Fire Behavior Assessment Team (FBAT) Report

2020 Red Salmon Complex - Fuels, Vegetation, Fire Behavior, and Fire Effects in the Plummer Creek Drainage, Klamath National Forest

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Effects of fire in Plummer Creek drainage where surface fire intensities were low, but heavy fuels were dry and often consumed.

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Table of Contents

Summary

The Fire Behavior Assessment Team (FBAT) sampled fuels, vegetation, fire behavior, and fire effects on 5 plots in the Plummer Creek drainage on the Klamath National Forest on the eastern side of the 2020 Red Salmon Complex. The plots were installed within and outside of the footprint of the 1987 Hotelling wildfire, the only recorded wildfire in an area with no other treatment history. Severity of the 1987 fire was low in the drainage as mapped using Landsat satellite imagery by the Monitoring Trends in Burn Severity program. Based on plot sampling and re-mapped severity, effects of fire on vegetation and substrate in the drainage 33 years later during the Red Salmon Complex were also modest. Based on limited plot data, effects of the Hotelling Fire were apparent in reduced shrub and tree seedling cover and increased loadings of downed woody material and standing Douglas fir snags. In the 4 plots that burned during the Red Salmon Complex, surface fire intensities were low and spread was patchy under moderate fire weather, but downed woody material was dry and often consumed. Our data suggest that the ecological effects of the Red Salmon Complex in the Plummer Creek Drainage will be to maintain the woodland character of open grass-dominated stands on serpentine parent material because they reduced the cover of shrubs and tree seedlings. A considerable proportion of the area within the perimeter of the Red Salmon Complex, particularly areas on the periphery, were coded as “very low/unburned” to “low” severity on the Soil Burn Severity map produced to guide Burned Area Emergency Rehabilitation (BAER). We suggest that fire effects like those we observed open opportunities for future fire management in fire-dependent woodland systems, including wildfire management for resource benefit and prescribed fire application. Beneficial effects of the Red Salmon Complex build on legacies of a long history of fire, including fire management by Karuk, Tsnungwe (Hoopa), and other indigenous peoples.

Objectives

FBAT objectives on the Red Salmon Complex were to:

1. Safely and efficiently maximize the number of plots inventoried both pre- and post-fire
2. Contrast areas previously burned during a 1987 wildfire with those in areas with no recorded 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 a report for the benefit of land and fire managers, FBAT data archive users, and facilitate future plot re-measurement

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 Red Salmon Complex (Figure 1). The Red Salmon Complex of fires started on July 27, 2020, as 2 separate incidents, the Salmon Fire on the Shasta-Trinity NF and the Red Fire on the Six Rivers NF. Both fires were located in the NW corner of the Trinity-Alps Wilderness Area, near the point of intersection of the Klamath, Shasta-Trinity and Six Rivers National Forests coinciding with the intersection of Humboldt, Trinity and Siskiyou Counties in NW California. Management of the two fires was merged into a single incident, known as the Red Salmon Complex, on July 30th, 2020. The perimeters of the two fires merged into a contiguous polygon on August 16th, after the Salmon Fire had burned 811 acres and the Red Fire had burned 14,271 acres. Fire size at containment was 144,698 acres on 17 November and included portions of three National Forests (Klamath, Six Rivers, and Shasta-Trinity) and a corner of the Hoopa Reservation. The Red Salmon Complex burned within the traditional territories of Tsnungwe (Hoopa, Shasta) and Karuk peoples (see https://native-land.ca/). The Red Salmon Complex overlaps the footprints of multiple past fires (Figure 2).

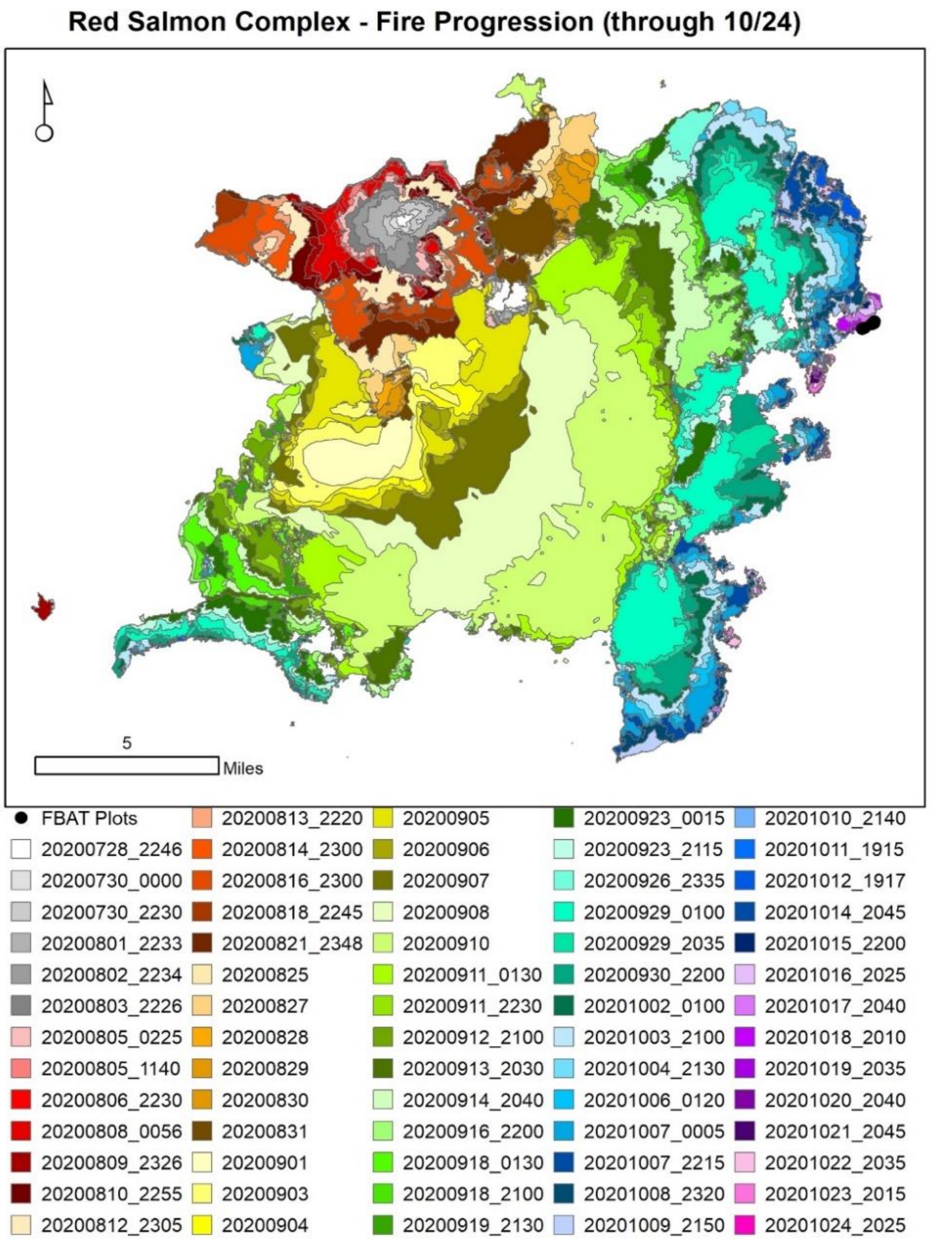

Figure 1. Red Salmon Complex Fire progression map and FBAT plot locations (black dots in NE corner).

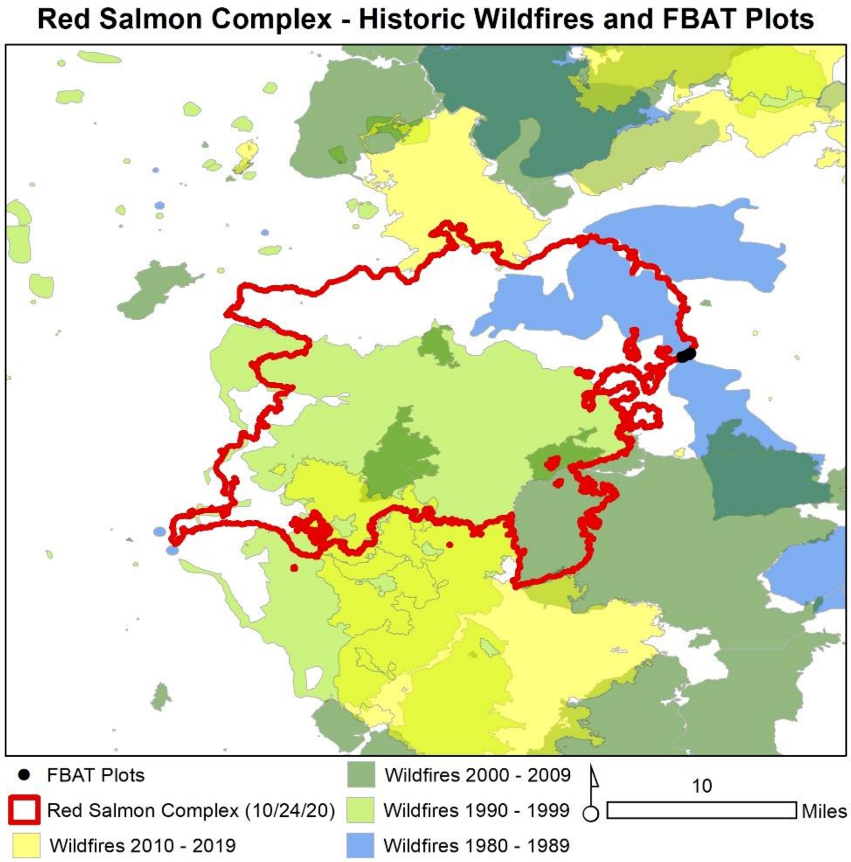

Figure 2. Recent wildfire history in the vicinity of the Red Salmon Complex. FBAT plots locations are the black dots in the NE corner.

