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A BIOLOGICAL EVALUATION OF TREE SURVIVORSHIP WITHIN THE LOWMAN FIRE BOUNDARY, 1989-1993

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ABSTRACT

In 1989, the Lowman fire burned 47,600 acres in the South Fork Payette River drainage near the town of Lowman, Idaho. Impact plots were installed to monitor tree survivorship and causes of mortality. Eighty two percent of the ponderosa pine and 52 percent of the Douglas-fir monitored in this study survived the fire. Trees which died from fire had an average crown scorch of 74 percent and trees which died from beetles had an average crown scorch of 48 percent. The data set compiled during this study was used to validate a probability of mortality equation developed by Reinhardt and Ryan (1988). This equation accurately classified trees as dead or alive 83 percent of the time. Marking guidelines for both Douglas-fir and ponderosa pine based upon DBH and percentage of the crown volume scorched could be developed using this equation.

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INTRODUCTION

On July 26, 1989 a lightning storm ignited over 100 fires on the Boise National Forest in south-central Idaho. Four of these fires burned together to form the Lowman fire complex covering 47,600 acres in the South Fork Payette River drainage near the town of Lowman, Idaho. The Lowman fire complex was controlled on August 29, 1989.

Prior to the fire and after four consecutive years of drought, Douglas-fir beetle (DFB) and western pine beetle (WPB) populations reached outbreak status. The 1989 annual aerial detection survey by Forest Pest Management (FPM) detected 53 DFB mortality centers ranging in size from 10 to 700 trees per center within what was to become the fire boundary. Additionally, WPB caused 93 mortality centers ranging in size from 10 to 200 trees per center within the same area. Within a 3 mile radius of the fire boundary an additional 140 DFB caused mortality centers and 50 WPB caused mortality centers were detected. Beetle populations were very high in the area.

Immediately following the fire a large fire salvage effort was initiated. FPM was asked to help develop marking guidelines for fire damaged trees at greatest risk of death from beetle attack. The assumption was that significant numbers of trees which would normally survive the fire would be killed by bark beetles. In addition, the Forest requested our prognosis for the existing beetle outbreaks both within and outside of the fire boundary. We provided these predictions but felt the need to monitor the situation through a series of ground plots. This report documents our findings between 1989 and 1993.

LITERATURE REVIEW

The survival potential of conifers after a fire is dependent upon the season of the fire (Dieterick 1979, Wagener 1961), percentage of crown scorched (Dieterick 1979, Herman 1954, Wagener 1961, Lynch 1959, Van Wagner 1973, Ryan 1982, Ryan et al. 1988, Reinhardt & Ryan 1988, Peterson 1985), the amount of cambial kill (Ryan 1982, Ryan et al. 1988), the amount of root kill (Ryan 1982, Reinhardt & Ryan 1988) and other secondary factors such as site conditions (Dieterick 1979, Wagener 1961), availability of growing season moisture (Dieterick 1979) and insect population pressure (Dieterick 1979, Miller & Keen 1960, Miller & Patterson 1927, Furniss 1965, Fischer 1980). Survival of ponderosa pine is best predicted by the percentage of crown scorched while Douglas-fir survival is best predicted by the amount of cambial damage (Ryan et al. 1988). Lynch (1959) found that few ponderosa pine greater than 4 inches DBH died if crown damage was less than 80 percent. Ryan et al. (1988) found that the number of dead cambial quadrants is the most important predictor of mortality in Douglas-fir and mortality is likely if more than 1 quadrant is dead at breast height.

In burned-over forests, trees which are likely to be attacked by bark beetles would normally recover from fire damage (Miller & Patterson 1927, Furniss 1965). WPB is reported to prefer trees which have been lightly to moderately burned (Miller & Patterson 1927): lightly burned trees had blackened boles and minor amounts of foliage scorch; while moderately burned trees had some cambium damage, total crown scorch and live buds. Furniss (1965) reported that the incidence of DFB attack "increased with the degree of crown injury and cambial injury, but declined abruptly in completely defoliated trees." In fire damaged ponderosa pine and Douglas-fir, survival of beetle brood was much reduced over that observed in unburned areas (Miller & Patterson 1927, Furniss 1965). Therefore beetle populations did not seem to build within the fire boundary.

