USDA FOREST SERVICE PACIFIC SOUTHWEST REGION
FIRE BEHAVIOR IN TREE MORTALITY SUMMARY REPORT

SEQUOIA NATIONAL FOREST AND GIANT SEQUOIA NATIONAL MONUMENT
2017 PIER FIRE

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Executive Summary

On the Pier Fire, which burned in the Sequoia National Forest and Giant Sequoia National Monument in late August and September 2017, the Fire Behavior Assessment Team (FBAT) installed monitoring plots and obtained observations of fire behavior in tree mortality areas to answer the question “What is the actual fire behavior in tree mortality areas?” Key FBAT observations from the Pier Fire include:

- Dead trees torched below wind and fuel moisture thresholds at which live trees were observed torching.
- Red phase dead trees are more likely to torch than live trees, however, gray phase or more deteriorated red phase trees (‘old red’ phase) did not often torch.
- Intense fire behavior was observed in areas with grey phase mortality, presumably due to increased dead surface fuel loading.
- Fire climbs dead tree trunks and bark more readily than live trees leading to higher than normal levels of tree top breakage after fire in dead trees.
- General fire effects observed in areas with giant sequoia suggest that the Pier Fire will end up being positive overall for the resiliency of giant sequoia.

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Background and Overview

The Pier Fire ignited on Tuesday, August 29th, 2017 at approx. 15:30 on the Western Divide district of the Sequoia National Forest, part of the southern Sierra Nevada Range. The area was in high fire danger rating and the month of August had a continual high pressure system that:

- Brought temperatures above 80°, with high temperatures above 100° at a nearby RAWS (Oak Opening) the day before and the day the fire started.
- Brought a decline in relative humidity, from the upper 40s to the teens the day the fire started,
- Reduced 1000-hour fuel moistures to under 10%.

The above factors, coupled with the amount and types of available fuel (grass, brush, downed woody, and drought/bug-kill) led to the Pier Fire's rapid growth and intense fire behavior. The Fire Behavior Assessment Team (FBAT) arrived on the fire on August 30th, collected observations and monitoring data through September 12th and downloaded, post-processed and summarized data through September 21st.

Goals and Objectives

The Pacific Southwest Region asked FBAT to answer the question "What is the actual fire behavior in tree mortality areas?" The Fire Behavior Assessment Team's (FBAT's) goal coming into fire season was to collect short-turnaround intelligence on fuel/weather/topography/fire behavior conditions to support current and future incidents by helping to understand fire behavior in areas with tree mortality. The methods we used to answer these questions include FBAT plot sampling and observations of fire behavior.

Accomplishments

- Maintained safety as first priority.
- Installed 7 plots (fuels measured and fire behavior instrumentation installed) (Figure 1).
- Obtained 10 days of fire behavior observations in tree mortality.
- Provided FBAN/IMET/Air Resources Advisor with fireline observations of weather, fire behavior and smoke.

