Research Brief for Resource Managers

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Burn weather and fuel structure help to determine post-fire tree mortality

Jeronimo, S.M.A., J.A. Lutz, V.R. Kane, and J.F. Franklin. 2020. Burn weather and three-dimensional fuel structure determine post-fire tree mortality. Landscape Ecology 35: 859–878. https://doi.org/10.1007/s10980-020-00983-0.

Understanding post-fire tree mortality is important for planning restoration fire treatments that modify fire behavior and effects. Current models are often not spatially or temporally explicit, so they don't capture potential differences in scale or timing of mortality (i.e., immediate versus delayed mortality). In this study, the authors found that controls on post-fire tree mortality differed depending on the scale considered. Variation at the neighborhood scale was driven by landscape controls such as burn weather and fuel amounts (Fig. 1). However, at the individual-tree scale, whether a given tree was killed outright by the fire or by a delayed response depended on a series of conditions (Fig. 1). This difference in scale emphasizes the importance of incorporating spatial patterns when modeling post-fire tree mortality.

Management Implications

- Understanding post-fire tree mortality is important for planning restoration fire treatments that modify fire behavior and effects and models that reflect multiple spatial and temporal scales are effective tools.
- Mortality rates of trees are size-dependent with smaller trees dying immediately following a fire and in the first year and larger trees dying several years after a fire.
- Both immediate and delayed mortality is related to direct fire damage while beetles and other pathogens account for most delayed mortality.

Factors like forest structure, topography, and fire weather operate on varying spatial scales to affect post-fire tree mortality. Post-fire tree mortality is dependent on characteristics of each individual tree but also on the arrangement of groups of trees. For example, vertical continuity amongst tree crowns can support passive or active crown fires and modify the way fire moves across a forest. Likewise, delayed mortality can also be affected by forest structure at multiples scales, with fire-caused damage at the individual-tree level leading to the death of a tree several years after a fire. In contrast, bark beetles are density dependent and operate on a broader scale than the individual tree. The objective of this study was to quantify forest structure one to four years after fires to capture factors impacting immediate and delayed post-fire tree mortality across multiple spatial scales. This empirical data could help improve ecological understanding of post-fire tree mortality and better inform models used by forest managers.

Data on post-fire tree mortality was used from the plots located in a long-term study site in the Sierra Nevada that was burned in the 2013 Rim fire (Yosemite Forest Dynamics Plots). Metrics at both the individual-tree scale and groups-of-trees scale (neighborhood) were calculated. This included both structural metrics derived from

