Research Brief for Resource Managers

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Drought and bark beetle induced tree mortality elevates wildfire severity of California's Sierra Nevada forests

Wayman RB and Safford HD. 2021. Recent bark beetle outbreaks influence wildfire severity in mixed-conifer forests of the Sierra Nevada, California, USA. Ecological Applications. doi:10.1002/eap.2287.

Management Implications

- Removal of recently dead trees from the landscape *may* reduce the severity of a subsequent wildfire
- Managers should weigh the chance that a wildfire will occur within the short red phase window (2-3 years) against the need to spend limited fuels reduction dollars elsewhere
- Further research is needed but fire severity is likely linked to topography, fire weather, and the presence of dead trees, especially during the red phase
- In the study system, the red phase of tree mortality is now largely past, and impacts of later stages of tree mortality on wildfire severity in frequent fire forests are not well-understood and further research is needed.

Introduction

In temperate forests, elevated frequency of drought related disturbances is increasing the incidence of interactions between disturbances such as bark beetle epidemics and wildfire. Our understanding of the influence of recent drought and insect-induced tree mortality on wildfire severity has largely lacked information from forests historically adapted to frequent fire, such as the mixed-conifer forests of California's Sierra Nevada. We used field data from two wildfires (the 2015 Rough Fire and 2016 Cedar Fire) that burned in areas of recent severe tree mortality to examine whether and under what conditions the pre-fire tree mortality affected wildfire severity.

Key Findings

We found support for a positive but nuanced relationship between pre-fire red phase (when trees still support their dead leaves) tree mortality and subsequent wildfire severity in these Sierra Nevada mixed-conifer forests. Pre-fire tree mortality was associated with two of three fire severity metrics on the Rough Fire, and all three metrics on the Cedar Fire. On the Rough Fire, topographic position was also strongly associated with our fire severity metrics. On the Cedar Fire, fire weather (as measured by relative humidity, RH) had a stronger influence on wildfire severity than red phase tree mortality. (Fig. 1).

Methods

We collected data on 180 0.04 ha circular plots within the two fire footprints one year after the fires. We examined each dead tree to determine the timing and cause of mortality (i.e. killed by beetles or other causes pre-fire, killed by fire, or killed by beetles post-fire), and we collected a suite of forest stand structure, fire severity, and site physical variables. The fire severity metrics we analyzed were percentage of tree basal area killed by fire, mean canopy torch percent (needles consumed by fire), and RdNBR, a remotely sensed fire severity metric.

We used a random forests analysis to first identify variables that were influential to fire severity. We further examined those influential variables using a regression tree analysis to determine whether hierarchies existed between them. We also used partial dependence analysis to investigate the individual effects of pre-fire tree mortality and other influential variables on fire severity. Finally, we quantified changes in dominant tree species composition resulting from these interacting disturbances.

Results

On both fires, pre-fire tree mortality was associated with what we considered our most direct and biologically meaningful fire severity metric: basal area killed by fire. On the Cedar Fire, RH had a stronger influence on wildfire severity, and pre-fire tree mortality had a stronger influence on basal area killed by fire when RH was high (Fig. 1). On the Rough Fire, pre-fire tree mortality had the strongest influence on basal area killed by fire, and higher topographic positions were also consistently associated with our fire severity metrics.

On both fires, increasing severity of bark beetle mortality was only associated with increased fire severity up to pre-fire mortality levels of 30-40% of plot basal area; increases in pre-fire mortality above this threshold were not associated with further increases in fire severity (Fig. 1). Increases in fire severity were more pronounced when pre-fire tree mortality was above ~15% for most fire severity metrics.

The interacting disturbances drastically reduced forest cover on both fires. The Rough Fire plots were largely dominated by fire tolerant and shade intolerant pines pre-disturbance, but after wildfire the dominant trees were more evenly split between ponderosa pine (Pinus ponderosa), incense cedar (Calocedrus decurrens), and white fir (Abies concolor). The latter two species are fire sensitive and shade tolerant. The Cedar Fire plots were largely dominated by white fir and incense cedar pre-disturbance, and the proportional species composition post-fire remained unchanged.

