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Resources for Managing the Impact of Bark Beetle Activity on Conifer Fuels and Fire Behavior

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Bark beetle (Coleoptera: Curculionidae, Scolytinae) outbreaks have resulted in the loss of hundreds of thousands of conifers on approximately 30 million hectares of forested lands in western North America during the last decade. Many forests remain susceptible to bark beetle infestation and will continue to experience high levels of conifer mortality until suitable host trees are depleted, or natural factors cause populations to collapse. Stand conditions and drought, combined with warming temperatures, have contributed to the severity of these outbreaks, particularly in high-elevation forests (USDA 2009).

Fire managers will increasingly encounter timber fires burning in fuels affected by bark beetles. It has long been assumed that fuels altered by bark beetle outbreaks increase the probability of ignition and the potential for increased fire intensity. We reviewed literature relating to the effects of bark beetles on fuels and fire behavior and the implications on forest management (Jenkins et al. 2008). Our recent research has shown that bark beetles do affect fuels by increasing litter and fine woody fuel loads and decreasing canopy sheltering which dries fuels and allows for increased midflame windspeeds. These factors are most important in increasing the probability of ignition and rate of fire spread for the relatively short period (5-10 years) during the beetle epidemic when yellow to red needles are present in conifer stands. During this phase of bark beetle infestation there is also an increased likelihood of crown fire initiation and spread due to increased flammability of canopy fuels. In the post-bark beetle epidemic phase fire potential may decrease, however, as canopy fuel continuity is lost and herbaceous and shrub fuels dominate in many forest cover types. There may be an increase for high intensity fire several decades post-epidemic as standing and

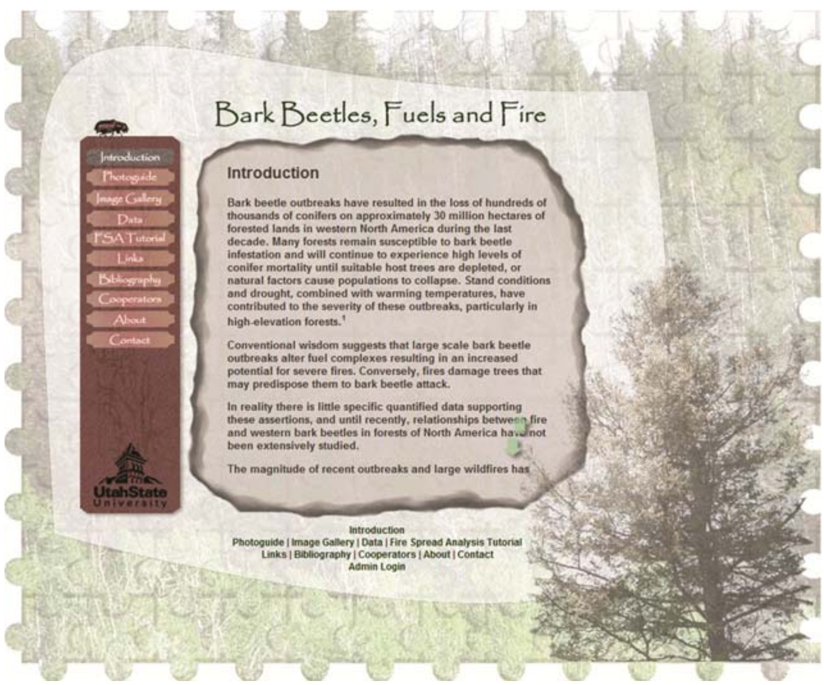

Figure 1. The Bark Beetles-Fuels-Fire project website at http://www.usu.edu/forestry/disturbance/bark-beetles-fuels-fire/index.html.

fallen snags share the site with advanced regeneration creating fuel ladders in the presence of increased coarse woody fuels (Page and Jenkins 2007 a and b, Jorgensen and Jenkins 2010 a and b, Hill and Jenkins in review and Jenkins 2010).

Online Resources

We have developed and are maintaining a website containing research findings and technology useful to forest health and wildland fire professionals responsible for managing conifer forests affected by bark beetles. The website contains tabs accessing research papers, conference presentations, a photo guide for appraising bark beetle-affected fuels, a tutorial for modeling fire spread in bark beetle affected fuels, an image gallery and a comprehensive, up-to-date bibliography and links to other websites and resources. You can visit the website at www.usu.edu/forestry/disturbance/bark-beetles-fuels-fire/index.html (Figure 1).

