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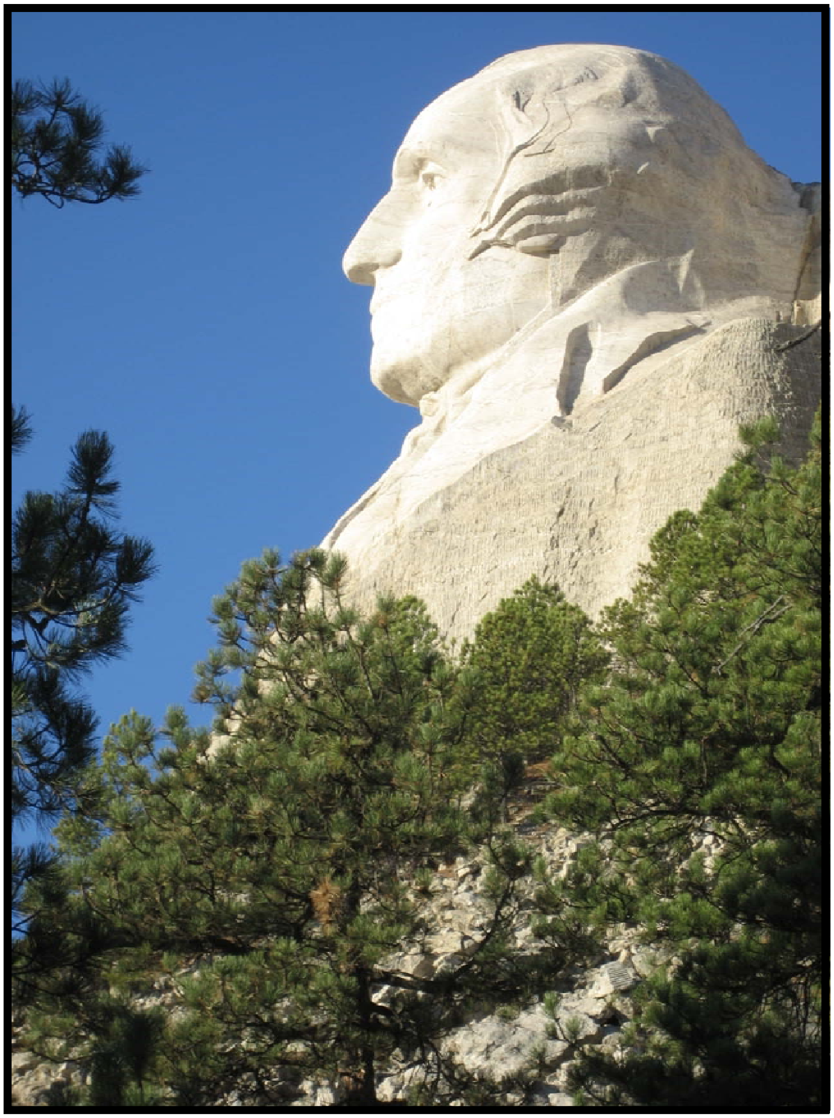
Natural Resource Program Center

Mount Rushmore National Memorial Condition Assessment

Natural Resource Report NPS/NRPC/WRD/NRR—2009/115



ON THE COVER
Sculpture of George Washington
Photograph by Paul Merani, University of Nebraska–Lincoln

Mount Rushmore National Memorial Condition Assessment

Natural Resource Report NPS/NRPC/WRD/NRR—2009/115

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Executive Summary

Mount Rushmore National Memorial is a small cultural park (517 ha in size) with limited but important natural resources that are somewhat sheltered in a landscape dominated by the Black Hills National Forest. Important natural resources include about 344 ha of old-growth ponderosa pine forest—or about 17 percent of this forest type in the Black Hills—and the Starling Basin wetland complex, which is considered an important conservation site in the Black Hills for bats, reptiles and amphibians, and butterflies.

This condition assessment was undertaken to provide NPS managers, interpreters, and planners with a concise synthesis, and "scorecard", of the most current information on the natural resources in and around the memorial. The assessment is divided into four sections: (1) **Ecological Context** provides an overview of the natural resources of the memorial and region; (2) **Natural Resource Condition** identifies habitat indicators and associated measures, assigning a condition and trend score to each indicator; (3) **Stressors and Management Strategies** discusses stressors and proposes management strategies; and (4) **Conclusion** determines an overall condition and trend score for major habitats.

The major habitats in the memorial—identified by a land-cover classification of the vegetation—are **forest**, **rock outcrop and barren**, and **stream and wetland**. These habitats provide the ecological framework for this assessment, and their condition and trend are assessed by a suite of biodiversity and process indicators. Indicator condition was characterized as poor (red box) or good (green box) and trend was characterized as deteriorating (down arrow), stable (horizontal arrow), improving (upward arrow), or no trend (no arrow). These characterizations were based on a comparison of reference and existing values for the measures of each indicator. The indicators and their condition and trend are:

old-growth ponderosa pine	poor and deteriorating
breeding birds	good and no trend
brown creeper	good and no trend
mountain pine beetle	poor and no trend
land cover (forest)	poor and deteriorating
fire	poor and deteriorating
mountain goat	poor and improving
land cover (rock outcrop and barren)	poor and deteriorating
native and exotic fish	poor and no trend
aquatic macroinvertebrates	good and stable
northern leopard frog	good and no trend
bats	good and no trend

In addition, three indicators, **birch/hazelnut vegetation association**, **lichens**, and **stream flow (Grizzly Bear Creek)**, were included but not scored due to lack of site-specific information. They were discussed to highlight rare or unique resources and important information needs.

The major stressors emerging from this condition assessment are:

fire suppression: more than a century of fire exclusion resulted in a higher probability of catastrophic crown fire in the old-growth forest.
exotic trout competition: the presence of exotic brook trout in streams and ponds may be limiting the presence and abundance of native fish.
mountain pine beetle infestation: most ponderosa pine stands have a moderate or high risk of attack.

Other existing or potential stressors are **air tour noise**, **air quality/visibility reduction**, **drought**, **mountain goat abundance**, **horse trail use**, **water quality impairment**, and **exotic plant infestation**.

Based on a subjective evaluation of the indicators of the major habitats, their condition and trend are:

forest	poor and deteriorating
rock outcrop and barren	poor and no trend
stream and wetland	good and no trend

Priority management strategies to address stressors include continuing mechanical removal of dense stands of small ponderosa pine trees followed by prescribed burns, eliminating exotic brook trout and restoring native fish to streams and ponds, and mitigating horse trail erosion and limiting use, if necessary. Future stressors may include invading exotic plants, especially salt cedar, and deteriorating regional air quality and visibility as a result of new power plant operations in the region. In addition to the vital-signs monitoring that will be initiated by the Northern Great Plains Inventory and Monitoring Network in the near future, monitoring should be considered for **lichens, mountain goats, native and exotic fish, northern leopard frogs, and bats.**

Acknowledgements

Jeff Albright, program lead, Watershed Condition Assessment Program, Water Resources Program Center, National Park Service, provided valuable information on possible condition assessment approaches and suggested supporting material to strengthen this condition assessment. The staff of the Northern Great Plains Inventory and Monitoring Network, National Park Service, particularly Mike Bynum, biological technician, and Dr. Amy Symstad, ecologist, Northern Prairie Wildlife Research Center, U.S. Geological Survey, provided unpublished data and extensive and useful comments on two drafts of this condition assessment. Dr. Janet Eckhoff, natural landmarks coordinator, National Park Service, also provided extensive comments on a draft of this condition assessment. Dr. Kyle Hoagland, professor of aquatic ecology, University of Nebraska–Lincoln, and Jay Glase, fisheries biologist, National Park Service, provided comments on the aquatic macroinvertebrate and native and exotic fish indicators. In addition, Cody Wienk and Dan Swanson, fire ecologists, National Park Service, provided information on fuel loads and reviewed the fire indicator. Frank Turina, program specialist, Natural Sounds Program Center, National Park Service, provided background information on the sound environment. Several graduate students in the School of Natural Resources, University of Nebraska–Lincoln, analyzed land cover and other data and produced maps for this condition assessment. Finally, Mike Pflaum, former chief ranger, and Bruce Weisman, resource manager, Mount Rushmore National Memorial, provided a managerial perspective in commenting on a draft of this condition assessment.

Introduction

In response to increasing threats to the biological integrity of national parks, the U.S. Congress passed legislation in 2003 that instructed the National Park Service to assess environmental conditions in watersheds where park units are located. In response to this legislation, the Water Resources Division of the National Park Service initiated a multi-year program to fund natural resource condition assessments for each of the 270 park units with significant natural resources. These condition assessments will synthesize existing research and inventory and monitoring data into a knowledge base for use in park resource planning, decision making, accountability reporting, and partnership and education efforts. Condition assessments answer this important question: what does the best available science say about the overall condition of important park natural resources?

Each condition assessment results in a written report and maps that

- characterize park natural resources within a larger ecosystem context;
- convey resource condition status for a set of individual indicators as well as overall conditions by watershed, habitat types, or park management zones;
- highlight data and knowledge gaps, and resource condition threats;
- describe resources considered most at-risk;
- recommend effective resource management strategies.

Condition assessments are likely to contribute to

- strategies and priorities for a park's resource management program;
- watershed or landscape scale partnership/education efforts;
- mid- to long-term park planning efforts, including a General Management Plan and Resource Stewardship Strategy;
- Department of Interior land-health goals and Office of the Management and Budget natural resource condition scorecards.

The condition of natural resources at Mount Rushmore National Memorial is assessed based on a synthesis of preexisting data (i.e., data available before April 2009) identified in a review of the natural resource literature about the memorial; the Black Hills National Forest; and, to a lesser extent, other national park units in the northern Great Plains. Interviews with scientists, inventory and monitoring specialists, and resource managers provided information not recorded in the literature. No new field data were collected for this condition assessment. This assessment uses a scorecard approach to present the condition of major habitats in the memorial that is similar in format to the State of the Parks reports for Canadian National Parks (Dobbie 2006). Scorecards are a status assessment tool that reflect where a site or project is during a particular point in time and provide easy to understand feedback for management decisions (Stem et al. 2005).

This condition assessment includes five major sections:

Ecological Context: This section includes a brief history and administrative description of the memorial and provides an overview of its natural resources in the context of the natural resources of the Black Hills region.

Natural Resource Condition: This section describes the scorecard approach used to assess the condition of the major habitats in the memorial. It identifies habitat indicators and associated measures and establishes reference and existing values for those measures. It provides a synthesis of existing information for each indicator and, when data are adequate, assigns a condition score and trend that is based on a comparison of the values of reference and existing measures.

Stressors and Management Strategies: This section identifies the stressors emerging from the condition assessment and proposes management strategies to deal with those stressors.

Conclusion: This section determines an overall condition and trend score for each habitat and discusses the rational for assigning that score.

Appendices A and B: Appendix A includes a summary of sampling method and data analysis for each indicator and Appendix B describes GIS file structure and products.

Ecological Context

Physical Setting

History and Location

Mount Rushmore National Memorial was dedicated on August 10, 1927, as the “Shrine of Democracy,” the mountaintop sculpture of four presidents of the United States (Fig.1). In 1933, the memorial came under the jurisdiction of the National Park Service. The primary natural resource management objectives of the memorial are to manage the geologic features and vegetation cover of Mount Rushmore and adjacent environs to maintain its historical integrity and natural setting (National Park Service 1980).

Figure 1. Mount Rushmore sculpture (photo by Paul Merani).

The memorial encompasses 517 ha in the central Black Hills of South Dakota near the small town of Keystone (population 311) (Fig. 2). The developed zone of the memorial at about 49 ha includes the Lincoln Borglum Visitor Center, Avenue of Flags, amphitheater, Sculptors Studio, Presidential Trail, and roads and parking (Fig. 2). The majority of the memorial is designated as either a natural or historic zone. The memorial is bounded by the Black Hills National Forest and private property to the east and north and by the Black Elk Wilderness, designated by Congress in 1980, and the Norbeck Wildlife Preserve to the west and south (Fig. 3).

Climate

Within the Black Hills, precipitation is greater, air temperature less variable, and wind velocities lower than on the surrounding Great Plains (Froiland 1990). Mean annual precipitation averages 51–61 cm, with about 70 percent falling as rain from April through September. For the years 1931 to 1998, annual precipitation was highly variable although the middle to late 1990s stand out as a wet period (Fig. 4). Monthly precipitation increases through mid-July, and then drops off sharply with a dry season beginning in late July and running through early September.

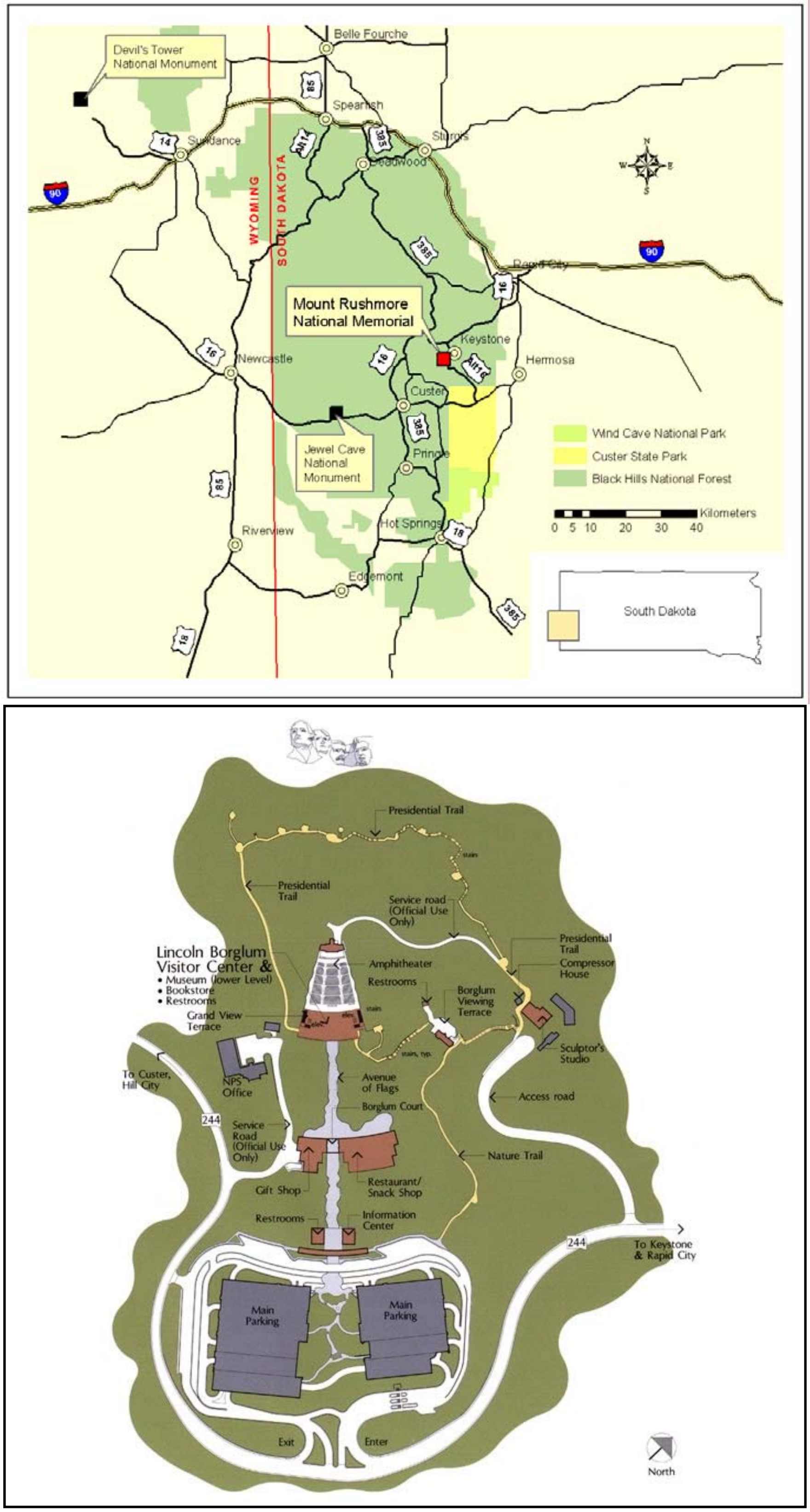


Figure 2. Locator and development zone maps of Mount Rushmore National Memorial.

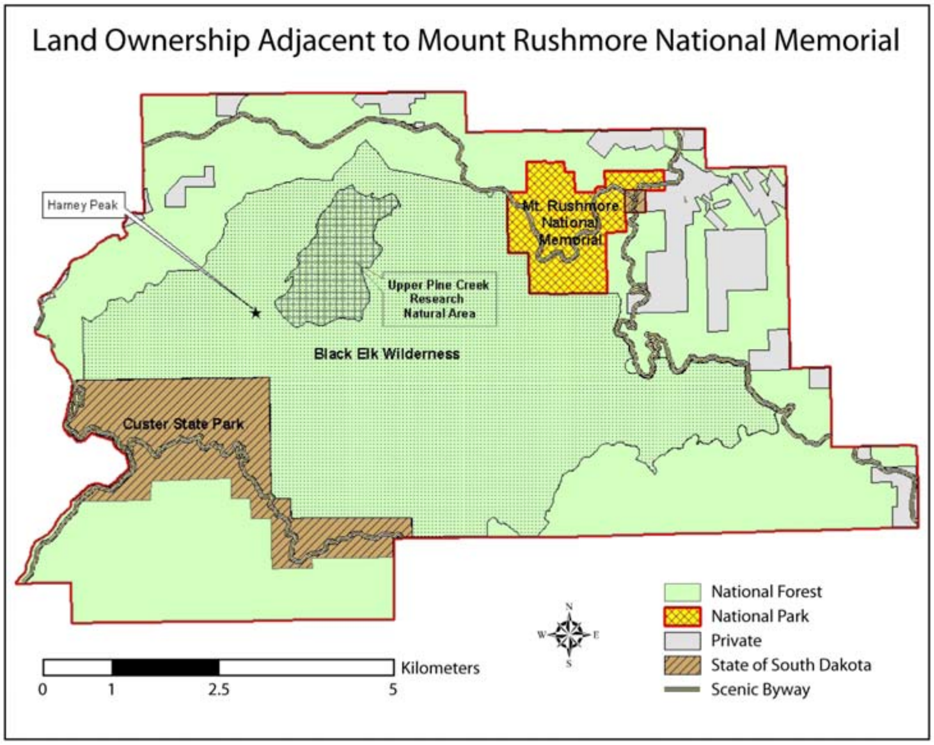


Figure 3. Land ownership adjacent to Mount Rushmore National Memorial (*Source*: USDA Forest Service 2006).

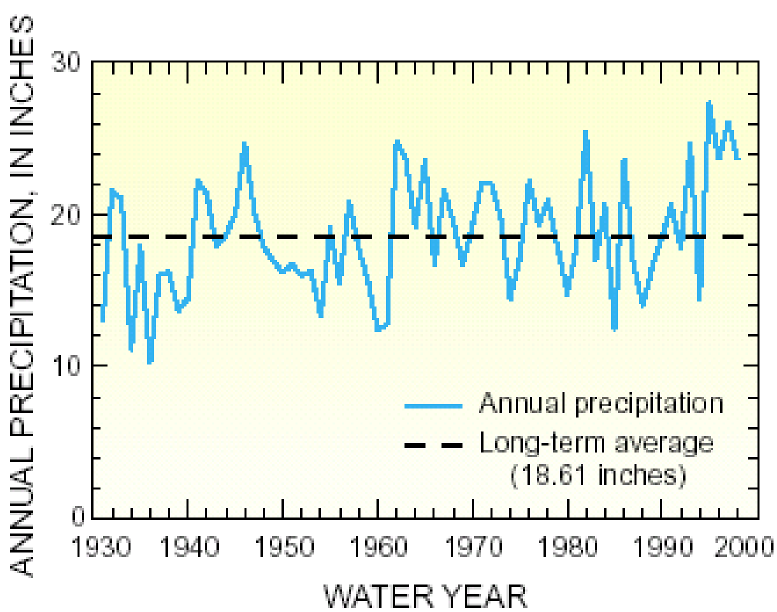


Figure 4. Long-term trends in precipitation for the Black Hills area, water years 1931–1998 (*Source:* U.S. Geological Survey 2002).

Typically, snow falls from October to April. Average annual temperature ranges from 8 to 2°C depending on elevation. Temperatures above 38°C are common at low elevations in July and August, and lows below -26°C occur occasionally throughout the region in the winter. The prevailing winds are from the west. On average, severe or extreme drought occurs with a frequency of 10–15 percent in a 10-year period (Fig. 5). For the Black Hills region, a climate change scenario of doubled CO_2 would produce an average annual increase of 4.6°C in temperature and a 24 percent increase in precipitation (Giorgi et al. 1994).

From 1948 to 2004, annual precipitation recorded at the memorial headquarters averaged 53 cm most of which fell during summer thunderstorms. Snowfall averaged 133 cm. Average temperatures during this period ranged from 25°C in July to -2°C in Janaury.

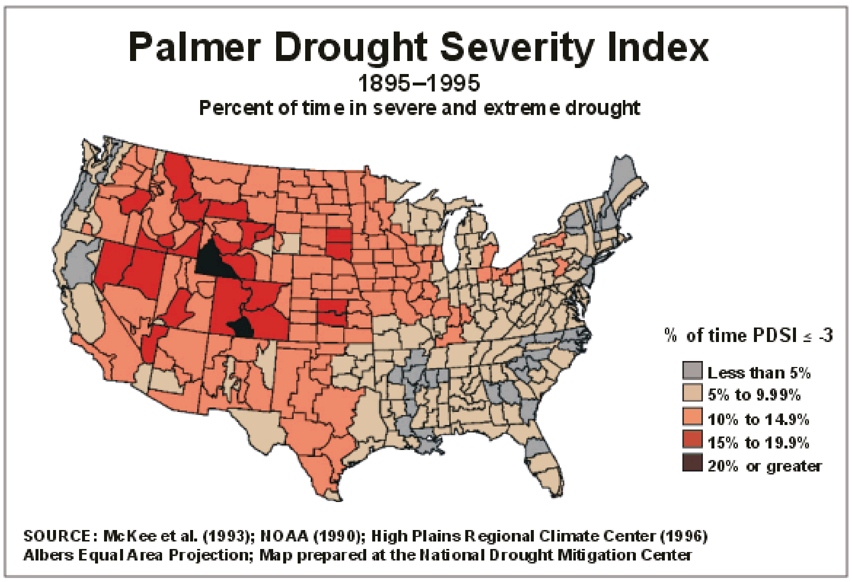


Figure 5. Palmer Drought Severity Index (*Source:* National Drought Mitigation Center 2008).

