# Wildfire Interactions of the 2011 Lion Fire and Recent Wildfires on the Sequoia National Forest and Sequoia National Park

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Prepared by:

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a unit of

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# EXECUTIVE SUMMARY


*This report explores whether fire as a natural process is self-limiting and examines whether recurring wildfires over time ultimately constrain the spatial extent and lessen the fire-induced effects of subsequent wildfires.*

This study explored the interactions of the 2011 Lion Fire with other recent wildfires using field data and remote sensing data focusing on fire effects and impacts to resources. The Lion Fire was ignited by lightning on July 8, 2011 and reached a final size of 20,674 acres. The fire burned in mixed conifer timber and brush fuels in the Sequoia National Forest, including parts of the Golden Trout Wilderness and the Sequoia National Park. The Lion Fire was managed for multiple objectives, one of those being resource benefit. Impacts associated with managing the fire to achieve resource benefits included air quality degradation and trail closures. Burning Indices and Energy Release Components were above the 50th percentile during mid-late July when the Lion Fire experienced the most growth. The Lion Fire overlapped two recent wildfire areas and was near or adjacent to three more recent fires. These recent fires affected the burning characteristics of the Lion Fire and aided fire managers in the ultimate control of the fire on November 8, 2011.

**Results Summary**

- Reduced tree torching (and potential tree mortality) occurred where the Lion Fire reburned into recent fire perimeters.
- Less litter cover was found post-Lion Fire in areas that had not previously burned.
- Fire severity ratings for substrate indicated less fire severity in areas where the Lion Fire reburned into recent fire perimeters.
- Plots further away from the Lion Fire edge and deeper into the recent fire perimeters tended to have slightly lower fire severity.
- In several instances, the Lion Fire transitioned from high severity to lower severity and stopped spreading when it interacted with previous recent wildfires.
- Burned areas from recent wildfires and natural barriers were used by fire managers to control large segments of the Lion Fire.

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# BACKGROUND

The purpose of this study is to explore the interactions of the 2011 Lion Fire with other recent wildfires, focusing on fire effects and impacts to resources. Remote sensing and field data on substrate, understory, and overstory fire severity were used to compare areas within the Lion Fire that overlapped recent wildfires and areas with no recorded fire history (90-year period of record). This study of the Lion Fire is smaller in scope, but similar to work completed by Collins et al. (2009) who conducted a spatial analysis of wildfires in Yosemite's Illilouette Creek Basin over a 31-year period. Similar to the work completed by Collins et al. (2009), 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 lessen the fire-induced effects of subsequent wildfires.

The Lion Fire was ignited from lightning July 8, 2011 and burned within the Golden Trout Wilderness of the Sequoia National Forest and Sequoia National Park, in the southern Sierra Nevada. During the first weeks, fire growth ranged from approximately 100 to 2,000 acres a day. The fire had burned a total of 11,411 acres on July 16 and 19,046 acres by August 1. The final fire size was 20,674 acres (Figure 1).

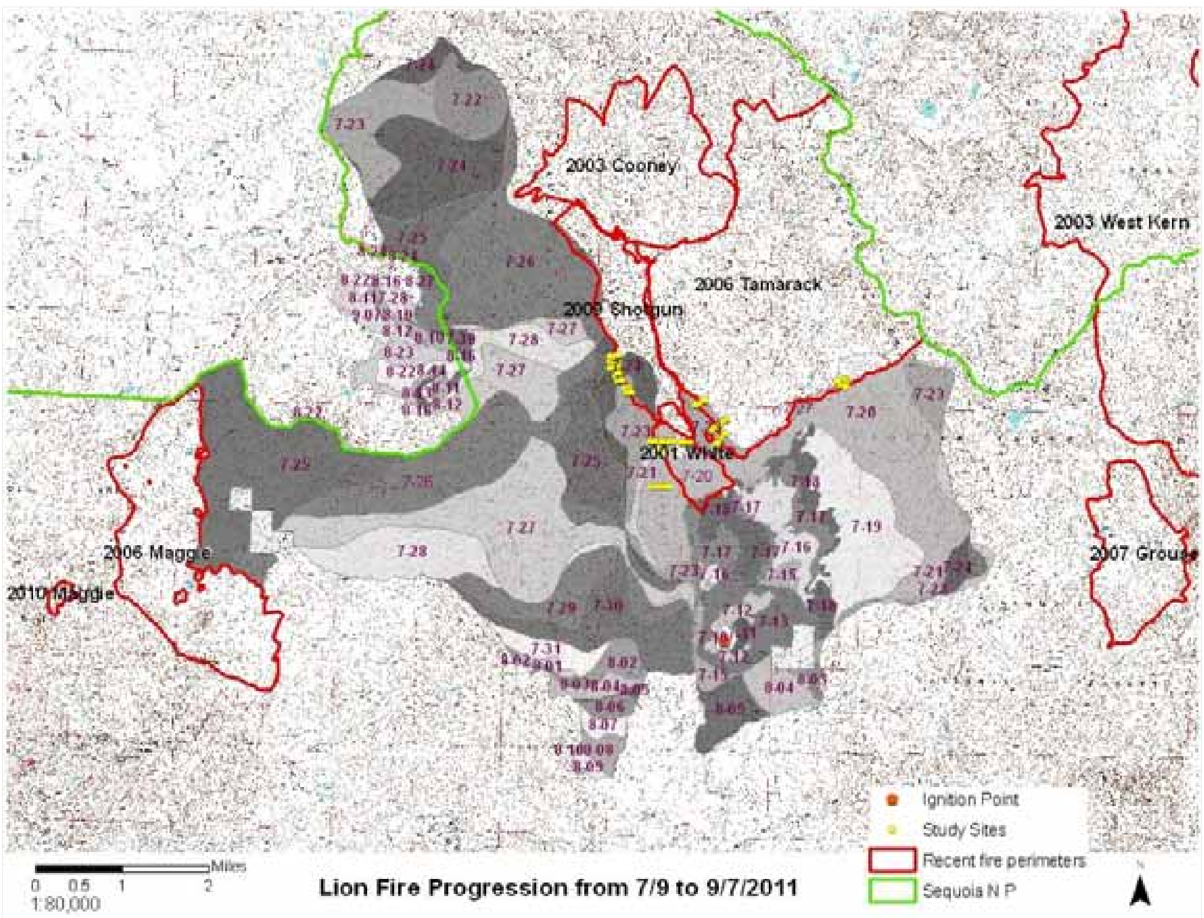


**Figure 1. Lion Fire progression and other recent wildfires**

The Lion Fire burned in mixed conifer timber and timber litter fuels as well as brush. Areas within the fire perimeter contained meadows, riparian corridors, and exposed rocky ridges (Figures 2 and 3), which often acted as barriers to fire spread or were used in backfiring and holding operations during the Lion Fire. Elevations range between 6,000 and 10,000 feet in the fire area. Local topography includes steep river canyons and ridges in the vicinity of the Little Kern River and Soda Springs Creek, as well as flatter, meadow areas such as Peck's Cabin, Lion and Table meadows. The fire was bounded on the east by the steep rocky slopes of the Great Western Divide and rocky ridges and alpine areas on the west side.

The southern Sierra Nevada has a Mediterranean climate with warm, dry summers and cool, wet winters. The Lion 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 the thermal low that develops in the desert during afternoons. The thermal low draws cooler, mountain and canyon air into the desert.

Orographic lifting is a main process for summer time thunderstorm development and winter precipitation distribution in the southern Sierra Nevada. Winter storms approach the area from the west and drop most of their moisture on the Western Divide Mountains along the west side of the fire area. A rain shadow effect reduces moisture in the North Fork Kern River as weather systems drop down the eastern side of the Western Divide Mountains and the slopes of the Great Western Divide in to the North Fork. More precipitation falls along the Sierra Nevada crest and then significantly tappers off as storms move down the eastern escarpment into Owens Valley. Summer time thunderstorms are infrequent and produce limited moisture.

The Kern River basin received 195% of average snowpack during the winter of 2010/2011. Even though the winter snowpack was significantly above average, fuels dried rapidly after snow melt. National Fire Danger Rating System Energy Release Component and Burning Indices ranged from below to above average during July, when much of the fire spread occurred in the Lion Fire. During the period of largest fire growth, July 18 to 27th, the Burning Index ranged from 51 to 85 percentile (BI 43-64), and the Energy Release Component ranged from 55 to 73 percentile (ERC 58-73). Live and dead fuel moistures were generally below the average for July and winds were lighter than average for this period (Appendix V).

**Figure 2. Right photo shows view of the Great Western Divide (northeast side of fire) from Camelback ridge area, left photo shows Camelback ridge in Lion Fire area**

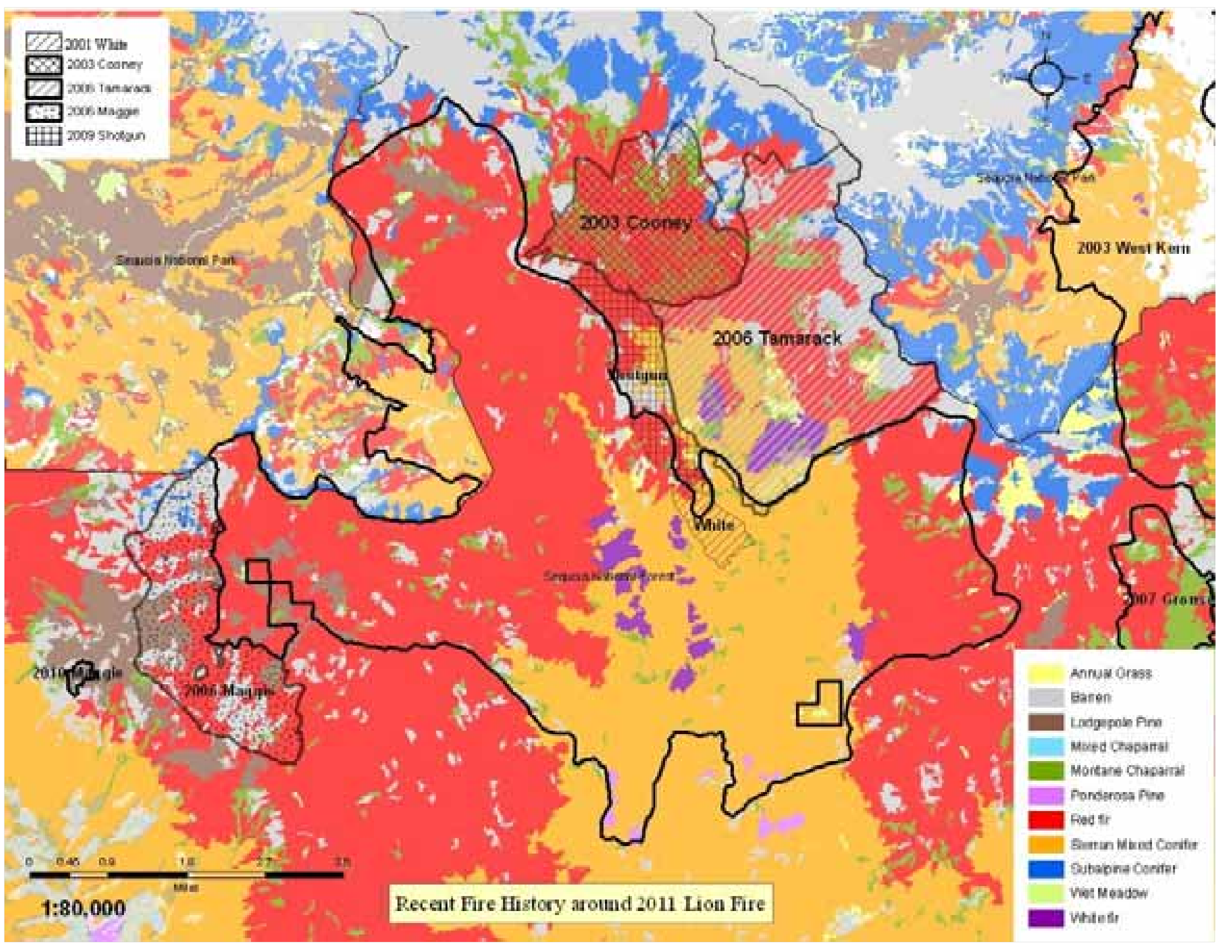


**Figure 3. Lion Fire, recent wildfires, and California Wildlife Habitat Relationship (CA WHR) vegetation types**

Although little is known with certainty regarding the intensity and severity of historic fires in the lower-montane forest zone, fire occurred frequently enough to keep surface fuel loadings and tree densities reduced to a level where surface fire was the dominant fire pattern. 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.

When forest managers developed the strategy of how to manage the Lion Fire, the social impacts on local communities and forest visitors from smoke and trail closures were weighed against the ecological benefit of managing the fire to increase forest resiliency. Smoke from the Lion Fire settled at night into the Kern River Drainage, along Highway 395 in Owens Valley, and into the San Joaquin Valley. Several hiking trails in the Forest and the Park were closed to assure public safety. The Lion Fire, which originated as a natural ignition, was allowed to burn within planning boundaries to restore ecosystems to more sustainable, resilient, and healthier conditions.

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Tactics employed on the Lion Fire included the use of a series of natural barriers including rocky ridges, meadows, bare ground, previous wildland fires and watercourses to control fire spread. Incident managers also used existing trails and short segments of fireline to protect private lands and other values within the management area of the fire. Aerial and ground-based ignitions were used to consume fuel ahead of the fire spread to provide strategic containment areas. Firing operations were synchronized with smoke management forecasts, which suggested favorable conditions for smoke dispersal.

The wide spread reduction of understory (surface fuel), litter (ground fuel) and tree canopy from the Lion Fire area is expected to aid in reducing the probability of a large, high severity wildfire in the near future. The tree canopy thinning (reduction in amount and density) caused by the Lion Fire may reduce stand susceptibility to disease and competition, leading to a healthier, more fire resilient forest stand.

## Recent Wildfires Adjacent to the Lion Fire

Five recent wildfires occurred adjacent to the Lion Fire. Key components from each of these five fires as they relate to the Lion wildfire interaction study are outlined below.

**2001 White Fire**

- The White Fire was overlapped the Lion and Shotgun Fires in separate areas.
- Plot data was collected in this area.

### 2003 Cooney Fire

- This fire perimeter was utilized as a part of the natural barrier strategy for containing the Lion Fire as it represented an area of reduced fuels on the northeast side of the Lion Fire.
- No overlapping fire perimeters. No plot data was collected.

### 2006 Maggie Fire

- The Maggie was adjacent to, but did not overlap the Lion Fire. No plot data was collected.
- The Maggie Fire was contained at trail 31E14 in 2006. This trail was also used as a holding feature for backfire / burnout during the Lion Fire management, partially due to the reduced fuel zone associated with past actions on the Maggie Fire.

### 2006 Tamarack Fire

- Tamarack Fire overlaps northeastern edge of Lion Fire in a narrow strip.
- Plot data was collected in this area.
- A spot fire from Lion ignited the interior of the Tamarack burn area, however this spot fire self-extinguished.

### 2009 Shotgun Fire

- The Shotgun Fire had little to no overlap with Lion Fire. The Lion Fire was stopped at the edge of the 2009 Shotgun by a series of fireline and trail improvements as well as low fuel areas.
- Plot data was collected in this area.

# METHODS

Fire monitors collected field data in and adjacent to the Lion, Tamarack, Shotgun, and White Fires in order to quantify the relationships between fire severity and recent fire occurrences. Data was collected between August 27 and September 2, 2011. Protocols followed were similar to those established by the US Forest Service, Pacific Southwest Region Ecology Program for quantification of fire severity relating to fuel treatment areas (Merriam 2008, Safford et al. 2009), and included some modifications adapted for wildfire boundaries and time / access constraints.

Three to eleven study plots were established along transects approximately perpendicular to the perimeter of the sampled fires. Plots were established along transects:

1. where the Lion Fire reburned or overlapped a recent fire perimeter, termed "overlap;"
2. where only the Lion Fire burned, termed "Lion only;" and
3. where the recent fires burned, but not the Lion Fire, termed "recent fire."

These three groupings functioned as "treatment" categories for data analysis. Additional plot data was collected in the "no known fire" or unburned areas in the vicinity of the Lion Fire in attempt to characterize the surrounding landscape where no recorded fire had burned. The number of plots along transects as well as distances between plots along transects varied, generally between 20 to 75 meters depending on the extent of the overlap area. Methods are detailed in Appendix I. Data collected at each plot included:

- GPS coordinates
- Slope
- Aspect
- Photographs up and down transect
- Distance from plot center to trees
- Tree heights
- Average bark char heights
- Average scorch heights
- Average torch heights
- Heights to live crown
- Species
- DBH
- Tree damage / disease

Data were analyzed and graphically displayed using Microsoft Excel and SigmaPlot. Data were analyzed in SAS v9.2 statistical software using PROC GLIMMIX, a versatile and robust procedure. Many variables were transformed using an arcsine transformation. A natural log transformation was used for litter and duff data. Data were not always able to be analyzed statistically as several variables did not meet statistical test assumptions.

Remote sensing or satellite imagery was utilized to fill in portions of the fire area where no field data was gathered as well as to compare multi-year spatial datasets through geographic information system (GIS) analysis. The Sequoia National Forest utilizes a recently updated GIS vegetation layer, based on the California Wildlife Habitat Relationship (CA WHR) vegetation types (CDFG 2011), for planning and analysis purposes. This CA WHR spatial layer was used for all vegetation analysis in this report (Figure 3). Remotely sensed post-burn vegetation severity data was used for comparisons where the Lion Fire overlapped previous recent fires. This dataset is called the Composite Burn Index (CBI, USFS 2006-2011) and is explained further in the "Comparisons of Vegetation Severity based on Satellite Imagery" section of this report and Appendix III.

# RESULTS AND DISCUSSION

Analyses of field data and remote sensing capture differences between areas where the Lion Fire overlapped recent wildfires and where it did not. Overlap areas include areas where the 2001 White and 2006 Tamarack Fires were burned by the Lion Fire. These areas have been burned twice in 10 years. The Lion only areas were not directly affected by any other fire within the approximate 90 year known fire history for the area.

## Fire Weather Based on RAWS

This summary characterizes the weather, burning conditions and fire behavior relevant to the White, Maggie, Tamarack, and Shotgun Fires when they originally burned, and also when the Lion Fire burned into these areas. The Peppermint Remote Automated Weather Station (RAWS) data was used in the analysis. The Peppermint RAWS is located 13 miles southwest of the Lion Fire at 7,385 feet and is located in the same drainage as the Lion Fire. Data from the RAWS indicates that there were no significant wind events during any of the five fires (Appendix V, Figures 62-66, 78-86). During the Lion Fire, burning indices and energy release components were sometimes below, but mainly above the 10-year average (Figure 4, next page).

*During the Lion Fire, burning indices and energy release components were sometimes below, but mainly above the 10-year average.*

Very little precipitation was recorded during the Lion Fire. The precipitation events that did occur were most likely thunderstorms and may not have been widespread enough to rain throughout the Lion Fire area (Table 1, next page).

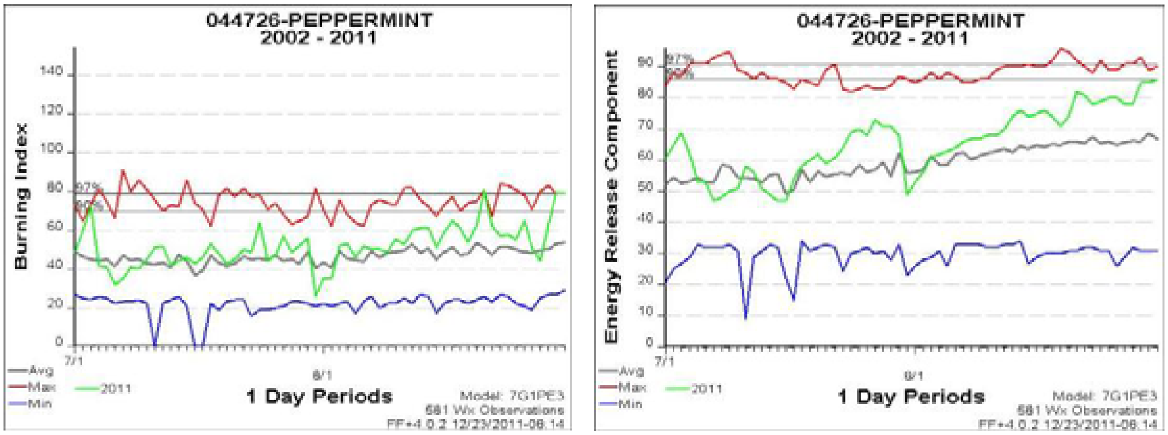


**Figure 4. Burning Index and Energy Release Component for 2011 (green line) and the 10-year average (grey line) at the Peppermint RAWS**

**Table 1. Summary of precipitation events at the Peppermint and portable Lion RAWS before and during the White, Maggie, Tamarack, Shotgun, and Lion Fires interaction periods**

| Fire | RAWS | Precipitation Amounts / Dates - inches |
|---|---|---|
| 2001 White | Peppermint | None Recorded<br>(Missing days data from May 1 – 5, 15, 18, 19) |
| 2006 Maggie / Tamarack | Peppermint | July 21 – 0.35 in., July 22 – 0.10 in., July 23 – 0.20 in. |
| 2009 Shotgun | Peppermint | June 5 – 0.14 in., 6 - 0.02 in., July 18 – 0.01 in.<br>July 1 – 0.02 in., July 23 – 0.03 in. |
| 2011 Lion – interaction with above fires | Peppermint | July 5 – 0.51 in, July 7 – 0.18 in, July 31 – 0.38 in.<br>August 2 – 0.1 in. |
| 2011 Lion – interaction with above fires | Lion Meadow | July 30 – 0.02 in., 31 – 0.25 in. (Missing days data from July 22, 0800 to July 26, 1800) |

The dates the four fires originally burned are important because fuel moistures decreased over the course of the fire seasons, increasing the potential intensity of fires (Table 2). An analysis of fire weather and fuels conditions for the White, Maggie, Tamarack, and Shotgun Fires was performed using the 1978 National Fire Danger Rating System (NFDRS) though the FireFamilyPlus (version 4) program using fuel model G (0-25% slope). Fuel model G represents mixed conifer areas on the Sequoia National Forest that have not burned for many decades (heavier fuel loadings). For the post-fire analysis, the fires were converted to fuel model H to show the reduced fuel loads. The Forest uses Fuel Model H for mixed conifer areas that have been recently burned. NFDRS outputs for the four past fires are summarized in Table 3 using the model outputs detailed in Appendix V, Figures 30 through 66. Detailed weather observations for all five fires are also available in Appendix V, Table 20.

**Table 2. Dates the White, Maggie, Tamarack, and Shotgun Fires burned relevant to the dates they interacted with the Lion Fire**

| Fire | Original Burn Dates of Interaction Area with Lion Fire | Dates of Lion Fire Interaction |
|---|---|---|
| White | May 21 - 26, 2001 | July 18, 20, 21, 23, 2011 |
| Maggie | July 20 - August 2, 2006 | July 25, 26, 2011 |
| Tamarack | July8 - 16 2006 | July 20, 23, 27, 2011 |
| Shotgun | June 25 - July 5, 2009 | July 20, 23, 24, 26, 2011 |

**Table 3. Summary of NFDRS weather and fuels conditions during the dates the White, Maggie, Shotgun, and Tamarack Fires originally burned and when they interacted with the Lion Fire***

| Fire | Burning Index (BI) | Energy Release Component (ERC) | 1,000-hour Time Lag Fuel (%) | 100-hour Time Lag Fuel (%) | Live Woody Fuel Moisture (%) | Live Herbaceous Fuel Moisture (%) | 1300 Observation Winds Speed (mph) |
|---|---|---|---|---|---|---|---|
| 2001 White | 22-38 | 22-37 | 20-23 | 9-16 | 70 - dormant | 4-6 - dormant | 2-5 |
| 2006 Maggie | 29-55 | 46-61 | 11-13 | 8-13 | 78-91 | 64-76 | 3-9 |
| 2006 Tamarack | 45-82 | 82-88 | 7-8 | 4-8 | 70 - dormant | 30-33 | 2-10 |
| 2009 Shotgun | 47-64 | 59-74 | 10-13 | 5-7 | 70-81 | 17-33 | 4-9 |
| 2011 Lion interaction with above fires | 43-64 | 58-73 | 10-11 | 5-10 | 70-80 | 41-60 | 4-8 |

* Definitions are provided in Appendix V

## Fire Behavior Based on NFDRS

Fire monitoring, weather and fire behavior observations data for White, Maggie, Shotgun and Lion Fires is limited. More complete data was available for the Tamarack Fire. Burning Index and Spread Component outputs from NFDRS were used for estimating flame lengths and rates of spread during the dates the White, Maggie, Shotgun and Lion Fires burned because few field fire behavior observations were available. Table 4 shows the differences in fire behavior between the five fires that were due to the varying weather and fuels conditions that occurred when the fires burned. Fire behavior observation summaries from the Tamarack Fire are included to illustrate the value of collecting daily field observations on large fires.