Photo Guides

The photo guide provides appraisals of fuels associated with endemic, epidemic and post-epidemic populations of bark beetles in Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco), lodgepole pine (*Pinus contorta* Engelm.) and Englemann spruce (*Picea engelmannii Parry ex Engelm.*) forests in the Intermountain region of the western United States (Figure 2). All three forest types have experienced varying levels of bark beetle-caused tree mortality since the late 1980's. The primary bark beetle species infesting Douglas-fir, lodgepole pine and Englemann spruce are Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins), mountain pine beetle (*D. ponderosae* Hopkins), and spruce beetle (*D. rufipennis* Kirby) respectively. Specialists within fire and forest health communities may use this photo guide in conjunction with other information to help characterize bark beetle-induced changes in fuels complexes over time. The photo guide provides a link to custom fuel models used for predicting potential fire behavior in bark beetle-affected landscapes.

Fuels data used in developing this photo guide were collected from a number of stands in each of the three major forest types are available by clicking the data tab in the photo guide section of the website.

Selected stands in each forest type were classified as either endemic, epidemic, or post-epidemic. Stands with endemic populations of bark beetles were defined

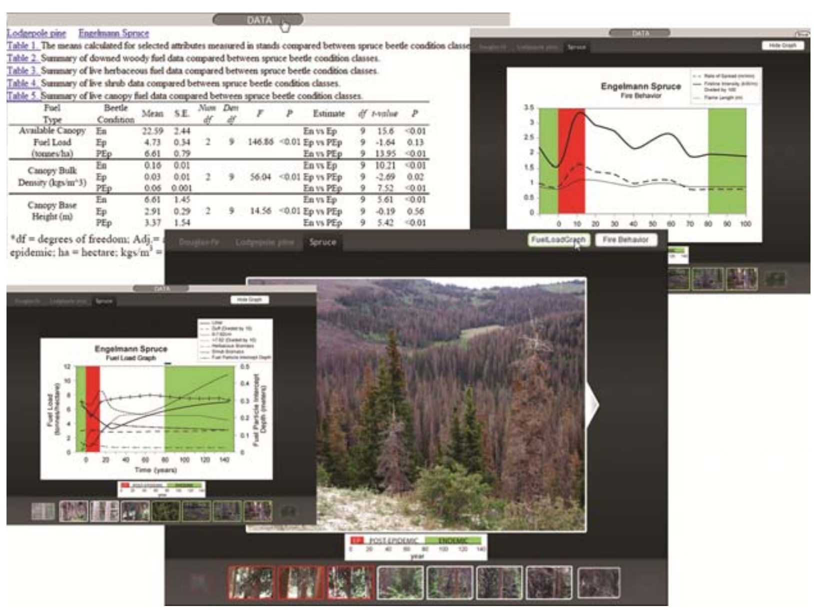

Figure 2. The Bark Beetle-Fuels-Fire photo guide provides appraisals of fuels associated with endemic, epidemic and post-epidemic populations of bark beetles in Douglas-fir, lodgepole pine and Englemann spruce forests in the Intermountain region of the western United States

as those having no evidence of current or older tree mortality attributed to bark beetle infestation. Stands with epidemic populations of bark beetles were defined as those having increasing levels of tree mortality and/or at least four clumps of five or more standing infested trees per hectare. Only plots with at least one infested tree were sampled in epidemic stands. Post-epidemic stands had more than 60% host tree mortality that was generally older than five years. However, only plots with greater than 80% host mortality were sampled in post-epidemic stands.

The specific locations of stands sampled by bark beetle population level in each forest type are provided in Table 1.

Table 1

Locations of stands sampled by bark beetle population level in each forest type.

