



Status of Forest Structure and Fuel Loads at Mount Rushmore National Memorial

2010-2011 Report

Natural Resource Report NPS/NCCN/NRTR—2012/591



ON THE COVER

A view of a long-term forest monitoring plot at Mount Rushmore National Memorial, 2010
Photograph by: NGPN, NPS

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Natural Resource Technical Report NPS/NCCN/NRTR—2012/591

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June 2012

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

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Please cite this publication as:

Ashton, I. W., M. Prowatzke, M. Bynum, T. Shepherd, S. K. Wilson, K. Paintner-Green, D. Swanson. 2012. Status of forest structure and fuel loads at Mount Rushmore National Memorial: 2010-2011 report. Natural Resource Technical Report NPS/NGPN/NRTR—2012/591. National Park Service, Fort Collins, Colorado.

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Executive Summary

Sixty forested plots at Mount Rushmore National Memorial (MORU) were surveyed by the Northern Great Plain Inventory and Monitoring Network (NGPN) and Northern Great Plains Fire Ecology Program (FEP) in 2010. This effort will be repeated in 2016 and every 5 years thereafter to better understand status and trends in forest composition, structure, and fuel loading. We measured tree stem density, basal area, 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 across the park as a whole. We found the following:

- Ponderosa pine was the only species to occur in all plots. Chokecherry seedlings were common and occurred in about one-third of the plots. Other than ponderosa pine, the most common trees or poles we encountered were quaking aspen and paper birch.
- In 2010, basal area averaged 30 m² per hectare (131 ft² per acre) which is considerably higher than the average of the Black Hills National Forest and historical densities, but similar to past surveys done in MORU.
- In 2010, we found 23% of the park had evidence of mountain pine beetles. We expect that current infestation rates are higher as mountain pine beetles have become more abundant across the Black Hills in recent years.
- Thinning efforts in MORU have resulted in reduced basal area and density of small diameter trees. These efforts may move the forest closer to the historical condition.

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 yellow symbol indicates a fair, but deteriorating forest condition due to increasing mountain pine beetle infestation and high densities of small diameter trees. Further details about the table and its content are presented in the discussion of this paper.

Resource	Condition Status/Trend	Rationale
Forest condition		The ponderosa pine forest surrounding the monument is an outstanding natural resource with a low abundance of exotic species. As of 2010, overall condition of the forest community was fair and deteriorating. Mountain pine beetles had begun to reach epidemic levels and are increasing. The high density of ponderosa pines require active management intervention to decrease susceptibility to stand-replacing fires and pine beetle outbreaks.

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 Management team for ongoing assistance with fieldwork and development of methods. We greatly appreciate the staff at MORU for providing logistical support particularly Bruce Weisman. The 2010 NGPN vegetation field crew, Alexa Armstrong, Lee Margadant, Luke Carlberg, Michael Bynum, and Kara Paintner, collected much of 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. Comments provided by Amy Symstad and Cody Weink improved this manuscript.

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). Natural and anthropogenic disturbances, such as fire and logging, have been an integral part of the history 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 prevalence of large-scale disturbances, such as drought stress (Allen et al. 2010). In recent years, mountain pine beetles (*Dendroctonus ponderosae*) outbreaks have been of particular concern because they are increasing throughout the Black Hills and have caused 100% mortality of ponderosa pines in some areas (Allen and Long 2008, Hocking et al. 2010).

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). 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). Recently, mechanical fuel reduction projects have been undertaken to reduce stand density in MORU with the hope that this will reduce the susceptibility to mountain pine beetle attacks and high severity fires and to restore old growth structural characteristics (Wienk 2010). Scientifically credible information on the current status and long-term trends of the composition, structure, and function of the forests in MORU is required for the sound management of this threatened resource.

In 2010, the National Park Service Northern Great Plains Inventory & Monitoring Network (NGPN) and the Northern Great Plains Fire Ecology Program (FEP) sampled 60 forested sites in MORU 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 MORU's forest by sampling and characterizing tall shrubs and trees (or woody vegetation), exotic plant prevalence, and fire and fuel dynamics (Gitzen et al. 2010). More specifically, the long-term monitoring objectives are to: (1) determine park-wide status (at 5-year intervals) and long-term trends of tree density by species, height class, and diameter class, and of fuel loads 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). In this report, we present the results from 2010, our first year of monitoring, which we hope will provide a baseline from which to compare our future efforts. With the exception of 2 plots (PCM_060 & PCM_070), this report summarizes data collected prior to a large scale thinning project that was started in Fall of 2010.

Northern Great Plains Network Parks and Ecoregions

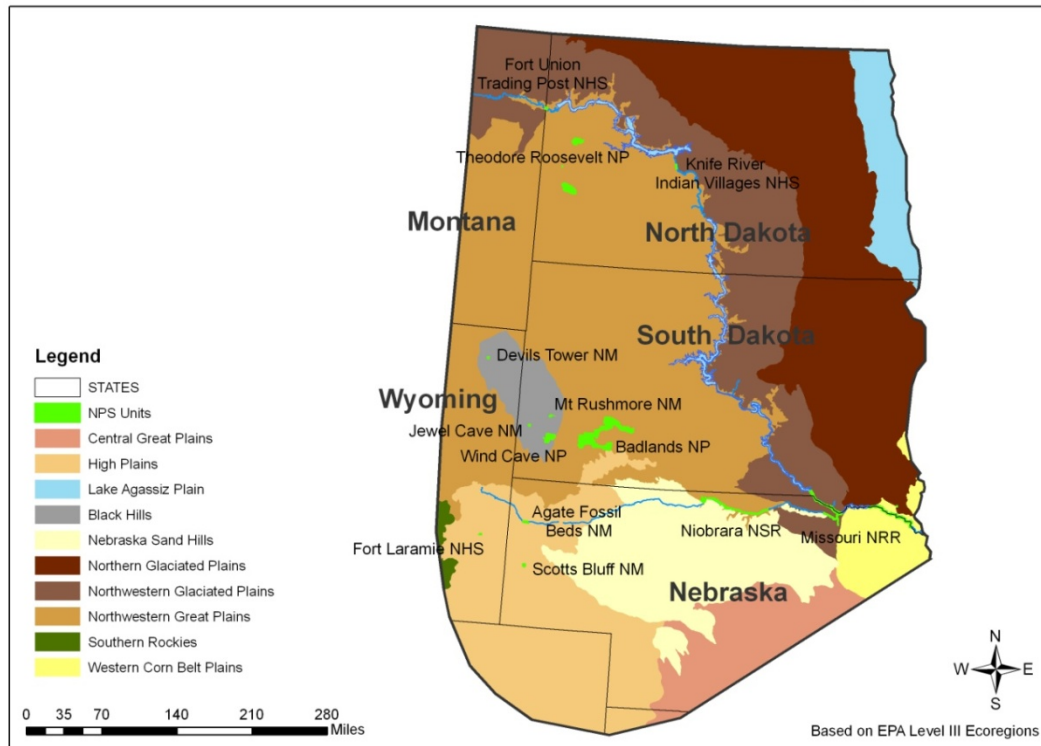


Figure 1. Parks and ecoregions of the Northern Great Plains Network. Based on the U.S. Environmental Protection Agency's Level III ecoregions classes (Omernik 2007).

Methods

The NGPN Plant Community Composition and Structure Monitoring Protocol (Symstad et al. 2011) describes in detail the methods used for sampling long-term plots in MORU forests. 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. 2011, available at <http://science.nature.nps.gov/im/units/ngpn/monitor/plants/plants.cfm>.

