# Fuels, Vegetation, Fire Behavior, and Fire Effects on the 2021 River Complex, Klamath and Shasta-Trinity National Forests

16 November 2021

Pre-, Active-, and Post-Fire Conditions on Plot 1

## Fire Behavior Assessment Team (FBAT)


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# Summary

The Summer Fire, along with other fires in the River Complex (i.e., the Haypress and Cronan Fires), were ignited by lightning on July 30th, 2021. The Fire Behavior Assessment Team (FBAT) started active monitoring on the Complex on August 8th, focusing on the Summer Fire. Summer Fire growth to the northwest towards the South Fork Salmon River and the town of Cecilville provided opportunities to establish plots on sites with a range of fuel treatment and silvicultural histories.

Prior to the start of the fires, fire weather indices (Burning Index and Energy Release Component) in the area were at or near record levels. At the Sawyers Bar RAWS, the station most representative of FBAT plots, indices dropped to near average levels with the rain (~0.5 in) that accompanied the lightning and indices were subsequently suppressed by the buildup of smoke in a persistent inversion below about 4000 ft elevation, a situation common of active fire seasons in the Klamath River basin.

Treatment histories were extracted from the FACTS (Forest Service Activity Tracking System) database. Within the area of the FBAT sampling plots, past vegetation management activity ranged from no recent management to a mix of commercial thinning, under-burning, pre-commercial thinning, and pile and burning over the last 25 years. One study plot was located in a limited area of clearcutting that occurred during the 1960s. Two ridgeline fuel breaks had been created by a mix of treatments to provide options for containing wildfires and along which four of the FBAT plots were established. No prior wildfires had been recorded in the area where the plots were installed but old fire scars on large conifers suggest persistent effects of unrecorded past fires. Fire behavior was primarily backing and flanking through the area where FBAT installed plots. The plots were within a smoke-filled inversion during much of the two-week period during which FBAT was working, with reduced temperatures, increased relative humidity, and light winds. A break in the inversion led to downslope spotting and an uphill run through one of the plots (Plot 4) but, otherwise, fire activity was primarily characterized by downslope backing under the influence of westerly daytime winds and wildfire management operations (e.g., holding, ignition) intended to contain the fire within an interior road network on the southern side of the South Fork Salmon River. Study plots were primarily located within a closed-canopy mixed-conifer ecosystem, some with a significant oak component. Backing fires in forested stands with a significant overstory (characterized by Plots 1-3, 5, 6, and 8) primarily consumed surface fuels. In plots with no prior treatment, duff loading appeared to be higher and, consequently, soil heating was likely greater. Plots that burned at night and in the early morning had the lowest percent consumption. The immediate effects of backing fires on trees and soil heating appeared relatively limited. However, weakening and subsequent downing of large live trees occurred within FBAT plots and extensively across the area because of burnout of fire scars, tree bases, and roots.

A key message from the FBAT fuels, fire behavior, and fire effects dataset under development since 2003 and supported by new data from the Summer Fire, is that opportunities for using wildfires to achieve ecological benefits often exist, even during fire seasons like 2021 that were characterized by drought and during which wildfires caused severe ecological effects elsewhere. Limited personnel on the River Complex fires and the presence of the smoky inversion, which restricted the ability to conduct piloted airborne operations, dictated the primary use of indirect tactics. Use of a drone for aerial ignition, both near control lines and along interior ridges (“ridge ignition”) on the Northwest side of the Summer Fire suggests that use of drones could substantially increase the acreage managed to meet ecological benefit objectives in the future under the right conditions, even where ground personnel are not available to do the ignition. Ridge ignition could be used to preempt slope reversals where fires backing downslope transition to fires heading uphill that can generate intense fire behavior and associated effects. Results from the Summer Fire support the conclusion that, under the right conditions and given certain risks (e.g., frontal scouring of inversions, high mortality of legacy trees during droughts), wildfires can be used in any year to meet ecological benefit objectives.

# Introduction

This report summarizes the results of the Fire Behavior Assessment Team's (FBAT's) coordinated, plot-based measurements of vegetation, fuel loading, fire behavior, fuel consumption, and fire effects on the Summer Fire. The Summer Fire, along with other fires in the River Complex (i.e., Haypress and Cronan Fires, see below), were ignited by lightning on July 30th, 2021 on the Klamath and Shasta-Trinity National Forests. At the time of this writing, the fires are still not fully contained. FBAT determined that the best available opportunity on the River Complex was to install plots across a range of fuel reduction and silvicultural treatments on the northwestern side of the Summer Fire (Figure 1). After FBAT completed post-fire sampling on August 21st, the fire continued to spread as planned by incident operations to the west along the south bank of the South Fork Salmon River, ultimately reaching the edge of the 2020 Red-Salmon Complex.

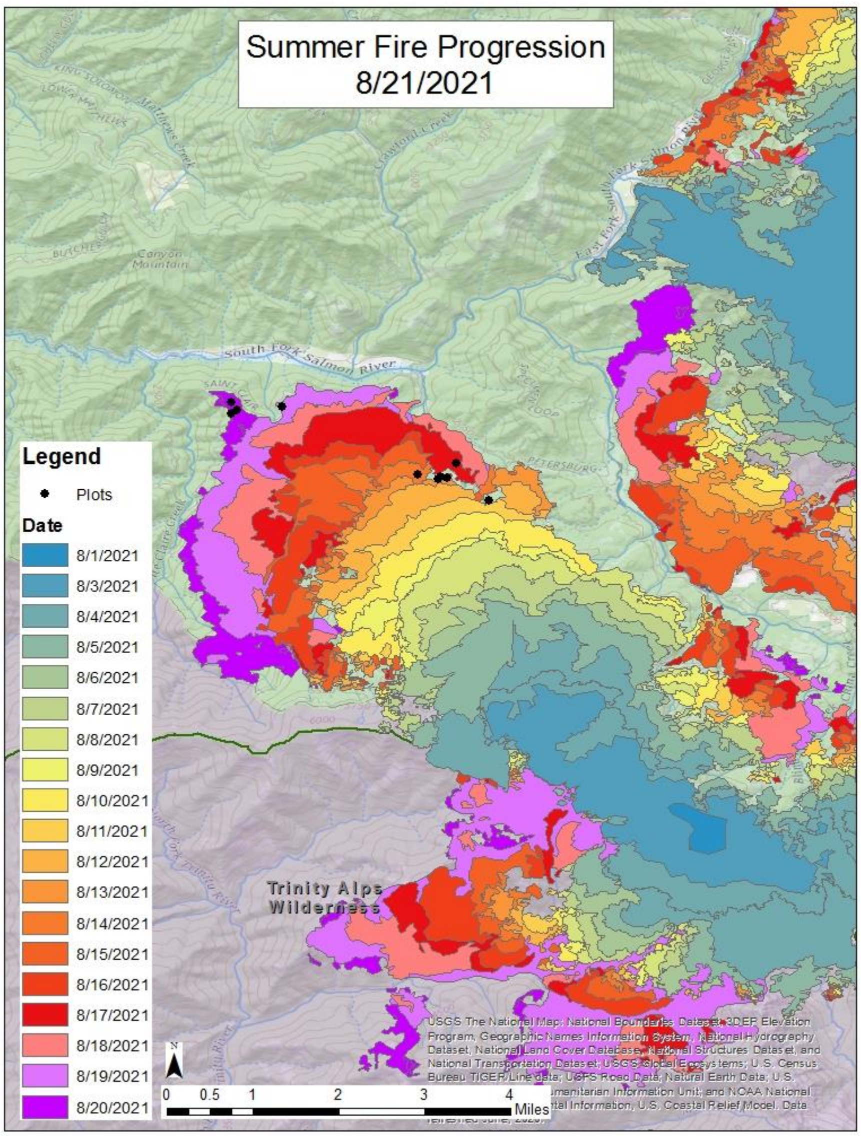


**Figure 1.** Progression map of Summer Fire towards the South Fork of the Salmon River with FBAT plot locations. Updated through August 21st, 2021 when FBAT revisited the last post-fire plots.

FBAT objectives on the Summer Fire were to:

1. Safely and efficiently maximize the number of plots inventoried for fuels, vegetation, fire behavior, and fire effects
2. Examine the effects of past fuel and silvicultural treatments on the Summer Fire
3. Continue to build the FBAT data archive to reflect a broad range of fuels, vegetation, treatment, and climatic conditions in support of fire and land management decision-making
4. Deliver this summary report for the benefit of land and fire managers, FBAT data archive users, and to facilitate future plot re-measurements

## Fire Indices and Weather Trends

Energy Release Component (ERC) is a fire danger index used to describe potential fire energy release (related to fuel consumption and fire intensity) and resistance to suppression. ERC reflects the potential worst case, total available energy (BTUs) per unit area (in square feet) within the flaming front at the head of a fire. The ERC is a function of the fuel model and fuel moisture (live and dead). Loading (determined by fuel model) and moisture contents of larger-diameter woody fuel have a large influence on ERC, while the lighter fuels have less influence, and wind speed has none. ERC has low variability and is the best fire danger index for indicating overall seasonal severity potential. The Burning Index (BI) estimates the potential difficulty of fire containment as it relates to the flame length at the head of the fire. BI is a function of the ERC and the Spread Component (SC). The SC is a function of live and dead fine fuel loads and moistures and wind. The index charts for Sawyers Bar Remote Access Weather Station (RAWS) are included to illustrate the seasonal changes in fire potential for the area of the FBAT plots (Figure 2). Sawyers Bar is the RAWS most representative of the fire weather in local drainages, particularly E-W drainages like the South Fork Salmon River, where both the Summer and Haypress Fires were primarily backing (Figure 1). In contrast to ridgeline RAWS stations above 4000 ft in the Klamath Mountains, Sawyers Bar RAWS captured inversion effects that were relevant for the FBAT plot sampling area. Sawyers Bar RAWS was affected by moisture (0.48 in.) that came with the lightning ignitions on 7/30/2021 (see Inciweb.nwcg.gov) as indicated by the sharp decline in indices toward average values. Other stations showed less rain and a faster rebound to long-term highs for these indices.

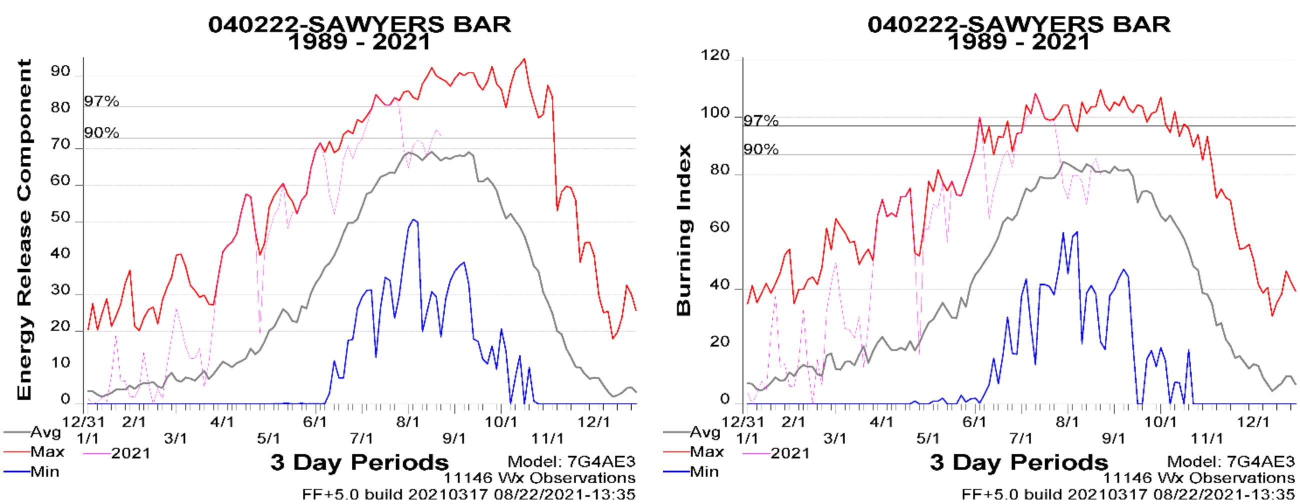


**Figure 2.** Energy Release Component and Burning Index graphs updated through 8/22/2021. The dotted line represents 2021 conditions. Note drop in index values with rainfall on July 30$^{th}$, reinforced by the subsequent smoky inversion.

RAWS in the area of the River Complex are mapped in Figure 3 and described in Table 1. Reported fire behavior and Sawyers Bar RAWS data indicate that the NW side of the Summer Fire area was affected by a persistent inversion during the period when FBAT was working. Days with inversion tend to have higher minimum and maximum RHs, higher state of weather readings (e.g., cloud-type cover), and lower solar radiation compared to ridgetop stations (e.g., Blue Ridge and Backbone RAWS). The Blue Ridge RAWS may best represent fire weather along ridges and in higher elevation areas, including areas of active fire growth on the east side of the Haypress Fire that were not affected by the inversion. Callahan RAWS should be consulted for fires burning further east in drier areas. Scorpion RAWS represents a sheltered, mid-slope location and it received no moisture on July 30th. Observations at Scorpion RAWS align more closely with ridgetop stations than drainage stations. Somes Bar RAWS is located in a wetter area at much lower elevation and at a farther distance from the Summer Fire than Sawyers Bar RAWS. The north-south drainage at Somes Bar RAWS picks up mostly light SSE winds and did not receive moisture on July 30th. Somes Bar RAWS may be an alternate option for areas affected by inversions. Given smoke from the Summer and Cronan Fires and prevailing wind directions, the inversion effect seemed to be greater at the Sawyers Bar than the more distant Somes Bar RAWS. Backbone RAWS may be a good alternative to Blue Ridge RAWS for higher elevation areas not affected by the inversion to the south of the Summer Fire.