**Table 4. Summary of fire behavior on the White, Maggie, Tamarack, Shotgun, and Lion Fires based on detailed analysis found in Appendix V, Figures 30- 35, 74 – 77**

| Fire | Head Fire Flame Lengths (FL) Based on NFDRS BI (feet) | Head Fire Spread Component (ROS in chains/hr) | Observed Fire Behavior NA = Data Not Available |
|---|---|---|---|
| 2001 White | 2-4 | 3-6 | NA |
| 2006 Maggie | 3-6 | 4-9 | NA |
| 2006 Tamarack | 5-8 | 3-5 | 7/16/2006 - Obs. 8,900 ft., slope 40%, aspect N, backing / head, FL 1-10ft shrubs, ROS 0.5 to 6 ch/hr, most perimeter backing, eastern flank torching and running |
| | | | 8/7/2006 - Obs. 8,100-8,600 ft., slope 10-15%, aspect N, W, S, backing FL 1ft litter, head FL 3ft shrubs, ROS NA, active western flank |
| | | | 8/9/2006 - Obs. 8,400-8,880 ft., slope 3-40%, aspect SW, W, NW, backing FL 2ft litter / shrubs, ROS NA, isolated torching |
| | | | 8/11/2006 - Obs. 8,430ft, slope 15-25%, aspect NW, backing and flanking FL 1-2ft litter and shrubs, R0S 0.5 ch/hr, isolated torching, flanking towards W and SE |
| | | | 8/12/2006 - Obs. 8,430 ft., slope 25%, aspect W, backing and flanking FL0.5- 4ft litter and shrubs, ROS 0.5 ch/hr, flanking W, NW of Tamarack Cr., isolated torching |
| | | | 8/13/2006 - Obs. 8,430 ft., slope 25%, aspect W, backing FL 1ft litter, FL 2ft shrubs, ROS 0.10-0.25 ch/hr, slow backing, no torching, afternoon 10 chain burnout head fire FL 4ft shrubs, ROS 6 ch/hr |
| | | | 8/14/2006 - Obs. 8,430 ft., slope 25%, aspect S, E, flanking and backing towards Little Kern River, isolated torching, late afternoon short uphill runs |
| 2009 Shotgun | 5-6 | 5-12 | NA |
| 2011 Lion – interaction with above fires | 4-6 | 1-3 | NA |

## Overstory and Midstory Trees

**Tree Height, Diameter, and Height to Live Crown** – Tree characteristics were compared between four "treatment" areas: no known fire, recent fire only, Lion Fire only, and overlap. The no known fire area, or unburned area, had slightly shorter tree heights and larger diameter trees (Figure 5), although differences in tree height and diameter were not statistically significant. The p-value was 0.2174 for tree height and 0.5225 for diameter (a "p-value" lower than 0.05 indicates that results are probably due to a real difference, rather than chance alone). This no known fire area was close to or on the Camelback ridgeline where the east side of the Lion Fire bordered the west side of the

Shotgun Fire. Trees in this area were large, sparse and many were junipers and / or had krumholtz characteristics (shaped by wind and snow and bent over).

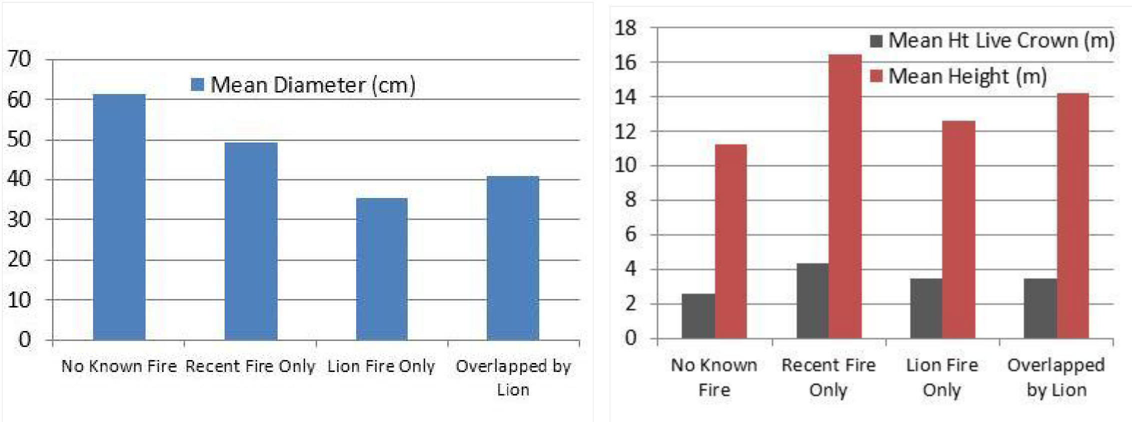


**Figure 5. Mean overstory tree diameter, total height, and height to live crown compared by fire history** (see Table 9 in Appendix II for more details)

Trees with taller average heights and heights to live crown were found in the recent fire only areas of the White, Tamarack, and Shotgun Fires. Again, these differences were not statistically significant. The p-value was 0.6486 for height to live crown. The Lion Fire did not burn into these recent fire only areas with large trees and high canopies. Trees that had been affected by only the Lion Fire only had the smallest mean diameters and were in the middle height category (12 to 14 meters or 39 to 46 feet). The fact that the tree canopies in the overlap areas were slightly higher and had slightly larger tree diameters supports the concept that a more frequent fire regime favors larger trees, which tend to be more resistant to future fires.

*Trees with taller average heights and heights to live crown were found in the "recent fire only" areas of the White, Tamarack, and Shotgun Fires. The Lion Fire did not burn into these recent fire only areas with large trees and high canopies.*

**Basal Area** - Overstory basal area for live and dead trees combined was similar in overlap and Lion only areas (Figure 6 and Appendix II-Table 10). Slightly greater live tree basal area was found in areas outside the Lion Fire where recent fires had burned. The p-value was 0.5074 for basal area, so any differences are not statistically significant.

**Dead Tree Component** – Although the p-value was 0.3414 for tree density (trees per acre) and results were not statistically significant, some minor trends show in the data. The greatest number of dead trees per acre was found in Lion only plots, followed by the overlap plots. The recent fire (no Lion Fire) plots had the least amount of dead trees per acre among plots having been burned recently. The no known fire area was represented by plots on the ridge, which have lower trees per acre and no dead trees recorded in the plots. There was evidence of small tree removal on this ridge along the fireline boundary corridor, which influenced the tree metrics in the no known fire area.

North et al. (2009) suggest that forest landscapes with active fire regimes varied in stand characteristics (basal area, snag density, tree density, etc.) depending on structural conditions produced by topography's influence on fire frequency and intensity. The field data on trees per acre supports this.

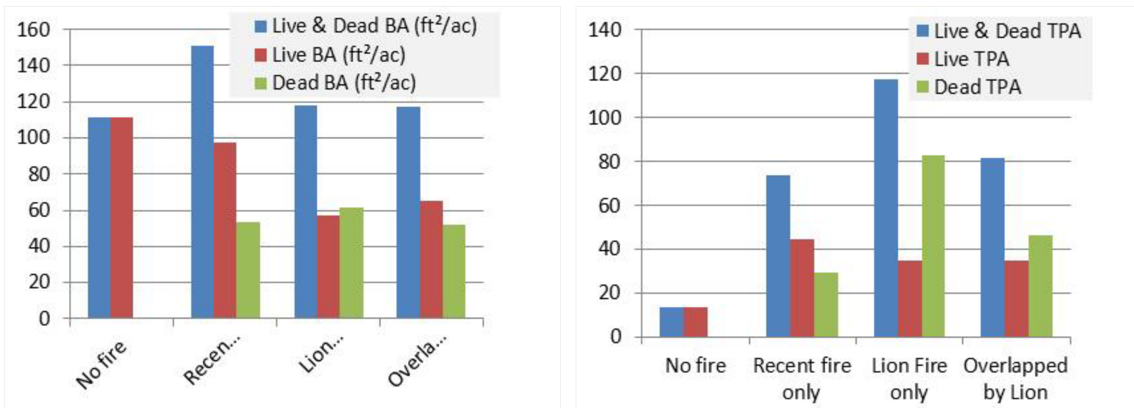


**Figure 6. Overstory tree basal area (BA) on right side and trees per acre (TPA) on left side for all trees and separated for live and dead trees compared by fire history** (see Table 10 in Appendix II for more details)

Insect infestations can interact with wildfire areas. Recently burned forests may be more susceptible to insect damage. In turn, dead and weakened trees that have been infested with insects increase wildfire risk. Ecosystem vulnerability to climate change will depend on a suite of interacting factors, including changes in disturbance regimes comprised of insects, pathogens and wildland fire in key ecosystem process (USFS 2010). Many trees measured in the Lion wildfire interaction study plots had mistletoe, a tree parasite. High levels of mistletoe may indicate forest conditions are currently unhealthy, which might be connected to departure from fire return intervals. Fire is known to thin forest canopies and kill individual trees. These breaks in forest continuity and the associated reduction in competition between trees allow stands to grow healthier and more resilient to not only fire, but to forest pathogens as well.

**Scorch and Torch -** Average percent scorch (orange/brown needles) was 57% in overlap plots and 77% in Lion Fire only areas. Percent scorch results were not quite significantly different (p=0.0678) between overlap and Lion Fire only areas. Average percent torch (needles consumed) was 15% in overlap areas and 34% in Lion Fire only areas (Figure 7). Percent torch was significantly higher in Lion Fire only areas (p=0.0349) than overlap areas. These results indicate that slightly higher tree canopy damage occurred in areas of the Lion Fire where wildfires had not burned through in recent years. This could be due to the fact that recent past wildfires had reduced surface and ladder fuels enough that Lion Fire intensity was lower in overlap areas compared to areas that were not recently burned.

*Results indicate that slightly higher tree canopy damage occurred in areas of the Lion Fire where wildfires had not burned through in recent years.*

Trees that have 100% of their needles scorched are often considered to be killed by the fire, although some portion of these trees may actually survive depending on the level of additional stresses several years following the fire. In the study plot data, 65% of the trees in the Lion Fire only plots experienced 100% scorch, whereas only 24% of the trees in the overlap areas experienced 100% scorch. Within the Lion Fire only plots, 3% of the trees had no scorch recorded, whereas 21% of the trees in the overlap areas had no scorch recorded. These trends from the plot data suggest that lower tree mortality and less ladder fuel reduction may be seen in areas of the Lion Fire where recent fires had burned compared to areas which have not experienced fire in recent history.

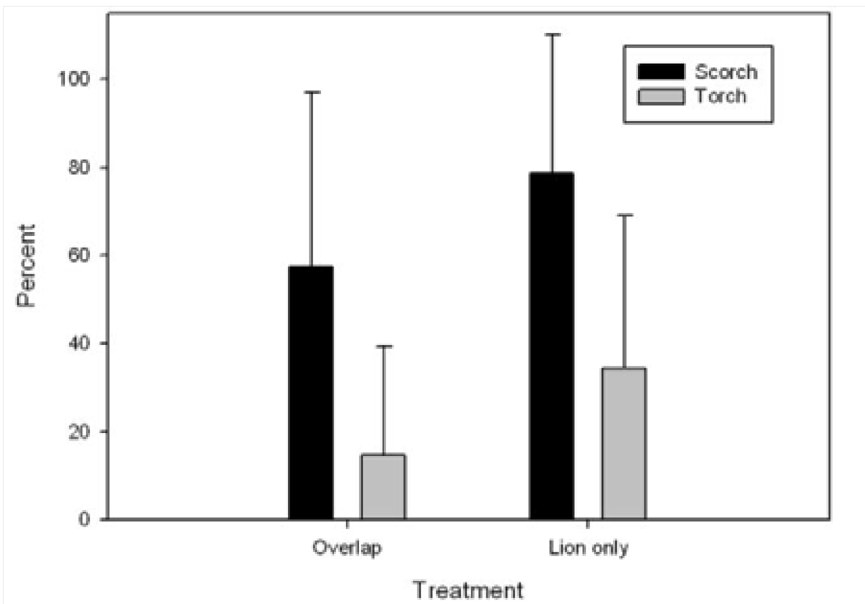


**Figure 7. Graph of mean and standard deviation (indicated by vertical lines) percent tree scorch and torch for overlap and Lion only plots**

Within the overlap areas the mean percent scorch was 39% among plots previous burned by the 2006 Tamarack Fire, whereas percent scorch was 80% in plots where the 2001 White Fire had previously burned. Due to a high degree of variation and a low sample size, this difference was not statistically significant (p=0.2157). Percent torch followed similar patterns. Mean percent torch was 7% in areas where the Lion and Tamarack overlapped, and was 24% in areas where the Lion overlapped the White (Figure 8). Similar to percent scorch, this difference was not statistically significant either (p=0.1120). In summary, although not statistically different, there was a trend increased fire effects in areas where fire occurred 10 years ago (White Fire area), rather than 5 years ago (Tamarack Fire area). This data alludes to the fact that as time-since fire increases, higher levels of scorch and torch may occur. This conclusion is tempered by the fact that more gentle slopes were found within Tamarack/Lion overlap than the White/Lion overlap. The true effects of time-since-fire could be better studied if additional overlap areas were measured on future fires.

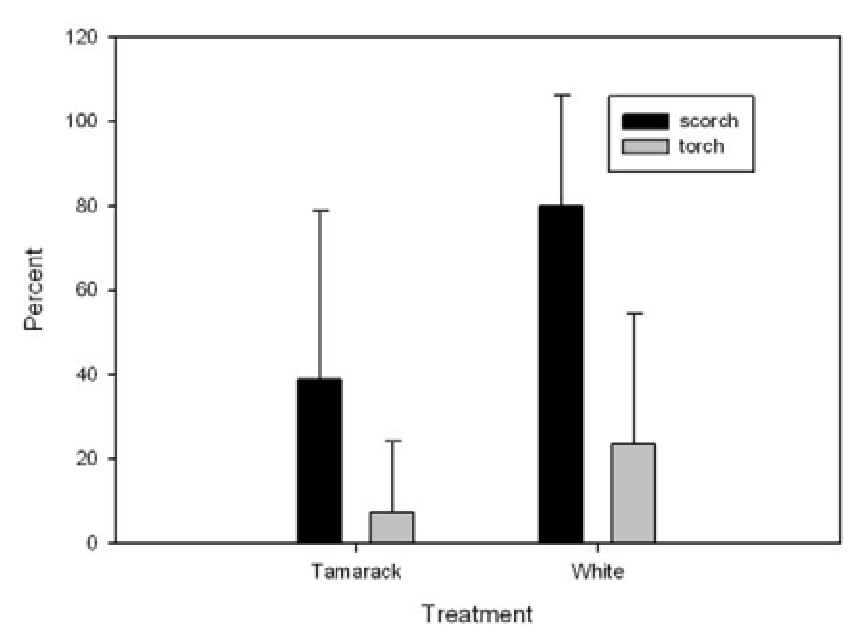


**Figure 8. Graph of mean and standard deviation (indicated by vertical lines) percent tree scorch and torch by fire within overlap areas only**

## Substrate and Understory Vegetation Burn Severity

In areas where recent fires were overlapped by the Lion Fire, litter and duff cover was 30% and bare ground cover was 54% post-burn. In Lion only areas litter and duff cover was 73% lower and bare ground was 35% higher post-burn. Both of these measures were statistically different. Summarized plot data shows that more bare ground and less litter cover were found after the Lion Fire where wildfires had not burned in the past decade. In overlap areas, the percent cover of woody debris was 6%, whereas in plots where only the Lion Fire burned, woody debris made up only 1.4% of ground cover, which was statistically different (Table 5). These results indicate that surface fuels covered more ground area after the Lion Fire burned through overlap areas than Lion only areas. Areas outside of the Lion Fire that were burned by recent fires had the highest percentage of litter and duff. The plots in the no known fire area on the west side of the Shotgun Fire showed 82% of the surface area was rock and less than 1% was basal vegetation (area filled with the base of a shrub or tree) or woody debris (Figure 9).

**Table 5. Mean (standard deviation) percent ground cover type in overlap and Lion Fire only plots**

| | Basal Vegetation | Litter and duff | Bare ground | Rock | Woody debris |
|---|---|---|---|---|---|
| Overlap | 4.3 (9.8) | 28.6 (23.0) | 52.1 (28.4) | 4.5 (5.3) | 6.0 (8.2) |
| Lion only | 2.6 (4.0) | 7.6 (11.5) | 80.4 (24.2) | 2.4 (5.9) | 1.4 (2.6) |
| P-value | 0.2168 | *0.0007 | *0.0002 | 0.0591 | *0.00015 |

* Indicates a significant difference

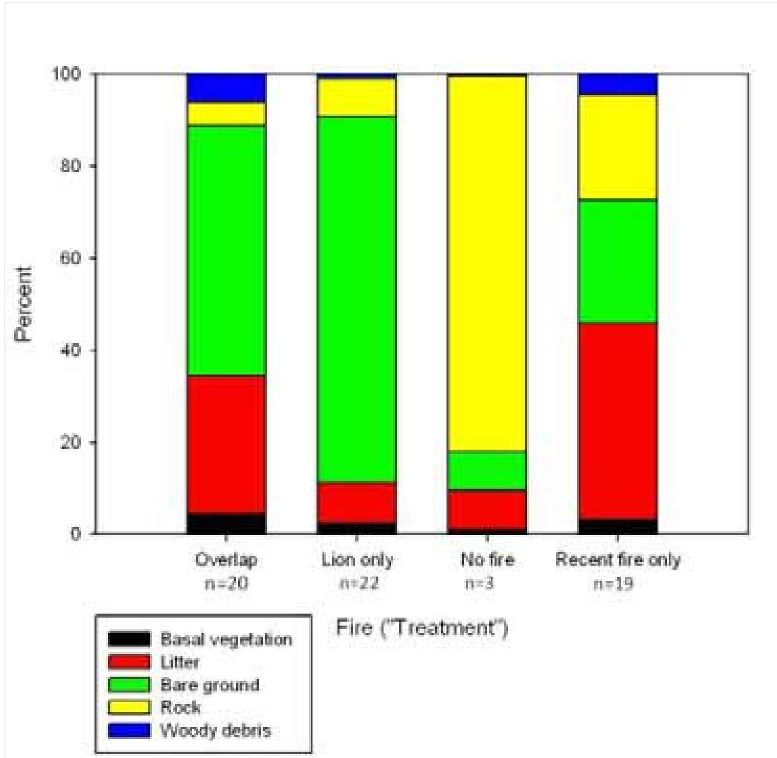


**Figure 9. Percent ground cover by type by fire history (treatment) where n = number of study sites**

In overlap areas, the mean depth of litter and duff combined was 1.5 cm. In Lion only areas, the combined litter and duff depth was 0.9 cm. In the three plots on the ridge that did not experience fire, as well as the areas burned by recent fires only (not the Lion Fire), litter and duff depths combined were about 2 cm (Figure 10).

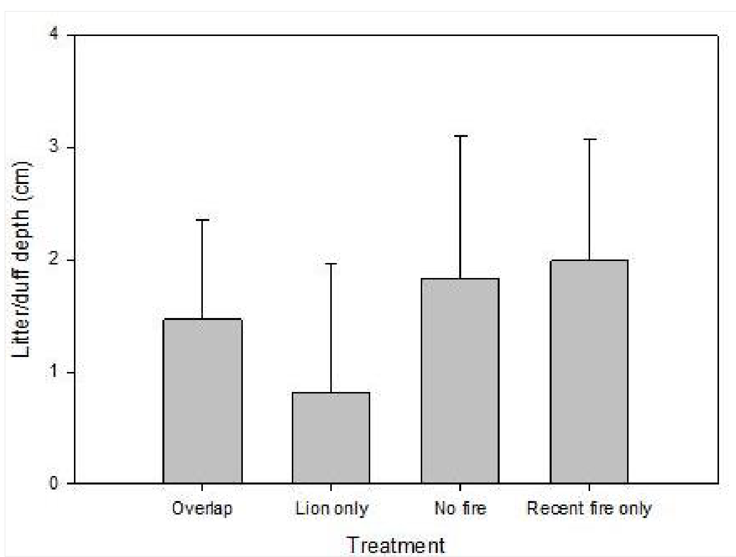


**Figure 10. Mean and standard deviation (indicated by vertical lines) of combined litter and duff depth in centimeters by recent fire history (treatment)**

**Fire Severity** - The National Park Service (NPS) uses fire severity ratings from 1 to 5 when evaluating fire severity. In this rating system, 1 represents high fire severity, while 5 represents unburned areas (Appendix II). The mean NPS understory vegetation severity rating was 3.7 in Lion Fire only plots and 2.5 in overlap plots, both with a standard deviation of 1.0 (Figure 11). Understory vegetation severity ratings were not quite significantly different between the overlap and Lion Fire only areas (p=0.0517). Mean substrate NPS ratings was 3.8 for the overlap areas and 2.8 for the Lion Fire only, with standard deviations of 0.9 and 0.7 respectively (Figure 12). Substrate severity ratings were mildly significantly different between the overlap and Lion only areas (p=0.0441). These differences show that generally lower severity levels were found in overlap areas. This dataset serves as one demonstration of how fire frequency affects vegetation structure and affects the severity level of the next fire.

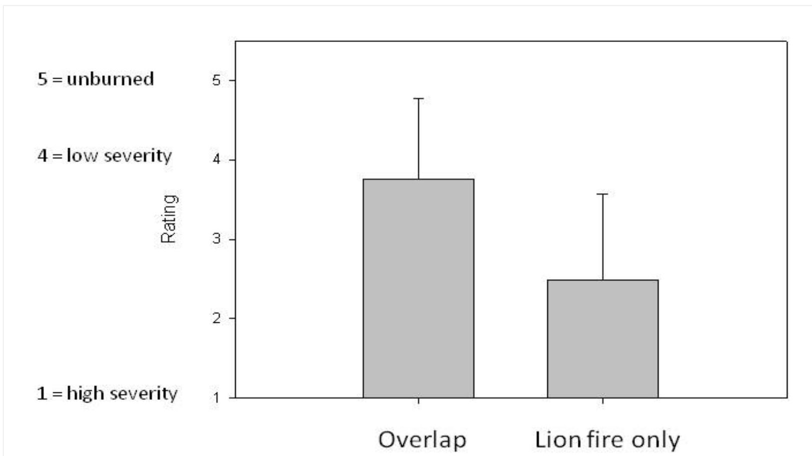


**Figure 11. Mean and standard deviation (indicated by vertical lines) National Park Service (USDI 2003) understory vegetation severity ratings in overlap and Lion Fire only plots**

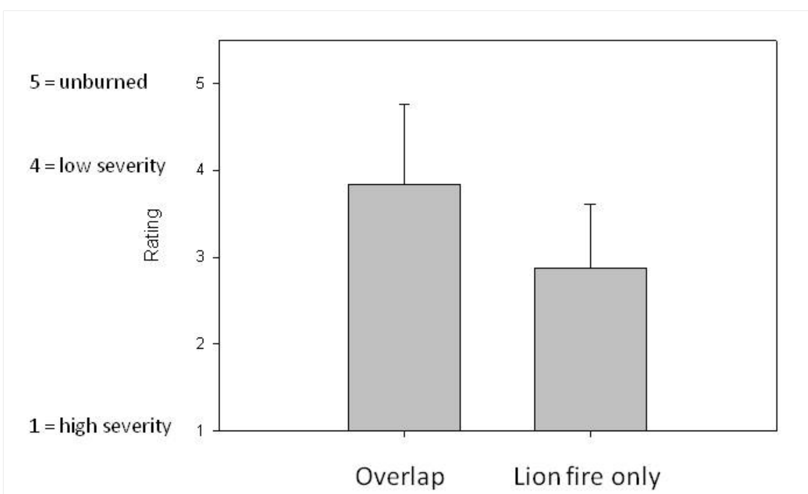


**Figure 12. Mean and standard deviation (indicated by vertical lines) National Park Service (USDI 2003) substrate severity ratings in overlap and Lion Fire only plots**

The substrate and understory vegetation severity ratings as presented in previous graphs show minor changes between where only the Lion Fire burned and where the Lion Fire overlapped recent wildfires. Further exploration of the Lion overlap areas between the Tamarack and White Fires was conducted (Figure 13). Means for NPS substrate and understory vegetation severity in these wildfire overlap areas were only slightly lower (less severe) in the 2006 Tamarack Fire than the 2001 White Fire. Neither the difference in substrate nor vegetation severity ratings were statistically significant (p=0.8102 and p=0.6816, respectively). It is possible that with more data, the minor trend of lower severity in the more recently burned area would be more definitive.

