DRAFT

Forest Fire *Prevention*, or Forest *Resiliency*?

Monitoring Report on the §1038 Forest Fire Prevention Exemption

Top photo: A Shasta County Forest Fire Prevention Exemption being monitored; Middle left and right: a young plantation, post-thinning, and a more mature mixed conifer stand post-thinning. Bottom: A Forest Fire Prevention Exemption, pre-thinning, post-thinning, and post-2021 Caldor Fire.

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Executive Summary

Forest Fire *Prevention*, or Forest *Resiliency*?

Monitoring Report on the §1038 Forest Fire Prevention Exemption

CAL FIRE undertakes ongoing monitoring of timber harvests that are exempt from the traditional Timber Harvesting Plan ("THP") process ("Exemptions" and "Emergencies" or "Notice of Emergency Timber Operations"). This fourth report focuses on the §1038.1 "Forest Fire Prevention" Exemption ("FFP Notice"), which is oriented towards forest thinning operations for wildfire resiliency.

The FFP Notice serves as a rapid permitting tool for exempt commercial and non-commercial timber harvesting, with the goal of improving forest fire resiliency via "thinning from below", or removing the smallest and most flammable trees, eliminating surface-to-tree crown fuel continuity, and reducing the risk of catastrophic wildfire.

The FFP Notice has increased in popularity in recent years across the state. Following its introduction in 2005 (then under §1038(i)), FFP numbers were initially variable. However, in 2015 after regulatory changes were made to the allowable slash depth and maximum diameter limit on trees to be harvested, **the number of FFP Notices has continued to increase each year or hold steady, while the *reported* acres treated under FFP Notices has continued to increase.** Overall, large Industrially owned timberlands account for the majority of reported acres treated under the FFP Notice statewide using mostly larger-sized FFP Notices, but small Non-Industrial timberlands account for the majority of FFP Notices accepted by CAL FIRE; many Non-Industrial FFP Notices are small in reported size, although recent years have seen some exceptions to this fact. **However, the overwhelming majority of FFP Notices are still less than 100 acres in reported size, despite the 300-acre size limit**. Finally, 15, 56, and 85% of FFPs were within 10, 25, or 50 miles of biomass facilities, while 23, 67, and 88% of FFPs were within 10, 25, or 50 miles of active sawmill facilities, with greatest proportions of FFPs within some proximity of biomass or sawmill facilities in the Cascade and Coast Forest Practice Areas.

Monitoring randomly selected 44 FFP Notices across the state from 78 Notices that were accepted by CAL FIRE between March 1, 2019 and July 31, 2020, **in order to achieve an outcome with a 95% confidence level and 10% margin of error in population-level results. The sample was 41% Industrial timberland FFPs, and 59% small, Non-Industrial timberland FFPs, reflective of annual distributions**. The majority of sampled FFPs were in the interior of California, either in the Cascade or Sierra Forest Practice Areas, followed by 36% in the Coast Forest Practice Area. Finally, as monitoring is required to be an inter-agency endeavor, the California Department of Fish and Wildlife attended 80% of monitoring visits, Regional Water Quality Control Boards attended 50% of the sample, and the California Geological Survey (who are not required to be part of monitoring by legislative Statute, but participate in Forest Practice Review and EX/EM monitoring) attended 70% of the sample.

Monitoring was rapid and objective, with quantitative, binned quantitative, and qualitative measurements, across objectively located plots and locations on each FFP Notice, with sampling intensity based on the size of the FFP. Almost all FFP Notices reported harvest and removal of substantial volumes of timber (> 25 thousand board feet). FFP Notices rarely indicated exceptions to remove timber within a watercourse lake protection zone on a Class I or II fish bearing stream ("WLPZ"). **A total of 48% of the sample reported being adjacent to a "Community at Risk" or permitted structures (i.e., residences)**, with 62% Non-Industrial FFP Notices being adjacent to these communities and structures, compared to only 28% of Industrial FFP Notices. However, only 23% of FFP Notices occurred in areas with housing density fitting the requirement of Wildland Urban Interface ("WUI") and/or Intermix.

Water quality related outcomes on FFP Notices were generally positive for roads, road-watercourse crossings, and watercourse protection. Of the 66 road segments assessed in monitoring, 6% had a sediment discharge, found on four (4) or 9% of sampled FFP Notices. Sediment discharges were generally associated with lower standard roads that were poorly maintained, and all roads with a discharge had native surfacing (used underlying soils as the road surface). **On Non-Industrial FFPs, 28% of assessed roads also doubled as residential access roads (i.e., driveways) as well**. **Additionally, temporary road construction or re-construction on FFP Notices was found on <u>only 18% of the sample</u>**, similar to an internal review of 101 FFP Notices from a 22-month period where 17% of all FFP Notices planned temporary road work. None of the sampled temporary roads violated associated construction prohibitions, and none resulted in a sediment discharge.

Watercourse crossings were found on 64% of the sample. Generally, the majority of crossings had stabilized fills, indicating less potential for erosion. The potential for diversion, or for a channel to divert onto a road prism and run downslope, before realigning with the original channel (and risking significant water quality impacts), was found on 30% of sampled crossings, with most of these occurring on Non-Industrial lands. Additionally, 62% of the crossings with diversion potential were also unable to freely pass water and debris, or in need of immediate maintenance. Overall, 56% of the watercourse crossings had some level of sediment discharge present, found on 61% of the FFPs that had crossings. **Of the discharges, 79% were less than one cubic yard, indicative of likely low-magnitude sediment delivery**. Where more substantial sediment discharges were observed on crossings, **observations indicated causal factors were related to initial improper road and crossing design, a lack of or minimal maintenance, and a failure to utilize appropriate best management practices ("BMPs") relative to site specific conditions**. Where sediment discharges occurred, they were related to road drainage, and typically found on pre-existing, non-upgraded crossings.

Classified watercourses were found on 66% of the FFP sample, for a total of 44 assessed watercourses. Sediment discharges to watercourses on FFPs in our monitoring were very limited in occurrence; four (4) sediment discharges were observed, occurring on two (2) FFPs. Of note is that one of these discharges was a minor less than one cubic yard discharge, on a Class III tractor crossing, while the remaining discharges were more significant in estimated volume. These occurrences were related to tractor operations (i.e., log skidding) within equipment limitation zones, on watercourse segments with substantial equipment encroachment. **Harvesting within Class I or II WLPZ areas, or in Class III or IV overhead canopy, was either absent entirely, or extremely limited in extent**. Temporary Class III tractor crossings were found on 20% of the FFP sample, the majority of which (77%) were appropriately removed and treated after operations.

Harvested areas generally had high surface cover, downed wood present, and standing dead trees greater than 8 inches, indicating that a variety of habitat elements were present on most Notices. Average post-harvest slash depth across the sample was 2 inches, with the highest slash depths (5 inches) occurring in coastal redwood and Douglas fir forests. **Fixed plots and fuel transects generally showed that slash wasn't horizontally continuous, with the exception of some sites within the higher biomass (e.g., Redwood and Douglas Fir forest types) Coast Forest Practice Area**. However, sixty-one percent of Notices had instances where slash exceeded the maximum requirement of 18 inches. Generally, the slash was one inch or less in size (i.e., 1- to 10-hour fuels).

The canopy closure requirements for FFP vary by forest type and proximity to structures (see §1052.4(d)(3)(B)(1)), and rapid monitoring methods were not accurate enough to definitively determine compliance with these requirements. However, monitoring suggested that 39% of Notices may have not met canopy closure requirements, with the majority of departures occurring in drier mixed conifer and east side pine forest types in the Cascade (39% met the requirement) and Sierra (33% met the requirement) Forest Practice Areas ("FPAs"). Overall, the Notices that did not meet the requirement averaged a 13% departure from the required canopy closure metric. Canopy closure was best explained by the percent of trees in crown contact (R^2=0.55). Observations also indicated that average forest stand diameter mattered when it came to meeting canopy closure requirements, with small diameter stands often unable to meet requirements.

Fixed plots were assessed for the proportion of space occupied by ladder fuels, and 71% of the plots had one-third or less of the plot area occupied by ladders fuels, and only 5% of plots had ladder fuels occupying two-thirds or greater of the plot area. The plots with lowest spatial coverage of ladder fuels generally had ladder fuels less than 2 feet in height, whereas the plots with largest spatial coverage of ladder fuels generally had ladder fuels in excess of 5 feet in height. Mastication greatly decreased the horizontal and vertical continuity of ladder fuels. When comparing the height of ladder fuels to the crown base height of residual trees, FFPs averaged 22% of the residual trees with vertical continuity from surface fuels to crown fuels. **Stands composed predominantly of 10-15 diameter classes had preferentially high vertical fuel continuity, indicating the difficulty of effectively treating smaller diameter "plantation" type stands.**

Across the entire sample, average distance between trees increased an average of 66% between pre-treatment (geometric mean distance of 6.6 feet) and post-treatment conditions (geometric mean distance of 11 feet). Industrial timberland had a significantly higher pre-treatment and post-treatment tree spacing than non-industrial timberland, although the change in tree spacing did not significantly differ between ownership types**. In general, the smaller diameter size classes (e.g., 10-15 inch) had larger post-harvest increases in spacing than higher diameter size classes.**

The quadratic mean diameter (QMD) of conifer species eight inches or greater was increased on all but one FFP Notice, and the single instance of a decrease was 0.1 inches; when including hardwood species, that FFP Notice increased QMD. In general, there were larger QMD increases on Non-Industrial timberland vs. Industrial timberlands, but these increases were not statistically different between ownership types. Although intuitive, the largest QMD increases occurred in the largest diameter stands. Out of 1,457 sampled trees that were harvested, only eight stumps (0.5%) were measured as 30 inches or larger eight inches above the ground. This indicates that the 30-inch maximum diameter limit stated in the California Forest Practice Rules (FPRs) was seldomly exceeded, and is consistent with the relatively low frequency of violations issued for this particular FPR requirement.

In terms of generalized forest structure change, QMD size class and Wildlife-Habitat Relationship (WHR) classes either remained static or increased, with 39% of the sample increasing QMD size class, while 17% increased in WHR class. Over 75% of the harvested conifer trees were 20 inches or lower in diameter, with conifers exceeding 15 inches in diameter representing 53% of the residual (remaining) trees. **Across Industrial and Non-Industrial landowners, the overwhelming focus was on removing smaller diameter trees (< 10-inches), while maintaining larger diameter trees (>20-inches)**.

Basal area was generally higher on Non-Industrial ownerships, both before and after harvest, when compared to Industrial ownerships. When evaluating FFP Notices for the ability to meet basal area and trees per acre requirements, 30% of the sample failed to meet at least one of these requirements. Despite this, these Notices showed no decrease in QMD, and in most cases an increase in QMD. Also, distance between trees increased an average of six feet on these FFPs.

As expected, tree density decreased following treatment. Trees per acre pre- and post-treatment were higher on Non-Industrial timberlands, and had significantly more hardwood trees per acre. Stand density index ("SDI") for conifers was reduced by 35%, and SDI for both conifer and hardwoods was reduced by 36%. SDI was lower pre- and post-harvest on Industrial ownerships, although Non-Industrial ownerships had the largest changes in SDI following harvest. Coastal forests had the highest SDI following harvest. On average, over one-third (38%) of the harvested trees across the sample population were targeted towards shade tolerant species, which serve as potential ladder fuels in interior forest types.

While the ability to meet the varying regulatory requirements of the §1038.1 was mixed, the sampled Notices generally followed the basic principles of fuels reduction outlined by Agee and Skinner (2015) of: 1) reducing surface fuels; 2) increasing the height to the live crown base; 3) lowering the density of trees; and 4) retaining the largest and most fire-resistant trees. These principles were successfully implemented on Notices within the interior and east side forests. In wetter, coastal forests, tree density and ladder fuels were decreased, but often at the expense of increased surface fuels. Overall, these treatments targeted the smallest diameter classes, thereby removing the most fire susceptible trees.

Despite the increasing use of FFP Notices, less than one-quarter of them are located in areas fitting the definition of WUI and/or Intermix. There is great promise for strategically co-locating FFPs with structure-centric exemptions such as the 0-150 (§1038(c)) and 150-300 foot (§1038(c)(6)) fuel hazard reduction exemptions, with FFP treatments constituting the matrix between structure-specific treatments. **Advocating for the strategic use of the FFP exemption, alongside other exemptions, has the potential for facilitating the use of pyrosilviculture, as well as increasing the resiliency of communities to wildfire, and increasing overall watershed resiliency**. The numeric FFP requirements related to canopy and stocking might be too constraining, especially when treating younger, even-aged stands. As such, there is opportunity to simplify FFP, so that emphasis is placed on the basic principles of fuels reductions. However, guidance is necessary to help achieve this outcome. There is also opportunity to increase the performance of roads and watercourse crossings associated with FFP activities.

Recommendations from this report include:

1. Incorporation of strategic planning into the implementation of Forest Fire Prevention Exemptions.
2. The development of maintenance plans for treated FFPs to maintain these areas in a fire resilient state.
3. Consider the introduction of prescribed fire for select FFPs to increase the pace and scale of pyrosilviculture.
4. Seek funding for Non-Industrial landowners to upgrade native surface roads and watercourse crossings associated with FFP Notices.
5. Improve guidance on surface and ladder fuel treatments, particularly in the higher biomass areas of Coast District.
6. Revisit canopy closure metrics, and determine if more appropriate regulatory limits exist based on stand conditions.

7. Revisit stocking standards using the best available research in relation to potential fire behavior and forest resiliency, while explicitly considering the role of hardwoods in forest stands.

Recommendations six (6) and seven (7) will require potential revision of statute (Public Resources Code, Section 4584).

Acknowledgements

Thanks are owed to all landowners for allowing access to the Exemption projects involved in this monitoring, and the Registered Professional Foresters and Licensed Timber Operators involved for sharing their perspectives and providing valuable information. Additionally, input in the field from CAL FIRE Unit Forest Practice Inspectors, and staff from the Department of Fish and Wildlife, Regional Water Quality Control Boards, and California Geological Survey, was appreciated.

This report would not be possible without the substantial efforts in the field of the CAL FIRE Exemption and Emergency Monitoring Specialists and Watershed Protection Program staff.

Ross Mathewson, ***Michael Novak***, ***Ethan Gicker***, ***Peter Smith***, ***Dorus Van Goidsenhoven*** (now with the Nevada-Yuba-Placer Unit, Forest Practice Inspector), and ***Roberta Lim*** (Senior Environmental Scientist, CAL FIRE Forest Practice Biologist) primarily conducted the field work. Additionally, the assistance in the field from the Department of Fish and Wildlife, Regional Water Quality Control Boards, and the California Geological Survey was greatly appreciated.

Field protocol was developed by the CAL FIRE Watershed Protection Program staff, with input from the CAL FIRE Exemption and Emergency Monitoring Specialists and other Review Team Agencies. Pete Cafferata (retired Forester III, CAL FIRE) also assisted with protocol development and initial field work. Will Olsen undertook the majority of protocol development, data analysis, and report writing, with substantial input on canopy cover/closure methods and analysis from Roberta Lim, and input and report revisions from Drew Coe. Additional input and revisions came from CAL FIRE Forest Practice and Executive Staff., and external Review Team Agencies.

Introduction

- **Historically, wildfires were widely and frequently present in California forests, largely burning at low to moderate severity, often removing the smallest trees, along with understory vegetation and surface fuels. Recent years have seen an increasing trend in the occurrence and extent of high severity wildfire, in addition to an overall increase in spatial extent of wildfire.**
- **California wildfires are presently strongly influenced by both climactic stressors (vapor pressure deficit, drought, temperature), and forest density and fuel loading issues due to past fire suppression and legacy forest management.**
- **Research has shown California forests, in particular dry, inland conifer forests, can be managed to increase resiliency to severe wildfire and other stressors, through restoration to appropriate conditions for fire regimes, especially when specifically combined with ladder fuel treatments and prescribed fire following forest thinning and surface fuel treatments.**
- **On non-Federal private timberland in California, landowners have options to manage their forests outside of the traditional Timber Harvest Plan process via non-discretionary exempt timber harvests that follow specific guidelines, including the §1038.3 "Forest Fire Prevention" Exemption.**

Wildfires in California Forests

Wildfire is no stranger to the forests of California, where historically an estimated 4.5 million acres burned annually across all habitat types in the state (Stephens et al., 2007). Subsequently, modern fire suppression efforts substantially limited wildfire extent in the last century from the historic levels that the forests were adapted to in California (Steel et al., 2015, Murphy et al., 2018).

Research has also shown that the **patch size** of stand-replacing **high severity wildfire** in the Sierra Nevada and Cascade mountains of California has increased (Miller et al., 2009, Stevens et al., 2017), particularly within "*fuel-limited*[9]" ecosystems (i.e., dry inland mixed conifer forests; Steel et al., 2015).

A decade ago, modeling exercises predicted forested areas in California could experience a median increase in burned area of 15-19% by 2020 (Westerling et al., 2011). Climate change and historic drought have added to the susceptibility of California's forests to extensive wildfire, particularly due to the impacts of **increasing vapor pressure deficit** (i.e., atmospheric aridity), or the *amount of water absorbed by the atmosphere from plants and soil* (Williams et al., 2019). Presently, "**megafires**" (>100,000-acre fires) have become a norm, with **21 such fires in the last five years**, while the August Complex brought the first modern "**gigafire**" (>1,000,000-acre fire) in 2020, followed by the 2021 Dixie Fire as a singular, nearly one-million-acre (960,000 acres) wildfire.

[9] "Fuel limited" refers to areas where climatic conditions during fire season are always conducive to burning. Fire ignition and spread is therefore dependent on the presence of fuels. Fire suppression has made fuels abundant in these "fuel limited" ecosystems.

Research has highlighted the impacts of greater **vapor pressure deficit**, helping **drive fires to grow faster and larger than previously documented**, and increasing overall burned area (Juang et al., 2022). Recent research has also indicated wildfires are burning with greater intensity at night, even outpacing daytime burning on a relative scale (Freeborn et al., 2022). Statewide, 10 of the top 20 largest modern wildfires in California have occurred in *2018*, *2020*, and *2021* (CAL FIRE, 2022a), and the combined fire seasons of 2020 and 2021 involved over **6.8 million acres** of burned area (CAL FIRE, 2022b) (Figure 1). Additionally, human-caused fire ignitions (arson, power lines, vehicles) have dominated wildfire-causes in California, alongside natural ignition sources (lightning) (Keeley and Syphard, 2018), with human-caused wildfires burning across both public and private lands (Downing et al., 2022)

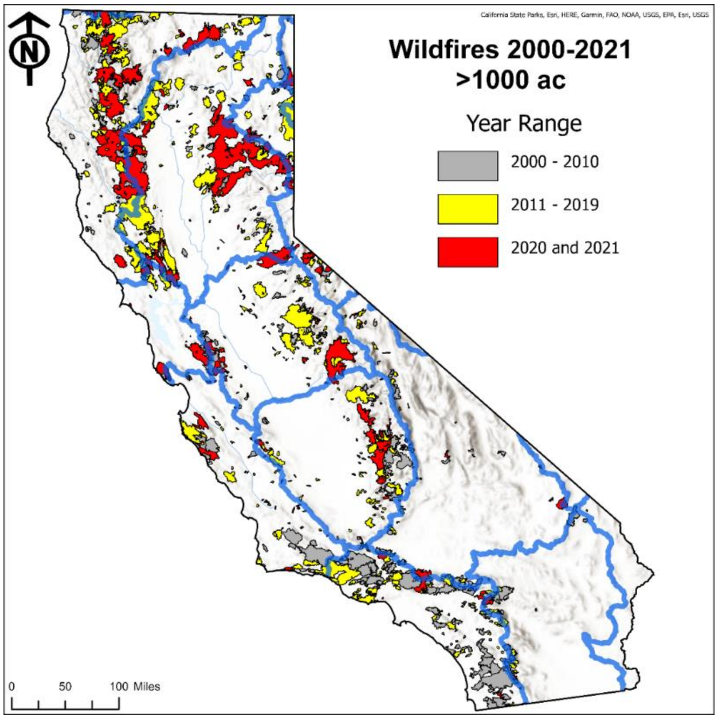


Figure 1: *Wildfires in California over 1000 acres in size, from 2000 through 2021. Fire color indicates time-period of occurrence, blue lines indicate major California watersheds.*

The 2020 fire season was exceptional not just in fire size and occurrence, but in severity as well, with a **greater extent of high severity fire in forested ecosystems than previously recorded**, at nearly 750,000 acres (Safford et al., 2022). The 2021 Dixie Fire alone accounted for potentially over 500,000 acres of high severity fire in forests (RAVG, 2021), and watershed impacts of over 500,000 acres of ***soils*** burned at moderate and high severity (USDA Forest Service, 2021), likely impacting the California State Water Project. The Dixie Fire also demonstrated the effects of previous wildfires, and the **ecological memory of the landscape in reburns, with previously intensively burned areas re-burning intensively again; in fact, areas of high burn severity reburned at a greater severity than previously unburned areas** (Taylor et al., 2022).

Forest Management and Wildfires

While practitioners and researchers have focused on the role of forest management to reduce fire hazard and promote resiliency[10] of forests, recent wildfires and tree mortality events in California have increased interest from both forest landowners and the public.

Within <u>frequent-fire type forests</u>, from Agee and Skinner (2005), basic principals in forest management and fuel reduction are:

- ***Reduce surface fuels***
- ***Increase the height to the live crown base of a tree***
- ***Lower the density of trees***
- ***Retain the largest and most fire-resistant trees and species***

Consequently, **stand type matters**, as effective fire hazard treatments in **biomass heavy forests** that historically had stand-replacing events are more climate-limited; that is, they are often wet, west side forests (e.g., coastal forests) that burn under non-normal, exceptionally dry, wind driven conditions, and are more difficult to mechanically treat (i.e., via tree harvest) (Halofsky et al., 2018). Further, the choice of specific operations during treatment implementation can impact post-harvest outcomes relative to fire hazard (e.g. whole tree yarding versus lop and scatter or leaving tree limbs and tops within harvest units), including if the use of prescribed fire occurs (Agee and Skinner, 2005, Skinner et al., 2005).

Recent research has indicated that many frequent-fire forests in California are six to seven times denser than a century ago and consist of trees 50% smaller than were present historically (North et al., 2021a). Fire exclusion, past management practices, or both factors, have led to a need for fuel reduction in many forest stands that may also align with forest restoration, either to minimize wildfire impacts, minimize drought and insect stressors, and/or to allow reintroduction of prescribed fire (Stephens et al., 2020). Research within frequent-fire forests within National Forests in California found that when **surface and ladder fuels were treated concurrently with forest thinning**, extensive canopy fire and tree mortality were reduced, and fire within the canopy of untreated areas was almost always **reduced to surface fire within 200 feet of entering treated stands** (Safford et al., 2012).

However, research has indicated that in recent years **high severity wildfire** has increased in probability in industrial forests, possibly due in part to forest density and the ability of crown fire to initiate or be sustained in these stands (Levine et al., 2022). Meanwhile, **small non-industrial forest owners** may not have the resources or land base to make forest thinning and restoration **within the Timber Harvest Plan (“THP”)**

[10] This report will refer to “resiliency” as a catch-all term promoting the ability of a forest to experience wildfire and other stressors while minimizing widespread high severity fire, and thus mortality and impacts, particularly with respect to larger, older trees or those stands on the cusp of growing larger and older, in addition to preserving or enhancing ecological and watershed processes.

process economical or practical, yet account for a large proportion of non-Federal forest ownership in California, while still experiencing extensive wildfire and tree mortality impacts.

Within the Forest Practice Rules ("FPRs") there are several Exemption or Emergency Notice types that allow for fuel treatments without a THP. Previous reports by CAL FIRE focused on the §1038(c) and §1038(c)(6) Exemptions (Olsen and Coe, 2021a, 2021b) that are structure-centric (i.e., focused on treating the area around permitted buildings) in their intent and boundaries for harvesting commercial tree species for fire hazard reduction.

Figure 2: *Forest Fire Prevention before (left) and after (right) photos from Nevada County, courtesy of the Nevada Irrigation District and used with permission. The red circles highlight the same hardwood trees in each photo.*

The **Forest Fire Prevention Exemption** (Figure 2) (hereafter also called "FFP") was added to the FPRs in 2005, and has undergone various changes. The FFP existed under §1038(i) and §1038(j) initially, both as the Forest Fire Prevention and as a "Pilot" following regulatory changes. Currently the Exemption exists under §1038.3, and allows for stand-level treatments and timber harvesting of up to 300 acres, with operational constraints and a number of post-harvest regulatory requirements. The current §1038.3 iteration also allows for non-discretionary temporary road construction or re-construction of up to 600 feet, in order to facilitate operations, within certain conditions. The introductory sentence to 1038.3 states:

"…the cutting or removal of trees, limited to those trees that eliminate the vertical continuity of vegetative fuels and the horizontal continuity of tree crowns for the purpose of reducing flammable materials to reduce fire spread, duration and intensity, fuel ignitability, or ignition of tree crowns…."

As such, the FFP is meant to exist as a tool for Registered Professional Foresters (RPFs) and timberland owners to **undertake forest thinning outside the bounds of the THP process** in stands less than 300 acres in size to address overstocked stands and promote forest restoration and resiliency (Figure 2, Figure 3).

Figure 3: *Pre (top) and post (bottom) photos from Trinity County, of a Forest Fire Prevention Exemption accepted in 2016 on industrial timberland. Note the leaf/canopy seasonal change in hardwoods outside the harvest boundary. Photos courtesy of Dan Craig, CAL FIRE Forester II.*

Monitoring of the Forest Fire Prevention is part of ongoing, legislatively mandated monitoring of Exemption and Emergency Notices (Figure 4), as part of the 2018 Senate Bill 901 and other legislation. Portions of the adopted law includes (bold font added for emphasis), amongst other items, provisions for monitoring such that:

> "…The department and board, in **consultation with** the **Department of Fish and Wildlife**, and the **State Water Resources Control Board**, shall…review and submit a report to the Legislature on the trends in the use of, compliance with, and **effectiveness of, the exemptions and emergency notice provisions** described in Sections 4584 and 4592 of this code and Sections 1038 and 1052 of Title 14 of the California Code of Regulations. **The report shall include an analysis of exemption use and whether the exemptions are having the intended effect.** The report shall also include recommendations to improve the use of those exemptions and emergency notice provisions…."

The inherent nature of determining "effectiveness" may be viewed in multiple ways, from the effectiveness of the Exemption in achieving the desired ***intent***, or the effectiveness of allowing for streamlined efficiency in non-discretionary forest management without detrimental ecological impacts.

As such, this monitoring effort, as with past efforts, is rapid, random, and objective in nature, and meant to capture data and information about Forest Fire Prevention Exemptions ***statewide***, and not to be an exhaustive analysis of ***individual projects***. As in past efforts, monitoring utilizes a combination of quantitative data, binned quantitative data, qualitative data, and unbiased field sampling within each Exemption, and is explicitly undertaken by the Watershed Protection Program as a non-regulatory/non-enforcement endeavor. Rather, our goal is data gathering and objective analysis, using field-oriented monitoring to inform the California Board of Forestry and Fire Protection, CAL FIRE, Review Team Agencies, licensed professionals, the general public, and finally state representatives and the Governor's Office of findings and recommendations pertinent to the §1038.3 Forest Fire Prevention Exemption.

Figure 4: *Monitoring in Shasta County in October 2021 on a 2020 FFP Exemption.*

Forest Fire Prevention Exemption Usage, Statewide

- **FFP Exemptions initially saw large numbers of spatially small Notices from 2005-2013, followed by increasing annual exemption numbers and reported acres starting in 2015.**
- **2015-2021 saw increasing numbers of FFP Notices and greater annual reported acres, indications of spatially larger Notices in some parts of the state, relative to 2005-2014.**
- **The newest §1038.3 version of the Exemption has seen a high annual number of FFPs, in addition to the highest annual reported acres being treated, of all versions of the FFP Exemption.**
- **Small Non-Industrial timberland owners represent the majority of FFP Exemptions, while large Industrial timberland owners account for the majority of treated forest acres, although that outcome varies throughout the state.**
- **Both Non-Industrial and Industrial landowners frequently use spatially small (i.e., <100 acres) FFP Notices, however Industrial owners frequently also undertake large (100-300 acre) projects with the Exemption.**
- **The FFP Exemption represents a growing proportion, and overwhelming majority of acres reportedly treated, of all wildfire-oriented Exemption and Emergency Notices available for use.**

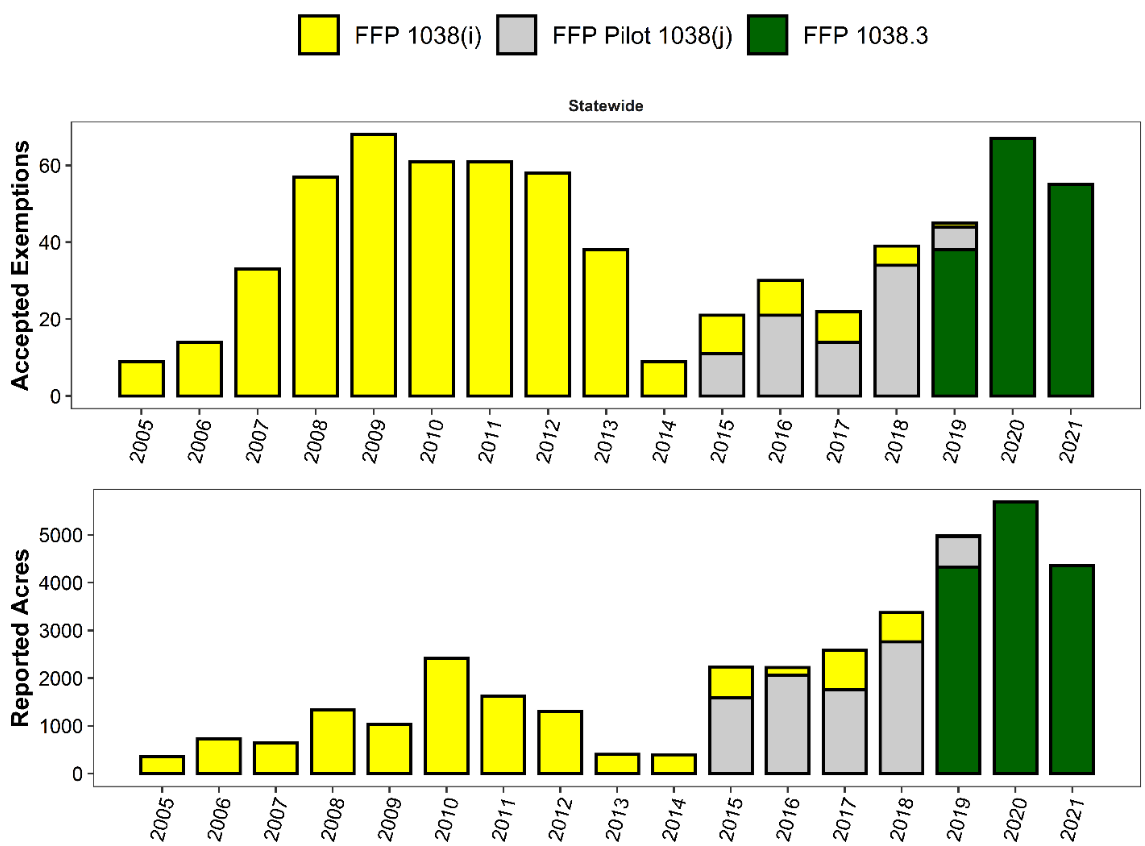


Figure 5: *Yearly Forest Fire Prevention Exemption acceptance numbers and reported acres, statewide, with colors indicating the version accepted by CAL FIRE, 2005-2021. Note the two different y-axis scales.*

The Forest Fire Prevention Exemption saw increasing numbers and moderately increasing acreage initially (Figure 5) under the first “(i)” iteration of the Exemption. The FFP “Pilot”, §1038(j), under which diameter limits and maximum allowable slash depths were both increased, saw relatively moderate usage statewide, peaking in 2018 with both numbers and acres. Since 2019, the FFP Exemption usage has increased in terms of accepted Exemptions, nearing previous usage levels seen in the early 2000’s (Figure 5), under the §1038.3 version, **while annual reported acres are the highest since the FFP Exemption was introduced.**

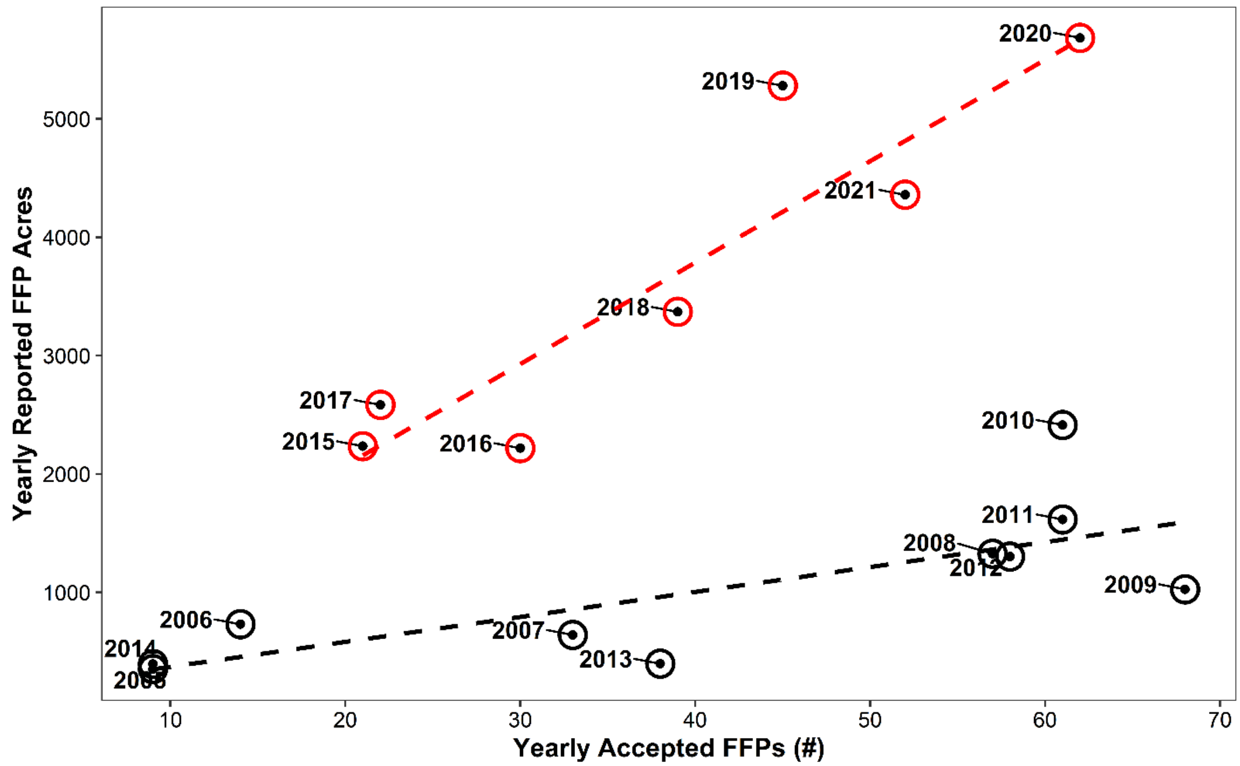


Figure 6: *Yearly accepted FFPs and reported annual acres associated with FFPs, statewide. Results are grouped by 2005-2014 and 2015-2021 periods, and each point has the associated year labeled. The dashed black line is the regression line for 2005-2014, while the red dashed line is for the 2015-2021 period.*

Starting in 2015, there has been a significant upward trend between annual FFP Exemption numbers and reported acres within FFPs (Figure 6). From 2005 to 2014, there were an average of 41 FFPs per year, accounting for an annual average of 1,020 acres (Appendix 1, Table 25). From 2015 to 2021 the annual average was 39 FFP Notices, while the **average annual acreage tripled to over 3,600 acres** (Appendix 1, Table 25). Largely, the Coast and Cascade FPAs have seen increasing FFP numbers and acreage during the latter time period of 2015 to 2021. Additionally, from 2005 to 2014, individual FFPs across the state were dominated by smaller-sized spatial footprints (Appendix 1,Table 27, Figure 74), with 74% of FFPs 25 acres or less in size. After 2015, 57% of FFPs have been over 50 acres in size, and 34% have even exceeded 100 acres in size.

Using mapped GIS boundaries of Forest Fire Prevention Exemptions between 2015 and 2021, and best available ownership type data, clear differences between small Non-Industrial and large Industrial forest owners emerge (Table 1). Statewide, approximately **61% of all accepted FFP Notices were for small, Non-Industrial landowners**, however, **54% of the reported acres on FFPs in that time period** were on **Industrial timberland ownerships** (Table 1).

Table 1: *Percentage of FFP Notices by ownership type (small Non-Industrial vs large Industrial) between 2015 and 2021, by statewide totals. Bottom, percentage of FFPs by <50 acres, 50-100 acres, and >100 acres in reported size within each ownership type.*

FFP Exemption Ownership Type, 2015-2021

	Non-Industrial	*Industrial*
Accepted FFPs *Total*	61%	39%
Reported Acres *Total*	46%	54%
FFP Size	*Non-Industrial*	*Industrial*
<50 Acres	53%	21%
50-100 Acres	22%	28%
>100 Acres	25%	51%

This observation holds for the Coast and Cascade FPAs as well, where both FPAs had 60% of the accepted FFPs on Non-Industrial ownerships and 40% on Industrial ownerships, but 56% and 54% (respectively) of the reported acres were on Industrial timberland ownerships (Appendix 1, Table 28). Meanwhile, in the Sierra FPA, 63% of FFPs between 2015 and 2021 were for small Non-Industrial timberland owners, yet 72% of the reported acres in the Area for the time period were on Industrial timberland ownership. One-hundred percent (100%) of all FFP Notices and acres in the Southern FPA were small Non-Industrial owners (Appendix 1, Table 28).

Within the Coast FPA, 2020 and 2021 saw a larger percentage of FFPs being for small Non-Industrial owners, which has also held true for reported acres (Appendix 1, Table 28). Meanwhile, in the Cascade FPA, 2020 and 2021 saw 71% and 68% of FFPs being for Non-Industrial timberland owners, respectively, while 53% and 56% of reported acres in 2020 and 2021 were on Non-Industrial timberlands (Appendix 1, Table 28).

The implication being that while accepted FFP Notices from **small Non-Industrial landowners** dominated **submitted numbers of Notices**, **reported acreage** is dominated by **large Industrial landowners, with a potential shift to a Non-Industrial majority in the last two years**. A total of 53% of FFP Notices on small ownerships were under 50 acres in reported size, and 22% were 50 to 100 acres, indicating that 75% of FFPs on Non-Industrial ownerships were less than 100 acres in size (Table 1). Conversely, on Industrial timberland ownerships, 51% of FFPs involved 100 acres or more, while only 21% of FFPs on Industrial ownership between 2015 and 2021 were under 50 acres in size (Table 1). **However, the last two years of FFP Notice usage may indicate a shift towards popularity not only with Industrial timberland owners,**

but also an increasing *proportional* popularity with small, Non-Industrial timberland owners (Appendix 1, Table 28).

