Interactions of the 2015 Cabin Fire and Recent Wildfires on the Sequoia National Forest

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Executive Summary

This report explores the interaction of the Cabin Fire with previous fires, with focus on the 2011 Lion Fire. The self-limiting potential of successive fires in the same general area is supported by plot data results.

This study explores the influences of two previous fires on 2015 Cabin Fire operations and vegetation burn severity. The Cabin Fire's northern extent overlapped with a portion of the southern extent of the 2011 Lion Fire. Light and patchy fuel conditions in this overlap area, due in part to the Lion Fire's effects, allowed the Cabin Fire Incident Command Team (ICT) to more extensively use monitoring tactics on this portion of the fire and to focus suppression actions elsewhere. Firefighters used the reduced fuels of the 2006 Maggie and 2011 Lion Fires as containment tools to hold or slow the spread of the Cabin Fire's western and northern flanks and stop the fire before it reached the next drainage system which contained private property.

Both field and satellite data were used in this study to examine the potential effects of the Lion Fire area on the Cabin Fire's severity and spread patterns. Burn severity data were recorded in August 2015 in 15m-diameter Composite Burn Index (CBI) plots located in a grid pattern both in and outside of the Cabin and Lion Fire overlap zone. The focus of CBI methodology was to 'answer how ecologically significant the consequences of a given fire are' (Key and Benson 2006). The goal was to identify differences in fire effects between areas that had *and* had not burned previously. Weather data patterns were considered during analysis. Results were analyzed graphically and summarized below. The self-limiting potential of successive fires within the same geographic area over a relatively short time span is supported by plot data results.

Results Summary

- The field severity data demonstrates a case where understory, overstory, and combined burn severity were generally lower in the areas of the Cabin Fire which overlapped the Lion Fire, when compared to nearby areas in the Cabin Fire that had not recently burned.
- Field data showed a mild trend of lower Cabin Fire severity in areas where the Lion Fire had burned with higher severity, and vice versa.
- The rapid slowing of fire spread on the Cabin Fire's northern flank in mid-August, as it burned into the Lion Fire footprint, cannot be attributed to milder weather conditions. This slowing spread was likely the result of some diminished fuel loading from the previous fire. Fire danger indices, reflective of weather patterns, chronicled an increasing potential for extreme fire behavior during the weeks that the Cabin Fire progressed, including days it burned within the Lion Fire footprint.
- The overlap area was deemed too small for effective geospatial analysis of trends in remotely-sensed data. The analysis is presented in Appendix II.

Purpose

The purpose of this study was to explore the influences that the 2011 Lion and 2006 Maggie Fire areas had on the 2015 Cabin Fire, with a focus on (a) use of fire effects as post-fire indicators of fire intensity at different locations, and (b) operational tactics that utilized recent fire areas. Field and remote sensing data reflective of fire effects, as well as first-hand accounts, were used to compare burn severity in areas of the Cabin Fire with no recorded fire history (95-year period of record) with those areas that had also burned in the Lion fire. Similar to the work completed by Collins et al. (2009) in Yosemite National Park's Illilouette Creek Basin (within 100 miles north of the Cabin Fire), this report explores whether fire as a natural process is self-limiting, meaning that recurring wildfires over time (the fire regime) ultimately constrain the spatial extent, and if previous fires lessen the effects of subsequent wildfires. Ewell et al.'s (2012) study of the 2011 Lion Fire interactions with previous fires found some similar trends.

Background

Fire Regime Patterns

Fires in upper montane forests in the Sierra Nevada "…are usually of low intensity and spread slowly through the landscape except under extreme weather conditions. Natural fuel breaks such as rock outcrops and moist meadows prevent large scale fires from occurring. . ." (van Wagtendonk and Fites-Kaufman 2006). Skinner and Chang (1996) reported that fire return intervals as determined by several studies in upper montane forests ranged from 11 to 69 years. Communities and forest visitors are sometimes impacted by smoke and trail closures during fires. Compared to single objective suppression strategies, the ecological benefit of meeting multiple objectives with incident management increases forest resiliency and has lasting spatial and temporal effects including: lowering subsequent wildfires' resistance to control (less fuels) and costs, lower future risk to communities, smoke production and ecological impacts.

Since the 1990s, increased occurrence of warmer, drier springs coupled with a growing frequency of high- to extreme- fire weather have exacerbated fire activity (Westerling et al. 2006, Keeley and Syphard 2015). As a result wildfire occurrence, size, and annual area burned has increased substantially (Miller et al. 2009). Additionally deviations from the natural patterns of known fire severity have been observed in modern versus historic fires, namely a lack of low and moderate severity fire occurrence (Mallek et al. 2013). However, in areas of the Sierra Nevada, when incident management includes strategies focuses on natural resource objectives, severities have been achieved that optimize fuel reduction and the restoration of natural fire and vegetation patterns (Meyer 2015).

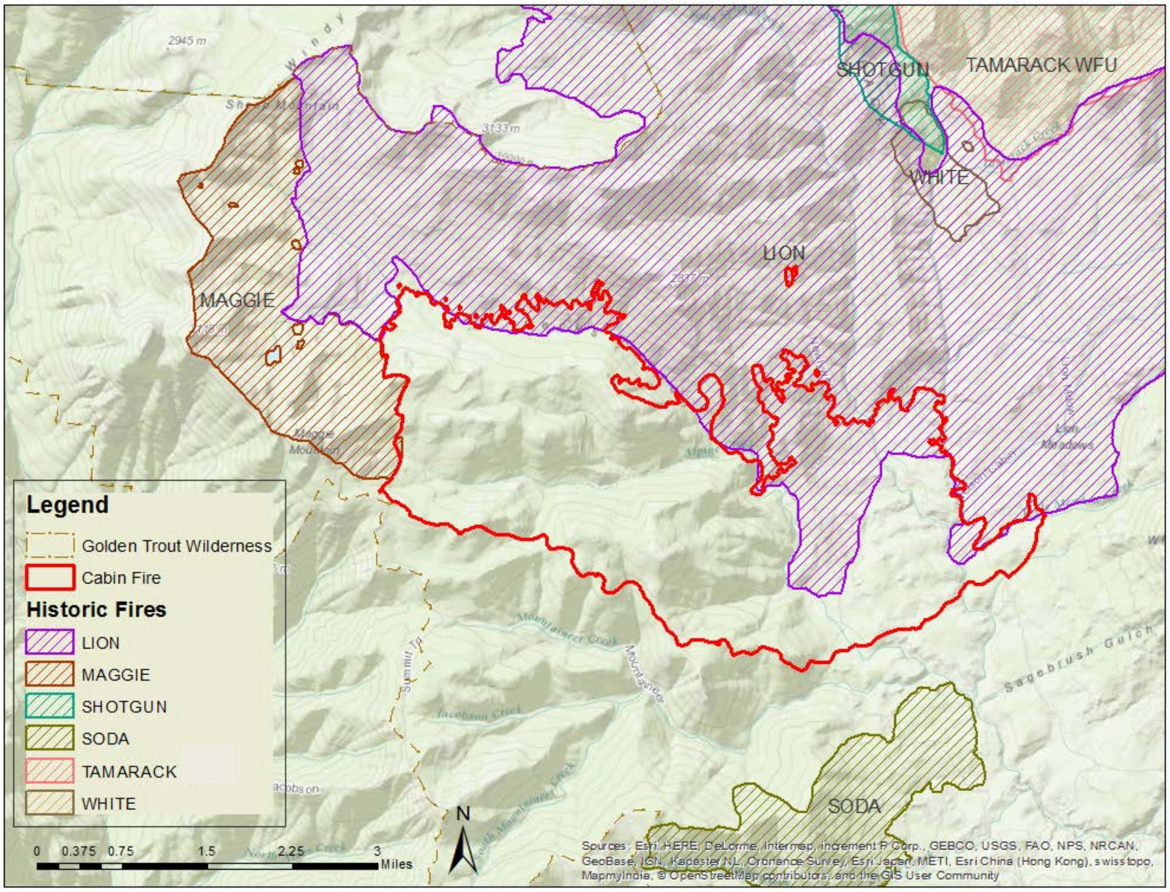


Figure 1. Recent fires in the vicinity of the Cabin Fire.

Weather Patterns

Like most of California, the Southern Sierra Nevada has a Mediterranean climate with warm, dry summers and cool, wet winters. The Cabin Fire burned in the Kern River drainage, which is bounded by the San Joaquin Valley to the west and the Mohave Desert to the east. While the weather influencing the drainage generally moves from west to east, the proximity of the desert plays a major role in drying fuels, which has the potential of increasing fire behavior. Light, dry winds typically blow from the desert through the Kern River drainage at night drying live vegetation and dead fuels. During fire season, strong daytime canyon winds in the lower north and south forks of the Kern River are created by a thermal low that develops in the desert during afternoons. The canyon winds also affect inversion layers and smoke dispersal.