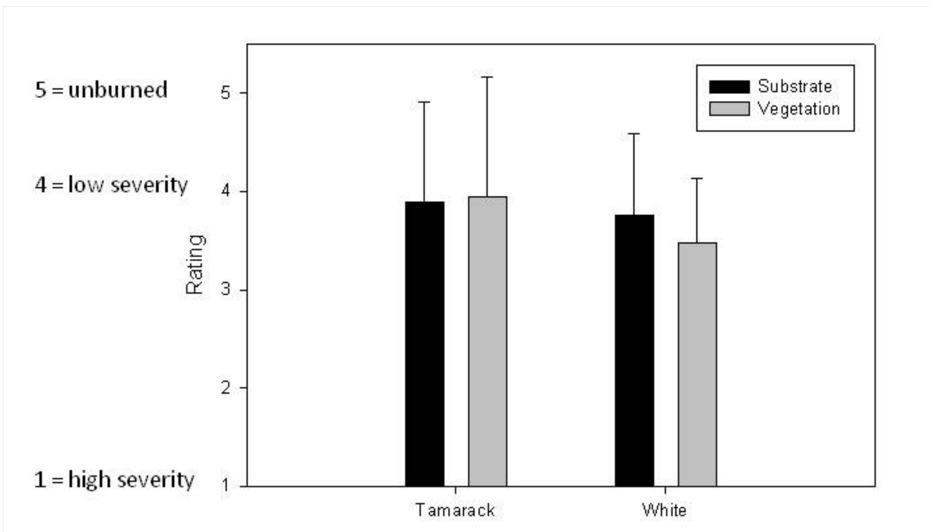


**Figure 13. Means and standard deviations (indicated by vertical lines) of substrate and understory vegetation severity ratings (NPS) in areas where the Lion Fire overlapped two recent fires**

## Understory Severity Relationships to Distance from Fire Edge

Attempts were made to explore relationships between understory severity ratings and the distances from the recent fire edge. As wildfires burn into fuel treatments, it is possible to observe first-hand decreases in fire behavior. Because real-time fire behavior transitions in fuel treatments are hard to capture, post-fire field data characterizing fire severity can be used as a surrogate for fire behavior. The concept of illustrating the fire behavior changes imposed by fuel treatments is described in Safford et al. (2009). By utilizing transects paralleling fire spread where fires burn quickly and directly into fuel treatment areas in relatively flat terrain, fire behavior changes can be seen (Safford et al. 2009). The Lion Fire burned through and abutted recent wildfires through topographically diverse areas over the course of several days. Efforts were made to place transects in areas where the Lion Fire spread directly into recent fire areas, however the Lion Fire did not necessarily spread perpendicularly to recent fire boundaries. Despite the limitations with the Lion Fire dataset, scatter plots and regressions were created and show minor relationships between severity measures and distance from recent fire edges.

When plotted against the distance from the treatment edge (positive distances are in overlap areas, negative distances are in the Lion Fire only area), a trend can be seen in the substrate severity ratings. Plots further away from the Lion Fire edge and deeper into the recent fire perimeter tend to have slightly lower fire severity, whereas plots in the Lion Fire only area, which were farther away from the recent fire, tended to have higher fire severity. In Figure 14, the regression R-squared statistic of 0.29 (on a scale of 0 to 1) means that some of the variation in substrate severity rating is explained by the distance from the edge of recent fire. In Figure 15, the R-squared statistic of 0.10 means that a little of the variation in vegetation severity rating is explained by the distance from the edge of recent fires.

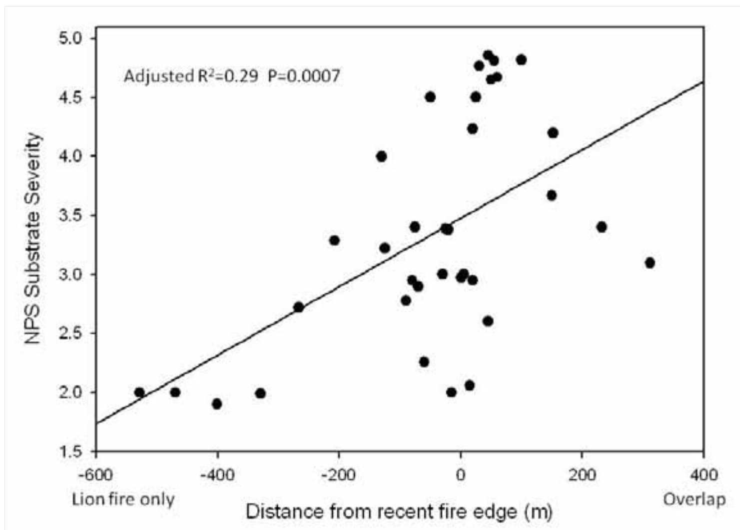


**Figure 14. Substrate severity rating (NPS) related to distance from edge of recent fire**

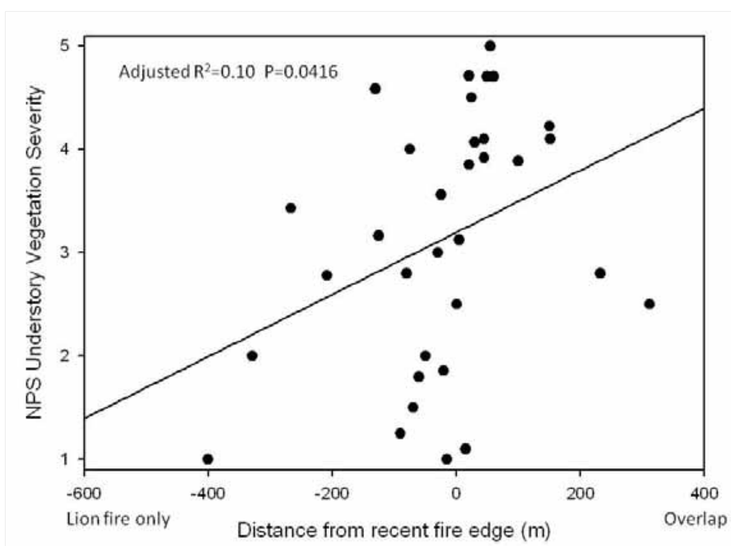


**Figure 15. Understory vegetation severity rating (NPS) related to distance from edge of recent fire**

Very little of the variation in percent tree scorch and torch are explained by distance from the edge of recent fires (Figures 16 and 17). The R-squared for both scorch and torch were 0.07 and P-values were not quite significant. However, most of the trees with less than 50% scorch and 0% torch were found in overlap areas.

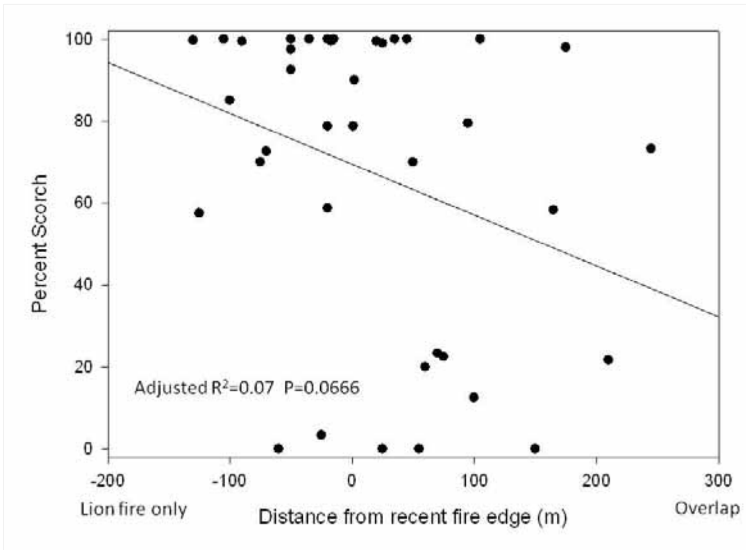


**Figure 16. Percent tree scorch related to distance from edge of recent fire**

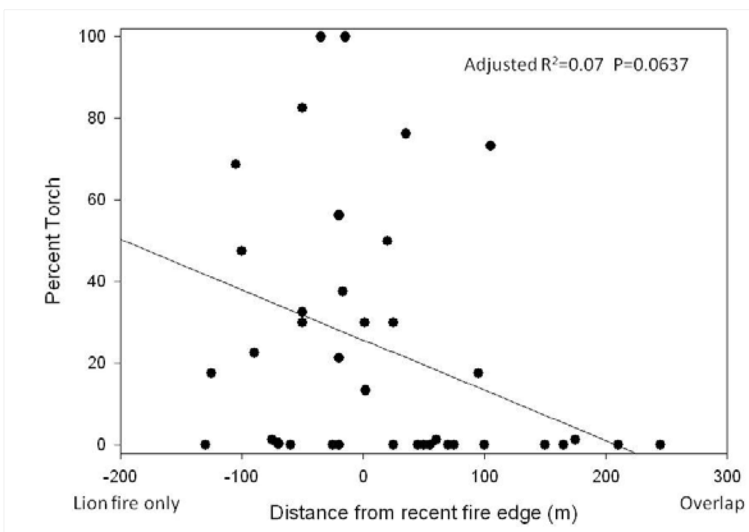


**Figure 17. Percent torch versus distance from edge of recent fire**

## Comparisons of Vegetation Severity based on Satellite Imagery

### Wildfire Interactions: Exploration of Concepts

Three concepts are explored through case studies within the Lion Fire area using the USFS spatial data on post-burn vegetation severity, called Composite Burn Index (CBI). Key and Benson (2006) describe CBI as an index value to summarize general fire effects within an area representing the average post-burn condition across multiple strata (substrate, understory, and overstory vegetation), usually on a 30 by 30 meter scale, as done in this study. Further justification and use of satellite spatial data, including the soil severity map is in Appendix III. Case studies are used to support the exploration concepts rather than spatial statistics because a small area (totaling 393 acres) contained limited fire interactions within the Lion Fire.

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*Concept 1:* **The Lion Fire overlapped recent wildfire perimeters where enough fuel remained post-fire or where sufficient time had elapsed to allow for the accumulation of surface fuels.**

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The Lion Fire did not always burn readily into areas where fuel had been reduced by previous fire (Figure 18). The amount of available fuel appeared to be a factor in whether the Lion Fire burned into recent fire areas. This concept includes the assumption that weather, topography, vegetation type, and management activities were equal factors. This concept is similar to the study conducted by Collins et al. (2009) regarding interactions among wildfire in the Illilouette Creek Basin in Yosemite, also located in the central Sierra Nevada Mountains, north of the Lion Fire. Collins' work suggests that nine years since the last fire was a threshold where previous fires constrained the extent of subsequent fires.

**Figure 18. Tamarack Fire area in foreground, Lion Fire in background**

An example of this concept is demonstrated by the 2009 Shotgun Fire, which was not reburned or overlapped by the Lion Fire.[1] It is likely that the fuel reduction that occurred from the

[1] Note in spatial analysis, the Lion Fire overlaps the Shotgun Fire, but the field crew did not observe this after multiple days. The field crew observed that the two fires' perimeters touched at the "fireline" or the walking trail along the ridgeline. The overlap in GIS layers might be from imagery issues (aspect, time of year, smoke obstruction) or a fire boundary GPS error might have occurred by recording the fire edge from helicopter. Where they do overlap in GIS, the severity was coded as mostly in the two lowest categories, meaning no burn / change or low severity.

Shotgun Fire played a part in limiting Lion Fire spread either as a direct barrier, or in association with physiographic fire barriers such as Camelback Ridge and the Litter Kern River. The self-limiting characteristics of the Shotgun Fire burn area assisted the indirect fire control actions utilized by Lion Fire incident managers. The Lion Fire bounded the Shotgun Fire burn area on three sides, but did not spread into the Shotgun Fire area. No spot fires became established within the Shotgun Fire perimeter during the Lion Fire.

*The Lion Fire bounded the Shotgun Fire burn area on three sides, yet did not spread or establish spot fires within the Shotgun Fire perimeter.*

A second example of this concept is the interaction between the 2001 White Fire and the 2009 Shotgun Fire. The north side of the White Fire was reburned eight years later by the Shotgun Fire. The Shotgun Fire burned into areas of the White Fire where severity (CBI) was classified as unchanged or low severity. The entire overlap area of these two fires is 875 meters at its longest and 425 meters at its widest point (about ½ mile by ¼ mile). The Shotgun Fire burned only 100 meters into the moderate and high severity areas of the White Fire. Data suggest that the Shotgun Fire burned where fuel loading was mostly unchanged by the White Fire, but the Shotgun Fire burned briefly and self-extinguished within 100 meters of entering the higher severity areas of the White Fire (moderate and high CBI). This is an example of a reburn occurring within eight years in low severity areas, versus extent-constrained fire behavior in the previous fire's high severity areas.

*Concept 2:* **When CBI was low or moderate severity in previous fires, the Lion Fire had more fuel to burn and produced higher severity effects on resources (higher CBIs). Conversely, when the CBI of a previous fire was high, the Lion Fire produced lower severity effects.**

Concept 2 highlights the influence of fuel reduction by previous fires on the severity of subsequent fires. This concept builds on Concept 1 in which fuel reduction from previous fires creates fuel conditions where subsequent fires either self-extinguish or are easily contained. Concept 2 can be applied to a spatial overlap of any width, including a transition zone, where an active fire transitions from heavier fuels into recently burned / reduced fuels. This transition zone is similar to Collins et al. (2009) study, which considered extent-constrained fire interactions to include up to a 200 meter (656 ft.) overlap area.

**Figure 19. View from Lion only area, looking into "overlap" between Lion and Tamarack**

An example of this concept is where the Lion Fire burned approximately 121 acres of the 2006 Tamarack in a narrow transition zone or extent-constrained pattern (Figure 19). In the overlap area, the fuel conditions created by the severity of the Tamarack Fire seemed to influence the Lion Fire (Figure 20). In the overlap area, Lion fire effects (CBI) transitioned from higher to lower severity as it burned deeper into the Tamarack perimeter and as it crested the ridge on the east side of the overlap area (Figure 21). The Lion Fire burned with higher severity inside the Tamarack perimeter where the Tamarack Fire had unchanged to low CBI severity (1 year post-burn). This area was approximately 100 meters (328 ft.) in the widest areas. The severity within this overlap is confounded with other factors that likely had an influence on the severity of the Lion Fire, including topography, weather and the direction and momentum of fire spread. Fire severity in overlap areas and the entire Lion Fire is listed in Table 6.

**Table 6. Summary of composite burn index (CBI) where Lion overlapped recent fires**

| Overlap area | CBI category (acres) | | | | Total Acres |
|---|---|---|---|---|---|
| | No burn/change | Low | Moderate | High | |
| Lion Fire CBI where it overlapped Tamarack Fire* | 42 | 48 | 17 | 14 | 121 |
| Tamarack Fire CBI where it was overlapped by Lion Fire | 20 | 58 | 39 | 4 | 121 |
| Lion Fire CBI where it overlapped White Fire* | 37 | 165 | 64 | 7 | 272 |
| White Fire CBI where it was overlapped by Lion Fire | 13 | 127 | 117 | 15 | 272 |
| Entire Lion Fire including overlapping areas with recent fires* | 4,150 | 8,694 | 5,490 | 3,174 | 21,543[1] |
| Lion Fire where it did not overlap with other fires*[2] | 3,916 | 8,438 | 5,416 | 3,157 | 20,962[1] |

[1] 35 acres were obscured or cloudy during final imagery, see Appendix III for more information.

[2] In GIS there is overlap with the Shotgun Fire (not observed in the field) that was removed for this row of data.

* CBI imagery from the same fire season as Lion Fire was used, rather than 1 year post-fire as in other fire overlap areas.

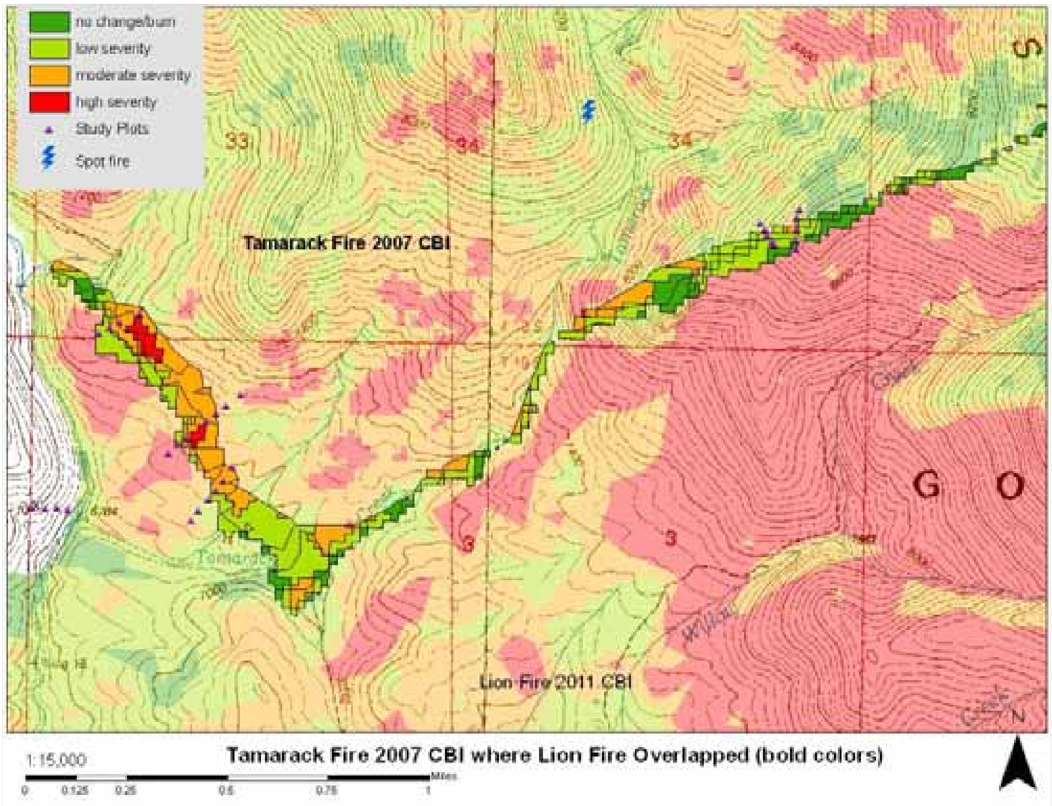


**Figure 20. 2006 Tamarack Fire composite burn index (CBI) in 2007 in bold colors where the Lion Fire overlapped it in 2011. The faded colors are the respective fires' CBI.**

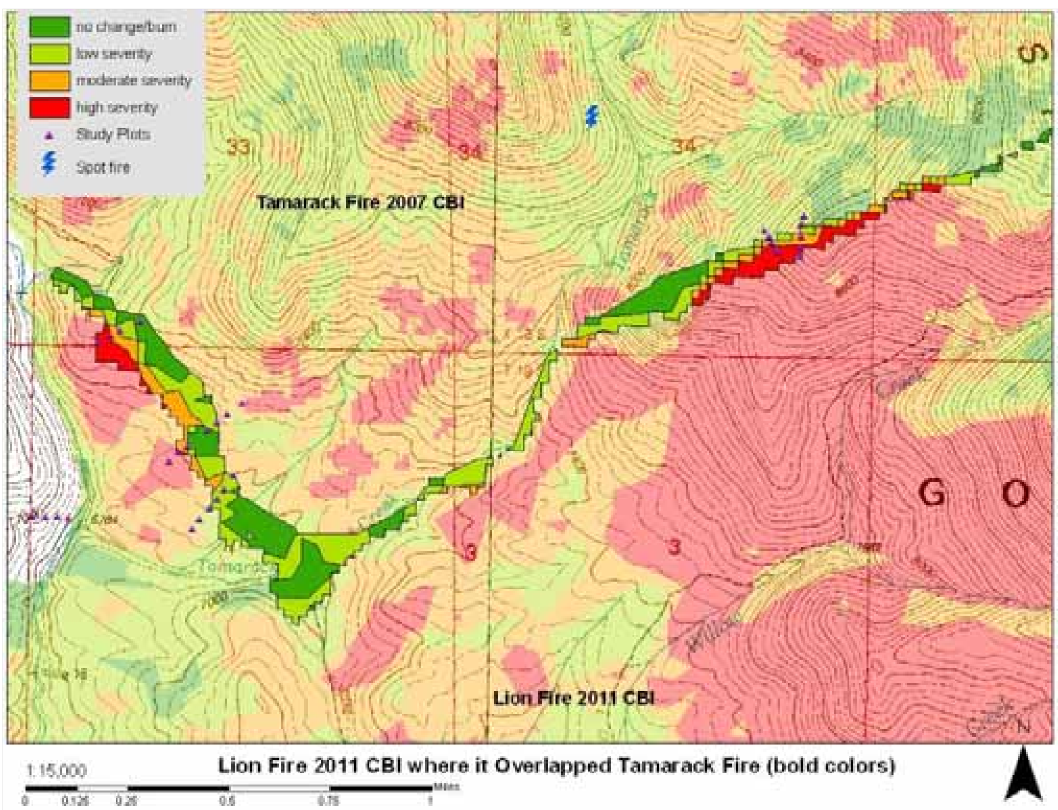


**Figure 21. Lion Fire composite burn index (CBI) immediately after the fire in 2011 in bold colors where it overlapped the 2006 Tamarack Fire. The faded colors are the respective fires' CBI.**

In a second example of this concept, the Lion Fire spotted (a burning ember was lofted a distance ahead of the fire and ignited fuels) into the Tamarack Fire perimeter approximately ½ mile north of the nearest Lion Fire edge. The spot fire occurred in a low severity (CBI) patch of the Tamarack fire, igniting a small fire that failed to spread and was only monitored from afar. The self-extinguishment of the spot fire serves as an example where recent fires create a fuel bed that limits the potential for fire spread, thus providing fire managers greater flexibility to focus firefighting personnel on more critical portions of the incident. A press release from the Sequoia National Forest stated:

> Several spot fires have, once again, proven the ecological benefit and improved firefighter safety of managing wildfire in the Golden Trout Wilderness. Spot fires ignited in areas previously burned went out on their own, with little effort from firefighters. Spot fires ignited in other places, where fire hasn't burned for over 90 years, took great efforts from firefighters and helicopters to douse the flames before they spread. "A direct result of the Lion and other managed wildfires in the Golden Trout Wilderness is that future fires should be smaller, and much less destructive," stated Western Divide District Ranger Priscilla Summers.

The overlap examples explored in Concepts 1 and 2 highlight the interrelatedness of historic fire return intervals often creating a patchwork of self-limiting fire spread perimeters (Vaillant 2009, Collins et al. 2009).