Plot Installation

FBAT installed plots in the Plummer Creek Canyon, one of the few remaining areas of fire growth in early October (Figure 1). Plots were located on the north side of Plummer Creek, uphill from the confluence of Plummer Creek and the South Fork of the Salmon River, in the Trinity Alps Wilderness and within the Gray Pine Botanical Area.

Plot elevation ranged from 2300 to 2500 ft (Table 1) and tree vegetation in this area consisted of a mix of grey pine (*Pinus sabiniana*), incense cedar (*Calocedrus decurrens*), Douglas fir (*Pseudotsuga menziesii*), Oregon white oak (*Quercus garryana*), and ponderosa pine (*P. ponderosa*). A few sugar pine (*P. lambertiana*), canyon live oak (*Q. chrysolepsis*), and black oak (*Q. kellogii*) were also present. Stands ranged from closed canopy to open woodland (Figure 3). Soil quality appears to be relatively poor with some serpentine influence. In this landscape, the presence of grey pine is frequently a serpentine indicator. There was considerable variation in both the degree of serpentine influence and overstory species composition, with some areas almost exclusively dominated by grey pine, and others having more of a mixed conifer/hardwood character. Understory vegetation was heavier in the more open areas and dominated by buck brush (*Ceanothus cuneatus*) and native perennial bunch grasses (likely fescue - *Festuca* sp.). Plots with more canopy cover contained very little understory vegetation. Litter, duff, and fine dead and down surface fuels were relatively light, likely due to the low productivity of the sites. Three of the five plots (Plots 3-5) were placed in areas that last burned in the 1987 Hotelling Fire where fire severity was mapped as "low" (Figure 4). Downed coarse woody debris, presumably originating from Hotelling Fire, was present. The sites had open canopies with herbaceous-dominated understories. The remaining two plots were located outside the Hotelling Fire footprint with no treatment history. Plot 1 had a closed canopy while Plot 2 had an open canopy dominated by gray pine.

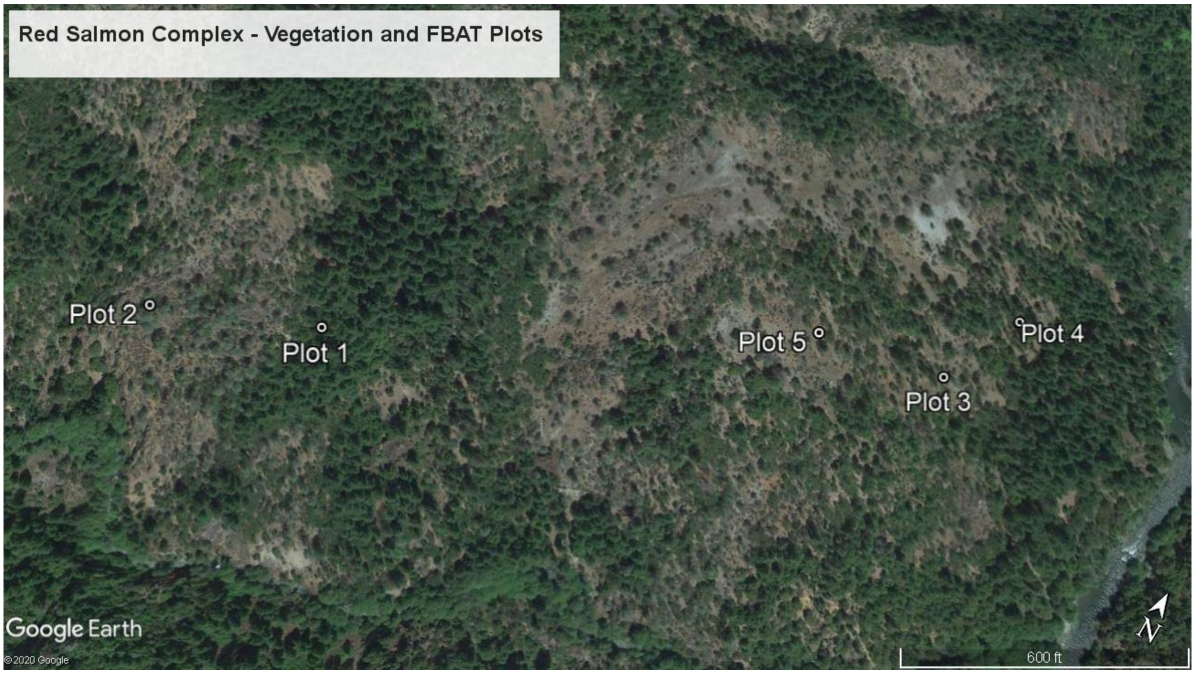

Figure 3. FBAT plots and overstory cover on the Red Salmon Complex.

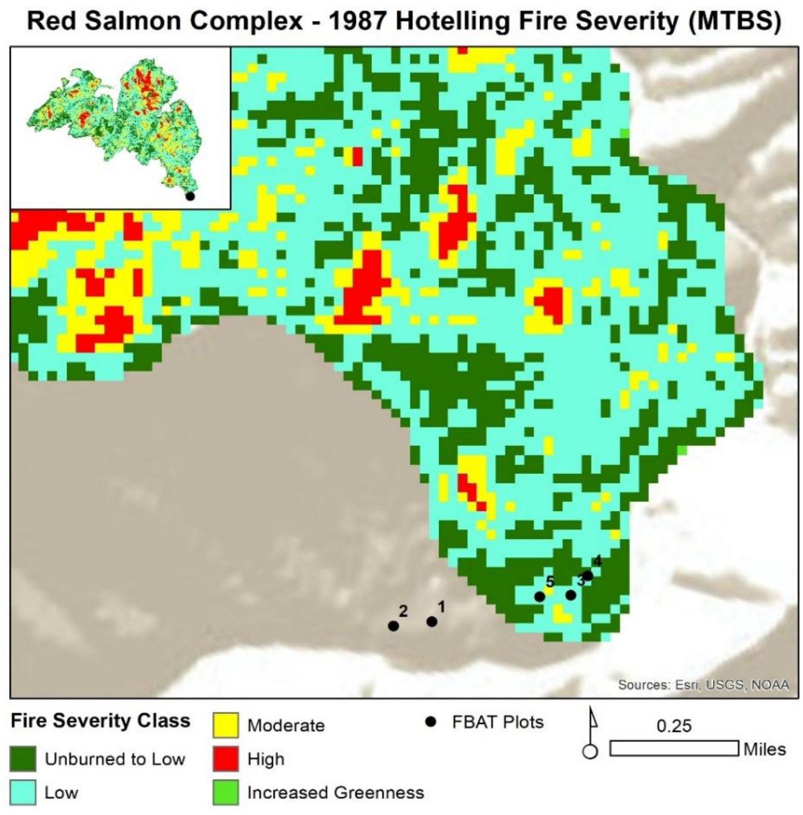

Figure 4. Vegetation severity of the 1987 Hotelling Fire from the Monitoring Trends in Burn Severity dataset are shown with the FBAT plot locations. Data Source: MTBS.

We installed the plots in expectation that they would burn before an oncoming rain event. Instead, the fire moved slowly and around 0.4 inch of rain fell on 10 October before fire arrived at our plots. We left the incident and returned as the fuels dried and the fire started moving again. Four FBAT plots burned between Oct 17 and Oct. 20, 2020 and one, Plot 4, did not burn (Figure 5). Based on fire behavior observations by FBAT team members and operations personnel and evidence from plot measurements, fire entered all four of the burned plots as a backing fire with slow rates of spread. General fire effects were of low severity, with the only areas of substantial heating the result of concentrated heavy dead and down fuels. One plot had not burned by the time of our final field measurement day on October 22, 2020. Some very slow-moving pockets of fire were still in the area but perimeter maps in Fire EGP suggest that this plot did not burn.

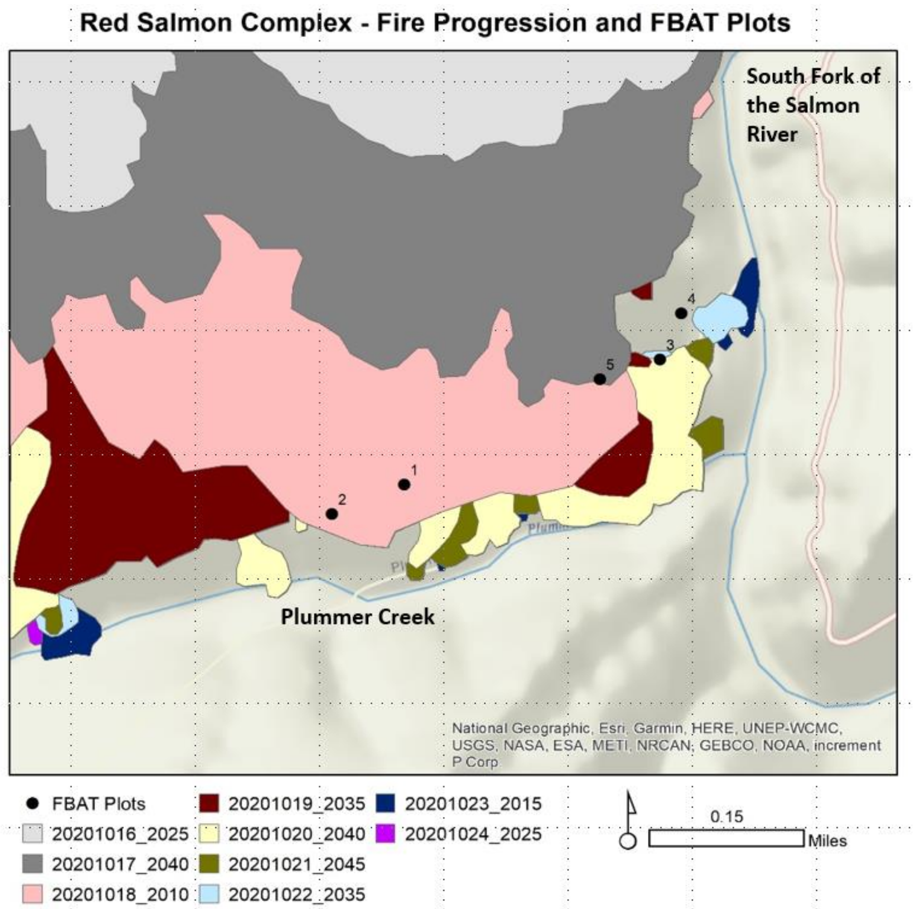

Figure 5. FBAT plots and daily progression on the Red Salmon Complex Fire. Plots 1, 2, 3, and 5 burned and were re-measured post-fire.

