NGPN does not sample vegetation in these areas, so our estimates of exotic cover are likely lower than what is truly in the park. Still, because the average exotic cover in the park between 2010 and 2012 was lower than 5%, we determined that the park is in good condition (Table 4). Future plant community monitoring will provide data on trends of increasing or decreasing abundance of exotic species.

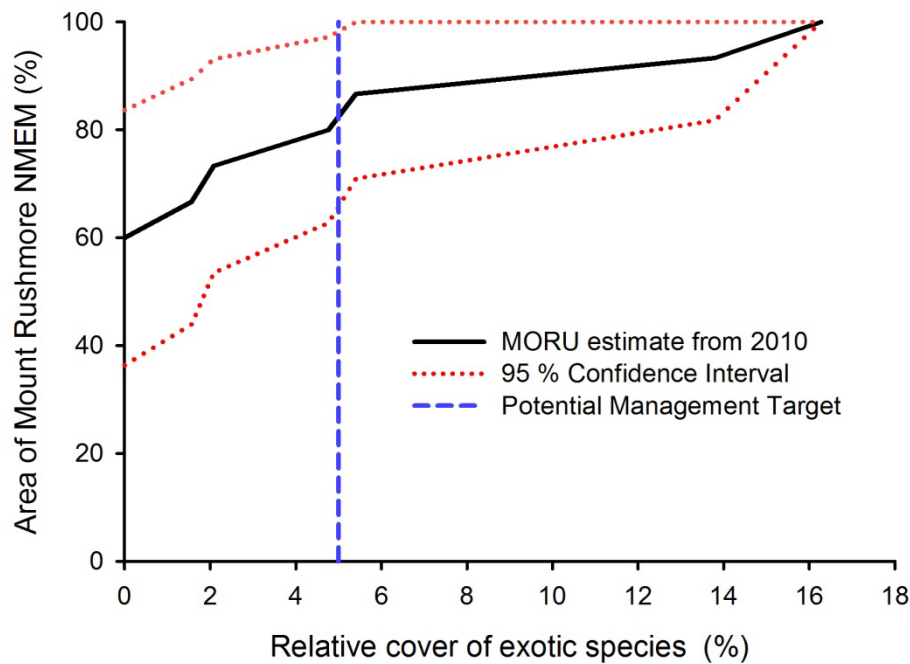


Figure 8. Cumulative distribution function of relative cover of exotic species in Mount Rushmore National Memorial.

In conclusion, MORU understory plant communities are in good condition. The mission of many NPS park units includes maintaining native plant diversity. MORU has a low diversity of native plants and a low cover of understory plants, but this is consistent with older ponderosa forests with high conservation value. The large reduction in plant cover in 2011 may be due to large scale thinning projects in the park. Future monitoring will allow us to determine whether thinning causes a sustained decline or whether this is a short-term effect. To date, MORU has maintained a low cover of exotic plants. We estimate that 60% of the park has no exotic species present.

Table 4. Natural resource condition summary table for upland plant communities in MORU.

Indicator of Condition	Specific Measures	2010 Value (mean $\pm$ SE)	2011 Value (mean $\pm$ SE)	2012 Value (mean $\pm$ SE)	Reference Condition	Condition Status/Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Absolute herb-layer cover	21.5 $\pm$ 4.3 %	11.4 $\pm$ 3.2 %	18.8 $\pm$ 6.6 %	TBD		The mission of many NPS park units is to maintain native plant diversity. MORU has a low diversity of native plants and a low cover of understory plants, but this is consistent with older ponderosa forests with high conservation value. The large reduction in plant cover in 2011 may be due to large scale thinning projects in the park. Future monitoring will allow us to determine whether thinning causes a sustained decline or whether this is a short-term effect. At this time, our condition assessments are based on professional judgment, but as we collect more data and understand the natural range of variability our confidence in these assessments will increase
	Native species richness (based on average of 10 1m ² quadrats per plot)	3.6 $\pm$ 0.4 species	4.2 $\pm$ 0.6 species	3.7 $\pm$ 0.9 species	TBD		
	Evenness (based on point-intercept of 2-50m transects per plot)	0.86 $\pm$ 0.02	0.86 $\pm$ 0.02	0.90 $\pm$ 0.02	TBD		
Exotic Plant Early Detection and Management	Relative cover of exotic species	2.9 $\pm$ 1.2%	0.4 $\pm$ 0.3%	0.3 $\pm$ 0.3%	$\leq$ 5% cover		To date, MORU has maintained a low cover of exotic plants. We estimate that 60% of the park has no exotic species present.