Sample design

We implemented a survey to monitor forest structure and fuel loads in MORU using a spatially balanced probability survey design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). For MORU, we defined the target population as vegetation in the entire park. A 54 m x 54 m grid was overlaid on the park to create the sample frame, and sampling locations were at the center of a random subset of grid cells. We excluded the following areas from the sample frame: administrative areas, the firing range, roads, and utility lines and an appropriate buffer, areas within 10 m of a park boundary, paved trails, and areas with little to no potential for terrestrial vegetation (e.g., large areas of bare rock). The final design included 60 randomly located sites (Figure 2).

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). In other words, we can use data from our randomly selected sites to estimate the condition of the entire extent of MORU forests (minus administrative areas, the firing range, etc.). When these sites are revisited in 2016 and every five years thereafter, we will be able report on the change in the condition of MORU forests over time.

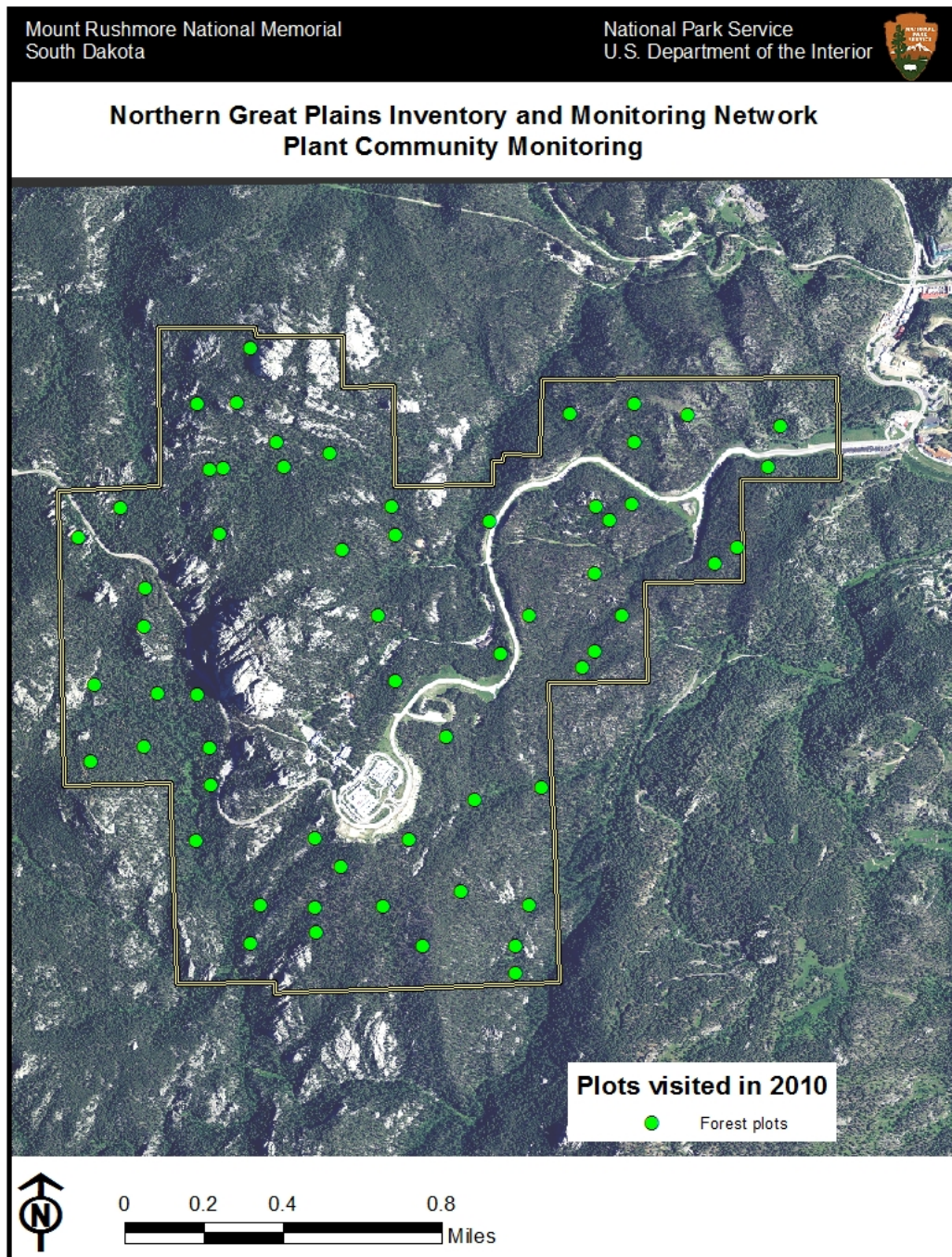


Figure 2. Map of Mount Rushmore National Memorial and locations of the 60 forest plots visited in 2010.

Plot layout and sampling

At each of 60 sites, we sampled tree regeneration and density in a 10-m radius permanent plot (0.03 ha, 0.07 ac; Figure 3). Live individuals of tree and tall shrub species with diameter at breast height (DBH, where breast height = 137 cm) < 2.54 cm (i.e., seedlings or saplings) were tallied by species. Saplings are those plants that have a DBH < 2.54 cm and a height of > 137 cm. For all poles (2.54 cm ≤ DBH ≤ 15 cm), species, DBH, and status (live or dead) were recorded. Species, DBH, status, and condition (leaf-discoloration, insect-damaged, etc.) were recorded for each tree with DBH > 15 cm. Dead and downed woody fuel load data were collected on two perpendicular, 100-ft (30.49 m) transects centered at the center of the plot (Figure 3), following Brown's Line methods (Brown 1974, Brown et al. 1982).

