Drivers of fire severity in three short-interval successive fires in the Sierra Nevada, California

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In the mixed conifer forests of the Sierra Nevada, long-term fire exclusion has increased fuel loads and stem densities while fundamentally altering species compositions and other stand metrics relative to historical estimates. These stand conditions, along with hotter, drier, and longer fire seasons, have created increasingly large and severe wildfires across the western United States, with many areas experiencing successive reburns. Given the growing number of challenges faced by managers to increase forest resilience to future wildfires, it is crucial to understand the implications of reintroducing repeated fire into fire-excluded landscapes, and to assess the capacity of successive low-to-moderate severity fires to restore forests to resilient structural parameters.

Researchers at UC Berkeley and the US Forest Service sought to evaluate the influence of forest structure and composition, topography, and weather on fire severity in a third successive fire. They investigated the structural conditions emerging after successive burns, whether these conditions contributed to fire severity, and how these conditions compared to historical estimates. Their study utilized a network of Forest Service field plots in the Plumas and Lassen National Forests that had been initially burned in the Storrie and Rich Fires in 2000 and 2008, reburned in the Chips Fire in 2012, and were then subject to a second reburn in the 2021 Dixie Fire. Plots were sampled in 2017 and 2018 following the Chips Fire and in 2023 following the Dixie Fire.

MANAGEMENT IMPLICATIONS

- Successive reburns produce a range of post-fire structural conditions that can influence fire severity in a subsequent burn and therefore may require different management interventions. Examples of these dominant structural conditions include high shrub cover, high live biomass (live tree basal area and density), and high dead biomass (snag basal area and CWD loads). Shrub cover was shown to have a negligible effect on fire severity in a third successive fire.
- Areas subject to low-to-moderate severity reburns may still support high live tree densities and basal areas relative to the natural range of variation, requiring the integration of diverse management tools (e.g. mechanical treatments) in addition to prescribed burns to meet desired restoration outcomes.
- High dead biomass was the strongest predictor of high severity fire after three successive burns, suggesting that the legacy of fire exclusion can persist well beyond the initial reintroduction of fire into forested landscapes. In areas with high dead biomass post-fire, selective removal of standing snags could reduce the accumulation of CWD over time, and therefore lessen the likelihood of high severity fire in a successive burn.

Plot-level measurements included tree species, diameter at breast height (DBH), and status (live or dead) with seedlings (<1.7 m), saplings (>1.7 m), and percent shrub cover measured in 5-m radius subplots. Live and snag basal area, coarse woody debris (CWD) loads, and live tree density were calculated for each plot after the second and third fires using the RStudio "BerkeleyForestAnalytics" package. Fire severity for each fire was estimated using the remotely sensed Relative Differenced Normalized Burn Ratio (RdNBR). Weather variables influencing fire severity for each plot were extracted from two automated weather stations near the study region. Statistical analyses were performed to rank the relative importance of variables from topographic, weather, and 2017-2018 plot data in explaining the magnitude of plot-level Dixie Fire RdNBR values. To understand the trajectory of the plots over time, researchers compared forest structural metrics after the second and third fires to average estimates of pre-settlement natural range of variation (NRV) for tree density (60 to 328 trees ha−1) and basal area (21 to 54 m2 ha−1), and estimates of historical average coarse woody debris from reference studies (1–1000-h fuels; 17.7 Mg ha−1).

Statistical analyses identified snag basal area as the most important predictor of plot-level RdNBR fire severity in the third successive fire (Dixie Fire), followed by CWD loads, elevation, slope, and energy release component (ERC). Dixie Fire severity was highest on average in plots with a snag basal area greater than 11.62 m2 ha-1. Further analyses were

