# 2019 Caples Fire

**Eldorado National Forest**
**First Order Fire Effects, Assessed November 2019**

Fire Behavior Assessment Team (FBAT)
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Caples Creek Watershed, post-fire, April 2020

Caples Creek Watershed, pre-fire 2014

Caples Creek Watershed, Historic Conditions 1899[4]

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[4] Cover page photo credits: 1899 photo taken by George Bishop Sudsworth (Gruell, 2002); 2014 photo taken by former Placerville RD District Ranger, Duane Nelson; 2020 photo taken by R5 Province Ecologist, Becky Estes.

## SUMMARY

The objective of this report is to provide land managers with information for a better understanding of first order fire effects resulting from the 2019 Caples Fire. Data was collected at 46 plots previously established by the USFS Pacific Southwest Region (Region 5) Ecology Program to assess pre-treatment condition of the Caples Creek Watershed for the Eldorado National Forest. In this report we present preliminary information on data collected immediately post-fire, including burn severity metrics for substrate (soil, litter and duff), understory vegetation, and trees, tree mortality and associated changes in tree density, and ground and surface fuel consumption.

## KEY FINDINGS

The general findings from the immediate post-fire data taken on the Caples Fire in November 2019 show that although many portions of the fire appeared to display high severity impacts, overall the fire effects were actually close to typical fire regime patterns and produced post-fire forest structure and fuel loading which more closely align with the natural range of variability.

**Burn Severity:**

- Burn severity fraction across the entire burn area was 43% low, 43% moderate, and 13% high severity.
- Burn severity was less in areas where prescribed burn was performed compared to wildfire areas. In prescribed burn areas low burn severity was 60% compared to 43% in the wildfire portions of the Caples Fire.
- High burn severity was low in both prescribed burn and wildfire portions of the fire, at 10% and 7% respectively.
- Burn severity fraction in the prescribed burn areas was similar to resource benefit fires which studies have shown to align with the natural range of variability (NRV). The burn severity fraction in wildfire areas was different than burn severity metrics defined by studies of wildfires across California, with high burn severity at 7% being much less, but moderate burn severity being higher at 50%.
- The potential for much higher burn severity existed in the Caples Creek Watershed, as seen in the results of the 2014 King Fire which had 53% high burn severity. The King Fire occurred on the Eldorado National Forest at the same time of year, across a similar elevation range, and with similar fuel types.

**Tree Mortality / Changes in Tree Density:**

- There was no mortality of trees greater than 30 inches dbh sampled in prescribed burn areas, successfully staying below the 5% threshold for mortality of large trees set in the Caples Restoration Project Decision Memo.
- Mortality of trees greater than 30 inches dbh in wildfire areas was 23%, which exceeded the 5% threshold set in the Caples Restoration Project Decision Memo.
- Tree mortality was much higher in smaller trees (50%), than larger trees (14%).
- Wildfire brought the density of smaller trees, less than 16 inches dbh, closer to the NRV than prescribed fire.
- Prescribed fire resulted in the density of larger trees, greater than 24 inches dbh, closer to the NRV than wildfire.

**Ground and Surface Fuel Consumption:**

- Post-fire fuel loading was brought closer to the NRV across all ground and surface fuels, regardless of fire type.
- Fuel consumption targets set in the Caples Creek Burn Plan were met for fuels less than 1 inch (1+10-hr).  Consumption for fuels 1 to 3 inches (100-hr), and greater than 3 inches (1,000-hr) exceeded burn plan targets.
- Litter and duff depth was reduced from 267% above the NRV pre-fire, to 67% below NRV post-fire.
- For surface fuels less than 3 inches diameter (1 to 100-hr), prescribed fire resulted in post-fire fuel loads closer to the NRV than wildfire.
- For surface fuels greater than 3 inches diameter (1,000-hr), wildfire resulted in post-fire fuel loads closer to the NRV than prescribed fire.

# Contents

# INTRODUCTION

Beginning on September 30, 2019 prescribed burning was initiated as part of the Caples Creek Watershed Restoration Project, which was designed to improve ecological function in the watershed. Approximately 1,080 acres burned as a prescribed fire from September 30 through October 9th. On October 10th the prescribed fire was converted to a wildfire. An additional 2,355 acres burned as a wildfire, for a total of 3,435 acres burned. In late October, the Fire Behavior Assessment Team (FBAT) was requested to collect field data to capture first order fire effects. During the first 2 weeks of November 2019 FBAT collected data at 46 pre-existing vegetation monitoring plots that fell within the Caples Fire footprint. This report presents the results from analysis of that data to summarize immediate (first-order) fire effects. The objective of the report is to provide data to inform continued efforts to complete the Caples Creek Watershed Restoration Project. We pursued this by providing a baseline that helps define the effects of the portion of the fire that burned under conditions that were within prescription as a prescribed burn treatment, compared to the effects of the fire that burned as wildfire.

## Background

The Caples Creek Watershed is located on the Eldorado National Forest, approximately 70 miles east of Sacramento, California in the Sierra Nevada. The watershed covers 20,236 acres, and ranges in elevation from approximately 5,100 to 10,370 feet. Vegetation in the area includes a mix of forested areas dominated by white fir, incense cedar, yellow pine, lodgepole pine, and sugar pine, along with lesser areas of mixed and montane chapparal found mostly on south facing slopes. Barren ground, consisting mostly of granitic and volcanic rock outcrop, makes up approximately 20 percent of the area.

The Caples Creek Watershed is unique in that it's one of few forested areas in the Northern Sierra Nevada that's been without any substantial vegetation management activities, with the exception of active fire suppression. The area has not experienced any wildfire since 1916 (USFS, 2016). In an area where pre-European fire return intervals would have mostly ranged from 5 to 35 years, lack of fire for over a century has resulted in degraded ecological conditions including overly dense vegetation and unnaturally high accumulations of forest fuels (Figure 1). Forest health and resilience was compromised, leaving the area vulnerable to future disturbances such as drought, insects, and wildfire. The watershed was identified in 2011 as a priority watershed in need of restoration. The re-introduction of fire was presented as a key need for watershed restoration. Prescribed burning treatments were planned with the goal of improving forest health and resiliency to disturbances, improving the function of meadow and aspen ecosystems, and to improve wildlife habitat.

Figure1:  Typical pre-treatment conditions in the Caples Creek Project area.

## Caples Fire, October 2019

Following fuel treatment work that included strategic understory thinning and pile burning, prescribed burning treatments that included pile and broadcast burning were initiated on September 30, 2019.  For over a week burning was within prescription and achieving goals of the project (USFS, 2019).  A red flag warning for a wind event was forecasted, and fire managers began taking action to secure fire lines.  Shifting winds resulted in increased fire activity that took the project out of prescription, and on October 10th the prescribed fire was converted to a wildfire to begin management to meet full suppression objectives.  There was containment line around the fire by October 25th.  The total area burned was 3,435 acres (Figure 2).
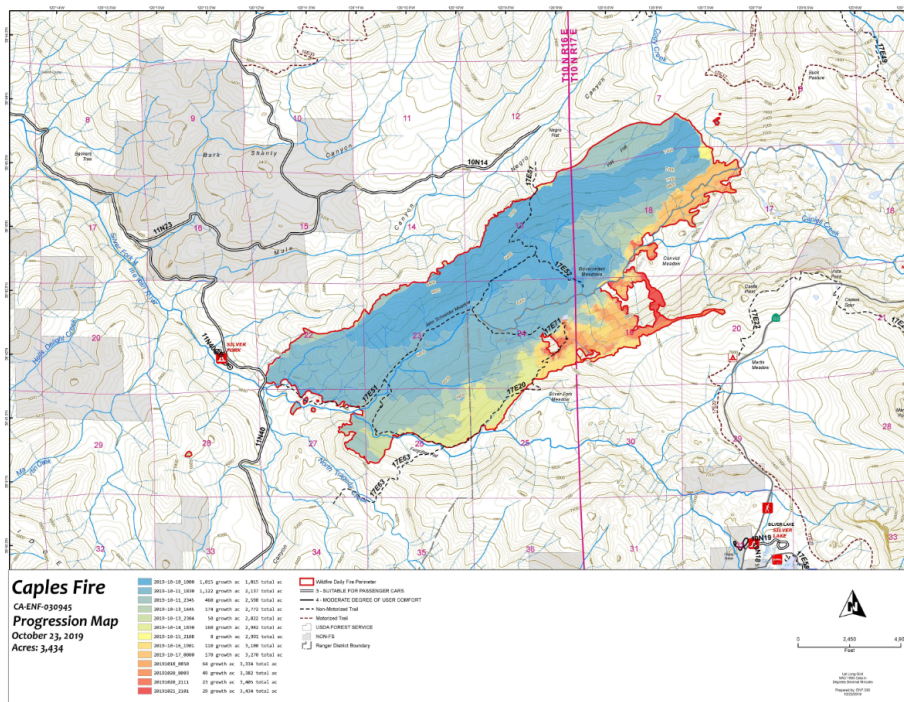


Figure2:  Caples Fire progression map from September 30 to October 23, 2019.

# METHODS

At the request of the Eldorado National Forest, the Fire Behavior Assessment Team (FBAT) began collecting data in the Caples Fire area in early November, 2019. The direction for FBAT was to assemble first order fire effects data in order to meet several objectives. These objectives were to provide a preliminary assessment of the following:

1) Burn severity across the fire area,
2) Immediate tree mortality caused by the fire, and
3) Hazardous fuel reduction

FBAT staff worked with the Central Sierra Province Ecologist to ensure that methods used for collecting first order fire effects data for the Caples Fire would align with ongoing ecological monitoring efforts in the Caples Creek Watershed being carried out by the USFS Pacific Southwest Region (Region 5) Ecology Program in coordination with the Eldorado National Forest, as well as associated work on avian habitat being carried out by the Pacific Southwest Research Station and California Academy of Sciences. Between 2013 and 2018 a gridded network of study plots was established across the Caples Creek watershed with data collected to define pre-treatment conditions. FBAT collected data on 46 of those plots which fell within the Caples Fire footprint (Figure 3) to analyze first order fire effects on the Caples Fire, including 38 forest dominated plots, and 8 shrub dominated plots. FBAT utilized the Region 5 Caples Creek Watershed Monitoring Protocol, (a modified Common Stand Exam protocol) which had been used for collecting pre-treatment data, as a foundation for data collection methods (field protocol details are presented in Appendix A). Some elements of the Region 5 Monitoring Protocol were adjusted (usually pared down) in an effort to sample a greater number of plots representing conditions across the fire area. FBAT added measures of burn severity to the protocol to assess the immediate fire effects.
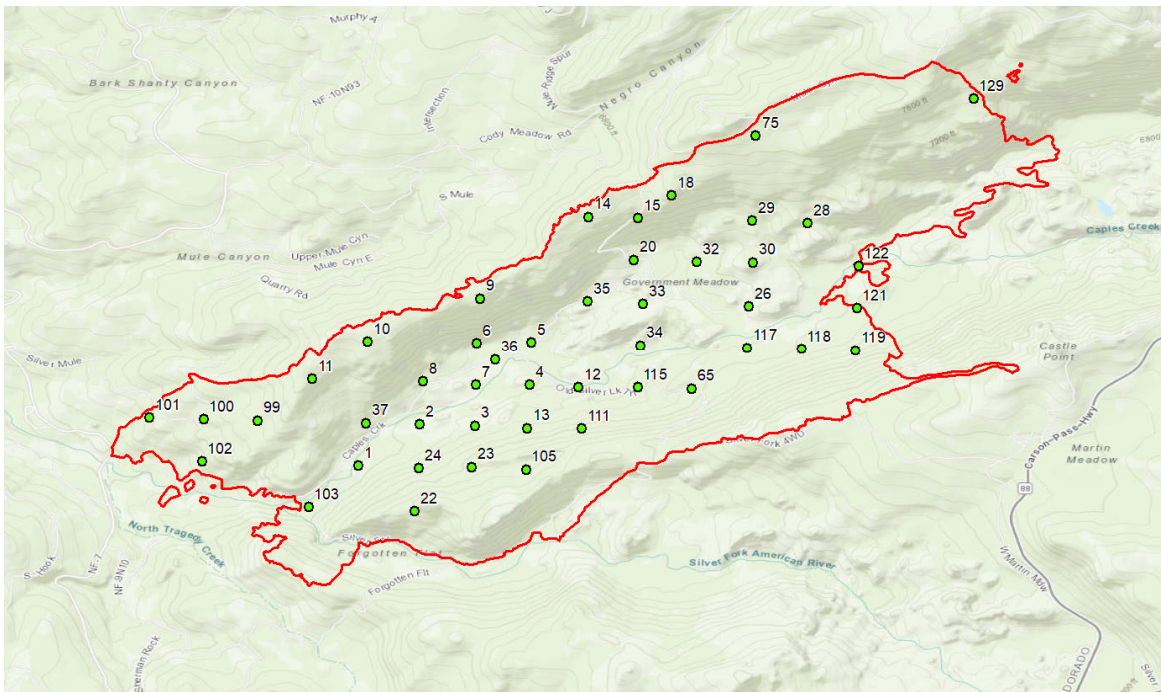


Figure 3: Caples Fire, locations of plots where first order fire effects data were collected in November 2019.

## Burn Severity

Data was collected to classify burn severity in several strata, including 1) Substrate, 2) Understory Vegetation, and 3) Tree burn severity metrics.

