Ashes to asters: the short-term impact of the Calwood Fire on plant communities

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SECTION 1, Abstract

The Calwood Fire changed Heil Valley Ranch for decades to centuries to come, in the matter of days. Plant communities at Heil have been highly studied over the last decade, making it a critical learning lab for understanding post-fire recovery. We revisited 21 previously established sites to examine how pre-fire communities compared to post-fire communities, and how fire severity and restoration treatment history affected these comparisons. We found that non-native species cover did not increase but there was a shift in species pre- to post-fire, with an increase in forbs and a decrease in shrubs and graminoids. Our findings should assist managers in mitigating non-native species invasion where needed and better plan for long term post-fire recovery efforts.

SECTION 2, Introduction, Objectives, Hypotheses, Anticipated Value, Literature Review

As climate continues to change, the frequency and severity of wildfires across the globe is increasing at an unprecedented rate (Pachauri et al. 2014). In 2020, >4 million ha (10 million ac) burned across the US including >240,000 ha (600,000 ac) in Colorado alone (NIFC.gov). As wildfires increasingly impact our ecosystems, managers aim to mitigate fire risk and reduce fire hazards. In many lower elevation, dry forest types these efforts can include fuels management strategies such as thinning, mastication, and prescribed fire, all done in the hopes of restoring ecologically-appropriate forest densities and fire regimes and reducing human values lost when wildfires do occur (Colorado State Forest Action Plan 2020). However, when extreme weather drives wildfire events, managers are often still left with charred landscapes and many questions about potential short- and long-term post-fire changes.

Wildfires can alter the successional trajectories of plant communities, with pre-fire species composition, as well as site factors such as fire severity and management history, playing key roles in shaping immediate post-disturbance outcomes (Johnstone et al. 2016). These communities, in turn, can set longer-term successional trajectories (Romme et al. 2011). However, the impact of changing disturbance regimes coupled with climate change has challenged our understanding of post-disturbance trajectories (Coop et al. 2020).

Many post-fire studies have been conducted across the wildfires that have burned in Colorado and across the west. One of the common limitations of this post-fire research is that pre-fire data are often unavailable to serve as a benchmark for evaluating post-fire change (but see Fornwalt and Kaufmann 2014). Some studies attempt to overcome this limitation by collecting data in unburned areas, but this approach requires an assumption that the unburned areas were comparable to the burned areas prior to burning (e.g.Stevens-Rumann and Fornwalt 2018,)). Other studies only focus on post-fire dynamics (e.g, Day et al. 2017, Dodge et al. 2019).

The Calwood Fire presents a unique opportunity to examine how plant communities change after wildfires due to the availability of multiple plant species datasets that were created for projects at Heil Valley Ranch in the past 10 years (Briggs and Fornwalt 2012; Briggs et al. 2017; Stevens-Rumann and Fornwalt 2018). Given the existing datasets we ask: a) How did plant richness (i.e., number of species at a site), cover, and composition change immediately post-fire? Are changes associated with site factors such as fire severity and management history?

b) How many pre-fire species were found immediately post-fire? How many new species? Do these numbers vary with site factors?

We hypothesized that the largest plant community change will be seen in those area that experienced high severity fire. Additionally, those sites with higher non-native species presence pre-fire will have high proportional increases in non-native species. This project will allow managers of Heil Ranch to identify non-native species of concern that may need more active removal in the early post-fire years and understand how these plant communities have changed as a result of the Calwood Fire allowing managers to make critical early-post fire management decisions such as what and where to seed.

Methods

This study leveraged 21 ponderosa pine (*Pinus ponderosa)*– dominated sites that were initially measured between 2011-2018 at Heil Valley Ranch and that subsequently burned in the 2020 Calwood Fire (Figure 1). We had an additional two untreated and two treated sites that we did not re-measure because they were outside the fire perimeter. Study sites were established to look at the effects of mechanical restoration treatments on plant communities, and consequently fell into two categories: 1) sites treated 5-9 years prior to the initial measurement (7 sites), and 2) previously untreated sites (14 sites). Precise plot relocation was difficult post-fire, as many of the identifying markers including small tin tree tags and wooden stakes were consumed during the fire. Coordinates and pre-fire plot pictures facilitated close matching of sites and most we felt confident in relocating to within 10m.