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. It is related to 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); fuel loading and larger-diameter woody fuel moistures have an 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 ERC charts for the Somes Bar and Blue Ridge Remote Access Weather Stations (RAWS) are included to illustrate the seasonal changes in fire potential for the area of the FBAT plots (Figure 6). Blue Ridge is the closest RAWS, but may not be the most representative station due to its ridge top placement at 5,859 ft. Somes Bar is farther from the plots but is in a similar river-bottom location that captures diurnal canyon temperature inversions that occurred below the elevation of the Blue Ridge RAWS. During October, inversions occurred below about 4,000 ft.

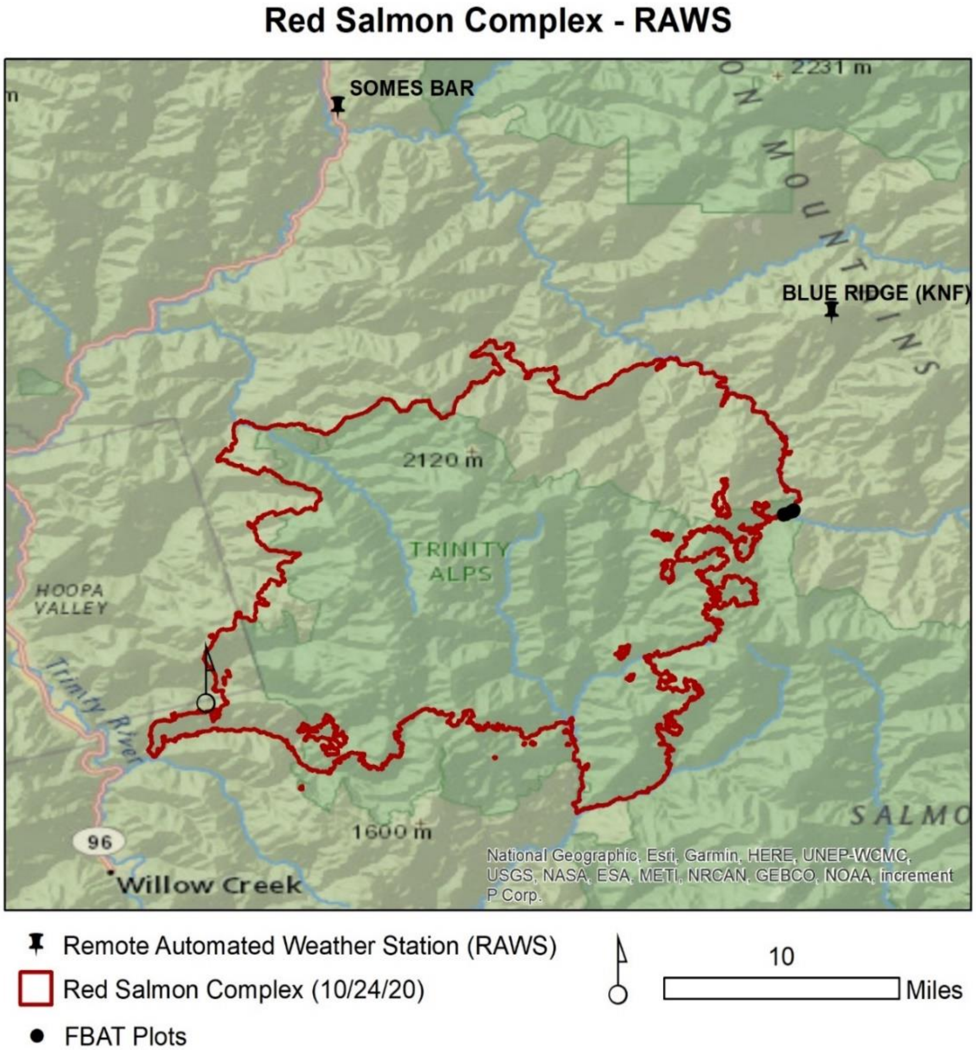

Figure 6. Location of the Somes Bar and Blue Ridge RAWS relative to the FBAT plots (black dots in NE corner) and the Red Salmon Complex.

The winter preceding the Red Salmon Complex had warm temperatures with below average precipitation and snowfall. February set records for dryness across much of northern California, with some locations recording no rain in February for the first time in climatological records. The ERC graphs for both stations capture the dry winter conditions, with late winter and early spring ERC values well above average, hitting record highs for the past 15 years in late February and throughout March and April. A cooler and wetter than average late spring offered some relief, with ERC values at both RAWS dropping below average in May and remaining near average through early summer. At the time of ignition in late July, both RAWS show ERC values above average and approaching 90th percentile values (though it should be noted that the large contrast in seasonal temperatures and precipitation from spring through summer and into fall pushes the 15-yr average late-summer average ERC value very near to 90th percentile values). Periods of rapid fire growth on the 2020 Red Salmon Complex were associated with elevated ERC, with both RAWS hitting daily maximum values in mid-August, early September and late September (Figure 7). All of these periods were also correlated with unstable atmospheric conditions and increased winds, resulting in large fire growth not only on the Red Salmon Complex but on numerous large fires across California and the western United States.

The FBAT plots burned during a period of drying following a small rain event (precipitation at Blue Ridge RAWS = 0.39 inches on October 10th). This rain event led to a dip in the ERC graph to near average conditions (Figure 7, just before red arrows). After the rain, ERC values recovered with warmer, drier weather pushing ERC to near record daily maximums by late October. The warming and drying coincided with a less stable atmosphere and windier conditions, resulting in renewed growth on the Red Salmon Complex. However, by this time of year, seasonal cooling and shorter days typically limit the number of hours of active burning per day, moderating fire behavior despite the unusually warm and dry conditions for this time of year.

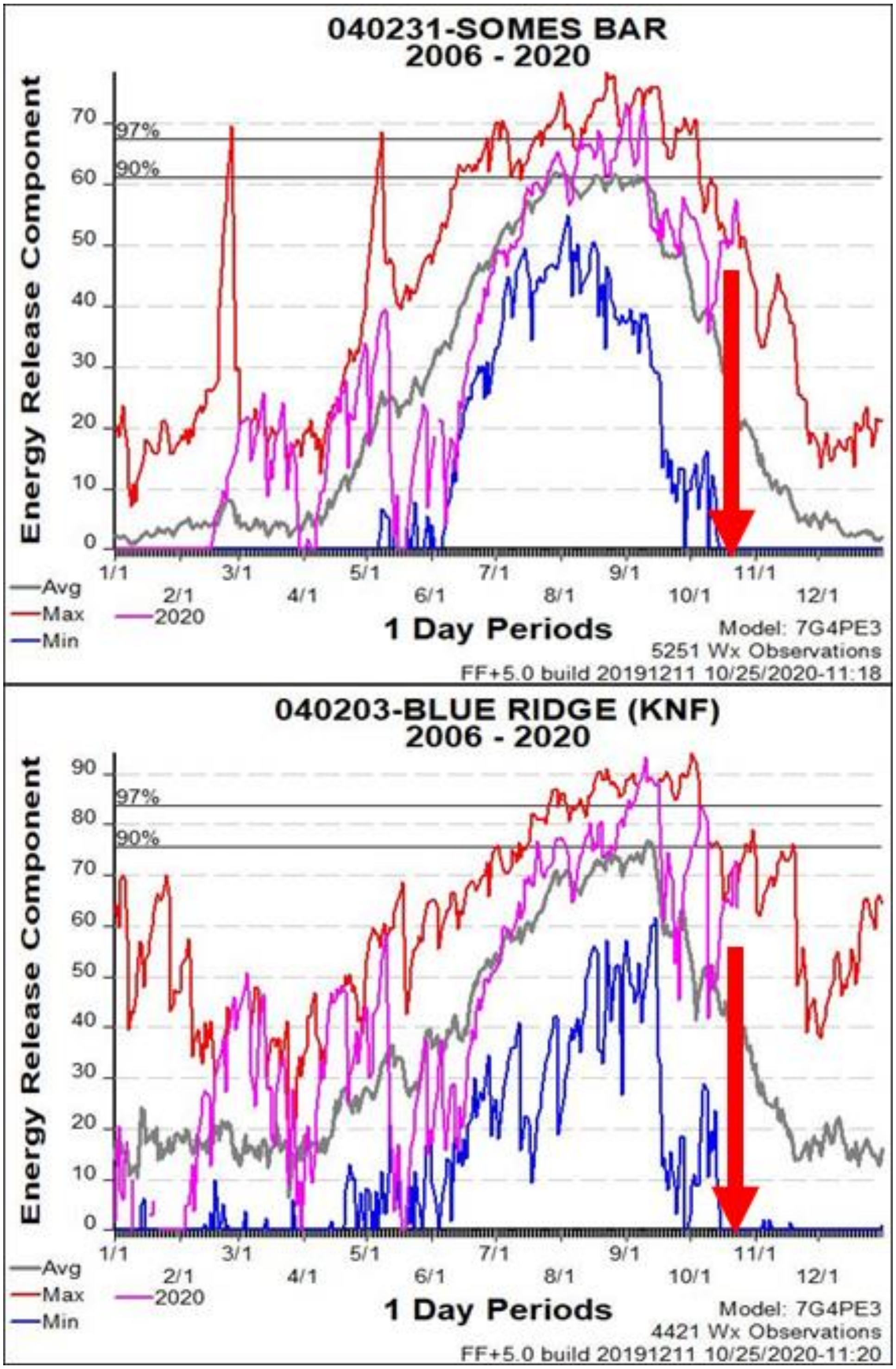

Figure 7. Energy Release Component based on weather from the Somes Bar (top) and Blue Ridge (bottom) RAWS showing 15-year trends and the 2020 season through October 24, 2020. The 2020 ERC dropped sharply on October 10th with wetting rain but increased again as the fuels dried out. FBAT plots burned between Oct. 17 and Oct. 20 (indicated by red arrows).

