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ESTIMATING SURVIVAL AND SALVAGE POTENTIAL OF FIRE-SCARRED DOUGLAS-FIR

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ABSTRACT

*A dichotomous event regression model is used to estimate survival of fire-injured interior Douglas-fir (*Pseudotsuga menziesii *var.* glauca*) 1 year after burning. A preliminary salvage marking guide is presented based upon stem diameter at breast height and crown scorch height.*

KEYWORDS: Douglas-fir, crown scorch, postfire mortality, timber salvage

Tree mortality following fire has been of concern to timber managers since the mid-1920's. This concern has historically centered around the identification and salvage of trees most likely to die as a result of fire damage or subsequent insect or disease infestation. The objectives of a salvage timber sale following fire are to recover the value of dead and dying trees and to protect survivors from insect attack.

Most investigators have related percentage of tree mortality during the first year or two after fire to one or more indicators such as fire intensity, crown scorch, cambium damage, stem diameter, bark char height, degree of needle consumption, presence or absence of bark beetles, and season of the year during which the fire occurred. Postfire tree mortality research began in the ponderosa pine (*Pinus ponderosa* Laws.) region of the southwest and dealt mainly with increased susceptibility of fire-damaged pines to western bark beetle (*Dendroctonus* spp.) attack (Miller and Patterson 1927; Salman 1934; Connaughton 1936; Herman 1954; and Wagener 1955). Herman (1950) was the first to relate postfire tree mortality to fire intensity and tree size and used the two factors in a "rule of thumb" salvage marking guide. Lynch (1959) used percentage of live crown scorched and stem diameter as the best indicators of ponderosa pine mortality in northeast Washington.

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Similar studies have been performed more recently in the loblolly (*Pinus taeda* L.), slash (*Pinus elliottii* Engelm.), longleaf (*Pinus palustris* Mill.), and shortleaf (*Pinus echinata* Mill.) pine region of the southeast (McCulley 1950; Ferguson 1955; Storey and Merkel 1960; Mann and Gunter 1960; and Martin 1965), and in the red pine (*Pinus resinosa* Ait.) and eastern white pine (*Pinus strobus* L.) areas of the north and midwest (VanWagner 1963; Sucoff and Allison 1968; and Methven 1971). The studies again related stand average fire-induced tree mortality to stem size, degree of crown damage, cambium injury, season of the fire, and insect attack.

Few studies to date have dealt directly with fire-induced mortality of interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*). Connaughton (1936) reported 82 percent Douglas-fir mortality 2 years after a 45,000-acre wildfire in Idaho. Furniss (1965) examined extent of injury to Douglas-fir crowns and cambium and its effect on the incidence and severity of attack by the Douglas-fir bark beetle; however, he did not report on tree mortality as a result of either fire damage or insect attack.

The present study is an attempt to relate survival of interior Douglas-fir 1 year following fire to various easily assessable indicators. This study is restricted to mortality resulting from fire injury only, and not as a result of subsequent insect or disease infestation.

FIELD METHODS

Nineteen plots within a western larch/Douglas-fir (*Larix occidentalis* Nutt./*Pseudotsuga menziesii* var. *glauca*) stand in west-central Montana were burned throughout the 1973 fire season to determine the characteristics and effects of understory burning on the stand.[2] Plots were burned on a variety of sites with different fuel loads, fuel moistures, and weather conditions. Douglas-fir stem diameters, tree heights, and live crown heights were recorded for 176 trees within the burned plots. Only trees of 5-inch d.b.h. (12.7 cm) or greater were tallied. The crown scorch height of each tree was recorded to the nearest foot a few weeks following burning.

Trees were inspected following emergence from dormancy in the spring of 1974 to determine first year postfire survival. An increment borer was used to remove four cambium samples at breast height from each tree. Cambium cores were sampled from the upslope, downslope, and two cross-slope faces of each stem. The cores were treated with a 1 percent solution of Orthotolidine[3] followed by a 3 percent solution of hydrogen perioxide as described by Hare (1965). This treatment turns living cambium blue while dead tissues remain uncolored. Trees were considered dead if three or more of the sample cores contained dead cambial tissue.