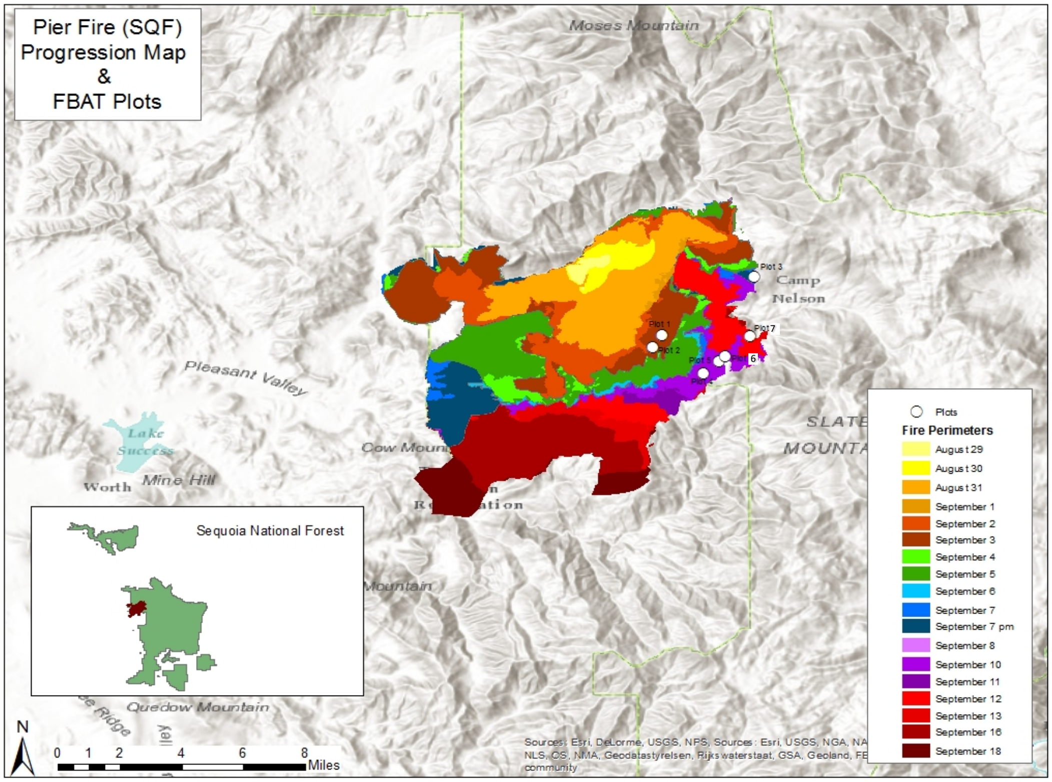

Figure 1. Progression map Pier Fire

FEMO/FOBS Observations

Fire behavior and associated weather were observed at several opportune times and locations 8/30-09/09/17 to document effects of tree mortality on fire behavior in the context of the fire environment. Fire Effects Monitoring (FEMO)-style observations were used. Time-lapse cameras were used to record any larger-scale crown fire events that may have occurred, however, no large crown fire runs were captured. https://www.fs.fed.us/adaptivemanagement/amset_videos.php

Although this observation dataset should be combined with datasets from other fires in order to draw more solid conclusions, several trends are evident. Most winds during observation periods appeared to be primarily associated with up-canyon flow during daytime heating, leading to a negative correlation between winds and fine dead fuel moisture (Figure 2), meaning that as winds increased, fine dead fuel moistures decreased. Fine dead fuel moisture estimates shown in Figure 3 are based on Wildland Fire Module Handbook tables integrating air temperature, relative humidity, observation elevation above or below the fire, aspect, and shading. Ground fire and surface fire in the absence of torching tended to occur under low wind and high fuel moisture conditions.

Data suggest that dead trees may be more likely to torch than live trees under low wind and high fine dead fuel moisture (Figure 3). Observations of torching events in the figure combine one or more separate torching events wherein only dead, both dead and live, and only live trees initiated torching during an observation period. It was difficult to determine whether the tree that started a torching event was dead or alive; proximity and binoculars helped. As such, observations are limited.

Table 1 provides statistics on weather and fire behavior and dead-tree prevalence. Observations encompassed dry, hot conditions at 4000 ft and cool, rainy conditions at 6000 ft. Only ground, surface, and torching behaviors were observed; crown fire was not observed. The proportion of dead trees in the landscapes where observations were made averaged 19%, but ranged up to 70%. Areas with no dead trees were oak dominated at lower elevations.

Table 1. Mean, maximum, and minimum values for weather, fire behavior, and dead tree observations.

Variable	Observations	Mean	Minimum	Maximum
Temperature (dry bulb, F)	57	78	68	97
RH (%)	57	42	21	70
Elevation (observation, ft)	56	5196	4000	6000
Fine dead fuel moisture (exposed, %)	45	10	6	14
Fine dead fuel moisture (shaded, %)	45	8	3	13
Wind (median, mi/hr)	59	3	1	8
Wind (gust, mi/hr)	51	6	N/A	20
Rate of spread (ch/hr)	44	6	N/A	60
Flame length (surface, ft)	36	5	N/A	20
Flame length (torch, ft)	28	29	N/A	140
Dead trees: yellow- and red-phase (% of total trees)	62	11	0	50
Dead trees: gray phase (% of total trees)	62	8	0	30
Dead trees: all dead trees (% of total total)	62	19	0	70

