The Extent and Significance of Old-growth Ponderosa Pine Forest at Mount Rushmore National Memorial

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SUMMARY

Mount Rushmore National Memorial (MORU) is a small portion – 517 ha (1,278 acres) – of the 1.5 million ha (3.8 million acres) that comprise the Black Hills. However, because it has been protected from logging and other extractive activities since the late 1930's, it may serve as an important part of the Black Hills forest as a whole. To understand this role, we determined the extent and location of unlogged and old-growth forest stands in the park using historical documents and field investigations. Our results suggest that approximately 29% of the park has had no tree harvesting activity, and 18% of the park has had selective cutting of larger trees. Some of these unharvested areas have had recent thinning of small trees. When "old-growth" forest is defined according to the only published description of "old-growth" Black Hills ponderosa pine forest (Mehl 1992), 365 ha (901 acres) of old-growth ponderosa pine forest occur in the Memorial; this is 83% of the area we surveyed and 71% of the Memorial as a whole. All of the forest in the undeveloped portions of the Memorial is in a "mature" structural stage. Based on current estimates of similar forest in the Black Hills National Forest and Custer State Park, the forest at MORU constitutes the second-largest area of old-growth ponderosa pine forest in the Black Hills (the largest being at Custer State Park). This forest provides habitat for species dependent upon mature forest that is rare elsewhere in the Black Hills. For example, Red-breasted Nuthatch densities are greater at MORU than in forest typical of the Black Hills National Forest. The close proximity of MORU's old forest to other old, relatively undisturbed ponderosa pine forest in the Black Hills in the National Forest and Custer State Park is also significant. The forest is not pristine, however, even in apparently unharvested areas. More than a century of fire suppression has increased the density of trees, particularly younger ones, as well as standing and downed dead wood, beyond that of pre-settlement times. These increased densities put the MORU forest in danger of intense, perhaps stand-replacing fires, that would likely be more intense than in pre-settlement times. Ongoing research will provide a clearer picture of management and restoration targets for the Memorial's forests.

In the mean-time, the importance of this natural resource should be of interest to visitors that come to see the Shrine of Democracy. To put things into perspective, the oldest trees within the MORU forest (that we found) were seedlings just 27 years after Christopher Columbus reached the American continent. The average large tree at the Memorial today was already 13

years old when the Declaration of Independence was signed. The forest itself is a memorial to an ecosystem that has changed drastically in the last 170 years.

Introduction

The Black Hills of western South Dakota and southeastern Wyoming are often described as an island in the prairie. The island metaphor comes not only from their geological and topographical differences from the surrounding plains, but also from the differences in flora and fauna between the hills and their surroundings. Most notably, the Black Hills are named for the dark appearance they have when viewed from a distance – a darkness caused by the dark green foliage of the ponderosa pine (*Pinus ponderosa* P. & C. Lawson) forest that blankets the hills. Within the forest is a mixture of species from western conifer forests, eastern hardwood forests, neighboring prairies, and other regions of the continent . Although ponderosa pine, as a species and as a forest type, occurs over a large part of western North America, from Mexico to British Columbia and from western Nebraska to the Pacific coast (Little 1971), the combination of species and ecosystem processes in the Black Hills makes the Black Hills ponderosa pine forest a unique ecosystem.

Mount Rushmore National Memorial (MORU) is a small portion – 517 ha (1,278 acres) – of the 1.5 million ha (3.8 million acres) that comprise the Black Hills (Froiland 1990). However, because it has been protected from logging and other extractive activities since the late 1930's, it may serve as an important part of the Black Hills forest as a whole. Euro-American settlers were relatively slow to enter the Black Hills, which were protected as tribal lands until 1874 (Froiland 1990), but once they did, they did so with a vengeance. The Timber and Mineral Land Free Timber Act of 1878 (U.S. Statutes at Large, Vol. 20, p. 88) provided the public with the free use of timber harvested on mineral and non-mineral lands within the public domain. Consequently, the felling of trees in the Black Hills for mining and domestic interests was legally sanctioned by the adoption of this Act. Unfortunately, Graves (1899, p. 88) found evidence that such laws did not prevent "the reckless waste of timber" in the region, including the cutting of thousands of mature trees that were never removed from the forest floor for any useful purpose, but also meaning that not all trees in area were harvested and used to their fullest extent. Forty-two sawmills were in operation in the Black Hills in 1897 (Graves 1899), many of them supporting gold and other mining operations that started in 1875. Estimates of early harvest rates suggest that approximately 160,000 m^3 (67.7 million board feet) of timber were harvested each year between the arrival of Euro-American settlers in the mid 1870's and the establishment of the Black Hills Forest Reserve in 1898 – a total of 1.5 billion board feet harvested in less than

twenty-five years by early pioneers (U.S. Department of Agriculture Forest Service 1996, Mahoney 1998). There were still approximately 10 sawmills active in the Black Hills region during the mid-1990's (U.S. Department of Agriculture Forest Service 1996). These sawmills supported the harvest of timber, largely from the Black Hills National Forest (BHNF), which encompasses approximately 486,000 ha (1.2 million ac) of the Black Hills and largely surrounds MORU. Current annual timber harvests are roughly equivalent to those of the early years of settlement (U.S. Department of Agriculture Forest Service 2003b).

These past disturbances and current practices mean that only a small portion of the forest of the Black Hills has the density of old trees and snags that partially distinguish "old growth." This is significant because many species require the structure and ecosystem processes that characterize old growth forest but do not exist in forest in earlier stages of development. Although this is the reason most often cited for protecting old-growth forest, there are many others (Kaufmann et al. 1992). For example, old-growth areas may harbor genetic resources not found in younger forest stands – those adapted to the environmental conditions of later stages. Old-growth stands also harbor long-term biological records of climate useful for understanding current, and perhaps future, conditions in the context of the past. Old-growth forest can also provide a unique recreational experience. Finally, old-growth areas are part of the cultural and spiritual heritage of indigenous peoples (Kaufmann et al. 1992). For these and other reasons, MORU natural resource managers are interested in understanding the conservation significance of the park's forest in the context of the Black Hills as a whole.

In this report, we describe the results of a study designed to address this information need. The specific objectives of the study, which are addressed in successive sections of the report, were:

1. Determine the logging history of the land within park boundaries.
2. Determine the extent and location of unlogged and old-growth forest stands in the park.
3. Determine the ecological and conservation significance of the forest within the park to the Black Hills as a whole.
4. Identify potential threats to the identified unlogged and old-growth forest stands in the park.
5. Collect and provide to park staff information about the forest of interest to the public to be used in park interpretation and outreach activities.

Logging History of Mount Rushmore National Memorial Property

Historical accounts suggest that extensive wood cutting and timbering have occurred in the area surrounding Keystone, SD, since the discovery of gold along Battle Creek in 1876. The demand for timbers associated with the construction of placer flues, mine shafts, and railroads; lumber for the construction of mine shacks, homes and businesses; and the need for cord wood to drive steam engines, heat buildings, and fuel cook stoves, was prominent for at least 50 years following Euro-American settlement. In addition, first-hand accounts by local residents indicate that some wood for construction and firewood was harvested in close proximity to MORU while the monument was being carved.

Because the city of Keystone and its associated mining district are directly adjacent to Mount Rushmore National Memorial, it is unlikely that the entire area within the park could have escaped the axe. Alluvial deposits of gold were discovered by early prospectors in 1876 approximately 3.2 km (2 miles) east of Keystone, where the pioneer city of Harney sprang up shortly thereafter (Hayes 1998). The first sawmill was erected at this site and began producing lumber for mining operations, new businesses, and domestic dwellings along the banks of Battle Creek in early 1877 (Linde 1984). Commensurate with the presence of valuable ores containing gold, silver, tin, arsenic, feldspar, mica, and various other minerals, there were at least 36 major groups of mineral claims and associated mining operations to spring up within the Keystone district (Bureau of Mines Staff Region V 1954).[a] Perhaps the most legendary of these is the Keystone Mine-Holy Terror Mine complex. The Keystone Mine was established in 1892, and the Holy Terror Mine was established in 1894. The two were consolidated in 1898 (Bureau of Mines Staff Region V 1954) and operated as the Holy Terror Mining Company.

During the period of 1894-1903, the Holy Terror enjoyed its heyday in gold production, and is reported to have used massive amounts of wood to build and power the mines. Graves (1899) estimated that, collectively, the two mines were using 16-20 cords of wood a day, or 7,200 cords a year, in addition to 2.4 million linear feet of mine shaft timbers each year. Linde (1984, p. 49) quotes longtime Keystone resident Willie Graham as saying, "It took half a dozen teams just hauling wood every day to the Holy Terror where a hundred men worked in two

[a] Indeed, in our field observations, we noted a stone that looked like a corner of a mine claim within MORU boundaries (GPS coordinates 13 T 0625363 easterly, 4860232 northerly, NAD83 projection). We could find no historical records of a claim in this location, however.

shifts." During this same time period, the population of Keystone grew to exceed that of Rapid City (Hayes 1998). Meanwhile, the 2,000 residents of Keystone were dependent upon wood for heating and cooking (Hayes, 2004, pers. comm.). Using figures from Graves' 1899 report, this population would have required at least 5,000 cords of wood each year for their stoves. After the completion of the railroad in 1900, coal was available to Keystone residents; even so, most residents continued to use wood for fuel (Hayes, 2004, pers. comm.). It wasn't until 1927 that Keystone had a reliable source of electricity when the diesel engines arrived for Gutzon Borglum's monumental carving project at MORU (Hayes, 2004, pers. comm.). Hence, it is easy to imagine that numerous timbering crews and other wood-harvesting parties would have been working daily in the forests around Keystone.

Henry S. Graves, a forester with the U.S. Geological Survey (USGS), surveyed the area surrounding Keystone in 1897 and referred to it as the Battle Creek region. His assessment states that of the 178 km^2 (68.7 mi^2) in this region, 32 km^2 (12.4 mi^2) had been cut over for lumber. He does not state how intense this cutting was, i.e., how many trees were left standing, and whether trees of all sizes or just larger trees were cut. However, his descriptions of timber harvesting practices and photographs (**Figure 1**) of harvested areas other than the Battle Creek region suggest that areas were not clear-cut. For example, in the Beaver Creek region of the southern Black Hills, he describes an area being cut at the time of his survey: "The forest which remains after lumbering is chiefly composed of scrubby and defective trees and such as were too small for lumber. … There are, however, occasional trees left which are now suitable for lumber. These trees are scattered…" (p. 100). In an area south of Sylvan Lake where harvesting concentrated on lumber, and not mine props and firewood, "the forest after lumbering is composed of large, defective, scrubby trees and small trees not large enough for saw lumber. There are usually as many trees left as have been taken, and often two and even three times as many" (p. 111). Because of the mining industry in Keystone, harvesting practices in the MORU vicinity were probably more like the former than the latter. A map (Plate XVII) developed by Graves indicates that approximately 15 km^2 (5.8 mi^2) (from Arc/Info calculations by Brumm, 2004, pers. comm.) directly adjacent to and contiguous with the town of Keystone had been cut over by the time of his survey. The bulk of these lands are west and south of the city, and they include portions of what is now within park boundaries. According to this map and best attempts to match it to current maps, we estimated that timber harvest had occurred in roughly 42% of

MORU's current boundaries by 1897. The whole northeastern corner, a portion of the southeastern corner, and the center of the Memorial are included in this area (**Figure 2**).

Somewhat ironically, the historical record of logging in the Keystone and Mount Rushmore area does not improve after this time. The reason for Graves' survey of the forest in the Black Hills in 1896-97 was the creation of the Black Hills Forest Reserve (BHFR), which apparently completely encompassed the current property owned by NPS within the Memorial's boundaries[a] (U.S. Department of Agriculture Forest Service 1996). The Forest Reserve Act of 1891 (U.S. Statutes at Large, Vol. 26, p. 1095) gave the President of the United States the legal prerogative for creating Forest Reservations in an effort to protect the timberland resources of the nation. On February 22, 1897 the BHFR was created by President Grover Cleveland (U.S. Statutes at Large, Vol. 29, p. 902). However, the boundaries of the Reserve were not officially delineated until President William McKinley declared their limits on September 19, 1898 (U.S. Statutes at Large, Vol. 30, p. 1783), which is now recognized as the date of origin of the BHFR. The Forest Reserve Organic Administration Act (a.k.a. the Organic Act, U.S. Statutes at Large, Vol. 30, p. 32) of June 4, 1897, provided the legal prescriptions for managing the BHFR and other public forests in an effort to conserve timber and watershed resources. Settlers, proprietary miners and prospectors were still provided with free timber, but were required by law to seek a permit when harvesting trees on public lands (Pinchot 1905, Sharpe et al. 1995). Large mining operations, on the other hand, were not given free use of timber and entered into timber sale agreements with the federal government in order to purchase large quantities of trees. For instance, the first timber sale on Reserve lands in the U.S. was executed in the Black Hills to the Homestake Mining Company of Deadwood, SD (Mahoney 1998). Consequently, this Act ushered in a new era in the federal regulation of timber harvesting on what would later be known as "National Forests". [On March 4, 1907, the Black Hills Forest Reserve became the Black Hills National Forest (BHNF), and all U.S. Forest Reservations had a similar name change at this time.] The irony of this new era of regulation is that there seems to be little historic record of this regulation remaining today. We could find no historical documents, such as U.S.

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[a] Forty acres of land within the Memorial's boundaries but currently owned by the State of South Dakota (SW ¼ SW ¼ Sec. 8, T.2S R.6E; or the parcel of land encompassing the Iron Mountain Road-Highway 244 junction) appear to be the only property within the boundaries that was ever privately owned. This parcel was purchased from the U.S. government on October 12, 1900, and a homestead patent granted to Mr. Roy in 1905. The property changed hands at least two more times before it was sold to the South Dakota State Park Board in May 1928 (Pennington County Record of Deeds). We found no other records of deeds for any of the property within the Memorial's boundaries in the Pennington County records.

Department of Agriculture (USDA) Forest Service timber sale records, to provide harvesting information after 1897. Current Forest Service employees within the BHNF believe that such records either have been lost or are not catalogued and are therefore extremely difficult to find (B. Cook and D. McKee, pers. comm.)..

The land comprising the present-day Mount Rushmore National Memorial remained a part of the National Forest system only until 1920. Following a Presidential Proclamation by William H. Taft (U.S. Statutes at Large, Vol. 37, p. 1680), the southern half of the BHNF and various unreserved lands belonging to the State of South Dakota were joined to create the Harney National Forest in 1911. In 1920, approximately 12,145 ha (30,000 ac) of Harney National Forest were set aside to form the Custer State Park Game Sanctuary (CSPGS), which included approximately 410 ha (1,020 ac) of the land that is now within MORU boundaries (U.S. Statutes at Large, Vol. 41, pp. 986 and 1805). In 1924, Congress approved the expansion of the CSPGS by another 6,478 ha (16,000 ac) (U.S. Statutes at Large, Vol. 43, p. 632) which apparently resulted in the present-day Memorial being entirely within the CSPGS; a 1937 National Park Service map (in MORU Collections) indicates the Memorial as being within the CSPGS. Information on land management practices within the boundaries of the CSPGS between 1920 and 1940 is extremely fuzzy. Disputes as to whether the federal or state governments owned certain parcels of land, and therefore had timber management rights thereof, occurred during this time period in the vicinity of Mount Rushmore, but whether the land currently in the Memorial fell into this area of dispute is not clear. However, there was state legislation in 1927 that halted timber harvesting within state park boundaries because of wasteful practices (B. Hill, Custer State Park Senior Forester, pers. comm.). Thus, management of the Memorial was potentially different between 1897-1920 and 1920 to the time of National Park Service acquisition of the property.

The carving of Mount Rushmore was enabled by federal (U.S. Statutes at Large, Vol. 43, p. 1214) and state (Chapter 232, Session Laws, 1925) legislation in 1925. The state law also established the Mount Harney Memorial Association as an oversight committee for the project (Fite 1952). This committee was replaced by federal regulation on February 25, 1929, when the Congress of the United States established Mount Rushmore National Memorial (U.S. Statutes at Large, Vol. 45, p. 1300). In this same action, the Mount Rushmore National Memorial Commission (MRNMC) was created as an independent governing body to oversee the

completion of the project. The Commission was charged with all financial and managerial aspects of the undertaking, while receiving all property related to the project, including the granite cliffs of Mount Rushmore where the carving was taking place. The National Park Service (NPS), assumed the administrative responsibilities of the Commission and the Memorial over the course of several years, from 1933 to 1939 (Fite 1952). In 1938, a congressional budget act (U.S. Statutes at Large, Vol. 52, p. 694) charged the Commission with delineating up to 1,500 ac (607 ha) of the surrounding Harney National Forest (i.e., the CSPGS) as Memorial grounds, an area sometimes referred to as the Rushmore Memorial Reservation on early maps. Hence, Mount Rushmore National Memorial was officially expanded beyond the granite cliffs of the mountain with the passage of this Act, in June of 1938. Another adjustment to the Memorial boundary was made on October 6, 1949 (U.S. Department of Interior National Park Service 2003).

In summary, the land upon which the Memorial is situated has been managed in modern times (post-1897), at least theoretically, by a host of federal and state entities including: The U.S. Department of Agriculture Forest Service, or its predecessors (e.g., the Division of Forestry [1898-1901] and the Bureau of Forestry [1901-1905]); the South Dakota State Park Board; the Mount Harney Memorial Association; the Mount Rushmore Memorial Commission; and the U.S. Department of Interior National Park Service. Little information exists as to how each of these agencies managed the property, (i.e., whether timber harvest was permitted, and if it was, how much), though it can be assumed that once the property was under complete NPS control, all commercial logging activity therein ceased. Some anecdotal information for this time period does exist, however, in the form of memories of local residents. Robert Hayes and Nick Clifford, both longtime residents of Keystone, recall cutting dead trees for firewood on what is now the Memorial. Nick worked on the granite faces of Mount Rushmore from 1938 to 1940 as a driller and winchman. He was also involved in the construction of the Sculptor's Studio and in woodcutting (Clifford, 2004, pers. comm.). Besides peeling logs for the studio, which were harvested "in the vicinity" by his brother and another skidder, Nick cut firewood on the site for heating the bunkhouse and fueling the cook stoves in the kitchen. Robert Hayes, a retired mining engineer, local historian, and former seasonal employee at MORU, remembers cutting dead trees for firewood with his father along Horse Thief Lake Road (the road that became the current Highway 244) and in the area of the parking lot adjacent to the present day Sculptor's Studio

(Hayes, 2004, pers. comm.). In addition, the NPS has cut some trees in various areas of the park for safety reasons, including thinning the understory to reduce fire danger. Thus, although commercial logging has not occurred within park boundaries since 1939, all trees in the forest have not been spared the axe or saw since then. In addition, historical records (Graves 1899) suggest that approximately 42% of the park had been harvested to some degree prior to 1897.

Extent and Distribution of Unlogged Forest at Mount Rushmore National Memorial

This historic record obviously leaves much to be desired in understanding the logging history of MORU. Aside from the almost complete lack of documents indicating how the property was managed between 1897 and 1939, the area that Graves (1899) documented as being cut-over in 1897 is difficult to reconcile with the current landscape because of improvements in mapping since that time. Consequently, we supplemented our research on the logging history of MORU with field work.

During the summer of 2004, we visited 200 points throughout the majority of the Memorial. For logistical reasons, we did not work in the area restricted to general public access (near the main administration building and surrounding Mount Rushmore) or in areas near there with high proportions of bare rock (**Figure 3**). This eliminated approximately 12% of the park from consideration for sampling. The points were established with a Geographic Information System (GIS) by arranging a systematic grid in which the east-west distance between points was approximately 240 m (780 ft) and the north-south distance approximately 135 m (439 ft) over the park.