Most fires have not contributed to large bark beetle outbreaks (Miller & Keen 1960). Increased levels of tree mortality have occurred within a 2 to 3 year period immediately following these fires but the mortality has been confined to damaged trees (Miller & Patterson 1927). Seldom have populations built-up within the fire perimeter and moved into green stands outside of the fire boundary. One exception is the Tillamook Fire of 1933 in western Oregon. DFB fully colonized fire-injured Douglas-fir before moving into green trees in adjacent stands. DFB activity covered 5 counties and was reportedly a result of beetle population expansion from the burn (Bedard 1950).

METHODS

Twenty-four transects of 3 plots each were installed within the Lowman fire boundary. Sample stands were widely distributed within the burn boundary and had relatively easy access from a system road.

Site and stand characteristics including elevation, aspect and habitat type were recorded at each plot. All trees within each 10 basal area factor (BAF) variable plot were tagged with a discreet number and the following information was recorded: species, diameter at breast height (DBH), total height, pre-fire crown ratio, percentage of crown volume scorched, relative intensity of bole char, percentage of circumference affected by bole char, uphill height of bole char, downhill height of bole char, intensity of ground fire, percentage of area under the drip line burned and tree vigor. Relative bole char intensities ranged from none (Bole char = 1) to deep bark damage thought to affect the cambium (Bole char = 4). Bole char ratings were calculated by multiplying the relative intensity of the bole char by the percentage of circumference affected.

Plots were installed in November 1989 and revisited in 1990 and 1993. During the revisits the status of each tree either alive, dead, cut or missing and any evidence of bark beetles along with the status of the attack (successful mass attack, unsuccessful attack, strip attack, etc.) were recorded. A tree was considered to be beetle-killed if the gallery patterns associated with bark beetles were detectable and if evidence of attack occurred around more than 50 percent of the circumference of the bole. The presence of wood borers was noted but it was not considered the primary cause of death so these trees were not classified as beetle-killed.

Many of the plots were salvaged logged. Only trees which could be monitored until death or until the end of the 1993 evaluation period were included in the data set and analyzed.

Descriptive statistics were calculated using Number Cruncher®, a statistical program for personal computers. The data set was also used to validate a probability of mortality equation developed by Reinhardt and Ryan (1988). This equation was used to classify trees into 2 classes, dead or alive. Probabilities > .50 indicated that a tree was expected to die as a result of fire. Probabilities less than .50 indicated that a tree was predicted to survive. The prediction equation evaluated was:

$$Pm = 1/(1 + \exp(- (1.466 - 4.862B + 1.156B^2 + 0.000535C^2))),$$

where Pm = probability of mortality,
B = bark thickness in inches , and
C = percentage of crown volume scorched

Bark thickness for each tree in our data set was not directly measured but was predicted using DBH and bark thickness regression equations published for each tree species.

Ponderosa pine B = 0.070(DBH) (Keane et al. 1989)

Douglas-fir B = 0.065(DBH) (Monserud 1979)

B = single bark thickness
DBH = diameter of outside bark in inches

Actual crown volume scorched was estimated in the field.

RESULTS AND DISCUSSION

Five hundred and seventy eight sample trees were tagged at the beginning of this study in 1989. Fourteen percent of these trees were logged prior to our revisit in 1990 and an additional 11 percent were logged or recorded as missing between 1990 and 1993. Only 435 trees could be accounted for from 1989 to our final visit in 1993. These trees are the sample population discussed in the remainder of this paper.

Ponderosa pine, Douglas-fir and subalpine fir comprised 56, 43 and 1 percent of the sample trees,, respectively. Subalpine fir was poorly represented and was dropped from the analysis. Of the 243 ponderosa pine trees sampled, 82 percent survived during the 4 year evaluation period; as did 52 percent of the 188 Douglas-fir trees.