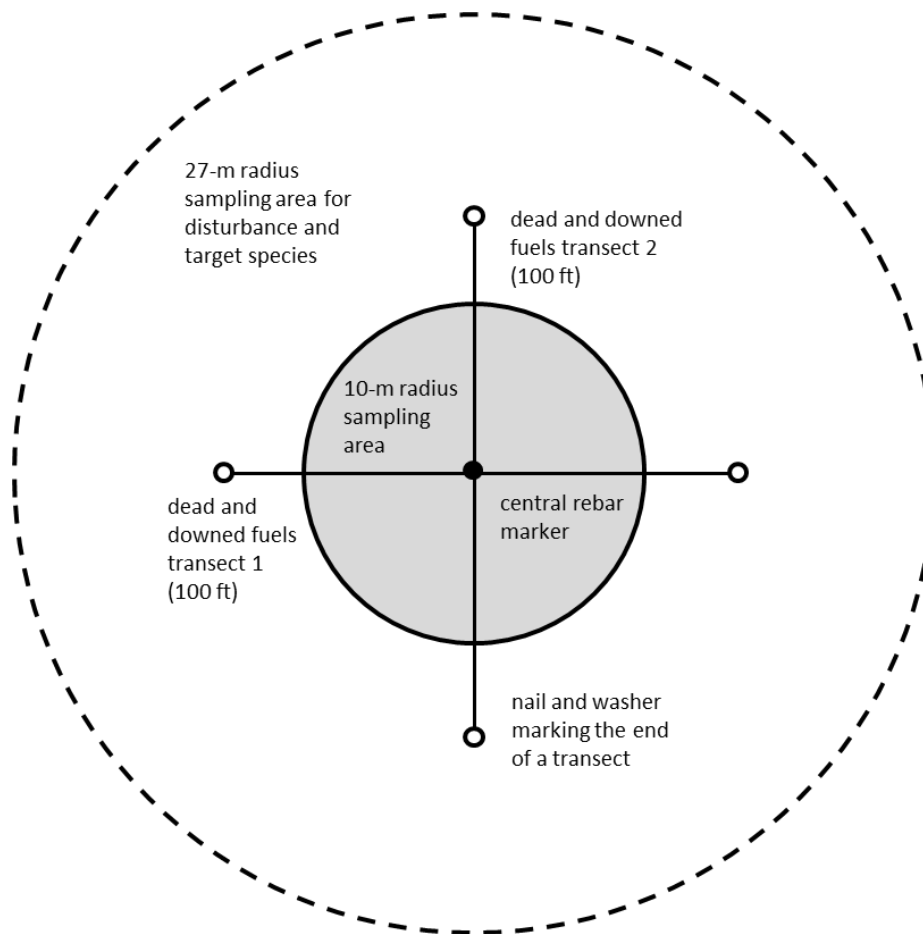


Figure 3. Long-term monitoring plot used for sampling forest structure and fuels in Mount Rushmore National Memorial.

In a subset of 15 sites, we sampled seedlings and poles in the 10-m radius and extended tree sampling to a 50 m x 20 m (0.1 ha, 0.25 ac) plot. In these 15 sites, trees were mapped and tagged and will be revisited two of every five years on a rotating schedule. The larger plot and greater sampling frequency are consistent with the more comprehensive NGPN vegetation monitoring protocol (Symstad et al. 2011).

At all plots, we surveyed the area for common disturbances and target exotic species of management interest (Table 1) in a 27 m circle around the center (Figure 3). Common disturbances included such things as roads, modern thinning activity, historical logging, 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).

Table 1. Target 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 thapus</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 ssp.</i>	Salt cedar
<i>Onopordum acanthium</i>	Scotch thistle
<i>Centaurea stobe</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 NPS 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.

Summaries were done using FFI reports and query functions 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. The code used for analysis can be found in Appendix A.

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 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.

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

We chose a set of 6 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. Confidence was calculated by averaging the scores for each of the three categories based on definitions given in Table 3. High confidence was given to indicators with an average score of >4 , medium with a score ≥ 2 and ≤ 4 , and low was items with a score < 2 .

Table 3. Key to calculating confidence values reported in the Natural Resource Condition Table. Confidence is based on relevance to the park unit, data quality, and temporal scale and reflects primarily the confidence in the data collected.

Confidence score	Relevance to the park unit	Data quality	Temporal scale of reference value (where applicable)
High (5)	Data are from multiple locations within the park that are representative of the resource. The best examples are studies with statistical inference to the entire resource or a survey of the entire park resource.	Data derived from published and peer-reviewed protocols with results appearing in peer-reviewed publications. Data and metadata are available.	Long-term data (e.g. >15 years)
Medium-high (4)	Data are from several locations within the park or a regional study with multiple locations in and around the park. Alternatively, one to two sites that represent a greater area (e.g. sampling that captures an entire airshed or watershed)	Data derived from established peer-reviewed protocols. Gray literature or thesis work exists but not many peer-reviewed publications have been derived from the data.	6-15 years
Medium (3)	Data are from one to two locations within the park resource; a regional study with multiple sites near the park; data from multiple locations for the same resource type (e.g. a global survey of caves)	Data derived from established protocols with known inconsistencies (e.g. SNOTEL temperature data) or few publications.	3-5 years
Medium-low (2)	Data are from one nearby location (<100mi); a regional study with no sites within 100mi of the park	Data with concerns regarding consistency or quality (e.g. many citizen science projects) with or without formal protocols established.	2-3 years
Low (1)	Data are from a global or US scale study that is not specific to the resource (e.g. global temperature trends)	Unknown methods used to acquire data. There are significant concerns regarding consistency or quality of data.	Data from 1 year

Results

We used a probability-based survey design that allows for unbiased inference from sampled sites (a selection of 60 grid cells) to un-sampled elements of the population of interest (the entire sample frame or the set of grid cells that cover the MORU minus select administrative areas and roads). Consequently, the results we present below are estimated means (or other metrics) of woody vegetation in MORU included in this discrete sample frame. For ease of interpretation, we hereafter will refer to these means as representing the park-wide status of MORU forests, with an understanding that they do not represent administrative areas, roads, or other areas excluded from the sample frame.

In 2010, we measured density of 12 tree and tall shrub species at 60 plots in MORU (Table 4). Ponderosa pine was the only species to occur in all plots. Chokecherry seedlings were common and occurred in about one-third of the plots. Most of the bur oak and serviceberry encountered were seedlings. Other than ponderosa pine, the most common trees and poles we encountered were quaking aspen and paper birch.

Table 4. Tree and tall shrub species occurrence in 2010 sampling of 60 plots in Mount Rushmore National Memorial.

Species Name	Common Name	Number of plots where species occurred in 2010
<i>Pinus ponderosa</i>	ponderosa pine	60
<i>Prunus virginiana</i>	chokecherry	22
<i>Quercus macrocarpa</i>	bur oak	17
<i>Amelanchier alnifolia</i>	western serviceberry	16
<i>Populus tremuloides</i>	quaking aspen	14
<i>Betula papyrifera</i>	paper birch	13
<i>Prunus pensylvanica</i>	pin cherry	6
<i>Salix bebbiana</i>	bebb willow	3
<i>Picea glauca</i>	white spruce	2
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	2
<i>Juniperus communis</i>	common juniper	1
<i>Salix ligulifolia</i>	strapleaf willow	1
<i>Populus deltoides</i>	eastern cottonwood	1

Park-wide status: tree density and basal area

We estimate 2010 stand density for live trees to be 8,446 stems per hectare (3419 stems per acre, Table 5). The large variance associated with this value is driven by the variation in seedling densities, which ranged from 0 to 192,234 stems per hectare (0 to 77,855 stems per acre). MORU tree and pole density is 1,164 stems per hectare (471 stems per acre, Table 5). Ponderosa pine makes up the majority of stand density (Table 5). Approximately 90% of the park has a stand density that is greater than the reconstructed historic density of 1870 (Figure 4). The two most common trees after ponderosa pine were quaking aspen and paper birch, and park-wide density estimates are 147 ± 35.2 and 319 ± 99.4 stems per hectare, respectively (59 and 129 stems for per acre).