Vascular understory plant species and substrate data were collected using the same methodology both during the initial measurement period and during the post-Calwood measurement period (Briggs and Fornwalt 2012; Briggs et al. 2017; Stevens-Rumann and

Fornwalt 2018). Vascular understory plant species and substrate types (e.g., litter, bare ground, fine wood, coarse wood) were recorded at 100 evenly-spaced observation points along four transects, for a total of 400 observation points per site. Transects radiated from the site center in the cardinal directions. All additional species present within a 0.04 ha circular plot were also noted for species richness metrics. Unknown species were collected and identified later. Species were also classified later into functional groups (e.g., reflecting growth form, nativity) using multiple available references.

Additionally, we conducted overstory tree (>1.4 m tall) inventories in a 0.02ha fixed radius plot. Pre-fire only 7 plots followed similar methods while the remaining plots used a variable radius plot. Tree seedling inventories were conducted on the entire plot post-fire. Canopy cover was measured using a point intercept method along two transects post-fire and pre-fire on only seven sites. Burn severity was assessed at each site by determining percent overstory tree mortality within each plot.

Data were analyzed at the community level, the functional group level, and individual key species level. We used a repeated measure two-way analysis of variance to compare treatment and pre- to post-fire richness and cover analyses were done for functional groups and total cover and richness. All analyses were conducted in R (R Core Team 2021).

Results

The majority of our sites experienced high severity fire, regardless of treatment (13 out of 21 sites). Of the remaining 8 sites, a range of tree mortality was observed, from 0% tree mortality on 1 site, to 3-13% tree mortality by density on an 6 sites, to 56% tree mortality by density at the final site. Tree mortality by density or basal area did not differ between treated and untreated sites ($F<3.08$, $P>0.09$). Living post-fire canopy was highly correlated with burn severity ($R^2=0.31$, $P<0.01$) and treated sites lost less living canopy cover than untreated sites ($F=5.25$, $P=0.04$).

Tree seedling germinants were observed on 12 of the 21 sites. Tree seedling density did not differ between treated and untreated sites ($F=0.27$, $P=0.61$). Burn severity did predict early post-fire tree seedling density, with few to no seedlings in high mortality sites ($R^2=0.20$, $P=0.04$).

Substrate cover varied substantially pre- to post-fire, with mean litter cover pre-fire at 90% and 88% for untreated and treated plots, respectively. Conversely, litter cover post-fire was 57% and 37% for the same plots ($P=0.03$). By contrast bare ground cover increased from 12% on untreated sites and 15% on treated sites pre-fire to 43% for control sites and 67% for treated sites ($P=0.01$).

Understory plant cover was highly variable both pre- and post-fire (Figure 2). Total plant cover was higher on treated sites ($F=6.1$, $P<0.01$) but did not vary pre- to post-fire ($F<1.0$, $P>0.10$). Additionally, total plant cover response did have a significant interaction effect between treatment and pre- to post-fire, meaning that while treated sites had higher cover than control sites pre-fire, their cover did not differ post-fire. Total mean plant cover was 13% in untreated sites pre-fire and was 21% post-fire, while treated sites had a mean total plant cover of 37% in treated areas pre-fire compared to 21% post-fire.

Forbs were the most dominant growth form and did not vary significantly, either by treatment or by measurement period ($F<3.6$, $P>0.06$. Similarly, no factors were significantly related to shrub cover ($F<1.2$, $P>0.27$). Graminoids did vary between sampling periods, and had a significant interaction ($F>7.6$, $P<0.008$). Graminoids were highest on treated areas pre-fire but cover decreased to similar levels in both treated and control areas post-fire.

Total richness did not vary pre- to post-fire (F=0.39, P=0.53), however some growth forms did experience significant changes in richness (Figure 3). Forb species richness significantly increased post-fire (F=9.78, P=0.003), while graminoid species richness declined (F=9.30, P=0.004) as did shrub species richness (F=9.54, P=0.004). Treatment had no impact on richness of these growth forms either pre or post-fire (F<0.9, P>0.1). As such there were slight shifts in species compositions even though the total richness was unchanged. Generally, one-year post-fire these sites had increased dominance of forb species with a smaller component of the community being comprised of grasses and shrubs. The majority (~90% of species) found pre-fire were found post-fire within each site. Several grass and shrub species were not seen post-fire, while multiple forbs not previously seen were observed post-fire.