2015 Cabin Fire

The Cabin Fire was lightning-ignited on July 19th and burned within the Golden Trout Wilderness of the Sequoia National Forest. During the first two weeks the fire grew to over 2,600 acres. By August 9th, the fire was almost 6,000 acres, and by the end of September, fire spread ceased at about 7,000 acres (Figure 2). The Cabin Fire burned into approximately 1,200 acres of the 2011 Lion Fire area, and the remaining burned acres had no known fire history (since about 1908).

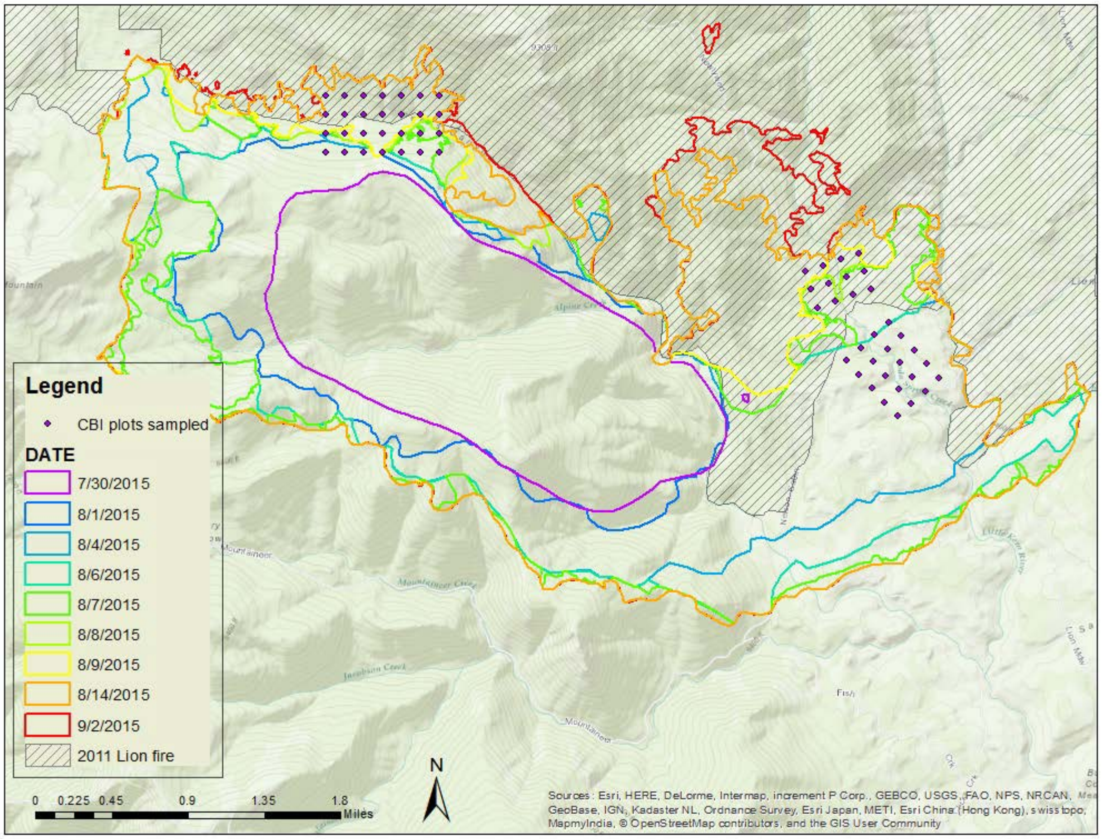


Figure 2. Progression of the Cabin Fire.

The Cabin Fire burned in mixed conifer timber and litter fuels as well as shrubs. Areas within the Cabin Fire perimeter contained meadows, riparian corridors, and exposed rocky ridges, which often served as barriers to fire spread or were used in backfiring and holding operations. Elevations ranged from 6,200 to 9,400 feet, and local topography includes steep river canyons and ridges in the vicinity of Alpine Creek and Peck's Canyon, as well as flatter, meadow areas such as Lion and Table Meadows. The fire was bounded on the West by the Maggie fire and on the North and East by the Lion Fire. Recent fires in the area also include the 2001 White, 2006 Tamarack, 2009 Shotgun and 2014 Soda Fires (Figure 1), all with large acreage proportions on the Sequoia NF.

Crews were able to contain the Cabin Fire's west flank by using the reduced fuel zone and previous containment lines of the 2006 Maggie fire area in combination with the naturally sparse fuels along this ridge. The 2006 Maggie fire burned 2,100 acres within the western edge of the Golden Trout Wilderness in red fir and mixed conifer forest types. The North Fork of the Middle Fork of the Tule River, a steep drainage west of the Maggie fire and southwest of the Cabin Fire, includes private property accessible by backcountry trails or helicopter. Considering Cabin Fire behavior up to this point and that typical of other fires on this landscape, there was substantial risk of fire progressing into this drainage and the North Fork of the Tule River's Middle Fork, where gaining control of the fire and protecting private property would have been difficult and costly.

During the last few days of July and the first days of August, hotshot crews were flown into the Peck's Cabin area, and built fireline along the eastern edge of the Maggie Fire, connecting the containment line into a creek and meadow area near Peck's Cabin on the north end, and into rocky ridges on the south end. A helitorch was used to assist in burnout operations along this fireline which largely used the edge of the Maggie Fire. Decreased fuel loading in the Maggie Fire (Figure 3) area enabled crews increased access, visibility to look for any spot fires and hazards across the fireline during burnouts, and enhanced the function of the new fireline. The western edge of the Cabin Fire was successfully contained, and prevented the Cabin Fire from reaching private property in the drainage below by firefighters using the 2006 Maggie Fire.

Figure 3. Photos from the western edge of the Cabin Fire adjacent to Maggie Fire. Maggie Fire is on left and Cabin Fire area is on right.

During the Cabin Fire, firing operations were synchronized with smoke management forecasts that had predicted favorable conditions for smoke dispersal. It was expected that consumption and smoke emission amounts where the Cabin Fire burned in the reduced fuel zone within the Lion Fire footprint were lower than when it burned areas with no recent fire activity. The wide spread reduction of surface and ground fuels from the Cabin Fire, as well as the occurrence of the high severity patches where crown fuels have been eliminated, are expected to aid in reducing the probability of larger, higher severity wildfires in the near future. The tree density reduction caused by the Cabin Fire should reduce stand susceptibility to disease and competition induced mortality in the future, leading to a healthier, more fire resilient forest stand and landscape.

Learning from and Understanding Burn Severity

With the ongoing trend of increasing wildland fire activity in the Sierra Nevada, understanding the conditions that drive and hinder wildland fire are crucial to improving tactics to meet present day and future needs of fire management. Multiple studies describe broad trends in how topography, vegetation, and weather can exert important controls on *burn severity*, or the magnitude of ecological change caused by fire, in the Sierra Nevada and the western United States. Burn severity primarily reflects the alteration of soil, vegetation, and dead fuels prior to the fire, and can be measured using field plots or multi-spectral imagery, such as that acquired by the LANDSAT satellite programs. Dillon et al. (2011) found that across many ecoregions climate and topography alone consistently predicted the occurrence of high burn severity with 68-84% accuracy. Southern and western aspects, for example, have been associated with higher burn severity, which is likely due to warmer and drier conditions on those slopes (Taylor and Skinner, 1998; Dillon et al., 2011). Vegetation patterns, however, can serve an important role as fuel breaks.

Kobziar and McBride (2006) found that riparian cover effectively restricted the spread of backing fire through two drainages, among all levels of burn severity, in the Plumas National Forest in the northern Sierras. It is worth noting, however, that topographic characteristics can be correlated with other variables that affect fire behavior, such as vegetation patterns and fuels, and have a strong role in local weather patterns (Agee 1993, Holden et al. 2009, Lydersen and North 2012).

Previous fires can also limit subsequent fires. Analyses of effects of wildland fires on subsequent fire severity has found time since burn to be an important control of subsequent fire severity, while burn severity of the preceding fire was not (Collins et al. 2007, 2009). Other work in two separate geographic areas outside the Sierras also found that recent burns reduce burn severity of subsequent fire with a diminishing effect through time (Parks et al. 2014b). Many studies contend that in the Sierras fires managed for resource benefit objectives is likely the best option to achieve fuel reduction and ecosystem restoration goals (Miller et al. 2012, Mallek et al. 2013).

