Mountain pine beetle – fire interaction study*

Key results from Simard et al. (2011) Ecological Monographs

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In the last 10 years, outbreaks of native bark beetles have affected more than 47 million hectares of forests in western North America. The abundance of dead trees across the landscape has raised concern among land managers and the public about whether or not bark beetle outbreaks increase the likelihood of crown fires.

In this study, we wanted to know whether mountain pine beetle (MPB) outbreaks changed the probability of active crown fire in lodgepole pine forests of the Greater Yellowstone Ecosystem (northwestern WY and adjacent MT and ID). This ecosystem has a natural fire regime characterized by relatively infrequent stand-replacing crown fires (150-300 yr return interval) and by recurrent outbreaks of the MPB; the current outbreak began around 2003.

We selected 35 lodgepole pine stands that were either undisturbed by MPB or that had been attacked 1 to 36 years ago, including stands in the red-needle (dead dry needles still on trees) and gray-needle stages (needles have fallen to the ground). For each stand, we measured all the different fuel components (live and dead, surface and canopy). These field data were then used to predict potential fire behavior using the model NEXUS, which has the same structure and equations as other well-established models such as BehavePlus and FARSITE. All stands were comparable (stand age, stand basal area, etc.) when they were attacked by the MPB.

Finding #1: Mountain pine beetle outbreaks in lodgepole pine forests of Greater Yellowstone do not appear to increase the probability of active crown fire. Under certain conditions, MPB may actually decrease this likelihood.

Compared to undisturbed stands, the red and gray-stage stands had about 50% lower canopy fuel loads and density, had a dryer canopy, but had similar canopy base heights. Under intermediate fire weather conditions (see below), probability of active crown fire was predicted to be lower in the red and gray-stage stands, compared to the undisturbed stands, probably because canopy fuels were much lower. Likelihood of active crown fire was also low in stands that were attacked 25 to 35 years ago ("old attacks") because canopy fuel loads had not returned to pre-outbreak levels.

Beetles do not attack all trees in a stand simultaneously, so tree mortality occurs over several years. Stands in the red-needle stage may appear uniformly red, but such stands always contain at least some green and/or gray trees. Moreover, red trees lose their needles over a period of 2-3 years, such that trees with red needles actually may retain only a fraction of their original needle mass. Thus even if overall canopy moisture content

declines in a red stand, the net effect on fire behavior is a decrease in the likelihood of crown fire because of the reduced canopy fuel loads.

Finding #2: Probability of torching is predicted to increase in old attacks (25 to 35 yrs after the outbreak), but surface fire behavior is unaffected by MPB outbreak.

Fine surface fuel loads (1-h to 100-h, that is, less than 3" in diameter) were similar among the undisturbed, red-stage, gray-stage, and old attacks, although the depth of needle litter was higher in the red and gray stands. Simulated surface fire behavior did not differ among these stages. However in the old attacks, fuel loads of coarse downed wood (1000-h fuels, that is, more than 3" in diameter) increased considerably, and growth of understory trees created ladder fuels that increased the probability of torching and passive crown fires.

Finding #3: Effects of mountain pine beetle on fuels matter for fire behavior only when fire weather is not extreme.

Fire behavior was modeled under different wind and fuel moisture conditions to compare the effects of fire weather vs. fuels. The differences in crown fire behavior among the different stages of MPB outbreak were only observed under intermediate fire weather conditions; when fuels were very dry or winds were strong, all stands showed active crown fires regardless of previous beetle activity, and under moderate to wet conditions or low wind speeds, no stands achieved active or passive crowning.

It is well known that fire weather is the primary driver of fire behavior in subalpine forests, including those of Greater Yellowstone. Differences in fuel loads and distribution are important only when fire weather is dry but not extreme, a situation observed in Yellowstone during some years (e.g., 1981). However, during the 1988 Yellowstone Fires, under conditions of extreme drought and high winds, fires burned through forests of all ages and structures.

Management implications

- **#1. Even though red and dead trees killed by MPB are abundant and conspicuous throughout Greater Yellowstone, our results suggest that the forests are not more likely to burn than undisturbed forests of the same age.** There is no question that MPB changes forests and affects human values, and no question that tree mortality is extensive. Further, beetle-killed forests certainly can burn. However, our results suggest that the beetle-induced changes do not increase the likelihood of active crown fire relative to comparable undisturbed forest, as the beetles are thinning the forest canopy fuels.
- **#2. The presence or absence of MPB attack may not be a useful criterion to determine where and when fuel treatments should be carried out.** Fuel treatments may be important to protect buildings or other infrastructure from fire. However, our findings indicate that green lodgepole pine forests can burn as readily

as beetle-killed forests; therefore fuel reduction may be equally important in green, red, and gray stands--wherever vulnerable resources are at risk of fire damage.