Native species cover had a significant interaction effect (F=5.27, P=0.03), where the highest native species cover was on treated areas pre-fire, however control sites, post-fire had the second most abundant cover (Figure 4). Non-native or exotic species cover was significantly influenced by treatment (F=9.54, P=0.004), but was not significantly impacted by wildfire (F=0.24, P=0.42). Non-native cover most dominant on treated sites pre and post-fire, with the fire resulting in a slight, yet insignificant, mean decline in non-native species from 16% to 14.5% cover. Untreated sites had a mean of 2.8% non-native cover pre-fire and 7.5% cover post-fire, which were not significantly different. Presence of *Artemisia ludoviciana, Verbascum thapsus, Bromus tectorum,* and *Carduus nutans* was consistent pre-fire to post-fire, and found on the majority of sites. However, *Artemisia ludoviciana* and *Verbascum thapsus* had less than one percent mean cover and *Bromus tectorum* only had a mean cover of 1.5% on untreated sites and 5.2% cover post-fire, which was not higher than pre-fire mean cover. *Carduus nutans* was present on 11 of the 21 sites and *Cirsium arvense* was present on 8 of the 21 sites never exceeding 1% cover.

Discussion and Conclusion

This study is one of the few to examine pre to post-fire plant communities. Multiple studies have examined plant communities post-fire (e.g. Day et al. 2017, Dodge et al. 2019), even multiple time steps post-fire, however rarely do fires occur where pre-fire data has been collected (Fornwalt and Kauffman et al. 2014). Here we saw consistency in pre to post-fire vegetation communities, and a decline in cover and some transitions in species dominance. Whether sites experienced pre-fire treatments had little impact on tree survival and post-fire plant cover. The Calwood Fire burned in a high wind and low fuel moisture conditions that resulted in generally high severity fire throughout much of the burn perimeter (inciweb.com last accessed January 1, 2022). This does not address questions of treatment effectiveness but rather an artifact of the location of our pre-fire plots that did burn, especially in this fast moving fire.

Substrate changed from predominantly litter and duff cover to bare ground and rock exposure (Figure 4). Surprisingly, total plant cover did not change between untreated sites pre to post-fire, but did decline in treated sites. This change in cover was predominantly driven by a decrease in graminoid cover, while forb cover either remained the same or in many cases increased post-fire and little change was detected in shrub cover. Vegetation cover was higher on these sites in Boulder than other studies that examined immediate post-fire vegetation cover, such as Dodge et al. (2019) in Oregon who found less than 10% cover on average in both treated and untreated forests burned at low and high severity. Fornwalt and Kauffman (2014) also found slightly lower mean plant cover the year following the Hayman Fire, though it rebounded to mean cover values observed here. Similar to Fornwalt et al. (2010) we don’t see high dominance in exotic species and presence of exotic species was consistent pre to post-fire. Plant communities did shift to higher dominance of forb species and less representation of shrubs and grass species similar to a study in Arizona that showed differences in plant communities early in the post-fire period (Shive et al. 2013). This is likely because Shive et al. (2013) had larger representation of varying burn severities in both treated and untreated sites, compared to our sites which may have shown more variability in plant communities compared to our largely high severity sites.

We were unable to answer one of our originally hypothesized questions: “for species found immediately post-fire, what is the role of post-fire regeneration mechanisms?” during data collection identifying this across most species was impeding progress to complete all 21 site remeasurements. We would like to revisit the regeneration mechanism data collected on a subset of sites in the future to continue to explore these questions of regeneration mechanisms in the early post-fire time period.

Overall this study demonstrates the resilience of understory plant communities even in the face of extreme fire weather and high severity fire. While overstory characteristics change precipitously, with high mortality in many of our sites, understory plant community response and even ponderosa pine germinants were abundant. Numerous post-fire management considerations are warranted, however, from the perspective of plant communities, many are recovering similar if not in higher abundance than seen in other sites. Additionally, one year post-fire tree germinants offer hope for forest reestablishment at least at some sites. Additional post-fire data collection is needed to truly understand the trajectory of these recently burned stands but these early post-fire community responses bode well for long term vegetation response, even in the absence of trees.