Methods

The general layout of an FBAT plot is shown in Figure 8 where measurement methods include variable radius plots for pole-sized and overstory trees; Brown's line transects for duff, litter, and downed woody material; belt transects for understory vegetation; an array of fire arrival detectors for rate of spread; video; and energy transport measurements. Soil heating measurements are made at the far ends of the Brown's lines.

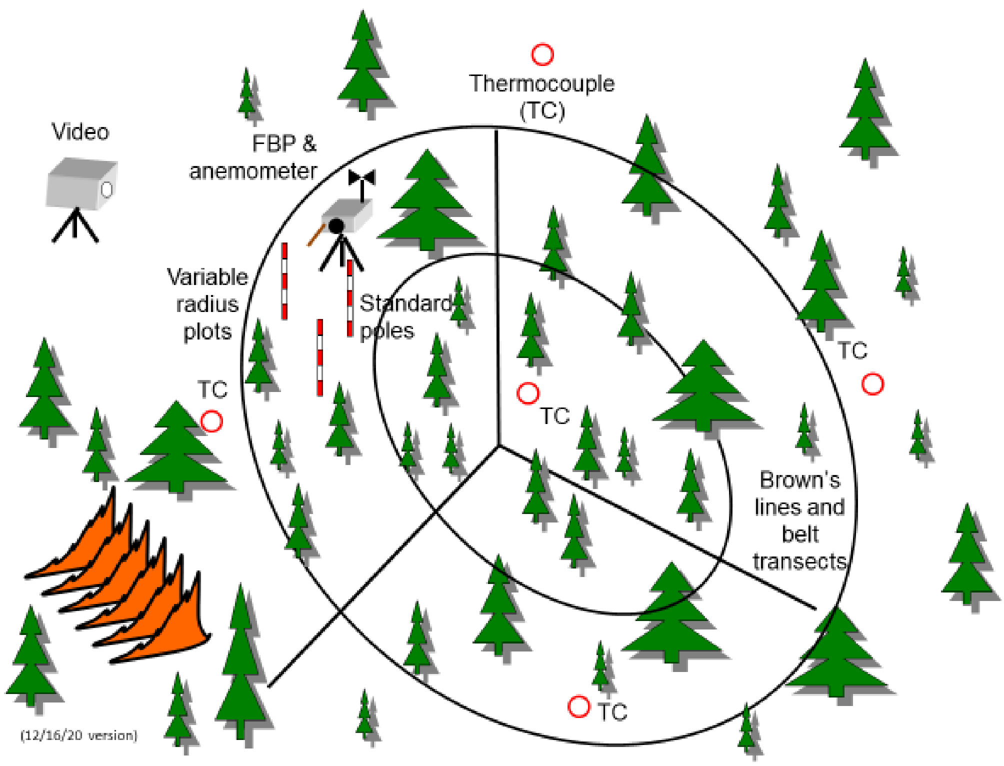

Figure 8. Plot layout. Browns lines and understory vegetation belt transects are anchored at plot center. The concentric circles represent tree variable-radius plots, TC stands for thermocouple (fire arrival detection for rate of spread, ROS), the Fire Behavior Package (FBP) and standards are positioned within the field of view of the video camera. ROS and tree plots are offset from plot center.

Pre- and Post-Fire Vegetation and Fuels

Vegetation and fuels were inventoried before fire arrival and repeated post-fire for burned plots 1, 2, 3, and 5. Fire behavior measurements were also made on each burned plot, along with first order fire effects assessments. Plots were monumented with a single rebar at the center of the fuel transects to facilitate long-term monitoring.

Overstory Vegetation Structure and Crown Fuels

Variable radius plots were used to characterize crown fuels and overstory vegetation structure. A relascope (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.

After the fire, minimum and maximum bole char, average height to which the crown was affected by the fire (either scorched or consumed), 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") were recorded for each tree. Trees are assumed to have survived (at least in the short term) the fire if any green needles were present after fire. Changes in canopy base height were estimated from the average height to which the crown was injured.

The Forest Vegetation Simulator program (FVS, Crookston and Dixon 2005) and its Fire and Fuels Extension (FFE-FVS, Rebain 2010) were run in ArcFuels10 to calculate canopy bulk density, canopy base height, tree density, and basal area both pre- and post-fire. FVS/FFE-FVS are stand level growth and yield programs used throughout the United States. The Inland California and Southern Cascades (CA) variants were used for all calculations. Canopy base height (CBH) and canopy bulk density (CBD) are reported. CBH, CBD, 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 one indicator for how likely passive (torching) or active crown fire behavior would be. As stated in Scott and Reinhardt (2001), "Defined in terms of its consequences to crown fire initiation, CBH is the *lowest* height above the ground at which there is sufficient canopy fuel to propagate fire vertically through the canopy." Canopy base height is defined in FVS as the height where the 13-foot running mean canopy bulk density is greater than 30 lbs/acre/ft, or 0.111 kg/m^3. CBD is the mass of canopy fuel available per unit canopy volume (Scott and Reinhardt 2001).

Understory Vegetation Structure and Loading

Understory vegetation was characterized before and after the fire in a 3 ft wide belt centered on the 50-foot Brown's Lines. The fuel and vegetation transects were in view of the video camera (which will be described below in the "Fire Behavior Measurements and Observations" section). 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 (Scott 2005).

Surface and Ground Fuel Loading

Surface and ground fuels were measured along the same three 50-foot transects used to characterize understory vegetation both pre- and post-fire. Surface fuel loadings (litter, 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 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 dead fuel height was recorded from 0 to 6 ft, 6 to 12 ft and 12 to 18 ft. Litter and duff depths were measured at 1, 6, and 12 ft along the transect, These measurements were used to calculate surface and ground fuel loading (fuel/area) with basal area weighted species-specific coefficients (van Wagtendonk *et al.* 1996; 1998). Fuel consumption was the difference between pre- and post-fire measurements.

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 8). The thermocouples arrayed across the plot captured date and time of fire arrival. Their location and distance from each other allowed rate of spread to be calculated. An anemometer at eye level recorded wind speeds leading up to the fire. Where imagery was successfully captured, it was used to determine fire type, flame lengths, variability and direction of rate of spread in relation to slope and wind, flame duration, and wind direction. The camera was triggered by fire arrival at thermistors which were connected into a wire circuit that was placed around the plot.

Rate of Spread

Rate of spread was determined both by estimating rate of spread from video analysis (above) and by calculating rate of spread from fire arrival times at thermocouples at known positions. The data loggers that recorded thermocouple temperatures were buried underground with the 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, allowing a precise measurement of fire arrival. The distances and azimuths among thermocouples were measured and these position and time of fire arrival data were used to estimate rate of spread (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 reported.

Fire Type

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 and Flaming Duration

Flame length was primarily determined from video footage. The metal poles in the video camera’s field of view are marked in 1-foot increments, allowing an approximate flame length to be estimated. Flaming duration (where it is possible to measure) is based on direct video observation and can be supplemented by duration of flaming at thermocouples.

Plot Wind Speed

Wind data were collected with cup anemometers placed 5 feet above ground at the location of the camera and give an indication of the wind experienced at each plot as the fire passed through. These data are used in the BEHAVE fire model. The instrument is not fire hardened and can be damaged and stop recording when moderate to intense fires arrive at its location. Wind data were recorded at 10 second intervals. The maximum value and average over 20 minutes before fire arrival is reported.

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 surface and ground (USDI National Park Service 2003). 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 (Appendix 2).

Trees

Fire-effects related measurements on trees included minimum and maximum 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 a prototype device (a “soil stake”) that is easier to use and provides less biased results than existing methods. This device provided measurements of mineral soil temperature at 2, 4, and 6 inch 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 inches. The low-temperature loggers had lower memory capacity which proved to be an issue. Given the small size of the FBAT team on the Red Salmon Complex, we did not collect pre- and post-fire soil samples.

Results and Discussion

Site Description

There is evidence of intensive mining disturbance around the Salmon River and along Plummer Creek. Gullying from hydraulic mining is evident along with the remains of a ditch designed to bring water downhill from Plummer Creek. Plummer Creek Trail runs along the ditch until it crosses the creek upstream. Parking is at the Plummer Creek trailhead on east side of the Salmon River. A serviceable site for fording the river exists at the end of the pool below the parking area. Under low flow conditions, the river can be waded or crossed on exposed rocks. General plot history, plot location, and plot sampling information are in Table 1.

Table 1. Site descriptions for five FBAT plots sampled in the Plummer Creek drainage. Latitude and longitude datum is WGS 84. No fuels treatment history was evident in the FACTS (Forest Service Activity Tracking System) database. Wildfire history was determined from perimeters available in the Wildland Fire Decision Support System (WFDSS) and EGP. Altitudes are from GPS.