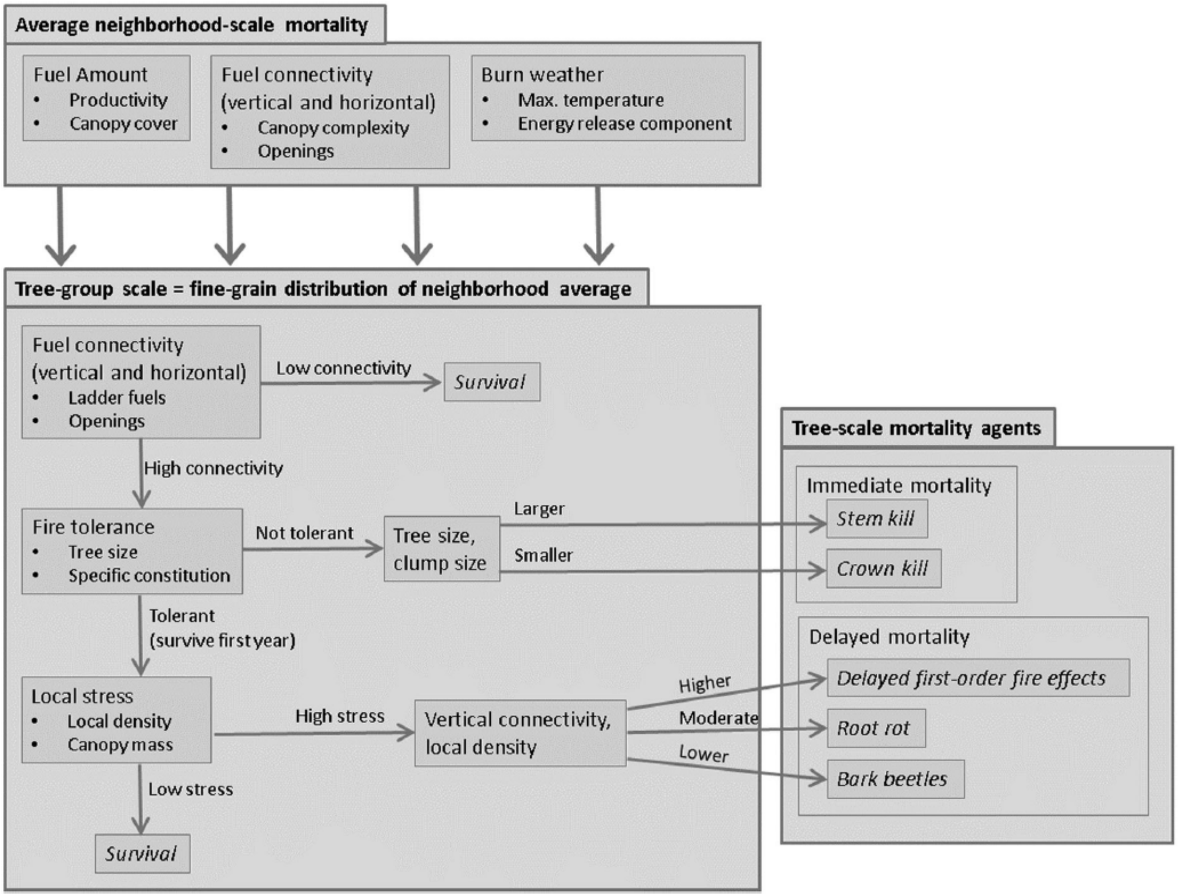

Figure 1: Conceptual framework of post-fire tree mortality based on study results. Post-fire tree mortality at the broad scale is influenced by fuel characteristics and fire weather while individual-tree scale mortality is determined by a series of filters related to immediate fire-caused mortality and delayed mortality due to bark beetles and root rot.

LiDAR (e.g., crown base height, crown bulk density) and biophysical metrics (e.g., topography, water balance, burn weather). Tree mortality and survivorship were recorded at the study site post-fire from 2014-2017 to parse out immediate versus delayed fire effects. Independent validation plots were also surveyed within the Rim Fire in Yosemite and covered similar conditions as the study site. Post-fire tree mortality was modeled at the neighborhood- and individual-tree scales using both structural and biophysical predictors.

The best model included topography, water balance, and burn weather predictors along with an interaction term indicating the number of trees killed across the individual and neighborhood scales. Neighborhood-scale mortality was best explained by burn weather predictors such as Energy Release Component, maximum burn day temperature, as well as fuel connectivity and amount (Fig.1). Fine-grain mortality (individual to groups of trees) was explained by a fuel connectivity, individual fire tolerance, and local

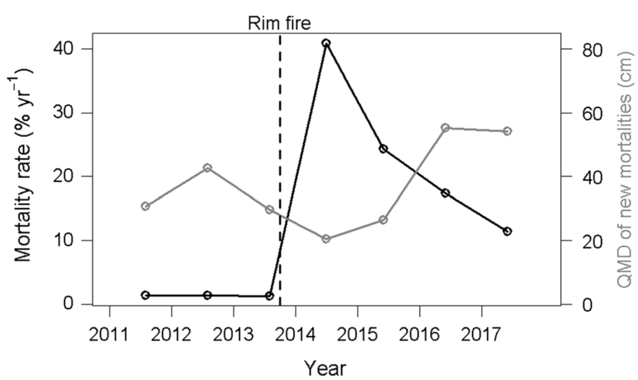

Figure 2: Rate of mortality (black) and QMD of new mortalities (gray) for trees ≥ 10 cm DBH on the Yosemite Forest Dynamics Plot (YFDP) for three years pre-fire and four years post-fire.

stress (e.g., canopy mass or density) (Fig. 1). Mortality rates of trees decreased from a high of 39% after the first year, to 23% the second year, 16% the third year and 6% the fourth year (Fig. 2). Smaller trees died immediately following the fire or in the first year while larger trees experienced delayed response dying in later years (Fig. 2).

Immediate mortality was related directly to the fire with 98% of trees dying from crown damage, stem damage, or other mechanical type damage. Delayed mortality was also strongly associated with fire-related factors while other non-fire related factors such as bark beetles and other pathogens accounted for the next highest cause of death.

Suggestions for future reading:

Cansler, C.A., M.E. Swanson, T.J. Furniss, A.J. Larson, and J.A. Lutz. (2019) Fuel dynamics after reintroduced fire in an old growth Sierra Nevada mixed-conifer forest. Fire Ecology15:16.

Furniss, T.J., A.J. Larson, V.R. Kane, and J.A. Lutz. 2019. Multi-scale assessment of post-fire tree mortality models. Int J Wildland Fire 28:46–61.

Hood, S.M., J.M. Varner, P. van Mantgem, and C.A. Cansler. 2018. Fire and tree death: understanding and improving modeling of fire-induced tree mortality. Environ Res Lett 13:113004