Air Quality

Air quality in the Black Hills is excellent (South Dakota Department of Environment and Natural Resources 2008). Most of the Black Hills region, including the memorial, is designated a federal Class II area under the National Ambient Air Quality Standards set by the Clean Air Act of 1963. Class II areas allow higher concentrations of pollutants to be added to the air than Class I areas, which allow only minimal deviation from baseline pollution concentrations. Class I areas in the region include Wind Cave National Park and Badlands National Park. Wind Cave National Park, which is located about 26 km from the memorial, monitors particulates, sulfur dioxide, nitrogen dioxide, and ozone. Particulate concentrations at Wind Cave National Park have increased slightly since 2005, most likely due to wild land fires in Wyoming, Montana, and Idaho and prescribed fires near the sampling site (South Dakota Department of Environment and Natural Resources 2008) (Fig. 6). Concentrations of the other pollutants have remained constant.

Air quality is not monitored in the memorial but has been estimated for visibility from data collected at Wind Cave. For data collected between 1996 and 2006, visibility improved on clearest days and showed no trend on haziest days (National Park Service 2007a). In addition, an assessment of the risk of foliar injury from ozone was conducted in the memorial in 2004. Based on low levels of ozone exposure (interpolated from Wind Cave data) and the relatively dry soil-moisture conditions in the memorial, the risk was low (National Park Service 2004).

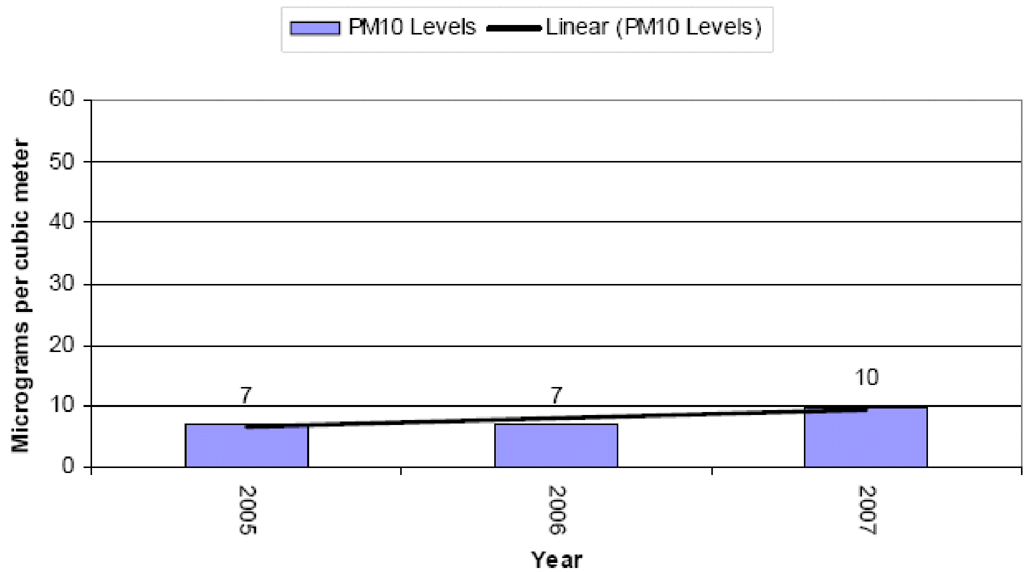


Figure 6. Wind Cave National Park PM10 (particulates) annual averages (*Source:* South Dakota Department of Environmental and Natural Resources 2008).

Soundscape

Soundscape is an aggregate of natural and human-made sounds. Sources of natural sound in the memorial include a variety of animal calls and physical processes such as wind and water. Noise sources in the memorial are mainly vehicles on roads and aircraft overhead, including commercial air-tour operations.

Data collected at the memorial in 2007 indicated existing levels of all natural and human-caused sounds without air tours, were as high as 60 to 65 dBA near Highway 244 and 45 to 50 dBA on the Grand View Terrace in the Development Zone (dBA is a weighted decibels scale from zero to 110 that covers most of the range of everyday sounds) (Fig. 7). As distance from the highway and other high visitor-use areas increased, the sound level ranged from 40 to 45 dBA in most remaining areas of the memorial (Volpe 2008). The natural ambient sound level is the environment of sound that exists in the absence of human-caused noise. According to National Park Service policy, "the natural ambient is the baseline condition and the standard against which impacts to a soundscape will be measured and evaluated (National Park Service 2006). In 2007, the natural ambient in the memorial was between 20 and 25 dBA (Volpe 2008).

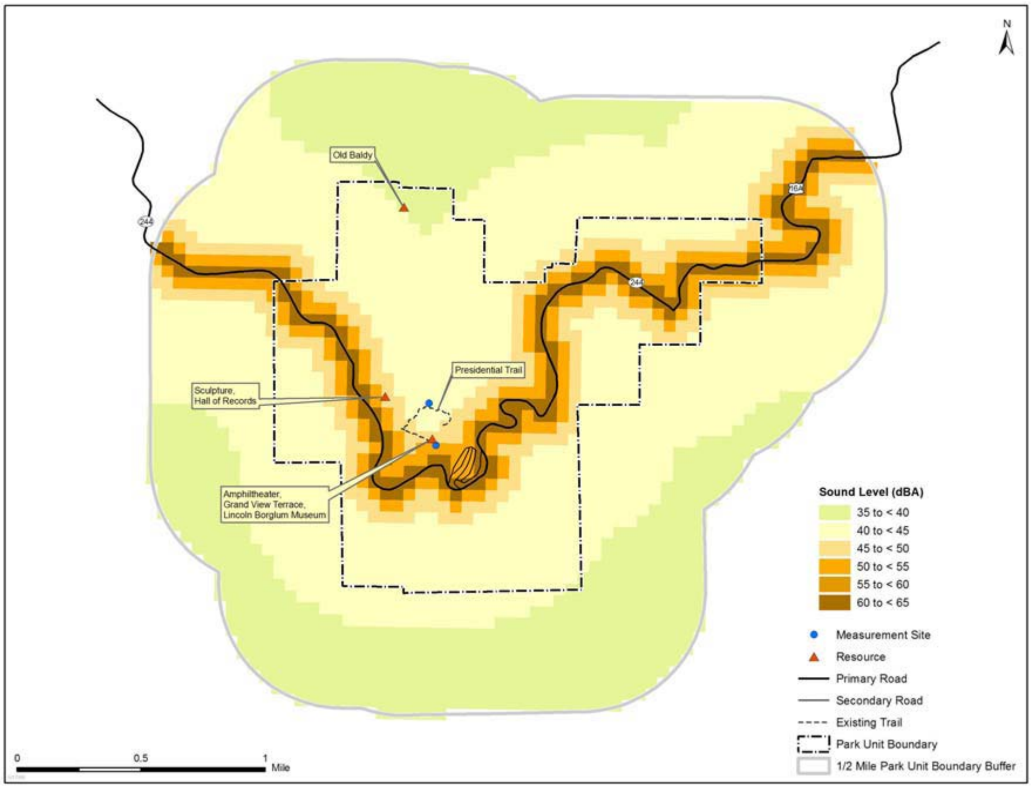


Figure 7. Existing ambient sound without air tours (*Source:* Volpe 2008).

Topography and Geology

The Black Hills is an isolated mountain range in the Great Plains of western South Dakota and northeastern Wyoming (Froiland 1990). The Black Hills uplift is a product of the Laramide orogeny, a series of mountain building events that produced most of the ranges in the Rocky Mountains about 60 to 65 million years ago. Trending roughly northwest to southeast, the uplift is approximately 200 km long and 100 km wide, with an area of 809,372 ha. Elevations range from 975 meters to 2,207 meters.

The oldest geologic structure in the Black Hills is the Precambrian crystalline (igneous and metamorphic) rocks which are exposed in the central core of the uplift. The memorial falls within this Central Core region. Prominent granitic outcrops in the Central Core include Harney Peak (2,207 m), Mount Rushmore (1,745 m), and the Needles. Surrounding the Precambrian core is a layed series of sedimentary rocks including limestones, sandstones, and shales that are exposed in roughly concentric rings around the uplifted flanks of the Black Hills (Fig. 8).

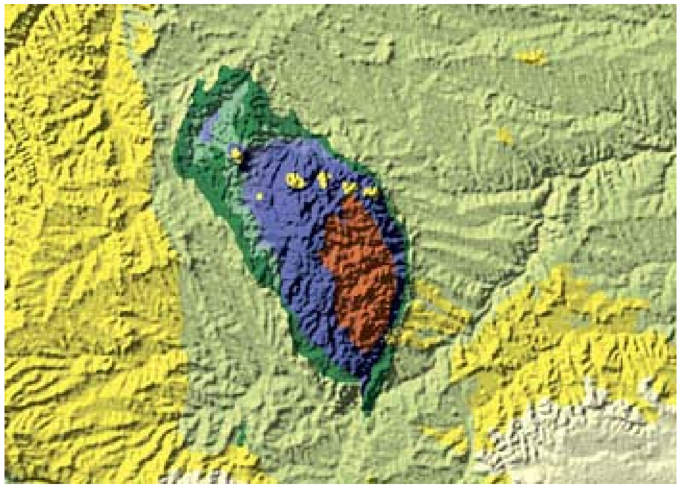


Figure 8. Geologic map of the Black Hills showing Precambrian (red orange), Paleozoic (blue), and Mesozoic (green) rock (*Source:* National Atlas of the United States 2008).

Soils

The soils of the Central Core of the Black Hills are shallow, sandy-to-gravelly loams weathered from the granite bedrock. A large portion of the Core area is bare rock outcrop. The major soil types within the memorial are Buska, Mocmont, and Cordeston (USDA Forest Service 2006a).

Watershed and Water Quality

The memorial lies within the Middle Cheyenne Spring Creek watershed (Fig. 9). Creeks or drainages within the memorial include Lafferty Gulch, Starling Basin (includes Beaver Dam Creek), and Grizzly Bear Creek (Fig. 10). Lafferty Gulch and Beaver Dam Creek are intermittent. Stream flow in Grizzly Bear Creek is highly variable (U.S. Geological Survey 2008). Under a conservative climate change scenario of 4°C increase in temperature and either a 10 percent increase or 10 percent decrease in precipitation, modeled annual water yield (i.e., annual stream flow) for the Spring Creek sub-watershed ranged from a maximum reduction of 38 percent to a maximum increase of 53 percent (Fontaine et al. 2001).

Water quality in the region and memorial is generally characterized as good to excellent (Rust 2006). During the years 1957 to 1998, thirty-six water quality monitoring stations in and around the memorial provided baseline information for 143 different water quality parameters (National Park Service 2000) (Fig. 11). Four of these stations were within the boundaries of the memorial and were sampled in 1957, 1967, and 1982 through 1989. Measurements of five parameters (dissolved oxygen, pH, antimony, fecal coliform, and turbidity) exceeded state of South Dakota water quality standards at least once during the monitoring years. However, no samples from the memorial exceeded these standards (National Park Service 2000). More recent water quality sampling of the creeks in the memorial in 2004 and 2005 revealed that Beaver Dam Creek is impaired due to dissolved oxygen and pH falling below state standards and turbidity and total dissolved solids exceeding state standards (Rust 2006, Troelstrup 2006). Water quality in Grizzly Bear Creek and Lafferty Gulch was characterized as good to excellent.

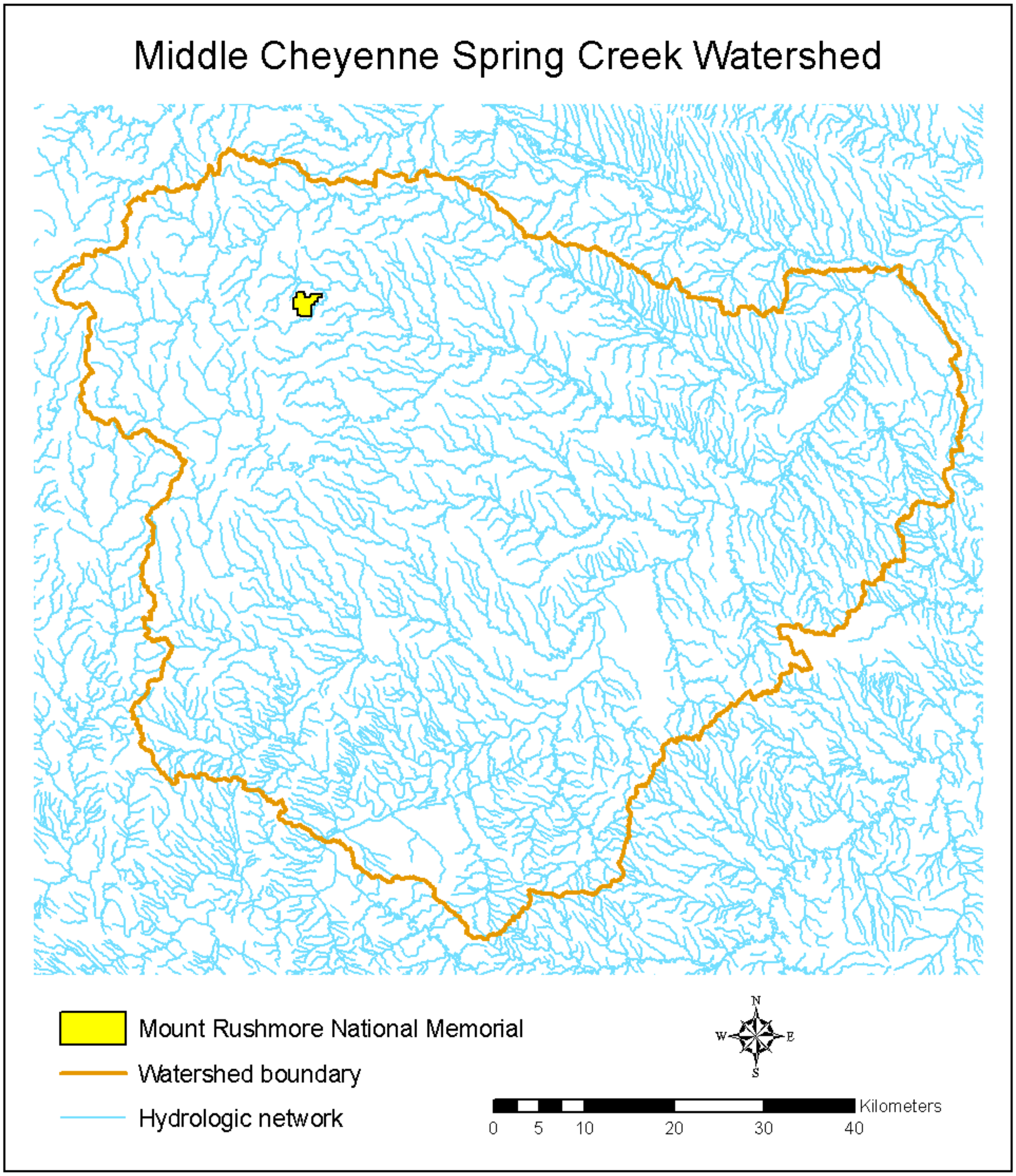


Figure 9. Middle Cheyenne Spring Creek watershed.

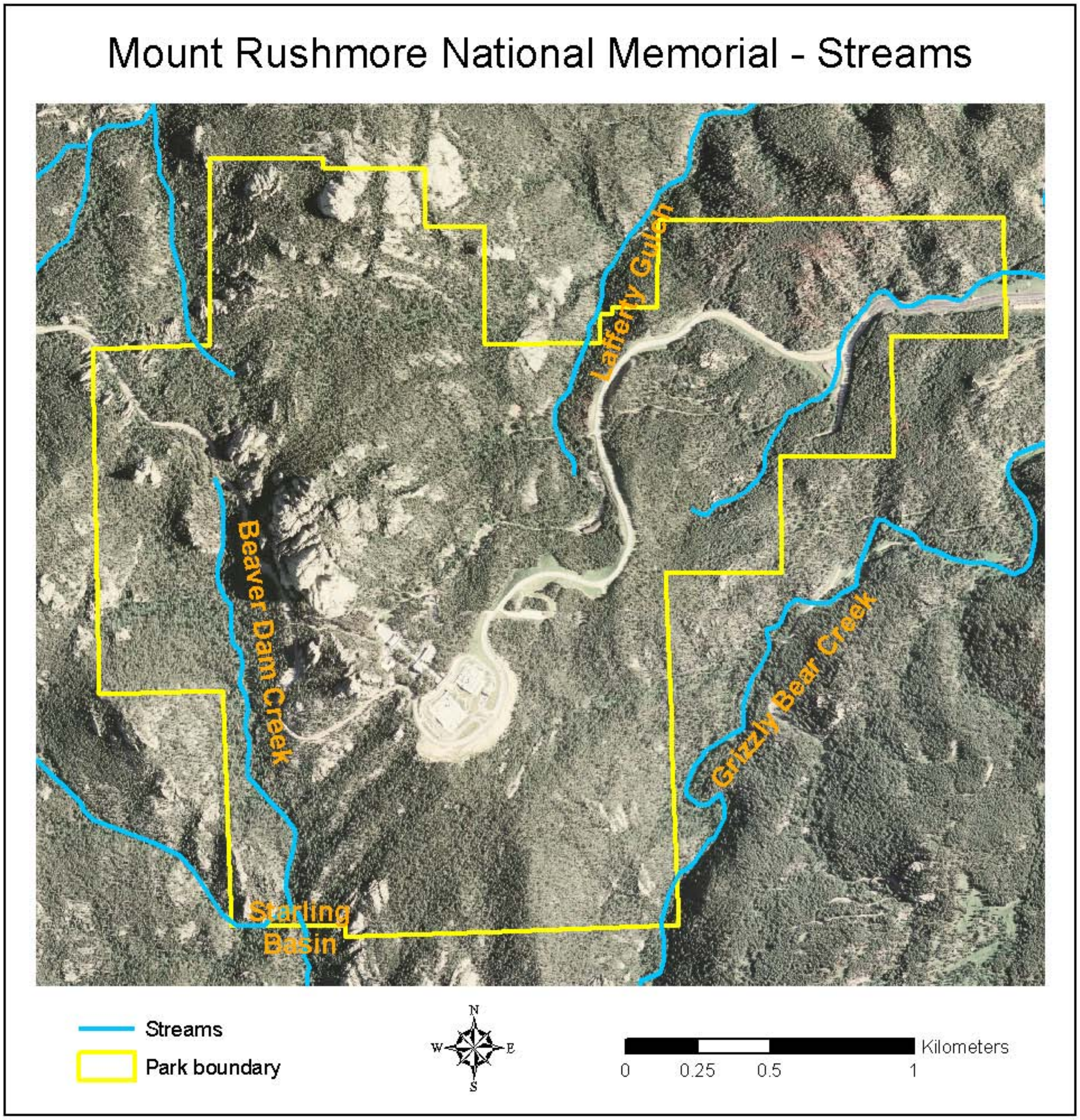


Figure 10. Streams and water drainages within Mount Rushmore National Memorial.

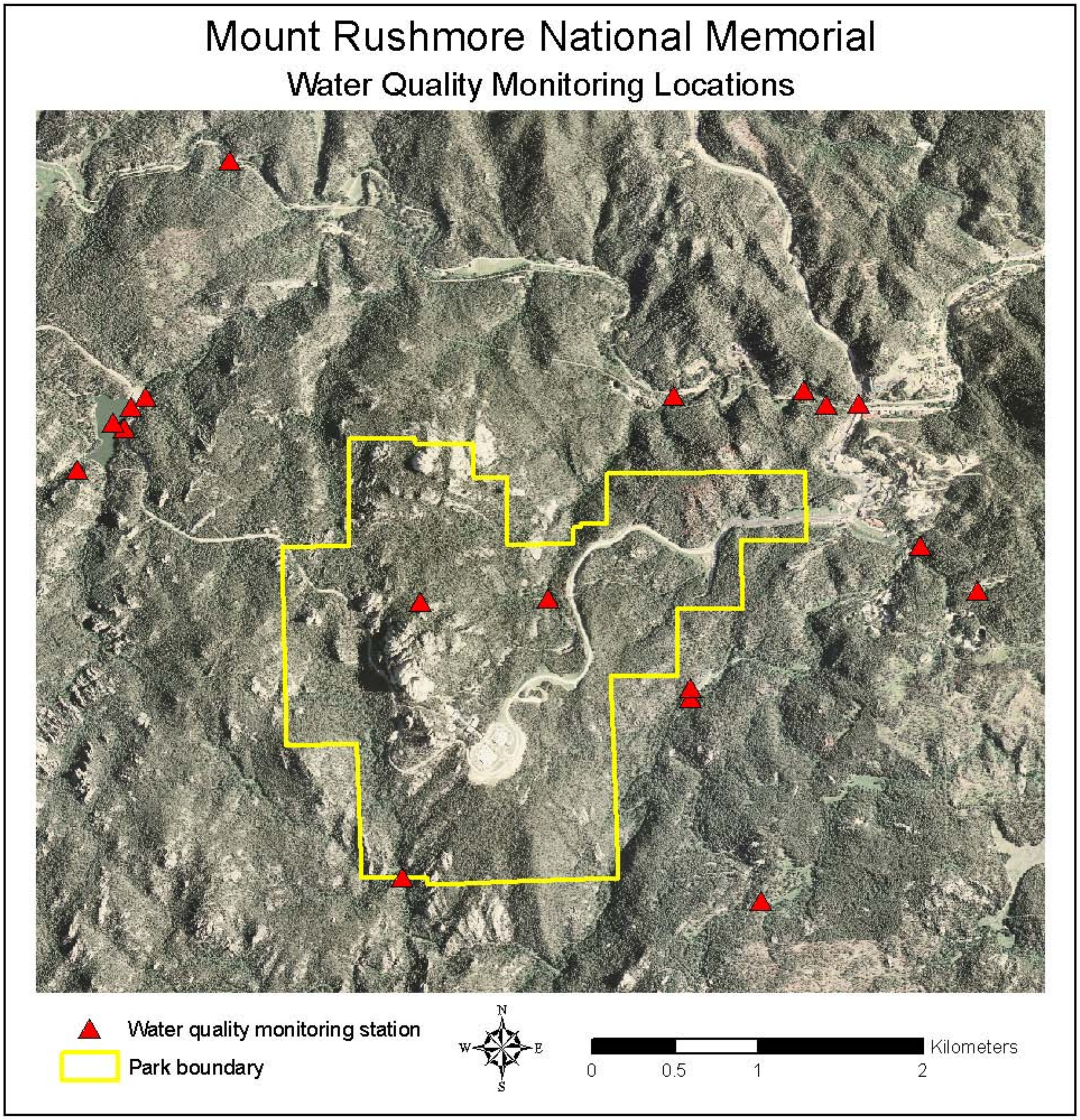


Figure 11. Water quality monitoring stations in and near Mount Rushmore National Memorial (*Source:* National Park Service 2000).