Trees which died were classified as fire-killed or beetle-killed. Table 1 lists the frequencies of trees by species which survived, died from fire alone or died as a result of bark beetle attack. Table 1 also contains 2 measurements of damage; percentage of crown volume scorched and a bole char rating. Trees which survived the fire and beetles had an average crown scorch of 17 percent. Trees which died from fire had an average crown scorch of 74 percent and trees which died from beetles had an average crown scorch of 48 percent. There was a considerable difference in the average crown scorch between Douglas-fir trees which died from fire (74 % crown scorch) and Douglas-fir trees which died from bark beetles (39 % crown scorch). While not as pronounced, the same trend was apparent in ponderosa pine. Ponderosa pine which died from fire had a 79 percent crown scorch while ponderosa pine which died from beetles had a 60 percent crown scorch.

Mean bole char ratings for trees which survived the fire (208, SE = 6.05) were similar to bole char ratings for trees which died from bark beetles (224, SE = 15.83). Trees which died as a result of the fire alone had a higher bole char rating (302, SE = 12.65).

Figure 1 displays the mean crown scorch and the 95 percent confidence interval for trees which survived the fire, died from fire alone or died as a result of beetle attack. Except in the case of ponderosa pine the confidence intervals for the 3 classes; alive, dead from fire, and dead from beetles, did not overlap. This suggests that the crown scorch characteristics for each class can help discriminate which trees will survive and which trees will die from fire or beetles. Figure 2 displays the mean bole char ratings and their confidence intervals. The confidence intervals for bole char ratings are less distinct but it appears that the more intensive bole char ratings are characteristics of the group which will die from fire, while the bole char on trees which survived the fire and on trees which died from bark beetle attacks are very similar.

Larger diameter trees have thicker bark and are therefore reported to withstand fire (Martin 1963, Hare 1965), however these larger diameter trees tend to be preferred by bark beetles particularly

DFB and WPB. The average DBH for trees which survived the fire was 19.33 inches. This can be compared to an average DBH of 14.14 inches and 20.20 inches for trees which died from fire and bark beetles, respectively. It is apparent that DFB selected the largest trees. However this trend did not necessarily hold for ponderosa pine. Figure 3 displays this relationship.

The probability of mortality equation developed by Reinhardt and Ryan (1988) uses bark thickness and observed crown volume scorched (percent) to predict the likelihood that a tree will die as a result of a fire. The model accurately classified 83 percent of the trees in our data set into 2 classes, alive or dead. Only 17 percent were misclassified. Douglas-fir trees were misclassified more frequently than ponderosa pine. Six percent of the trees which, actually survived were predicted to die. An additional 11 percent of the trees which died were predicted to survive the fire. Fifty four percent of the trees which were expected to survive but actually died, did so as a result of bark beetle attack, indicating that a significant proportion of the misclassifications occurred on trees which were killed by beetles rather than fire. DFB killed 29 of the 188 Douglas-fir trees monitored during this study. Twenty-one of these trees which died from beetles were predicted by the Reinhardt and Ryan model to survive the fire. WPBs and pine engraver beetles killed 19 of the 243 ponderosa pine trees monitored. Only 6 of these ponderosa pines which died from beetle attack were predicted by the Reinhardt and Ryan model to survive, suggesting that WPBs and pine engraver beetles were more likely to attack heavily damaged trees which were predicted by the model to die as a result of the fire. The predictive equation performed well on this independent data set. Minor improvement in prediction could possibly be achieved if some threshold of bark beetle susceptibility could be factored into the equation.

SUMMARY

The probability of mortality equation developed by Reinhardt and Ryan (1988) accurately classified trees as dead or alive 83 percent of the time. Marking guidelines for both Douglas-fir and ponderosa pine based upon DBH and percentage of crown volume scorched can be developed from this equation. Figure 4 displays the relationships between DBH and percentage crown volume scorched which results in mortality 50 percent of the time. Because the lines for ponderosa pine and Douglas-fir are nearly equal both species could be adequately described with 1 equation. As an example, a 10 inches DBH tree with a 49 percent crown volume scorch has a 50 percent probability of dying while a 20 inches DBH tree must sustain 75 percent crown volume scorch to have the same probability of dying.

