Sarah J. Flanary and Robert E. Keane

ABSTRACT

Fire exclusion since the 1930s across western U.S. landscapes has greatly altered fire regimes and fuel conditions. After a lightning-caused fire swept through the center of the Bob Marshall Wilderness Area in 2003, researchers initiated a comprehensive study along the South Fork of the Flathead River. This study assessed the post-fire survival of over 600 iconic, relict ponderosa pine trees. These trees are of great interest as they are ancient (>400 years old), and some have Native American bark-peeling scars and fire scars. This area had not seen fire since 1910, if not earlier, despite having frequent fire (20-30 year fire return interval) prior to European settlement. Some of the trees sampled in 2003 experienced another fire in 2011 (Hammer Creek Fire). In 2017, these trees were remeasured for post-fire mortality by size class for the fifth time since the 2003 Little Salmon Complex fires. We found that mortality rates were quite low (<8%) for the larger trees (>20 inches diameter) despite the heavy pre-suppression fuel buildup and recent insect outbreaks. Ponderosa pine mortality rates remained somewhat low (<24%) throughout the sample period (2003-2017) with the larger trees having the least mortality (<18%) and the smaller trees having approximately 24% mortality. These surviving large relict ponderosa pine trees continue to thrive in the sampled areas despite a second Hammer Creek wildfire in 2011 that burned in the high fuel loading conditions created by the 2003 Little Salmon Fire.

Keywords: Bob Marshall Wilderness, wilderness prescribed fire, bark-peeled trees, postfire mortality, old growth, *Pinus ponderosa*

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Robert E. Keane has been a Research Ecologist with the USDA Forest Service, Rocky Mountain Research Station at the Missoula Fire Sciences Laboratory since 1994. His most recent research includes 1) developing ecological computer simulation models for exploring the landscape, fire, and climate dynamics, 2) conducting basic research in wildland fuel science, and 3) investigating the ecology and restoration of whitebark pine. He received his B.S. degree in forest engineering from the University of Maine, Orono; his M.S. degree in forest ecology from the University of Montana, Missoula; and his Ph.D. degree in forest ecology from the University of Idaho, Moscow.

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Introduction

The valley bottom of the South Fork of the Flathead River within the Bob Marshall Wilderness Area (BMWA) of Montana, USA includes a unique area of river terraces near the Big Prairie Ranger Station (fig. 1). This flat area is approximately 8 miles by 14 miles and is somewhat drier that the surrounding landscape because it lies in the rain shadow of the Swan Range to the west. The soils are well drained alluvial till. Prior to Euro-American settlement, the fire return interval for these areas was 20-30 years (Arno et al. 1997). Other researchers found that many of these historic fires may have been started by the Native American populations who occupied the area (Östlund and others 2005). This historical fire regime created open ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson var. *ponderosa* C. Lawson) savannas composed of widely spaced relic trees that are somewhat renowned in the BMWA. Ponderosa pine stands make up only 2 percent of the BMWA and are only found along these river bottoms.

Figure 1. Ponderosa pine savanna at White River Park in the Bob Marshall Wilderness Area (BMWA) of Montana, USA. Frequent fires kept these stands open and the trees widely spaced.

Denser forest types of western larch (*Larix occidentalis Nuttall*), Douglas-fir (*Pseudotsuga menziesii* var. *glauca* Beissn.), and lodgepole pine (*Pinus contorta* Douglas ex Loudon) are found on the slopes above the savannas. These forests historically experienced mostly mixed-severity or stand-replacement fire regimes at longer fire intervals (Arno et al. 2000). The relatively high elevation (1,350-1,500 meters AMSL) and frequent cold air pooling in the valley bottoms because of the surrounding sun-blocking mountain peaks often result in short, frost-free growing seasons that hinder effective ponderosa pine regeneration and cone production (Keane et al. 2006; Ryker and Losensky 1973). Without fire, this area would most likely revert to Douglas-fir/lodgepole pine forests over time. This area is even more unusual due to the presence of Native American bark-peeling scars on some older ponderosa pine boles (Arno et al. 2008; Östlund et al. 2005) (fig. 2). Within the South Fork valley, there are bark-peeling scars on many living ponderosas that date back as far as 1665 (Östlund et al. 2005).