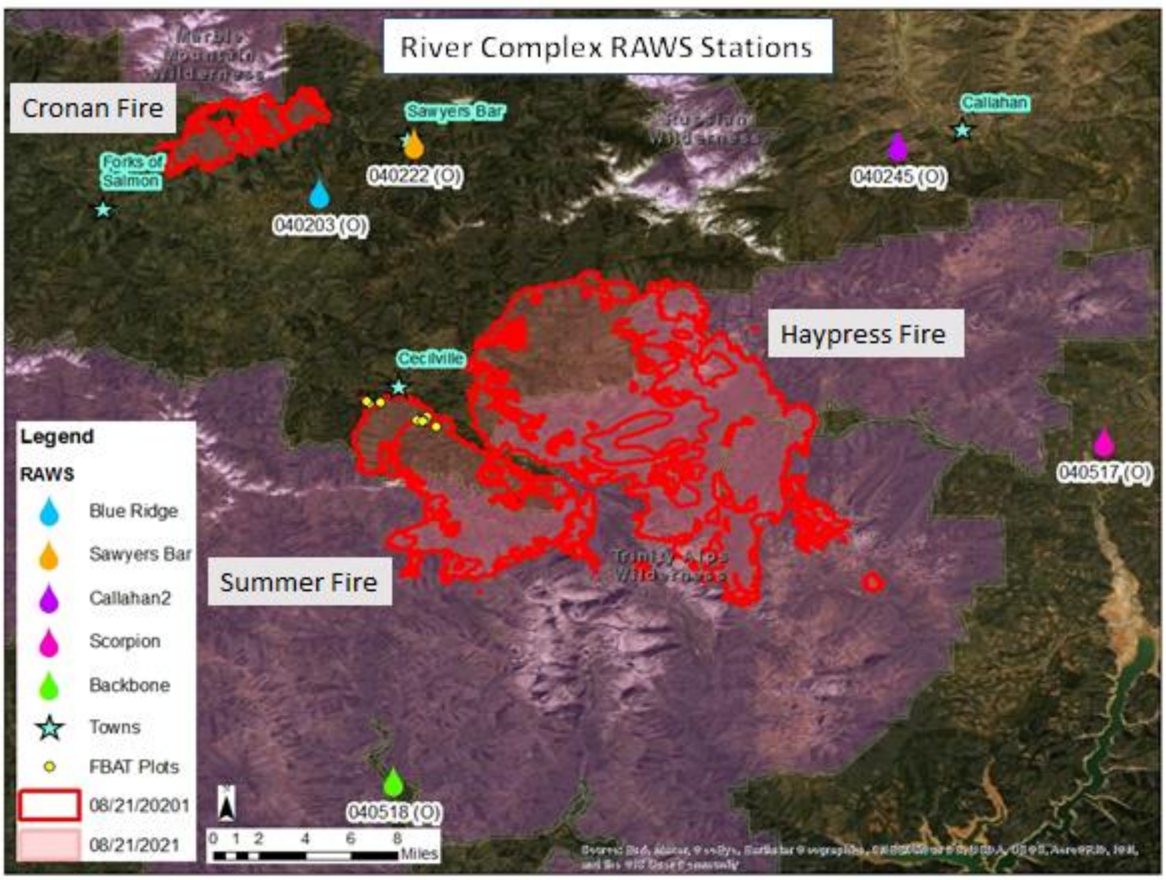


**Figure 3.** Location of RAWS stations relative to FBAT plots and Summer Fire perimeter. Wilderness areas are indicated by purple shading.

**Table 1**. Remote Automatic Weather Stations (RAWS) in the vicinity of the 2021 River Complex. Distance refers to miles from the origin of the Haypress Fire, west of the Summer Fire (Figure 3).

| RAWS Name | ID | Dist. | Aspect | Slope % | Slope Position | Elev. (ft) | Avg Precip. (in) | Descriptive Location |
|---|---|---|---|---|---|---|---|---|
| Blue Ridge | 40203 | 12.6 | S | 56-75 | Ridge/ Peak Top | 5859 | 35 | 3 miles south of Cronan Fire; 8.5 miles NW of Haypress Fire; 4 miles SW of Sawyers Bar RAWS atop Blue Ridge |
| Somes Bar | 40231 | 30.1 | S | 56-75 | Valley Bottom/ Flat | 915 | 60 | 14 miles NE of Cronan Fire, along Klamath River |
| Sawyers Bar | 40222 | 12.5 | S | 56-75 | Valley Bottom/ Flat | 2455 | 45 | 3 miles SE of Cronan Fire; 8 mi NNE of Haypress Fire; 4 miles NE of Blue Ridge RAWS; just above North Fork Salmon River |
| Scorpion | 40517 | 16.8 | SW | 41-55 | Midslope | 3365 | 47 | 15 miles E of Haypress and Summer Fires, along Trinity River; east of Coffee Creek drainage |
| Callahan | 40245 | 14.7 | SW | 31-45 | Ridge/ Peak Top | 3910 | 21 | 10 miles NW of Haypress Fire, above South Fork Scott River |
| Backbone | 40518 | 18.7 | SW | 41-55 | Ridge/ Peak Top | 4609 | 40 | 10 miles S of Summer Fire, above North Fork Trinity River |

## Precipitation

The isolated thunderstorms on July 30$^{th}$, 2021, had variable effects on fuels and climatology across the Klamath National Forest. Rainfall at the Sawyers Bar RAWS (0.48 in.) created a large dip in ERC, which fell from near maximum to below average for the date. The ERC then rebounded to the long-term average near where it stayed through August 22$^{nd}$, 2021. The area of the Summer Fire where FBAT established plots received rain during the same period (based on personal communication with local staff), but no weather stations are located nearby that would provide the amount.

## Winds

Sawyers Bar RAWS winds during the period of FBAT pre- and post-fire sampling are shown in Figure 4. Because of its relatively low elevation and the orientation of the North Fork Salmon River drainage at that location, winds were mostly light and WSW during the day and ESE at night, rarely from other directions. For Somes Bar RAWS, the other RAWS in the drainage (X miles to the NW), winds were mostly calm and light from the SSE. Scorpion RAWS commonly recorded calm winds. Otherwise, winds were mostly light southerlies. Blue Ridge RAWS (locally, the highest elevation station) captured winds from all directions though the most common early morning hour winds are from the east, then shifting west by late morning and into the afternoon.

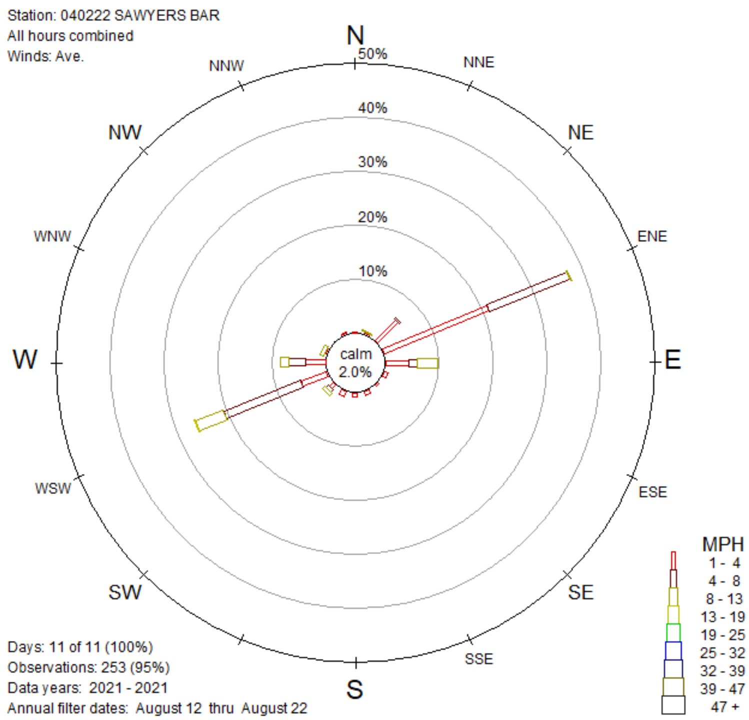


**Figure 4**. Wind rose for Sawyers Bar RAWS from August 12-22, 2021, the period during which FBAT was sampling plots on the Summer Fire.

# Methods

The general layout of an FBAT plot is shown in Figure 5 where measurements include: variable radius plots for pole-sized and overstory trees; modified Brown's line transects for duff, litter, and downed woody material; belt transects for understory vegetation centered on the modified Brown's line; an array of fire arrival detectors for rate of spread; and a video camera and anemometer at 4.5 ft. Canopy cover measurements are taken at intervals along the modified Brown's lines and an instrument measuring soil heating profiles is placed at a designated position along each transect. Transect measurements are repeated post-fire and fire effects assessments are conducted on substrate, understory vegetation, and trees. The center and ends of the modified Brown's Lines were monumented with rebar to facilitate long-term monitoring. The FBAT protocol document is available at: https://www.frames.gov/fbat/home.

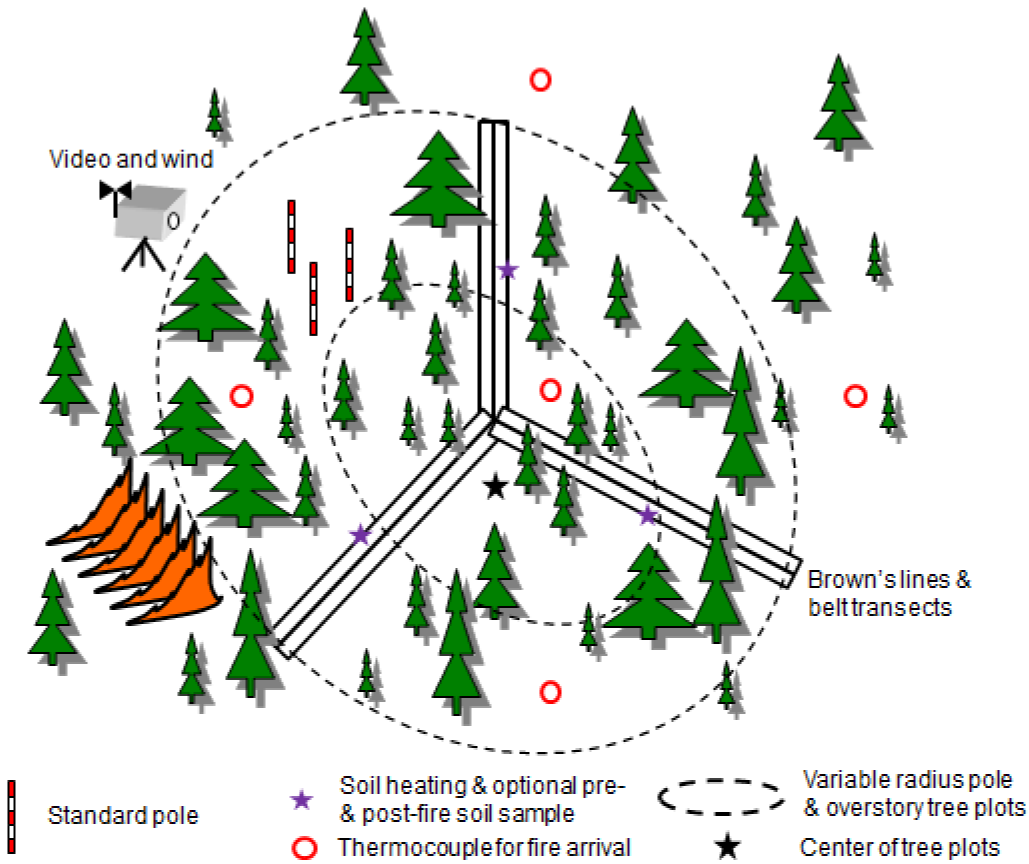


**Figure 5**. Plot layout. Modified Brown's lines and understory vegetation belt transects are anchored at plot center. The concentric circles represent pole and overstory tree variable-radius plots. The thermocouples (TC) are for determining fire arrival for calculating rate of spread (ROS), and the standards are positioned within the field of view of the video camera. The centers of the thermocouple array and tree plots are offset from plot center. Soil temperatures are measured at three depths at one location along each transect.

## Pre- and Post-Fire Vegetation and Fuels

Vegetation and fuels were inventoried before fire arrival and measurements were repeated post-fire.

### Overstory Vegetation Structure and Crown Fuels

Variable radius plots were used to characterize crown fuels and overstory vegetation structure. A Spiegel Relaskop (slope-correcting tree prism) was used to select both pole (>2.5 to 5.9 in. diameter at breast height, DBH) and overstory (>6 in. DBH) sized trees. A basal area prism factor was selected to include approximately 10 trees for each size class (when possible). Tree species, status (alive or dead), DBH, height, and canopy base height were collected for each tree before the fire. Tree heights were measured with a laser rangefinder, and DBH was measured with a diameter tape.

Post-fire measurements were collected for each tree, including minimum and maximum bole char, average height to which the crown was affected by the fire (i.e., injured in some way as indicated by either foliage scorch or consumption), the percentage of the crown that was affected by fire, and the percentage of the affected crown volume that was consumed (also known as "torch"). Trees are assumed to have survived the fire (at least in the short term) if any green needles were present after fire. Changes in canopy base height were estimated from the average height to which the crown was affected.

The Forest Vegetation Simulator (FVS, Crookston and Dixon 2005) was used to summarize tree characteristics from pre-fire data. We used the latest software release (FVS_install_20210630.exe). Pole and tree data from the variable-radius plots were entered into an Access database for input. The Northern California variant was used. Summary statistics include biomass, basal area (BA), and quadratic mean diameter (QMD) estimated for all trees (overstory and pole) and crown height, crown base height (CBH), and crown bulk density (CBD) estimated for the overstory. Canopy base height, canopy bulk density, and canopy continuity are key characteristics of forest structure that affect the initiation and propagation of crown fire (Albini 1976, Rothermel 1991). CBH, or the bottom of the tree canopy, is important because it is an indicator of the likelihood of passive (torching) or active crown fire behavior. CBH is defined in FVS as the height where the 13-foot running mean canopy bulk density is greater than 30 lbs/acre/ft, or 0.11 kg/m$^3$. CBD is the mass of canopy fuel available per unit canopy volume (Scott and Reinhardt 2001). Ground-based estimates of canopy cover were made with a Moosehorn device that estimates percent cover from multiple point-intercept measurements.

### Surface and Ground Fuel Loading

Surface and ground fuels were measured pre- and post-fire along three 50-foot modified Browns lines. Surface fuel loading and fuel height were measured using the line-intercept method (Brown 1974, Van Wagner 1968). Fuel loading measurements were taken for 1-hr (<¼in. diameter), 10-hr (¼ to 1in. diameter), 100-hr (1 to 3 in. diameter), and 1000-hr (>3 in. diameter) time lag fuel classes. 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 dead fuel height was recorded for the intervals of 0 to 6 ft, 6 to 12 ft and 12 to 18 ft. Litter and duff depths were measured at 1, 6, and 18 ft along each transect. These measurements were used to calculate surface and ground fuel loading (tons/acre) from bulk density estimates derived from the ratio of species-specific contributions according to tree basal area (van Wagtendonk *et al.* 1996; 1998). Basal area per species was derived from FVS, using inputs of variable radius plot data. Basal areas were determined from variable radius plot data using FVS. Fuel consumption was the difference between pre- and post-fire measurements.

### Understory Vegetation Structure and Loading

Understory vegetation was characterized before and after the fire in a 3 ft wide belt centered on three 50-foot modified Browns line transects (see below). The fuel and vegetation transects were in view of the video camera. Species, average height, percent alive, and percent cover (based on an ocular estimation, % of 50 ft x 3 ft area covered) were recorded for all understory shrubs, seedlings, grasses and herbaceous plants. Biomass of live woody fuels (shrubs and seedlings) and live herbaceous fuels (grasses, forbs, subshrubs) were estimated using coefficients developed for the BEHAVE Fuel Subsystem (Burgan and Rothermel 1984). Calculations were completed using an Excel spreadsheet developed by Scott (2005) and adapted for use with FBAT data.