Biological Setting

Vegetation

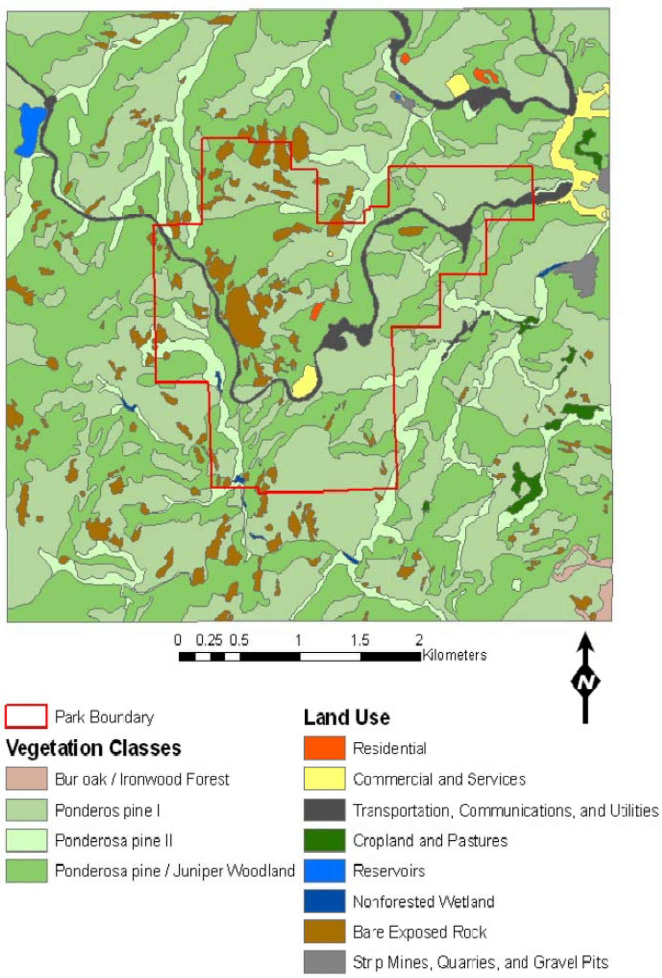
The flora of the memorial includes 425 species of vascular plants in eight vegetation associations (Symstad and Bynum 2005, Salas and Pucherelli 1998) (Fig. 12). Ponderosa pine (*Pinus ponderosa*) forest is the dominant vegetation type in the memorial and throughout the Black Hills (Shepperd and Battaglia 2002; Salas and Pucherelli 1998). It is found from low to high elevations and in all soil types. This forest type was shaped by large-scale, stand-replacing fires and by low-intensity ground fires, both of which have been suppressed since the late 1880s (Brown et al. 2008). The most common understory shrub of the ponderosa pine forest in the memorial is common juniper (*Juniperus communis*), followed by snowberry (*Symphoricarpos occidentalis*), currant (*Ribes* spp.), and chokecherry (*Prunus virginiana*). The herbaceous layer consist of Kentucky bluegrass (*Poa pratensis)*, sedges (*Carex* spp.), Junegrass (*Koeleria macrantha*), rough-leaved ricegrass (*Oryzopsis asperifolia*), bluejoint reedgrass (*Calamagrostis canadensis*), poison ivy (*Toxicodendron radicans*), bearberry (*Arctostaphylos uva-ursi*), harebell (*Campanula rotundifolia*), timothy (*Phleum pretense*), and pinedrops (*Pterospora andromedea*) (National Park Service 2003).

Quaking aspen (*Populus tremuloides*) is an important component of the vegetative cover of the memorial and region, occurring mostly along streams in cool, moist sites (Jones 1985). Aspen is the first tree to regenerate after fire, but the lack of this disturbance is causing existing stands to be lost to pine encroachment (Mueggler 1985). White spruce (*Picea glauca*) and bur oak (*Quercus macrocarpa*) also occur in the memorial. Bur oak is typically found in the stringer bottoms and in lowland riparian plant communities with other deciduous trees or as a shrub under ponderosa pine stands (Hoffman and Alexander 1987). White spruce is found at high elevations and in cooler drainage bottoms (Nienstaedt and Zasada 1990).

At medium to high elevations in the Black Hills, a dense shrub zone occurs along streams and around the edge of wet meadows and beaver dams. The vegetation consists of a mixture of several willow species, including *Salix bebbiana*, *Salix lutea*, and *Salix interior*. Shrubs include red osier dogwood (*Cornus stolonifera*), wild rose (*Rosa* spp.), raspberry (*Rubus* spp.), and currant (*Ribes* spp.) (Froiland 1990). The wet meadows are dominated by several species of sedge, including *Carex aurea* and *Carex rostrata*. In better drained meadows, grasses such as tufted hairgrass (*Deschampsia caespitosa*) and northern reed grass (*Calamagrostis inexpansa*) also occur along with many wildflowers, particularly asters (*Aster* spp.) and sunflowers (*Helianthus* spp.) (Froiland 1990). Most of these plant communities have been disturbed by clearing, burning, and spraying. In the memorial, relatively intact but small (<0.1 ha) wet meadows are found along the creeks, especially Beaver Dam Creek in Starling Basin.

No federally endangered or threatened or state-listed plant is known to occur in the memorial. However, one plant, Selkirk's violet (*Viola selkirkii*), is listed by the Black Hills National Forest as sensitive and does occur in the memorial (National Park Service, M. Bynum, biological technician, personal communication, 28 January, 2009). Two vegetation associations, bur oak/ironwood forest and paper birch/becked hazelnut, occur in the memorial but are considered rare in the Black Hills (Symstad and Bynum 2005).

Exotic plants comprise about 19 percent of the known flora of the memorial (Symstad and Bynum 2005). This is a relatively low occurrence when compared to exotic plants in ten small park units in the Great Plains and Midwest (Stubbendieck et al. 1992) (Table 1). Noxious weeds (i.e., highly invasive plants that are difficult to control) found in the memorial include musk thistle (*Carduus nutans*), Canada thistle (*Cirsium arvense*), leafy spurge (*Euphorbia esula*), St. Johnswort (*Hypericum perforatum*), and yellow toadflax (*Linaria vulgaris*) (Symstad and Bynum 2005; Natural Resource Conservation Service 2009).



Map Unit	Map Unit Name	Associations Included
HB	Bur Oak / Ironwood Forest	• Bur Oak / Ironwood Forest
PJ	Ponderosa Pine / Common Juniper Woodland	• Ponderosa Pine / Common Juniper Woodland
P1	Ponderosa Pine Complex I	• Ponderosa Pine / Little Bluestem Woodland • Ponderosa Pine / Sun Sedge Woodland • Ponderosa Pine / Bearberry Woodland • Ponderosa Pine / Rough Leafed Rice Grass Woodland
P2	Ponderosa Pine Complex II	• Ponderosa Pine / Bur Oak Woodland • Paper Birch / Beaked Hazel Forest

Figure 12. Mount Rushmore National Memorial vegetation classes/land use (*Source:* Salas and Pucherelli 1998).

Table 1. Total area, number of plant species, exotic plant species, and percentage of exotic plant species for Mount Rushmore National Memorial and ten small park units in the Great Plains and Midwest (*Sources:* Stubbendieck et al. 1992; U.S. Geological Survey, A. Symstad, ecologist, personal communication, 5 February, 2009).

Park	Area (ha)	No. of species	No. of exotics	% exotic
Memorial	517	425	79	19
Agate Fossil Beds	798	230	35	15
Effigy Mounds	597	420	68	16
Fort Larned	291	224	54	24
Fort Scott	9	66	31	47
George Washington Carver	85	612	111	18
Herbert Hoover	80	74	30	41
Homestead	79	184	46	25
Pipestone	113	476	92	19
Scotts Bluff	1,214	278	52	19
Wilson's Creek	709	419	105	25

Wildlife

The mammals of the Black Hills include 62 species of which 59 are native and three are introduced, i.e., exotic (Froiland 1990). At the time of European settlement of the region in 1876, common large mammals included bison (*Bison bison*), Manitobon elk (*Cervus elaphus manitobensis*), Audubon bighorn sheep (*Ovis cunadensis auduboni*), grey wolves (*Canis lupus*), and grizzly bears (*Ursus arctos horribilis*) (Turner 1974). These species were extirpated from the Black Hills as a result of overharvesting and loss of habitat. In addition, beavers (*Castor canadensis*), black bears (*Ursus americanus*), mountain lions (*Puma concolor*), white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) were nearly eliminated in the early 1900s. By the mid-1990s, regulated harvests restored the deer populations; and transplants successfully reestablished elk (*Cervus elaphus canadensis*), bighorn sheep (*Ovis canadensis canadensis*), and beavers, although the first two are different subspecies than the original populations (Turner 1974). In recent years, the mountain lion population has increased, but the black bear is only occasionally seen and individuals may be transients. The mountain goat (*Oreamnos americanus*) was introduced to the Black Hills in 1924, but limited habitat has restricted its numbers and range (Richardson 1971). A recent inventory of the mammals of the memorial documented 22 species including eight species of bats (Schmidt et al. 2004). The mountain goat is the most prominent exotic mammal.

A total of 139 species of birds occur regularly in the Black Hills, either as permanent residents or as migrants (Froiland 1990). A majority of these are western species that reach the eastern limit of their breeding ranges in the Black Hills. Examples are white-winged juncos (*Junco hyemalis*), Cassin’s finches (*Carpodacus cassinii*), white-throated swifts (*Aeronautes saxatalis*), Lewis’s woodpeckers (*Melanerpes lewis*), poor-wills (*Phalaenoptilus nuttallii*), western wood pewees (*Contopus sordidulus*), western flycatchers (*Empidonax difficilis*), violet-green swallow (*Tachycineta thalassina*), pinon jays (*Gymnorhinus cyanocephalus*), dippers (*Cinclus mexicanus*), mountain bluebirds (*Sialia currucoides*), Townsend’s solitaires (*Myadestes *townsendi*), and western tanagers (*Piranga ludoviciana*) (Tallman et al. 2002). Eastern species approaching the western limit of their breeding range include the ovenbird (*Seiurus aurocapillus*) and indigo bunting (*Passerina cyanea*) (Tallman et al. 2002). A recent inventory of the breeding birds of the memorial found 48 species, including the brown creeper (*Certhia familiaris*), which is considered an old-growth forest obligate (Panjabi 2005a).

Temperature extremes, particularly low temperatures in the winter, and low humidity throughout the year contribute to a relatively hostile environment for amphibians and reptiles in the Black Hills (Froiland 1990). Only 22 species, including seven amphibians and 15 reptiles, are known from the region. Of these, four occur in the memorial (Smith et al. 2004).

Seventeen fishes are known from the Middle Cheyenne Spring Creek watershed including species that are exotic to the region (NatureServe 2004) (Table 2). In addition, species of trout have been introduced to the Black Hills and are common in certain habitats although none are on the NatureServe list for the Middle Cheyenne Spring Creek watershed. Of the two species of fish known from the memorial, one is the exotic brook trout (*Salvenlinus fontinalus*); and the other, the native longnose dace (*Rhinichthys cataractae*) (White et al. 2002).

Of the terrestrial invertebrates, only the butterflies are well known in the Black Hills. Pennington County (the county in which the memorial is located) has 123 species of butterflies; and of these, 39 have been collected in the memorial (Marrone 2004).

No federally endangered or threatened or state-listed wildlife species is known from the memorial. In addition, the number of exotic wildlife species is low; but two exotic species, the mountain goat and brook trout, appear to impact native species (see Stressors and Management Strategies).

Table 2. Fishes of the Middle Cheyenne Spring Creek Watershed (*Source:* Nature Serve 2004).

Scientific Name	Common Name
Couesius plumbeus	Lake Chub
Hybognathus placitus	Plains Minnow
Platygobio gracilis	Flathead Chub
Notropis stramineus	Sand Shiner
Pimephales promelas	Fathead Minnow
Rhinichthys cataractae	Longnose Dace
Catostomus commersoni	White Sucker
Moxostoma macrolepidotum	Shorthead Redhorse
Ameiurus melas	Black Bullhead
Ictalurus punctatus	Channel Catfish
Noturus flavus	Stonecat
Fundulus zebrinus	Plains Killifish
Perca flavescens	Yellow Perch
Sander vitreus	Walleye
Macrhybopsis gelida	Sturgeon Chub

Visitor Use

The Black Hills region receives about 4 million tourists annually. Mount Rushmore National Memorial is the most visited site with an average of about 2 million visitors per year during the period 1999 through 2008 (Fig. 13). Almost all visitors see the carved mountain and associated visitor exhibits and facilities; only a few participate in rock climbing, hiking, and horseback riding.

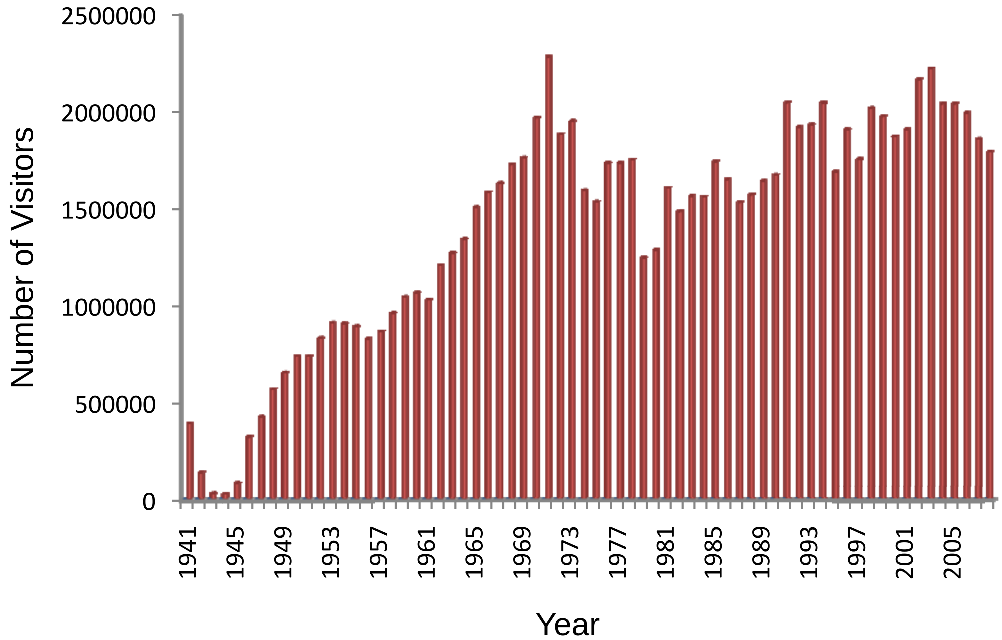


Figure 13. Annual number of visitors to Mount Rushmore National Memorial, 1941–2008 (*Source:* National Park Service 2008).

Important Natural Resources

Old-Growth Ponderosa Pine Forest

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Although rare in the Black Hills, about 66 percent of the ponderosa pine forest in the memorial is classified as old-growth (Symstad and Bynum 2007). Some timber harvest occurred in portions of the memorial before 1930, but most of the area was unsuitable for lumbering due to the roughness of the terrain. Approximately 29 percent of the memorial has had no tree harvesting and 18 percent has had selective cutting of larger trees (Symstad and Bynum 2007). The old-growth forest in the memorial provides habitat for several rare species that require the structure and ecosystem processes that characterize old-growth (Table 3).

Although the old-growth forest in the memorial is of significant conservation value in the Black Hills, it is not pristine. More than a century of fire suppression has increased the density of small trees and the amount of standing and down woody fuel beyond those occurring before settlement (Symstad and Bynum 2007). These increases put the forest in the memorial in danger of intense, stand-replacing crown fires (Brown et al. 2008).

Table 3. Some species that are associated in the Black Hills with mature, closed-canopy ponderosa pine forest (i.e., old-growth) and are confirmed or expected in Mount Rushmore National Memorial. Species with known particular affinity for this habitat in the Black Hills are underlined (*Source:* Symstad and Bynum 2005).

Species	Scientific Name	Important forest characteristics	Presence at MORU
Birds			
Ovenbird	*Seiurus aurocapillus*	Closed canopy	Summer resident; uncommon
Townsend's Solitaire	*Myadestes townsendi*	Closed canopy in winter	Permanent resident; common
<u>Western Tanager</u>	*Piranga ludoviciana*	Multi-storied coniferous forest with hardwood understory, stands > 10 ha	Summer resident; common
<u>Ruby-crowned Kinglet</u>	*Regulus calendula*		Summer resident; uncommon
<u>Brown Creeper</u>	*Certhia americana*	Cavity nester, large diameter (DBH > 38 cm, 15 inches) trees, dense canopy	Permanent resident; uncommon
Black-capped Chickadee	*Parus atricapillus*	Snags, either soft or with cavities, for nesting	Permanent resident; common
Hairy Woodpecker	*Picoides villosus*	Trees with DBH > 25 cm (10 inches) and snags for nesting	Permanent resident
White-breasted Nuthatch	*Sitta carolinensis*	Cavitites for nesting	Permanent resident; fairly common
<u>Red-breasted Nuthatch</u>	*Sitta canadensis*	Ponderosa pine seed in large amounts for food	Permanent resident; common
Northern Saw-whet Owl	*Aegolius acadicus*	Cavity nester	Permanent resident; fairly common

Table 3. Some species that are associated in the Black Hills with mature, closed-canopy ponderosa pine forest (i.e., old-growth) and are confirmed or expected in Mount Rushmore National Memorial. Species with known particular affinity for this habitat in the Black Hills are underlined (*Source:* Symstad and Bynum 2005) (continued).

Species	Scientific Name	Important forest characteristics	Presence at MORU
Mammals			
American pine martin	*Martes americana*	Typically in mature or old-growth spruce stands, but mature/old-growth ponderosa pines may serve as connecting habitat or territory for younger (less dominant) individuals	Present
Fringed bat	*Myotis thysanodes*	Cavities and cracks in large ponderosa pine snags for roosting	Present
Long-legged myotis	*Myotis volans interior*	Large and semi-decayed snags for roosting	Present
Silver-haired bat	*Lasionycteris noctivagans*	Cavities of trees in stands with high snag density and relatively high basal area for maternal roosting	Present
Northern myotis	*Myotis septentrionalis*	Crevices and cavaties of live trees and snags for roosting	Present
Northern flying squirrel	*Glaucomys sabrinus*	Cavities for nesting	Expected, but not confirmed
Red squirrel	*Tamiasciurus hudsonicus*	Cavities for nesting; pine seeds for food	Common

Starling Basin Wetland Complex

The Starling Basin wetland complex in the memorial is considered an important conservation site in the Black Hills for bats (Schmidt et al. 2004), herpetofauna (Smith et al. 2004), and butterflies (Marrone 2004). However, the water quality of Beaver Dam Creek, which flows through the basin, shows signs of water quality impairment based on chemical and physical measurements and the presence of pollution-tolerant aquatic macroinvertebrates (Rust 2006). Water quality "impairment" exists if a body of water does not support its designated uses. In addition, native fish such as the longnose dace are missing, possibly due to the large number of exotic brook trout that inhabit the creek (White et al. 2002).

Starling Basin

Natural Resource Condition

Condition Assessment Approach

The major habitats in the memorial—identified by a land-cover classification of the vegetation—are forest, rock outcrop and barren, and stream and wetland (Fig. 14). These habitat types provide the ecological framework for this assessment, and their condition and trend are assessed by a suite of biodiversity and process indicators (Table 4). Stressors affecting the condition and trend of these habitats are presented in Table 4, but they are discussed more fully in the section titled "Stressors and Management Strategies." Vital signs (i.e., key natural resources) of the memorial that were identified in the Northern Great Plains Inventory and Monitoring Plan (Gitzen et al. 2009) are the basis for nine of 14 indicators used in this condition assessment (Table 5). The other five indicators are included based on monitoring recommendations in natural resource inventories of the memorial and recent research reports (Table 5). Indicators are organized by habitat and their condition assessed in the next section.

Table 4. Habitat indicators and stressors.

Habitat	Biodiversity indicator	Process indicator	Stressor
Forest (92%)	• Old-growth ponderosa pine • Birch/hazelnut vegetation association • Breeding birds • Brown creeper • Mountain pine beetle	• Land cover • Fire	• Air tour noise • Air quality /visibility reduction • Drought • Mountain pine beetle infestation • Fire suppression
Rock outcrop and barren (5%)	• Mountain goat • Lichens	• Land cover	• Mountain goat abundance
Stream and wetland (<1%)	• Native and exotic fish • Aquatic macroinvertebrates • Northern leopard frog • Bats	• Stream flow (Grizzly Bear Creek)	• Drought • Exotic trout competition • Horse trail use • Water quality impairment • Invasive plant infestation

Note: Estimated percentage of each habitat in the memorial appears in parentheses. Remaining area is developed.