Figure 2. Conifer encroachment into former pine savanna. Douglas-fir and lodgepole pine are moving into the open areas within the ponderosa pine savanna, creating higher surface and canopy fuel loads. The ponderosa pine in the middle of the photograph is over 400 years old and has a Native American bark peeling scar—note the buildup of bark peelings at the base of the tree. Photo was taken near Big Prairie Ranger Station, Bob Marshall Wilderness Area, Montana, USA.

The effective fire exclusion policy in place until the 1980s may have resulted in long-lasting ecosystem changes in the BMWA, especially in these iconic ponderosa pine stands (Arno et al. 2000; Fischer 1984; Keane et al. 2002a; Keane et al. 2002b). The absence of frequent fire in these dry, valley bottom parklike stands has resulted in increased amounts of surface fuels (litter, duff, and woody material) and the encroachment and densification of competing species such as Douglas-fir and lodgepole pine that have invaded these open pine savannas. The higher fuel loadings and abundance of canopy fuels could foster higher intensity fires that may kill these iconic ponderosa pines (Arno et al. 2008; Keane et al. 2006) (fig. 2).

In the summer of 2003, the Little Salmon Complex fire burned through many stands within the BMWA that had not seen fire in nearly a century, including the savanna river terraces (Leirfallom and Keane 2011). Within the BMWA, fires are sometimes allowed to burn to protect, maintain, and enhance resources and, as practically as possible, be allowed to function in its natural ecological role (Glickman and Babbitt 1995). The Little Salmon Complex fire, which was allowed to burn in the pine savannas during the summer, presented an opportunity to assess the effects of fire on a rare and unique wilderness ecosystem that hadn't experienced fire in some time.

While the Little Salmon Complex fire was burning, wilderness managers raised concerns that the heavy fuel buildup during the lengthy fire exclusion period could result in high mortality in these relict ponderosa pine stands and perhaps destroy bark-peeling scars. In 2004, we initiated a monitoring study to document fire-caused ponderosa pine mortality in the BMWA savanna (Keane et al. 2006). A second fire in 2011 (Hammer Creek fire) allowed us to examine the impacts of multiple fires on the old, previously burned trees. Here, we report on tree evaluation and mortality data collected during five sampling trips from 2004 to 2017 and summarize the results from the 2017 field measurements.

Methods

The study site is defined by the 8-mile long area that runs from Brownstone Creek through Big Prairie and north up to the White River (fig. 3). As this study site is within wilderness boundaries, we could not establish monumented permanent plots. Instead, previous efforts measured diameter at breast height (d.b.h.) on all large (>20 in d.b.h.) ponderosa pine trees within broadly defined transects (Keane et al. 2006). These transects, with some over 200 m wide, were located in order to sample most (>90%) of the large ponderosa pine within the study area. Maps of transect locations were created and used in all subsequent measurements. All trees sampled by Keane et al. (2006) were georeferenced during the first measurement; these coordinates were used as much as possible to find sampled pines for later remeasurement.