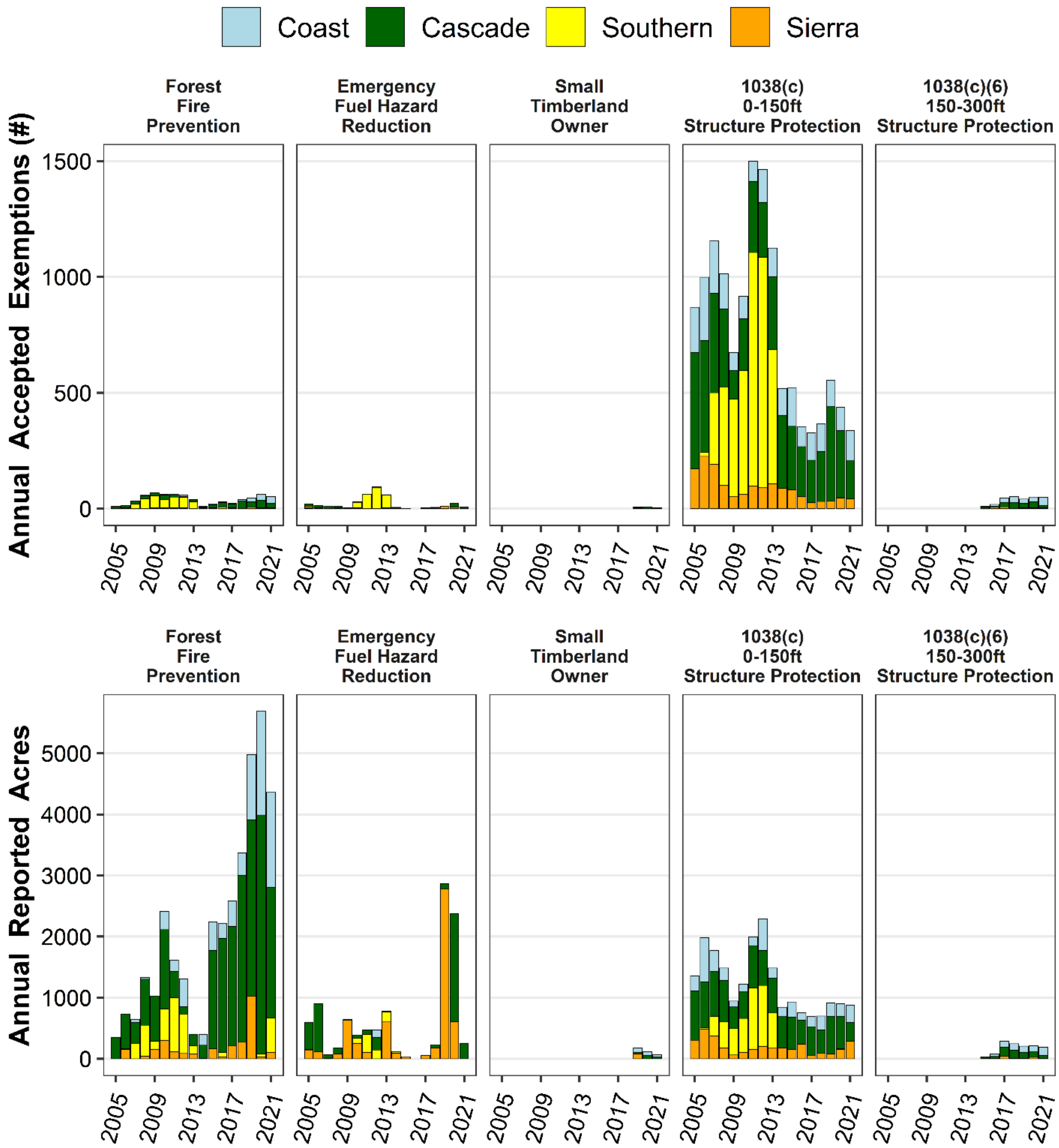


Figure 7: *Statewide acceptance numbers and reported acres for 2005 to 2021, for the wildfire-forest treatment related Notice types. Bar colors indicate the FPA of the Exemptions each year.*

Finally, amongst the Exemption and Emergency documents that have a more wildfire hazard-related specific intent, the Forest Fire Prevention, §1038(c) and §1038(c)(6) structure centric, and Small Timberland Owner Exemptions, in addition to the Emergency Fuel Hazard Reduction Notice, clear differences emerge. While other EX-EM types may influence potential fire behavior (e.g., removal of standing dead trees under the Drought Mortality Exemption), they do not have explicit expectations relative to treating fuels that influence fire behavior. Statewide, between 2005 and 2021 (acknowledging that some EX-EM types have either only recently been introduced or have gone through regulatory changes), **it is clear that the FFP Exemption is now beginning to account for the overwhelming majority of reported treated forest acres in the state via timber harvesting through Exemptions and Emergencies** (Figure 7). Substantial Exemption numbers and reported acreages in the Southern FPA in Figure 7 reflect grant funding for forest treatments previously made available to the public that were used extensively in southern California (Olsen et al., 2019a).

For detailed Exemption acceptance information, please see Appendix 1 **Forest Fire Prevention Exemption Usage, Inspections, and Enforcement**

Study Area, Sample, and Field Methods

- **Forty-four (44) Forest Fire Prevention Notices were randomly selected from an eligible pool of 78 §1038.3 Exemptions (56% sampled), resulting in a statewide random sample that achieved a 10% margin of error with a 95% confidence level for population-wide results.**
- **Field monitoring was rapid and objective, and sampling intensity was based on the reported size of each FFP Notice. Measurements were focused on residual and harvested trees, canopy closure, sub merchantable trees, ladder fuels, canopy base heights, habitat features, harvest-related slash, roads, road-watercourse crossings, watercourse segments, Class III tractor crossings, and temporary road construction and reconstruction.**
- **Fish and Wildlife, Regional Water Quality Control Boards, and California Geological Survey participation in monitoring efforts ranged between 50-80% of the sample.**

Study Area and Sample

We randomly sampled 44[11] Forest Fire Prevention Notices from a statewide group of 78 eligible FFP Notices that CAL FIRE accepted between March 1st, 2019, which was when the §1038.3 version of the Exemption became available, and July 31st, 2020. The latter end date was chosen in order to ensure operations and over-wintering had a chance to occur before monitoring commenced in mid-2021. The final random sample, shown as red dots in Figure 9, resulted in 39% of the sampled Notices being in the Coast FPA (n=17), 54% in the Cascade FPA (n=23), 2% in the Southern FPA (n=1), and 7% in the Sierra FPA (n=3). Our random sample achieved a 10% margin of error at the 95% confidence level, for population-wide results. A visual representation of what this means is shown in Figure 8.

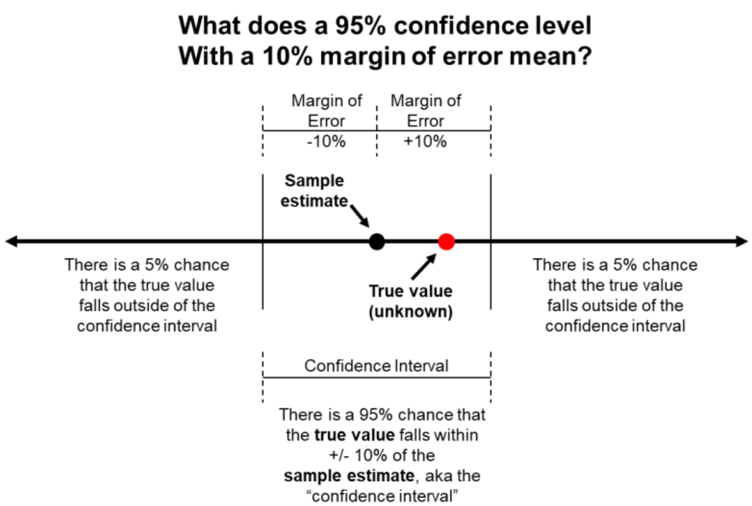


Figure 8: *Visual representation of the confidence level and margin of error used in the study design.*

The mean reported size of our FFP sample was 115 acres, ranging from six to 299 acres in size. Fifty-five (55) percent of the sample were FFPs under 100 acres in size. Small Non-Industrial timberland FFPs averaged 96 acres in reported size, while Industrial timberland FFPs averaged 145 acres in reported size. **Industrial timberland owners**

[11] In one instance, upon arriving to an FFP Notice in the Cascade FPA, and during field work, it was discovered that the 2019 FFP Exemption was not operated on *under that Notice*, but instead the exact same harvest boundary *was* operated on using an identical 2020 FFP Exemption, that was accepted by CAL FIRE in October 2020. In one other instance, during field monitoring it was found that a 2019 FFP Notice footprint was partially cut in 2019, and fully completed shortly after using subsequent 2020 Exemptions on the *exact* same footprint. It is our professional opinion that these instances do not alter the integrity of the random sample.

comprised 41% of our sample, with 50% of these FFPs in the Cascade FPA and 39% in the Coast FPA. **Non-Industrial FFPs accounted for 59% of our sample.** Fifty-four (54) percent of Non-Industrial timberland FFPs were in the Cascade FPA, while 38% were in the Coast FPA. Just under 8% of small Non-Industrial timberland FFPs were in the Sierra and Southern FPAs.

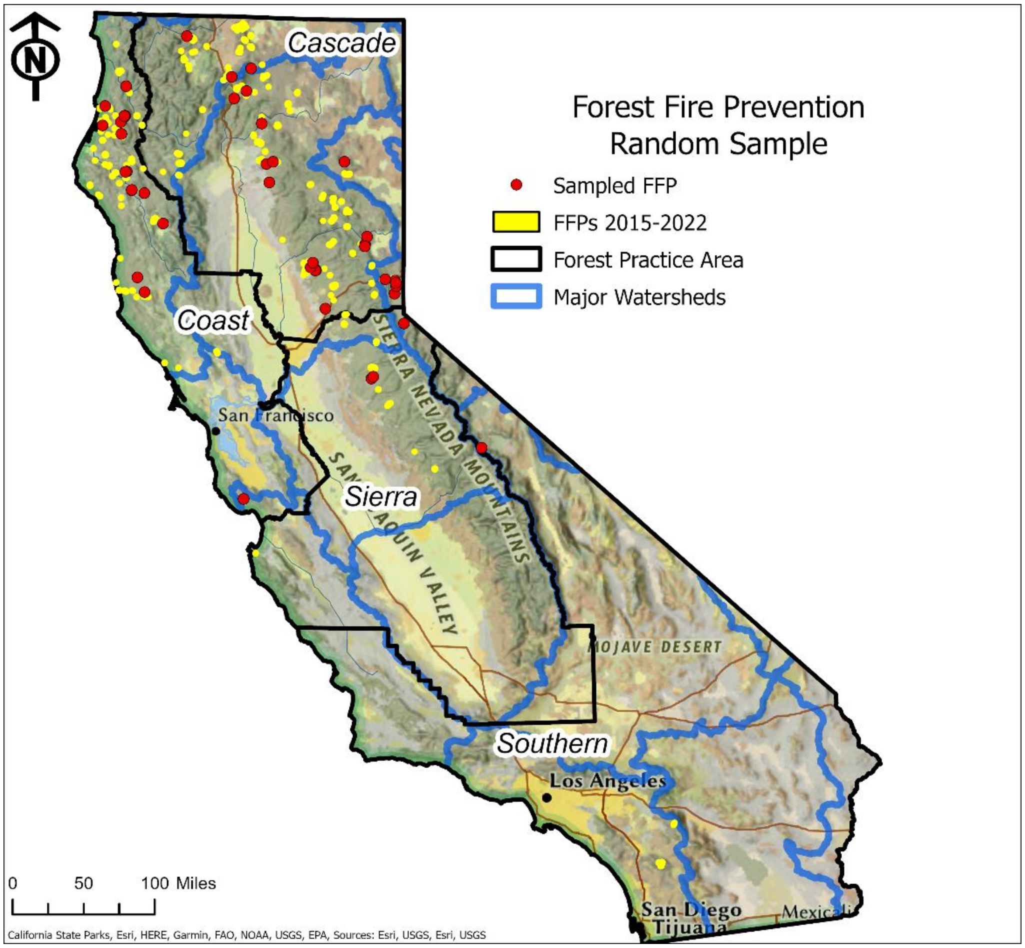


Figure 9: *Randomly sampled FFP Notices between 2021 and 2022 (red dots), and other FFP Notices accepted by CAL FIRE between 2015 and 2022 (yellow dots, GIS data accessed June 2022). Forest Practice Areas and major watersheds of California also shown.*

The number of months between CAL FIRE acceptance of an FFP Notice and subsequent monitoring of the Notice ranged between 12 to 37 months, with an average of 24 months, or two years, between acceptance and potential start of operations, and monitoring. The timeframe between Exemption expiration and monitoring averaged twelve months, ranging between one and 25 months. **As such, monitoring captured a range of post-harvest settings, from immediately post-expiration to over two years after the Exemption expiration and operations.**

Excluding an initial internal CAL FIRE pilot FFP Notice monitoring, and a second FFP Notice inclusive to only CAL FIRE and the Department of Fish and Wildlife (DFW), all other monitoring efforts were open to full interagency participation amongst DFW, the Regional Water Quality Control Boards (RWQCB), and the California Geological Survey

(CGS) (although legislation does not require CGS to participate). **Joining CAL FIRE Exemption-Emergency Monitoring Specialists' was DFW for <u>80%</u> of the sample, RWQCBs for <u>50%</u> of the sample, and CGS for <u>70%</u> of the sample.**

Field Methods

For each randomly selected FFP Notice, a "centroid" or centermost point *within* the mapped harvest boundaries was determined in GIS. This center most point was used to determine the nearest (as present) road-watercourse crossing on an appurtenant road either within or adjacent to the FFP (as long as within the same ownership), and tiered off of this crossing a road and watercourse segment was sampled. In absence of a watercourse crossing, rule-based criteria within the protocol were used to determine watercourse and road segments to be assessed (when present). Additionally, monitoring assessed Class III tractor crossings and temporarily constructed or re-constructed roads.

Each FFP Notice was split into spatially even-sized "blocks" in GIS, based on the reported acreage on the FFP, and each "block" had a centroid point delineated in GIS (Figure 10). FFPs less than 40 acres were split into three blocks, Notices 40 to 80 acres in size were split into four blocks, and those Notices over 80 acres were split into five blocks. For FFP Notices over 80 acres, two road-watercourse, road, watercourse, Class III tractor crossings, and temporary road segments were assessed (as present).

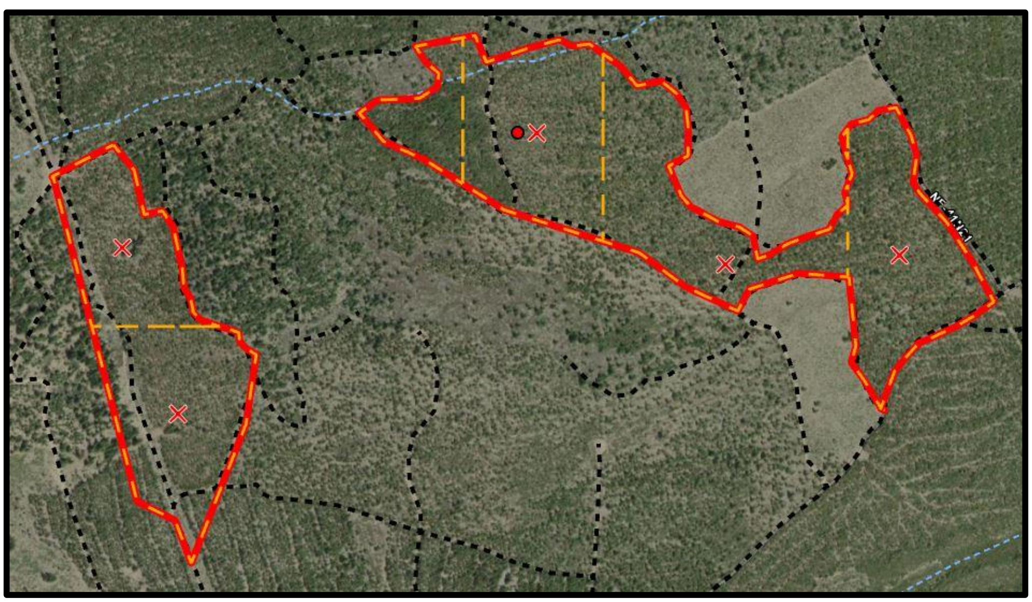
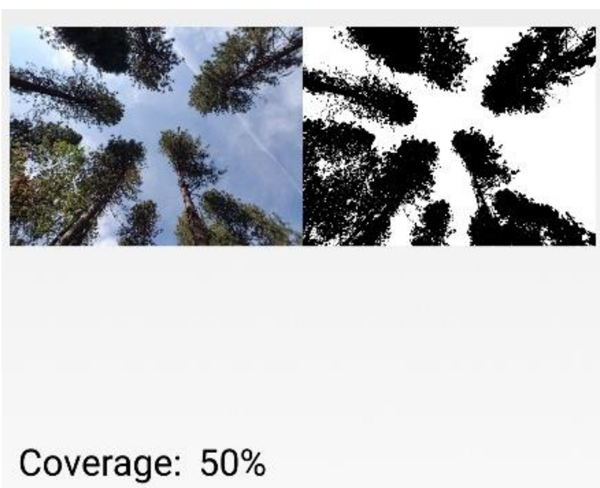


Figure 10: *An FFP example of sampling on a Notice over 80 acres in size, with the GIS mapped boundaries shown (red solid line), plot centers shown by red x's, and the centroid shown by a red dot. Orange dashed lines indicate "block" boundaries.*

The block centroid points were used for placing 1/10th acre fixed-radius plots and 200-foot slash transects. Fixed plots assessed residual trees and stumps 8" diameter or larger, tree species, presence/absence of habitat features, and sub-merchantable residual trees and stumps. Slash transects used a modified Browns transect approach and were placed 100 feet in each direction from plot center, with data recorded every four feet on *harvest-related slash* depth, and *harvest-related* standard fuel size class presence/absence (1 hour, 10 hour, 100 hour, 1,000 hour, and 10,000 hour fuels).

Last, each plot recorded four separate **canopy closure**[12] measurements using a smartphone-based app (HabitApp), at approximately 37 feet out in each cardinal direction. We opted to use a smartphone-based app approach to estimate canopy closure, as it was rapid, involved less bias than other traditional methods, field-based, and recorded images for later reference (as needed). Comparisons of the app, concave spherical densiometers, site tubes, and remotely sensed data indicated that the app-based approach yielded closure results at the lower end of all methods and below “cover” measurements, but also consistent results, including identifying overhead canopy gaps accurately. Analysis indicated that the HabitApp did best in homogenous stands, that were fully treated, and captured consistent results in low canopy ‘cover’ stands. Areas with dense overhead canopy cover (viewed from above), were not captured as uniformly by HabitApp, as all incoming light was captured. Further, “closure” values with HabitApp were more variable in younger even-aged (i.e., plantation) type stands.

While these measurements in a regulatory, enforcement, or detailed scientific approach will likely require established hemispherical photography methods, for this monitoring we feel the results are representative of post-harvest field conditions. Further discussion on the use of this new, novel approach for rapidly quantifying canopy closure is discussed in Appendix 2.



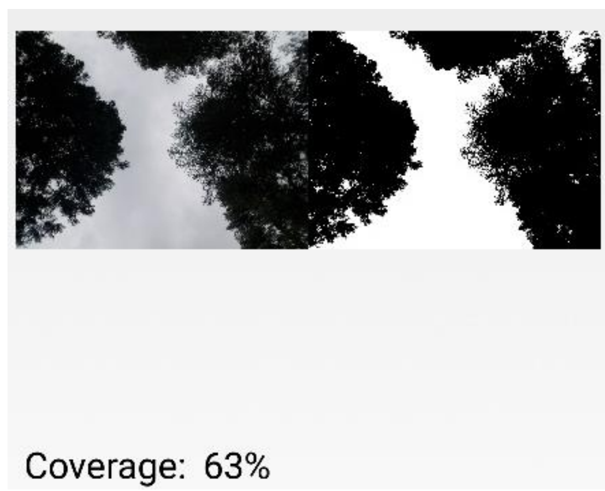


Figure 11: *Examples of canopy closure measurements within the smartphone-based app.*

[12] Canopy closure, which is the canopy regulation language used in the FFP Exemption, is the amount of sky and overhead sunlight obscured by overhead cover, as viewed from the ground surface at a single point, looking in all directions; it can be influenced by vegetation height and type. Canopy cover, however, is the presence of overhead cover in a vertical measurement (looking up or down).

Results

General Forest Fire Prevention Exemption Characteristics

- **The FFP Notice generally reported larger timber volume removal, and very few FFP Notices indicated a watercourse lake protection zone exception to harvest trees in the zone.**
- **Timber stands were mainly marked by RPFs and/or their Supervised Designees, with only 32% of the sample having marking done by RPFs only. On only small Non-Industrial timberland FFPs, 50% of the marking in the sample was done only by RPFs.**
- **Most FFP Notices utilized harvest tree marking (marking only trees to be harvested), with 73% of Non-Industrial timberland FFPs using this approach to tree marking.**
- **Only 36% of the FFP Notice sample used timber marking across the entire harvest area, while various sample marking approaches (i.e., guidance to LTOs for trees to harvest or leave only on a small portion of the project area) accounted for 64% of the sample.**
- **The majority of FFPs involved harvesting of mixed conifer, Douglas Fir, and east side pine/conifer stands, with many stands reportedly on site class II or III ground.**
- **Less than half of FFP Notices were proximal to listed "Communities at Risk", with small Non-Industrial FFPs more frequently with this differentiation.**

Reported Timber Removal

Over 90% of sampled FFP Notices reported the removal of 25 thousand board feet (MBF), indicative of the greater timber volume removal intensity under this type of Exemption, and this observation was true for both Industrial and Non-Industrial timberland owners. In only six instances did an RPF indicate a WLPZ exception for harvesting and removal of dead or dying timber within a Class I or II watercourse.

Timber Stand Marking

According to the Notice form, RPFs and/or their supervised designee(s) reportedly marked timber stands for 64% of the sample, while in 32% of the Notices only an RPF marked the stand, and in 5% of our sample only a Supervised Designee marked the stand. For Industrial timberland FFPs, 94% of the timber marking was done by both the RPF and a Supervised Designee, **while Non-Industrial timberland FFPs saw 50% of the stand marking done by an RPF only**.

Table 2: *Methods used by RPFs to mark timber stands in FFP Notices, for the entire sample and by ownership type. Columns may not add up to 100% due to rounding.*

	All FFPs	Non-Industrial FFP	Industrial FFP
Entire Area	36%	42%	28%
Sample	18%	19%	17%
Sample – 10%	32%	35%	28%
Sample 20 ac/type	7%	0%	17%
Sample, Both	7%	4%	11%

The majority of projects utilized harvest tree marking (i.e., marking trees to be cut down and removed), while 36% of the sample used leave tree marking (i.e., marking **only** trees to **retain**, indicating **all others** are to be cut down and removed). **Interestingly, 73% of FFPs on Non-Industrial ownerships used harvest tree marking, while Industrial timberland FFPs used leave tree marking for 50% of our sample**. Further, 42% of Non-Industrial timberland FFPs involved timber marking on the entire harvest area, followed by using a sample mark on 10% of the stand (Table 2). Industrial owners utilized more varied approaches, split between marking the entire harvest area, and various sample marking (Table 2).

Forest Type and Site Classifications

Figure 12: *FFP Notices where the entire harvest area was marked for leave trees only, with a coastal Douglas Fir stand in Humboldt County on the left, and an east side pine/conifer stand in Lassen County on the right. Both FFP Notices reported a site class of III.*

The forest type and site class on each FFP Notice determines, in part, canopy closure and post-harvest minimum stocking standards, amongst other factors. Forty-three (43) percent of our sample involved harvesting in mixed conifer stands, 23% Douglas Fir, 9% Redwood, 9% pine, 3% in true Fir, and 14% involved harvesting east side pine/conifer stands. All Douglas Fir and Redwood stands were within the Coast FPA, while mixed conifer stands were split amongst the Cascade FPA (68%), Coast FPA (16%), and Sierra FPA (11%). East side pine/conifer stands were exclusively in the Cascade and Sierra FPAs.

Table 3: *Reported forest type and site classification on sampled FFP Notices. Rows may not add up to 100% due to rounding.*

Reported Forest Type	***Reported Site Classification***			
	I	*II*	*III*	*IV*
Redwood	0%	50%	50%	0%
Douglas Fir	0%	50%	50%	0%
Mixed Conifer	32%	21%	42%	5%
Pine	0%	25%	25%	50%
East Side Pine/Conifer	0%	17%	83%	0%
True Fir	0%	100%	0%	0%

Redwood and Douglas Fir stands were both found on either site class II or III ground, while mixed conifer spanned all site classifications, with most stands on either class I or III ground (Table 3). Eighty-three (83) percent of the east side pine/conifer stands were on less productive site class III ground (Table 3).

Communities at Risk and Structure Density

As reported on the Exemption form, 48% of the FFP Notices had, or were adjacent to, structures and a community at risk, per the "Communities at Risk List". Proximity to or location within a community at risk results in regulatory changes to canopy closure requirements, along with expectations of slash treatment from operations near structures. By ownership type, 62% of Non-Industrial FFP Notices indicated they were proximal to structures and/or communities at risk, while only 28% of Industrial FFP Notices were proximal to these areas. **Lastly, only 23% of FFP Notices further indicated that the structure density within or proximal to the Exemption area was more than one structure per 20 acres.**

Exemption Road Characteristics and Hydrologic Performance

- **Roads on Forest Fire Prevention Exemption Notices were largely native surface logging roads, with adequate drainage present. Where adequate drainage features were absent, sampled roads generally were flat and on less steep hillslopes.**
- **Very few sampled roads had sediment discharge from the road prism to a classified watercourse. Causal factors where discharges were present appeared to be lack of dense cover below discharge points, proximity to a watercourse, and inadequate road design and/or maintenance.**
- **Anecdotally, roads ranged from well maintained, to seasonal-use only roads, regardless of ownership type.**
- **Temporarily constructed or reconstructed roads were found on 18% of the FFP Notices, averaging 415 feet in length.**
- **Overall, temporary roads met regulatory expectations for placement and construction or sediment discharge, although the roads varied in constructed quality and erosion control performance.**
- **A majority of the temporary roads were not adequately abandoned following operations, including some that were even re-opened and actively used following operations, inspection, and closure of the FFP Notice by a Unit, although in at least one instance the temporary road was behind gated access and not accessible by the public.**

Pre-existing Exemption Forest Roads

A total of 66 road segments were assessed during monitoring, on all 44 FFP Notices. Fifty (50) percent of the FFPs were larger Notices that involved more intensive sampling of two road segments. Of all road segments, 77% were assessed for the full 1,320 feet, with an average road length assessment of 1,220 feet, and 91% were actively used for hauling and harvest activities. The remaining 9% that were not used for harvest operations were nonetheless either mapped as appurtenant roads on the Exemption, or unmapped but actively used for some type of recent activity by the timberland owners. Fifty-nine (59) percent of roads assessed were on Non-Industrial FFP Notices, assessing an average length of 1,160 feet per segment, compared to 1,300 feet per segment on Industrial timberland FFPs. **On 28% of the Non-Industrial FFPs, assessed road segments also doubled as residential access roads as well (Figure 13).**

The majority (71%) of FFP roads were native surface logging roads, followed by rocked road surfaces (17%); both FFP timberland ownership types were dominated by native surface logging roads. Likewise, 85% of our surveyed roads were on hillslopes less than 40%, while 49% and 42% of the road segments themselves were less than 5% in slope or 5-10% in slope, respectively.

Figure 13: *A road on an FFP Notice in Plumas County that acted as both a haul road, and as residential access, on a Non-Industrial timberland FFP.*

Figure 14: *A native surface road within an FFP Notice on Industrial timberland that was less than 5% in slope and on generally flat hillslopes.*

Average sampled road length between drainage structures (e.g., rolling dips, waterbars) ranged between 120 and 581 feet, with a minority of instances where road segments had only one drainage structure or an absence of drainage structures (35%). Where this occurred, roads were almost overwhelmingly on hillslopes less than 40%, and had road slopes of less than five percent (Figure 14). Only two road segments, associated with one FFP Notice, had visual signs of operations under saturated soil conditions on the road surface.

Table 4: *Road segment characteristics, shown by road-to-watercourse discharge absence or presence.*

		Road Segments with No Discharges (#)	*Road Segments with Discharges (#)*
Road Slope Category	*< 5%*	30	2
	5-10 %	25	2
	> 10%	6	0
Hillslope Gradient	*< 40%*	52	4
	> 40%	9	0
Road Surface	*Native*	45	3
	Rock/Gravel	15	1
	Paved	6	0
	Other	1	0

Table 5: *Characteristics of each road-to-watercourse sediment discharge on roads actively used for harvest operations. Each column is data for an FFP and associated discharge.*

	FFP 1 Discharge 1	*FFP 2 Discharge 1*	*FFP 3 Discharge 1*	*FFP 4 Discharge 1*	*FFP 4 Discharge 2*
Source	Road Surface	Road Surface	Road Surface	Road Surface, Cutslope, Fillslope	Road Surface, Cutslope, Fillslope
Discharge Point	Road Outslope	Waterbar	Ditch Failure	Road Drainage Failure	Road Drainage Failure
Discharge Point to Watercourse Distance	< 100 feet	< 100 feet	< 100 feet	< 100 feet	< 100 feet
Downslope Roughness	> 50% bare soil, < 50% veg.	Bare mineral soil	< 50% bare soil, > 50% veg.	> 50% bare soil, < 50% veg.	> 50% bare soil, < 50% veg.
Receiving Watercourse Classification	Class III	Class III	Class III	Class III	Class III
Estimated Volume ($yards^3$)	1-5 $yards^3$	1-5 $yards^3$	"Trace"	1-5 $yards^3$	1-5 $yards^3$
Notes	Road drainage onto mostly bare road fillslope, resulting in downslope erosion and delivery	Waterbar drainage onto exposed bare mineral soil downslope	Plugged culvert causes water backup, occasional light flow across road prism, and downslope flow into channel with sediment	Runoff and sediment from entire road prism leaves road at drainage point, connects to watercourse below crossing	Runoff from entire road prism diverted off road at low point (not purposeful road dip), connects to watercourse downstream of a crossing

Finally, only five discharges were recorded from road segments in our sample, and these were found on four individual road segments (**6% of the sampled roads**), on four different FFP Notices (**9% of the total FFP sample**). There was one additional discharge from a road segment, however, it was on an appurtenant yet unused road, and thus not directly attributable to harvest operations.

When considering those road segments where sampling was initiated in proximity to a watercourse crossing, and therefore in closer proximity to a watercourse, 13% of road segments had a discharge related to operations, found on 17% of the FFP sample when road surveys were initiated from a road-watercourse crossing.

Three discharges were found on Industrial timberland FFP Notices, while the remaining two were on Non-Industrial timberland FFPs. One discharge was identified as only a "Trace" amount of sediment entering a Class III watercourse, while the remaining four were all estimated as 1-5 yards^3 in volume.

Figure 15: *Road segment discharge points. Left, discharge below a waterbar into a Class III watercourse, top right a discharge point from a rolling dip onto bare soil into a Class III below, and bottom right sediment discharge below a road drainage point on bare soil with a Class III below. Red arrows indicate direction of runoff.*

While Table 4 shows roads with sediment discharge issues in conjunction with harvest activity were associated with less steep hillslopes, and less steep road segments, it is important to note that only eight of twenty (21%) of the road segments initiated at a crossing (and therefore closest in proximity to a watercourse) were on hillslopes greater than 40%, and none of the road segments with a slope greater than 10% were in close proximity to watercourses. Further, Table 5 indicates that where road-to-watercourse discharges were identified, they were largely related to inadequate road drainage and/or maintenance, in close proximity to watercourses, **and a lack of sufficient ground cover and downslope roughness to intercept runoff and sediment at or below discharge points**. In fact, the only discharge that was estimated as only a "Trace" volume, was the only one where **vegetative cover exceeded 50% on the downslope area between the discharge point and the watercourse**.

Anecdotally, there were observations, including outside of sampled road segments, of native surface roads that were either actively used for harvest activities, or were mapped by RPFs within FFP Notice boundaries, that exhibited signs of rilling and surface erosion. Such signs, in addition to observations from the limited road-to-watercourse discharges, **suggests that some forest roads on these Exemptions would benefit from upgrading and activities such as rocking, in order to allow for <u>unimpeded future access for maintenance and/or fire suppression activities</u>.**

Figure 16: *Examples of sampled roads on **Industrial** timberland FFP Notices. All roads shown are native surface seasonal roads, with the exception of the bottom right photo which is a rocked permanent road.*

Figure 17: *Examples of sampled roads on* ***Non-Industrial*** *timberland FFP Notices. All roads shown are native surface seasonal roads, with the exception of the bottom left photo which is a rocked road, and the upper right photo, which is native surface road used year-round.*

Temporary Roads (Constructed or Re-constructed)

Monitoring assessed eight (8) temporary roads on FFP Notices, on eight (8) separate FFP Notices, **implying only 18% (+/- 10%) of FFP Notices utilize the temporary road construction or reconstruction option**. This is similar to a review of all accepted FFP Notices between March 1, 2019 and December 31, 2020 (n=101), where 17% (n=17) of the FFPs had proposed temporary roads. Field estimates were that the eight roads averaged 415 feet in length, ranging from 130 to 620 feet.

Three of the eight temporary roads were found on Industrial timberland FFP Notices, while the remaining five temporary roads were found on small, Non-Industrial timberland FFP Notices. Temporary roads on Industrial and Non-Industrial timberlands averaged approximately 450 and 390 feet in length, respectively. Road width, per regulatory expectations that roads constructed or re-constructed temporarily under the FFP Exemption not exceed single land width, averaged just under 15 feet in width, ranging from nine (9) feet to 22 feet in width, based upon three equidistance measurements within the road length of the drivable road running surface. None of the temporary roads sampled violated regulatory requirements about proximity to watercourses, construction on steep or unstable slopes, crossing of connected headwater swales, or sediment discharge to a watercourse. However, some did display poor drainage and thus significant erosion of the road prism surface (Table 6). One temporary road was built on hillslopes that were nearly exactly at the 30% slope restriction, but it was the professional opinion of the monitoring specialists and present Review Team Agencies that it did not violate the regulatory requirement, and further investigation fell outside the rapid nature of this monitoring.

Figure 18: *Abandoned temporary roads on an FFP Notice in Tehama County, two years post-Exemption expiration. Red arrows indicate approximate road direction.*

Table 6: *Characteristics of temporary roads sampled on FFP Notices, and the count of the number of temporary roads on each hillslope and road slope category. The ** indicates the hillslope for that sampled road was nearly exactly 30% slope, a borderline violation.*

	Yes (#)	*No (#)*
Signs of saturated operations?	0	8
Hillslope > 30%?	0	8
Crossing of unstable area?	0	8
Crossing of connected headwater swale?	0	8
Within 200 feet of a Class I/II watercourse?	0	8
Within 50 feet of a Class III watercourse?	0	8
Rilling present in road prism?	2	6
Gullies present in road prism?	1	7
Sediment Discharge to watercourse?	0	8
Abandoned?	3	5
Hillslope Category		
< 5%	n = 2	
5-20%	n = 4	
20-30%	n = 1	
30-100%	n = 1**	
Road Slope Category		
0-5%	n = 3	
5-10%	n = 5	
>10%	n = 0	

Three of the eight temporary roads were successfully abandoned, with the remaining five still usable to a degree. Two of the three Industrial temporary roads were fully abandoned and decommissioned, while only one of the five temporary roads on Non-Industrial timberland FFPs was abandoned. The Industrial temporary road that was not abandoned had an attempt to create abandonment via a “tank trap” style use of earthwork, and, further, was behind multiple locked gates, limiting potential public access. The remaining temporary roads that were not abandoned, and were on Non-Industrial timberlands, had low-level attempts at abandonment and were well past the completion of operations. **Monitoring on these temporary roads occurred between six and 16 months after expiration of the FFP Notice, and the timberland owners, following operations and inspections by Unit Forest Practice Inspector staff, re-opened and began using the temporary roads in question.**

Three of these four instances of temporary roads being used after operations for active use were found on timberland properties in the Coast FPA and on ownerships where additional types of management and economic activity outside of forestry were occurring (i.e., legal cannabis cultivation).

Figure 19: *Open and actively used (not abandoned) temporary roads in the Coast FPA (top and bottom left) with visible road surface and drainage rills present, and a temporary road that was abandoned in the Cascade FPA (right).*

Watercourse Crossings

- **Road-watercourse crossings were found on 64% of the sample for a total of 41 assessed crossings, with Class III crossings the most prevalent.**
- **The majority of assessed watercourse crossings were used for harvest activity, and crossings not actively used for operations yet still shown on appurtenant roads and mapped by an RPF were mostly found on Non-Industrial FFP Notices.**
- **Thirty percent (30%) of sampled crossings had a potential for diversion if failure occurred, while over two-thirds of those with diversion potential were not able to freely pass water and/or debris, or in need of immediate maintenance. Crossings were more likely to be in proper working order and maintained on Industrial timberland FFP Notices, although many Non-Industrial crossings were adequate or exceeded expectations.**
- **Watercourse crossing estimated discharges in excess one yard^3 were associated largely with unmaintained, inadequately designed crossings and approaches. These types of discharges were in the overall minority (21% of all discharges, found on 9% of the entire FFP sample), however, they were avoidable if proper BMPs and crossing designs were implemented.**

Road-Watercourse Crossing Characteristics

Road-watercourse crossings were present on 64% (n = 28) of our sample, of which 42% were on Industrial timberland ownerships, while 58% were on Non-Industrial timberland ownerships. Of the 28 FFP Notices with watercourses, 15 were larger Notices (> 80 acres) where two crossings were assessed (as were present). As such, monitoring assessed 43 individual road-watercourse crossings, 58% of which were associated with Non-Industrial FFP Notices. Eighty-four percent (84%) of the crossings were also actively used for harvest operations and log hauling, while the remaining 16% were in proximity to harvest operations, mapped by RPFs on appurtenant roads, yet not used for any active harvest operations. The majority of these occurrences were on Non-Industrial FFP Notices. This latter result is similar to results found on Emergency Notices in 2019, where not all mapped appurtenant roads and watercourse crossings were actually used for harvest operations (Olsen et al., 2019b).

Figure 20: *Two examples of approaches to watercourse crossings, with an improved rocked approach (left), and an unimproved native surface approach (right). Yellow arrows indicate direction towards the crossing.*

The majority of sampled watercourse crossings were Class IIIs, followed by Class IIs, Class IVs, and lastly single occurrences of a Class I and “Other[13]” type crossings (Table 7). Soils were identified as stabilized[14] in 60% of the sampled crossings, generally through the use of large rock and/or gravel, natural grass and vegetation, and in four cases straw and mulch. Generally, Class III crossings were the most problematic classification type in terms of a lack of soil stabilization (Table 7).