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[2]Norum, Rodney A. 1975. Characteristics and effects of understory fires in western larch/Douglas-fir stands. Unpubl. Ph.D. diss. School of For., Univ. Mont., Missoula, Mont. 155 p.

[3]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

ANALYTICAL METHODS

Previous studies have expressed postfire tree mortality as the percentage of stems killed within a tree size or fire damage class. The assumption was that all trees within the class had similar survival probabilities represented by the class's mean percentage of survival. In fact, individual tree survival at any point in time following fire is a dichotomous event; either the tree is alive or it is dead. A model representing a continuous dichotomous event rather that a class mean percentage of survival permits the characteristics of, and damage sustained by, each tree to be used in estimating the individual's survival probability. Rather than assign each tree to a group based upon some tree stem or fire damage criteria and compute a group survival, a regression equation was used to predict the dicotomous outcome (1 = live, 0 = dead) for each tree 1 year following fire based upon a set of predictor variables.

A dichotomous event regression routine, RISK (Hamilton 1974), was used to obtain tree survival predictions within the probability interval (0,1). The routine fits the data to a logistic function form:

$$p = (1 + e^{(a + b'x)})^{-1} \text{ , where}$$

P = event outcome probability in the interval (0,1),

e = base of the natural logarithms,

a = regression constant,

b'= transpose of the vector of regression coefficients, and

x = vector of independent variables.

Potential survival indicators were restricted to those factors that could be easily measured or estimated in the field without any knowledge of prefire stand conditions or behavior of the fire. Candidate survival indictors examined were stem diameter at breast height, crown scorch height, and percentage of live crown scorched. The indicators were tested alone and in combination to select a model which best fit the data. Goodness-of-fit was tested using the chi-square statistic as incorporated into the RISK routine and recommended by Hamilton (1974). The chi-square evaluates the deviation of the model predictions from the data to be fitted over the range of predictions (0,1). If the chi-square is significantly large for the chosen confidence level, the model does not adequately fit the test data.

The RISK program also computes Student's t statistics for each regression coefficient in the model to determine whether they are significantly different from zero, and an analysis of variance F ratio to test the significance in the amount of variation in the data explained by the model.

RESULTS

Seventy-five of the 176 Douglas-fir (43 percent) were dead 1 year following fire. Surviving trees tended to be taller and have greater stem diameters than those that died (table 1). Surviving trees also had lower scorch heights and percentage of live crown scorched than the dead trees.

Table 1.--*Characteristics of live and dead fire-injured Douglas-fir 1 year following fire*

Cambial condition	Number	Stem d.b.h.			Tree height			Scorch height			Crown scorch		
		Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
		- - - *Inches* - - -			- - - *Feet* - - -			- - - *Feet* - - -			- - *Percent* - -		
Dead	75	5.0	7.3	15.0	25.0	45.5	80.0	0.0	27.1	70.0	0	31	100
Live	101	5.0	8.9	18.9	25.0	49.0	80.0	0.0	16.4	57.0	0	10	73
Total	176	5.0	8.2	18.9	25.0	47.5	80.0	0.0	20.9	70.0	0	19	100

The combined use of stem d.b.h. and crown scorch height as independent variables in the dichotomous event regression represented the outcomes (death or survival) more closely than any other combination of predictor variables. The chi-square goodness-of-fit statistic was not significant at $p = 0.995$ indicating good agreement between regression predictions and field observations. The derived survival probability equation is:

$$P = \left(1 + e^{(0.1688 - 0.3174 X_1 + 0.09321 X_2)}\right)^{-1}, \text{ where}$$

P = survival probability,

X_1 = stem diameter at breast height (inches), and

X_2 = crown scorch height (feet).

The analysis of variance F ratio for the relationship is highly significant ($p < 0.005$), and the regression coefficients' Student's t statistics are also highly significant ($p < 0.005$) for stem d.b.h. and crown scorch height. The regression constant was not significantly different from zero.

The relationship between Douglas-fir postfire survival and crown scorch height is represented graphically in figure 1 for several stem diameters.