In the field, we located each point using recreation-grade Global Positioning System receivers. At each point, we first decided whether the point was suitable for data collection. Points on a road or developed area, or within their zone of influence (e.g., trees removed and area mowed), were deemed not suitable. In some cases, we moved the point slightly (30-50 m) to avoid being on treeless rock outcrops. These restrictions limited our data collection to 169 points (**Figure 3**). After we decided a point was suitable for data collection, we counted all cut stumps within a 25 m (81 ft) radius of the point, keeping separate counts for “old” and “new” stumps. Old stumps were in a state of decay that indicated they were cut more than twenty years ago (**Figure 4**); these were generally large diameter and sometimes showed evidence of having been cut with an axe. New stumps were relatively intact (bark usually still on the stump) and

almost exclusively small diameter, resulting from fire-hazard reduction thinning (**Figure 4**). In addition, we located the tree within the 25 m radius with the largest diameter at breast height [DBH = 1.37 m (4.5 ft) from the mid-slope base of the tree]. These were all ponderosa pine. For this tree, we recorded its DBH, height, and the degree and aspect of the slope on which it stood. We also used an increment borer to extract a 5.15 mm (0.200 inch) diameter core from the lowest point possible (usually approximately 30 cm) on the mid-slope portion of the tree. We dried, mounted, and sanded the cores, then used standard dendrochronological techniques to determine the tree's age and the year or years in which the tree may have been released from competition with other trees, potentially because of logging activity. These techniques included using skeleton plots to compare ring width patterns to those of a composite ring-width index compiled from trees cored in the central Black Hills[a] (Meko and Sieg 2004). Release dates were defined as those dates corresponding to an increase in ring width not occurring in the reference index.

Sixty-six (39%) of the 169 points had no old stumps in the approximately 0.2 ha (0.5 ac) area we surveyed for each point, and an additional nine points had just one old stump (**Figure 5a**). Interestingly, an area in the southern portion of the park with no old stumps was indicated as having been cut-over by Graves in 1897 (**Figure 5b**). In general, the density of old stumps was consistent with expectations, in that areas near Keystone had the greatest number of stumps per point (**Figure 5c**). Density of old stumps also tended to be higher in areas of more gentle topography, as evidenced by inspection of the location of the stumps on a topographical map (**Figure 5b**). Two components probably contributed to this pattern. First, ease of access to a site and transport of logs after cutting them was likely an important determining factor in where trees were harvested. Second, trees in areas with more moisture (generally in valleys and in less steep areas) tend to be larger, and therefore more valuable for timber.

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[a] A skeleton plot indicates deviation of ring width from normal by year by the length of line on the plot. One skeleton plot is made from standardized ring widths determined by compositing ring widths, by year, of many trees in the area of interest, in this case the central Black Hills. A year in which most trees had a very narrow ring (indicating, for example, a severe drought; large magnitude negative ring-width index) would be indicated on the plot by a long vertical line, and a year in which most trees' rings were average width (ring-width index near zero) would have no line. A similar plot is made for an individual tree, in which the observer does not actually measure ring width but uses her judgment to gauge its width against other rings in the vicinity on that core. The plot from the individual tree is then compared to the plot from the index, matching distinct patterns of line lengths. This method corrects for missing or "false" rings (more than one ring per year) to more accurately determine the age of a tree than by simply counting rings.

We were not able to determine dates of logging from our methods. At only nine points (5.3%) did the largest trees have post-settlement germination dates, which might indicate post clear-cutting establishment. However, the density of stumps in at least some of these points does not suggest that high-intensity logging occurred there; three of these points had no stumps, and one point had just four stumps. Although ring widths from many cores indicated years of release for specific trees, 70% of these dates were before 1876 when Euro-American settlers first came to the area (**Figure 6**). Also, many of the areas with old stumps, even those with the greatest old stump density, showed neither post-1875 release dates nor post-1875 germination dates for the largest trees. In addition, five points with no old stumps had post-1875 release dates (**Figure 7**). Consistencies in release dates within two areas do hint at certain logging dates, however. In the area of the park closest to present-day Keystone, three trees with release dates of 1896 might indicate that as a year of logging for that location, and three trees with release dates of 1927 or 1928 just west of Lafferty Gulch might indicate a period of logging for that area (**Figure 7**).

There are many possible reasons why we were not successful in determining dates of logging. First, we did not use the most sensitive or objective method for determining dates of release. Quantitative measurements of the widths of all rings on all cores with subsequent standardization of ring widths for tree size and locale are required for the most accurate detection of release dates unique to a small area that might indicate logging. This very labor and time-intensive methodology was beyond the scope of this study. Second, it is possible that logging intensity was low enough that remaining trees did not benefit significantly from the reduction of tree density. Third, approximately half of the trees we cored were relatively old (>100 years), and therefore potentially less sensitive to decreases in neighboring tree density, at the time of Euro-American settlement. Finally, the pre-settlement density of trees may have been sufficiently low, due to frequent, low-intensity fires, that competition between neighboring trees was not great enough that removal of some trees would significantly benefit others. Further, more intense research that will build upon our results will begin in September 2005 (Wienk et al. 2004); it may shed some light on the times when various areas of the Monument were logged.

Our field data support Graves' observations that loggers of the late 19th century left many trees standing but that older trees were usually removed. Old stump density and sampled large tree age were weakly negatively correlated ($r^2 = 0.09$, $P < 0.0001$; **Figure 8**), which suggests that in more intensively logged areas, all older trees were removed. For example, in the areas with

the highest old stump density (indicated by the largest symbol size in **Figure 5c**), the largest trees today are 175 to 257 years old. These trees would have been 47 to 129 years old at the time of earliest settlement, perhaps too small at the time to be worth cutting – trees were considered suitable for mine timbers at about 80-100 years and suitable for lumber at approximately 150 years (Graves 1899, p. 95). Our field data also support statements by the local residents we interviewed and expectations about timber harvest from MORU's proximity to a large mining district. Graves (1899) characterized the forests around Keystone as having, on average, 10 merchantable trees and 21 other trees per half acre (p. 121). Since the area we surveyed around each point was this same size, points with more than 10 stumps were probably logged for more than just the best trees. This is of course a generalization, as density of trees of different size classes undoubtedly varied from one location to the next. However, it does suggest a cut-off (10 old stumps per point) for distinguishing intensively logged areas from areas that were more selectively cut.

To summarize our findings on the logging history of MORU, Graves' (1899) maps indicate that roughly 42% of the land within current park boundaries had been cut-over by 1897, although we observed no old stumps in part of the area that he indicated as having been cut-over. Loggers at that time did not use clear-cut methods; many trees were left standing because they were not deemed suitable for lumber at that time. Of the area we surveyed, 39% of the points had no old stumps that would indicate logging had occurred there, and 25% of the points had between 1 and 9 old stumps, indicating selective, rather than intensive, cutting. The spatial distribution of these points suggests that nearly all of the southern third of the park, as well as a section in the northwest corner of the park, could be considered as either not logged at all, or only selectively cut, based on our observations (**Figure 5c**). In our field work, we did not survey 59 of 228 points in the park, 41 because they were heavily disturbed by buildings and/or roads and 18 because they were inaccessible or had little or no forest because of large rock outcroppings. Using these figures (i.e., assuming that the heavily disturbed areas do not qualify as unlogged or selectively cut), our results translate into 29% of the whole park having no historical logging, 18% having selective cutting, and 8% having unknown status due to lack of sampling. Some of the apparently selectively logged areas have had extensive thinning however, particularly just south of Highway 244 in the western portion of the park (**Figure 9**). It should be noted that, although our field observations provided more complete information than what we

could glean from historical documents, we could have missed some areas that were logged if all historically cut stumps in an area had completely burned and/or decayed. The ubiquity of fire scars on large trees and stumps throughout the park (**Figure 10**) suggests that the former is particularly possible, although there are no records of fires within the park since Euro-American settlement (U.S. Department of Agriculture Forest Service 2003a).

Extent and Distribution of Old-growth Forest at Mount Rushmore National Memorial

Our field work and historical documentation suggest that slightly less than a third of the forest at MORU has not been logged to any extent, and part of this unlogged area (6 of 66 points) has had some recent thinning activity. This does not necessarily mean that less than a third of the area of MORU could be considered as having old-growth forest, however. The portion of the forest at MORU that can be considered old-growth depends on the definition of old-growth, and a concrete definition does not exist, partially because the term "old-growth" means different things to different people.

Some might think a forest must be "pristine" or "virgin" to be old growth, implying that humans have had no impact on the forest. This does not exist anywhere, but especially in the Black Hills, for three reasons. First, humans have been part of the forest ecosystem of the Black Hills for thousands of years (Froiland 1990), using forest products for food and shelter and probably setting fires for various reasons (Graves 1899). Second, since Euro-American settlers entered the Black Hills, they have brought new species that have infiltrated even the least disturbed areas, altered the abundance of various wildlife species, and suppressed fires, a vital process of the Black Hills ponderosa pine forest ecosystem (Brown and Sieg 1999, Brown et al. 2000), causing significant changes in stand structure and tree density (Progulske 1974, Grafe and Horsted 2002, Brown and Cook in press). Finally, regional and global human impacts on climate and atmospheric composition have also affected all forests in the world.

An ecological definition of old-growth forest, on the other hand, depends on scientifically determined ecological conditions. Specifically, a group of forest scientists convened in 1992 to devise a generic definition of old-growth forest. Their resulting definition was: "Old-growth forests are distinguished by old trees and related structural features. Old-growth encompasses the later stages of stand development that typically differ from earlier stages in structure, composition, function, and other attributes" (Kaufmann et al. 1992). This definition stresses that

it is important to remember that, in an ecological sense at least, old-growth forest is one of many stages in a successional pathway. The presence of trees near the end of their natural life span is important, but not enough, to have old-growth forest (Moir 1992). The ecological definition of old-growth for a specific forest type, such as Black Hills ponderosa pine, also depends on structural and functional aspects of the forest. For example, in most forest types, ecological old-growth is characterized by trees in decline (structural characteristic) (Moir 1992), as well as by net ecosystem productivity being lower than in mature stands (Law et al. 2001, Irvine and Law 2002, Desai et al. 2005).

For many forest types, sufficient information does not yet exist to determine all of the ecological criteria that distinguish the old-growth stage from other successional stages. Consequently, rigorous definitions of old-growth do not exist for many forest types, including Black Hills ponderosa pine forest. Currently, the USDA Forest Service uses a combination of objective and subjective methods to determine whether or not to designate a forest stand as old-growth[a] in the Black Hills National Forest (U.S. Department of Agriculture Forest Service 2004). A potential old-growth stand is identified by structural characteristics determined from a stand exam. Stands that are categorized from this exam, using purely quantitative methods (U.S. Department of Agriculture Forest Service 1993), as "mature" (structural stage 4) can be considered as potential old-growth stands. To designate a stand as old-growth (structural stage 5), however, the district silviculturalist and wildlife biologist must inspect the stand in the field, where they look for other characteristics, such as the amount and quality of standing and downed dead wood. Specific guidance for determining these characteristics comes from a description of old-growth Black Hills ponderosa pine forest published by Mehl (1992). According to this description, old-growth in the Black Hills has at least ten live trees per acre (24.7 trees/ha) that are larger than 16 inches (40.6 cm) DBH and the average age of these large trees is at least 160 years. In addition, it has at least two dead, standing trees per acre (4.9 trees/ha) that are larger than 10 inches (20.5 cm) DBH.

This description is useful for a couple of reasons. First, it is published and therefore reproducible in the field. Second, it is based on quantitative measures of forest structure obtained through a standard methodology, the USDA Forest Service stand exam (U.S.

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[a] The preferred term in the Forest Service is "Late Successional" but we will continue to use "old-growth" to refer to the same thing.

Department of Agriculture Forest Service 1993). However, this description is somewhat minimal, as well as controversial. For example, the criteria used to describe old-growth are based on canopy structure, tree size, and dead wood. It does not describe understory or ground vegetation characteristic of old-growth stands. In addition, it does not necessarily describe the structure of an old-growth forest as would have occurred prior to European settlement, since relatively frequent fires would have influenced the amount of standing and down dead wood, as well as the density of large, old trees (Brown and Cook in press). Finally, given the variability in fire regimes across the Black Hills, it is probable that two different types of old-growth forest could have existed: one more savanna-like with widely spaced, large trees and a nearly continuous herbaceous ground layer in more frequently burned areas, the other more closed-canopy and with trees of various ages and sizes in less frequently burned areas (Brown 2003).[a]

Despite these shortcomings, this is the definition of old-growth we chose to use for the purposes of this report, primarily for the reasons given at the beginning of the preceding paragraph. Consequently, the method we used for determining the extent of old-growth forest at the Memorial is the stand exam. This general process is thoroughly described in the USDA-Forest Service Handbook 2409.17 (U.S. Department of Agriculture Forest Service 1993). In summary and specific to MORU, stands were delineated by visual examination of aerial photographs. A minimum of four (range 4-10, depending on stand size) sampling points within each stand were scattered approximately evenly through each stand (**Figure 11**). At each point, trees were measured using a variable radius plot (Basal Area Factor 20[b]) for all live trees greater than 5 inches (12.7 cm) DBH, a small fixed plot (radius 6.8 feet, or 2.07 m) for all live trees less than 5 inches (12.7 cm) DBH, and a large fixed plot (radius 58.9 feet, or 17.95 m) for all standing or down dead trees. For each tree measured, information on its size (DBH and height), crown structure, condition (disease or damage), and a variety of other factors were recorded. Two trees at each point were cored and their ages estimated by counting rings in the field. The data were then processed using RMStand, a USDA Forest Service program, to determine the

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[a] This dichotomy is one reason that the USDA Forest Service uses the term "Late Successional" instead of "old-growth", since forests designated as such so far all fit the closed-canopy description, not the savanna-like description (B. Cook, BHNF Silviculturalist, 2004, pers. comm.).

[b] Basal Area Factor (BAF) 20 means that all trees of the size that would produce a basal area of 20 square feet/acre are included in the plot measurement. Consequently, the larger the tree, the greater the distance from the center point of the plot it can be and still be included in the plot. Field samplers use an instrument such as an optical prism or Spiegel Relaskop specifically designed to determine whether a tree is included in the plot measurement based on the chosen BAF, recording all trees meeting that criterion in a 360º arc around the plot center.

habitat structural stage, origin date, tree density, and many other characteristics of each stand. All of this was done through a contract with the BHNF. We used both the summarized data for each stand and the raw data for each tree in our analyses.

A brief summary of the results of the stand exam are presented in **Table 1**, and **Appendix 1** shows graphs of stem density by diameter class for all stands. Stand structure varies considerably among the stands, with much of this variability due to differences in the density of small trees. The average density of live ponderosa pine trees with DBH > 2.5 cm (1 inch) is 944/ha (382/acre) and the standard deviation is 69% of that (652/ha or 264/acre). In contrast, the standard deviation of density of live ponderosa pine trees with DBH > 20.3 cm (8 inches) is only 30% of the mean (257 ± 77/ha; 104 ± 31/acre). Stands 4 and 22 have a high density of quaking aspen and a relatively low density of ponderosa pine, and stand 18 has a high density of bur oak and paper birch (and low density of pine) compared to most other stands (**Table 1**).

There is also considerable variability within stands, with larger stands generally being more variable among points (**Figure 12**). Total tree density is particularly variable, with eleven of the 26 surveyed stands having a standard deviation at least as large as the mean, and one of these stands (stand 17) having a standard deviation more than twice the mean. Such variability is to be expected in un-managed stands such as those at MORU. However, the variability within stands implies that, although a given stand meets the description of old-growth forest, not all areas within a stand may do so; conversely, areas within a stand may meet the description of old-growth forest even though the stand as a whole does not.[a] Though we do not consider this to be a major issue, the discussion of areas of old-growth at MORU below should be interpreted with this caveat in mind.

All of the stands surveyed at MORU are classified by the RMStand software as mature, and nineteen of the 28 stands surveyed qualify as old-growth using the description in Mehl (1992; Table 2). This yields a total of 365 ha (901 acres) of old-growth ponderosa pine forest in the Memorial; this is 83% of the surveyed area and 71% of the Memorial as a whole. **Figure 13** shows the location of these stands within the park. Comparing this map with that in **Figure 5c** illustrates that even relatively heavily logged areas can still meet the Mehl (1992) description of

[a] We did not analyze stand exam data outside the context of the stands delineated at the beginning of the stand exam for the purposes of defining old-growth areas in order to remain consistent with the manner in which the USDA Forest Service designates old-growth stands.

old-growth. Conversely, at least one area that apparently was not logged does not meet the description (stand 12).

Of the seven surveyed stands that did not meet the description of old-growth, five had an average age of large trees below 160 years and two had fewer than 10 trees per acre of the minimum DBH (**Table 2**). In the latter category, stand 4 likely did not meet the old-growth description because of its location along a draw where aspen are abundant, yielding a relatively low density of large pines. The large pines that do occur there are quite large, yielding the greatest average DBH for pine trees over 20.3 cm (8 inches) DBH for all stands (**Table 2**). Stump density in this location was relatively low (**Figure 5c**), suggesting low-intensity logging occurred in this stand. In contrast, stand 27 also had a density of large (> 16 inches DBH) pine trees too low to meet the old-growth definition, but this stand had a high density of stumps. This and its close proximity to Keystone suggest that past logging is the reason for this part of the Memorial not having old-growth forest. Four of the five stands that did not meet the old-growth description because their large trees were relatively young had either a relatively high density of old stumps (stands 18, 19, and 20) or were located in areas disturbed by development, and therefore were not sampled for stumps (stand 22). Stand 22 also had a high density of hardwoods. The remaining stand in this category (stand 12) occurs on the southwest edge of the Memorial. There are very few stumps in this area (**Figure 5c**), suggesting that a natural disturbance occurred in this stand in the relatively recent past. Fire is the most likely candidate for this disturbance, as most of the large trees had fire scars, many of them severe (A. Symstad, M. Bynum, and A. Kenyon, pers. observation). The disturbance was not completely stand-replacing, however, since old trees do exist in the stand; the ages of the largest DBH trees within 25 m of our five stump-count points in this stand ranged in age from 179 to 330 years.

Thus, somewhere around 80% of the undeveloped area at MORU meets the only published description of old-growth for Black Hills ponderosa pine forest. We emphasize, however, that the structure of the forest is probably quite different from pre-settlement times. No data on the exact structure (i.e., distribution of age and size classes) of the MORU forest before 1875 exist, but historical descriptions of this and the Black Hills in general, as well as the results of a recent study give some hints as to what it was like. Photographs from the 1874 Custer expedition into the Black Hills show a much more open forest (lower tree density) than today, with large areas having no trees at all (Progulske 1974, Grafe and Horsted 2002). This

expedition did not visit the area that became MORU, however, so no photographs from this expedition are available for this area. Probably the most detailed descriptions of pre-settlement-like forest are found in Graves' (1899) report, since he looked at the forest with a forester's eye at a time when fire suppression had not long been in practice. Some of his descriptions follow:

- "The forest as it appears today, irregular and broken, and composed in many places of defective and scrubby trees… There are trees of every age and size, and there are large areas where there are no trees at all." – p. 73
- "Taking the forest as a whole, it is composed of trees of nearly every age class. The original growth is broken by patches of younger trees varying in extent from a few to several hundred acres. The old timber has an age of 250 to 300 years. It is chiefly found along streams, in ravines and canyons, at the heads of creeks and side draws, and on protected flats and lower slopes." – p. 74
- The most widespread type of forest was specifically mentioned as the type represented by the forest around Hill City and Custer. The older trees in this type of forest had an average diameter of 51 cm (20 inches), with a maximum diameter of 91 cm (36 inches). The average height was approximately 20 m (65-70 feet), with the clear length (height of lowest branches) 7-12 m (25-40 feet). – pp. 74-75
- Three specific descriptions of stands in the vicinity of MORU were:
    - "One of the heaviest bodies of timber" he encountered was between Keystone and Hill City; the average diameter of older trees was 56 cm (22 inches), height 24-27m (80-90 feet), and clear length 9-12 m (30-40 feet). – p. 120.
    - Near Keystone, there occurred an "old stand of pine averaging 18 to 20 inches in diameter and 70 to 80 feet high, with numerous groups of second growth about 10 to 14 inches in diameter. On bottom lands oaks are found as large as 18 inches in diameter and 40 feet high and elm 12 to 18 inches in diameter. Ironwood, box elder, aspen, birch, and shrubs are abundant." A large percentage of the trees showed effects of old fires, and approximately 5 % of the timber was dead. – p. 125
    - Graves measured the diameter of all trees within four one-half acre plots in the vicinity of Keystone. In these plots, the average live tree density was 153/ha (62/acre), the average live tree diameter was 41 cm (16 inches), and the average dead tree density was 6.2/ha (2.5/acre), or 2.1% of all trees.

