Impacts of management following bark beetle outbreaks on fuels and predicted fire behavior under varying climate scenarios

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Introduction

Landscape-level bark beetle outbreaks have occurred throughout the western US in recent decades. 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, plus 120,000 acres of Douglas-fir impacted by Douglas-fir beetles in the Shoshone NF and 10,000 acres in the Bighorn NF. Concerns about elevated fire hazard following these outbreaks have led to calls for fuel reduction treatments. The impact of bark beetle outbreaks on stand structure and fuel profiles depends in part on forest type and time-since-outbreak (Jenkins et al. 2008, Hicke et al. 2012). Yet, little information is available for drier forest types and it remains unclear how fuel reduction treatments influence potential fire behavior following a bark beetle outbreak. Our study will provide insights for managing stands impacted from extensive bark beetle outbreaks in South Dakota and Wyoming.

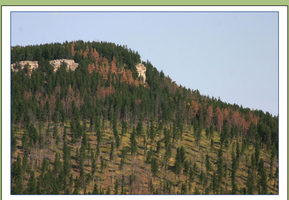

Figure 1. *Mountain pine beetle-caused ponderosa pine mortality and logging operations on the Black Hills National Forest, South Dakota.*

Figure 2. *Douglas-fir beetle-caused tree mortality on the Shoshone National Forest.*

Figure 3. *Douglas-fir beetle caused tree mortality and logged area, on the Bighorn National Forest, Wyoming.*

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 simulated fire behavior.

Preliminary Results

1. In the Black Hills NF, 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. 4a*). Logging opened stand structures further and reduced snags to <2 per acre. Logging in the Black Hills NF tended to increase fuels in all classes (except 1000-hr rotten) and total fuel loadings compared with no mortality stands 2 years after attack (*Fig. 4b)*.
2. In the Shoshone NF, BA in Douglas fir beetle-infested stands averaged 76% lower than in no-mortality stands, and in logged stands was 82% lower than in no-mortality stands *(Fig. 5a)*. Woody surface fuels showed a slight but non-significant increase 1-year post-outbreak in mortality and mortality/logged stands (*Fig. 5b).*
3. In the Bighorns NF, 7-years post-outbreak, snag densities in Douglas fir mortality plots averaged nearly 200/A *(Fig. 6a, 7)*, and total woody surface fuels in logged plots were nearly twice the loads found in unlogged mortality plots, mostly due to higher100-hour fuels *(Fig. 6b, 8).*

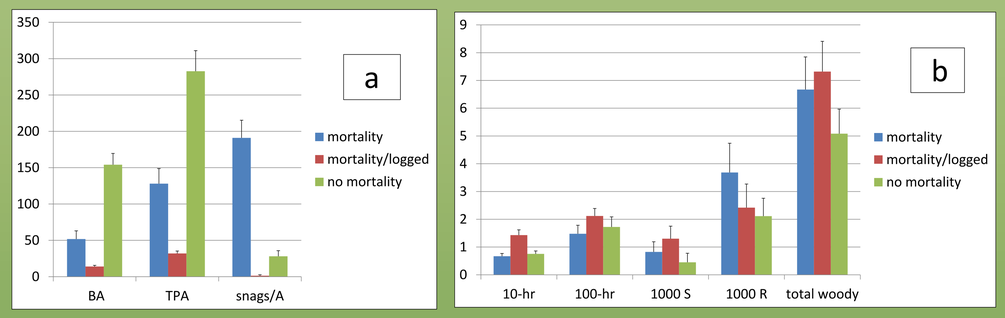

Figure 4. *Stand conditions (a) and surface fuel loadings (b) by size classes and total in 2-year-old ponderosa pine plots in the Black Hills NF infested by mountain pine beetle (mortality), infested stands logged (mortality + logged), and no mortality (mean + SE).*

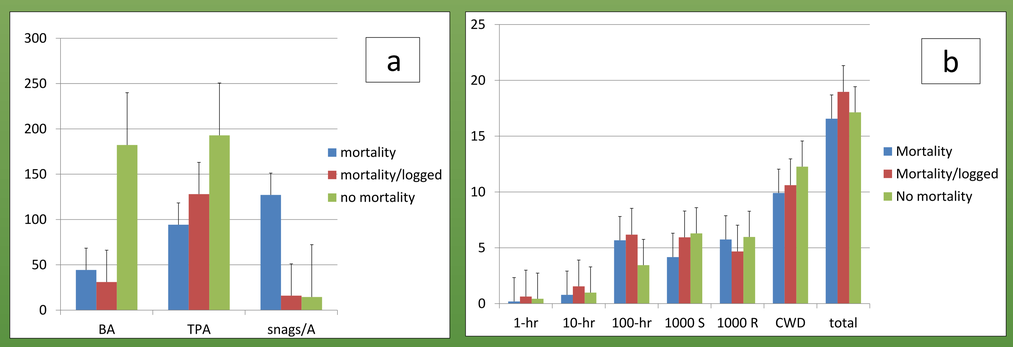

Figure 5. *Stand conditions (a) and surface fuel loadings (b) in 1-year-old Douglas-fir plots in the Shoshone NF infested by Douglas-fir beetle (mortality), infested stands logged (mortality + logged), and no mortality (mean + SE).*