*Concept 3:* **Fuel conditions from a previous fire aided fire managers in securing portions of the Lion Fire.**

The Lion Fire burned up to, but not into, the Maggie Fire. The 31E14 trail between the Lion and Maggie Fire was used as a fire management control feature from which burnout operations were conducted. In a burnout operation, firefighters ignite fire slowly from a fireline or trail, which consumes fuel ahead of the main fire. This burned area then serves as a barrier to further spread of the main fire. The post-fire fuel loading created by the 2006 Maggie Fire (Figure 22) allowed firefighters to ignite a backing fire from the trail, constructing a barrier to the westward spread of the Lion Fire. Had the Maggie fire not occurred, fuel conditions may have required significant modification prior to burnout operations.

Firefighters utilized the trail system and firing techniques to limit resource damage to the Wilderness and private inholdings by controlling fire severity in this portion of the Lion Fire. Both the Maggie and Lion Fires in this area resulted in undetectable to low severity due to fuel conditions, the prevalence of rocky areas, the season of burn (Maggie Fire occurred in May) and the ignition technique (backing fires were ignited in the Lion Fire).

*The 2006 Maggie Fire created fuel conditions which allowed firefighters to ignite a backing fire from the trail, constructing a barrier to the westward spread of the Lion Fire.*

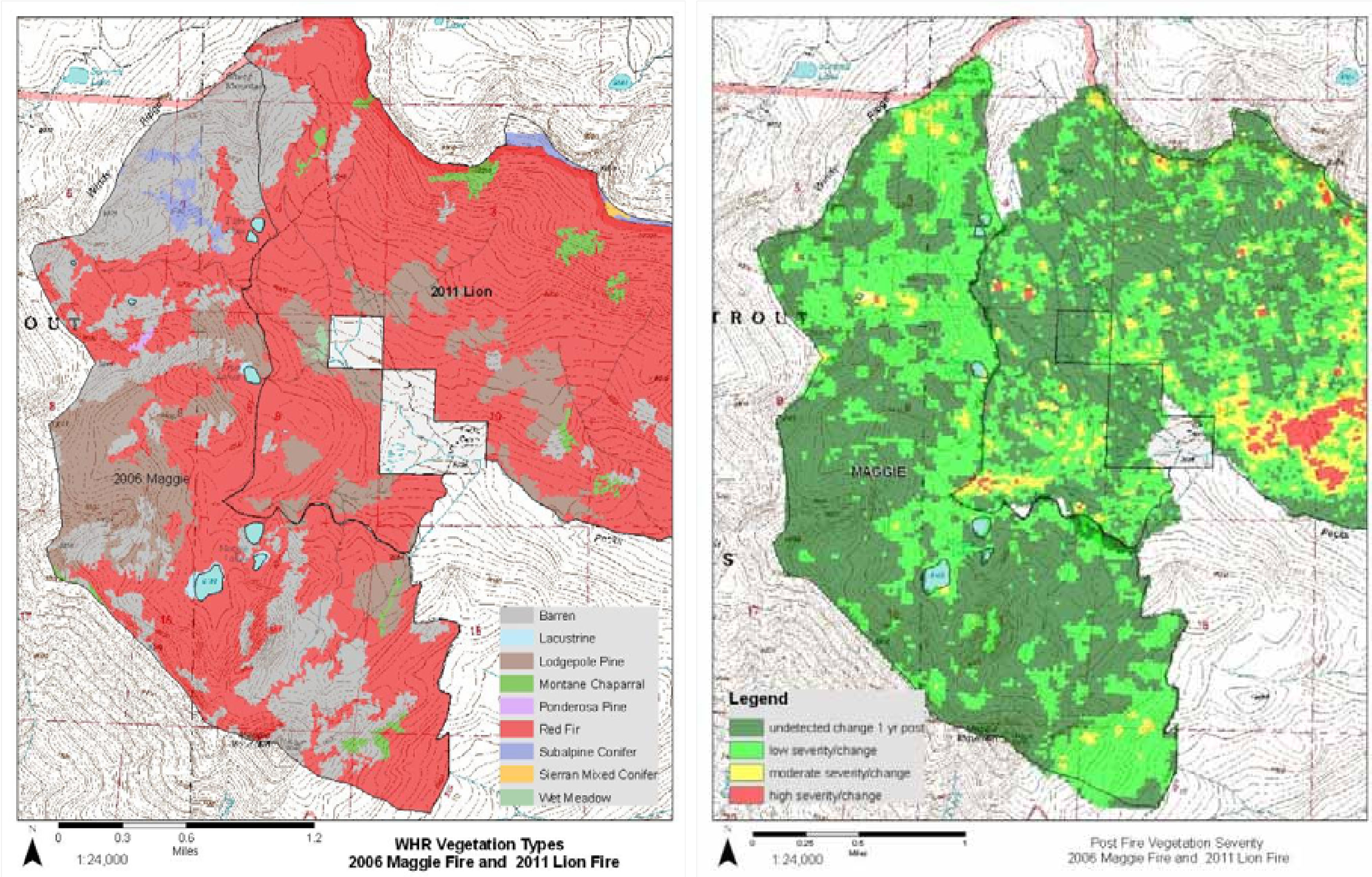


**Figure 22. 2006 Maggie and 2011 Lion Fire interaction areas**

Left figure depicts CA WHR vegetation types. Right figure depicts the CBI: immediate post-Lion Fire within the Lion Fire area, and one year post-Maggie Fire within the Maggie Fire area.

# Fire and Land Management Guidelines Related to the Lion Fire

The land management guidelines that influenced management before and during the Lion Fire are briefly introduced below.

**1. The National Cohesive Wildland Fire Management Strategy (2011)**

The vision:

- safely and effectively extinguish fire, when needed
- use fire where allowable
- manage our natural resources
- as a nation, live with wildland fire

Eleven guiding principles and core values are listed in Part II of the Cohesive Strategy. Of these principles and core values, the land mangers associated with the Lion Fire actively demonstrated a commitment to several of these principles and values during the management of this incident. The values and principles that most applied to the management actions on the Lion Fire are:

- Sound risk management is the foundation for all management activities.
- Actively manage the land to make it more resilient to disturbance, in accordance with management objectives.
- Wildland fire, as an essential ecological process and natural change agent, may be incorporated into the planning process and wildfire response.
- Fire management decisions are based on the best available science, knowledge and experience, and used to evaluate risk versus gain.
- Fire management programs and activities are economically viable and commensurate with values to be protected, land and resource management objectives, and social and environmental quality considerations.

**2. The Sierra Nevada Forest Plan Amendment (SNFPA or "Framework" 2004)**

The 1988 Sequoia National Forest Land and Resource Management Plan was amended in 2004 by the Framework. For fire, fuels, and wilderness management guidelines within SQF, the Framework is most current. The following are applicable experts from the Framework related to the management of the Lion Fire study area.

- **Lightning-caused fires (SNFPA Record of Decision [ROD] p. 35):** "Lightning-caused fires may be used to reduce fuel loads or to provide other resource benefits, such as conserving populations of fire-dependent species. Before wildland fires can be used, national forest managers must prepare a fire management plan that describes how prescribed fires and naturally caused wildland fires will achieve resource management objectives." (The Chief exempted the SQF from the fire management plan requirement.)

- **Fire and Fuels Management Goals (SNFPA ROD p. 34):** "Goals for fire and fuels management include reducing threats to communities and wildlife habitat from large, severe wildfires and re-introducing fire into fire-adapted ecosystems. Broad-scale goals include: treating fuels in a manner that significantly reduces wildland fire intensity and rate of spread, thereby contributing to more effective fire suppression and fewer acres burned; treating hazardous fuels in a cost-efficient manner to maximize program effectiveness; and actively restoring fire-adapted ecosystems by making demonstrated progress in moving acres out of unnaturally dense conditions (in other words, moving acres from condition class 2 or 3 to condition class 1)."
- **Strategy (SNFPA ROD p. 34-35):** "The landscape-scale fire modification strategy adopted in this Decision is based on the premise that disconnected fuel treatment areas overlapping across the general direction of fire spread are theoretically effective in changing fire spread. . . . As such, the Decision explicitly recognizes two criteria that must be met for the strategy to be effective: the pattern of area treatments across the landscape must interrupt fire spread, and treatment prescriptions must be designed to significantly modify fire behavior within the treated area. The Decision directs strategic placement of area treatments, ranging in size from 50 to over 1,000 acres (generally averaging between 100 to 300 acres), across landscapes to interrupt fire spread and thereby reduce the size and severity of wildfires."
- **Land Allocation - Wilderness Areas and Wild and Scenic Rivers (SNFPA ROD p. 36). Desired Condition:** Wilderness is a unique and vital resource. It is an area where the earth and its community of life are untrammeled by humans, where humanity itself is a visitor who does not remain . . . Natural conditions are protected and preserved. Consistent with the National Fire Plan's goal for restoring fire-adapted ecosystems, fire is restored as a natural process through wildland fire use (appropriate wildfire response). The area generally appears to have been affected primarily by the forces of nature, with the imprint of humanity's work substantially unnoticeable. Human influence does not impede or interfere with natural succession in the ecosystems.

Both the vision and principles of the Cohesive Strategy and the land management direction of the Framework informed the decision making process associated with the management of the Lion Fire. The flexibility to use a multiple objective approach to wildfire management permits the Forest to address agency direction and policy, while also assuring that appropriate risk management processes are in place to assure for the safety of firefighters and the public.

# SUMMARY AND CONCLUSIONS

Only two recent fires were measurably overlapped by the Lion Fire, the 2006 Tamarack and the 2001 White Fires. The Lion Fire stopped at the perimeter of two other recent fires, the 2009 Shotgun and the 2006 Maggie Fires. The 2003 Cooney Fire, nearly adjacent to the east side of the Lion Fire, did not reburn. If embers from the Lion Fire did land in the Cooney Fire area, spot fires did not noticeably develop. The documented wildfire interactions lead to one overriding conclusion: recent fires not only affected the extent and effects of the Lion Fire, but also aided fire managers to corral the Lion Fire. Additionally, the fuel and ecological conditions created by the Lion Fire are an incremental step toward landscape level resiliency.

*The documented wildfire interactions lead to one overriding conclusion: recent fires not only affected the extent and effects of the Lion Fire, but also aided fire managers to corral the Lion Fire.*

Another recurring theme of wildfire interactions was that the fuel reduction that occurred on recent fires played a role in reducing fire behavior and severity of the subsequent fire. The field data showed trends of lower severity in areas where the Lion Fire overlapped other recent fires compared to areas where fires had not recently burned. The Lion Fire burned into the Tamarack Fire in a narrow overlap zone, which can be partially attributed to the lower fuel loadings associated with the Tamarack Fire. Previous to the Lion Fire, the 2009 Shotgun Fire displayed similar burning characteristics, as the spread from this fire stopped or was held by fire management actions, within 100 meters of entering the moderate and high fire severity (CBI) areas of the 2001 White Fire.

The lower fire severity levels found in the portions of the Lion Fire where recent wildfires overlapped is more consistent with historic fire regimes for the lower and upper montane forests of the Sierra. During the Lion Fire, 1000-hour fuel moistures were generally at or below average for that time of year and Energy Release Components were average or slightly above average during the active burning days of the Lion Fire.

Prior to European settlement, fire severity in the lower montane forests was generally low to moderate. High burn severity would have only occurred during extreme weather conditions (van Wagtendonk and Fites-Kaufman 2006) in a natural fuel and fire regime. The weather conditions during the Lion Fire did not constitute extreme weather conditions, so given postulated historic fire severities, high fire severity probably should not have been recorded in as large of patch sizes as was measured on the Lion Fire if natural fire regimes had been acting on the landscape over the entire past century. Most of the Lion fire area contained the first recorded fire activity in the last 90 years, so the built up fuel conditions were potentially hazardous to Wilderness users, firefighters, and natural resources including water and air quality. Firefighters assigned to the Lion Fire chose to ignite backing fires on the west side of the fire in order to avoid the high severity burn patches they observed on the east side when the fire spread in a head fire orientation. Nesmith et al. (2011) compared effects of prescribed fires and wildfires managed for resource objectives at Sequoia and Kings Canyon National Parks (the Parks on the north side of the Lion Fire). They found that fire effects observed between managed wildfires and prescribed fires indicate that both fire types are creating post-fire conditions similar to natural fires when reviewed on a fine spatial scale, despite constraints to days when managed fires can burn freely.

As management allows wildfires to reestablish natural patterns on the landscape, fuels and tree densities in the lower and upper montane forests will be reduced on a more wide-scale basis, and fire regimes and severity could be more aligned with the historic range of variability. Reduced fuel loads and less-dense forest conditions associated with a resilient fire regime process in the Sierra Nevada could lower the total number of personnel needed to manage a fire, because recent burns will self-limit fire spread under moderate burning conditions.

Additional monitoring efforts and some revisions to this monitoring approach in future projects would allow stronger conclusions to be drawn regarding the effectiveness of wildland fire treatments. Monitoring wildfire interactions on more fires in future years would create a larger dataset from which to draw conclusions about the interaction of wildfires with areas previously burned. In future efforts, locating plots using a grid-based approach rather than the transect approach could yield a stronger dataset, however, it may also require a longer time commitment for navigating to widely-spaced plots in a wilderness setting. Stratifying plot locations based on vegetation and severity level would also yield a more even dataset for the type of conclusions drawn. Gathering tree data in a fixed-radius plot would yield a stronger dataset for analysis of tree data by diameter class, however would also require more time. Additionally, larger scale and longer-term monitoring of fire effects and post-fire regeneration would provide data needed to clarify the fire effects of wildland fire treatments.

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# APPENDIX I. DETAILED METHODS

Three to eleven study plots were established along transects approximately perpendicular to the perimeter of the sampled fires. Plots were established along transects in: (1) the area where the Lion Fire reburned or overlapped a recent fire perimeter, termed "overlap"; (2) where only the Lion Fire burned, termed "Lion only": (3) and in some areas where the recent fires burned, but not the Lion Fire, termed "recent fire". These three groupings functioned as "treatment" categories for data analysis. The number of plots along transects as well as distances between plots along transects varied, generally between 20 to 75 meters depending on the extent of the overlap area.

Overlap areas were defined by the field crew by visual indicators of recent fire prior to the current Lion Fire, such as large numbers of snags that obviously burned before the Lion Fire. The fire monitors considered the burn indicators they observed at the plots to be more accurate than fire perimeters data, which were likely GPS-located via helicopter, satellite imagery, or on foot. On two transects, indicators of recent fires could not be determined, so GIS information of recent fire perimeters was utilized. Distances from fire boundaries and between plots were measured in the field and corroborated with GPS locations after field data collection.

At each plot along the transects tree data was sampled based on the point-center quarter (PCQ) method (Cottam and Curtis 1956) in which the closest tree greater than or equal to 10 cm diameter at breast height (DBH) in each quadrant of the plot was measured. For each PCQ tree, a laser range-finder was used to measure the distances and tree measurements other than DBH. Height to live crown was measured as the height to the lowest part of the canopy where branches filled 1/3 of a horizontal slice of canopy. Tree scorch was defined as fire-caused brown or orange needles/leaves, and torch occurred where needles were consumed. At each plot recorded data included:

- GPS coordinates
- Slope
- Aspect
- Photographs up and down transect
- Distance from plot center to trees
- Tree heights
- Average bark char heights
- Average scorch heights
- Average torch heights
- Heights to live crown
- Species
- DBH
- Tree damage/disease

Trees were considered "dead" if all foliage were either scorched or consumed by the fire, although some trees in this category may grow green needles and survive one or more years later. If a tree was dead prior to the Lion Fire was the closest in the quadrant, it was measured in order to include effects of previous wildfires on tree health.

Additional tree metrics measured at each plot included a count of live and dead trees greater than or equal to 10 cm DBH within an 8 meter radius of plot center and within a recorded basal area factor (variable radius plot) using a relaskop (slope correcting prism). Percent cover of live and dead trees was estimated within a 2-meter radius circle, which is a subplot area further described.

Understory vegetation and severity measures were also collected within a 2-meter radius circle subplot located at the tree plot center. Percent cover of total understory vegetation, basal vegetation, litter and duff, bare ground, rock and woody debris were estimated in the 2-meter radius plot. Percent shrub, grass and forb cover was also estimated separately. Litter and duff depth was measured as a combined depth in three random places within the 2-meter radius plot and an average depth was recorded. Pre-fire shrub cover was estimated when possible. Categorical severity ratings (1 to 5 and Not Applicable; see Appendix II for details) were assigned to both the substrate and the understory vegetation (USDI 2003).

The remote sensing and GIS-based methods are explained further in Appendix III.

# APPENDIX II. ADDITIONAL TABLES AND FIGURES

**Table 7. Field study number of plots and transects subdivided by recent fire name and treatment type**

| Transect number | Overlap with Lion | | Lion only | | | No fire | Recent fire only | | | Total Plots |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tamarack | White | near Shotgun | near Tamarack | near White | Shotgun/ Lion boundary | Shotgun | Tamarack | White | |
| 1 | 2 | | | 1 | | | | 1 | | 4 |
| 2 | | 4 | | | 2 | | | | 5 | 11 |
| 3 | 4 | | | 1 | | | | | | 5 |
| 4 | 2 | | | 2 | | | | 1 | | 5 |
| 5 | 3 | | | 3 | | | | 1 | | 7 |
| 6 | 2 | | | 3 | | | | 1 | | 6 |
| 7 | | | | | 6 | | | | | 6 |
| 8 | | 3 | | | | | | | | 3 |
| 9 | | | | | | 1 | 2 | | | 3 |
| 10 | | | | | | 1 | 2 | | | 3 |
| 11 | | | | | | 1 | 2 | | | 3 |
| 12 | | | 1 | | | | 1 | | | 2 |
| 13 | | | 1 | | | | 1 | | | 2 |
| 14 | | | 1 | | | | 1 | | | 2 |
| 15 | | | 1 | | | | 1 | | | 2 |
| Total plots | 13 | 7 | 4 | 10 | 8 | 3 | 10 | 4 | 5 | **64** |

**Table 8. Burn severity coding matrix from the National Park Service (USDI 2003)**

| | Forests | | Shrublands | |
|---|---|---|---|---|
| | **Substrate** | **Vegetation** | **Substrate** | **Vegetation** |
| **Unburned (5)** | not burned | not burned | not burned | not burned |
| **Scorched (4)** | litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged | foliage scorched and attached to supporting twigs | litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged | foliage scorched and attached to supporting twigs |
| **Lightly Burned (3)** | litter charred to partially consumed; upper duff layer may be charred but the duff layer is not altered over the entire depth; surface appears black; woody debris is partially burned | foliage and smaller twigs partially to completely consumed; branches mostly intact | litter charred to partially consumed, some leaf structure undamaged; surface is predominately black; some gray ash may be present immediately after burn; charring may extend slightly into soil surface where litter is sparse otherwise soil is not altered | foliage and smaller twigs partially to completely consumed; branches mostly intact; less than 60% of the shrub canopy is commonly consumed |
| **Moderately Burned (2)** | litter mostly to entirely consumed, leaving course, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common | foliage, twigs, and small stems consumed; some branches still present | leaf litter consumed, leaving course, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common | foliage, twigs, and small stems consumed; some branches (0.25-0.50 inch in diameter) still present; 40-80% of the shrub canopy is commonly consumed. |
| **Heavily Burned (1)** | litter and duff completely consumed, leaving fine white ash; mineral soil visibly altered, often reddish; sound logs are deeply charred and rotten logs are completely consumed. This code generally applies to less than 10% of natural or slash burned areas | all plant parts consumed, leaving some or no major stems or trunks; any left are deeply charred | leaf litter completely consumed, leaving a fluffy fine white ash; all organic material is consumed in mineral soil to a depth of 0.5-1 in., this is underlain by a zone of black organic material; colloidal structure of the surface mineral soil may be altered | all plant parts consumed leaving only stubs greater than 0.5 in. in diameter |
| **Not Applicable (0)** | inorganic preburn | none present preburn | inorganic preburn | none present preburn |

**Table 9. Mean (minimum-maximum) diameter, total height, and height to live crown for all measured trees in the study plots. See figure in main document for graphic display**

| Fire History (treatment) | Mean DBH (min-max) cm. | Mean height (min-max) m. | Mean height to live crown (min-max) m. |
|---|---|---|---|
| No Known Fire | 61 (16-200) | 11 (4-22) | 3 (0-7) |
| Recent fire only (Tamarack, White, Shotgun) | 49 (10-218) | 16 (2-38) | 4 (0-55) |
| Lion Fire Only | 35 (10-152) | 13 (2-33) | 4 (0-20) |
| Recent fires Overlapped by Lion Fire | 41 (10-143) | 14 (2-47) | 3 (0-17) |

**Table 10. Overstory tree basal area (BA) and trees per acre (TPA) for all overstory trees and separated for live and dead trees compared by fire history. See figure in main document for graphic display.**

| Fire History (treatment) | Live & Dead BA ($ft^2/ac$) | Live BA ($ft^2/ac$) | Dead BA ($ft^2/ac$) | Live & Dead TPA | Live TPA | Dead TPA |
|---|---|---|---|---|---|---|
| No Fire | 112 | 112 | 0 | 13 | 13 | 0 |
| Recent Fires Only | 151 | 97 | 54 | 73 | 44 | 29 |
| Lion Fire Only | 118 | 57 | 61 | 117 | 35 | 83 |
| Recent Fires Overlapped by Lion Fire | 117 | 65 | 52 | 81 | 35 | 47 |

**Table 11. Mean (minimum to maximum) overstory tree char, scorch, and torch**

| Fire History (treatment) | Mean Char m. (min-max) | Mean Scorch m. (min-max) | Mean Scorch % | Mean Torch m. (min-max) | Mean Torch % |
|---|---|---|---|---|---|
| Lion Fire Only | 6 (0-32) | 12 (0-100) | 78 | 5 (0-45) | 34 |
| Recent Fires Overlapped by Lion Fire | 2 (0-28) | 6 (0-72) | 38 | 1 (0-10) | 10 |

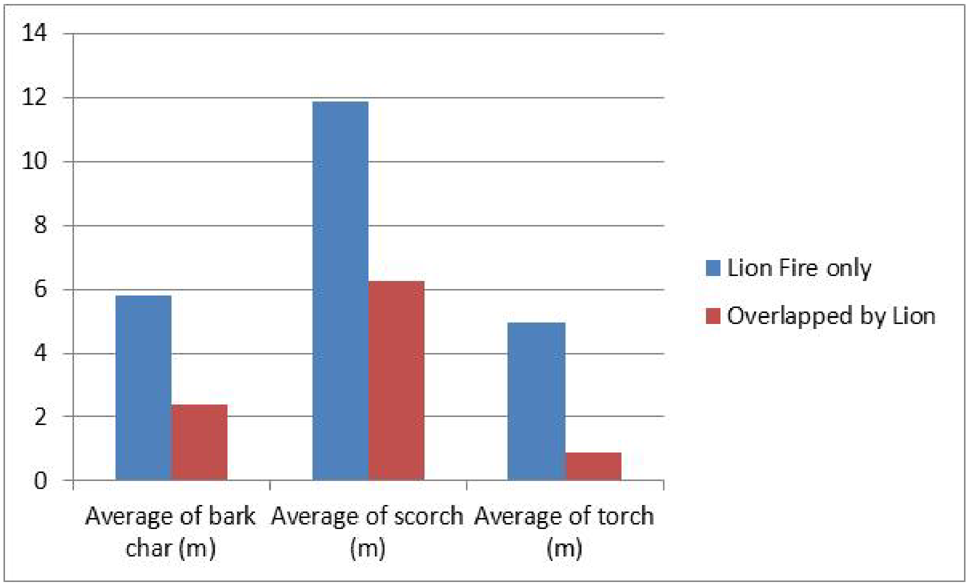



**Figure 23. Mean overstory tree char, scorch, and torch compared to fire history**

# Appendix III. Exploration of Satellite Imagery Data

Satellite imagery was utilized to summarize burn severity patterns, separately and combined for the vegetation and substrate layers, across the entire Lion Fire as well as other fires discussed in the main report. Satellite derived post-burn severity imagery was used in this report to draw conclusions about wildfire interactions in areas where limited field data was collected (see main report). The Lion Burned Area Emergency Response (BAER) team's final soil severity map is a modification of the Burned Area Reflectance Classification (BARC) satellite derived map using field measured / verified fire effects to the soils and characteristics from the previously mapped soil types (Parsons et al. 2010, Safford et al. 2007).