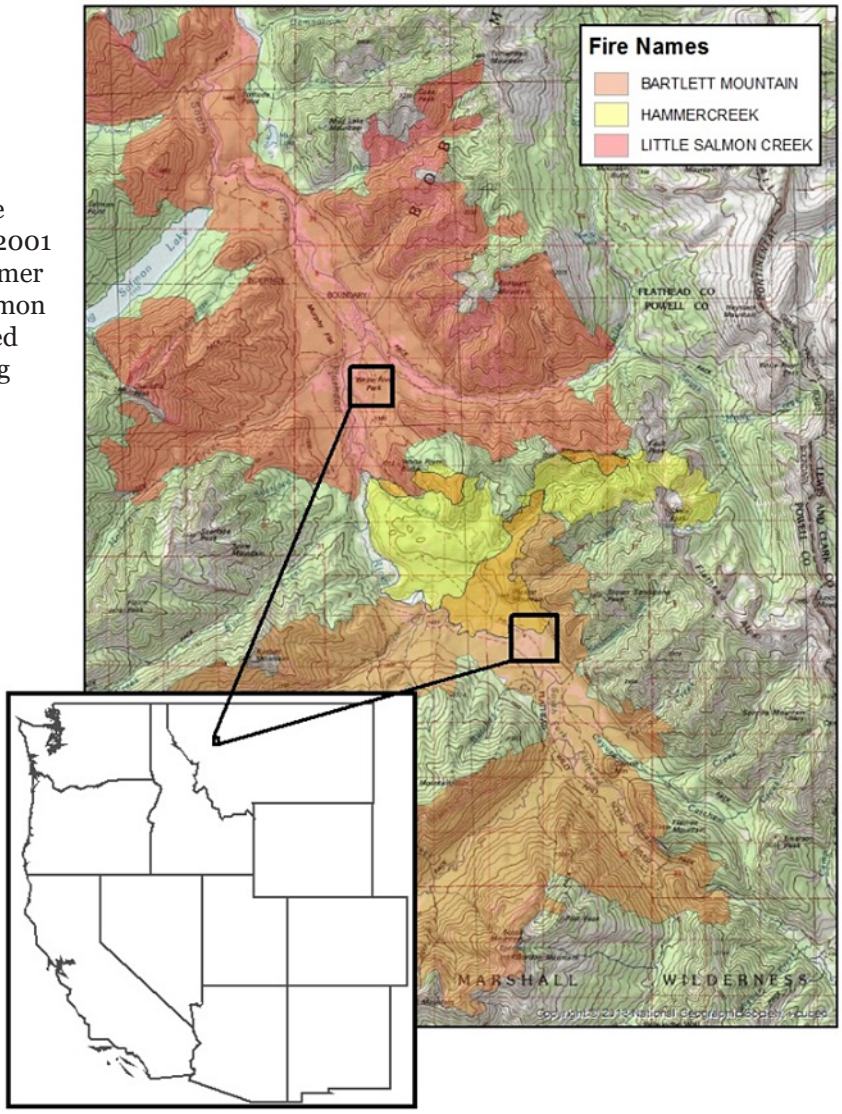

Figure 3. Map of the three fires that have burned in or around the study area since 2001 (Bartlett Mountain fire in the south, Hammer Creek fire in the middle and the Little Salmon Complex fire to the north. The two outlined boxes indicate the location of the sampling transects installed in 2004.

The geographic coarseness of the georeferenced locations and the long length of the transects meant that not all of the same trees were recorded each time. As a result, there is some variation in sample sizes across the 13 years of remeasurements and, more importantly, because of wilderness protocols and funding constraints, we could not follow the health of individual trees through time. Because of this, all analyses were performed at the population level using proportions rather than at the individual tree level.

Beginning with the first sampling effort in 2004, the d.b.h. of all large diameter ponderosa pine (>20 inch d.b.h.=diameter at breast height or 4.5 ft above groundline) were measured. Also recorded were visual assessments of health status (live, unhealthy, sick, dead) and the presence of fire or Native American bark-peeling scars. For this study, a tree was considered healthy if it had little or no sign of fire damage or beetle attack and unhealthy if it had minor injury with full expectation for recovery, and sick if it was expected to die from a combination of high crown scorch (>40%) and mountain pine beetle attack (Lutes et al. 2006). Starting in 2009, data on smaller ponderosa pines (>12 inches d.b.h. and < 20 inches d.b.h.) were also recorded. We attempted to relocate the specific trees used as bearing trees based on GPS coordinates, but the spacing and similarity of the size of the trees often made this impossible. Our target sample size was 500 trees.

Results

In 2017, we sampled 1,367 trees in the study area; 603 of these trees were greater than 20 inches d.b.h. The majority of both dead and live trees ranged from 14 to 24 inches d.b.h. (56%) (fig. 4). Of the total sample, 21 percent of the trees were dead, and 8 percent of the total trees were both greater than 20 inches in d.b.h. and dead (fig. 5). Of all recorded trees, 7 percent had a fire or Native American bark-peel scars, and of these scarred trees, we found that approximately 9 percent were killed by the fire. We also found that the larger, relict pines (>20 in d.b.h.) had significantly less mortality (18%) than the smaller sampled pine trees (24%, α=0.05, p=.019) (fig. 5).