Remote sensing techniques used to identify patterns of burn severity in conifer forests have been extensively described over the past decade and include the Relative Differenced Normalized Burn Ratio (RdNBR) (Miller and Thode 2007, Parks et al. 2014a). The accuracy of RdNBR estimates rely on calibration to ground based data, which is most commonly conducted using the Composite Burn Index (CBI) (Key and Benson, 2004). CBI incorporates visually ranked degree of change in factors in discrete forest strata (e.g. substrates, herbs and low shrubs, tall shrubs and seedlings, intermediate and poll sized trees, big trees). In this report, the type of remotely-sensed severity data used was from the Rapid Assessment of Vegetation Condition after Wildfire (RAVG) project (RSAC) (Figure 4). RAVG data is processed soon after wildfires, and is based on RdNBR calibrated with CBI field data from several 2001-2006 fires.

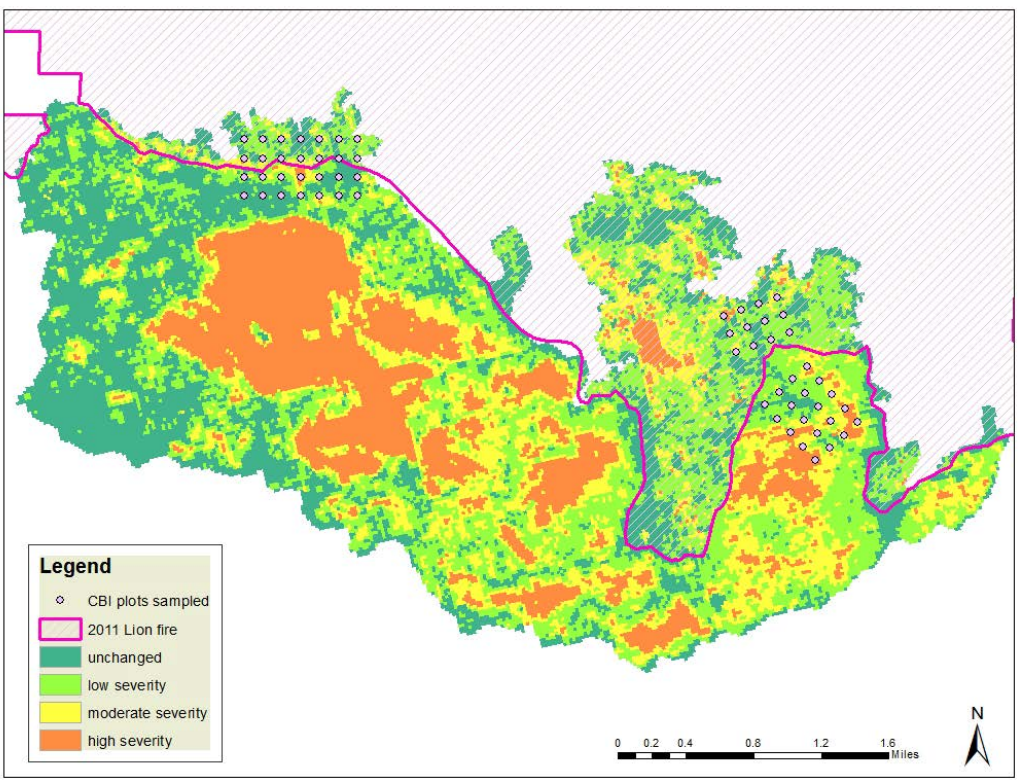


Figure 4. Map (immediate post fire) of the burn severity of the Cabin Fire (RAVG data) including where it overlapped the Lion Fire.

Several weaknesses of burn severity estimates should be considered when developing estimates. One weakness in estimating burn severity using the CBI method is there is often a lack of pre-fire fuels data, and therefore pre-fire conditions must be estimated post-fire when they have potentially been dramatically altered (Lentile 2007, Hudak et al. 2011, Hudak et al. 2013). In very sparse vegetation cover situations, burn severity can appear be drastically higher than in places where more biomass was consumed (Miller and Thode 2007).

Methods

In August of 2015, we took advantage of an opportunity to study effects of slope, aspect, and two recent wildfires on the immediate post-Cabin Fire severity. We conducted burn severity estimates using the ground-based CBI plot method (Key and Benson 2006) in two drainages, with plots in settings that burned in both fires, or in the Cabin Fire only. We also gathered pictures and information from fire managers on the interaction of the Cabin Fire with the Maggie Fire.

Plot data was collected on the fire severity of various strata in 30m-diameter plots to 'derive index values that summarize general fire effects within an area, that is, the average burn condition on a plot,' according to Key and Benson (2006). A score of 0 to 3 was given for various factors in each of five strata: substrates; herbs, low shrubs and small trees; tall shrubs, and sapling trees; intermediate trees; and big trees. An overall (or composite) plot burn severity score was computed from the scores from these five strata. Photos and GPS waypoints were taken at each plot.

Due to the size of the fire (approximately 6 miles by 3 miles), the steep terrain, lack of roads and risk of falling trees, plots were not gathered across the entire fire area. Plot locations were assigned prior to field work by placing small grids in several drainages where the Cabin Fire burned into the Lion Fire in order to encompass areas burned only by the Cabin Fire as well as areas where the Cabin Fire reburned in the Lion Fire area (Figure 5). Our design attempted to balance the effects of slope and aspect on fire behavior. GPS coordinates were used during field work to navigate to grid intersections. Plot locations were not pre-stratified by severity so that the relative abundance of severity levels within the areas sampled could be detected.

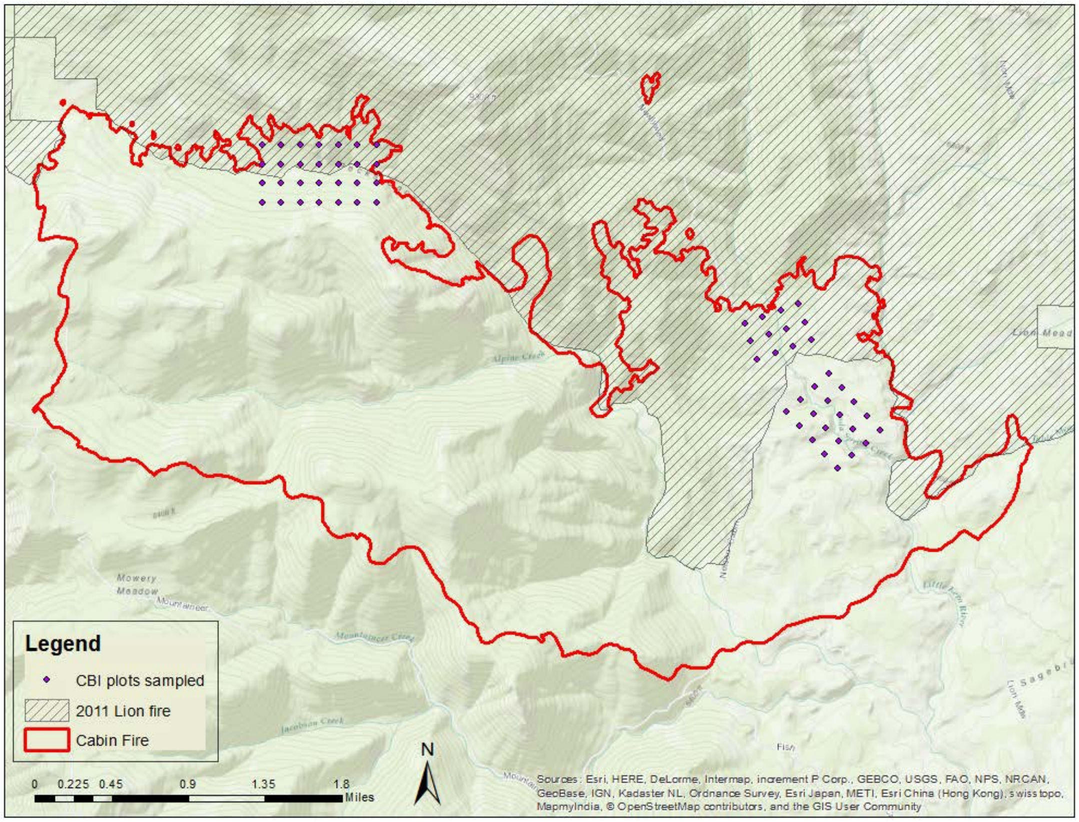


Figure 5. Map of 2015 Cabin Fire and 2011 Lion Fire and field plot locations.

Plot data were analyzed graphically to explore trends and relationships. Statistical analysis was not performed on field plot data due to pseudoreplication, which is an issue because the overlap area between the Cabin and Lion Fires was a relatively small area, and plots are similar in conditions and are not strong replicates. The severity scores from RAVG data were assigned to the plot data based on the severity value of the RAVG data at the plot location for comparison of plot data CBI versus the RAVG fire severity ratings of the Lion fire. Several GIS analyses were completed with remotely sensed fire severity data in order to explore the relationships of severity and fire interactions.

