BEHAVIOR AND SHORT-TERM EFFECTS OF FIRE IN MASTICATED FUEL BEDS

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INTRODUCTION

Shrubs and small trees that have grown since harvest, wildfire, or other disturbance present a fuel management challenge in many areas in the western US. Mechanically treating these ladder fuels with mastication is increasingly used to reduce fire hazard. The objective of this research was to provide managers with tools for modeling fire behavior and predicting fire effects in this novel fuel type.

METHODS

This study took place at two sites in northern California consisting of dense shrubs dominated by *Arctostaphylos* sp. and *Ceanothus* sp., under a stand of young ponderosa pine trees. The "Challenge" site was located on the Challenge Experimental Forest, Plumas National Forest (Elev. 850m), while the "Whitmore" site was located on private timberland near the town of Whitmore in Shasta County (Elev. 700m). Four units, each at least 0.4 ha in size were established at both locations. Units were masticated with a Rayco forestry mower in March 2003 (Challenge) and May 2003 (Whitmore). Diameter at breast height (dbh), height, and height to base of live crown were measured on a subset of trees within each unit.

Fuel loading was estimated by systematically placing a 0.5m x 0.5m metal sampling frame at 20 points per unit at Challenge and 10 points per unit at Whitmore. All organic material within the sampling frame was collected, brought back to the laboratory, sorted into fuel categories (woody fuels by size class, litter and duff), and oven-dried for at least three days at 75C^{o}. At Challenge, a subset of 130 trees of average size were selected and half were randomly assigned to a raking treatment (fuels removed around the base of trees out to 0.5 m) in order to separate mortality as a result of bole damage from mortality caused by crown scorch. Loading of woody fuels and litter were both visually estimated under the canopy of each tree in the raking experiment, according to a rough scale where 1 = low, 2 = moderate, and 3 = high.

Prescribed burns were conducted in May and June of 2005 at Challenge, and in June of 2006 at Whitmore. Prior to the burns, thermocouples were placed at the drip line of 6-12 trees in each unit to evaluate soil heating. One thermocouple lead was placed at the duff/ mineral soil boundary, and others at depths of 2.5 cm, 5cm and 10cm in the soil. Ignition was accomplished primarily though strip-head fires, with strips approximately 2m apart. On steeper slopes at Challenge, strip headfires resulted in excessive scorching given the relatively small size of the trees, and firing in these areas was accomplished primarily through backing. Where possible, flame length and rate of spread were estimated for both heading and backing fires.

Post-burn fire severity measures were made at both sites in the months after the burns. Scorch height and height of bole char on both the uphill and downhill sides of each tree were measured, and percentage of the bole circumference at the base of the tree that experienced fire and percentage of crown volume scorched were visually estimated. At Challenge, each tree was re-visited in July 2006 and status (live, dead, or dead and down) noted. Significance of factors contributing to tree mortality was determined using PROC GLIMMIX in SAS, with mortality as the dependent variable, fire damage measurements and pre-burn fuel loadings as independent variables (fixed effects), and unit as a random effect.

RESULTS AND DISCUSSION

Prior to the burns, fuel loading averaged 71.8 Mg/ha at Challenge and 26.1 Mg/ha at Whitmore. These values are at the high end and low end, respectively, of fuel loadings noted in a survey of masticated sites in California and southern Oregon (Kane et al., 2006). At both sites, fine fuels (<2.54 cm diameter) comprised more than half of the woody fuel load. While the substantial loadings and continuity of fine fuels could potentially lead to excessive heating with flaming combustion, fire behavior may have been moderated by the compactness of the fuel bed. Fuel bed depth averaged just 13 cm at Challenge and 7 cm at Whitmore.

Flame lengths for backing and head fires were similar at both sites (Table 1). Rate of spread for heading fires was approximately two times faster at Challenge than at Whitmore, a difference likely due to steeper slopes at Challenge. Flame length and rate of spread were adequately predicted with BehavePlus, employing several standard fuel models. However, scorch height measured on the residual trees was substantially greater than predicted by BehavePlus. Scorch height at Challenge (high fuel loading) was nearly four times model predictions, while scorch height at Whitmore (low fuel loading) was approximately twice model predictions. The high heat content of the woody shrub fuels and long flaming duration likely contributed to higher than expected crown scorch. In spite of the aboveground fire intensity, little heat appeared to penetrate deeply into the soil. At Challenge, only 2% of thermocouples experienced >60^{o}C at 2.5cm soil depth while at Whitmore temperatures did not exceed this threshold at any depth. It is likely that high soil moisture levels limited soil heating (Busse et al. 2005).

Mortality of trees one year after the burns at Challenge was not significantly affected by raking fuels from the base (25% w/ raking, 30% without). For the full tree data set, tree mortality appeared to be due primarily to crown scorch. When all measured post-fire variables were analyzed with status one-year post-fire as the dependent variable, percentage of crown volume scorched was the strongest predictor of mortality ($P < 0.001$). Tree diameter at breast height was also significant ($P = 0.016$), with smaller trees more prone to die. Bole char height (downhill or low side) was nearly significant ($P = 0.054$).

Table 1. Fire behavior parameters for prescribed burns in masticated fuels at two sites.

	Site	
Variable	Challenge	Whitmore
Fuel moisture – 10hr (%)	13.2	12.5
Fuel moisture – duff (%)	83.0	29.8
Soil moisture (%)	36.6	23.5
Flame length-backing (m)	0.35	0.29
Flame length-heading (m)	0.72	0.73
Rate of spread-backing (m/hr)	4.3	4.4
Rate of spread-heading (m/hr)	57.3	26.8
Scorch height (m)	9.9	5.5

SUMMARY AND CONCLUSIONS

Mastication may moderate fire behavior by reducing fuel bed depth, but high loadings of surface fuels can still result in substantial mortality of residual trees when burned. Even so, it is possible to reduce masticated fuel loads using prescribed fire. In this study, the high soil moisture levels at the time of the burns limited heat penetration into the soil. Under these conditions, the major cause of initial mortality appeared to be due to crown scorch, which can be mitigated by adjusting firing techniques, and burning when air temperature is low.

LITERATURE CITED

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