Fire and Forest History at Mount Rushmore National Memorial: Application and Demonstration of Fire Science

Final Report to the Joint Fire Science Program

Project # 05-2-1-26

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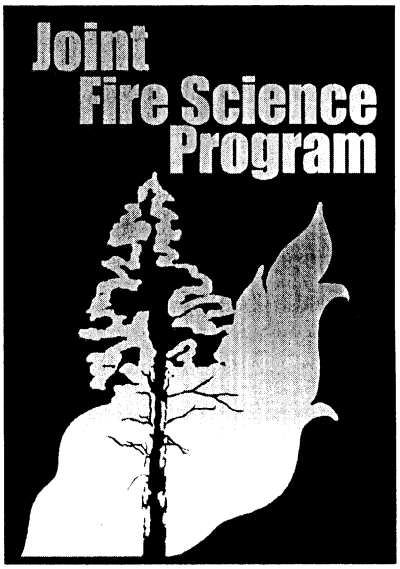

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Project Location:
Mount Rushmore National Memorial, Black Hills, South Dakota

Project Summary

Mount Rushmore National Memorial in the Black Hills of southwestern South Dakota is known worldwide for its massive sculpture of four of the United States' most respected presidents. However, the sculpture is surrounded by extensive ponderosa pine (*Pinus ponderosa*) forest that has not burned in over a century. We compiled dendroecological and forest structural data and used fire behavior modeling to reconstruct the historical fire regime and forest structure and compare these to current conditions. Our overall objective was to provide data needed for an ecological restoration program designed to reduce crown fire hazard and restore ecosystem structure and function across the 517 ha Memorial.

The historical fire regime at Mount Rushmore is best characterized as one of low-severity surface fires with occasional (> 100 years) patches (< 100 ha) of passive crown fire. We estimate that ~3.3% of the landscape burned as crown fire during 22 landscape fire years (recorded in at least 25% of plots) between 1529 and 1893. The last landscape fire was in 1893. Mean fire intervals varied depending on spatial scale, from 34 yrs based on scar-to-scar intervals on individual trees to 17 years between the landscape fire years. Modal fire intervals were 11 to 15 years and did not vary with scale. Fire rotation (the time to burn an area the size of the study area) was estimated to be 30 yrs for surface fire and 800+ yrs for crown fire based on the landscape fire years. Tree densities, basal areas, and canopy base heights reconstructed from the historical forest in 1870 were significantly different ($P < 0.01$) than structural conditions measured in the current forest. The current forest contains more smaller-diameter trees, fewer large trees, and lower canopy base heights than the historical forest. Fire behavior modeling using the Nexus Fire Behavior and Hazard Assessment System suggests that surface fires would have dominated fire behavior in the 1870 forest during both moderate and severe weather conditions, while current forest structure would support both passive and active crown fire. Changes in the fire regime and forest structure at Mount Rushmore parallel those seen in ponderosa pine forests from the southwestern United States. Restoration of both forest structure and surface fires, if done in the near future, could prevent catastrophic wildfire from occurring and adversely impacting the ecological and aesthetic setting of the Mount Rushmore sculpture. The abundance of old and large ponderosa pine trees make restoration to historic stand structure within a short time frame more feasible than in most of the Black Hills, and this area could be a valuable reference landscape for Black Hills old-growth forest conditions.

Objectives and Outcomes

Objective 1 was to document changes in the historical fire regime - including the relative proportion of crown to surface fires - and forest structure at Mount Rushmore National Memorial (MORU) over the past several centuries.

- We used a systematic sample design to collect increment cores and cross sections from 988 ponderosa pine and 12 trees of other species (3 each of burr oak, aspen, paper birch and white spruce) from 29 gridded plots across the MORU landscape. We also collected tree and stand structural data (tree density, basal area, and canopy base height) for each plot.
- We successfully crossdated a total of 902 trees. We then compiled fire and tree recruitment chronologies for each plot to document stand histories and fire frequency, seasonality, severity, and spatial patterning. The oldest trees extended back to the early 1300s.
- Historically (from 1529 to 1893) fire varied by spatial scale, from a mean fire interval (MFI) of 34 years on individual trees, to 16 years for fires that burned somewhere within MORU, to 17 years for fires that burned at least 25% of the landscape. The last widespread fire occurred in 1893.
- During most years, fires occurred late or post growing season, likely from August to October.
- A major goal of the project was to estimate the relative proportions of crown to surface fire in an effort to determine if MORU historically experienced a "variable-severity" fire regime in the past. Variable-severity fire regimes are those in which both surface and crown fire behavior occurred, either spatially during individual fires or in individual stands through time. We found that although there is evidence of crown fire in the tree-ring reconstructions, surface fire dominated fire behavior over the past *c.* five centuries. Only 223 ha were estimated to have burned in crown fires out of a total of 6529 ha burned in 22 landscape fires between 1529 and 1893, or ~3.3% of the total area burned. We conclude that MORU did not experience a variable-severity fire regime, but one that is best characterized as one of low-severity surface fires with occasional (> 100 years) patches (< 100 ha) of passive crown fire.
- Current forest structure measured in 2005 - including tree densities, basal areas, and canopy base heights - significantly differed ($P < 0.01$) from reconstructed conditions in 1870. The current forest - similar to ponderosa pine forests throughout the western US - contains more smaller-diameter trees (because of exclusion of episodic surface fires that would have thinned seedlings and saplings

before they had a chance to establish in the overstory), fewer large trees (both because of timber harvest in parts of MORU as well as recent death of older trees due to asymmetric competition with doghair trees), and lower canopy base heights than the historical forest. Although there was considerable structural heterogeneity in the historical forest including the presence of dense stands, in general there has been a shift in density from relatively open to relatively closed stands across the range of variation in basal areas in the current forest.

