CALIFORNIA FIRE SCIENCE CONSORTIUM

Research Brief for Resource Managers

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Heading fires consume more fuels than backing fires

Birch, Joseph D., Matthew B. Dickinson, Alicia Reiner, Eric E. Knapp, Scott N. Dailey, Carol Ewell, James A. Lutz, and Jessica R. Miesel. 2023. "Heading and backing fire behaviours mediate the influence of fuels on wildfire energy." *International Journal of Wildland Fire* 32, no. 8 (2023): 1244-1261.
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A better understanding of relationships among pre-fire fuel loadings, environmental conditions, and fire behavior help support pre-fire land management and tactical decision-making on wildfires, particularly relative to ignition and holding operations that are intended to moderate fireline intensities and fire effects on vegetation. As well, differences in the mode of fire advancement (e.g., heading, backing, or flanking fires) may alter rates of fire spread, fuel preconditioning, or intensities. Researchers from Michigan State University and the USFS Fire Behavior Assessment Team used 15 years of immediate pre- and post-fire fuel (Fig. 1) and wildfire behavior data to identify the role of fire advancement mode and pre-fire environmental drivers (e.g., topography, fire weather, and fuel loadings) on fuel consumption and fire effects in California mixed-conifer forests.

Heading fires consumed 232% more litter and 202% more duff than backing fires (Fig. 2), despite similar pre-fire fuel loadings. Flanking fires had intermediate levels of fuel consumption, and did not differ from either heading nor backing fires. Greater fuel pre-conditioning or flame-front continuity (i.e. less patchy spread) in heading fires may explain the differences in consumption, relative to backing fires. Topography (e.g., slope,

Management Implications

- Heading fires consumed more litter and duff fuels than backing fires, while flanking fires had intermediate consumption
- Litter, duff, and 1000-h fuels had the largest absolute consumption of any fuel classes and most directly contributed to the heat produced by wildfire
- Between 47 – 82% of fuels were not consumed by wildfire, and therefore could be consumed in subsequent fires.
- Fuel consumption was poorly related to remotely-sensed burn severity (RdNBR), highlighting the indirect processes between fire and tree mortality

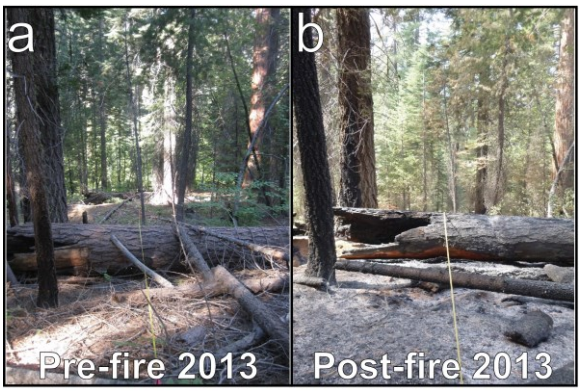

Figure 1. (a) Pre- and (b) post-fire images from the 2013 Rim wildfire. Plot burned under backing wildfire.

aspect, elevation) alone had no direct influence on fuel consumption except for its role in influencing fuel moistures and mode of fire advancement (e.g., heading or backing).

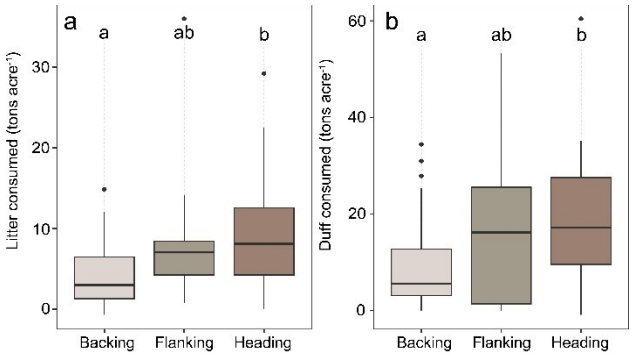

Figure 2. (a) Litter and (b) duff consumption (tons acre^{-1}) under backing, flanking, and heading fire. Significant differences are marked by different letters.

Litter, duff, and 1000-h fuels had the largest absolute reduction in loadings and contributed the most to the total energy (heat) release from wildfire. Our results suggest that forest management actions such as thinning or prescribed fires that target consuming or removing litter, duff, and 1000-hr fuels would most directly reduce total fire energy, which may reduce the injury and mortality of overstory trees.

On average, fuel consumption was incomplete, with 47 – 82% carryover of pre-fire fuel loadings. The proportion of fuel consumption increased with greater relative delta normalized burn ratio (RdNBR), a measurement of burn severity, but had a generally weak relationship ($R^2 = 0.14$). Because RdNBR is derived from remotely-sensed measures of the change in canopy reflectance, the poor association between fuel consumption and RdNBR suggests that indirect fire effects (e.g., basal area change, vegetation mortality) and environmental stressors (e.g., drought, bark beetles) may have a stronger role in overstory mortality than fuel consumption alone.

Managing wildfires to achieve more backing fire behavior may limit negative effects on large overstory trees and consume less litter and duff fuels, thereby reducing fire energy and emissions. In contrast, managing wildfires for more heading fire behavior may increase effects on trees and consume more forest floor fuels.

Suggestions for further reading:

Frames.gov/FBAT/fire-videos

Miesel, Jessica, Alicia Reiner, Carol Ewell, Bernardo Maestrini, and Matthew Dickinson. 2018. "Quantifying changes in total and pyrogenic carbon stocks across fire severity gradients using active wildfire incidents." *Frontiers in Earth Science* 6: 41. https://doi.org/ 10.3389/feart.2018.00041