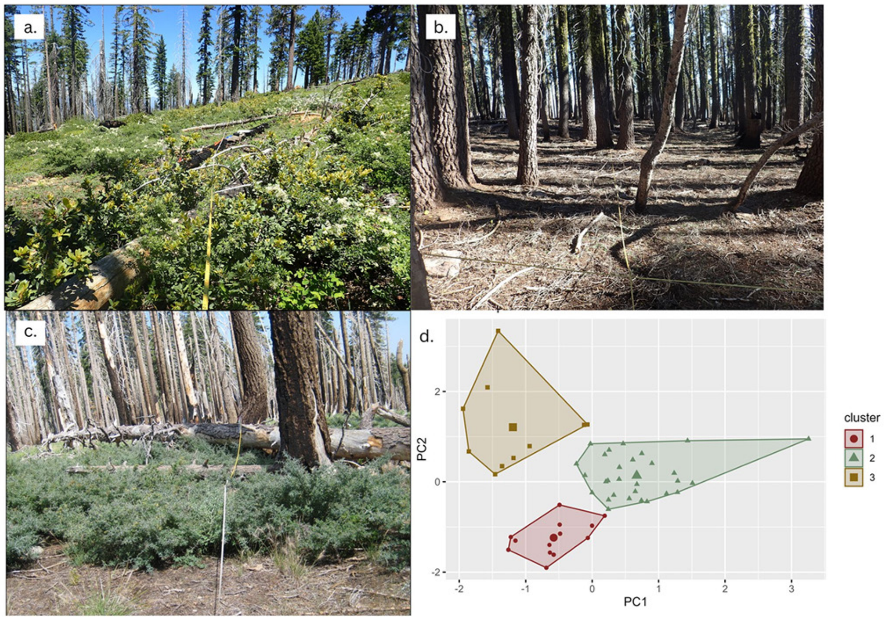

Fig. 4 Plot photos representing structural conditions after the second fire (measurements taken in 2017 or 2018) across K-means clusters (**a**–**c**), where cluster 1 (**a**) represents plots with relatively high shrub cover, cluster 2 (**b**) represents plots with relatively high live tree density and basal area, and cluster 3 (**c**) represents plots with relatively high coarse woody debris and snag basal area. K-means clusters (*n* = 52; **d**) with principal component analysis (PCA) reduction, where axes represent principal component 1 (PC1) and principal component 2 (PC2) scores, indicating the position of each plot in the PCA reduced dimensional space. Photo credit: USDA Forest Service, 2017 and 2018

performed to cluster the plots by structural characteristics after the second fire, yielding three distinct clusters with different median structural metrics and fire severities (Fig. 4). Cluster 1 was associated with high shrub cover (48.8%), cluster 2 with high live basal area and live tree density (38.3 m2 ha−1 and 175.0 trees ha−1), and cluster 3 with high CWD and snag basal area (120.3 Mg ha−1 and 61.5 m2 ha−1). Cluster 3 (high dead biomass) was associated with the highest plot-level Dixie Fire severity, while cluster 1 (high shrub cover) had the lowest. After the third fire, median live tree density and basal area decreased across all clusters compared to the second fire. In cluster 2 particularly, over half the plots fell below the NRV for live basal area and tree density by the third fire. Even so, many plots in each cluster still exceeded historical NRV estimates for live tree density. The third fire decreased CWD across all three clusters, increasing the proportion of plots falling within the NRV compared to the second fire. Notably, 67% of the cluster 3 plots retained CWD greater than the NRV even after the third successive fire.

In forests that have historically experienced frequent fire, reintroducing any amount of low-to-moderate severity fire is often viewed as restorative, even without the integration of structural restoration (i.e. mechanical treatment). This study suggests that the legacy of fire exclusion may persist even after two low-to-moderate severity fires, producing conditions that continue to support high live biomass and where dead wood, such as snags and heavy fuels, may prime forests to burn at higher severity in a future fire. This phenomenon departs from the assumption that successive reburns will uniformly produce a stabilizing feedback of lower severity fire. In reality, three or more successive burns combined with long-term efforts to return forests to within their historical NRV may be needed to achieve forest restoration, future resilience, and fuel management objectives.

Additional Information

This brief is based on the following article:
Jasperse, Lindsey and Brandon M. Collins et al. 2025. Drivers of fire severity in repeat fires: implications for mixed-conifer forests in the Sierra Nevada, California. Fire Ecology 21, 46. https://doi.org/10.1186/s42408-025-00378-z

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