- Hollow and wounded trees were common in old forest, with as many as 50% of the trees "defective" (unsuitable for saw timber) in some areas. Graves estimated the amount of dead timber as 3-4% throughout forest relatively unaffected by fire. – pp. 75-76

Comparing the data from the stand exam to these descriptions gives a rough estimate of the state of the forest at MORU today compared to pre-settlement times. Overall, the average diameter of older pine trees (> 30 cm, or 12 inches, DBH)[a] in the forest today is 42 cm (17 inches), and the average height is approximately 19 m (65 feet), whether or not the stands not meeting the old-growth description are included. This is only slightly smaller than the verbal description for the "heaviest body of timber" between Keystone and Hill City. However, when all trees greater than 2.5 cm (1 inch) DBH are included, which may be similar to the plot data Graves collected near Keystone[b], average diameter is 32 cm (12.5 inches), about 25% lower than the average in the plots Graves measured quantitatively. Average live tree density today – 944/ha (382/acre) – is almost six times that in the plots Graves measured. The density of dead trees, or snags, in MORU's forest today is also much larger than Graves estimated for the forest as a whole (3-4%) or measured in his plots (2.1%) near Keystone. Today, 19.8% of the standing trees in old-growth stands at MORU are dead; 24% of the trees in all stands are dead. Because Graves did not specify his exact methods in data collection, it is difficult to determine how many of these differences are due to changes in forest structure versus differences in data collection methods. However, the smaller average diameter and much greater density of both live and dead trees today compared to 1897 is consistent with the trends in southwestern U.S. ponderosa pine forests in which fire has been suppressed (e.g., Covington and Moore 1992, Moore et al. 1999, Youngblood 2001). Comparison of current and historical aerial photographs also show increased density of trees (**Figure 14**).

The most thorough attempt to reconstruct the structure of pre-settlement Black Hills ponderosa pine forest is in Brown and Cook (in press), a study done in the western Black Hills. Their measurements were restricted to larger-diameter trees and stumps. Thus, comparisons between today's forest and pre-settlement conditions can only be made for trees with DBH > 30

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[a] Graves (1899) does not state how he distinguished "older" trees from younger for the descriptions quoted above. We used 30 cm as a threshold to be consistent with Brown and Cook (2004).

[b] Graves (1899) does not specify whether he recorded all trees, or if he excluded trees below a certain size. Since trees < 2.5 cm DBH are often excluded from measurements in such large plots, we assumed that these were not included in Graves' data.

cm (12 inches); the structure of smaller size classes is not known. The mean basal area of pine trees at MORU now is similar to that of forests in 1900 (**Table 3**), as is the distribution of plot basal areas (**Figure 15a**). The average tree diameter is substantially lower now (**Table 3**), however, because of a greater frequency of trees in the 40-60 cm (16-24 inches) size classes and lack of very large (DBH > 90 cm; 35 inches) trees (**Figure 15b**). In addition, the overall density of large trees at MORU now is lower than in the reconstructions of the areas they sampled (**Table 3**), perhaps because of the historical logging that occurred in some parts of the Memorial. These differences between the old-growth stands at MORU and the reconstructed 1900 forest are similar to the differences that Brown and Cook found between the reconstructed and existing forest within their plots.

These comparisons show that the old-growth forest at the Memorial today is probably quite different from old-growth forest before 1875. The values for forest structure given above are not meant to be used as restoration prescriptions, but simply to illustrate how the history of intensive and even selective cutting, as well as fire suppression, has changed the structure of the forest. We anticipate specific prescriptions for restoration to come from an on-going study (Wienk et al. 2004). The difference in structure from pre-settlement times is a key reason that some might not consider any forest in MORU or the Black Hills to be in old-growth condition. Clearly, however, a large part of the forest at MORU contains significant numbers of large and old trees. These stands are also clearly in a mature stage, in which growth is still occurring, but so are death and decay. Irrespective of whether the forest at MORU is called "old-growth" or "late-successional", it plainly possesses characteristics different from the majority of ponderosa pine forest in the Black Hills, making it a significant part of the Black Hills ecosystem as a whole. We discuss this significance in the next section.

Significance of Old-growth Forest at Mount Rushmore National Memorial to the Black Hills as a Whole

The wide-spread logging that has occurred throughout the Black Hills has rendered old-growth ponderosa pine forest a relatively rare phenomenon in the Hills. According to the most recent figures (U.S. Department of Agriculture Forest Service 2004), the amount of ponderosa pine forest in the old-growth (late-successional) structural stage in the Black Hills National Forest is 1071 ha (2,646 acres). This is substantially lower than a 1996 estimate of 9,072 ha

(22,409 acres) for three reasons. First, all areas of the BHNF had not been inventoried for the 1996 estimate and projections were used. Second, "Since structural stage 5 is subjectively determined, some specialists are reluctant to label stands to this category" (U.S. Department of Agriculture Forest Service 2004, p. 3-12). Finally, some of this structural stage was consumed in the Jasper fire of 2000.

The amount of old-growth forest in the Black Hills outside of BHNF is difficult to estimate. No figures exist for private property. Jewel Cave National Monument may have a very small (< 5 ha) amount of old-growth forest (R. Ohms, pers. comm.), but the area has not been quantitatively evaluated. Wind Cave National Park also likely has some old-growth forest, but it too has not been evaluated. The South Dakota Department of Game, Fish, and Parks manages 20,233 ha (49,975 acres) of forest at Custer State Park. Although timber harvest is part of this management, the park's Resource Management Plan (1994) calls for maintaining a diversity of forest structure, including "old", multi-strata forest. The park's most recent forest inventory data (2000) show that there are 630 ha (1555 acres) of Stand Class 6 ("old", multi-strata forest) and 147 ha (362 acres) of Stand Class 5 ("old", single-stratum forest) forest in the park. The methods used for inventory did not consider age (using tree size instead), but based on an algorithm developed by the USDA Forest Service (Crookston and Stage 1999), these Stand Classes would probably qualify as old-growth following the definition used in this report (B. Hill, Custer State Park Senior Forester, pers. comm.). Most of this old-growth occurs in the French Creek Natural Area, which has not been harvested since 1940, with portions of it probably never harvested.

These uncertainties make any assessment of the relative contribution of MORU to the old-growth ponderosa pine forest in the Black Hills necessarily rough. If we use the 2004 BHNF figure of 1,071 ha and the Custer State Park figure of 777 ha (1,917 acres), then MORU accounts for 16% of the 2,213 ha (5,464 acres) of old-growth ponderosa pine forest in the Black Hills. This is most likely an over-estimate because of the issues described above. The largest contiguous areas classified as old-growth/late-successional in the BHNF are all less than 260 ha (640 acres) in size (**Figure 16**; data from USDA Forest Service Database RMRIS, http://www.fs.fed.us/r2/blackhills/projects/gis/index.shtml). Two of these areas are relatively close to MORU, in the Black Elk Wilderness Area and the Norbeck Wildlife Preserve, including six sites recently recommended as old-growth research areas in the Needles Timber Sale area

(Shepperd et al. 2004). Based on this information and the concentration of old-growth forest in the French Creek Natural Area (total area is 894 ha or 2,209 acres), the old-growth forest at MORU appears to be the second largest contiguous area of old-growth within the Black Hills. However, since some areas that meet the definition of old-growth but have not been classified as such probably exist, we make this statement with great caution. Larger contiguous areas (> 2430 ha, 6200 acres) are currently being managed as late successional areas (Appendix G in U.S. Department of Agriculture Forest Service 2004); the forest within these areas may not be classified as old-growth, but it is being managed to achieve this condition.

All of this uncertainty makes it unlikely that MORU can claim to have the largest area of old-growth forest in the Black Hills. However, it is still a substantial area of forest that certainly has ecological and conservation significance. Of particular importance is its location; the largest areas of known old-growth forest in the Black Hills all occur within a relatively small area with a radius of approximately 10 km (6 miles). Proximity and connectedness of habitat are extremely important to some species.

Old-growth forest appeals to people because of its large, stately trees, its variety of tree sizes, and its "unspoiled" appearance. As mentioned before, old-growth forest is also appealing to other organisms – sometimes so much so that they can't live without it. The characteristics that appeal to humans (large trees) sometimes are the same as those required by these species. For example, Northern Goshawks (*Accipiter gentiles astricapillus*) in the Black Hills use only mature ponderosa pine trees as nest sites. Their nests are usually in the largest tree in the stand, with the DBH of nest trees in the Black Hills averaging 41 cm (16 inches; Shepperd and Battaglia 2002).

Although there are no confirmed Northern Goshawk sightings at MORU, many other species that prefer the structure of an old-growth forest have been confirmed to occur within the Memorial's boundaries (**Table 4**). Some of these species (e.g., Red-breasted Nuthatch and red squirrel) feed on the seeds of ponderosa pine, of which older stands produce copious amounts. Many of these species rely not on the large live trees that characterize old-growth, but instead depend on the large dead trees, both standing and fallen. Large, standing dead or partially dead trees, or snags **(Figure 17)**, provide important nesting habitat for many birds, as well as habitat for their insect prey (**Table 4**), with bird use of snags being positively related to snag diameter (Shepperd and Battaglia 2002, Spiering and Knight 2005).

There is some evidence that the MORU forest provides better habitat for some of these species than does the managed ponderosa pine forest of the BHNF. In a recent study, Spiering and Knight (2005) measured the relationship of cavity-nesting bird density to snag density, size, and condition in managed stands of ponderosa pine in the BHNF. Although they found no significant relationship between snag density and cavity-nesting bird density, they hypothesize that this may be due to the relatively small size of most of the snags and to the skewed distribution of snag density in their sampled areas, with most snags being small diameter and most stands having few snags and just a few having high snag densities. Snag densities in the Spiering and Knight study were identical to what we found at MORU [32/ha (13.0/acre), defined as ≥ 8.0 cm DBH and ≥ 2.0 m tall], but densities at MORU may be less skewed towards smaller sizes than the Spiering and Knight data (**Table 5**). In addition, MORU's snags tend to have a larger DBH than those sampled by Spiering and Knight; 81% of the snags in the BHNF samples were in the smallest category, whereas only 60% fell in this category in MORU (**Table 5**). These differences in the snag characteristics may explain the much greater density of Red-breasted Nuthatch in MORU compared to in their study: 0.47/ha (1.2/acre) at MORU (Panjabi 2005) vs. 0.09/ha (0.04/acre). This comparison suggests an important role of MORU old forest for cavity-nesting birds in the Black Hills, but more information is needed to confirm a similar effect for other species, most of which are difficult to make quantitative comparisons for because of MORU's relatively small size.

Specific information on how individual species use snags in the Black Hills is quite accessible (e.g., Mills et al. 1996, Rumble et al. 1999). Information on species' use of fallen trees, or coarse woody debris, is less available. However, coarse woody debris, which is comprised of fallen trees and tree parts in various stages of decay, can be an equally important component of old-growth forest in areas of relatively low fire frequency. Studies from other forest types suggest that this debris not only provides habitat for a variety of organisms, including certain species of reptiles, amphibians, small mammals, insects, fungi, microbes, and plants (**Figure 18)**, but it also holds water in the ecosystem during dry spells, reduces erosion, provides shade and wind protection for new forest growth, and plays an important role in nutrient cycling within the forest (Shepperd and Battaglia 2002). It should be noted, however, that the amount of coarse woody debris in today's old-growth forests of the Black Hills is almost definitely significantly higher than in pre-European settlement times, given the more frequent

fires that occurred at that time. Information is also lacking as to whether there are any plant or fungi species that are dependent on, or at least prefer, old-growth ponderosa pine habitat.

Potential Threats to the Old-Growth Forest at Mount Rushmore National Memorial

The old-growth forest of MORU has survived more than a century of occupation and use by Euro-American settlers and their descendants. Its survival until this day has largely not been planned, but serendipitous. Although much of the area was harvested early on, it was not clear cut because of logging practices at the time and probably because of rough terrain. When Gutzon Borglum chose this location for his monumental carving, it was not because of the forest, but because of the rock. The National Park Service was not originally interested in accepting responsibility for protecting the monument or surrounding forest. However, because it is part of the National Park Service, it has enjoyed the greatest level of protection available to almost any public land. Until very recently, however, protection of the forest has been largely hands-off, meaning no active management applied to areas outside of administration areas. This has resulted in increasing the chance of probably the largest threat to the old-growth forest at MORU – catastrophic fire.

Fire is obviously a natural part of the forest, but the accumulation of fuels, both live and dead, from more than a century of forest fire suppression makes it more likely that any fire that does start will have very different effects than it would have in pre-suppression times. Covington and Moore (1992) discuss how the effects of previous fire suppression influence future restoration activities in ponderosa pine forests. Although their discussion is for the southwestern United States, where fire return intervals were shorter than in the Black Hills, the effects are likely to be similar. Long-term fire suppression leads to increased tree density, vertical fuel continuity, and surface fuel loadings; these in turn result in decreased tree vigor, decreased herbaceous and shrub production, decreased on-site water availability, stream-flow and ground water recharge from greater transpiration, decreased nutrient availability, and changed soil characteristics. Simply reintroducing fire is unlikely to reverse all of these effects. Even if forests are thinned prior to a prescribed fire (a management action essential in most areas), litter accumulation, particularly at the bases of large trees, could result in greater than anticipated tree mortality (Arno 1988). In areas where native understory vegetation is sparse

because of heavy litter loads and/or shade from the canopy, removing the litter layer via fire could provide prime habitat for undesirable herbaceous species at the expense of native species.

Management actions that could help prevent a catastrophic fire from eliminating or damaging the old-growth forest at MORU include thinning and prescribed fire, perhaps combined with planting of understory species. All of these must be done carefully, however, to maintain the characteristics of the forest that make it excellent habitat for the species described above, as well as to maintain the relatively "unspoiled" feel that some of the forest provides for visitors.

Aside from this most obvious of threats, other natural processes could significantly affect the structure and extent of old-growth forest at MORU. Disease and/or insect outbreaks are expected in old-growth forest; indeed, their presence and effects on trees are part of what makes old-growth good habitat for certain species (**Table 4**). A severe outbreak of a pathogen or insect could substantially alter the appearance of the forest, however. Probably the most well known insect to significantly affect ponderosa pine trees is the mountain pine beetle (*Dendroctonus ponderosae*), a native species that, at endemic levels, causes mortality only in trees that are already stressed from other causes. Outbreaks (or epidemics) of this beetle often occur after there is widespread stress in a forest (such as during a drought), when the greater density of beetles causes them to attack not only stressed trees, but also healthy ones. Unlike other insects that attack ponderosa pine, the mountain pine beetle is most common in relatively large (20-30 cm, or 8-12 inches, DBH) trees (Shepperd and Battaglia 2002). Pine engravers (*Ips pini*), red turpentine beetles (*Dendroctonus valens*), and pine tip moths (*Rhyacionia bushnelli* and *R. neomexicana*) generally attack smaller, or dead, trees. Diseases that can affect ponderosa pine trees include Armillaria root disease (*Armillaria ostoyae*), which affects healthy and stressed trees of all ages, red rot (*Dichomitus squalens*), which affects pines of all ages except seedlings and small saplings, western gall rust (*Peridermium harknessii*), needle cast (*Elytorderma deformans*), and diplodia tip blight (*Sphaeropsis sapinea*), to which mature trees are most susceptible (Shepperd and Battaglia 2002). Because all of these are native species that are a part of the natural cycle of forest growth and decline, they are not something that will necessarily be actively managed in a national park. Monitoring and identifying the causes of significant areas of tree mortality should be part of natural resource management at MORU, however, so that if diseases or pests, particularly those not native to the system, occur, necessary containment

procedures can be implemented immediately following park natural resource management policy.

Other natural processes that could affect the old-growth forest at MORU include wind-throw and breakage from heavy snow. These processes generally affect relatively small areas, making their threat to the old-growth forest as a whole less than that of fire and disease.

Anthropogenic threats to the old-growth forest at MORU range from those that park staff have direct control over, such as trail construction and use, to those largely out of their hands, such as climate change. Trails have immediate, localized impacts during their construction, but they may also have longer term and larger scale effects. For example, studies have shown that the diversity and abundance of non-native plant species is greater along trail edges than away from trails (Patel and Rapport 2000), and that weedy plant species, both native and non-native, are more abundant along trails than away from trails (Potito and Beatty 2005). Trails also can change water flow patterns, possibly leading to erosion problems (Sutherland et al. 2001). Depending on the frequency of use of the trails, they can also affect bird communities, with specialist species avoiding areas with trails (Miller et al. 1998). Vandalism to trees is also a potential impact. Tradeoffs between these threats that trails bring and the increased awareness of the resources at the Memorial that would occur by greater visitor use must be weighed carefully in the decision of where a new trail is to be built, if at all, as well as in the use and promotion of existing trails.

Forest management practices along the boundaries of the Memorial, such as cutting or thinning in adjacent USDA-Forest Service property, could affect the attractiveness of the old-growth of MORU to certain species if continuity of habitat is disrupted. Air pollution in the form of nitrogen fertilization is another threat. Although nitrogen deposition rates in the immediate vicinity of the Memorial have not been monitored long enough to detect any trends, monitoring in the northern Great Plains region do indicate rising concentrations and deposition rates of ammonium and nitrate (Pohlman and Maniero 2005). These nitrogen additions to the system have the potential to affect plant community composition, particularly of the understory layer, although no studies have been done yet to asses the potential impacts in this ecosystem. The forest could also be impacted by increasing carbon dioxide concentrations and the climate change that they and other greenhouse gas increases could induce. Predicting these impacts is extremely difficult, however, because of uncertainties about future emissions rates and non-

linear responses of climate and ecosystems to changes in atmospheric composition. General predictions for the region suggest a 5-10°F annual temperature increase, with winters in particular being warmer, and a 10-20% increase in precipitation, but with severe drought potentially becoming more common (National Assessment Synthesis Team 2000). How these changes, combined with those of nitrogen deposition, fire, and other management practices, will affect the old-growth forest at Mount Rushmore is difficult to predict, but their potential for impact should not be ignored when making management decisions.

Of all of these potential threats to the forest of any age at Mount Rushmore, the three that management staff at the park have the most control over are trail use and construction, management practices in adjacent property (through close cooperation with the Forest Service), and fire (through thinning and prescribed fire).

Information of Particular Interest for Interpretation to Public

Translating a technical report such as this one into information that catches the attention of visitors to the Memorial and the general public is not always easy. Visitors are often interested in superlatives (largest, oldest, etc.), whereas scientists often present data in terms of averages. Thus, in this section we supplement the data in preceding sections of the report with some facts that we thought would be useful for interpretation staff when they speak about the forests at Mount Rushmore.