## Fire Weather and Behavior

At each plot, thermocouples, an anemometer, and a video camera were set up to gather information on wind and fire behavior (Figure 5). The thermocouples arrayed across the plot captured date and time of fire arrival and were used to estimate rate of spread. An anemometer affixed to the camera box at 4 ft above ground recorded wind speeds leading up to the fire. Where imagery was successfully captured, it was used to determine fire type, flame lengths, and variability in direction and rate of spread of fire in relation to slope and wind, flame duration, and wind direction. The camera was triggered by fire arrival at thermistors (which act as circuit breakers) connected into a wire circuit that was placed surrounding the plot.

Rate of spread was determined both from video analysis and by calculating rate of spread from fire arrival times at thermocouples at known positions. Data loggers used for recording temperatures were buried underground with the attached thermocouple positioned at the surface of the fuel bed. Distances from the central to outer thermocouples is typically about 50 ft. Thermocouples recorded temperatures at two second intervals. The distances and azimuths among thermocouples were measured and these position and time of fire arrival were used to estimate fire rate of spread through the plot (Simard *et al.* 1984). Rate of spread can be calculated with any combination of three sensors forming a triangle. If more than one triangle of sensors triggered, all rates of spread were calculated and mean and standard deviation are available.

Fire type was 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 from post-fire effects at each plot. For example, plots with complete consumption of tree canopy needles (torching) indicate at least passive crown fire.

Flame length was primarily determined from video footage. Reference poles in the video camera's field of view are marked in 1-foot increments, allowing flame length to be estimated. Flaming duration (where it is possible to measure) is based on direct video observation.

Wind speeds were estimated from the anemometer and video was used to estimate wind direction. The anemometers are not fire hardened and are damaged by heat during intense fires, indicating fire arrival at the anemometer. The maximum wind speed and average over 20 minutes before fire arrival is reported. If the anemometer is not damaged, the 20 minute averaging period ends after peak winds occur while the fire is near the anemometer (as indicated by arrival at nearby ROS sensors). If no peak is evident, the time of fire arrival at the nearest ROS sensor determines the end of the averaging period.

## Fire Effects

### 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 substrate and understory vegetation (USDI National Park Service 2003, Appendix 2). The National Park Service (NPS) uses fire severity ratings from 1 (high) to 5 (low) when evaluating fire severity. FBAT uses the same coding matrix but reverses the scale so that it is more intuitive, with 1 representing unburned areas and 5 representing high fire severity.

### Trees

Fire-effects related measurements on trees included minimum and maximum bole char heights and canopy impacts. The combination of minimum and maximum char heights can be a better reflection of fireline intensity than maximum char height alone (Inoue 1999). Canopy measurements included scorch (foliage killed but not consumed) and torch (foliage consumed) heights and the percentage of the canopy that was scorched or torched. Percentage scorch and torch values were determined using ocular estimations and heights were measured utilizing an instrument that combines a laser rangefinder and clinometer.

### Soil heating

Soil temperature profiles were measured using an “iStake”. This device provided measurements of mineral soil temperature at 2, 4, and 6 in. (5, 10, and 15 cm) depths below the surface of the mineral soil. A high-temperature iButton logger was used at 2 inches and low-temperature loggers were used at 4 and 6 in. We did not collect pre- and post-fire soil samples on the Summer Fire. Duff and litter depth were measured at the soil stake location to correlate the ground fuel load with soil heating.

# Results and Discussion

A complete set of pre-, active-, and post-fire measurements were collected for burned Plots 1-6 and 8-10. It was not safe to re-visit Plot 7 post-fire because of the presence of large diameter trees that were actively burning out at their bases on the last day of the assignment (August 22, 2021).

## Site Description

The area in which FBAT plots were established on the Summer Fire (Figure 6) is in the Klamath Mountains Eco-Region and is classified as dry mixed conifer and oak woodlands. The plots are south of the South Fork Salmon River.

Summary information is provided in Table 2 while wildfire (Figure 7) and treatment histories are provided in Table 3 and Figure 8. Plot elevations ranged from, approximately, 3200 to 3600 ft across a range of aspects. The area is steep with slopes on plots ranging up to 80%. The plots are in an area where there is no recorded wildfire history in the Wildland Fire Decision Support System (WFDSS) and Enterprise Geospatial Portal (EGP). Old fire scars are evident on large diameter trees.

Plots had a range of treatment histories, from no treatment to commercial thinning, under-burning, and pile and burning. Treatment histories were extracted from the FACTS (Forest Service Activity Tracking System) database. Table 3 shows information for each plot from the FACTS database accessed through CITRIX. Treatment polygons are displayed spatially in Figure 8. Local Klamath National Forest Fuels staff who worked in the area confirm the accuracy of the mapping. The only known discrepancy is a large Douglas Fir stump in Plot 3 (with no recorded treatment history) which may have been a felled snag, the plot being relatively close to the 26 road. The pile and burn treatments on or near ridgelines (Plots 2, 7, 9, and 10) were intended to serve as holding features for wildfires spreading from the west, providing areas with reduced fuel loading where control lines could be established and off of which backfiring could be accomplished. No historical wildfires were recorded for the sampling area even though fire scars on large trees indicated past fire (see below).

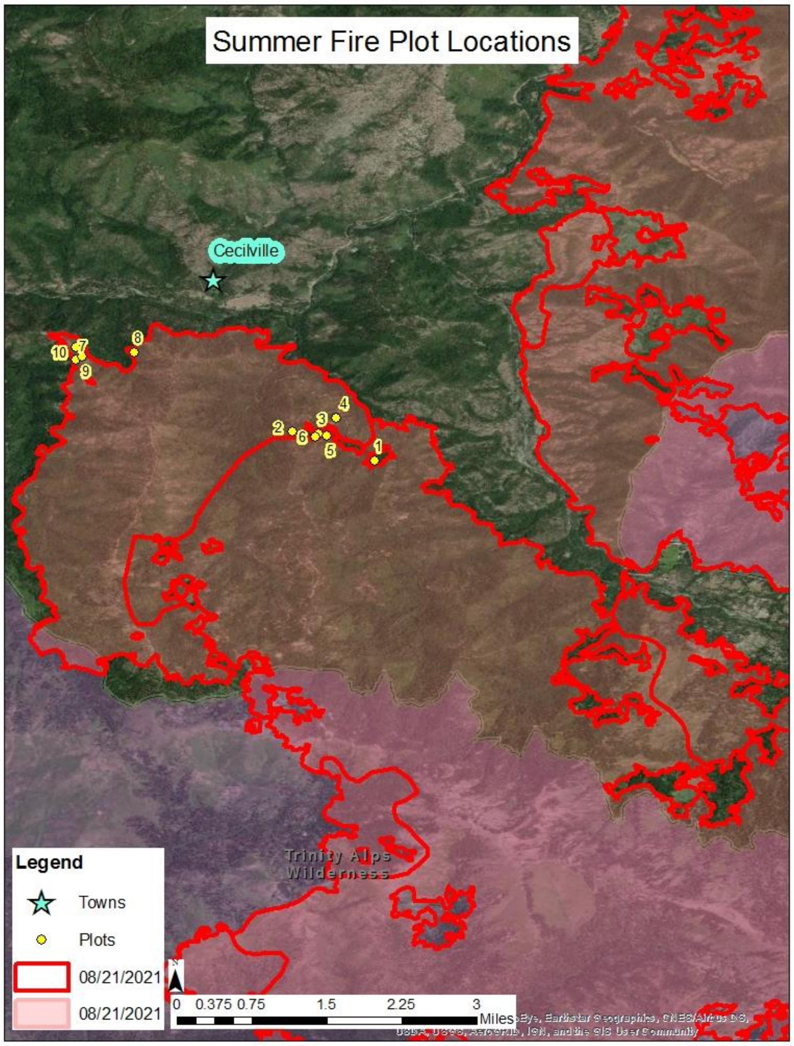


**Figure 6.** FBAT plot locations on the NW side of the Summer Fire. The mapped perimeter is from August 21st.

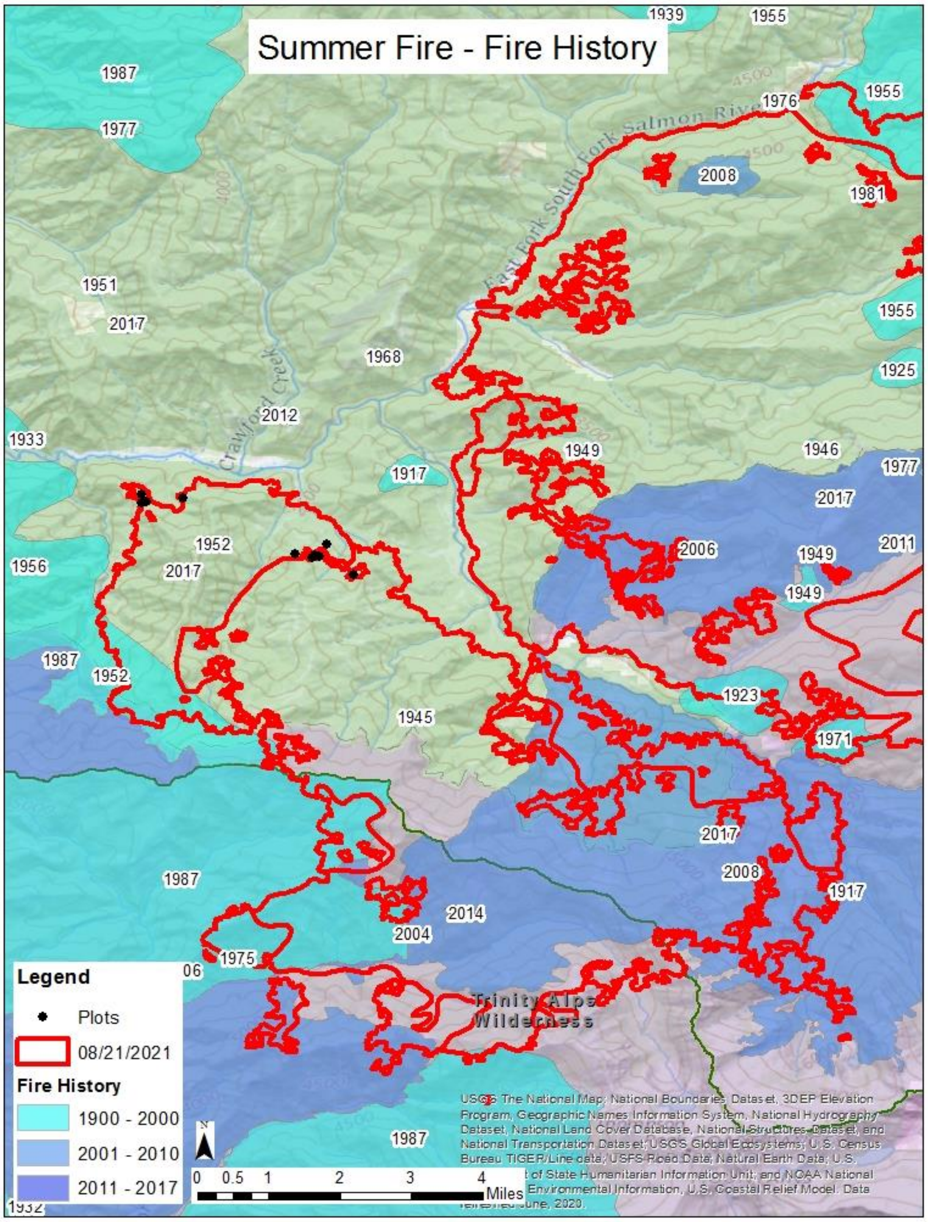


**Figure 7.** Recent wildfire history in the vicinity of the Summer Fire. No recorded wildfire history exists where plots were sampled. Perimeter updated through August 21st, 2021 when FBAT sampled the last post-fire plots.

**Table 2.** Site descriptions for ten FBAT plots sampled on the Summer Fire. Latitude and Longitude datum is WGS 84. Wildfire history was determined from perimeters available in WFDSS and EGP. Elevations are from GPS.

| Plot | N Lat. | W Lon. | Wildfire history | Slope (%) | Aspect (deg) | Elev. (ft) |
|---|---|---|---|---|---|---|
| 1 | 41.11747 | 123.11643 | None Recorded | 55 | 260 | 3335 |
| 2 | 41.12183 | 123.12835 | None Recorded | 30 | 352 | 3635 |
| 3 | 41.12145 | 123.12452 | None recorded | 32 | 350 | 3301 |
| 4 | 41.12377 | 123.12195 | None Recorded | 27 | 20 | 3103 |
| 5 | 41.12117 | 123.12338 | None Recorded | 30 | 10 | 3222 |
| 6 | 41.12097 | 123.12497 | None Recorded | 40 | 35 | 3332 |
| 7 | 41.13213 | 123.15975 | None Recorded | 65 | 290 | 3265 |
| 8 | 41.13317 | 123.15120 | None Recorded | 55 | 210 | 3045 |
| 9 | 41.13257 | 123.15882 | None Recorded | 80 | 60 | 3255 |
| 10 | 41.13397 | 123.15968 | None Recorded | 60 | 70 | 3231 |

**Table 3**. Treatment history for each plot from the FACTS database.

| Plot ID | FACTS IDs | Treatment pre-1990 | Treatment 1990-2000 | Treatment 2001-2010 | Treatment 2011-2020 | Treatment 2021 |
|---|---|---|---|---|---|---|
| 1 | NA | | | | | Wildfire[3] |
| 2 | 4440132000 | | | | PCT[1], handpile and burn 2013-2015 | Wildfire |
| 3 | NA | | | | | Wildfire |
| 4 | NA | | | | | Wildfire |
| 5 | 4440088000 | | Commercial thin 1997-2000[2] | Underburn 2004 | PCT, handpile and burn 2011 | Wildfire |
| 6 | NA | | | | | Wildfire |
| 7 | 4450120000 | | | | PCT, handpile and burn 2013-2015 | Wildfire |
| 8 | 4450020000 | | Commercial thin 2000 | Underburn 2005 | | Wildfire |
| 9 | 4450021000, 4450120000 | | Commercial thin 1999 | Underburn 2005 | PCT, handpile and burn 2013-2015 | Wildfire |
| 10 | 4450002000, 4450120000 | Clearcut 1969, planted 1971 and 1981, PCT 1985 | | PCT, pile, and burn 2005-2006 | PCT, handpile and burn 2013-2015 | Wildfire |

Notes:

[1]PCT = Pre-commercial thinning, i.e., cutting of trees that are sub-merchantable size (typically $\leq$8 in. DBH according to staff with local experience). Cut trees are typically left on site and associated fuel accumulations may be removed through prescribed burning.