Three local Remote Automated Weather Stations (RAWS) were used to describe weather conditions in this report. The weather data were combined from three RAWS into a Special Interest Group (SIG) for which weather variables are discussed. Fire danger variables were created based on 20 years of data (1996-2015) for July 1st through Oct. 31st which exemplify the fire season (Fire Family Plus 2013).

Results and Discussion

Fire Weather Based on RAWS

Table 1. Names, elevations and locations of RAWS stations used in special interest group used for weather analysis.

Station Name	Elevation (ft)	Location in relation to Cabin Fire's origin
Peppermint	7385	13 miles south
Black Rock	8200	20 miles southeast

Fire danger variables which occurred during the Cabin Fire exemplified some high category fire danger conditions (Table 1). The 10-hour fuel moisture, which is correlated with the ease with which fires will spread and the intensity of fires, ranged as high as 10% and almost down to 2% during the latter days of fire growth of the Cabin (Figure 6). During the latter days of the Cabin Fire, the 10-hour fuel moistures dropped down below the 90^{th} and 97^{th} percentile, meaning that only 10% and 3% of days (in the dataset) had lower fuel moistures (fuels more ready to burn) during the past 20 years. Energy Release Component (ERC) is a number related to the available energy per unit area in the flaming front at the head of the fire (Schlobohm and Brain 2002) and is slow to react because it is heavily based on (slow-adjusting) 1000-hr fuel moistures, and not wind. ERC values during the Cabin Fire started out moderate, and then increased to high levels as the Cabin Fire growth slowed (Figure 7). The Burning Index (BI) is a number related to the contribution of fire behavior to the effort of containing a fire, and is quick to change based on wind. BI values were also moderate during the start of the Cabin Fire, and grew to roughly the 90^{th} percentile during the last days of fire growth (Figure 8).

The fire danger indices generally increased as the Cabin Fire progressed. The trending toward more active fire weather conditions as the Cabin Fire progressed likely played a role in fire spread rates during the first few days of August. However, despite increases in fire danger indices in August and early September, the growth of the Cabin Fire slowed. This slowing fire spread is not attributed to suppression actions on the north and northeast flanks of the fire, because none were taken. This slowing spread cannot be attributed to cooler, wetter weather, because that was far from the case. Reduction in fuels due to the 2011 Lion Fire, other terrain and low fuel areas in the Wilderness likely played a prominent role in the slowing of fire spread in August on the north and northeast flanks where the Lion Fire was situated. Where the Cabin wildfire began to out flank or go southeast of the Lion footprint is when suppression action occurred south of Lion Meadow.

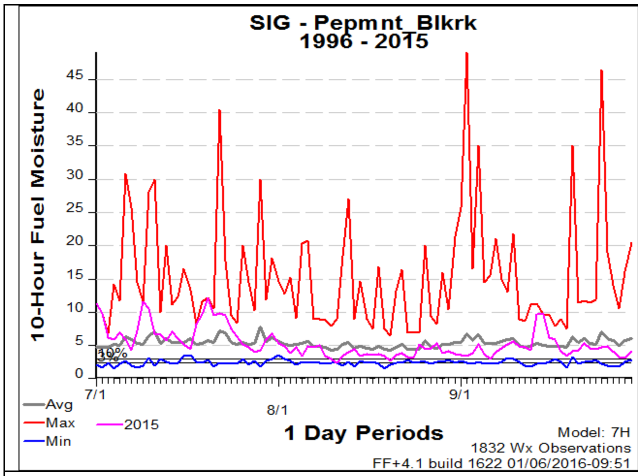


Figure 6. Average, maximum and minimum 10-hour fuel moistures for the 20-year period between 1996 and 2015. The red pink line shows 10-hour fuel moisture for July through September of 2015 for the Cabin SIG. Straight black lines are percentiles from the 20-year period.

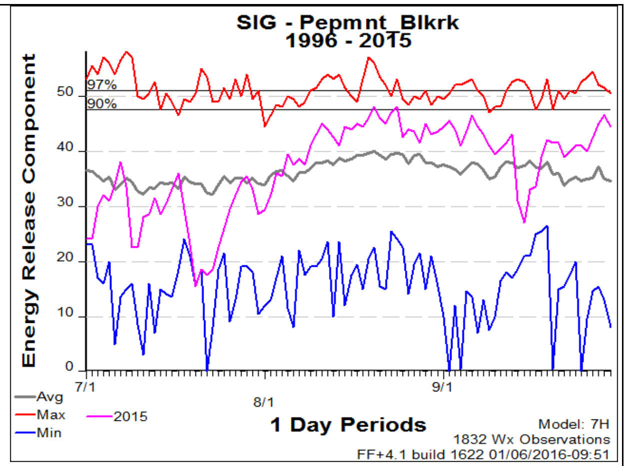


Figure 7. Average, maximum and minimum Energy Release Component for the 20-year period between 1996 and 2015. The red pink line shows Energy Release Component for July through September of 2015 for the Cabin SIG. Straight black lines are percentiles from the 20-year period.

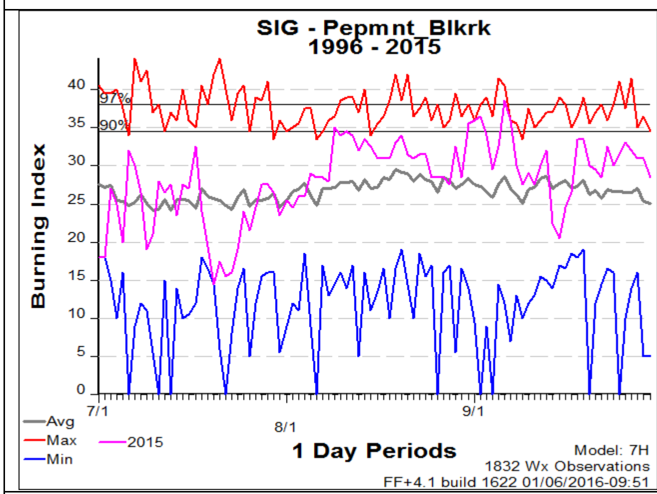


Figure 8. Average, maximum and minimum Burning Index for the 20-year period between 1996 and 2015. The red pink line shows Burning Index for July through September of 2015 for the Cabin SIG. Straight black lines are percentiles from the 20-year period.

Plot Data Analysis

Plot data show these key relationships:

- CBI scores from field plot data showed lower fire severity in the area where the Cabin Fire overlapped the Lion Fire, than the part of the Cabin Fire in which the Lion Fire did not burn.
- Lower fire severity was found in the Cabin Fire in areas where the Lion Fire burned with higher severity. Higher severity occurred in parts of the Cabin Fire where the Lion fire burned with low severity or did not burn.
- Once overstory trees have been thinned and/or smaller trees have been removed by fire, fire effects experienced by the tree stratum in subsequent fires is lower.
- There was no relationship between Cabin Fire CBI field data and either slope or aspect. Red fir had slightly lower severity than mixed conifer. None of these results showed strong relationships and so are presented in Appendix II.
- Data suggest that lower ground fuels existed in areas of the Cabin Fire where the Lion Fire had previously burned.

Basic analyses of the plot data showed that understory, overstory, and combined CBI values from plot data were lower in the overlap area of the Cabin and Lion Fires than in the area where only the Cabin Fire burned (Figure 9). On a scale of 0 to 3 with 3 meaning highest severity, understory CBI values were higher than overstory values, and this trend was more apparent in the overlap area. In the Cabin Fire only area, the understory CBI scores were about 2, and the overstory CBI scores were just above 1.5. The mean combined CBI for plots in the Cabin Fire only was 1.9 and the mean combined CBI for plots in the overlap was 1.1, which is a difference of one standard deviation for the combined CBI data (0.8). The overstory CBI values showed more differences between the overlap and Cabin Fire only area than the understory. The mean overstory CBI in the area only burned by the Cabin Fire was higher (1.7) than overstory CBI in the area previously burned by the Lion Fire (0.6), a difference greater difference than one standard deviation (1.0). Note a difference of one or more standard deviations generally means a strong trend.

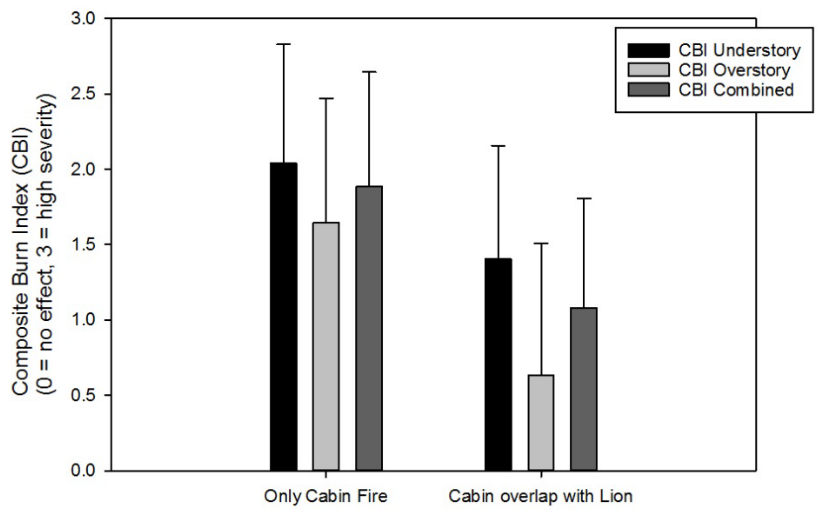


Figure 9. Bar chart with error bars showing standard deviation for Cabin Fire overstory, understory, and combined CBI values from plot data in the area of the Cabin Fire unaffected by the Lion Fire and also in the area where the Cabin Fire overlapped the Lion Fire.