Plot	N Lat.	W Lon.	Wildfire history	Slope (%)	Aspect (deg)	Elev. (ft)	Pre-fire data collection
1	41.15053	123.21716	None recorded	46	150	2280	10/5/2020
2	41.15010	123.21851	None recorded	47	184	2282	10/5/2020 and 10/6/2020
3	41.15236	123.21241	1987	35	81	2145	10/6/2020
4	41.15303	123.21201	1987	58	69	2106	10/7/2020
5	41.15207	123.21352	1987	29	96	2123	10/7/2020

Plot Descriptions

This section includes descriptions of individual plots that are intended to support future use of the datasets and plot revisits as funding allows.

Plot 1

Access: Plot is located northwest (uphill) from the Plummer Creek Trail. Take trail approximately 0.4 miles, just past 2 large house-sized boulders. Head uphill through the open oak stand into a mixed conifer-hardwood stand. Plot is centrally located in the mixed conifer/oak stand approximately 0.10 miles NW from the second large boulder above the trail.

Description: Plot is located in a Douglas fir dominated, mixed conifer-hardwood stand that has not experienced fire in modern fire history records. The dominant overstory tree is Douglas fir with some pine component. Mid and understory is comprised of stunted/suppressed live oak and black oak with small amount of pacific madrone present. Surface fuels in the plot are light, mainly oak leaves and needle litter. Duff is present and discontinuous but occurs up to 2 in in depth in small patches. The steep slope and light litter result in a fuel bead that is easily disturbed by traversing the plot.

Plot 2

Access: Plot is located northwest (uphill) from the Plummer Creek Trail, approximately 0.08 miles W of Plot 1. Take trail approximately 0.4 miles, just past 2 large house-sized boulders. Head uphill through the open oak stand into a mixed conifer-hardwood stand. Angle left (west) through mixed conifer stand toward the open gray pine/brush stand to the west. Multiple game trails transect the area, the one that goes through bottom of Plot 1 leads toward Plot 2. Direct uphill/downhill ascent/descent between Plummer trail and the plot not advisable due to slope and rock outcrops.

Description: Plot is located in a stand of widely scattered gray pines with brush and grass understory that has no modern recorded fire history. The rock composition, open stand character and apparent low soil quality indicate possible serpentine soils in this plot. Large, widely spaced gray pines dominate the overstory. Understory is dominated by ceanothus buck brush with other minor species present. Bunch grasses are present in patches but not continuous. Some gray pine and deciduous oak regeneration is in evidence but neither is a significant component of stand. Surface fuel is mainly pine needles and small diameter litter from brush. Rock outcrops and bare soil comprise a good portion of the surface and reduce overall surface fuel continuity.

Plot 3

Access: Plot located 150 ft uphill from Plummer Creek trail, approximately 600 ft. from where the trail leaves the Salmon River. Head uphill through the open oak woodland to plot center.

Description: Plot is an open white oak woodland that burned in the 1987 Hotelling Fire. Overstory is small white oaks with some conifer, including incense cedar, gray pine and ponderosa pine. Understory is generally grassy with bunch grasses dominating. Small patches of rock/bare soil are present but overall surface fuel coverage is relatively high. Pockets of heavy dead and down are present, likely resulting from mortality from the 1987 fire. Adjacent stands change type very quickly over short distances, with surrounding stands having much higher conifer component.

Plot 4

Access: Plot is immediately uphill from Plummer Creek trail as it comes up out of pine flat near the South Fork of the Salmon River. As trail turns south, plot is on the right-hand side.

Description: Plot is located in a true mixed conifer stand that burned in the 1987 Hotelling Fire. Overstory is dominated by Douglas fir with incense cedar and ponderosa pine present. Middle and understory contain similar species as overstory with addition of some live oak and deciduous oak. Snags from small diameter (under 10”) Douglas fir are present and were presumably killed by the 1987 Hotelling fire yet were more rot resistant than other overstory species. Surface fuels are mostly continuous and composed of bunch grasses and conifer litter, with a significant layer of needle cast present in the vicinity of pine trees. The Limited number of snags/downed logs indicate the area was likely a low severity patch in the 1987 fire. It is apparent that the Plummer Creek Trail was a holding feature in 1987, meaning that this plot is on the perimeter of the fire.

Plot 5

Access: Plot is located almost due west of Plot 3, approximately 300 ft uphill from Plot 3. Walk uphill through varying stands of conifer and oak, trending slightly to the south. The plot is near the nose of the ridge that runs NW to SE towards the confluence of Plummer Creek with the South Fork of the Salmon River.

Description: Plot is located in an open stand that burned in the 1987 Hotelling Fire. Stand appears to have had a more significant overstory prior to the fire, with numerous conifer logs on the ground. Manzanita in the area of the plot also shows multiple dead stems and fire scarring. Loss of some overstory conifers with retention of others, along with scarring on manzanita and oaks, indicates moderate severity effects from the 1987 fire. Current vegetation type is best categorized as oak woodland, with the dominant oak being Oregon white oak. Cedar is also a component of the relatively short overstory. Adjacent areas have gray pine and Douglas fir, though none appear in the tree plot. Small amounts of conifer and oak regeneration are present but not a significant portion of the stand. Surface fuels are light timber litter from conifer and oak trees with light needle cast. Bunch grasses are also present through much of the plot. Short, small patches of ceanothus buckbrush are present as well. Small bare areas and rock outcrops also present. The slow recovery of conifers since fire hints at poor soil with a likely serpentine influence. Rock and surface fuels are similar to Plot 2, but with less brush and larger oak component.

Pre-Fire Vegetation and Fuels

Overstory Vegetation Structure and Crown Fuels

Plot 1 was the most heavily forested plot with the least herbaceous cover while Plots 2, 3, and 5 were open with more of a woodland character and the highest herbaceous cover (Table 2). Plot 4 had moderate basal area, canopy cover, and grass cover. Plot aboveground biomass followed the ordering in basal area and canopy cover (Table 3). The overall woodland vs closed canopy character of the sites indicated by Table 2 can be visualized in the remotely sensed imagery in Figure 3.

Table 2. Canopy characteristics for plots inventoried on the Red Salmon Complex. 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).

Plot	**Density (trees/ac)**		**QMD (in)**	**BA (ft^2/ac)**	**Canopy Cover (%)**		**CH (ft)**	**CBH (ft)**	**CBD (kg/m^3)**
	Overstory[1]	**Pole[2]**			**FVS**	**Moosehorn**			
1[1]	110	87	10.9	127.0	60	62	80.7	4.0	0.069
2[1]	17	73	9.3	42.8	24	69	35.1	11.0	0.029
3[1]	132	57	7.8	62.7	39	31	49.6	5.0	0.072
4	128	0	12.7	112.0	46	54	64.1	14.0	0.068
5[1]	50	0	10.0	27.1	19	23	25.9	5.0	0.038

[1]≥6 in DBH; [2]<6 in DBH; [3]Burned in the Red Salmon Complex

Table 3. Pre-fire tree biomass based on tree sampling and the Forest Vegetation Simulator (FVS) implemented in ArcFuels

Plot	Biomass (tons/acre)				
	All DBH		<6”DBH	≥6”DBH	All DBH
	Snags	Stem and foliage	Foliage	Foliage	Total
1[1]	0.5	62.3	0.2	3.4	64.8
2[1]	0	19.3	0.02	0.9	19.3
3[1]	0.7	24.2	0.01	2.2	24.9
4	0.8	45.7	0	3.2	46.5
5[1]	0	10.7	0	1.0	10.7

[1]Burned in the Red Salmon Complex.

Surface, Ground, and Understory Vegetation Fuel Loading

Herbaceous loading (Table 4, grass and forbs) had an inverse relationship with canopy cover, with Plot 1 having the least herbaceous loading and the highest canopy cover. Plots 2, 3, and 5 had the most herbaceous cover and the least canopy cover. Plot 4 was intermediate for both. The greater downed woody loading in 100 and 1000 hr classes in plots 3-5 appears to reflect tree mortality from the 1987 Hoteling Fire. Shrub cover was greatest in Plot 2 which is arguably a reflection of a long history without fire in this open stand.

Table 4. Surface fuel loads and fuel bed depths for plots inventoried pre-fire on the Red Salmon Complex.

Plot	Loading (tons/acre)									Fuel Bed Height (in)
	Duff	Litter	1hr	10hr	100hr	1000hr	Grass & Forb	Shrub & Seedling	Total	
1	25.55	2.45	0.86	1.19	0.00	6.65	0.00	0.05	36.75	3.9
2	6.20	1.34	0.09	0.10	0.00	0.00	0.40	6.51	14.64	5.6
3	9.19	9.95	0.07	0.12	1.94	34.46	2.08	0.16	57.98	5.3
4	10.42	6.83	0.28	0.64	0.55	10.44	0.30	0.01	29.47	6.2
5	5.25	3.56	0.01	0.74	0.75	21.43	0.48	2.43	34.66	3.9

Fire Weather and Behavior

The narratives below describe fuels and fire spread through the plots, and fire weather when the plots burned. For general plot locations, see plot descriptions above. Plots 1 & 2 were located in an area with no recorded fire history. Plots 3-5 were located in the 1987 Hotelling fire footprint. All times are in Pacific Daylight Time (local time). The Somes Bar RAWS provides the best comparison for summer and fall weather for Plummer Creek at its confluence with the South Fork of the Salmon River. While 1000 hr fuels were relatively dry, weather conditions affecting fire spread rates and intensities (temperature, RH, and wind) were at low to moderate levels (Table 5). General fire characteristics are shown in Table 6.

Table 5. Air temperature, relative humidity, 10 & 1000 hr fuel moisture, and wind from the Somes Bar RAWS[1] on fire arrival. Wind speed at 4.5 ft above ground on plots is the average and peak of the 10s running average over a 20-minute period.

