Reduced fire severity in fuel-treated forests at the Wildland-Urban Interface during the Caldor Fire (2021)

Research Brief • December 2025

Fire-prone conifer forests in the Western United States have become increasingly impacted by severe wildfire over the last four decades (Parks and Abatzoglou, 2020; Parks et al., 2023). In California, these impacts are most viscerally visible at the wildland-urban interface, where more than 25% of Californians live, and where tens-of-thousands of structures were destroyed by wildfire between 2015 and 2021 (Safford et al., 2022). The Lake Tahoe Basin (LTB) is one of California's landscapes most threatened by these trends. Since 2002, the LTB has experienced the Gondola, Showers, Angora, and Caldor Fires, among others. The Caldor Fire was caused by a human ignition near the town of Grizzly Flat in early August 2021, and burned under extreme weather conditions in one of the driest state water years on record. It required the evacuation of thousands of residents, burning 89,773 hectares.

This study assessed tree and stand characteristics and metrics of fire severity in areas within the footprint of the Caldor Fire that had experienced fuel reduction by the Forest Service between the early 2000s and 2019. Treatments were varied, and included hand-thinning and piling (HTP) followed by pile-burning, HTP where the piles were still onsite, and areas where treatment involved two rounds of "cut to length" tree-felling (DBH < 76.2 cm) followed by mastication and surface fuel redistribution to stay below a threshold of 15 cm depth (CPCM). Pre- and post-treatment fuel loadings, stand densities, and basal areas were calculated by combining field data, allometric modeling methods (Forest Vegetation Simulator), and photo series. Each of these metrics was significantly lower in treated stands.

MANAGEMENT IMPLICATIONS

- Across all treatment types, forests that underwent fuel treatments had significantly lower fire severity in three of five metrics (crown scorch percent, crown torch percent, and torch height) and 3x more surviving trees.
- In management units where logistical or personnel constraints impose limits on prescribed burning activities, effective fuel treatments can still be accomplished through multiple-entry mechanical and hand thinning followed by mastication, with a maximum fuel depth restriction to reduce severity of surface fire.
- Hand thinning and fuel piling followed by pile burning was also an effective treatment for reducing fire severity and tree mortality in the Caldor Fire.
- Areas that had been thinned but supported unburned fuel piles posed similar fire severity and tree mortality risks in the Caldor Fire to areas with no fuel treatments at all, highlighting the importance of proactive fuels management and resolving long-standing agency capacity constraints.

The authors and field staff sampled 20 transects, each 225 meters long, going from treated to neighboring untreated forest in the Caldor Fire footprint. Field methods followed those in Safford et al. (2009, 2012), and the authors' analyses showed that HTP-with pile burning and CPCM treatments in the Meyers and Christmas Valley area significantly reduced key measures of fire severity, including crown scorch[1], crown torch[2], and torch height[3], and increased tree survival three-fold relative to untreated forest. The lowest metrics of fire severity were recorded in CPCM transects, while the highest severity was recorded in untreated and HTP-no burn areas, which were not significantly different. The clear contribution of unburned fuel piles to increased fire severity and tree mortality may be attributed to logistical and temporal constraints on LTBMU fuel treatments. These constraints include high

1 Percent of tree's foliage that was burned but is retained.
2 Percent of tree's foliage that is completely combusted.
3 The highest point of completely combusted foliage on a tree.

rates of thinning and piling accompanied by burning backlogs, the rareness of weather conditions that allow multi-day burn windows, burn crew staffing shortages, and progressively shorter prescribed burning seasons. Other factors influencing tree survival and fire severity included species composition and slope. Among the tree species sampled, Jeffrey pine survived at by far the highest rate, in both treated and untreated stands, while white fir was the least likely tree to survive fire. Areas with steep, rocky slopes with sparse canopies inhibited severe burning.

A recent study summarizing the efficacy of forest management in the Sierra Nevada over 20 years found that treatments combining mechanical thinning and prescribed fire were the most successful in both reducing fire risk and increasing forest resilience (Stephens et al. 2023). The evidence from the Caldor Fire underlines the importance of mechanical treatments, and suggests that deeper analysis of the contexts in which these treatments are more successful than combined fire and mechanical treatments is warranted. Overall, forests in the LTB are much denser and less dominated by fire and drought-tolerant species than they were prior to Euroamerican settlement. This current reality, combined with a likely future of increased severe fire weather, water stress, and insect mortality, highlights the urgency of integrating fire and fire-surrogate treatments into forest management plans throughout the Sierra Nevada.

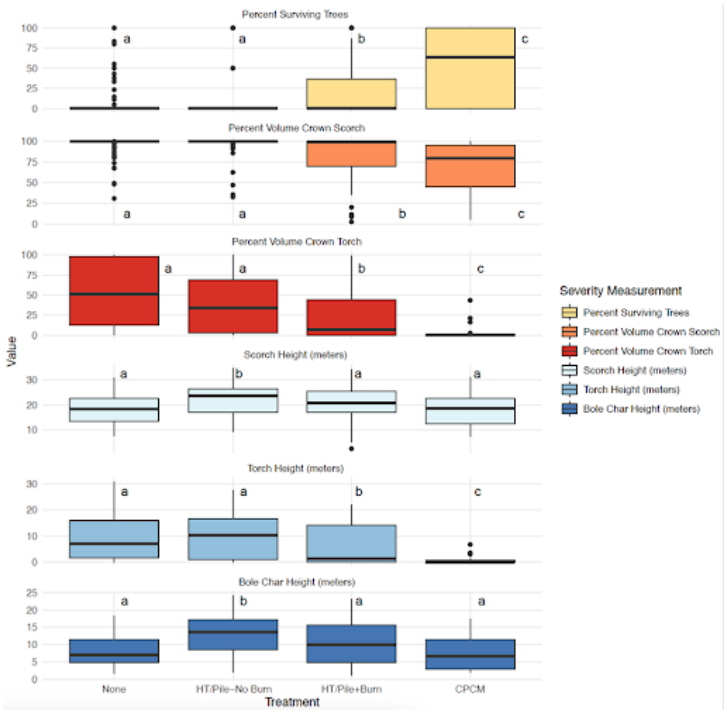

Figure 1. Box plots comparing tree survival and five fire severity metrics measured along the transects for untreated forests ("none") and three treatment types (see text for definitions). Horizontal lines depict the median, boxes delineate 25th and 75th percentiles. Different letters in each of the comparison categories denote statistically significant differences among treatments (all $P < 0.01$).

Additional Information

This brief is based on the following article:
Hugh Safford and Saba Saberi. "Fuel treatment effects on fire severity during the Caldor Fire (2021), Lake Tahoe, California, USA." under review, Forest Ecology and Management.

This brief was written by Sachi Srivastava, reviewed by Hugh Safford and Saba Saberi, and produced by the CFSC Sierra Nevada Subregion

For additional information, contact: cafirescience@gmail.com, hdsafford@ucdavis.edu (Hugh Safford, Brief Editor, Publication Author, and Correspondence), sasriv@ucdavis.edu (Sachi Srivastava, Brief Author)