Table 5. Estimated means, errors, and confidence intervals for select indicators of Mount Rushmore National Memorial forests

Indicator	N	Estimated Mean	Standard Error	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Total Stem Density (stems /ha)	60	8446	3265	2048	14845
Tree & Pole Density (stems/ha)	60	1164	92.	983	1344
Ponderosa Pine Tree & Pole Density (stems/ha)	60	1071	91	893	1249
Total Basal Area (m ² / ha)	60	30	1	28	32
Ponderosa Pine Basal Area (m ² / ha)	60	29	1	27	31.1
Snag Density (stems/ha)	32	57	6	47	69
Seedling density (stems/ha)	60	6992	3270	583	13401
Live Trees with Evidence of Insects (%)	60	22	4	14	30

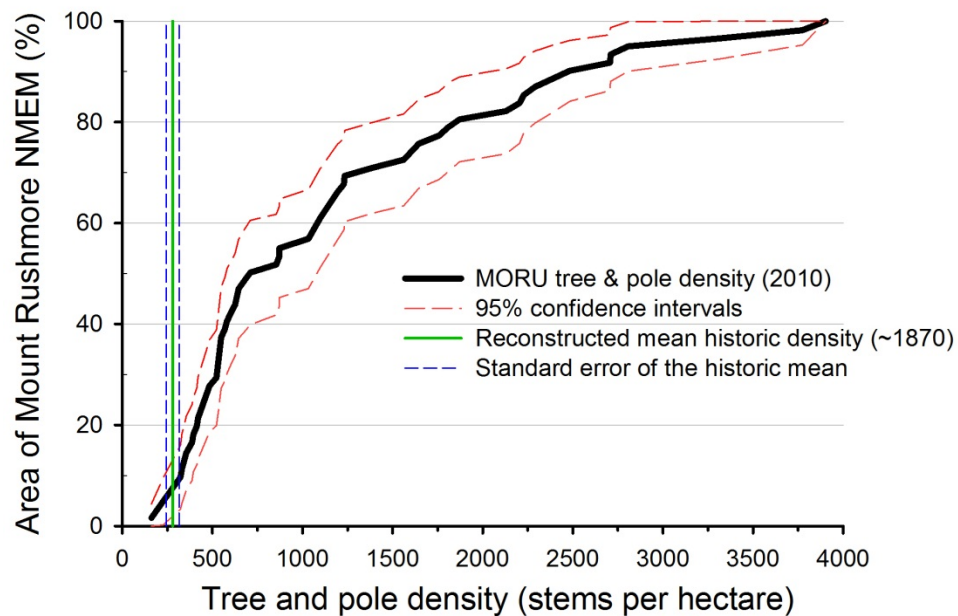


Figure 4. Cumulative distribution function of tree and pole density in Mount Rushmore National Memorial. The black line indicates the estimated distribution, the red dashed lines are upper and lower 95% confidence intervals, the green line is the reconstructed historic value (Brown et al. 2008), and the blue dashed line indicates the standard error around the mean historic basal area. This graph indicates that as of 2010, between 5 and 10% of MORU was at or below the forest density found in 1870. Conversely, 90 to 95% of the park had a larger number of trees than the MORU forest in 1870.

Basal area of forests in MORU averaged 30 m² per hectare (131 ft² per acre, Table 5). Ponderosa pine accounts for most of the basal area in MORU. Approximately 30% of the area of MORU has stands with basal area equivalent to or less than that reconstructed for 1870 (Figure 5). Size class structure of MORU forests indicate that there is a high density of poles when compared to larger diameter trees (Figure 6).

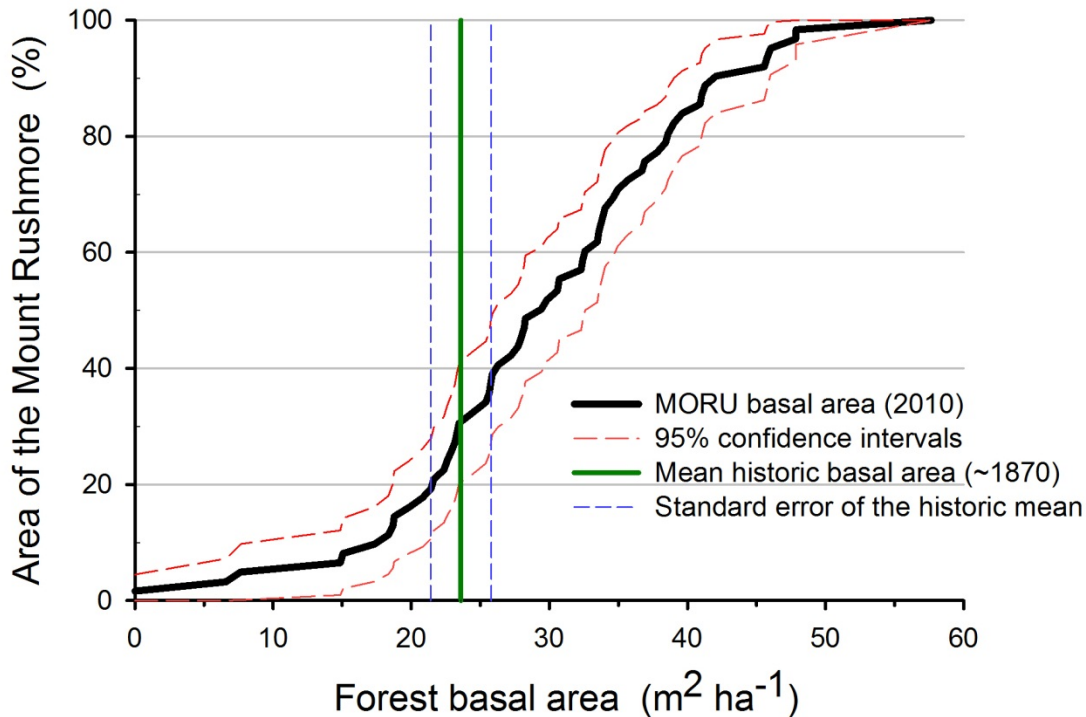


Figure 5. Cumulative distribution function of tree and pole basal area in Mount Rushmore National Memorial. The black line indicates the estimated distribution, the red dashed lines are upper and lower 95% confidence intervals, the green line is the historic value (Brown et al. 2008), and the blue dashed line indicates the standard error around the mean historic basal area. This graph indicates that as of 2010, between 20 and 40% of MORU was at or below the basal areas found in 1870. Conversely, 60 to 80% of the park had higher basal areas than in 1870.

Snag (standing dead trees with DBH > 15 cm) density averaged 57 stems per hectare across the park (23 stems per acre, Table 5). Old growth forests in the Black Hills have been described as having at least 10 live trees per acre (24.7 trees/ha) that are larger than 16 inches (40.6 cm) DBH at least two dead, standing trees per acre (4.9 trees/ha) that are larger than 10 inches (20.5 cm) DBH, and an average age of ≥ 160 years (Mehl 1992). Our methods were not developed to describe old growth structure – we did not core trees to estimate age and our plot size (0.03 ha) was too small to sufficiently capture large snag density at the stand scale. Nevertheless, when considering only large tree density, we estimate that 74 ± 4.9 % of MORU could meet the definition of old growth forests.

