Contribution of landscape level bark beetle outbreaks to fuel loading and fire behavior in piñon-juniper woodlands of the Southwest

Joel McMillin[1], Chad Hoffman[2], Carolyn Sieg[3], Pete Fulé[4]

[1] USFS FHP, Flagstaff, AZ; [2] Uni. of Idaho, Moscow, ID; [3] USFS RMRS, Flagstaff, AZ; [4] NAU, Flagstaff, AZ

INTRODUCTION

Record low precipitation and suitable forest conditions led to tremendous bark beetle incidence across piñon-juniper woodlands of the Southwest in 2002–2003 (Figure 1). During and after these outbreaks there was public concern over how beetle-caused tree mortality affects fuel loading and fire behavior. To date there has been a paucity of information addressing this concern in southwestern pine forests. Some have argued that stand replacement fires are not likely to occur in piñon-juniper woodlands; however, such eventualities have recently occurred in northern Arizona (Figure 2). Romme et al. (2006) hypothesized that bark beetles effects on fire behavior follow a fuel succession: 1) Increased risk of crown fire initiation immediately following outbreak, 2) Reduced crown fire spread and initiation after needle drop, 3) Increased crown fire initiation and spread after snags fall. This Forest Health Monitoring-funded study examines the effects of bark beetle outbreaks during the second and third stage (Figure 3) of the hypothesized succession in changing fuels.

Figure 1. *Piñon mortality in New Mexico (left) and Arizona (right) caused by pinyon ips (center) attacking drought-stressed trees.*

Figure 2. *Stand replacement fires on the Kaibab (left) and Coconino National Forests (right) following high levels bark beetle-caused piñon mortality in northern Arizona.*

Figure 3. *Piñon mortality following majority of needle fall (left) and after snags have begun to contribute to large surface fuels (right).*

OBJECTIVES

1. Quantify the contribution of bark beetle outbreaks to fuel loading in piñon-juniper woodlands of the Southwest
2. Model potential fire behavior in areas of high, moderate, low and no beetle-caused tree mortality

METHODS

1. GIS maps used to determine plot location (Figure 4).
2. Install sets of paired mortality/non-mortality 1/20th acre plots across a range of elevations and percent piñon on National Forests in Arizona. Criteria for pairing included elevation, topography, % piñon in the stand.
3. Mensurational (tree species, size, crown base height, density) collected on live and dead trees.
4. Brown's (1974) planar intercept transects used to measure surface fuels, fuel bed and duff depth (Figure 5).
5. Fuel Characteristic Classification System (FCCS) fuelbed variables including fine fuels (Figure 5), mid-canopy fuels, and the spatial arrangement of canopy and surface fuels also measured (Ricardi et al. 2007).
6. Fire behavior will be modeled using operational modeling systems Behave and NEXUS (Table 1).

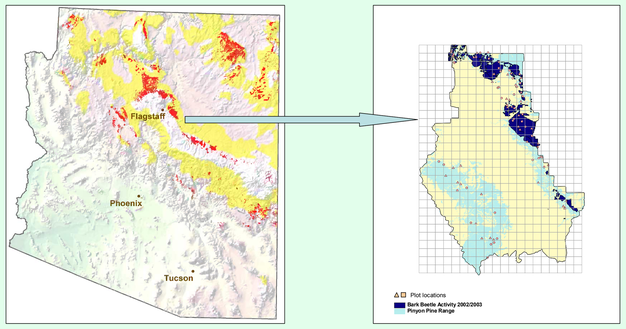

Figure 4. Potential plot location was determined using aerial detection survey maps (left), a 5 km grid over National Forests (Coconino NF is shown, right), and GIS methods.

Figure 5. Effects of piñon mortality on surface fuel loading was measured using Browns planar intercept method (left). In addition, ground cover (center) and fine fuels were measured (right).

Table 1. Modeling methods being used to determine the effects of piñon mortality on fire behavior.

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

Preliminary fire behavior modeling assumed all fires burned under the 97.5th percentile weather conditions for the Coconino National Forest for the month of June from 1968 to 2004.

Figure 7. *Vertical and horizontal heterogeneity of canopy and surface fuels in piñon-juniper woodlands.*

PRELIMINARY RESULTS

1. Forty sets of paired mortality/non-mortality plots were installed in piñon-juniper woodlands on National Forests in Arizona.
2. Stand and fuel metrics are currently being analyzed.
3. Trend of greater fine fuels in plots with piñon mortality (Figure 6).
4. Anecdotal observations suggest that the distribution of canopy and surface fuels are non-homogeneous (Figure 7).

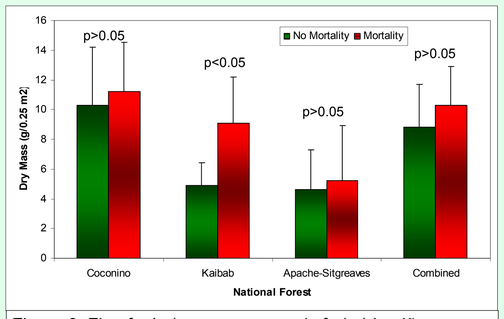

Figure 6. Fine fuels (grass, non-woody forbs) in piñon-juniper plots without or with piñon mortality.

FUTURE WORK

The Wildland Fire Dynamics Simulator (WFDS) (Mell et al. 2006) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The use of CFD models such as WFDS includes interactions between fire and atmosphere as well as between fire and fuel. These methodologies also allow investigation of effects of non-homogeneous fuel arrangements and properties. and may be better suited to investigate the effects of bark beetle caused mortality compared to operational fire behavior models.

ACKNOWLEDGEMENTS

Funding provided by Forest Health Monitoring Evaluation Monitoring grant INT-F-07-01.

Our gratitude is extended to Chris Hoffman and Chris Looney for their dedicated field work, data entry and creation of GIS maps.

Mell, W.E., et al. 2006. Numerical modeling of fire spread through trees and shrubs. V international Conference of Forest Fire Research. Viegas (Ed.).
Ricardi, C.L. et al. 2007. The fuelbed: a key element of the Fuel Characteristic Classification System. Can. J. For. Res. 37: 2394–2412.
Romme, W.H., et al. 2006. Recent Forest Insect Outbreaks and Fire Risk in Colorado Forests: A Brief Synthesis of Relevant Research. Colorado State University, Fort Collins, CO, p. 24.