This equation worked well for the Lowman fire situation but the equation did misclassify many of the larger (>15inch DBH) Douglas-fir trees which died from beetles. DFB attacked large diameter trees which were expected to survive the fire. WPBs and pine engraver beetles were more frequently found in trees which were expected to die from damage sustained during the fire. Therefore these beetles did not influence the misclassification errors.

We have little evidence either as a result of this study or from subsequent aerial surveys that the Lowman fire exacerbated beetle caused mortality in the burned over areas or outside of the fire boundary. Beetle caused mortality did occur within the fire boundary but the beetle caused mortality rate was not noticeably higher than in surrounding areas.

Table 1. Mean percentage crown volume scorched, mean bole char rating and mean DBH for sample trees which survived the fire, died as a result of the fire or died as a result of bark beetle attacks during a 4 year post Lowman fire recovery period, Lowman, Idaho 1993.

Tree Condition	Species	N	Crown Scorch Mean(%)	SE	Bole Char Rating Mean	SE	DBH Mean (in.)	SE
Alive	Combined	296	17.42	1.40	207.77	6.05	19.33	0.51
	DF	95	19.84	2.40	230.73	12.70	15.90	0.61
	PP	200	16.28	1.73	197.,90	6.42	20.99	0.67
Dead (fire)	Combined	91	73.72	3.98	302.31	12.65	14.14	0.75
	DF	64	73.66	4.79	313.83	16.78	14.19	0.89
	PP	24	78.96	6.76	275.21	9.60	14.64	1.56

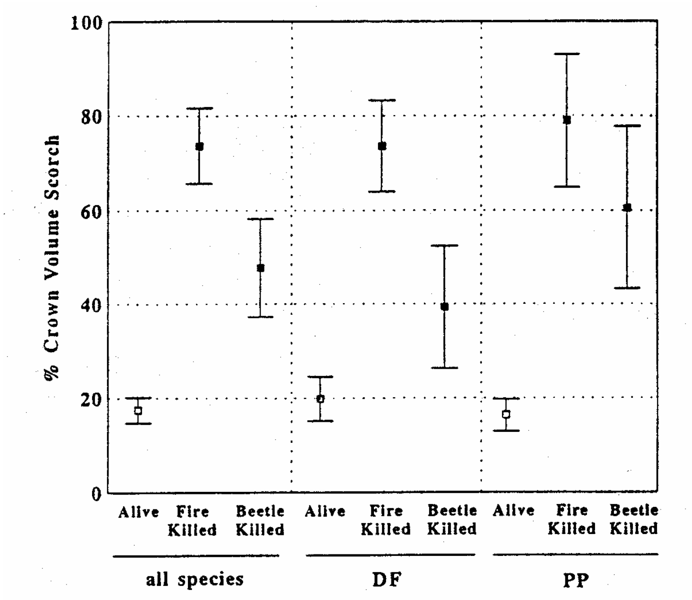

Figure 1. Mean percentages of crown volume scorched and 95 percent confidence intervals for sample ponderosa pine and Douglas-fir trees which either survived the fire, died from fire or died from bark beetle attack within the Lowman fire complex, 1989-1993.

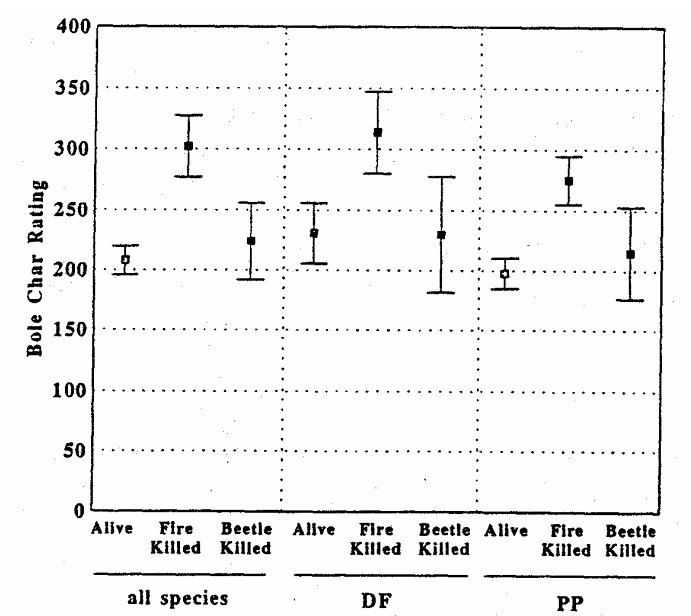

Figure 2. Mean bole char ratings with 95 percent confidence intervals for sample ponderosa pine and Douglas-fir trees which either survived the fire, died from fire or died from bark beetle attack within the Lowman fire complex, 1989-1993.