**Substrate Burn Severity:**

Substrate burn severity classifies fire effects to soil and ground fuels (litter and duff).  Within each plot, the percent of inorganic/unburnable was estimated (eg: bare ground and rock outcrop).  For the remaining organic/burnable portion, the percent of the plot area was estimated that fell within each of the 5 burn severity ratings, ranging from unburned "1", up to the highest rating of "5", for heavily burned.  A mean substrate burn severity score for each plot was assigned based on the percentage that fell within each of the severity ratings from 1 to 5.  The burn severity categories for substrate are defined as follows:

- 0 = Inorganic (eg. Bare soil or rock outcrop)
- 1 = Unburned
- 2 = Scorched. Litter partially blackened.  Duff nearly unchanged.  Wood/leaf structures unchanged.
- 3 = Lightly burned. Litter charred to partially burned.  Duff upper layer charred but not already for entire depth.  Wood debris partially burned.  Logs blackened, not charred.
- 4 = Moderately burned. Litter mostly to entirely consumed, leaving course light colored ash.  Duff deeply charred, but underlying mineral soil not visibly altered.  Logs deeply charred.  Burned out stump holes common.
- 5 = Heavily burned. Litter and duff completely consumed, leaving fine white ash.  Mineral soil visibly altered, often reddish.  Sound logs deeply charred.  Rotten logs completely consumed.

**Understory Vegetation Burn Severity:**

Understory burn severity classifies the burn severity for all grasses, herbs, forbs, and small trees up to 3 inches dbh[5].  Within each plot the percent was estimated that was not occupied by understory vegetation.  For the remaining portion occupied by understory vegetation, the percent of vegetation that fell under each of 5 burn severity classes was estimated; from unburned "1", up to the highest burn severity rating "5", for heavily burned. A mean understory burn severity score for each plot was assigned based on the percentage that fell within each severity category from 1 to 5. The burn severity categories for understory vegetation are defined as follows:

- 0 = None present to burn
- 1 = Unburned
- 2 = Scorched. Foliage scorched and attached to supporting twigs
- 3 = Lightly burned. Foliage and smaller twigs partially to completely consumed, branches/stems intact
- 4 = Moderately burned. Foliage, twigs, and small stems consumed, some branches/stems present
- 5 = Heavily burned. All plant parts consumed, leaving some or no major stems

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[5] dbh = Tree diameter at breast height (4.5 feet)

**Overstory Trees Burn Severity:**

Burn severity for overstory trees (trees greater than 3 inches dbh) was defined with measurements of bole char, canopy scorch, and canopy torch.

- Minimum and maximum height of bole char[6]
- Min and max height for canopy scorch[7]
- Min and max height for canopy torch[8]

For plots with lower tree densities (less than 30 trees/plot) bole char, scorch, and torch heights were measured for all trees.  For higher density plots (30 trees or more), every-other tree was measured for char, scorch and torch height values for trees greater than 12 inches dbh, and a visually estimated height for char, scorch, and torch height values was assigned for all trees in the plot grouped by dbh range: 3-6 inches dbh, and 6-12 inches dbh.


**Overall Burn Severity:**

In order to distill the burn severity ratings for substrate, understory vegetation, and overstory trees into a single 'overall burn severity' rating, the data was processed through several steps.  For substrate and understory vegetation:  Each of the five severity rating categories were multiplied by the percent allocated under that category and summed to arrive at a weighted average for each substrate and understory vegetation.  (Note: If the entry for any data category was 'not present' or 'not applicable' the category was removed from the weighted average for calculating overall burn severity for that particular plot.

Data processing for tree measurements was modeled after Key and Benson (2006) Composite Burn Index methods.  Measurements of minimum and maximum tree char, scorch, and torch heights were averaged into a mean and then converted to a ratio of the tree height.  (Note that tree heights were not measured in 2019 post-Caples Fire, nor were all heights measured pre-fire, so estimated heights were assigned to each tree based on pre-fire dbh classes and their associated mean tree heights.)  Next, severity scores were assigned for a series of bins modeled after the CBI intermediate and big tree data collection datasheet questions pertaining to the percent of scorch and torch and height of char.  These 'scores' were averaged by plot for the CBI 'intermediate tree strata' (trees coded as intermediate or suppressed, or having a dbh pre-treatment of less than 10 cm) or CBI 'big tree strata' (trees coded as dominant or codominant or having a pre-treatment dbh of 10 cm or greater).  Field data taken on the scorch, torch and char for small trees was averaged and similarly assigned 'small tree scores' based on CBI protocols.

The CBI protocols (Key and Benson 2006) yield an overall CBI category which averages all 5 strata: Substrate, Understory Vegetation, Tall Shrubs and Small Trees, Intermediate Trees and Big Trees.  Our field data on substrates and understory vegetation was used for the first two strata.  Our data for small, intermediate, and big tree strata were converted to a 5-class scale to match the understory data, which

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[6] Bole char is the char mark left on the stem of the tree
[7] Canopy scorch is identified by discolored and/or desiccated foliage
[8] Canopy torch is identified by the total consumption and/or charring of foliage

was collected via NPS 5-scale methods.  Then all 5 strata were averaged to yield a CBI-like 5-class overall severity rating. A fire ecologist familiar with the plots reviewed the final severity ratings and adjusted the ratings of 4 out of 46 of the plots were moved to a different severity class (2 were moved up and 2 moved down) based on review of the data, photos, and field experience of the area to better align the assigned severity of those plots for consistency with burn severity designations for other plots in the project area.

## RAVG Derived Burn Severity

Rapid Assessment of Vegetation Condition after Wildfire (RAVG) program provides assessments of vegetation condition for wildfires.  These data are derived from moderate resolution multi-spectral imagery (e.g., from the Landsat 8 Operational Land Imager or the Sentinel 2 Multispectral Instrument). The pre- and post-fire image subsets for this fire were used to create a Relative Differenced Normalized Burn Ratio (RdNBR). The RdNBR is correlated to the variation of burn severity within a fire. The RdNBR data are calibrated with the Composite Burn Index (CBI) as well as tree mortality variables. See the USGS National Burn Severity Mapping website (http://burnseverity.cr.usgs.gov) for generic information on fire severity mapping procedures. The severity ratings provided by the derived products listed below are based on the severity to vegetation. At this time, the layers are still considered draft. For a description of RdNBR, see: Miller, J. D. and A. E. Thode (2007). Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). Remote Sensing of Environment, 109:66-80.

## Trees

Data was collected on trees greater than 3 inches diameter at breast height (dbh) within the 1/10 acre plot.  The tree tag number was verified, and tree status (live vs. dead) was recorded.  Trees were noted as dead when 100% of the tree canopy was scorched and/or torched.  Height to live crown[9] was also recorded on all trees sampled.  Tree species, diameter at breast height (dbh), and total height were not recorded in order to save time.  Because the trees had been previously measured no more than 6 years previously, it was was decided that it was worth sacrificing these measurements to save time for sampling a greater number of plots across the fire area.  For any plots with 30 trees or greater, every-other tree would have data collected.  It was known that this choice would compromise within-plot data quality to some degree, but again this was a trade-off to help sample a greater number of plots. The primary objective was to collect data on trees to define the level of tree mortality and associated changes in tree density, and other measures of fire effects on trees.  It's understood that a thorough and intensive data collection will occur on all trees in each plot during the first growing season following the fire (Spring/Summer 2020).

For analysis, basic calculations were performed, comparing pre-fire tree data to post-fire tree data to determine the percent of tree mortality and associated changes in tree density by diameter size class, by tree species, and by general ecotype (forest vs. shrub plots).  Calculations were also performed to

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[9] Height to live crown = the lowest live portion of the tree canopy which would be capable of carrying fire further up into the remainder of the live tree canopy

determine differences in tree mortality according to areas burned with prescribed fire to areas burned as wildfire.  Any missing trees, or trees that were intentionally skipped in dense plots were removed from the pool of data for analysis.  This skipping of trees in dense plots is likely have some limited impacts on the accuracy of our results, especially for trees in the large tree size classes, greater than 24 inches dbh, where there were some cases where only 1 or 2 of those larger trees existed within a plot.  In hindsight, we should've collected data on every tree greater than 24 inches dbh so that data quality was not compromised, especially for larger trees which are of greater interest.

## Raked Trees

Prior to implementation of the Caples prescribed burn, efforts had been made to provide protection to the largest trees in the restoration area by raking away deep accumulations of ground and surface fuels from the bases of those trees.  A plan was being put into place to monitor the effectiveness of protective raking around larger trees, but it wasn't possible to carry out that monitoring prior to burning.  FBAT was requested to add the collection of data on raked trees along with the plot data being collected.  The intent was to collect data demonstrating how effective tree raking efforts were at reducing impacts from the fire.  Definitive identification of raked trees proved to a challenge for FBAT field crew, as much or all of the evidence of raking was typically burned away.  Fifteen large trees were identified in burned areas which were believed to have received raking treatment.  Each tree was GPSed so that they can be revisited in the future to track survival.  For each tree identified, photos were taken to show the base and canopy of the tree, and the surrounding conditions.  Additionally, data was collected on each tree, including species, dbh, status (live/dead), and whether or not mortality was caused by fire.  Fire effects measures were also recorded, including tree bole char height, and percent of tree canopy scorch and torch.  The raking method used was noted (bermed versus scattered). An estimate of pre-fire litter and duff depth that had been removed by raking was also noted.  Descriptive information was also recorded about the fire effects in the $1/10^{th}$ acre area surrounding each tree.  Results of the data was compiled, and basic descriptive statistics (mean, minimum, and maximum) are presented for information collected on the 15 trees.  GPS coordinates along with photographs will be provided to Eldorado NF and PSW Region Ecology Program staff in separate files and documents.  The protocol used for FBAT's data collected on raked trees is provided in Appendix B.

## Ground and Surface Fuels

To determine fuel consumption, a standard Brown's planar transect approach (Brown, 1974) was used for measuring ground and surface fuels along four transects in each plot.  The depths of ground fuels (litter and duff) were measured to the nearest centimeter at designated points along each transect.  In the field, litter and duff depths were measured separately.  Litter and duff depth data were analyzed and results reported according to the combined depth of litter and duff.

Fine woody debris by size class (1 hour, 10 hour, and 100 hour[10]) was tallied within designated segments along each of the four the transects in each plot.  Each piece of course woody debris greater than 3 inches diameter which intersected a transect was tallied and measured.  The diameter at small and large ends was measured, along with the total length, and decay class.

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[10] 1 hour fuels are dead and downed woody debris (twigs and branch material) less than ¼" diameter, 10hr = ¼ to 1", and 100hr = 1 to 3"

Basic calculations were performed to determine differences in fuel loads found pre- and post-fire in order to determine fuel consumption according to fuel size class, and by general ecotype (forest vs. shrub plots). Calculations were also performed to determine differences in fuel consumption according to areas burned as a prescribed burn to areas burned as wildfire.

## Weather

We used burn indice data covering the dates of the fire derived from the Cottage and Owens Camp remote area weather stations (RAWS), both located near the Caples Creek Watershed. This data was provided in a spreadsheet and used for comparison of burn indices occurring before and after the wildfire was declared. It should be noted that fire indice data was missing on October 10, 2019, the day that wildfire was declared. It was explained by Eldorado NF staff that data for this day was likely missing due to the priority of the wildfire that demanded the attention of many fire staff that day. To fill in the gap of data for October 10 for analysis and graphing purposes, we used the average of the day before (October 9) and the day after (October 11).

## Natural Range of Variability

In different sections of this report we compare conditions in the Caples Fire area to conditions under the natural range of variability (NRV). NRV provides a meaningful benchmark for determining the effectiveness of the 2019 Caples Fire in accomplishing progress towards a healthier and more resilient ecosystem. The NRV values for tree density and fuel loading used in this report were developed for the Caples Creek Watershed Mixed Conifer Ecological Assessment (Estes and Gross, 2013). For the NRV of burn severity across the fire, we referred to studies investigating the burn severity patterns of resource benefit fires and standard wildfires (van Wagtendonk and Lutz, 2007; Miller et al, 2009; Miller and Safford, 2012; Meyer, 2015; Safford and Stevens, 2017).

# RESULTS

## Burn Severity

Burn severity ratings are reported here for categories including substrate (soils, duff, and litter), understory vegetation (grass, herbs, forbs, shrubs, and trees up to 3 inches dbh), intermediate trees (3-12 inches dbh), large trees (greater than 12 inches dbh), and overall burn severity which is a combination of all previous categories mentioned calculated and assigned to each plot. The results reported only include information collected on plots that were burned, not on unburned plots which did occur in locations where the fire left unburned islands. Except for where *"within plot burn severity"* fraction is presented, the values for burn severity percentage refers to the percent of plots that were assigned a given burn severity rating of low, moderate, and high.

**Substrate Burn Severity:**

Substrate burn severity describes the degree of fire effects on soils, duff, and litter. Analysis of substrate burn severity was performed to differentiate forest plots from shrub plots (Figure 4), but was not performed differentiate Caples prescribed burn area plots from Caples wildfire area plots. High burn severity fraction for substrate was greater in forested plots than shrub plots. Substrate burn severity across forested plots was classified as follows: 37% of plots were low, 24% moderate, and 39% high. Shrub plots had substrate burn severity classified as follows: 25% of the plots were low, 50% moderate, and 25% high.
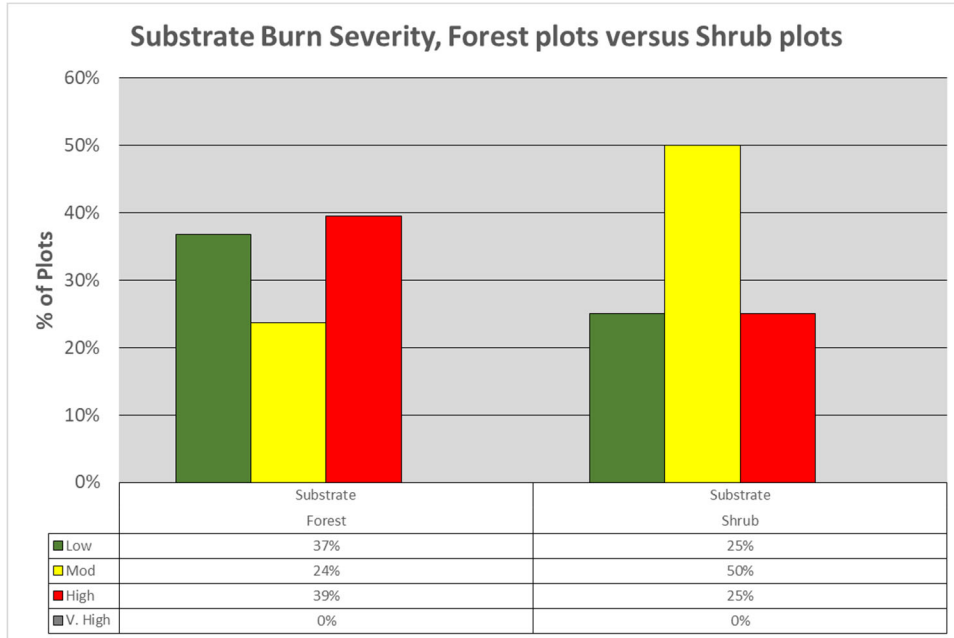


Figure 4. Substrate burn severity (soils, litter, and duff) for plots in forested versus chaparral dominated ecotypes across the Caples burn area.