- The largest trees in the park occur in gulches, such as in Starling Basin or along the unnamed trail in the northeastern part of the park, where moist soil and protection from wind provide good growing conditions.
- The largest-diameter tree we found in the park is 34½ inches (88.5 cm) in diameter. The tallest tree we recorded is approximately 128 feet (39.4 m) tall. Both of these trees are in Starling Basin. The tallest known tree in the Black Hills is approximately 138 feet (42.5 m) tall and 41 inches (103 cm) in diameter – this is in Custer State Park (Custer State Park 1994 Resource Management Plan).
- The oldest trees we found in the park are 485 and 486 years old. They are in the western portion of the park. The oldest known tree in the Black Hills, located in the vicinity of Hill City, is more than 710 years old.

- The largest trees aren't necessarily the oldest trees. The Memorial's tallest tree is only 240 years old. (The largest-diameter trees were impossible to age, as they were rotten in the middle.) In contrast, the two oldest trees we found are only about 19 inches (48 cm) in diameter. The 700-year-old tree mentioned above is less than 24 inches in diameter, and the big tree in Custer State Park is only 256 years old.
- The average age of the large trees in the Memorial is 241 years. Only 8% of the large trees that we could age are younger than our country – a different sort of memorial than the Shrine of Democracy.

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TABLES AND FIGURES

Table 1a. Summary of stand exam results for all live trees for Mount Rushmore National Memorial, metric units.

		DBH > 2.54 cm*					DBH > 20.3 cm			
Stand	**Species**	**Trees/ ha**	**Mean DBH† (cm)**	**Mean Height (m)**	**Basal Area (m^2/ha)**	**SDI¢ (trees/ ha)**	**Trees/ ha**	**Mean² DBH (cm)**	**Mean Height (m)**	**Basal Area (m^2/ha)**
1	*Betula papyrifera*§	22.2	16.3	7.6	0.1		0.0	--	--	0.0
	Pinus ponderosa	831.9	19.3	10.4	4.0	573	235.6	30.0	13.1	2.7
	Populus tremuloides	40.8	20.8	11.3	0.2		20.5	23.9	11.9	0.2
2	*Betula papyrifera*	113.1	10.2	8.8	0.2	788	0.0	--	--	0.0
	Pinus ponderosa	1432.4	17.0	9.5	5.4		329.7	30.2	17.1	3.9
3	*Pinus ponderosa*	626.6	22.9	12.2	4.3	556	206.5	35.3	18.0	3.3
	Populus tremuloides	41.5	16.8	11.0	0.2		0.0	--	--	0.0
4	*Betula papyrifera*	159.8	16.5	10.4	0.6		38.3	23.9	9.8	0.3
	Pinus ponderosa	679.3	15.2	9.5	2.1	558	43.7	44.7	17.1	1.1
	Populus tremuloides	311.7	16.5	7.9	1.1		98.6	23.6	16.2	0.7
	Quercus macrocarpa	20.0	23.4	10.7	0.1		20.0	23.4	10.7	0.1
5	*Pinus ponderosa*	831.6	19.6	9.1	4.1	546	199.3	34.3	15.5	3.0
6	*Pinus ponderosa*	2222.8	13.0	9.1	4.8	758	248.7	32.3	15.2	3.3
7	*Betula papyrifera*	29.6	27.9	11.9	0.3		29.6	27.9	11.9	0.3
	Pinus ponderosa	333.7	29.0	14.9	3.6	551	254.2	31.8	14.9	3.3
	Populus tremuloides	356.9	8.6	7.3	0.4		0.0	--	--	0.0
8	*Pinus ponderosa*	1011.5	19.1	10.4	4.7	632	272.4	32.8	17.1	3.8
10	*Pinus ponderosa*	999.9	18.0	10.1	4.2	580	239.1	32.8	16.2	3.3
11	*Betula papyrifera*	17.5	36.6	12.2	0.3		17.5	36.6	12.2	0.3
	Pinus ponderosa	198.1	36.8	21.3	3.5	410	198.1	36.8	21.3	3.5
	Populus tremuloides	18.0	25.4	13.7	0.2		18.0	25.4	13.7	0.2
12	*Pinus ponderosa*	1511.4	17.0	11.6	5.6	820	263.1	36.6	20.4	4.5
	Populus tremuloides	33.6	22.9	11.9	0.2		33.6	22.9	11.9	0.2
13	*Picea glauca*	13.1	30.0	18.0	0.2	781	13.1	30.0	18.0	0.2
	Pinus ponderosa	2202.0	13.0	8.2	4.8		275.4	33.3	16.2	3.9
14	*Pinus ponderosa*	369.3	29.2	13.1	4.1	499	301.1	31.2	14.0	3.8
	Populus tremuloides	148.2	5.1	2.7	0.0		0.0	--	--	0.0

		DBH > 2.54 cm*					DBH > 20.3 cm			
Stand	Species	Trees/ ha	Mean DBH† (cm)	Mean Height (m)	Basal Area (m^2/ha)	SDI¢ (trees/ ha)	Trees/ ha	Mean[2] DBH (cm)	Mean Height (m)	Basal Area (m^2/ha)
15	*Betula papyrifera*	42.5	19.8	10.1	0.2	588	0.0	--	--	0.0
	Pinus ponderosa	704.0	33.0	12.2	4.4		237.9	37.1	16.5	3.8
16	*Pinus ponderosa*	1381.0	15.5	7.6	4.3	650	218.8	34.0	17.1	3.3
	Populus tremuloides	9.4	32.0	17.1	0.1		9.4	32.0	17.1	0.1
17	*Betula papyrifera*	53.1	21.1	9.1	0.3		23.2	22.4	9.5	0.2
	Pinus ponderosa	332.2	29.5	14.6	3.7	504	249.2	32.5	16.2	3.4
	Populus tremuloides	74.1	3.6	3.0	0.0		0.0	--	--	0.0
	Quercus macrocarpa	62.7	13.7	3.0	0.2		0.0	--	--	0.0
18	*Betula papyrifera*	110.2	20.1	12.2	0.6		69.9	20.3	11.3	0.4
	Pinus ponderosa	271.7	32.8	17.7	3.8	521	209.0	36.6	19.2	3.6
	Quercus macrocarpa	63.0	15.2	10.1	0.2		0.0	--	--	0.0
19	*Pinus ponderosa*	1214.5	16.3	10.1	4.2	600	210.2	34.8	16.5	3.3
20	*Pinus ponderosa*	463.4	26.2	17.4	4.1	484	366.8	28.2	18.6	3.8
21	*Betula papyrifera*	10.4	33.5	10.7	0.2	546	10.4	33.5	10.7	0.2
	Pinus ponderosa	891.7	18.3	8.5	3.9		200.6	31.5	14.6	2.6
22	*Betula papyrifera*	415.9	13.2	9.5	0.9		34.3	29.2	15.9	0.4
	Pinus ponderosa	290.5	34.0	22.0	4.3	874	242.8	36.3	22.9	4.1
	Populus tremuloides	439.4	14.0	12.8	1.1		103.7	23.6	18.3	0.8
23	*Pinus ponderosa*	1103.3	20.3	11.6	5.8	768	425.1	29.2	16.2	4.7
24	*Pinus ponderosa*	2735.0	13.7	9.5	6.7	1030	352.7	30.5	15.9	4.2
25	*Pinus ponderosa*	605.9	22.4	11.3	3.9	492	198.3	32.5	16.2	2.7
26	*Pinus ponderosa*	529.6	24.6	14.0	4.2	506	300.4	30.2	16.5	3.5
27	*Pinus ponderosa*	724.5	24.1	13.1	5.4	664	404.6	29.5	16.8	4.5

*These data are inclusive, i.e., for all trees > 2.54 cm DBH.

† Arithmetic mean; quadratic mean diameter (QMD), a standard forest mensuration, is nearly identical to the arithmetic mean in these data.

§*Pinus ponderosa* = ponderosa pine; *Populus tremuloides* = quaking aspen; *Betula papyrifera* = paper birch; *Quercus macrocarpa* = bur oak; *Picea glauca* = Black Hills spruce (white spruce)

¢SDI (Stand Density Index) is a relative measure of stand density the converts a stand's current density into a density at a reference size. Specifically, it is the equivalent number of trees per hectare of quadratic mean diameter 25 cm for a stand. SDI = (trees/ha)*$(QMD/25)^{1.6}$. The value shown is for all species in a stand.

Table 1b. Summary of stand exam results for all live trees for Mount Rushmore National Memorial, English units.

		DBH > 1 inch*					DBH > 8 inches			
Stand	**Species**	**Trees/ acre**	**Mean† DBH (in)**	**Mean Height (ft)**	**Basal Area (ft^2/ac)**	**SDI¢ (trees /ac)**	**Trees/ ac**	**Mean² DBH (in)**	**Mean Height (ft)**	**Basal Area (ft^2/ac)**
1	*Betula papyrifera*§	9.0	6.4	25	2		0.0	--	--	0.0
	Pinus ponderosa	336.8	7.6	34	105	232	95.4	11.8	43	72
	Populus tremuloides	16.5	8.2	37	6		8.3	9.4	39	4
2	*Betula papyrifera*	45.8	4.0	29	4	319	0.0	--	--	0.0
	Pinus ponderosa	579.9	6.7	31	143.1		133.5	11.9	56	104
3	*Pinus ponderosa*	253.7	9.0	40	113.2	225	83.6	13.9	59	88
	Populus tremuloides	16.8	6.6	36	4		0.0	--	--	0.0
4	*Betula papyrifera*	64.7	6.5	34	15		15.5	9.4	32	7.5
	Pinus ponderosa	275.0	6.0	31	54.5	226	17.7	17.6	56	30
	Populus tremuloides	126.2	6.5	26	29		39.9	9.3	53	18.7
	Quercus macrocarpa	8.1	9.2	35	3.8		8.1	9.2	35	3.8
5	*Pinus ponderosa*	336.7	7.7	30	108.5	221	80.7	13.5	51	80
6	*Pinus ponderosa*	899.9	5.1	30	127.8	307	100.7	12.7	50	88
7	*Betula papyrifera*	12.0	11.0	39	8		12.0	11.0	39	8
	Pinus ponderosa	135.1	11.4	49	96	223	102.9	12.5	49	88
	Populus tremuloides	144.5	3.4	24	9.6		0.0	--	--	0.0
8	*Pinus ponderosa*	409.5	7.5	34	124.1	256	110.3	12.9	56	100
10	*Pinus ponderosa*	404.8	7.1	33	111.8	235	96.8	12.9	53	88
11	*Betula papyrifera*	7.1	14.4	40	8		7.1	14.4	40	8
	Pinus ponderosa	80.2	14.5	70	92	166	80.2	14.5	70	92
	Populus tremuloides	7.3	10.0	45	4		7.3	10.0	45	4
12	*Pinus ponderosa*	611.9	6.7	38	148.2	332	106.5	14.4	67	120
	Populus tremuloides	13.6	9.0	39	6		13.6	9.0	39	6
13	*Picea glauca*	5.3	11.8	59	4	316	5.3	11.8	59	4
	Pinus ponderosa	891.5	5.1	27	128.8		111.5	13.1	53	104
14	*Pinus ponderosa*	149.5	11.5	43	107.9	202	121.9	12.3	46	100
	Populus tremuloides	60.0	2.0	9	1.3		0.0	--	--	0.0

		DBH > 1 inch*					DBH > 8 inches			
Stand	Species	Trees/ acre	Mean† DBH (in)	Mean Height (ft)	Basal Area (ft^2/ac)	SDI¢ (trees /ac)	Trees/ ac	Mean[2] DBH (in)	Mean Height (ft)	Basal Area (ft^2/ac)
15	*Betula papyrifera*	17.2	7.8	33	5.7	238	0.0	--	--	0.0
	Pinus ponderosa	285.0	13.0	40	116.8		96.3	14.6	54	100
16	*Pinus ponderosa*	559.1	6.1	25	115.1	263	88.6	13.4	56	86.6
	Populus tremuloides	3.8	12.6	56	3.3		3.8	12.6	56	3.3
17	*Betula papyrifera*	21.5	8.3	30	8		9.4	8.8	31	4
	Pinus ponderosa	134.5	11.6	48	98	204	100.9	12.8	53	90
	Populus tremuloides	30.0	1.4	10	0.3		0.0	--	--	0.0
	Quercus macrocarpa	25.4	5.4	10	4		0.0	--	--	0
18	*Betula papyrifera*	44.6	7.9	40	15		28.3	8.0	37	10
	Pinus ponderosa	110.0	12.9	58	100	211	84.6	14.4	63	95
	Quercus macrocarpa	25.5	6.0	33	5		0.0	--	--	0
19	*Pinus ponderosa*	491.7	6.4	33	110.8	243	85.1	13.7	54	86.6
20	*Pinus ponderosa*	187.6	10.3	57	107.9	196	148.5	11.1	61	99.9
21	*Betula papyrifera*	4.2	13.2	35	4	221	4.2	13.2	35	4
	Pinus ponderosa	361.0	7.2	28	102.4		81.2	12.4	48	68
22	*Betula papyrifera*	168.4	5.2	31	25		13.9	11.5	52	10
	Pinus ponderosa	117.6	13.4	72	115	354	98.3	14.3	75	110
	Populus tremuloides	177.9	5.5	42	29.3		42.0	9.3	60	20
23	*Pinus ponderosa*	446.7	8.0	38	155.1	311	172.1	11.5	53	124.3
24	*Pinus ponderosa*	1107.3	5.4	31	178.3	417	142.8	12.0	52	112
25	*Pinus ponderosa*	245.3	8.8	37	102.9	199	80.3	12.8	53	72
26	*Pinus ponderosa*	214.4	9.7	46	110.6	205	121.6	11.9	54	94
27	*Pinus ponderosa*	293.3	9.5	43	143.7	269	163.8	11.6	55	119.9

*These data are inclusive, i.e., for all trees > 1 inch DBH.

† Arithmetic mean; Quadratic mean diameter, a standard forest mensuration, is nearly identical to the arithmetic mean in these data.

§*Pinus ponderosa* = ponderosa pine; *Populus tremuloides* = quaking aspen; *Betula papyrifera* = paper birch; *Quercus macrocarpa* = bur oak; *Picea glauca* = Black Hills spruce (white spruce)

¢SDI (Stand Density Index) is a relative measure of stand density the converts a stand's current density into a density at a reference size. Specifically, it is the equivalent number of trees per acre of quadratic mean diameter 10 inches for a stand. SDI = (trees/ac)*$(QMD/10)^{1.6}$. The value shown is for all species in a stand.

Table 2. Results of 2004 USDA Forest Service stand exam for Mount Rushmore National Memorial. The final column indicates whether the stand qualifies as old-growth according to the description in Mehl (1992), with the values used to determine this in the preceding three columns.

Stand	Size (acres)	Size (ha)	Number of points measured	Origin date*	Habitat structural stage**	Live trees per acre with min. DBH	Dead trees per acre with min. DBH	Mean age of trees with min. DBH	Old-growth following Mehl 1992
1	93	38	10	1852	4B	10.0	17.2	259	yes
2	23	9	5	1866	4C	19.3	20.5	170	yes
3	27	11	5	1831	4B	28.1	16.2	162	yes
4	7	3	4	1881	4B	8.2	14.0	190	no
5	43	17	5	1833	4B	19.7	97.1	256	yes
6	39	16	5	1825	4C	14.7	142.0	274	yes
7	29	12	5	1900	4B	16.5	26.8	161	yes
8	37	15	5	1866	4C	14.3	133.7	189	yes
9	(153)	(62)	0	--	--	--	--	--	--
10	55	22	6	1872	4B	20.4	96.7	191	yes
11	31	13	5	1812	4B	38.9	12.0	170	yes
12	36	15	5	1860	4C	35.0	114.4	149	no
13	24	10	5	1800	4C	30.8	15.2	260	yes
14	28	11	5	1846	4B	19.6	16.8	227	yes
15	68	28	7	1801	4B	28.5	10.3	267	yes
16	60	24	6	1838	4C	22.8	24.7	189	yes
17	98	40	10	1853	4B	22.0	20.4	185	yes
18	4	2	4	1830	4B	26.5	14.0	155	no
19	52	21	6	1853	4B	32.3	8.0	146	no
20	37	15	5	1911	4B	13.2	10.2	100	no
21	21	9	5	1882	4B	11.0	41.7	213[§]	yes
22	13	5	5	1900	4C	23.6	50.2	125	no
23	63	26	7	1789	4C	23.4	4.0	164	yes
24	27	11	5	1859	4C	21.3	6.4	217	yes
25	42	17	5	1873	4B	18.1	8.8	178	yes
26	93	38	10	1879	4B	17.5	8.4	188	yes

Stand	Size (acres)	Size (ha)	Number of points measured	Origin date*	Habitat structural stage**	Live trees per acre with min. DBH	Dead trees per acre with min. DBH	Mean age of trees with min. DBH	Old-growth following Mehl 1992
27	32	13	5	1878	4C	8.3	5.1	.	no
28	(34)	(14)	0	--	--	--	--	--	--
Total†	1082	438	150						

*Stand Origin Date is the calculated as the year of the survey minus the average age of the stand; average age of the stand is calculated as the average age of trees greater than 9 inches DBH, where age of trees is estimated in the field from counting rings and adding 15 years to account for the age being estimated from a core taken at breast height.

**Habitat Structural Stage (=Wildlife Structural Stage) is based on stand size class (number) and extent of crown closure (letter). Stand size class 4 is mature; canopy closure class B is 41-70% crown closure; canopy closure class C is >70% closure.

§We calculated the average age of minimum diameter trees from three of our points that fell in this stand, since data collected for the stand exam did not include any ages for trees greater than 16 inches DBH. The three trees we sampled in this stand all had DBH above this threshold.

†Totals in this row do not include area of stands not surveyed. All stand areas are somewhat approximate, as they were derived from GIS.

Table 3. Present old-growth forest structure at Mount Rushmore National Memorial from this study's stand exam and past forest structure in the greater Black Hills from Brown and Cook (2005). Data are for trees with DBH > 30 cm. 2004 stand exam data are calculated from individual sampling points within only those stands meeting the old-growth definition of Mehl (1992).

	2004 Stand Exam	1900 Reconstruction
Mean basal area (m^2/ha)	14.8	15.8
Maximum basal area (m^2/ha)	36.8	55.1
Mean DBH (cm)	42.3	58.4
Maximum DBH (cm)	82.6	100.0
Mean density (trees/ha)	116.5	127.3
Maximum density (trees/ha)	328.0	710.3

Table 4. Some species that are associated in the Black Hills with mature, closed-canopy ponderosa pine forest like that at Mount Rushmore National Memorial. Species with known particular affinity for this habitat in the Black Hills are underlined.

