Fuel Dynamics in Southern Pine Beetle-Killed Stands and Their Implication to Fire Behavior

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Introduction

The Southern pine beetle (SPB) (*Dendroctonus frontalis* Zimm) (Figure 1) is the most destructive native insect pest of pine forests throughout the southern U.S. Periodic SPB outbreaks regularly occur within coniferous forests. However, in recent decades outbreaks have been severe and persistent in several regions, including the Piedmont. The most damaging SPB outbreak in recent years lasted from 1999 to 2003, impacting almost one million acres of forest land across eight states. A smaller outbreak occurred from 2007 to 2008 across several Piedmont states. Severe outbreaks can produce 100 percent mortality of pines over an area of a hectare or more, and dead pines typically fall within one to two years. As a result, fuel loading in these SPB-killed spots increases suddenly and dramatically soon after outbreak. Over time, this unique fuel complex gradually changes due to natural decomposition. However, few studies have quantified fuel characteristics of SPB-killed stands, and none has studied the dynamics of this fuel complex. Moreover, how changes in these fuels affect fire behavior remains unknown. The increase in both SPB outbreak and wildfire occurrence in recent decades has resulted in a growing concern regarding possible interactions. This project used a combination of field measurements and fire behavior modeling to study fuel dynamics in SPB-killed stands and their implication to fire behavior. Understanding fire behavior associated with the SPB-killed fuel complex is essential for land managers when making fuel management decisions in these areas.

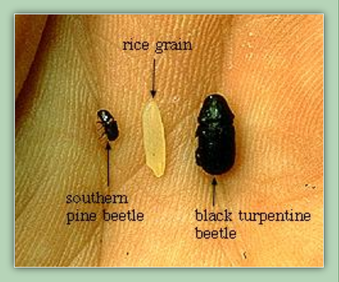

Figure 1. SPB (left) compared to a grain of rice and black turpentine beetle. Photo credit: Southern Forest Insect Work Conference, www.forestryimages.org

Objectives

The objective of this project was to study fuel dynamics of loblolly pine (*Pinus taeda* L.)-dominated forest stands killed by SPB outbreak within the Piedmont ecoregion, and to determine their implication to wildfire behavior. Specifically, the objectives were to:

(1) provide baseline measurements of live and dead fuels in post-epidemic stands killed by SPB at different years
(2) characterize and compare fuel dynamics of unaffected stands with those of SPB-killed stands
(3) model fire behavior by using measured fuel data to understand the consequences of these fuel changes

Methods

Twenty-six loblolly pine-dominated forest stands killed by SPB outbreak at different years ranging from 2 years since outbreak (early post-epidemic) to 8 years since outbreak (late post-epidemic) were identified based on existing records and aerial photos. In addition, 16 nearby control stands (i.e., not affected by SPB) were also identified. The study area included three sites within the Piedmont ecoregion (Figure 2):

- Oconee National Forest (ONF) (N=7 control; N=7 early post-epidemic)
- Clemson Experimental Forest (CEF) (N= 3 control; N= 3 late post-epidemic)
- Sumter National Forest (SNF) (N=6 control; N=7 early post-epidemic; N=9 late post-epidemic)

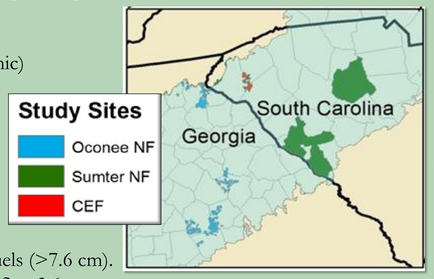

Figure 2. Locations of study sites within the Piedmont of South Carolina and Georgia.

Fuels Data Collection

Downed woody fuels data were collected from September 2009 to January 2010 using the planar intersect methodology (Figure 3) [3]:

- Three 15 m transects were established at each of 4 randomly-selected points within each stand (N=12 transects/stand).
- Fuels intersecting the sampling plane were tallied in the standard fire size classes: 1-hr (0–0.635 cm in diameter), 10-hr (0.636–2.54 cm), 100-hr (2.51–7.6 cm), and 1,000-hr fuels (>7.6 cm).
- 1- and 10-hr fuels were counted along the first 1.8 m and 100-hr fuels were counted along the first 3.6 m.
- Fuels in the 1,000-hr class were recorded by species, diameter, and decay class along the entire 15 m transect.
- Aboveground height of dead and down wood was measured along 30 cm sections beginning at 4, 8, and 12 m.
- Litter and duff depth, and percent grass, forb, and woody vegetation cover were measured at 4, 8, and 12 m.
- Counts of 1-, 10-, 100- and 1000-hr fuels were converted to weights using equations given by Brown (1974).
- Litter and duff weights were converted using regression equations developed by Waldrop *et al.* (2004).
- Differences in mean fuel loading (1-, 10-, 100- and 1000-hr fuels), litter depth, duff depth, fuelbed depth, basal area, percent woody and non-woody coverage, and percent slope were detected using the Mixed Procedure ($a = 0.05$) [5].