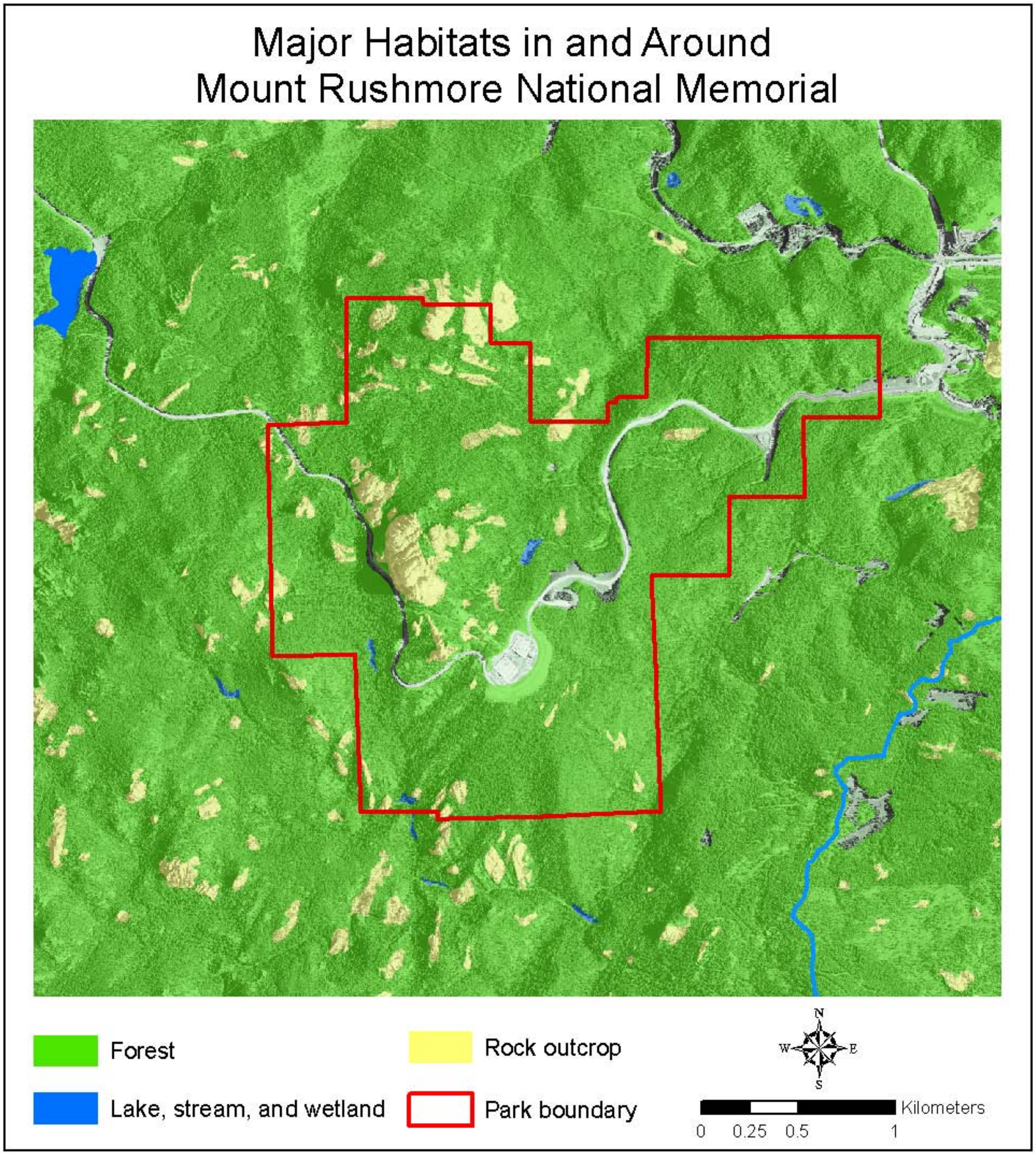


Figure 14. Major habitats in and around Mount Rushmore National Memorial (based on the vegetation classes/land use in Figure 12).

For most indicators, one or more measures are identified; and the existing values of these measures (i.e., existing conditions) are compared to reference conditions suggested by historical data, monitoring data from the memorial or an environmentally similar area, or expert opinion (Table 6). Ideally, reference conditions should be based on the natural range of variation in undisturbed ecosystems; but, for the Black Hills, quantitative baselines that predate significant human disturbance do not exist (except for presettlement stand characteristics of ponderosa pine reconstructed from old trees and remnant stumps). For three indicators, no condition assessment is possible due to inadequate, site-specific information. They are included to highlight rare or unique resources and important information needs.

An indicator is considered in good condition when 50 percent or more of its measures have existing values that correspond with or fall within a range of reference values. Conversely, an indicator is considered in poor condition when less than 50 percent of its measures have existing values that correspond with or fall within a range of reference values. Trend is noted for an indicator that has a measure or measures with multiple year data that are similar (stable) or different (deteriorating or improving). Indicator condition is summarized by a red box (indicating poor), a green box (indicating good), or an open box (no assessment). Trend is indicated by a downward arrow (deteriorating), a horizontal arrow (stable), an upward arrow (improving), or no arrow (no or insufficient data). Details of each indicator, including a summary of sampling method and data analysis, are available in Appendix A. A summary of GIS (Geographic Information Systems) products derived from indicator sources are available in Appendix B.

Table 5. Indicators, corresponding vital signs, and primary information sources used in this condition assessment.

Indicator	Vital sign[a]	Information source[b]
Old-growth ponderosa pine	Upland plant communities	Research
Birch/hazelnut vegetation association	Upland plant communities	Vegetation map
Breeding birds	Land birds	Inventory
Brown creeper	Land birds	Inventory
Mountain pine beetle	Forest insects and diseases[c]	Risk assessment
Lichens	None	Inventory
Mountain goat	None	Observation
Native and exotic fish	None	Inventory
Aquatic macroinvertebrates	Water quality	Inventory
Northern leopard frog	None	Inventory

Table 5. Indicators, corresponding vital signs, and primary information sources used in this condition assessment (continued).

Indicator	Vital sign[a]	Information source[b]
Bats	None	Inventory
Land cover	Land cover and use	Satellite data
Fire	Fire and fuel dynamics; Extreme disturbance	Research; Monitoring
Stream flow (Grizzly Bear Creek)	Surface water dynamics[d]	Gage record

[a] Vital signs not included as indicators are Stream and River Channel Characteristics, **Surface Water Chemistry**, Aquatic Contaminants, Aquatic Microorganisms, **Exotic Plant Early Detection**, and **Soundscape**. The vital signs in bold are discussed as stressors.
[b] Primary source of information used to assess the condition of indicators.
[c] USDA Forest Service monitoring
[d] U.S. Geological Survey monitoring

Table 6. Mount Rushmore National Memorial natural resources summary.

Habitat	Indicator	Measure	Reference condition	Existing condition	Source
Forest	Old-growth ponderosa pine	Tree basal area [mean (SE) m^2/ha]	23.6 (2.2)	30.7 (2.7)	Brown et al. 2008
		Tree density [mean (SE) trees/ha]	280 (36)	1,309 (288)	
		Canopy base height [mean (SE) m]	6.1 (0.3)	4.2 (0.5)	
		Fire interval (yrs)	16–34	>100	
	Birch/hazelnut	None			
	Breeding birds	Red-breasted nuthatch density (birds/ha)	0.48–0.58	0.39–0.60	Panjabi 2005a, Panjabi 2005b
		Yellow-rumped warbler density (birds/ha)	0.67–0.76	0.11–0.72	
	Brown creeper	Abundance (birds/point)	0.11–0.17	0.07–0.27	Panjabi 2005a, Panjabi 2005b
	Mountain pine beetle	Risk of infestation (%)	Moderate 26–34 High 11–15	Moderate 71 High 29	USDA Forest Service 1999, Bynum 2008
	Land cover	Contagion index	82.08	85.66	Narumalani 2008
		ShDI index	0.94	0.74	
	Fire	Fuel loads (tons/acre)	9.74	37.71	Northern Great Plains Fire Management 2006, Brown et al. 2008
		Dominant type	Surface	Crown	
		Crowning index (km/h)	<40.2	>100	
		Fire int. (yrs)	16-34	>100	

Table 6. Mount Rushmore National Memorial natural resource summary (continued).

Habitat	Indicator	Measure	Reference condition	Existing condition	Source
Rock outcrop and barren	Mountain goat	Abundance (no.)	0	<25	D. Licht personal communication
	Lichens	None			
	Land cover	Contagion index ShDI index	82.08 0.94	85.66 0.74	Narumalani 2008
Stream and wetland	Native and exotic fish	Longnose dace abundance (no./100m) Brook trout abundance (no./100m)	180 0	6 22–168	South Dakota Department of Fish, Game, and Parks 2005; White et al. 2002
	Aquatic macroinvertebrates	EPT richness HBI (0–10 index)	0–8 3.1–9.6	8 (GrzCrk) 2 (BvDmCrk) 3 (LftGlch) 4.41 (GrzCrk) 5.99 (BvDmCrk) 4.56 (LftGlch)	Troelstrup 2006, Rust 2006
	Northern leopard frog	Occupied habitat (%)	60–100	100	USDA Forest Service 2004, 2006b, 2007; Smith 2003
	Bats	Species richness	11	7	Schmidt et al. 2004
	Stream flow (Grizzly Bear Creek)	None			

Indicator Assessment

Habitat: Forest

Indicator: Old-Growth Ponderosa Pine
Source for Reference Condition: Reconstructed Stand Characteristics and Fire History


Old-growth ponderosa pine

Old-growth ponderosa pine forest in the Black Hills is characterized by stands of mature, tall trees and large-diameter snags (Mehl 1992). Both of these provide nesting habitat and abundant food sources for certain forest animals such as the red-breasted nuthatch (*Sitta Canadensis*) and red squirrel (*Tamiasciurus hudsonicus*). The memorial contains 344 ha of old-growth ponderosa forest, or about 17 percent of the 2,074 ha of this forest type on public lands in the Black Hills (Symstad and Bynum 2007) (Fig. 15). The area of old-growth forest in the memorial is larger than any individual area of old-growth ponderosa pine in the Black Hills National Forest and second only to the area of old-growth ponderosa pine in Cluster State Park (Symstad and Bynum 2007). In addition, the old-growth forest in the memorial is located within a relatively short (approximately 10 km) distance of most of the other large stands of old-growth ponderosa pine forest in the region (Fig. 16). Thus, the old-growth ponderosa pine forest in the memorial may be sufficiently large and connected to be of substantial conservation and restoration reference value in the Black Hills region.

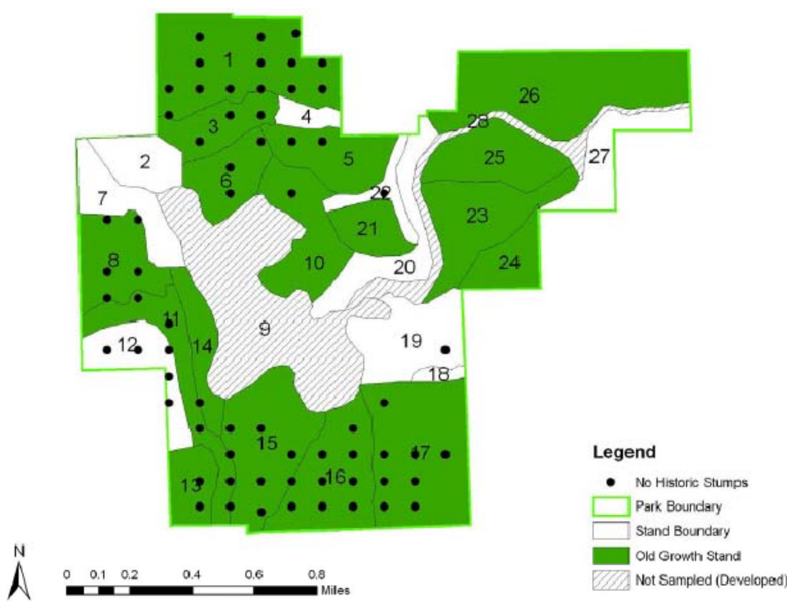


Figure 15. Old-growth ponderosa pine stands in Mount Rushmore National Memorial (*Source:* Symstad and Bynum 2005).

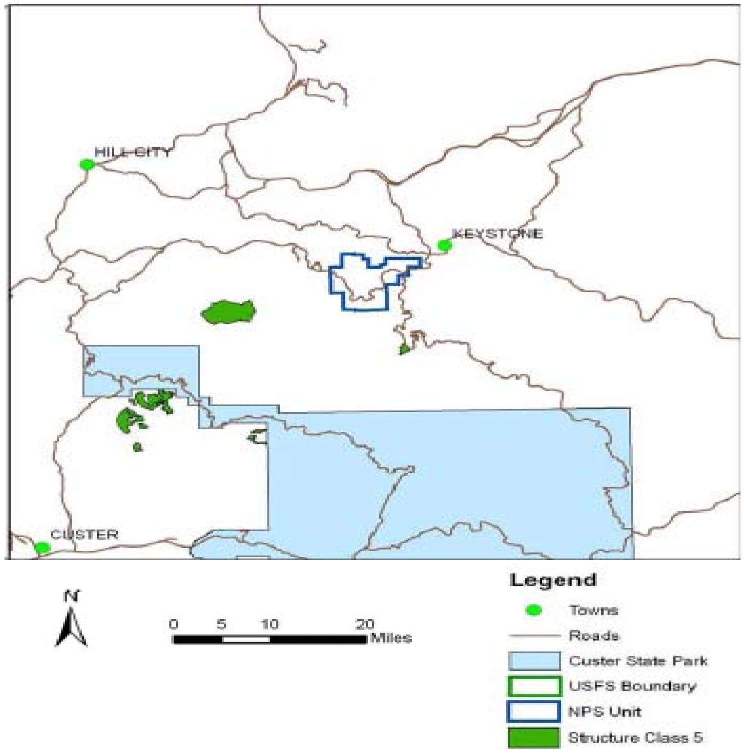


Figure 16. Areas designated by the USDA Forest Service as Structural Class 5 (late successional/old-growth) within the Black Hills National Forest near Mount Rushmore National Memorial (*Source:* Symstad and Bynum 2005).

Although classified as old-growth, the mature ponderosa pine forest in the memorial today is different from the presettlement forest. A comparison of forest-stand characteristics in 2005 to those in an 1870 reconstruction shows that tree basal area and density are significantly higher now as compared to the historic forest (Fig. 17, Table 7). Average basal area was measured to be 30.7 m^2/ha in 2005 and estimated to be 23.6 m^2/ha in 1870 (Brown et al. 2008). Tree density increased from an average of 280 trees/ha in 1870 to 1,309 trees/ha in 2005, due to a large increase in the numbers of trees less than 20 cm dbh (diameter breast height) and a decrease in the number of trees greater than 60 cm dbh (Symstad and Bynum 2007; Brown et al. 2008). In addition, canopy base height was higher in the 1870 forest versus the 2005 forest (Brown et al. 2008). Increased density of smaller trees is due to the elimination of surface fires in the early 1900s, which resulted in unchecked tree recruitment. Logging prior to the memorial's establishment and, in recent decades, mortality caused by mountain pine beetles have resulted in the loss of some large trees (Brown et al. 2008).

The old-growth ponderosa pine forest indicator is in poor condition and declining (less than 50 percent of its measures have existing values that correspond with or fall within a range of reference values, see Table 6). More than a century of fire exclusion in the memorial caused the fire interval to increase from 16–34 years to over 100 years (Brown et al. 2008). This resulted in greater tree density in the smaller tree size classes, an increase in vertical and surface fuels, and a higher probability of catastrophic crown fire from a natural or human ignition. Other potential threats include disease and insect outbreaks, trail construction and use, air pollution, and climate change.

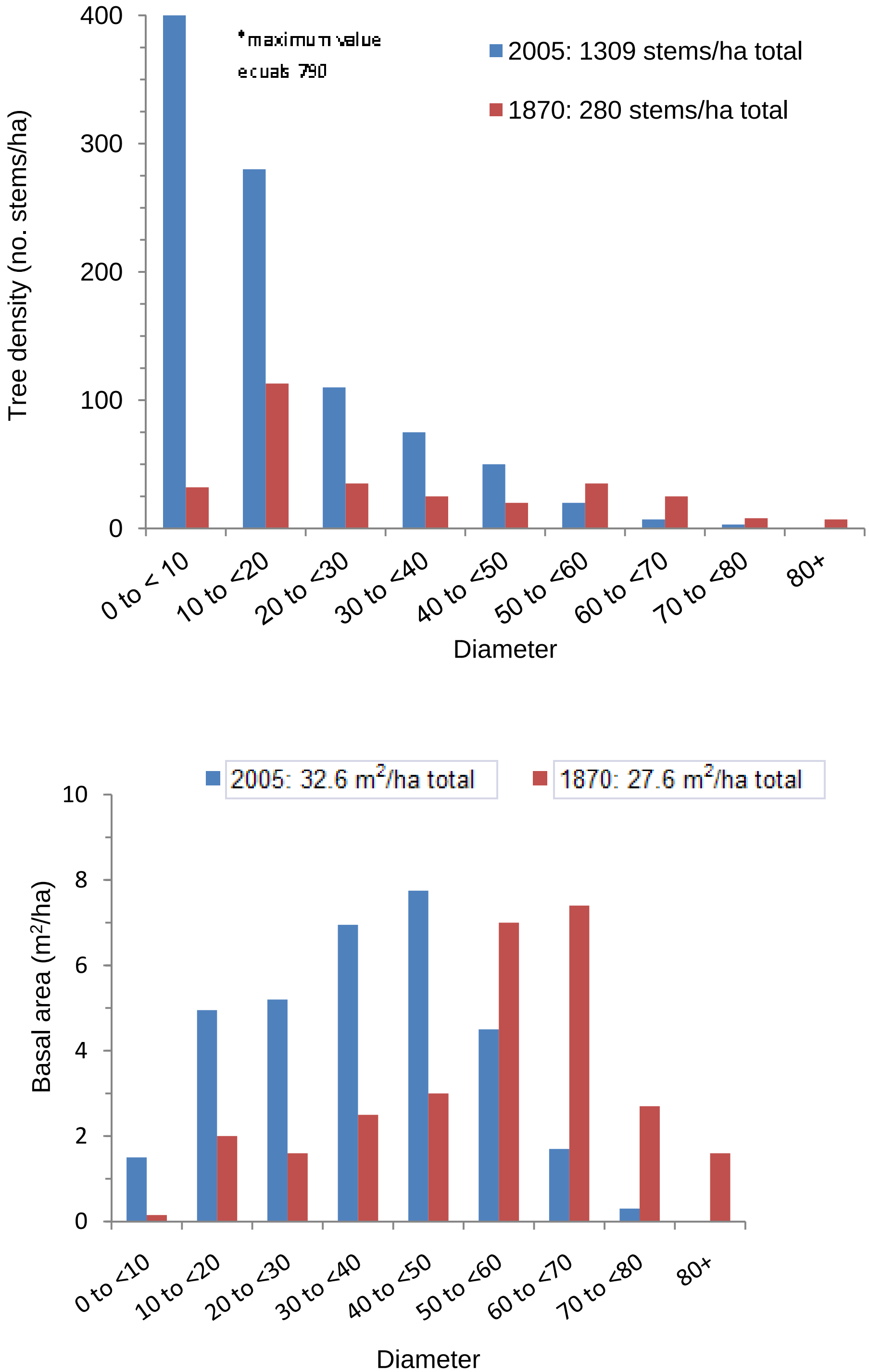


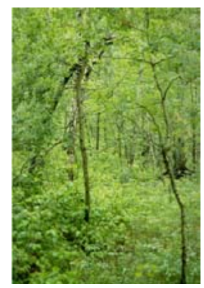
Figure 17. (a) Total tree densities and (b) basal areas by dbh size classes reconstructed in 1870 and measured in 2005 (*Source:* Brown et al. 2008).

Table 7. Present (2005) old-growth forest structure [mean and (SE) for density (no. trees/ha), basal area (BA), and canopy base height (CBH)] at Mount Rushmore National Memorial and past (1870) forest structure in the greater Black Hills. Data are for trees with dbh greater than 30 cm. Asterisks mark significant differences between column means ($P < 0.01$) (*Source:* Brown et al. 2008).

Year	Trees (no./ha)	BA (m^2/ha)	CBH (m)
1870	280 (36) **	23.6 (2.2)**	6.1 (0.3)**
2005	1309 (288)**	30.7 (2.7)**	4.2 (0.5)**

Indicator: Birch/Hazelnut Vegetation Association
Source for Reference Condition: Not Identified

The birch/hazelnut vegetation association typically forms a closed canopy that is dominated by paper birch (*Betula papyrifera*). Other trees, including quaking aspen, bur oak, and ponderosa pine, are present but not dominant. The most abundant shrub is beaked hazelnut (*Corylus cornuta*). Herbaceous cover is usually greater than 60 percent and very species-rich.


Birch/hazelnut vegetation association

This vegetation association occurs in North Dakota and Wyoming and in the Black Hills of South Dakota, where it is considered rare (Marriott et al. 1999). It is most often found in moist, open forest and along meadow borders. In the memorial, the association is best developed in the major drainages including Grizzly Bear Creek, Starling Basin (Beaver Dam Creek), and Lafferty Gulch (Salas and Pucherelli 1998).

The birch/hazelnut vegetation association is very vulnerable to extinction or elimination because of its highly restricted range and patchy occurrence (see Symstad 2004). However, most of the extant sites of the association in the Black Hills are in good condition (Marriott et al. 1999). This indicator is not assessed due to the lack of data from the memorial on the demographics of the plant species in the association.

Indicator: Breeding Birds
Source for Reference Condition: Density of Breeding Birds in the Black Hills National Forest

Bird communities integrate a broad array of ecosystem conditions and serve as indicators of biological integrity and ecosystem health. During 2002 through 2004, initial inventory and monitoring of the breeding birds in the memorial detected 33 species along a 15-point transect that is located primarily in old-growth ponderosa pine forest (Fig. 18).