Literature Cited

- Ashton, I., M. Prowatzke, M. Bynum, T. Shepherd, S. K. Wilson, K. Paintner-Green, and D. Swanson. 2012a. Status of forest structure and fuel loads at Mount Rushmore National Memorial: 2010-2011 report. Natural Resource Technical Report NPS/NGPN/NRTR—2012/590. National Park Service, Fort Collins, Colorado.
- Ashton, I., M. Prowatzke, M. Bynum, T. Shepherd, S. K. Wilson, and K. Paintner-Green. 2012b. Wind Cave National Park plant community composition and structure monitoring: 2011 annual report. Natural Resource Technical Report NPS/NGPN/NRTR—2012/534. 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, P. M., C. L. Wienk, and A. J. Symstad. 2008. Fire and forest history at Mount Rushmore. *Ecological Applications* 18:1984-1999.
- 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. 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.
- Hoffman, G. R. and P. L. Hansen. 1986. Vegetation baseline study of Mount Rushmore National Monument. University of South Dakota.
- Kincaid, T. M. and A. R. Olsen. 2011. spsurvey: Spatial survey desing and Analysis. R package version 2.2.
- Larsen, D. P., N. S. Urquhart, and D. L. Kugler. 1995. Regional-scale trend monitoring of indicators of trophic condition of lakes. *Water Resources Bulletin* 31:117-140.
- 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.
- Narumalani, S., G. D. Willson, C. K. Lockert, and P. B. T. Merani. 2009. Mount Rushmore National Memorial condition assessment. Natural Resource Report NPS/NRPC/WRD/NRR—2009/115. National Park Service, Fort Collins, Colorado.

- Omernik, J. M. 2007. Level III Ecoregions of the Continental United States. U.S. EPA National Health and Environmental Effects Laboratory, Corvallis, Oregon.
- 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. and M. Bynum. 2007. Conservation Value of Mount Rushmore National Memorial's Forest. *Natural Areas Journal* 27:293-301.
- Symstad, A. J., R.A. Gitzen, C. L. Wienk, M. R. Bynum, D. J. Swanson, A. D. Thorstenson, and K. J. Paintner. 2012a. Plant community composition and structure monitoring protocol for the Northern Great Plains I&M Network-Standard Operating Procedures: version 1.01. Natural Resource Report NPS/NGPN/ NRR-2012/489.1.
- Symstad, A. J., R.A. Gitzen, C. L. Wienk, M. R. Bynum, D. J. Swanson, A. D. Thorstenson, and K. J. Paintner. 2012b. 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.
- USDA-NRCS. 2012. The PLANTS Database (<http://plants.usda.gov>, 24 January 2012). National Plant Data Team, Greensboro, NC 27401-4901 USA.

Appendix A: List of plant species found in 2010-2012 at MORU

Species found in monitoring plots (Panel 1-5) at Mount Rushmore National Memorial. Species in bold are not on the park's certified species list. In cases where a new species name is recognized the older certified species code is listed in parentheses.