Table 7: *Sampled road-watercourse crossing attributes, showing by crossing classification the percentage and count from the sample, and for each classification if the crossing prism soil was stabilized, if the crossing showed the potential for diversion in the case of failure, and if there were any signs of operations on saturated soils on the crossing. Red boxes indicate an unfavorable outcome.*

	Watercourse Crossing Classification									
	Class I		*Class II*		*Class III*		*Class IV*		*Other*	
% / Count	2% / 1		14% / 6		74% / 32		7% / 3		2% / 1	
Crossing Soil Stabilized? (%)	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*
	100%	0%	83%	17%	50%	50%	100%	0%	0%	100%
Diversion Potential? (%)	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*
	0%	100%	50%	50%	31%	69%	0%	100%	0%	100%
Signs of Saturated Soil Operations? (%)	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*
	0%	100%	0%	100%	0%	100%	33%	67%	0%	100%

Figure 21: *A Class III culvert crossing used for harvest operations that was not able to freely pass water and/or debris, and in need of maintenance and improvement.*

13 The “Other” watercourse was an unclassified channel, that did not connect to other watercourses, but the presence of convergent hillslopes and a culvert on the road, and signs of overland flow within the culvert and channel, led to this sampled crossing being assessed as “Other”.

14 Stabilized soil at a crossing indicates there is not bare exposed soil capable of eroding and discharging, or otherwise degrading the crossing integrity, from the road prism and fill.

The potential for watercourse diversion[15] in the occurrence of a failure was found on 30% of the Class IIIs sampled, and 50% of the Class IIs sampled. For all classification types, only 30% of our sampled crossings had diversion potential. Where diversion potential was present, 62% of those occurrences were on Non-Industrial FFP Notices. **Further, sixty-two percent (62%) of the crossings *with* diversion potential were identified as *unable* to freely pass water and debris, or were *in need of maintenance* to better ensure free passage of water and debris (in addition to road design issues)** (Figure 21). On Non-Industrial timberland ownerships, 64% of assessed crossings were freely able to pass water and debris and not in need of maintenance, while 78% of crossings on Industrial timberland FFP Notices met this expectation. Lastly, 37% of the assessed crossings had rills and/or gullies present on at least one crossing approach, indicative of road surface erosion proximal to the watercourse. Where rilling or gullying was present on an approach to a watercourse, 75% of these occurrences were found on Non-Industrial ownerships.

Of our assessed crossings, 74% were pre-existing, 23% were upgraded pre-existing watercourse crossings, while in 3% of cases it was unknown when the crossing was constructed, and a landowner or associated licensed professional was not present to provide information. **Pre-existing, non-upgraded crossings were the most common crossing, regardless of ownership type**. Upgraded crossings were generally indicative of new culverts, or the addition of measures such as rock armoring of outlets or rocking of the approaches. Within our sample, 65% of the crossings were culverts, 30% were dry fords, with the remaining instances being a rock armored ford and a vented ford.

Road-Watercourse Crossing Sediment Discharges

Table 8: *Binned estimated discharge volume group, and watercourse crossing classification, with percentage and total number of occurrences. Rows may not add up to 100% due to rounding.*

	Estimated Discharge Volume Group		
Crossing Classification	**None Directly Visible**	**Less Than 1 yard^3**	**Over 1 yard^3**
Class I	100% / 1	0% / 0	0% / 0
Class II	83% / 5	0% / 0	17% / 1
Class III	34% / 11	53% / 17	13% / 4
Class IV	33% / 1	67% / 2	0% / 0
Other	100% / 1	0% / 0	0% / 0
TOTAL #	19	19	5

A total of 56% of the 43 assessed watercourse crossings had some level of sediment discharge associated with them, and these occurrences were found on 17 or 61% of those FFP Notices that had watercourse crossings. We should also note that the implication is not that the remaining 44% of crossings had zero sediment input into watercourses, as this is unlikely, but there was no visible evidence of erosion and flow

[15] Potential for diversion indicates in the case of the watercourse crossing failure, the channel would re-align and travel down the road prism itself, before rejoining the channel downstream, which results in significant sediment discharge and aquatic impacts.

paths from the crossing prism to the watercourse, and/or no visible sediment deposition or plumes in the channel itself. All discharges occurred on road watercourse crossings actively used for harvest operations and log hauling.

Figure 22: *A dry ford Class III crossing that resulted in a sediment discharge in excess of one yard^3, in the Coast FPA. Red arrows indicate direction of runoff and sediment delivery.*

Of the discharges, 19 or 79% were either less than one yard^3, or a "Trace[16]" volume. The remaining 21% of discharges involved three 1-5 yard^3 discharges, and two 5-10 yard^3 discharges. In terms of the ownership of the FFP timberland involved with discharges, small Non-Industrial FFPs had 13 crossing discharges as either "Trace" or less than one yard^3, while Industrial FFP Notices had six (6) crossings with the same discharge levels. **For the more excessive discharges from poorly performing crossings, three were found on Non-Industrial FFPs while only two were found on Industrial FFPs.**

The more excessive discharges of sediment at crossings, those over one yard^3, most frequently were associated with crossings that:

- **Did not have the fill material around an inlet or outlet properly stabilized by some means**
- **Were not in a condition to freely pass water and/or debris, or were in need of immediate maintenance in order to allow free passage of water/debris**
- **Had a potential for a watercourse diversion in the case of a crossing failure**
- **Had rill/gully features present on the crossing approach**

Further, where larger, *likely* significant sediment discharges occurred, the runoff and sediment source was found to be related to either the road surface itself, or the road surface and a portion of the cut- or fillslope. In only one case did a larger discharge involve additional runoff from the upslope hillslope, while the rest only had visible flowpaths for runoff and sediment coming from the road prism *only*. Additionally, only one upgraded pre-existing crossing had over one yard^3, while the rest came from pre-existing crossings. What these results, and the aforementioned characteristics involving soil stabilization,

[16] "Trace" volumes reflect visible surface erosion and deposition into a watercourse, but not a large enough volume to produce measurable surface voids to use for volume estimation.

functionality of a crossing (typically a culvert), lack of proper road design to prevent watercourse diversion, and influence of rill or gully features on a crossing approach all indicate, **is that the minority of sediment discharges** found on our sampled FFP Notice crossings are likely directly related to **initial improper road design**, **lack of or minimal maintenance**, and **failure to utilize appropriate BMPs as site specific conditions warrant them**.

As shown in Table 9, a lack of directly identifiable sediment discharge or minor, less than one yard^3 discharges, had larger numbers associated with stabilized soil, proper functionality, proper design to avoid watercourse diversion, and an absence of rill or gully features on approaches.

Table 9: *Associated characteristics of crossings and discharges, with discharges grouped into "None Directly Visible", Less Than 1 yard^3, and Over 1 yard^3. Numbers indicate the number of crossings associated with each characteristic. Red highlight indicates an unfavorable outcome.*

	Estimated Discharge Volume Group		
	None Directly Visible	Less Than 1 yard^3	Over 1 yard^3
Crossing Soil *Stabilized*	15	10	1
Crossing Soil *Not Stabilized*	4	9	4
Can Pass Water/Debris Freely	16	13	1
Unable to Pass Water/Debris Freely/Needs Maint.	3	6	4
Pre-existing Crossing/Unknown Construction	17	12	4
Upgraded Pre-existing Crossing	2	7	1
Diversion Potential *Absent*	14	16	0
Diversion Potential *Present*	5	3	5
Rill/Gully *Present* on an Approach	14	7	5
Rill/Gully *Absent* on an Approach	3	12	0
Runoff/Erosion Source is Road Prism *Only*	NA	17	4
Runoff/Erosion Source Prism *AND* upper hillslope	NA	2	1
Crossing/Road Prism Runoff/Erosion Source			
Road Surface *Only*	NA	10	3
Cutslope and/or Fillslope *Only*	NA	3	0
Road Surface *AND* Cut or Fill	NA	3	0
Road Surface *AND* Cutslope *AND* Fillslope	NA	2	2
Unknown/Were Not Able to Determine	NA	1	0

Watercourse Protection

- **Classified watercourses were identified on 66% of sampled FFP Notices, and generally were Class III or IV types, with a minority being Class II or I watercourses.**
- **Harvesting of the riparian canopy was generally very light and limited to Class III or IV type watercourses.**
- **Sediment discharges to watercourses from operations were very limited in occurrence, with adequate watercourse protection observed across the entire sample. However, in some of the isolated incidences where sediment delivery occurred, the discharges were potentially detrimental.**
- **Class III tractor crossings were generally mapped by RPFs as verified in the field, and only present on 20% of the FFP sample. There were only limited instances of unmapped tractor crossings, and generally the crossings were adequately pulled and treated to minimize or eliminate runoff and discharge to the channel (i.e., slash packing).**
- **Longer approach lengths to Class III tractor crossings were associated with surface erosion (rills) and larger sediment discharges.**
- **Some Class III tractor crossings, while mapped and used, were used very minimally, essentially to facilitate equipment access or retrieval of a single turn of logs.**

Watercourse Characteristics on FFP Notices

Figure 23: *A Class I watercourse, no harvest present, within an FFP Notice in the Cascade FPA.*

A total of 44 watercourses were assessed on 29 of the FFP Notices, implying that watercourses are present on 66% of FFP Exemptions. Our sampling, similar to the road-watercourse crossing results, assessed Class IIIs as 73% (n=32) of the sample, Class IIs as 16% (n=7), Class IVs as 7% (n=3), Class Is as 2% (n=1), and an "Other Classification[13]" as 2% (n=1). Class IIIs were the most prevalent type of watercourse sampled, as they often are the most prevalent type of watercourse present on a landscape as well. Monitoring assessed between 150 to 400 feet of watercourses, for an average of 366 feet, sample wide.

Table 10: *Estimates of riparian percent canopy cut (WLPZ or Class III/IV overhead canopy), by binned category (rows), for watercourse classification type, total, and timberland ownership type (columns).*

Riparian Percent Canopy Cut (#)	Class I	Class II	Class III, IV, "Other"	Total	Industrial Timberland FFP	Non-Industrial Timberland FFP
0%	1	6	18	25	11	14
0-33%	0	1	17	18	6	12
33-66%	0	0	1	1	1	0
> 66%	0	0	0	0	0	0

Figure 24: *Top, a Class III watercourse, downstream of a culvert, on an FFP Notice in Sierra County, and bottom, a Class III watercourse as mapped by the RPF in the Lake Tahoe region. Yellow arrows indicate direction of runoff.*

Overall, harvesting within the riparian areas of classified watercourses was light; the lone Class I watercourse had no harvesting occur, per the FPRs (Table 10). Only one Class II watercourse, in the Coast FPA, had timber harvest occur within the WLPZ, with no more than 33% of the riparian canopy removed, and anecdotally the field observations were that harvest was on the edges and minimal. Otherwise, the riparian areas around

Class III and IV watercourses, where the FPRs are not restrictive, still largely only saw 0% or 0-33% of the overhead canopy harvested (Table 10). Heavy equipment encroachments were only identified on three watercourses, on three different FFP Notices (10% of FFPs where watercourses were present), and numbered as one, two, and eight encroachments (on singular 200-foot watercourse segments), all on Class III watercourses.

Field observations indicated that some Class III watercourses had indicators present that potentially would have required the watercourse to be upgraded to a Class II (e.g., mayfly larvae present). Additionally, some observations of watercourses were that they had only very minimal bed, bank, and channel morphology present, possibly indicative of extra protection when RPFs assessed and mapped Exemption watercourses. Overall, these anecdotal observations were from a small minority of FFP Notices and watercourse features.

Watercourse Protection and Sediment Discharges from Operations

A total of four (4) sediment discharges were recorded to classified watercourses, on two (2) separate watercourse segments found on two (2) different FFP Notices. As such, 5% of all sampled watercourses had at least one sediment discharge in our sample, representing 7% of sampled FFPs with watercourses present.

One discharge was due to a tractor crossing of a Class III watercourse, which was also appropriately mapped by the RPF, that had an estimated volume of less than one $yard^3$. The remaining three sediment discharges to the other watercourse segments were all three identified as 1-5 $yard^3$ discharges. All three of these instances were related to tractor operations (i.e., log skidding), and discharged to Class III watercourses, where operations occurred within the equipment limitation zone (ELZ). Two of these discharges had more than 50% bare ground between the source and watercourse, while the third had more than 50% vegetative cover. This same watercourse segment also had eight (8) occurrences of equipment encroachments. This isolated incident within our monitoring sample represents what is likely the exception of how operations occur on FFP Notices, where there are isolated incidences of improper operations (see also ***Exemption Inspections and Violations***).

Considering any discharge greater than one $yard^3$ as likely resulting in significant impacts to water quality at and downstream of the discharge point, **2% and 3% of all sampled watercourses and FFP Notices with classified watercourses, respectively, had significant occurrences of sediment discharge.**

Within our monitoring, we also identified and assessed 13 Class III tractor crossings, found on nine (9) separate FFP Notices (20% of the entire FFP sample). In at least three (3) cases, the FFP document had *unmapped* Class III tractor crossings that were identified and evaluated in the field on mapped Class III watercourses. Generally, waterbars were adequately installed on either side of each crossing, frequently with slash packing utilized to further reduce the chances of sediment discharge or excessive surface runoff entering the channel (Figure 25, right). **Ten (10) of the thirteen tractor crossings were adequately pulled, with fill from the channel removed and graded appropriately**.

In the case of one crossing that was not pulled, it was a legacy Class III tractor crossing from a previous harvest entry; in the field, it was the professional opinion of all involved that the channel had already geomorphically adjusted to the legacy crossing, and its removal would involve substantial soil disturbance and sediment inputs to the downstream drainage network.

Figure 25: *Two Class III tractor crossings, with a mapped, minimally used crossing (left), and a heavily slashed approach to the channel in the Coast FPA (right).*

The approach lengths between the Class III channel and hydrological break in the skid trails generally had a longer mean approach length when rills were present (Table 11), although most approaches on the tractor crossings had an absence of surface rills. Surface rilling on tractor crossing approaches was also associated with sediment discharge. **Approach lengths, on average, were longer as the estimated sediment volume discharged to the Class III increased (Table 11, Figure 26)**.

Table 11: *Class III tractor crossing characteristics related to erosion control, hydrologic disconnect, and sediment discharge.*

	Mean Approach Length	Occurrences
Rills present in approach to channel		
Yes?	108 feet	3
No?	42 feet	10
Sediment Discharge		
None	49 feet	4
<1 yard^3	65 feet	2
1-5 yards^3	107 feet	2

It should also be noted that some of the tractor crossings, while mapped and used, essentially were used for one to two complete crossings of the watercourse, in order to facilitate equipment travel, or to remove one to two loads of cut logs (Figure 25, left).

Figure 26: *A Class III tractor crossing that was unmapped on a mapped Class III watercourse, with extended approach lengths a sediment discharge over one yard[3].*

Post-Harvest Habitat Elements

- **Spatial ground cover was high on the overwhelming majority of FFP Notices, while shrub cover and grass cover were generally moderate-to-minimal in spatial coverage. Observationally, mastication or chipping treatments did reduce the spatial coverage of shrubs to largely the lowest coverage category.**
- **Grass cover spatial extent was largely limited to less than 20% on FFP Notices, and did not seem to correspond strongly to decreasing canopy closure estimates (and therefore increasing incoming sunlight) within the sampled FFP Notices.**
- **Grass, shrub, and forb establishment is dependent on site conditions, canopy reduction, and time since harvest. These attributes would be expected to increase where site conditions are not limiting.**
- **The habitat element of large wood pieces were found on 37% of all plots, and 72% of the sampled FFP Notices (at least one plot). Large wood pieces were slightly more prevalent on Non-Industrial timberland plots.**
- **Commercial species of dead standing trees 8 inches or larger were found on at least one plot on 53% of sampled FFP Notices, and were generally more prevalent on Non-Industrial timberland FFP Notices.**
- **Dead standing non-commercial trees 8 inches or larger were far less prevalent, found on only 16% of the Exemptions. Coast Redwood stands had the highest prevalence of plots with this type of dead standing tree (8% of plots).**

Post-harvest binned estimates of ground, grass, shrub, and forb cover were generally the same throughout the sample. Ground cover met or exceeded 50% in 88%

of plots, found on 98% of the FFP Notices; the only Notice where ground cover was estimated as less than 50% throughout the FFP, was a high elevation dry forest. Shrub cover in plots was overwhelmingly found to be 0 to 20% in spatial coverage (82% of plots), and covered 20 to 50% of the plot area on 15% of the plots; where mastication or chipping occurred, 90% of the plots had 0 to 20% shrub cover, while in the absence of mastication or chipping, 79% of the plots had this level of shrub cover. Forb cover was largely absent or sparse on nearly all plots, regardless of the addition of mastication or chipping.

Grass cover was found to cover 0 to 20% of the plot areas on 88% of all plots, and 20 to 50% of the plot area on only 6% of plots, and over 50% of the plot on only 6% of plots. This is a favorable result from a fuel hazard standpoint, as spatially continuous light grass can carry fire easily, and concerns exist about increased overhead sunlight and understory fuel growth following thinning operations (Figure 27).

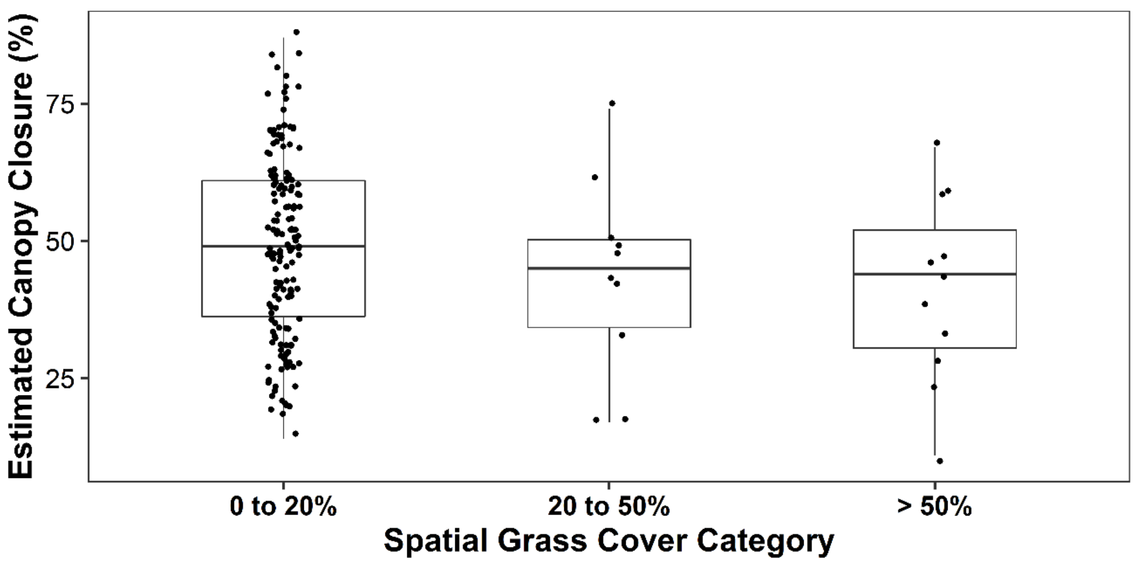


Figure 27: *The spatial coverage of grass coverage in all plots, by binned category, and the estimated overhead canopy closure in each plot. The box represents the 25th and 75th percentiles of the closure values, the black line within the box the median (50th) value, and the top and bottom "whiskers" or vertical lines show the extent of values that are 1.5 times the 25th and 75th percentiles. Points outside those two lines are statistical outliers.*

Large wood pieces, defined within this and previous protocols by both CAL FIRE and the Department of Fish and Wildlife as pieces of wood within or intersecting the plot at least 12 inches in diameter and 10 feet in length, were found on 37% of the plots, however these plots were on 72% of the sampled FFPs. Large wood pieces were found on 26% of plots on Industrial timberland FFP Notices, and 44% of plots on Non-Industrial timberland FFP Notices.

Dead standing commercial tree species 8 inches or large in diameter were found on 14% of the plots, encompassing 53% of the sampled FFP Notices. It is of note that of FFP Notices with at least one plot with dead standing commercial trees, 65% of these Notices were on Non-Industrial timberland. The implication and our estimation being that

FFP Notices on Industrial timberland had a far lower prevalence of dead standing commercial tree species 8 inches or larger in diameter. Meanwhile, dead standing non-commercial tree species of the same minimum diameter were found on only 4% of plots, which in turn were on 16% of sampled FFP Notices. Interestingly, the highest percentage of plots with dead standing non-commercial tree species was in coast Redwood forest types, with 8% of all plots having this type of dead tree present.

Harvest Related Slash Depths and Extent

- **Overall, higher biomass forests had deeper harvest-related slash depths, often consisting of larger slash sizes, covering a larger spatial area, than drier interior "fuel limited" type forests.**
- **Average slash depth across all sampled FFP Notices was below the 18-inch regulatory maximum, although there were frequently individual instances of slash depths in excess of 18 inches (1-16% of measurements on FFPs, on 61% of sampled FFP Notices).**
- **Timberland ownership type had no influence on average slash depth for projects, while coastal forests, namely Redwood and Douglas fir, generally had greater post-harvest slash depths than other interior forest types.**
- **Average *maximum* slash depths and average FFP slash depth had a significant positive relationship, and both were minimal in drier forest types, in particular east side dry forests.**
- **Higher biomass forests, such as coastal Redwood and Douglas Fir, had higher continuous spatial coverage of slash (all size classes) and greater percentages of slash over three and twelve inches deep, compared to drier interior forests.**
- **There were instances of large patches of slash concentrations on some FFPs, and various sized piles of harvest-related fuels to be treated (e.g., hand thinned piles).**

Figure 28: *Slash transect measurement on an FFP Notice in the Lake Tahoe region, with minimal post-harvest slash depths and coverage.*

Harvest-related slash had an average depth across FFP Notices between 0 and 9 inches[17] (Figure 29). When comparing the averages across our entire sample by timberland ownership type, there was no clear difference (analysis of variance, p=0.84, F=0.05). Non-Industrial timberland FFPs had a mean of 2.2 inches, while Industrial timberland FFPs had a mean of 2.4 inches of harvest-related slash (Figure 29).

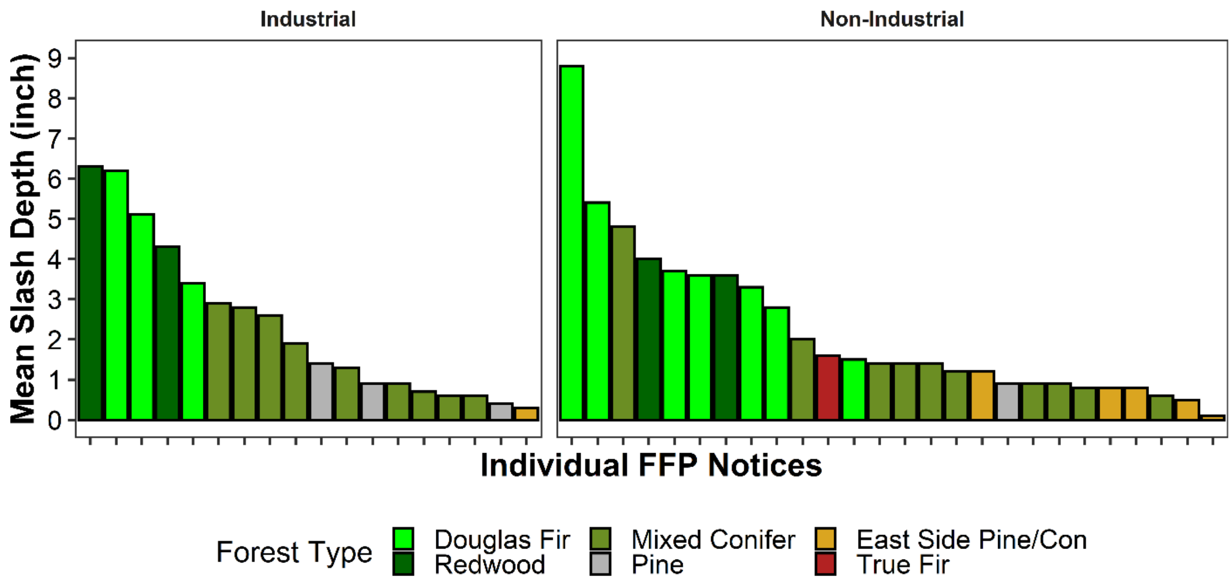


Figure 29: *Average slash depth on individual FFP Notices, by timberland ownership type. Bar colors indicate the reported forest type.*

Coast Redwood stands averaged the highest slash depth from operations at 5 inches, followed by Douglas Fir at 4 inches (Table 12). Mixed conifer stands and the one True Fir stand both averaged 2 inches, while pine stands averaged 1 inch, and lastly those stands that were east side pine/conifer had a mean value of 1 inch of slash (Table 12). While Douglas Fir and Redwood stands in our sample were only within the Coast FPA, mixed conifer stands were sampled in all four FPAs, and Table 12 shows that within the Coast FPA, where forests typically are wetter and have higher unit area biomass, average slash depth was also greater than in other FPAs for that forest type.

Table 12: *Average slash depth by FPA, and forest type. Slash depths have been rounded to the nearest inch. A dash indicates no sampled FFPs in the FPA or forest type.*

	Forest Practice Area				
Forest Type	*All FPAs*	*Coast*	*Cascade*	*Sierra*	*Southern*
All Forest Types	2”	4”	1”	1”	1”
Redwood	5”	5”	-	-	-
Douglas Fir	4”	4”	-	-	-
Mixed Conifer	2”	4”	1”	1”	1”
Pine	1”	-	1”	-	-
East Side Pine/Conifer	1”	-	1”	1”	-
True Fir	2”	-	2”	-	-

[17] We have determined Notice-wide mean slash depth as inclusive of depths without harvest-related slash, including an absence of slash measurement in the mean (i.e., depth of zero).

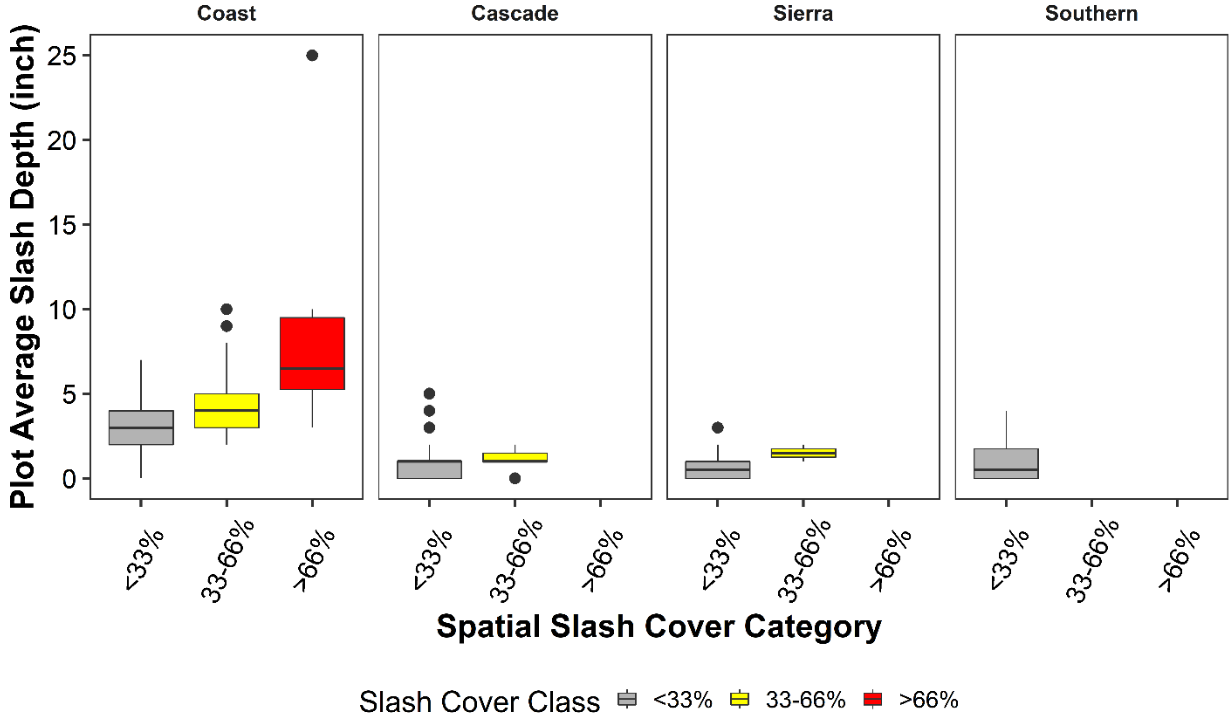


Figure 30: *Average slash depth within plots, for the spatial coverage of slash within the plot by binned category, shown by Forest Practice Area. Boxplot characteristics are the same as* ***Figure 27****.*

At the individual plot scale, across all FFP Notices, Figure 30 shows average plot slash depth results by FPA and the spatial extent of slash in each plot[18]. When slash was patchy, or in only small, isolated clusters (i.e., < 33% coverage), slash depths were less than when the spatial slash coverage was 33-66% and more than 66% of a plot. Likewise, there is a clear trend where for each slash coverage category, the Coast FPA had greater slash depths than the other FPAs. However, there was only a significant statistical difference between the Coast and Cascade FPAs for the < 33% and 33-66% coverage classes, and Coast and Sierra FPA for the < 33% coverage. Differences between plot slash depth for other coverage classes and FPAs were not statistically different. The lone plot that averaged 25 inches of depth, shown in the Coast FPA panel and > 66% coverage class in Figure 30, was a Douglas Fir type forest.

The *average maximum* slash depth[19] on FFPs ranged between three and 54 inches, with a median of 15 inches. A total of 27 FFPs (61%) had slash measurements within transects that exceeded 18 inches, while 17 FFPs (39%) did not have slash depths exceeding 18 inches on any sample transects. On the 27 FFPs with slash depths greater than 18 inches present, between one (1) and 16% of all measured points on transects

[18] Spatial extent categories capture the extent of slash coverage across the entire plot, as viewed from above.
[19] Determined as the average value of the highest slash-depth values in all plots on an FFP.

exceeded 18 inches in depth. It is important to note that some of these were singular incidences, or a small number of excess slash depths, and not continuous.

As the average maximum observed slash depth increased, Notice-wide mean slash depth also increased ($p < 0.0001$, $r^2=0.76$, Figure 31). For every one-inch increase in the average maximum observed slashed depth, overall average slash depth increased 0.15 inches (e.g., if the average maximum observed slash depth was seven inches, Notice-wide slash depth was one inch). Where the average maximum slash depth was 18 inches or less, Notice-wide slash depth averaged one inch, while where the average maximum depth exceeded 18 inches, average Notice-wide slash depth was four (4) inches. **The implication being that where operations result in discrete incidences of deeper slash, overall slash depth increases as well, particularly for wetter coastal forests *(*Figure 31*).***

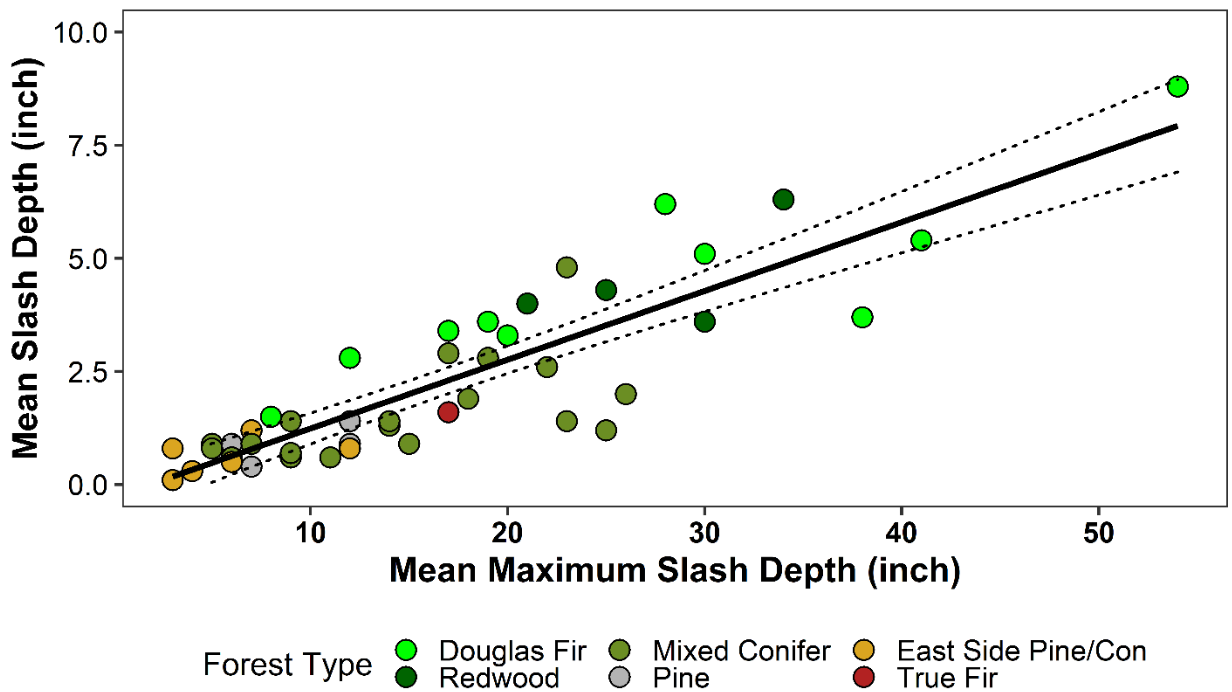


Figure 31: *Average maximum slash depth vs Notice-wide mean slash depth. Point colors indicate the forest type on the FFP Notice. The upper and lower dashed lines show the 95% confidence interval.*

The continuous presence of slash on the landscape[20] is an important influence on potential fire behavior. For slash depths greater than three (3) inches, FFP Notices averaged between zero (0) and 33% maximum continuous slash on transects, with a median value of eight (8) percent. Coastal Douglas Fir and Redwood forests, following treatment, averaged 20% and 21%, respectively, while mixed conifer stands averaged

[20] Calculated here as the maximum number of continuous slash hits >3 inches deep on each end of a 200-foot transect at four-foot increments (up to 25 hits per 100 feet). For each end of the transect for every FFP plot, we divide the number of positive slash hits by 25 and multiple by 100 for a percentage, and that value is averaged across all transects for each FFP Notice.

eight (8) percent continuous slash (Table 13). The True Fir FFP averaged nine (9) percent continuous slash, while pine and east side pine/conifer stands averaged five (5) and eight (8) percent, respectively (Table 13). The average percent of transects with point measurements of slash greater than three inches in depth was 17%, while for slash depths greater than 12 inches it was 4.5% (Table 13). Industrial timberland FFPs had a slightly higher average presence of slash greater than three inches in depth than Non-Industrial FFP timberlands (19% versus 15%), while for slash depths above 12 inches, there was effectively no difference (5% vs 4%, Industrial versus Non-Industrial) (Table 13). Generally, biomass heavy forest types such as Redwood and Douglas Fir had greater percentages of slash depths over three and 12 inches in depth (Table 13), with mixed conifer stands having median values, and pine and eastern dry-forest types were minimal in post-harvest slash depths of any level (Table 13).

Table 13: *The average maximum continuous slash greater than three inches in depth, average percent of transects with slash over three and 12 inches deep, across the entire sample, by ownership type, and forest type.*

	Average Maximum Continuous Slash Presence >3"	Average Percent of Transects with Slash >3"	Average Percent of Transects with Slash >12"
Sample-wide Mean (n=44)	**11% of transect length**	**17%**	**4.5%**
Industrial Ownership (n=18)	**11% of transect length**	**19%**	**5%**
Non-Industrial Ownership (n=26)	**11% of transect length**	**15%**	**4%**
Redwood (n=4)	**21% of transect length**	**35%**	**11.5%**
Douglas Fir (n=10)	**20% of transect length**	**32%**	**9%**
Mixed Conifer (n=19)	**8% of transect length**	**11%**	**3%**
Pine (n=4)	**5% of transect length**	**7%**	**1%**
East Side Pine/Conifer (n=6)	**4% of transect length**	**4%**	**< 1%**
True Fir (n=1)	**9% of transect length**	**14%**	**2%**

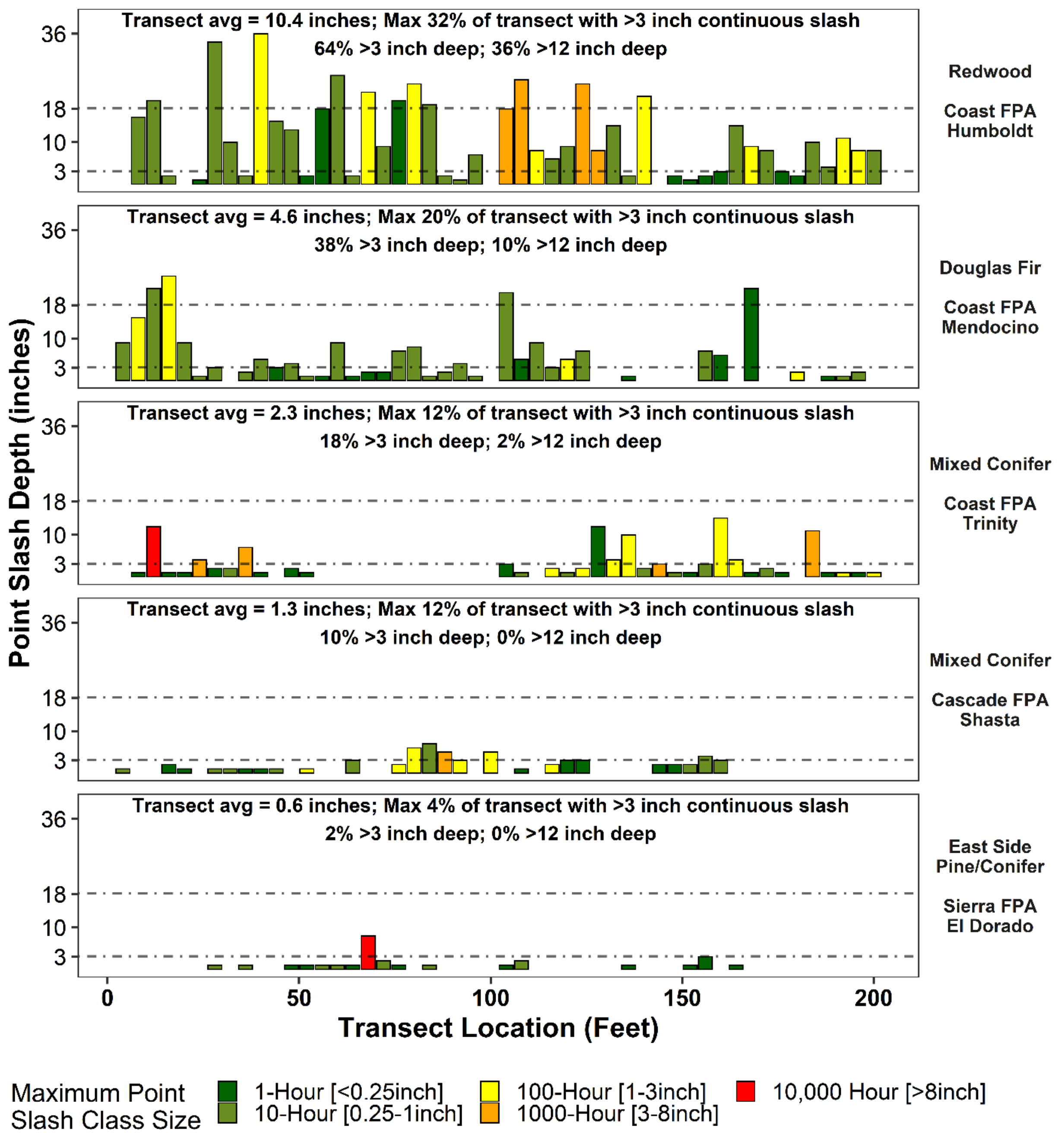


Figure 32: *Slash results for a full transect on five different FFP Notices, where each panel is a different forest type and/or FPA. Bar height indicates the point slash depth every four feet along the transect, and bar color indicates the maximum fuel class size at that point (multiple size classes may be present). The two dashed lines indicate the three inch and 18-inch depths. No bar indicates a lack of harvest-related slash. The average transect slash depth is also shown in each panel, in addition to the average maximum percentage of the transect with continuous slash over three inches in depth, and percent of transect with slash over three and twelve inches deep.*

A visual representation of slash-transects from select FFP Notices in certain forest types and FPAs is shown in Figure 32, with the largest slash piece size at each measurement point and depth shown. Forests in the Coast FPA show more continuous slash coverage with incidences of 100 and 1000-hour slash sizes[21], while interior dry forest-type pine and eastern pine/conifer stands show much less continuous slash coverage, in addition to lower average depths and small slash piece sizes.