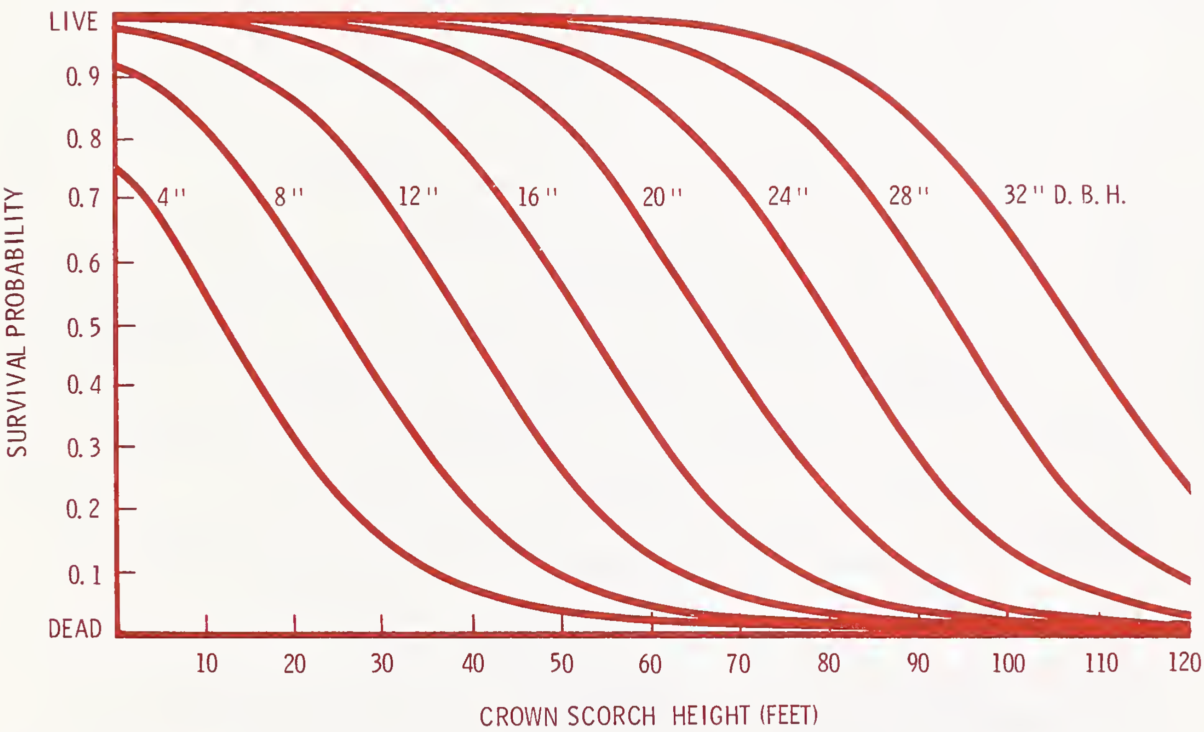

Figure 1.--Interior Douglas-fir postfire survival probability as a function of stem diameter at breast height and crown scorch height.

DISCUSSION

Several investigators have demonstrated relationships between stem d.b.h. and post-fire tree survival (McCulley 1950; Mitchell 1954; Ferguson 1955; Lynch 1959; Storey and Merkel 1960). Larger stemmed conifers tend to have thicker barks, which insulate the cambial tissues and increase the tree's ability to withstand high heat fluxes.

Percentage of the live crown length scorched by the fire has also been a useful indicator of fire-induced tree mortality (Herman 1954; Ferguson 1955; Lynch 1959; Mann and Gunter 1960; VanWagner 1963; Sucoff and Allison 1968; Methven 1971). Crown scorch height is a function of the fireline intensity (VanWagner 1972).

The Douglas-fir postfire survival probability equation therefore contains two variables that are independent of each other and account for the two most important components determining survival: the amount of heat applied to the tree (as manifested by the crown scorch height) and the ability of the tree to withstand the applied heat flux (as indicated by the stem d.b.h.).

A preliminary guide for marking salvable interior Douglas-fir was developed from the survival probability equation. Figure 2 presents the relationship in a form suitable for field use. The survival probability of an individual Douglas-fir stem 1 year following fire is found at the intersection of the tree's d.b.h. (x axis) and the observed crown scorch height (y axis). For example, a 20-inch (51 cm) d.b.h. Douglas-fir with a 20-foot (610 cm) crown scorch height has a survival probability of 90 to 99 percent. The same tree with a 75-foot (2 286 cm) scorch height has only a 10 to 50 percent chance of survival.