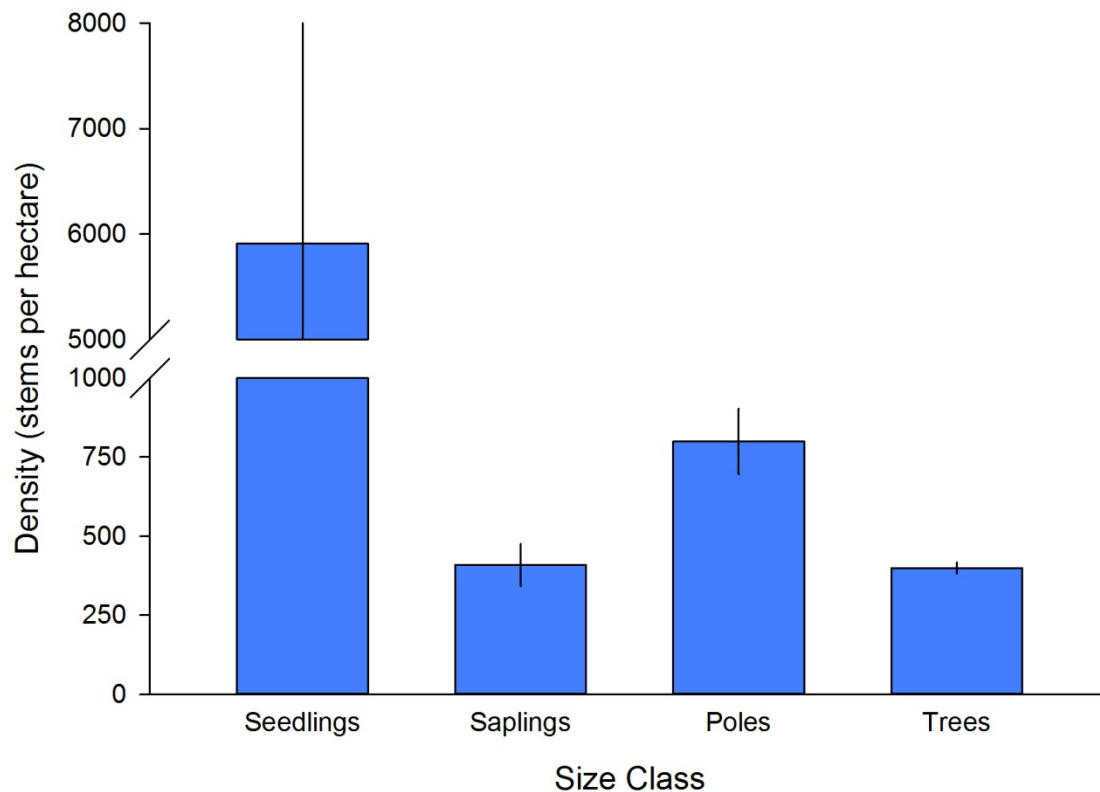


Figure 6. Size class distribution of MORU forests from the 2010 survey.

Park-wide status: surface fuels

Surface fuels were measured only in areas with relatively undisturbed ponderosa pine litter on the forest floor. In 21 of the sites visited in 2010, there were burn piles, layers of wood chips, and other indications of active management. These plots were excluded from the analysis because no sets of fuel load calculation constants have been developed for areas of wood chips and burn piles. From the 39 remaining plots, we found the estimated mean of total surface fuels in MORU to be 22.7 ± 1.73 tons per acre (Figure 7). The estimated mean of total fine fuel loads was 1.9 ± 0.24 and total litter and duff depth in the park was 1.4 ± 0.06 in.

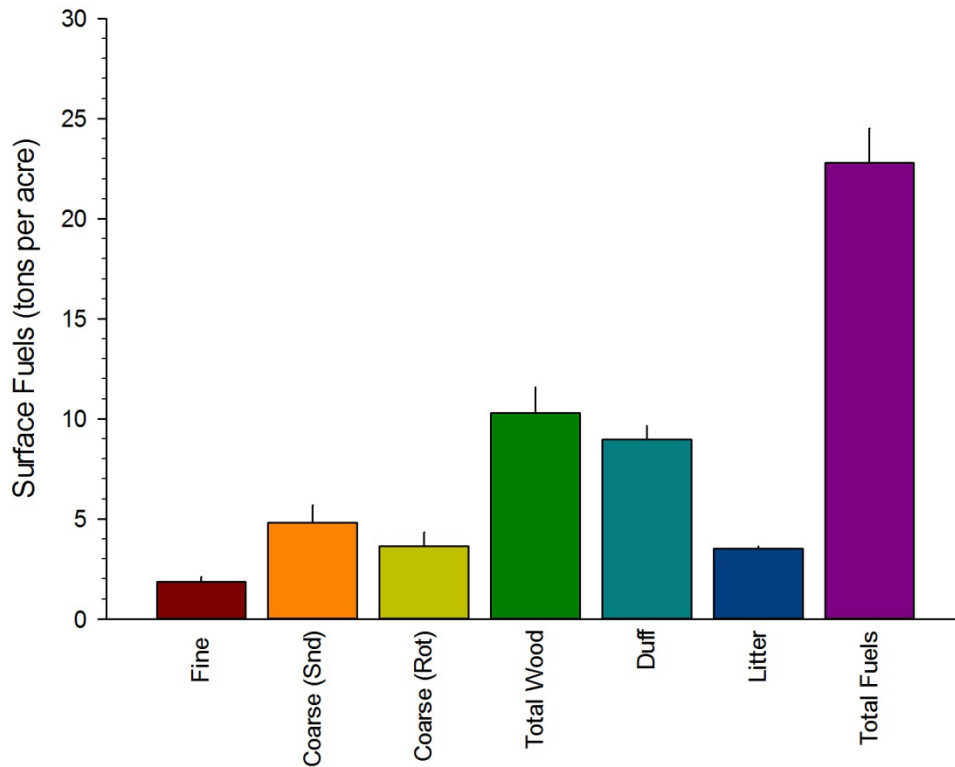


Figure 7. Surface fuels at Mount Rushmore National Memorial in 2010. Bars represent means $\pm$ standard errors, N = 39. Fine includes 1 to 100 hour fuels, coarse sound and rotten refers to 1000 hour fuels.

Park-wide status: disturbance

We documented 4 of the target exotic species (Table 1) in the park including houndstongue (7 plots), bull thistle (1 plot), Canada thistle (9 plots), and common mullein (14 plots). Thirty-eight plots had no target species present. At the scale of the whole park, we found the average target species cover class was 0.9 ± 0.1 , which is equivalent to one individual or less in a plot area.

At each plot, the forest was surveyed for evidence of historic logging, chipping, recent thinning, storm damage (including snow, ice, and water), and damage from insects or disease. We found a large portion of the park shows evidence of past fires ($62 \pm 5.0\%$), historical logging ($48 \pm 5.4\%$), and recent thinning activity ($50 \pm 5.0\%$; Figure 8). As of summer 2010, evidence of chipping activity was not widespread and only covered 8% of the park. These plots fell within the area of a research project to examine the effects of chipping on forest structure (Figure 8). Plots that showed evidence of at least one tree infested with mountain pine beetles covered $23 \pm 4.8\%$ of the park in 2010.



Northern Great Plains Inventory and Monitoring Network Plant Community Monitoring