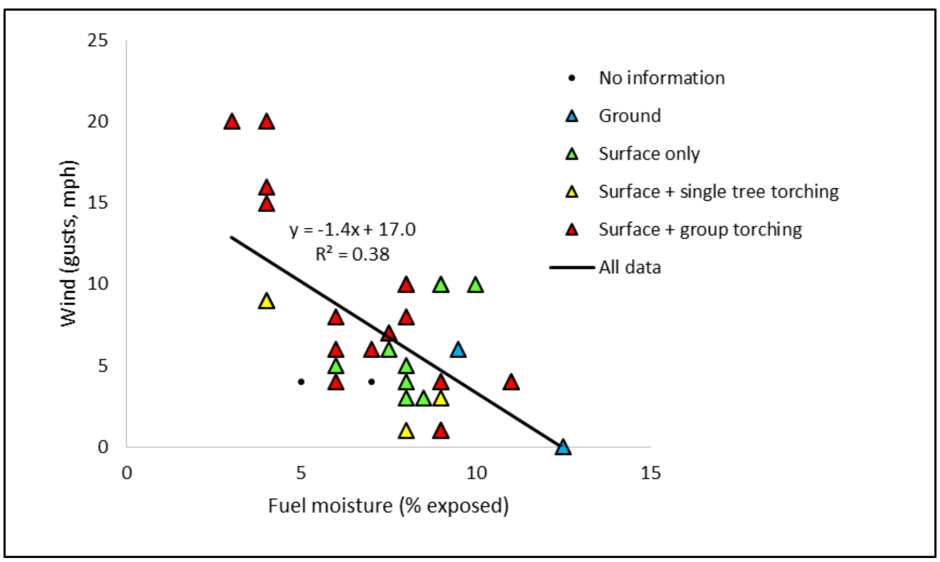

Figure 2. Fire observations as a function of wind gusts and exposed fine dead fuel moisture. Fire observations are categorized as ground fire (no flames), surface fire alone (no torching), and surface fire with either single or group-tree torching. The trend line is fit to all data.

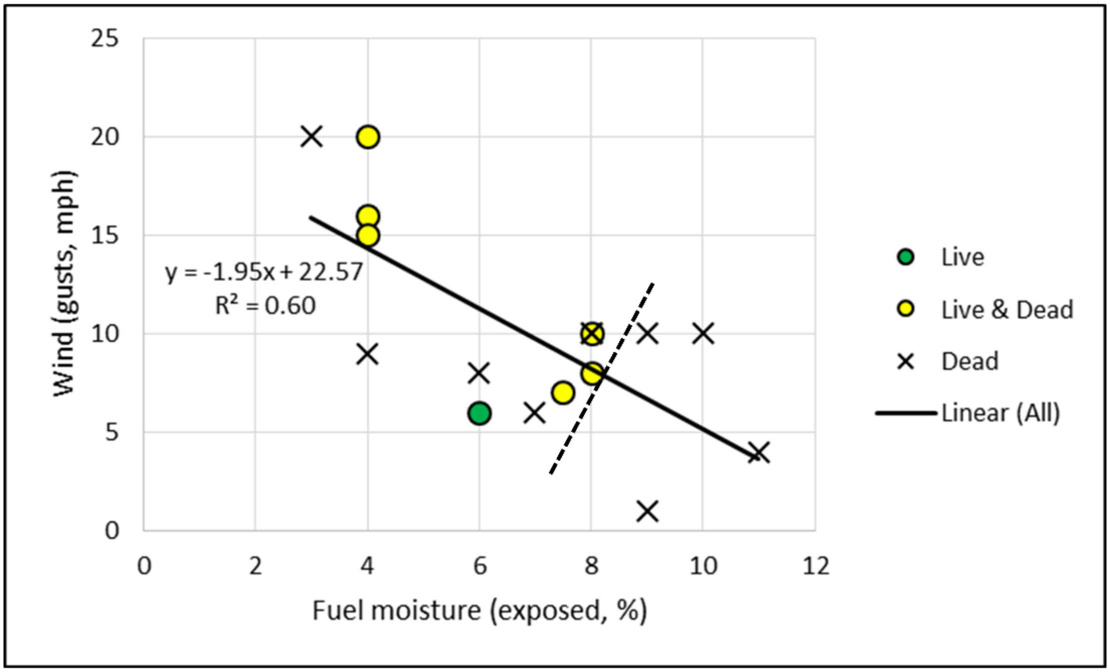

Figure 3. Torching events within separate observation periods categorized by the kinds of trees that initiated them. Single tree and group torching events are combined. Data from each observation period is represented by an icon on the graph. Wind gust and fine dead fuel moisture estimates are shown for each observation period. The dotted line was placed on the figure to emphasize the more moderate conditions under which some dead trees initiated torching events.

Pre- and Post-Vegetation and Fuel Measurements

Vegetation and fuels were inventoried both before the fire reached each plot, and then again after the fire spread across each plot.

Overstory Vegetation Structure and Crown Fuels

Variable radius sub-plots were used to characterize crown fuels and overstory vegetation structure. A Relaskop (slope-correcting tree prism) was used to create individual plots for both pole (>2.5 to 5.9 in diameter at breast height (DBH) and overstory (>6 in DBH)) trees. When possible a basal area prism factor was selected to include between 5 and 10 trees for each classification. Tree species, status (alive or dead), DBH, height, canopy base height, and crown classification (dominant, co-dominant, intermediate or suppressed) was collected for each tree before the fire. Tree height measurements were completed with a laser rangefinder; DBH was measured with a diameter tape.

After the fire, maximum bole char, crown scorch, torch heights and percentages scorch and torch were recorded for each tree. After fire, trees were assumed to be alive if any green needles were present. Changes in canopy base height were estimated from heights of scorch and torch on tree branches, or if necessary from percent of scorch rather than the maximum heights because uneven scorch values occurred sometimes due to trees affected by slope and alignment with heat. Due to smoke and poor lighting, visibility of the full crown is sometimes difficult. If a more accurate assessment of tree survivorship in the plots is desired, we recommend another plot visit next year.