The Pacific Southwest Region of the Forest Service uses a relative index calibration process (Miller and Thode 2007) to create standardized post-fire severity spatial data and maps, including the Composite Burn Index (CBI) generated from satellite imagery by Miller and the *Rapid Assessment of Vegetation Condition* staff (2006 to 2011). Calibration equations are based on field data taken on multiple fires in the Sierra Nevada utilizing CBI field protocols as described in Key and Benson (2006). Key and Benson (2006) describe CBI as an index to represent fire effects combined across multiple strata (substrate, understory, and overstory vegetation). The field protocol was designed for easy remote sensing comparisons, usually on a 30 by 30 meter scale, as done in this report. The satellite derived CBI data is based on multi-temporal change detection, usually made by comparing pre-fire and *one year* post-fire imagery for wildfires. All stand replacing areas are assigned the high severity classification regardless of pre-fire cover (Safford et al. 2007). For the Lion Fire, CBI data was compared to *immediate post-fire imagery* in 2011. The Lion Fire vegetation severity was preliminarily assessed with imagery taken *immediately* post-fire until a 2012 version is available. Contrastingly, for the fires recently preceding the Lion Fire discussed in the main report, the available spatial data follows the normal process of using *one-year* post-fire imagery.

Post-fire effects to soil and vegetation are often described using the same terms despite having potentially different natural resource implications. Table 12 lists the four vegetation severity categories used for post-fire CBI vegetation and substrate strata combined by Miller and Thode (2007). Table 13 lists the soil severity definitions used by the BAER team for the soil severity map (Parsons et al. 2010).

**Table 12. Composite Burn Index (CBI) severity category definitions (Miller and Thode 2007)**

| CBI Severity Category | Index Definition |
|---|---|
| Unchanged | One year after the fire, the area was indistinguishable from pre-fire conditions. This does not always indicate the area did not burn. |
| Low | Areas of surface fire occurred with little change in cover and little mortality of the structurally dominant vegetation. |
| Moderate | The area exhibits a mixture of effects ranging from unchanged to high. |
| High | Vegetation has high to complete mortality. |

**Table 13. Burned Area Emergency Response (BAER) team soil severity map definitions (Parsons et al. 2010)**

| Severity category | Soil Burn Severity Indicators (definitions) |
|---|---|
| Unburned/Very low | unburned to lightly burned/scorched (assumed definition) |
| Low | Surface organic layers are not completely consumed and are still recognizable. Structural aggregate stability is not changed from its unburned condition, and roots are generally unchanged because the heat pulse below the soil surface was not great enough to consume or char any underlying organics. The ground surface, including any exposed mineral soil, may appear brown or black (lightly charred), and the canopy and understory vegetation will likely appear "green." |
| Moderate | Up to 80 percent of the pre-fire ground cover (litter and ground fuels) may be consumed but generally not all of it. Fine roots (~0.1 inch or 0.25 cm diameter) may be scorched but are rarely completely consumed over much of the area. The color of the ash on the surface is generally blackened with possible gray patches. There may be potential for recruitment of effective ground cover from scorched needles or leaves remaining in the canopy that will soon fall to the ground. The prevailing color of the site is often "brown" due to canopy needles and other vegetation scorch. Soil structure is generally unchanged. |
| High | All or nearly all of the pre-fire ground cover and surface organic matter (litter, duff, and fine roots) is generally consumed, and charring may be visible on larger roots. The prevailing color of the site is often "black" due to extensive charring. Bare soil or ash is exposed and susceptible to erosion, and aggregate structure may be less stable. White or gray ash (up to several centimeters in depth) indicates that considerable ground cover or fuels were consumed. Sometimes very larger tree roots (>3 inches or 8 cm diameter) are entirely burned extending from a charred stump hole. Soil is often gray, orange, or reddish at the ground surface where large fuels were concentrated and consumed. |

This exploration uses the satellite derived severity layers and field based severity ratings to compare how well they align. This exploration compares: (1) satellite severity layers to severity ratings from field data; (2) BAER compared CBI layers; and (3) satellite severity compared to California Wildlife Habitat Relationship (vegetation) types.

### Comparisons of Satellite Imagery Compared to Field Data

A GIS comparison was done between the BAER team soil severity layer and 51 field plot's substrate severity assessments within the Lion Fire perimeter. A second GIS comparison was done between the CBI overall severity index and the field data assessment for under and overstory vegetation severity within the Lion Fire perimeter. Using a 4-meter diameter "snapshot" around the center point of the field plots, the overlaid satellite imagery resulted in 12 out of 51 field plots with multiple CBI and BAER severity codes. When multiple GIS severity codes resulted for one field plot, then the severity code that aligned to the greatest proportion of the field plot is displayed in the summary tables (Table 14 and Table 15a, b, and c).

The field data for substrate severity was based on ocular estimates using the 5-code NPS (2003) protocol (Appendix I). Field data Overstory vegetation severity assessment was based on handheld laser measurements and ocular estimates for each tree in the variable radius plot. Field plot understory and substrate / soil severity measurements were based on ocular estimates in a 4-meter diameter subplot. See Appendix I for detailed methodology. Multiple severity codes were assigned to each field plot severity category based on percentage, and these were averaged to determine one overall code for each strata used in the comparisons. The data scale for comparisons of plot level data and remote satellite imagery is not similar and makes case study conclusions difficult because satellite imagery uses a 30 by 30 meter pixel scale, while field plot data was assessed from a 4-meter diameter and a variable radius plots as mentioned above.

Lion Fire understory vegetation covered the landscape in a patchy, non-continuous pattern. Partially for this reason, understory burn severity for an entire plot area was difficult to analyze and show trends during comparisons. For ease of comparison, both the unburned / not applicable and scorched / lightly burned categories for field plot severity are combined to compare to the four-category BAER soil severity codes. Table 14 and Table 15 are color coded where the same severity code was assigned by both protocol. The most obvious differences during comparisons were in the low and moderate severity categories.

Another difference was the BAER soil severity data assigned higher severity categories to more field plot locations than the field plot protocol. This might be explained by a 5-code field protocol being compared to a 4-code satellite image. The difference for the field plot protocol between the moderate and high (heavily burned) severity substrate rating for forested sites was mostly if the mineral soil was visibly altered (often reddish). On average per plot, heavily burned or high soil severity did not describe the majority of any 4-meter subplots, but did make up portions of some subplots.

Vegetation and substrate assessments in field plot and satellite CBI comparisons (Table 15a, b, and c) had similar trends to those found in the BAER substrate comparison. The CBI rating was almost evenly distributed among all 51 of the field plots in the Lion Fire. The average ratings for field plot vegetation scorch and torch trended toward: more plots being unburned / not applicable according to field data; a similar amount of plots being moderate severity in both datasets; field based low and high overstory severity plots were less than the CBI ratings; and field based low understory and substrate severity was greater represented when compared to the CBI ratings.

In summary, the field plot and satellite derived data comparisons have both similarities and differences, which can be partly explained by methods used to derive each data layer. Comparisons would be improved if the field methods were more closely aligned to the assumptions / protocol of the satellite derived data layers (both CBI and BAER protocol). Improved methodology in field data collection and greater quantities of field data would assist in better calibration of the satellite fire severity ratings with ground-based observations as done by Miller and Thode (2007), Miller et al. (2009), and some BAER teams.

**Table 14. Burned Area Emergency Response (BAER) soil severity ratings and 4-meter diameter field subplot substrate severity assessment comparison within the Lion Fire**

| Field Plot Substrate/Soil Severity | Burned Area Emergency Response (BAER) Soil Severity | | | | Total plots |
|---|---|---|---|---|---|
| | No change/burn | Low | Moderate | High | |
| Unburned/NA | 17 | 2 | 2 | | 21 |
| Low | 5 | 6 | 11 | | 22 |
| Moderate | 1 | 1 | 4 | 2 | 8 |
| Total Plots | 23 | 9 | 17 | 2 | 51 |

**Table 15 a, b, and c. Comparison of 4-meter diameter Composite Burn Index (CBI) overall severity ratings overlaid on field plot severity assessments within the Lion Fire.** Unburned/NA means that strata was not present in the subplot or was not burned by the Lion Fire.

**15a. Field Plot Overstory Vegetation Severity Compared to CBI**

| Field Plot *Overstory* Veg. Severity | Composite Burn Index (Overall Severity) | | | | Total plots |
|---|---|---|---|---|---|
| | No change/burn | Low | Moderate | High | |
| Unburned/NA | 11 | 9 | 1 | 2 | 23 |
| Low | 2 | 1 | 3 | 1 | 7 |
| Moderate | | 2 | 9 | 3 | 14 |
| High | 1 | | | 6 | 7 |
| Total Plots | 14 | 12 | 13 | 12* | 51 |

**15b. Field Plot Understory Vegetation Severity Compared to CBI**

| Field Plot *Understory* Veg. Severity | Composite Burn Index (Overall Severity) | | | | Total plots |
|---|---|---|---|---|---|
| | No change/burn | Low | Moderate | High | |
| Unburned/NA | 12 | 6 | 1 | 3 | 22 |
| Low | 1 | 6 | 12 | 1 | 20 |
| Moderate | 1 | | | 4 | 5 |
| High | | | | 4 | 4 |
| Total Plots | 14 | 12 | 13 | 12 | 51 |

**15c. Field Plot Substrate/Soil Severity Compared to CBI**

| Field Plot *Substrate/Soil* Severity | Composite Burn Index (Overall Severity) | | | | Total plots |
|---|---|---|---|---|---|
| | No change/burn | Low | Moderate | High | |
| Unburned/NA | 13 | 6 | 2 | | 21 |
| Low | | 6 | 11 | 5 | 22 |
| Moderate | 1 | | | 7 | 8 |
| Total Plots | 14 | 12 | 13 | 12* | 51 |

*During plot level averages there were no high substrate severity (USDI 2003) field subplots in the Lion Fire area that was studied.

### Comparisons between BAER and CBI layers

In order to explore the differences between two burn severity spatial data products used in fire management and monitoring, comparisons were made between the BAER and the CBI layers (described more above).

### Fire Severity Differences between Habitat Types

The Sequoia National Forest's California Wildlife Habitat Relationship (CA WHR) vegetation map was used to compare fire severity a between habitat types. Almost 50 percent of the Lion Fire area consisted of the CA WHR vegetation type red fir, which is defined as single species dominated, but in some areas of the Lion Fire consisted of multiple mixed conifer species (Table 16 and Figure 24). The **red fir** type was mostly represented in the lower soil severity categories, except for approximately five percent of the total fire area, which was assessed to have high soil severity. The **Sierra mixed conifer** type covered about 30 percent of the Lion Fire area, and was mostly assessed to have low to moderate soil severity effects. In **all vegetation types combined** post-burn soil severity in the Lion Fire was rated as:

- 34 percent unburned or very low severity
- 26 percent low severity
- 32 percent moderate severity
- 7 percent high soil severity

**Table 16. Sequoia National Forest vegetation type and soil severity from Lion BAER Team inside Lion Fire**

| BAER Soil Severity | Unburned Soil | Low Soil | Moderate Soil | High Soil | Total Acres |
|---|---|---|---|---|---|
| Alpine dwarf-shrub | 43 | 1 | 7 | 0 | 50 |
| Annual grassland | 50 | 6 | 30 | 0 | 86 |
| Barren | 609 | 87 | 250 | 7 | 955 |
| Jeffrey Pine | 1 | 2 | 3 | 0 | 5 |
| Lacustrine (lakes) | 3 | | 0 | 0 | 3 |
| Lodgepole pine | 496 | 17 | 53 | 1 | 567 |
| Montane chaparral | 227 | 181 | 194 | 76 | 678 |
| Ponderosa pine | 7 | 29 | 31 | 0 | 67 |
| Inside Sequoia Park | 760 | 383 | 215 | 16 | 1374 |
| Red fir | 4,472 | 2,296 | 2,916 | 1,036 | 10,720 |
| Subalpine conifer | 99 | 13 | 3 | 0 | 116 |
| Sierra Mixed Conifer | 606 | 2,504 | 3,061 | 286 | 6457 |
| White fir | 36 | 197 | 157 | 38 | 428 |
| Wet meadow | 31 | 1 | 4 | 0 | 37 |
| Total Acres | 7,439 | 5,717 | 6,925 | 1,461 | 21,543 |

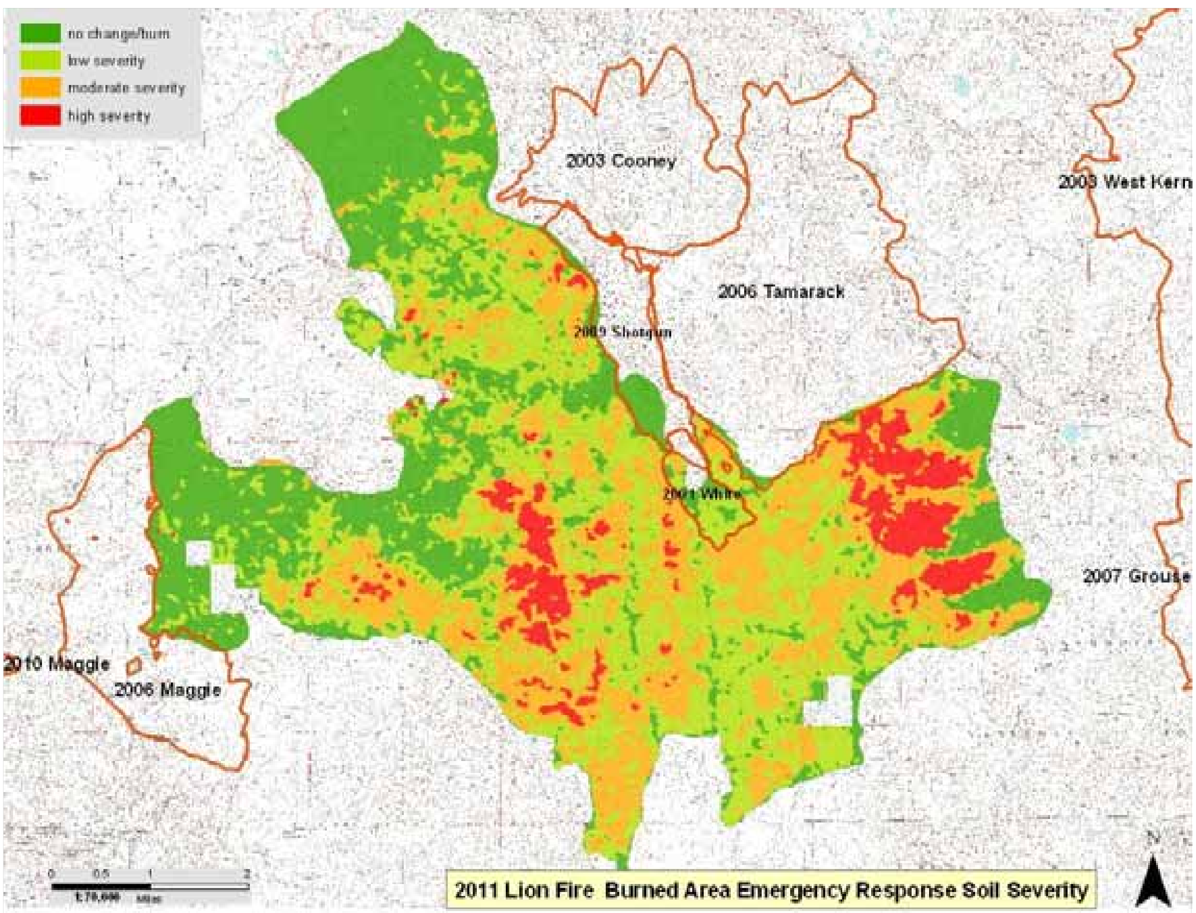



**Figure 24. 2011 Lion BAER Team's soil severity assessment**

**Vegetation Burn Severity** - The **red fir** CA WHR, which makes up nearly 50% of the Lion Fire, was mostly assessed to be in the lower severity categories in CBI imagery, except for approximately 8 percent of the area, which was assessed to have high vegetation severity (Table 17 and Figure 25). The **Sierra mixed conifer** type covered about 30 percent of the Lion Fire area, and was predominately assessed to have lower overstory severity effects. **Lodgepole pine**, which is often known to have intense fire behavior, was not detected as displaying higher severity, while **chaparral,** often known for higher fire severity effects, displayed a mixed severity. In **all vegetation types combined,** post-burn vegetation severity in the Lion Fire was rated as:

- 19 percent unburned or unchanged
- 40 percent low severity
- 25 percent moderate severity
- 15 percent high severity.

**Table 17. Sequoia National Forest vegetation type and immediate post-fire vegetation severity (CBI from USFS PSW) inside the Lion Fire.**

| CBI - vegetation severity | Unchanged | Low | Moderate | High | Total Acres |
|---|---|---|---|---|---|
| Alpine dwarf-shrub | 35 | 10 | 5 | 0 | 50 |
| Annual grassland | 19 | 45 | 21 | 1 | 86 |
| Barren | 246 | 445 | 182 | 68 | 955 |
| Jeffrey Pine | | 1 | 4 | 1 | 5 |
| Lacustrine (lakes) | 3 | 0 | | | 3 |
| Lodgepole pine | 352 | 194 | 15 | 5 | 567 |
| Montane chaparral | 132 | 185 | 214 | 146 | 678 |
| Ponderosa pine | 0 | 28 | 35 | 4 | 67 |
| Inside Sequoia Park | 288 | 798 | 226 | 62 | 1374 |
| Red fir | 2,776 | 4,166 | 2,032 | 1,725 | 10,720 |
| Subalpine conifer | 58 | 47 | 8 | 3 | 116 |
| Sierra Mixed Conifer | 205 | 2,606 | 2,631 | 1,015 | 6457 |
| White fir | 7 | 161 | 116 | 145 | 428 |
| Wet meadow | 27 | 9 | 1 | | 37 |
| Total Acres | 4,150 | 8,694 | 5,490 | 3,174 | 21,543 |

Note 35 acres were removed from comparison due to obscured CBI imagery.

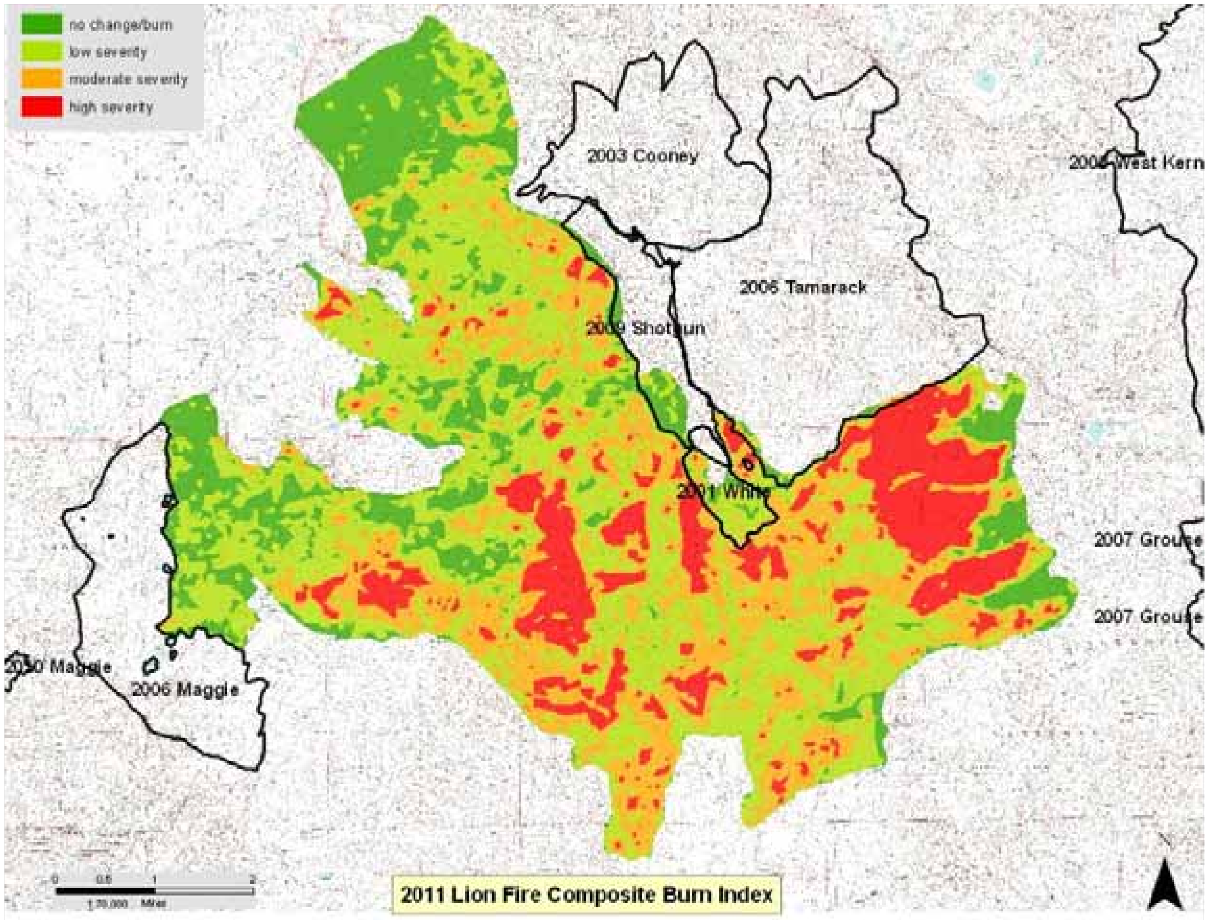



**Figure 25. 2011 Lion Fire Composite Burn Index**

Overall Fire Severity - Table 18 is a comparison of two fire severity layers for the entirety of the Lion Fire. The BAER team's soil severity data categorized 3,289 acres more than the CBI data as unburned / unchanged, while the soil severity data categorized 1,713 acres less than the CBI data as high severity (Table 18).

Generally, satellite derived data depicts post-fire changes in overstory trees more accurately than understory or surface changes; and fire effects to the soil layer appear to vary at finer scales than fire effects to the overstory (Lentile et al. 2007). This difference in scale and use of satellite imagery explains why the BAER team also includes the soil type and other soil characteristics as well as incorporating the BARC satellite imagery to determine the soil burn severity. Vaillant (2009) stated that immediate post-fire imagery (CBI data) has the potential to overestimate severity compared to one year post-fire data, which is not currently available for the Lion Fire. An improved comparison should be conducted in 2012 when the Lion CBI data is available, following the one-year post fire protocol, such as similar to the other fires discussed in this report. Comparisons between the vegetation and soil severity data can be somewhat erroneous based on the accuracy of the imagery between upper and lower forest layers. The main focus of the soil severity map was to locate and create a map of larger higher severity patches in need of possible rehabilitation or erosion control work (Lentile et al. 2007, Nicita pers. comm. 2011).

This comparison of fire severity mapping illustrates different aspects of burn severity. Burn severity is difficult to summarize concisely and might be more apparent when the strata are considered as separate soil and vegetation severity ratings, each with their own effects to ecosystem health and productivity. Discussions of fire severity with concerned public may also benefit from the key points unique to the BAER soil severity and CBI mapping efforts.

**Table 18. Comparison between CBI and BAER soil severity ratings inside the Lion Fire (based on mid-Sept. burn perimeter).**

Note 35 acres were removed from comparison due to obscured CBI imagery.

| Severity | CBI unburned | CBI low | CBI moderate | CBI high | Total Acres |
|---|---|---|---|---|---|
| BAER soil unburned | 3,916 | 3,257 | 194 | 41 | **7,439** |
| BAER soil low | 134 | 4,866 | 1,868 | 53 | **6,925** |
| BAER soil moderate | 90 | 560 | 3,411 | 1,657 | **5,717** |
| BAER soil high | 10 | 11 | 17 | 1,423 | **1,461** |
| **Total Acres** | **4,150** | **8,694** | **5,490** | **3,174** | **21,543** |

# Appendix IV. Pictures

The severity notes associated with pictures describe the NPS understory vegetation and substrate severity ratings.