**Understory Vegetation Burn Severity:**

Understory vegetation burn severity describes the degree of fire effects on all grass, herbs, forbs, shrubs, and trees less than 3 inches dbh. Understory vegetation burn severity across forested plots was classified as follows: 38% of the plots were low, 32% moderate, 16% high, and 14% very high. Shrub plots had understory vegetation burn severity classified as follows: 13% of the plots were low, 38% moderate, 38% high, and 13% very high (see Figure 5).
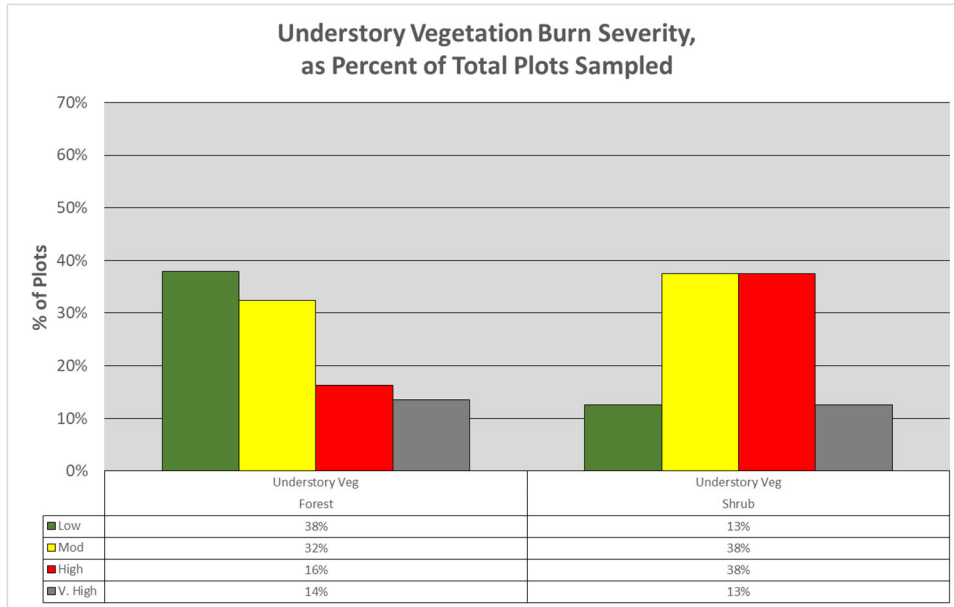
Figure 5: Burn severity fraction for understory vegetation, in forest plots and shrub plots, as a percent of plots.

**Tree Burn Severity Rating:**

Tree burn severity describes the degree of fire effects according bole char, and tree crown scorch and torch.  Although trees were present in shrub plots, tree burn severity is only reported for forested plots because the sample size of trees in shrub dominated plots was far too small.  Burn severity fraction is presented here as the fraction of plots that fall under each burn severity rating of low, moderate, and high.  Burn severity fraction for intermediate sized trees (3 to 12 inches dbh) was 59% low, 36% moderate, and 5% high.  Burn severity for large sized trees (greater than 12 inches dbh) was 72% low, 23% moderate, and 5% high (Figure 6).
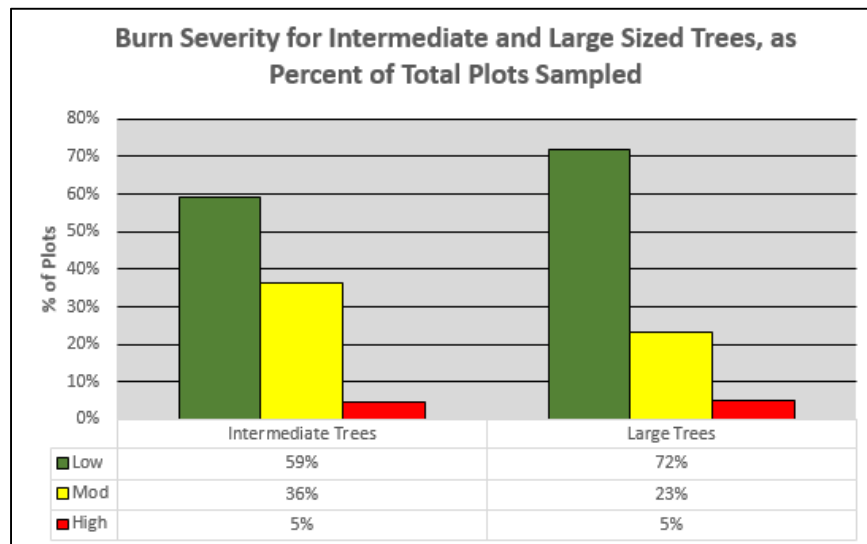


Figure 6: Burn severity fraction for intermediate trees (3" to 12" dbh), and large trees (>12" dbh), as a percent of Forest plots.

**Overall Burn Severity:**

Each plot was assigned an overall burn severity rating that was produced from the combined burn severity ratings assigned for each category of substrate, understory vegetation, and overstory trees within that plot.  For forested plots 45% were low, 47% moderate, and 8% high.  For shrub plots 38% were low, 25% moderate, and 38% high.  For all plots (all veg types), the mean value was as follows: 43% were low, 43% moderate, and 13% high (Figure 7).
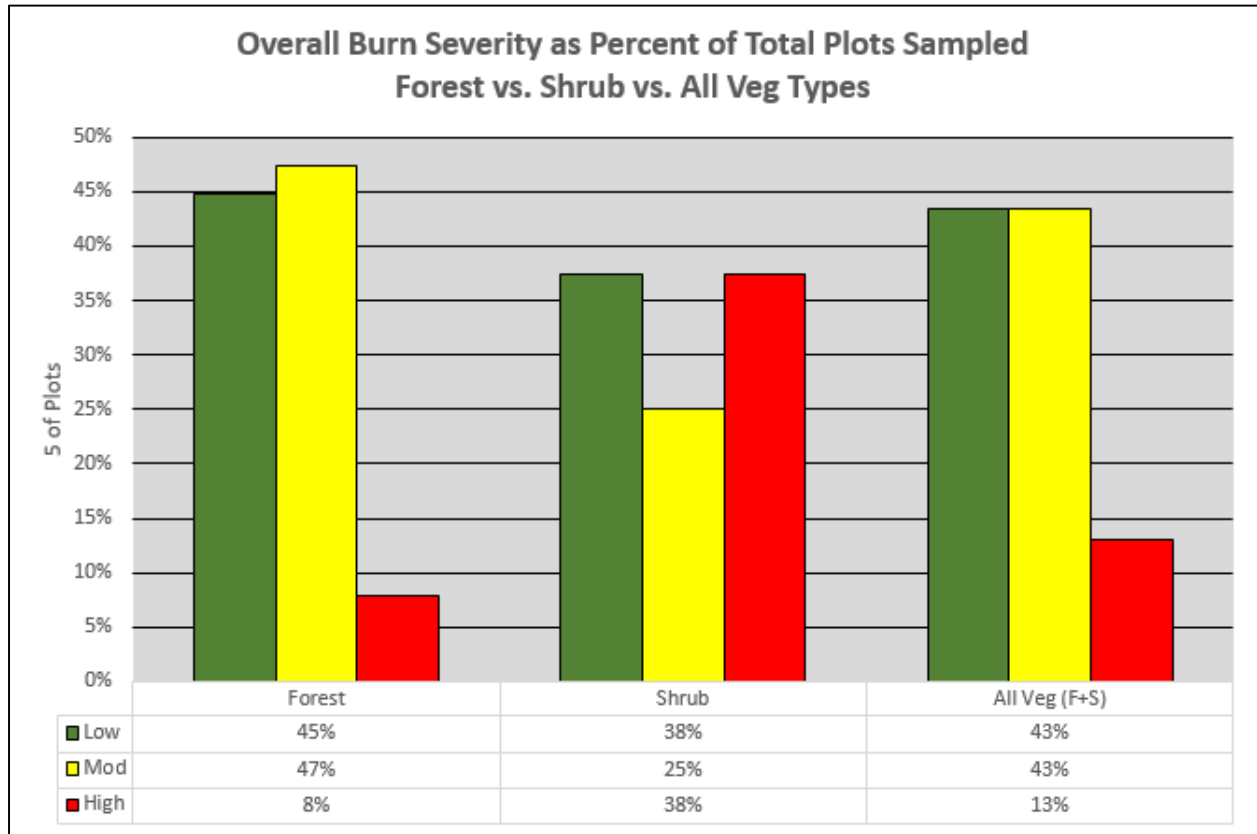


Figure 7: Overall burn severity fraction of forest plots, shrub plots, and all plots.

Overall burn severity results were was analyzed to compare burn severity for plots burned during prescribed burning (September 30 to October 9), to plots burned during wildfire (on and after October 10).  See Figure 8.
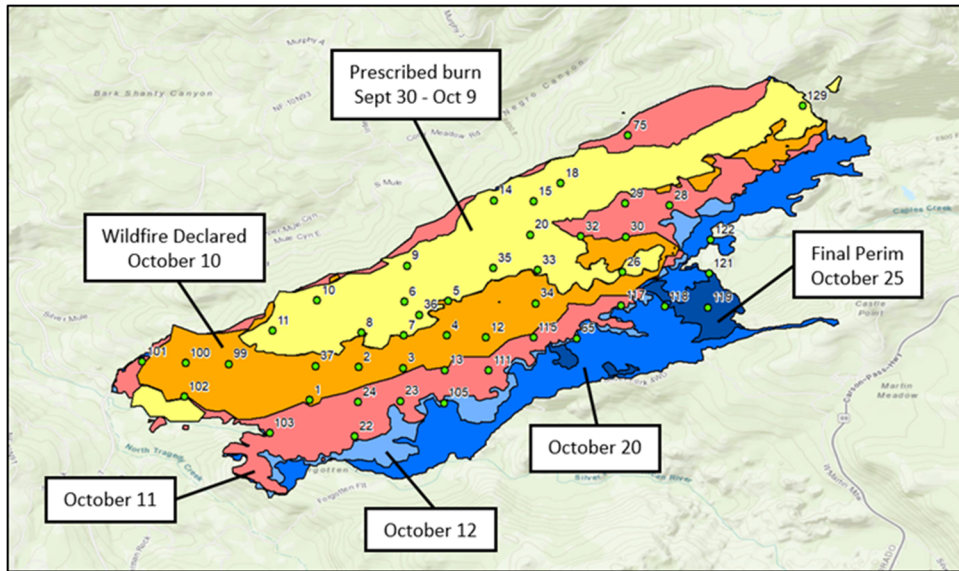
Figure 8: Location of monitoring plots relative to Caples Fire progression.

The data shows that overall burn severity was considerably lower in the prescribed burn areas compared to the wildfire areas (Figure 9).  Overall burn severity for plots within the prescribed burn area was 60% low, 30% moderate, and 10% high.  For areas burned after the wildfire was declared (from October 10 to 25) burn severity for plots was 43% low, 50% moderate, and 7% high.



| | RxBurn | Wildfire |
|---|---|---|
| Low | 60% | 43% |
| Mod | 30% | 50% |
| High | 10% | 7% |
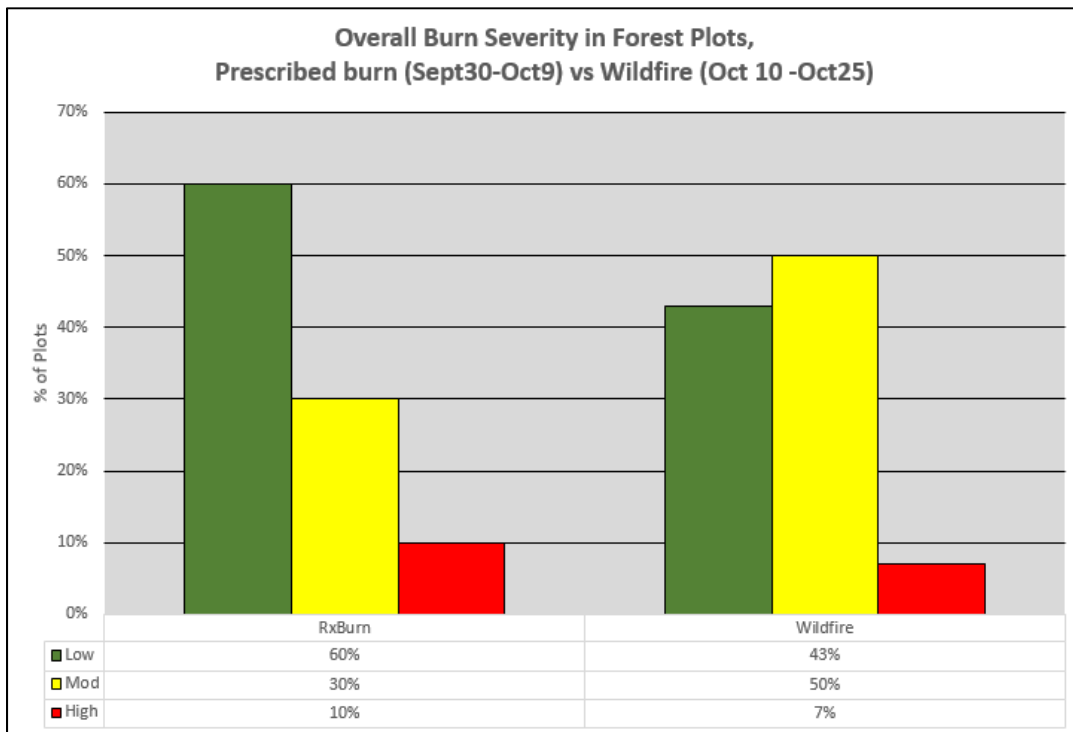
Figure 9: Overall Burn Severity fraction:  Prescribed burn area (plots burned September 30 through October 9), vs. plots burned after the wildfire was declared on October 10.