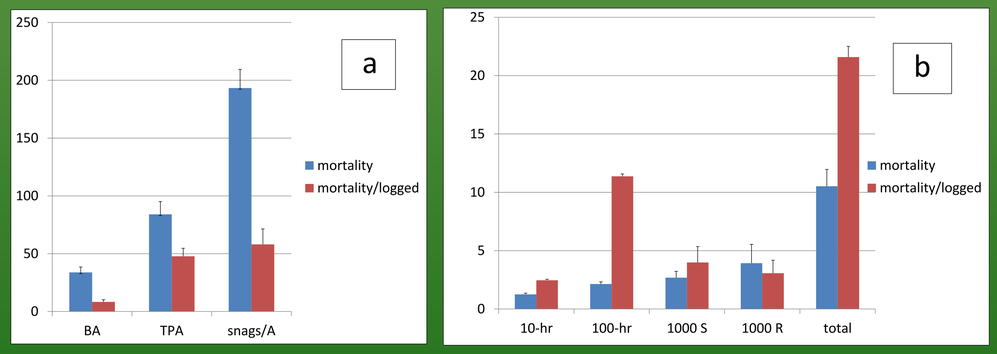

Figure 6. *Stand conditions (a) and surface fuel loadings (b) in 7-year-old Douglas-fir plots in the Big Horn NF infested by Douglas-fir beetle (mortality) and infested stands logged (mortality + logged) (mean + SE).*

Implications for fire behavior

Fire simulations comparing no mortality, mortality without logging, and logged mortality plots with decreasing levels of residual basal area show different trends for crowning and torching indices. Crowning index increases with decreasing canopy bulk density (figure 9a), but torching index decreases with the reduction in canopy base height (figure 9b). That is, no-mortality stands are predicted to be more susceptible to crown fire spread than the increasingly more open stand types. In contrast, no-mortality stands are less vulnerable to torching compared to the other more open stand types due to higher crown base heights and lower within-stand wind speeds. As snags continue to fall to the ground in unlogged areas, we expect surface woody fuels to increase which may have implications for fire containment and tree regeneration. Total woody fuel loadings were nearly 2.5 times higher in mortality stands compared to no-mortality stands five years after bark beetle mortality in southwestern ponderosa pine stands (Hoffman et al. in press).

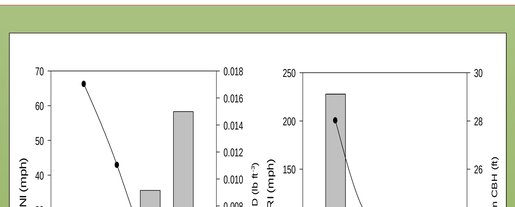

Figure 9. a) Crowning Index (bars; CRNI; left axis) and canopy bulk density (dots; CBD; right axis); and b) torching index (bars; TORI; left axis) and canopy base height (dots; CBH; right axis) for no mortality, mortality without logging, and mortality/logged stands with moderate post-logging residual basal areas and low residual basal areas. Fuel models were held constant (model 9) and wind reduction factor was 0.1, 0.2, 0.3, 0.4, respectively, for the 4 treatments.

Figure 8. *Douglas-fir mortality 7 years post-outbreak on the Bighorn NF. Note the large number of snags, but small amount of 100-hr fuels.*

Figure 7. *Three years post-logging of an area heavily impacted by a 7-year-old Douglas-fir beetle outbreak on the Bighorn NF. Note the abundance of 100-hr fuels.*

Methods

- 15 (1/20th acre) plots on each of 4 treatments in the Black Hills NF: 1) 2-yr old mortality, 2) 2-year old mortality w/logging (moderate residual basal area), 3) 2-year old mortality w/logging (low residual basal area), and 4) no mortality. Plots sampled in 2009 -2011.
- 15 plots in each of 3 treatments on the Shoshone NF: 1) 1-yr old mortality, 2) 1-yr old mortality w/logging, and 3) no mortality (Fig. 2). Plots sampled in 2010 and 2011.
- 15 plots in each of 2 treatments on the Big Horn NF: 1) 7-yr old mortality, 2) 7-yr old mortality w/logging (Fig. 3). Plots sampled in 2010 and 2011.
- Stand structure quantified by species for dead and alive trees; basal area (BA) and trees per acre (TPA) calculated for each plot.
- Woody surface fuels tallied by size class along 2 planar transects (Brown 1974).
- Predicted crowning index and torching index using NEXUS (Scott and Reinhardt 2001).

Future Plans

Our ultimate goal is to provide long-term data on fuel loading and forest regeneration in these two less-studied dry forest types. We are also using physics-based fire models to account for spatial patterns and low foliar moisture contents to compliment Nexus modeling.

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