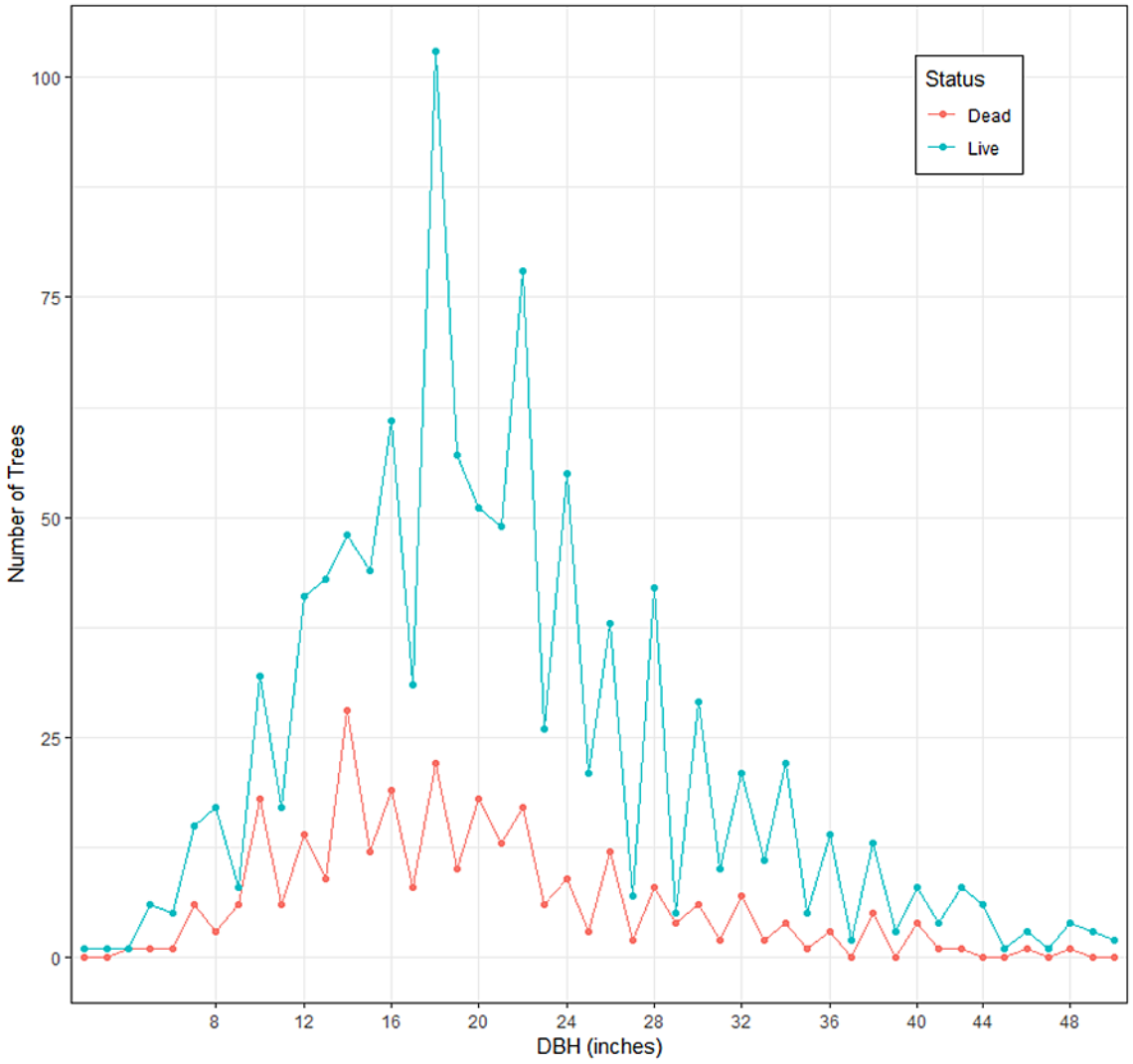

Figure 4. The diameter (d.b.h., diameter at breast height) distribution of live and dead ponderosa pine trees by one inch d.b.h. classes as sampled in 2017. Note the high frequency of trees between 16 inches and 24 inches d.b.h. All dead trees died since the 2003 Little Salmon fire.