Overall, across the entire sample, where slash from harvest operations was encountered on transects, 1- and 10-hour sized slash pieces were the most frequent observations (Figure 33). A precipitous drop in presence is seen in Figure 33 for 100-hour slash sizes, while 1000- and 10,000-hour slash sizes were even less frequently encountered. The overall implication being, while there are isolated incidents of higher slash depths, and generally the higher biomass, coastal forest types may have greater continuous slash following harvest in addition to higher average slash depths, a large majority of slash from harvesting was less than one inch in diameter. While small sized slash pieces at times accumulated into deeper concentrations (Figure 32), generally the less favorable results of deeper and more continuous slash was due to the presence of larger slash size classes (i.e., 100, 1000, and 10,000 hour sizes). However, these incidences were in the minority of measurements.

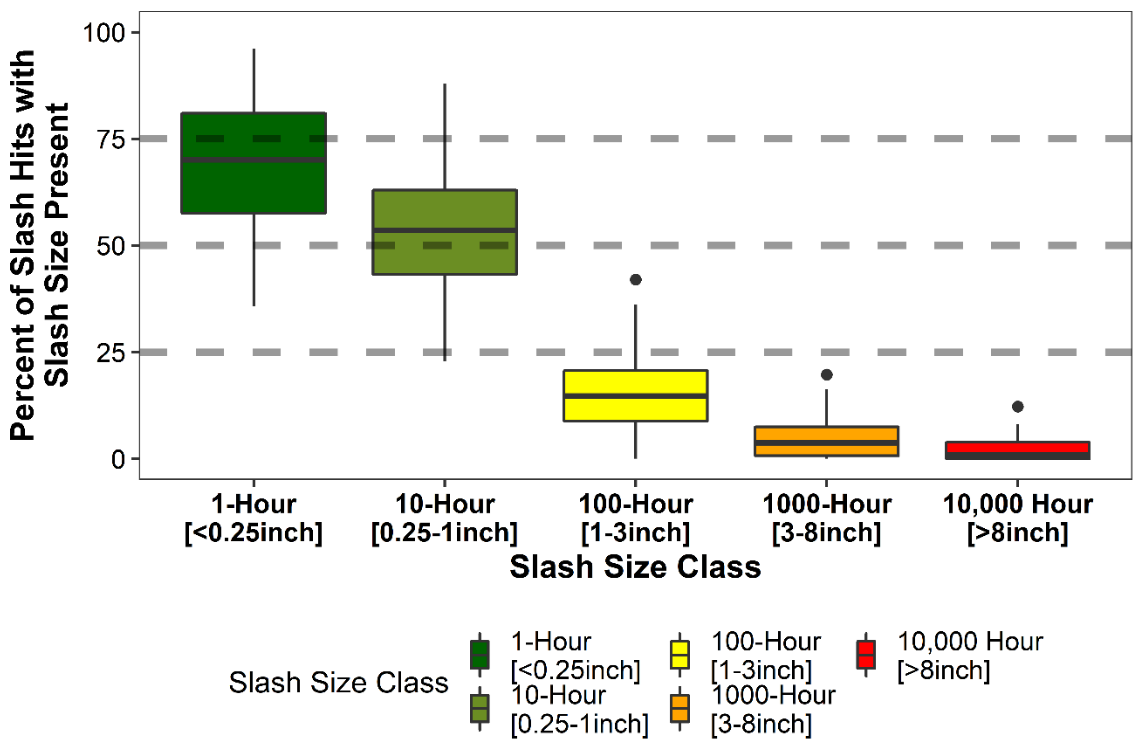


Figure 33: *Percent of slash size class present for each slash size class across all sampled FFP Notice transects. Where slash is encountered on a transect, multiple size classes may be present, in a layered order. Box colors indicate slash size class, and grey dashed lines indicate 25, 50, and 75% values. Boxplot characteristics are the same as* ***Figure 27.***

[21] Slash size class, same as Fuel Size Class, reflective of the characteristics of how quickly woody debris will dry out under warming conditions. They are 1, 10, 100, 1000, and 10,000-hour, equivalent to <0.25, 0.25-1, 1-3, 3-8, and >8 inches in diameter.

Figure 34: *Top image, an example of minimal, non-continuous, small sized slash coverage and depth on an FFP Notice in a mixed conifer forest in Calaveras county within the Sierra FPA. Bottom, a mixed conifer forest type in Trinity county and Coast FPA with greater residual slash present.*

Figure 35: *An example of continuous, small diameter slash coverage on a Coast FPA, Humboldt county FFP Notice (top image). Examples of continuous, large sized, and/or deep concentrations of slash in coastal forest types on FFP Notices (bottom three images).*

Figure 36: *Isolated instances of post-harvest slash, with residual piles yet to be treated on an FFP accepted in June 2020 and monitored in June 2022 in the Southern FPA (top image), and an approximately 15 foot by 20 foot concentration of limbs from felled and skidded trees within an FFP unit in the Cascade FPA in Shasta county (bottom image).*

Canopy Closure Estimates

- **Using a rapid, smartphone-based assessment approach, 61% of FFP Notices likely met current canopy closure regulatory requirements, however, this finding was driven in part by FFP results in the Coast FPA and wet, “climate limited”, forest types with natural dense overstory. Where FFP Notices failed to meet FPR regulations, values ranged from 6% to 27% below the regulatory requirement.**
- **Timberland ownership type had no influence on canopy closure results, while the geographical location within California and forest type had a far greater control on post-treatment canopy closure and ability to meet regulations.**
- **Canopy retention standards are commonly used to limit canopy reduction in forests that support species that require old forest characteristics such as large trees, high canopy cover, and complex structure. Most sampled FFPs (89%) occurred in relatively younger forests with a QMD of 20 inches or less.**
- **While some traditional metrics, such as basal area, quadratic mean diameter, and trees per acre, were significant predictors of post-harvest canopy closure estimates, unsurprisingly, the percent of tree crowns in contact with each other after harvest explained post-harvest canopy closure the best, followed by geometric mean tree spacing.**
- **The implication being that canopy closure is an accurate regulatory method to control tree spacing and canopy density in many settings, but may not relate well across different forest types and management histories relative to traditional forest inventory measurements that are also part of the FPR regulations on the Forest Fire Prevention Exemption.**

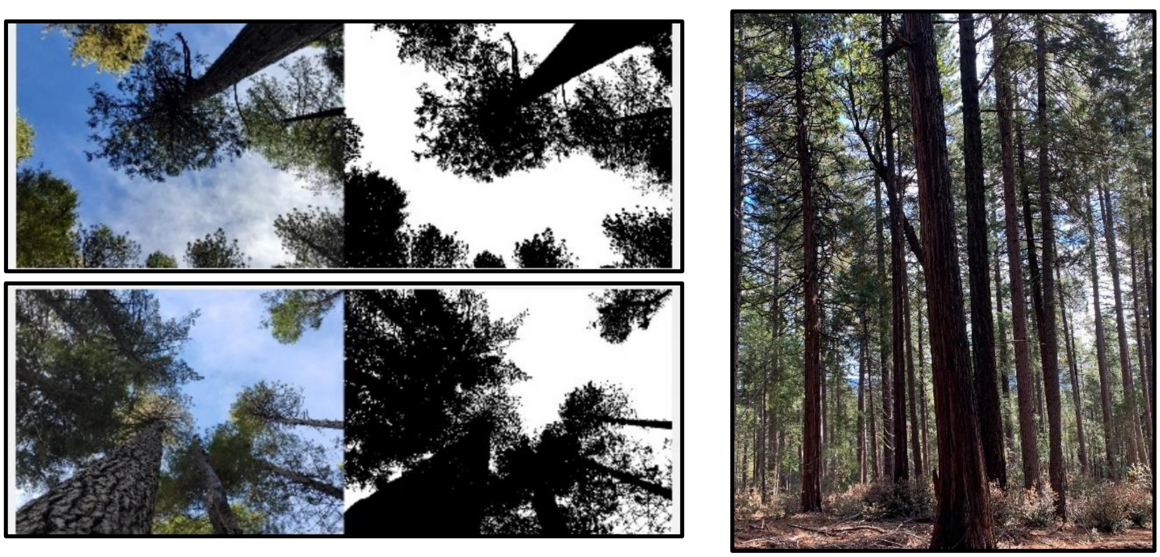


Figure 37: *Two canopy closure estimates from an FFP Notice in Yuba county and the Cascade FPA. The FFP had a requirement of 50% closure, the plot shown had an estimated 61% closure, and the entire Notice had a mean estimated closure value of 54%, 100% of the trees within plots on the FFP were in crown contact, and the geometric mean tree spacing was six (6) feet.*

Mean canopy closure estimates sample-wide ranged between 22 and 77% on FFP Notices (Figure 38). Allowing for 5% error in closure estimates and regulatory requirements, and understanding that our rapid methodology likely captures the lowest end of closure values (Appendix 2: Canopy Closure Method Comparison), 61% of the sampled FFPs met canopy closure requirements (n=27), while 39% (n=17) likely did not (Figure 38). At the Forest Practice Area level, 94% of the FFPs in the Coast FPA met canopy closure regulations; meanwhile, in the Cascade and Sierra FPAs, only 39% and 33% of the FFPs met canopy closure requirements. The lone Southern FPA Exemption met the FPR regulations. In terms of timberland ownership level, 61% (n=11) of Industrial and 62% (n=16) of Small Non-Industrial timberland FFP Notices met canopy closure requirements, respectively. Estimated canopy closure was highest in “climate limited[22]” coastal Redwood and Douglas Fir type forests, and lowest in east side pine and conifer forests (Figure 38,Table 14). Across all climate-limited forest types sampled, closure averaged 61%, while dry, fuel-limited interior forests had a mean closure value of 40% following harvest (Table 14).

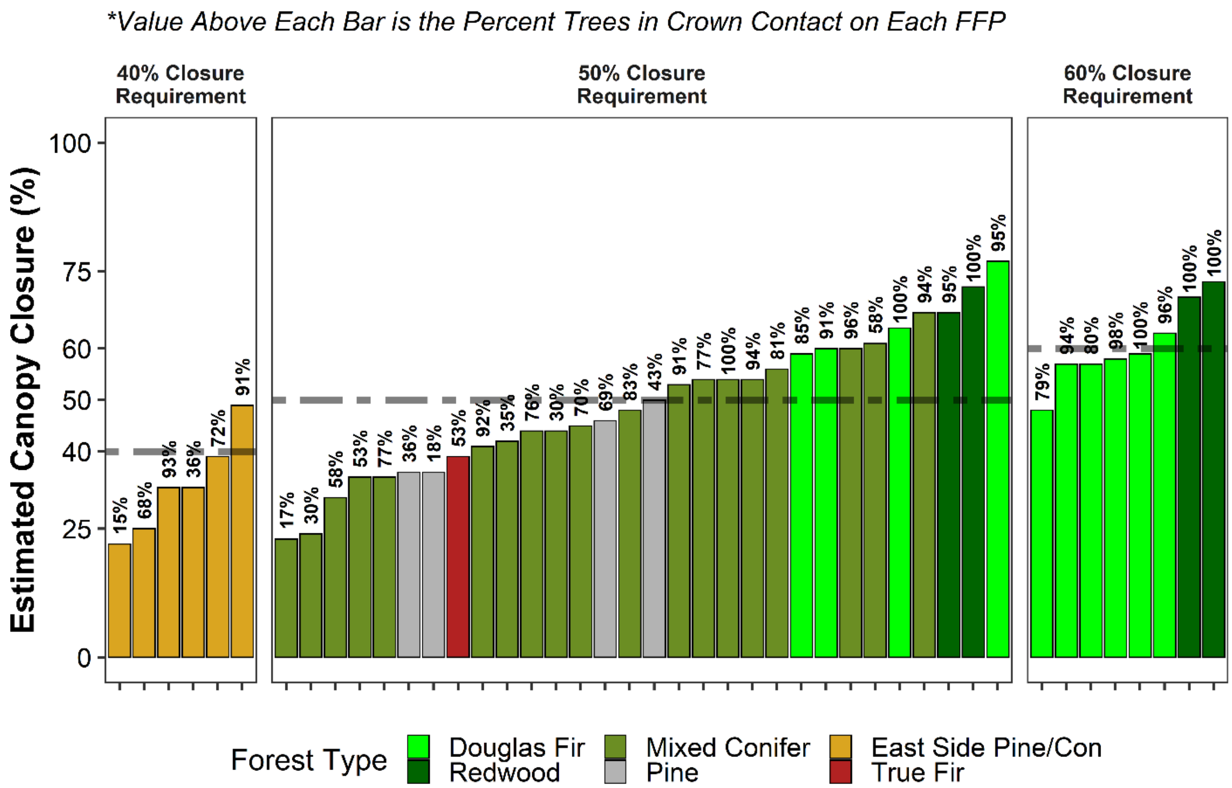


Figure 38: *Estimated mean canopy closure values, after the lowest value in each plot was removed, for the entire sample of FFP Notices. Panels indicate the regulatory minimum canopy closure value, bar colors indicate the reported forest type of the FFP Notice, and the number above each bar indicates the percentage of trees in crown contact on the FFP. In each panel, bars are sorted from left to right by increasing canopy closure values.*

Where estimated canopy closure on FFPs failed to meet regulations, the average closure value was 13% under, ranging between 27% to 6% below the rule requirements. Where closure regulations were met, the mean was 6% above the requirement, ranging between being within 5% of the regulatory minimum and 27% above the minimum canopy closure value. Interestingly, regardless of the type of timberland ownership, both Industrial and Non-Industrial ownerships, when their FFPs failed to meet closure requirements,

[22] “Climate limited”, unlike “fuel limited”, implies systems where conditions are conducive to burning under certain climatic conditions (e.g., periods of extreme heat, dryness, and wind) where fuel presence is continuous and substantial.

were 13% below the expected standard. However, Industrial ownerships that met or exceeded closure regulations had a mean value of 3% above regulations, while Non-Industrial ownerships had a mean value 9% above the regulatory expectation.

Figure 39: *An FFP in the Coast FPA in Humboldt county with 100% of trees in crown contact and a geometric tree spacing of four (4) feet, and a plot average of 64% canopy closure (shown) and overall closure average of 70% on the FFP Notice, which had a 60% closure requirement.*

Table 14: *Estimated canopy closure mean values and ranges by forest type, ownership type, and Forest Practice Area.*

	Mean Canopy Closure	Canopy Closure Range
Forest Type		
Redwood (n=4)	71%	67 – 73%
Douglas Fir (n=10)	60%	48 – 77%
Mixed Conifer (n=19)	46%	23 – 67%
True Fir (n=1)	39%	39%
Pine (n=4)	42%	36 – 50%
East Side Pine/Conifer (n=6)	34%	22 – 49%
Ownership Type		
Industrial (n=18)	48%	22 – 73%
Non-Industrial (n=26)	50%	23 – 77%
Forest Practice Area		
Coast (n=17)	62%	48 - 77%
Cascade (n=23)	40%	22 - 60%
Sierra (n=3)	39%	33 - 48%
Southern (n=1)	61%	61%
Forest Setting		
Coastal “Climate Limited” (n=17)	62%	48 – 77%
Interior “Fuel Limited” (n=27)	41%	22 – 61%

Statistical results[23] indicated that at the FPA level, the Coast had significantly higher closure values than both the Cascade and Sierra FPAs (marginal mean differences of 22% and 24%, p-value <0.0001 and p = 0.002, respectively). Meanwhile, the Cascade, Sierra, and Southern FPAs did not have a statistically significant difference in canopy closure values. **Timberland ownership had no significant effect on canopy closure values, as the marginal mean difference between the two ownership types was 1%, with a p-value of 0.77**. Lastly and unsurprisingly, coastal Redwood and Douglas Fir forest types on FFP Notices had significantly higher canopy closure estimates than all other forest types (marginal mean differences between 18% and 37% higher), while all other forest types had no statistical difference in closure estimates within our sample.

Linear regression results indicated that **the percentage of trees in crown contact on an FFP had the strongest relationship with canopy closure estimates (Figure 40), and that for every one percent increase in trees in crown contact, closure increased 0.4%** (Table 15). When considering only conifer trees in crown contact, the initial intercept (minimal closure value) was higher (25% closure), but the increase in closure values with conifers in crown contact was less (0.33% closure increase for every one percent increase in conifer crown contact) and explained less variation with a higher standard error (Table 15). Geometric mean tree spacing was a metric by which initial closure values were highest, with a slope of -1.2 (i.e., a decrease in closure values of 1.2% for every one-foot additional tree spacing) (Table 15, Figure 41), but only explained 20% of the variation in canopy closure results, while the standard error was higher at 13.1%.

[23] Analysis of variance in R Statistical Software, using the emmeans package to produce statistical comparisons of marginal means.

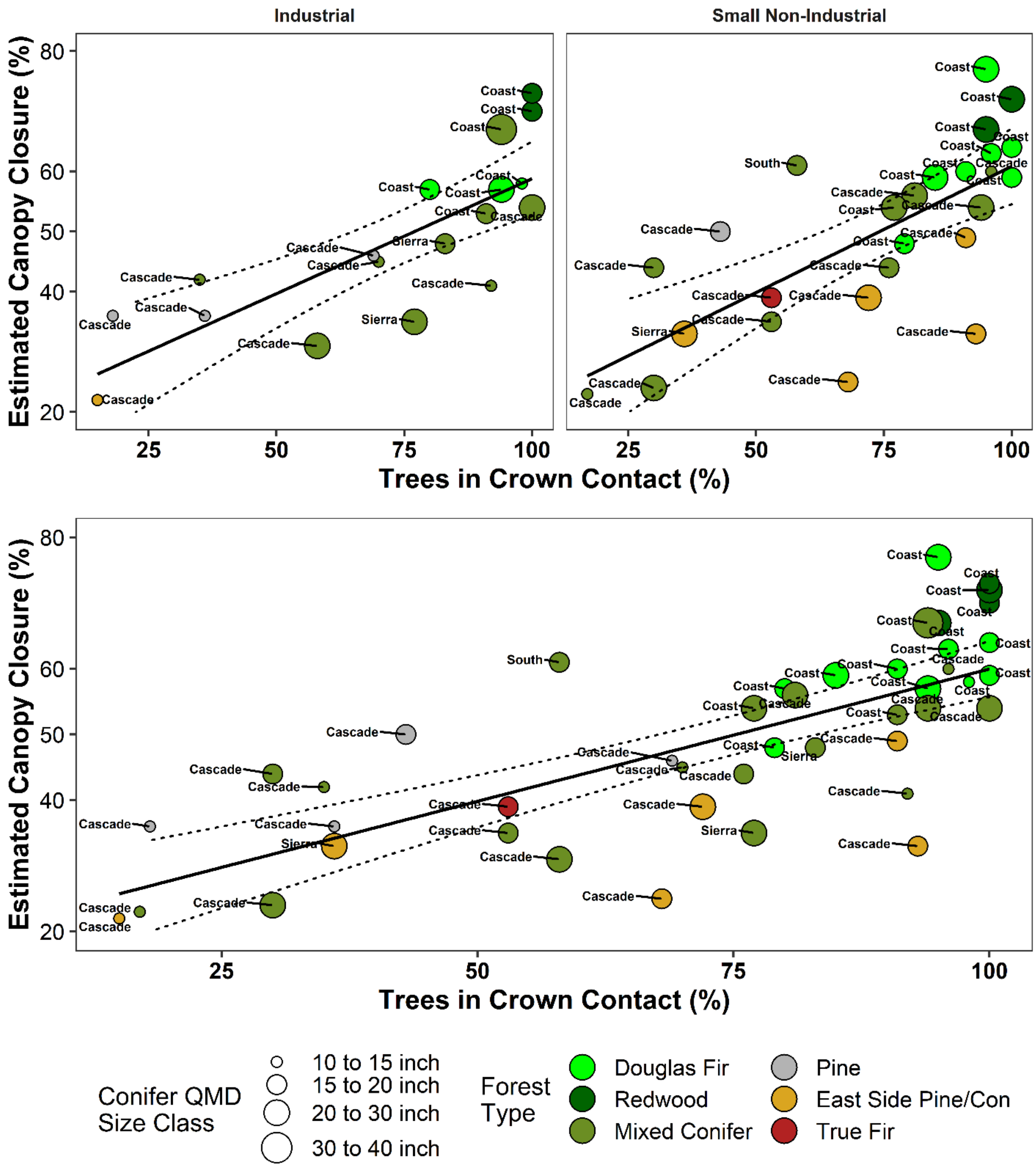


Figure 40: *Estimated canopy closure values and the percentage of trees in crown contact on each FFP Notice with a panel showing each timberland ownership type (top), and estimated canopy closure values and the percentage of trees in crown contact on each FFP Notice across all ownership types. Point colors indicate the forest type, and point size indicates the QMD size class for conifers on the FFP Notice.*

Table 15: *Selected linear regression predictors of canopy closure and their associated intercept values (minimal starting canopy closure percentage at the lowest value of the predictor), the slope (the percent change in canopy closure for every one-unit increase in the predictor), and the associated p-value (anything less than 0.05 considered significant), R^2 value (percent of canopy cover outcome explained by the predictor variable), and standard error.*

	Intercept	Slope	p-value	R^2	Standard Error
% Trees in Crown Contact	20%	0.40	<0.0001	0.55	9.8%
% Conifer Trees in Crown Contact	25%	0.33	<0.0001	0.45	10.8%
Geometric Mean Tree Spacing (feet)	63%	-1.2	0.003	0.20	13.1%
Estimated Basal Area (ft^2 ac^{-1}), Conifers	38%	0.09	0.0006	0.25	12.6%
Estimated Basal Area (ft^2 ac^{-1}), All Species	35%	0.10	<0.0001	0.35	11.7%
Estimated QMD, Conifers >8"	28%	1.1	0.02	0.12	13.7%
Estimated QMD, All Species >8"	33%	0.86	0.09	0.07	14.1%
Estimated SDI, Conifers >8"	37%	0.07	0.0006	0.25	12.6%
Estimated SDI, All Species and Sizes	33%	0.08	<0.0001	0.38	11.5%
Estimated Trees $Acre^{-1}$, Conifers	38%	0.17	0.03	0.10	13.8%
Estimated Trees $Acre^{-1}$, All Species	30%	0.06	0.0002	0.29	12.3%
Geometric Mean Crown Base Height (ft)	38%	0.54	0.0003	0.27	12.4%
Geometric Mean Tree Height (ft)	19%	0.41	0.001	0.23	12.8%

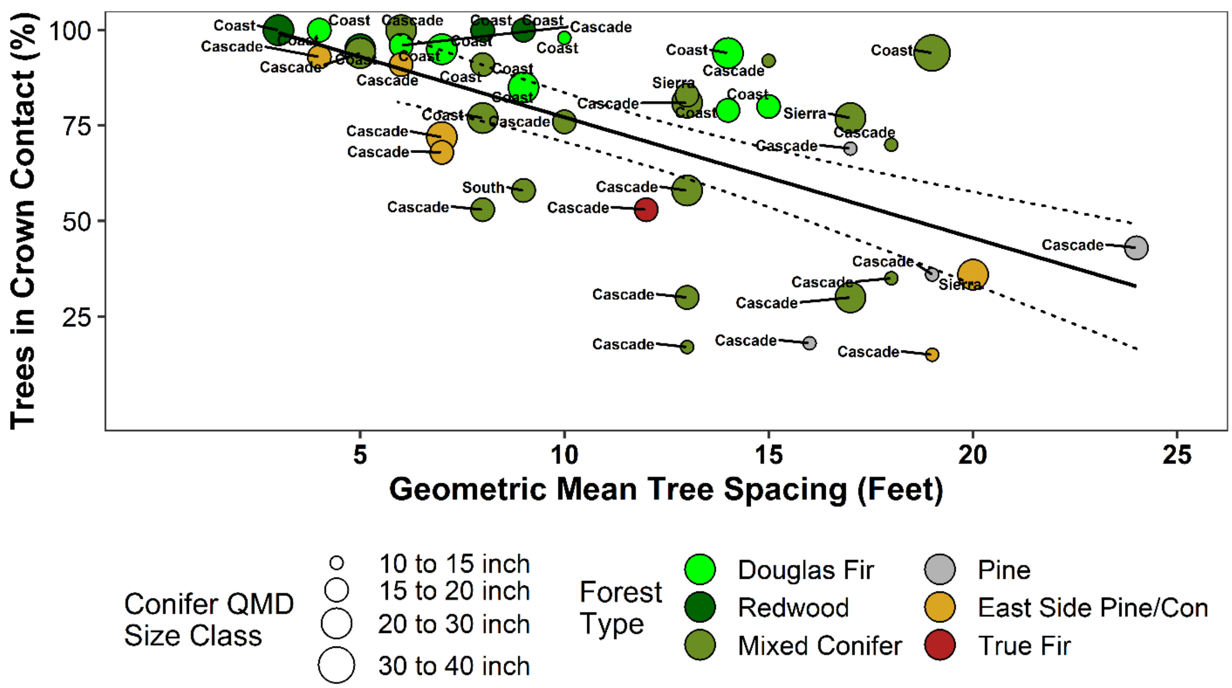


Figure 41: *Geometric mean tree spacing, and percentage of trees in crown contact, on each FFP Notice. Point color indicates the forest type, and point size indicates the QMD size class for conifers on the FFP Notice.*

The relationship between percent trees in crown contact and the geometric mean tree spacing was highly significant (p<0.0001), and tree spacing explained 41% of the variation in crown contact percentage; however, the residual standard error was high (21%) (Figure 41).

Table 16: *Number and percentage of FFP Notices that likely met or did not meet FPR requirements for post-harvest canopy closure and basal area retention of conifer species, and geometric mean tree spacing and percent trees in crown contact (and sd [standard deviation]). Green highlighting indicates most favorable outcome, yellow highlights indicate least desirable outcome, as applicable.*

	Canopy Closure Estimate Met *FPRs*	*Canopy Closure Estimate* Below *FPRs*
Basal Area Retention Met *FPRs*	20 / 45%	11 / 25%
Basal Area Retention Below *FPRs*	7 / 16%	6 / 14%
Geometric Mean Tree Space (feet)	10 feet (sd= 4.6 feet)	14 feet (sd= 5.3 feet)
% Trees in Crown Contact	87% (sd= 14.5%)	51% (sd= 26.2%)

Basal area, for both only conifers and for all species, and the stand density index (SDI) for both conifers eight inches or larger, and for all species and tree diameters, were significant predictors of canopy closure, but only explained canopy closure results by a maximum of 38%, with higher standard errors (Table 15). Crown base height was significantly related to canopy closure as well, however it only explained 27% of the results. Quadratic mean diameter (QMD) of conifers only explained 12% of the variation in canopy closure, while QMD for all tree types (conifer and hardwood) was not a significant predictor of estimated canopy closure (Table 15).

When considering basal area retention requirements under the FFP Notice, 45% of the sample met canopy closure and basal area requirements, while 14% did not meet either (Table 16). Forty-one percent (41) of the sample only met one of the two requirements (either canopy closure or basal area retention, only). **Across the entire sample (all forest types and ownership types), where our canopy closure estimates met the FPRs, tree spacing was 10 feet, with 87% of residual trees in crown contact, compared to tree spacing of 14 feet and 51% of trees in crown contact when estimates of closure did not meet the FPRs** (

Table 16).

The overall implication is that due to the wide-ranging structure and condition of forests in California, canopy closure may be difficult to correlate with any standard forest metrics (basal area, trees per acre, stand density indices), outside of the number of trees in crown contact, followed by tree spacing values. **When applying a broad regulatory requirement across a range of forests and forest management histories, the simplest metrics that control said requirement (e.g., proximity of tree crowns to each other and overhead canopy closure) may inform better than more traditional metrics that describe stand size, density, or volume.**

Figure 42: *An FFP with 15% of trees in crown contact and a geometric mean tree spacing of 19 feet in the Cascade FPA and Lassen county, with a plot average of 28% canopy closure.*

Figure 43: *Post-harvest panoramas of two Cascade FPA Forest Fire Prevention Exemptions. Top is a thinned plantation-type stand, and bottom is a more mature thinned mixed conifer stand.*

Ladder Fuels and Vertical Connectivity of Fuels

- **Where ladder fuels were highest in density, ladder fuels on plots were also predominantly the tallest, while when ladder fuel density was minimal, the fuels that can initiate surface-to-crown fire were shortest (two feet or less in height).**
- **Generally, it appeared purposeful treatments of surface and ladder fuels, where present, lowered the overall density of ladder fuels and their overall dominant height.**
- **Following operations, FFP Notices had an average of 22% of residual trees with potential vertical fuel continuity, or the ability for flames to transition from a surface fire to the tree crown via ladder fuels. However, three-quarters of the FFP sample had at least 75% of residual trees lacking vertical fuel continuity.**
- **Smaller diameter, shorter stands (particularly "plantation" style stands) had higher percentages of residual trees susceptible to likely surface-to-crown fuel continuity via ladder fuels; this was not necessarily the case when small, short, young stands had ladder fuels treated and/or crowns pruned, or where thinned stands were in locations with inherently low biomass surface fuels.**
- **Stands could have nearly uniform crown contact of residual trees, while due to elevated crown base heights, treated surface and ladder fuels, or forest settings, there was minimal or even a near absence of surface-to-crown potential fuel continuity.**

Figure 44: *An FFP Notice in the Sierra FPA, with a near absence of any ladder fuels greater than two feet in height, limited density, and a crown base above likely surface flame lengths.*

Following operations, the density of ladder fuels on 71% of our plots was less than 33% of the entire plot area, while 23% and 5% of plots had ladder fuel densities of 33-66% and greater than 66%, respectively. On plots where less than 33% of the area had ladder fuels present, 62% of plots were also dominated by ladder fuels two feet or less in height (Table 17). Alternatively, where ladder fuels covered at least two-thirds of a plot area or more, 70% of plots were also dominated by ladder fuels five feet or greater in height. Generally, it held across forest types that as ladder fuel density increased, dominant ladder fuel heights increased in prevalence as well, with exceptions due to additional treatments or specific forest structure and location.

Where mastication or other types of mechanical and hand treatments were present, 76% of plots were dominated by ladder fuels two feet or less in height, with only 13% and 0% of plots treated in the same way having ladder fuels two to five or over five feet in height as the dominant ladder fuel type (Table 18). In absence of these treatments, while the majority of plots (46%) were also dominated by ladder fuels less than two feet in height, 36% and 11% of plots had two to five and over five-foot-tall ladder fuels as the dominant type, respectively, compared to 13% and 0% where understory treatments occurred (Table 18). Similarly, a majority of both mechanically treated and untreated plots had ladder fuel density of less than 33%, though where treatments were done 91% of plots had less than one-third of their area as ladder fuels, compared to only 64% of plots where no active surface and ladder fuel treatment was done (Table 18).

Table 17: *Percentage of each ladder fuel height class present on plots by ladder fuel density, i.e., the dominant ladder fuel height class and how much of each plot it took up, for all plots across the entire sample. Yellow highlighting with bold text indicates the greatest value in each row. Rows may not add up to 100% due to rounding.*

	Plot Dominant Ladder Fuel Height Class			
Plot Ladder Fuel Density	*Absent*	*< 2 Feet*	*2 to 5 Feet*	*Over 5 Feet*
< 33%	10%	**62%**	24%	4%
33-66%	2%	40%	**51%**	7%
> 66%	0%	10%	20%	**70%**

Table 18: *Differences in the plot dominant ladder fuel height classes present and ladder fuel density present based on the use of mastication treatments in the plot. Bold text and yellow highlighting indicate the largest percentage in each row. Rows may not add up to 100% due to rounding.*

	Plot Dominant Ladder Fuel Height Class			
Masticated Treatment?	*Absent*	*< 2 Feet*	*2 to 5 Feet*	*Over 5 Feet*
Yes	11%	**76%**	13%	0%
No	7%	**46%**	36%	11%
Masticated Treatment?	**Ladder Fuel Density**			
	< 33%	*33-66%*	*> 66%*	
Yes	**91%**	9%	0%	
No	**64%**	28%	7%	

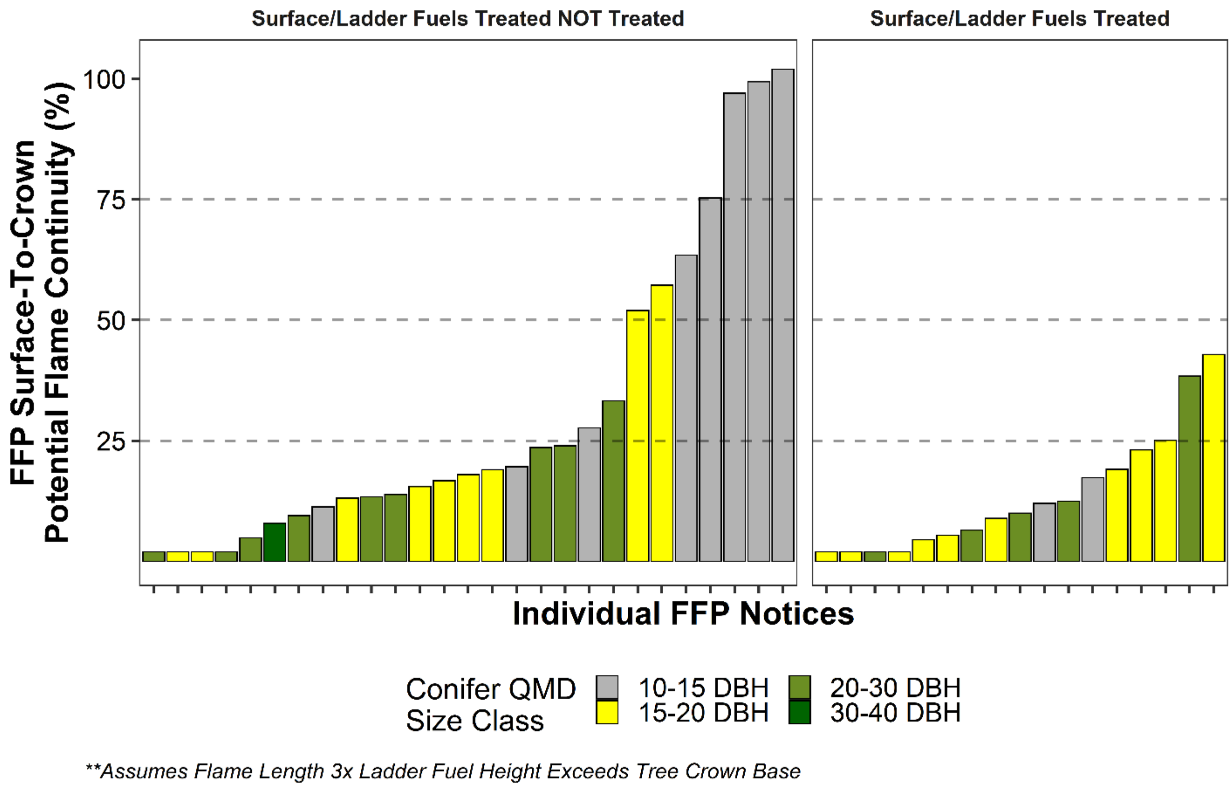


Figure 45: *Percentage of residual trees on each FFP Notice with the potential for fire to transition from surface to tree crowns via ladder fuels, by the presence or absence of some level of surface and ladder fuel treatment. Bar colors indicate the size class based on the QMD of residual conifers, and dashed lines indicate the 25%, 50%, and 75% thresholds.*

Across all sampled FFP Notices, working under a set of assumptions for ladder fuels and potential flame lengths[24], FFPs averaged 22% of residual trees as potentially susceptible to crown ignition. Individual FFPs ranged between 0% and 100% potential surface-to-crown fuel continuity; 84% of the sample had at least 50% of the residual stand lacking vertical-fuel continuity, while 75% of the sample had at least three-quarters of the residual stand lacking vertical-fuel continuity (Figure 45). Observationally, Figure 45 shows from a simple stand QMD size class, larger sized stands typically have less vertical fuel continuity to the canopy, regardless of surface/ladder fuel treatments; however, the smallest size class of 10-15 inch conifer stands with an absence of treatments to non-timber fuels may have substantial vertical fuel continuity. **These stands were generally "plantation" style stands, in areas with high enough productivity to grow**

[24] We assume median ladder fuel heights of 0.1, 1, 4, and 5 feet for the ladder fuel categories of "absent", < 2 feet, 2 to 5 feet, and > 5 feet, respectively. We next assume a flame length of 3x the ladder fuel height (Readyforwildfire.org), and that a tree has an absence of potential vertical continuity if the crown base height (lowest limbs with the potential to carry fire into the crown) is greater than 3x the assumed median ladder fuel height. This assumption is based on the dominant ladder fuel height in each plot, and excludes potential singular, isolated ladder fuel classes that may be taller than the dominant class, and does not take into account ladder fuel density. As such, our approach may be taken as a worst-case scenario for each plot and FFP Notice, but would not capture fire behavior under most extreme burning conditions.

substantial surface and/or ladder fuels (e.g., manzanita). Some larger diameter stands also had vertical continuity observed and measured via small sub-merchantable trees growing beneath larger trees.