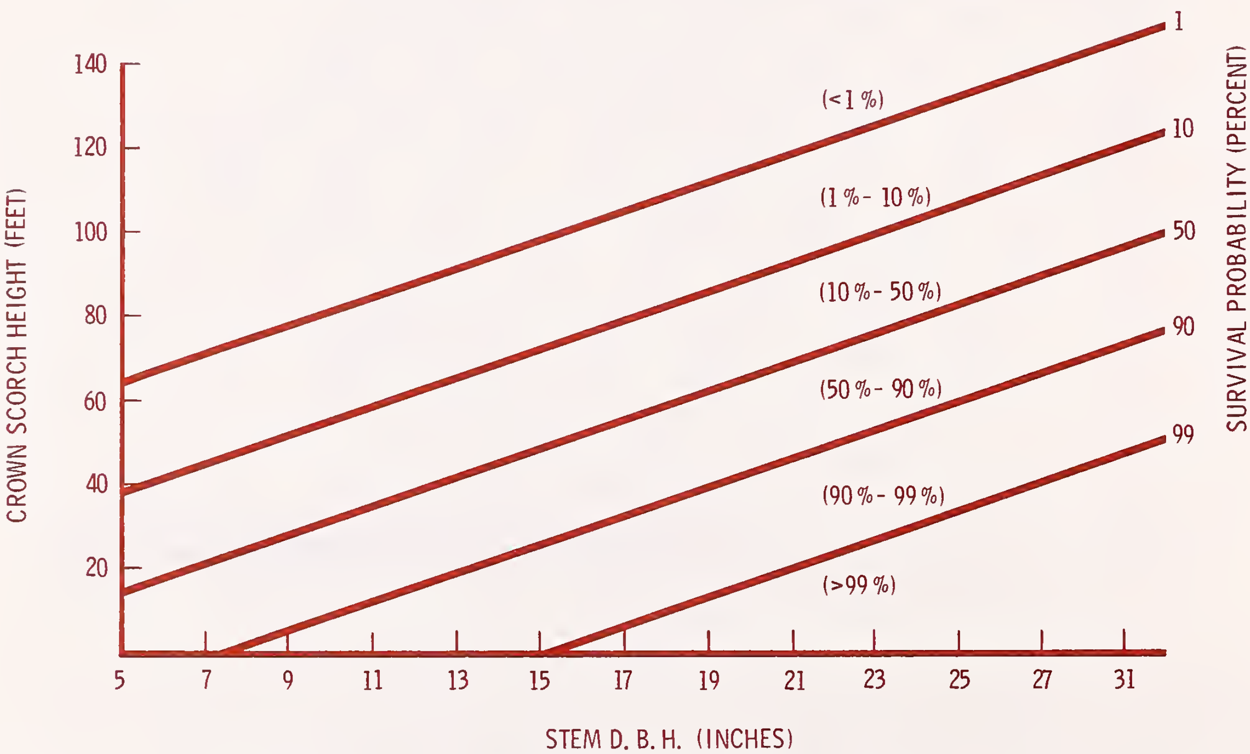

Figure 2.--A preliminary salvage marking guide for fire-injured interior Douglas-fir. Individual tree survival probability is determined from stem d.b.h. (x axis) and observed crown scorch height. Survival probability is indicated on the dark lines, and ranges indicated within brackets between the lines.

The guide should be considered a trial procedure due to several limitations in its development. First, the survival probability was based upon a limited sample of 176 interior Douglas-fir with stem diameters in the 5- to 19-inch (12.7 to 48.3 cm) range. Second, trees were inspected only the first year after burning, and data are not available on survival past the first year. Third, no information is available on the incidence of subsequent insect attack and its effect on Douglas-fir survival.

Finally, the test plots were fired using understory burning techniques, resulting in low to moderate fire intensities. The restricted range of fire intensities should not adversely affect the performance of the guide since higher fire intensities (with higher scorch heights) would only have made the "live or dead" outcome more certain. In fact, the proposed guide may be usefully applied in the determination of acceptable scorch heights in Douglas-fir stands requiring understory burning precisely because it was developed from low-intensity fire treatments.

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