Red-breasted nuthatch

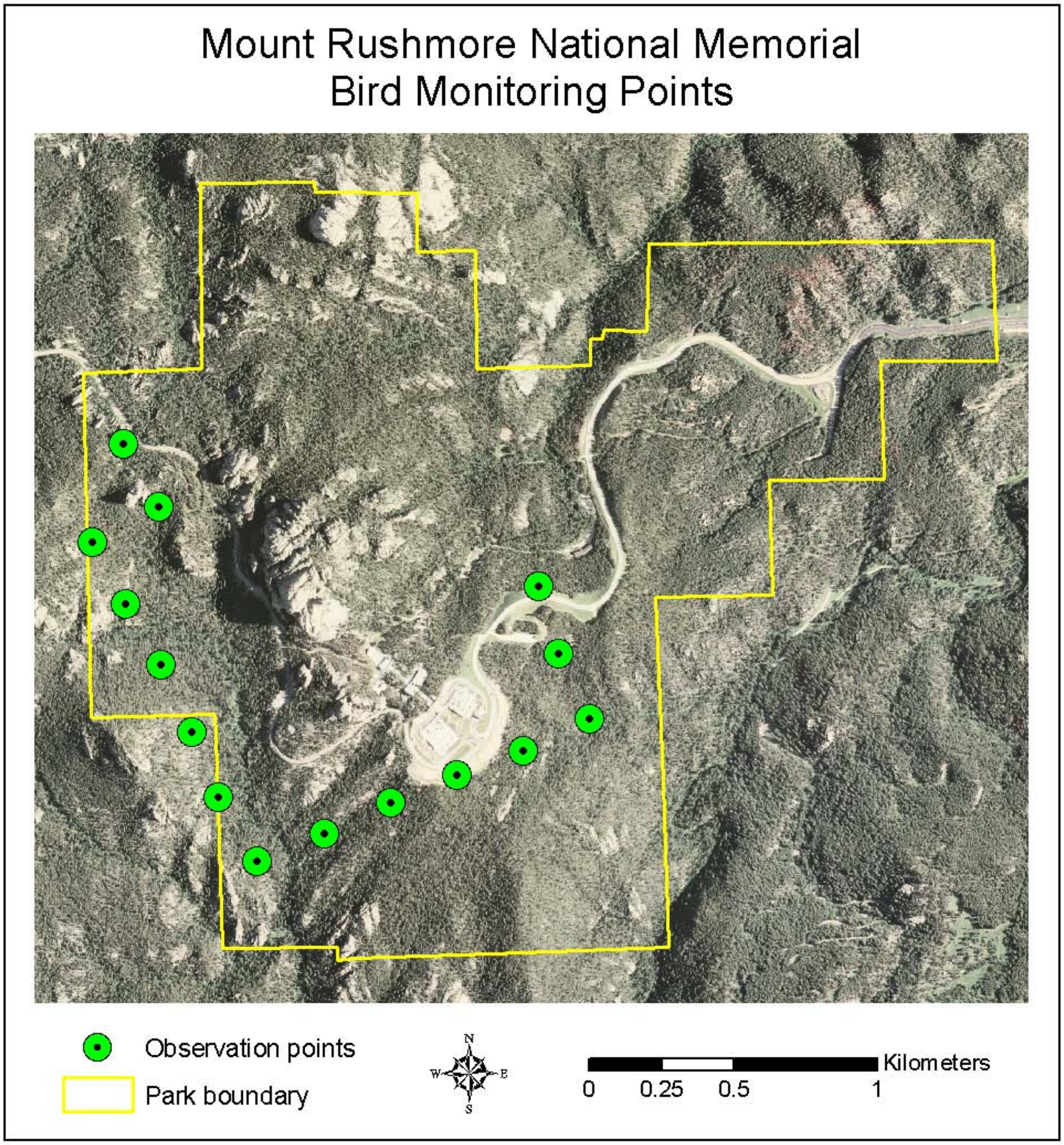


Figure 18. Location of the point transect for bird monitoring in Mount Rushmore National Memorial (*Source:* Panjabi 2005a).

Two species, the red-breasted nuthatch and the yellow-rumped warbler (*Dendroica coronata*), were observed frequently enough to generate density estimates for future trend monitoring (Panjabi 2005a) (Table 8). In addition, the average annual density of all breeding birds may provide a more sensitive index for monitoring the overall condition of the old-growth ponderosa pine forest in the memorial (Panjabi 2005a) (Table 8).

Concurrent monitoring of the warbler and nuthatch in the memorial and in 30 late-successional ponderosa pine stands in the Black Hills National Forest found similar densities in the memorial and national forest for these species over a three-year period (Panjabi 2005a; Panjabi 2005b) (Table 9). The low estimate for the warbler in the memorial in 2004 may be a result of observer error due to high winds (Panjabi 2005a) (Table 9).

Based on monitoring in the memorial and in the Black Hills National Forest, breeding birds in the memorial are in good condition (50 percent or more of its measures have existing values that correspond with or fall within a range of reference values, see Table 6). This is supported by another study that found a higher density of the nuthatch in the memorial as compared to managed forest stands in the national forest (Spiering and Knight 2005). Trends in certain species in the memorial may be discernable in 12–15 years with annual sampling (Hanni and Panjabi 2004).

Table 8. Estimated annual densities of breeding birds in ponderosa pine forest at Mount Rushmore National Memorial, 2002–2004 (*Source:* Panjabi 2005a).

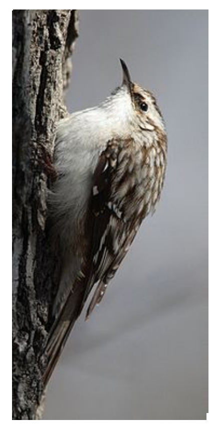
Common Name	Year	D	LCL	UCL	%CV	df
Red-breasted nuthatch	2002	0.39	0.19	0.81	37	27
	2003	0.42	0.20	0.86	36	27
	2004	0.60	0.15	0.23	75	27
Yellow-rumped warbler	2002	0.72	0.45	1.15	24	50
	2003	0.58	0.35	0.96	26	50
	2004	0.11	0.04	0.29	52	50
All birds	2002	3.79	3.02	4.75	12	340
	2003	5.09	4.14	6.27	11	340
	2004	1.18	0.84	1.67	18	340

Note: D = estimated density (birds/ha); LCL = lower 95% confidence limit; UCL = upper 95% confidence limit; %CV = coefficient variation; df = degrees of freedom

Table 9. Estimated densities (birds/ha) of red-breasted nuthatchs and yellow-rumped warblers in Mount Rushmore National Memorial and in late-successional ponderosa pine forest in the Black Hills, 2002–2004 (*Sources:* Panjabi 2005a; 2005b).

Common name	Year	Density(birds/ha)	
		Memorial	Forest
Red-breasted nuthatch	2002	0.39	0.58
	2003	0.42	-
	2004	0.60	0.48
Yellow-rumped warbler	2002	0.72	0.76
	2003	0.58	-
	2004	0.11	0.67

Indicator: Brown Creeper (Old-Growth Obligate)
Source for Reference Condition: Abundance of the Brown Creeper in Old-Growth Ponderosa Pine Stands of the Black Hills National Forest


Brown creeper

Although old-growth ponderosa pine stands have lower density and diversity of birds than other forest types in the Black Hills, they provide habitat, typically a dense, mature forest, for several rare or uncommon species, such as the northern goshawk (*Accipiter gentilis*), brown creeper, and black-backed woodpecker (*Picoides articus*). The brown creeper has been confirmed in the memorial; the northern goshawk and black-backed woodpecker are possible (Panjabi 2005a).

The brown creeper was selected as a management indicator species by the Black Hills National Forest because the species population trends are an indicator of the abundance and condition of large trees and late successional coniferous forest habitat (USDA Forest Service 2005). The species prefers mature and old-growth trees that provide both foraging and nesting habitat (peeling bark). Brown creepers typically nest far from forest edges thus are sensitive to forest management practices such as clearcut logging that increase edge habitats.

From 2002 through 2004, the brown creeper was observed in the memorial each year but not frequently enough to generate density (birds/ha) estimates for trend monitoring (Panjabi 2005a). However, the abundance (birds/point count) of the brown creeper in the memorial during 2002–2004 was similar to the abundance of the species during the same years in other old-growth stands in the Black Hills (Panjabi 2005a; 2005b) (Table 10).

Based on the comparison of abundance of this species between the memorial and the national forest, the brown creeper indicator is in good condition (50 percent of its measures have existing values that correspond with or fall within a range of reference values, see Table 6). Although there is insufficient data to indicate a trend in this species, lack of fire and insect infestations in the old-growth ponderosa pine forest in the memorial has led to changes in stand characteristics that are likely to continue and eventually may result in changes in the population of the brown creeper.

Table 10. Abundance (birds/point count) of the brown creeper in old-growth ponderosa pine forest in Mount Rushmore National Memorial and in the Black Hills National Forest, 2002–2004 (*Source:* Panjabi 2005a; 2005b).

	No. of bird observations			Ave. no. of birds/point count		
	2002	2003	2004	2002	2003	2004
Memorial	1	4	1	.07	.27	.07
Forest	41	-	73	.11	-	.17

Indicator: Mountain Pine Beetle
Source for Reference Condition: Risk of Infestation in the Black Hills National Forest


Mountain pine beetle infestation

The mountain pine beetle (*Dendroctonus ponderosae*) is native to the forests of western North America, including the Black Hills. Both adult beetles and larvae feed on the inner bark or sapwood of ponderosa pine and to a lesser extent on the sapwood of lodgepole pine (*Pinus contorta*) and limber pine (*Pinus flexilis*). The beetle's feeding introduces the parasitic blue stain fungus (*Ceratocystic montia*) within the water-conducting tissue of the tree (Leatherman et al. 2008). The combined effect of feeding by the beetle and growth of the fungus stops the flow of plant sugar from the leaves to the roots and the flow of water from the roots to the leaves. Most trees die within one year of being attacked (Knight 1994).

Mountain pine beetle attacks are usually limited to trees under stress from injury, poor site conditions, fire damage, disease, or old age. Generally, in the Black Hills, the annual mortality from the mountain pine beetle is less than 2–3 trees per ha (Sheppard and Battaglia 2002). However, during prolonged drought conditions or following large-scale fires, the number of beetles may increase dramatically. During an outbreak, dense, even-aged, stands of ponderosa pine in the range of 18–33 cm in diameter appear to be the most vulnerable (Allen 2003). In these stands, tree mortality may exceed 25 percent (Allen 2003).

In 2004, a forest inventory was conducted in the memorial to assess the presence of old-growth ponderosa pine and to look for evidence of historical logging (Symstad and Bynum 2007). As a component of this investigation, the USDA Forest Service determined the presence of mountain pine beetle infestation or future risk of infestation for 26 pine stands in the memorial. As a result, two stands show evidence of beetle infestation, while seven stands have a high risk for beetle infestation and 17 have a moderate risk (Bynum 2008) (Fig. 19). The percentage of area in the memorial that was assessed as moderate or high risk of beetle infestation was considerably higher than the percentage of area assessed as moderate or high risk in the Black Hills National Forest (Table 11). This is due to the predominance of old trees in the memorial and the stress on some of these trees from competing dense stands of small pine that have established following fire exclusion (Brown et al. 2008). This indicator is judged to be in poor condition due to elevated risk of pine beetle infestation resulting from altered forest stand characteristics (less than 50 percent of its measures have existing values that correspond with or fall within a range of reference values, see Table 6).

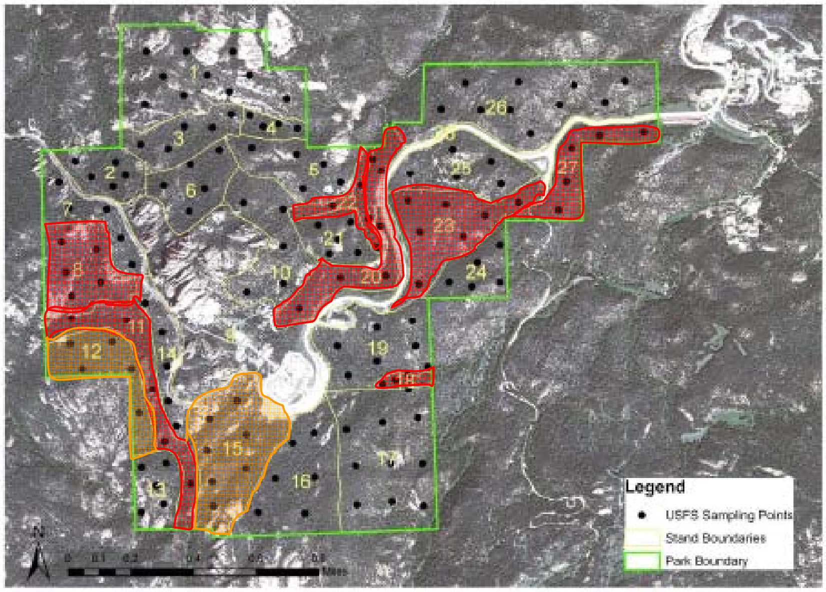


Figure 19. Presence and risk of infestation of mountain pine beetle in forest stands of Mount Rushmore National Memorial. Two stands (in gold) have evidence of beetle infestation, seven (in red) have a high risk for beetle infestation, and 17 (no color) have a moderate risk (*Sources:* Symstad and Bynum 2005; Bynum 2008).

Table 11. Risk (ha and percentage of total ha) of mountain pine beetle infestation in 1995 and 1999 in the Black Hills National Forest and in 2004 in forest stands in Mount Rushmore National Memorial (*Sources:* USDA Forest Service 1999; Bynum 2008).

Risk rating	Forest 1995 ha (%)	Forest 1999 ha (%)	Memorial 2004 ha (%)
Low	251,417 (59)	239,209 (57)	0 (0)
Moderate	112,146 (26)	140,533 (34)	308 (71)
High	63,968 (15)	42,891 (11)	130 (29)

Indicator: Land Cover
Source for Reference Condition: Analysis of 1992 and 2001 Land Cover Datasets

The National Land Cover Dataset (NLCD) 1992 was the first land cover mapping project with a national scope. NLCD 1992 provides 21 land cover classes that were derived from unsupervised classification, modeling, and ancillary data (see Vogelmann et al. 1998). The NLCD 1992 effort was completed in December 2000, and it is one of the most widely used land cover datasets in the United States for a variety of applications, including environmental reporting, climate-change modeling, Clean Water Act studies, and biodiversity and conservation assessments. The success of NLCD 1992 initiated the process for developing NLCD 2001. This effort provided additional information beyond land cover, including impervious surface and canopy density.

Because of the differences in methodologies used and the land cover categories, a direct, pixel-to-pixel comparison of NLCD 1992 and 2001 is not recommended. In 2008, the NLCD 1992/2001 Retrofit Land Cover Change Product was developed as a stopgap measure to offer a more accurate and useful guide to change analysis than was possible by direct comparison of the two land cover products. A comparison of the NLCD 1992 and 2001, using the retrofit change product, identified changes in the number of patches and percent land cover for seven land cover classes in an 69 km^2 area that is centered on the memorial (Fig. 20, Table 12). Percent land cover in the forest class showed the largest relative increase while percent land cover in the barren class showed the largest relative decrease.

The retrofit product also calculated landscape indices, including a Contagion Index and Shannon Diversity Index (ShDI). The Contagion Index refers to the tendency of patch types to be spatially aggregated—that is, to occur in large, contiguous distributions. Contagion Index values increased from 1992 to 2001, indicating that larger continuous patches of land cover were detected for the later date. This may be due to the increase in percent land cover of forest from 66.49 to 73.84. Forest increased during this time period as ponderosa pine encroached on meadows (herbaceous) and barren areas (USDA Forest Service 2006a). This is supported by the substantial decrease in percent land cover of barren from 1.05 to 0.03. The ShDI further reiterates this observed decrease. ShDI is one of several indices that are often used to measure biodiversity. A decrease in ShDI from 0.94 in 1992 to 0.74 in 2001 is indicative of an increased dominance of a land cover class (i.e., forest) when compared to the previous observation.

This indicator is in poor condition and declining based on the increase in forest that has resulted in a less diverse land cover (less than 50 percent of its measures have existing values that correspond with or fall within a range of reference values, see table 6). Since 2001, pine beetle infestations have had deleterious impacts on the ponderosa pine forests near the memorial (USDA Forest Service 2006a). These additional changes will likely be detected in future NLCD products.

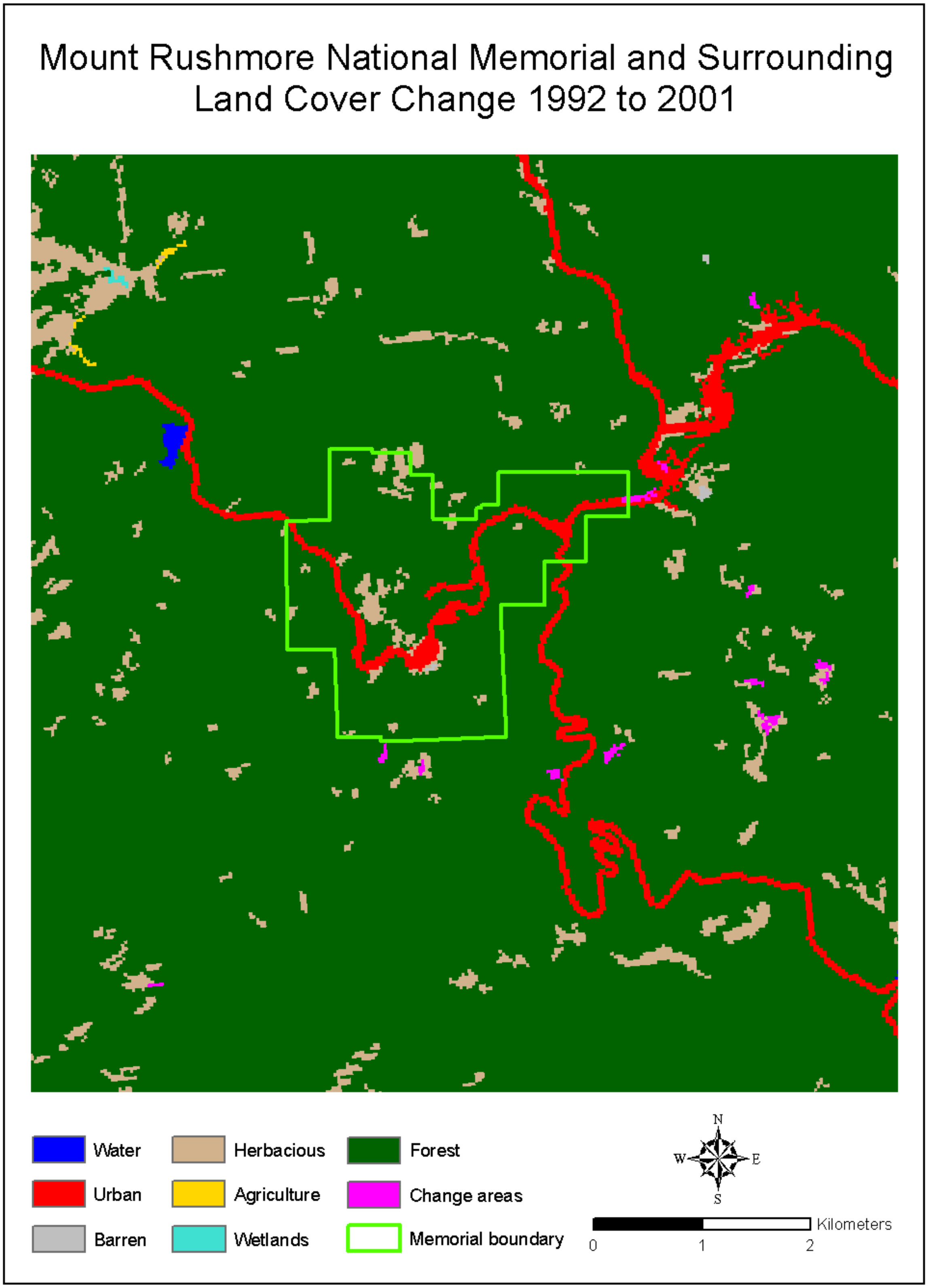


Figure 20. Mount Rushmore National Memorial and surrounding land cover change, 1992–2001.

Table 12. Number of patches, percent land cover, and changes, 1992–2001, for Mount Rushmore National Memorial and the surrounding area. Contagion and Shannon Diversity Indices for 1992 and 2001 are for the same area.

	1992		2001			
	Contagion 82.0805	ShDI 0.9367	Contagion 85.6587	ShDI 0.7408		
Class	# of patches	% land cover	# of patches	% land cover	Change in # of patches	Change in % land cover
Water	421	0.24	292	0.22	-129	-0.02
Forest	7127	66.49	4374	73.84	-2753	7.35
Barren	3285	1.05	158	0.03	-3127	-1.02
Agriculture	9738	5.53	3288	0.96	-6450	-4.57
Herbaceous	18162	24.80	17908	22.01	-254	-2.79
Urban	4012	1.27	5627	2.58	1615	1.32
Wetlands	2857	0.41	843	0.13	-2014	-0.27

Indicator: Fire
Source for Reference Condition: Fire History and Fuel Loads Following Mechanical Thinning and Fire

The presettlement fire regime in the memorial was characterized by low-severity surface fires with occasional (more than 100 years apart) patches of crown fire (Brown et al. 2008) (Fig. 21). Mean fire intervals before 1893 varied, depending on spatial scale, from 16 to 34 years (Brown et al. 2008). Fire rotation (the time to burn an area the size of the memorial) is estimated to be 30 years for surface fire and over 800 years for crown fire (Brown et al. 2008). Fire behavior modeling suggests that surface fire would have dominated fire behavior in the presettlement forest under both moderate and severe weather conditions, while crown fire would dominate the current forest (Brown et al. 2008).

Surface fire in ponderosa pine forest in the Black Hills

Based on a dendrochronological analysis of tree ages and fire scars (Brown et al. 2008), the ponderosa pine forest in the memorial has not burned in over a century. However, records of fire occurrence in the memorial document 19 ignitions in 11 years (Table 13). These fires were all small and most began in the adjacent Black Elk Wilderness which has averaged 1.6 fire starts per year since 1973 (USDA Forest Service 2006a). The total area burned and the number of large crown fires have escalated in recent years in the Black Hills as a result of drought conditions and high fuel loads. High fuel loads in over 80 percent of the adjacent Black Elk Wilderness (USDA

Forest Service 2006a) may support future large crown fires that would be very difficult to stop before spreading into the memorial.

