Bark beetle outbreaks in ponderosa pine forests: Implications for fuels, fire, and management under different climate scenarios

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INTRODUCTION

Wildland fires, bark beetle outbreaks, and forest management are politically charged issues throughout the West. With the extent of bark beetle outbreaks and post-outbreak vegetation treatments being implemented throughout the West, we need to improve our knowledge of how these outbreaks and treatments are influencing fuel loading, fire behavior, and other aspects of forests. Mountain pine beetle outbreaks have historically and are currently impacting ponderosa pine forests in the Black Hills of South Dakota and Wyoming (*Figure 1*). Previous studies with other bark beetle-host systems in other geographic locations have demonstrated that bark beetle outbreaks can affect fire behavior attributes (predicted flame length, fire rate of spread, torching) due to increased fuel loading, higher wind speeds and quicker drying of fuel (reviewed by Jenkins et al. 2008). These findings can have profound implications for managing dead trees resulting from extensive bark beetle outbreaks and restoration of damaged ecosystems.

This Forest Health Monitoring-funded study will extend our knowledge of how mountain pine beetle outbreaks and subsequent vegetation treatments influence fire behavior in ponderosa pine forests. By modeling fire behavior across varying weather conditions we will be better able to predict how these relationships will change under projected climatic scenarios.

Figure 1. *Mountain pine beetle-caused ponderosa pine mortality and thinning/salvage operations to minimize mortality and fuels on the Black Hills National Forest, South Dakota.*

OBJECTIVES

1. Quantify fuels in ponderosa pine stands experiencing (a) tree mortality in 2006 or 2007, (b) tree mortality followed by vegetation/fuels treatments (low vs. moderate residual basal area), and (c) no tree mortality (controls).
2. Model fire behavior in these stands under different weather, climate and management scenarios.

METHODS

1. Fifteen sets of 1/20th acre plots per treatment installed on Black Hills National Forest in South Dakota.
2. Baseline data (tree species, size, crown base height, density) collected on live and dead trees (*Figure 2, left*).
3. Brown's (1974) planar transects used to measure surface fuels, fuel bed and duff depth (*Figure 2, right*).
4. Preliminary results are shown only for 2006 mortality plots & controls. Data from other treatments and fire behavior modeling are currently being analyzed.

Figure 2. *Mensurational (left) and surface fuels (right) data collected in stands impacted by mountain pine beetle on the Black Hills National Forest, South Dakota.*

CANOPY FUEL MODELING METHODS

Fire Model Variable	Definition	Units	Reference
Canopy Fuel Loading (1-, 10-, 100-, 1000-hr woody fuels and canopy foliage biomass (needles))	Mass of canopy fuel load per unit area by time-lag size classes.	Mg ha^{-1}	Brown 1978; Reinhardt et al. 2000
Canopy Fuel for Crown Fire	Foliage biomass plus 50% of 1-hr woody canopy fuel load.	Mg ha^{-1}	Brown 1978; Reinhardt et al. 2000
Canopy Bulk Density	Mass of available canopy fuel per unit of canopy volume.	kg m^{-3}	Brown 1978; Reinhardt et al. 2000

FIRE BEHAVIOR MODELING METHODS

Fire Model Variable	Units	Reference
Fire Rate of Spread (ROS)	m min^{-1}	Rothermel 1972; Rothermel 1991
Fire Line Intensity (FLI)	kW m^{-1}	Byram 1959
Flame Length	m	Byram 1959
Fire Type	Surface fire, Passive and active crown fire	Alexander 1988; Van Wagner 1993
Torching Index	km h^{-1}	Rothermel 1972; Van Wagner 1977
Crowning Index	km h^{-1}	Van Wagner 1977; Rothermel 1991

Weather Parameter	97.5 Percentile
6 m wind speed (km h^{-1})	42.0
1-hr fuel moisture (%)	2.9
10-hr fuel moisture (%)	4.7
100-hr fuel moisture (%)	6.6
1000-hr fuel moisture (%)	9.3
Herbaceous fuel moisture (%)	51.1

Fire behavior modeling will assume all fires burn under the 97.5th percentile weather conditions for the Black Hills National Forest.