Species	Scientific Name	Important forest characteristics	Presence at MORU
Birds			
Northern Goshawk	*Accipiter gentiles atricapillus*	For nesting, mature ponderosa pine trees with DBH > 30 cm (12 inches), stand basal area > 27.5 m^2/ha (120 ft^2/acre), and dead and down woody material present. Variety of forest structures for foraging and raising young after fledging[a]	None[b]
Ovenbird	*Seiurus aurocapillus*	Closed canopy [a, k]	Summer resident; uncommon[b,c]
Townsend's Solitaire	*Myadestes townsendi*	Closed canopy in winter(?)[a]	Permanent resident; common[b,c]
Western Tanager	*Piranga ludoviciana*	Multi-storied coniferous forest with hardwood understory, stands > 10 ha (25 acres)[a]	Summer resident; common[b,c]
Ruby-crowned Kinglet	*Regulus calendula*	?	Summer resident; uncommon[b,c]
Brown Creeper	*Certhia americana*	Cavity nester, large diameter (DBH > 38 cm, 15 inches) trees, dense canopy[a]	Permanent resident; uncommon[b,c]
Black-capped Chickadee	*Parus atricapillus*	Snags, either soft or with cavities, for nesting[a]	Permanent resident; common? [b,c]
Black-backed Woodpecker	*Picoides arcticus*	Snags for nesting and foraging [a]	None[b]
Three-toed Woodpecker	*Picoides tridactylus*	Large-diameter (23-51 cm, 9-20 inches) dead or live trees with heart rot for nesting; damaged trees for foraging[a]	None[b]
Hairy Woodpecker	*Picoides villosus*	Trees with DBH > 25 cm (10 inches) and snags for nesting[a]	Permanent resident[b]
White-breasted Nuthatch	*Sitta carolinensis*	Cavities for nesting [a]	Permanent resident; fairly common[b,c]
Red-breasted Nuthatch	*Sitta canadensis*	Ponderosa pine seed in large amounts for food[a]	Permanent resident; common[b,c]

Species	Scientific Name	Important forest characteristics	Presence at MORU
Northern Saw-whet Owl	*Aegolius acadicus*	Cavity nester [a]	Permanent resident; fairly common[b,c]
Mammals			
American pine martin	*Martes americana*	Typically in mature or old-growth spruce (*Picea glauca*) stands, but mature/old-growth ponderosa pines may serve as connecting habitat or territory for younger (less dominant) individuals[d]	Present[b]
Fringed bat	*Myotis thysanodes pahspensis*	Cavities and cracks in large ponderosa pine snags for roosting[e]	Present[f]
Long-legged myotis	*Myotis volans interior*	Large and semi-decayed snags for roosting[g]	Present[f]
Silver-haired bat	*Lasionycteris noctivagans*	Cavities of trees in stands with high snag density and relatively high basal area for maternal roosting[h]	Present[f]
Northern myotis	*Myotis septentrionalis*	Crevices and cavities of live trees and snags for roosting[i]	Present[f]
Northern flying squirrel	*Glaucomys sabrinus*	Cavities for nesting[j]	Expected, but not confirmed[b]
Red squirrel	*Tamiasciurus hudsonicus*	Cavities for nesting; pine seeds for food[j]	Common[b]

[a]Shepperd and Battaglio 2002; [b]Northern Great Plains Inventory and Monitoring Program draft species list; [c]Panjabi 2005; [d]Buskirk 2002; [e]Schmidt 2003a; [f]Schmidt 2004; [g]Schmidt 2003b; [h]Schmidt 2003d; [i]Schmidt 2003c; [j]Higgins et al. 2000; [k](Mills et al. 1996).

Table 5. Snag density and size distribution in Mount Rushmore National Memorial (MORU, this study) vs. Black Hills National Forest (BHNF) ponderosa pine forest (Spiering and Knight 2005). Note that Spiering and Knight did not provide quantitative data for snag density distribution in the BHNF. Snags for this comparison are defined as ≥ 8.0 cm (3.2 inches) DBH and > 2.0 m (6.6 feet) ht following Spiering and Knight (2005).

Snag Density (#/ha)	% of MORU Stands	Snag Size (cm DBH)	% of Snags at MORU	% of Snags in BHNF
0.0-10.0	15.4	8.0-23.0	60	81
10.1-20.0	7.7	23.1-38.0	22	16
20.1-30.0	34.6	38.1-48.0	14	2
30.1-40.0	11.5	>48.0	3.5	0.8
40.1-50.0	11.5			
50.1-60.0	15.4			
≥60.0	3.8			

Figure 1. Photographs showing lumber practices of the time from Graves' 1896-7 Black Hills forest survey (Graves 1899). The top photo is from the vicinity of French Creek, which is south of Mount Rushmore National Memorial. The bottom photo is from the vicinity of Hill City, which is northwest of the Memorial.

B. A LUMBERED TRACT ON FRENCH CREEK, SOUTH DAKOTA.

B. WASTEFUL METHODS OF LUMBERING NEAR HILL CITY, SOUTH DAKOTA.

Figure 2. Approximate boundaries of areas harvested for timber near Mount Rushmore National Memorial prior to 1897, based on map in Graves' report (1899). Boundaries are very approximate because mapping done in 1897 was difficult to match to contemporary maps.

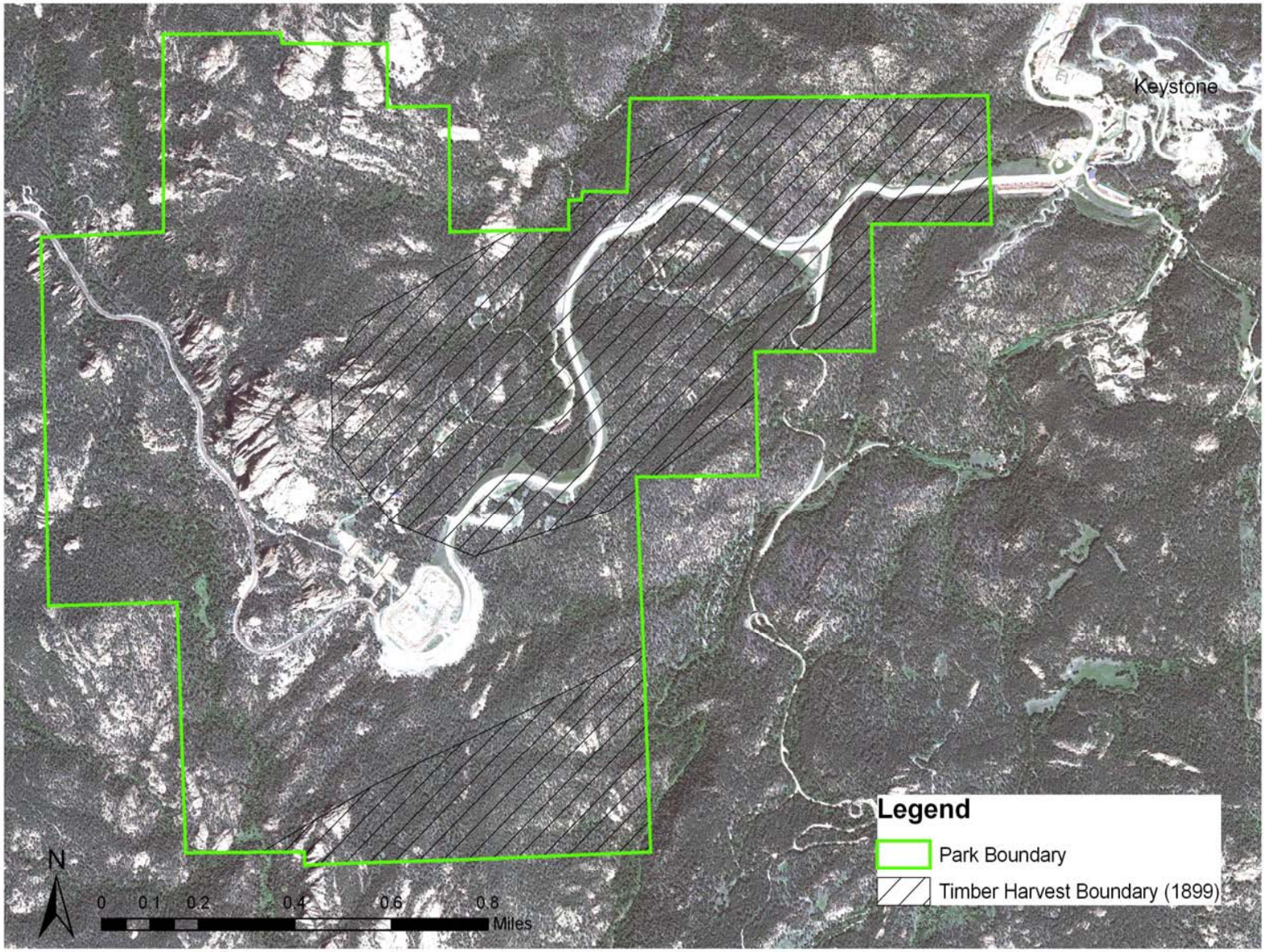


Figure 3. Points for field investigation of logging activity and tree age at Mount Rushmore National Memorial. Open squares are points not visited; open circles are points visited but deemed not suitable for data collection; and closed circles are points where data were collected.

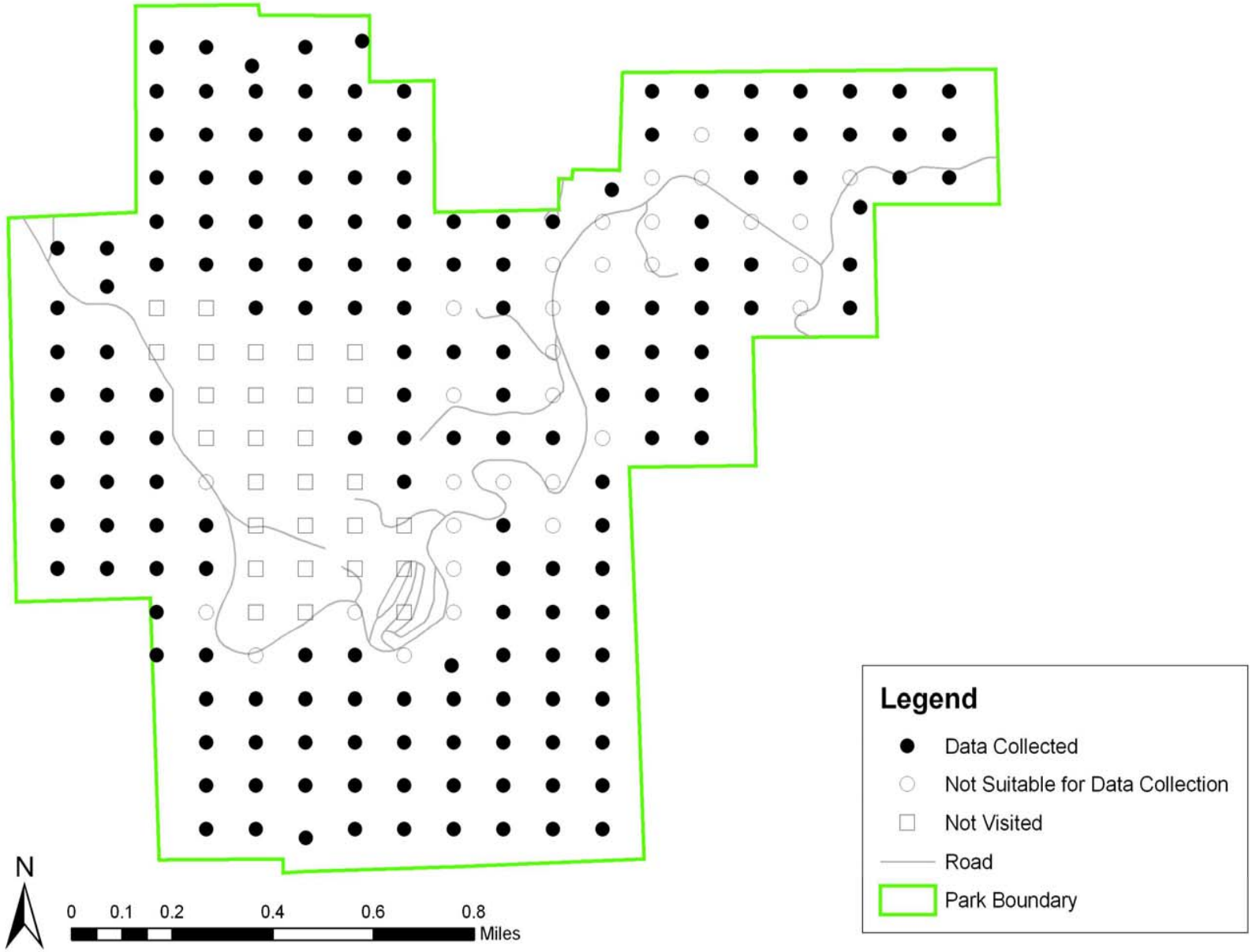
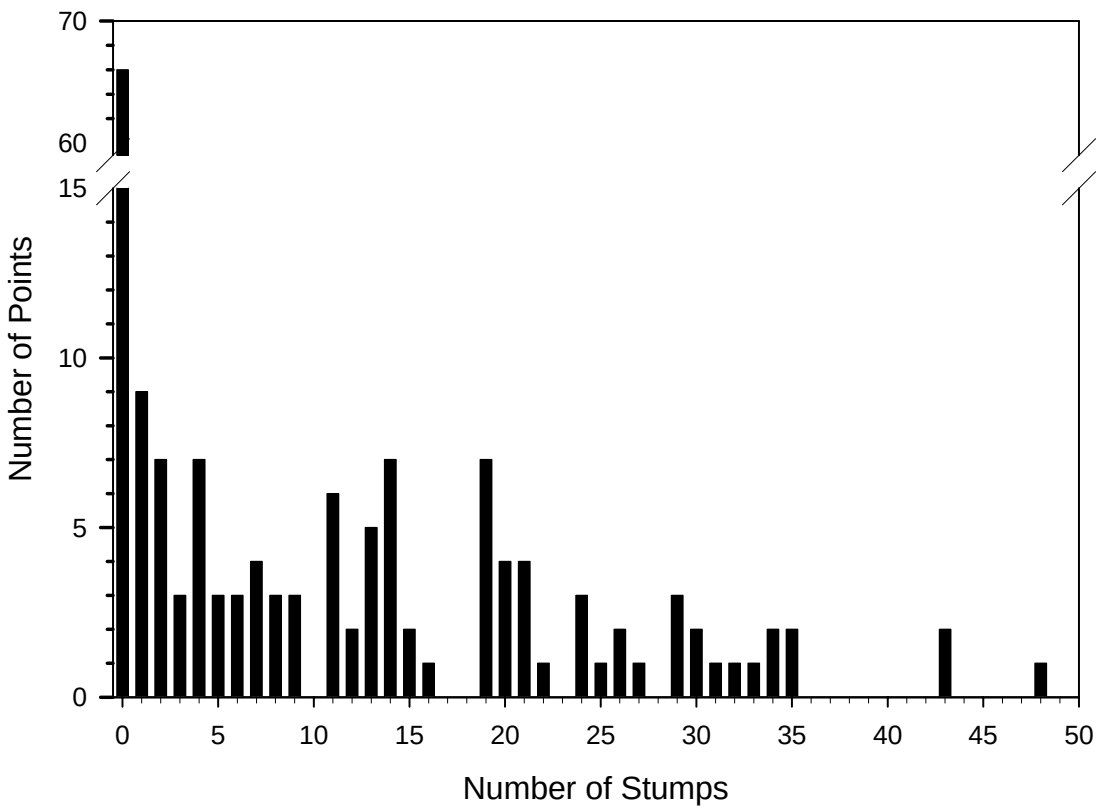


Figure 4. Examples of “old” (top) and “new” (bottom) stumps counted at each point in field investigation of logging extent at Mount Rushmore National Memorial. Old stumps have no bark, usually lack sapwood, and often have lichens on them. New stumps are generally small, have bark and intact wood, and are cut close to the ground with a chainsaw.

Figure 5. Old stump density and distribution at Mount Rushmore National Memorial. (a) Number of sample points containing each number of stumps. (b) Logged areas according to field evidence (filled circles indicating points with one or more stumps) and historical map (Graves 1899; hatched area). (c) Stump number at each point (indicated by symbol's size) and rough boundaries of large areas where field data suggest no or selective cutting (shaded in green).

(a)



(b)

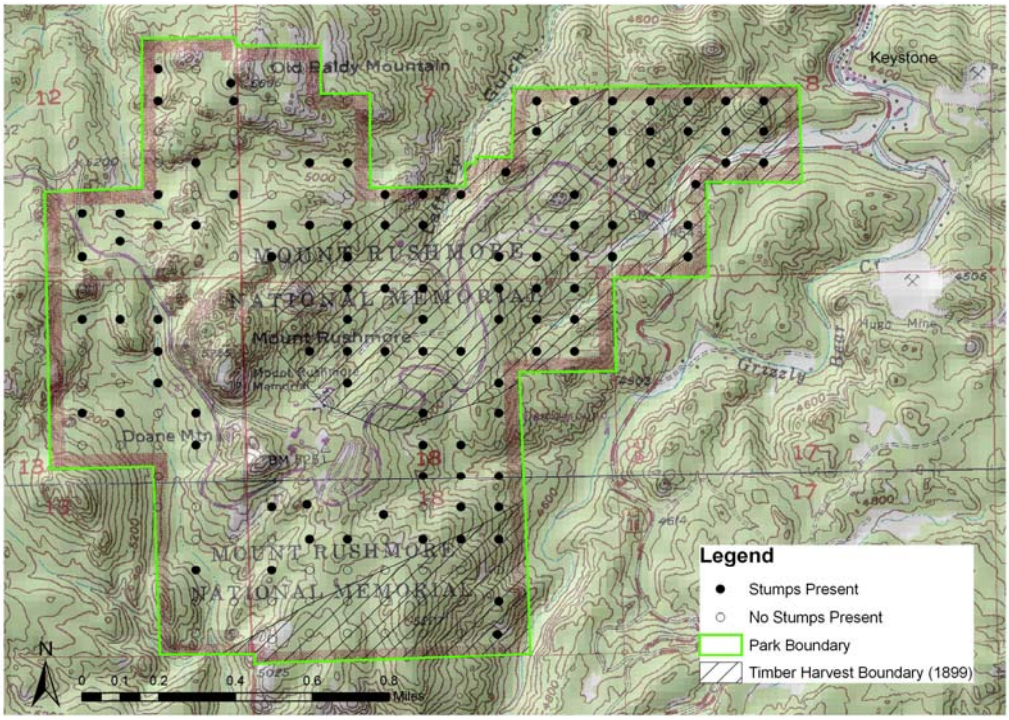


Figure 5, continued.

(c)

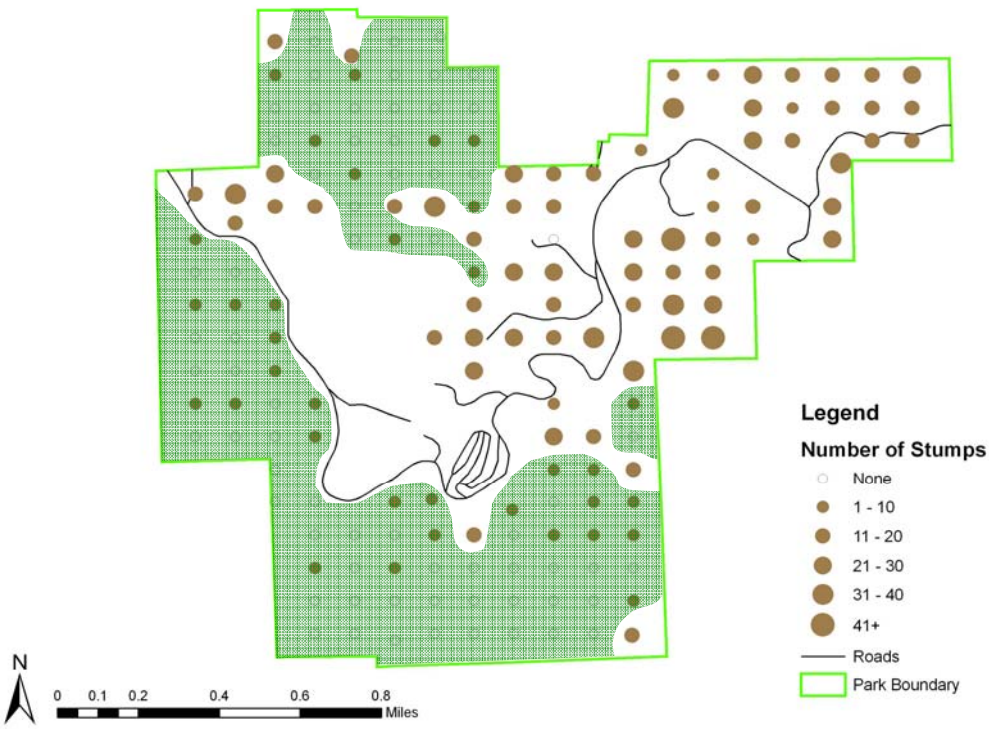


Figure 6. Histogram of tree growth release dates estimated from ring width of large trees sampled at Mount Rushmore National Memorial. The inset shows the span of the entire sample of trees, whereas the main graph shows the period of most release dates discerned from the cores. The dotted vertical line at 1876 indicates the year at which Euro-American settlers came to the Keystone area.