[2]Commercial thinning = removal of trees of merchantable size to meet a variety of objectives.

[3]Wildfire = Summer Fire 2021, part of the River Complex, natural ignition (lightning).

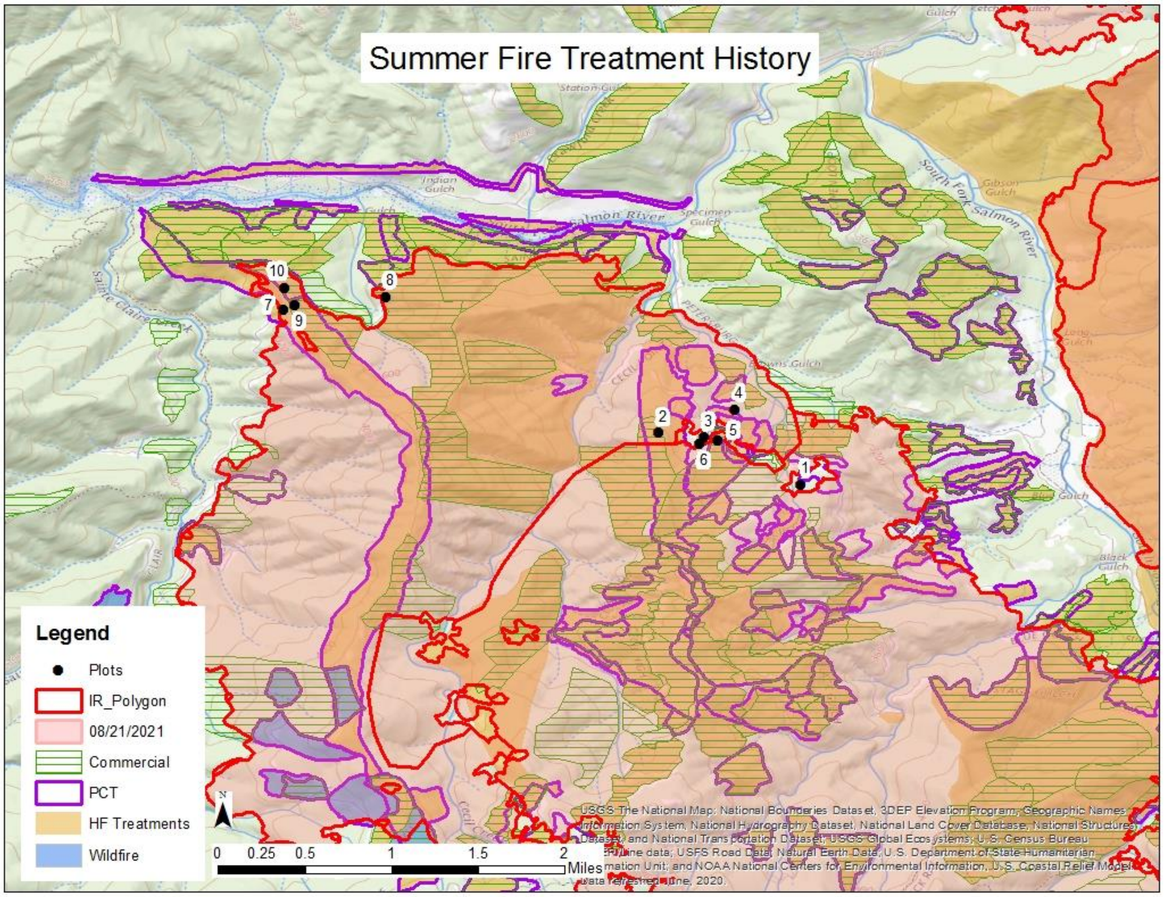


**Figure 8.** Treatment history. Plots 1, 3, 4, and 6 had no recorded prior treatments. The remaining plots had some combination of commercial or pre-commercial thinning (PCT, differentiated by whether trees of merchantable size are removed from the site) and hazardous fuels reduction (HF Treatments), including underburning, cutting and piling of small-diameter trees, and pile burning. See Table 3 for treatment history information specific to each plot.

## Plot Descriptions

The following plot descriptions are intended to support data use and plot re-sampling as funding allows.

### Plot 1

Access: Progress approximately 0.35 miles up FSR 38N27 from its junction with FSR 37N02. The plot is approximately 200 yds up a small drainage to the Southeast.
Description: Location was chosen because slope was shallow enough to sample (ground otherwise is very steep). Fuels are untreated in the area. There was fire at some time in the past (though fire is not indicated in the FACTS record). There is no char on trees but fire scars are present.

### Plot 2

Access: Drive to end of 37N26A road onto the ridgeline pile and burn treatment. Plot is up the ridge from the end of the road. Distance from end of road to plot is about 200 yards. Ridge runs north-south.

Description: The plot is located on a dry, narrow, and descending ridge with a mix of pine and hardwoods. Pacific madrone is in area but none are within the plot. Pile burns have charred and wounded some of the trees. We expect that fire will run to the ridge south of the plot and then flank through the plot from the east slope.

## Plot 3

Access: South side of 37N26. Plot is on a descending ridge above the road.
Description: Plot is between fuel treatment units, that is, untreated. FACTS data indicate no treatment history. A large Douglas fir stump on the plot may have been from a felled snag. Vegetation is a mix of Douglas fir in the overstory and midstory with black oak and a madrone. Douglas fir poles are fairly dense. An opening down ridge from plot center contains large shrubs and some grass. Large shrub is canyon live oak (QUCH). Plot is intended to be a contrast with treated ridges. After post-fire sampling on 8/15/2021, the large Douglas Fir stump south of center burned out and ignited surrounding litter and duff. Transect 1 fuels data were updated accordingly.

## Plot 4

Access: Plot is best accessed downhill from the 37N26 road. Leave road from the opposite side of an old log deck with regenerating vegetation that was killed subsequently in an uphill run. Plot is roughly midway between roads 37N26 and 38N27.
Description: We expected fire to back down from above but a spotting event during the afternoon of 17 August led to an uphill run through the plot. There was evidence of past fire on the plot, including fire scars. Bug injury in evidence on big trees. We chose this plot as a contrast with the ridge pile and burn treatments.

## Plot 5

Access: Plot is south of the 37N26 road in fuel treatment.
Description: Open stand with scattered large trees. Midstory thinned out, but still a lot of Douglas fir in midstory. Treatment was pile and burn. Large cat-faced ponderosa pine on north side of plot that burned out in the fire but had not come down before we re-sampled the plot. Duff mounds were present on large trees. Soil is composed of mostly small stones. For this reason, we didn't do soil heating measurements.

## Plot 6

Access: Plot is south of 37N26 road.
Description: Plot is on a narrow ridge that descends to the north. Relatively close to the other untreated ridgeline plot (~75 yards, Plot 3). No other good untreated ridge options were present on the road network. Fire scars were present on a madrone. Large overstory trees (sugar pine and Douglas fir) with Douglas fir dominated midstory. Plot intended to be a contrast to treated ridgeline pile and burn treatments.

## Plot 7

Access: Plot is uphill from the 38N16 road, ~0.38 miles beyond the sharp bend where the dozer line crosses a landing and descends down the ridge and across the 38N16 road towards the South Fork Salmon River and Saint Claire Creek. Plot is roughly east of the south-trending road.
Description: Ridgeline pile and burn treatment. Mix of oak, Douglas fir, sugar pine, madrone, and ponderosa pine (large overstory conifers were present uphill and outside of the plot). Midstory of oak and Douglas fir. Steep with open understory. We expect backing fire. Some trees were charred. Old catfaces were present on

oaks, presumably from the pile and burn operation. Dozer line was opened above the plot (~250 ft) along main ridgeline. Plot 7 burned but we were not able to re-visit the plot post-fire as of August 22nd, 2021, because of two large canopy trees that were burning out right above the plot.

### Plot 8

Access: Drive ~1.81 miles out FSR 38N16. The plot is upslope from the road generally to the East
Description: Douglas fir and ponderosa pine dominated the overstory while the midstory was characterized by black oak, Douglas fir, Pacific madrone, and canyon live oak. The understory was open. The 2008 underburn appeared to be of low to moderate intensity and superimposed on an older fire (perhaps a wildfire that was not in the historical database). Both fires appeared to have backed downslope. Char and cat faces were present from recent fire but most cat faces were from the older fire. Two large Douglas fir had been cut and their butt logs left on site. Maybe snagged or TSI. One of the felled butt logs was fire scarred. Some smaller stems had been cut on west side of plot. No sign of pile and burn in agreement with the FACTS data. This plot was one of the least disturbed available. Plot was near the road because large snags prevented us from establishing a plot further uphill.

### Plot 9

Access: Plot is up the dozer line from the sharp bend in the 38N16 road where the dozer line crosses a landing and heads Southeast along the same ridge on which the 37N04 road terminates. Plot is approximately 0.4 miles up the dozer line. Plot is off the left of the dozer line (east), downhill approximately 70 ft. Dozer line rocks out and deviates downhill 50 yards prior to plot access.
Description: A previous prescribed underburn killed many of the trees, overstory and midstory. The canopy consisted of a few remaining large overstory trees with high heights to live crown; otherwise, the canopy over the fuel transects and ROS sensors was open and the vegetation shrub dominated, including some tree regeneration. Pile and burn was preceded by logging of large Douglas firs and followed by a broadcast burn. Remaining overstory trees had high bark char heights. All trees downslope had fire scars. We had fallers drop one snag in the plot. The snag is included in the tree data but not in the CWD sample.

### Plot 10

Access: Plot is approximately 0.28 miles up the dozer line from the sharp bend in the 38N16 road where the dozer line crosses a landing and heads Southeast along the ridge on which the 37N04 road terminates. Plot is downhill @60 degrees. Plot is before the rocks that stopped the dozer (and from which it deviated to the west). Distance to rock from location on road above the plot is about 50 yards.
Description: Similar plot history to Plot 9, there were few canopy trees in the vicinity and none over the fuels transects and ROS sensors resulting in high light levels at the top of the shrubby vegetation. Piling was evident from remaining, unconsumed midstory trees. Large Douglas fir had been logged. Plot is intended to represent re-burning in moderate to high severity patch. Patch is small - maybe 20 acres. We had fallers drop four snags in the plot for the safety of the crew. Felled snags were included in the tree data but excluded from the CWD sample.

## Pre-Fire Vegetation and Fuels

The overstory trees (Figure 9) were predominantly Douglas-fir, except for three plots treated in 2015 where Plot 9 was 60% pine (sugar or ponderosa pine), and Plots 2 and 7 were 45% oak (canyon live or black oak). Plots 2, 5, and 6 also had a significant pine component (25-30% pine). Pacific madrone was present on all sites except Plot 2 and even on that plot it was nearby. Plots 1-8 were relatively closed canopied with limited understory vegetation. Plots 9 and 10 were open canopied with a shrub-dominated understory and scattered overstory trees that had persisted through the fuel and silvicultural treatments.

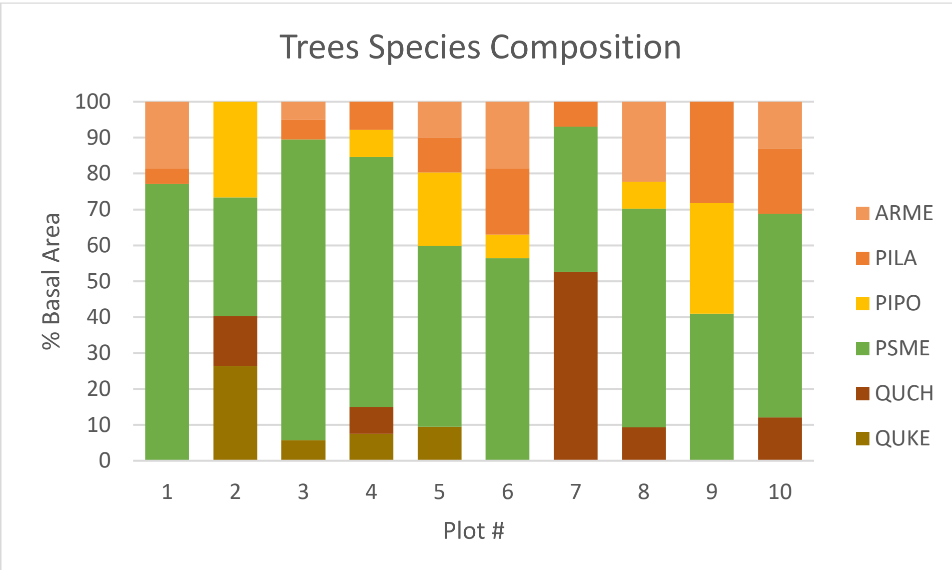


**Figure 9**. Overstory tree species composition on variable-radius tree sampling plots. ARME = Pacific madrone (*Arbutus menziesii*), PILA = Suga Pine (*Pinus lambertiana*), PIPO = Ponderosa Pine (*Pinus ponderosa*), PSME = Douglas Fir (*Pseudotsuga menziesii*), QUCH = Canyon Live Oak (*Quercus chrysolepis)*, and QUKE = Black Oak (*Quercus kelloggii*).

In the understory, perennial bunch grasses were present on most sites (though not Plots 4, 6, or 7); forbs were present on half the sites (Plots 1, 2, 3, 5, and 10); seedlings were found on all plots, with Plots 2, 3, 8, and 10 having the most detections. Shrubs were only present on three sites: Plots 2, 9, and 10 (all treated in 2015). Species included *Festuca idahoensis* (a common bunchgrass with narrow leaves), *Bromus carinatus*, *Iris douglasiana*, yerba santa (*Eriodictyon californicum*), *Lupinus spp.*, *Lonicera hispidula*, alder (*Alnus spp.)*, Pacific madrone (*Arbutus menziesii)*, sugar pine (*Pinus lambertiana)*, ponderosa pine (*Pinus ponderosa)*, Douglas fir (*Pseudotsuga menziesii)*, canyon live oak (*Quercus chrysolepis)*, black oak (*Quercus kelloggii)*, *Ceanothus cuneatus*, *Rubus ursinus*, and poison oak (*Toxicodendron diversiloba)*.

## Overstory Vegetation Structure and Crown Fuels

None of the ten plots had burned in a wildfire according to the interagency fire history record (since approximately 1908). Most plots had generally higher tree densities than would be expected under a historical regime of frequent fire for these mixed conifer forest types (Table 4). Untreated Plot 6 was the most heavily forested plot with high densities of both overstory (> 6 in DBH) and pole (<6 in DBH) trees. Plots 1, 2, 5, 7, and 9 contained no pole trees. All of these plots except for Plot 1 had received fuels treatments in the past 10 years. Plots 3, 6, and 10 contained high densities of small (pole) trees. The open-canopied plot 10 had primarily hardwood re-sprouts and conifer regeneration. Aboveground biomass (Table 4 and 5) and canopy cover were highest on plot 6, and lowest on plot 9.