Combined Cabin Fire CBI field data showed a mild relationship with Lion Fire CBI satellite data (Figure 10). Areas of the Cabin Fire which were not burned in the Lion fire had a mean combined CBI score of about 2.0, or moderate severity. Areas within the Lion Fire perimeter showing as unburned by the Lion fire in satellite data (meaning they were likely unburned islands within the main Lion fire area) had a mean CBI of 1.4 in the Cabin Fire according to plot data. Areas within low and moderate severity areas of the Lion Fire had mean combined CBI scores of 1.3 and 0.8, respectively. The Cabin Fire CBI in areas of moderate Lion Fire severity burned with lower severity in the Cabin Fire by more than a standard deviation. Only three plots sampled were located in areas of high Lion Fire severity, and these three plots had a mean CBI score of 0.6 (low severity). *This trend of lower fire severity in the Cabin Fire in areas where the Lion Fire burned with higher severity demonstrates the capacity of fire as an ecosystem process to be self-limiting, by the tendency of fires burning through recent fire scars to be of lower severity, and possibly extinguish.*

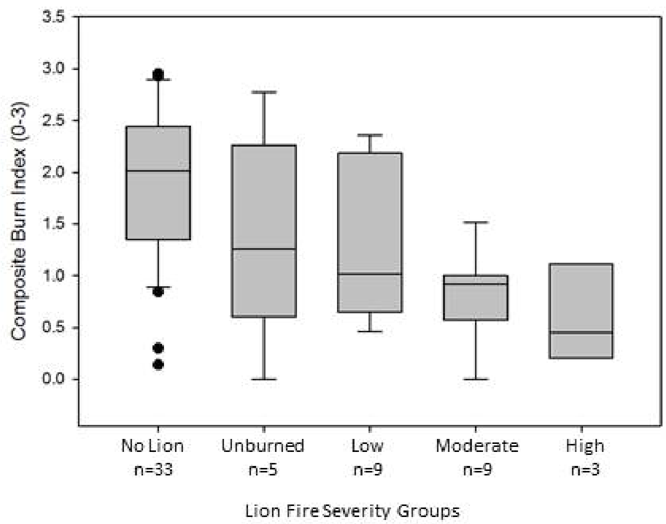


Figure 10. Boxplot of combined CBI scores of Cabin Fire field plots grouped by the Lion fire's satellite-data CBI category in which the Cabin Fire field plots were located. "No Lion" refers to plots located outside the perimeter of the Lion Fire. "Unburned" refers to plots within the Lion fire perimeter which were categorized as unburned in the Lion's satellite data.

A graphical analysis of the understory (Figure 11) and overstory (figure 12) CBI components show that the trend of lower severity in areas of higher Lion Fire severity is similar in both overstory and understory, but the **overstory** CBI scores were generally lower. Understory and overstory Cabin CBI from plot data in areas of moderate Lion Fire severity were 1.5 and 0.9, respectively, with the *overstory being lower than the understory* by more than a standard deviation. The overstory CBI scores for the three plots in the Cabin Fire which were located in high Lion Fire severity areas were 0 and 0.6, showing that the Cabin Fire had very little effect on overstory trees in areas where the Lion Fire burned with high severity. *These differences demonstrate that once overstory trees have been thinned and/or smaller trees have been removed by fire, subsequent fire effects experienced by the tree stratum is lower.*

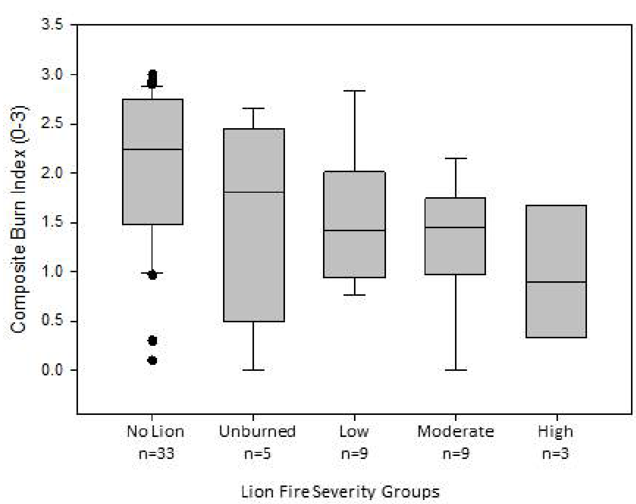


Figure11. Boxplot comparing understory Cabin CBI field scores grouped by the Lion Fire's RAVG CBI category in which the Cabin Fire field plots were located. "No Lion" refers to plots located outside the perimeter of the Lion Fire. "Unburned" refers to plots within the Lion fire perimeter which were previously categorized as unburned areas by the Lion RAVG data.

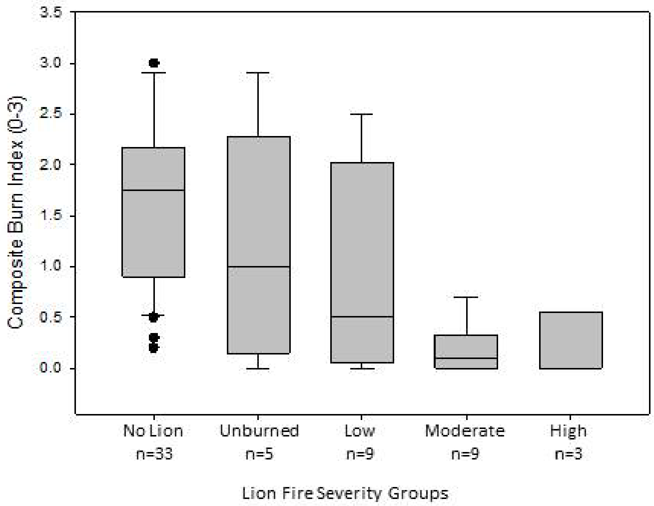


Figure 12. Boxplot of overstory CBI scores of Cabin field plots grouped by the Lion Fire's RAVG CBI category in which the Cabin field plots were located. "No Lion" refers to plots located outside the perimeter of the Lion Fire. "Unburned" refers to plots within the Lion fire perimeter which were categorized as unburned in the Lion RAVG data.

Although the Cabin Fire understory severity scores were moderate in areas of low and moderate Lion fire severity, it is likely that less litter and duff were available due to consumption of ground fuels during the Lion Fire. The CBI field protocol includes estimates of pre-fire litter and duff percent cover and depths. Note this data is not based on pre-fire sampling, but these field estimates can generalize basic trends. Mean estimates of pre-Cabin Fire litter and duff **cover** in areas where the Lion fire *had not burned* were estimated at 74% and 57%, respectively (std dev = 26 and 36), whereas in areas of the Cabin Fire where the Lion Fire *had burned* estimates of pre-fire litter and duff cover were 63% and 33%, respectively (std dev = 28 and 31). Mean estimates of pre-Cabin Fire litter **depth** in areas where the Lion Fire had not burned were 1.2 inches (std dev 0.8), but were 0.9 inches (std dev = 0.7) in areas where the Lion fire had previously burned. These differences are not greater than one standard deviation, yet they *suggest lower ground fuels probably existed in areas of the Cabin Fire where the Lion Fire had previously burned*.

Conclusions

Previous fires increased the incident management possibilities and probably limited the extent and severity of the Cabin Fire. This is evidenced by plot data, incident management strategies, and the effects of Cabin Fire within the Maggie and Lion Fire footprints. Had the Maggie Fire been suppressed and only burned several hundred acres, fire crews may not have been able to stop the Cabin Fire's western flank or prevent fire from entering riskier parts of the Tule River and threatening properties. Had the Lion Fire been suppressed or kept to minimal acres, incident managers may not have been willing to use a monitor strategy as the Cabin Fire spread north into the Golden Trout Wilderness and be limited by the Lion fire footprint. Had both the Maggie and Lion Fires not burned the acres they did, it is likely that more money would have been spent on suppressing the Cabin Fire, and more firefighters would have been put at risk in the rough and remote terrain of the Golden Trout Wilderness. More smoke impacts to surrounding airsheds may have occurred had the Lion and Maggie Fires not impacted the spatial extent and available fuels of the Cabin Fire.