**Within Plot Burn Severity Fraction:**

Burn severity levels presented in the report thus far have been based on a single value of burn severity assigned to a plot. Here, we present the mean fraction of each burn severity rating found within plots. This data is important to consider, particularly the unburnable fraction shown for the substrate category, as it helps to show the large amount of bare ground and rock outcrop that exists in the Caples Creek watershed; 21% in forested areas, and 50% in shrub areas.

Within forested plots, substrate burn severity fraction was found to be as follows: 21% non-burnable, 15% unburned, 9% low, 14% moderate, 36% high, and 5% very high. Understory vegetation burn severity within forested plots was as follows: 61% non-burnable (no vegetation present), 11% unburned, 9% low, 6% mod, 6% high, and 7% very high (Figure 10).

Within shrub plots, substrate burn severity fraction was as follows: 50% non-burnable (inorganic), 5% unburned, 8% low, 18% high, and 1% very high (Figure 8). Understory vegetation burn severity within shrub plots was as follows: 37% non-burnable, 5% unburned, 6% low, 7% moderate, 26% high, and 20% very high.
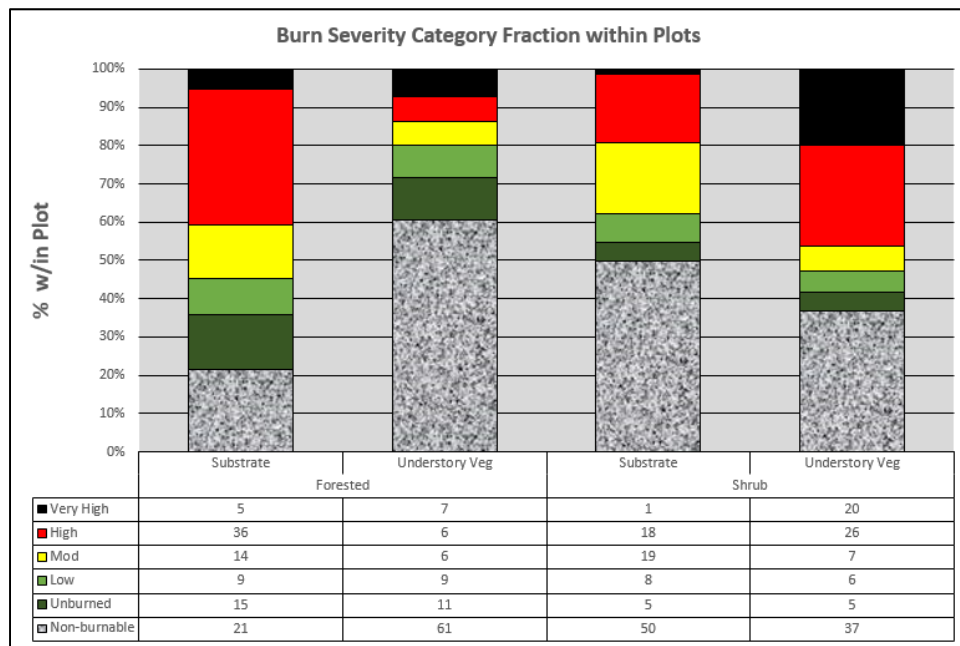


Figure 10: Mean percent of each burn severity category, including fraction of non-burnable (inorganic, bare ground) for substrate and understory vegetation. Both Forest and Shrub plots are shown. Note: Understory vegetation includes all vegetation except trees >3in dbh.

## RAVG Derived Burn Severity

Remote sensing data was derived from the Rapid Assessment of Vegetation Condition after Wildfire (RAVG) program (Figure 11). There are various different products available to define burn severity. The values of burn severity ratings shown in Table 1 are based on the severity to vegetation only, and

produces different results than other methods such our field data assessment which includes the burn severity for substrate.

The RAVG product shows that across the entire fire area, 35% was unchanged.  This includes areas that were unburnable (inorganic), burnable (organic) areas which did not burn.  The later may also include areas where understory burned that was undetectable via satellite imagery.  Looking at the entire fire area, 19% was low, 13% was moderate, and 33% is designated high burn severity.  Looking at only the forested portion of the fire, 44% was unchanged, 21% was low burn severity, 13% was moderate, and 21% was high.
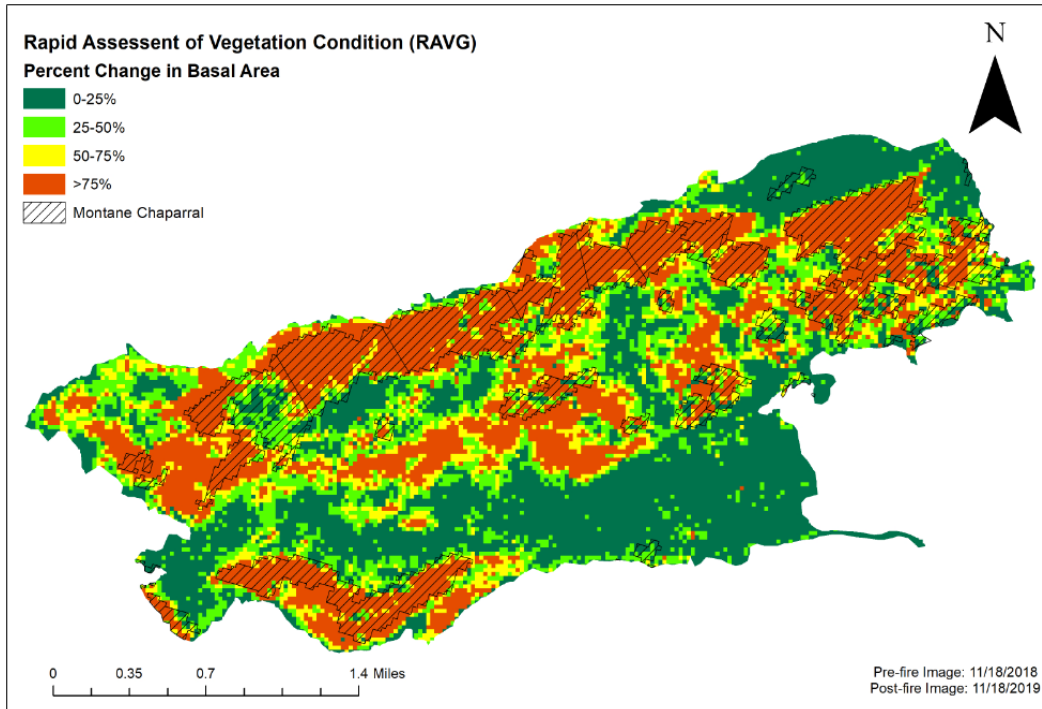


Figure 11. Rapid Assessment of Vegetation Condition (RAVG), illustrating burn severity based on change in basal area of vegetation. The areas of diagonal hash-marks show areas of montane chaparral, which constitute a large portion of greatest burn severity.

Table 1. Burn severity fraction derived from RAVG measure of change to basal area.

|          | All Veg | Forested |
|----------|---------|----------|
| **High** | 33%     | 21%      |
| **Mod**  | 13%     | 13%      |
| **Low**  | 19%     | 21%      |
| **Unch** | 35%     | 44%      |

## Trees

Forested plots across the Caples Fire area showed a total reduction in mean tree density from 251 to 158 trees per acre (TPA), a 37% reduction (Table 2).  The greatest amount of tree density reduction

occurred in the smaller tree size classes: 50% reduction for the 3-8 inch dbh size class, and a 30% reduction for both the 8-16 inch and 16-24 inch dbh size classes.  Larger sized trees, in both the 24-31 inch dbh size class and the greater than 31 inch dbh size class, showed much smaller reductions of tree density at 16% and 18% respectively.

The most substantial drop in tree species occurred for white fir (ABCO) and incense cedar (CADE27), with drops from 90 to 47 TPA (-48%), and 116 to 77 TPA (-34%) respectively (Table 2).  These two species had the greatest reductions in the smallest size class, 3-8 inch dbh.  White fir dropped 65%, and incense cedar dropped 44%.  Other species had greater reductions percentage-wise, but were very sparse to begin with.

Table 2: Tree Density (trees/acre) in Forest Plots, according to dbh class and tree species.

| DBH | | ABCO | ABMA | CADE27 | JUOC | PICO | PIJE | PILA | PIPO | POTR | QUKE | TOTAL | TPA Reduced | %Reduced |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-8in | Pre | 37.7 | 0.3 | 57.4 | 0.3 | 4.0 | 4.3 | 0.3 | 0.0 | 0.3 | 0.9 | 105.4 | 52.8 | 50.0% |
| | Post | 13.4 | 0.3 | 32.3 | 0.0 | 2.9 | 3.0 | 0.0 | 0.0 | 0.3 | 0.6 | 52.7 | | |
| 8-16in | Pre | 27.4 | 0.3 | 40.0 | 0.0 | 6.0 | 6.6 | 0.0 | 0.0 | 0.3 | 4.0 | 84.6 | 25.4 | 30.1% |
| | Post | 17.9 | 0.3 | 27.9 | 0.0 | 4.0 | 5.6 | 0.0 | 0.0 | 0.0 | 3.4 | 59.1 | | |
| 16-24in | Pre | 16.9 | 0.7 | 10.7 | 0.0 | 1.4 | 2.4 | 0.7 | 0.3 | 0.0 | 0.0 | 33.1 | 10.0 | 30.1% |
| | Post | 9.1 | 0.7 | 9.5 | 0.0 | 0.7 | 2.4 | 0.7 | 0.0 | 0.0 | 0.0 | 23.1 | | |
| 24-31in | Pre | 4.0 | 0.0 | 4.5 | 0.0 | 1.0 | 3.5 | 1.0 | 0.0 | 0.0 | 0.0 | 14.0 | 2.3 | 16.3% |
| | Post | 2.9 | 0.0 | 3.9 | 0.0 | 0.5 | 3.5 | 1.0 | 0.0 | 0.0 | 0.0 | 11.7 | | |
| >31in | Pre | 3.5 | 0.0 | 3.5 | 0.0 | 0.6 | 4.7 | 1.2 | 0.0 | 0.0 | 0.0 | 13.5 | 2.5 | 18.4% |
| | Post | 3.5 | 0.0 | 2.9 | 0.0 | 0.0 | 3.4 | 1.2 | 0.0 | 0.0 | 0.0 | 11.0 | | |
| TOTAL | Pre | 89.5 | 1.3 | 116.1 | 0.3 | 13.0 | 21.5 | 3.2 | 0.3 | 0.6 | 4.9 | 251 | 93 | 37% |
| | Post | 46.8 | 1.3 | 76.6 | 0.0 | 8.0 | 17.9 | 2.9 | 0.0 | 0.3 | 4.0 | 158 | | |
| TPA Reduced | | 42.8 | 0.0 | 39.6 | 0.3 | 4.9 | 3.6 | 0.3 | 0.3 | 0.3 | 0.9 | 93 | | |
| % Reduced | | 48% | 0% | 34% | 100% | 38% | 17% | 9% | 100% | 50% | 18% | 37% | | |

## Changes in Tree Density:  Forest versus Shrub Areas:

In the absence of fire to keep tree encroachment in check, smaller trees were becoming more established in some chaparral areas.  In shrub plots, the Caples Fire reduced trees in the 3-8 inch size class from 33 to 7 TPA (-80%).  For comparison, in forested plots, trees in the 3-8 inch size class were reduced from 105 to 52 TPA (-50%) (Figure 12).
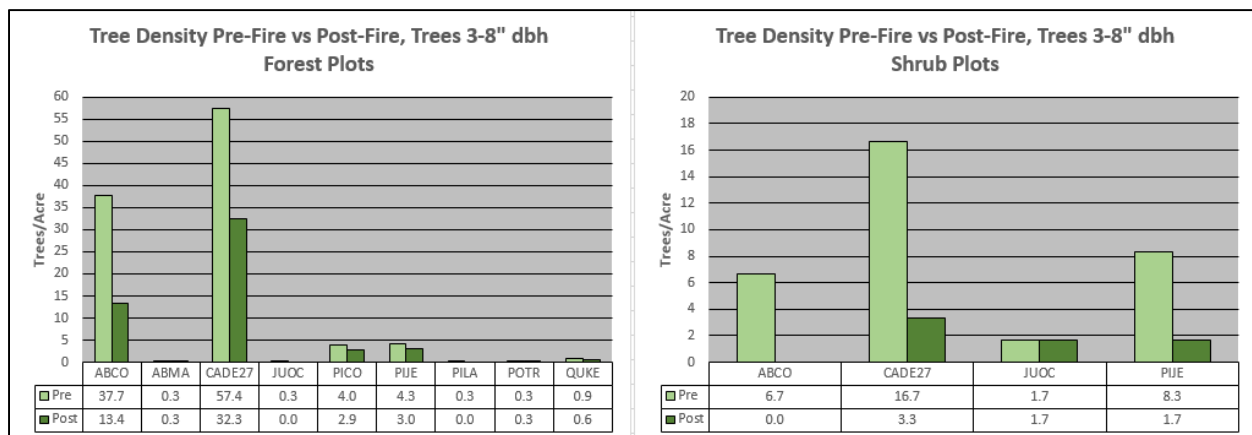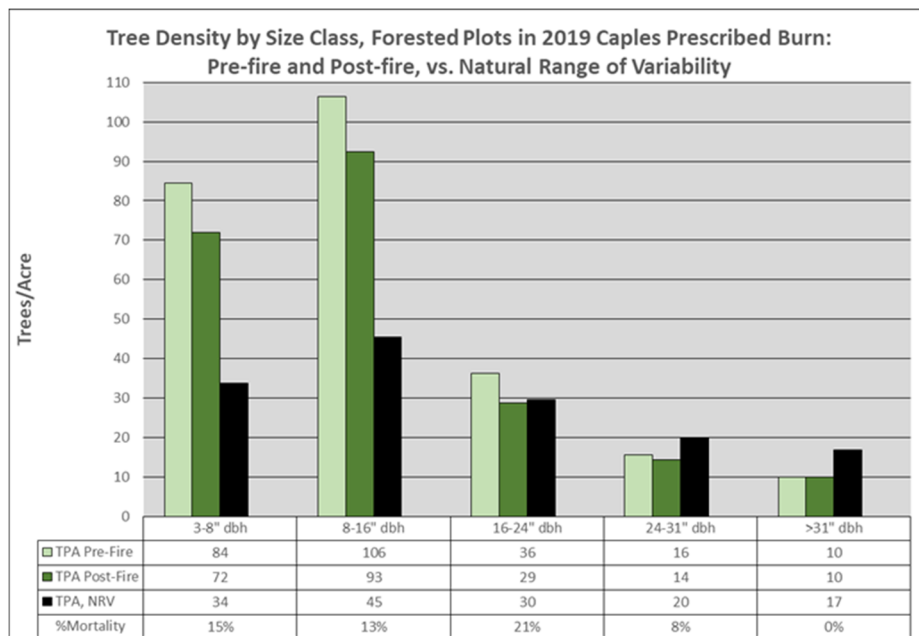