CBH estimated from FVS in plots where treatments have occurred since 2011 averaged 43 ft (range 20-78 ft), whereas plots that had not received any treatments in the same time period averaged 19.4 ft (range 16-23 ft). Thinning to reduce CBD to less than 0.10 kg/m$^3$ is generally recommended to minimize crown fire hazard (Agee 1996, Graham et al. 1999); below this CBD, active crown fire is unlikely (Scott and Reinhardt 2001). Plots 3, 4, 6, and 8 were all above this threshold. Canopy biomass totals were highest in Plots 6, 7, and 8 prior to the Summer Fire (Table 5). Plots 2 and 8 contained a higher pre-fire biomass of snags.

On some plots, there is a substantial difference between canopy cover estimated by FVS and ground-based canopy cover measurements (using the Moosehorn device). In the future, ground-based estimates of tree spatial patterning (even, random, clumped, etc.) are needed as inputs to FVS to increase accuracy of cover estimates. The Moosehorn sample is also not intensive. Plots 9 and 10 had no canopy cover and the trees in the sample were outside the fuels transects.

**Table 4.** Pre-fire canopy characteristics for plots inventoried on the Summer Fire. All variables are outputs of FVS except for the "Moosehorn" measurement of canopy cover. Abbreviations: quadratic mean diameter (QMD), basal area (BA), canopy height (CH), canopy base height (CBH), crown bulk density (CBD). BA and QMD were estimated using combined data from both overstory- and pole-sized trees while CH, CBH, and CBD were estimated from overstory data. All plots burned in the Summer Fire.

| Plot | Density (trees/ac) | | QMD (in) | BA (ft$^2$/ac) | Canopy Cover (%) | | CH (ft) | CBH (ft) | CBD (kg/m$^3$) |
|---|---|---|---|---|---|---|---|---|---|
| | Overstory[2] | Pole[3] | | | FVS | Moosehorn | | | |
| 1 | 192 | 0 | 14.3 | 213.1 | 64 | 100 | 71 | 20 | 0.093 |
| 2T[1] | 78 | 0 | 16.8 | 119.9 | 52 | 77 | 50 | 25 | 0.054 |
| 3 | 117 | 465 | 7.5 | 179.5 | 76 | 92 | 53 | 18 | 0.170 |
| 4 | 331 | 131 | 10.2 | 264.2 | 18 | 85 | 127 | 23 | 0.211 |
| 5T[1] | 60 | 0 | 18.1 | 107.7 | 5 | 38 | 182 | 24 | 0.040 |
| 6 | 394 | 356 | 8.8 | 319.1 | 32 | 100 | 115 | 16 | 0.244 |
| 7T[1] | 148 | 0 | 19.3 | 300.1 | 82 | 69 | 64 | 20 | 0.087 |
| 8T[1] | 298 | 90 | 11.3 | 270.7 | 80 | 92 | 68 | 23 | 0.156 |
| 9T[1] | 8 | 0 | 29.6 | 38.3 | 11 | 0 | 118 | 78 | 0.006 |
| 10T[1] | 8 | 291 | 6.8 | 75.9 | 21 | 0 | 120 | 68 | 0.013 |

[1]T = Understory thinned, piled, and burned in 2011 or 2015 (FACTS)

[2]$\geq$6 in DBH; [3]<6 in DBH

## Surface, Ground, and Understory Vegetation Fuel Loading

Untreated Plots 1, 3, 4, and 6 had higher duff loadings than treated plots (Figure 10 and Table 6). Otherwise, differences among treated and untreated plots were not obvious. The most open plots (Plots 9 and 10) had more shrub growth and seedling regeneration. Overall, understory vegetation had a limited contribution to fuel loading, with the largest fuel loadings in duff, litter, and 1000-hr logs. Most plots had about 5 logs, with an average diameter of 5 in. Treated Plot 10 had the largest 1000-hr fuel load with ten sound logs ranging from 3-19 in diameter. Large log retention was an objective of fuel treatments in the area which may partly explain log densities on Plot 10. Many small logs present on plots where pile and burning occurred were the result of incomplete consumption of fuel piles. Untreated Plots 4 and 6 also had large logs (at 17 in. and 16 in. diameter, respectively).

**Table 5.** Pre-fire tree biomass based on tree sampling and the Forest Vegetation Simulator (FVS). All plots burned in the Summer Fire.

| Plot | Biomass (tons/ acre) | | | | |
|---|---|---|---|---|---|
| | Snags | Foliage | Live <3 in DBH | Live ≥3 in DBH | Total |
| 1 | 0.0 | 5.1 | 17.7 | 104.0 | 126.8 |
| 2T[1] | 13.3 | 2.9 | 12.9 | 49.0 | 78.1 |
| 3 | 6.0 | 6.2 | 14.8 | 62.0 | 89.0 |
| 4 | 0.0 | 7.2 | 20.4 | 103.0 | 130.6 |
| 5T[1] | 0.0 | 2.3 | 9.3 | 48.0 | 59.6 |
| 6 | 1.0 | 8.3 | 22.7 | 139.0 | 171.1 |
| 7T[1] | 0.0 | 6.6 | 32.3 | 116.0 | 154.9 |
| 8T[1] | 12.9 | 7.4 | 21.9 | 110.0 | 152.2 |
| 9T[1] | 1.2 | 0.5 | 3.2 | 20.0 | 24.9 |
| 10T[1] | 7.4 | 1.3 | 8.2 | 35.0 | 51.9 |

[1]T = Understory thinned, piled, and burned in 2011 or 2015 (FACTS)

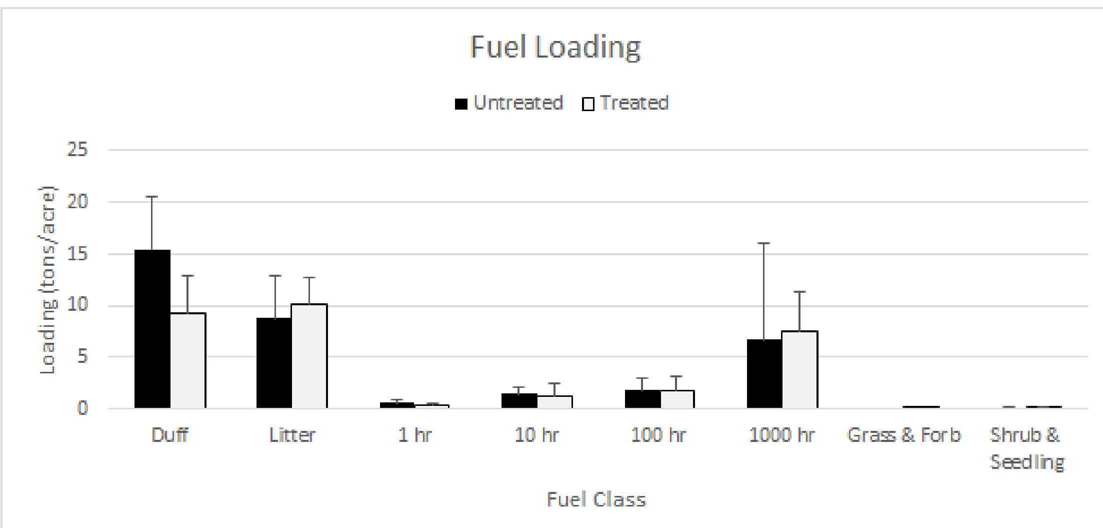


**Figure 10**. Fuel loading in untreated and treated sites (see Table 3). Standard deviation bars are shown.

**Table 6.** Surface fuel loads and fuel bed depths for plots inventoried pre-fire on the Summer Fire.

| Plot | Loading (tons/acre) | | | | | | | | | Fuel Bed Ht. (in) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Duff | Litter | 1hr | 10hr | 100hr | 1000hr | Grass & Forb | Shrub & Seedling | Total | |
| 1 | 19.9[2] | 11.3 | 0.41 | 0.60 | 1.52 | 4.93 | 0.03 | 0.01 | 38.6 | 2.4 |
| 2T[1] | 11.4 | 11.8 | 0.44 | 0.84 | 1.28 | 1.92 | 0.03 | 0.05 | 27.8 | 2.7 |
| 3 | 12.9 | 6.9 | 0.43 | 2.56 | 2.63 | 2.58 | 0.01 | 0.01 | 28.0 | 1.6 |
| 4 | 12.3 | 6.2 | 0.65 | 0.51 | 0.00 | 8.16 | 0.00 | 0.00 | 27.8 | 1.6 |
| 5T | 9.9 | 11.5 | 0.48 | 1.91 | 2.44 | 7.03 | 0.00 | 0.00 | 33.3 | 2.3 |
| 6 | 17.0 | 10.7 | 0.77 | 2.36 | 3.24 | 11.04 | 0.00 | 0.01 | 45.1 | 2.6 |
| 7T | 16.6 | 9.2 | 0.90 | 1.60 | 1.17 | 1.92 | 0.00 | 0.00 | 31.4 | 2.4 |
| 8T | 11.0 | 16.2 | 0.29 | 0.86 | 3.20 | 9.07 | 0.00 | 0.00 | 40.7 | 2.8 |
| 9T | 3.4 | 3.6 | 0.12 | 0.59 | 0.00 | 0.00 | 0.13 | 0.49 | 8.4 | 0.8 |
| 10T | 3.6 | 8.0 | 0.20 | 1.96 | 2.81 | 25.42 | 0.05 | 0.20 | 42.3 | 1.3 |

[1]T = Understory thinned, piled, and burned in 2011 or 2015 (FACTS).

[2]One deep duff mound excluded from plot-level average.

## Fire Weather, Fuel Consumption, and Fire Behavior

The narratives below describe fire weather at the time when plots burned, fire spread rates through the plots, and fuel consumption. General weather and fuel moisture conditions when plots burned are shown in Table 7.

Summertime weather on the western Klamath follows a pattern of inversion followed by troughing with atmospheric instability. During periods of instability, fire growth is rapid due to lower RH, higher winds, and better mixing. Under the inversion, RH were observed between 30-50% during the main burning window. Once the inversion lifted, RH often dropped to single digits with 10 degrees or more of temperature rise. The chart above specifies inversion, though the RH is also a clear indicator.

**Table 7**. Air temperature, relative humidity, 10 & 1000-hr fuel moisture, and wind from the KNF 95 Portable RAWS1 (Plots 1, 3, 5, and 6) or Sawyer's Bar RAWS (Plots 2, 4, 7-10) on fire arrival. The KNF 95 station was close to the plot sampling area but the station failed before all the plots had burned. Plot wind is taken with an anemometer at 4.5 ft above ground, usually fixed to the camera housing. See methods for how average and peak values are determined.

| Plot | Temp. (F)[1] | RH | Fuel moisture (%)[2] | | RAWS Wind (mph) | | Plot Wind (mph)[3] | | Inversion |
|---|---|---|---|---|---|---|---|---|---|
| | | | 10-hr | 1000-hr | 10 min Avg | Peak | 20 min Avg | Peak | |
| 1 | 77 | 39 | 7.4 | 9 | SW2 S | 5E | 2.3 | 10 | Y |
| 2T[4] | 81 | 41 | 7 | 8 | 5 WSW | 5 WSW | NA | NA[3] | Y |
| 3 | 69 | 51 | 10.1 | 8 | 0.7 WSW | 7 E | 2.3 | 3.8 | Y |
| 4 | 85 | 9 | 2 | 8 | 10 WSW | 22 WSW | 3.3 | 15 | N |
| 5T | 70 | 51 | 9.9 | 8 | 1.8 WSW | 7 E | 0 | 0 | Y |
| 6 | 78 | 38 | 8.2 | 9 | 2 WSW | 5NW | 8.8 | 17.5 | Y |
| 7T | 75 | 38 | 7 | 8 | 3 SW | 5 SW | NA | NA[3] | Y |
| 8T | 90 | 15 | 3.5 | 8 | 8 WNW | 27 WNW | 7.2 | 17.5 | N |
| 9T | 59 | 58 | 8.9 | 8 | 2 ENE | 9 NE | 0.3 | 6.2 | Y |
| 10T | 61 | 56 | 8 | 8 | 3 ENE | 8.5 ENE | 7.7 | 30 | Y |

[1]RAWS report hourly data, the temperature, RH, and wind observation closest to the median arrival time based on the fire arrival times were used.

[2]The 10hr moistures are from the fuel stick as reported in Mesowest or from KNF95 portable RAWS or Sawyer's Bar RAWS. The 1000-hr fuel moistures are modeled in FireFamily Plus.

[3]NA means the anemometer failed on the plot

[4]T = Understory thinned, piled, and burned in 2011 or 2015 (FACTS)

## Fuel Consumption

No consistent differences were detected in surface fuel loading and consumption (from duff through shrubs) between treated and untreated plots, except for higher duff loadings and consumption on untreated plots (Figure 11 and Table 8). The percentage of fuel consumed (Figure 12 and Table 9) was generally lowest for 100-hr fuels, but relatively high for other fuel classes. According to firefighter experience on the Klamath, complete duff consumption, which occurred on four plots (Table 9), only happens during drought conditions. Untreated Plots 1 and 4 and treated Plots 8 and 10 saw the highest total fuel percent reductions. Plots 4 and 8 burned under high temperature, low RH, and low 10-hr fuel moisture conditions. Plot 1 showed a high percent consumption with duff and 1000-hr fuels that burned nearly completely, while Plot 10 exhibited high percent consumption resulting from high loadings and consumption of 1000-hr fuels. Plots 2, 3, 5, and 9 burned at night or in the early morning and had the lowest percentage consumption (Table 9).

