Bark Beetle Outbreaks in ponderosa pine and Douglas-fir forests: Implications for fuels, fire, and management under different climate scenarios

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Introduction

Landscape-level bark beetle outbreaks have occurred throughout the western US during recent years in response to dense forest conditions, drought, and fire (Fettig et al. 2007). FHM aerial detection surveys (ADS) reported >150,000 acres of ponderosa pine impacted by mountain pine beetle in the Black Hills between 2002 and 2008. Douglas-fir beetle outbreaks have been detected by ADS in the Shoshone NF (120,000 acres) and Bighorn NF (10,000 acres) over the same time period. Concerns about elevated fire hazard following these landscape level outbreaks and the vast expanses of high density stands have led to calls for forest and fuel treatments to decrease standing and surface fuels. However, it remains unclear how these treatments influence fire behavior following a bark beetle outbreak. Previous studies with other bark beetle-host systems in other geographic locations have demonstrated that bark beetle outbreaks can affect simulated 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). Our findings will provide insights for managing stands impacted from extensive bark beetle outbreaks in South Dakota and Wyoming.

Figure 1. Mountain pine beetle-caused ponderosa pine mortality and logging operations on the Black Hills National Forest, South Dakota.

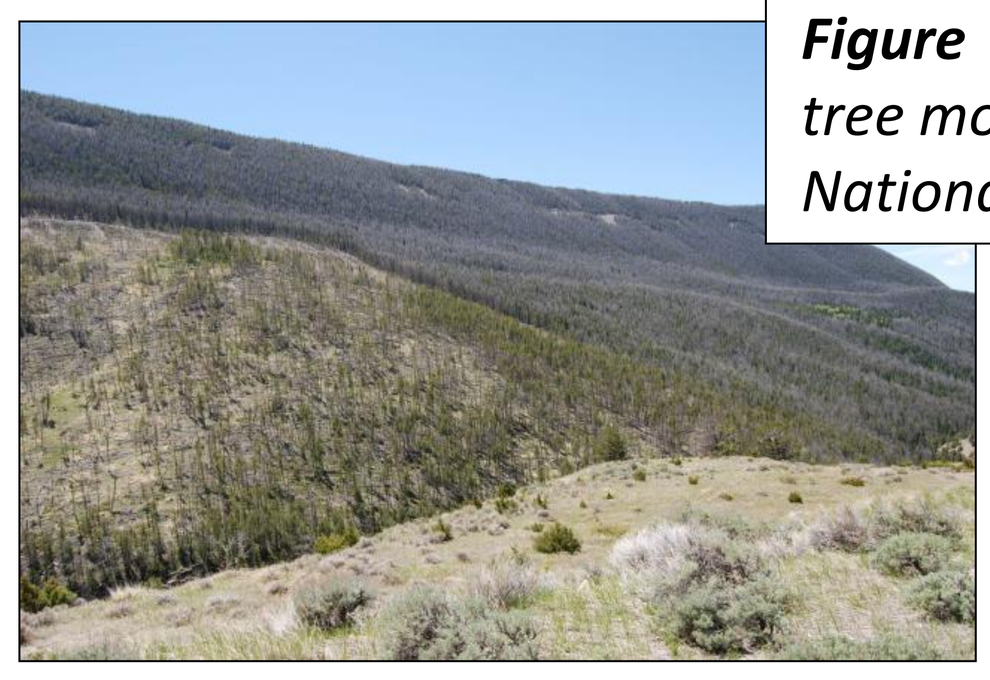

Figure 2. Douglas-fir beetle caused tree mortality and logged area, on the Bighorn-National Forest, Wyoming.

Figure 3. Douglas-fir beetle caused tree mortality on the Shoshone National Forest.

Figure 4. Stand structural (left) and surface fuels (right) data were collected in stands impacted by mountain pine beetle on the Black Hills National Forest, South Dakota and in stands impacted by Douglas-fir beetle on the Big Horn and Shoshone National Forests in Wyoming.

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Objectives

1. Quantify stand structure and fuels in stands experiencing a) high levels of bark beetle-caused ponderosa pine (Black Hills NF) and Douglas-fir (Big Horn & Shoshone NFs) mortality, b) high tree mortality followed by logging dead trees, and c) no tree mortality.
2. Explore the implications of these changes on fire behavior in these stands under different weather, climate and management scenarios.