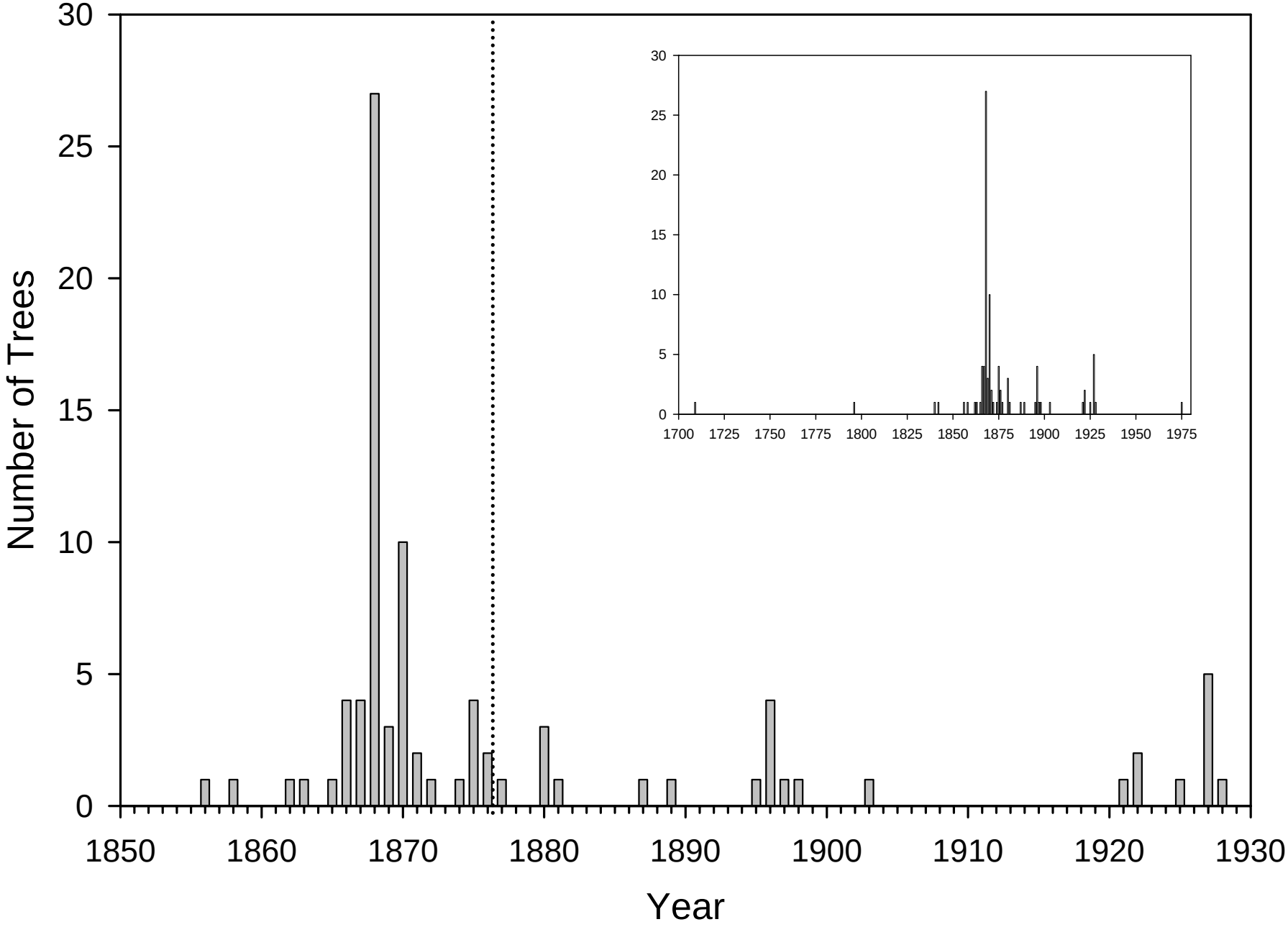


Figure 7. Post-1875 release dates of large trees cored at Mount Rushmore National Memorial, shown by their location within the park. Blank spots were not sampled. Dates of "0" indicate the tree had either no obvious release date, or a release/germination date prior to 1876. Dates are color-coded by the number of old stumps sampled at the point from which the core was taken.

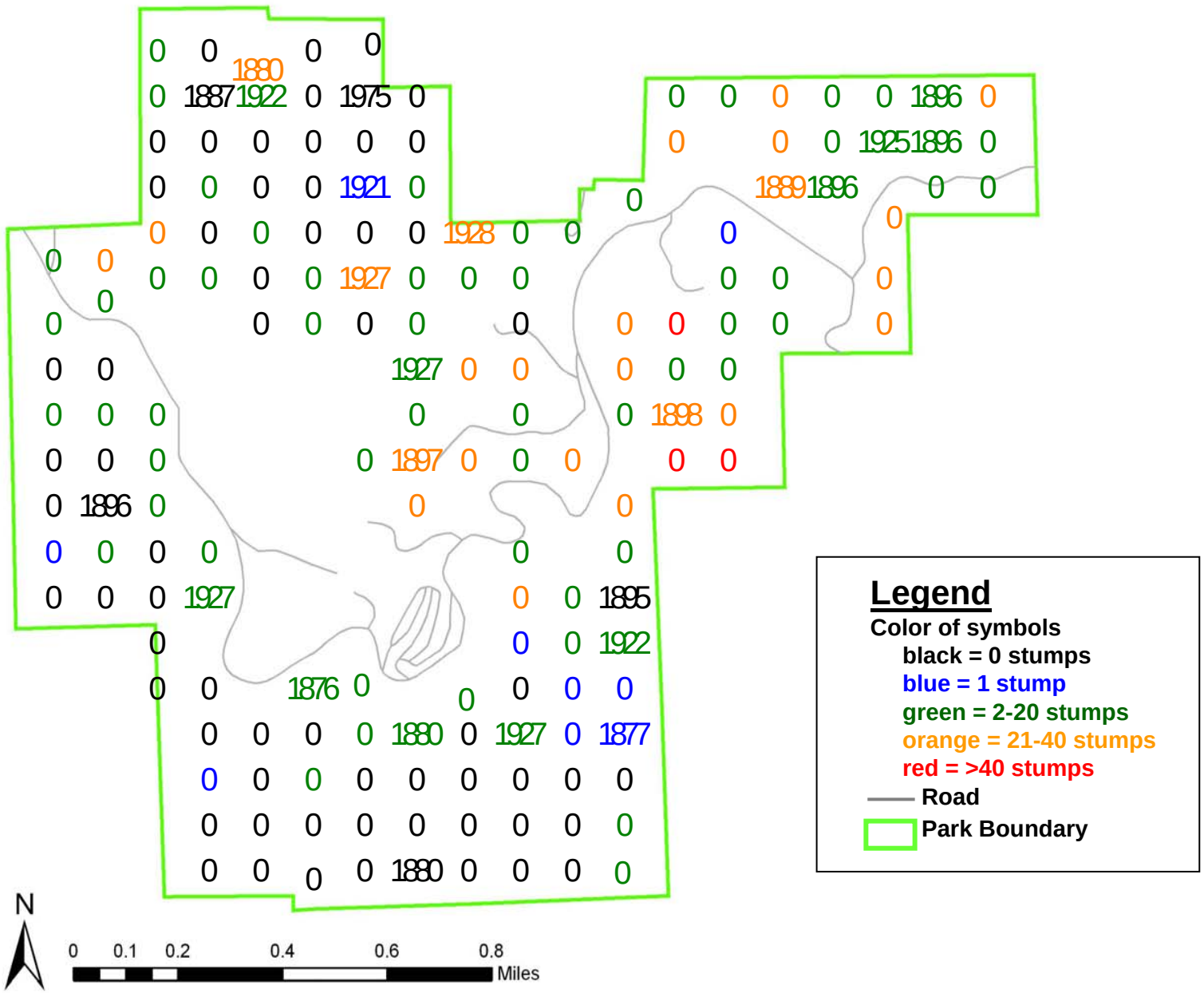


Figure 8. Correlation between number of old stumps and largest tree age at sample points in Mount Rushmore National Memorial.

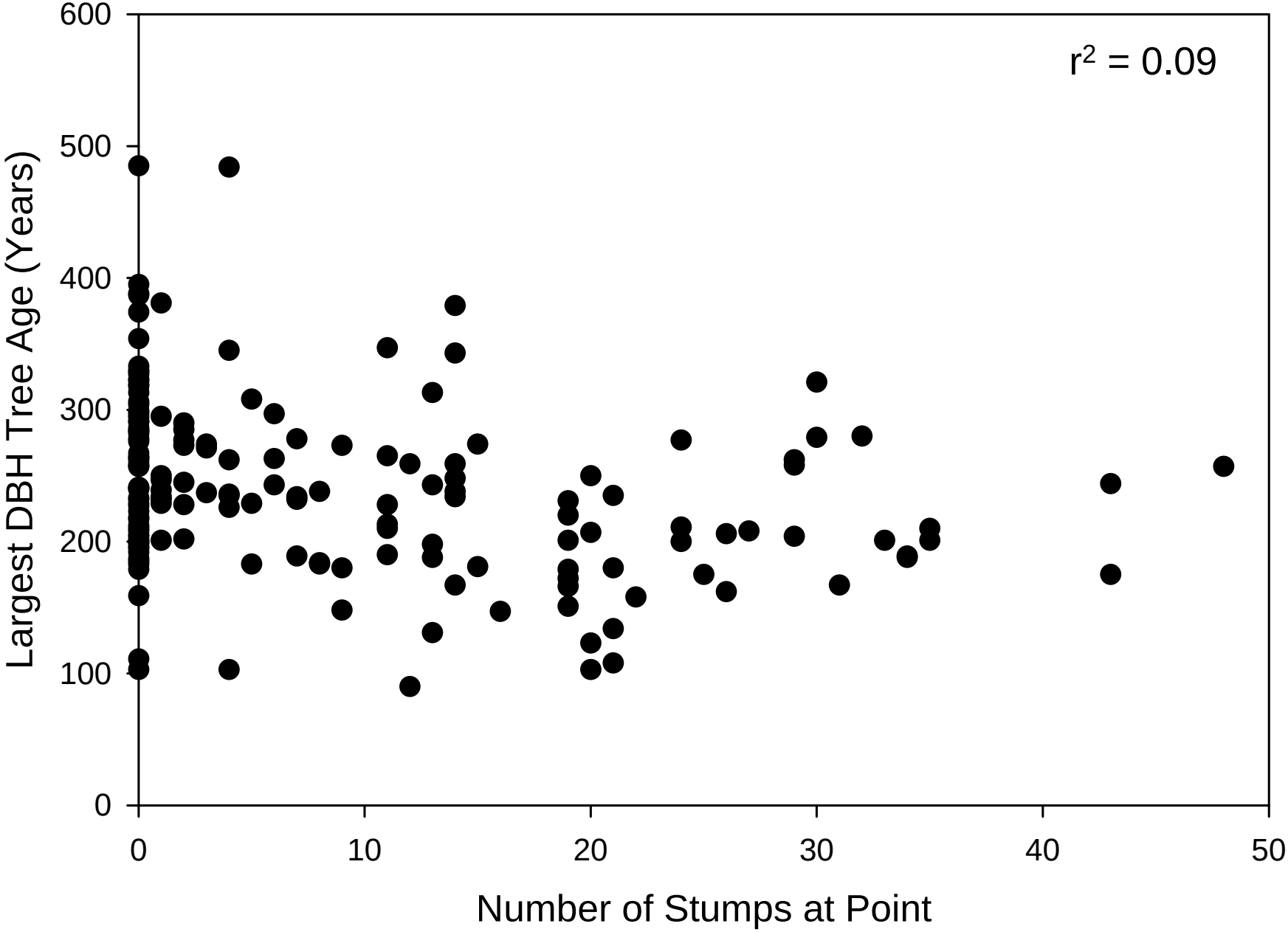


Figure 9. Location and number of "new" stumps at sample points in Mount Rushmore Memorial. Symbol size increases logarithmically with stump number, with stump number ranging from 0 to 298. The smallest symbol size indicates no new stumps at a site; blank spaces indicate the point was not sampled. Shaded areas are those in which old stumps indicate selective harvest of larger trees and new stumps indicate thinning has occurred.

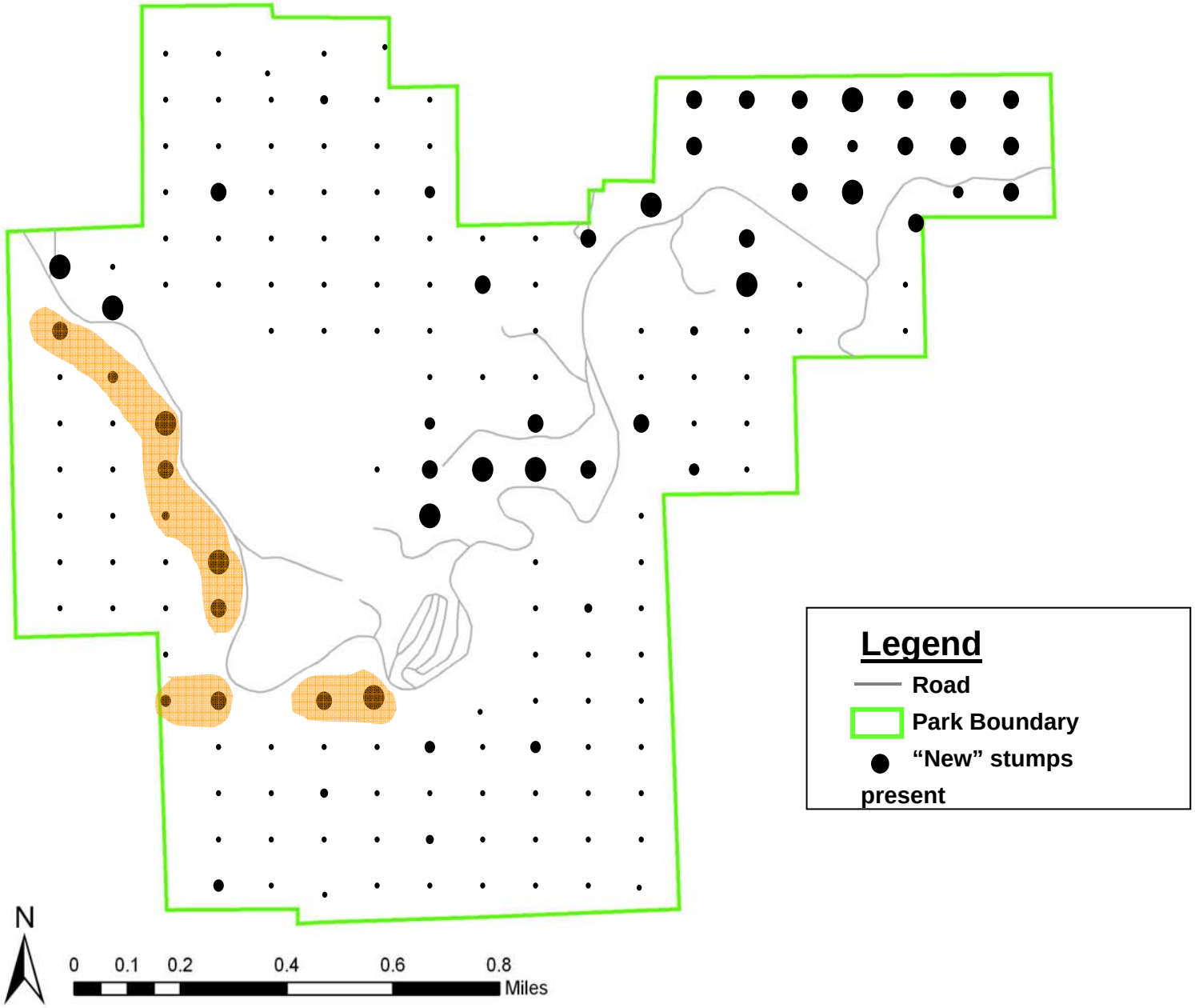


Figure 10. Evidence of fires as shown by burned stumps and snags in Mount Rushmore National Memorial.

Figure 11. Stand boundaries and points sampled for stand exam at Mount Rushmore National Memorial.

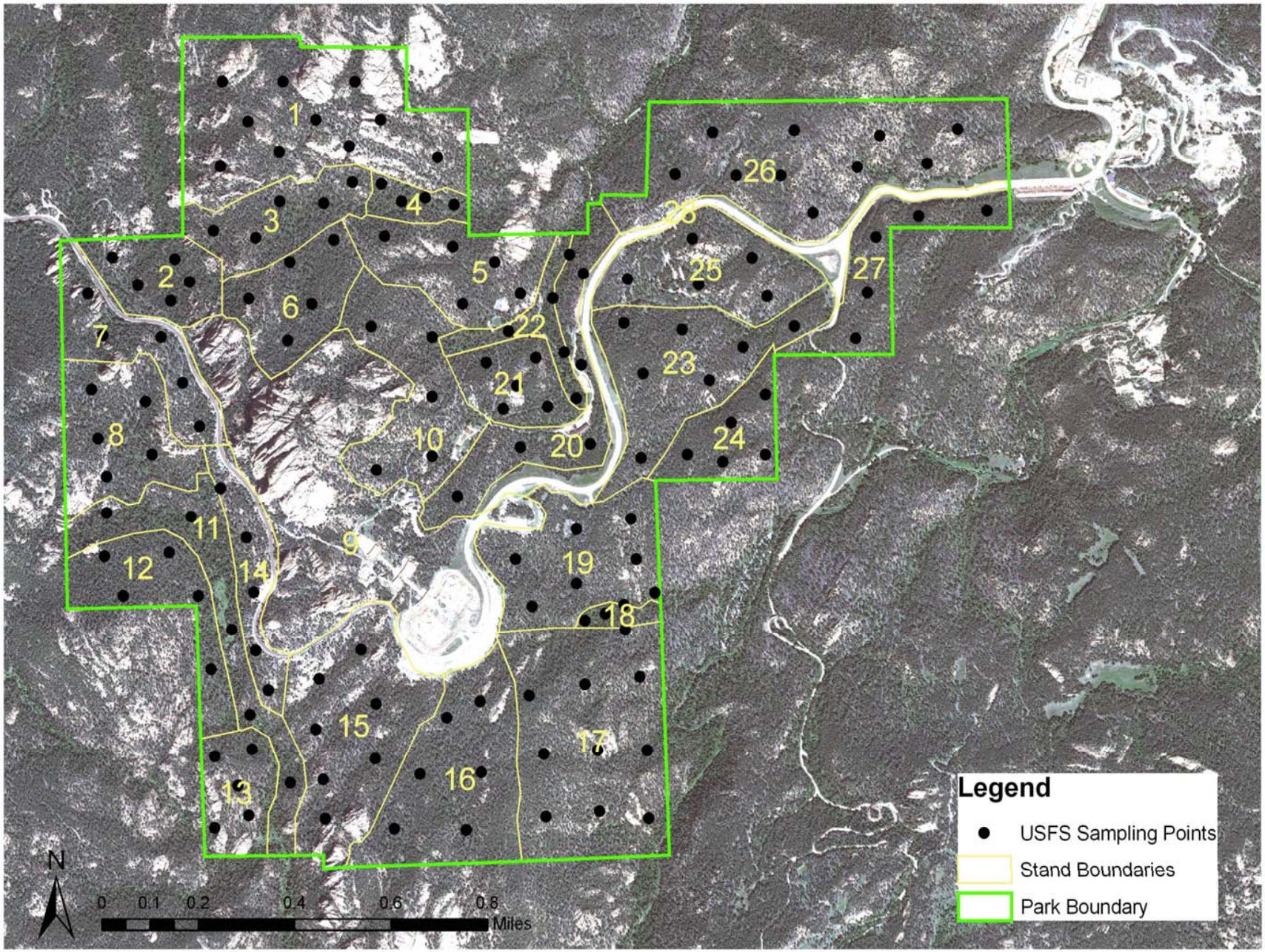


Figure 12. Relationship between coefficient of variation (CV) of basal area (blue squares), tree density (red triangles), or tree age (black circles) and stand area, as measured in the stand exam at Mount Rushmore National Memorial. Basal area (dashed line) and tree density (solid line) regressions are significant (P = 0.025 and P = 0.030, respectively), whereas the tree age (dotted line) regression is not (P = 0.27).