Acknowledgement

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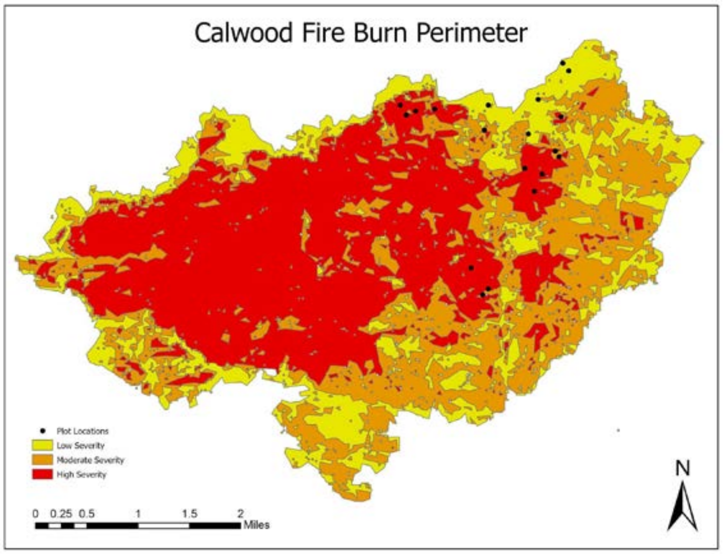

Figure 1. Pre-existing sites at Heil Valley Ranch that were measured between 2011-2018 and were remeasured in 2021 following the Calwood Fire.