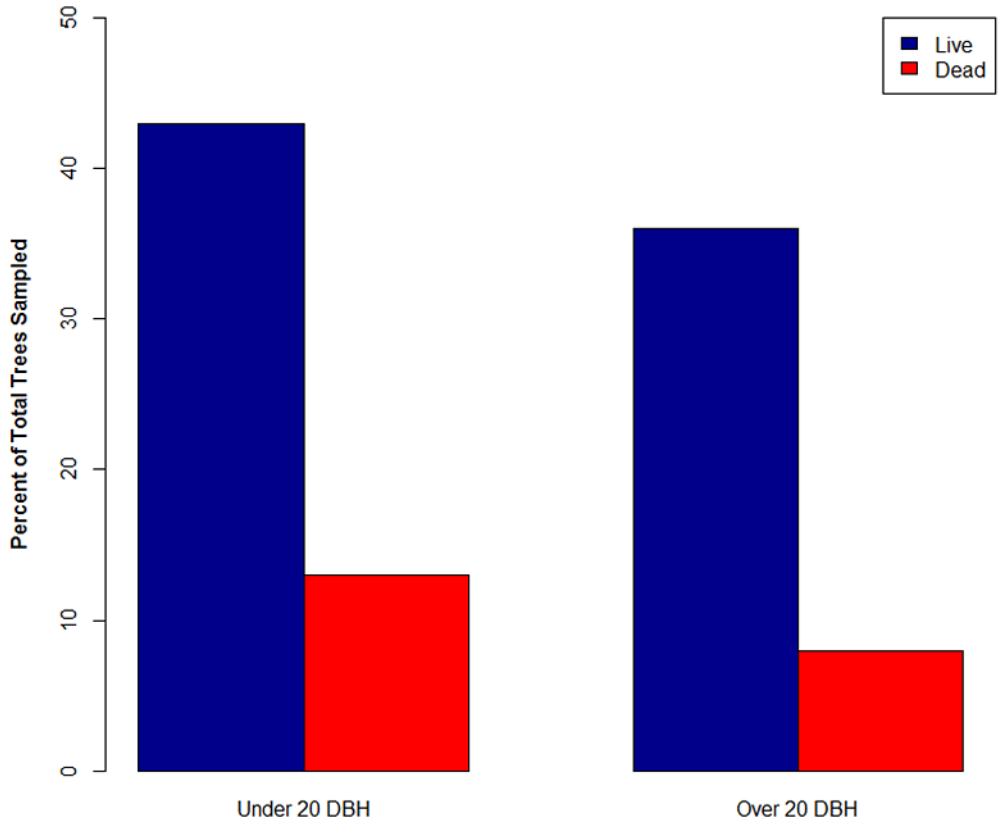

Figure 5. Percent mortality and survival (%) for all 1,367 trees broken down by the two diameter classes (less than 20 inches d.b.h. and trees greater than 20 inches d.b.h.). Note that only 8 percent of all the sampled trees were both large and dead when we sampled them in 2017 (fourteen years after the first fire), while 12 percent of the trees were less than 20 inches in d.b.h. and dead.

When comparing the 2017 fire-caused mortality rates with the rates from previous measurements, we computed mortality rate as a percent within each of the two diameter classes to be consistent with previous measurements. We found only slight fluctuations in mortality percentages over the 13 years in this monitoring period (fig. 6). The difference between the 2004 and 2017 mortality proportions for trees greater than 20 inch in d.b.h. is not statistically significant (α=0.05, p= 0.17). The difference between the 2009 measurements, when trees smaller than 20 inches d.b.h. began to be measured, and the 2017 measurements, is also not statistically significant (α=0.05, p= 0.21), even after the 2011 Hammer Creek Fire.