Figure 12: Comparison of tree density and species composition found in Forest vs Shrub plots for the 3-8"dbh size class.  *Note difference in the scales of the two graphs*.

**Changes in Tree Density:  Prescribed Burn versus Wildfire:**

Tree mortality and associated changes to tree density were less in forested areas burned with prescribed fire than areas burned under wildfire conditions.  It's worth noting that total pre-fire tree density (across all size classes) was greater in areas burned as prescribed fire (253 TPA) compared to the area burned as wildfire (194 TPA).  Areas burned with prescribed fire saw a 14% reduction of trees across all size classes, while areas burned as wildfire saw a 47% reduction.  In the smaller tree size classes of 3-8 inches and 8-16 inches dbh, prescribed fire saw reductions of 15% and 13% respectively, compared to reductions of 62% and 39% in areas burned as wildfire (Figure 13).  In larger trees, 24-31 inches dbh, and greater than 31 inches dbh, prescribed fire areas had reductions of 8% and 0%, compared to reductions of 30% and 23% in areas burned as wildfire.  Reductions in the 16-24 inch dbh size class were 21% in prescribed fire areas and 35% in wildfire areas.



**Tree Density by Size Class, Forested Plots in 2019 Caples Prescribed Burn: Pre-fire and Post-fire, vs. Natural Range of Variability**

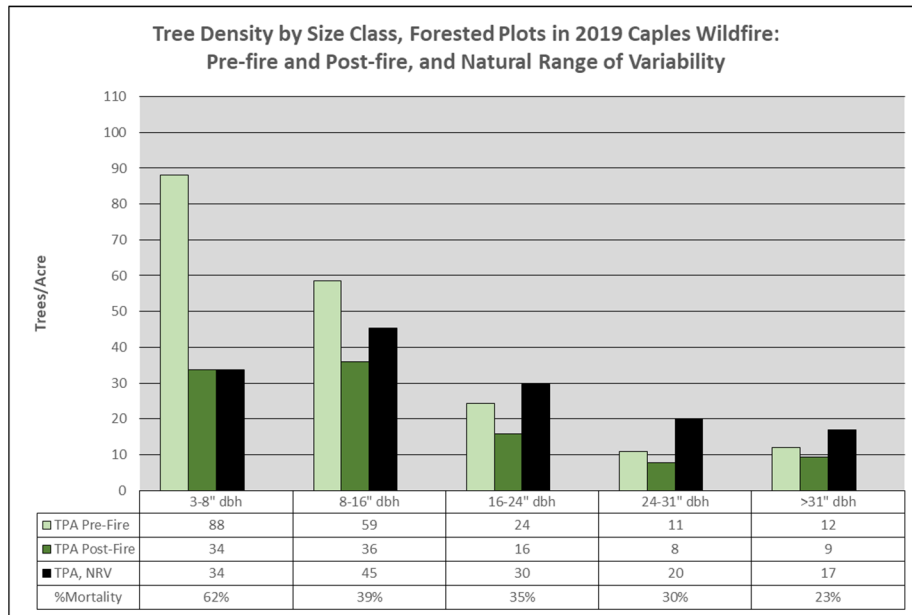|  | 3-8" dbh | 8-16" dbh | 16-24" dbh | 24-31" dbh | >31" dbh |
|---|---|---|---|---|---|
| ☐ TPA Pre-Fire | 84 | 106 | 36 | 16 | 10 |
| ■ TPA Post-Fire | 72 | 93 | 29 | 14 | 10 |
| ■ TPA, NRV | 34 | 45 | 30 | 20 | 17 |
| %Mortality | 15% | 13% | 21% | 8% | 0% |

Figure 13: Tree Density, pre-fire, post-fire, and the NRV, showing the difference of change resulting from prescribed fire and wildfire in the Caples Fire.

## Raked Trees

Presented below are key findings from data collected on the 15 trees identified in the field as having being trees raked pre-fire for protection.  The complete summary of data collected on raked trees is presented in Appendix C.

Notable results from the raked trees found included:

- Jeffery pine accounted for 53%, followed 20% by Ponderosa pine, and 13% White fir, with lesser amounts of sugar pine, and incense cedar.
- Mean diameter was 52.5 inches dbh, the largest was 69 inches dbh.
- The mean bole char height was 4.9 feet
- In 1 of 15 cases tree raking stopped fire from creating char on the tree bole
- The estimate of pre-fire duff depth (inches):  Mean = 5.4, Max = 15.7

Status of Surrounding Trees (within 1/10 acre):

|                     | 6-12" dbh | 12-36" dbh | >36"dbh |
|---------------------|-----------|------------|---------|
| % Trees Alive       | 47.8      | 89.4       | 95      |
| %Trees Killed by Fire | 24.6    | 0          | 0       |
| %Snags Pre-Fire     | 27.5      | 10.5       | 5       |

## Ground and Surface Fuels

Both ground and surface fuels were substantially reduced with the Caples Fire.

**Litter and Duff Depths Reduction:**

Litter and duff buildup had been substantial in many areas of the Caples Creek Watershed due to the extended period of fire exclusion.  The fire, both prescribed fire and wildfire, effectively reduced litter and duff depths across forest and shrub areas.  In forest dominated areas, combined litter and duff depth was reduced by 78% and 91% in prescribed burn and wildfire areas respectively.  In shrub areas, combined litter and duff depth was reduced by 94% and 97% in prescribed burn and wildfire areas (Figure 14).
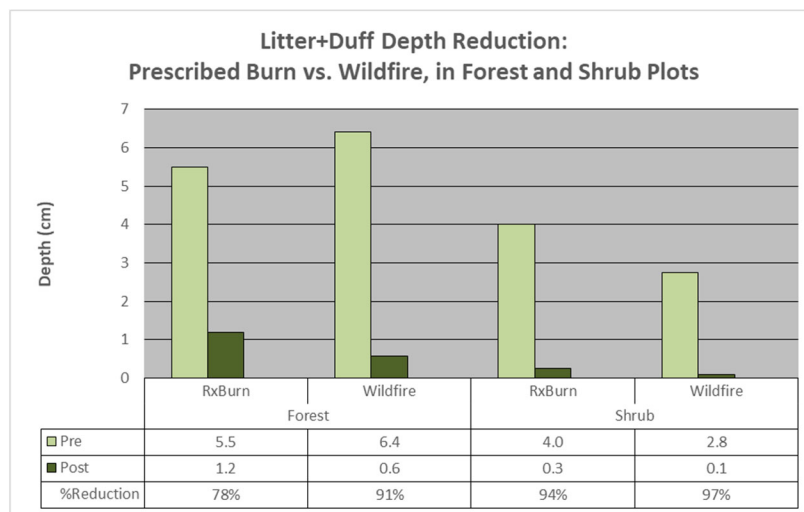


| | Forest | | Shrub | |
|---|---|---|---|---|
| | RxBurn | Wildfire | RxBurn | Wildfire |
| Pre | 5.5 | 6.4 | 4.0 | 2.8 |
| Post | 1.2 | 0.6 | 0.3 | 0.1 |
| %Reduction | 78% | 91% | 94% | 97% |

Figure 14: Combined litter and duff depth reduction in prescribed burn versus wildfire areas in forest and shrub plots.

**Surface Fuel Reduction:**

Substantial surface fuel reduction occurred in both prescribed burn and wildfire areas of the fire, with greater reductions occurring with wildfire than prescribed burn.  Combined 1 and 10 hour fuels (fuels less than 1 inch diameter), were reduced by 67% in prescribed burn areas, and 75% in wildfire areas.  For 100 hour fuels (1 to 3 inches diameter), reduction was 86% in prescribed burn areas and 73% in wildfire areas.  For 1,000 hour fuels (greater than 3 inches diameter), reduction was 51% in prescribed burn areas and 81% in wildfire areas (Figure 15).
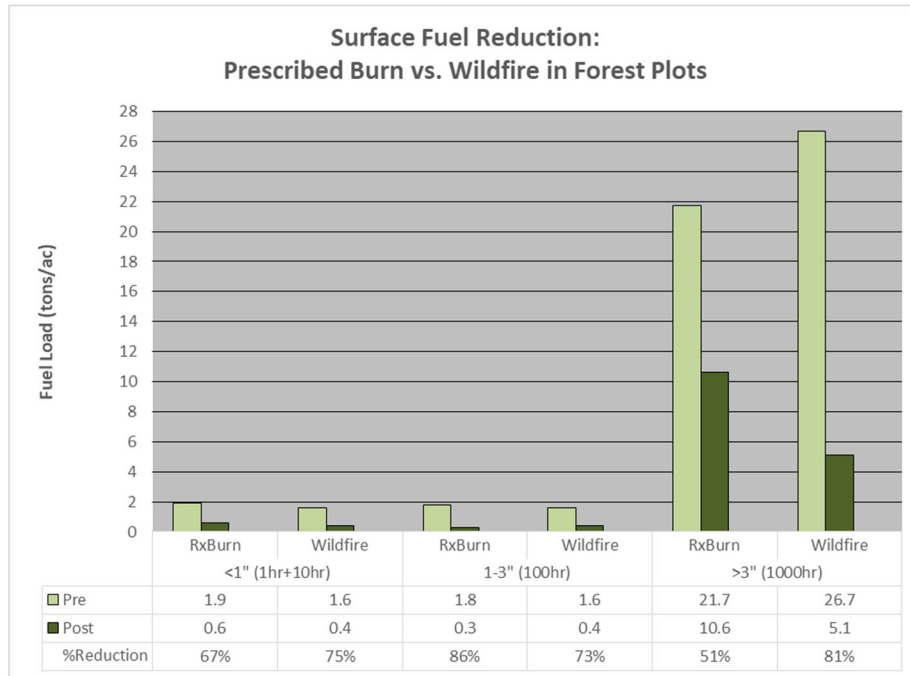
Figure 15: Surface fuel load reduction in prescribed burn versus wildfire areas.

## Weather

Fire managers track the weather and associated fire indices prior to and throughout a prescribed burn operation, and during wildfires.  Along with winds and relative humidity, fire indices are carefully considered to gauge the ability to control a fire, along with the expected fire effects.  These fire indices are created from a combination of weather and fuel moisture variables, and change from day to day as weather parameters and fuel moistures change.  Three key fire indices typically considered are Energy Release Component (ERC), Burning Index (BI), and Ignition Component (IC).  Definitions for these indices are presented below (NWCG website):

- **Energy Release Component (ERC)**:  The computed total heat release per unit area (BTUs) within the flaming front at the head of a moving fire.
- **Burning Index (BI):**  An estimate of the potential difficulty of fire containment as it relates to the flame length at the head of the fire.
- **Ignition Component (IC):**  A rating of the probability that a firebrand will cause an actionable fire.