Plot	Temp. (F)	RH	Fuel moisture (%)[2]		RAWS Wind (mph)		Plot Wind (mph)	
			10 hr	1000 hr	10 min Avg	Peak	20 min Avg	Peak
1	85	27	10	13.26	3 S	7	0.0[3]	0.0
2	79	31	10	13.26	3 SW	6	0.0[3]	0.0
3	80	30	10	13.25	2 SSW	5	1.6[3]	11.5
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	92	24	7	13.43	3 SSW	6	2.0[4]	6.0

[1]RAWS report hourly data, observation closest to initial arrival time based on ROS array used.
[2]The 10hr moistures are from the fuel stick as reported in Mesowest. The 1000 hr fuel moistures are modeled.
[3]Based on first arrival at a ROS sensor
[4]Fire arrival based on Fire Behavior Package temperature data

Plot Fire Behavior

A description of fire behavior in plots follows. Appendix 1 contains pre- and post-fire photos along fuel sampling transects.

Plot 1

Fire reached Plot 1 at 2:08 PM PST on the afternoon of October 18th. The fire reached this plot from the north, backing downhill, as indicated by the fire reaching the northern sensor first, then spreading downhill through the rest of the plot. Fire reached the last and southern thermocouple at 3:45 the same afternoon, meaning the fire took approximately 97 minutes to traverse the plot. Based on the arrival times from the thermocouples, fire moved through Plot 1 at a mean speed of 0.81 chainer per hour (Table 6). This was the quickest rate of spread recorded of the 4 plots reached by the fire. Though Plot 1 had the highest rate of spread of our plots, fire behavior is still considered to be low intensity and low rate of spread, consistent with a downhill backing fire. The camera in Plot 1 did not record spread across the plot.

Surface fuel consumption in Plot 1 was similar to the other plots that burned, with a 75% reduction in total surface loading. The only category of surface fuel that did not show a large decrease was litter, which actually increased from pre to post-fire. There are multiple explanations for this increase. One possibility is needle and leaf fall after the passing the fire, another is errors in data collection or slight differences in interpretation of observed litter depth. A third possible explanation is disturbance of the site by the data collectors. Regardless of the cause, the total tons per acre of litter was far less than duff in Plot 1, and the reduction in duff resulted in the large overall decrease in surface fuel load.

Table 6. Fire type, flame lengths, and rates of spread (ROS) for FBAT plots burned on the Red Salmon Complex. For rate of spread (ROS), a flame front moving at 1 chain/hour is roughly 1 foot/minute. The mean and standard deviation for ROS based on fire arrival at sensors is provided. Fire arrival is the time the fire was first detected at the Plot by the ROS fire-arrival sensors in Pacific Daylight Time. Departure time is the last time a fire arrival sensor was burned.

Plot	Fire Type	FL (ft)	FA (%)	ROS (ch/hr)		I^4 (kW/m)	Detection Date &Time	
				Video	Sensors		First	Last
1	Backing downslope	N/A	N/A	N/A	0.81 (0.15)	257	10/18/2020 2:08:22 PM	10/18/2020 3:45:38 PM
2	Backing downslope, some evidence of spotting with limited uphill surface movement	N/A	N/A	N/A	0.74 (NA)[2]	108	10/18/2020 12:55:54 PM	10/18/2020 8:24:42 PM
3[1]	Flanking with slow uphill creeping in surface fuels	N/A	N/A	N/A	N/A	N/A	10/20/2020 1:40:00 PM	10/20/2020 2:07:20 PM
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	Backing downslope and flanking across slope	1.5	30	2	0.68 (0.20)[3]	47	10/17/2020 3:21:10 PM	10/18/2020 10:58:28 AM

[1]No video was available for Plot 3 and not enough fire-arrival sensors (<3) burned over to estimate a rate of spread.
[2]Fire arrival at sensors was highly variable, reflecting inconsistent spread. Reported is the highest spread rate. Based on all sensors, spread rate was 0.34 ch/hr (standard deviation 0.35 ch/hr).
[3]The southern sensor burned a day after the remainder of the plot, resulting in significant reduction in ROS (0.29 ch/hr) relative to ROS reported above with arrival time at the southern sensor removed from the analysis.
[4]Fireline intensity is the product of fuel consumption (kg/m^2, excluding 1000 hr and shrubs and seedlings), rate of spread (m/s), and heat of combustion (18600 kJ/kg).

Plot 2

The first sensor to detect fire arrival at Plot 2 on October 18th was the western thermocouple, at 12:55 in the afternoon. There was a delay of nearly 6 hours before the next sensor (north) experienced fire at 6:52 in the evening of the same day. After the north sensor, the center and eastern sensors recorded fire arrival at 7:35 and 8:24 respectively. The southern sensor did not record a fire arrival time but was burned. The mean rate of spread from these arrival times is 0.35 chains per hour. The mean value was reduced by the long gap between the first and second arrival times. The large standard deviation in ROS reflects the inconsistent spread. The maximum rate of spread was 0.74 chains per hour, which we expect is the best estimate of relatively steady spread (Table 6). The camera in Plot 2 recorded some images in the evening of October 18th that show fire downhill of the camera, with embers moving uphill. The camera does not accurately time stamp the image, so it is not possible to know exactly what time the images were captured. The camera may have been triggered by an animal running uphill given that the ends of the wire circuit used to trigger the camera were pulled apart at the junction with the camera and the camera box was dislodged in an uphill direction. The images from the camera do not show fire directly, but instead capture the glow of the fire downhill over the course of approximately an hour. During this time numerous embers land in front of the camera (https://www.frames.gov/documents/fbat/videos/shorts/REDS002_C1.mp4)[1], none of which cause ignition. About an hour after no more light from the fire downhill is visible, a flame uphill from the camera at the edge of the field of view is visible for several minutes followed by no visible fire.

Plot 3

Fire arrived at Plot 3 on October 20th, 2 days after arrival at plots 1 and 2, and 3 days after arrival at Plot 5. The fire rate of spread sensor to record fire arrival was the eastern sensor at 1:40 PM, followed by the center sensor at 2:07 PM. Though a reasonable percentage of the plot burned, the remaining 3 sensors did not record fire arrival. In fact, the eastern sensor did not appear obviously burned at the time of collection but a weak signal (44.6º C) was recorded in the datalogger. The lack of fire recording at the majority of sensors in the rate of spread array prevents us from determining rate of spread through the plot. Additionally, the camera in this plot did not record useful images or video, limiting the knowledge of fire behavior in the plot.

The evidence from burn patterns in the plot (see photos in Appendix 1) indicates that the fire backed and flanked into the plot from the west and south. Plot 5, which burned 3 days prior, is located immediately SSW of Plot 3 by approximately 260 ft. Visual indicators showed a slow surface fire that resulted in moderate scorch heights and consumption of downed logs and brush but that did not spread in areas of light herbaceous and grass fuels. Overall surface fuels were reduced by 62%, which is the least amount of consumption as a percentage of the 4 FBAT plots included in this report. Plot 3 had the highest initial surface fuel load and remained the highest post-fire of the plots that burned. The 62% reduction did result in a final surface fuel load below that of the lone unburned plot.

Plot 4

Plot 4 remained unburned on FBAT's last day in the Plummer Creek drainage on 22 October 2020. Based on final perimeter in Fire EGP, it appears that Plot 4 did not burn even though there was a patchy and creeping fire in the flats above the river and within 150 feet of a position directly below the plot.

[1]*Note: the videos require buffering before they play.*

Plot 5

Fire reached Plot 5 on the afternoon of October 17th. The first thermocouple sensor to record fire was on the west (uphill) side of the plot, arriving at 3:21 pm. The fire that reached the plot was backing downhill on an eastern aspect, as evidenced by the footage captured in the video (Figure 9, https://www.frames.gov/documents/fbat/videos/shorts/REDS005_C2.mp4) and by the pattern of arrival at thermocouples. Fire arrived at the north thermocouple at 3:49, the center at 4:42 and the east (downhill) at 5:01. Based on sensors, we estimate a spread rate at about 0.7 chain/hour (Table 6). Video captured behavior after being triggered (apparently) by fire on the uphill side of the plot. The camera looked across the plot roughly from south to north across slope, triggering at about 2:49 PM. Based on smoke, wind was mostly upslope (easterly) with some shifting to southerly for most of the first 1 hr 45 min after triggering. A wind shift to the northeast occurred when the surface fire was near the large incense cedar so that fire burning up the bark high into the crown was facing the camera (Figure 10, https://www.frames.gov/documents/fbat/videos/shorts/REDS005_C4.mp4).

Based on qualitative observations of fire behavior from the camera imagery, and from effects observed post-fire, we can interpret that the fire backed and flanked through the majority of the plot with low intensity. The exception to this were locations with concentrations of heavy dead and down woody fuels and shrub clumps. The heavy dead and down often consumed completely, resulting in locally much higher flame lengths and intensities than throughout the majority of the plot (Figure 11, https://www.frames.gov/documents/fbat/videos/shorts/REDS005_C3.mp4). We could not estimate the rate of spread and other quantitative flame characteristics because the standards were too far away given video resolution. However, we could see fire burning at the Fire Behavior Package (FBP) and as fire burned near the incense cedar. Fire flanked across slope and through the standards and around the FBP around 4:39 PM (the time fire arrived at the FBP; about 1 hr 50 min after video started). Flame heights were about 1-2 ft around the FBP and incense cedar (1.5 median). Fire rate of spread between FBP and incense cedar was approximately 2 chains/hr. Fire burned around the incense cedar around 1:59 video time (4:52 PM).

Figure 9. Predominant fire spread behavior across Plot 5 was backing and flanking at low intensity.

Figure 10. Flaming combustion of bark on a large incense cedar on Plot 5. Although ignited by the surface fire, the combustion spread up the tree independently.