Cabin Fire effects and management decisions will probably influence the fire effects and management options of future fires in the Golden Trout Wilderness on Forest Service and National Park Service lands. The widespread reduction of surface and ground fuels from the Cabin Fire, as well as the high severity patches where crown fuels have been eliminated, are expected to aid in reducing the probability of a large, high severity wildfire and lower smoke emissions in the Golden Trout Wilderness in the near future. The tree density reduction caused by the Cabin Fire should decrease stand susceptibility to disease and competition in the future, leading to a healthier, more fire-resilient forest stand. Fire management priorities which retain fire as an ecosystem process, and facilitation of safe, containable fire spread when and where risks are manageable, will foster a recovering fire regime made up of more easily manageable wildland fires and positive, heterogeneous ecological effects.

We feel that CBI methodology with a regular sampling design, such as the grids used in this study, could easily be replicated on other fires in the future which overlap past fire(s). A dataset with several fires spanning many years would have more statistical rigor and value. With a multi-fire dataset of CBI field data it may be possible to determine effects of vegetation type, topography, drought and moisture on severity as we were unable to do with a one-fire dataset. The growing amount of field data, reports, and investigations on this topic in the Central and Southern Sierra Nevada shows encouraging trends in land management evolution and lessons learned (Collins et al. 2007, Collins et al. 2009, Mallek et al. 2013, Miller et al. 2009, Fites-Kaufman et al. 2005, Vaillant 2009, Ewell et al. 2012, and Ewell et al. 2013).

References

Agee, James K. 1993. Fire ecology of Pacific northwest forests. Washington (DC): Island Press.

Collins, Brandon M., M. Kelly, J.W. van Wagtendonk, S.L. Stephens. 2007. Spatial patterns of large natural fires in Sierra Nevada wilderness areas. Landscape Ecology 22.4: 545-557.

Collins, Brandon M., J.D. Miller, A.E. Thode, M. Kelly, J.W. van Wagtendonk, S.L. Stephens. 2009. Interactions among wildland fires in a long-established Sierra Nevada natural fire area. Ecosystems 12.1: 114-128.

Dillon, Gregory K., Z.A. Holden, P. Morgan, M.A. Crimmons, E.K. Heyerdahl, C.H. Luce. 2011. Both topography and climate affected forest and woodland burn severity in two regions of the western US, 1984 to 2006. Ecosphere 2.12: art130.

Ewell, Carol, A. Reiner, and S. Williams. 2012. Wildfire Interactions of the 2011 Lion Fire and Recent Wildfires on the Sequoia National Forest and Sequoia National Park. URL: http://www.fs.fed.us/adaptivemanagement/reports/Lion_Wildfire_Interactions_Final.pdf

Ewell, Carol, D. Kerr. 2013. Fire Management Lessons Learned, Evolving Fire Management Programs, on the George Washington and Jefferson National Forests and the Sequoia National Forest and Giant Sequoia National Monument. Report to the USFS Washington Office and the Wildland Fire Lessons Learned Center. URL: http://www.wildfirelessons.net/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=c15e24f4-8277-439c-b82e-e93622acf7a4

FireFamilyPlus V 4.1 Februrary 2013. USDA Forest Service, Fire and Aviation Management, National Information Systems Group.

JoAnn Fites-Kaufman, E. Noonan, and D. Ramirez. 2005. Evaluation of Wildland Fire Use Fires on the Sequoia and Stanislaus National Forests in 2003: Effects in Relation to Historic Regimes and Resource Benefits. Adaptive Management Services Enterprise Team (AMSET), USDA Forest Service, Nevada City, Ca. URL: http://www.fs.fed.us/adaptivemanagement/reports/SQF_STF_WFU_report_final_updateJan2013.pdf

Holden Z.A., Morgan P., Evans J.S. 2009. A predictive model of burn severity based on 20-year satellite-inferred burn severity data in a large southwestern US wilderness area. For Ecol Manage 258:2399–406.

Hudak Andrew T., I. Rickert, P. Morgan, E. Strand, S.A. Lewis, P.R. Robichaud, C. Hoffman, Z.A. Holden. 2011. Review of fuel treatment effectiveness in forests and rangelands and a case study from the 2007 megafires in central, Idaho, USA. USDA Forest Service, Rocky Mountain Research Station RMRS-GTR-252. (Fort Collins, CO).

Hudak, Andrew T., R.D. Ottmar, B.E. Vihnanek, N.W. Brewer, A.S. Smith, P. Morgan. 2013. The relationship of post-fire white ash cover to surface fuel consumption. International Journal of Wildland Fire 22, 780–785.

Keeley, Jon E., and A. D. Syphard. Different fire–climate relationships on forested and non-forested landscapes in the Sierra Nevada ecoregion. International Journal of Wildland Fire 24.1 (2015): 27-36.

Key, Carl H., and N.C. Benson. 2006. Landscape assessment (LA). FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD, Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Kobziar, Leda N., and J.R. McBride. 2006. Wildfire burn patterns and riparian vegetation response along two northern Sierra Nevada streams. Forest Ecology and Management 222.1: 254-265.

Lentile, L.B, P. Morgan, A.T. Hudak, M.J. Bobbitt, S.A. Lewis, A.M.S. Smith, and P.R. Robichaud. 2007. Post-fire burn severity and vegetation response following eight large wildfires across the western United States. Fire Ecology 3(1): 91-108.

Lydersen, Jamie, and M. North 2012. Topographic variation in structure of mixed-Conifer forests under an active-fire regime. Ecosystems 15:1134–46.

Mallek, Chris, H. Safford, J. Viers, J. Miller. 2013. Modern departures in fire severity and area vary by forest type, Sierra Nevada and southern Cascades, California, USA. Ecosphere 4.12: art153.

Meyer, Marc D. 2015. Forest fire severity patterns of resource objective wildfires in the southern Sierra Nevada. Journal of Forestry 113.1: 49-56.

Miller, Jay D., and Andrea E. Thode. 2007. Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). Remote Sensing of Environment 109.1: 66-80.

Miller, Jay D., H.D. Safford, M. Crimmins, A.E. Thode. 2009. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. Ecosystems 12.1: 16-32.

Miller, Jay D., B.M. Collins, J.A. Lutz, S.L. Stephens, J.W. van Wagtendonk, D.A. Yasuda. 2012. Differences in wildfires among ecoregions and land management agencies in the Sierra Nevada region, California, USA. Ecosphere 3.9: art80.

Parks, Sean A., Gregory K. Dillon, and Carol Miller. 2014a. A new metric for quantifying burn severity: the Relativized Burn Ratio. Remote Sensing 6.3: 1827-1844.

Parks, Sean A., C. Miller, C.R. Nelson, and Z.A. Holden. 2014b. Previous fires moderate burn severity of subsequent wildland fires in two large western US wilderness areas. Ecosystems 17.1: 29-42.

Remote Sensing applications Center (RSAC), RAVG project.   Website: http://www.fs.fed.us/postfirevegcondition/whatis.shtml

Scholbohm, Paul and J. Brain. 2002. Gaining and understanding of the National Fire Danger Rating System. USDA and DOI, Publication of the National Wildfire Coordinating Group. PMS 932. 82pp.

Skinner, C.N., and C. Chang. 1996. Fire regimes, past and present. In Sierra Nevada Ecosystem Project: Final report to Congress, Vol. II, Chapter 38. University of California, Davis 1528 p.

Taylor, Alan H. and C.N. Skinner. 1998. Fire history and landscape dynamics in a late-successional reserve, Klamath Mountains, California, USA. Forest Ecology and Management 111:285-301.

van Wagtendonk, J. and J. Fites-Kaufman. 2006. Sierra Nevada Bioregion. In: Sugihara, N.G., J.W. van Wagtendonk, K.E. Shaffer, J. Fites-Kaufman, A.E. Thode. Eds. Fire in California's ecosystems. University of California Press, Berkeley and Los Angeles, CA.

Vaillant, Nicole. 2009. Characterizing fire severity patterns in three wildland fire use incidents in the southern Sierra Nevada. Report to the Sequoia National Forest. URL: http://www.fs.fed.us/adaptivemanagement/reports/fbat/SQF_WildlandFireUse_Report_2009_Vaillant.pdf

Westerling, Anthony L., H.G. Hidalgo, D.R. Cayan, T.W. Swetnam. 2006. Warming and earlier spring increase western US forest wildfire activity. Science 313.5789: 940-943

Appendix I. Photos

The following figures are photos from the field plots within the Cabin Fire. The number is the composite burn index (CBI) or combined severity score of 0 to 3 (unburned to high severity) based on field protocol.