When prescribed burning was initiated on September 30, these indices were all relatively low: ERC = 35, BI was 31, and IC was 6.  These values increased over the following week with an increase in temperature, reductions in relative humidity, and increases in wind speed.  By October 9, the fire indices were the following:  ERC = 60, BI = 45, and IC = 23.  On October 10, it was decided to declare the prescribed fire a wildfire incident to improve access to resources needed to control the fire (Figure 16).
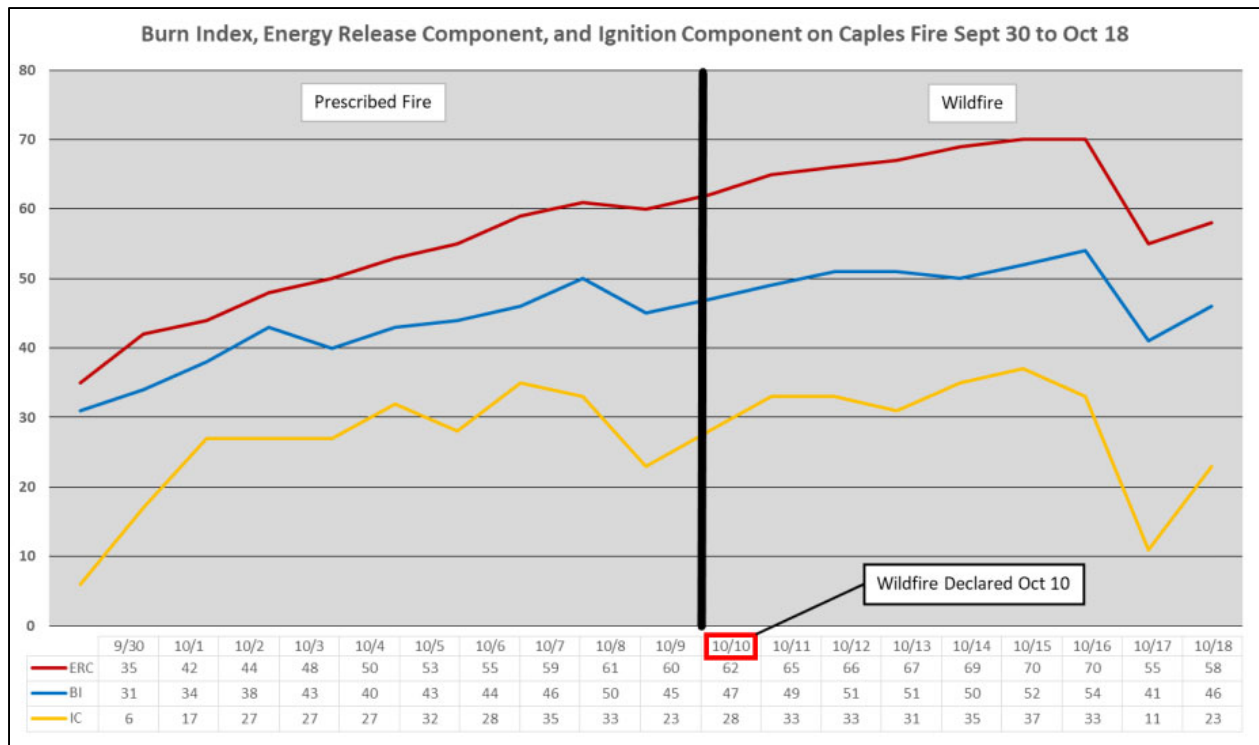
Figure 16: Fire indices: ERC, BI, and IC from September 30, to October 18, 2019. The Caples prescribed burn occurred from September 30 to October 9. The prescribed burn was converted to wildfire on October 10. The last day of noted fire growth occurred on October 18. The values shown on October 10 are interpolated (RAWS data was unavailable for 10/10).

During the prescribed fire phase of the burn, from September 30 to October 9, Energy Release Component ranged from 35 to 61, with a mean of 51. By comparison, during the wildfire phase of the burn, from October 10 and beyond, ERC ranged from 55 to 70, with a mean of 65 (22% higher). (Figure 17)

During the prescribed fire phase of the burn, Burning Index ranged from 31 to 50, with a mean of 41. During the wildfire phase BI ranged from 36 to 62, with a mean of 49 (16% higher).

During the prescribed fire phase of the burn, Ignition Component ranged from 6 to 35, with a mean of 26. During the wildfire phase IC ranged from 5 to 41, with a mean of 29 (10% higher).
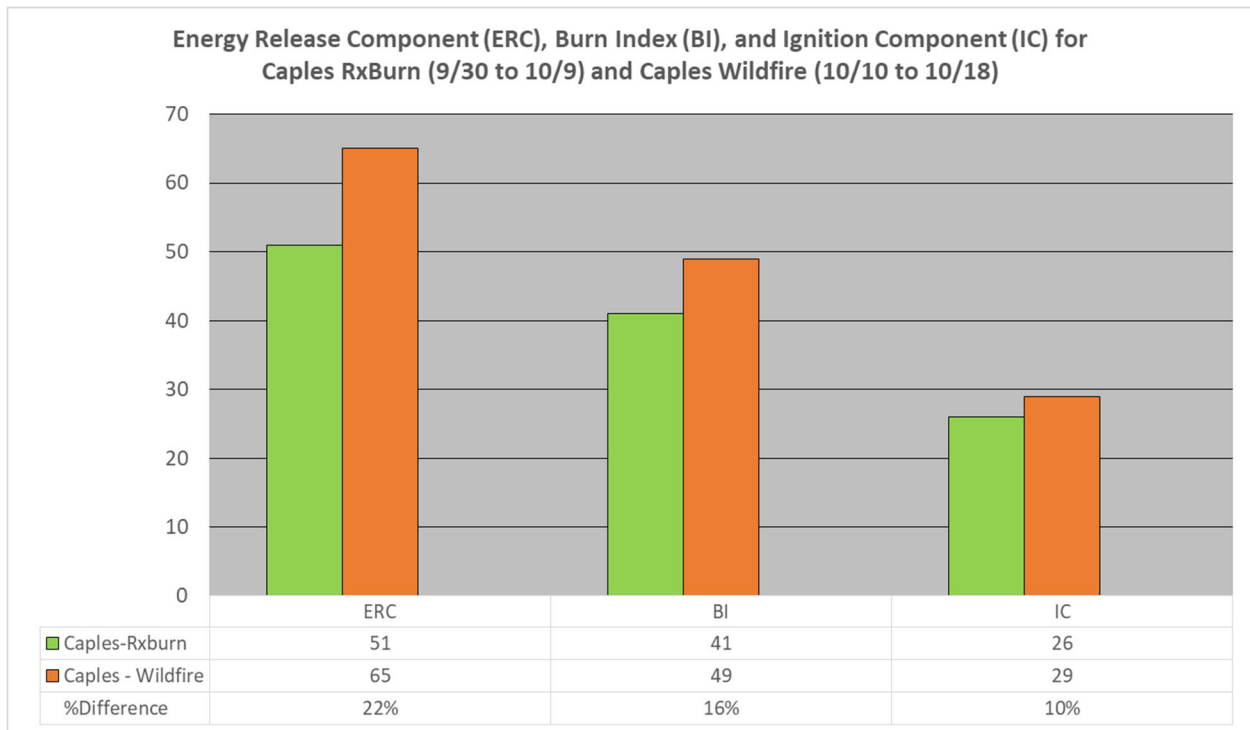
Figure 17: Mean values of fire indices for the period of the Caples prescribed burn (Sept 30 to Oct 9), and the Caples wildfire period (Oct 10 to Oct 18). October 18 was chosen as the end date for the wildfire period because that was the last day of fire growth. The indices shown include Energy Release Component (ERC), Burning Index (BI), and Ignition Component (IC).

# DISCUSSION

Objectives for the restoration of Caples Creek Watershed include re-establishing the health and resilience found in a fire-adapted ecosystem, and reducing fire hazard through fuels reduction.  To gauge the effectiveness of the Caples Fire in meeting those objectives, we compared our measurements of fire effects of the Caples Fire to metrics of burn severity to the natural range of variability, as well as targets set in the Caples Prescribed Burn Plan (USFS, 2017).

## Burn Severity:  Caples Prescribed Burn Compared to Caples Wildfire

Natural range of variability (NRV) is an approach to defining project objectives when the goal is to move existing conditions closer to historical (pre-European) conditions as a benchmark for healthy natural ecological function.  It's been determined that fires managed for resource benefit, or "resource benefit fires"[11] fit the natural range of variability in the Sierra Nevada (Meyer, 2015).  The prescribed burn portion of the Caples Fire, which burned from September 30 to October 9, has a burn severity fraction that closely resembles the burn severity of resource benefit fires examined for the Meyer 2015 study, thus we can say that with respect burn severity fraction, the prescribed fire portion of the Caples Fire

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[11] Resource Benefit Fires, once called "Wildland Use Fires" are fires that are managed to burn naturally with little or no interference for the purpose of allowing fire to resume its natural role in the ecosystem.

appears to be within the NRV.  The percentage of high burn severity in the prescribed burn portion of the Caples Fire is 10%, compared to 9% found in resource benefit fires burning in Yosemite NP from 1974 to 2005 (van Wagtendonk and Lutz, 2007), 11% in resource benefit fires in Yosemite and Kings Canyon NPs from 2000 to 2011 (Meyer, 2015), and 10% in resource benefit fires occurring in wilderness areas on US Forest Service land in the Southern Sierras from 2000 to 2011 (Meyer, 2015).  (Figure 18).



### Comparison of Burn Severity Fraction, Caples Prescribed Fire & Resource Benefit Fires, VS Caples Wildfire & Other Sierra Wildfire, including 2014 King Fire (ENF)

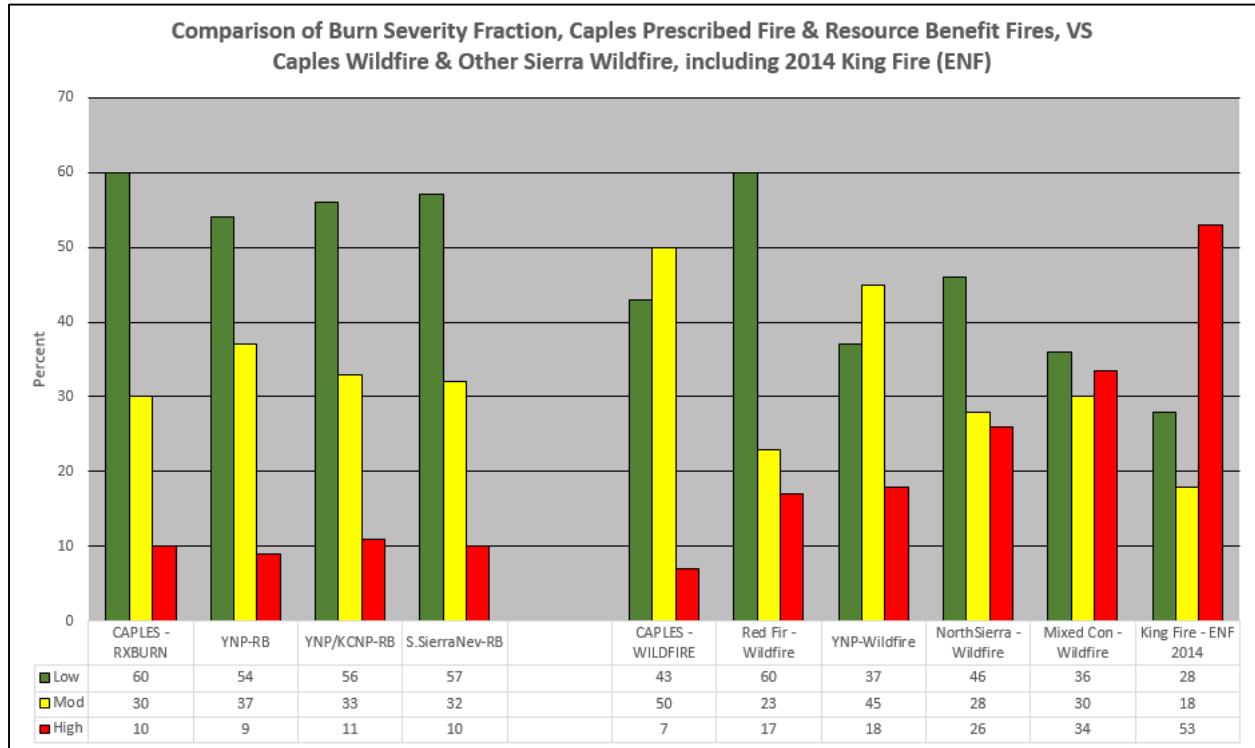| | CAPLES - RXBURN | YNP-RB | YNP/KCNP-RB | S.SierraNev-RB | | CAPLES - WILDFIRE | Red Fir - Wildfire | YNP-Wildfire | NorthSierra - Wildfire | Mixed Con - Wildfire | King Fire - ENF 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Low | 60 | 54 | 56 | 57 | | 43 | 60 | 37 | 46 | 36 | 28 |
| Mod | 30 | 37 | 33 | 32 | | 50 | 23 | 45 | 28 | 30 | 18 |
| High | 10 | 9 | 11 | 10 | | 7 | 17 | 18 | 26 | 34 | 53 |

Figure 18. Comparison of burn severity fraction in Caples prescribed burn area compared to resource benefit fires, and burn severity fraction in Caples wildfire area compared to burn severity in other wildfire across California, and burn severity of the 2014 King Fire located on the Eldorado National Forest.

The portion of the Caples fire which burned as a wildfire (October 10 and later), shows burn severity fraction that is different, when compared to results of studies looking at wildfires across California occurring in areas where active fire suppression has occurred over the past century.  The fraction of high burn severity in the wildfire portion of the Caples Fire was 7%, compared to High burn severity fraction ranging from 17 to 34% for fires in comparable ecotypes and geographic locations.  The fraction of moderate burn severity in the wildfire portion of the Caples Fire (50%) is higher than what's found in other wildfires which range from 23 to 45%.

A study looking at burn severity of wildfires across the Sierra Nevada and Southern Cascade Mountains from 1984 to 2006 (Miller et al, 2009) showed levels of high burn severity fraction at 17% in red-fir ecotypes, 26% across Northern Sierra wildfires, and 34% in mixed-conifer wildfires.