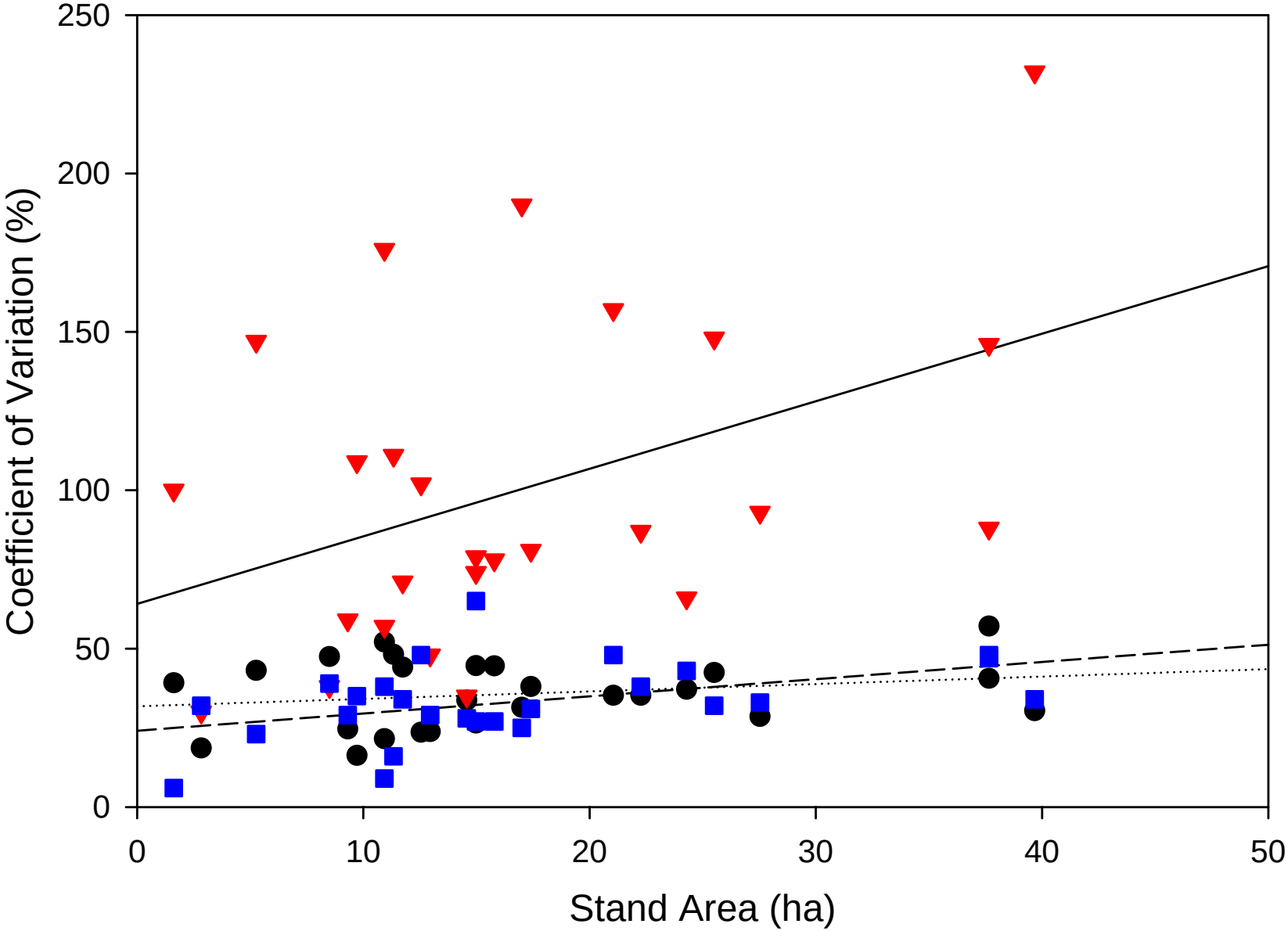


Figure 13. Stands meeting the description of old-growth forest in Mehl (1992), shaded in green, with presumably unlogged areas indicated by points with no old stumps (black circles).

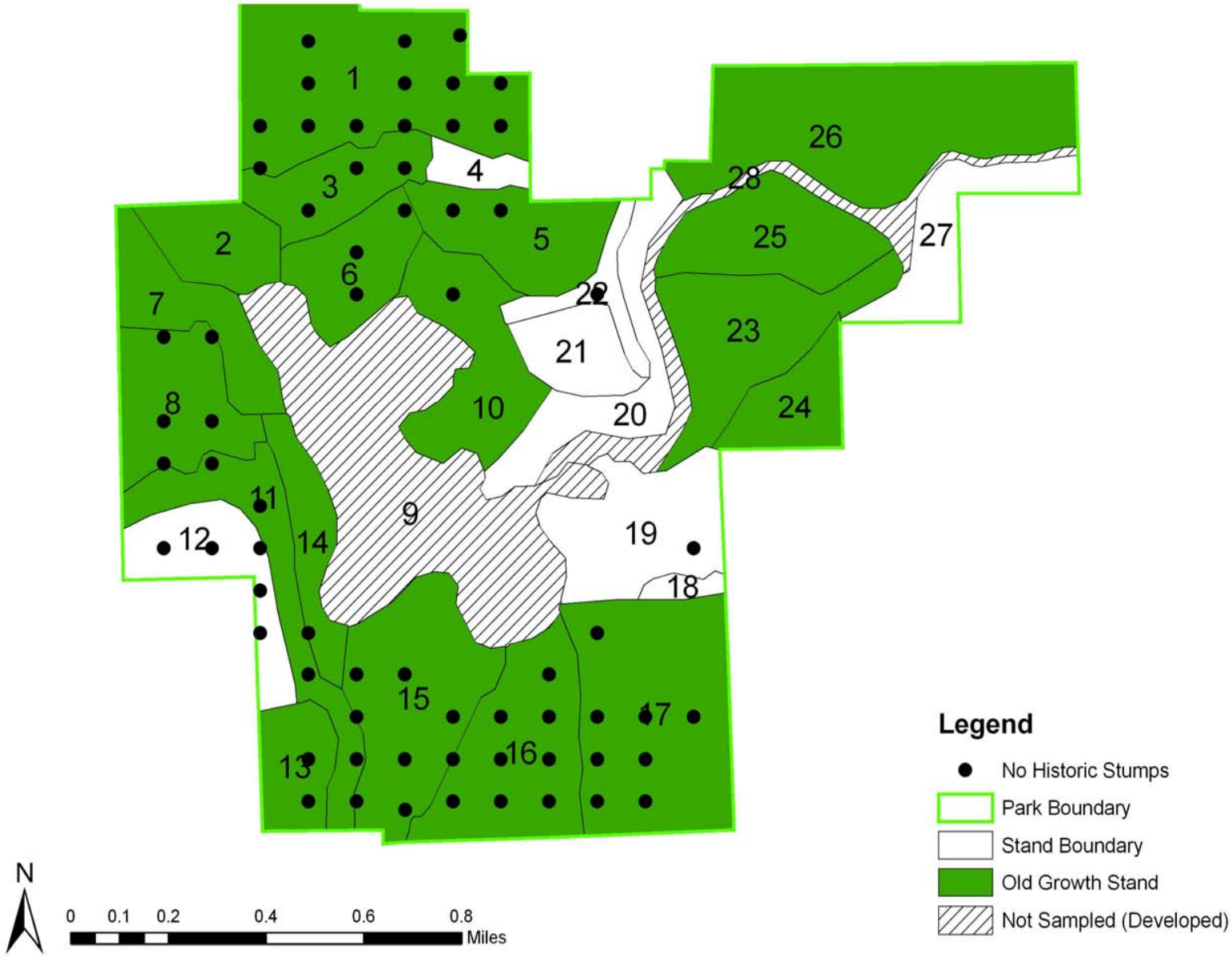


Figure 14. Aerial photographs from 1928 and 2004 illustrating increased density of trees in Black Hills ponderosa pine forest in and around Mount Rushmore National Memorial (boundary shown). 1938 photos for northeastern part of the Memorial were not available. Comparison courtesy of B. Cook.

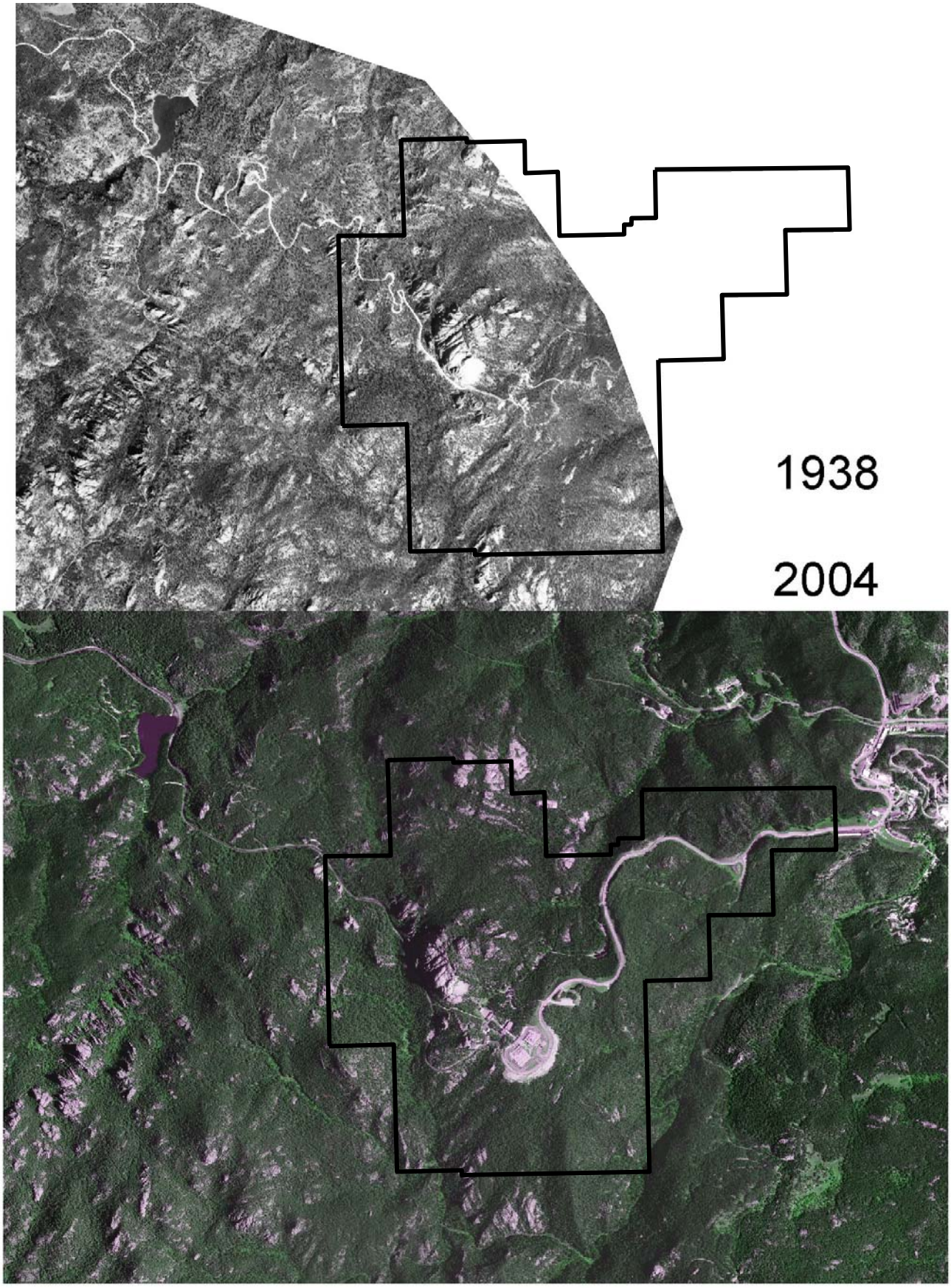
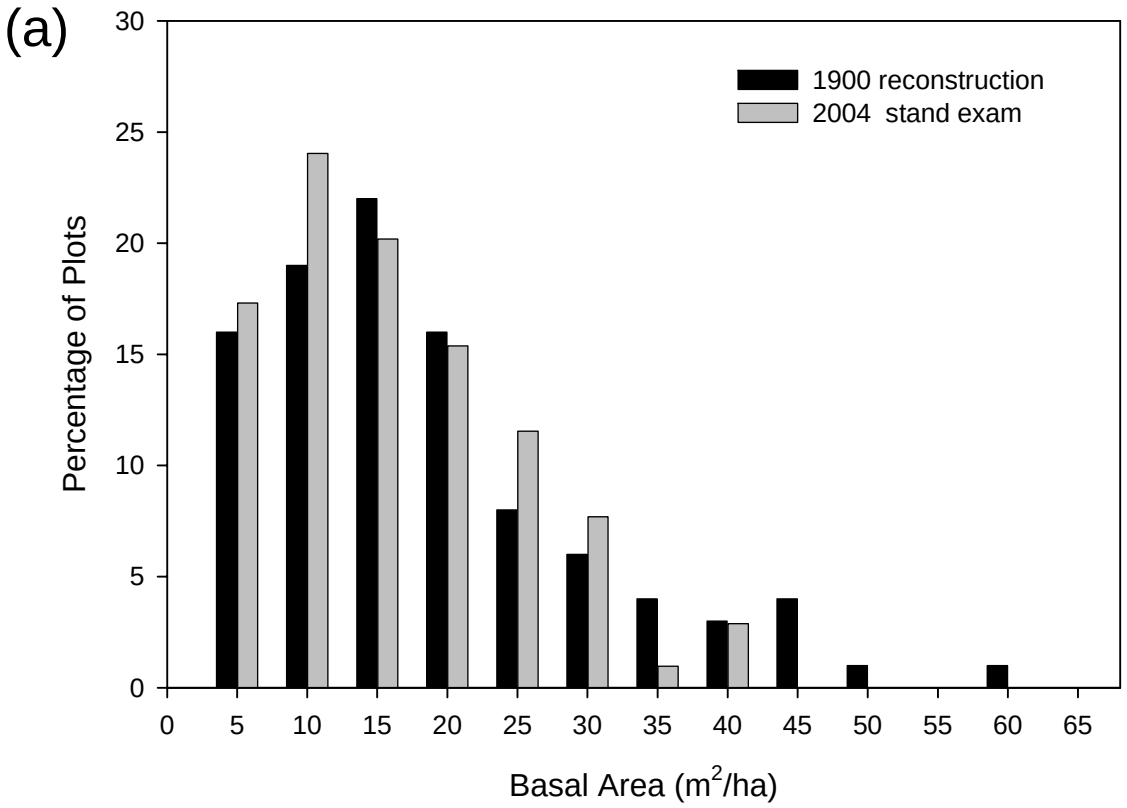


Figure 15. Comparison of forest structure at Mount Rushmore National Memorial in 2004 as measured in a stand exam (gray bars), to 1900 forest structure in the central Black Hills as reconstructed by Brown and Cook (2004; black bars). (a) Distribution of plots by basal area. (b) Distribution of trees by DBH.



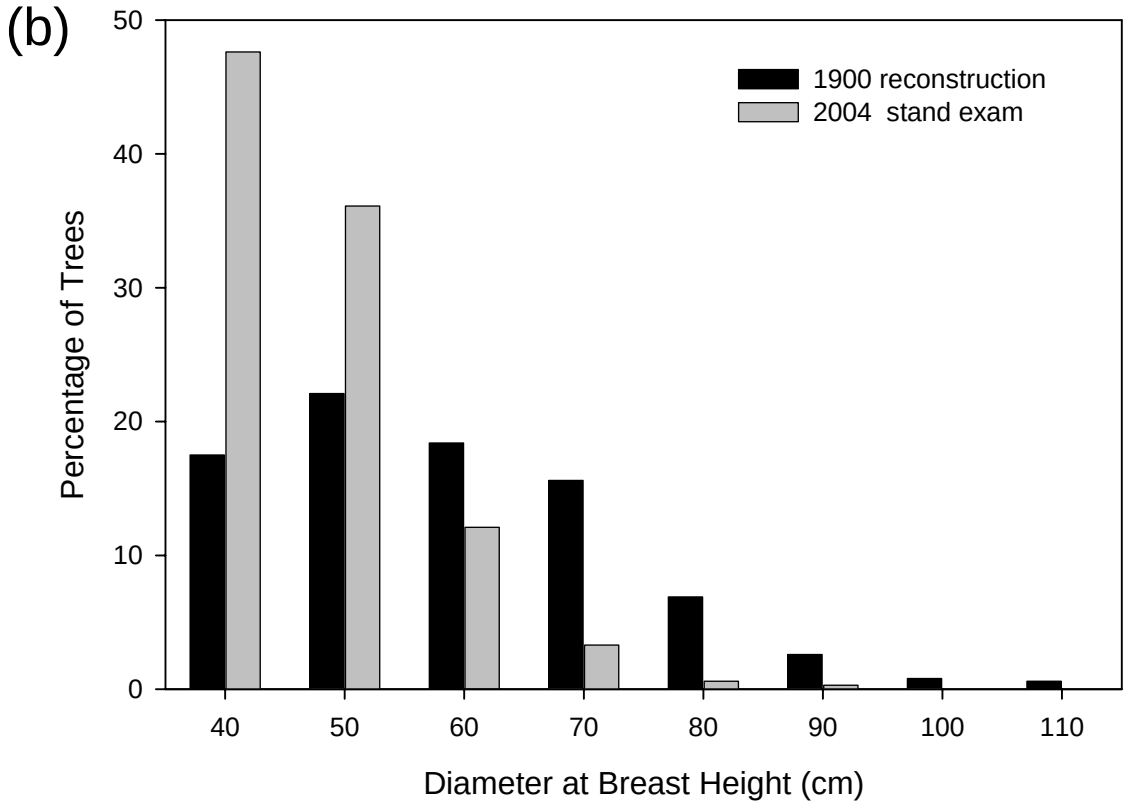


Figure 16. Areas designated by USDA Forest Service as Structural Class 5 (late-successional/old growth) within the Black Hills National Forest as a whole and, enlarged at right, near Mount Rushmore National Memorial. Arrows in the figure at left point to Class 5 stands (outside of the enlarged area), whose small size makes them difficult to see on this map.