The Forest Vegetation Simulator program (FVS, Crookston and Dixon 2005) and its Fire and Fuels Extension (FFE-FVS, Rebain 2010) was used to calculate canopy bulk density, canopy base height, tree density, and basal area both pre- and post-fire for all tree species. FVS/FFE-FVS is stand level growth and yield program used throughout the United States. The Western Sierra variant was used for all calculations.

Understory Vegetation Structure and Loading

Understory vegetation was measured in a one meter wide belt along three 50-foot transects before and after the fire. The fuel and vegetation transects were always in view of the video camera (which will be described below in the "Fire Behavior Measurements and Observations" section). Species, average height and percent cover (based on an ocular estimation) were recorded for all understory shrubs, grasses and herbaceous plants. Biomass of live woody fuels (shrubs and seedlings) and live herbaceous fuels (grasses, herbs, subshrubs) were estimated using coefficients developed for the Behave Fuel Subsystem (Burgan and Rothermel 1984), but calculations were done on a spreadsheet (Scott 2005).

Surface and Ground Fuel Loading

Surface and ground fuels were measured along the same three 50-foot transects as the understory vegetation at each plot. Surface fuel loadings (litter, 1-hr, 10-hr, 100-hr and 1000-hr time lag fuel classes and fuel height) were measured using the line intercept method (Brown 1974, Van Wagner 1968). One and 10-hr fuels were tallied from 0 to 6 ft, 100-hr from 0 to 12 ft and 1000-hr from 0 to 50 ft. Maximum fuel height was recorded in three transect intervals from 0 to 6 ft, 6 to 12 ft and 12 to 18 ft. Litter and duff depths were measured at 1 and 6 ft. All measurements were taken both pre- and post-fire. The measurements were used to calculate surface and ground fuel loading with basal area weighted species specific coefficients (van Wagtendonk *et al.* 1996; 1998); and ultimately percent fuel consumption.

Burn Severity

A rapid assessment of burn severity was completed along each transect and for the entire plot area to document the effects of fire on the surface and ground (USDI National Park Service 2003). The National Park Service (NPS) uses fire severity ratings from 1 to 5 when evaluating fire severity. In this rating system 1 represents unburned areas, and 5 represents areas with high fire severity (Appendix B).

Fire Behavior Measurements and Observations

At each plot, multiple sensors (thermocouples and anemometers) and a video camera were set up to gather information on fire behavior. The thermocouples arrayed across the plot have the capability to capture day and time of temperatures from which rate of spread can be calculated. The anemometer captured wind speed. The video camera is used to determine fire type, flame length, variability and direction of rate of spread, flame duration, wind direction and the direction of fire spread in relation to slope and wind.

Rate of Spread and Temperature

Rate of spread was determined both by estimating rate of spread from video analysis and by calculating rate of spread with time stamps from sensors (data loggers with a thermocouple attached). The data loggers are buried underground with the thermocouple at the surface of the fuel bed. The thermocouple is able to record temperature up to six days or until the thermocouple and/or data logger is damaged by heat. The distances and azimuths among thermocouples were measured and these geometrical data and time of fire arrival were used to estimate rate of spread from Simard *et al.* (1984).

Fire Type and Flame Length

Fire type is classified as surface fire (low, moderate or high intensity) or crown fire. Crown fire can be defined as either passive (single or group torching) or active (tree to tree crowning). Fire type was determined from video as well as post-fire effects at each plot. For example, plots where there was complete consumption of tree canopy needles indicate at least torching or passive crown fire. Flame length was primarily determined from video footage.

Plot Wind Speed

Wind data collected with cup anemometers placed 5 feet above ground gives an indication of the wind experienced at each plot as the fire passed through. Wind data on plots with intense fire are only valid only up until the plastic anemometer melts or otherwise is compromised. Wind data were recorded at 1-second intervals and averaged over 10 seconds.

Findings/Results

Pre-fire data were collected at six of the seven plots that were established on the Pier Fire. Data were not collected at Plot 4 (video camera setup only). The six plots where data were collected represent different forest/vegetation types and management areas (Table 2), including a range of tree mortality phase levels. Paired photographs of plots with fuels data are available in Appendix A. Video cameras were set up at all seven plot locations, with three cameras successfully capturing video of fire behavior. Camera malfunctions were caused by rainfall, excessive heat, and a falling tree. Rate of spread and wind speed sensors were set up and functioned properly at three plots where they were installed.

Table 2: Site description of the 7 plots.