These findings are directly relevant to dry mixed-conifer systems historically adapted to frequent fire but with highly altered stand structure and species composition due to decades of fire suppression and lack of Indigenous burning, and they pertain specifically to recent tree mortality events. The finding that the influence of pre-fire tree mortality on wildfire severity may depend on other site conditions capable of driving extreme fire behavior (i.e. weather) is broadly relevant to temperate conifer forests experiencing these interacting disturbances, and it contributes to a small but growing body of evidence observing similar dependencies.

Further Reading

Harvey, B. J., D. C. Donato, W. H. Romme, and M. G. Turner. 2014. Fire severity and tree regeneration following bark beetle outbreaks: the role of outbreak stage and burning conditions. Ecological Applications 24:1608–1625.

Kane, J. M., J. M. Varner, M. R. Metz, and P. J. van Mantgem. 2017. Characterizing interactions between fire and other disturbances and their impacts on tree mortality in western US Forests. Forest Ecology and Management 405:188–199.

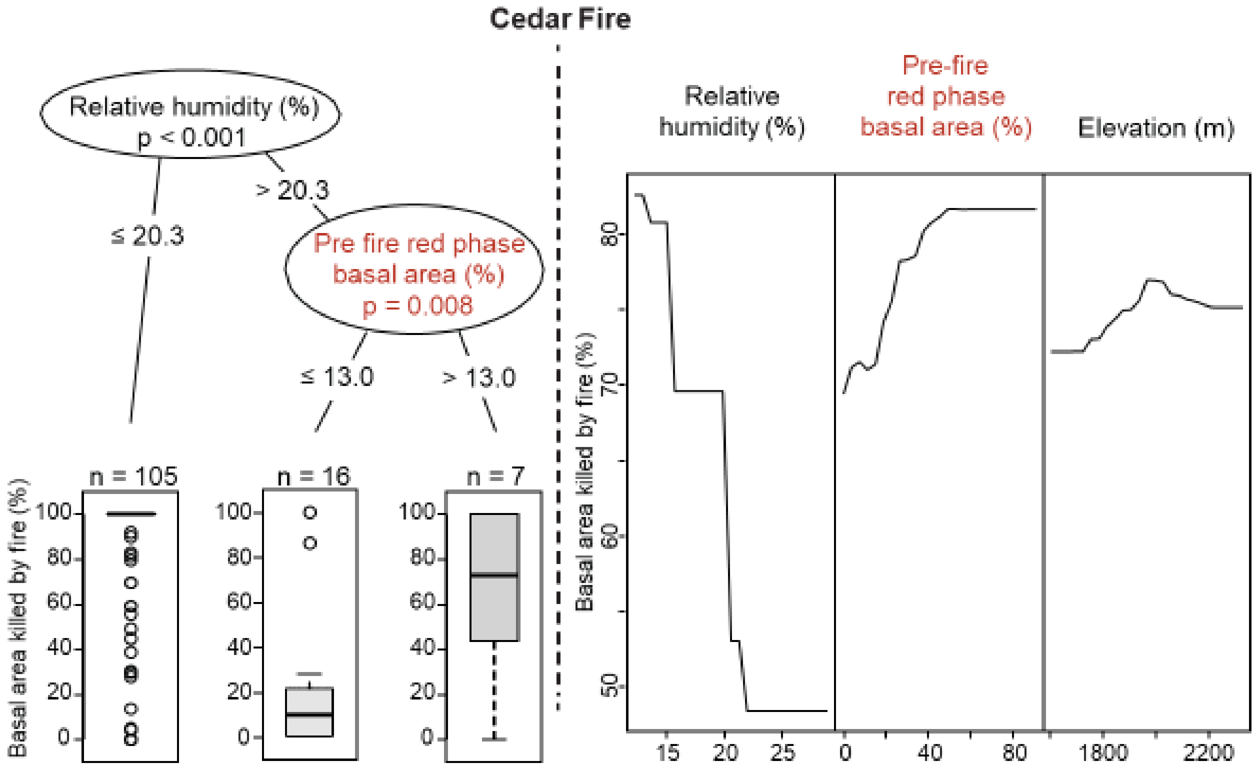

Figure 1. Regression tree (left) and partial dependence plots (right) for the percentage of plot basal area killed by fire on the 2016 Cedar Fire, using the predictor variables identified as important to this metric by the random forest model. On the regression tree, n is the number of plots in group, and p-values at each node are from a Monte Carlo randomization test (α=0.1). Partial dependence plots characterize the dependence of model predictions on each influential variable.