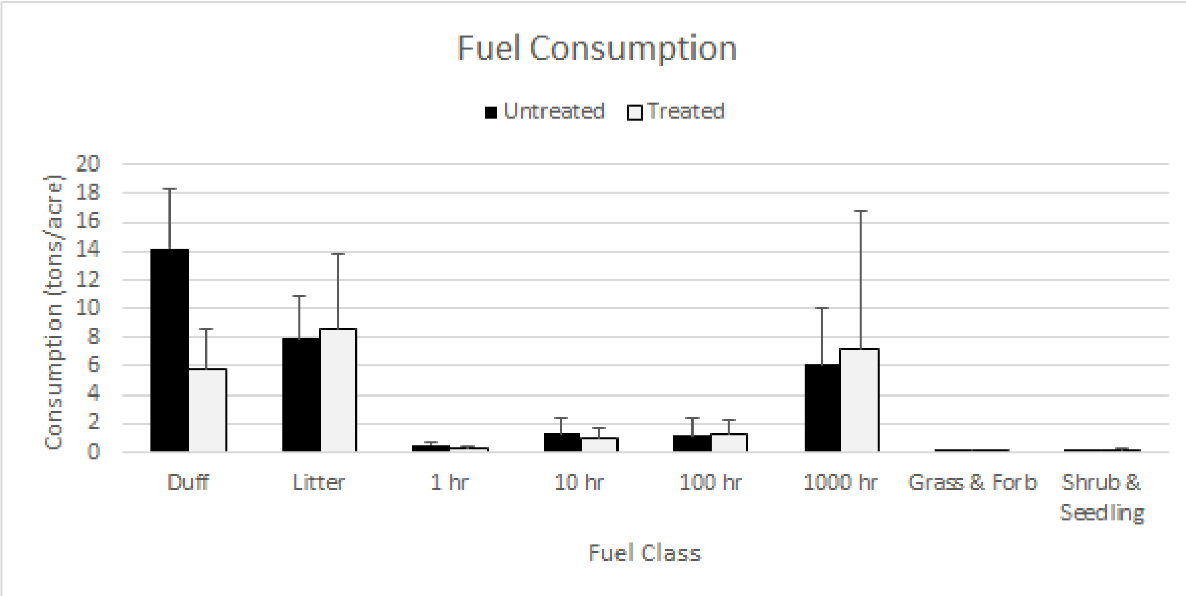


**Figure 11**. Fuel consumption by fuel type or strata in untreated and treated sites. Standard error bars are shown.

**Table 8.** Forest floor and downed-woody (surface) fuel consumption (tons/acre). Plot 7 burned but was unsafe to access and remeasure due to weakened snags and large live trees actively burning out at their bases upslope from the plot.

| Plot | Consumed loading (tons/acre) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Duff | Litter | 1hr | 10hr | 100hr | 1000hr | Grass & Forb | Shrub & Seedling | Total |
| 1 | 19.9[2] | 11.3 | 0.41 | 0.52 | 0.76 | 4.93 | 0.03 | 0.01 | 37.8 |
| 2T[1] | 6.7 | 7.0 | 0.31 | 0.25 | 0.41 | 0.73 | 0.03 | 0.03 | 15.4 |
| 3 | 10.3 | 4.9 | 0.40 | 2.13 | 1.12 | 1.22 | 0.01 | 0.00 | 20.1 |
| 4 | 12.3 | 6.2 | 0.63 | 0.43 | 0.00 | 8.05 | 0.00 | 0.00 | 27.6 |
| 5T | 5.4 | 10.1 | 0.45 | 1.74 | 2.03 | 7.03 | 0.00 | 0.00 | 26.7 |
| 6 | 14.3 | 9.5 | 0.76 | 2.27 | 2.81 | 10.33 | 0.00 | 0.01 | 40.0 |
| 7T | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 8 | 10.1 | 16.2 | 0.28 | 0.86 | 1.21 | 8.41 | 0.00 | 0.00 | 37.1 |
| 9T | 3.4 | 2.0 | 0.07 | 0.50 | 0.00 | 0.00 | 0.08 | 0.34 | 6.4 |
| 10T | 3.6 | 8.0 | 0.18 | 1.68 | 2.42 | 25.42 | 0.05 | 0.14 | 41.5 |

[1]T = Understory thinned, piled, and burned in 2011 or 2015 (FACTS)
[2]One deep duff mound excluded from plot-level average.

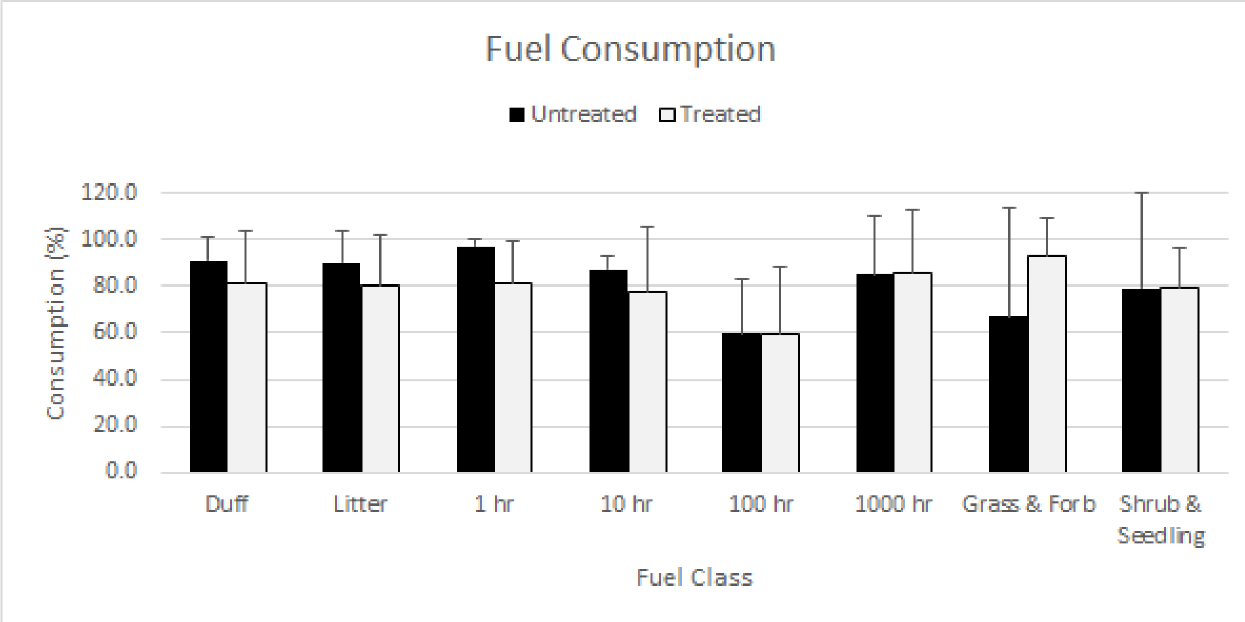


**Figure 12.** Percent consumption in untreated and treated sites. Standard deviation bars are shown.

**Table 9.** Percent consumption of forest floor, downed-woody, and herb and live woody fuel. "NA" indicates that pre-fire fuels in that class did not occur in the sample area, though they may have been found in the overall plot area. Plot 7 burned but was unsafe to access and remeasure due to falling snags and other hazards.

| Plot | Percent Consumption (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Duff | Litter | 1hr | 10hr | 100hr | 1000h | Grass & Forb | Shrub & Seedling | Total |
| 1 | 100% | 100% | 100% | 86% | 50% | 100% | 100% | 100% | 99% |
| 2T[1] | 58% | 59% | 69% | 30% | 32% | 38% | 100% | 60% | 56% |
| 3 | 80% | 71% | 93% | 83% | 43% | 47% | 34% | 17% | 72% |
| 4 | 100% | 100% | 97% | 83% | NA | 99% | NA | 100% | 99% |
| 5T | 55% | 87% | 94% | 91% | 83% | 100% | 100% | 97% | 80% |
| 6 | 84% | 89% | 99% | 96% | 87% | 94% | NA | 100% | 89% |
| 7T | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 8 | 92% | 100% | 98% | 100% | 38% | 93% | 100% | 100% | 91% |
| 9T | 100% | 55% | 57% | 84% | NA | NA | 63% | 69% | 76% |
| 10T | 100% | 100% | 88% | 86% | 86% | 100% | 100% | 70% | 98% |

[1]T = Understory thinned, piled, and burned in 2011 or 2015 (FACTS).

## Fire Behavior

A description of fire behavior in plots follows and is summarized in Table 10. Appendix 1 contains pre- and post-fire photos along fuel sampling transects. Apart from the uphill spread through Plot 4, rates of spread were low, ranging from 0.1 to 1.2 chains/hr. The highest rates of spread were associated with breakdown of the inversion (Plots 4 and 8, see Table 7). The lowest rates of spread were under the inversion and during the early morning (Plots 2 and 3). Fireline intensity (Byram's intensity) indicates heat release rates and is a function of consumption of surface fuels and rate of spread. Surface fuels are defined here as fuels that would normally be most important in flame front propagation and included litter, woody fuels up to 100-hr, and herb and shrub fuels. The lowest fireline intensities occurred on Plots 2, 3, and 5 where rates of spread were lowest and on Plot 9 where surface fuel consumption was low. These plots burned at night or in the early AM.

**Table 10**. Fire behavior on Summer Fire FBAT plots. Flame length (FL) and flame angle (FA) were estimated from video where available. For rate of spread (ROS), a flame front moving at 1 chain/hour is roughly 1 foot/minute. Rate of spread estimated from both video and fire arrival sensors are reported where available. The mean and standard deviation for ROS based on fire arrival is provided where there were two or more estimates available (i.e., two or more triangles of sensors with useable data). Fire arrival is the time the fire was first detected at the Plot. Departure time is the last time a fire arrival sensor was burned. Fireline intensity (also known as Byram's intensity) is a measure of flame-front heat release rate.

| Plot | Fire Type | FL (ft) | FA (%) | ROS (ch/hr) | | *Fireline Intensity*[5] (kW/m) | Fire Detection Date & Time (PDT) | |
|---|---|---|---|---|---|---|---|---|
| | | | | Video | Sensors | | First | Last |
| 1 | Backing downslope | 1.75 | 65 | 0.64 | 0.67 (0.13)[2] | 199 | 8/11/2021 19:43:56 S | 8/12/2021 03:25:50 W |
| 2T[1] | Backing downslope | NA | NA | NA | 0.09 (002)[3] | 17 | 8/14/2021 04:06:40 S | 08/14/2021 14:53:16 E[2] |
| 3 | Backing downslope and creeping in surface fuels | NA | NA | NA | 0.12 (NA) | 24 | 8/13/20210 5:48:48 S | 8/13/2021 10:54:44 N |
| 4 | Backing uphill, heading uphill, torching and passive crown fire | 3 | 120 | 0.6-37 | NA | 6032 | 8/17/2021 17:48:42 C | 8/17/2021 17:48:40 S |
| 5T | Backing downslope and creeping in surface fuels | NA | NA | NA | 0.38 (0.12) | 129 | 8/13/2021 03:09:47 W | 8/13/2021 06:51:41 E |
| 6 | Backing downslope | 2.25 | 35 | 1.25 | 0.61 (0.42) | 213 | 8/12/2021 20:08:15 S | 8/12/2021 23:00:31 N |
| 7T | Backing | 0.37 | 20 | 0.27 | 1.19 (0.62)[4] | NA | 8/20/2021 10:17:35 N | 8/20/2021 11:31:35 W |
| 8 | Backing | 1.0 | 30 | 0.6 | 0.87 (0.08) | 375 | 8/19/2021 12:55:12 E | 8/19/2021 14:40:02 W |
| 9T | Mixed[6] | NA | NA | NA | 0.9 (0.64) | 62 | 8/20/2021 06:11:32 C | 08/20/2021 07:35:15 N |
| 10T | Mixed[6] | NA | NA | NA | 0.85 (0.61) | 252 | 8/20/2021 05:17:14 N | 8/20/2021 06:40:34 E |

[1]No video was available for Plots 2,3,5,9,10. T = Understory thinned, piled, and burned in 2011 or 2015 (FACTS).
[2]Fire arrival at west sensor occurred long after arrival at other sensors. Statistics are based on three triangles that did not include the west sensor.

**Table 10**. Continued.
[3]Fire arrival at west sensor occurred long after arrival at other sensors. The burn was patchy and remained unburned on top of sensor. Statistics are based on three triangles that did not include the west sensor.
[4]One outlier ROS value excluded. Fire arrived at east and south sensors and center at nearly the same time, apparently a severe violation of the linear flame front assumption.
[5]Fireline intensity is the product of surface fuel consumption (kg/m$^2$, litter, 1-100-hr woody, grass, herbs, shrubs, and seedlings), rate of spread (m/s), and heat of combustion (18600 kJ/kg). Rate of spread was from sensors except for Plot 4 where the maximum value estimated from video was used.
[6]Fire type would be described as backing and flanking based on arrival times at ROS sensors relative to slope but fire effects suggested at least some heading fire. Clearly, spread was not uniform. Plots 9 and 10 burned in patchy fuels in the early AM (between 0517 and 0735 PDT) probably under the influence of ignition operations the previous day.

## Fire Effects

Fire effects on the Summer Fire varied greatly depending on the fire type, which was linked above to the presence of a smoke inversion. Plots 1, 2, 3, 5, and 6 experienced a backing fire under an inversion, exhibiting low to moderate fire effects with little scorch or torch and moderate to high duff and litter consumption. Plots 4, 7, 8, 9, and 10 burned with increased fire behavior following the lifting of the main inversion and tended to have more severe effects (Figure 13). When a head fire aligned with weather and topography (Plots 4, 10), scorch heights averaged around 60 feet (Figure 14). Generally, soil heating increased with litter and duff consumption except where there was little duff and litter to consume and surface heating was high because of the consumption of other fuels (Figures 15 and 16). Looking forward, early or immediate-post fire effects from all the plots, except for Plot 4, indicated that ecosystem structure will likely remain similar. However, it remains to be seen how consumption of duff mounds at the bases of large trees will affect mortality. In addition, the steep slopes across our plots (27-80%) will likely be a large factor, along with remaining canopy cover and fuels, in the retention of soil during winter storms.