Plot	Slope %	Aspect (deg.)	Equipment	Description
1	70	335	No ROS installed, video captured	Steep mixed conifer area just below ridge near Deadman's Creek with moderate levels of mainly grey phase mortality
2	20	30	No ROS installed, video captured	Moist mixed conifer area in drainage with dogwoods and Giant Sequoia with minor amounts of tree mortality.
3	40	50	No ROS installed, video triggered due to rain, fire not captured	Mixed conifer area with moderate tree mortality in old red phase with roughly 15% of needles still remaining.
4			Just video, no fuels plot or ROS; video camera melted	Mixed conifer area with moderate tree mortality.
5	36	270	ROS installed, camera triggered due to rain, fire not captured	Mixed conifer area with heavy fuels and heavy grey phase tree mortality at ridgetop near top of Wilson Creek drainage.
6	30	28	ROS installed, video camera smashed by tree	Mixed conifer area with heavy fuels and heavy grey phase tree mortality at ridgetop near top of Wilson Creek drainage.
7	50	270	ROS installed, video captured	Mixed conifer/oak woodland with several grey phase incense cedar uphill 8 chains of the mine road, which was used as a control line and burned out. This area had been treated with cut of small diameter trees and shrub, then piled and burned.

Stand Characteristics, Tree Canopy Scorch, Torch, and Bole Char

A few days after the fire burned through each plot (allowing for smoldering combustion to complete and some fire-weakened trees to fall) additional measurements were gathered (char height, maximum heights and percentage of crown scorch and torch) to better assess the fire effects at each plot. Percentage values were determined using ocular estimations, and heights were measured with a laser rangefinder. Severity or fire effects can be accessed from the percentage of scorch and torch for each study plot (Figures 5 and 6). Plots 1, 2, and 7 had elevated levels of scorch and torch, at 91/100%, 87/13%, and 92/62%, respectively. Plots 5 and 6 had moderate scorch and torch, at 48/29% and 31/0%. Plot 3 did not have any scorch and torch. Plots 1 and 5 showed the greatest maximum height of bole char at 49 and 27 feet, respectively. Plots 2, 3, 6, and 7 showed similar moderate levels of bole char height at 14, 16, 12, and 15 feet, respectively. Plots that showed more severe fire effects had lower canopy base height, higher canopy cover, and canopy bulk density values; particularly plots 1 and 7 (Table 3). Tree density of pole and overstory sized trees appear to have had little common influence on severity (Table 3). Higher understory vegetation fuel loading (Table 5) appears to be a common factor for plots which showed more severe fire effects. Plots 2 and 5 both had higher levels of pre-fire grass/herb fuel loading, and plots 1 and 7 had the highest measured fuel loading for shrubs and seedlings. Interestingly, measured dead and downed fuel loading appears to show common influence on fire effects more than live understory fuel load and standing tree metrics.

Table 3: Pre- and post-fire overstory vegetation and crown fuel data by plot, estimated by FVS-FFE[1].

Plot	Overstory (>6 in DBH) trees/acre		Pole-size (<6 in DBH) trees/acre[2]		Basal Area (ft^2/acre)		Canopy Cover (%)		Canopy Height (ft)		Canopy Base Height (ft)		CBD (kg/m^3)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	112	35	0	0	121	42	61	14	40	39	2	12	0.118	0.053
2	34	34	383	383	179	179	52	52	75	77	5	13	0.090	0.062
3[2]	47	47	0	0	163	163	36	36	78	78	37	36	0.044	0.044
5	180	180	273	273	171	171	55	55	71	71	4	4	0.097	0.097
6	324	324	37	37	125	125	52	52	42	42	14	19	0.077	0.032
7	372	372	0	0	159	159	83	83	45	29	1	9	0.170	0.105

[1] FVS was programmed to include hardwood species in above estimates.
[2] No plot data was taken on Plot 4, it was just a video camera site.

Table 4. Percent of tree scorch, torch of tree crowns and maximum height of bole char in feet by plot.

Plot	Scorch %	Torch %	Bole Char (ft)
1	91	100	49
2	87	13	14
3	0	0	16
5	48	29	27
6	31	0	12
7	92	62	15

Understory Vegetation Loading and Consumption

The understory vegetation loading varied for each plot, but was usually less than 1 ton/acre for grass, herb, shrub, and seedlings combined, with two exceptions. Plot 2 had 1.7 tons/acre of dead herb/grass and plot 5 had 6.4 tons/acre of dead herb/grass. Full consumption of the above-ground grass and herb layer occurred, and nearly full consumption of shrub/seedling layer occurred except for plots 3 and 7 (Table 5). The paired photographs in Appendix A show a sample of the distribution and density of understory flora for each plot, as well as illustrate the change post-burn.

Table 5: Average understory vegetation fuel loading pre-fire and post-fire for plots 1 to 7 (excluding site 4).