These measures of burn severity on historic wildfires help to provide benchmarks for comparison of contemporary fires, but it should be noted that there is a trend of increasing percentage of burn severity since many of those fires occurred.  A study looking at trends in wildfire severity from 1984 to 2010

throughout California, including the Sierra Nevada (Miller and Safford, 2012) showed that the trend for percent of high severity has risen from 21% in 1984, to 31% in 2010.  Under the assumption that this trend continued through 2019, the mean high severity fraction for wildfires in this area would be over 34%.  Similarly, a report looking into the Natural Range of Variation for yellow pine and mixed-conifer forests throughout California (Safford and Stevens, 2017), reported similar proportions of burn severity variation as the other reports for reference fires compared to contemporary fires across many forest types.  In the Safford and Stevens study, reference fires ranged in high burn severity fraction from 5% to 18% in Ponderosa pine, White fir, Red fir, and 'Northern Sierra'; while current fires ranged in high burn severity fraction from 12% to 32% for the same forest types (Figure 19).
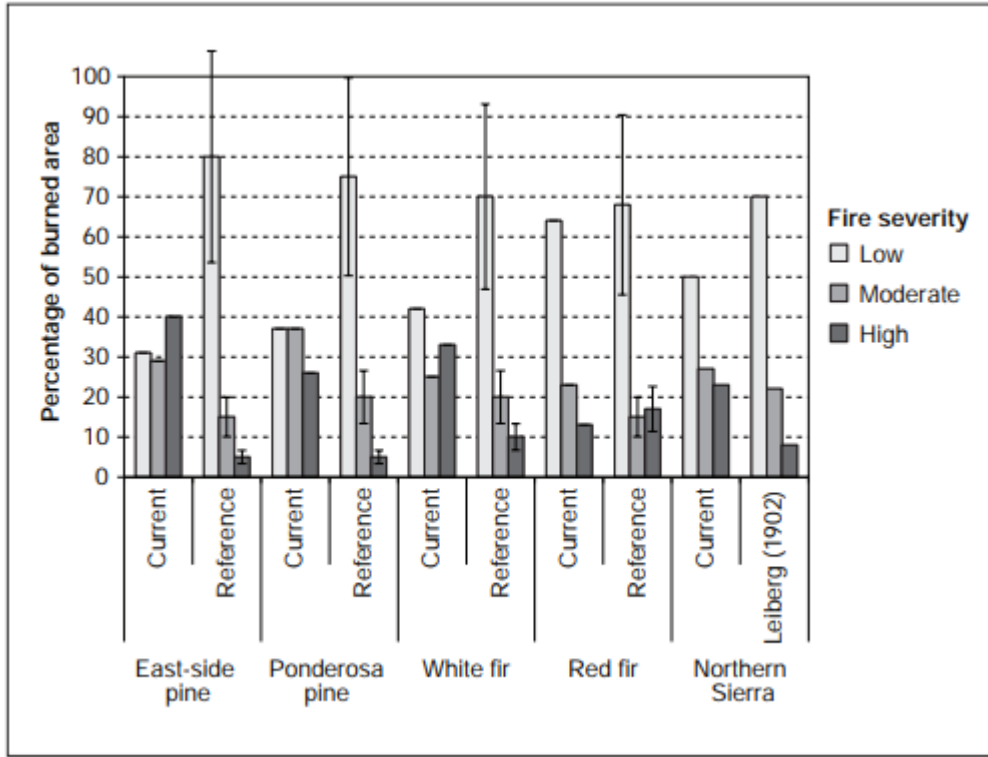


Figure 19. This graphic, pulled directly from GTR-256 (Safford and Stevens, 2017), illustrates a comparison of average burn severity fraction for current fires (1984-2004), compared to reference (pre-European) fires.

Given the high level of fuel accumulation in the Caples Creek Watershed with over a century of fire exclusion, there was great risk for a fire with more severe fire effects.  Had a fire started in the Caples Creek watershed at a time when weather and fuel moisture conditions supported more intense fire, the area of high severity fire effects could have been far higher.  The King Fire which burned on the Eldorado National Forest in September 2014, burned at the same time of year, across similar elevations, and had similar fuel types as the Caples Fire.  Weather conditions were conducive to more intense burning during the King Fire, resulting in 53% high burn severity compared to the Caples Fire which resulted in 10% high burn severity in the prescribed fire portion and 7% high severity in the wildfire portion (Figure 17).

## Tree Density:  Are Conditions Closer to the Natural Range of Variability?

Changes to tree density were presented in the Results section of this report with a focus on tree mortality or the percent of tree density reduction.  Here, we'll discuss how the post-fire tree density levels align with the natural range of variability (NRV) per tree size class.

With over a century of fire exclusion, tree density levels in the Caples Creek Watershed deviated considerably from the natural range of variability.  The density of smaller trees, less than 16 inches dbh, was 136% above the NRV.  Intermediate sized trees in the 16 to 24 inch dbh range were closer to the NRV at 12% over.  Larger trees, greater than 24 inches dbh, were 26% below the NRV.

There was less tree reduction in the prescribed burn areas compared to wildfire areas in the Caples Fire. The lower reduction of trees in the prescribed burn area was a benefit in preserving larger sized trees which were below the NRV pre-burn, but was less effective at bringing the high tree density of smaller trees closer to the NRV.  The greater reduction of trees in wildfire areas proved more beneficial in bringing smaller sized trees closer to the NRV, but took larger trees which were already below the NRV further away from the desirable condition (Figure 20).

For trees in the 3 to 8 inch dbh size class:  In areas burned with prescribed fire, tree density was reduced from 150% above to 113% above the NRV.  In areas burned with wildfire, tree density was reduced from 161% above the NRV, to a level that matches the NRV at 34 trees per acre.

For trees in the 8 to 16 inch dbh size class:  In areas burned with prescribed fire, tree density was reduced from 134% above to 104% above the NRV.  In areas burned with wildfire, tree density was reduced from 29% above to 21% below the NRV.

For trees in the 16 to 24 inch dbh size class:  In areas burned with prescribed fire, tree density was reduced from 22% above to 3% below the NRV.  In areas burned with wildfire, tree density was reduced from 18% below to 47% below the NRV.

For trees in the 24 to 31 inch dbh size class:  In areas burned with prescribed fire, tree density was reduced from 22% below to 28% below the NRV.  In areas burned with wildfire, tree density was reduced from 45% below to 62% below the NRV.

For trees greater than 31 inches dbh:  In areas burned with prescribed fire, there were no trees lost in monitoring plots, so we show that tree density stayed the same at 41% below the NRV.  In areas burned with wildfire, tree density was reduced from 29% below to 45% below the NRV.

**Tree Density by Size Class, Forested Plots in 2019 Caples Prescribed Burn: Pre-fire and Post-fire, vs. Natural Range of Variability**

| | 3-8" dbh | 8-16" dbh | 16-24" dbh | 24-31" dbh | >31" dbh |
|---|---|---|---|---|---|
| TPA Pre-Fire | 84 | 106 | 36 | 16 | 10 |
| TPA Post-Fire | 72 | 93 | 29 | 14 | 10 |
| TPA, NRV | 34 | 45 | 30 | 20 | 17 |
| %Diff NRV | 113% | 104% | -3% | -28% | -41% |



**Tree Density by Size Class, Forested Plots in 2019 Caples Wildfire: Pre-fire and Post-fire, and Natural Range of Variability**

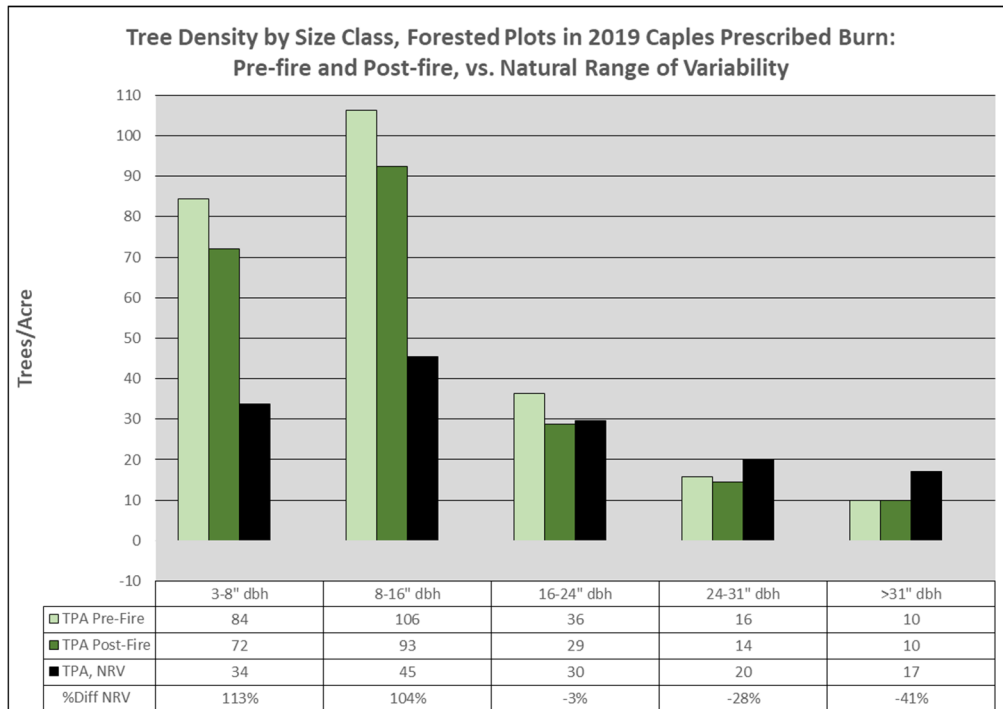| | 3-8" dbh | 8-16" dbh | 16-24" dbh | 24-31" dbh | >31" dbh |
|---|---|---|---|---|---|
| TPA Pre-Fire | 88 | 59 | 24 | 11 | 12 |
| TPA Post-Fire | 34 | 36 | 16 | 8 | 9 |
| TPA, NRV | 34 | 45 | 30 | 20 | 17 |
| %Diff NRV | 0% | -21% | -47% | -62% | -45% |

Figure 20: Tree density change pre- versus post-fire, in Caples prescribed fire areas (top) and Caples wildfire areas (bottom), according to size class. Attached table list post-fire difference compared to the natural range of variability (NRV).

## Large Tree Mortality:  Were Caples Burn Plan Objectives Met?

The Caples Prescribed Burn Plan set the upper limit for mortality of trees greater than 30 inches dbh at 5%.  In areas burned as prescribed fire (from September 30, thru October 9) this target was met, with no

tree mortality for trees greater than 30 inches dbh found within monitoring plots.  In areas burned as wildfire, October 10 and later, tree mortality was 20% for trees greater than 30 inches dbh.

The reality is that there's probably some small amount of mortality in trees greater than 30 inches dbh that wasn't captured with our data collection.  Because we were counting every other tree in plots with greater tree density to help succeed at visiting all plots, it's quite possible that some trees killed by the fire were not counted.  It's expected that following more thorough collection of data for secondary fire effects, it will stand that tree mortality in prescribed burn areas is within the Caples Burn Plan limit.

## Drought Related Tree Mortality:  Something to Consider

The Caples Creek Watershed experienced severe drought between the time the data was first collected in 2013, and when the fire occurred in fall 2019. There were varying levels of drought related tree mortality across the Sierra Nevada during this time period, with more pronounced tree mortality occurring further south.  Comparisons of aerial imagery 2013 versus 2018 shows a noticeable increase in tree mortality had occurred in Caples Creek Watershed during this time (Figure 21).  It's presumed that this mortality is drought caused.  Data to quantify this tree mortality in Caples Creek Watershed doesn't currently exist.

This observation of drought caused tree mortality in Caples Creek Watershed is being pointed out here, as it's likely a source for some overestimates of tree mortality caused by the Caples Fire.  Careful data collection for secondary fire effects may be able to distinguish tree mortality caused by the Caples Fire and trees that were killed due to drought related causes.



Figure 21: Comparison of forest condition in 2013 (left) versus 2018 (right), showing evidence of drought related tree mortality (Images Google Earth).

It's also worth considering that in the wake of the 2013-2018 drought, trees in the Caples burn area suffered from some degree of lowered resiliency which could have played a role in higher tree mortality levels observed immediately post-fire.  Further analysis looking at relationships between tree mortality and basal area may show correlations.

Precipitation since the Caples Fire has been low thus far.  As of May 7, 2020 Northern Sierra precipitation is at 57% of average for the water year (CA Dept. of Water Resources website).  This lack of precipitation may have some impact on the ability for trees injured in the Caples Fire to survive going forward.  If drought conditions continue, the impact on tree survival may be substantial.

## Fuel Load:  Are Conditions Closer to the Natural Range of Variability?

The NRV for litter+duff depth is 0.6 inches.  Combined litter and duff depths across all plots were reduced from 2.2 inches (267% above the NRV) to 0.2 inches (67% below the NRV).  The fire effectively brought litter and duff depth closer to NRV.  Analysis to differentiate prescribed burn from wildfire effects was not performed for litter and duff depth.

For combined 1, 10, and 100-hr surface fuels (fuels less than 3 inches) the NRV is 1.4 tons/acre.  In areas burned with prescribed fire, fuel load was reduced from 3.7 tons/acre (164% above the NRV), to 0.9 tons/acre (36% below the NRV). In areas burned by wildfire, fuel load was reduced from 3.2 tons/acre (129% above the NRV), to 0.8 tons/acre (43% below the NRV).  In the case of surface fuels less than 3 inches diameter, prescribed fire brought the fuel load closer to the NRV than wildfire (Figure 22).