Cabin Fire CBI = 0.75, in Lion footprint	CBI = 0.3, outside the Lion footprint
	

CBI = 1.26, in Lion	CBI = 1.5, no Lion
	

CBI = 2.25, in Lion	CBI = 2.4, no Lion
	

Appendix II. Results which did not show strong trends

Other Influencing Factors: slope, aspect, vegetation types, humidity

Other factors often associated with fire behavior and fire severity were assessed to find relationships explaining severity patterns on the Cabin Fire. There was no relationship between Cabin Fire CBI field data and either slope or aspect (Figure 13).

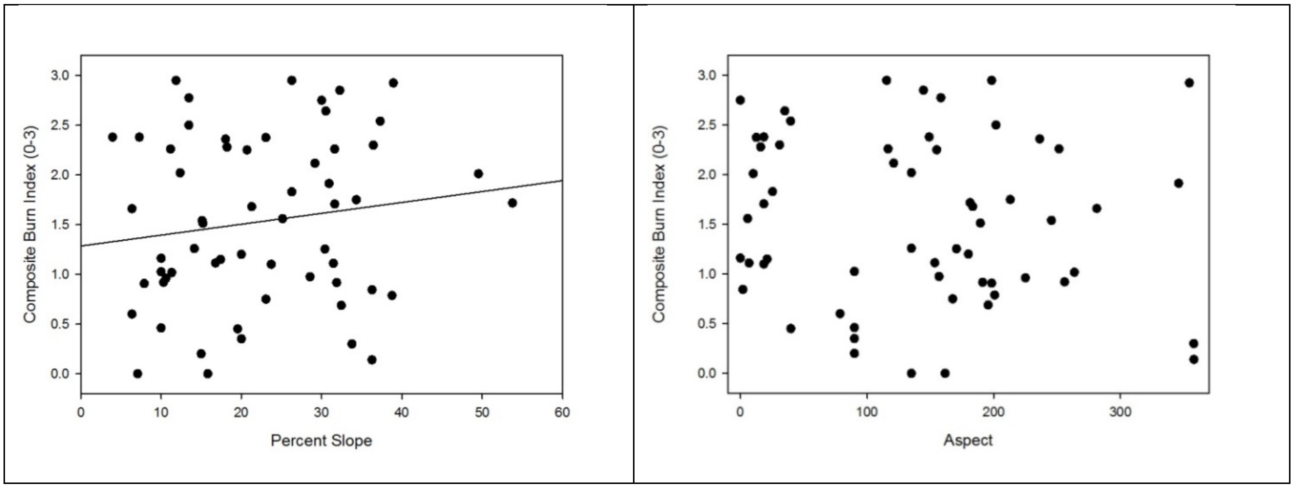


Figure 13. Scatter plot of percent slope and aspect (shown in degrees) versus overall CBI score for plot data.

Only two vegetation types were present in the plot data on the Cabin Fire, red fir and Sierra mixed conifer. A bar chart of combined CBI data from plots grouped by vegetation type shows that CBI values appear slightly higher in Sierra mixed conifer than in red fir; however, these differences are not greater than one standard deviation (Figure 14). This trend is similar to the trend found by Collins et al. (2007) where lower severities were found in red fir. Collins et al. (2007) found that relative humidity was the factor which played the largest role in severity. We did not assess the effect of weather on the severity of plot data because plots were located in areas where fire perimeters were only created for 8/1, 8/9 and 8/14, which would not allow daily weather to be assigned to each plot.

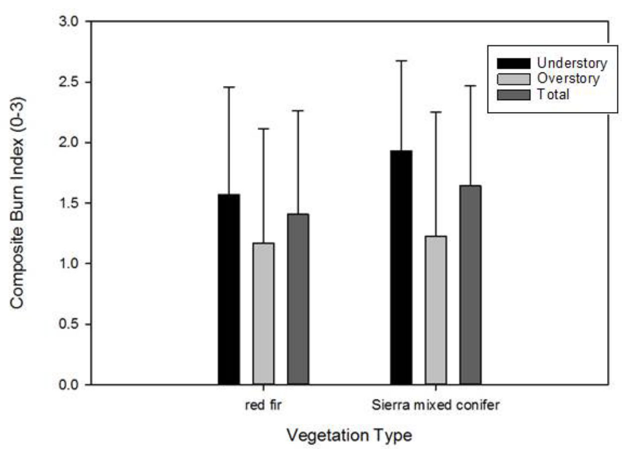


Figure 14. Bar chart with error bars showing standard deviation for Cabin Fire overstory, understory, and combined CBI values from plot data in red fir and Sierra mixed conifer vegetation types.

Analysis of Remotely-Sensed Severity Data

Fire severity data based on remote sensing (RAVG) was used as a second method to analyze the area where the Cabin Fire overlapped the Lion Fire. Severity data compiled through the 'Rapid Assessment of Vegetation conditions after Wildfire' (RAVG) process (RSAC) was used. The final CBI severity map products separated fires into four categories: unchanged; low severity; moderate severity; and high severity with values of 0.1, 1.25 and 2.25 as thresholds between the categories. The category of 'unchanged' refers to areas within the fire which appear to be unburned in the remote sensing data. Generally these islands are near the perimeter, however, some occur interior.

Pie charts were used show the Cabin Fire distribution by severity class both inside and outside of where it reburned part of the 2011 Lion Fire. Maps were used to show the spatial distribution of this severity.

The pie chart of the Cabin Fire area outside of the 2011 Lion Fire (not burned by the Lion Fire) shows that unburned, low, moderate and high severity each make up about a fourth of the burn area, (Figure 15) which shows higher percentages of high fire severity than any of the Lion overlap area pie charts in the next figure. The area within the Cabin Fire which overlapped areas of the Lion fire categorized as 'unchanged' in the RAVG data were largely also unchanged by the Cabin Fire. It is quite likely that these areas were rocky or barren and therefore had little capacity to burn in either fire. The percentages of Cabin Fire severity levels within areas of the Lion Fire classified as low, moderate and high severity did not have many differences large enough to note. One difference is that the area classified as high severity in the Lion RAVG data burned with more moderate than low severity in the Cabin Fire (Figure 16). This trend is slight and incongruent with the trend in the field plot data. This could be due to the fact that areas which had burned with high severity in the Lion fire had minor amounts of shrub and grass growth, which when burned by the Cabin Fire, were classified as more moderate than low CBI, even though a relatively low amount of fuel was burned. This different mild trend found when using the remote sensing data, and the entire area of overlap between the two fires could be due to sampling error found in the plot data because the entire Cabin/Lion Fire overlap was not sampled (Figure 17 and Figure 18).

The results this remote-sensing data analysis is only based the small area of interaction with the Cabin and Lion fires, and is not as strong as analyses which include multiple fires. The severity of the Cabin Fire may have be influenced more by daily weather patterns and the availability of patches of continuous fuels than the severity and effects of the Lion fire. Drought may have made more fuels available this particular year than in others. Accounts of the Lion fire noted that many areas in the Golden Trout Wilderness are rocky and the Lion fire tended to only spread with intense fire behavior uphill in patches where fuels were continuous. Sometimes in these uphill runs in the Lion fire, fuels were reduced, and other times, fuels were created by scorching brush and trees which would later add to available fuels for later fires. Overall, our results tend to mirror previous research in that the occurrence of previous fire has a more defined effect on a second fire than does the severity of the previous fire.

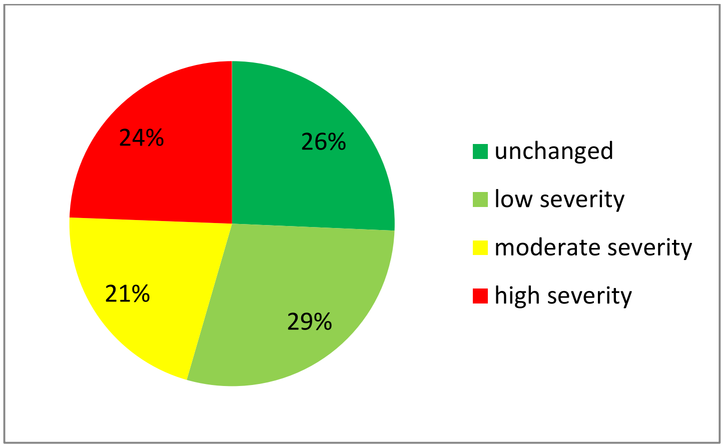
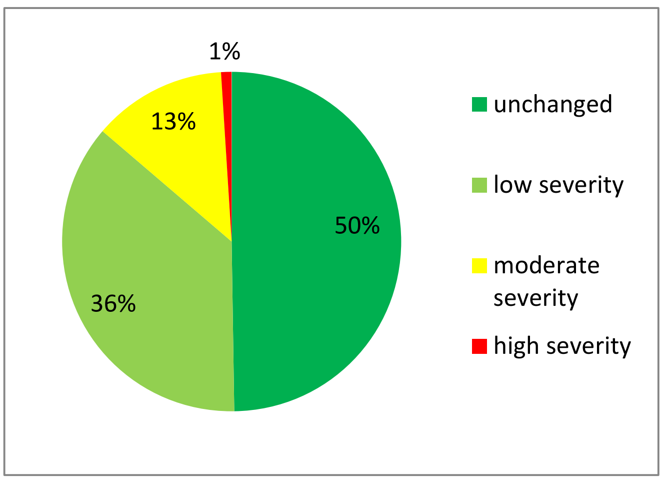
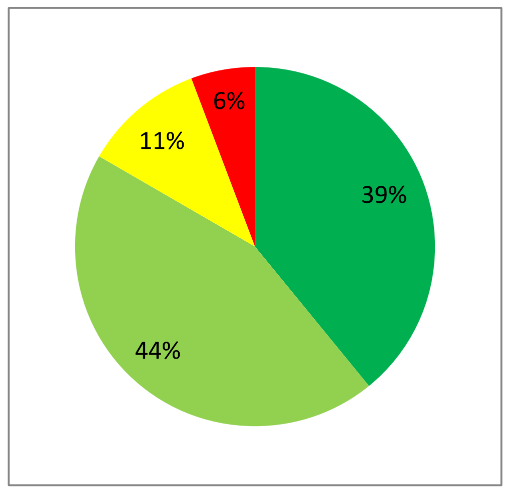