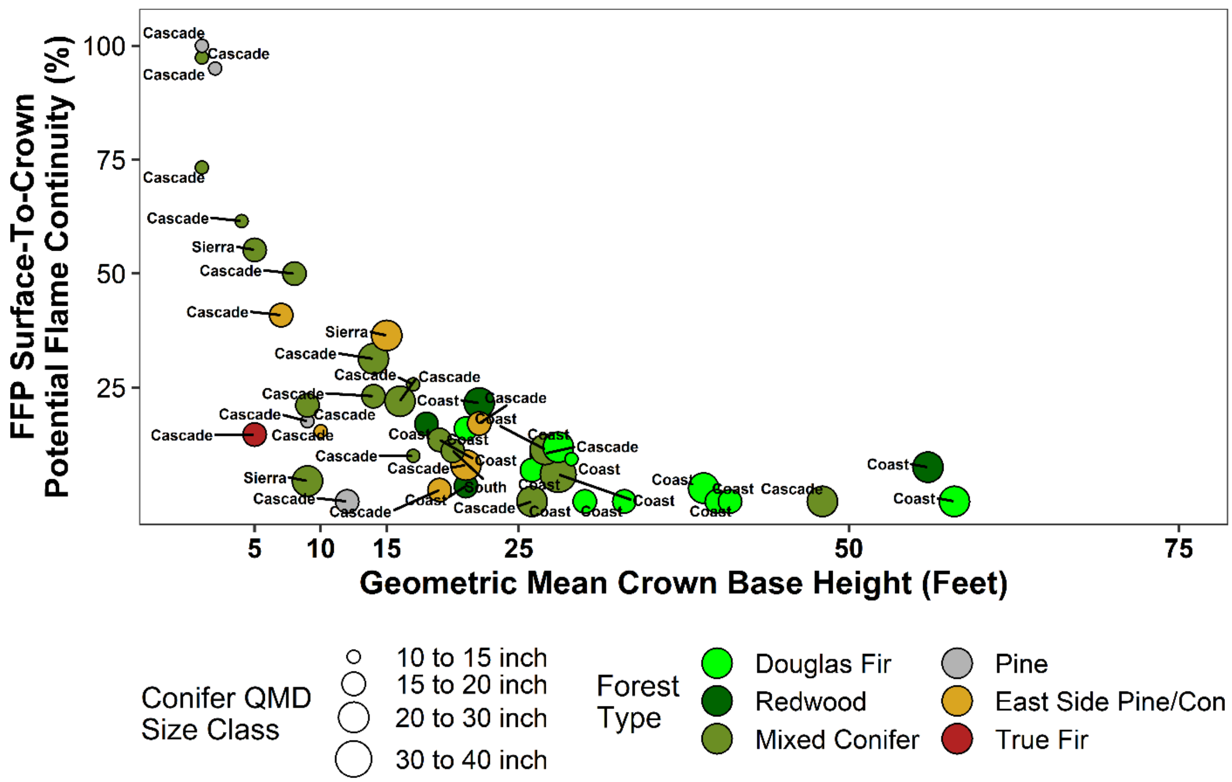


Figure 46: *Geometric mean crown base height and the percentage of each sampled FFPs post-harvest stand at risk for surface-to-crown fuel continuity. Point color indicates the sampled forest stand type, while point size indicates the QMD size class of residual conifers.*

Unsurprisingly, as the geometric mean crown base height across entire FFP Notices increased, the percentage of the stand at potential risk for surface-to-crown fire transition decreased (Figure 46). Noticeably, biomass heavy-type forests such as Douglas Fir and Redwood, and those stands in a larger QMD class, had lower post-harvest surface-to-crown fuel/flame connectivity percentages (Figure 46, Figure 48). Alternatively, Figure 46 visually shows how the stands in the smaller QMD size classes typically have a much lower crown base and thus susceptiblity to surface-to-crown fire connectivity during a wildfire. In general, little surface-to-crown fuel continuity exists once the mean crown base height exceeded 25 feet, coinciding with greater stand QMD values.

Similarly, as the geometric mean tree height on an FFP increased, there was an observed trend in lower potential continuity between ladder fuels and tree crowns, which also aligned with larger diameter stands; the upper left quadrant of the left panel of Figure 47 (top) shows what can be thought of as even-aged “plantation” type young forest stands (Figure 49). Finally, the percentage of trees in crown contact on an FFP Notice did not necessarily appear to have a strong relationship with potential surface-to-crown connectivity of fuels (Figure 47, bottom). If anything, while **Canopy Closure Estimates** noted the strong relationship between trees in crown contact and canopy closure, Figure 47 (bottom) indicates that across our sample, regardless of timberland ownership type or forest stand type, a stand may have almost all, or all, trees in crown contact while simultaneously having a *lack* of surface-to-crown fuel connectivity via ladder fuels.

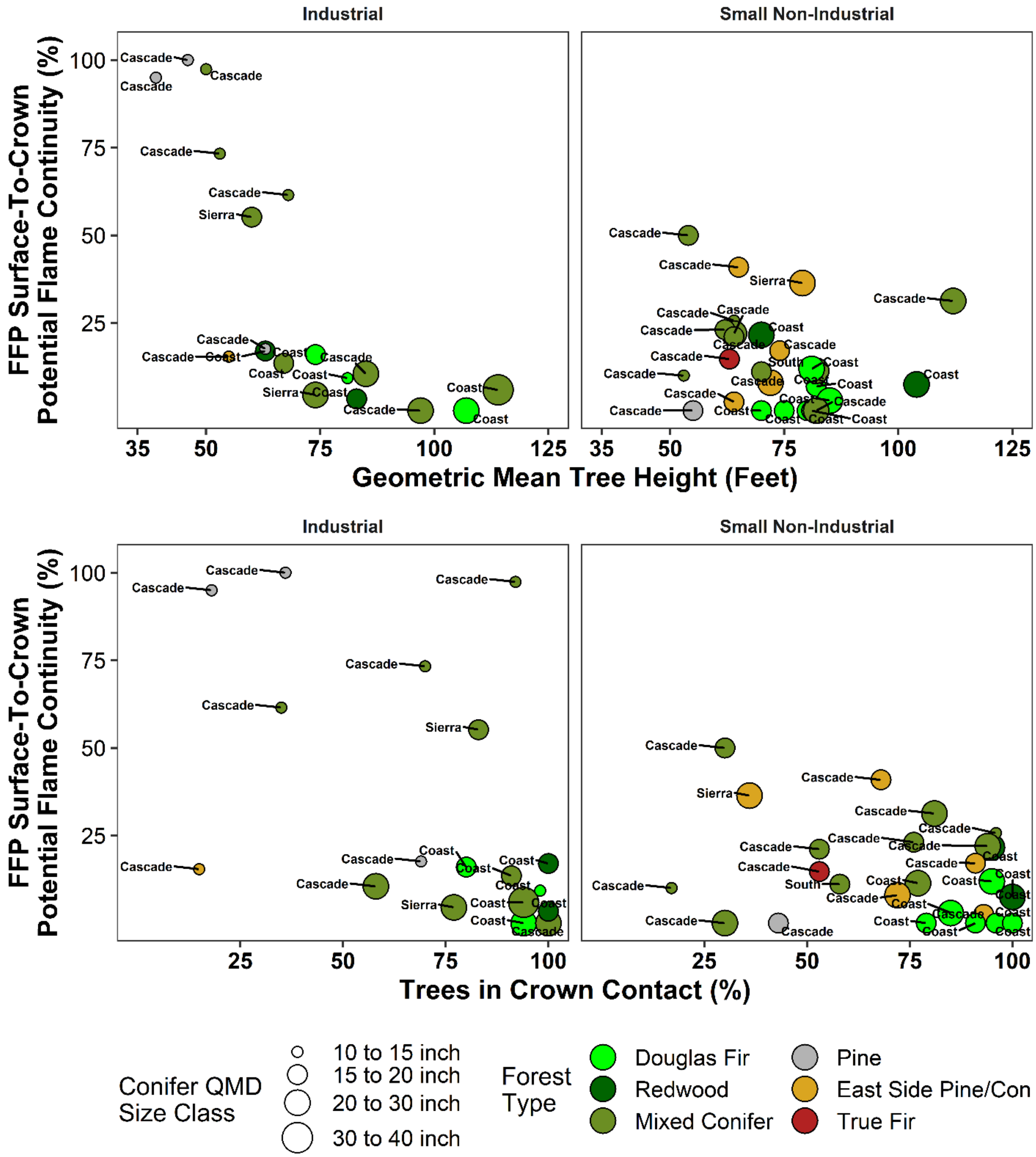


Figure 47: *Geometric mean tree height (top) and the percent trees in crown contact (bottom) and the percentage of each sampled FFPs post-harvest stand at risk for surface-to-crown fuel/fire connectivity. Point color indicates the sampled forest stand type, while point size indicates the QMD size class of residual conifers, and panels show results by timberland ownership type.*

Figure 48: *Cascade FPA Exemption Notices with a lack of ladder fuels, and tree crown base heights generally above any potential surface or ladder fuel flame lengths.*

Figure 49: *Thinned plantations in the Cascade FPA, thinned under FFP Notices. Left top and bottom, examples with some susceptibility to surface and ladder fuel vertical connectivity to the tree crowns due to smaller trees size and lower crown bases. Right top and bottom, examples with high horizontal crown continuity, but lower surface-to-crown continuity.*

Figure 50*: A Douglas Fir-type FFP Notice in the Coast FPA, where within the mapped and treated Notice boundary, post-harvest slash was intermixed with ladder fuels of all size classes including predominantly those ladder fuels over five feet in height.*

Tree Spacing and Horizontal Crown Continuity

- **Tree spacing, inclusive of conifer and hardwood species, averaged 6.6 feet across the entire sample before harvesting, and 11 feet post-harvest.**
- **Both pre- and post-harvest tree spacing was significantly greater on Industrial ownerships, however, there was no significant difference in mean tree spacing *change* between Industrial and Non-Industrial ownership types.**
- **Observationally, it appears that most of the stands of the smallest conifer QMD size class increased tree spacing the greatest amount, while some larger size class stands increased tree spacing likely through focused removal of the smallest diameter trees, or selective removal of larger trees, to remove ladder fuels or disrupt horizontal crown continuity.**
- **FFP Notices had between 15% and 100% of residual trees (conifer and hardwood) in crown contact, with a sample-wide mean of 73% trees in crown contact after operations. Trees in crown contact did not, on average, differ between timberland ownership types, but instead by forest type and stand conifer QMD size class.**
- **Differences between mean tree spacing when crown contact was absent and when crown contact was present differed by a factor of 1.5 to 3 times.**

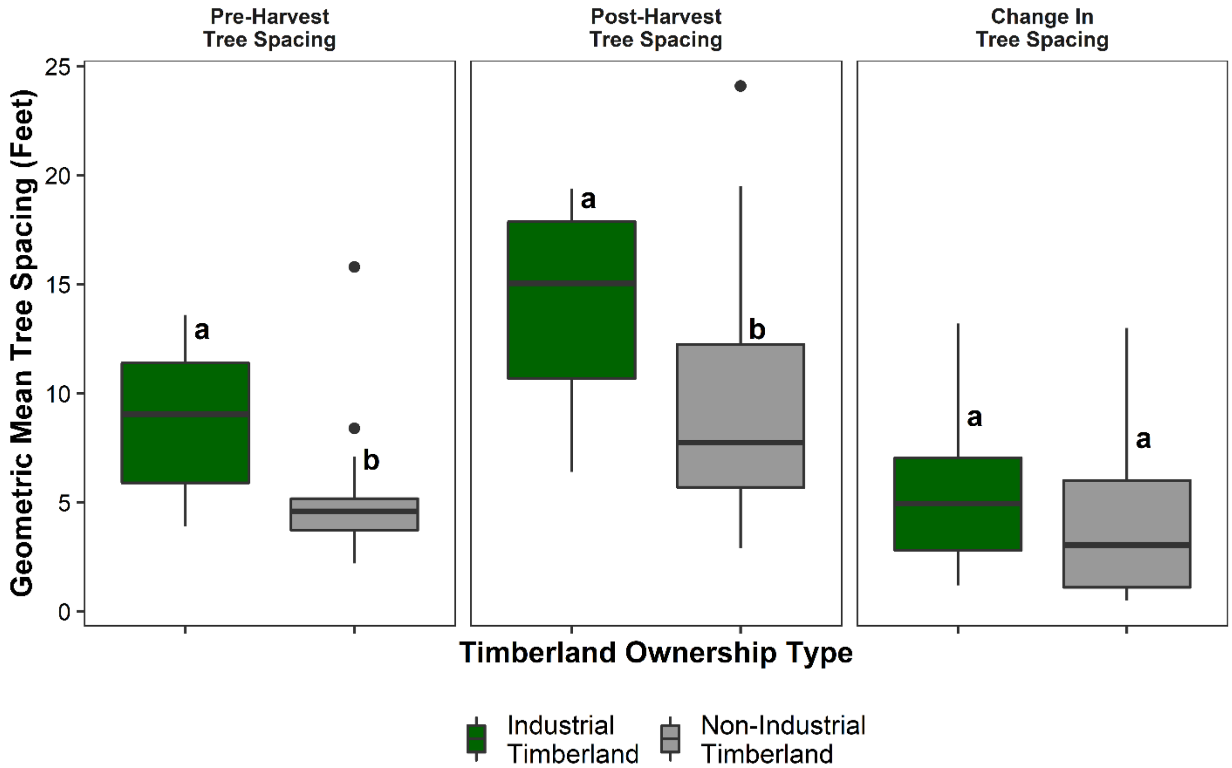


Figure 51*:* *Pre-harvest and post-harvest average geometric mean tree spacing, and average geometric mean tree space change, by timberland ownership type. Different letters in each panel denote a significant difference between ownership types in tree spacing or tree spacing change. Boxplot characteristics are the same as* ***Figure 27****.*

Pre-harvest tree spacing[25,26] had an average sample-wide geometric mean value of 6.6 feet (sd = 3.3 feet), ranging between two (2) and 16 feet. On Industrial timberlands, the average geometric mean tree spacing pre-harvest was nine (9) feet (sd=3.0 feet), while on small Non-Industrial timberland FFPs that spacing was only five (5) feet (sd = 2.6 feet), and there was a statistically significant difference between ownership types in pre-harvest tree spacing (Figure 51).

Following harvesting the average geometric mean tree spacing across the sample was 11 feet (sd = 5.4 feet), and ranged between three (3) and 24 feet. Industrial and Non-Industrial timberlands had average post-harvest tree spacing means of 14 and nine (9) feet (Table 19), respectively (respective standard deviation of 4.3 and 5.2 feet), and again, there was a significant difference in post-harvest tree spacing between ownership types (Figure 51).

[25] In order to minimize the effect of outliers, we calculate the central tendency of tree spacing as the geometric mean spacing. For more information, please see Olsen and Coe 2021a and 2021b.
[26] We estimate pre-harvest tree spacing by measuring, for each plot, the distance between all residual trees ≥8 inches and the nearest tree stump and tree ≥8 inches (either in or outside of the plot), and taking the minimum value of these two measurements as the pre-harvest spacing, while post-harvest spacing is the distance between nearest residual trees, averaged for an entire FFP Notice.

The difference between pre- and post-harvest geometric mean tree spacing on FFPs (i.e., the distance increased between trees by treatment) ranged between 0.5 and 13 feet, for a sample average of 4.6 feet (sd = 3.5 feet). **Interestingly, there was no statistically significant difference in tree spacing change between ownership types (Figure 51); Industrial timberlands increased the geometric mean tree spacing an average of five (5) feet, while Non-Industrial ownerships increased and average of four (4) feet (Table 19).**

Table 19*: Mean percent trees in crown contact (post-harvest), the average geometric mean tree spacing, and average geometric mean tree spacing for tree in and not in crown contact, by forest type, post-harvest conifer QMD size class, and timberland ownership type.*

	Mean % Trees Crown Contact (Post-Harvest)	Average Geometric Mean Tree Spacing (Post-Harvest)	Average Geometric Mean Tree Spacing – *No* Crown Contact (All Species)	Average Geometric Mean Tree Spacing – *Crown Contact* (All Species)	No Crown Contact to Crown Contact Spacing Difference Factor
Forest Type					
Redwood	99%	6 feet	16 feet	6 feet	2.7x
Douglas Fir	92%	9 feet	18 feet	9 feet	2x
Mixed Conifer	69%	12 feet	19 feet	10 feet	1.9x
True Fir	53%	12 feet	21 feet	7 feet	3x
Pine	42%	19 feet	22 feet	16 feet	1.4x
East Side Pine/Conifer	63%	10 feet	19 feet	8 feet	2.4x
Conifer QMD Size Class					
10-15 inch DBH	55%	15 feet	20 feet	13 feet	1.5x
15-20 inch DBH	78%	9 feet	19 feet	8 feet	2.4x
20-30 inch DBH	78%	10 feet	18 feet	9 feet	2x
30-40 inch DBH (n=1)	94%	19 feet	27 feet	18 feet	1.5x
Ownership					
Industrial	73%	14 feet	22 feet	13 feet	1.7x
Non-Industrial	73%	9 feet	17 feet	7 feet	2.4x

Figure 52 shows the relationships between pre- and post-harvest mean tree spacings. In all panels in Figure 52, the higher vertically a point is from the dashed red line, the greater the pre- to post-tree spacing change was. Interestingly, some of the FFPs with the smallest post-harvest QMD size class (10-15 inches), had some of the greatest pre- and post-harvest tree spacing, **while as the stand QMD size class increased, spacing change generally was lower, or even near unchanged (i.e., closer to the 1:1 red line), indicative of likely greater harvesting of understory non-dominant trees, on many FFP Notices (Figure 53)**. Figure 52 also indicates that small Non-Industrial timberland ownerships (bottom right panel) largely saw tree spacing increases where the pre-harvest stand had a geometric mean tree spacing of five (5) feet or more, and below that tree spacing largely did not change. **Conversely, Industrial timberland ownerships (bottom left panel in Figure 52) visually appear to have almost all harvests on this ownership type resulting in increased tree spacing, driven in part by small 10-15 inch size class forest stands (i.e., plantations).**

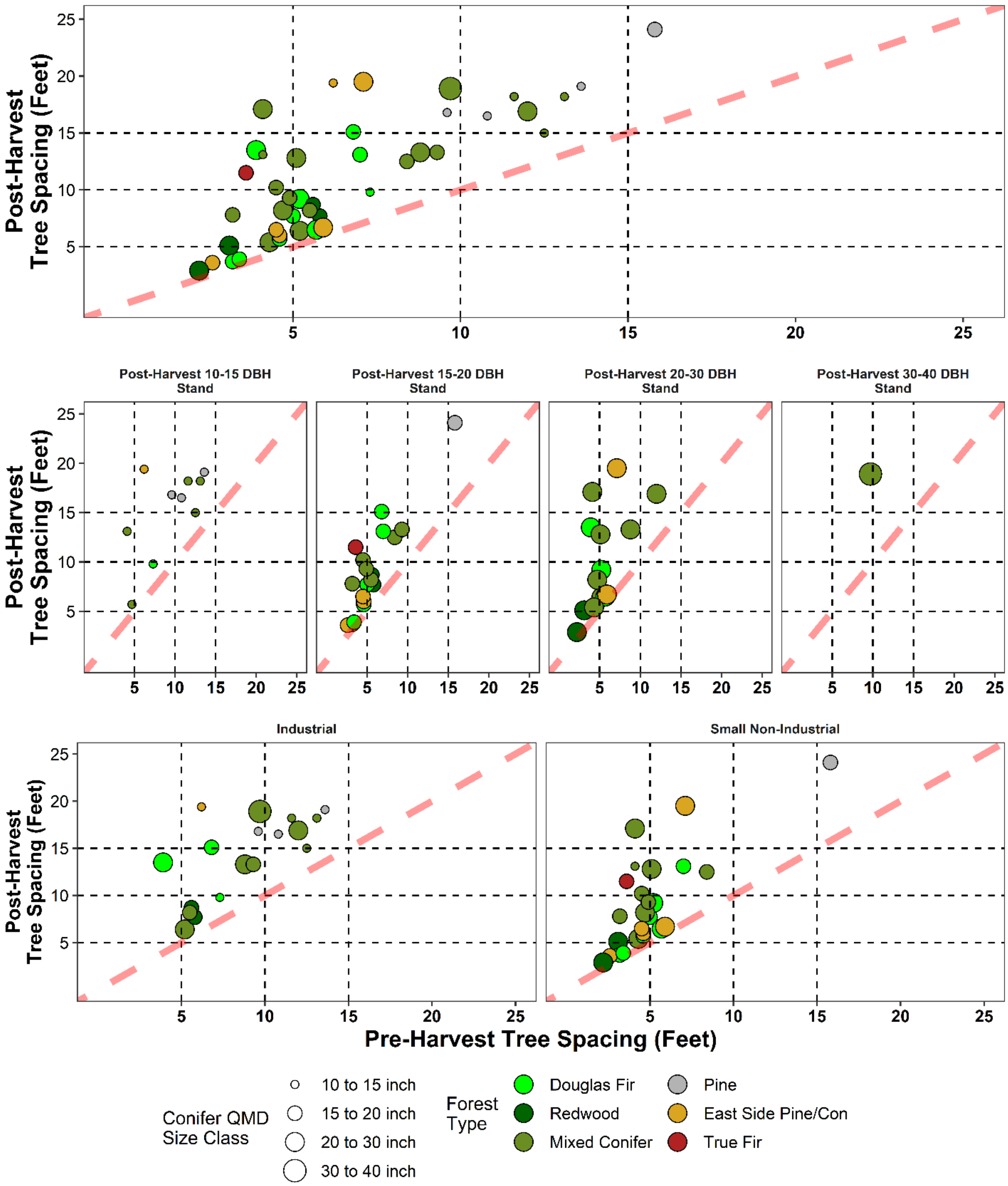


Figure 52*: Pre-harvest geometric mean tree spacing on FFP Notices (in feet) versus post-harvest geometric mean tree spacing. The top panel shows results across the entire sample, the middle panels show results by post-harvest stand conifer size class, and the bottom panels show results by timberland ownership type. Point size indicates the post-harvest conifer QMD size class on the FFP, and point color indicates the forest type. The horizontal and vertical black dashed lines show the five-, ten-, and 15-foot thresholds, and the red dashed line is the 1:1 line. All panels, the higher a point is vertically from the red line, the greater the tree spacing increased via timber harvesting.*

Figure 53: *An example of a plot on an Industrial timberland FFP Notice where tree spacing increased approximately three feet following harvesting, to 19 feet on average, due to a focus on small diameter understory tree removal (merchantable and sub-merchantable tree sizes), in addition to surface fuel treatments. Of note, the treated stand had a pre-harvest QMD size class of 15-20 inches, and post-harvest this increased to the 20-30 inch size class, indicative of thinning from below. 58% of residual trees were in crown contact as well.*

While timberland ownership types had significant differences in pre- and post-harvest tree spacing, the result that tree space change did not statistically differ between ownership types might be indicative of **differences between homogenous versus heterogenous size classes found in different forest stands with different management histories. That is, a difference in thinning even aged stands, and thinning multi-cohort stands with an abundance of intermediate or small trees amongst larger dominant trees.**

As reported previously in **Canopy Closure Estimates**, and shown in Figure 41, tree spacing and percent crowns in contact were significantly related, with 41% of the variation in crown contact explained by geometric mean tree spacing. Figure 40 also revealed the significant relationship between percent trees in crown contact and canopy closure, explaining 55% of our FFP closure results. **Sampled FFP Notices had between 15% and 100% of residual trees in crown contact, with an average of 73%** (sd = 26%). Interestingly, regardless of timberland ownership type, both Industrial and Non-Industrial ownerships averaged 73% crown contact across the sample, with the implication being that forest stand type and size matters more for horizontal crown continuity than ownership. As the post-harvest conifer QMD size class increased the percent trees in crown contact increased, while for increasingly dry or high elevation interior forest types, the percent trees in crown contact following operations decreased (Table 19).

Figure 54: *Approximate pre- and post-harvest photos of a part of a 2016 FFP Notice in Trinity County, showing the visual change in tree spacing after harvest operations. Photos courtesy of CAL FIRE Forester II Dan Craig.*

Figure 55: *Tree spacing examples in the Lake Tahoe Basin (top images), where geometric mean tree spacing was four feet pre-harvest, and 17 feet post-harvest, and in Sierra County where tree spacing increased from four feet pre-harvest to 13 feet post-harvest. Of note, is the Lake Tahoe Basin FFP example was in the 15-20 inch QMD size class pre-harvest, and increased to the 20-30 inch size class post-harvest, demonstrating approximate individual-clump-opening ("ICO") stand structure, while the Sierra county FFP was in the 10-15 inch QMD size class both pre- and post-harvest (closer to a non-industrial "plantation" stand structure).*

Quadratic Mean Diameter

- **QMD of conifer species 8 inches and larger was increased on all but one FFP Notice in our sample. The only FFP Notice with a slightly negative QMD change did have a positive QMD change when considering hardwood species as well.**
- **Generally, Non-Industrial timberlands had greater QMD values both before and after timber harvesting, and higher QMD change values, but the differences from Industrial timberlands were not significant.**
- **Smaller sized forest stands had lower QMD change than larger sized stands, and was likely indicative of "thinning from below" or the removal of the smallest diameter trees in a stand, or selective removal only of larger, dominant conifers, where conditions warranted removal.**
- **There were limited occurrences of harvesting of trees that exceeded the 30-inch stump diameter limit (0.5% of all measured stumps, and only one FFP Notice with a noticeably oversized stump).**

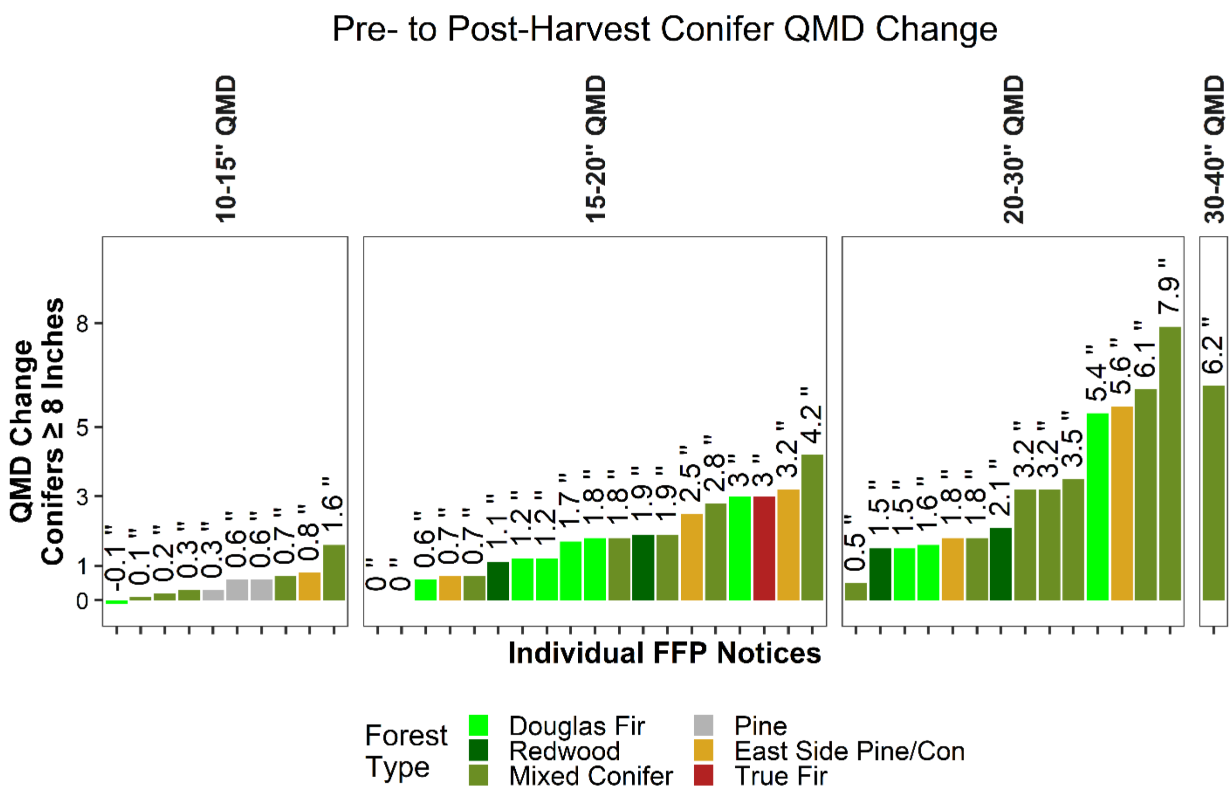


Figure 56*: QMD change for conifers eight inches and larger, by post-harvest QMD conifer size class. Bars are individual FFP Notices, and the numbers above each bar indicate the estimated QMD change. Bar colors indicate the forest type. Results are ordered left to right by increasing QMD change.*

Quadratic mean diameter (QMD) for conifers eight (8) inches and larger generally increased for all FFP Notices in our sample[27]. While our rapid approach provides only estimates, they are representative of reported harvest areas from RPFs; as such, only one (1) FFP Notice had a negative QMD change for conifers (-0.1 inches), and

[27] For more information on the approach used within monitoring for this, please see **Appendix 3: QMD Change Calculation**

two FFP Notices had estimates of no change in QMD (Figure 56). However, when considering both conifer and hardwood trees eight (8) inches and larger, the lone FFP with a negative QMD change actually had an increase of 0.2 inches, indicative of treatment of hardwood species as well.

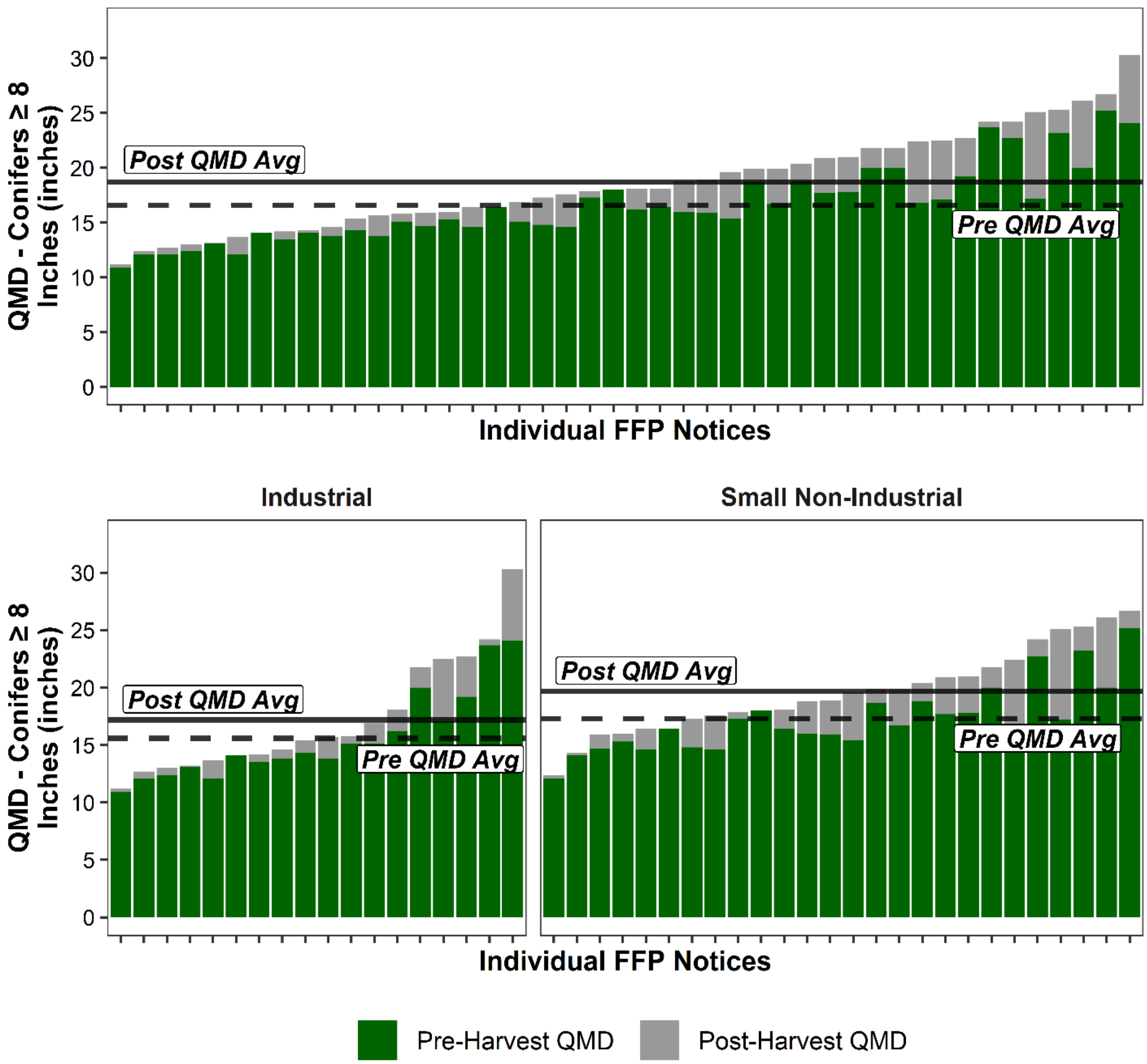


Figure 57: *Pre- and post-harvest QMD, based on conifers eight inches and larger, across the entire sample (top), and by timberland ownership type (bottom). The dashed lines indicates the sample-wide or ownership type mean pre-harvest QMD value, while the solid line indicates the post-harvest mean QMD values. The bars are individual FFP Notices, and the green color indicates the pre-harvest QMD, the gray color indicates the change and final post-harvest QMD value. Bars are ordered from left to right in the top and bottom panels by increasing post-harvest QMD values.*

Across the entire sample, the QMD of conifers eight (8) inches and greater had a mean of 16.6 inches pre-harvest, and 18.7 inches post-harvest (Figure 57). Within Industrial timberlands, pre- and post-harvest QMD means were 15.6 and 17.2 inches, respectively (Figure 57). Non-Industrial timberlands had a mean pre-harvest QMD of 17.3 inches, which increased after harvest to 19.7 inches (Figure 57). QMD *change* on

Industrial timberland ownerships ranged between -0.1 and 6.2 inches, with a mean of 1.6 inches, while on Non-Industrial timberlands QMD ranged between 0 and 7.9 inches, with a mean of 2.3 inches (Figure 56).

Our results, interestingly, point towards the presence of larger trees (based on conifer QMD) on small, Non-Industrial timberlands both before and after harvesting, and greater QMD changes due to timber harvesting. However, there were no statistically significant differences in pre- or post-harvest QMD values, nor QMD changes, between timberland ownership types. Likewise, there were no significant differences in any these aforementioned QMD measurements amongst forest types.

However, there were significant differences in QMD changes between QMD size classes; the 10-15 inch size class had significantly lower QMD changes than the 15-20, 20-30, and 30-40 inch size class stands, and the 15-20 inch size class stands were significantly lower in QMD change than the 20-30 and 30-40 inch size class stands. The marginal mean QMD changes by stand size classes were 0.5, 1.8, 3.3, and 6.2 inches for the 10-15, 15-20, 20-30, and 30-40 inch size classes, respectively. **While this may be an intuitive result, it highlights the limited range of structure size change in smaller "plantation" and/or younger forest stands, and the QMD increases due to "thinning from below" in more developed, larger diameter forest stands.**

Finally, in the assessment of dead standing trees eight (8) inches and larger on FFP Notices (where present), the average QMD was 17 inches, ranging between nine (9) and 38 inches. Effectively, there was no difference between ownership types, with Industrial FFPs averaging a QMD of 17.6 inches, and Non-Industrial FFPs averaging a QMD 16.7 inches.

Across our entire sample, there were only seven (7) instances of FFPs with stumps that exceeded the 30-inch diameter limit *at eight (8) inches above the ground*, totaling eight (8) stumps total, per FPR regulations[28]. **The eight (8) stumps 30 inches or larger that were found during sampling, represented 0.5% of all measured stumps (n = 1,457), and *Stand Structure and Change* results are further indicative of "thinning from below" and a focus on the smallest trees on each FFP Notice.** In our sample, all but one instance was the identification of a single stump within our random plots, and only one FFP had two plots with a single stump in excess of 30 inches. None of these instances were related to road construction or re-construction. However, three of the seven FFPs had stumps measured at exactly 30 inches diameter, at the point of potential measurement error (both in rapid monitoring and by licensed professionals). Three other FFPs had stumps that were 31 or 32 inches in diameter, while only one FFP had a stump measured at 37 inches. As such, our rapid, limited assessment of this regulation implies

[28] The rapid nature of our monitoring is such that we did not *explicitly* measure stump diameter at 8 inches above ground. This particular regulatory metric is difficult to assess due to differences in harvest methods, both by equipment type (feller buncher, hot saw, hand falling) and by operator style, in addition to particular timberland owner preferences.

that 7% of the sample had singular occurrences of stumps slightly over the diameter limit (30, 31, or 32 inches), and 2% (or n = 1) of the sample had a more obviously oversized stump (37 inches). As such, where harvesting of trees 30 inches in diameter or larger, eight inches above the ground, may be occurring, **it is seemingly extremely limited both within individual FFPs and across all FFP Notices in the state.** The lone occurrence of a larger than allowable sized tree being harvested, was on an FFP that was marked for leave trees only, using only a sample marking.

From 2015 through 2021, five (5) FFP Notices received Notices of Violation for the harvesting of trees over the diameter limit (which did change over that time period), which equates to 1.8% of all FFP Notices in that time period (*Exemption Inspections and Violations*, n = 271). Our monitoring result aligns with proportional documented violations from the CalTREES database for FFP Notices.

Stand Structure and Change

- **On the basis of different stand QMD size classes, post-harvest every FFP Notice either remained in the same size class or increased to the next higher size class. 61% of the sample remained static in size class, and 39% increased to a larger QMD size class. The largest percentage of the sample remained static in the 15-20 inch size class**
- **Across the entire sample, as individual tree size class increased, the proportion of harvested trees in the sample decreased, indicative of an overall focus on smaller trees; 39% of all measured conifer trees that had been harvested were under 10 inches in diameter.**
- **Individual FFPs largely focused on removal of trees less than 10 inches, mainly kept a large proportion of trees over 20 inches, and varied in harvest level intensity of trees 10-20 inches in diameter. Both Industrial and Non-Industrial ownership types averaged the same proportion of harvested 10-20 inch trees (49%), overall.**
- **The majority of FFP Notices met basal area retention requirements, or met trees acre^{-1} (TPA) retention requirements within applicably sized (<14 inch dominant and co-dominant trees) forest stands. A minority (30%) did not strictly meet retention requirements, and when considering alternative metrics, such as inclusion of hardwood basal area, 23% did not; however, other forest structure and fire-resiliency metrics indicate many of the FFP Notices still pursued the Exemption intent.**
- **Overall, Non-Industrial FFP Notices had higher basal area before and after timber harvesting, than Industrial FFP Notices.**
- **Hardwood species were estimated to make up an average of 19% of basal area (where present) on FFPs, particularly on Non-Industrial timberland ownerships which had an average of 23% basal area as hardwoods, post-harvest.**
- **Tree density (trees acre^{-1} or TPA) was generally higher pre- and post-harvest on Non-Industrial FFP Notices; for hardwoods and conifer and hardwoods combined, Non-Industrial FFPs had significantly more trees acre^{-1} than Industrial FFPs pre-harvest, and post-harvest had significantly more hardwood trees acre^{-1}.**
- **Tree density change varied across forest types on FFPs, often with patches of higher density trees, even amongst FFP Notices that underwent more uniform thinning operations.**
- **Similar to basal area results, hardwood components on some FFPs accounted for a large portion of overall trees per acre, both in the interior and coast areas of the state.**
- **Stand density index (SDI) generally was lower in interior and east side forests in the state than wet coastal forest types, although there was not a substantial difference in changes in SDI between coastal forests and interior and east side forests.**
- **Non-Industrial FFP Notices had higher pre- and post-harvest SDI values, and also a higher mean change (reduction) in SDI values than Industrial FFP Notices. Results indicate changes in forest structure relative to SDI are more reflective of geographical and ecological settings of forests, site-specific stand conditions, and management histories (or lack thereof) and different landowner goals.**
- **Shade tolerant species were generally harvested in higher intensity (where present) than shade intolerant species, but largely not completely eliminated from stands. Remaining shade tolerant trees had larger average diameters than harvested shade tolerant species.**

Generalized Forest Structure Change

Based on our re-created pre-harvest QMD values, and post-harvest residual tree QMD values, we additionally assessed overall size class changes on FFP Notices. **For both QMD size classes and WHR ("Wildlife-Habitat Relationship") classes, forest stands on all FFP Notices either remained static (same class) or increased** (Figure

58, Table 20). Stands that were 15-20 inches in size pre- and post-harvest (n = 13) were the majority of the sample, followed by both stands that remained 10-15 inches and stands that increased from 15-20 to 20-30 inches in size (n = 10) (Figure 58).