The evening of October 17th had high humidity recovery in the valley and drainage bottoms, which slowed fire behavior significantly overnight. Video showed that fire activity declined through evening and up to about 10:20 pm when video recording ended. Reported inversion level was between 2000 and 2500 ft, with this plot sitting at 2,123 ft, it was near the transition between the drier upper air and the moister drainage air. Plots below this in elevation had fire stop burning in grass just short of the plot as a result of the increase in humidity below the inversion. In Plot 5, the southern portion of the plot did not burn on October 17th due to decreases in fire activity at sundown and likely partially as a result of the inversion and high humidity. On October 18th, as the inversion lifted and humidity dropped, fire activity increased and some portions of Plot 5 that did not burn on the 17th burned in late morning on the 18th. On a visit to the plot at 10:15 AM on October 18th, fire was burning at low intensity in and near the plot, but a small percentage of the plot remained unburned. The area that did not burn was dominated by very light, herbaceous fuels that were fully cured but did not have enough horizontal continuity to sustain spread.

Figure 11. In Plot 5, downed coarse woody debris, sometimes in association with buckbrush, burned intensely while general fire behavior was low intensity backing and flanking.

Surface fuel consumption in Plot 5 was high, with 75% of surface fuels consuming (by weight of fuel in tons per acre). Some of the categories of surface fuels appear to have had little or no consumption (duff and 1hr fuels), however these categories had very small, almost trace, amounts of fuel pre-fire (Table 4). See table 7 and 8 for details on consumption of surface fuels by size class. The level of consumption is consistent with the pre and post fire photos in appendix 1.

Fuel Consumption

Plots 3-5 within the 1987 burn footprint had the highest 1000hr fuel loadings (Table 4) and, excluding Plot 4 which did not burn, also had the highest 1000hr consumption (Table 7). It appeared that the downed logs were killed in the 1987 fire. In contrast, Plots 1 and 2 had the lowest 1000 hr loadings and consumption. Plot 1, with the greatest tree basal area and cover, also had the highest duff loadings and duff consumption but low herbaceous and shrub loading. In Plot 1, a problem with discriminating litter from duff led to an apparent increase in litter loading post-fire (a negative litter consumption value in Table 7). Plot 2 was an open stand dominated by gray pine and had the lowest consumption levels, dominated by duff and understory vegetation (primarily shrub). The small increase in post-fire 1 hr woody fuels in Plot 2 might be the result of twig deposition from partial shrub consumption. Percent consumption showed generally moderate levels in plots (Table 8). Patchy consumption can explain much of that result. Unburned area within belt transects ranged from 0-67% while across entire plots, unburned area ranged from 1–27%.

Table 7. Forest floor and downed-woody (surface) fuel consumption (tons/acre).

Plot	Consumption (tons/acre)								
	Duff	**Litter**	**1hr**	**10hr**	**100hr**	**1000hr**	**Grass & Herb**	**Shrub & Seedling**	**Total**
1	23.53	-1.11	0.75	0.74	0.00	3.82	0.00	0.01	27.74
2	4.74	0.66	-0.02	0.05	0.00	0.00	0.40	5.33	11.16
3	4.08	7.15	0.02	0.00	1.94	20.40	2.05	0.06	35.70
4	Unburned								
5	0.00	1.78	0.00	0.74	0.75	21.43	0.43	1.32	26.46

Table 8. Percent consumption of forest floor and downed-woody (surface) fuel. “No fuel” indicates that pre-fire fuels in that class did not occur in the sample, though they may have occurred on plots.

Plot	Percent Consumption (%)								
	Duff	**Litter**	1hr	**10hr**	**100hr**	**1000hr**	**Grass & Forb**	**Shrub & Seedling**	**Total**
1	92	-45	87	62	No fuel	57	No fuel	17	75
2	76	49	-27	51	No fuel	No fuel	100	82	76
3	44	72	34	0	100	59	99	34	62
4	Unburned								
5	0	50	0	100	100%	100	89	54	76

Fire Effects

Fire effects measured on FBAT plots in the Plummer Creek drainage were modest and, overall, fires are expected to reinforce the woodland character of open stands represented by Plots 2, 3, and 5. In these woodland sites, shrub cover was reduced, an effect that will likely benefit the grass-dominated herbaceous cover. We collected post-fire measurements one to three days after fire in each burned plot, including NPS severity ratings (substrate & understory, see Appendix 2), char heights, maximum and percentage crown scorch (foliage brown), and torch heights (foliage consumed). Soil heating stakes were retrieved at this time.

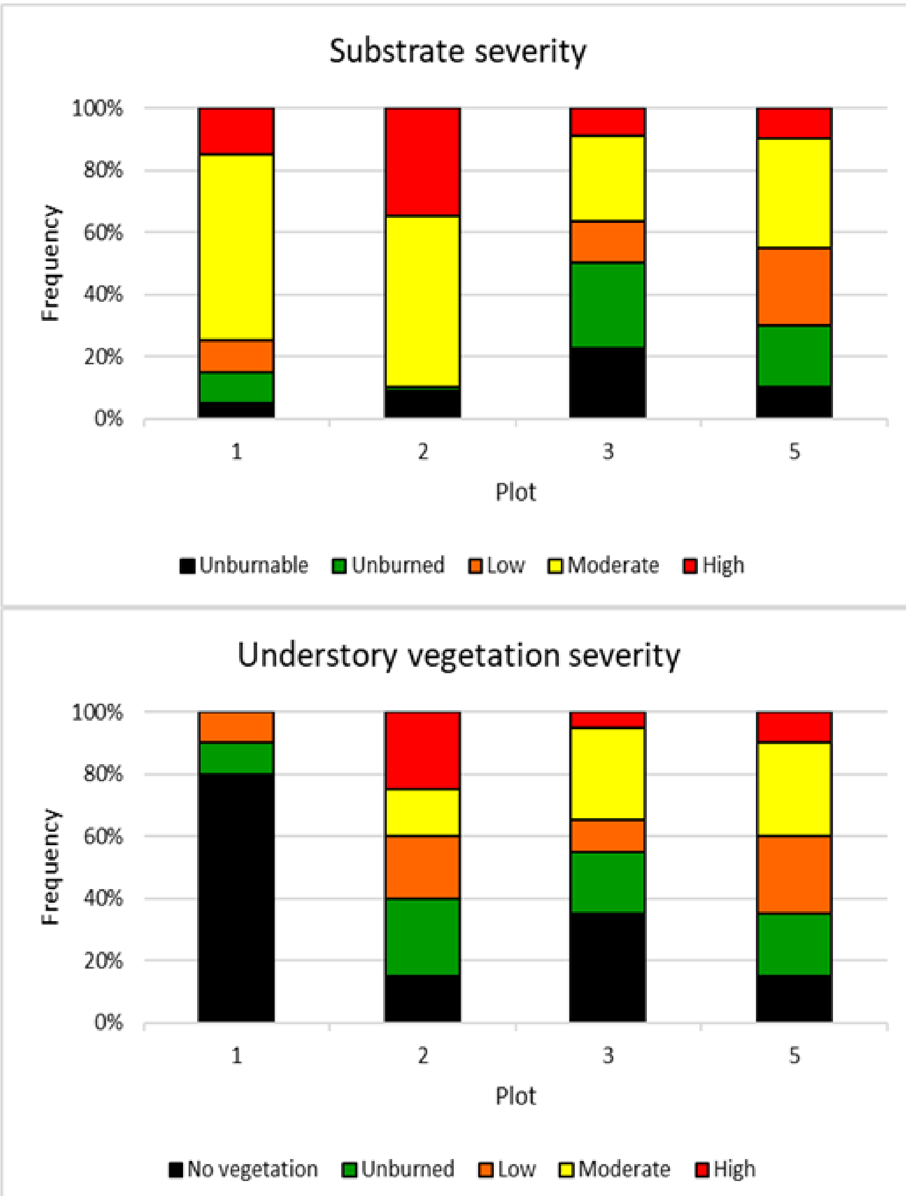

Figure 12. Substrate (top) and understory (bottom) vegetation severity on burned plots. No plots had “very high” severity. See NPS severity definitions in Appendix 2.

Synthetic fire severity ratings for understory vegetation were low to moderate, capturing the patchy impact of fires on shrub cover in open stands (Table 9, Figure 12). Patches of unburnable substrate and areas without understory vegetation (herbaceous or woody) were present in all open stands that burned (Plots 2, 3, and 5) which, combined with low herbaceous and shrub fuel loads (Table 4) and low-wind conditions (Table 5) contributed to low spread rates and intensities (Table 6) and modest effects on the overstory (Table 9, Figure 13).

Table 9. Plot level bole char height and average 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		Severity	
	Min	Max	Live crown	Scorch	Scorch	Torch	Substrate	Vegetation
1	1.3	8.9	17.9	32.3	17	0	2.8	1.5
2	2.2	7.8	12.4	18.4	11	0	3.4	2.5
3	2.2	7.1	8.6	24.5	31	0	2.2	2.3
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	3.2	11.2	7.6	10.1	22	0	2.4	2.4

No tree foliage was consumed (torched) though crown scorch ranged from 10-30%. Relatively high maximum bark charring on Plot 5 (27 ft on a large incense cedar) was related to bark flaming ignited by the surface fire but otherwise independent of it (Figure 10), a phenomenon that probably led to high maximum char heights on cedars in other plots as well.

