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RESEARCH REPORT

CONDITION OF LIVE FIRE-SCARRED PONDEROSA PINE ELEVEN YEARS AFTER REMOVING PARTIAL CROSS-SECTIONS

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ABSTRACT

Our objective is to report mortality rates for ponderosa pine trees in Oregon ten to eleven years after removing a fire-scarred partial cross-section from them, and five years after an initial survey of post-sampling mortality. We surveyed 138 live trees from which we removed fire-scarred partial cross-sections in 1994/95 and 387 similarly sized, unsampled neighbor trees of the same species. These trees were from 78 plots distributed over about 5,000 ha at two sites in northeastern Oregon. The annual mortality rate for sectioned trees from 1994/95 to 2005 was 3.6% compared to 2.1% for the neighbor trees. However, many of the trees that died between 2000 and 2005 were likely killed by two prescribed fires at one of the sites. Excluding all trees in the plots burned by these fires (regardless of whether they died or not), the annual mortality rate for sectioned trees was 1.4% (identical to the rate from 1994/95 to 2000) compared to 1.0% for neighbor trees. During these fires, a greater proportion of sectioned trees died than did catfaced neighbor trees (80% *versus* 64%) but the difference was not significant.

Keywords: ponderosa pine, fire history, Oregon, effect of sampling, partial cross-sections, fire scar, wounding, dendrochronology, tree rings, catface.

INTRODUCTION

Trees that are repeatedly injured before cambium can re-establish around the full circumference often have a cavity that is surrounded by woundwood ribs (Smith and Sutherland 2001) called a catface. Fire-scarred partial cross-sections have been removed from catfaces on thousands of live ponderosa pine trees (*Pinus ponderosa* Dougl. ex Laws.) across western North America to reconstruct past fire regimes. We used fire-scarred ponderosa pine trees in the Blue Mountains of northeastern Oregon in a previous study to reconstruct the history of surface fires by removing partial cross-sections from live and dead trees in 1994 and 1995 (Heyerdahl *et al.* 2001). In 2000, to address concerns over the effects of removing partial cross-sections from live trees, we began monitoring tree mortality. At that time, we located the 138 sectioned trees and identified 387 similarly sized neighbor trees (109 or 28% with catfaces) at two sites (Imnaha and Dugout; Heyerdahl and McKay 2001). We found that by 2000, mortality was low for both groups, although it was significantly higher for the sectioned trees than their neighbors (8% *versus* 1%). We suggested that mortality among sectioned trees was low in part because we removed relatively small sections, averaging 7 cm in vertical depth and only 8% of the tree's cross-sectional area, from large trees of a species with effective, resin-based defenses against insects and pathogens. Since that time, two prescribed fires burned much of the Imnaha site in 2002 and 2003 (24 of 30 plots). Our objective here is to estimate mortality rates for the sectioned and neighbor trees in 2005, ten to eleven years after we removed fire-scarred partial cross-sections.

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METHODS

In 2005, we determined whether each sectioned tree and its neighbors were alive or dead (green needles present or absent, respectively). For sectioned trees, we examined the sampling cavity for fine sawdust (as an indication of insect activity), resin, and callus tissue. We assessed whether the dead *versus* surviving sectioned trees differed in diameter (mean dbh) or size of sample removed (mean cross-sectional area and mean vertical depth) using non-paired two-sample t-tests that account for differences in variance. We assessed whether sectioning led to more deaths among sectioned than neighbor trees by testing for a difference in the proportion of trees that died in each group (equivalent to a χ^2 test of homogeneity; Zar 1984). We conducted this test both including and excluding all trees in the plots burned by the prescribed fires at Imnaha. For trees in the plots burned by the prescribed fires, we assessed whether a greater proportion of sectioned trees than catfaced-neighbor trees died. We estimated annual mortality as the percentage of trees that died divided by the number of years since the fire-scarred section was removed (geometric mean of the percentage computed for trees sampled in 1994 *versus* 1995).