Table 20: *QMD size class changes, based on conifers ≥ 8 inches in diameter, from pre- to post-harvest, sample wide and by timberland ownership type. Also shown are sampled wide pre- to post-harvest WHR (Wildlife Habitat Relationship) class changes. Gray shading indicates a stands that did not alter classes, yellow indicates stands that increased size classes.*

Pre-Harvest QMD Class	Post-Harvest QMD Class Outcome
10-15 inch	**Static** remained **10-15 inch** = **23%** of sample **Increase** to **15-20 inch** = **14%** of sample
15-20 inch	**Static** remained **15-20 inch** = **29%** of sample **Increase** to **20-30 inch** = **23%** of sample
20-30 inch	**Static** remained **20-30 inch** = **9%** of sample **Increase** to **30-40 inch** = **2%** of sample
Industrial Ownership	
10-15 inch	**Static** remained **10-15 inch** = **44%** of ownership type **Increase** to **15-20 inch** = **11%** of ownership type
15-20 inch	**Static** remained **15-20 inch** = **17%** of ownership type **Increase** to **20-30 inch** = **17%** of ownership type
20-30 inch	**Static** remained **20-30 inch** = **5%** of ownership type **Increase** to **30-40 inch** = **5%** of ownership type
Non-Industrial Ownership	
10-15 inch	**Static** remained **10-15 inch** = **8%** of ownership type **Increase** to **15-20 inch** = **15%** of ownership type
15-20 inch	**Static** remained **15-20 inch** = **38%** of ownership type **Increase** to **20-30 inch** = **27%** of ownership type
20-30 inch	**Static** remained **20-30 inch** = **11%** of ownership type **Increase** to **30-40 inch** = **0%** of ownership type
Pre-Harvest WHR Class	**Post-Harvest WHR Class**
WHR 3 (6-11 inch)	**Static** at **WHR 3** = **0%** of sample **Increase** to **WHR 4** = **2%** of sample
WHR 4 (11-24 inch)	**Static** at **WHR 4** = **82%** of sample **Increase** to **WHR 5** = **11%** of sample
WHR 5 (>24 inch)	**Static** at **WHR 5** = **5%** of sample

Pre-harvest, 36% of the FFPs were in the 10-15 inch size class, 53% were in the 15-20 inch size class, and 11% were in the 20-30 inch size class (Table 20). Post-harvest, only 23% were in the 10-15 inch size class, 43% were 15-20 inches, 32% were 20-30 inches, and 2% increased to the 30-40 inch size class (Table 20).

By timberland ownership type and following harvest, 44% of Industrial timberland FFPs were 10-15 inches in QMD, 28% 15-20 inches, 9% 20-30%, and 2% 30-40% (Table 20). Non-Industrial ownerships saw 8% of FFPs in the 10-15 inch QMD size class after harvest, followed by 54% in the 15-20 inch class, 38% in the 20-30 inch size class (Table 20). **A total of 17% of Industrial FFPs increased from a QMD of 15-20 to 20-30 inches in size after harvest, while 27% of Non-Industrial FFPs made the same QMD size class increase** (Table 20).

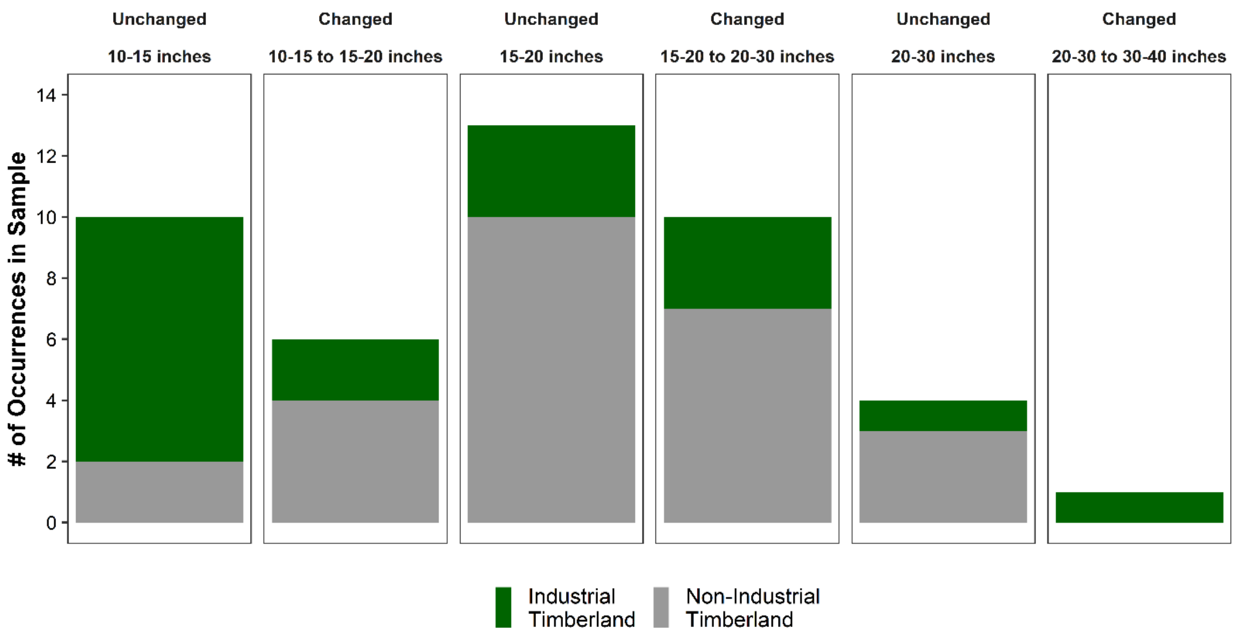


Figure 58: *Number of respective FFP Notice QMD size class changes, from pre- to post-harvest. Bar colors indicate the timberland ownership type. No bars indicate no changes of that type, for that ownership type.*

Residual and Harvested Trees

Statewide, across our entire FFP Notice sample, the size class within which the largest proportion of trees were harvested was the under 10-inch DBH trees, for both conifers and hardwoods (Figure 59). Visually, as tree size class increased, the proportion of trees in each class that were harvested decreased (Figure 59), for both tree types. Overall, less than one-quarter of trees that were over 20 inches were found to have been harvested on FFPs (Figure 59). For conifer trees 10-20 inches in size, across the entire sample approximately half (51%) of the sampled trees in that size class were harvested (Figure 59); however, only 28% of the hardwoods between 10 and 20 inches in diameter were harvested.

Proportionally across our sample, by residual and harvested trees (as opposed to within each size class), over three-quarters of the harvested conifers were either less than 10 inches or 10-15 inches in diameter. Conversely, less than half of the residual conifer trees fell into either of these smallest size classes (Figure 60); specifically, **conifer trees under 10 inches in diameter represented 39% of harvested conifer trees, but only 9% of residual conifers after operations.** Over 75% of the harvested hardwoods were less than 10 inches in diameter (Figure 60). Meanwhile, approximately 48% of the residual conifers were either 15-20 or 20-30 inches in diameter, while 5% of the residual conifers were 30-40 inches in diameter in our sample (Figure

60). In terms of harvested trees, the same aforementioned size classes, 15-20 and 20-30 inches, only represented 16% and 5% of harvested conifers across the entire sample (Figure 60).

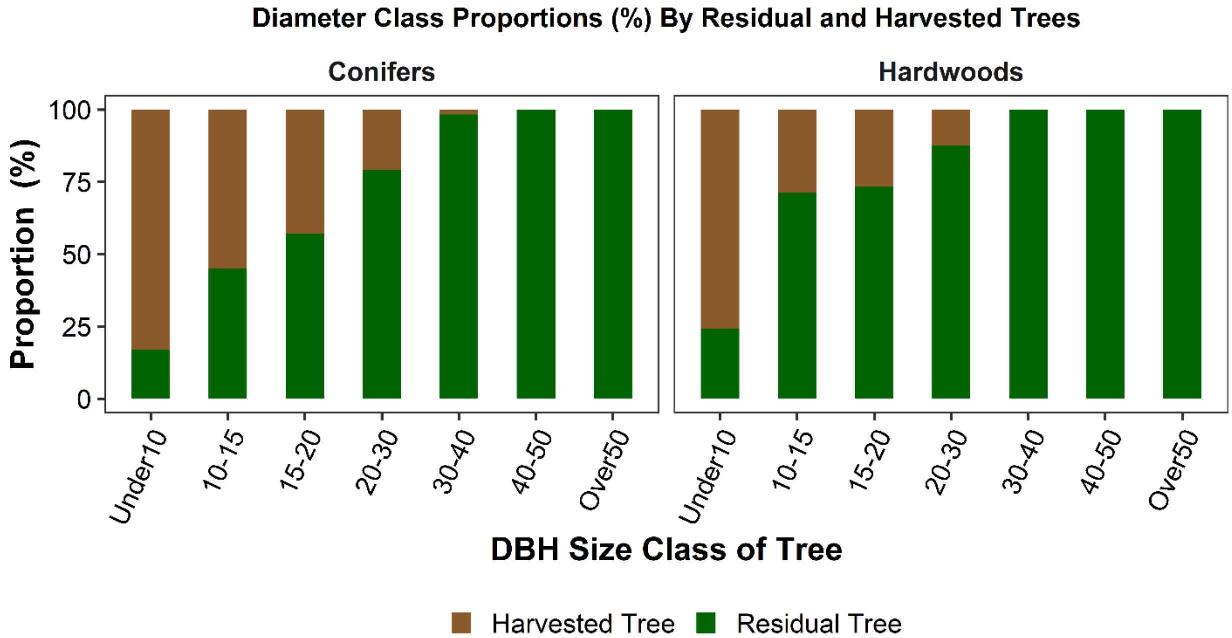


Figure 59: *Proportion* ***within*** *each size class of residual and harvested trees, by tree type, for the entire FFP sample. Bar color indicates if the proportion is a harvested or residual (leave) tree.*

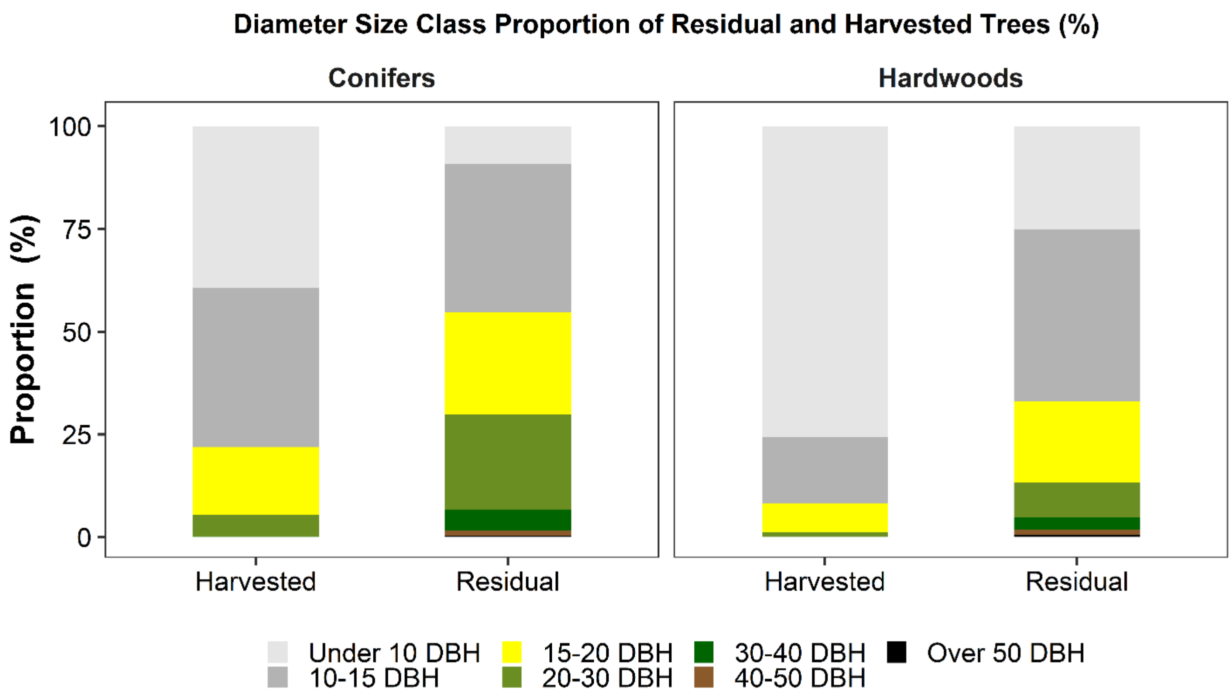


Figure 60: *Size class proportion within harvested and residual (leave) trees for the entire FFP sample, for conifer and hardwood species. Bar colors indicate the size class of trees.*

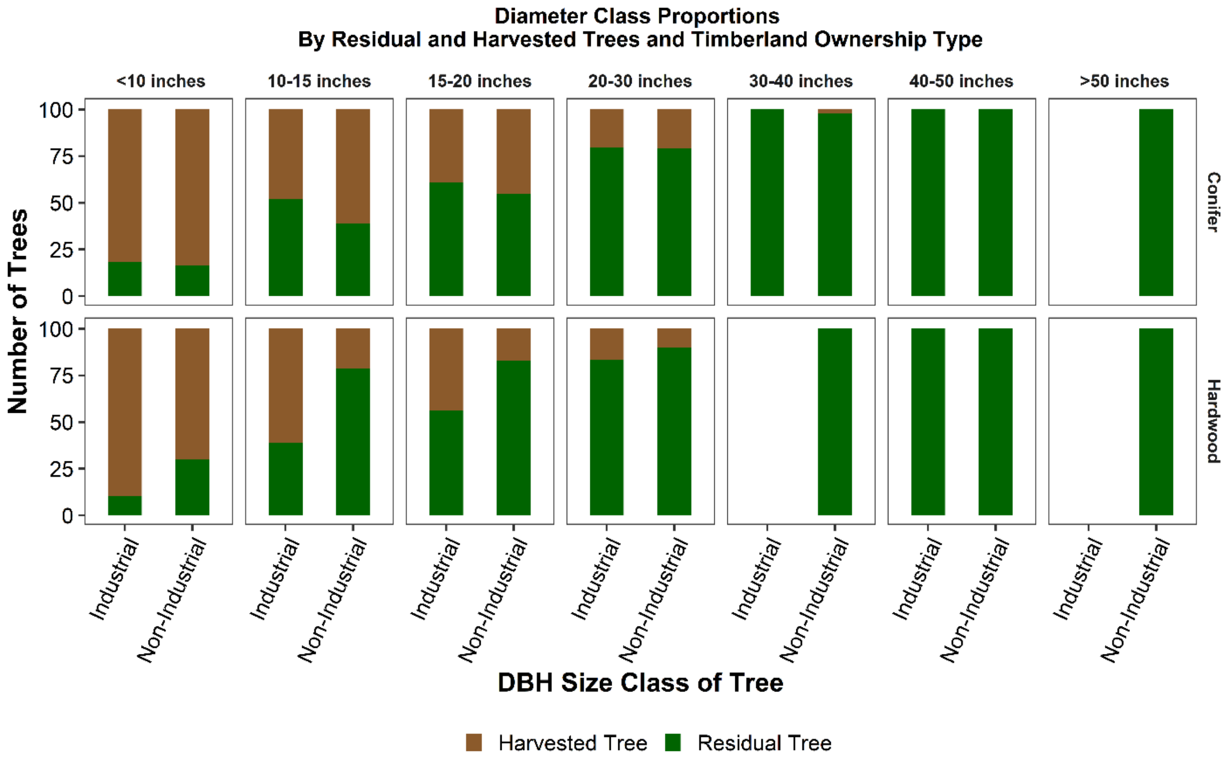


Figure 61: *Proportion* ***within*** *each size class across the entire FFP sample, by timberland ownership type. Panels are size classes, with both types of ownership in each panel (no bar indicates no trees found in that size class and ownership type), and bar colors indicate if the proportion is harvested or residual (leave) trees.*

By timberland ownership type across our entire sample, both Industrial and Non-Industrial FFPs had approximately equal proportions of residual conifers under 10 inches in diameter, while Industrial ownerships had a higher proportion of conifers 10-15 inches and 15-20 inches in size (52% versus 39% and 61% versus 55% for each size class and industrial versus non-industrial, respectively) (Figure 61). **For hardwoods, within each size class from 20-30 inches and smaller, Non-Industrial FFP Notices had a far greater proportion of residual hardwood trees present** (Figure 61).

On an individual FFP Notice basis, for conifers and hardwoods combined, Figure 62 shows the outcomes across our sample with proportions within each generalized size class on each FFP, **with an overwhelming focus on the harvesting and removal of the smallest diameter trees (less than 10-inches), proportionally. Observationally, we see as well that regardless of timberland ownership type, trees greater than 20 inches in diameter make up the majority or even full proportion of residual trees on individual FFPs after harvesting**, with a handful of exceptions on each ownership type (Figure 62). Of note, is that due to our rapid sampling, a proportion of 100% may be reflective of only one to two trees (harvested or residual) within a size class, and there is influence on some FFPs of large retained hardwood species.

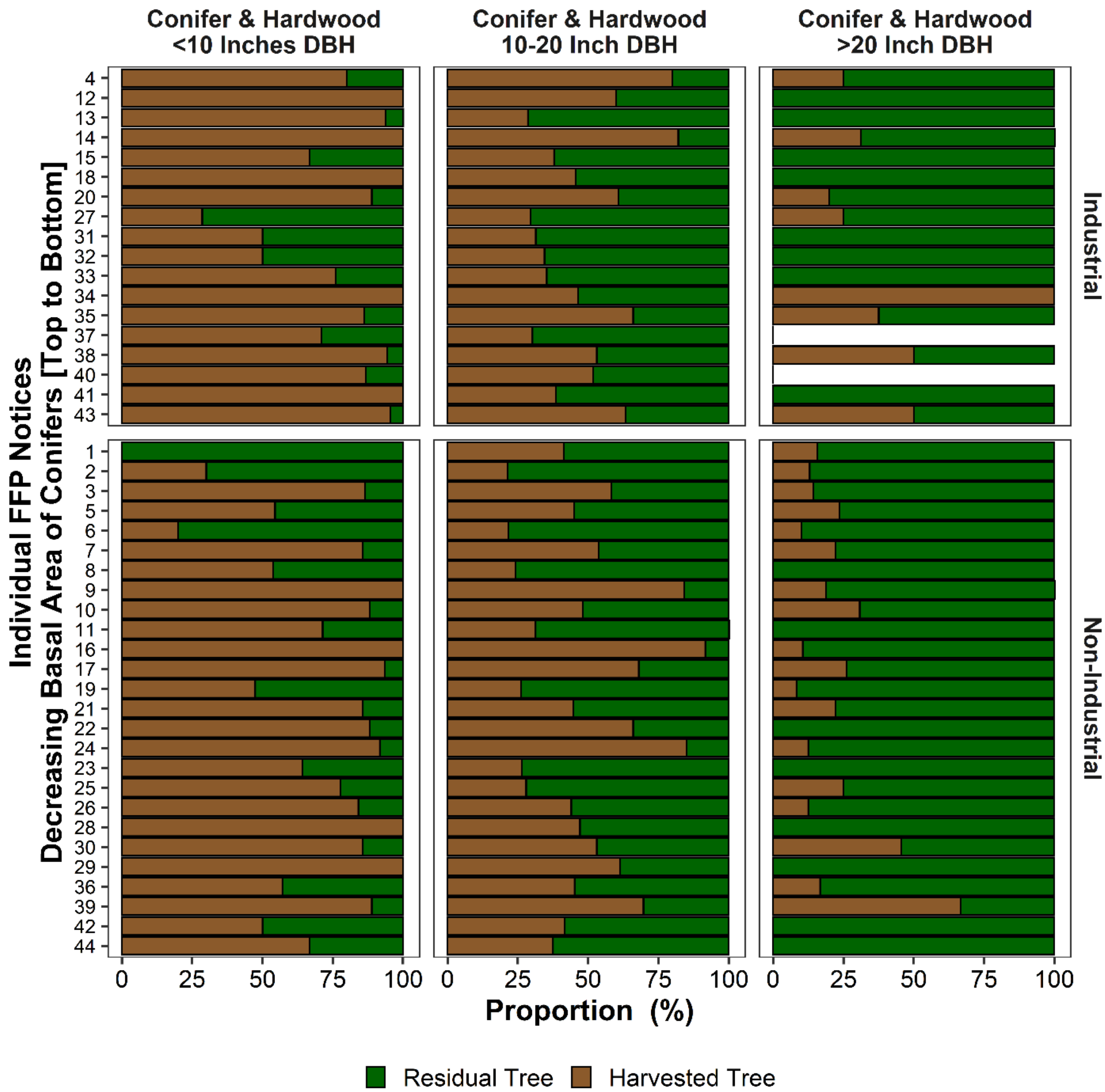


Figure 62: *Proportion of harvested and residual trees within each generalized size class, for each individual FFP Notice. Top and bottom panels show timberland ownership type of the FFP Notice, and Notices are ordered from top to bottom in each panel by decreasing total post-harvest conifer basal area. The numbers on the y-axis indicate the sample ranking of an FFP for conifer basal area (1=highest, 44=lowest), and bar colors indicate if the proportion is for harvested or residual (leave) trees. A missing bar indicates neither stumps or residual trees present in the generalized size class.*

The greatest variation came in the harvesting and leaving of trees 10-20 inches in diameter, varying from 21 to 92%. The mean proportion of harvested trees 10-20 inches in diameter was 49% (Figure 62). Comparatively, on individual FFP Notices the mean proportions of harvested trees less than 10 inches and over 20 inches diameter were 76% and 17%, respectively (Figure 62). At the ownership level, both industrial and non-industrial timberland FFPs had a mean proportion of 49% of trees 10-20 inches harvested; however, industrial FFPs had a mean proportion of 82% for trees less than 10 inches harvested, compared to 72% on Non-Industrial FFPs.

Basal Area

Table 21: *Mean pre- and post-harvest basal area estimates for conifers, hardwoods, and all (total) trees, by forest type and ownership type. Standard deviation is shown in italics within the parentheses.*

	Conifer BA ($Feet^2$ $Acre^{-1}$)		Hardwood BA ($Feet^2$ $Acre^{-1}$)		Total BA ($Feet^2$ $Acre^{-1}$)	
Forest Type	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
Redwood	324 (*160*)	272 (*147*)	27 (*22*)	25 (*20*)	344 (*157*)	291 (*146*)
Douglas Fir	190 (*57*)	120 (*51*)	31 (*15*)	24 (*19*)	218 (*54*)	142 (*56*)
Mixed Conifer	166 (*72*)	109 (*50*)	30 (*33*)	19 (*28*)	187 (*76*)	122 (*56*)
Pine	71 (*41*)	39 (*19*)	26 (*32*)	19 (*23*)	84 (*19*)	49 (*3*)
East Side Pine/Conifer	184 (*59*)	128 (*61*)	0 (*na*)	0 (*na*)	184 (*59*)	128 (*61*)
True Fir (n=1)	195 (*na*)	108 (*na*)	0 (*na*)	0 (*na*)	195 (*na*)	108 (*na*)
Ownership Type						
Industrial	142 (*57*)	94 (*47*)	17 (*16*)	9 (*12*)	154 (*60*)	100 (*50*)
Non-Industrial	207 (*102*)	142 (*92*)	40 (*27*)	31 (*25*)	230 (*100*)	160 (*93*)
FFP QMD Size Class						
10-15 inches	118 (*33*)	63 (*24*)	32 (*40*)	26 (*43*)	132 (*51*)	73 (*50*)
15-20 inches	165 (*75*)	108 (*56*)	24 (*18*)	19 (*17*)	182 (*71*)	121 (*53*)
20-30 inches	239 (*107*)	179 (*98*)	40 (*27*)	26 (*22*)	265 (*104*)	195 (*100*)
30-40 inches (n=1)	262 (*na*)	200 (*na*)	3 (*na*)	0 (*na*)	265 (*na*)	200 (*na*)

Basal area was generally higher on Non-Industrial ownerships (mean total post-harvest value of 160 $feet^2$ $acre^{-1}$) compared to Industrial timberland ownerships (mean total post-harvest value 100 $feet^2$ $acre^{-1}$), both before and after harvest, driven in part by a greater basal area of hardwoods, in addition to area of conifers (Table 21). Pre-harvest, Non-Industrial FFP Notices had 27 $feet^2$ $acre^{-1}$ more hardwoods than Industrial FFPs, while post-harvest Non-Industrial FFPs had 22 $feet^2$ $acre^{-1}$ more basal area of hardwoods. Redwood forest types had the highest average total and conifer basal area before and after harvesting, while Pine-type forests had the lowest basal area (Table 21). As the post-harvest QMD size class of FFPs increased, average post-harvest basal area of conifers increased as well, from 63 $feet^2$ $acre^{-1}$ (10-15 inch size class) to 200 $feet^2$ $acre^{-1}$ (30-40 inch size class) (Table 21).

Interestingly, where present, hardwoods made up 16% of total basal area before harvesting on FFP Notices. Post-harvest, the estimated hardwood basal area had a mean of 19% of the total basal area, ranging from 1 to 77% on FFP Notices (where present), **indicative that certain forest types and/or FFP Notices have a large hardwood component** (Figure 63, Table 21). **This was more prevalent on Non-Industrial FFPs, where the pre- and post-harvest average hardwood proportion of total basal area was 24% and 23%, respectively**. On Industrial timberland FFPs, pre-harvest hardwood proportion of total basal area averaged 11%, and post-harvest this value dropped to 8%. The hardwood proportion of all basal area by ownership type is also reflective in actual basal area change in hardwoods (Table 21), where hardwood area decreased nine (9) and eight (8) $feet^2$ $acre^{-1}$ on Non-Industrial and Industrial FFPs, respectively; that is, despite nearly a similar decrease (on average) of hardwoods on FFPs by ownership, Non-Industrial FFPs had more hardwood basal area.

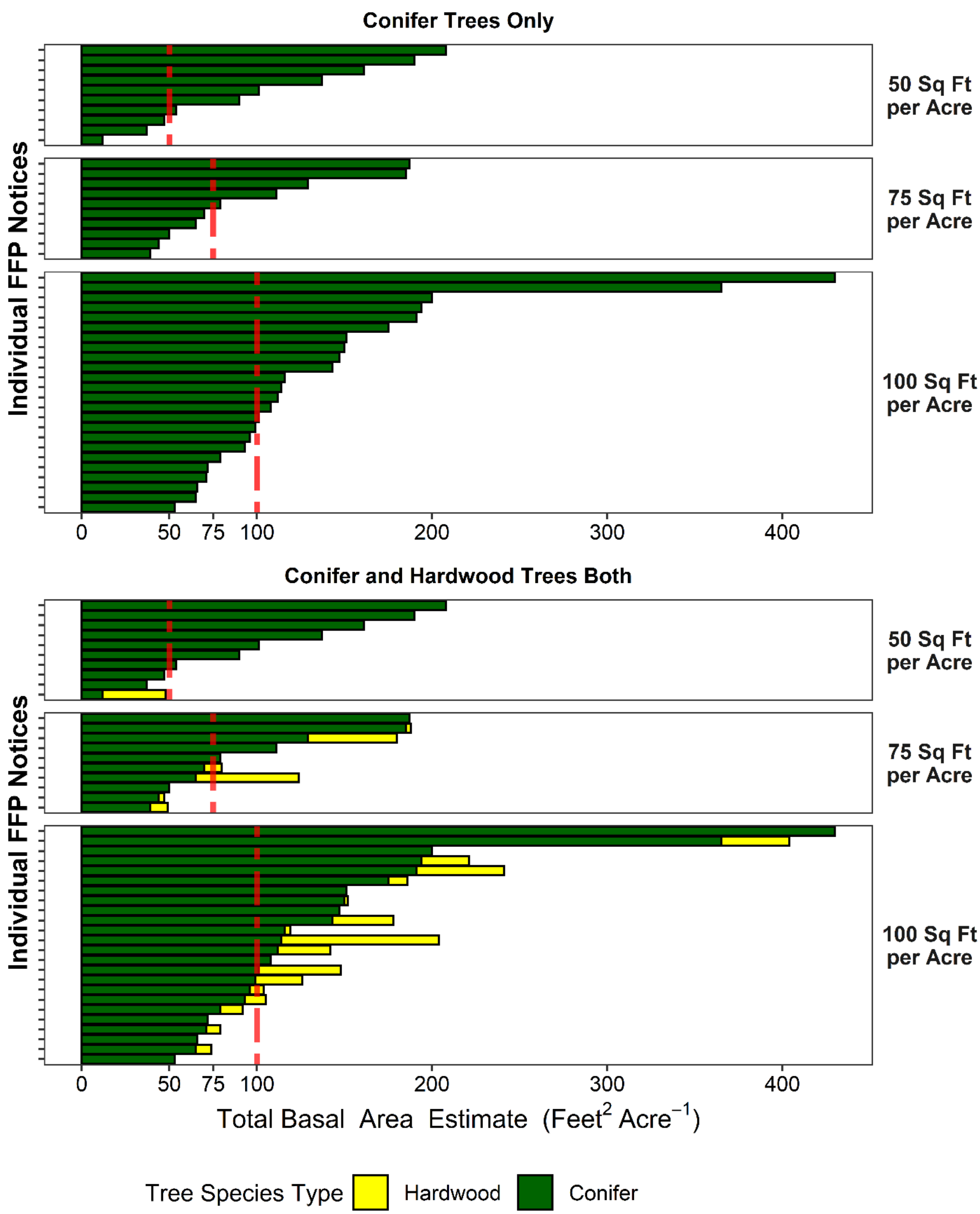


Figure 63: *Estimated basal area on all FFP Notices, for conifers only (top) and conifers and hardwoods combined (bottom). Panel groupings are the applicable basal area retention requirement, and dashed red lines in each panel show the applicable retention level in each panel. Bar colors indicate tree type (conifer or hardwood).*

Overall, based on basal area retention requirements or trees per acre ("TPA" or "trees $acre^{-1}$") requirements in stands occupied by dominant and co-dominant trees less than 14 inches in diameter, 13 of 44 FFP Notices (30%) likely did not meet the applicable retention requirement[29], eight (8) of which missed basal area requirement, and five (5) of which missed the TPA requirement (Table 22, Figure 63). For the eight FFP Notices that did not meet the basal area retention target, **two (2) of the Notices did meet basal area stocking when hardwoods were included with conifers in the basal area estimate** (Table 22). One met the non-applicable TPA requirement when considering conifer and hardwood species, which was also part of five of the Notices that met non-applicable TPA requirements when considering conifers, or conifers and hardwoods, with all trees less than eight inches in diameter within sample plots (Table 22). For the FFP Notices that required a TPA target, one met the rule when considering conifers and hardwoods for TPA, and also met TPA along with one other FFP Notice when considering conifers or conifers and hardwoods in addition to plot trees less than eight inches in diameter (Table 22). This implies that overall, when considering alternative metrics to applicable retention requirements (i.e., including conifers and hardwood species together), 10 of 44 (23%) FFP Notices likely missed retention requirements.

Table 22: *Summary of FFP Notices that did not meet their intended basal area retention or trees per acre retention requirements. Green shading indicates that as applicable, an alternate metric met stocking standards, yellow indicates a non-applicable metric met a stocking standard, and a * indicates that either basal area or trees per acre were not applicable to that FFP Notice based on information from the RPF. We assume if basal area is within 5 $feet^2$ $acre^{-1}$, or trees per acre is within 10 TPA, it is within the margin of error for stocking due to the rapid nature of monitoring.*

Reported Stocking Type	FPA	BA Retention	TPA Retention	Post-Harvest Conifer QMD	Conifer BA	Conifer + Hardwood BA	TPA Conifer	TPA All	TPA Conifer + <8 inches	TPA All + <8 inches
> 14 inch	Cascade	75	100*	16.5	39	49	27	33	100	107
> 14 inch	Cascade	50	75*	18.0	12	47	7	23	7	23
> 14 inch	Coast	100	100*	16.9	65	75	42	50	244	252
> 14 inch	Coast	75	100*	18.9	65	124	33	93	97	157
> 14 inch	Cascade	50	100*	14.5	37	37	33	33	40	40
> 14 inch	Coast	100	100*	18.1	79	92	44	66	194	216
> 14 inch	Coast	100	100*	14.2	66	66	60	60	80	80
> 14 inch	Sierra	100	100*	13.2	72	72	76	76	106	106
< 14 inch	Cascade	100*	100	14.2	66	66	60	60	80	80
< 14 inch	Cascade	100*	100	13.2	72	72	76	76	106	106
< 14 inch	Cascade	100*	100	13.9	93	105	88	94	202	208
< 14 inch	Cascade	75*	100	13.7	53	53	52	52	66	66
< 14 inch	Cascade	75*	100	13.0	44	47	48	50	64	66

It is important to note, that in every case where either an alternative metric was met, or no alternative metric was met, the QMD of conifers on every FFP Notice either was increased, or was estimated as unchanged in our monitoring. Tree spacing averaged an increase of six feet on these FFPs, with a final post-harvest average

[29] We assume, due to the rapid nature of our monitoring, that is the estimated basal area value on an FFP is within 5 $feet^2$ $acre^{-1}$ of the retention requirement, or estimated TPA is within 10 trees $acre^{-1}$, the rule was satisfied.

tree spacing on the Notices of 15 feet, and sampling indicated between 3% to 100% of the trees lacked vertical fuel continuity, with a mean of 62% lacking vertical fuel continuity. The implication being that while stocking standards on part of our sample may not have been met, the intent on many of these particular FFP Notices was likely in good faith.

Finally, through monitoring it was found that 43% of the sample had occurrences of standing, dead trees greater than eight (8) inches in diameter. Between one (1) and 59 $feet^2$ $acre^{-1}$ of dead standing trees were present, with an average of 12 $feet^2$ $acre^{-1}$. Effectively there was no average difference between ownership types in terms of dead standing basal area, with 11.9 and 12.5 $feet^2$ $acre^{-1}$ on Industrial and Non-Industrial ownerships, respectively.

Forest Density

Trees Per Acre

Tree density, both pre- and post-harvest, appeared to be influenced by underlying biomass level of the forest type, and forest stand QMD size (Table 23). Overall, pre-harvest, there was no difference between timberland ownership types in conifer trees $acre^{-1}$ (difference of 20 trees $acre^{-1}$, $p = 0.23$) (Figure 64), however, **conifer and hardwoods trees combined on Non-Industrial FFPs averaged significantly more than Industrial FFPs, with 32 more trees $acre^{-1}$ before any harvesting ($p = 0.04$).**

Table 23: *Mean trees $acre^{-1}$ for conifers, hardwoods, and conifers and hardwoods combined, by forest type, ownership type, stand QMD size class, and Forest Practice Area. Italic numbers in parentheses is the standard deviation value for each measurement.*

	Conifer Trees $Acre^{-1}$		Hardwood Trees $Acre^{-1}$		Total Trees $Acre^{-1}$	
Forest Type	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
Redwood	153 (*36*)	103 (*20*)	20 (*19*)	18 (*15*)	168 (*21*)	116 (*13*)
Douglas Fir	128 (*31*)	61 (*20*)	38 (*23*)	22 (*19*)	162 (*25*)	81 (*18*)
Mixed Conifer	128 (*65*)	56 (*21*)	29 (*36*)	13 (*21*)	149 (*65*)	64 (*28*)
Pine	98 (*66*)	46 (*29*)	17 (*22*)	9 (*11*)	51 (*51*)	51 (*22*)
East Side Pine/Conifer	141 (*37*)	68 (*37*)	0 (*na*)	0 (*na*)	141 (*37*)	68 (*37*)
True Fir (n=1)	194 (*na*)	64 (*na*)	0 (*na*)	0 (*na*)	194 (*na*)	64 (*na*)
Ownership Type						
Industrial	119 (*37*)	59 (*21*)	17 (*20*)	5 (*5*)	131 (*35*)	62 (*22*)
Non-Industrial	139 (*60*)	65 (*30*)	41 (*32*)	24 (*21*)	163 (*56*)	79 (*33*)
FFP QMD Size Class						
10-15 inches	148 (*56*)	65 (*21*)	21 (*19*)	11 (*17*)	157 (*57*)	69 (*30*)
15-20 inches	134 (*58*)	65 (*32*)	28 (*24*)	16 (*16*)	153 (*54*)	75 (*29*)
20-30 inches	118 (*41*)	59 (*24*)	41 (*41*)	20 (*25*)	145 (*42*)	72 (*32*)
30-40 inches (n=1)	85 (*na*)	40 (*na*)	5 (*na*)	0 (*na*)	90 (*na*)	40 (*na*)
Forest Practice Area						
Coast	131 (*32*)	69 (*26*)	33 (*24*)	18 (*16*)	160 (*31*)	85 (*25*)
Cascade	130 (*61*)	58 (*26*)	35 (*39*)	16 (*25*)	143 (*57*)	64 (*30*)
Sierra	100 (*29*)	43 (*8*)	5 (*1*)	5 (1)	104 (*26*)	46 (*11*)
Southern (n=1)	255 (*na*)	108 (*na*)	3 (*na*)	0 (*na*)	258 (*na*)	108 (*na*)

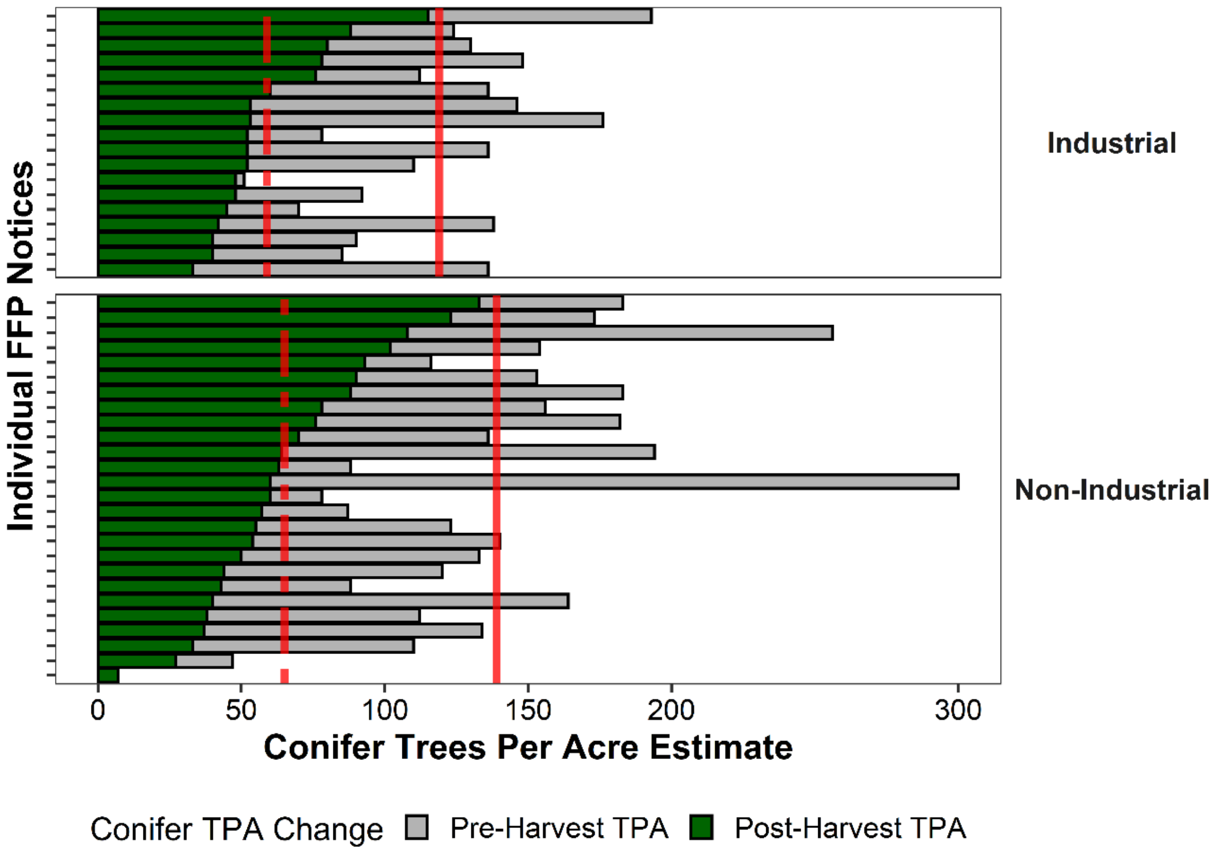


Figure 64: *Trees acre^{-1} for conifers only on each FFP Notice, pre-harvest and post-harvest, by timberland ownership type. Bar colors indicate pre- and post-harvest values, the solid red line indicates the ownership type pre-harvest mean value, and the red dashed line is the ownership type post-harvest mean value. Both panels are sorted from top to bottom by decreasing trees acre^{-1}.*

Post-harvest, Non-Industrial FFP Notices had more trees acre^{-1} than Industrial timberland FFPs, reflective of management histories and goals, although for both conifers and when considering conifers and hardwoods together, there was not a statistically significant difference between ownership types (conifer TPA, difference of six (6) trees acre^{-1}, $p = 0.43$; conifer and hardwoods combined, difference of 17 trees acre^{-1}, $p = 0.06$) (Table 23). **However, of note, is that both pre- and post-harvest Non-Industrial FFP Notices had more hardwood trees acre^{-1} than Industrial FFPs (pre-harvest, $p = 0.006$, post-harvest $p = 0.03$) (Table 23)**. Industrial FFP Notices averaged a change of 69 trees acre^{-1} (conifers and hardwoods combined), while Non-Industrial FFPs saw tree density decrease by 84 trees acre^{-1}, based on the sample estimate.