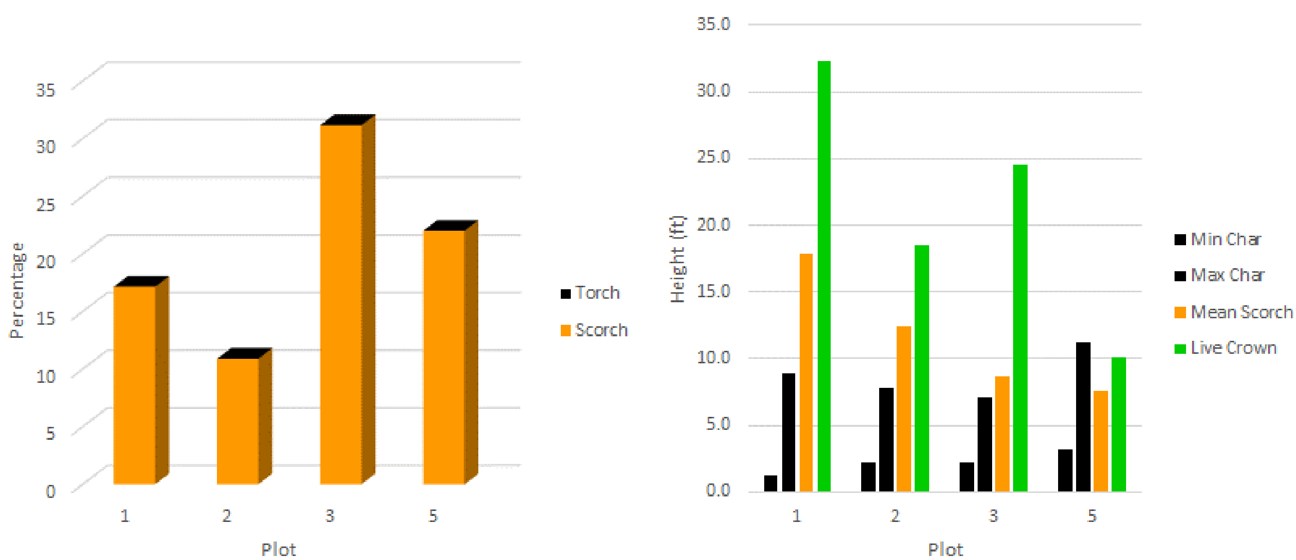

Figure 13. Percentage of the canopy on burned plots that was scorched (left). Consumption (torch) was not recorded on any tree (0%). Mean bark char height (minimum and maximum), scorch height, and height to live crown on burned plots (right). The high maximum mean bark char height on Plot 5 is owing to independent bark flaming on a large incense cedar. The low mean scorch heights relative to higher average heights to live crown on Plots 1-3 indicate that the smallest trees accounted for most of the scorched foliage.

Substrate severity (Figure 12) was higher than might have been expected primarily because downed woody material (which appears to have originated largely from the 1987 fire) was dry and often consumed. Where logs burned, we would expect more soil heating as suggested from the soil temperatures experienced by one of our soil-temperature stakes that was located next to a downed log

(Figure 13). In contrast, soil heating at 2 in was minimal for other stakes where there was no heavy woody material. Unfortunately, the total run time for the low-temperature iButton loggers was 14 days at a 10 minute logging interval, which meant that we had incomplete data on some plots due to the long interval between plot establishment and when the plots burned.

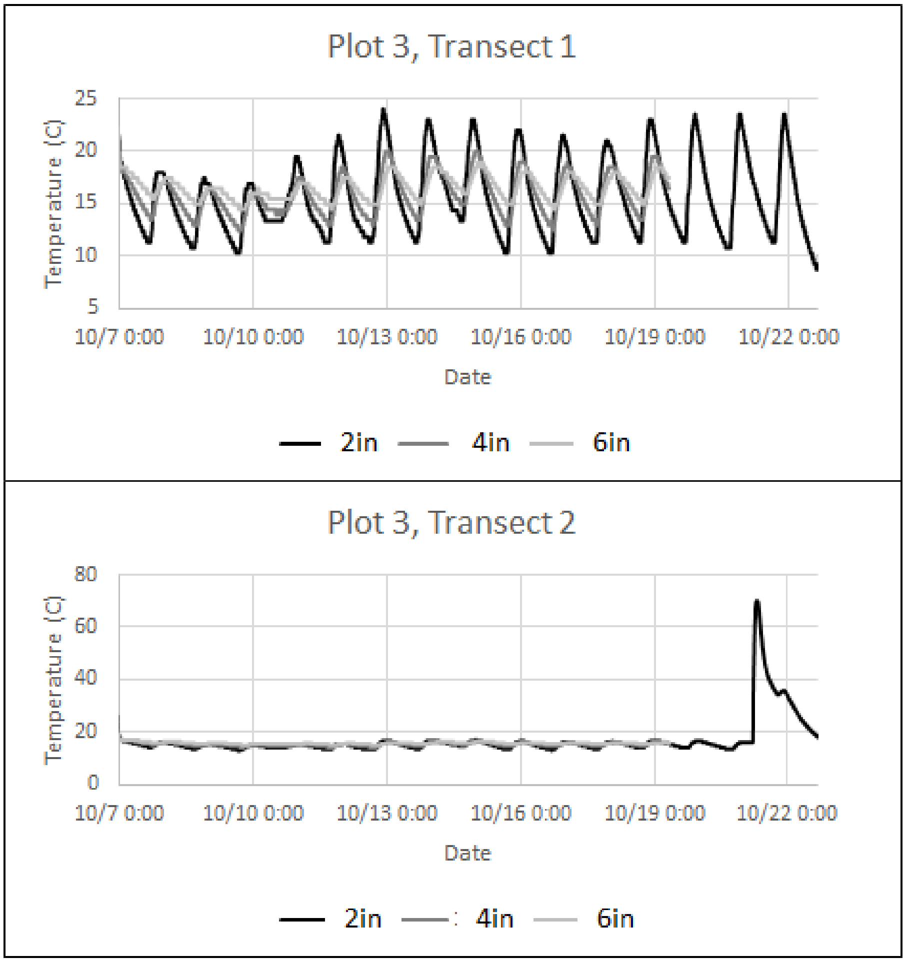

Figure 13. Soil temperature profiles from burned Plot 3. On Transect 1, daily soil heating and cooling (top) can be seen. The soil heating stake was in an unburned patch of fuels. In contrast, heating from log consumption (bottom) occurred next to the stake on Transect 2. Temperature sensors at 4 and 6 inch depths had stopped recording before the plot burned because the fire was slowed by a rain event on 10 October (Figure 7).

Conclusions

The Fire Behavior Assessment Team (FBAT) continues to build an archive of pre-, active-, and post-fire data from prescribed and wildfires extending from 2003 to the 2020 Red Salmon Complex. The archive is supporting advances in knowledge about wildfire behavior and effects. Although we did not sample enough plots on the Red Salmon Complex itself to draw statistical conclusions about the influence of the 1987 Hotelling Fire on fuel consumption, fire behavior, and fire effects on the Red Salmon Complex, trends are evident. Overstory conifer mortality in the 1987 Hotelling Fire appeared to result in the higher downed woody fuel loads that we sampled in Plots 3, 4, and 5. In contrast, Plots 1 and 2 were outside the Hotelling Fire footprint and had little downed woody debris. Herbaceous cover was higher in plots with lower canopy cover. An average of 72% of total surface fuel was consumed in the 4 plots that burned. Shrub and seedling cover, loading, and consumption were highest in Plot 2, the open stand that was not burned in the Hotelling Fire, suggesting that the Hotelling Fire reduced the cover of understory woody vegetation where it did burn. Along with overstory tree mortality, reduced tree seedling and shrub cover from both the Hotelling Fire and the Red Salmon Complex is expected to benefit herbaceous species such as native bunch grasses and help maintain the woodland character of open stands. While we do not expect much delayed tree mortality on our plots from the Red Salmon Complex because canopy effects were modest, response of grey pine and other serpentine-associated species to fire are not well understood. These plots will allow longer-term fire effects to be monitored. We suggest that low intensity fire such as occurred in the Plummer Creek Drainage during the Red Salmon Complex will help maintain woodland systems and build on a legacy of past fire regimes, including long-term fire management by Karuk, Tsnungwe (Hoopa), and other indigenous peoples. The outcomes in the Plummer Creek drainage demonstrate that beneficial effects can be attained once ERC moderates with shorter day lengths in the fall, even in long-unburned areas and even during periods where the ERC is at record highs for that time of year. Another benefit of the fires was the high consumption of large downed woody debris, which may help limit the severity of future wildfires burning under more extreme conditions. Low intensity wildfire, where it occurs, increases fire management options, including use of fire for ecosystem management in the future.

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APPENDIX 1 - Pre- and post-fire plot photographs

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

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

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

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

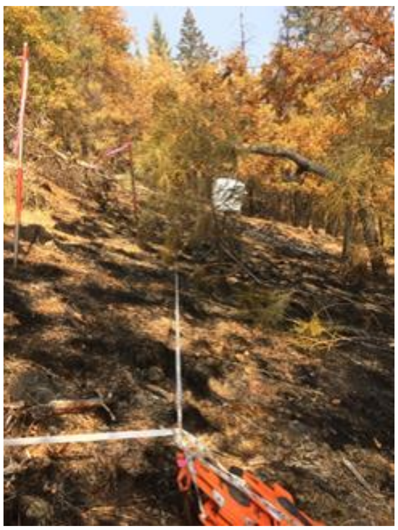
		
Plot 3 Transect 1, 50-0 Pre	Plot 3 Transect 2, 50-0 Pre	Plot 3 Transect 3, 50-0 Pre

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

		
Plot 4 Transect 1, 50-0 Pre	Plot 4 Transect 2, 50-0 Pre	Plot 4 Transect 3, 50-0 Pre

Plot 4 remained unburned

		
Plot 5 Transect 1, 50-0 Pre	Plot 5 Transect 2, 50-0 Pre	Plot 5 Transect 3, 50-0 Pre

		
Plot 5 Transect 1, 50-0 Post	Plot 5 Transect 2, 50-0 Post	Plot 5 Transect 3, 50-0 Post

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 entry 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