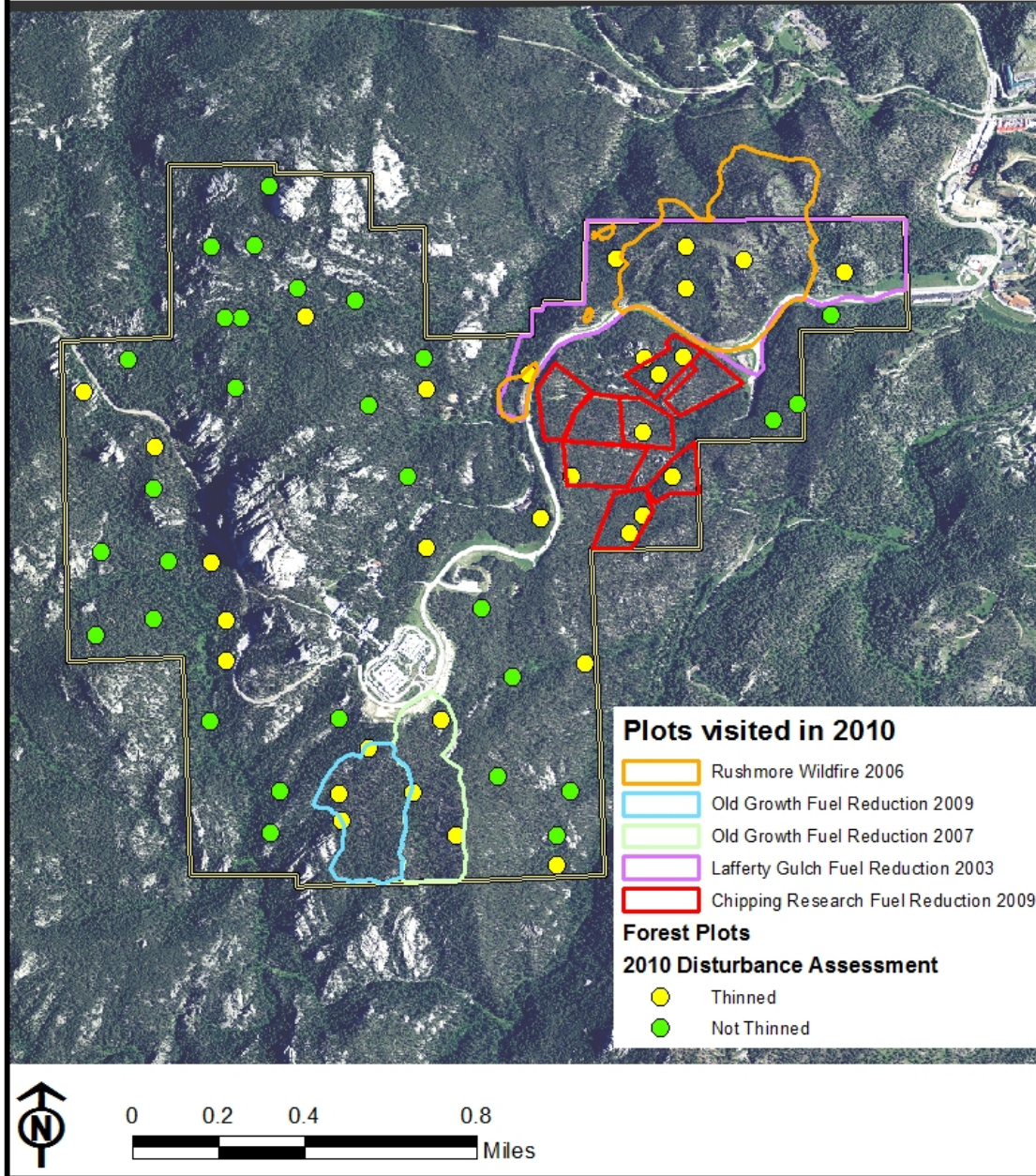


Figure 8. Map of plots that were assessed in the field in 2010 as having evidence of recent thinning activity. Boundaries of recent mechanical thinning projects and a 2006 wildfire are presented for comparison.

Relationships between mechanical thinning disturbance and forest indicators

Thinned areas had a lower density of trees and poles (780 stems per hectare, 316 stems per acre) when compared to areas that had not been thinned (1575 stems per hectare, 638 stems per acre; $F_{1,58}=12.9$, $P<0.001$). Plots with evidence of thinning activities had lower densities of ponderosa pine poles (401 stems per hectare, 162 stems per acre) when compared to areas that had not been thinned (1101 stems per hectare; $F_{1,48}=8.0$, $P=0.007$), but ponderosa pine tree densities did not differ. While not significant, thinned areas also had a tendency towards lower basal areas ($F_{1,58}=2.9$, $P=0.09$). Thinned plots had a significant reduction in the density of dead poles ($F_{1,34}=6.9$, $P=0.01$), but no difference in large snag density. Thinned plots had higher cover of exotic target species ($F_{1,58}=8.5$, $P=0.005$) than plots that were not thinned, but in both cases exotic cover was very low (thinned plots had maximum cover of just over 1 individual plants and un-thinned plots were closer to zero).

Discussion

We encountered 13 species of trees and tall shrubs in the forests of MORU in 2010 (Table 2), but the forest was dominated by ponderosa pine, as is typical of the Black Hills region. Average stand density of trees and poles (DBH > 15 cm) in the park was estimated at 1164 stems per hectare (471 stems per acre; Table 5). We estimate that 48% of the park had been logged historically, which is quite close to past estimated of 42% (Graves 1899). Basal area of ponderosa pine across the park averaged 29 m² per hectare (Table 5) and total basal area averaged 30 m² per hectare (131 ft² per acre). These values are only slightly higher than the average basal area, 28 m² per hectare, measured in 2004 in MORU (Symstad and Bynum 2005) and higher than the 21.2 m² hectare that is the average basal area of the Black Hills National Forest (Brown and Cook 2006). The difference between the 2004 and 2010 assessments could be due to different methods or simply 6 years of growth, with roughly 2 good growing seasons beyond the drought (2001-2007). There is the compounding factor that some of the plots were manipulated between 2004 and 2010—for instance those in the south-central portion of the park were thinned, and there was a wildfire in 2006 in the NE corner of the park (Figure 8). When compared to the historic reference values for the park (Brown et al. 2008), between 60 to 80% of the park had higher basal area than the 23.6 m² per hectare that characterized the forest in 1870 (Figure 5). For this reason, we conclude that forest basal area and density are of significant concern (Table 6).

Forests in the Black Hills 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). Less than 10% of the park meets this criterion (Figure 5). However, we found no evidence that ponderosa seedling establishment was inhibited in areas with high densities of trees (there was no correlation between seedling density and tree or pole density). Dense forests have likely inhibited invasion by exotic species. In 2010, we found an average of less than one individual exotic target species per plot, with mullein being the most common invasive species. This indicates that in terms of exotic plant prevalence, MORU is in good condition (Table 6).

High ponderosa density can increase susceptibility to attack by mountain pine beetles (Negrón et al. 2008). In 2010, we found 23% of the park had evidence of mountain pine beetles. Mountain 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). Therefore, we concluded that the status of forest insects was of significant concern (Table 6). Data from this report were taken at the beginning of a major effort in MORU to protect high value trees in visitor use areas and significant stands of old growth from mountain pine beetles. Still, mountain pine beetles are spreading quickly and despite efforts made at control, it is likely that they have increased in prevalence since this 2010 survey. The number of fading trees detected in the Black Hills from aerial surveys doubled from 22,000 acres to 44,000 acres between 2009 and 2010 (Harris and R2staff 2011) and increased to 67,000 acres in 2011 (USDA 2012).

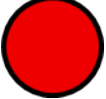
We found that 74% of forests in the park had a structure of large trees consistent with old growth forests in the Black Hills. This is similar to the 66% estimated in 2004 by Symstad and Bynum (2007). However, we caution the comparison to the Symstad & Bynum study because the methods differed significantly and our analysis only considers live trees. We report it here,

because we will continue to survey MORU forests every 5 years and the 2010 value can provide a baseline comparison.

In 2010, we estimated total fuel loads across MORU to be 22.7 tons per acre (Figure 7). Fine fuel loads were 1.9 tons per acre and total litter and duff depth in the park was 1.4 inches. After the mechanical thinning and the 2006 fire, the fire effects program measure plots to have fuel loads of 9.74 tons per acre and this value was used in the natural resource condition assessment as a management target with a goal of decreasing fire danger (Narumalani et al. 2009). However, it is worth noting that downed wood provides foraging habitat and refugia for small wildlife species, substrate for mosses, fungi and sometimes downed snags act as “nursery” logs of vascular plant establishment. Moreover, a healthy forest will have a mosaic of conditions that range from open areas with low fuel loads to denser areas. Using a broader management target of 2-15 tons per acre may be more reasonable, but the current value is still well outside this range (Table 6).