Forest Type	**Bark Beetle Population Level**		
	Endemic	Epidemic	Post-epidemic
Engelmann spruce	*LaSal Mountains Fishlake Hightop	Wasatch Plateau Fishlake Hightop	Wasatch Plateau Fishlake Hightop
Douglas-fir	S. Wasatch Mountains Uinta Mountains (E)	S. Wasatch Mountains Uinta Mountains (E)	S. Wasatch Mountains Uinta Mountains (E)
Lodgepole pine	Uinta Mountains (W) Sawtooth NRA	Uinta Mountains (W) Sawtooth NRA	Uinta Mountains (E)

*LaSal Mountains: Manti-LaSal National Forest, southeastern Utah; Fishlake Hightop: Fishlake National Forest, southcentral Utah; Wasatch Plateau: Manti-LaSal National Forest, southcentral Utah; Uinta Mountains (E): Ashley National Forest, northeastern Utah; Uinta Mountains (W) and S. Wasatch Mountains: Uinta-Wasatch-Cache National Forest, northern Utah; Sawtooth NRA, central Idaho;

Ground, surface, and canopy fuels data were collected on plots systematically distributed throughout endemic, epidemic, and post-epidemic stands in each of the three forest types. Ground and surface fuels were measured using methods developed by Brown (1971), Brown et al. (1982), and Anderson (1974). Data used for calculating canopy fuels (total available canopy fuel load and crown bulk density) were collected from healthy and bark beetle-affected trees on variable radius plots superimposed from plot center using methods developed by Brown (1978), Call and Albini (1997), and Page and Jenkins (2007a). Fixed and variable radius plots were also used to collect standard forest mensuration data (tree species, diameter at breast height, crown class, tree heights, tree ages, and regeneration). Other data recorded included the slope, aspect, and habitat type of each plot. Page and Jenkins (2007a) provide a detailed discussion of these methods.

Following the collection of fuels data, digital photos of all fuels transects were taken from plot center. Camera settings were selected to obtain high resolution, high quality photos suitable for publication. The set of images used in this guide were those that best represented the spectrum of bark beetle-affected fuels observed in endemic, epidemic, and post-epidemic stands when paired with the 'average' fuel appraisal and fire prediction outputs. Fuel appraisals or fire behavior predictions for individual images were not provided due to the varibility of fuels encountered in bark beetle-affected stands and because fire behavior estimates were deemed unrealistic at an individual photo scale.

We used the measured fuel characteristics to construct custom fuel models using the methods developed by Burgan and Rothermel (1984). This work produced fuel models customized to the actual set of fuel conditions resulting from bark beetle activity over the course of epidemics. With these custom fuel models and average worst case fire weather estimates we predicted potential fire behavior (rate of spread, flame length, intensity and potential for crowning) using the Rothermel (1983) fire spread model and BEHAVEplus.

Image Gallery

Images used in the photo guide and others taken during the project are organized in the image gallery of the website. Each image is labeled by species, bark beetle condition and location representing a broad geographic range in the Intermountain West.

Spread Model Tutorial

Two-dimensional fire growth and intensity simulations that help predict the consequences of bark beetle-altered fuels on fire hazard at the landscape scale are vital to fire planners and land managers. This FSA Tutorial tab provides information for using custom fuel models and the landscape scale fire behavior models FARSITE and FlamMap to simulate fire spread across bark beetle-affected landscapes. Experienced fire managers will find the tutorial useful in simulating the effect of bark beetles on fire spread.

As an example we utilized aerial detection survey maps from 2000 to 2006, our custom fuel models, historic weather data and data from the LANDFIRE project to create FARSITE/FlamMap landscapes (Figure 3). These landscapes were then used to model and compare fire growth and intensity in a lodgepole pine forest prior to and during a current mountain pine beetle epidemic on the Sawtooth National Forest, ID. Figure 4a and b show the FARSITE projections of endemic and current epidemic mountain pine beetle conditions, respectively. The different colors represent the probability of fires growing from the ignition point to a given boundary over the randomly selected, three-day weather window. The acres in the output legend display the cumulative acre sizes that include all of the polygons with higher probabilities. For example, the less than 5% acre value is the size of the entire polygon including all of the smaller polygons within it. Interpretation of these FARSITE model simulations should consider the weather windows used and the limitations inherent in conventional surface and crown fire spread and

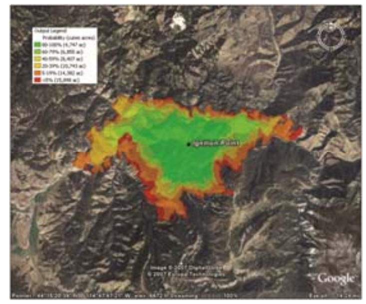

Figure 3. FARSITE/FlamMap landscape created using aerial detection survey maps (2000 to 2006), custom fuel models, historic weather data and data from the LANDFIRE project.