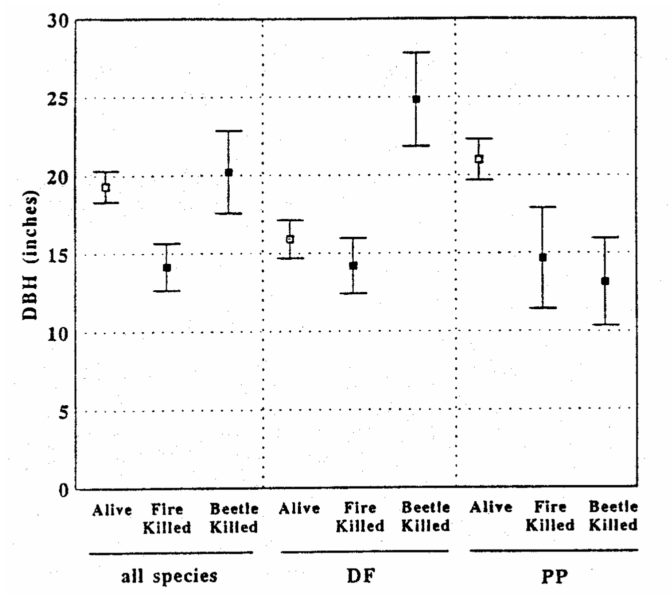

Figure 3. Mean diameters at breast height (inches) and 95 percent confidence intervals for sample ponderosa pine and Douglas-fir trees which either survived the fire, died from fire or died from bark beetle attack within the Lowman fire complex, 1989-1993.

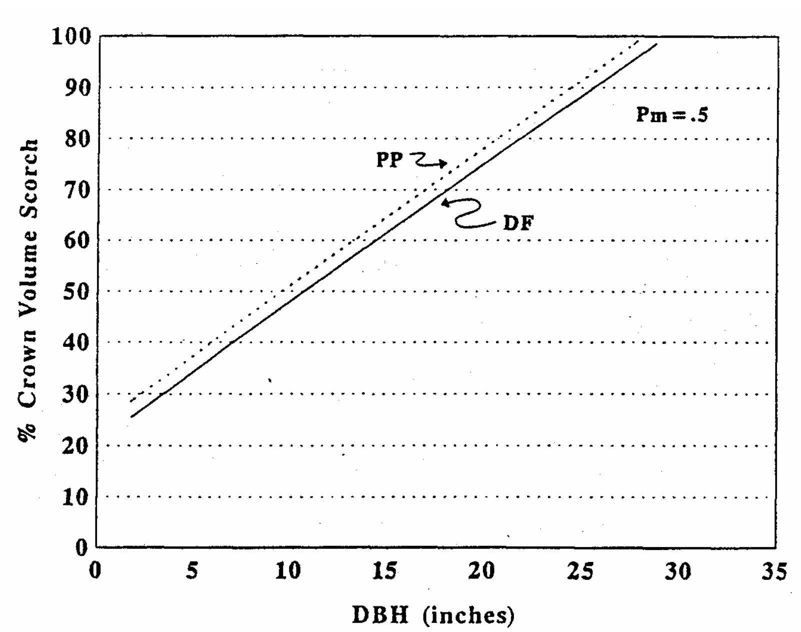

Figure 4. Linear combinations of diameters at breast height (inches) and percentages of crown volume scorched resulting in 50 percent predicted probability of mortality (Pm) from the Reinhardt and Ryan (1988) equation, $Pm = 1/(l + \exp(-(1.466 - 4.862B + 1.156B^2 + 0.000535C^2)))$ where B = bark thickness (inches) and C = percentage of crown volume scorched.

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