Hardwoods, for certain FFP Notices, were present from minimal density to higher density on others (Figure 65), similar to basal area estimates. This finding was present in both the northern interior of the state, and north Coast region (Figure 68, Figure 69).

Visually and anecdotally, while some FFP Notices treated stands in a widespread homogenous manner, many Notices created heterogenous post-harvest forest structure; even on Notices with more widespread even tree spacing,

there were pockets of varying density (Figure 66). Such a result is likely due in part to on-the-ground operating limitations or professional discretion, landowner goals, or pre-existing forest structure. All forest types saw varying levels of trees acre^{-1} reduction, from substantial to limited (Figure 67). Figure 66 also highlights two east side pine/conifer type forests that represent the end members of tree density estimates in Figure 67; the visual and numerical post-harvest results are indicative of a need to decide what kind of post-harvest outcome is desired, visually, structurally, and most importantly in terms of success in forest resiliency in a changing climate and fire regime.

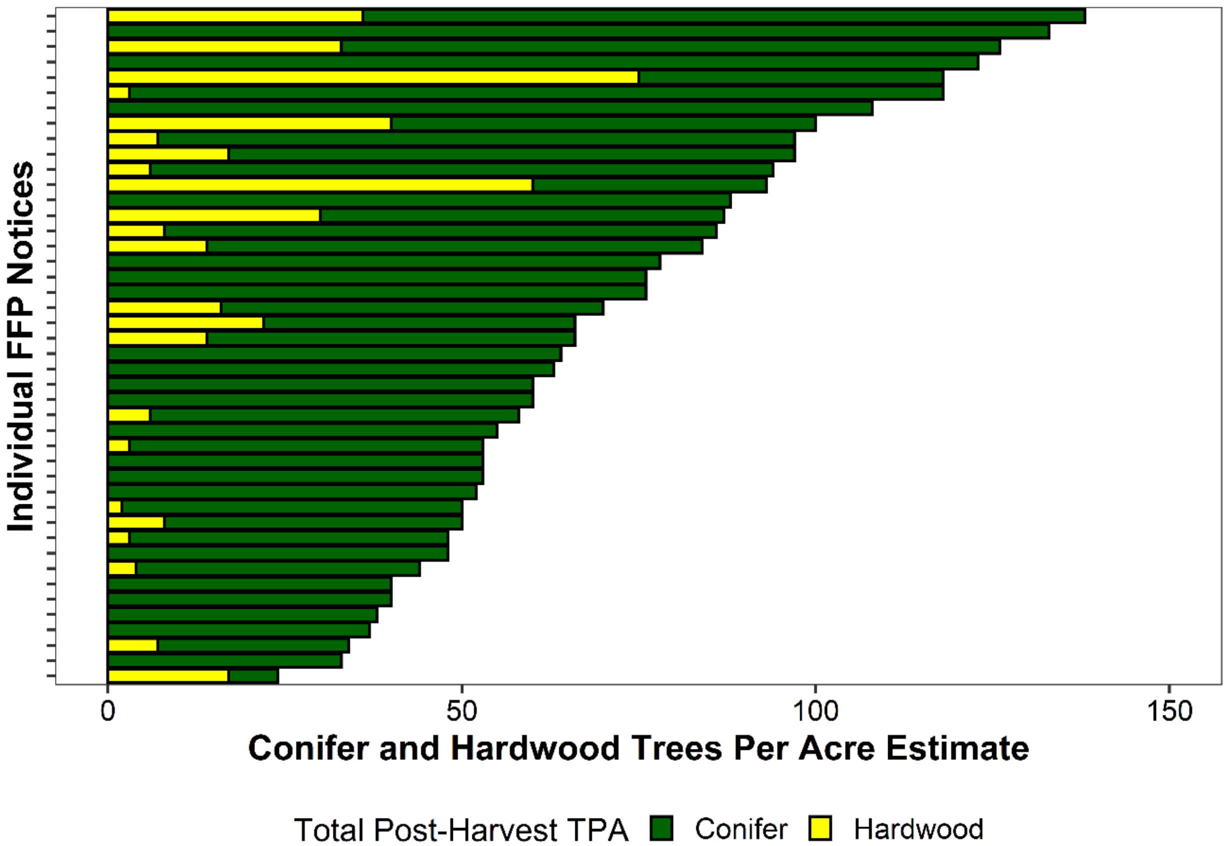


Figure 65: *Post-harvest trees acre^{-1} of conifers and hardwoods combined for all FFP Notices, ordered from top to bottom by decreasing trees acre^{-1}. Bar colors indicate the conifer and hardwood component of the TPA value.*

Figure 66: *TPA examples from East Side Pine Conifer forest types. Left three images, is an FFP Notice from Lassen County that had an estimated 33 conifer trees acre^{-1}.Right three images, is an FFP Notice in Plumas County that had an estimated 133 conifer trees acre^{-1}. The Lassen County FFP did not meet any stocking standards based on monitoring sampling, but did increase QMD approximately 0.7 inches. The Plumas County FFP Notice met stocking standards.* ***Note, some parts of each FFP are more or less dense than others, despite mean values****.*

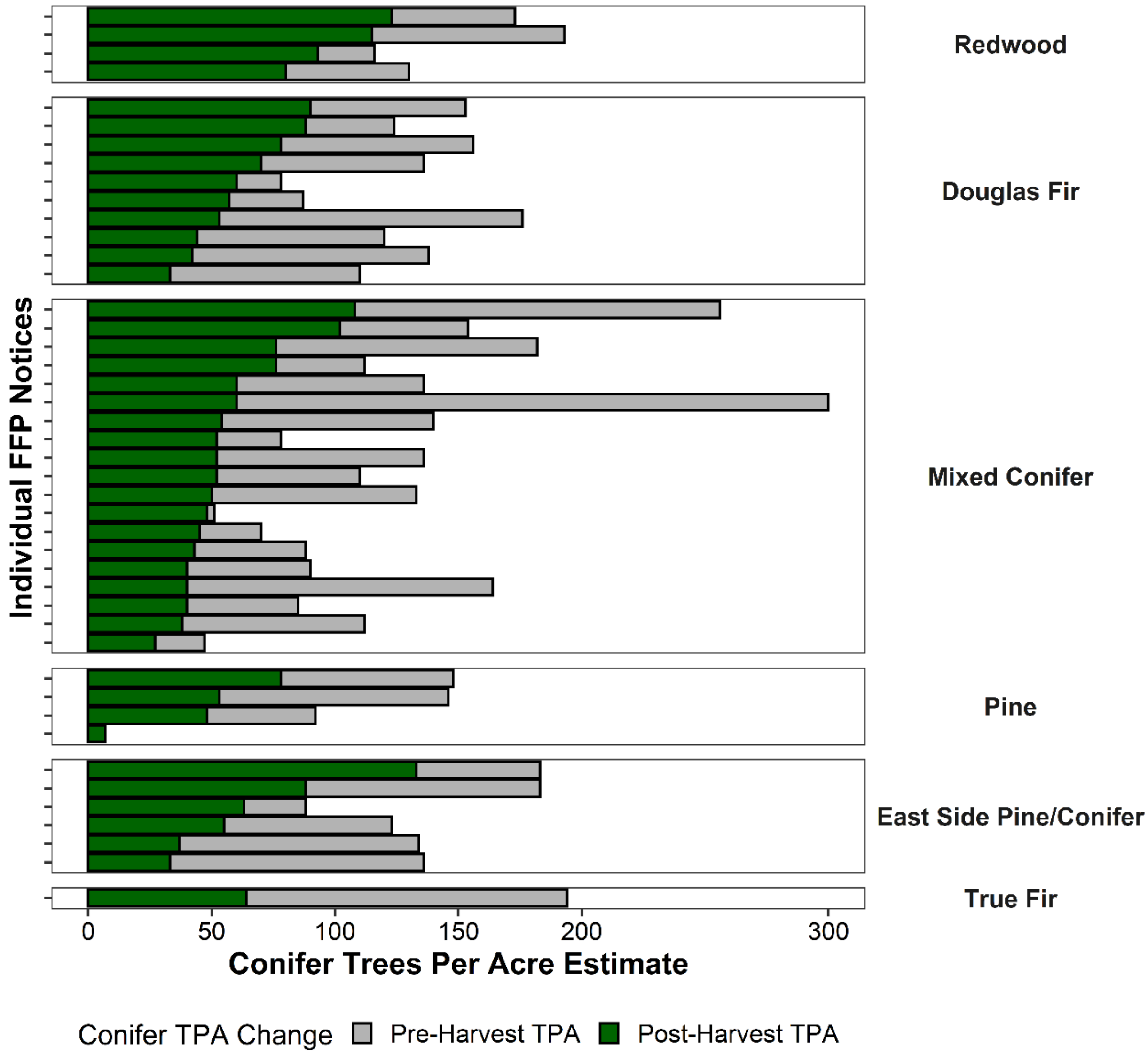


Figure 67: *Conifer TPA estimates on individual FFP Notices, pre- and post-harvest, by forest type. Bar colors indicate if values are pre- or post-harvest.*

Figure 68: *A northern interior Mixed Conifer FFP Notice, with more a more substantial hardwood component present (estimated at 75 hardwood trees acre^{-1}).*

Figure 69: *Two coastal Douglas Fir forest types with larger hardwood components, estimated as 60 (top) and 40 (bottom) hardwood trees acre^{-1}.*

Stand Density Index

Stand density index[30] ("SDI") of conifers across the sample spanned between 17 and 620 trees acre^{-1}, pre-harvest, and 17 to 503 post-harvest; the post-harvest mean was 165 trees acre^{-1}, a decrease of 87 trees acre^{-1} from pre-harvest estimates. When considering conifers and hardwoods together, values ranged between 88 and 620 trees acre^{-1} pre-harvest. The post-harvest mean SDI value for conifers and hardwoods was 184 trees acre^{-1}, with a mean change of 103 trees acre^{-1}.

Overall, Industrial FFP Notices had lower mean SDI values than Non-Industrial FFPs both before and after harvesting (Table 24), however, Non-Industrial FFP Notices had higher average change in SDI values. SDI change was not significantly different amongst the QMD size classes on FFPs, but as QMD size class increased, the stand density index increased as well (pre- and post-harvest)(Table 24, Figure 70).

Table 24: *Combined SDI for conifers and hardwoods pre- and post-harvest, and average change between, for forest types, timberland ownership type, FFP QMD size class, and Forest Practice Area. Numbers in parentheses and italics are the standard deviation of pre- and post-harvest estimates.*

	Conifer and Hardwood SDI		
Forest Type	*Pre*	*Post*	*Change*
Redwood	453 (*160*)	369 (*148*)	84
Douglas Fir	318 (*62*)	198 (*65*)	121
Mixed Conifer	273 (*102*)	165 (*67*)	107
Pine	139 (*40*)	77 (*12*)	62
East Side Pine/Conifer	270 (*79*)	177 (*85*)	94
True Fir (n=1)	301 (*na*)	151 (*na*)	150
Ownership Type			
Industrial	230 (*72*)	141 (*59*)	88
Non-Industrial	328 (*120*)	214 (*109*)	114
FFP QMD Size Class			
10-15 inches	215 (*75*)	114 (*68*)	100
15-20 inches	273 (*100*)	173 (*71*)	100
20-30 inches	356 (*121*)	247 (*115*)	110
30-40 inches (n=1)	325 (*na*)	228 (*na*)	97
Forest Practice Area			
Coast	349 (*112*)	237 (*112*)	112
Cascade	241 (*89*)	147 (*72*)	95
Sierra	226 (*62*)	140 (*29*)	86
Southern (n=1)	496 (*na*)	282 (*na*)	214

Within interior and east side forests, which generally were dry type forests, the overall average pre-harvest SDI value was 249 trees acre^{-1}, while following harvest that average value dropped to 151 trees acre^{-1}. Within the coastal wet forest types, pre-harvest mean SDI was estimated at 349 trees acre^{-1}, which decreased after harvest to 237 trees acre^{-1}. The average change in interior and east side forests was 98 trees acre^{-}

[30] Stand density index or SDI was calculated as Trees acre^{-1}*[$QMD \div 10$]^$^{1.605}$ for each diameter class (less than 10 inches, 10-15 inches, etc). Results for each diameter class were summed for a final SDI value.

^{1}, and 112 trees acre^{-1} in coastal wet forests. **So, while both forest groups experienced approximately equal SDI changes, on average, the wet coastal forests had inherently higher density of trees following harvest**. Actual estimated change in SDI across FFP Notices was highly variable by the individual Notice, regardless of the QMD size class of the Notice or forest type group (Figure 70).

When SDI values and changes were grouped by diameter class, across the sample the only significant difference in post-harvest SDI between interior forests and wet coastal forest groups was in the 20-30 inch diameter class ($p < 0.0001$), where coastal wet forests had a marginal mean of 36 more trees acre^{-1} (Figure 71). Across Industrial FFP Notices, the difference in post-harvest SDI between interior and coast forest groups was only significant for the 10-15 inch ($p = 0.019$) and 15-20 inch diameter classes ($p = 0.001$) (Figure 71). On Non-Industrial timberland FFPs, the 20-30 inch and 30-40 inch diameter classes had significantly different post-harvest SDI values between interior and coast forest groups ($p = 0.003$ and $p = 0.025$, respectively; 31 and 24 more trees acre^{-1} in coastal forests, respectively) (Figure 71).

SDI changes (or reduction in relative trees acre^{-1}) were not significantly different between interior and coast forest groups for any diameter class except for the 20-30 inch size class ($p = 0.046$), with a marginal mean reduction of 16 more trees acre^{-1} in wet coast forests than interior and east side forests (Figure 71). By ownership types, neither ownership type saw a significantly different change in tree density between forest groups for any diameter size class, although Non-Industrial FFPs had a nearly significant reduction in 10-15 inch diameter trees ($p = 0.056$) between forest groups, with interior and east side forests reducing this size class of trees by a marginal mean of 15 trees acre^{-1} more (Figure 71). None of the timberland ownership types significantly differed in SDI change within diameter classes in each respective forest group; that is, SDI change in a size class in each forest group was not affected by timberland ownership type.

These results further imply the inherent structural forest differences between geographical and ecological parts of the state, historic forest management or lack thereof, and point towards a lesser effect of ownership type. While there are underlying differences in management approaches and goals on Industrial and Non-Industrial FFP Notices, individual stand conditions are likely a greater influence on final outcomes in terms of relative density changes via harvesting of trees.

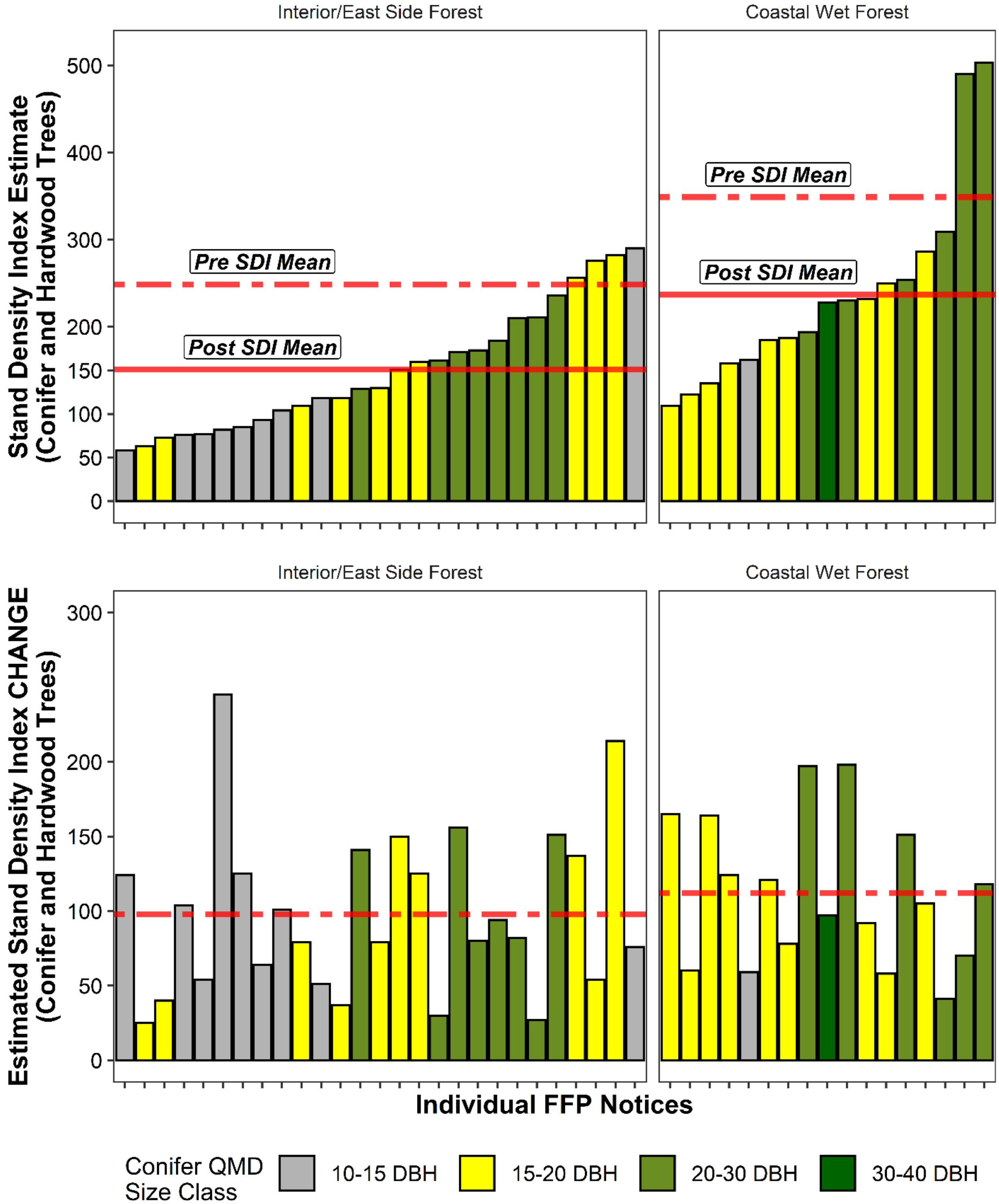


Figure 70: *Stand density index for hardwoods and conifers combined, summed by diameter class groups, shown by interior and eastern forests, and coastal wet forests (panels). Top figure is the estimated post-harvest stand density index, with bar colors indicating the FFP Notices' post-harvest QMD size class, where the dashed red line is the pre-harvest mean in each forest type grouping, and the solid red line is the post-harvest SDI mean in each grouping. Bottom figure is the estimated change in SDI by forest grouping, with the same bar color schema, and the dashed red line represents the mean SDI change in each group.*

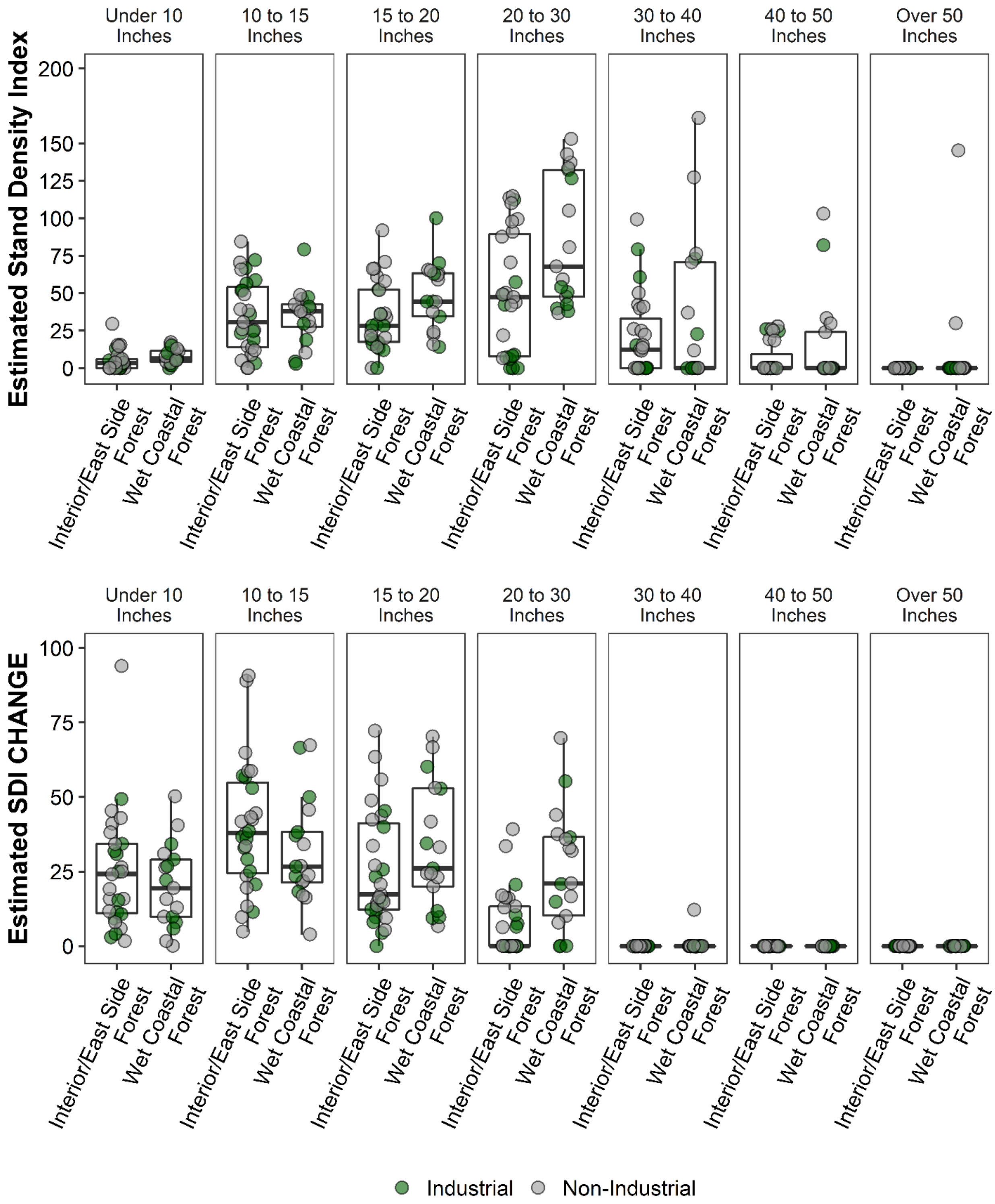


Figure 71: *Estimated stand density index values by tree diameter class and forest type group (top), and estimated stand density index change by diameter class and forest type group. Point colors indicate FFP ownership type, and boxplot characteristics are the same as* **Figure 27**.

Shade Intolerant and Tolerant Species Harvesting

Within our sample, we considered shade tolerant species to be White Fir, Red Fir, Incense Cedar, and western Red Cedar. While these species have varying levels of fire tolerance, all may act as understory ladder fuels in some stands, necessitating treatment in absence of wildfire. Overall, between 0 and 100% basal area of shade tolerant tree species were harvested on FFP Notices (where present), and across the entire sample an average of 38% of the basal area of shade tolerant tree species was proportionally harvested on FFPs (Figure 72, top). The average diameter (not quadratic mean diameter)

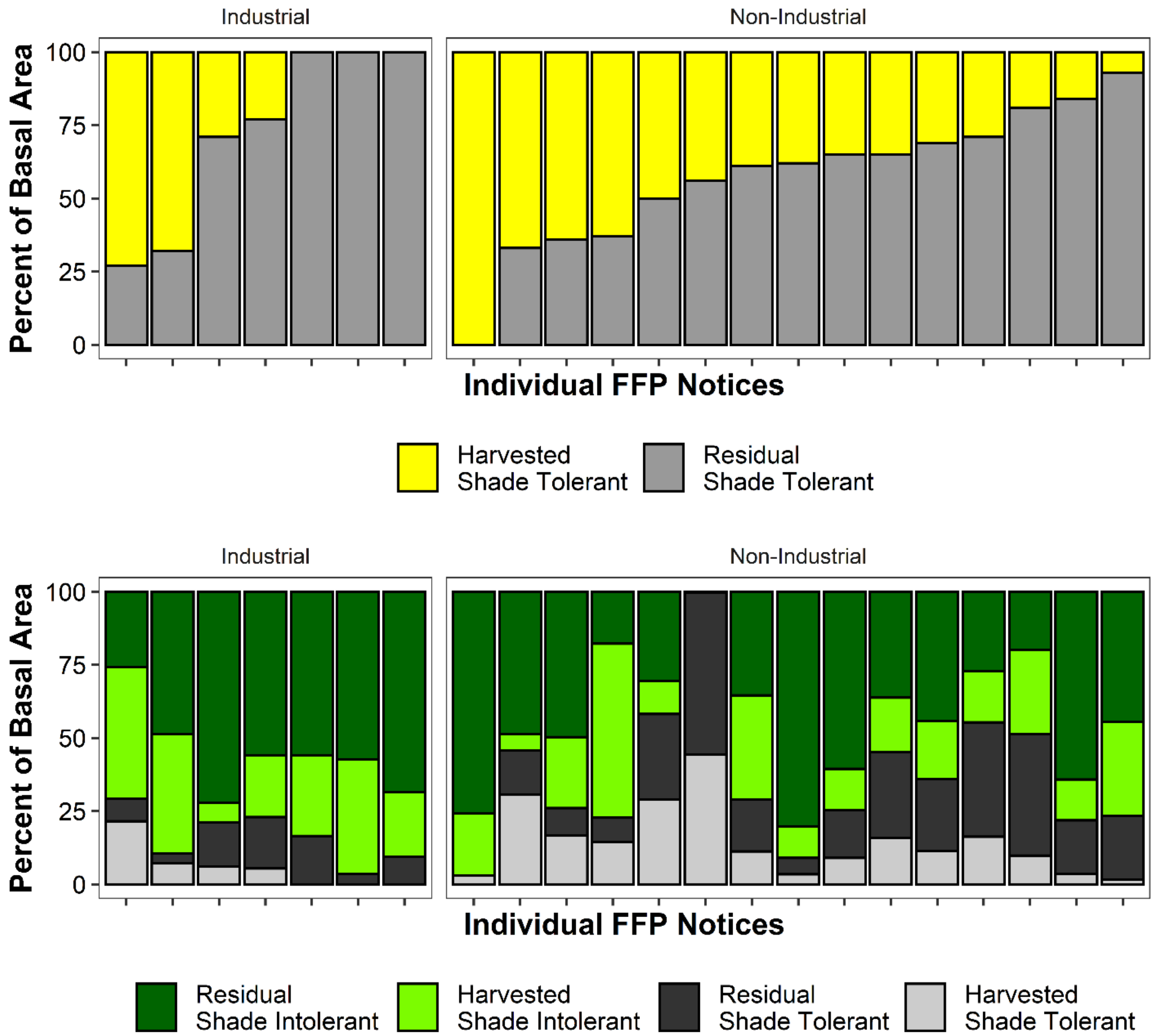


Figure 72: *Proportional changes in basal area of shade tolerant species, where present on FFP Notices, by ownership type. Top figure shows proportions of shade tolerant species* only, *with bar colors indicating the proportion on each FFP of shade tolerant trees harvested and remaining post-harvest. Bottom figure, proportion of basal area of shade tolerant and intolerant species harvested and remaining post-harvest; bar colors indicate tree species type and harvest status. Both top and bottom are ordered, in each panel, from left to right by increasing proportion of residual shade tolerant tree species basal area.*

of remaining shade tolerant trees was 18 inches, while harvested trees of this species type averaged 12 inches in diameter. Tree heights had a range of mean values between 33 and 108 feet, for average height of 65 feet, while crown base mean heights ranged between three (3) and 48 feet, for a sample wide average mean of 17 feet. Very few FFP Notices either undertook full or near full removal of all shade tolerant species basal area, or undertook harvesting of *only* shade intolerant species (leaving on tolerant species behind) (Figure 72). Only one FFP had full removal of shade tolerant basal area, and shade intolerant tree species comprised the majority of the forest stand pre-harvest (Figure 72). Post-harvest and where still present, shade tolerant tree species had between 6 and 100% of the residual basal area, with an average proportion of 30% (Figure 72).

Discussion

- **FFP Notice Exemptions largely thinned from below, reducing basal area and trees per acre on Exemptions. FFP Notices, particularly in light of the expanse of landscape in California with potential for thinning and treatment, due to fire suppression and legacy management, should focus around communities at risk, infrastructure and critical ecosystem services.**
- **FFP Notice road networks and road-watercourse crossings would benefit from upgrades, for both watershed health and to better facilitate future maintenance activities or fire suppression activities. Non-Industrial landowners especially may benefit from pursuing various grant programs to fund forest road upgrade and improvement.**
- **Slash, surface, and ladder fuel treatments would benefit from improved research and guidance, in order to achieve desired post-harvest and fire-related outcomes.**
- **Canopy "closure" and the more easily quantifiable canopy "cover" should be reconciled, along with stocking standards and considerations for hardwood species, in future discussions of the FFP Exemption. The current diameter limit does not appear to be a substantial barrier to treating small diameter, ladder fuel or fire-prone, trees and where larger diameter trees exist in higher densities, surface and ladder fuel treatments in conjunction with limb pruning may be more beneficial within the current framework of the FFP Exemption, and for work outside of a THP document.**
- **Generally, the scale, pace, and extent of FFP Notices within watersheds is unlikely to have affects on peak flow or other watershed processes of concern; rather, point source issues (e.g., forest roads or skid trails) are of greater concern and potential**

Forest resiliency to wildfire, within historically fire-adapted forests in California, can be achieved through direct forest management following simple, sound methods as discussed by Agee and Skinner (2005), by way of:

- ***Reduce surface fuels***
- ***Increase the height to the live crown base of a tree***
- ***Lower the density of trees***
- ***Retain the largest and most fire-resistant trees and species***

Largely, it appears that within interior and east side forests in California, the §1038.3 Forest Fire Prevention Exemption and subsequent outcomes are following this approach, with caveats on certain Notices within certain forest types. In the wetter, coastal forests of the state, landowners and licensed professionals are striving for a reduction in tree density, and the elimination of vertical fuel continuity. However, the trade-off is greater surface fuel accumulation from logging slash. Regardless of forest type and location in the state, overwhelmingly the operations involved with the Forest Fire Prevention are focusing the majority of timber harvesting on the smallest diameter trees within a forest stand, and the harvest of many fire-prone shade tolerant species that would normally experience high mortality from wildfires. **However, it is critical to discuss the nuances of the findings within this monitoring report in regards to previous management histories on projects, ecological and geographical setting, and to view the Exemption beyond simply a one-time treatment of timber resources alone, instead to address non-timber aspects of each Exemption and plan for the future of each FFP Notice.**

Geographical Location of FFP Notices

With substantial areas of forests outside of a natural range of variation due to fire suppression or legacy management, and in need of thinning, most treatments should focus on forest stands in proximity to communities at risk or other critical infrastructure (i.e., reservoirs). However, our sample indicated that less than half (i.e., 48%) of the FFPs were located adjacent to communities at risk, and only 23% were located in areas with a housing density class that met the definition of WUI and/or intermix areas (FRAP, 2019). FFP Notices near communities at risk or other locations where residential development is present would tie in with activities around structures (i.e., **§1038(c)** and **§1038(c)(6) 0-150-** and **150-300-foot structure-centric fire hazard reduction Exemptions**), creating a matrix of decreased fuel loading proximal to the wildland urban interface (WUI) and within areas of intermix not covered by the structure-centric exemptions.

The FFP is a tool, when followed through in the underlying intent, that can work to facilitate pyrosilviculture, with treatments working to reduce fire severity within stands, and protect ecosystem services from the adverse effects of severe wildfire (e.g., water quality and fisheries), economic interests (timber), and allowing for resiliency in managed wildfire use, or as buffers against fire in wildlands away from communities (anchor points, fire severity reduction) (North et al., 2021b).

Prescribed fire treatments in Australia were most effective in reducing wildfire impacts to communities when done within approximately 0.3 miles of those communities (Gibbons et al. 2012). Fuel treatments adjacent to communities allowed for lower intensity wildfire and more active engagement of firefighters on structure protection during the 2007 Grass Valley Fire outside Lake Arrowhead, CA (Rogers et al., 2008). Fuel treatments largely reduced crown fire to surface fire within approximately 165 feet of entering treated areas in the 2007 Angora Fire in the Lake Tahoe Basin, and more intensive fire effects where fuel piles had not been burned or treated following activity but before the fire (Safford et al. 2009). Recent modeling exercises also indicate that beyond the WUI area, fuel treatments in WUI-adjacent forested areas may also result in significant reduction of threat to communities and interspersed singular homes (Evans et al., 2022). However, the authors noted the effect of extreme fire weather events and their ability to overwhelm forest thinning treatments, underscoring the need for home hardening as well (Cohen, 2000, Knapp et al., 2021a). When combined with home hardening and structure-centric treatments, properly located FFPs have the potential to work in synergy with these efforts for achieving community wildfire mitigation and resilience.

Wildfires also represent a substantial threat to water resource systems (e.g., reservoirs), due to increased sedimentation and debris flows, which increase under more severe fire effects (Gould et al., 2016, Sankey et al., 2017, Murphy et al., 2018). Past research in Colorado implied the lower likelihood of wildfire impacting water supply systems and enhanced cost of fuel treatments, resulting in a poor return on investment (Gannon et al., 2019). However, substantial proportions of watersheds in California have experienced wildfire, including large patches of near complete surface and overstory vegetation mortality and high soil burn severity, such as in the Feather River watershed. In addition to community resiliency to wildfires, the FFP Exemption is another tool to assist in improving watershed health outcomes following what are likely inevitable wildfire events, through the reduction of widespread severe wildfire; this may be particularly true for small Non-Industrial landowners within in certain watersheds, in addition to larger Industrial ownerships. **The co-benefit of increased watershed resiliency should be factored into the strategic placement and/or aggregation of future FFP and associated fuel treatments.**

In California, past research indicated that treatments are best when strategically located (Schmidt et al., 2008), where less area may be treated for greater benefit in the northern interior of California (Tubbesing et al., 2019). **As one literature review of management within mixed severity fire forests noted, "How much and where" is a necessary question** (Hessburg et al., 2016). Strategic aggregation of multiple FFP treatments near forested WUI and intermix areas is a means to achieve "pace and scale", although there appears to be no effort to do this currently. It is unclear whether this is due to lack of familiarity with FFP as a means for fuels reduction, or whether the requirements of FFP are thought to be too constraining for use in pre-fire planning and implementation. **If the former is true, then it is important to communicate the utility of FFPs for Unit fire planning and further advocate its use in a strategic manner by fire safe councils and local resource conservation districts. If the latter is the case, then it will be necessary to define the limiting constraints (e.g., are some Notice requirements too limiting relative to the intent?) on its strategic application for fuels reduction**.

Exemption Road Networks

Road networks within the FFP sample did not have excessive impacts in relation to hydrologic disconnection and sediment discharge, unlike previous monitoring findings on post-fire Emergency Notices (Olsen et al., 2019b). This is due in part to the more resilient setting of a green tree timber harvest, in addition to Notice-specific settings where roads were of a lower risk to water quality. Also, the relatively good road performance documented in this report is potentially reflective of the drought conditions experienced over the life of the sampled Notices. Despite the fact that excessive impacts were not observed across the sampled portions of the road network, 21 percent of watercourse crossings had a discharge greater than one cubic yard. This suggests lower watercourse crossing performance than in previous monitoring efforts (Brandow and Cafferata, 2014), although it is unclear whether this difference in performance (i.e., 87% vs. 79%) is meaningful given the difference in methodology and the margin of error associated with our sample. We did note a relatively low occurrence of road upgrades (e.g., only 23% of watercourse crossings were improved) in this sample. Given the relatively low implementation of road improvements in the sampled FFPs, we might expect lower road performance when Notice areas are subject to higher magnitude, lower frequency storm events. A more focused look at road performance after these types of storm events is a potential way to determine whether desired outcomes are truly being achieved on road networks on these exemptions.

Regardless of monitoring findings, it is well accepted that forest roads contribute sediment and excess runoff in many situations to the stream network, particularly in wetter climates, or when road systems do not implement effective best management practices (Luce and Wemple, 2000, MacDonald and Coe, 2008). **Knowing this, from a watershed perspective, the upgrading of the native surface roads on FFP Notices within the sample, and road-watercourse crossings (particularly those currently inadequate per the Forest Practice Rules), would benefit the health of watersheds where treatments occur**. Research has indicated road and road-watercourse crossing upgrades can have wide-ranging improvements in sediment delivery reduction and road-hydrologic disconnect, particularly when identifying the road segments and crossings with greatest water-quality impact for subsequent improvement and watershed health improvement (Sugden 2018, Benda et al., 2019). Landowners and associated professonals, particularly small, Non-Industrial landowners, should pursue state, federal, or non-governmental grant or assistance programs to upgrade road systems to year-round usability (i.e., rocking of the road prism) and upgrading watercourse crossings to increase hydraulic conveyance and decrease sediment inputs.