Site	Average Grass/Herb (ton/ac)						Average Shrub/Seedlings (ton/ac)					
	Pre-Fire			Post-Fire			Pre-Fire			Post-Fire		
	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total
1	0.002	0.002	0.004	0	0	0	0.074	0.007	0.081	0	0	0
2	0	1.667	1.667	0	0	0	0.001	0	0.001	0	0	0
3	0	0.003	0.003	0	0	0	0	0	0	0.0004	0.001	0.001
5	0.001	6.374	6.375	0	0	0	0.002	0.0001	0.002	0	0	0
6	0	0	0	0	0	0	0.001	0.001	0.002	0	0	0
7	0	0.003	0.003	0	0	0	0.397	0.028	0.425	0.026	0.003	0.029

Surface and Ground Fuel Loading and Consumption

As considered normal in forested ecosystems, the predominant fuel layer making up the bulk of the total surface and ground fuel loading was duff, followed by litter (Table 6). Loading at the unburned plots 2, 5, and 6 is much higher, than the other plots. One- and 10-hour fuels contributed only slightly to total fuel loads. 1000-hour fuels were present on all plots, but less abundant on plot 7. Fuel bed depths were generally less than one-foot, except for plot 5, which mirrors the relatively low numbers of small diameter woody fuels. Dead and downed woody and forest floor consumption was high, mostly above the 90 percentage, except for plot 3 for 100-hr and fuel bed depth change and plot 5 for fuel bed depth change (Table 7).

Table 6: Average surface and ground fuel loading and fuel bed depth based on 3 transects per plot, and post-fire data for burned plots 1 to 7 (excluding site 4).

Plot	Mean Fuel Loading (tons/acre)												Total Load	
	Duff		Litter		1-hr		10-hr		100-hr		1000-hr			
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	38.5	0.0	17.5	0.0	0.6	0.0	0.5	0.0	3.5	0.0	26.1	0.0	86.7	0.0
2	58.3	0.0	39.7	0.0	0.1	0.0	0.5	0.1	3.2	0.0	36.2	19.4	137.9	19.5
3	41.3	3.2	14.0	0.0	0.2	0.0	1.8	0.2	1.4	0.5	13.6	11.3	72.3	15.1
5	67.2	1.1	25.0	0.1	1.3	0.0	3.4	0.1	6.6	0.0	53.1	23.9	156.5	25.3
6	83.3	0.7	37.8	1.0	0.2	0.0	1.3	0.1	2.3	0.0	1.5	0.2	126.3	2.0
7	18.3	0.0	9.3	0.0	0.2	0.0	1.1	0.0	0.4	0.0	4.1	0	33.4	0.0

Table 7: Average percent fuel consumption per category and fuel bed depths for plots 1 to 7 (excluding site 4, based on Table 6).

Plot	Percent Consumption %					Change in Fuel Bed Depth (%)	Fuel Bed Depth (in.)	
	Duff	Litter	1-hr	10-hr	100-hr		Pre	Post
1	100	100	100	100	100	100	0.9	0.0
2	100	100	100	87	100	95	0.4	0.0
3	92	100	98	90	66	49	0.4	0.2
5	98	99	100	97	100	78	1.3	0.3
6	99	97	100	96	100	99	0.9	0.0
7	100	100	100	100	100	97	0.4	0.0

Soil and Understory Vegetation Burn Severity

The National Park Service's severity categories were used to assess post-burn soil/substrate and understory vegetation severity along each transect and for the entire plot. Vegetation burn severity is only based on the vegetation that was documented pre-burn. For full descriptions of the categories, please see Appendix B. Substrate severity was mostly high and very high in the six burned plots with small pockets of unburned to moderate severity (Figure 4). Understory vegetation severity was similar to soil/substrate, with plots 1 and 2 being very high severity. Some portions of plots 3, 6, and 7 had unburned to moderate understory severity. Measurements are based on immediate post-fire conditions, and some plant communities are known to recover well after fire events based on multiple factors.