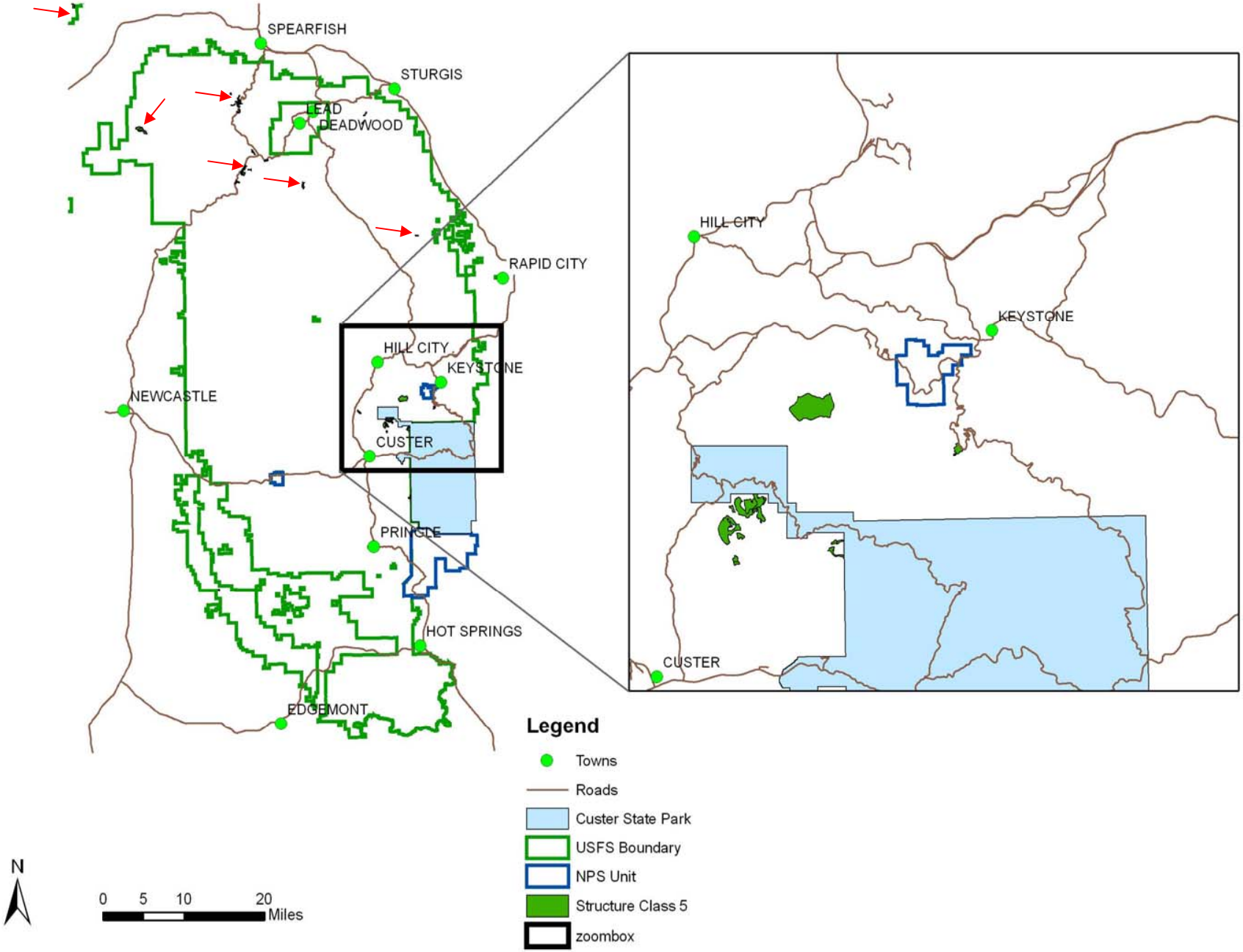
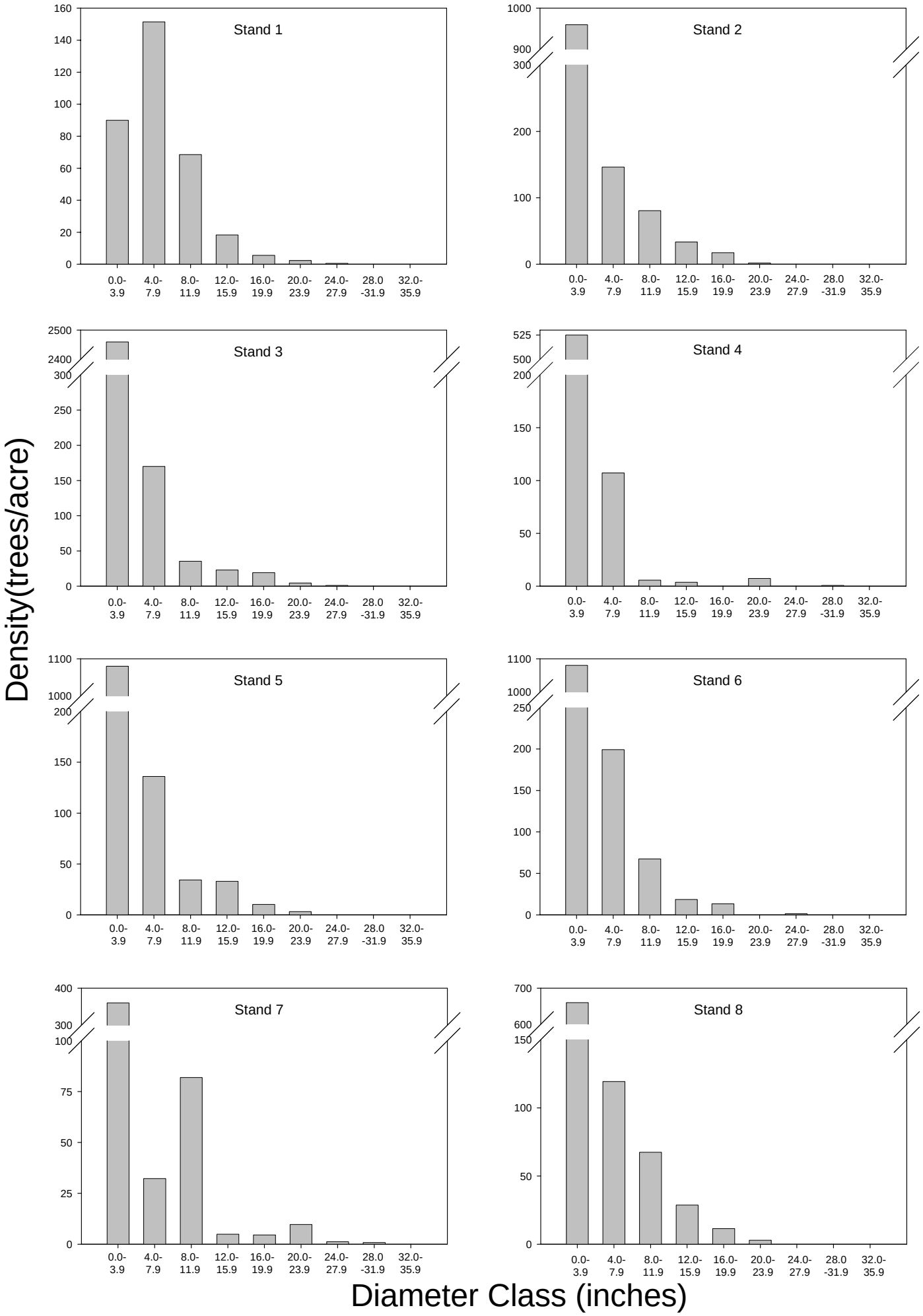


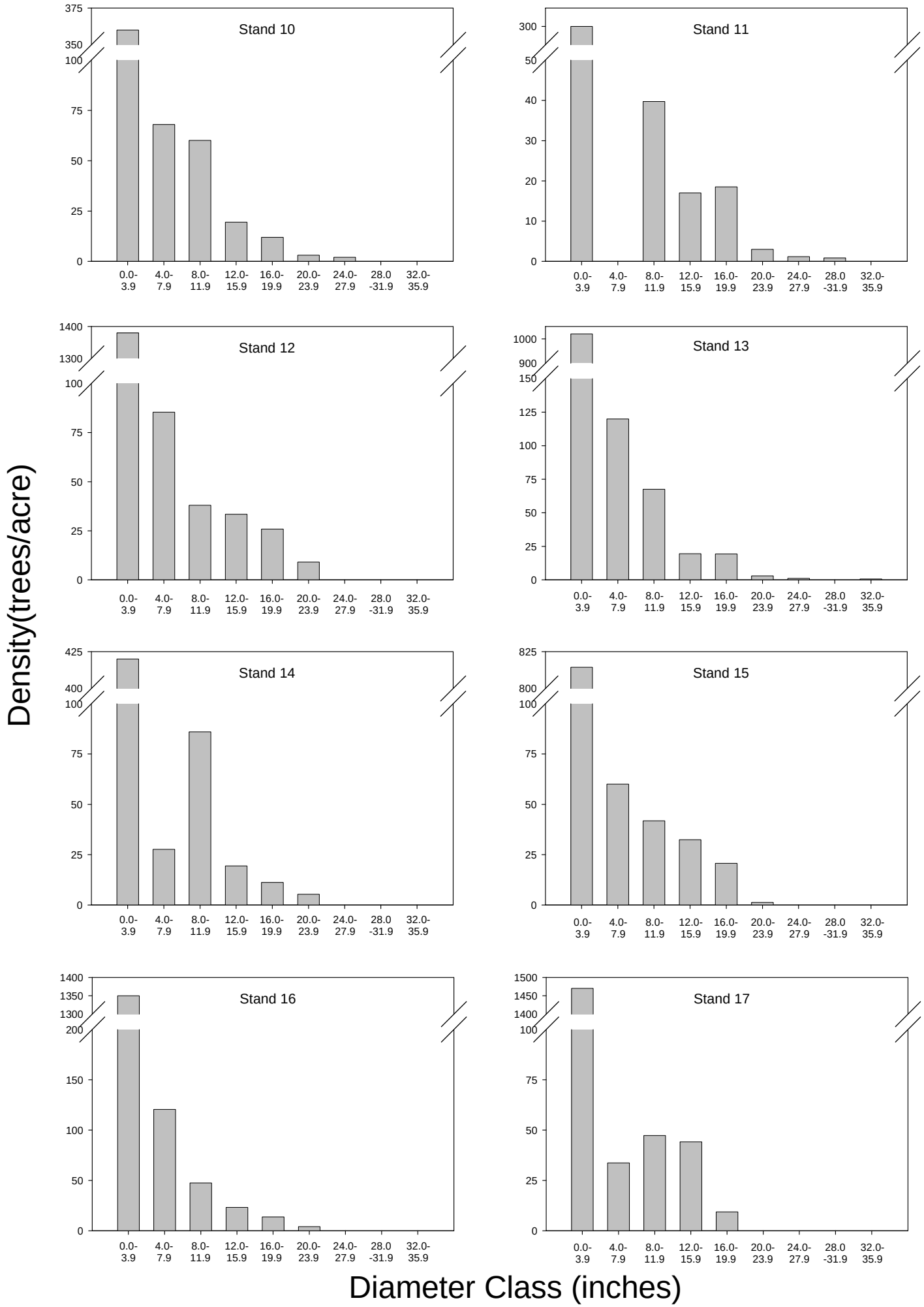
Figure 17. Large snags (standing, dead trees) provide food and shelter for many cavity-nesting birds and are an important component of old-growth forest. Notice the holes (indicated by arrows), excavated by woodpeckers, in the snags in the photos to the right and below.

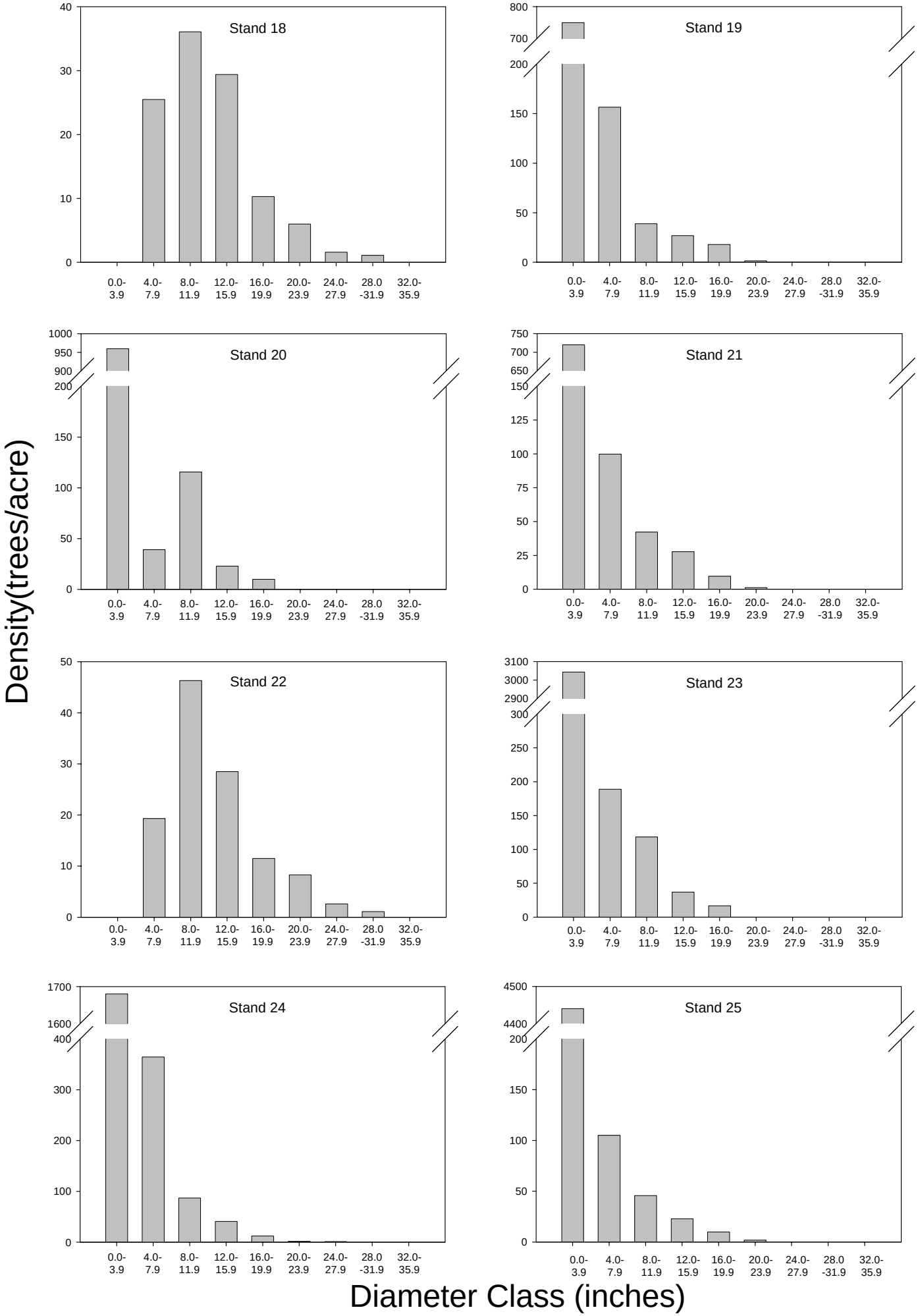
Figure 18. Coarse woody debris on the forest floor provides substrate for mosses and lichens. As the wood decays, seeds germinate and grow in the moisture-rich substrate.

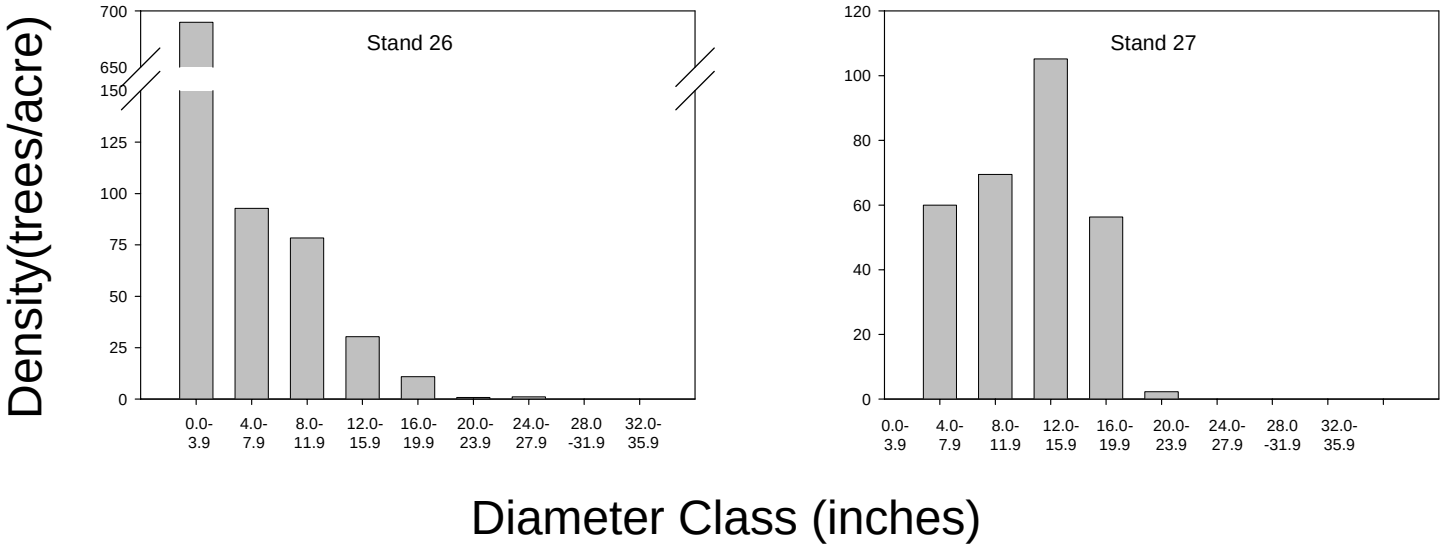
APPENDIX 1.

The following pages show the stand structure of all stands sampled in stand exam, shown as density of trees by diameter class (English units). Only data for ponderosa pine are shown.


Density(trees/acre)
Stand 1
Stand 2
Stand 3
Stand 4
Stand 5
Stand 6
Stand 7
Stand 8
0.0-3.9
4.0-7.9
8.0-11.9
12.0-15.9
16.0-19.9
20.0-23.9
24.0-27.9
28.0-31.9
32.0-35.9
Diameter Class (inches)


Stand 10
Stand 11
Stand 12
Stand 13
Stand 14
Stand 15
Stand 16
Stand 17
0.0-3.9
4.0-7.9
8.0-11.9
12.0-15.9
16.0-19.9
20.0-23.9
24.0-27.9
28.0-31.9
32.0-35.9
Density(trees/acre)
Diameter Class (inches)


Stand 18
Stand 19
Stand 20
Stand 21
Stand 22
Stand 23
Stand 24
Stand 25
0.0-3.9
4.0-7.9
8.0-11.9
12.0-15.9
16.0-19.9
20.0-23.9
24.0-27.9
28.0-31.9
32.0-35.9
Density(trees/acre)
Diameter Class (inches)


Density(trees/acre)
Stand 26
700
650
150
125
100
75
50
25
0
0.0-3.9
4.0-7.9
8.0-11.9
12.0-15.9
16.0-19.9
20.0-23.9
24.0-27.9
28.0-31.9
32.0-35.9
Stand 27
120
100
80
60
40
20
0
0.0-3.9
4.0-7.9
8.0-11.9
12.0-15.9
16.0-19.9
20.0-23.9
24.0-27.9
28.0-31.9
32.0-35.9
Diameter Class (inches)