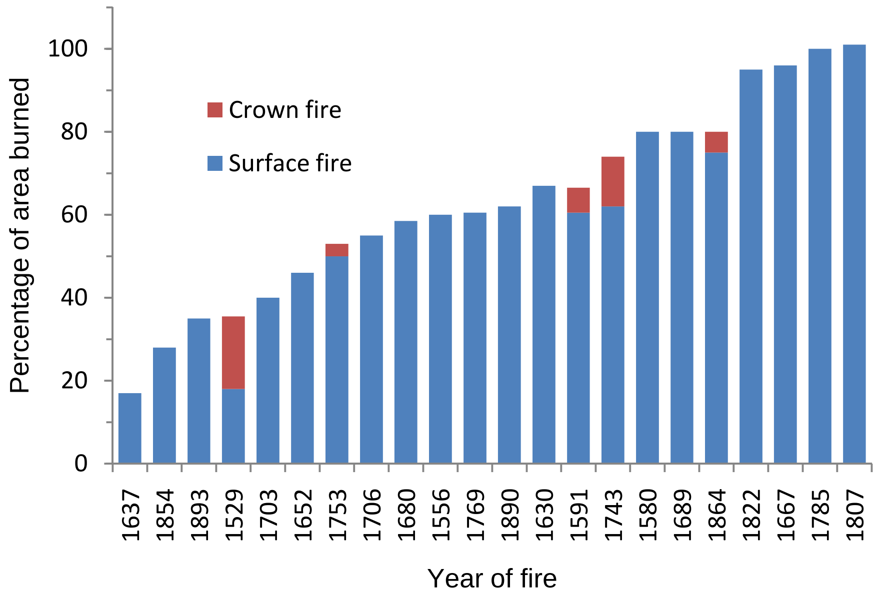


Figure 21. Relative percentages of the Mount Rushmore landscape estimated to have burned in 22 landscape-fire years, by both crown and surface fire. Fire years are arranged in order of estimated total size (*Source:* Brown et al. 2008).

Table 13. Mount Rushmore National Memorial wildland fire occurrence history 1983–2001 (*Source:* National Park Service 2002).

Year	Month	Number of fires
1983	August	1
1984	July	1
1985	August	1
1988	August	1
1989	June	1
1991	April	1
	August	2
1993	December	1
1998	December	1
1999	July	1
	September	1
2000	March	2
	July	2
	October	1
2001	July	1
	September	1
Total		19

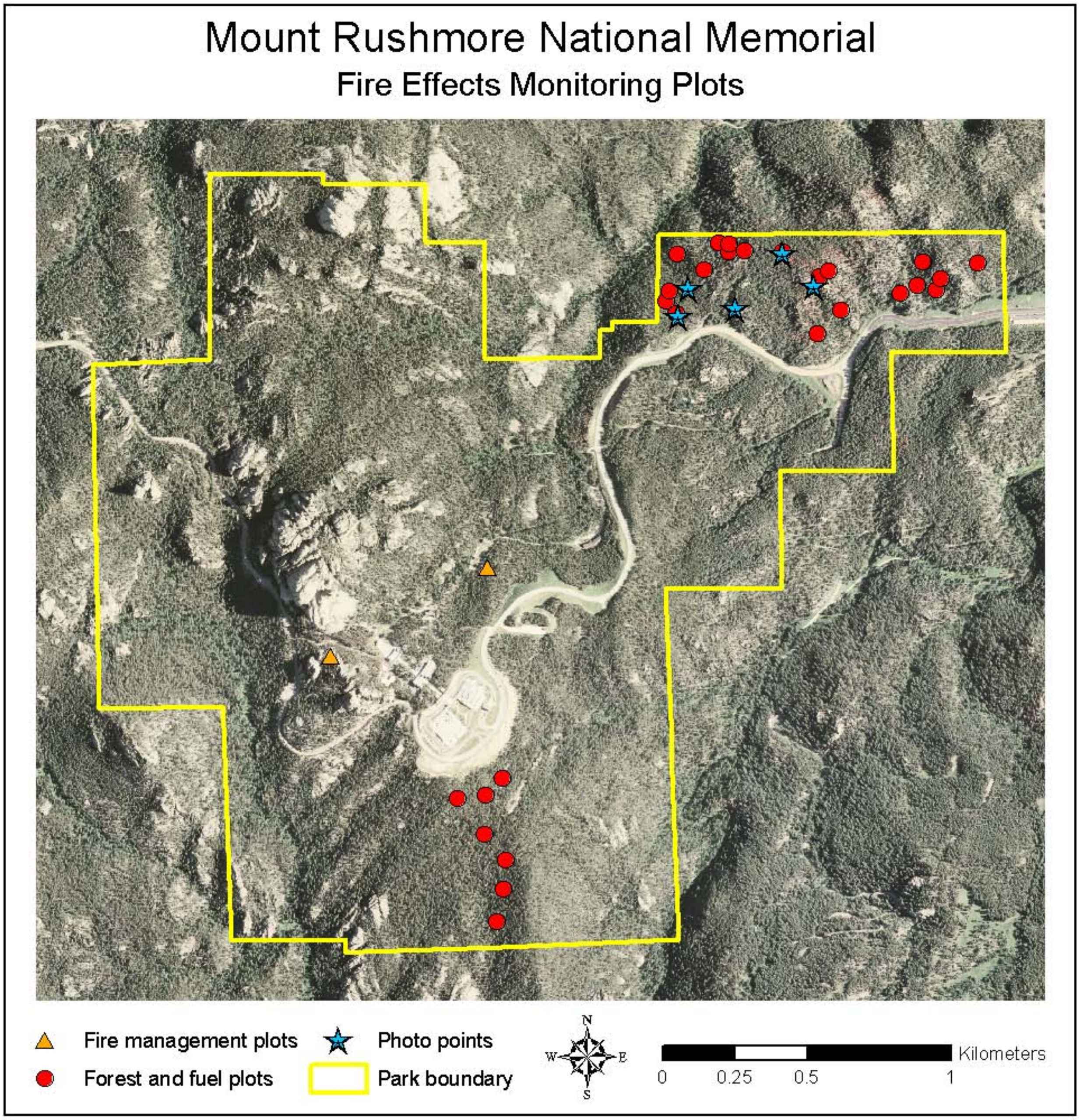


Figure 22. Location of fire effects monitoring plots in Mount Rushmore National Memorial (*Source:* Northern Great Plains Fire Management 2006).

In anticipation of the approval of a fire management plan for the memorial that would initiate a program of prescribed burning, two long-term monitoring plots (see Fire Monitoring Handbook 2003), 27 forest and fuels plots, and five photo points were established in 2003 (Fig. 22). The forest and fuels plots were established in two areas undergoing hazardous fuels treatments. Mechanical thinning of dog-hair stands of ponderosa pine in these areas and a subsequent wildfire reduced total fuels loads in six forest and fuels plots from a mean of 37.71 tons/acre to a mean of 9.74 tons/acre (Northern Great Plains Fire Management 2006) (Figs. 23 and 24). Further reductions in fuel loads are likely after repeated burns, but, as of 2008, the memorial had not initiated a regular program of prescribed fire. This indicator is in poor condition and declining (less than 50 percent of its measures have existing values that correspond with or fall within a range of reference values, see Table 6) due to high fuel loads in the memorial and adjacent wilderness and the potential for a crown fire to spread into the memorial from an offsite ignition.

Figure 23. Thinning of "dog-hair" stands of ponderosa pine in Mount Rushmore National Memorial (photo by National Park Service).

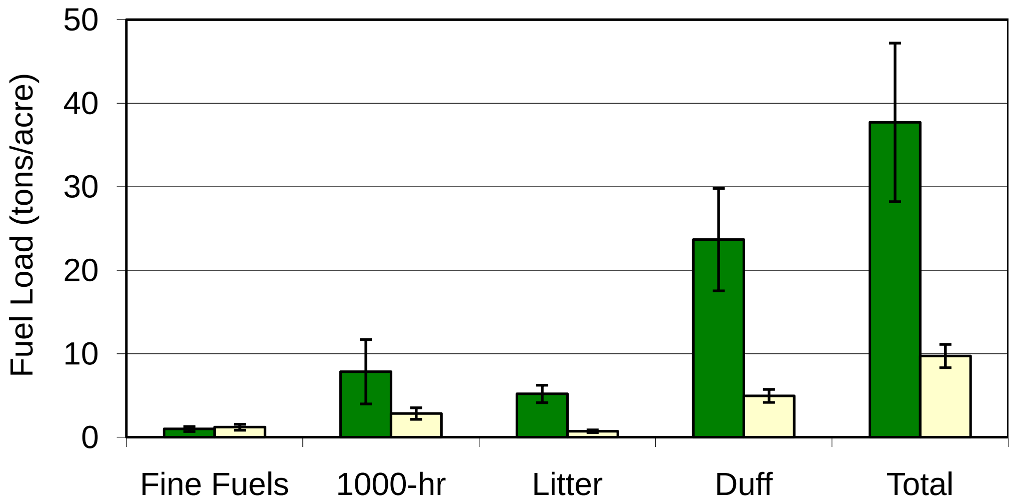
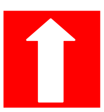


Figure 24. Fuel loads in pre- and post-thinning/burning treatments in Mount Rushmore National Memorial (green bars are pretreatment in 2002; yellow bars are posttreatment in 2006) (*Source:* Northern Great Plains Fire Management 2006).

Habitat: Rock Outcrop and Barren



Indicator: Mountain Goat
Source for Reference Condition: History of Introduction

In the Black Hills, the mountain goat is restricted almost entirely to the Black Elk Wilderness and the Norbeck Wildlife Preserve. A few animals are found within the memorial and Custer State Park. The species inhabits rock outcrops and associated talus slopes and high-elevation meadows. These habitats are limited in the Black Hills.

Mountain goat

Most individuals are descendants of six Canadian mountain goats introduced to the Norbeck Wildlife Preserve in 1924. The current population in the Black Hills is estimated at 100 to 125 animals, down from the approximately 300 to 400 animals that were estimated in 1971 (Richardson 1971). The number of individuals in the memorial also has declined in recent years (National Park Service, D. Licht, wildlife biologist, personal communication, 26 February, 2009). Reasons for the decline are uncertain but could be related to the small founder population, loss of foraging habitat due to ponderosa pine encroachment, human recreation disturbances, and predation from a growing mountain lion population.

The mountain goat is considered a highly watchable wildlife species by visitors to the memorial. However, it is an exotic species that may compete for forage and browse with native white-tailed and mule deer. This measure is in poor condition but improving (less than 50 percent of its measures have existing values that correspond with or fall within a range of reference values, see Table 6).

Indicator: Lichens
Source for Reference Conditions: Not Identified


Lichen

Lichens are small organisms consisting of a fungus and an alga growing together in a symbiotic relationship. Some are extremely sensitive to air pollutants, primarily sulfur dioxide and heavy metals, and as such are useful biomonitors of air quality (Eversman 1987). Of the 222 species of lichens known from the Black Hills region, 13 have been collected in Mount Rushmore National Memorial, mostly on rock substrate in barren areas (Gabel and Ebbert 2003; Bennet and Wetmore 2005). Of the 13, one species, *Usnea hirta*, is highly sensitive (i.e., causes slower growth) to sulfur dioxide concentration (U.S. Geological Survey, J. Bennett, ecologist, personal communication, 22 August, 2008).

Several coal-fired power plants (the primary source of atmospheric sulfur dioxide) are either in the planning or construction phase in eastern Wyoming (Stone 2008). These plants are within 200 km of the memorial and have the potential to degrade regional air quality. Although air quality is monitored by instruments at Wind Cave National Park, knowledge of the presence and abundance of lichens, particularly pollution-sensitive species in the memorial, would provide an onsite record of changes in air quality. This indicator is not assessed due to the lack information on the distribution and abundance of *Usnea hirta* and potentially other sensitive lichens in the memorial.

Indicator: Land Cover
Source for Reference Condition: Analysis of 1992 and 2001 Land Cover Datasets

See discussion of land cover under the section Forest Habitat (page 35).

Habitat: Stream and Wetland

Indicator: Native and Exotic Fish
Source of Reference Condition: Abundance of Native Fish in Streams of the Black Hills

Aquatic resources within the boundaries of the memorial are limited to three primary areas: Grizzly Bear Creek, Starling Basin (Beaver Dam Creek flows through the basin), and Lafferty Gulch. An inventory of the fish communities in these small streams was completed in 2001 (White et al. 2002) (Fig. 25, note not all sampling sites are shown).



Exotic brook trout above, and the native longnose dace right

The composition of fish surveyed in Grizzly Bear Creek (the entire 51 m located within the boundaries of the memorial was surveyed) consisted of 84 brook trout and three longnose dace. Small pools in Starling Basin produced a total of 22 brook trout, and no fish were collected in either the small stream or multiple pools in Lafferty Gulch. The longnose dace is native to the Black Hills region, while the brook trout is exotic.

Longnose dace abundance in the memorial and in other small streams in the Black Hills ranged from zero to 180 fish per 100-m reach and appears to be negatively correlated with brook trout abundance (Table 14). The presence of the exotic brown trout (*Salmo trutta*) negatively influences the occurrence of the native mountain sucker (*Catostomus platyrhynchus*) in the Black Hills region of South Dakota (Dauwalter and Rahel 2008). Therefore, it is likely that the dominant populations of brook trout in the memorial may inhibit the native fish populations. Other species that were expected to be in the memorial, but were not collected, include the native white sucker (*Catostomus commersoni*) and mountain sucker, as well as the exotic common carp (*Cyprinus carpio*).

This indicator is in poor condition due to the large number of exotic brook trout and the minimal presence of native fish (less than 50 percent of its measures have existing values that correspond with or fall within a range of reference values, see Table 6).

Table 14. Longnose dace and brook trout abundance (no./100 m) in Mount Rushmore National Memorial and in creeks in the Black Hills comparable in size to those in the memorial (*Sources:* South Dakota Department of Game, Fish, and Parks 2005; White et al. 2002).

Location	Creek	Longnose dace	Brook trout
Memorial	Grizzly Bear Creek	6	168
	Beaver Dam Creek	0	22
	Lafferty Gulch	0	0
Black Hills	Iron Creek North, site 1	180	0
	Iron Creek North, site 2	0	66
	Sunday Gulch Creek	5	21

Note: Only pools were sampled in Beaver Dam Creek and Lafferty Gulch.

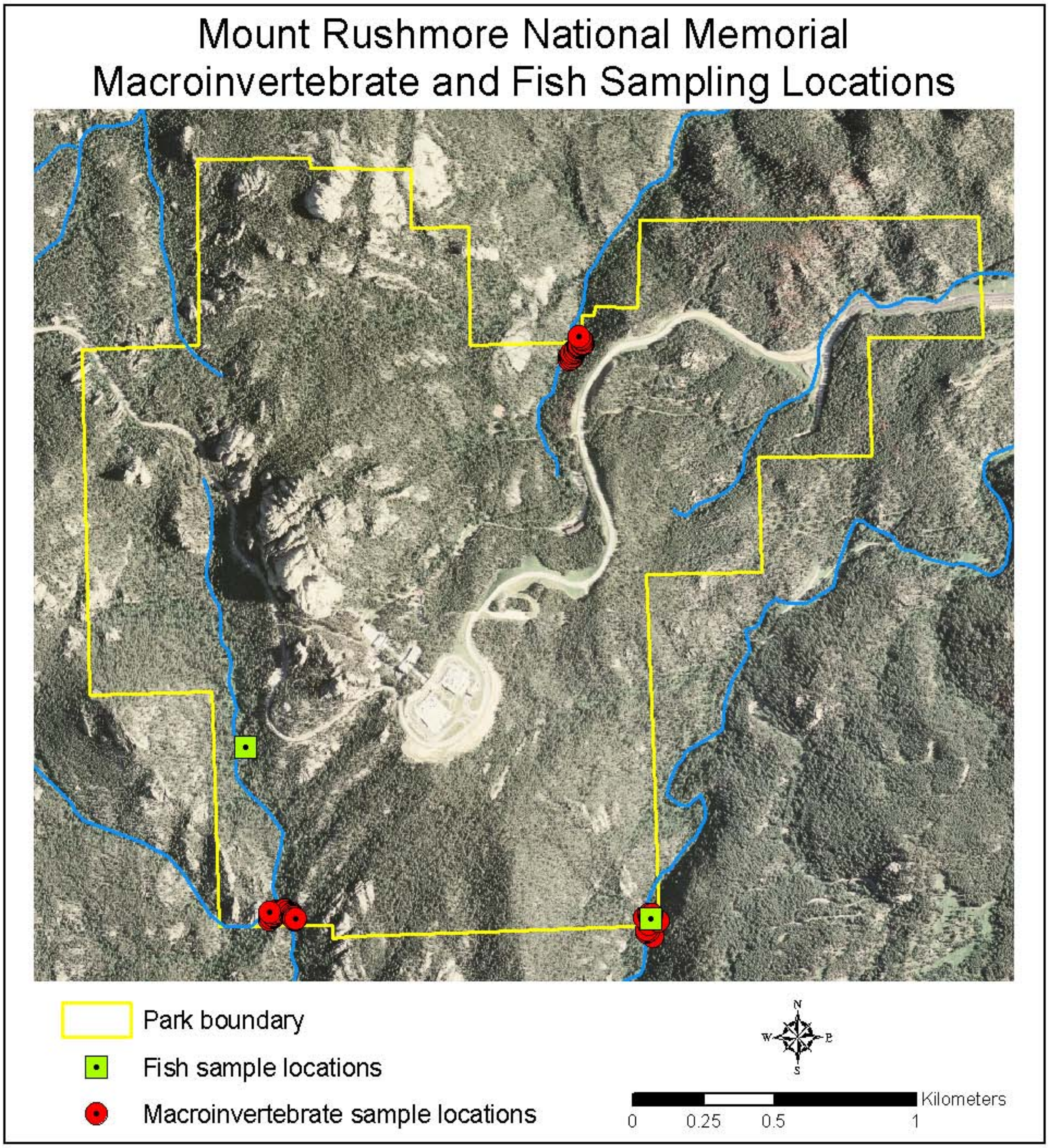
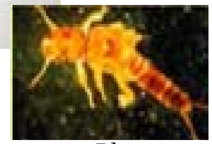


Figure 25. Aquatic macroinvertebrate and fish sampling sites in Mount Rushmore National Memorial (*Sources:* White et al. 2002; Rust 2006).

Indicator: Aquatic Macroinvertebrates (Water Quality)
Source for Reference Condition: Macroinvertebrates in Streams in National Park Units of the Northern Great Plains

Macroinvertebrate sampling

Ephemeroptera



Plecoptera

Aquatic macroinvertebrates can reveal whether a body of water is healthy or unhealthy based on the presence or absence of certain sensitive species, as well as the overall diversity of organisms. Different species show different sensitivity to pollution and changing stream conditions, with Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddis fly) (referred to as EPT) being among the most sensitive orders and Chironomidae, worms and midges, being less sensitive (U.S. Environmental Protection Agency 1997). In 2004 and 2005, aquatic macroinvertebrate communities were sampled in Grizzly Bear Creek, Beaver Dam Creek, and Lafferty Gulch in the memorial, and in aquatic systems in parks of the Northern Great Plains (Rust 2006) (Figs. 25 and 26). Several metrics were compared including EPT richness and the modified Hilsenhoff Biotic Index (HBI). EPT richness is the number of taxa (genera or species) in these three pollution sensitive orders, and the HBI is a measure of water quality based on the tolerance of specific organisms to organic pollution and associated decline in dissolved oxygen concentrations. High EPT values and low HBI values are indicators of better water quality (U.S. Environmental Protection Agency 1997).

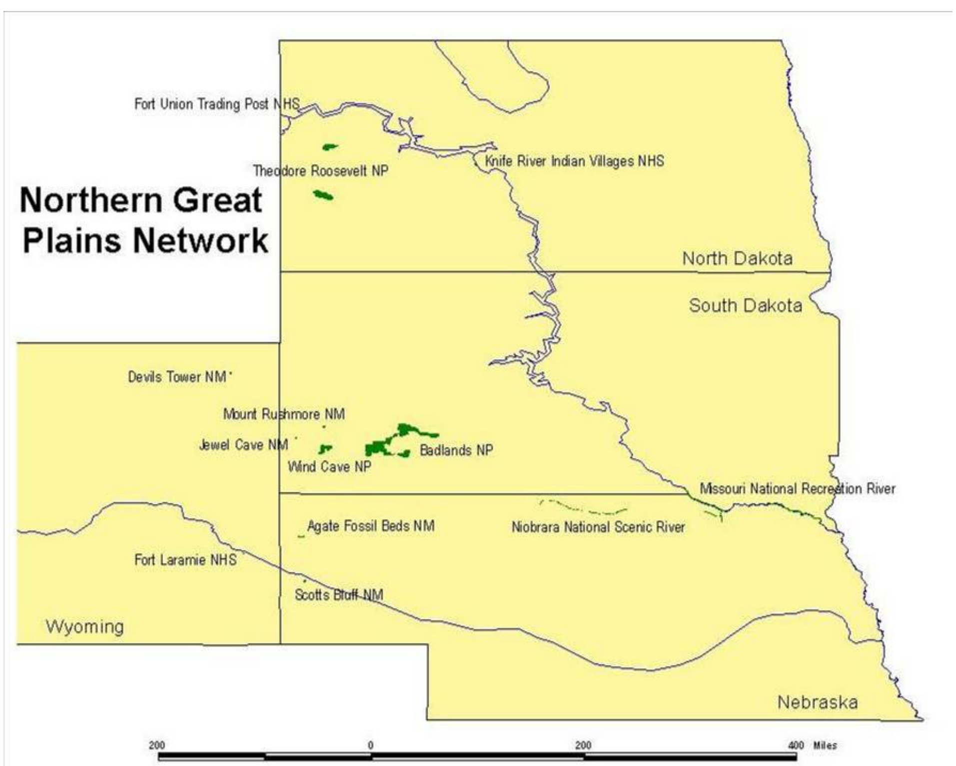


Figure 26. National park units of the Northern Great Plains Network sampled for aquatic macroinvertebrates (*Source:* Rust 2006).

Grizzly Bear Creek has high overall species richness and diversity, as well as the highest EPT richness (8) of the streams sampled in the memorial (Table 15). EPT dominate the community, comprising 61 percent of the total abundance of all macroinvertebrates, while Diptera, an order tolerant of pollution, comprised only 23 percent. Grizzly Bear Creek also had the lowest HBI of the memorial streams, indicating the macroinvertebrates in this stream are least tolerant of organic pollution. This is consistent with higher EPT numbers.