Tamarack and Lion overlap,
facing Tamarack Fire area

Transect 6, Plot 5
Very light to unburned

In Lion-only area,
facing Lion Fire area

Transect 6, Plot 2
Moderate severity

Tamarack and Lion overlap

Transect 5, Plot 3
Low severity and unburned

Lion-only area

Transect 5, Plot 7
Low and moderate severity

Tamarack and Lion overlap

Transect 3, Plot 1
Moderate and high severity

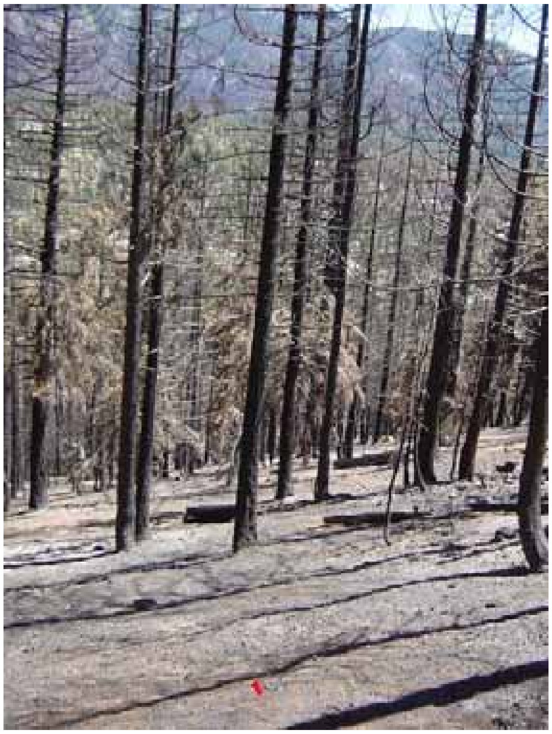
Lion-only area

Transect 3, Plot 9
Moderate and high severity

White and Lion overlap

Transect 8, Plot 1
Unburned and low severity

Lion-only area (near, but not in White Fire)



Transect 7, plot 1
Moderate and high severity

White and Lion overlap

Transect 8, Plot 2
Unburned and low severity

Lion-only area
(near, but not in White Fire)

Transect 7, Plot 3
High severity

White Fire (not in overlap with Lion)

Transect 8, Plot 3
Moderate severity

Lion-only area (near, but not in White Fire)

Transect 7, Plot 3
Moderate severity

In Lion only area near Shotgun,
Facing toward Shotgun

Transect 12, Plot 1
Moderate severity

In Lion only area near Shotgun,
facing toward Lion Fire area

Transect 12, Plot 1
Moderate severity

In Shotgun Fire area, not in Lion Fire,
facing toward Shotgun Fire area

Transect 12, Plot 2
Not burned

In Shotgun Fire area, not in Lion Fire,
facing toward Lion Fire area

Transect 12, Plot 2
Not burned

# Appendix V. Fire Weather and Fire Behavior Observations

Table 19 displays snow survey data from April 1, 2011. The table shows the snowpack was about 195% above average. April 1 is the annual benchmark date for snowpack measurement in California. Quinn Ranger Station is the closest to the Lion Fire and it received 193%.

**Table 19. April 1, 2011 snow survey data for 17 snow courses in the Kern River drainage**

| Number and Name | Elevation (ft.) | Date | Depth (in.) | Water Content (in.) | Density | April 1 Averag e (in.) | 2011 % of Average |
|---|---|---|---|---|---|---|---|
| 250 Bighorn Plateau | 11,350 | 31-MAR | 106.0 | 42.0 | 40% | 23.7 | 177% |
| 251 Cottonwood Pass | 11,050 | 04-APR | 69.5 | 28.8 | 41% | 14.8 | 195% |
| 252 Siberian Pass | 10,900 | 03-APR | 84.1 | 35.3 | 42% | 20.0 | 176% |
| 253 Crabtree Meadow | 10,700 | 30-MAR | 94.8 | 36.1 | 38% | 19.6 | 184% |
| 254 Guyot Flat | 10,650 | 30-MAR | 102.6 | 36.4 | 35% | 20.8 | 175% |
| 255 Tyndall Creek | 10,650 | 01-APR | 89.4 | 35.0 | 39% | 18.8 | 186% |
| 275 Sandy Meadows | 10,650 | 31-MAR | 93.7 | 34.8 | 37% | 19.2 | 181% |
| 257 Big Whitney Meadow | 9,750 | 28-MAR | 91.7 | 30.4 | 33% | 17.2 | 177% |
| 256 Rock Creek | 9,600 | 29-MAR | 95.5 | 35.4 | 37% | 17.8 | 199% |
| 258 Round Meadow | 9,000 | 31-MAR | 108.3 | 43.1 | 40% | 24.1 | 179% |
| 259 Ramshaw Meadows | 8,700 | 27-MAR | 67.3 | 22.7 | 34% | 11.5 | 197% |
| 260 Little Whitney Meadow | 8,500 | 26-MAR | 88.7 | 29.8 | 34% | 12.9 | 231% |
| 264 Quinn Ranger Station | 8,350 | 01-APR | 91.8 | 36.5 | 40% | 18.9 | 193% |
| 261 Bonita Meadows | 8,300 | 31-MAR | 61.5 | 25.6 | 42% | 13.6 | 188% |
| 262 Casa Vieja Meadows | 8,300 | 30-MAR | 96.8 | 38.5 | 40% | 19.8 | 194% |
| 265 Beach Meadows | 7,650 | 30-MAR | 50.0 | 22.5 | 45% | 8.3 | 271% |
| 249 Dead Horse Meadow | 7,300 | 29-MAR | 59.0 | 21.9 | 37% | 10.7 | 205% |

Source: California Department of Water Resources - http://cdec.water.ca.gov/cgi-progs/snow/COURSES.201104

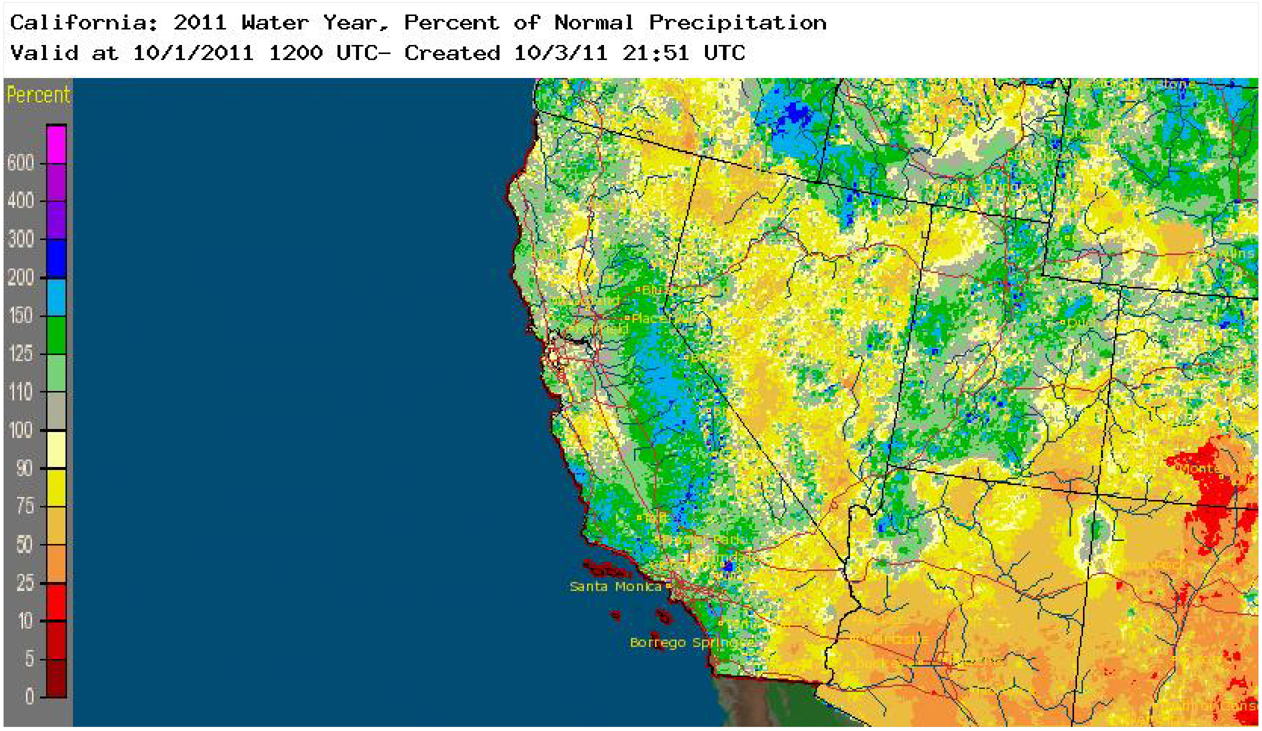



**Figure 26. Total Little Kern River drainage precipitation (rain and snow) was about 150% to 200% above normal during the water year October 1, 2010 to September 30, 2011**

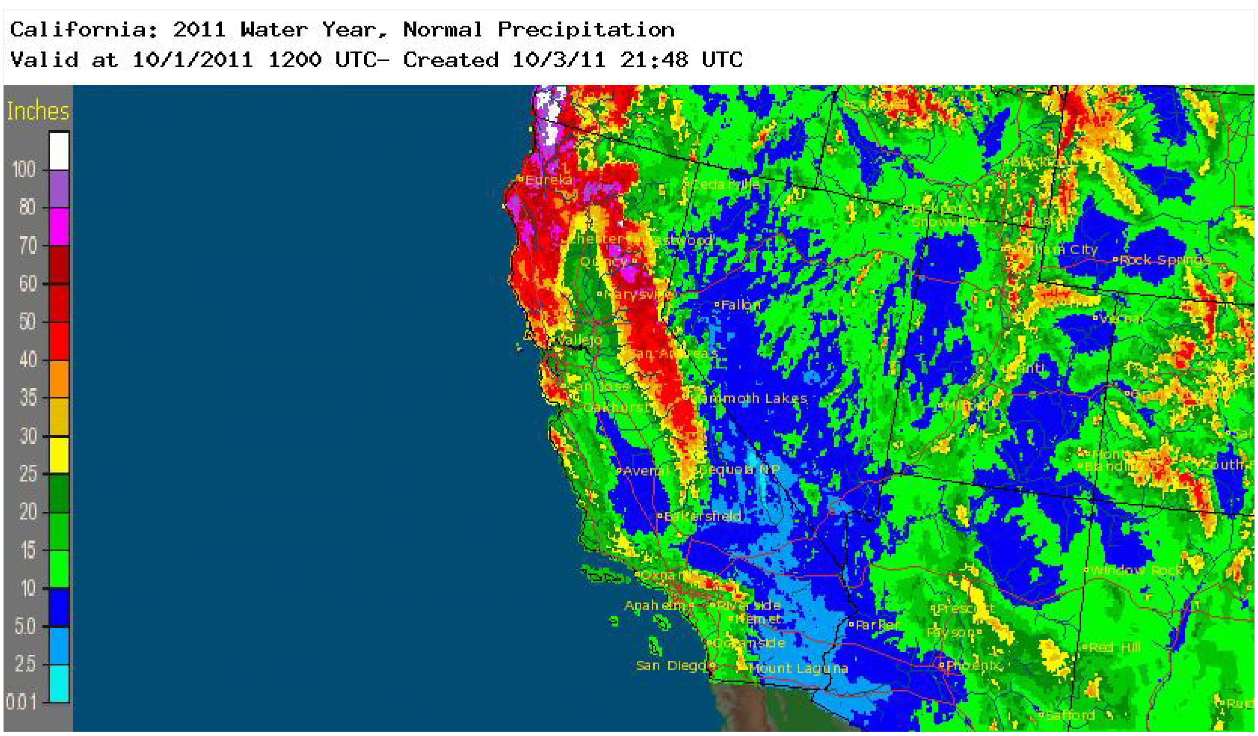



**Figure 27. Little Kern River drainage normally receives about 25 to 40 inches precipitation during the water year October 1, 2010 to September 30, 2011**

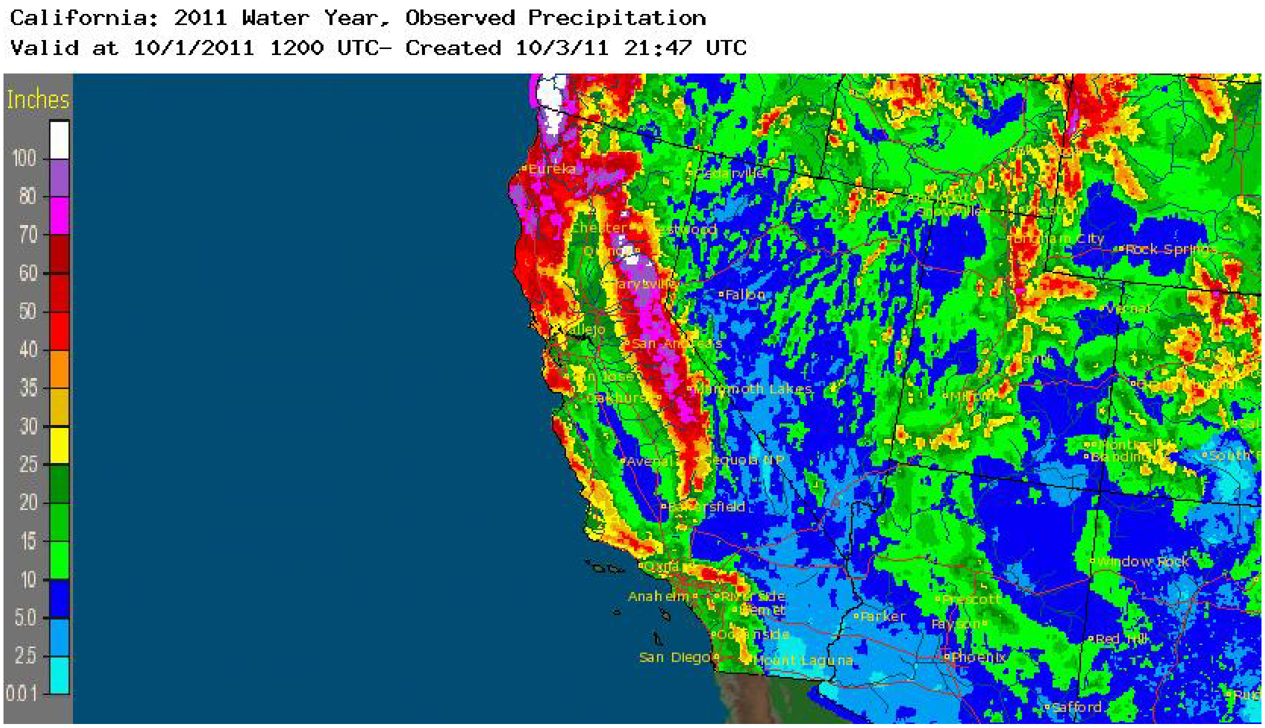



**Figure 28. Little Kern River drainage received about 40 to 60 inches precipitation during the water year October 1, 2010 to September 30, 2011**
(Source: Advanced Hydrologic Prediction Service, http://water.weather.gov/precip/)

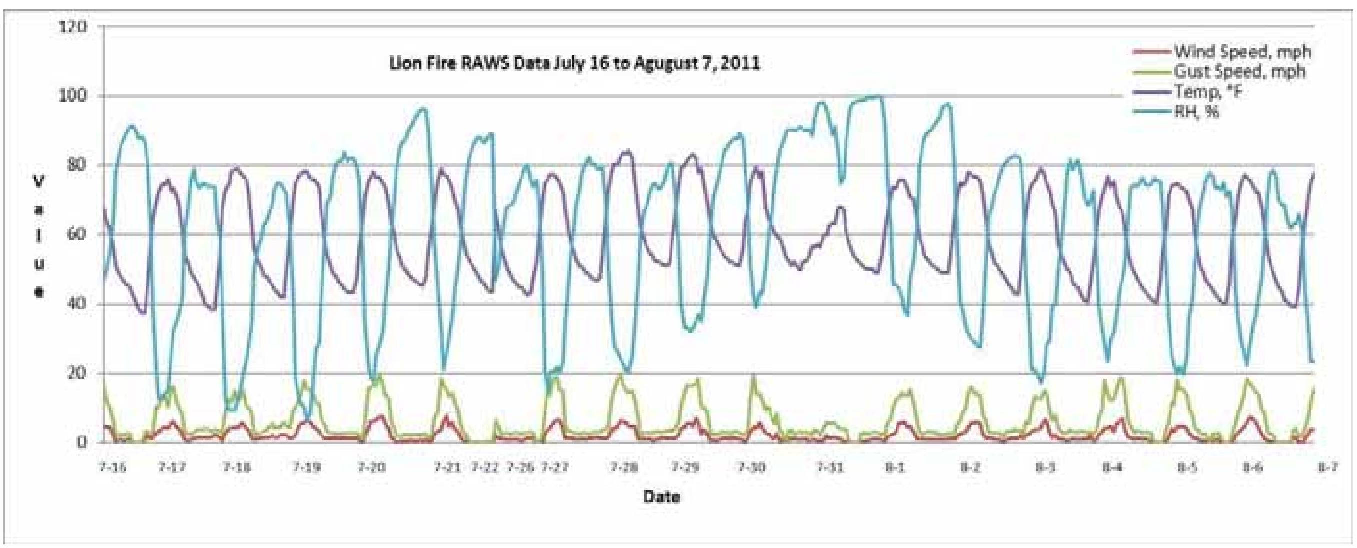



**Figure 29. Lion Fire RAWS data is summarized in figure 5. The station was located in western Lion Meadow near Lion Creek and recorded higher humidity compared to fire areas away from meadows.**
Missing data from 7/22, 0800 to 7/26, 1800 not available.

**Table 20. A summary of available weather and fire behavior observations data concerning the White, Maggie, Shotgun, and Tamarack Fires when they first burned, and the same information when the Lion Fire interacted with these previous recent fires***

| Dates of Fires and Interactions | Temp. Range ºF | R.H. Range % | Wind Speed Range mph | Wind Direction | Remarks | Fire Behavior |
|---|---|---|---|---|---|---|
| **2001 White Interaction with Lion** | | | | | | |
| 5/21 to 5/26/2001 | NA | NA | NA | NA | NA | NA |
| **2006 Maggie Interaction with Lion - Based on 3 to 10 daily observations documented on FWSFR forms** | | | | | | |
| 7/20/2006 | 69-75 | 40-46 | 2-5 G-7 | S, SE, E, N | 20-40% cloud cover | NA |
| 7/22/2006 | 62-75 | 33-41 | 1-5 G-10 | S, SW, W | 50-70% cloud cover | NA |
| 7/24/2006 | 65-71 | 35-46 | 3-5 | S, N | 0-10% cloud cover | NA |
| 7/26/2006 | 66-75 | 35-55 | 1-4 | W, NW, N | 20-35% cloud cover | NA |
| 7/27/2006 | 70-76 | 36-49 | 1-4 G-6 | SE, E, NE, N, NW, W | 0-40% cloud cover | NA |
| 7/28/2006 | 68-80 | 27-47 | 0-5 | NE, E, SE, S, W | 0-15% cloud cover | NA |
| 7/29/2006 | 63-75 | 29-64 | 2-7 | W, E, SW, NW | 0-40% cloud cover | NA |
| 7/30/2006 | 62-64 | 41-44 | 1-6 | NE, NW | 0-50%cloud cover | NA |
| 8/1/2006 | 45-65 | 34-70 | 1-4 | NW, SE, S, NW, | 0-10% cloud cover | NA |
| 8/2/2006 | 59-65 | 20-52 | 3-7 | SE, S, N, NW | 0-10% cloud cover | NA |
| **2006 Tamarack Interaction with Lion – Based on Fire Monitoring observations** | | | | | | |
| 7/16/2006 | 69-80 | 19-33 | 1-5, G-9 | W, SW, NW, E, N | 0-10% cloud cover | Obs. 8,900 ft., slope 40%, aspect N, backing / head, FL 1-10 ft. shrubs, ROS 0.5 to 6 ch/hr, most perimeter backing, eastern flank torching and running |
| 8/7/2006 | 60-72 | 17-26 | 1-5, G-10 | E, SE, S, SW | | Obs. 8,100 ft.-8,600 ft., slope 10-15%, aspect N, W, S, backing FL 1 ft. litter, head FL 3 ft. shrubs, ROS NA, active western flank |

| Dates of Fires and Interactions | Temp. Range ºF | R.H. Range % | Wind Speed Range mph | Wind Direction | Remarks | Fire Behavior |
|---|---|---|---|---|---|---|
| 8/9/2006 | 62-75 | 8-17 | 2-6, G-11 | E, S, SW, W | 10% cloud cover Red Flag Warning for low RH | Obs. 8,400 ft.-8,880”, slope 3-40%, aspect SW, W, NW, backing FL 2 ft. litter / shrubs, ROS NA, isolated torching |
| 8/11/2006 | 62-75 | 14-26 | 1-5, G-12 | W, NW, S, NE | | Obs. 8,430 ft., slope 15-25%, aspect NW, backing and flanking FL 1 ft.-2 ft. litter and shrubs, R0S 0.5 ch/hr, isolated torching, flanking towards W and SE |
| 8/12/2006 | 61-75 | 12-46 | 1-8, G-13 | SW | | Obs. 8,430, slope 25%, aspect W, backing and flanking FL0.5 ft.-4 ft. litter and shrubs, ROS 0.5 ch/hr, flanking W, NW of Tamarack Cr., isolated torching |
| 8/13/2006 | 60-74 | 10-21 | 2-7, G-15 | S, SW | | Obs. 8,430 ft. ft., slope 25%, aspect W, backing FL 1 ft. litter, FL 2 ft. shrubs, ROS 0.10-0.25 ch/hr, slow backing, no torching, afternoon 10 chain burnout head fire FL 4 ft. shrubs, ROC 6 ch/hr |
| 8/14/2006 | 59-74 | 15-29 | 2-7, G-9 | S, SE, SW | | Obs. 8,430 ft., slope 25%, aspect S, E, flanking and backing towards Little Kern River, isolated torching, late afternoon short uphill runs |
| **2009 Shotgun Interaction with Lion** | | | | | | |
| 6/25 to 7/5/2009 | NA | NA | NA | NA | NA | NA |
| **2011 Lion Interacts with White** | | | | | | |
| 7/18/2011<br>Lion RAWS<br>On Fire – Day<br>FWSFR | 38-79<br>56-78<br>56-77 | 9-79<br>14-36<br>14-29 | 1-5, G-15<br>1-6, G-8<br>2-8 | SW, NE<br>S, SW, W<br>SSW | | Obs. 6,900 ft. Fire Behavior Observations NA |

| Dates of Fires and Interactions | Temp. Range ºF | R.H. Range % | Wind Speed Range mph | Wind Direction | Remarks | Fire Behavior |
|---|---|---|---|---|---|---|
| 7/20/2011<br>Lion RAWS<br>On Fire - Day<br>FWSFR | 43-78<br>60-65<br>60-81 | 18-85<br>10-38<br>16-33 | 1-7, G-20<br>2-5, G-10<br>calm | SW, NNE<br>S, SE, SW | | Obs. 6,900 ft. Fire Behavior Observations NA |
| 7/21/2011<br>Lion RAWS<br>FWSFR | 45-77<br>58-82 | 21-96<br>19-65 | 1-8, G-19<br>1-5, G-8 | SSW, NE<br>S, SW | | Obs. 6,900 ft. Fire Behavior Observations NA |
| 7/23/2011<br>FWSFR | 63-81 | 13-55 | 3-6, G-10 | NE, SW | | Obs. 6,900 ft. Fire Behavior Observations NA |
| **2011 Lion Interacts with Maggie** | | | | | | |
| 7/25/2011<br>FWSFR | 67-80 | 17-43 | 6-12, G-14 | S, SW, NE | | Obs. 6,900 ft. Fire Behavior Observations NA |
| 7/26/2011<br>FWSFR | 59-82 | 19-66 | 2-7, G-10 | SE, S, SW | | Obs. 6,900 ft. Fire Behavior Observations NA |
| **2011 Lion Interacts with Shotgun** | | | | | | |
| 7/20/2011<br>Lion RAWS<br>On Fire - Day<br>FWSFR | 43-78<br>60-65<br>60-81 | 18-85<br>10-38<br>16-33 | 1-7, G-20<br>2-5, G-10<br>calm | SW, NNE<br>S, SE, SW | | Obs. 6,900 ft. Fire Behavior Observations NA |
| 7/23/2011<br>FWSFR | 63-81 | 13-55 | 3-6, G-10 | NE, SW | | Obs. 6,900 ft. Fire Behavior Observations NA |
| 7/24/2011<br>FWSFR | 65-81 | 20-45 | 2-8, G-13 | SW, NE, S | | Obs. 6,900 ft. Fire Behavior Observations NA |
| 7/26/2011<br>FWSFR | 59-82 | 19-66 | 2-7, G-10 | SE, S, SW | | Obs. 6,900 ft. Fire Behavior Observations NA |
| **2011 Lion Interacts with Tamarack** | | | | | | |
| 7/20/2011<br>Lion RAWS<br>On Fire - Day | 43-78<br>60-65 | 18-85<br>10-38 | 1-7, G-20<br>2-5, G-10 | SW, NNE<br>S, SE, SW | | Obs. 6,900 ft. Fire Behavior Observations NA |
| 7/23/2011<br>FWFSR | 63-81 | 13-55 | 3-6, G-10 | NE, SW | | Obs. 6,900 ft. Fire Behavior Observations NA |
| 7/27/2011<br>Lion RAWS<br>FWSFR | 43-78<br>65-71 | 15-80<br>17-24 | 1-7, G-19<br>1-3 | SW, NE<br>SE | | Obs. 8,800 ft., Fire Behavior Observations NA |

* The Tamarack Fire had the most complete monitoring data that includes daily on the fire weather and behavior observations. The Maggie Fire only had weather data available from spot weather forecast forms (FWSFR). No data was available for the White and Shotgun Fires. The Lion Fire had partial data on fire weather and no behavior observations. The Lion Meadow RAWS failed from July 22 to July 26. There are several days where spot weather forecast forms were the only weather data available (FWSFR). FWSFR data is the most limited because there are only about 4 observations per day.