Methods

- 15 (1/20th acre) plots on each of 3 treatments in the Black Hills National Forest: 1) 2-yr post-outbreak mortality, 2) 2-year post-outbreak mortality w/logging, and 3) no mortality. Plots were sampled in 2009.
- 15 plots in each of 2 treatments on the Big Horn NF: 1) 7-yr post-outbreak mortality, 2) 7-yr post-outbreak mortality w/logging (Fig. 2). Plots were sampled in 2010.
- 15 plots in each of 3 treatments on the Shoshone NF: 1) 1-yr post-outbreak mortality, 2) 1-yr post-outbreak mortality w/logging, and 3) no mortality (Fig. 3). Plots were sampled in 2010.
- Stand structure quantified by species for dead and alive trees; basal area (BA) and trees per acre (TPA), calculated for each plot (Fig. 4, left).
- Woody surface fuels tallied by size class along 2 planar transects (Brown 1974; Fig. 4, right).

Preliminary Results

1. In the Black Hills National Forest, mountain pine beetles reduced basal area (BA) and tree density (trees per acre, TPA) of ponderosa pine by 75-85%, resulting in nearly 200 snags per acre (*Fig. 5a*). Logging opened stand structures further and reduced snags to <2 per acre.
2. Logging tended to increase fuels in all classes (except 1000-hr rotten) and tended to increase total fuel loadings compared with no mortality stands 3 years after attack (*Fig. 5b*.
3. In the Bighorn National Forest, logging in Douglas-fir infested stands reduced basal area, tree density, and snag density *(Fig. 6a)*, and increased 100-hr fuels and total woody fuels *(Fig. 6b)* compared to mortality stands without logging.

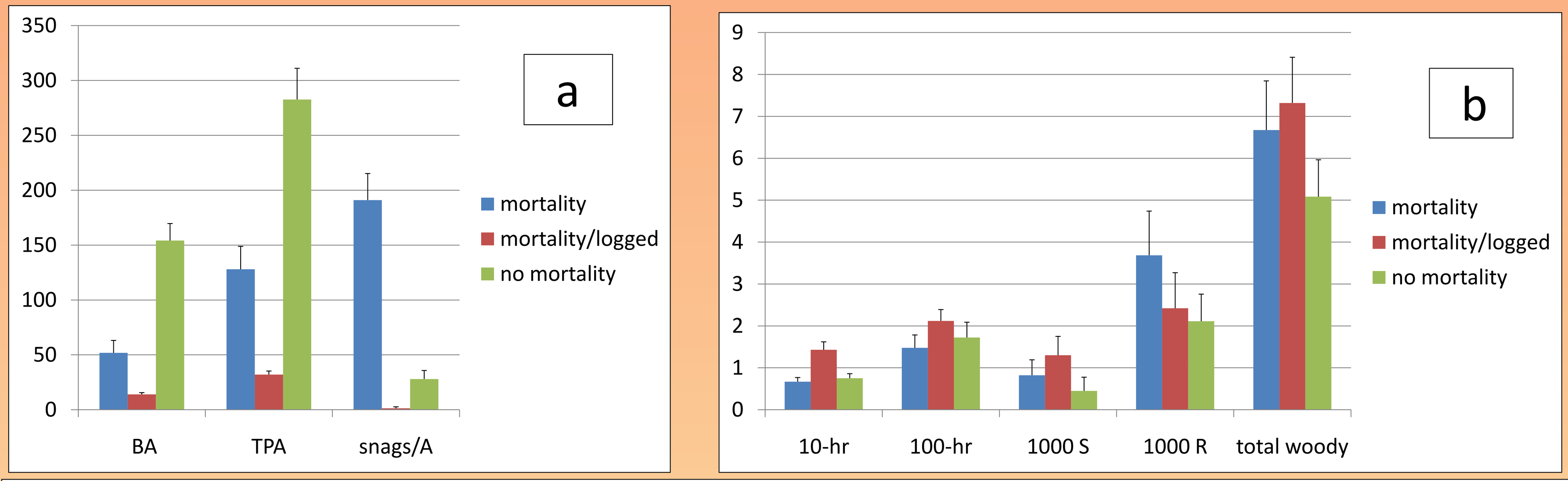

Figure 5. Stand conditions (a) and surface fuel loadings (b) by size classes and total in ponderosa pine plots in the Black Hills National Forest infested by mountain pine beetle (mortality), infested stands logged (mortality + logged) , and no mortality (mean + SE).