Figure 15. Pie chart of Cabin Fire CBI scores from RAVG data within the area of the Cabin Fire which was not burned by the Lion Fire.

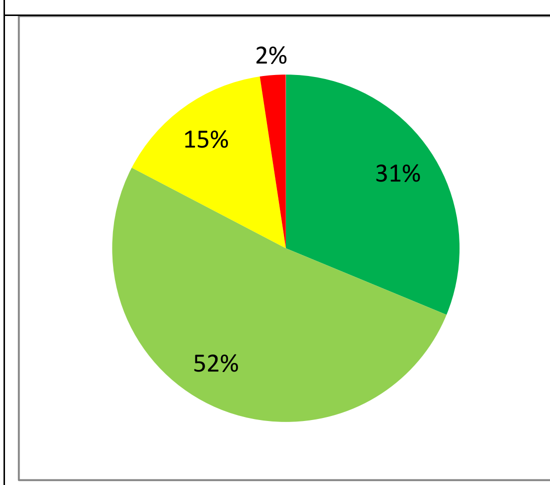
Cabin CBI within unchanged areas within perimeter of Lion Fire



Cabin CBI within Lion Fire areas of low severity



Cabin CBI within Lion Fire areas of moderate severity



Cabin CBI within Lion Fire areas of high severity

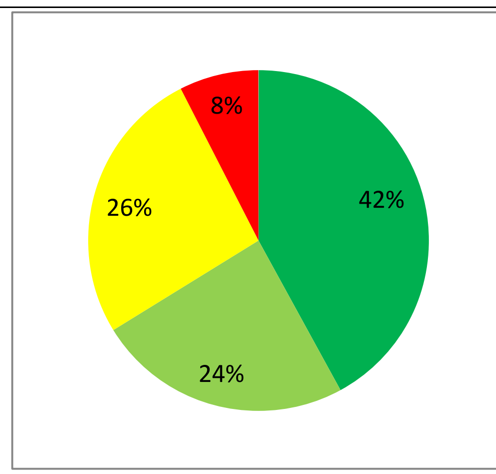


Figure 16. Pie charts of Cabin CBI scores from RAVG data within unburned, low, moderate and high severity areas the Lion Fire.

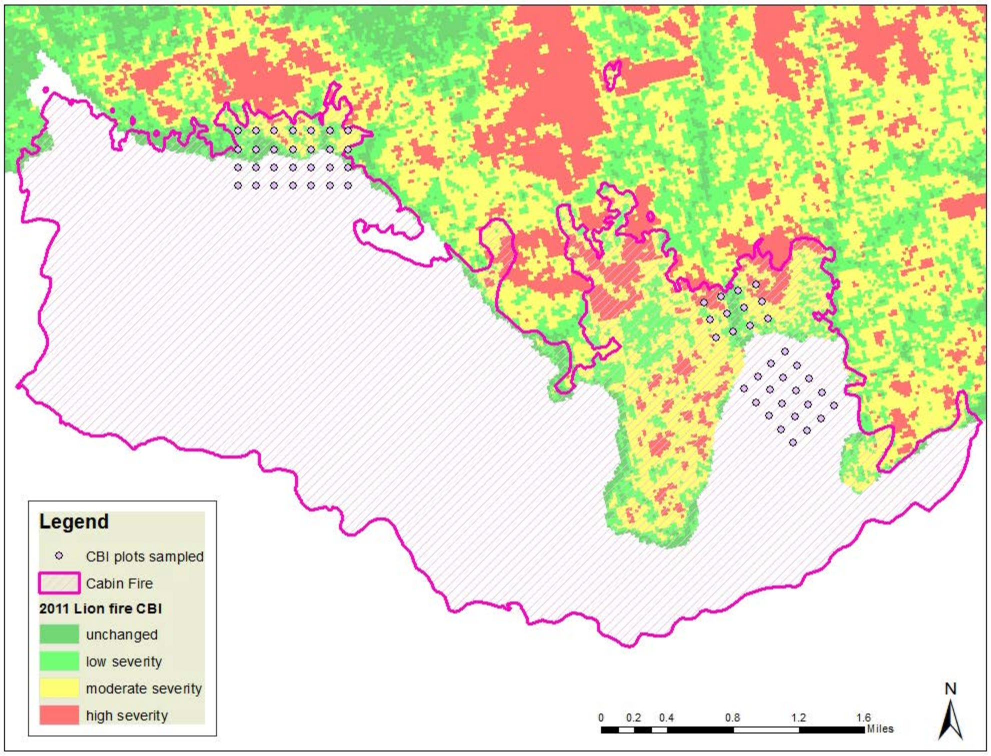


Figure 17. Map of the one year post-burn severity of the Lion Fire (RAVG data) near the Cabin Fire area.

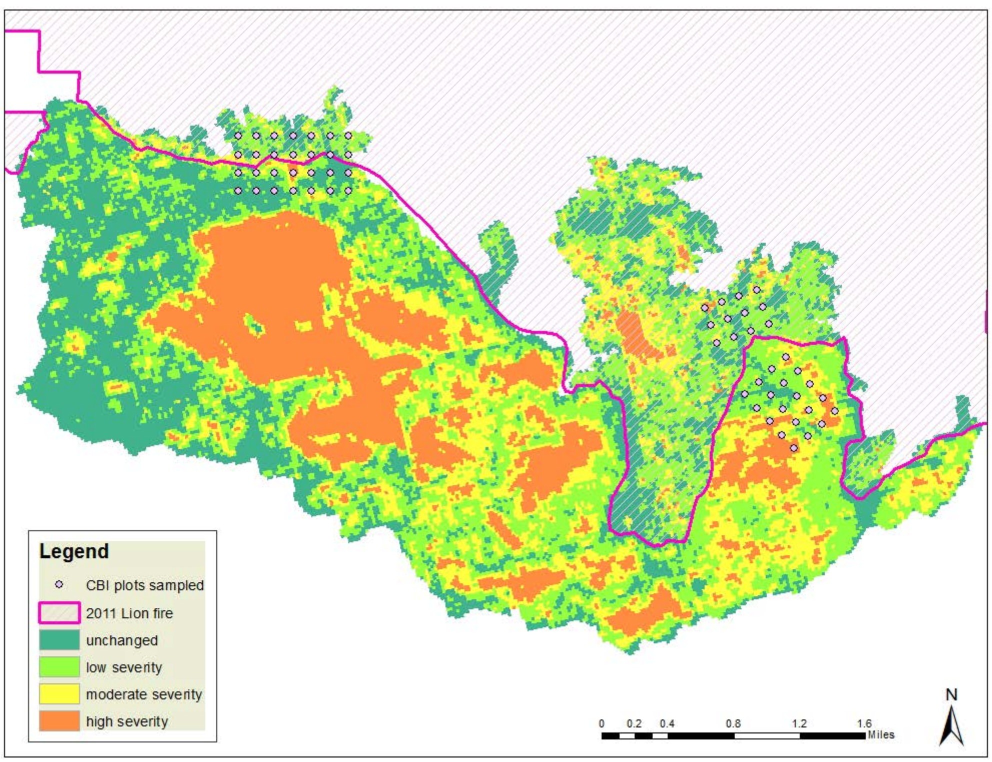


Figure 18. Map (immediate post fire) of the burn severity of the Cabin Fire (RAVG data) including where it overlapped the Lion Fire.