NA: Data Not Available, G: Wind Gust, FWSFR forms: Fire Weather Special Forecast Request, FL: Flame Length, ROS: Rate of Spread

The Peppermint RAWS at 7,385 ft., located 13 miles south, southwest of the center of the Lion Fire was the most representative weather station in the same drainage as the fire with an adequate historic record used to analyze fire weather and burning conditions concerning the fires examined in this report. The National Fire Danger Rating System (NFDRS) was used in the FireFamily Plus 4 computer program for analysis of long term 10 year trends and individual fire conditions.

NFDRS evaluates the "worst" conditions on a rating area by (1) taking fuel and weather measurements when fire danger is normally the highest (mid- to late-afternoon), (2) measuring fire danger in the open, and (3) measuring fire danger on south to west exposures. This means that extrapolation of fire danger to other areas not in the immediate vicinity of the fire danger stations would involve scaling the fire-danger values down, not up.

Gaps in graph lines are days of missing data.

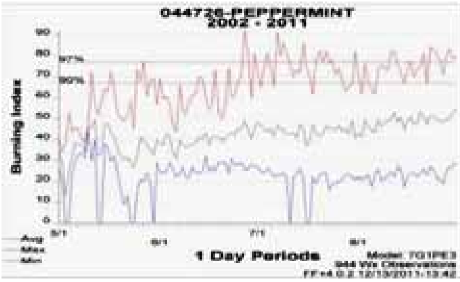



**Figure 30. Burning Index (BI) at the Peppermint RAWS during May through August, for 10 years 2002 to 2011 showing average ranges from about 13 to 54 for NFDRS fuel model G and slope class 1 – 0% to 25% (see Burning Index and fuel model descriptions below). The model's configuration predicted average flame lengths would have ranged from about 1 to 5 feet with extremes from 0 to 9 feet (upslope head fire). The G model is used in the Southern Sierra Special Interest Group – below.**

**Burning Index (BI):** A number relating to the potential amount of effort needed to contain a single fire in a particular fuel type within a rating area. NFDRS uses a modified version of Bryam's equation for flame length - based on the Spread Component (SC) and the available energy (ERC) - to calculate flame length from which the Burning Index is computed. Dividing the Burning Index by 10 produces a reasonable estimate of the flame length at the head of a fire.


**Figure 31. Lion Fire - Burning Index at the Peppermint RAWS during July through August, 2011, ranged from about 27 to 81 The model's configuration predicted flame lengths would have ranged from about 3 to 8 feet. The BI for the period generally was at average to above average during August.**


**Figure 32. Shotgun Fire - Burning Index at the Peppermint RAWS during June and July, 2009, ranged from about 22 to 82. The model's configuration predicted flame lengths would have ranged from about 2 to 8 feet. The BI for the period generally was below average during the first two weeks in June then increased to above average during late June through July.**


**Figure 33 . Maggie and Tamarack Fires - Burning Index at the Peppermint RAWS during July and August, 2006, ranged from about 30 to 75. The model's configuration predicted flame lengths would have ranged from about 3 to 7.5 feet. The BI for the period generally was at about average during June above average during August.**


**Figure 34 White Fire - Burning Index at the Peppermint RAWS during May, 2001, ranged from about 25 to 45. The model's configuration predicted flame lengths would have ranged from about 3.5 to 4.5 feet. The BI for the period about average.**

**NOTE**: The Peppermint weather station was manually operated in 2001 and there are many missing days of data.

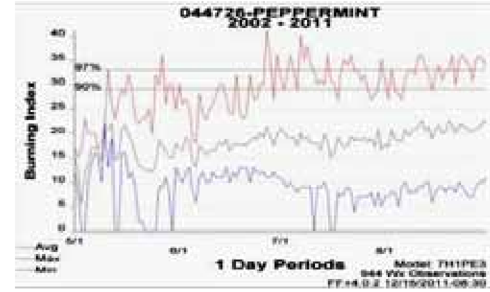



**Figure 35. Lion Fire Interactions - Burning Index (BI) at the Peppermint RAWS during May through August, for 10 years 2002 to 2011 showing average ranges from about 12 to 23 for NFDRS fuel model H and slope class 1 – 0% to 25%. The model's configuration predicted average flame lengths would have ranged from about 0.5 to 2.25 feet with extremes from 0 to 4 feet (upslope head fire).**

**Fuel Model H:** The short-needled conifers (white pines, spruces, larches, and firs) are represented by Fuel Model H. In contrast to Model G fuels, Fuel Model H describes a healthy stand with sparse undergrowth and a thin layer of ground fuels. Fires in the H fuels are typically slow spreading and are dangerous only in scattered areas where the downed woody material is concentrated.


**Figure 36. Energy Release Component (ERC) at the Peppermint RAWS during May through August, for 10 years 2002 to 2011 using fuel model G shows average ranging from about 20 to 68 with extremes from 10 to 95.**

**Energy Release Component (ERC):** Is defined as the potential available energy per square foot of flaming fire at the head of the fire and is expressed in units of BTUs per square foot. Like the Spread Component, the Energy Release Component is calculated using tables unique to each fuel model. The rate of combustion is almost totally dependent on the same fuel properties as are considered in the SC calculation. However, the principal difference in the calculation of the two components is that SC is determined primarily by the finer fuels, whereas ERC calculations require moisture inputs for the entire fuel complex, i.e., 1-hr., 10-hr., 100-hr., 1000-hr., and the live fuel moisture.

**Fuel Model G:** Fuel Model G is used for dense conifer stands where there is a heavy accumulation of litter and down woody material. Such stands are typically over mature and may also be suffering insect, disease, wind or ice damage—natural events that create a very heavy buildup of dad material on the forest floor. The duff and litter are deep and much of the woody material is more than 3 inches in diameter. The undergrowth is variable, but shrubs are usually restricted to openings.


**Figure 37. Lion Fire - Energy Release Component at the Peppermint RAWS during July and August, 2011ranged from about 47 to 85. The ERC for the period was above average.**


**Figure 38. Shotgun Fire - Energy Release Component at the Peppermint RAWS during June and July, 2009 ranged from about 28 to 86. The ERC for the period was below average until mid-June then increased to above average.**


**Figure 39. Maggie and Tamarack Fires - Energy Release Component at the Peppermint RAWS during July and August, 2006 ranged from about 40 to 84. The ERC for June was about average then increased to above average in August.**


**Figure 40. White Fire - Energy Release Component at the Peppermint RAWS during May, 2001 ranged from about 20 to 45. The ERC for May was about average.**

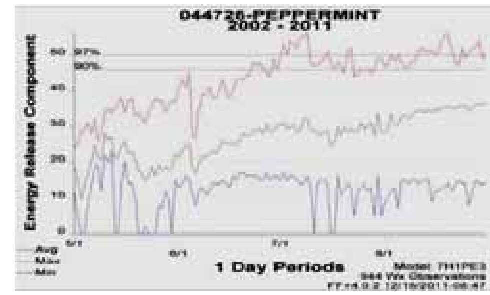



**Figure 41. Lion Fire Interactions - Energy Release Component (ERC) at the Peppermint RAWS during May through August, for 10 years 2002 to 2011 using fuel model H shows average ranging from about 10 to 36 with extremes from 0 to 58.**


**Figure 42. 1,000 Hour Time Lag Fuel Moisture (TLFM) at the Peppermint RAWS during May through August, for 10 years 2002 to 2011 shows an average from 20% down to 10%.**

**Dead Fuel Moisture:** This is the moisture content of dead organic fuels, expressed as a percentage of the oven dry weight of the sample that is controlled entirely by exposure to environmental conditions. The NFDRS processor models these values based on inputs such as precipitation and relative humidity. There is modeled fuel moisture for each of the four time lag fuel classes recognized by the system. Remember time lag is the time necessary for a fuel particle of a particular size to lose approximately 63 percent of the difference between its initial moisture content and its equilibrium moisture content in its current environment.


**Figure 43. Lion Fire - 1,000 Hour TLFM at the Peppermint RAWS during July and August, 2011 ranged from about 12% down to about 7%. 1,000 hour fuel moisture was drier than average.**

**1000-Hr Fuel Moisture Content:** This value represents the modeled moisture content in the dead fuels in the 3 to 8 inch diameter class and the layer of the forest floor about 4 inches below the surface. The value is based on a running 7-day average. The 1000-hour timelag fuel moisture is a function of length of day (as influenced by latitude and calendar date), daily temperature and relative humidity extremes (maximum and minimum values) and the 24-hour precipitation duration values for a 7-day period. Values can range from 1 to 141 percent.

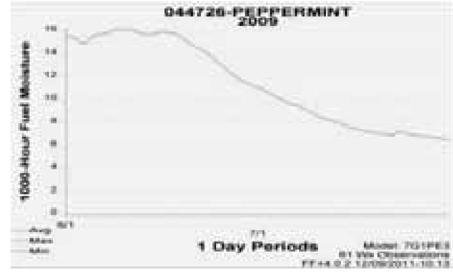



**Figure 44. Shotgun Fire - 1,000 Hour TLFM at the Peppermint RAWS during July and August, 2009 ranged from about 16% down to about 6%. 1,000 hour fuel moisture was drier than average.**


**Figure 45. Maggie and Tamarack Fires - 1,000 Hour TLFM at the Peppermint RAWS during July and August, 2006 ranged from about 18% down to about 7%. 1,000 hour fuel moisture was drier than average.**

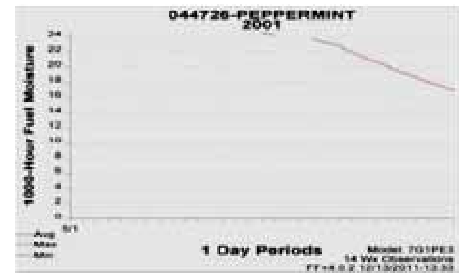



**Figure 46. White Fire - 1,000 Hour TLFM at the Peppermint RAWS during May, 2002 ranged from about 24% down to about 16%. 1,000 hour fuel moisture was slightly wetter than average.**

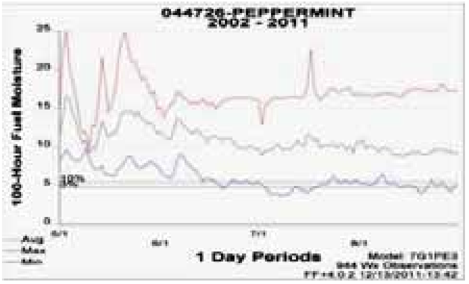



**Figure 47. 100 Hour TLFM at the Peppermint RAWS during May through August, for 10 years 2002 to 2011 shows an average range from about 16 down to 7.**

**100 Hr Fuel Moisture Content:** The 100-hour fuel moisture value represents the modeled moisture content of dead fuels in the 1 to 3 inch diameter class. It can also be used as a very rough estimate of the average moisture content of the forest floor from three-fourths inch to 4 inches below the surface. The 100-hour timelag fuel moisture is a function of length of day (as influenced by latitude and calendar date), maximum and minimum temperature and relative humidity, and precipitation duration in the previous 24 hours. Values can range from 1 to 53 percent. A default value based on the climate class of the priority #1 fuel model module in the station catalog will automatically be used if there is a break of 30 days or more in the observations entered.

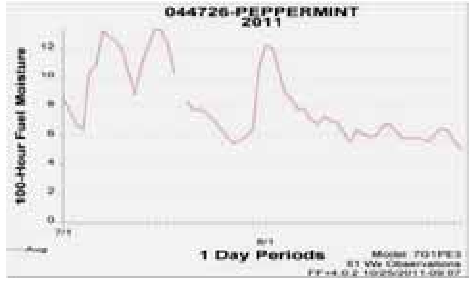



**Figure 48. Lion Fire - 100 Hour TLFM at the Peppermint RAWS during July and August, 2011 ranged from about 14% down to 5%. 100 hour fuel moisture fluctuated above and below average during July and then was drier than average in August.**


**Figure 49. Shotgun Fire - 100 Hour TLFM at the Peppermint RAWS during July and August, 2009 ranged from about 16% down to 4%. 100 hour fuel moisture was above average in June and then was drier than average in August.**

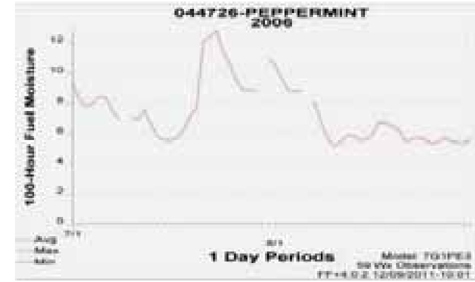



**Figure 50. Maggie and Tamarack Fires - 100 Hour TLFM at the Peppermint RAWS during July and August, 2006 ranged from about 13% down to about 5%. 100 hour fuel moisture fluctuated from below average during the first part of June to above average at the end of June, then dropped to below average during the last half of August.**

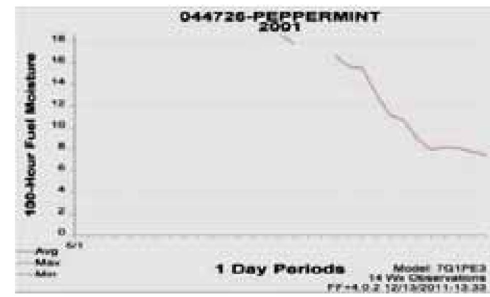



**Figure 51. White Fire - 100 Hour TLFM at the Peppermint RAWS during May, 2001 ranged from about 19% down to about 8%. 100 hour fuel moisture ranged from above average to below average.**


**Figure 52. Live Woody Fuel Moisture at the Peppermint RAWS during May through August, for 10 years 2002 to 2011 shows average ranging from about 100% down to 80%.**


**Figure 53. Lion Fire - Live Woody Fuel Moisture at the Peppermint RAWS during July and August, 2011 ranged from about 80% down to about 70%. Dormancy occurred on about July 22.**


**Figure 54. Shotgun Fire - Live Woody Fuel Moisture at the Peppermint RAWS during July and August, 2009 ranged from about 80% down to about 70%. Dormancy occurred on about July 4.**


**Figure 55. Maggie and Tamarack - Live Woody Fuel Moisture at the Peppermint RAWS during July and August, 2006 ranged from about 115% down to 70%. Dormancy occurred on about August 7.**

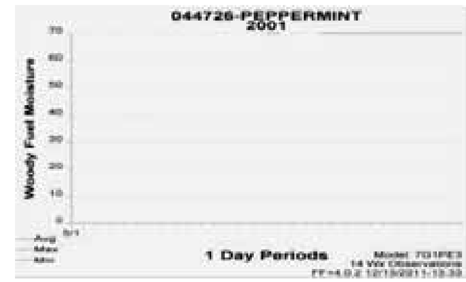



**Figure 56. White - Live Woody Fuel Moisture at the Peppermint RAWS during May, 2001 was at 70% in dormancy, which means the growing season had not started yet.**

**Woody Fuel Moisture:** This calculated value represents the approximate moisture content of the live woody vegetation (shrubs, small stems, branches and foliage) expressed as a percentage of the oven dry weight of the sample. As with the herbaceous fuel moisture, it varies significantly by climate class. Plants native to moist environments tend to have higher woody fuel moisture values than those native to more arid climates. Woody fuel moisture values typically range from a low of 50 or 60 observed just before the plant begins to grow in the spring to a high of approximately 200 reached at the peak of the growing season. The default value used in NFDRS processors to initiate the season varies by the climate class. In climate class 1 the default value is 50. For climate class 2 it is 60. Climate class 3 uses 70 and climate class 4 uses 80.


**Figure 57. Perennial Herbaceous Fuel Moisture at the Peppermint RAWS during May through August, for 10 years from 2002 to 2011 shows average ranging from about 5% up to 80%.**

**Herbaceous Fuel Moisture:** This calculated value represents the approximate moisture content of live herbaceous vegetation expressed as a percentage of the oven dry weight of the sample. Both the herbaceous vegetation type (annual or perennial) and the climate class control the rate of drying in the NFDRS processor. Faster drying occurs in annual plants than in perennials and plants native to moist climates respond differently to a given precipitation event than plants native to an arid climate would to an event of the same magnitude. Accurate recording of the herbaceous vegetation type and the climate class are critical if the calculated herbaceous fuel moisture is to be representative of the local area.

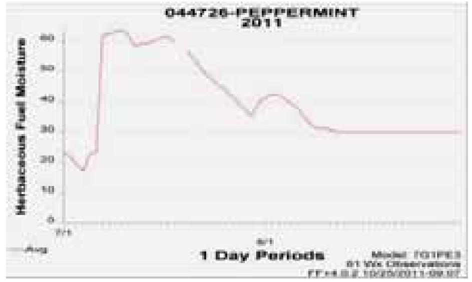



**Figure 58. Lion Fire - Perennial Herbaceous Fuel Moisture at the Peppermint RAWS during July and August, 2011 ranged from about 15% up to 63%, then down to about 30%. Herbaceous moisture was below average during July and then went into dormancy earlier than average on about August 12.**

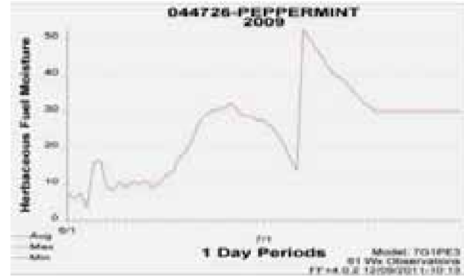



**Figure 59. Shotgun Fire - Perennial Herbaceous Fuel Moisture at the Peppermint RAWS during June and July, 2009 ranged from about 5% up to 52% then down to about 30%. Herbaceous moisture was below average during July and then went into dormancy on about August 12.**


**Figure 60. Maggie and Tamarack - Perennial Herbaceous Fuel Moisture at the Peppermint RAWS during July and August, 2006 ranged from about 60% up to 80% then down to about 30%. Herbaceous moisture was about average during July and below average during August, then went into dormancy earlier than average on about August 20.**

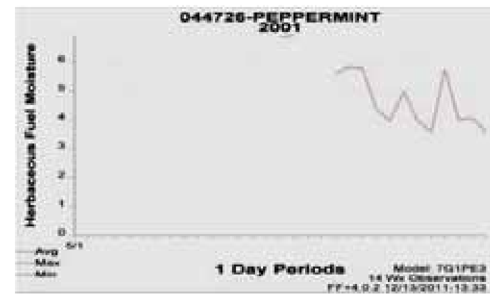



**Figure 61. White Fire - Perennial Herbaceous Fuel Moisture at the Peppermint RAWS during May, 2001 ranged from about 6% down 4%, which means the growing season had not started yet.**

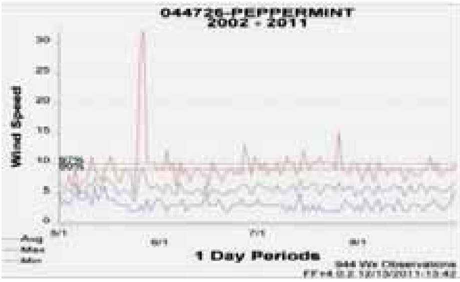



Figure 62. Average “10 minute” wind speed taken at 1300 hours - Peppermint RAWS during May through and August, for 10 years 2002 to 2011 shows average wind speed ranging from 4 to 8 mph.


Figure 63. Lion Fire - Average “10 minute” wind speed taken at 1300 hours - Peppermint RAWS during July and August, 2011. Wind speed ranged from 2 to 10 mph.


Figure 64. Shotgun Fire - Average “10 minute” wind speed taken at 1300 hours - Peppermint RAWS during June and July, 2009. Wind speed ranged from 2 to 12 mph.

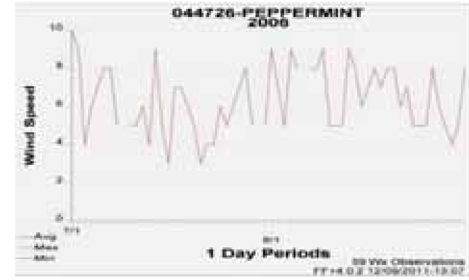



Figure 65. Maggie and Tamarack Fires - Average “10 minute” wind speed taken at 1300 hours - Peppermint RAWS during June and July, 2006. Wind speed ranged from 3 to 10 mph.


Figure 66. White Fire - Average “10 minute” wind speed taken at 1300 hours - Peppermint RAWS during May, 2001. Wind speed ranged from 2 to 6 mph.