RESULTS

From 1994/95 to 2000, 8% of the sectioned trees died (11/138 trees, Heyerdahl and McKay 2001). From 2000 to 2005 an additional 30% died (41 trees), most of them likely as a result the prescribed fires at Imnaha (36 trees, Figure 1), including 15 trees we could not relocate and

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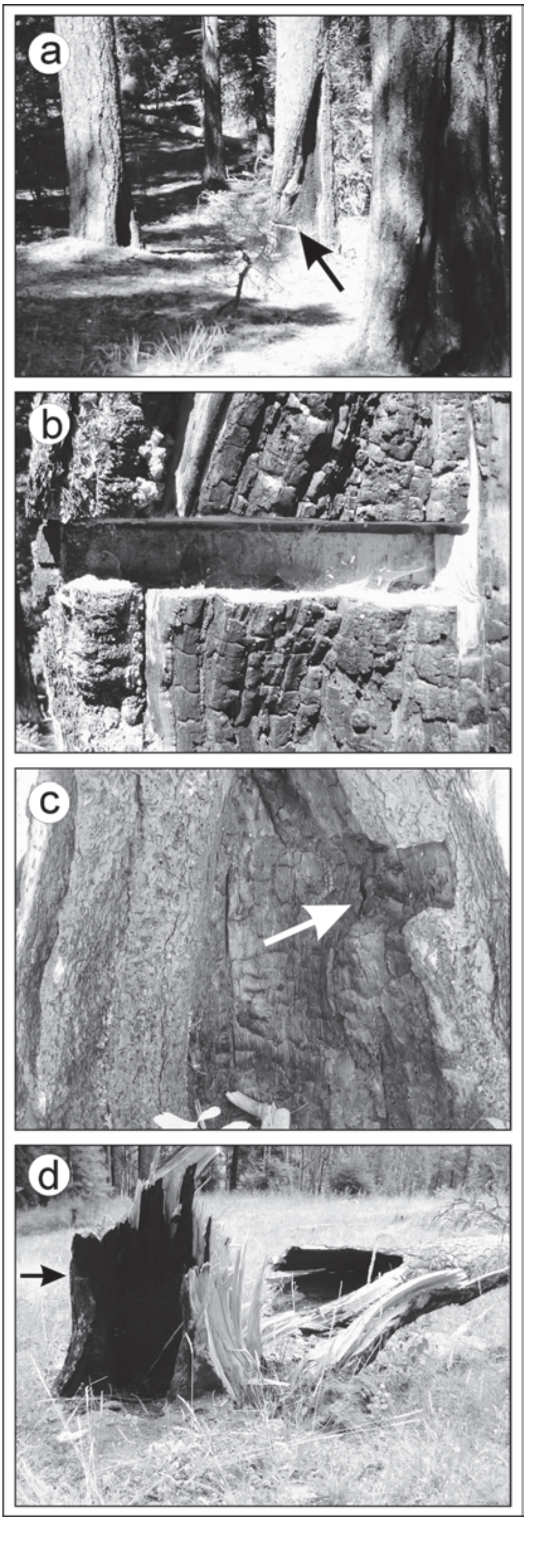

Figure 1. Condition of sectioned ponderosa pine trees in 2005 (sampling wounds indicated with arrows). (a) Tree at Dugout, sampled in 1994 and still living in 2005. (b) Typical condition in 2005 of a wound resulting from the removal of a partial cross-section in 1994. The condition of this particular wound in 2000 was shown in Figure 5a of Heyerdahl and McKay (2001). (c) Tree at Imnaha that survived the prescribed fires in 2002 and 2003. However, the sampling wound made in 1995 was partially consumed by these fires. (d) Tree at Imnaha sampled in 1994, which was alive in 2000 but likely killed during the prescribed fires in 2002 and 2003.

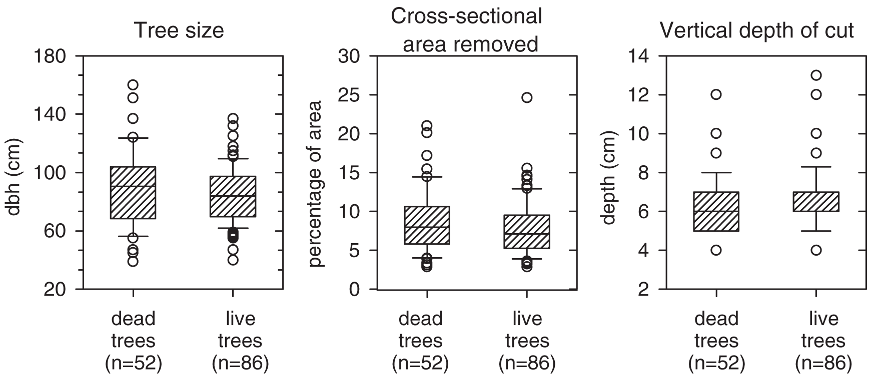

Figure 2. Characteristics of live *versus* dead sectioned trees. All 138 trees were alive in 1994/95 when fire-scarred partial cross-sections were removed from them. Eleven of the 52 dead trees died between 1994/95 and 2000 while the remaining 41 trees died between 2000 and 2005, most of them (36 trees) likely as a result of the prescribed fires at Imnaha in 2002 and 2003. The boxes enclose the 25^{th} to 75^{th} percentiles and the whiskers enclose the 10^{th} to 90^{th} percentiles of the distribution of trees. The horizontal line across each box indicates the median and all values falling outside the 10^{th} to 90^{th} percentiles are shown as circles.