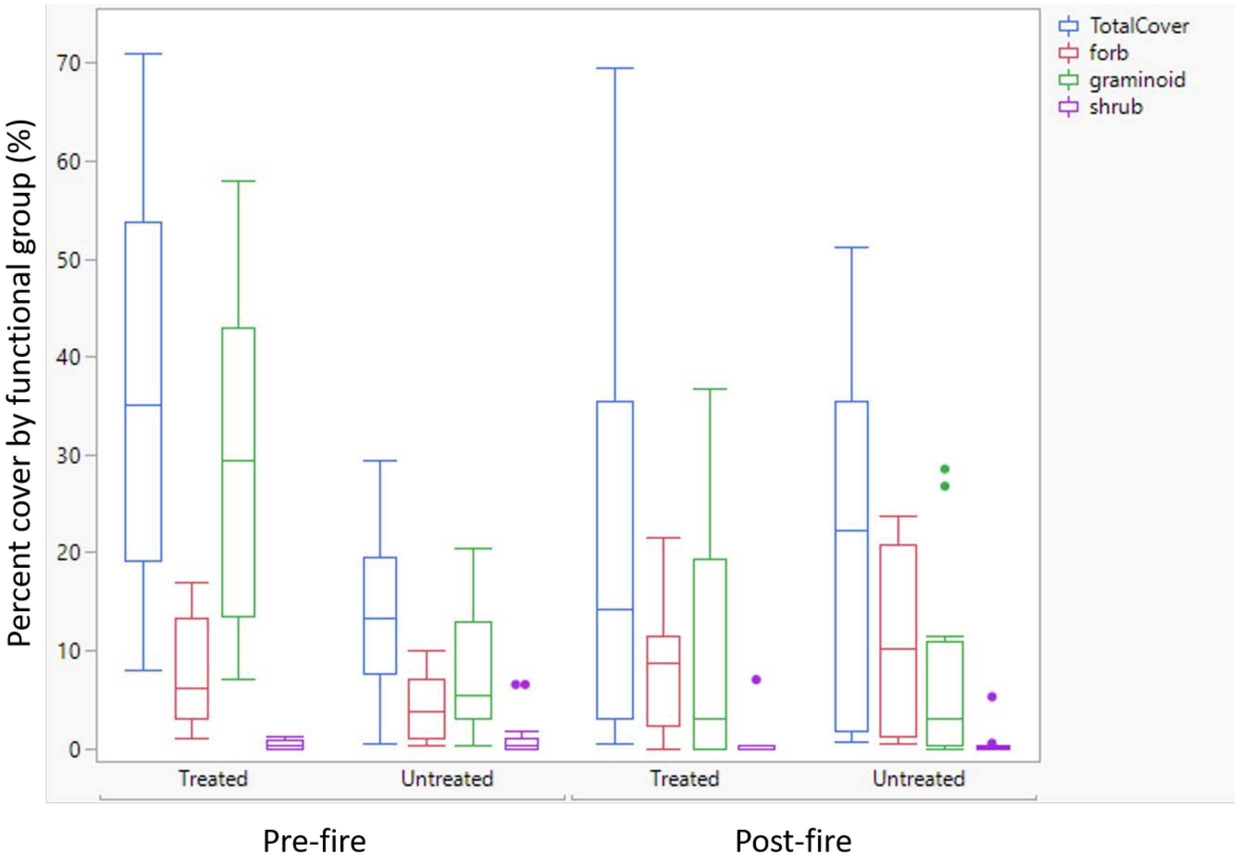

Figure 2: Total vegetation cover and vegetation cover by functional group in percent pre to post fire and by treatment.

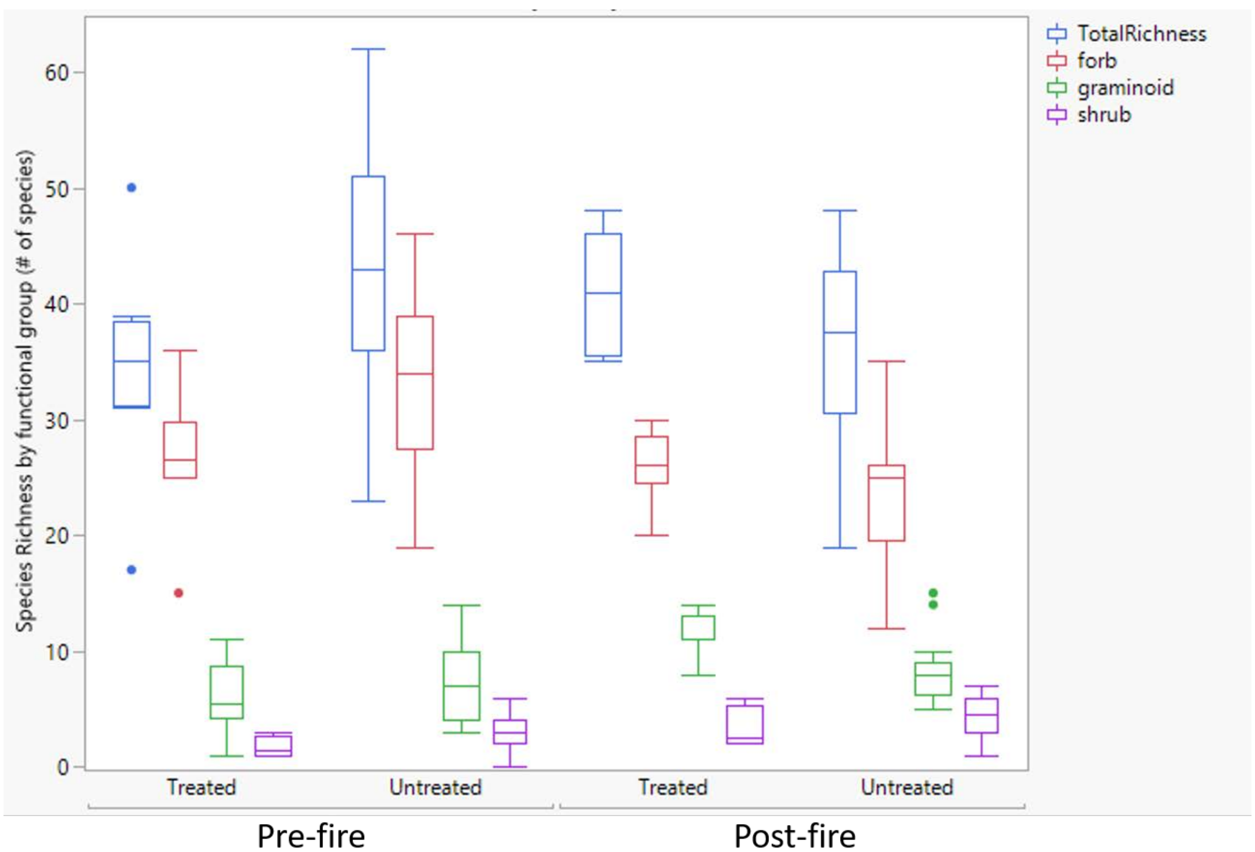

Figure 3: Total species richness and richness by functional group in percent pre to post fire and by treatment.