Family	Species Code	Scientific Name	Common Name	Exotic
Anacardiaceae	TORY	<i>Toxicodendron rydbergii</i>	western poison ivy	
Apocynaceae	APAN2	<i>Apocynum androsaemifolium</i>	spreading dogbane	
Araliaceae	ARNU2	<i>Aralia nudicaulis</i>	wild sarsaparilla	
Asclepiadaceae	ASPU	<i>Asclepias pumila</i>	plains milkweed	
Aspleniaceae	ASSE	<i>Asplenium septentrionale</i>	forked spleenwort	
Asteraceae	ACMI2	<i>Achillea millefolium</i>	common yarrow	
	ANNE	<i>Antennaria neglecta</i>	field pussytoes	
	ANPA4	<i>Antennaria parvifolia</i>	small leaf pussytoes	
	ARLU	<i>Artemisia ludoviciana</i>	white sagebrush	
	CIAR4	<i>Cirsium arvense</i>	Canada thistle	*
	CIDR2	<i>Cirsium drummondii</i>	dwarf thistle	
	CIVU	<i>Cirsium vulgare</i>	bull thistle	*
	COCA5	<i>Conyza canadensis</i>	horseweed	
	ERFO3	<i>Erigeron formosissimus</i>	beautiful fleabane	
	HICA3	<i>Hieracium canadense</i>	Canadian hawkweed	
	HIUM	<i>Hieracium umbellatum</i>	narrowleaf hawkweed	
	LACA	<i>Lactuca canadensis</i>	Canada lettuce	
	LASE	<i>Lactuca serriola</i>	prickly lettuce	*
	LOAR5	<i>Logfia arvensis</i>	field cottonrose	*
	PACA15	<i>Packera cana</i>	woolly groundsel	
	PSMA11	<i>Pseudognaphalium macounii</i>	Macoun's cudweed	
	RUHI2	<i>Rudbeckia hirta</i>	blackeyed susan	
	SERA	<i>Senecio rapifolius</i>	openwoods ragwort	
	SOGI	<i>Solidago gigantea</i>	giant goldenrod	
	SOMI2	<i>Solidago missouriensis</i>	Missouri goldenrod	
	SONE	<i>Solidago nemoralis</i>	gray goldenrod	
	SOPT4	<i>Solidago ptarmicoides</i>	prairie goldenrod	
	SOSP2	<i>Solidago speciosa</i>	noble goldenrod, showy goldenrod	
	SYCI	<i>Symphyotrichum ciliolatum</i>	Lindley's aster	
	SYLA3	<i>Symphyotrichum laeve</i>	smooth blue aster	
	TAOF	<i>Taraxacum officinale</i>	dandelion	*
	TRDU	<i>Tragopogon dubius</i>	yellow salsify	*
Betulaceae	BEPA	<i>Betula papyrifera</i>	paper birch	

Family	Species Code	Scientific Name	Common Name	Exotic
	COCO6	<i>Corylus cornuta</i>	beaked hazelnut	
Boraginaceae	CRFE3	<i>Cryptantha fendleri</i>	sanddune cryptantha	
	CRT04	<i>Cryptantha torreyana</i>	Torrey's cryptantha	
	CYOF	<i>Cynoglossum officinale</i>	houndstongue	*
Boraginaceae	LAOC3	<i>Lappula occidentalis</i>	flatspine stickseed	
	MELA3	<i>Mertensia lanceolata</i>	prairie bluebells	
Campanulaceae	CARO2	<i>Campanula rotundifolia</i>	bluebell, roundleaf harebell	
	TRPE4	<i>Triodanis perfoliata</i>	Venus lookingglass	
Caprifoliaceae	SYAL	<i>Symphoricarpos albus</i>	common snowberry	
	SYOC	<i>Symphoricarpos occidentalis</i>	western snowberry	
Caryophyllaceae	SIAN2	<i>Silene antirrhina</i>	sleepy silene	
	SIDR	<i>Silene drummondii</i>	Drummond's campion	
Chenopodiaceae	CHFR3	<i>Chenopodium fremontii</i>	Fremont's goosefoot	
	CHSI2	<i>Chenopodium simplex</i>	mapleleaf goosefoot	
	DYBO99 (CHBO2)	<i>Dysphania botrys</i>	Jerusalem oak goosefoot	*
Crassulaceae	SELA	<i>Sedum lanceolatum</i>	spearleaf stonecrop	
Cupressaceae	JUCO6	<i>Juniperus communis</i>	common juniper, dwarf juniper	
Cyperaceae	CADU6	<i>Carex duriuscula</i>	needleleaf sedge	
	CAFI	<i>Carex filifolia</i>	threadleaf sedge	
	CAFO3	<i>Carex foenea</i>	dryspike sedge, wind sedge	
	CAIN9	<i>Carex inops</i>	long-stolon sedge	
	CARI	<i>Carex richardsonii</i>	Richardsons sedge	
	CARO5	<i>Carex rossii</i>	Ross sedge	
Dryopteridaceae	CYFR2	<i>Cystopteris fragilis</i>	brittle bladderfern	
	WOSC	<i>Woodsia scopulina</i>	Rocky Mountain cliff fern	
Elaeagnaceae	SHCA	<i>Shepherdia canadensis</i>	russet buffaloberry	
Ericaceae	ARUV	<i>Arctostaphylos uva-ursi</i>	bearberry, kinnikinnick	
Fabaceae	AMCA6	<i>Amorpha canescens</i>	leadplant	
	ASLA27	<i>Astragalus laxmannii</i>	Laxmann's milkvetch	
	GLLE3	<i>Glycyrrhiza lepidota</i>	wild licorice	
	LAOC2	<i>Lathyrus ochroleucus</i>	cream pea, cream peavine	
	MELU	<i>Medicago lupulina</i>	black medick	*
	MEOF	<i>Melilotus officinalis</i>	yellow sweetclover	*
	PEAR6	<i>Pedimelum argophyllum</i>	silverleaf Indian breadroot	
	PEES	<i>Pedimelum esculentum</i>	breadroot scurfpea	
	THRH	<i>Thermopsis rhombifolia</i>	goldenpea	
	TRHY	<i>Trifolium hybridum</i>	alsike clover	*