**Table 11**. Plot average bole char height and height to live crown, scorch height, percent scorch and torch, and substrate and vegetation severity ratings. Substrate and severity ratings range from 1 (no fire) to 5 (very high, see Appendix 2).

| Plot | Bole char (ft.) | | Height (ft) | | Percentage[2] | | Severity | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Live crown | Scorch[1] | Scorch | Torch | Substrate | Vegetation |
| 1 | 2.0 | 17.2 | 34.1 | 52.6 | >1 | 0 | 3.2 | 3 |
| 2 | 0.9 | 3.9 | 29.1 | 25.1 | 3 | 0 | 2.8 | 2.2 |
| 3 | >0.1 | 3.5 | 36.0 | 42.0 | >1 | 0 | 2.3 | 2.3 |
| 4 | 30.1 | 54.0 | 27.7 | 63.3 | 95 | 20 | 4 | 4 |
| 5 | 0 | 3 | 35.1 | 23.0 | 2.6 | 0 | 2.7 | 2.8 |
| 6 | 0.8 | 10.3 | 35.0 | 26.0 | 3.7 | >1 | 3.4 | 3.8 |
| 7 | NA | NA | NA | NA | NA | NA | NA | NA |
| 8 | 0.6 | 9.2 | 32.7 | 38.8 | 33.5 | 0 | 3.6 | 3.2 |
| 9 | 1 | 20.0 | 51.8 | 26.6 | 5.9 | 0 | 2.9 | 2.6 |
| 10 | 4.6 | 42.7 | 54.4 | 64 | 11.7 | 0 | 3.8 | 2.9 |

[1]Trees that did not scorch are excluded

[2]Percentage of all trees, including those that did not scorch or torch

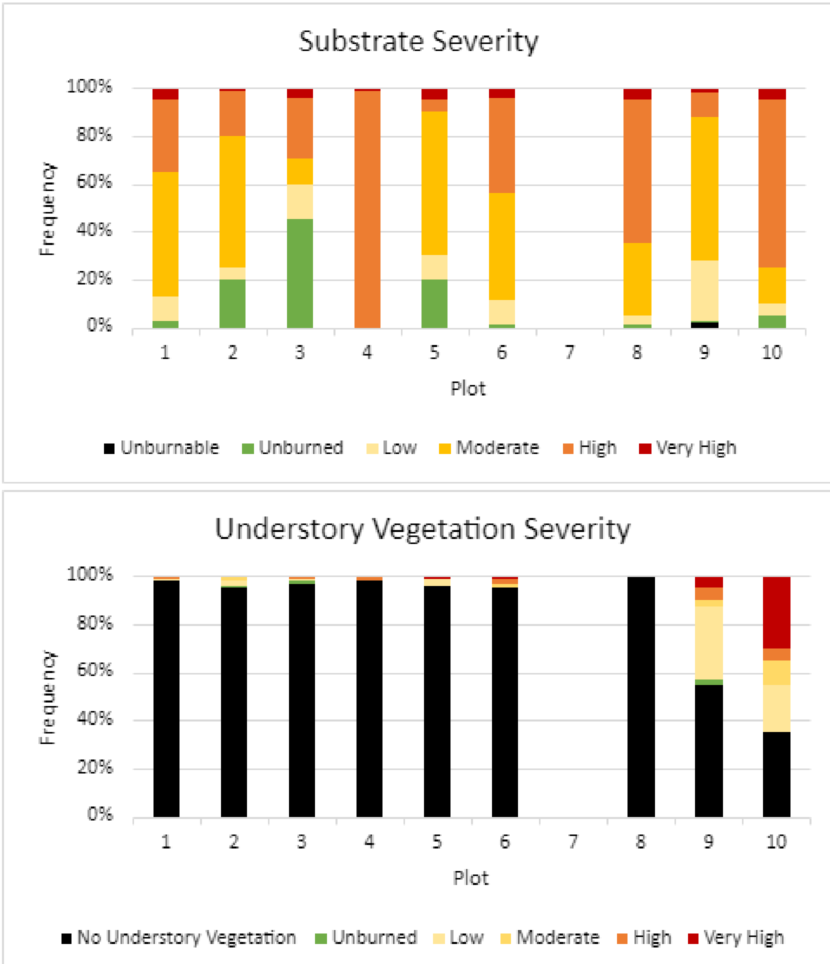


**Figure 13.** Substrate (top figure) and understory vegetation (bottom figure) burn severity assessed shortly after fire. Most plots had little understory vegetation. Plots 9 and 10 were more open than all other sites and had greater understory woody vegetation cover.

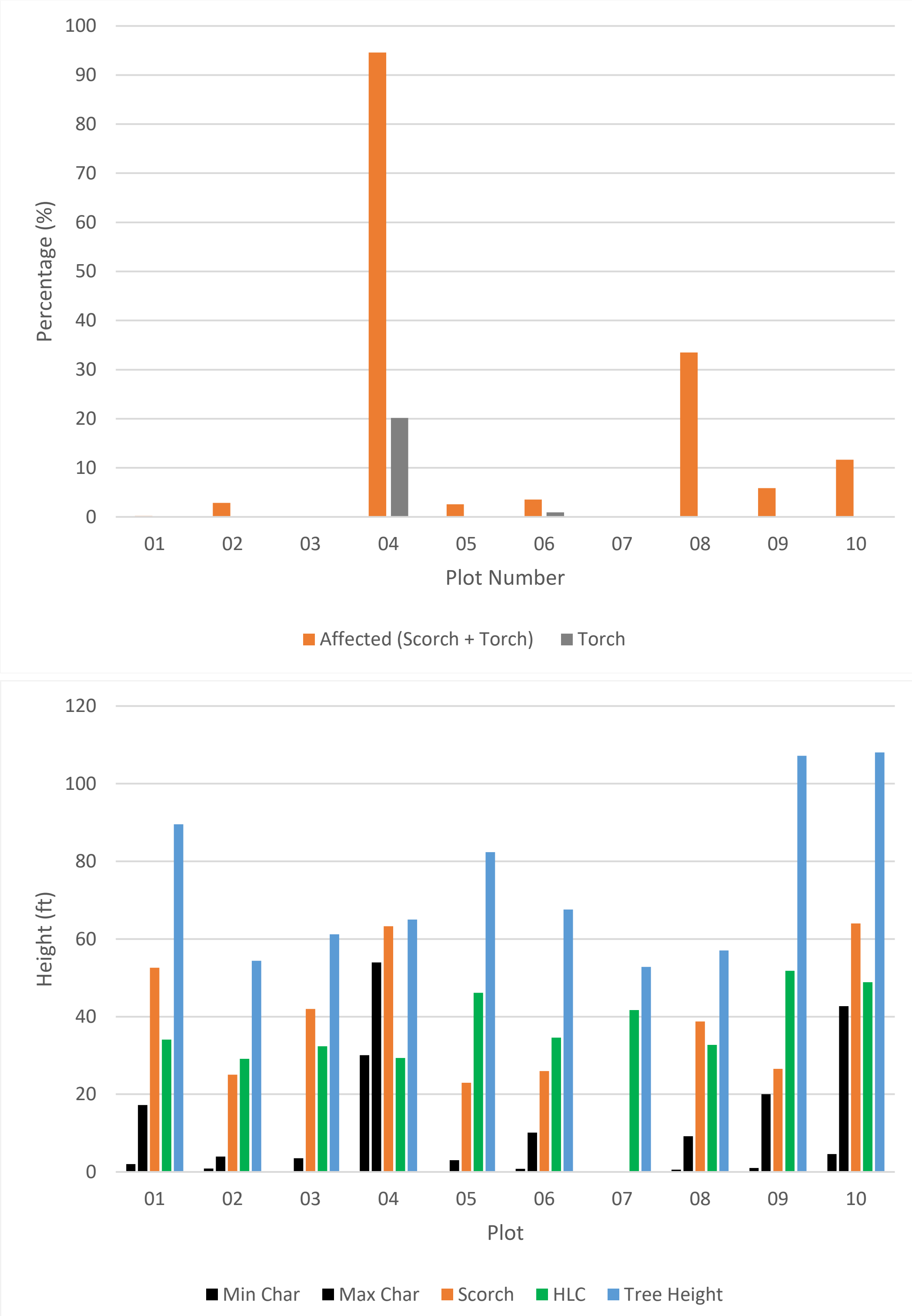


**Figure 14.** Percentage of the canopy on burned plots that was scorched and/or torched (top) and mean bark char heights (minimum and maximum), scorch height, height to live crown (HLC), and tree heights on burned plots (bottom). Plot 7 burned but fire effects were not assessed for safety reasons. Only trees with scorch are included in scorch height estimate which sometimes results in mean scorch height being less than HLC.

Background soil temperature ranged from 18-22 C (e.g., Figure 15). The data loggers continued recording post-fire, showing a trend in back towards background temperatures, but temperatures remained elevated several degrees above pre-fire background in areas where there was an overstory canopy. Duff and litter fuels were measured at the point where the soil stakes were placed. For plots that experienced backing fire, there was a clear relationship between duff and litter fuel consumption and soil heating, where litter and duff consumption in excess of 70 tons/acre caused soil heating above 60 C at 5 cm (2 in) depth (Figure 16). Sixty-degrees Celsius is a generally accepted threshold for fine root death and secondary fire effects. As has been documented in the literature, duff mound consumption around large trees on our plots would be expected to cause substantial soil and tree basal heating. Three sensors at 5 cm (2 in) in Plots 4 and 10 experienced substantial soil heating from the consumption of fuels other than litter and duff as indicated by the solid orange symbols above the 60 C reference line in Figure 16.

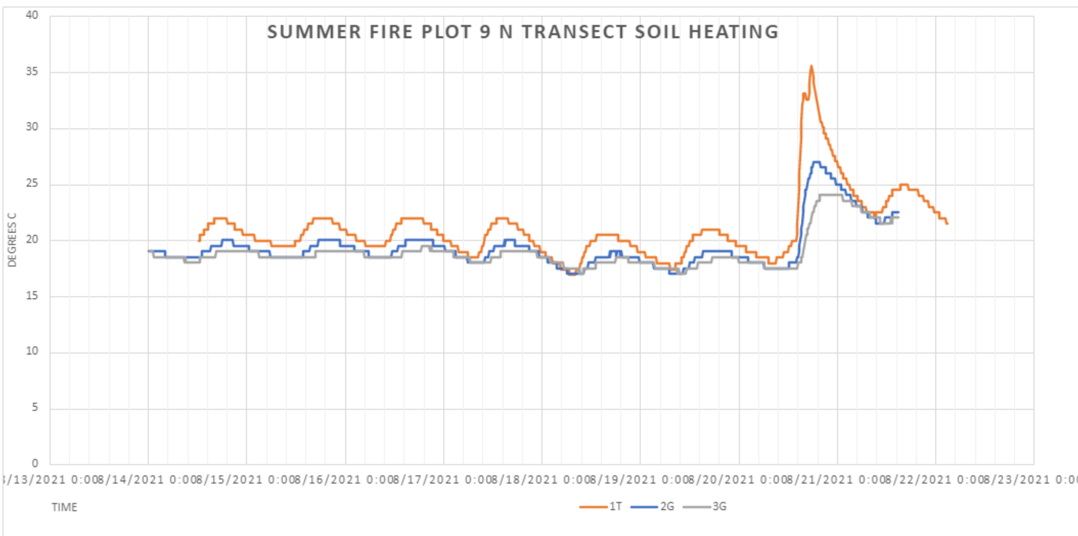


**Figure 15.** Example of soil heating graph showing fire and background soil temperature.

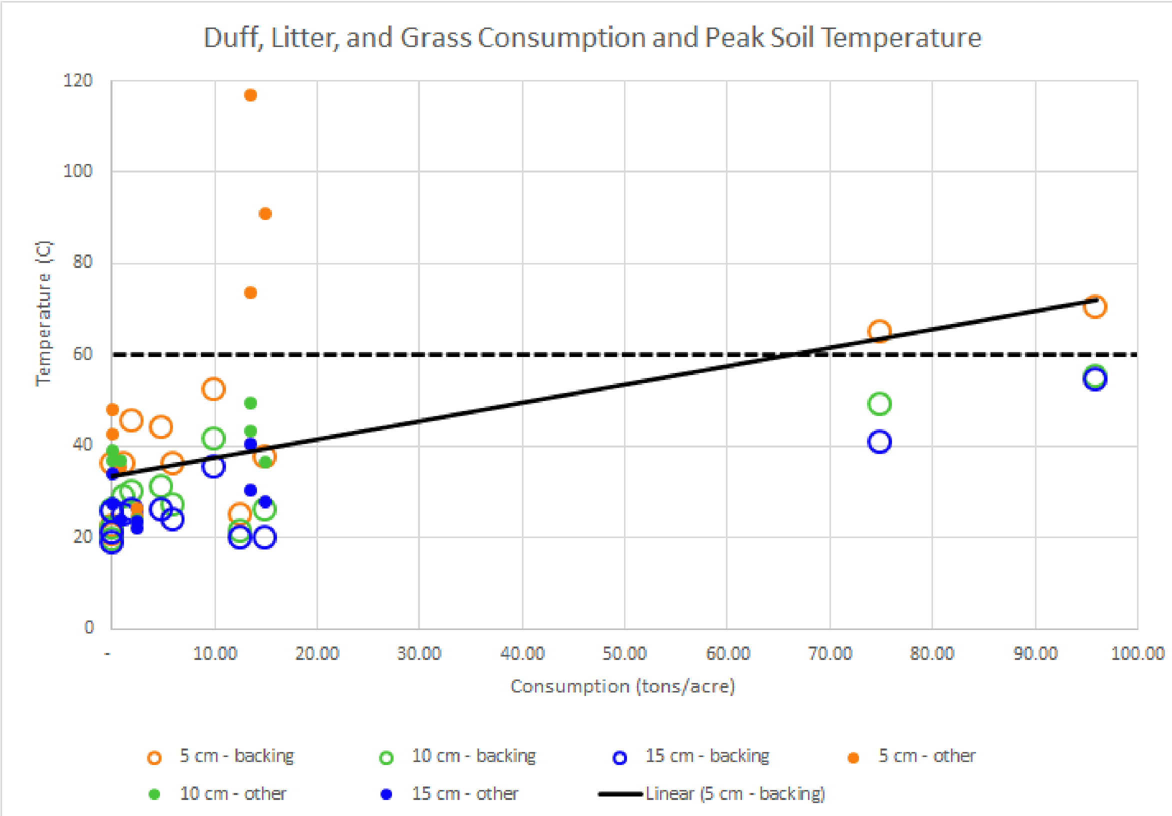


**Figure 16.** Soil heating as a function of duff, litter, and grass loading. Duff, litter, and grass consumption was estimated over the soil heating location. Open circles are results for backing fires that primarily consumed duff, litter, and woody fuels while filled symbols are for heading fire and other fire types that also consumed foliar fuels. The trendline is for backing fires at 5 cm (2 in) depth. The reference line (hashed) indicates 60° C (140° F), a commonly used temperature threshold for indicating fine root death.

## Fuels, Fire Behavior, and Fire Effects - Plot Summaries

Times reported below are PDT.

### Plot 1

Fire reached Plot 1 in the evening of August 11th. The fire reached Plot 1 from the South, backing downhill, as indicated by the fire reaching the southern sensor first, then spreading downhill on the easterly side of the plot and finally over the ridge to the western sensor arriving there early morning on August 12th. Video evidence confirms this spread pattern. Based on the arrival times from the thermocouples, fire moved through Plot 1 at a mean speed of 0.34 ch/hr (Table 10). Based on video estimates the fire moved through the plot at 0.64 ch/hr. Fireline intensities were low.

All strata of surface fuels in Plot 1 were totally consumed with the exception of 10-hour fuels (86% consumption) and 100-hour fuels (50% consumption). Combined fuel loading of duff, litter, 1 through 1000-hr fuels was 20 tons/acre. In general, 1000-hour fuels become available when fuel moisture content reaches 8%. During the time Plot 1 burned 1000-hour fuel moisture was modeled at 9% and consumption was 100%.

Plot 1 had a history of past fire indicated by fire scars on larger diameter trees and in the presence of charcoal in the soil, but no fire history is on record. Fire effects in the plot were low to moderate in severity due to a backing fire, the inversion, and a high relative humidity. There was little to no scorch in most trees except for large diameter trees that had accumulated substantial duff mounds. These duff mounds likely ignited neighboring understory trees leading to higher scorch levels. The sparse understory vegetation present before the fire lost all aboveground biomass.