In conclusion, the ponderosa pine forest of MORU is an outstanding natural resource with a low abundance of exotic species. As of 2010, overall condition of the forest community was fair and declining. Mountain pine beetles had begun to reach epidemic levels and are increasing. The high density of ponderosa pines require active management intervention to decrease susceptibility to stand-replacing fire and pine beetle outbreaks. It is also possible that increased tree mortality due to mountain pine beetles will reduce stand density and move it closer to the historic condition. Continued monitoring efforts and repeated forest surveys will be critical to track changes in MORU forest condition.

Table 6. Natural resource condition summary table for forest structure and fuels in MORU.

Indicators of Condition ^a	Specific Measures	2010 Value (mean ± SE)	Reference Value ^b	Scale of Assessment ^c	Condition Status ^d	Trend ^e	Condition Status/Trend Symbol	Rationale
Exotic Plant Early Detection	Average cover class of exotic species (0-5)	0.9 ± 0.1	Between 0 and 3 (< 5% cover)	Park-wide	Good	Insufficient Data		To date, MORU has had effective exotic plant management and has maintained a low cover of exotic plants .
Upland Plant Communities	Forest basal area (m ² /ha)	30 ± 1.1	23.6 ± 2.2	Park-wide	Significant Concern	Improving		Current forest density is greater than the historic range in 1870 (Brown 2008). Fire suppression has lead to dense forests in MORU that are susceptible to mountain pine beetle epidemics and large fires. Recent management actions (2010-2011) have been undertaken to thin the forests at MORU which is likely to improve status.
	Overstory Density (stems/ha)	1164 ± 92	280 ± 36	Park-wide	Significant Concern	Improving		
Fire and Fuel Dynamics	Total fuel loads (tons/acre)	22.7 ± 1.73	Between 2 and 15	Park-wide	Significant Concern	Insufficient Data		The current fire ecology program aims to maintain fuel loads of less than 10 tons/acre but in thick forests of MORU there is expected to be a range of conditions. The 2010 value was much higher, which can lead to increased risk of high intensity fires.
Forest Insects and Disease	Percent of park with mountain pine beetle infestations >1 infested tree per hectare (%)	23 ± 4.8	0	Park-wide	Caution	Deteriorating		Mountain pine beetles have increased from endemic levels to epidemic levels in some parts of the park. Recent data from the forest service indicate that the epidemic has spread further than recorded in 2010 (USDA 2012).

^a based on the Vital Signs Framework (<http://science.nature.nps.gov/im/monitor/VitalSigns.cfm>); ^b Reference Value is the numeric value used in against which current values and conditions are measured, interpreted, and reported.; ^c Spatial scale of inference. Scale is described as a sample size of plot-level data, park-wide, or regional; ^d Condition refers to the current status of a resource in relation to the reference value. Condition is described as good, caution, or significant concern; ^e Trend refers to the direction of change in condition of a resource. Trend is described as improving, unchanging, or deteriorating. Insufficient data is used when there are fewer than 5 years of data or the quality of the data is not appropriate for trend analyses.

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.
- Allen, K. and D. Long. 2008. Evaluation of mountain pine beetle activity in the Norbeck area, Black Hills National Forest. USDA Forest Service, Rocky Mountain Region, Forest Health Evaluation RCSC-08-03.
- 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. and B. Cook. 2006. Early settlement forest structure in Black Hills ponderosa pine forests. *Forest Ecology and Management* 223:284-290.
- 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.
- Graves, H. S. 1899. The Black Hills forest reserve. Govt. print off.
- 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.
- Harris, J. L. and R2staff. 2011. Forest Health Conditions, 2009-2010, in (R2) Rocky Mountain region. USDA Forest Service. Renewable Resources, Forest Health Protection , R2-11-RO-31.
- 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.

- 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.
- Mehl, M. S. 1992. Old-growth descriptions for the major forest cover types in the Rocky Mountain Region. Old growth forests in the Southwest and Rocky Mountain Regions. Gen. Tech. Rep. RM-213. U.S. Department of Agriculture, Forest Service. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.
- 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.
- 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.
- Omernik, J. M. 2007. Level III Ecoregions of the Continental United States. U.S. EPA National Health and Environmental Effects Laboratory, Corvallis, Oregon.
- 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.
- 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.
- 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. 2005. The extent and significance of old-growth ponderosa pine forest at Mount Rushmore National Memorial. Report available from: <http://science.nature.nps.gov/im/units/ngpn/reportpubs/reports.cfm>
- 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. 2011. Plant community composition and structure monitoring protocol for

the Northern Great Plains I&M Network: version 1.00. Natural Resource Report
NPS/NGPN/ NRR-2011/291.

USDA-NRCS. 2012. The PLANTS Database (<http://plants.usda.gov>, 24 January 2012). National
Plant Data Team, Greensboro, NC 27401-4901 USA.

USDA. 2012. Forest and Grassland Health- Aerial Detection Survey 2011
Results: <http://www.fs.usda.gov/detail/r2/forest-grasslandhealth/?cid=stelprdb5348787>

Wienk, C. 2010. Management of ponderosa pine forest at Mount Rushmore National Memorial
using thinning and prescribed fire. ParkScience 27:26-30.