PRELIMINARY RESULTS

1. Mountain pine beetle significantly reduced tree and stand density by 75-85% (*Figure 3a*) and also tree diameter, but not crown base height (*Figure 3b*). Pre-outbreak stand conditions were not significantly different from controls (*Figure 3c,d*).
2. Although there was a trend of increasing surface fuels in plots infested by mountain pine beetle in 2006 compared with controls, no significant differences were detected two years after attack (*Figure 4*).

Figure 3. Stand conditions of ponderosa pine plots infested by mountain pine beetle in 2006 (a, b) and control plots (c, d) (mean + SEM).

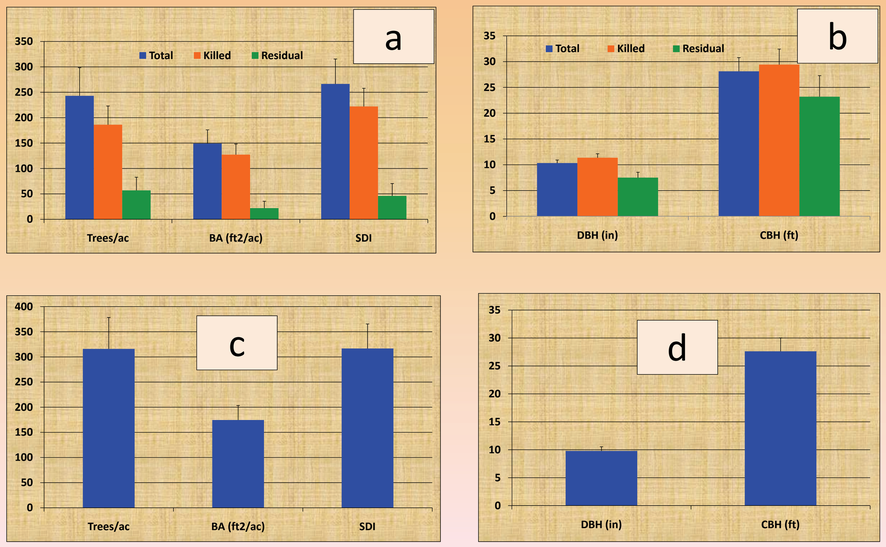
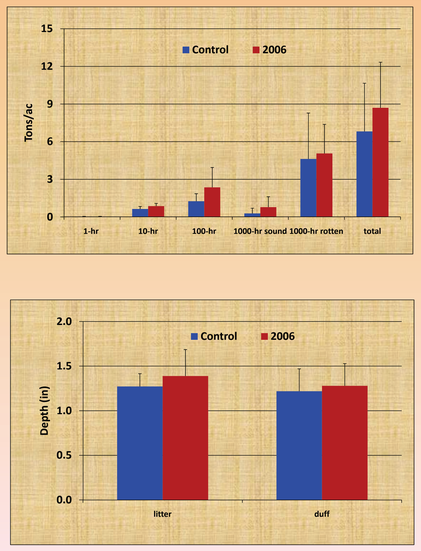


Figure 4. Surface fuels in ponderosa pine plots infested by mountain pine beetle in 2006 and control plots (mean + SEM).



FUTURE PLANS

1. Future work will focus on re-measurement of canopy and surface fuels to provide information detailing how fuel complexes and fire behavior change over time following an outbreak, and how post-outbreak vegetation/fuel treatments modify these fuel complexes.
2. We will model predicted fire behavior across the treatments and over a range of weather conditions to simulate predicted climate patterns using the NEXUS Fire Behavior and Hazard Assessment system.
3. Similar studies will be initiated in Douglas-fir dominated forests in 2010.

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