## Plot 2

Fire reached Plot 2 in the early morning of August 14$^{th}$. The fire reached this plot from the south, backing downhill, as indicated by the fire reaching the southern sensor first, then spreading downhill on the easterly side of the plot and finally over the ridge to the western sensor arriving there at mid-day on August 15$^{th}$. Based on the arrival times from the thermocouples, fire moved through Plot 2 at a mean speed of 0.09 chainer per hour (Table 10) with patchy spread. Fireline intensity was low.

Surface fuel consumption in Plot 2 was the lowest of the plots we sampled. Duff and litter consumption were 58 and 59%, respectively. Surface fuel reduction was 69%, 30%, 32%, and 38% for 1, 10, 100, and 1000-hr fuels respectively. Plots 1 and 2 burned under backing fire conditions. Overstory composition of Plot 2 was an almost equal mix of Ponderosa pine, Black oak, and Douglas-fir, whereas Plot 1 was almost entirely Douglas-fir (i.e., fuel model 9 vs. fuel model 8, which may have contributed to longer residence time and greater consumption in Plot 1). Additionally, Plot 2 had a lower density of 78 trees per acre vs. 192 trees per acre in Plot 1. During the time Plot 2 burned RH at the Sawyers Bar RAWS ranged from 41-75% vs. 34-53% for Plot 1.

Trees with significant previous fire injury and snags fell because of the fire, otherwise there was little fire effect upon the canopy. Fuel consumption was patchy and in areas that did not burn, understory vegetation survived. Plot 2 was part of a ridgeline pile burn unit, but other fire history is unavailable.

## Plot 3

Fire reached Plot 3 early in the AM, backing generally downhill, having reached the south sensor (uphill) first. Only one triangle of arrival times is available for ROS calculation. Spread was slow at 0.1 ch/hr. No video was available for this plot. Percent consumption was relatively low for 100 and 1000-hr fuels, and duff accounted for the greater part of total consumption. RH ranged from 42-62% when the plot burned, winds were light, and 10-hr and 1000-hr fuel moisture was modeled at 10% and 8%, respectively.

Plot 3 had multiple unburned patches and a lower litter loading than other plots. Overstory composition was primarily Douglas-fir with some black oak. The RH's when the plot burned would translate into a moisture content above the moisture of extinction for compact pine litter and may explain some of the unburned areas. Fire intensity was low in Plot 3. There was little to no scorch present in the canopy, only in shrubby oaks. The understory vegetation in burned areas was light to moderately affected.

## Plot 4

Breakdown of the inversion and spotting during the afternoon of August 15$^{th}$ resulted in an uphill run through Plot 4. During the timeframe in which Plot 4 burned, the inversion had lifted, RH was around 9%, temperature was 89 F, and 10-hr fuel moisture was recorded at 2% at the Sawyers Bar RAWS in contrast with plots that burned under an inversion with RH values roughly between 40-60%. The plot's anemometer recorded average winds of 3 mi/hr with gusts to 15 mi/hr. We experienced several thermocouple failures on Plot 4, at least one of them from a melted logger, making it impossible to calculate a rate of spread. We did get readings from two of the thermocouples allowing us to estimate a time of 17:48 for the fire's arrival. Video recording was successful allowing us to estimate the lower rate of spread at 0.6 ch/hr and a high rate of spread at 37 ch/hr. The video indicates strong winds across and down slope during the fire passage causing the spread rate to decrease during periods of countering wind. Winds shifted between across/down slope to upslope several times. During upslope winds the spread rate and fire behavior increase greatly. Ultimately, the fire progressed from North to South (upslope) through the plot. Fire behavior varied with wind shifts from low to high intensity exhibiting periods of rapid spread with pockets of group torching or passive crown runs upslope from the plot. The percentage of fuels consumed was high for all fuel classes present in the sample. Duff and 1000-hr fuels accounted for the majority of consumption.

Plot 4 had a history of past fire, evidenced by catfaces and fire scars on larger diameter trees. The plot had very high intensity fire and as a result most vegetation was 100% affected. Many trees were torched and only the tallest needles in the tallest trees escaped scorch. Duff mounds around these large trees were totally consumed and it is likely these trees will die due to a combination of soil heating and canopy scorch. All understory vegetation consumed. The litter and duff in Plot 4 were entirely consumed with high and very high severity. One large Douglas fir with a catface burned out and fell across the plot before the post-fire sample.

## Plot 5

Fire arrived at Plot 5 in the early AM when RHs were high (51%) and winds were light. Rates of spread were low at 0.4 ch/hr. Fuel loadings were modest presumably in relation to low basal area of overstory and pole-sized trees because of thinning treatments. Percent consumption of duff was on the low end relative to other plots, while percent consumption of woody fuels was relatively high.

Initial fuel loading of duff was low at 5.4 tons/acre. Plot 2 had similar initial duff loading at 6.7 tons/acre. Duff consumption of Plot 5 and Plot 2 were 58% and 55%, respectively. Plot 5's overstory is about ½ Douglas-fir and ½ pines, black oak and madrone. Plot 2 also had a more diverse pine/oak overstory.

Plot 5 had a history of past fire evidenced in fire-caused cat faces on the larger diameter trees. Plot 5 was underburned in 2004. Fire effects were similar to Plot 2. The fire was patchy, there was duff consumption around the base of larger trees and in cat faces, and little to no scorch except for an understory madrone.

## Plot 6

Plot 6 was similar in forest structure and fuels (except for more 1000-hr fuels along transects) to Plot 3 but fire arrived on the plot in the evening (rather than in the early morning as with Plot 3). RH was moderate at 38% (vs. 51% for Plot 3) and winds were light. Percent consumption was higher across the board for Plot 6 relative to Plot 3. Backing rates of spread were about 6 times higher on Plot 6 (0.6 ch/hr) than that measured on Plot 3 (0.1 ch/hr).

The fire burned 89% of the fuels but fire effects on the trees were rather minimal. Soil effects were generally either moderate or high. Despite the relative absence of canopy scorch, almost all large diameter fuels consumed including a standing dead snag.

### Plot 7

Fire arrived at Plot 7 during mid-morning when RH was 38% and RAWS 10-hr fuel moisture was 7%. Backing spread was the highest measured at 1.2 ch/hr. We quickly retrieved ROS sensors shortly after the plot burned but left the plot to reduce safety risk. We attempted to return on the last day of the assignment, but though one large overstory tree had fallen, others continued to burn out and we were not able to re-enter the plot to re-measure fuels and assess fire effects.

Video shows a low intensity backing/flanking fire. From quick observation, the fire enlarged cat faces on oaks, weakening them, and burned out the boles of nearby large Doulas-firs and a sugar pine causing them to fall.

### Plot 8

Fire arrived at Plot 8 in the early afternoon and backed through the plot at a rate of 0.8 ch/hr with no inversion. Plot 8 (and Plot 4) burned under hotter conditions than other plots, with a temperature of 90˚ F and RH of 15% recorded at Sawyers Bar RAWS. Winds recorded at Sawyers Bar were an average of 8 mph from the WNW, with gust of 27 mph. Winds recorded on plot were 7 mph with a gust of 18 mph. Litter loading and consumption were higher than in other untreated plots. Percent consumption was high across the board except for 10-hr fuels, which may be a function of a relatively small sample size. High consumption was likely a function of backing fire residence time coupled with low RH.

This plot had many weakened trees with upslope catfaces, evidence of a previous fire. There was complete consumption of 1000-hr fuels. In the canopy above the ash pile remnants of these fuels there was evidence of scorch, especially on conifer needles. The fire caused two canyon live oaks, one live and one snag, to fall over at their bases.

### Plot 9

Plot 9 burned early in the morning when temperatures were about 60˚ F and RHs were about 60%. Average wind speed was mild with a gust to 6 mi/hr. Rates of spread were about 0.9 ch/hr. There was no video from Plot 9, but from fire arrival times, it appeared that fire behavior was mixed between backing and flanking. Fuels were patchy with low consumed loading of fine fuels (see Table 9). The plot, being open canopy, had high loadings of shrub fuels, but percent consumption of shrub fuels was relatively low at around 70%. No 1000-hr fuels were sampled on Plot 9.

Thousand-hour fuels near the base of two of the trees consumed causing significant injury to their boles. Otherwise, tree canopies were scorched but scorch heights and percentages were not indicative of a high intensity fire. Impact to the soils was patchy. Because of the open canopy, trees in the sample were mostly at the periphery or well outside the fuel sampling area but in generally similar surface fuels.

### Plot 10

Plot 10 burned early in the morning when temperatures were 61° F and RHs were 56%. Average winds at the anemometer were relatively high with a gust of 30 mi/hr. Rates of spread were about 0.85 ch/hr. While there was no video to determine fire behavior, fire arrival times indicate a mix of backing and flanking fire. Based on fire effects on the plot, there may have been some head fire. Fuels were patchy with high consumption of fine surface fuels compared with Plot 9. Percent consumption of shrub fuels was relatively low at around 70%. Plot 10 had high consumption of 1000-hr fuels and overall consumption of fuels was 98% because fuel loads and consumption were dominated by 1000-hr fuels.

High scorch levels indictive of a high intensity head-fire were measured on sampled trees. Trees had a high live to crown height and suffered relatively low scorch despite the high scorch heights. A high percentage of the substrate and moderate percentage of the shrub vegetation was classified as being affected at high severity. Because of the open canopy, trees in the sample were mostly at the periphery or well outside the fuel sampling area and it appears that fireline intensities outside of the plot among the trees were greater than within the core area of the plot.

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# APPENDIX 1 - Pre- and post-fire plot photographs

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| Plot 1 Transect 1, 50-0 Pre | Plot 1 Transect 2, 50-0 Pre | Plot 1 Transect 3, 50-0 Pre |

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| Plot 1, Transect 1, 50-0 Post | Plot 1, Transect 2, 50-0 Post | Plot 1, Transect 3, 50-0 Post |

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| Plot 2, Transect 1, 50-0 Pre | Plot 2, Transect 2, 50-0 Pre | Plot 2, Transect 3, 50-0 Pre |

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| Plot 3, Transect 1, 50-0 Pre | Plot 3, Transect 2, 50-0 Pre | Plot 3, Transect 3, 50-0 Pre |

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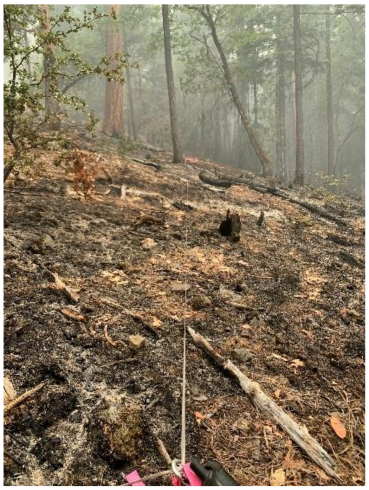
|  |  |  |
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| Plot 6, Transect 1, 50-0 Pre | Plot 6, Transect 2, 50-0 Pre | Plot 6, Transect 3, 50-0 Pre |

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| Plot 6, Transect 1, 50-0 Post | Plot 6, Transect 2, 50-0 Post | Plot 6, Transect 3, 50-0 Post |

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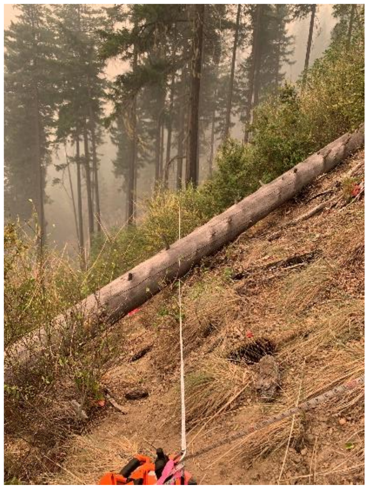
|  |  |  |
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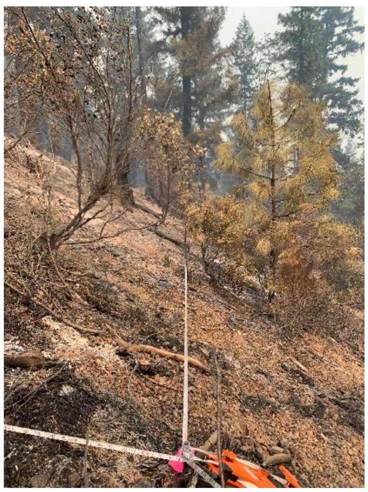
|  |  |  |
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# APPENDIX 2 - Substrate and Understory Vegetation Severity

Definitions of ordinal severity levels from the NPS Fire Monitoring Handbook. NOTE: FBAT reverses the scale in data collection and reporting because its more intuitive. That is, 1 = unburned and 5 = heavily burned.



**Table 28. Burn severity coding matrix.**

| | Forests | | Shrublands | | Grasslands | |
|---|---|---|---|---|---|---|
| | **Substrate (S)** | **Vegetation (V)** | **Substrate (S)** | **Vegetation (V)** | **Substrate (S)** | **Vegetation (V)** |
| **Unburned (5)** | not burned | not burned | 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 | litter partially blackened; duff nearly unchanged; leaf structures unchanged | foliage scorched |
| **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; logs are scorched or blackened but not charred; rotten wood is scorched to 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 postburn; 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 | litter charred to partially consumed, but some plant parts are still discernible; charring may extend slightly into soil surface, but soil is not visibly altered; surface appears black (this soon becomes inconspicuous); burns may be spotty to uniform depending on the grass continuity | grasses with approximately two inches of stubble; foliage and smaller twigs of associated species partially to completely consumed; some plant parts may still be standing; bases of plants are not deeply burned and are still recognizable |
| **Moderately Burned (2)** | litter mostly to entirely consumed, leaving coarse, 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 coarse, 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 (>.6–1 cm in diameter) (0.25–0.50 in) still present; 40–80% of the shrub canopy is commonly consumed. | leaf litter consumed, leaving coarse, light gray or white colored ash immediately after the burn; ash soon disappears leaving bare mineral soil; charring may extend slightly into soil surface | unburned grass stubble usually less than two inches tall, and mostly confined to an outer ring; for other species, foliage completely consumed, plant bases are burned to ground level and obscured in ash immediately after burning; burns tend to be uniform |
| **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 1–2.5 cm (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 1 cm (0.5 in) in diameter | leaf litter completely consumed, leaving a fluffy fine white ash, this soon disappears leaving bare mineral soil; charring extends to a depth of 1 cm (0.5 in) into the soil; this severity class is usually limited to situations where heavy fuel load on mesic sites has burned under dry conditions and low wind | no unburned grasses above the root crown; for other species, all plant parts consumed leaving some or no major stems or trunks, any left are deeply charred; this severity class is uncommon due to the short burnout time of grasses |
| **Not Applicable (0)** | inorganic preburn | none present preburn | inorganic preburn | none present preburn | inorganic preburn | none present preburn |