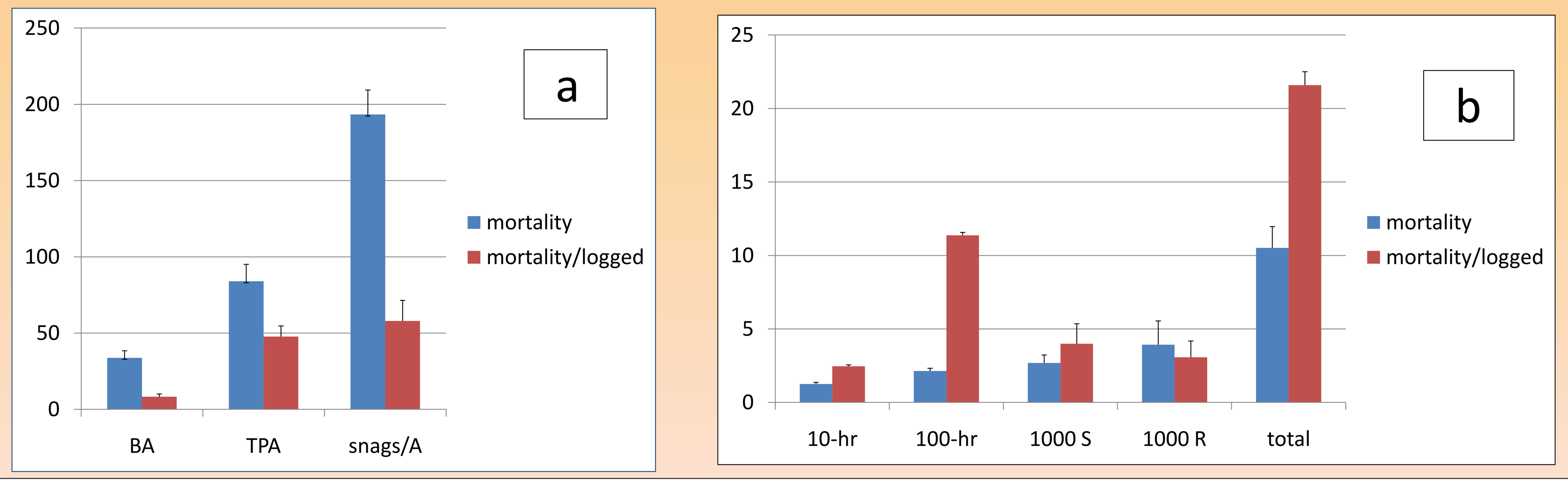

Figure 6. Stand conditions (a) and surface fuel loadings (b) in Douglas-fir plots in the Big Horn National Forest infested by Douglas-fir beetle (mortality) and infested stands logged (mortality + logged) (mean + SE).

Implications for fire behavior

The effects of bark beetle-caused mortality on forest stand structure, canopy fuels, and woody surface fuels can have highly variable and complex implications for fire behavior. More open stand structure resulting from reduced tree densities on our study sites can lead to greater wind speeds and higher drying potential, but reduced potential for tree-to-tree fire spread (Table 1). Increased woody surface fuels can support increased fire rate-of-spread and flame lengths., As snags continue to fall to the ground in the unlogged areas, we expect to observe large increases in surface woody fuels in the future.

Table 1. Observed changes in fuels caused by bark beetle mortality and subsequent logging and potential implications on fire hazard attributes (Adapted from Agee 2002, Hessburg and Agee 2003, and Agee and Skinner 2005)

Observed changes in the fuels complex	Potential effects on fire hazard
Decreased tree density and canopy fuel loadings	Increased surface wind flow and decreased surface fuel moisture and decreased risk of tree-to-tree fire spread.
Increased surface fuel loadings	Increased rate-of-spread, flame length, and increased torching potential.

Future Plans

Future work will focus on summarizing data from the Shoshone National Forest and on re-measuring canopy and surface fuels on all 3 sites to explore how fuel complexes and the implications for fire behavior change over time following an outbreak, and how post-outbreak logging treatments modify these fuel complexes.

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