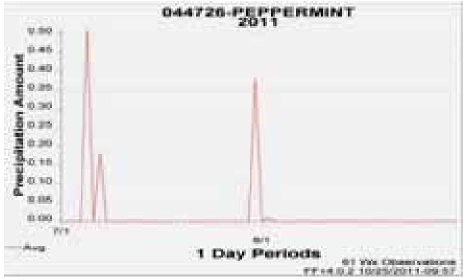



**Figure 67. Lion Fire - Precipitation at the Peppermint RAWS during July and August, 2011 shows 4 events.**

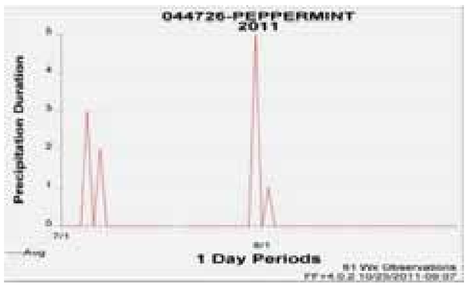



**Figure 68. Precipitation Duration at the Peppermint RAWS during July and August, 2011.**

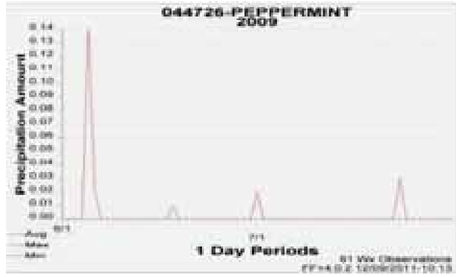



**Figure 69. Shotgun Fire - Precipitation at the Peppermint RAWS during June and July, 2009 shows 4 events.**

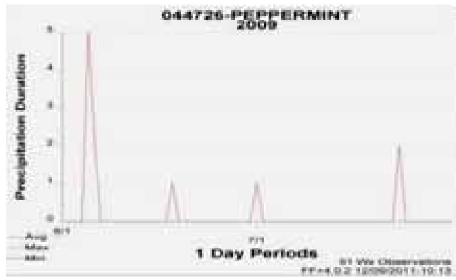



**Figure 70. Precipitation Duration at the Peppermint RAWS during June and July, 2009.**

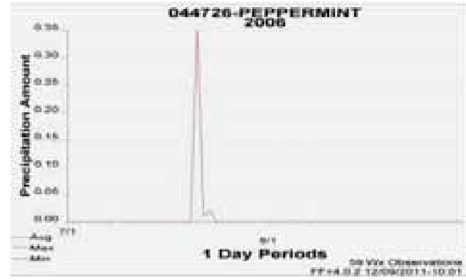



**Figure 71. Maggie and Tamarack Fires - Precipitation at the Peppermint RAWS during July and August, 2006 shows 2 events.**

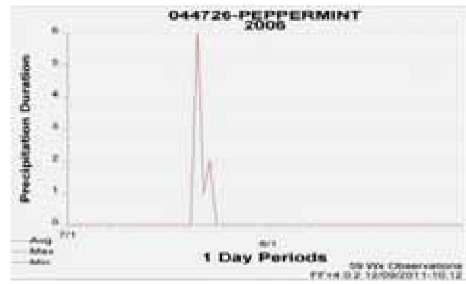



**Figure 72. Precipitation Duration at the Peppermint RAWS during July and August, 2006.**

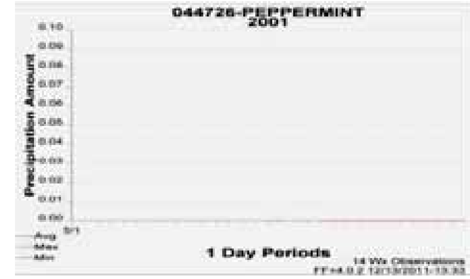



**Figure 73. White Fire - Precipitation at the Peppermint RAWS during May, 2001 shows no precipitation.**


**Figure 74. Spread Component at the Peppermint RAWS during May through August for 10 years 2002 to 2011 showing average ranges from about 2 to 12. (Fuel Model G). The high number (50+) is either an outlier buried in the data set or very windy few days.**

**Spread Component:** The Spread Component is a rating of the forward rate of spread of a headfire. Deeming, et al, (1977), states that "the spread component is numerically equal to the theoretical ideal rate of spread expressed in feet-per-minute." This carefully worded statement indicates both guidelines (it's theoretical) and cautions (it's ideal) that must be used when applying the Spread Component. Wind speed, slope and fine fuel moisture are key inputs in the calculation of the spread component, thus accounting for a high variability from day to day.

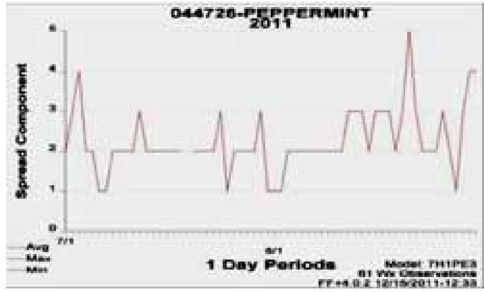



**Figure 75. Lion Fire - Spread Component at the Peppermint RAWS for July and August, 2011 shows a range from 1 to 5 feet per minute. (Fuel Model H).**

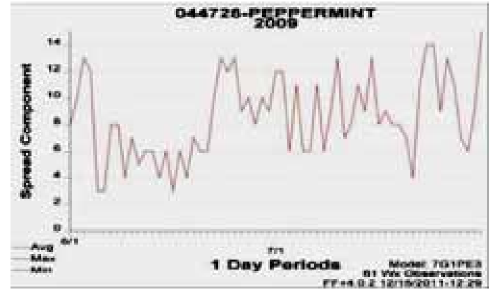



**Figure 76. Shotgun Fire - Spread Component at the Peppermint RAWS for June and July, 2009 shows a range from 3 to 15 feet per minute. (Fuel Model G).**

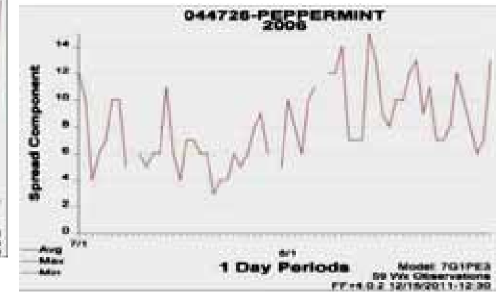
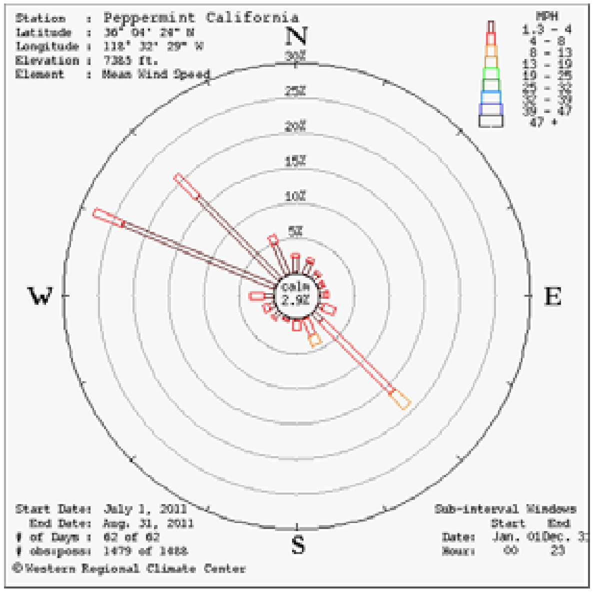



**Figure 77. Maggie and Tamarack Fires - Spread Component at the Peppermint RAWS for July and August, 2006 shows a range from 3 to 15 feet per minute. (Fuel Model G).**


**Figure 78. White - Spread Component at the Peppermint RAWS for May, 2006 shows a range from 3 to 7 feet per minute. (Fuel Model G).**

Wind speeds and directions at the Peppermint RAWS were remarkably consistent and showed no exceptional wind events in 2006, 2009, and 2011 when the Tamarack, Shotgun, Maggie and Lion Fires burned. Data was not for 2001 White fire.



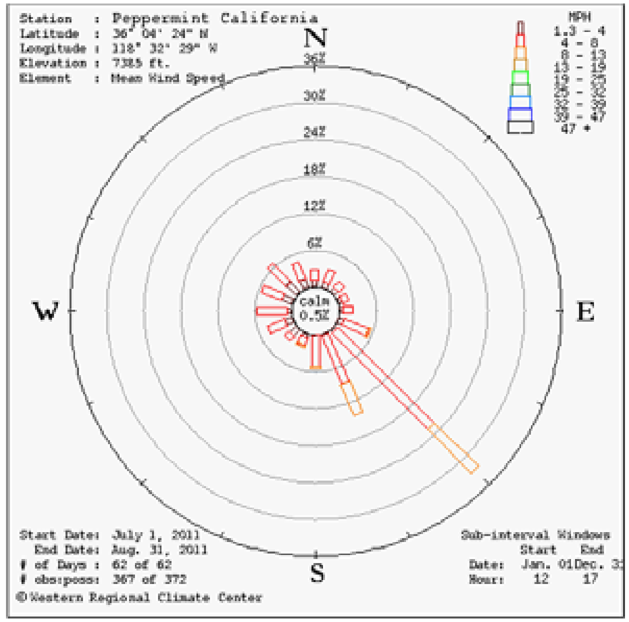

Latitude : 36° 04' 24" N
Longitude : 118° 32' 29" W
Elevation : 7385 ft.
Element :

Start Date : July 1, 2011
End Date : Aug. 31, 2011
# of Days : 62 of 62
# obs : poss : 1479 of 1488

Sub Interval Windows

| | Start | End |
|---|---|---|
| Date | Jan. 01 | Dec. 31 |
| Hour | 00 | 23 |

**Figure 79. Lion Fire - Diurnal winds at the Peppermint RAWS during July and August, 2011. Downslope from the northwest at night and upslope from the southeast during the day. The wind patterns show no extreme wind events during the fire.**



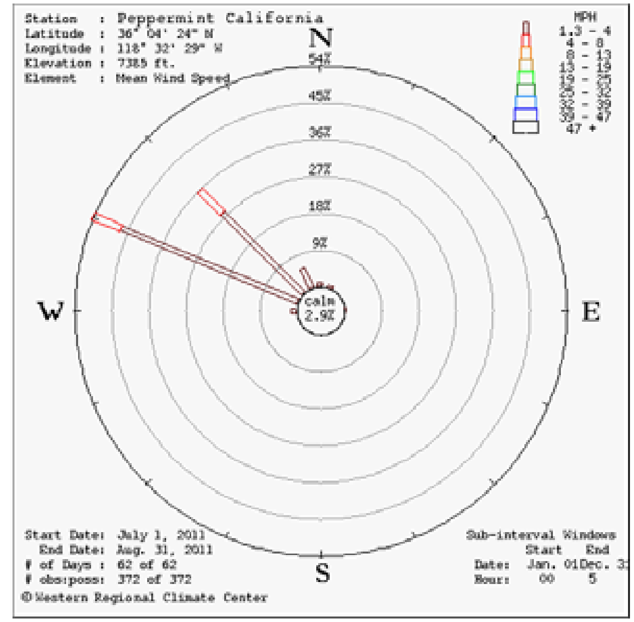

Latitude : 36° 04' 24" N
Longitude : 118° 32' 29" W
Elevation : 7385 ft.
Element :

Start Date : July 1, 2011
End Date : Aug. 31, 2011
# of Days : 62 of 62
# obs : poss : 367 of 1488

Sub Interval Windows

| | Start | End |
|---|---|---|
| Date | Jan. 01 | Dec. 3 |
| Hour | 12 | 17 |

**Figure 80. Lion Fire - Afternoon winds at the Peppermint RAWS during July and August, 2011.**



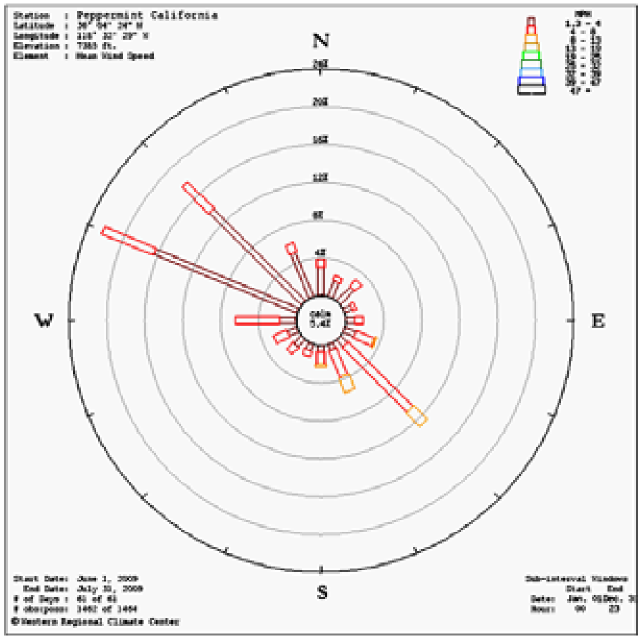

Latitude : 36° 04' 24" N
Longitude : 118° 32' 29" W
Elevation : 7385 ft.
Element :

Start Date : July 1, 2011
End Date : Aug. 31, 2011
# of Days : 62 of 62
# obs : poss : 372 of 1488

Sub Interval Windows

| | Start | End |
|---|---|---|
| Date | Jan. 01 | Dec. 31 |
| Hour | 00 | 5 |

**Figure 81. Lion Fire - Early morning winds at the Peppermint RAWS during July and August, 2011.**



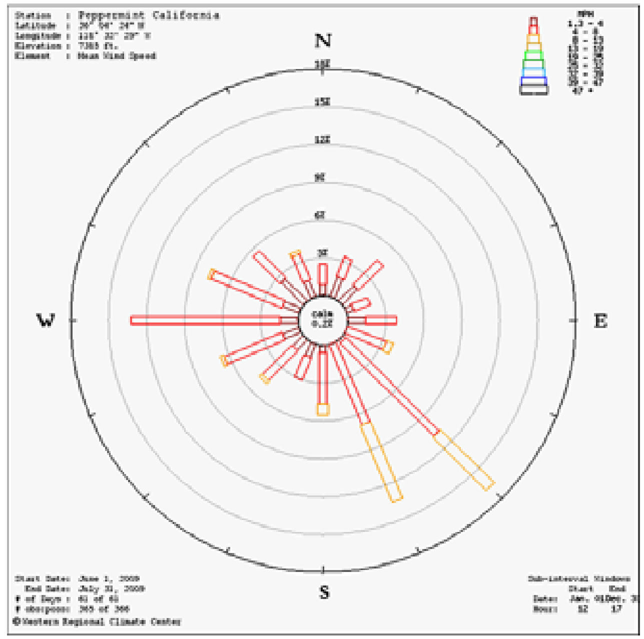

Latitude : 36° 04' 24" N
Longitude : 118° 32' 29" W
Elevation : 7385 ft.
Element :

Start Date : June 1, 2009
End Date : July 31, 2009
# of Days : 61 of 61
# obs : poss : 1462 of 1464

Sub Interval Windows

| | Start | End |
|---|---|---|
| Date | Jan. 01 | Dec. 31 |
| Hour | 00 | 23 |

**Figure 82. Shotgun Fire - Diurnal winds at the Peppermint RAWS during June and July, 2009.**



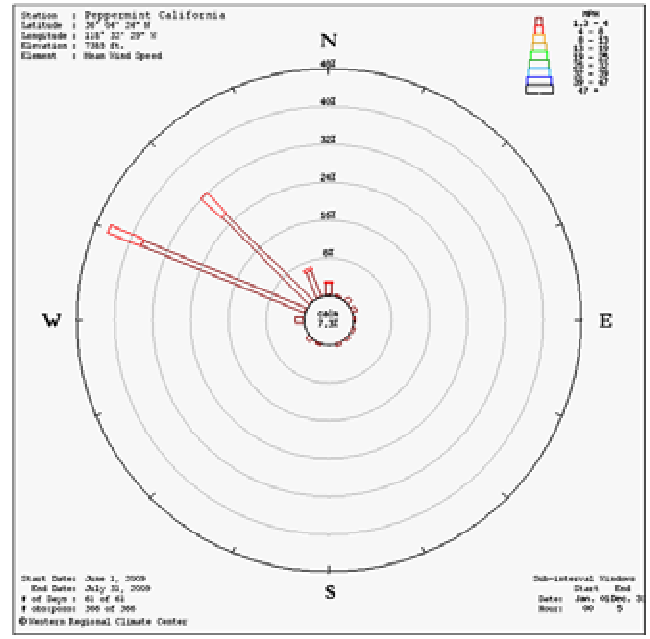

Latitude : 36° 04' 24" N
Longitude : 118° 32' 29" W
Elevation : 7385 ft.
Element :

Start Date : June 1, 2009
End Date : July 31, 2009
# of Days : 61 of 61
# obs : poss : 365 of 1464

Sub Interval Windows

| | Start | End |
|---|---|---|
| Date | Jan. 01 | Dec. 31 |
| Hour | 12 | 17 |

**Figure 83. Shotgun Fire - Afternoon winds (1200 to 1800 hours) at the Peppermint RAWS during June and July, 2009.**



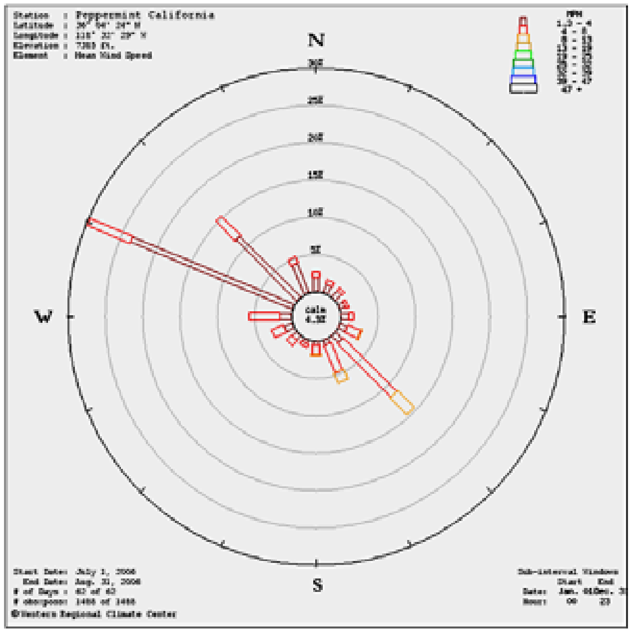

Latitude : 36° 04' 24" N
Longitude : 118° 32' 29" W
Elevation : 7385 ft.
Element :

Start Date : June 1, 2009
End Date : July 31, 2009
# of Days : 61 of 61
# obs : poss : 366 of 1464

Sub Interval Windows

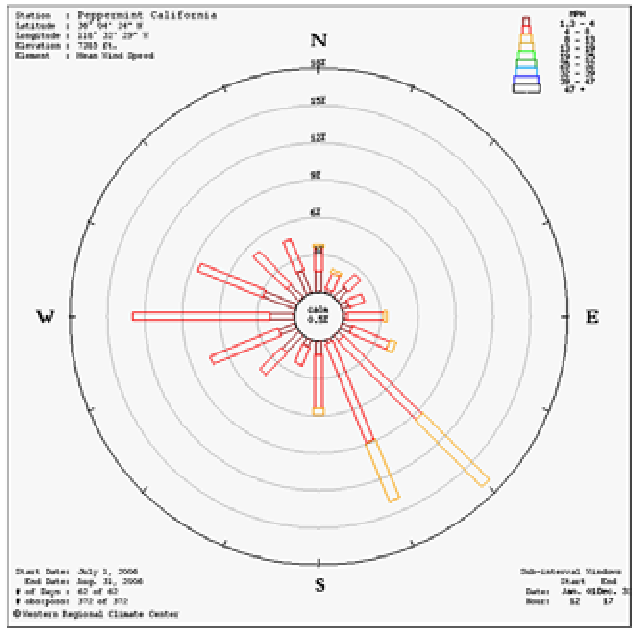
| | Start | End |
|---|---|---|
| Date | Jan. 01 | Dec. 31 |
| Hour | 00 | 5 |

**Figure 84. Shotgun Fire - Early morning winds (0001 to 0600) hours at the Peppermint RAWS during June and July, 2009.**



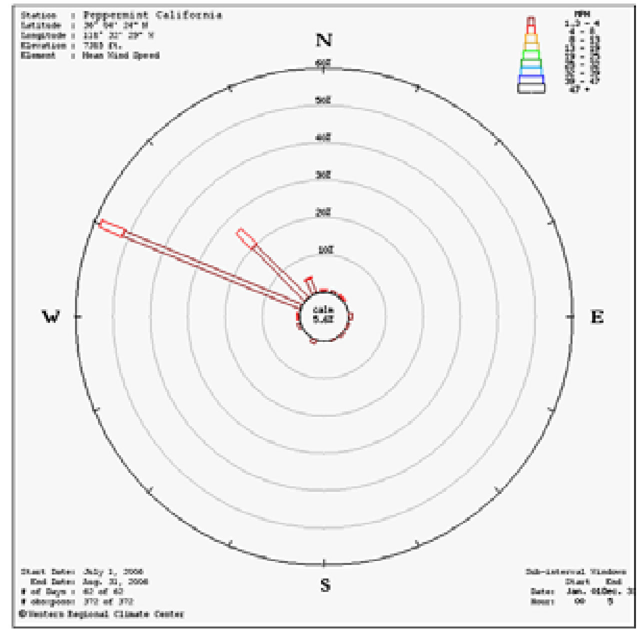

| Latitude : 36° 04' 24" N<br>Longitude : 118° 32' 29" W<br>Elevation : 7385 ft.<br>Element : | Start Date : July 1, 2006<br>End Date : Aug. 31, 2006<br># of Days : 62 of 62<br># obs : poss : 1488 of 1488 | Sub Interval Windows | | |
|---|---|---|---|---|
| | | | Start | End |
| | | Date | Jan. 01 | Dec. 31 |
| | | Hour | 00 | 23 |

**Figure 85. Maggie and Tamarack Fires - Diurnal winds at the Peppermint RAWS during July and August, 2006.**




| Latitude : 36° 04' 24" N<br>Longitude : 118° 32' 29" W<br>Elevation : 7385 ft.<br>Element : | Start Date : July 1, 2006<br>End Date : Aug. 31, 2006<br># of Days : 62 of 62<br># obs : poss : 372 of 1488 | Sub Interval Windows | | |
|---|---|---|---|---|
| | | | Start | End |
| | | Date | Jan. 01 | Dec. 31 |
| | | Hour | 12 | 17 |

**Figure 86. Maggie and Tamarack Fires - Afternoon winds at the Peppermint RAWS during July and August, 2006.**




| Latitude : 36° 04' 24" N<br>Longitude : 118° 32' 29" W<br>Elevation : 7385 ft.<br>Element : | Start Date : July 1, 2006<br>End Date : Aug. 31, 2006<br># of Days : 62 of 62<br># obs : poss : 372 of 1488 | Sub Interval Windows | | |
|---|---|---|---|---|
| | | | Start | End |
| | | Date | Jan. 01 | Dec. 31 |
| | | Hour | 00 | 5 |

**Figure 87. Maggie and Tamarack Fires - Early morning winds at the Peppermint RAWS during July and August, 2006.**

**Table 21. Burning index/fire behavior crosswalk; this illustrates in real terms the meaning of several levels of increasing BI**

| Burning Index NFDRS -1978 | Flame Length (ft.) | Fireline Intensity (BTUs/S/ft.) | Narrative Comments |
|---|---|---|---|
| 0-30 | 0-3 | 0-55 | Most prescribed burns are conducted in this range. |
| 30-40 | 3-4 | 55-110 | Generally represent the limit of control for direct attack methods. |
| 40-60 | 4-6 | 110-280 | Machine methods usually necessary or indirect attack should be used. |
| 60-80 | 6-8 | 280-520 | The prospects for direct control by any means are poor above this intensity. |
| 80-90 | 8-9 | 520-670 | The heat load on people within 30 feet of the fire is dangerous. |
| 90-110+ | 9+ | 670-1050+ | Above this intensity, spotting, fire whirls, and crowning should be expected. |

**Table 22. Locations of nearest RAWS to center of the Lion Fire**

| Name | Distance From Center of Lion Fire | Drainage | Direction From Lion Fire | Elevation (ft.) |
|---|---|---|---|---|
| Oak Opening | 13 | Tule River | WSW | 3,240 |
| Peppermint | 13 | Kern River | SSW | 7,385 |
| Wolverton | 14 | Kaweah River | NW | 5,240 |
| Rattlesnake - summer | 14 | Kern River | NE | 8,600 |
| Blackrock | 18 | Kern River | SE | 8,200 |
| Johnsondale | 20 | Kern River | SSW | 4,700 |
| Uhl / Hot Springs | 28 | White River | SSW | 3,720 |

**References:**

Fire Danger Working Group. 2002. Gaining a Basic Understanding of the National Fire Danger Rating System. National Wildfire Coordinating Group. Source: http://geology.isu.edu/geostac/Field_Exercise/wildfire/images/Basic_NFDRS.pdf