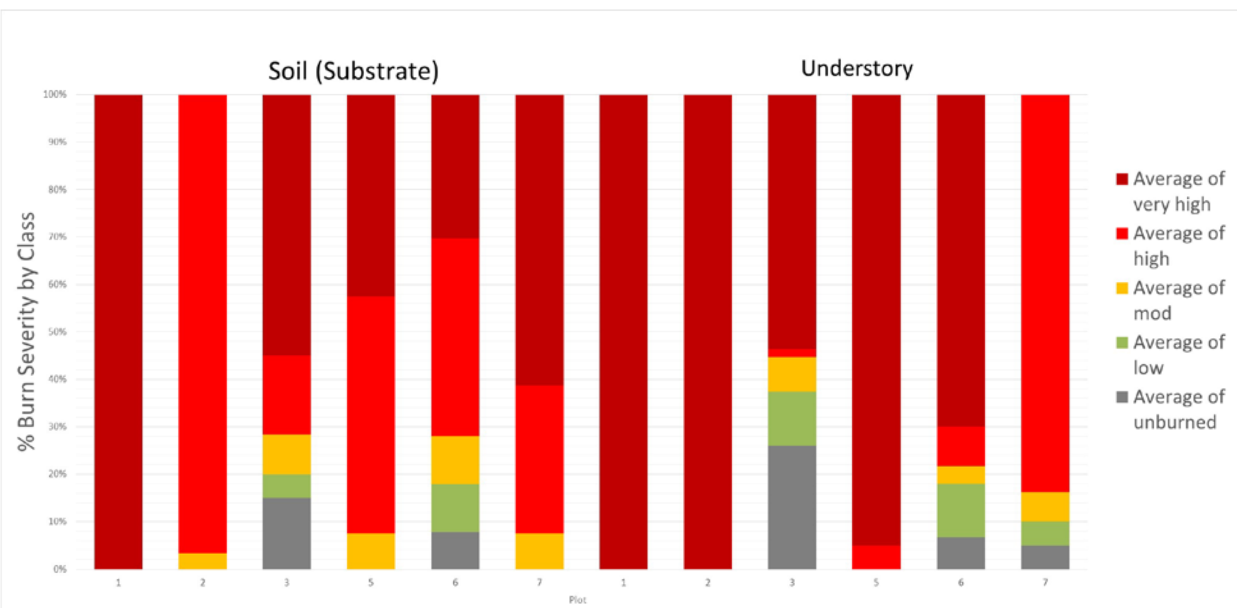

Figure 4: Average post-fire surface soil/substrate and understory vegetation severity rating for each plot.

Fire Behavior

Fire behavior captured on video and with rate of spread sensors ranged from slow-moving surface fire to intense group torching. Plot 1 was the most intense fire captured on video, and includes footage of fire spotting, torching and fire whirls. Plot 1 was in an area above Deadman's Creek where a fair amount of tree mortality in red, old red and grey stages was present. https://youtu.be/wtzYEwTl27w Plot 2 was in a flat, moist area among Giant Sequoia. The fire spread into this plot at night, and crept very slowly over the course of hours. https://youtu.be/CwTeVAIR-4g Camera trigger systems were triggered prematurely due to rain on plots 3 and 5. On plot 4 the video camera melted and on plot 6 a tree fell on the camera, destroying it. Plot 7 was located uphill about 7 chains of the Mine Road, along which burn-outs occurred. Plot 7 was lower in elevation than most of the other plots and included oak trees along with a stringer of smaller, old red and grey phase incense cedar. Plot 7 video captured moderate fire behavior with individual and group torching. https://youtu.be/SbbLSPG-4UU Rate of spread sensors were installed for plots 5, 6 and 7. Sensors provided estimates of fire spread in the absence of video cameras, and corroborated rates of spread estimated from video for plot 7.

Table 8: Fire behavior data based on the video camera footage and from sensors.

Plot	Fire Type	Direction of spread	Wind speed (mi/hr)*	Flame Length (ft)	ROS (ch/hr) camera	ROS (ch/hr) sensors	Date & Approx. Arrival Time**	End of Active Consumption
1	High Intensity surface fire, with individual and group torching	Uphill, spreading SE	20 (NA)	5 – 40 ft	26 ch/hr	N/A	09/02/17 1219	Unknown
2	Creeping and surface fire, with low intensity, no torching	Variable	N/A	0 – 4 ft	Variable and slow	N/A	09/02/17 2330	09/08/17
5	Moderate surface fire, with isolated high activity, high char heights but no torching.	Uphill, spreading NE	11 (7)	N/A	N/A	1-2ch/hr	09/08/17 1824	09/10/17
6	Low intensity creeping and surface fire with isolated high activity,	Some uphill, some backing, generally NE	NA	N/A	N/A	0.5ch/hr	09/09/17 1107	09/12/17
7	High Intensity surface fire, with individual and group torching	Flanking W, and uphill to the N	33 (10)	5 – 30 ft	8ch/hr	7ch/hr	09/10/17 1447	09/12/17

*Maximum wind speed over 10 seconds is noted in parentheses
**Time is local.

Fire Effects on Giant Sequoia

The Pier Fire burned into several areas with giant sequoia, a tree species that only occurs in limited areas of the western Sierra Nevada. Giant sequoia can grow to be 300 feet tall, and the oldest known is 3,200 years old. Giant sequoia may sprout from the bole when old branches are lost to fire or breakage, however most reproduce by seed. Giant sequoia cones are semi-serotinous, meaning when exposed to high heat they open, increasing seed dispersal. Seeds germinate best in bare mineral soil, which are conditions found after a fire consumes woody debris, litter, and duff. Mature giant sequoia have thick bark, self-pruned lower branches, and higher canopies than other trees; these are all adaptions which allow them to persist through fire events (Figures 5 and 6). In areas where fire does not occur frequently and forest floor material accumulates, germination of giant sequoia is limited.