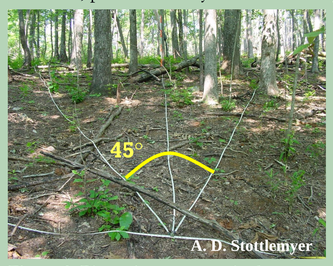

Figure 3. Planar intersect method

Fire Behavior Modeling

- Fire behavior was modeled under various weather and moisture conditions using the Fire Characteristic Classification System v. 2.2.1 (FCCS)[4] and BehavePlus v. 5.0[1].
- 80th, 90th and 99th percentile moisture conditions (i.e., representing moderate, dry, and extreme conditions, respectively) were derived from FireFamily Plus v. 4.0.2[2] using weather stations within the Piedmont.
- Custom fuelbeds were built using the fuels data collected in the field.
- Fire behavior among the post-epidemic stands was quantified and compared to control stands.
- Significant differences among means of predicted rate of spread and flame length for control and post-epidemic stands were compared using pairwise comparisons ($a = 0.05$)[5].

Plate 1: A = control stand; B = stand at two years since outbreak; C = stand at eight years since outbreak. Photo credit: H. Gambrell.

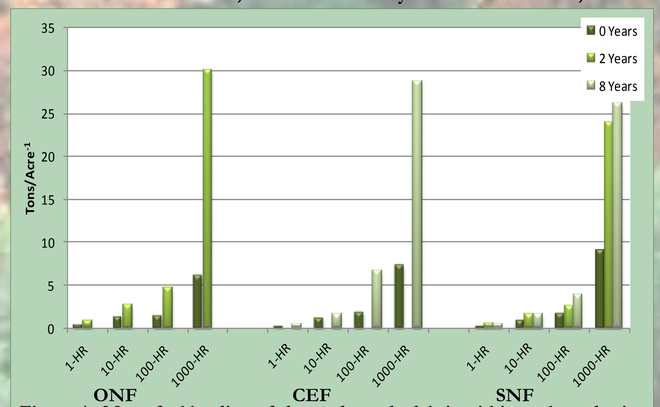

Figure 4. Mean fuel loading of downed woody debris within each study site.

Results and Discussion

Mean downed woody fuel (DWF) estimates were compared for control (0 years), early post-epidemic (2 years), and late post-epidemic (8 years) stands (Figure 4). All DWF loads were significantly higher in early post-epidemic stands than in control stands for the ONF. 100- and 1,000-hr fuel loads were significantly higher in the late post-epidemic stands than in control stands for both the CEF and SNF. Additional comparison found that aboveground fuel height was significantly higher in late post-epidemic stands than in control stands. Basal area of live conifers was significantly greater in control stands than in early or late post-epidemic stands.

According to predictions made by BehavePlus, surface rate of spread (ROS) was significantly faster for early and late post-epidemic stands than for control stands in the ONF and SNF (Figure 5). Flame length (FL) was significantly higher in early post-epidemic stands than in control stands for the ONF (Figure 6). There was no significant difference between late post-epidemic stands and control stands for FL. Both ROS and FL increased with increasing winds and drought conditions. Predictions made by FCCS produced similar results.

Results indicate that post-epidemic stands create a potential for extreme fire behavior, especially with increasing winds and drought conditions. Land managers should take care when applying prescribed burns or suppressing wildfires located in these areas.

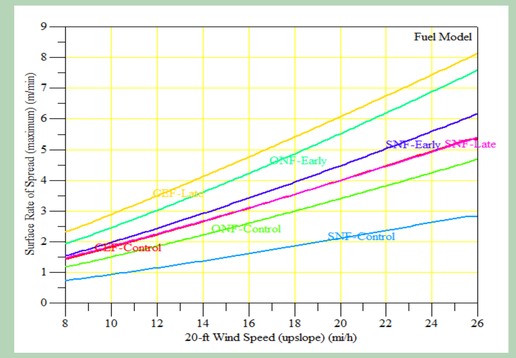

Figure 5. Comparison of surface rate of spread between stands as predicted by BehavePlus under varying winds and moderate (80th percentile) moisture conditions.

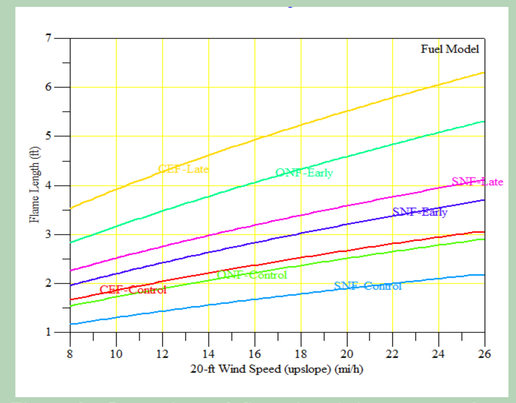

Figure 6. Comparison of flame length between stands as predicted by BehavePlus under varying winds and extreme (99th percentile) moisture conditions.

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Acknowledgements

This study was funded by the USDA Forest Service, Forest Health Monitoring Evaluation Monitoring Grant SO-F-09-03. We thank Dale Starkey for his assistance, James R. Rieck for statistical support, and Horace Gambrell for collecting and recording the field data.