- **#3. Harvesting may not be required in MPB-killed forests to reduce fire hazard and the likelihood of active crown fire.** MPB-killed forests might still be harvested for their timber, and hazard trees might need to be removed from populated areas to reduce the danger of falling trees. However, the rationale of mitigating a perceived increased likelihood of active crown fire in MPB-killed lodgepole pine using salvage harvesting would not be supported by this study.

Research approach and caveats

In this study, fuels were measured in beetle-killed and undisturbed stands that did not burn. Fire behavior was then simulated (prospective approach) using well-established computer models. Advantages of the prospective approach include the precise measurement of fuels that would otherwise be consumed; the control of fire weather conditions, which change from one fire to another; the possibility to study fire behavior in a relatively large number of stands; and the ability to verify that all stands were similar *before* the outbreak. This last point is particularly important to confirm because older lodgepole pine stands are more likely to burn (because of ladder fuels) and also more likely to be attacked by the MPB. In this study, to make sure that potential differences in fire behavior were caused by MPB attack and not by stand age, we selected undisturbed stands that were susceptible to MPB and had an age and basal area that were similar to those of beetle-attacked stands at the time of the outbreak; this validation was done by performing extensive dendrochronological analyses.

The disadvantage of the prospective approach is obviously that fires are simulated and are not 'real' fires. Other approaches, including studying beetle-killed forests that subsequently burned (retrospective approach), or performing experimental burns, have their own pros and cons, and are complementary to the prospective approach used here. No single study can resolve all aspects of a complex issue, and results from multiple studies using different research approaches will be necessary to understand the relationships between MPB outbreak and fire. The effects of MPB outbreak on other important aspects of fire activity, such as spotting distance, soil heating, and fire management operations, were not addressed in this study and could be addressed in future research.

Virtually all fire behavior models used in the United States are based on the same set of equations, and it has been shown that they all underestimate potential crown fire behavior[1]. However because the goal of the study was to determine the differences in fire behavior among the different MPB attack stages, the bias should be systematic, and the general conclusions should not be affected by this bias. Nonetheless, we caution against using the exact numerical results as a prediction. In addition, these models only predict fire behavior of wind-driven fires, not of the more intense plume-dominated fires. During plume-dominated fires, fuel conditions should exert even less influence on fire behavior, which would reinforce the conclusion that MPB outbreaks only matter under a narrow set of environmental conditions.

The study was carried out in lodgepole pine forests, and results may differ for other forest types such as ponderosa pine forests. Likewise, the characteristics of the forests (structure, density, etc.) and of the MPB outbreak (severity, duration, etc.) in Greater Yellowstone may be significantly different from those of other regions and thus these findings should be evaluated in other systems to determine how general they are.

What's next?

Future research on the following topics would further understanding of bark beetle-fire interactions :

-Determining, for forests that actually burned, if previous MPB outbreak severity influenced fire severity and area burned

-Quantifying the flammability of green, red, and litter needles as a function of water and volatile compound content; and using these data to improve fire behavior models

-Determining the effects of MPB outbreak-caused tree mortality on the probability of spotting

-Performing real-time observation of fire behavior during experimental burns of undisturbed and MPB-killed (different stages) stands under controlled conditions

-Studying other forest types and other regions

-Evaluating potential heat release and soil impacts from fires occurring in heavy fuels 15-30 yr after a beetle outbreak

Biosketches

Martin Simard is a post-doctoral fellow at the University of Wisconsin – Madison. His research focuses on insect outbreaks, wildfires, and forest harvesting in boreal and subalpine forests. Email: simard@wisc.edu

Bill H. Romme is a professor at Colorado State University. He is a forest ecologist and has been studying vegetation and fire ecology in Greater Yellowstone for >30 years. Email: romme@cnr.colostate.edu

Jake M Griffin is a Ph.D. candidate at the University of Wisconsin – Madison. His research interests are the effects of insects and pathogens on forest ecosystem processes. Email: jgriffin2@wisc.edu

Monica G. Turner is the Eugene P. Odum Professor of Ecology at the University of Wisconsin – Madison and a member of the National Academy of Sciences. She has studied disturbance in the Yellowstone landscape for >20 years, with a main focus on the 1988 fires. Email: turnermg@wisc.edu

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[1] Cruz, M. G., and M. E. Alexander. 2010. Assessing crown fire potential in coniferous forests of western North America: a critique of current approaches and recent simulation studies. *International Journal of Wildland Fire* 19:377-398.