Objective 2 was to model likelihood of crown fire incidence and extent in historical and current forests to gauge changes in crown fire risk and effects of potential mitigation measures.

- We used the Nexus Fire Behavior and Hazard Assessment System to model fire behavior based on surface and crown fuels, weather conditions, and environmental variables. Surface and crown fuels were estimated based on reconstructed conditions for the historical forest in 1870 and measured data from the forest in 2005.
- Structural conditions in the majority of historical stands in 1870 during both moderate (expected in 20% of fire seasons) and severe (expected in 3% of fire seasons) weather conditions were not capable of supporting crown fires. During moderate weather conditions only one stand out of 29 was estimated to be capable of supporting crown fire, which rises to 6 under severe weather conditions. Increased tree densities and the presence of many younger trees with lower canopy base heights in the 2005 forest have increased the likelihood of both passive and active crown fires, especially under severe weather conditions. Almost half of the stands are now capable of supporting crown fire even under moderate weather conditions, and almost 80% under severe weather conditions. Also based on changes in the crowning index, the 6.1m windspeed required to sustain active canopy burning, we found that the majority of the forest in 1870 was not at high risk for crown fire while the majority of the current forest is.

Objective 3 was to communicate results and implications of our findings to NPS personnel, managers of similar ponderosa pine forests in the Black Hills and elsewhere, and the public.

- A field trip was held with NPS fire, protective, and interpretive staff members in May, 2007, to discuss the implications of our results for restoration efforts in the Memorial, including thinning and prescribed fire. These include thinning of almost

all trees <20 cm in diameter to restore stand structure, exploring alternative methods for handling of resulting activity fuels, raking of duff and litter from around old trees to reduce likelihood of mortality from duff smoldering, and application of prescribed surface fires to restore fire as an ecosystem process. Initial application of surface fires could take place over the entire Memorial with the exception of developed areas, with subsequent applications using the spatiotemporal range of intervals reconstructed from the historical data as a guide. We also discussed a followup monitoring program to assess overstory and understory responses to restoration, using the MORU area as a model for old-growth forest conditions throughout the Black Hills.

- Cross sections from eight trees have been made into displays for both the Memorial Visitor Center and interpretative staff. Ongoing discussions will incorporate the historical data into interpretative programs and displays, including for an interpretative trail that is being planned for the Memorial.
- Study results have been presented in numerous professional talks and meetings (details in the following project deliverables section).
- A manuscript describing the results of the study has been submitted to the journal *Ecological Applications*.
- Further meetings and field trips are planned with NPS and Black Hills National Forest staffs as implementation of restoration treatments at MORU and adjacent forest lands occurs in fall, 2007, and afterwards.

Project Deliverables

Proposed	Delivered	Status
Website	http://www.rmtrr.org/MORU/MORUfirehistory.html	Done
Publications	Brown, P.M., C.L. Wienk, and A.J. Symstad. In review. Fire and forest history at Mount Rushmore. *Ecological Applications*.	Submitted, August 2007
Presentations	1) Brown, P.M., C.L. Wienk, and A.J. Symstad. 2006. Historical fire and forest structure at Mount Rushmore and implications for forest management. Black Hills Botanists and Ecologists Annual Meeting, Rapid City, SD; March 8. 2) Brown, P.M. 2006. Climate and fire effects on tree recruitment in the western US. 7th International Conference on Dendrochronology, Beijing, China; June 12. 3) Brown, P.M. 2006. Dendroecological evidence for variable-severity fire regimes in ponderosa pine forests. Conserving and Restoring Frequent Fire Landscapes of the West: Linking Science, Collaboration and Practice, Flagstaff, AZ; October 24. (Invited) 4) Brown, P.M. 2006. The evidence for mixed-severity fire regimes in Black Hills ponderosa pine forests. Third International Fire Ecology and Management Congress, San Diego, CA; November 15. (Invited) 5) Brown, P.M. 2007. Multi-proxy, Multi-century, Multi-scale fire and forest histories from tree-ring data. US-International Association for Landscape Ecology Annual Meeting, Tucson, AZ; April 10. (Invited)	Done
Tours/Site Visits	Restoration planning field trip, Mount Rushmore and NPS fire management staff, May 2007	Done
Interpretive displays	Cross sections for Memorial Visitor Center and Interpretative Staff	Done

Acknowledgments

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