Family	Species Code	Scientific Name	Common Name	Exotic
Fabaceae	TRPR2	<i>Trifolium pratense</i>	red clover	*
	TRRE3	<i>Trifolium repens</i>	white clover	*
	VIAM	<i>Vicia americana</i>	American vetch	
Fagaceae	QUMA2	<i>Quercus macrocarpa</i>	bur oak	
Gentianaceae	HADE2	<i>Halenia deflexa</i>	American spurred gentian	
Geraniaceae	GERI	<i>Geranium richardsonii</i>	Richardson's geranium	
Grossulariaceae	RICE	<i>Ribes cereum</i>	wax currant	
	RIHI	<i>Ribes hirtellum</i>	hairystem gooseberry	
	RIOX	<i>Ribes oxycanthoides</i>	Canadian gooseberry	
Iridaceae	SIMO2	<i>Sisyrinchium montanum</i>	strict blue-eyed grass	
Lamiaceae	MOFI	<i>Monarda fistulosa</i>	wild bergamot	
Liliaceae	ALCE2	<i>Allium cernuum</i>	nodding onion	
	LIPH	<i>Lilium philadelphicum</i>	wood lily	
	MACA4	<i>Maianthemum canadense</i>	false lily-of-the-valley	
	MAST4	<i>Maianthemum stellatum</i>	false Solomons seal, starry false lily of the vally	
Monotropaceae	PTAN2	<i>Pterospora andromedea</i>	woodland pinedrops	
Onagraceae	CHAN9	<i>Chamerion angustifolium</i>	fireweed	
	EPBR3	<i>Epilobium brachycarpum</i>	tall annual willowherb	
	EPCI	<i>Epilobium ciliatum</i>	fringed willowherb	
	EPHA	<i>Epilobium halleianum</i>	glandular willowherb	
	OEBI	<i>Oenothera biennis</i>	common evening primrose	
Orchidaceae	COWI5	<i>Corallorhiza wisteriana</i>	spring coralroot	
	GORE2	<i>Goodyera repens</i>	lesser rattlesnake plantain	
Pinaceae	PIPO	<i>Pinus ponderosa</i>	ponderosa pine	
Poaceae	AGHY	<i>Agrostis hyemalis</i>	winter bentgrass	
	AGSC5	<i>Agrostis scabra</i>	rough bentgrass, ticklegrass	
	ANGE	<i>Andropogon gerardii</i>	big bluestem	
	BRCI2	<i>Bromus ciliatus</i>	fringed brome	
	BRIN2	<i>Bromus inermis</i>	smooth brome	*
	DASP2	<i>Danthonia spicata</i>	poverty oatgrass	
	DILI2	<i>Dichanthelium linearifolium</i>	slimleaf panicgrass	
	DIOL	<i>Dichanthelium oligosanthos</i>	Heller's rosette grass	
	ELCA4	<i>Elymus canadensis</i>	Canada wildrye	
	ELVI3	<i>Elymus virginicus</i>	Virginia wildrye	
	FEOV	<i>Festuca ovina</i>	sheep fescue	*
	FESA	<i>Festuca saximontana</i>	Rocky Mountain fescue	
	HESP11	<i>Hesperostipa spartea</i>	porcupinegrass	