assumed were killed by the first fire and consumed by the second. The five remaining dead trees were at Dugout and still standing in 2005, except one that failed at the roots. Of the six trees that died but were still standing in 2000, one failed at the roots by 2005 and another was not found in 2005 but we assume it fell and was consumed during the prescribed fires. The sample cavities of the 86 sectioned trees that were still alive in 2005 appear relatively unchanged since 1994/95, except the cavities on six trees that were partly consumed during the prescribed fires (Figure 1). In the remaining unburned cavities, 48% had fine sawdust in the cavity (compared to 40% in 2000), 99% had secreted some resin into the cavity (93% in 2000), generally from the upper surface, and 85% had visible callus tissue along the vertical margins of the cavity (75% in 2000).

As in 2000, there was no significant difference among sectioned trees in the diameter of those that died *versus* those that survived (mean dbh; $p=0.29$, Figure 2). Nor was there a significant difference in the size of the partial cross-sections we removed (cross-sectional area, $p=0.12$; vertical depth, $p=0.05$).

From 1994/95 to 2000, 1% of the neighbor trees died (2/387 trees, Heyerdahl and McKay 2001). From 2000 to 2005, an additional 23% died (87 trees), most of them likely as a result of the prescribed fires at Imnaha (64 trees, including 44 trees we could not relocate). Of the dead neighbors not killed by the prescribed fires, all were still standing in 2005, except one that failed at the roots. Of the two neighbors that died but were still standing in 2000, one had failed at the roots by 2005.

Since 1994/95, a significantly larger fraction of the sectioned *versus* neighbor trees died (52/138 *versus* 89/387; $p<0.001$). However, this difference was not significant (15/92 *versus* 25/263; $p=0.078$) when we considered only trees that were not in the plots that burned during the prescribed fires at Imnaha. Moreover, considering only those cat-faced trees in the plots that did burn during these fires, there was no significant difference in the fraction of sectioned *versus* neighbor trees that died (37/46 or 80% *versus* 23/36 or 64%, respectively; $p=0.164$).

The annual mortality rate from 1994/95 to 2005 for sectioned trees was 3.6% *versus* 2.1% for the neighbor trees. However, excluding all trees in the plots burned by the prescribed fires at Imnaha (regardless of whether they died or not), the annual mortality rate for sectioned trees was 1.4% compared to 1.0% for neighbor trees.

DISCUSSION

Removing a small, fire-scarred partial cross-section does not substantially increase the mortality rate of live ponderosa pine trees in the first 11 years after sampling. Excluding trees likely killed by the prescribed fires at Imnaha, the annual mortality rate of live, sectioned trees from 1994/95 to 2000 was identical to the rate we estimated for the period from 2000 to 2005 (1.4%). For trees likely killed by the prescribed fires, trees with catfaces died at similar rates, regardless of whether they had been sectioned or not. Although post-fire mortality of ponderosa pine has been studied throughout the Interior West (Fowler and Sieg 2004), none of these studies reported post-fire mortality of trees with catfaces *versus* those lacking them. However, among large ponderosa pine trees (>20 cm dbh) after one wildfire in Montana, a significantly greater proportion of the trees with fire scars and/or peel scars died or were dying (41% of 117 trees) than were trees that lacked scars (31% of 338 trees; $p=0.116$; Keane *et al.* 2006). Given this result and our observations of the effects of fire on catfaced trees at Imnaha, it is likely that our 109 neighbor trees with catfaces are more representative of the sectioned trees than the remaining neighbor trees that lack catfaces, especially when the catfaces are similar in size to those of sectioned trees. We did not require our neighbor trees to have catfaces nor did we measure the size of those catfaces when they did occur but we recommend doing so in future studies of this kind. Removing small, fire-scarred partial cross-sections also does not appear to have decreased the strength of the stem in the years since sampling as the sectioned trees whose stems subsequently broke did not do so at the sample cavity. We continue to suggest that sampling live, fire-scarred ponderosa pine trees remains an important and generally non-lethal method of obtaining information about historical fires that can supplement the information obtained from dead fire-scarred trees.

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