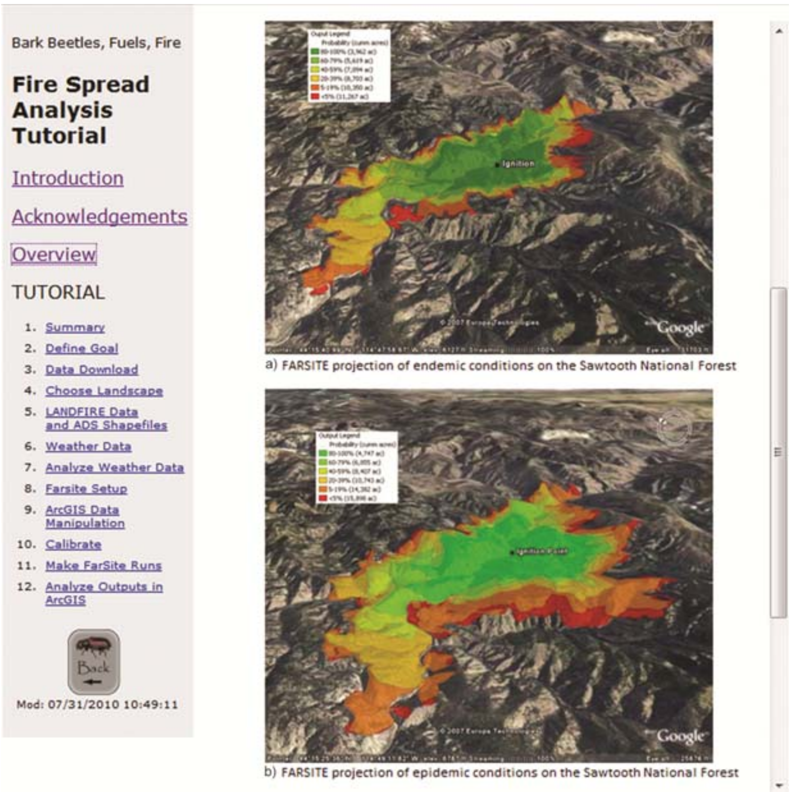

Figure 4. Screen capture from website showing FARSITE projections of endemic (a) and current epidemic (b) mountain pine beetle conditions. The different colors represent the probability of fires growing from the ignition point to a given boundary over randomly selected, three-day weather periods.

initiation models (e.g. live canopy fuel moisture).

Bibliography

The Bark Beetle, Fuels and Fire website manages literature using Digital Commons. The Digital Commons is an Institutional Repository (IR) which brings together all of the pertinent research under one umbrella, with an aim to preserve and provide access to that research. The IR provides open access to scholarly works, research, reports, publications, and courses produced by researchers working with bark beetles, fuels and fire. Coordinated by the Merrill-Cazier Library, USU's digital repository joins other universities worldwide in the ongoing development of new knowledge. The IR is an excellent vehicle for working papers or copies of published articles and conference papers presentations, theses, and other works not published elsewhere. The Bark Beetle, Fuels and Fire website bibliography is fully searchable and university librarians work with publishers to manage copyright issues and provide users access to pdf versions of papers.

Summary and Future Direction

The goal of the website is to provide a clearinghouse for bark beetle, fuels and fire research, resources and information. The Utah State University Disturbance Ecology Lab will maintain the Bark Beetle/Fuels/Fire website with periodic searches to locate pertinent literature for updating the bibliography. The image gallery is a fluid resource and is continually expanding as our work moves to other bark beetle/host systems and as we revisit stands that are transitioning into the post-epidemic condition. We encourage others engaged in bark beetle, fuels and fire research to contribute to the website or provide links to other information or useful websites.

The next phase in our research is to characterize fuel and fire behavior in high-elevation five- needle pines affected by mountain pine beetle. These species occupy a wide geographic, but limited elevational range often in “sky islands” in Intermountain Ecoregion. The ecosystems are ecologically important and especially sensitive to threats posed by climate change, changing fire regimes, habitat fragmentation and white pine blister rust.

We will use results of previous research to extensively sample high-elevation five- needle pines across a large geographic range in western North America. Our goal is to produce a spatially explicit population model using a species landscape approach and high-elevation five-needle pines as the focal species.

For information, questions or comments on the website, or to contribute your work to the bibliography contact Mike Jenkins (mike.jenkins@usu.edu).

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