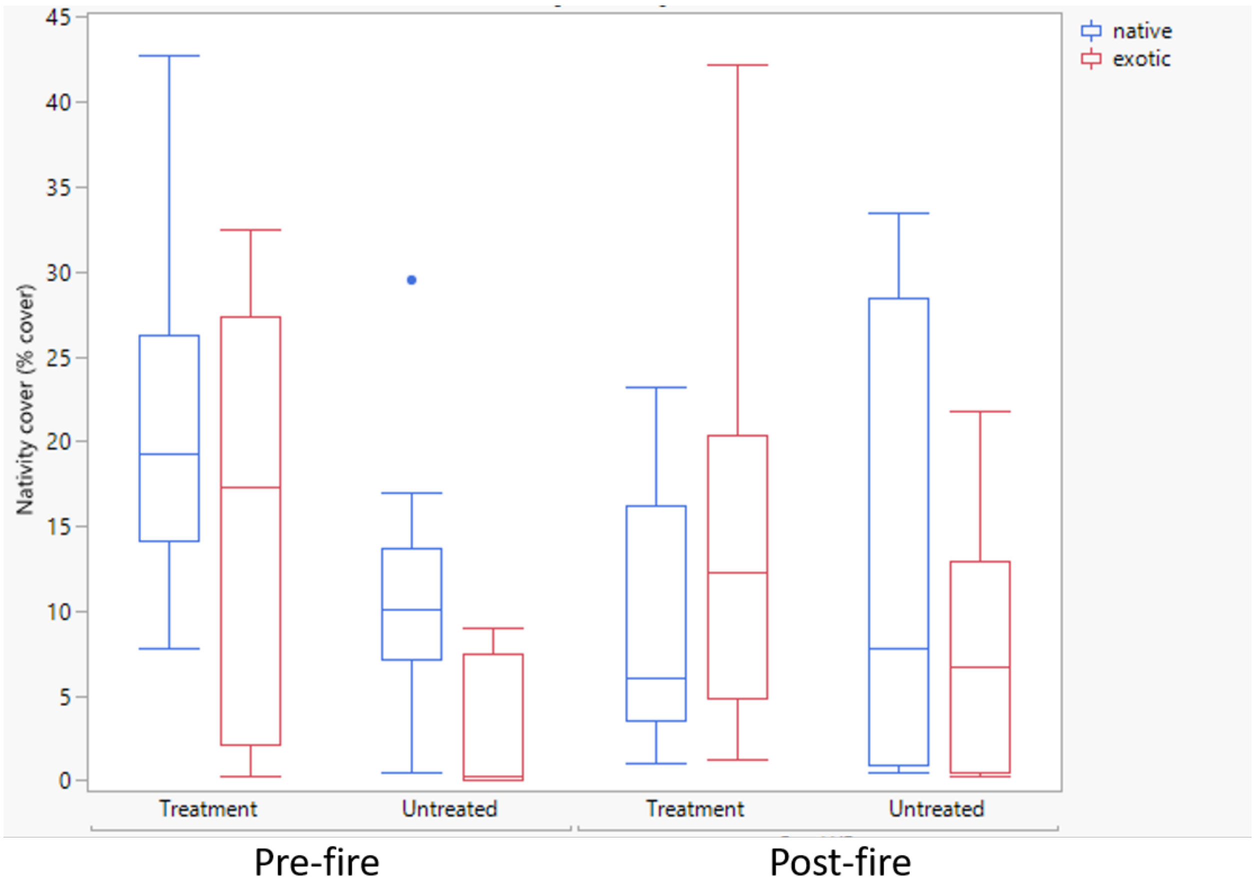

Figure 4: Percent cover by nativity (exotic versus native) pre- and post-fire and by treatment.

Figure 4: photos of sites pre to post-fire sites. Photos A and B demonstrate a treated site burned at high severity and Photos C and D demonstrate an untreated site burned at high severity