Lafferty Gulch has the lowest overall macroinvertebrate richness and diversity of the streams in the memorial (Table 15). However, intolerant organisms still comprised 51 percent of the species richness, and the average pollution tolerance was low. This indicates that, while the diversity is low, the species composition still favors sensitive taxa indicative of good water quality.

Beaver Dam Creek has the highest species diversity and total richness of the memorial streams, but the macroinvertebrate composition indicates signs of diminished water quality (Table 15). A high percentage of noninsect aquatic macroinvertebrates, high Chironomidae richness, and a high HBI value indicate that Beaver Dam Creek is populated by organisms tolerant of organic pollution. Beaver Dam Creek has a horse trail that runs beside it. As a result, it is subject to degradation by physical trampling, nutrient inputs, and increased turbidity due to runoff (Rust 2006).

Table 15. Selected macroinvertebrate metrics for Grizzly Bear Creek (GrzCrk), Beaver Dam Creek (BvDmCrk), and Lafferty Gulch (LftGlch) at Mount Rushmore National Memorial in 2004 and 2005 (*Source:* Rust 2006).

Metric	GrzCrk	BvDmCrk	LftGlch
Total abundance	211	276	334
Total richness	19	20	11
% Noninsecta	2.8	22.1	13.5
EPT:Chironomidae	0.78	0.40	0.68
EPT richness	8	2	3
Chironomidae richness	6	7	4
Shannon Diversity Index (H’)	2.34	2.49	1.58
Habit guild (H’)	1.34	1.30	1.04
% Sprawler	30.2	32.4	5.0
FFG H’	1.08	1.09	0.72
Predator richness	5	8	11
Modified HBI	4.41	5.99	4.56

In comparison to similar streams in parks of the northern Great Plains (Figs. 27 and 28), Grizzly Bear Creek had the highest EPT richness by a large margin, and both Grizzly Bear Creek and Lafferty Gulch had low HBI values. Based on the macroinvertebrate community compositions that reflect good water quality, Grizzly Bear Creek and Lafferty Gulch could be considered reference sites, or minimally disturbed benchmarks for future monitoring (Rust 2006). While Beaver Dam Creek had a higher HBI value and a lower EPT richness than the other two creeks in the memorial, it still had the highest macroinvertebrate diversity of any stream in parks of the northern Great Plains (Rust 2006). Overall, this indicator is in good condition and stable based on the presence of pollution-intolerant aquatic macroinvertebrates and the results of previous water quality monitoring on two of the three creeks in the memorial (see Watershed and Water Quality) (50 percent or more of its measures have existing values that correspond with or fall within a range of reference values, see Table 6).

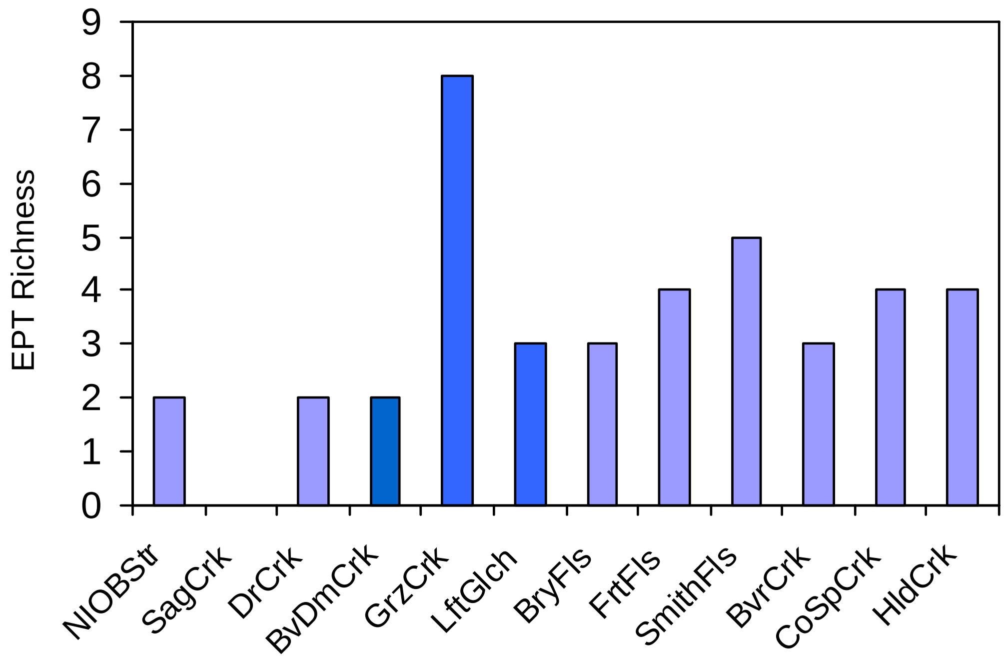


Figure 27. Mean EPT richness for small and medium streams of the Northern Great Plains Network. Site abbreviations: NiobStr = Niobrara River, SagCrk = Sage Creek, DrCrk = Deer Creek, BvDmCrk = Beaver Dam Creek, GrzCrk = Grizzly Bear Creek, LftGlch = Lafferty Gulch, BryFls = Berry Falls, FrtFls = Fort Falls, SmithFls = Smith Falls, BvrCrk = Beaver Creek, CoSpCrk = Cold Spring Creek, HldCrk = Highland Creek (*Source:* Rust 2006).

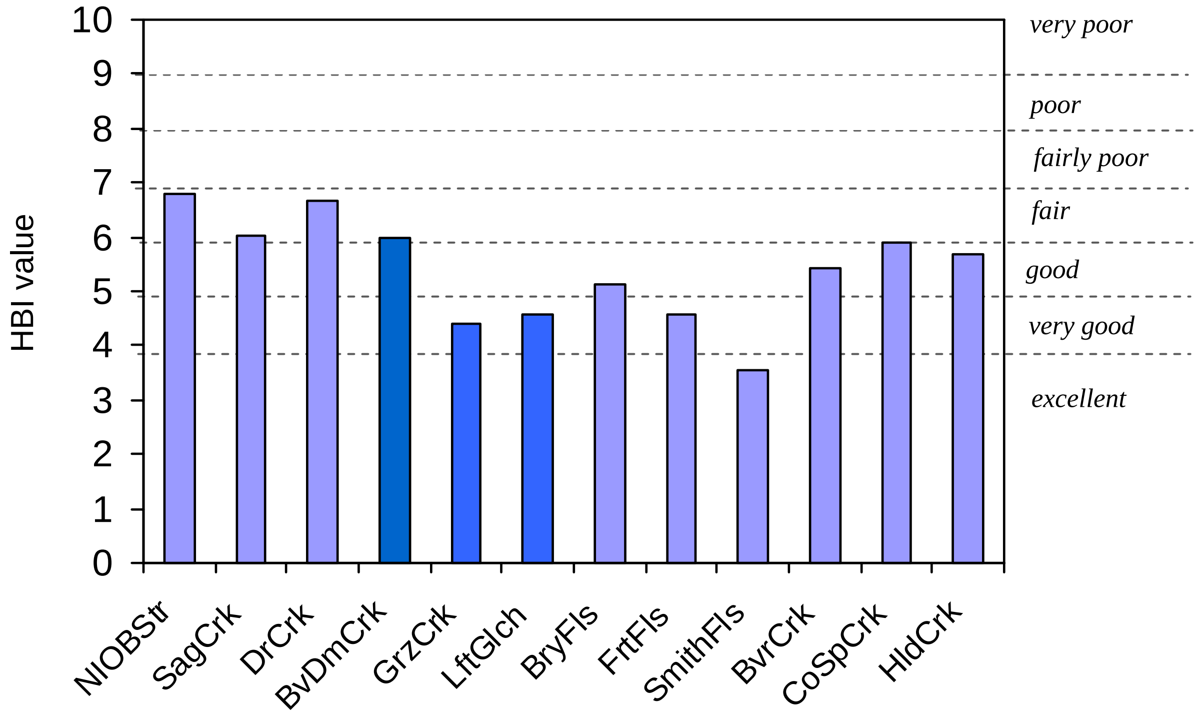
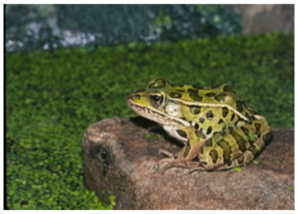


Figure 28. Intolerant taxa richness (HBI value) for small and medium streams of the Northern Great Plains Network. Site abbreviations: NiobStr = Niobrara River, SagCrk = Sage Creek, DrCrk = Deer Creek, BvDmCrk = Beaver Dam Creek, GrzCrk = Grizzly Bear Creek, LftGlch = Lafferty Gulch, BryFls = Berry Falls, FrtFls = Fort Falls, SmithFls = Smith Falls, BvrCrk = Beaver Creek, CoSpCrk = Cold Spring Creek, HldCrk = Highland Creek (*Source:* Rust 2006).

Indicator: Northern Leopard Frog
Source for Reference Condition: Occupied Monitoring Sites in the Black Hills National Forest



Northern leopard frog

The northern leopard frog (*Rana pipiens*) was once the most abundant and widespread frog species in North America. Over the last three decades, the species has undergone massive declines and is imperiled across much of its range in the western two-thirds of the United States and parts of Canada (Rorabaugh 2005). The population declines are likely due to a number of factors that vary from site to site, such as habitat destruction, disease, introduced predators, climatic change, and general environmental degradation (grazing, recreation, road construction, logging, and hydrologic alteration caused by development of water resources). However, there are locations where the northern leopard frog remains common, including the Black Hills, where the species remains one of the most abundant amphibians (Smith et al. 2005).

The USDA Forest Service designated the northern leopard frog as a sensitive species and monitors populations in the Black Hills National Forest (USDA Forest Service 2004). Monitoring data indicate that populations of the species are stable in suitable wetland habitats in the national forest (Table 16). Furthermore, a herpetological inventory of eight national parks in the northern Great Plains, including the memorial, revealed no strong evidence of northern leopard frog population declines. The frog was observed at both Lafferty Gulch and Starling Basin in the memorial (Smith et al. 2004). Starling Basin, which includes a beaver dam and wetlands, was identified as an important habitat for the frog and other amphibians in the memorial.

This indicator is in good condition based on the initial inventory of the species in the memorial and monitoring of the species in the Black Hills National Forest (50 percent or more of its measures have existing values that correspond with or fall within a range of reference values, see Table 6). However, it is reasonable to assume that this species is vulnerable in the Black Hills due to drought, the loss of wetlands, and introduction of predatory fish (Smith 2003). The exotic brook trout is the most abundant fish in the memorial, and introduced predaceous fish such as the brook trout have been shown to depress frog populations (Hecnar and M'Closkey 1997; Smith and Keinath 2007).

Table 16. Number of occupied monitoring sites of the northern leopard frog in the Black Hills National Forest (*Sources:* USDA Forest Service 2004; 2006b; and 2007).

Sample Year	Sites Visited	Sites Occupied	% Sites Occupied
2001/2002	73	44	60
2005	7	7	100
2006	9	7	77

Indicator: Bats
Source for Reference Condition: Biodiversity of Bats in the Black Hills

The Black Hills of South Dakota and Wyoming support a diverse assemblage of bat species. Of the 11 bats known from the Black Hills region (Turner and Davis 1969), eight are found within the memorial (Table 17) (Schmidt et al. 2004). All of these species are year-long residents that hibernate in caves and mines and roost in buildings, caves, mines, and tree snags. Typically, these species forage over meadows, ponds, and streams, where they feed on flying insects.

Fringed-tailed myotis

Because of their specific habitat requirements and the sensitivity of some species to human disturbance, bats are considered indicator species (Schmidt et al. 2004). In the memorial, the beaver pond at the bottom of Starling Basin is a critical resource for bats. Protection of the quality and quantity of water in this pond and the adjacent vegetation is important to ensure continuation of the bats' drinkable water and prey base of insects. Potential threats to bats in the memorial include incursions of trails into undeveloped areas, evening helicopter tours during bat maternity periods in early June through mid-August, and loss of pine snags due to prescribed fires (Schmidt et al. 2004).

Bats are in good condition considering the high species diversity in the memorial (50 percent or more of its measures have existing values that correspond with or fall within a range of reference values, see Table 6). Population sizes and trends are unknown.

Table 17. Bat species collected by mist nest over the beaver pond in Starling Basin during August 2004 (*Source:* Schmidt et al. 2004).

Species	Number caught
Big brown bat (*Eptesicus fuscus*)	6
Silver-hair bat (*Lasionycteris noctivagens*)	4
Small-footed bat (*Myotis ciliolabrum*)	2
Little brown bat (*Myotis lucifigus*)	13
Northern long-eared myotis (*Myotis sepentrionalis*)	6
Long-legged myotis (*Myotis volans*)	1
Western long-eared bat (*Myotis evotis*)[1]	
Fringed myotis (*Myotis thysanodes*)[1]	

[1]Species identified by acoustic recording of call.

Indicator: Stream Flow (Grizzly Bear Creek)
Source for Reference Condition: Not Identified

Gauge on Grizzly Bear Creek near Keystone, S.D. (photo by U.S. Geological Survey).

Grizzly Bear Creek flows for approximately 51 m across the southeast corner of the memorial and is the memorial's largest stream (White et al. 2002). Annual peak stream flow measurements for Grizzly Bear Creek are available from 1998 to the present for a gauge located downstream of the memorial near Keystone, South Dakota (U.S. Geological Survey 2008). These measurements are highly variable, ranging from a maximum of 713 cubic feet/second in 2001 to a minimum of 0.730 cubic feet/second in 2002. Daily stream flow is not continuously measured at this gauge, but daily flow measurements taken sporadically over the year document highly variable flows. The proximity of the gauge to the memorial suggests that stream flow in the memorial is also highly variable. Because of the relatively short length of the gauge record and the highly variable flow, trends in stream flow that may impact fish, amphibians, aquatic macroinvertebrates, and riparian vegetation are probably not detectable now but may be in the future following additional monitoring. Thus, this indicator is not assessed.

Stressors and Management Strategies

Only within the past five to seven years have resource inventories and associated research highlighted the significant natural resources in the memorial and the stressors acting on those resources. The memorial's small size leaves it highly susceptible to stressors originating from inside and outside its boundary (Fig. 29). However, the memorial is almost completely surrounded by national forest, including federal wilderness with monitoring (i.e., mountain pine beetle) and management (i.e., fuel loads) that may buffer some of these stressors.

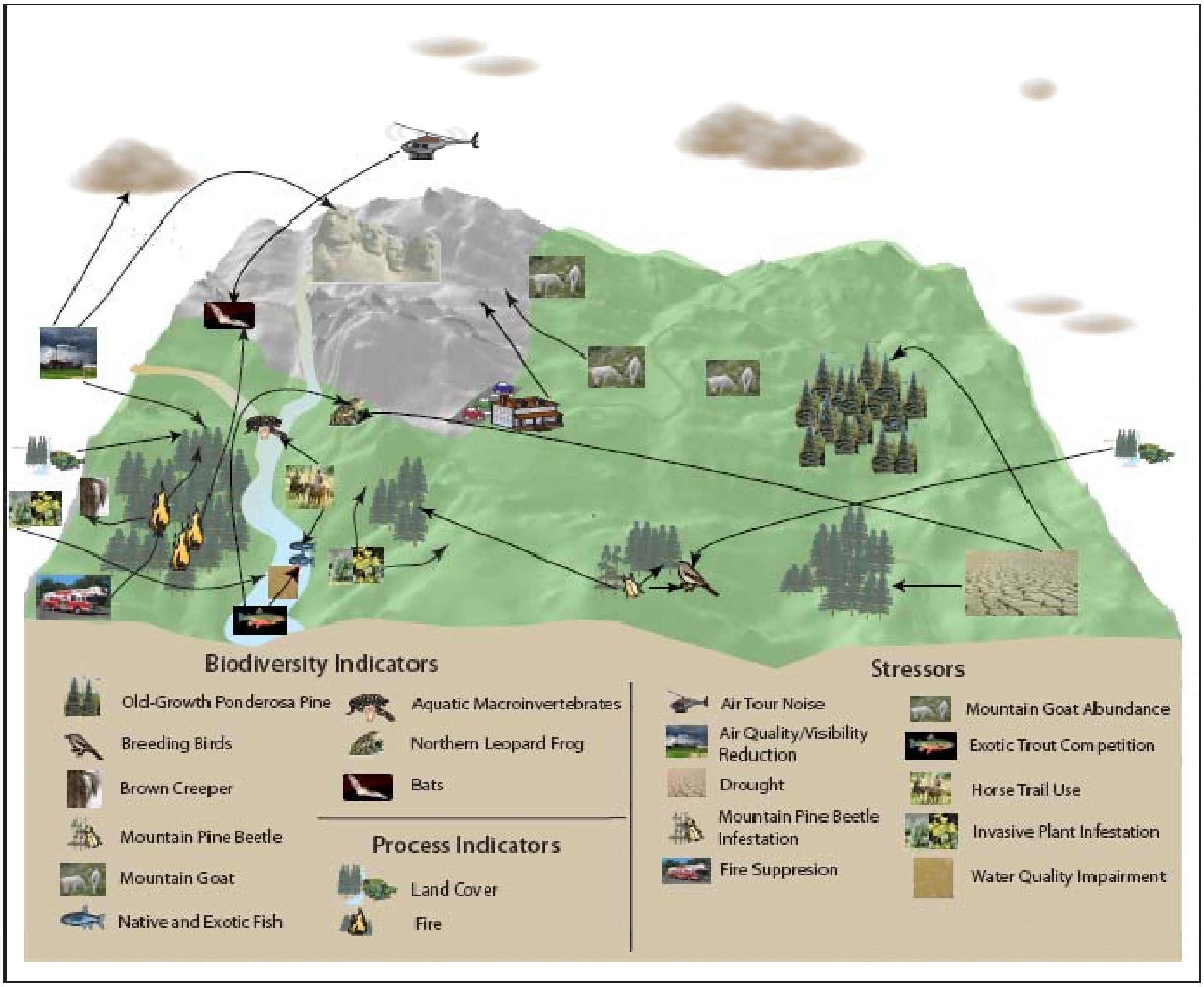


Figure 29. Mount Rushmore National Memorial conceptual diagram: existing and possible relationship of stressors to biodiversity and process indicators.

The major stressors and management strategies emerging from this condition assessment follow:

Fire Suppression
Prior to European settlement, surface fire shaped the ponderosa pine–dominated forest in the memorial by keeping tree densities and fuel loads low. Fire suppression has led to forest stand conditions that are unnatural and threatening to the future of the old-growth component of the forest. A mechanical hazard fuel reduction program was established in 1990 and a fire management plan was approved 2002. The fire management plan calls for the use of prescribed fire in conjunction with mechanical thinning of small trees to reduce fuel loads. Fuel reduction may be particularly urgent as warmer and earlier springs that are linked to climate change have lead to increased wildfire activity in the Black Hills and other areas of the west (Westerling et al. 2006).

The reintroduction of prescribed fire into the forest will help to restore and maintain sustainable levels of tree densities and fuels. In addition, the large presettlement trees will be less susceptible to catastrophic loss due to crown fire although litter accumulation at the bases of large trees could result in some tree mortality following prescribed burns (Symstad and Bynum 2007). In areas where native understory vegetation is sparse because of heavy litter loads and/or dense stands of small trees, burning could create prime habitat for invasive plants (Symstad and Bynum 2007). Also, changes in vegetation following prescribed burns may disrupt roosting and foraging activities of bats, and nesting and foraging activities of the brown creeper. In addition, the reintroduction of fire to the memorial raises safety concerns for visitors and facilities (the total value of 34 buildings in the memorial is in excess of 65 million dollars) and nearby residences and communities.

Management strategy should

- continue a mechanical tree thinning program (i.e., remove pine trees 20 cm dbh and smaller) that restores the stand characteristics of old-growth ponderosa pine forest, monitor response;
- use prescribed fire, following thinning, to mimic the effects of frequent, low-intensity natural fire while protecting the majority of large trees, monitor response;
- determine the species composition of the herbaceous and shrub layers of old-growth and monitor their response to tree thinning and prescribed burning;
- continue to monitor the bird community and estimate trends for species with high densities;
- monitor the response of old-growth obligate birds, such as the brown creeper, to thinning and prescribed burning;
- determine the distribution and abundance of bats;
- determine the effects of vegetation changes on bat foraging and roosting.

Exotic Trout Competition
The presence of the exotic brook trout in streams within the memorial may be limiting the presence and abundance of native fish species. A survey of Grizzly Bear Creek and the Starling Basin wetland complex in 2001 found that brook trout far outnumbered longnose dace, the only native fish found. For example, only three longnose dace were sampled from Grizzly Bear Creek, while 84 brook trout were sampled. Other native species that were expected but not found included the mountain sucker. The exotic trout may be inhibiting the ability of native fish to survive given increased competition for resources and direct predation. Furthermore, the presence of trout may also limit the number of northern leopard frogs, although abundance of the frog in the memorial is unknown. Trout are known to feed on the eggs and tadpoles of the frog (Smith and Keinath 2007). Sites where both species occur have few adult frogs.

Management strategy should

- continue surveys to monitor the presence and abundance of longnose dace and brook trout in the memorial and in the adjacent national forest;
- determine if longnose dace are reproducing;
- determine the prey species of brook trout;
- determine the feasibility of removing exotic trout and reintroducing native fish;
- determine the distribution and abundance of the northern leopard frog.

Mountain Pine Beetle Infestation
The mountain pine beetle is a natural component of the Black Hills forest ecosystem, with outbreaks occurring periodically. Unlike other insects that attack ponderosa pine, the mountain pine beetle is most common in relatively large (20–30 cm dbh) trees (Shepperd and Battaglia 2002). Live ponderosa pine trees in the memorial average 30.2 cm dbh (Symstad and Bynum 2007), and most are in stands that have a moderate or high risk of attack by mountain pine beetles (see Table 11). Furthermore, the area of the adjacent national forest infested with mountain pine beetle has increased substantially in recent years (U.S. Forest Service 2006a).

Management strategy should

- identify the causes of significant tree mortality;
- maintain information on pine beetle infestation of adjacent national forest.