Figure 5: Average Pre- and post-fire photos of giant sequoia on 21S12 road.

Figure 6. Pre- and post-fire of giant sequoia on 21S12 road.

Figure 7. Giant Sequoia at Mountain Aire before and after the fire.

A number of dead trees existed in this area pictured in Figure 7 prior to fire, and were fallen to allow crews to work in the area to safely protect the homes and control the fire. The combination of beetles and drought, which triggered the recent mortality event, has the effect of thinning the canopy fuels near giant sequoia, which reduced the likelihood of the Giant Sequoia torching due to adjacent canopy fuels.

Figure 8. A giant sequoia on the 21S12 road experienced torching of canopy on one side where taller trees in the surrounding canopy also torched.

Although most giant sequoia observed along the 21S12 road and Mountain Aire had minimal crown damage due to fire, the tree shown in Figure 8 experienced torching and lost a majority of needles on one side of the crown. Local knowledge estimates that this tree will likely survive fire. Note that this Giant Sequoia as well as some of the others were in areas that had not burned in the past 90 years or longer. No young giant sequoia were documented in any FBAT plots and in general did not seem prevalent in the area. The Pier Fire consumed woody debris, litter and duff and heated sequoia cones to allow for germination of the next generation of giant sequoia, which is needed to maintain its population.

Conclusions and Lessons Learned

- Dead trees (those with a fair amount of red needles still remaining) torched below wind and moisture thresholds than live trees that were observed torching.
  In FBAT observations on the Pier Fire, no live trees (only dead trees) torched when the combination of fine dead fuel moistures were higher than 7 and winds were lower than 10 mph. Dead trees initiated torching at conditions as low as 1 mph of wind and fine dead fuel moistures as high as 11.
- In the field, we did not observe many grey phase or older red phase trees (trees with very few red needles left) torching. While taking fire severity effects data in plots, we observed some areas where branches of dead trees were not scorched or burned in areas where most other fuels were otherwise fairly well-consumed.
- We did document intense fire behavior in areas with dead, grey phase mortality, suggesting that as these trees break apart and add to surface fuel loadings, higher levels of available fuels can lead to more intense fire behavior.
- We did notice that fire seems to climb the boles/bark of dead trees more readily than live trees. We observed this phenomenon in video, documented very high char heights (sometimes char went to the tree tops), and we noticed higher than normal levels of tree top breakage after fire due to fire climbing dead trees and weakening tree boles above ground level.
- Not including the one camera that was smashed by a tree, we had 50% camera failure. FBAT needs to find more reliable fire behavior equipment as well as equipment that requires less time to install and post-process data. Additionally, field fuels methods which require less post-processing time would increase efficiency.
- 100% of plots were burned, which does not always happen. We attribute this to FBAT arriving at the fire as soon as it went into extended attack and a team was ordered as well as the combination of remote areas and hot, dry weather, which led to open fireline on several divisions of this fire for a couple days.

References

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Background on FBAT

FBAT is a group which collects fuels and fire behavior data on wildland fires. FBAT can be ordered in ROSS. FBAT is made up of several members from the Enterprise Program, many on-call members from various agencies, collaborators as well as several wildland fire modules who are trained in FBAT methods and equipment use. More information can be found at: http://www.fs.fed.us/adaptivemanagement/projects_main_fbat.php

Appendix A. Pre and Post-fire Pictures of Fuels Transects

Plot 1, Transect 3, 50 to 0

Plot 2, Transect 3, 0 to 50

Pier Fire - Plot Photo Appendix

(Pre / Post)

Plot 3, Transect 2, 0 to 50

Plot 4 West

Pier Fire - Plot Photo Appendix

(Pre / Post)

Plot 5, Transect 2, 50 to 0

Plot 6, Transect 1, 50 to 0

Pier Fire - Plot Photo Appendix

(Pre / Post)

Plot 7, Transect 1, 0 to 50

Appendix B: Burn severity coding matrix from the National Park Service

Table 12. Burn severity coding matrix from the National Park Service (USDI 2003).

Code	Forests		Shrublands	
	Substrate	Vegetation	Substrate	Vegetation
Unburned (1)	not burned	not burned	not burned	not burned
Scorched (2)	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 (4)	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 (5)	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 diameter
Not Applicable (0)	inorganic pre-burn	none present pre-burn	inorganic pre-burn	none present pre-burn