Appendix A: R code used for adjusting weights and analyzing MORU survey data

```
# File: MORU_SiteEvalRcode_2012.r
# Purpose: MORU weight adjustment for whole park: Uses adjwgt function from spsurvey
# Programmer: Isabel Ashton
# Date: 20121209

# For complete instructions on how to start R, load the design library, etc. see:
# http://www.epa.gov/nheerl/arm/analysispages/software.htm or the Cran R site

library(spsurvey) # load spsurvey library

# Start R and set path to where input files are: change this path to your needs
(WD <- getwd())
setwd("N:/Monitoring/Plant_Community/MORU/ANALYSIS/Extensives")
getwd()

# Input files:
# For adjwgt: "MORU_GRTSextframe_2011.csv"
# Includes: all original design file fields
# Includes: site evaluation attributes as added during implementation of the design
# Add Target Status for each site in the frame
# Target = TS (target sampled), TO (target office), and NS (non sampled but target)
# NT = non target
# NN = not needed or evaluated
# Add a column "Resource" where all sites get "Park"

# Step one: read, QA and modify input file
# Reads in data from .csv file into SiteEvalMORU data.frame and displays field names and table
of sites by mdcaty
# Input file is described above
SiteEvalMORU <- read.csv('MORU_GRTSextframe_2011.csv')
names(SiteEvalMORU) <- tolower(names(SiteEvalMORU))
names(SiteEvalMORU)
nrow(SiteEvalMORU)
head(SiteEvalMORU)

## Create equal area coordinates for display and later variance estimation
tmp <- marinus(SiteEvalMORU$xcoord, SiteEvalMORU$ycoord)
SiteEvalMORU$xmarinus <- tmp[, 'x']
SiteEvalMORU$ymarinus <- tmp[, 'y']
# plot sites to visually QA the design extent and distribution
plot(SiteEvalMORU$xmarinus, SiteEvalMORU$ymarinus, pch='+')

# Step two: assign attributes used for adjwgt
```

```

#uses all park T* sites
sites1 <- !(SiteEvalMORU$status_2010 == "NN" | SiteEvalMORU$status_2010 == "NT")
sites1

#wgt is the initial weight (inverse of the sample inclusion probability) for each site
wgt1 <- SiteEvalMORU$wgt
wgt1

#wtcat is weight adjustment category name for each site = mdcaty.
wtcat1 <- SiteEvalMORU$resource
wtcat1

framesize=406.2 # this is the sum of the areas of the original grid cells/sample frame that the
GRTS draw came from: 4,062,771 sq meters; 406 ha; or 1004 acres
names(framesize) <- c("Park")
framesize

# calls adjwgt function with all attributes as created above and adds a new field
"adjwt2010_wholepark" to SiteEvalMORU that has the adjusted weights
# for the whole park and all years implemented to date:
SiteEvalMORU$adjwt2010_wholepark <- adjwgt(sites1, wgt1, wtcat1, framesize)
SiteEvalMORU$adjwt2010_wholepark

summary(SiteEvalMORU$adjwt2010_wholepark)
tapply(SiteEvalMORU$adjwt2010_wholepark, list(SiteEvalMORU$resource), sum)
plot(SiteEvalMORU$wgt, SiteEvalMORU$adjwt2010_wholepark, pch="+")

#outputs table with all adj weights
write.table(SiteEvalMORU,'MORU_AdjustedWeights.csv',sep=',',col.names=NA)

#Append these adjusted weights, x,y, and resource to the file with the data. The file is set up with
#all sites (including non-target & overdraws) as rows, each metric is a column.
# Missing data points should be left blank

# Read in Whole park data file with design, evaluation and data
MORUdata <- read.csv('MORU_Forest_2010b.csv')

names(MORUdata)
nrow(MORUdata)
head(MORUdata)
table(MORUdata$panel)

# Keep only target sampled site...retain this code incase data file ever includes non TS samples

```

```

samp1 <- MORUdata$status_2010 == 'TS'
Wholesampled <- MORUdata[samp1, ]
nrow(Wholesampled)

# check to see that all Whole sites are unique

table(duplicated(Wholesampled$siteid)) # if duplicated sites check why

#sites is a data frame consisting of two variables: the first variable is site IDs, and the second
# variable is a logical vector indicating which sites to use in the analysis. If spsurvey.obj is not
# provided, then this argument is required. The default is NULL.

Wholesites <- data.frame(Wholesampled$siteid, Wholesampled$status_2010 == 'TS')
names(Wholesites) <- c('siteID','Use')
Wholesites

# design: a data frame consisting of design variables.
# repeat of code from SiteEval code, must be run in same session

# Whole:

Wholedesign <- data.frame(siteID=Wholesampled$siteid,
                          wgt=Wholesampled$wgt_final,
                          xcoord=Wholesampled$xmarinus,
                          ycoord=Wholesampled$ymarinus,
                          stratum=Wholesampled$resource)

# data.cont: a data frame of continuous response variables. The first variable is site IDs.
# Subsequent variables are response variables. If psurvey.obj is not provided, then this argument
# is required. The default is NULL.

Wholedata.cont <- data.frame(siteID=Wholesampled$siteid,
                             Wholesampled[,c
("OneHr_tonacre","TenHr_tonacre",
"HunHr_tonacre","FineWood_tonacre","ThSound_tonacre",
"ThRotten_tonacre","TotalWood_tonacre","Duff_tonacre","Litter_tonacre","TotalFuels_tonacre",
"DuffDep_in","LittDep_in","TotDep_in",
"PIPO_Snag_stemsha","PIPO_Pole_stemsha","PIPO_Tree_stemsha","PIPO_TreePole_stemsha",
"AMAL2_stemsha",
"PIGL_stemsha","SABE2_stemsha",
"QUMA2_stemsha","POTR5_stemsha","POTR5_Snag_stemsha","BEPA_stemsha","BEPA_Sna
g_stemsha","ALL_TreePole_stemsha","ALL_Snags_stemsha",
"AMAL2_SeedSap_stemsha","JUCO6_SeedSap_stemsha","JUSC2_SeedSap_stemsha","PIGL_

```

```
SeedSap_stemsha", "PRPE2_SeedSap_stemsha",
"SABE2_SeedSap_stemsha", "SALI_SeedSap_stemsha",
"BEPA_Sap_stemsha", "BEPA_Seed_stemsha", "PIPO_Sap_stemsha", "PIPO_Seed_stemsha" ,
"PODE3_SeedSap_stemsha", "POTR5_Sap_stemsha", "POTR5_Seed_stemsha", "PRVI_Sap_stemsha",
"PRVI_Seed_stemsha" , "QUMA_Sap_stemsha", "QUMA_Seed_stemsha"
,"nonPIPO_Sap_stemsha", "nonPIPO_Seed_stemsha"
,"ALL_Sap_stemsha", "ALL_Seed_stemsha", "ALL_LIVE_stemsha",
"PIPO_LIVE_stemsha", "TargetSp_Max_Cover", "Number_Disturbances",
"Dieback_Trees_percent", "Insect_Trees_percent", "DieInsect_Trees_percent"))]
```

#data.cat: a data frame of categorical response variables. The first variable is site IDs.

```
Wholedata.cat <- data.frame(siteID=Wholesampled$siteid,
                           Wholesampled[,c
("InDi_Disturbance", "Log_Disturbance", "Pile_Disturbance", "ThinChip_Disturbance", "Wfire_Disturbance" )])
```

#subpops: a data frame describing sets of populations and subpopulations for which estimates will be calculated. The first variable is site IDs. Each subsequent variable identifies a Type of population, where the variable name is used to identify Type. A Type variable identifies each site with one of the subpopulations of that Type. If spsurvey.obj is not provided, then this argument is required. The default is NULL.

```
Wholesubpop <- data.frame(siteID=Wholesampled$siteid, allpark=Wholesampled$resource)
#allpark field has "allpark" in all cases
names(Wholesubpop) <- c('siteID','allpark')
Wholesubpop
```

```
popsizesize_whole <- list(allpark=c(allpark=406.2771)) #used frame size for MORU
```

```
Allpark_continuousVars <- cont.analysis(
  sites = Wholesites,
  subpop=Wholesubpop,
  design=Wholedesign,
  data.cont=Wholedata.cont,
  popsize=popsizesize_whole,
  vartype="Local",
  conf=95,
  pctval=c(5,10,25,50,75,90,95))
```

```
#write output
write.table(Allpark_continuousVars$CDF, 'MORU_continuousVars.CDF_2012.csv', sep =
",", col.names=NA)
```

```

write.table(Allpark_continuousVars$Pct,'MORU_continuousVars.Pct_2012.csv',sep =
",",col.names=NA)

#rough CDF plots of all variables in pdf file
cont.cdfplot("MORU_continuousCDFs_2012.pdf", Allpark_continuousVars$CDF, ylbl.r="Area
(hectares)")

Allpark_catVars <- cat.analysis(
  sites = Wholesites,
  subpop=Wholesubpop,
  design=Wholedesign,
  data.cat=Wholedata.cat,
  popsize=popsize_whole,
  vartype="Local",
  conf=95)

#write output
write.table(Allpark_catVars, file = "MORU_catVars_2012.csv", sep = ", ", col.names=NA)

```


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 323/115039, June 2012

National Park Service
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