Other existing or potential stressors identified through this condition assessment are:

Air Tour Noise
The Federal Aviation Administration permits 5,608 air tours of the memorial each year. This translates into approximately one to two air tours per hour in the development zone of the memorial and two to three tours in both the historic and natural zones. In the natural zone, air tours are potentially audible 50 to 60 percent of the time in a majority of the zone. In addition, the majority of the zone experiences air tour sounds louder than ambient for greater than 50 percent of the time (Volpe 2008).

Management strategy should

- monitor existing ambient sounds under a pending Air Tour Management Plan for the memorial;
- determine air tour sound impacts on wildlife activities, particularly on bat foraging.

Air Quality/Visibility Reductions
Several coal fired power plants are either in the planning or construction phase in eastern Wyoming. In addition, coalbed methane production is under development in Wyoming and Montana. Operation of these plants and production sites could reduce air quality in the region and visibility of the sculpture in the memorial. In addition, high vehicle traffic in the summer months may reduce air quality near the visitor center parking lot and along Highway 244 (National Park Service 2008) (Table 18).

Management strategy should

- inventory lichens and identify those sensitive to sulfur dioxide, monitor the distribution and abundance of sensitive species;
- obtain annual reports of instrument monitoring of air quality at Wind Cave National Park.

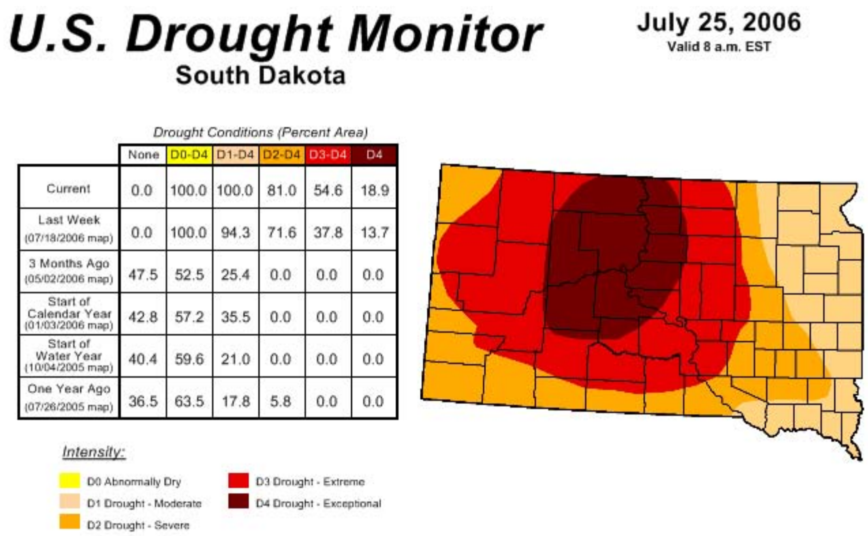
Table 18. Monthly and total year vehicle counts for Highway 244 and the parking lot at Mount Rushmore National Memorial in 2008 (*Source:* National Park Service 2008).

Month and total year	Vehicle count Highway 244	Vehicle count parking lot
Jan	12,455	2,668
Feb	12,794	2,963
Mar	20,495	7,218
Apr	26,596	8,509
May	68,808	31,630
Jun	146,011	80,701
Jul	195,707	105,570
Aug	182,282	100,717
Sep	85,991	46,346
Oct	35,428	17,345
Nov	16,145	5,283
Dec	13,644	2,779
Total year	816,356	411,729

Drought
The Palmer Drought Severity Index was developed in the 1960s and uses temperature and precipitation in a formula to determine dryness. Index values range from 0 (normal) to -4 (extreme drought). For the historic period (1895–1995), the memorial was subject to severe drought (PDSI = -3) from 10 to 14.9 percent of the time period (see Fig. 5).

Management strategy should

- monitor drought using online resources such as http://drought.unl.edu/monitor/monitor.htm (Fig. 30);
- suspend the use of prescribed fire during severe and prolonged drought.



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.0	100.0	100.0	81.0	54.6	18.9
Last Week (07/18/2006 map)	0.0	100.0	94.3	71.6	37.8	13.7
3 Months Ago (05/02/2006 map)	47.5	52.5	25.4	0.0	0.0	0.0
Start of Calendar Year (01/03/2006 map)	42.8	57.2	35.5	0.0	0.0	0.0
Start of Water Year (10/04/2005 map)	40.4	59.6	21.0	0.0	0.0	0.0
One Year Ago (07/26/2005 map)	36.5	63.5	17.8	5.8	0.0	0.0

Figure 30. U. S. Drought Monitor.

Mountain Goat Abundance
Populations of the nonnative mountain goat are in decline in the Black Hills and in the memorial. Although reduced in number, the remaining mountain goats may still have a negative impact on plant diversity and availability of forage and browse for native deer and other wildlife. Semitame mountain goats can pose a safety hazard for visitors and vehicle traffic.

Management strategy should

- census mountain goats to determine population size and trend;
- determine forage production and use.

Horse Trail Use
Horseback riding is allowed on a trail that enters the southwest corner of the memorial, parallels Beaver Dam Creek, and ends at hitching rails near the parking lot for the visitor center. The number of horseback riders is unknown, but trail erosion and braiding is significant and may affect water quality in the creek (Rust 2006) (Fig. 31). In addition, horse trails are possible corridors for the spread and establishment of exotic plants (Stroh and Struckhoff 2008, Wells and Lauenroth 2007).

Management strategy should

- determine horse trail use and measure trail erosion;

- mitigate trail erosion and limit use, if necessary;
- Inventory exotic plants along the horse trail, treat as necessary.

Figure 31. Horse trail erosion (photo by National Park Service).

Water Quality Impairment
Measurements of physical and chemical water quality parameters taken in 2004 and 2005 indicate that Beaver Dam Creek is impaired (or not able to support designated uses) with low dissolved oxygen levels, high suspended solids, and high turbidity although it has a high diversity of aquatic macroinvertebrates (Rust 2006; Troelstrup 2006). Dissolved oxygen levels fell below the state water quality standard 44 percent of the time during the sample period, pH also fell below the standard, and turbidity and total dissolved solids exceeded the standard to support beneficial uses (Table 19). The likely cause of the impairment is runoff from the horse trail near the creek (Rust 2006).

Despite receiving a discharge of up to 50,000 gallons a day (National Park Service 2007b) from the memorial's wastewater treatment facility, Lafferty Gulch was not impaired with levels of ammonia and fecal coliform well below state standards (Troelstrup 2006).

Management strategy should

- monitor physical and chemical parameters of surface water resources (e.g., creeks and beaver ponds) on a long-term basis;
- monitor aquatic macroinvertebrates in surface water resources and compare results with physical and chemical water quality monitoring.

Table 19. Measurements of physical and chemical parameters of Beaver Dam Creek in Mount Rushmore National Memorial and state of South Dakota standards for those parameters (Rust 2006, Troelstrup 2006).

Parameter	Mean	Min	Max	State standard
Dissolved oxygen (mg/L)	5.6	0.2	15.3	5.0
Conductivity (uS/cm)	146	69	291	7,000
pH	-	5.6	7.3	6.5–9.0
Water temperature (°C)	14.0	9.5	24.4	-
Alkalinity (mg/L)	40	25	55	1,313
Turbidity (NTU)	148	3	675	50[a]
TSS (mg/L)	305	3	1,418	-
TDS (mg/L)	1,596	45	7,631	4,375
Total phosphorus (mg/L)	0.97	0.012	4.310	-
TKN (mg/L)	2.46	0.25	10.60	-
NH_3 (mg/L)	0.07	<0.02	0.26	-
NO_3 (mg/L)	< 0.10	<0.10	<0.10	-
Fecal coliform (org/100mL)	8	<10	20	2000

[a] Water Resources Division screening criteria (National Park Service 2000).

Exotic Plant Infestation

Of the exotic plants found in the memorial, leafy spurge may be the most threatening (Fig. 32). It is an aggressive perennial weed that grows in a variety of environments but is primarily found in untilled, non-cropland habitats such as abandoned cropland, pastures, rangeland, woodland, roadsides, and waste areas. It can also establish in undisturbed native plant communities (Watson 1985). The mechanical thinning of pine stands and the introduction of prescribed fire to those areas may facilitate the spread of this species in the old-growth pine habitat and in other areas.

Figure 32. Leafy spurge (left) (photo by U.S. Geological Survey) and salt cedar (photo by Forest and Kim Starr, U.S. Geological Survey).

Salt cedar (*Tamarix* spp.) is an exotic deciduous shrub or tree that can grow to 12 m tall (Fig. 32). Although not currently known from the memorial, the species has dramatically expanded its range in the United States over the last 80 years and currently infests about 2,509 ha in South Dakota, mostly in the southwest corner of the state (South Dakota Department of Agriculture 2007) (Fig. 33). The species establishes on sand and gravel bars, stream banks, and in areas away from river systems including springs, seeps, lakeshores, roadsides, residential areas, and parks. Once established, the species will continue to spread. In the memorial, the riparian areas along the three drainages appear to be prime habitat for this species.

Management strategy should

- determine distribution and abundance of leafy spurge;
- track distribution and rate of spread of salt cedar in southwest South Dakota;
- treat exotic plants with herbicides or hand-pull them.

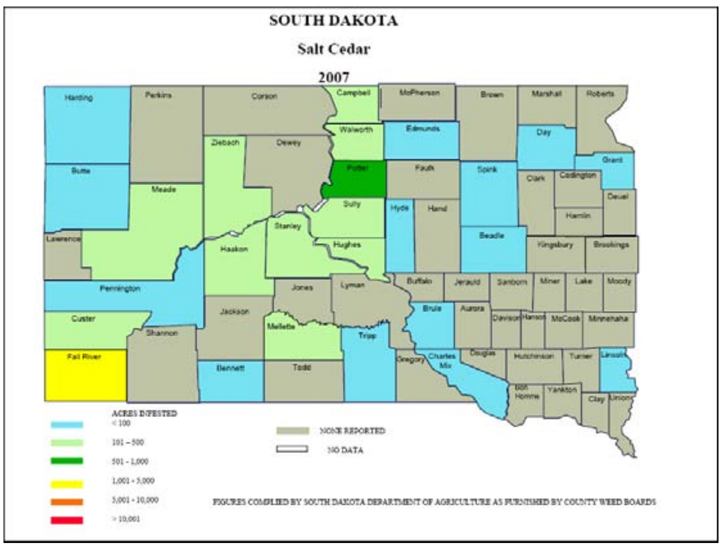


Figure 33. Salt cedar infestation in South Dakota (*Source:* South Dakota Department of Agriculture 2007).

Conclusion

The overall condition and trend of each major habitat in the memorial is based on a subjective appraisal of the condition and trend of its indicators. They follow:

Forest Habitat

Based on the condition and trend of its indicators, the forest habitat in the memorial is in poor condition and in decline. Four (i.e., old-growth ponderosa pine, mountain pine beetle, land cover, and fire) of the six assessed indicators of this habitat are in poor condition, and three of these (old-growth ponderosa pine forest, land cover, and fire) are in decline (Table 20). Most of the old-growth ponderosa pine forest in the memorial has not burned in over a century. This has resulted in greater tree density in the smaller tree size classes as compared to the presettlement or reference condition, an increase in vertical and surface fuels, and a higher probability of crown-replacing wildfire. The probability of crown fire may have increased due to earlier and warmer springs that are linked to climate change. Because of the age and structure of the ponderosa pine stands in the memorial, the risk of mountain pine beetle infestation in most of these stands is either high or moderate. An analysis of land cover changes in and near the memorial found an increase in the size of forest patches, an increase in percent land cover of forest, and overall a less diverse land cover. This may be due to an increased density of pine trees in established stands and the growth of trees in barren areas and meadows that were not previously forested. Information is lacking on the demography of plant species in rare components of the forest such as birch/hazelnut vegetation association. Possibly due to the presence of large trees and snags that provide abundant nesting and foraging sites, concurrent monitoring of breeding birds in the memorial and the national forest suggests that this indicator is in good condition, although it is also threatened by potential stand-replacing wildfire. Likewise, an old-growth obligate bird, the brown creeper, is in good condition.

Management of the forest has focused on mechanical thinning of dense stands of small ponderosa pine trees. Continued removal of small trees in conjunction with the use of prescribed fire will be necessary to reduce the potential for wildfire and the possible catastrophic loss of the old-growth trees and associated wildlife. However, the introduction of fire may have negative impacts, including the loss of some large trees, the disruption of roosting and foraging by bats, and the spread of exotic plants.

Rock Outcrop and Barren Habitat

The condition of the rock outcrop and barren habitat is poor. This is mostly based on a substantial decline in barren areas from 1.03 percent of land cover in 1992 to 0.03 percent land cover in 2001 for the memorial and the surrounding area. The invasion of, or overtopping of barren areas by ponderosa pine is believed to be the cause of the decline. In addition, the exotic mountain goat (an indicator and stressor) occurs in the memorial, where it may compete for forage and browse with native species. The distribution and abundance of lichens, particularly those sensitive to air pollution, are largely unknown in this habitat.

Stream and Wetland Habitat

The stream and wetland habitat is in good condition when compared to similar resources in the Black Hills and in other park units in the northern Great Plains. Three (aquatic macroinvertebrates, northern leopard frog, and bats) of the four indicators with sufficient baseline data are in good condition (Table 20). Only the native and exotic fish indicator is in poor condition. Based on aquatic macroinvertebrate metrics, the water quality of two creeks in the memorial is good and stable. For example, Grizzly Bear Creek has the highest EPT richness of the thirteen streams sampled in park units of the northern Great Plains. However, Beaver Dam Creek is considered impaired based on a comparison of measurements of its physical and chemical water quality parameters with state standards and the presence of pollution tolerant aquatic macroinvertebrates. Bat species diversity is high, with eight of the 11 species known from the Black Hills having been found foraging for food over this habitat. The condition of the northern leopard frog indicator is good based on an initial inventory of the species in the memorial and stable populations in the Black Hills National Forest. Stream flow measurements for Grizzly Bear Creek are probably not of sufficient length to identify trends.

Threats to this habitat include drought, erosion and sedimentation from the horse trail, exotic predatory fish, and the potential for salt cedar to invade riparian vegetation. Exotic brook trout dominate the creeks in the memorial and may have displaced native fish. Eliminating exotic trout and restoring native fish is the most critical management challenge in this habitat.

A variety of existing data sources were used to assess the conditions and trends of the three major habitats in the memorial. Most important are inventories of the vascular plants, aquatic macroinvertebrates, fish, reptiles and amphibians, birds, and mammals and research to determine the extent and conservation significance of old-growth ponderosa pine forest. Currently, monitoring in the memorial is limited to resources of prime concern to the memorial and the adjacent Black Hills National Forest, such as fuel loads, forest insects and diseases, and chemical and physical measurements of water quality. In the future, monitoring protocols being developed by the Northern Great Plains Inventory and Monitoring Network will provide timely information on water quality, exotic plants, plant communities, and birds and will detect trends in these resources over time. These protocols are expected to be phased in over the next two to three years. Additional inventory and/or monitoring should be considered for lichens, mountain goats, native and exotic fish, northern leopard frogs, and bats.

Table 20. Habitat conditions and trends.

Habitat	Percent of park area	Condition and trend of habitat indicators		Condition and trend of habitat
Forest	92		Old-growth ponderosa pine	
			Birch/hazelnut vegetation association	
			Brown creeper	
			Breeding birds	
			Mountain pine beetles	
			Land cover	
			Fire	
Rock outcrop and barren	5		Mountain goat	
			Land cover	
			Lichens	
Stream and wetland	<1		Native/exotic fish	
			Aquatic macroinvertebrates	
			Northern leopard frog	
			Bats	
			Stream flow	

Note: Green box = good condition; Red box = poor condition; open box = no assessment; Upward arrow = improving; Downward arrow = deteriorating; Horizontal arrow = stable; and No arrow = no or insufficient data.

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Appendix A: Sampling design and data analysis

Indicator: Old-growth ponderosa pine	
Reference condition ***Source:*** Brown et al. 2008 ***Sampling design:*** stand structure—29 plots in 26 stands; variable radius plots ***Data:*** measured—diameter (dbh) and canopy base height (cbh) of each tree in a plot; collected-cross sections from all dead fire-scarred trees within a plot and up to five additional dead fire-scarred trees outside of a plot; calculated-live tree density and basal area/ha by diameter class for 1870 based on tree radial measurements and derived relationship ***Statistics:*** mean and standard error ***Test:*** Student's *t* test	**Existing condition** ***Source:*** same as reference condition ***Sampling design:*** same as reference condition ***Data:*** same as reference condition except live tree density and basal area for 2005 ***Statistics:*** same as reference condition ***Test:*** same as reference condition
Indicator: Breeding birds	
Reference condition ***Source:*** Panjabi 2005a ***Sampling design:*** monitoring—point transects at monitoring site; 17 five-minute point counts at stations located at 250-m intervals along point transect; one observer ***Data:*** observed—bird species, sex, detection (call, song, drumming), distance from observer to bird; calculated—density, abundance ***Statistic:*** mean (density only) ***Test:*** confidence interval	**Existing condition** ***Source:*** Panjabi 2005b ***Sampling design:*** same as reference condition ***Data:*** same as reference condition ***Statistic:*** same as reference condition ***Test:*** same as reference condition

Appendix A: Sampling design and data analysis (continued).

Indicator: Brown creeper	
Reference condition ***Source:*** Panjabi 2005a ***Sampling design:*** monitoring—point transects at monitoring sites (in Black Hills National Forest); 430 five-minute point counts at stations located at 250-m intervals along 30 point transects; one observer ***Data:*** observed—bird species, sex, detection (call, song, drumming), distance from observer to bird; calculated—abundance ***Statistic:*** abundance ***Test:*** none reported	**Existing condition** ***Source:*** Panjabi 2005b ***Sampling design:*** monitoring—point transects at monitoring sites (Mount Rushmore National Memorial); 17 five-minute point counts at stations located at 250-m intervals along one point transect; one observer ***Data:*** same as reference condition ***Statistic:*** same as reference condition ***Test:*** same as reference condition

Indicator: Mountain pine beetle	
Reference condition ***Source:*** USDA Forest Service 1999 ***Sampling design:*** not reported ***Data:*** collected—tree diameter and stand density ***Statistic***: not reported ***Test:*** not reported	**Existing condition** ***Source:*** Bynum 2008 ***Sampling design:*** 26 stands; 150 sample points ***Data:*** collected—stand structure, density, and dbh; calculated—risk ***Statistic:*** not reported ***Test:*** not reported

Indicator: Fire	
Reference condition ***Source:*** Brown et al 2008 ***Sampling design:*** dendrochronological analyses of tree rings and fire scars to reconstruct fire history ***Data:*** collected—cross sections of all dead fire-scarred trees within a plot and up to five additional dead fire-scarred trees outside of a plot; calculated—fire frequency (fire interval), fire severity, and fire size. ***Statistic***: mean (fire interval only) ***Test:*** not reported	**Existing condition** ***Source:*** same as reference condition ***Sampling design:*** same as reference condition ***Data:*** same as reference condition ***Statistic:*** same as reference condition ***Test:*** same as reference condition

Appendix A: Sampling design and data analysis (continued).

Indicator: Native and exotic fish	
Reference condition ***Source:*** South Dakota Department of Game, Fish, and Parks ***Sampling design***: not reported ***Data:*** number of fish per 100 m ***Statistic:*** mean (abundance) ***Test:*** confidence interval	**Existing condition** ***Source:*** White et al. 2002 ***Sampling design:*** segments of streams were sampled with electrofishing ***Data:*** number of fish ***Statistic:*** not reported ***Test:*** not reported
Aquatic macroinvertebrates	
Reference condition ***Source:*** Rust 2006 ***Sampling design:*** five randomly chosen transects for each reach, D-frame net (350 um), disturbed for three minutes, five sweepnets ***Data***: collected—presence and abundance; calculated—EPT and HBI ***Statistic:*** mean (abundance) ***Test:*** confidence interval	**Existing condition** ***Source:*** same as reference condition ***Sampling design:*** same as reference condition ***Data:*** same as reference condition ***Statistic:*** same as reference condition ***Test:*** same as reference condition
Northern leopard frog	
Reference condition ***Sources:*** USDA Forest Service 2004, 2006b, 2007 ***Sampling design:*** site visit ***Data:*** collected—occupied monitoring site ***Statistic:*** not reported ***Test:*** not reported	**Existing condition** ***Source:*** Smith et al. 2004 ***Sampling design:*** 15-minute call surveys, ponds visited at least 3 times in spring and summer; and 1-hour visual encounter surveys ***Data:*** collected—presence and abundance ***Statistic:*** not reported ***Test:*** not reported

Appendix A: Sampling design and data analysis (continued).

Indicator: Bats	
Reference condition	**Existing condition**
Source: Turner and Davis 1969	***Source:*** Schmidt et al. 2004
Sampling design: not reported	***Sampling design:*** mist net; call recording
Data: diversity	***Data:*** presence
Statistic: not reported	***Statistic:*** not reported
Test: not reported	***Test:*** not reported

Appendix B: GIS data sources and products

Data set	Type	Year produced	Producer	Description
MORU Location Map	Shapefile	2009	CALMIT[1]	Location map of MORU within the Black Hills
Palmer Drought Severity Index	Shapefile	2008	National Drought Mitigation Center	Percentage of time severe and extreme drought in the U.S. 1895–1995
Ambient Sound	Shapefile	2008	Volpe 2008	Existing ambient sound without air tours
MORU watershed	Shapefile	2009	CALMIT	Middle Cheyenne Spring Creek watershed
MORU streams	Shapefile	2009	CALMIT	Stream network within MORU
MORU vegetation	Shapefile	1998	Salas and Pucherelli 1998	MORU vegetation/land use
MORU habitats	Shapefile	1998	Salas and Pucherelli 1998	MORU habitat—recode of MORU vegetation
MORU birds	Shapefile	2005	Adapted from Panjabi 2005a	MORU bird monitoring points
MORU pine beetle	Shapefile	2009	Adapted from Symstad and Bynum 2005; and Bynum 2008	Presence and risk of infestation of mountain pine beetle in forest stands at MORU
MORU land cover	Grid	2008	USGS	MORU land cover change as produced by the USGS using NLCD 1992 and 2001 retrofit products
MORU macro_fish	Shapefile	2009	Adapted from White et al. 2002; and Rust 2006	Aquatic macroinvertebrate and fish sampling

[1] Center for Advance Land Management Technologies

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