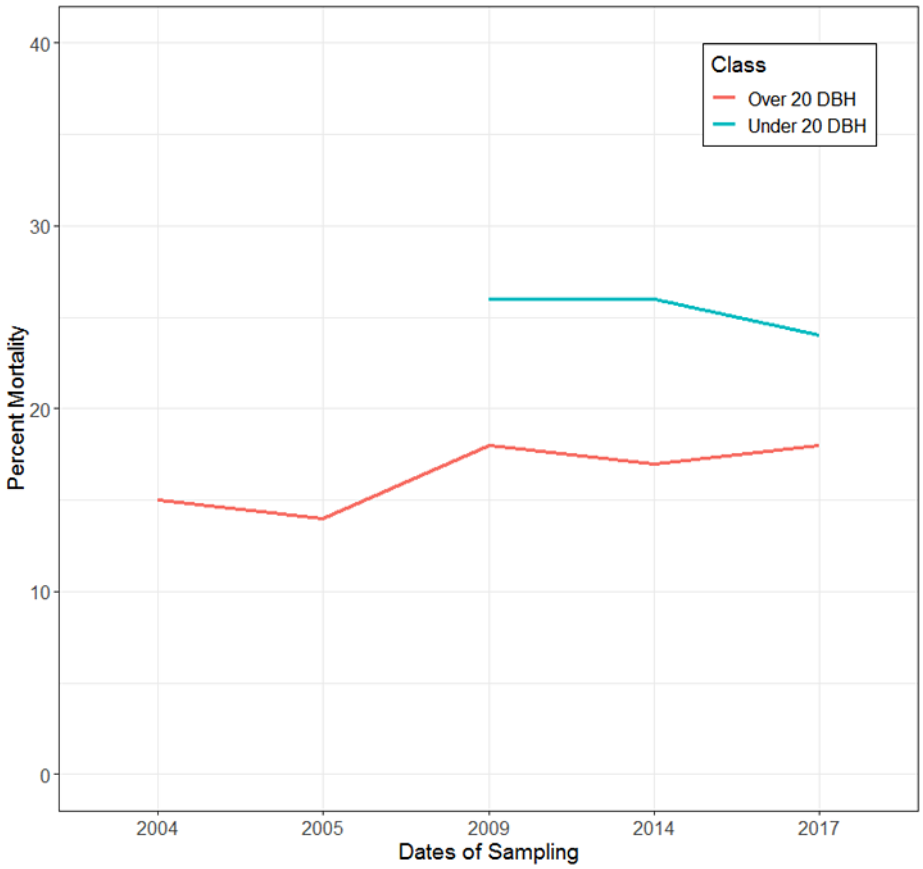

Figure 6. Mortality percentages over time since the 2003 Little Salmon Complex fires, comparing large diameter (>20 inches d.b.h.) ponderosa pine mortality to smaller diameter (<20 inches d.b.h.) ponderosa pine. To be consistent with the previous measurements, we computed the percent mortality using only trees in each of the two size classes. Percentages were calculated within diameter groupings of greater than or less than 20 inches d.b.h., rather than as a single pool. Measurements for trees under 20 inches d.b.h. did not begin until 2009 (Keane et al. 2006; Leirfallom and Keane 2011).

Management Implications

Despite concerns raised by managers about losing an iconic ecosystem by allowing wildfire to burn in a wilderness landscape that had not experienced fire for decades longer than the historical fire-return interval, our results show that these unique, relict ponderosa pine stands are remarkably resilient, experiencing less than 24 percent post-fire mortality. Most of that mortality occurred in the smaller, younger age classes (<20 inches d.b.h.). The surviving relict pines continued to thrive and experienced no significant increase in mortality (<18%) despite the occurrence of a severe mountain pine beetle outbreak and another wildfire (2011 Hammer Creek) over the 13-year sample period. We expect that larger diameter ponderosa pine will persist on the BMWA landscape as the smaller diameter trees are either thinned by successive fires or become large and survive the fires. This study also suggests that wildfire can limit encroachment by Douglas-fir and lodgepole pine and the build-up of surface fuels without causing significant mortality to the relict ponderosa pines in the BMWA.

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