For course woody debris, surface fuels greater than 3 inches diameter, (1,000-hr fuels) the NRV is 6.3 tons/acre.  In areas burned with prescribed fire, fuel load was reduced from 21.7 tons/acre (244% above the NRV), to 10.6 tons/acre (68% above the NRV).  In areas burned by wildfire, fuel load was reduced from 26.7 tons/acre (324% above the NRV) to 5.1 tons/acre (19% below the NRV).   In the case of surface fuels greater than 3 inches diameter, wildfire brought the fuel load closer to the NRV.
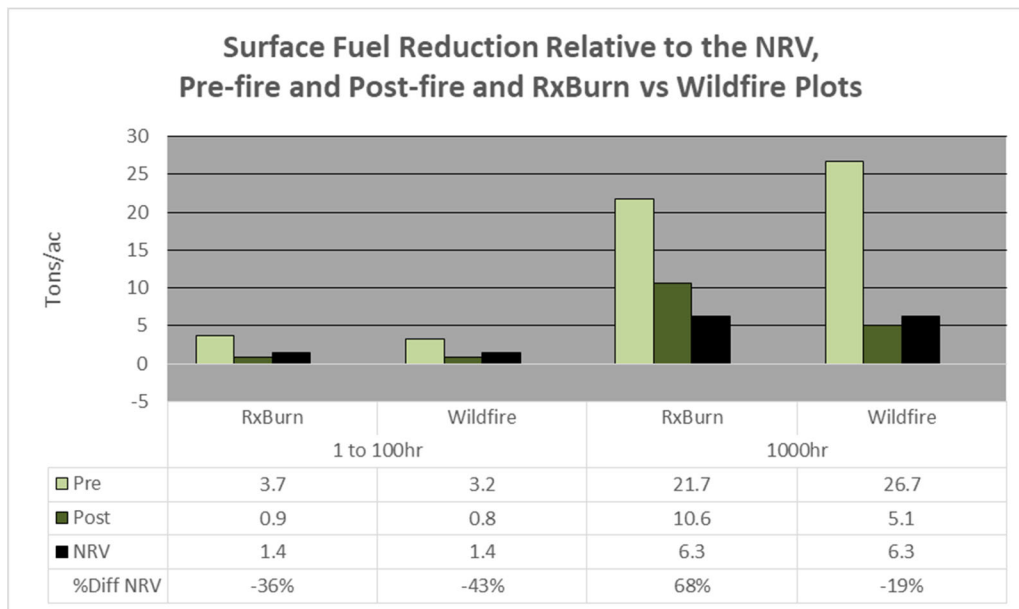


| | RxBurn | Wildfire | RxBurn | Wildfire |
|---|---|---|---|---|
| | 1 to 100hr | | 1000hr | |
| Pre | 3.7 | 3.2 | 21.7 | 26.7 |
| Post | 0.9 | 0.8 | 10.6 | 5.1 |
| NRV | 1.4 | 1.4 | 6.3 | 6.3 |
| %Diff NRV | -36% | -43% | 68% | -19% |

Figure 22.  Surface fuel reduction relative to the natural range of variability (NRV).

## Fuel Load:  Were Caples Burn Plan Objectives Met?

The objective was met for reducing the smallest surface fuels, 1+10 hour fuels (less than 1 inch diameter). The following objectives (and acceptable ranges) were presented for fuels reduction in the burn plan for the Caples Restoration Project:

- Reduce/consume fuels less than 1 inch diameter by 70%; Acceptable Range (50-80%)
- Reduce/consume fuels 1-3 inches diameter by 50%; Acceptable Range (30-60%)
- Reduce/consume fuels greater than 3 inches diameter by 25%; Acceptable Range (10-35%)
- Reduce /consume brush approximately 70% in areas with heavy brush to create a mosaic burn pattern; Acceptable Range (50-80%)

Table 3: Pre-fire and post-fire surface fuels (tons/ac), and consumption objectives with acceptable range.

| Plot Type | <1" (1hr+10hr) | | %Reduced | Objective | AcptRng | 1"-3" (100hr) | | %Reduced | Objective | AcptRng | >3" (1000hr) | | %Reduced | Objective | AcptRng |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pre | post | | 70% | 50-80% | pre | post | | 50% | 30-60% | pre | post | | 25% | 10-35% |
| FOREST | 1.7 | 0.5 | 73% | Yes | Yes | 1.6 | 0.4 | 77% | No | No | 25.3 | 6.6 | 74% | No | No |
| SHRUB | 1.1 | 0.2 | 85% | No | Yes | 0.8 | 0.2 | 79% | No | No | 2.0 | 0.7 | 64% | No | No |
| ALL | 1.6 | 0.4 | 74% | Yes | Yes | 1.5 | 0.3 | 77% | No | No | 21.7 | 5.7 | 74% | No | No |

The objective to reduce fuels less than 1 inch diameter (1hr+10hr fuels) by 70% was met in forest plots and all plots (forest and Shrub combined).  In shrub plots, fuels less than 1 inch diameter were reduced by 85% which was close, but greater than the acceptable range of 50-80% (Table 3).

In the 1-3 inch diameter size class (100hr fuels), consumption ranged from 77-79% among forest, shrub, and all plots.  This exceeded the 50% objective and acceptable range of 30-60%.

For fuels greater than 3 inches diameter (1,000hr fuels), consumption ranged from 64-74% among forest, shrub, and all plots. This exceeded the 25% objective and acceptable range of 10-35%.

We stratified fuels consumption data for differences in prescribed burn to wildfire, and there were no substantial differences to be seen in terms of meeting Caples Burn Plan objectives.

## Shrub Cover:  Were Caples Burn Plan Objectives Met?

The extended period without fire in the Caples Creek Watershed resulted in areas of overgrown, decadent homogenous shrub fields.  Based on within plot burn severity fraction, it's estimated that shrub cover was reduced by 73% in areas which burned, which is 3% more than the target of 70%, but falls within the Caples Burn Plan acceptable range of 50-80%. The percentage of shrub cover reduction resulting from the Caples Fire is based on the combined fractions of High and Very High burn severity categories for understory vegetation within shrub plots.

## Acknowledgments

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# Caples Creek Watershed Monitoring Protocol: Pre and post treatment

September 25, 2015

Caples Creek Watershed Monitoring is based on the Forest Service Common Stand Exam Protocol.  CSE plots are standard Forest Service plots used to collect data on trees, vegetation composition, ground surface cover, and down woody material/fuels. Complete information on the protocol, use of field data recorders, and the FSVEG database, can be found at http://www.fs.fed.us/emc/nris/products/fsveg/

## I. Overview

Plot shape: Circular

Plot size: Default for forested vegetation: 405 sq m (11.3 m radius) = 1/10 acre, but also sample species presence and cover in an expanded 809 sq m plot (16 m radius = 1/5 acre), centered at the same point. For shrubby vegetation or very dense forest with difficult access, it is OK to use 405 sq m (11.3 m radius) to assess species composition.

Plot location: Center the plots on the vertices of a grid that has been stratified by vegetation type across the Caples Watershed.  These areas have been predetermined in GIS (see maps for project area).

Permanently mark the Caples plot locations with 2' rebar topped by plastic caps. Leave only 3-5" above ground. Flag the rebar and a few trees near the center of the plot. Attach plot tag to rebar with wire and note number for future data entry.

All data recording will be completed in datasheets designed for tablets.

## II. Plot Data Form (1/10 acre plot)

1. Enter the plot #, date, time in and time out and observers initials

2. Photos

   a. Take a photo of the plot tag, make sure the tag number is visible.

   b. Take one photo at each cardinal direction from plot center moving clockwise (N, E, S, W).

## VII. Woody Fuels

1. Enter the plot

2. Fuels data will be collected from four Brown's Transects (J.K. Brown. 1974. The transects are laid out at the cardinal directions, stretching from the plot center to 37' (11.3 m). The ends of the transects are the starting points, i.e. they are read starting from at the edge of the plot, heading toward the middle

3. Enter the azimuth of the transect. Since they will be in the cardinal directions, it is OK to write, N,S,E, or W for the four different transects

4. Use a go/no go gauge to record the following:

   a. The number of 1-hr fuels (<0.64 cm) that intersect the transect between the 3.0 and 5.0 m mark

   b. The number of 10-hr fuels (0.64-2.54 cm) between the 3.0 and 5.0 m mark

   c. The number of 100-hr fuels (2.54-7.62 cm) between the 3.0 and 6.0 m marks

   d. Measure litter and duff depths at the transect starting point (i.e. at the outside of the plot) and again at 25' (7.6 m), enter these values

   e. Measure fuel depth at the transect starting point, at 12.5' (3.8 m) and at 25' (7.6 m).

4. Collect information on every piece of coarse woody debris (CWD) that intersects the transects and meets the minimum criteria:

   a. Central longitudinal axis of the CWD intersects the transect, the diameter at the point of intersection is $\geq$3" (7.6 cm) and the piece is at least 1 meter (3.3 feet) long

5. Enter the diameter of the CWD at the transect intersect, the diameter at the large end, the diameter at the small end, length and decay class

6. Notes:

   a. To qualify as fuels, particles must be severed from the original source of growth
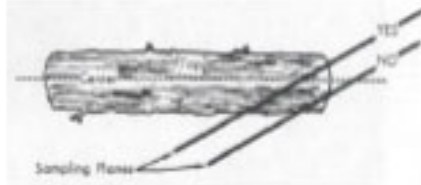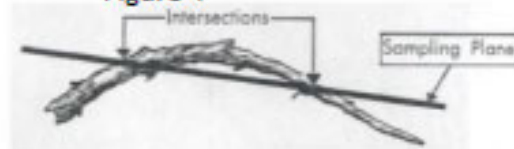
**Figure 3**



**Figure 4**



a. Be sure not to count dead shrub limbs that are attached to a standing shrub, whether the standing shrub is dead or alive.

b. Do not count needles, grass, bark, or cones

c. If a branch or log intersects the transect at its end, the central axis must intersect the transect for the piece to be tallied (Fig. 3)

d. Count both intersections for a curved piece (Fig. 4)

e. Regardless of size, pieces are only tallied when their intersection with the transect lies above the litter and duff layers (Fig. 5)

f. Do not count stumps that are still rooted in the ground

Yes = center of log is in duff layer or below.
No = center of log is above duff layer.

**Figure 5**



## VIII. Trees

Tree data: Use a dbh cutoff of 10 cm and a height cutoff of 1.37 m. This means that within the plot, all live and dead trees at or above 10cm dbh and 1.37 m  tall will be *individually* measured (although there are few measures made of dead trees).

1. Enter the plot #

2. Enter the tag # Enter status (L,D,S,X,Y), see Cheatsheet (live and dead trees)

3. Enter species (live and dead trees)

4. Enter dbh (d-tape) (live and dead trees)

5. Height to the nearest 0.1 m

   a.  If a tree leans, measure the height starting from the ground immedi-
       ately beneath the top of the tree. You may need someone to stand
       directly below the top of the tree in order to measure height accurate-
       ly with a hypsometer

   b.  Record the approximate angle of the tree in the Notes section
       (example: "leans at 45 degree angle")

6. Height to live crown base (HTLCB) to the nearest 0.1 m (only live trees)

   a.  This is defined as the height to the lowest live, vertically continuous

   b.  Must be a wedge of at least 30 degrees AND less than 2 m below con-
       tinuous crown

   c.  If a tree has a dead top, record its total height including the dead top
       under Height2015, then under Notes record the height to the top of
       its live crown

   d.  Measure HTLCB from the point where the lowest live branch inter-
       sects with the bole of the tree, not the tip of the branch

7. Enter decay class (1-5), see table (dead trees)

# Appendix B: Raked Tree Protocol

**Caples Raked Tree Plan** (approx. 5 to 10 min per tree)

1) Capture coordinates of the tree

2) Photos of Subject Tree:  (Take 2 photos each, from N and S side of tree, 4 total):
    i. Photo of base: From approx 5m away (5 large paces), take <u>landscape</u> pic of base of tree. Show tree bole and surrounding rake berm, if present
    ii. Photos of canopy: From approx 10m away (10 large paces), take <u>portrait</u> pic of tree canopy, including the top of the tree.  If necessary move further away

3) Photos of Surroundings (4 total):  With the tree at your back, take 1 photo each facing N,E, S, and W. *(<u>Portrait</u> orientation, with about 25% of photo view being the surface, and 75% tree boles/canopy)*

4) Collect basic info on the tree
    a. Species
    b. DBH (nearest 0.1 cm)
    c. Live/Dead
    d. Mortality caused by fire (Y/N)

5) Fire effects of tree
    a. Char Height: measure both min and max (nearest 0.1m)
    b. Canopy: %Alive, %Scorched, %Torched

6) Fire effects, surrounding trees (approx. 11.3m radius):
    (For the following size categories: Sm trees 6 -12", Med 12 - 36", Legacy 36"+)
    - % trees live
    - % killed by fire
    - % dead prior to fire

7) Burn severity of surroundings:
    (Collected w/in area <u>approx.</u> same as monitoring plots… ~11.3m radius)
    a. % total area inorganic *(ie: rock, sand) vs organic*
    b. % organic area unburned
    c. For organic area: note the <u>dominant</u> burn severity class  (2,3,4, or 5) for each substrate, and veg

8) Raking questions:
    a. Was raked material bermed or scattered?  (Yes, no, unsure)
    b. Did raking stop fire from creating char on the tree bole? (Yes, no, maybe)

9) Litter and Duff depth:  (visually estimate to nearest cm)
    a. Litter depth
    b. Duff depth

## Appendix C: Raked Tree Findings

Total Trees Sampled: 15

Species:  ABCO = 2, PIPO = 3, PIJE = 8, PILA = 1, CADE = 1

dbh:  Mean = 52.5in, Min = 23.2in, Max = 69.0in

Status:  Live = 15, Snag = 0

Char Ht:  Min = 0.7m, Max = 2.3m, Mean = 1.5m

%Canopy Scorch:  None

%Canopy Torch:  None

Burn Severity of 1/10th acre surroundings:

- %Area Inorganic: 10.2
- %Area Unburned: 4.1
- Dominant Burn Severity, Substrate:  4
- Mean Burn Severity, Substrate: 3.5
- Dominant Burn Severity, Understory Veg: None Present
- Mean Burn Severity, Understory Veg: 2

Status of Surrounding Trees (within 1/10 acre):

|  | 6-12" dbh | 12-36" dbh | >36"dbh |
|---|---|---|---|
| % Trees Alive | 47.8 | 89.4 | 95 |
| %Trees Killed by Fire | 24.6 | 0 | 0 |
| %Snags Pre-Fire | 27.5 | 10.5 | 5 |

Was raked material bermed or scattered?  Unsure = 13, Bermed = 2, Scattered = 0

Did raking stop fire from creating char on the tree bole?  No = 14, Yes = 1

Estimate of pre-fire litter depth (cm):  Mean = 1.5cm, Min = 0.1, Max = 4

Estimate of pre-fire duff depth (cm):  Mean = 13.7cm, Min = 3, Max = 40