Family	Species Code	Scientific Name	Common Name	Exotic
Poaceae	KOMA	<i>Koeleria macrantha</i>	junegrass	
	MUCU3	<i>Muhlenbergia cuspidata</i>	plains muhly	
	MURA	<i>Muhlenbergia racemosa</i>	green muhly, marsh muhly	
	NAVI4	<i>Nassella viridula</i>	green needlegrass	
	ORAS	<i>Oryzopsis asperifolia</i>	roughleaf ricegrass	
	PAVI2	<i>Panicum virgatum</i>	switchgrass	
	PASM	<i>Pascopyrum smithii</i>	western wheatgrass	
	PIMI7	<i>Piptatherum micranthum</i>	littleseed ricegrass	
	PIPU7	<i>Piptatherum pungens</i>	mountain ricegrass	
	POPR	<i>Poa pratensis</i>	Kentucky bluegrass	*
	SCSC	<i>Schizachyrium scoparium</i>	little bluestem	
	THIN6	<i>Thinopyrum intermedium</i>	intermediate wheatgrass	*
Primulaceae	ANSE4	<i>Androsace septentrionalis</i>	pygmyflower rockjasmine	
	PRPA99 (DOPU)	<i>Primula pauciflora</i>	darkthroat shootingstar	
Pyrolaceae	PYCH	<i>Pyrola chlorantha</i>	wintergreen	
Ranunculaceae	THDA	<i>Thalictrum dasycarpum</i>	purple meadowrue	
Rosaceae	AMAL2	<i>Amelanchier alnifolia</i>	western serviceberry	
	DRFI3 (POFI3)	<i>Drymocallis fissa</i>	bigflower cinquefoil	
	FRVI	<i>Fragaria virginiana</i>	wild strawberry	
	PHMO4	<i>Physocarpus monogynus</i>	mountain ninebark	
	PRPE2	<i>Prunus pensylvanica</i>	pin cherry	
	PRVI	<i>Prunus virginiana</i>	chokecherry	
	ROWO	<i>Rosa woodsii</i>	Wood's rose	
	SPBE2	<i>Spiraea betulifolia</i>	white spirea	
Rubiaceae	GABO2	<i>Galium boreale</i>	northern bedstraw	
	GATR3	<i>Galium triflorum</i>	sweet bedstraw	
	GALIUM	<i>Galium</i>	bedstraw	*
Salicaceae	PODE3	<i>Populus deltoides</i>	plains cottonwood	
	POTR5	<i>Populus tremuloides</i>	quaking aspen	
	SABE2	<i>Salix bebbiana</i>	Bebb willow	
Saxifragaceae	HERI	<i>Heuchera richardsonii</i>	Richardson's alumroot	
Scrophulariaceae	COPA3	<i>Collinsia parviflora</i>	maiden blue eyed Mary	
	MIFL2	<i>Mimulus floribundus</i>	manyflowered monkeyflower	
	PEGR5	<i>Penstemon gracilis</i>	slender penstemon	
	VETH	<i>Verbascum thapsus</i>	common mullein	*
	VEAM2	<i>Veronica americana</i>	American speedwell	
	VEOF2	<i>Veronica officinalis</i>	common gypsyweed	*
Selaginellaceae	SEDE2	<i>Selaginella densa</i>	dense clubmoss	

Family	Species Code	Scientific Name	Common Name	Exotic
	SERU	<i>Selaginella rupestris</i>	northern selaginella	
Solanaceae	PHVI5	<i>Physalis virginiana</i>	Virginia groundcherry	
Unknown Family	UNKFORBANN	<i>Unknown annual forb</i>	unknown annual forb	*
	UNKFORB	<i>Unknown forb</i>	unknown forb	*
	UNKGRAM	<i>Unknown graminoid</i>	unknown graminoid	*
	UNKTREE	<i>Unknown tree</i>	unknown tree	*
Violaceae	VIOLA	<i>Viola</i>	violet	*
	VIAD	<i>Viola adunca</i>	hookedspur violet	
	VICA4	<i>Viola canadensis</i>	Canada violet	
	VIPE2	<i>Viola pedatifida</i>	prairie violet	
	VIPU3	<i>Viola pubescens</i>	downy yellow violet	
Vitaceae	PAVI5	<i>Parthenocissus vitacea</i>	woodbine	

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 323/119664, January 2013

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™