Beyond watershed health implications, upgrading roads to non-native surface, year-round usability will benefit landowners for future maintenance of FFP projects (e.g., mastication, prescribed fire, re-entry's). Further, adequately drivable roads on these projects could be critical in fire suppression activities in the case of a wildfire (Thompson et al., 2021), by creating a perimeter through direct suppression, or as a location for backfiring operations. A most recent example being the use of the Foresthill Road to backfire and hold the Mosquito Fire during the Mosquito Fire incident, protecting portions of the town of Foresthill.

Approaches to forest thinning

Overall, results point towards "thinning from below" or a focus on the smallest diameter trees across the sample. Individual FFP Notices thinned trees less than 10 inches in diameter overwhelmingly, in addition to trees 10-20 inches in diameter, and seldomly trees in excess of 20 inches (Figure 59, Figure 60, Figure 61, Figure 62). It is possible that trees in the 10-20 inch range may be of commercially economic value (i.e., sawlogs), which can help to offset costs associated with small diameter thinning and surface fuel treatments on projects. Flexibility in forest treatments for fuel reduction require some flexibility in tree size harvest allowances and in basal area or tree density reduction, while still retaining larger fire-resistant conifers and hardwoods and treating ladder fuels; strict regulatory constraints can limit flexibility, thereby reducing the likelihood that desirable outcomes are achieved in some forest types (Lydersen et al., 2019).

Project outcomes that overwhelmingly increased QMD, reduced tree density, and resulted in absences of vertical fuel continuity were abundant throughout the sample.

Interestingly, the story that our sample data tells is a difference in application between forest types and ownerships; **certain forest types inherently are denser and harder to treat for wildfire resilience (e.g., Redwood versus east side pine/conifer), while management histories (commercial timber harvesting, fire exclusion, long-term fire exclusion and non-management) were made apparent in ownership types, resulting in inherently different forest stands before and after harvesting under an FFP Notice** (Figure 40 crown contact and canopy closure, Figure 47 tree heights and vertical fuel continuity, Figure 51 tree spacing changes, Figure 57 QMD changes, Figure 64 trees acre^{-1} changes, Figure 70 SDI changes). Many Industrial ownership forests were likely closer to true "even age" stands, due to previous management interventions and reforestation techniques, and as such many of the stands on Industrial timberlands remained static in their QMD size class (Figure 58, Table 20), had greater spacing between individual stems, had lower basal areas, and were comprised of a greater proportion of smaller diameter trees (relative to Non-Industrial FFPs). Non-Industrial FFPs were likely most closely described, pre-harvest, as "overcrowded" multi-cohort stands, with high density, small diameter trees intermixed with larger diameter "legacy" trees. This resulted in many Non-Industrial FFP Notices increasing QMD size classes (Figure 58, Table 20), and having larger quadratic mean diameters pre- and post-harvest (than Industrial FFPs), and lower degrees of vertical fuel continuity despite closer spaced stands (and still substantial changes in density and basal area). Management differences also need to be emphasized in the greater proportion of hardwoods found on Non-Industrial FFP Notices (Figure 63, Figure 65), reflecting a land base not exclusively utilized for timber production, and their prevalence on the landscape in terms of total forest structure.

Effectively, the FFP Notice appears to be a tool within which forests of different histories and management (via ownership) are effectively treated, per the intent and rules of the Forest Fire Prevention Exemption, with a caveat: small diameter, even aged stands. **These types of stands, "plantations", clearly have a higher susceptibility, even post-harvest, to vertical fuel continuity (lower crown bases to carry flames and/or prevalence of surface and ladder fuels to reach lower limbs), and less management discretion under the FFP regulations to achieve a fire resilient outcome as it is more difficult to meet all the FFP requirements (e.g., canopy closure and/or basal area) for younger, even-aged stands**. "Plantation" type forests have been found to possibly be susceptible to wildfire more than other forest ages in some research (Zald and Dunn, 2018, Levine et al., 2022), up to 25 years of age in one study in the Klamath Mountains of California (Thompson et al., 2011). The fact that 44% of the forest stands on Industrial ownership were in the 10-15 inch size class pre- and post-harvest, while only 8% of the Non-Industrial stands remained in the same size class following harvesting, is indicative of the different forest stand structures in addition to management goals.

Similarly, wet coastal forests such as Redwood and Douglas Fir were clearly larger and denser, prone to greater canopy closure, and less likely to have substantial vertical fuel continuity within the sample, particularly with purposeful surface and ladder fuel treatments, yet conversely had greater issues with post-harvest slash prevalence and depth, **which reflects limitations with fuel treatments within that type of forest and our current scientific understanding wildfire and fuel treatments in those ecological forest settings** (Halofsky et al., 2018). Halofsky et al. documented that wetter, climate-limited forests, where wildfire historically occurred mainly as infrequent stand-replacing wildfire, are best suited to managed wildfire, outright fire exclusion near critical resources and communities, and management to increase forest heterogeneity and decreasing forest density while protecting habitat.

In one process-based modeling exercise, fire spread and flame front, fire intensity, and wind behavior were shown as susceptible to changes due to thinning, however, results were dependent on the intensity of thinning, canopy moisture, and desired outcome of fire behavior (Banerjee, 2020). Increased thinning increased wind speed and implied flame fronts could move faster through a forest stand, yet in absence of any thinning or with only minimal thinning, resulting fire intensity and heat was greater – the implication being likely higher mortality, but slower fire spread (Banerjee, 2020). As such, changes to forest structure need to be viewed as part of a whole, inclusive of trees themselves (canopy), surface fuels, and location.

Finally, there is an abundance of research now indicating the strong potential benefits gained when mechanical fuel treatments are combined with prescribed fire treatments. Throughout the northern Interior of California, combined treatment types have been shown to result in lower fire severity, and decreased tree mortality, not only during wildfire events but also during extensive drought and insect impacts to forests (Lydersen et al., 2017, Knapp et al., 2021b, Taylor et al., 2022). **The FFP Exemption, while possibly a standalone treatment when followed through in all areas of the intent (thinning, reduction of ladder fuels, removal of slash), may not only treat a forest stand, but allow safe introduction of prescribed fire, furthering resiliency efforts**.

Post-harvest slash

Slash, as smaller diameter, dead woody debris, is especially prone to drying and ignitability and flammability, representing a valid concern relative to fire behavior following forest harvesting. While overall FFP Notices had low-depth post-harvest slash levels, there were larger slash accumulations in some instances, particularly in high biomass forest types, mainly in the north Coast area. As slash became more spatially widespread, and as maximum observed slash depth increased, overall slash depth increased, again most strikingly in the north Coast forests. The same forests also were more likely to have greater continuous slash present three (3) inches or deeper, compared to dry interior forests. Overall, ownership type did not seem to influence slash characteristics. Generally, however, larger slash pieces (1000 and 10,000 hour) were far less prevalent across the sample. **Overall, slash was adequately dealt with; however, whole-tree yarding would continue to be the encouraged yarding method to reduce excess slash accumulation with the harvested area**.

Slash, and submerchantable trees and tree residue, represent a difficulty for landowners and licensed professionals to address in some stands, both from a regulatory and practicality standpoint. In a GIS based exercise, it was found that all mapped FFP Exemptions in CAL FIREs Forest Practice GIS dataset fell either 15%, 56%, or 85% within 10, 25, or 50 miles of an active biomass facility. A total of 23%, 67%, or 88% of FFPs fell within 10, 25, or 50 miles of an active sawmill facility (**Appendix 4: Forest Fire Prevention Exemptions, Biomass Facilities, and Operating Sawmills)**. While these results do not account for market forces, transportation logistics, or individual facility restrictions, they do imply that to date, most FFPs have been within 50 miles of a biomass facility or operational sawmill.

Stand Density Index within treated interior forest types

Stand Density Index within northern Interior forests averaged 241 trees acre^{-1} pre-harvest and 159 trees acre^{-1} post-harvest; recent research within the California Sierra Nevada indicated that in various forest types SDI was historically between 75 to 158 trees acre^{-1} on public National Forests (North et al., 2021), approximate to our sample estimates within the California interior private forests, post-harvest. Current SDI values were estimated as 191-256 trees acre^{-1} on National Forests in the Sierra Nevada (North et al., 2021), which also spanned the range of our pre-harvest SDI estimates. **As such, within certain geographic locations and forest types, it appears the FFP Exemption is returning forest stand structures to a historic SDI level; however, it must be noted the prevalence of small diameter trees on some Notices, regardless of SDI values, reflecting landowner choices and/or economic constraints**.

Canopy Closure

Canopy closure most closely reflected crown contact percentage and tree spacing, however, there is nuance to this result. Residual trees may be in near or complete crown contact, and the lower end of tree spacing, yet have substantially high crown base heights and thus lower susceptibility to surface-to-crown fire transition, although typically only when larger trees dominated the post-harvest stand (**Canopy Closure Estimates**). In young eastern forests of Washington state, higher canopy "closure" values and lower crown base heights were found to correspond to lower tree mortality after wildfires mainly due to sufficient surface and ladder fuel treatments being done (Lyons-Tinsley and Peterson, 2012). In at least one wildfire event dominated by extreme fire weather and plume-dominated behavior (2013 Rim Fire), canopy "closure" was found to be minimally important, likely due to overarching fire weather (time since last fire, in particular low-severity fire, mattered more) (Lydersen et al., 2014).

In terms of enforcement, and project outcomes, the issue of canopy "closure" versus canopy "cover" needs to be addressed. Closure encompasses all incoming sunlight at a point, while cover is everything as viewed from a vertical projection (i.e., whether a vertical line intercepts vegetation). As such, there are differences between the two (Appendix 2: Canopy Closure Method Comparison). Under the current "Closure" rule language, either an acceptable and established method is needed to measure and enforce canopy "closure", or regulatory language needs to be changed to "cover", which has more readily enforceable approaches (site tube measurements).

Regardless, it is necessary to discuss stand age, diameter, and height, relative to canopy closure (or cover), and desired outcomes; small, young, forest stands likely will always have less closure/cover when spaced at a level close to a more mature and "fire resilient" forest stand, while currently acceptable (under the FPRs) closure/cover values in these stands would result in denser, possibly fire-prone stands. Larger diameter, more mature forest stands, where surface and ladder fuels are adequately treated either mechanically and/or under prescribed fire, may benefit from greater overhead closure values, limiting incoming solar radiation. The best available science should inform future decisions, especially in regard to the FPRs and FFP Exemption, and forest stand size and age. It may be necessary to develop and enforce stricter standards for surface and ladder fuel outcomes, rather than overhead canopy metrics.

Surface and Ladder Fuel Considerations

Surface fuel, ladder fuel, and slash treatments, while mentioned within the FFP Notice regulations, do not have robust guidance or outcome-based expectations, relative to fire behavior. While the FFP Exemption is focused upon the canopy fuels of the timber stand, fire behavior is overwhelmingly controlled by surface and ladder fuels, outside of extreme fire-weather and fire-behavior (Stephens et al., 2009, Safford et al., 2012). Similar to findings on the §1038(c)(6) (Olsen and Coe, 2021), slash did not exceed the FPR rules, however, in a specific reading, there were incidences of exceedance of the 18 inch limit (**Harvest Related Slash Depths and Extent**). Similar to reports on the §1038(c) and §1038(c)(6) Exemptions, better guidance and research in needed on appropriate post-harvest slash and ladder fuel conditions under changing climate conditions in California, particularly for non-commercial tree species (e.g., hardwood or ornamental species), in conjunction with future exempt forest management.

Considerations in young "plantations"

Young, short, even-aged forest stands, or plantations, are especially difficult to treat for forest fire resiliency. Crown base may be inherently difficult to raise when the trees themselves are less than 40-50 feet in height (Figure 46, Figure 47), ladder fuels may grow taller with greater incoming sunlight and solar radiation (Figure 40, Figure 41) especially on more productive ground, and smaller diameter trees may be more susceptible to fire-induced mortality even under low-intensity burning conditions (including prescribed fire). While one approach may be outright fire exclusion within these types of young even-aged stands, another consideration may be enhanced and continuous ladder fuel treatments until the stand reaches a more mature age, tree limb pruning, in addition to lower basal area, trees per acre, and canopy closure metrics that may fall outside of the existing requirements for FFP Notices. Fire exclusion in many parts of California may be unreliable if not impossible, necessitating further research on the best ways to reduce fire impacts to current and future "plantation" style forest stands. As such, explicit considerations of these stand types when revising FFP requirements should be considerations. Alternatively, the development of a new exemption to tackle the thinning of young plantations is another potential option.

Forest Thinning and Watershed Impacts

Across California, the western US, and world, research has occurred on forest management and watershed impacts, in particular runoff and sedimentation. It has been documented that when harvests treat or remove 20% or more of a watershed, peak flows may increase, however there is nuance involved in drainage area and ability to detect change (Grant et al., 2008). What has become clear from limited research is the inability of forest thinning, even at landscape-scale mechanical and prescribed fire treatments, to substantially alter water yields (runoff) at the watershed scale, at least in a way that exceeds overarching climatic controls, and is highly dependent on the ecological and geographical location in California of the forest in question (Saksa et al., 2020, Kurzweil et al., 2021, Bart et al., 2021). Likewise, sedimentation and runoff impacts following forest thinning treatments, at least within the California Sierra Nevada, have shown to have minimal to undetectable impacts on watersheds, compared to the effect of climate (e.g., storm magnitude) (Harris et al., 2016, Bart et al., 2021, Yang et al., 2022). Outside of California, recent research from Arizona indicated that forest thinning within ponderosa pine forests increased tree resistance to drought under the most extreme drought conditions, via greater soil moisture levels (Sankey and Tatum, 2022).

Overall, FFP Notices may serve to increase watershed health via reduced fire severity and extent of tree mortality, as well as the proportion of a watershed burned at moderate and high soil burn severity, while avoiding detrimental impacts to peak flow, runoff, and sedimentation, particularly at the scale that current FFP Notices occur at across watersheds.

Recommendations

Recommendation #1

- **Incorporate strategic planning into the implementation of Forest Fire Prevention Exemptions.**

Given the underlying intent of the Exemption, and in particular those Forest Fire Prevention Exemptions in proximity to communities and residences, integrate the FFP Notices into the Unit Fire Plan in order to facilitate treated stands for anchor points, direct suppression, or backburning tactics. When possible, aggregate FFP treatments in and around WUI and intermix areas, in conjunction with areas treated under the 1038(c) and 1038(c)(6) Exemptions. Use CAL FIRE’s Forestry Assistance Program to assist with planning and outreach so that FFPs can be located and aggregated in a manner than can achieve community wildfire resilience objectives.

Recommendation #2

- **Landowners and licensed professionals develop maintenance plans for treated stands, in order to keep ladder fuels from re-developing and reintroducing surface-to-crown fire hazard.**

Landowners should be aware that ongoing maintenance will be needed, particularly on more productive Site Classes where sunlight may be introduced and surface and ladder fuels regrown quickly. Recommendation #2 is made more feasible by incorporating FFPs into the Unit Fire Plan (Recommendation #1), where they can be placed on a maintenance schedule.

Recommendation #3

- **As appropriate with Forest Fire Prevention size and location and stand type, consider immediate introduction of prescribed fire to treated areas following timber harvesting.**

Abundant research has indicated that fuel treatments where timber resources are thinned in addition to surface and ladder fuel treatments, overwhelmingly benefit from prescribed fire for the reduction in future fire behavior, enhanced tree survival, and prolonged durability of fuel treatments (less ongoing maintenance).

Recommendation #4

- **Landowners, especially small Non-Industrial landowners, and professionals should seek funding sources to upgrade native surface roads and legacy watercourse crossings to year-round, more robust roads.**

Ensuring road networks associated with Forest Fire Prevention Notices are of the highest standard and drivability will help ensure not only future access for maintenance of treated fuel areas, but also help for access during wildfire events proximal to the Forest Fire Prevention Exemptions. Given that higher standard roads are critical for water quality protection and effective fire suppression operations, small non-industrial landowners should explore funding opportunities from programs such as the Natural Resource Conservation Service's (NRCS) Environmental Quality Incentives Program (EQIP), which can potentially provide financial assistance for road upgrades. Funding opportunities for road upgrades on FFPs should also be explored by CAL FIRE's Wildfire Resilience Program.

Recommendation #5

- **Improve guidance on surface and ladder fuel treatment, accounting for changing climate and fire behavior, in order to better eliminate crown fire initiation, particularly in high biomass areas in the Coast District.**

Determine economical methods to reduce surface fuel hazard in areas with higher biomass. This might include encouraging the development of a biomass sector that can utilize treatment-derived slash, so that surface fuels and ladder fuels can be treated more effectively to meet fuel hazard reduction objectives.

Recommendation #6

- **Revisit canopy closure metrics, and determine if beyond forest type and site class, there are more appropriate thresholds based on stand size and height.**

The older, more developed stands may benefit from denser canopies to limit overhead incoming light when surface and ladder fuels are reduced adequately, while younger stands ("plantations") may benefit from increased tree spacing to reduce horizontal continuity as the stand matures.

More clearly linking canopy closure metrics to fuels objectives and desired stand conditions will help to clarify how this retention standard should be implemented. If canopy retention standards are associated with retaining wildlife habitat, canopy would be measured at the stand level in order to mitigate unintended outcomes of creating homogenous forest stands to meet canopy retention standards. Providing additional guidance on how to measure canopy closure, or canopy "cover", may improve compliance on this standard.

Revision of PRC, Section 4584 will be necessary to make modifications to this rule requirement.

Recommendation #7

- **Revisit stocking standards using the best available research in relation to fire behavior and forest resiliency to other stressors such as drought and insects in addition to wildfire, and make considerations for hardwood components of forest stands.**

Forest stands should be viewed as more than just conifer species, with allowances for hardwoods, in order to help return forests to their natural range of variation as ecologically appropriate. Measurements of hardwood species, large snag trees providing habitat, and stand density indices may be alternatives to current FFP stocking standards.

Revision of PRC, Section 4584 will be necessary to make modifications to this rule requirement.

Conclusion

The Forest Fire Prevention Exemption has seen increasing use statewide in recent years, in both the number of accepted Exemptions and reported acres, particularly in relation to other wildfire- oriented non-discretionary timber harvesting permits. Small Non-Industrial landowners account for a majority of accepted FFP Notices, while large Industrial landowners typically account for the majority of reportedly treated acres. Between 2015 and 2021, a small minority (3.7%) of FFP Notices had Forest Practice Rule violations. Statewide monitoring of 44 randomly selected FFP Notices, an Exemption with the intent of thinning forests of small diameter trees and reducing flame length, surface-to-crown fuel continuity, and improving forest resiliency, **indicated that largely operations of most FFP Notices meet the intent of the Exemption**.

Forest Fire Prevention Exemptions generally had favorable water-quality outcomes. This result was in part due to the more resilient green-tree setting (opposed to a post-fire environment), low-risk road networks (minimally sloped or flat roads), and in some cases ongoing drought conditions during and after the Exemptions were sampled. Sediment discharges, where present from roads and road-watercourse crossings, were related to a need to upgrade road and crossing design, or ensure adequate maintenance. Watercourses themselves were well protected from sediment discharge overwhelmingly, and only minimal tree harvesting occurred where it was allowed under the FPRs. Class III tractor crossings performed well under operations, and tractor crossings were generally adequately removed; where issues existed, similar to roads, they were related to inadequate drainage, design, and/or removal.

Harvest related slash following operations generally met FPR regulations, however there were often isolated incidences of excessive slash depth, or continuous patches of shallow-depth slash. Forests with higher unit area biomass had the greatest issue with slash, counter to the intent of the Exemption.

Monitoring revealed important differences between timberland ownership types in FFP Notice management approaches, and pre- and post-harvest stand structure, reflective of legacy or recent management history. Canopy closure was likely met on the majority of FFP Notices, but was clearly influenced by forest type and forest-setting (dry interior versus wet coastal). Tree spacing and crown contact percentage related strongly to canopy closure; as spacing increased, closure decreased, and as crown contact percentage decreased, closure as well decreased, implying that two metrics that control tree density also affect the ability to meet the crown closure requirements. However, due to stand differences and management histories, many Industrial “even-aged” forests have smaller, more widely spaced trees post-harvest, while many Non-Industrial multi-cohort forests were less well spaced, had more trees in crown contact, and overall had larger trees. **But interestingly, Non-Industrial forests with larger, denser trees also typically had minimal surface-to-crown vertical fuel continuity, due to post-harvest stand conditions and/or purposeful treatment of ladder fuels. What was clear through monitoring is the inherent difficulties in**

properly treating "plantation" style stands or fire resiliency while also meeting landowner goals and FPR regulations.

Regardless, FFP Notices overwhelmingly all increased the QMD of forest stands through harvesting operations, with results pointing towards substantial increases in larger size class stands (indicative of thinning from below), and minor increases in smaller, younger stands, indicative of the often limited options for management in those types of stands. However, across the entire sample, operations resulted in either a static QMD or WHR stand size class, or an increase in these classes; this was very apparent on Non-Industrial FFPs, where 42% of the FFPs increased stand size class via operations. Sample wide, results clearly pointed towards an emphasis on the harvesting of the smallest trees, and retention of larger trees, and a large hardwood component on many FFPs, particularly Non-Industrial Notices. Stocking levels may need to be thought of in terms beyond simple conifer basal area or density, especially in regards to desired intent of forest resiliency. By one measure, stand density index estimates for stands within the interior of the state, following operations, may be nearing more desirable historic values as documented in recent research. Lastly, where shade tolerant tree species were present, operations place an emphasis typically on the harvesting of these trees, particularly smaller diameter specimens. **However, operations did not eliminate shade tolerant species entirely, and shade *intolerant* species still consisted of the greatest proportion of basal area (where present).**

The overall outcomes of monitoring of the Forest Fire Prevention Exemption point towards intent being met on most Notices. Improvements in the integration of FFP Notices into wildfire planning across landscapes, plans for long-term maintenance, and the introduction of prescribed fire as an additional treatment will help to fully realize the potential of the FFP as a tool for community-based wildfire resilience. Road improvements will benefit watershed health and future access for maintenance and suppression activities. Future research is necessary to improve upon surface and ladder fuel treatments under a changing climate, especially within the Coast District, and regulations may need to be altered in regards to stocking and overhead canopy levels to meet desired wildfire-related outcomes. **Finally, robust reporting on where wildfires impact FFP Notice Exemptions will inform future operations.**

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Appendix 1 - Forest Fire Prevention Exemption Usage, Inspections, and Enforcement Metrics

- **Forest Fire Prevention Exemptions peaked across the state from 2005 to 2013, largely within the Southern Forest Practice Area, followed by a lull in usage, and then an expanded number of accepted Exemptions starting in 2015 that also coincided with greater acreages and spatial sizes of the FFP Exemption, particularly in the northern interior and north Coast portions of the state.**
- **Large (> 100 acres) and small (< 50 acres) FFP Notices have equally become prevalent in recent years.**
- **Within the Cascade Forest Practice Area, Non-Industrial FFPs have dominated Exemption counts, while Industrial FFPs have dominated total reported acres. Between 2015 and 2021, the Cascade Area accounted for the most FFP Notices and reported acres, with a yearly average of 2,440 acres out of the statewide yearly average in that time period of 3,630 acres.**
- **Between 2015 and 2021, only 3.7% of all FFP Notices had at least one Notice of Violation of the Forest Practice Rules. Inspection numbers on FFPs have steadily increased, while the percent of FFPs with at least one inspection has slightly decreased each year, but remained well above 50%; this result must also be take in light of recent historic wildfire seasons and additional Forest Practice workload.**

Exemption Usage

From 2005 through 2021, 679 Forest Fire Prevention Exemptions have been accepted by CAL FIRE as reported in CalTREES (Figure 73). FFP Exemptions had substantial usage from 2007 through 2013, driven in part by grant funding and usage in the Southern Forest Practice Area (Olsen et al., 2019a) (Figure 73). Concurrent with the §1038(j) "Pilot" in 2015, statewide usage began to increase again, after a low in 2014 of only 9 FFP Notices, largely driven by usage in the Cascade FPA (Figure 73). The §1038.3

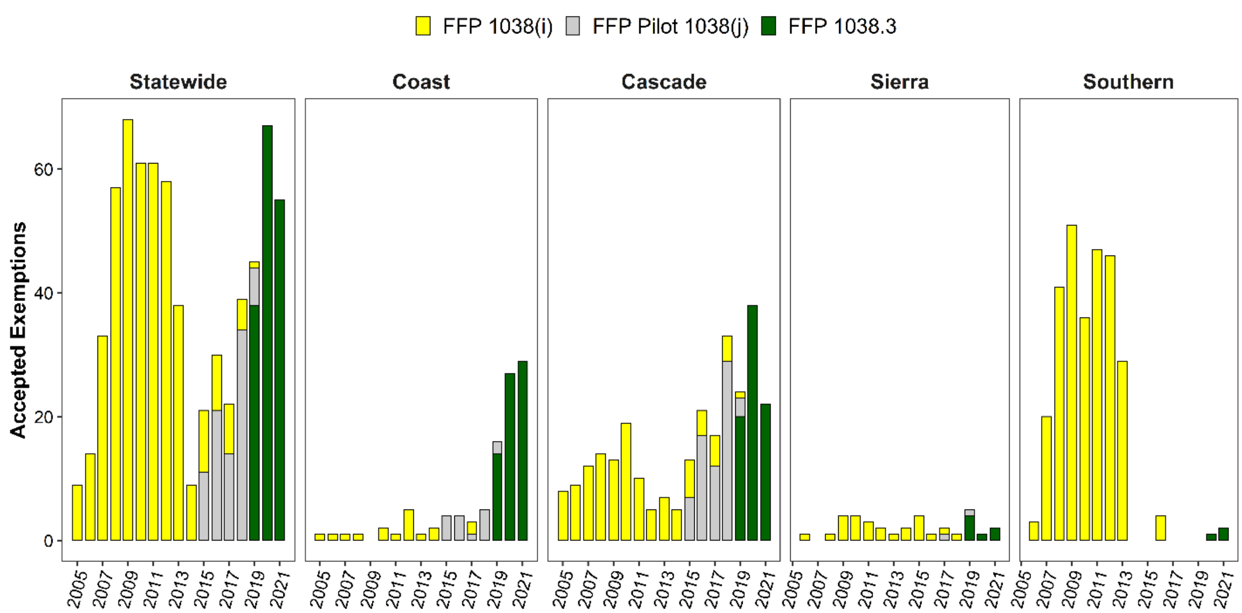

Figure 73: *Yearly FFP acceptance numbers both statewide and by FPA. Bar colors indicate the type of FFP accepted by CAL FIRE.*

iteration of the Exemption in 2019 led to a large increase in usage in the Coast FPA, sustained use in the Cascade FPA, and minimal Exemption usage in the Sierra and Southern FPAs (Figure 73).

Since the FFP Exemption was first introduced and through 2021, a total of over 35,600 acres have been reported as within FFP Exemption boundaries, with an average total of approximately 2,100 acres per year, statewide (Table 25). Total reported acreage under FFPs from 2005-2021 was dominated by the Cascade and Coast FPAs, with over 21,000 and 7,000 acres, respectively. While the Sierra FPA has only had 34 FFPs used, over 2,700 acres were reported within those Exemption boundaries; meanwhile, in the Southern FPA, 280 FFPs were accepted by CAL FIRE, yet only just over 3,700 acres in the Southern FPA were reported within FFP Notices, despite eight times more FFP Notices than in the Sierra FFP. In the Southern FPA, 90% of all FFPs in that Area were 25 acres or less (Table 27).

Statewide, there is a clear distinction between the periods of 2005-2014, and 2015-2021 in FFP usage; while the same or fewer FFPs were accepted in the last seven years, reported acreage within the Notices was substantially higher than it was from 2005-2014 (Figure 6). From 2005 to 2014, just over 10,200 acres were reported on accepted FFP Notices across the state, while from 2015 through 2021 that number saw a nearly 150% increase to over 25,400 acres, total.

In fact, the average yearly acreage under FFPs between 2005-2014 and 2015-2021 increased from 1,020 to 3,630 acres (Table 25). The implication being that not only

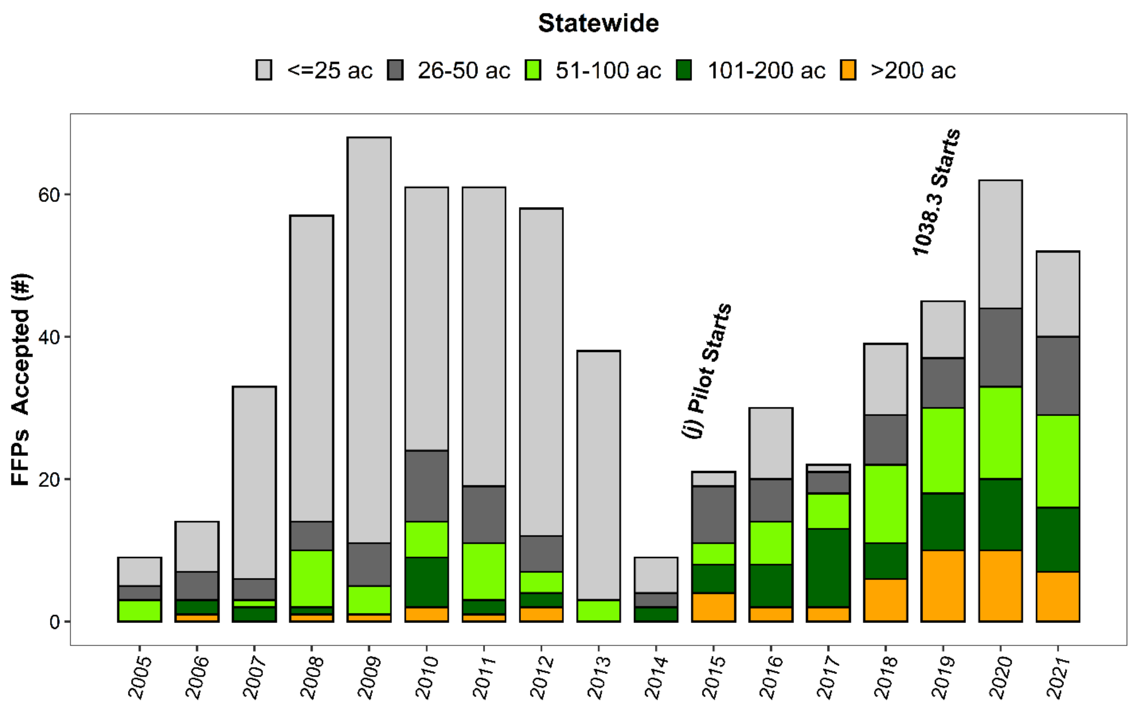

Figure 74: *FFP Exemption numbers by year, statewide, with bar colors indicating the FFP size class. The year that the §1038(j) "Pilot" and §1038.3 iterations started are indicated above the 2015 and 2019 bars.*

has the FFP Exemption seen more usage in recent years, but also the Exemptions now frequently have larger spatial footprints (Figure 74), especially so with the §1038.3 version. The first ten years of the FFP, only 6% of all Notices were 100 acres or larger in reported size, while in the last seven years 34% of all FFP Exemptions have been 100 acres or greater (Table 27, Figure 74). Interestingly, in the Coast FPA, the average size of FFPs has appeared to decrease in recent years, while in the Cascade FPA, five of the last seven years have seen the average FFP size exceed 100 acres (Table 27).

Meanwhile, Forest Fire Prevention Exemption usage since 2015 was initially largely used by Industrial timberland owners within the Forest Practice intensive Coast and Cascade FPAs (Table 28). However, small Non-Industrial landowners in the Cascade FPA began to have a greater proportion of accepted FFP Notices starting in 2017, coinciding with a near fifty-fifty split between small Non-Industrial and Industrial landowners in reported acres as well (Table 28). In the Coast FPA, Industrial timberland owners were the majority of FFP submitters, with a majority of acres under FFPs, until 2020; 2020 and 2021 both saw small landowners in the FPA account for a majority of Exemptions and acreage (Table 28). In the Sierra FPA, the majorities have gone back and forth each year since 2015; some years FFPs were entirely associated with small landowners (2015, 2016, 2020, 2021) (Table 28). Even in years where both small Non-Industrial and Industrial landowners had accepted FFPs, Industrial timberland owners accounted for a majority of reported acres being treated. To no surprise, the Southern FPA has had all FFPs entirely associated with small, Non-Industrial timberland owners (Table 28).

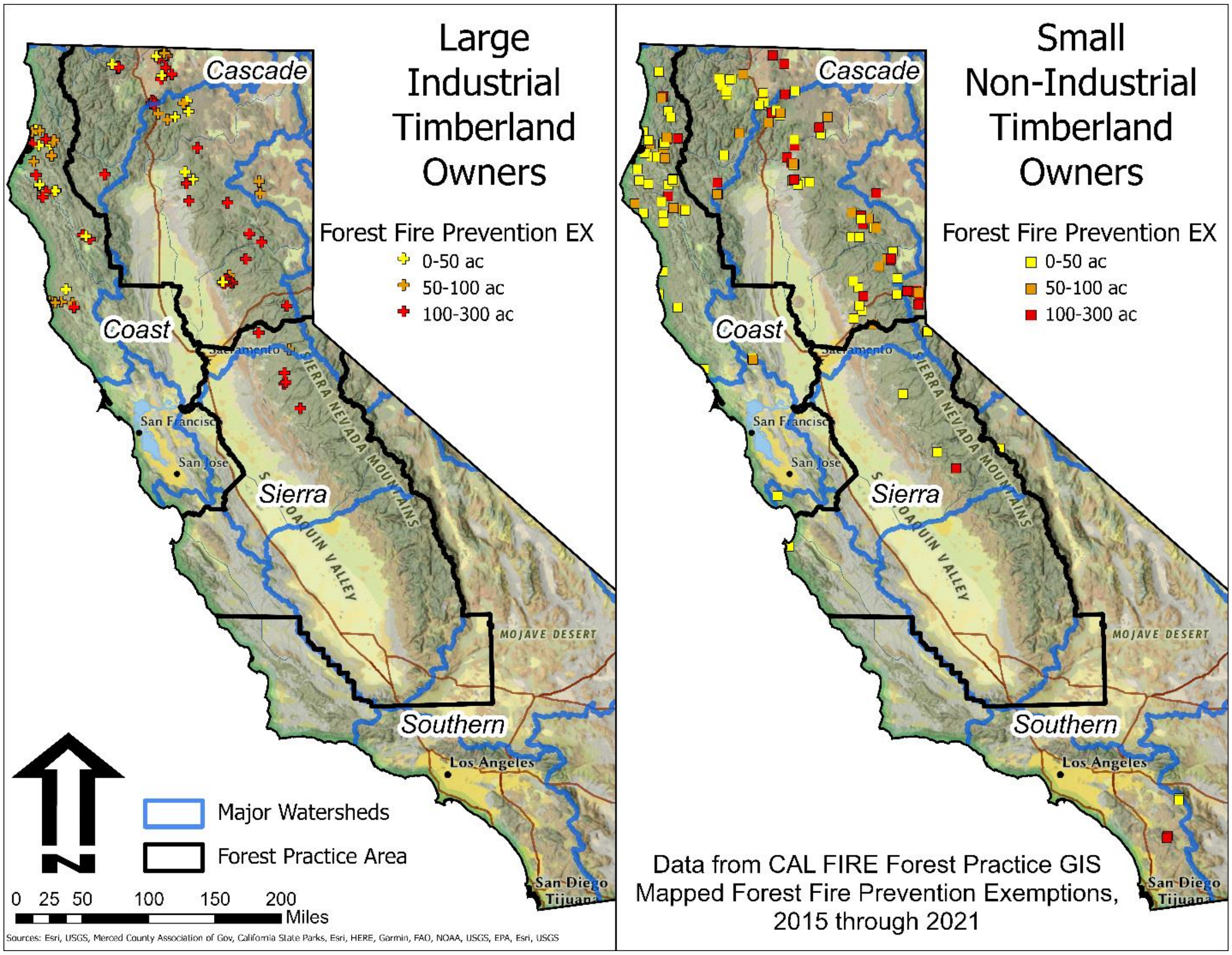

Figure 75: *Location and sizes of Forest Fire Prevention Notices, 2015-2021, statewide. Left panel shows locations of FFP Notices for large industrial timberland owners, while the right panel shows the same for small non-industrial timberland owners.*

Table 25: *Total accepted FFPs, yearly mean number of FFPs, total reported FFP acres, and yearly mean reported FFP acres for 2005-2021, 2005-2014, and 2015-2021 by statewide and Forest Practice Areas. Numbers may not add up to due to rounding.*

	2005 to 2021				***2005 to 2014***				***2015 to 2021***			
	Count (total)	Count (yearly mean)	Acres (total)	Acres (yearly mean)	Count (total)	Count (yearly mean)	Acres (total)	Acres (yearly mean)	Count (total)	Count (yearly mean)	Acres (total)	Acres (yearly mean)
Statewide	679	~40	35,639	~2,100	408	~41	10,208	~1,020	271	~39	25,431	~3,630
Coast	103	~6	7,016	~400	15	~2	1,205	~120	88	~13	5,811	~830
Cascade	262	~15	22,090	~1,300	102	~10	4,999	~500	160	~23	17,091	~2,440
Sierra	34	~2	2,761	~160	18	~2	922	~90	16	~2	1,839	~260
Southern	280	~16	3,771	~220	273	~27	3,082	~300	7	~1	689	~100

Table 26: *The average reported acres of FFPs by year, statewide and by Forest Practice Area, 2005-2021. "NA" indicates no FFPs were accepted in a Forest Practice Area in a given year. Numbers may not add up to due to rounding.*

	Statewide - Mean Reported FFP Size (Acres)	**Coast - Mean Reported FFP Size (Acres)**	**Cascade - Mean Reported FFP Size (Acres)**	**Sierra - Mean Reported FFP Size (Acres)**	**Southern - Mean Reported FFP Size (Acres)**
2005	39	4	44	***NA***	***NA***
2006	52	2	63	155	2
2007	19	45	29	***NA***	12
2008	23	27	54	40	12
2009	15	***NA***	57	38	3
2010	40	152	68	74	14
2011	27	192	43	38	19
2012	22	91	23	43	14
2013	10	3	26	74	5
2014	44	88	43	3	***NA***
2015	106	115	124	42	***NA***
2016	74	62	89	29	19
2017	117	138	115	109	***NA***
2018	86	74	83	269	***NA***
2019	112	64	120	217	***NA***
2020	89	59	118	30	50
2021	84	54	113	49	283

Table 27: *FFP size classes and corresponding proportions, 2005-2021, statewide, by Forest Practice Area, by the 2005-2014 and 2015-2021 time periods, and by time period as well as Forest Practice Area. Red bold italics indicate the largest proportion for each row. Numbers may not add up to due to rounding.*

	≤25 ac	26-50 ac	51-100 ac	101-200 ac	>200 ac
Statewide	***54%***	14%	14%	10%	7%
By FPA					
Coast	***30%***	22%	26%	15%	7%
Cascade	***29%***	20%	20%	18%	13%
Sierra	20%	***35%***	20%	12%	12%
Southern	***90%***	3%	4%	1%	1%
Statewide					
2005-2014	***74%***	11%	9%	4%	2%
2015-2021	***23%***	20%	***23%***	19%	15%
By FPA					
Coast 05-14	***33%***	27%	7%	20%	13%
Coast 15-21	***30%***	22%	***30%***	14%	6%
Cascade 05-14	***43%***	26%	18%	9%	4%
Cascade 15-21	19%	16%	21%	***24%***	19%
Sierra 05-14	***33%***	***33%***	22%	11%	0%
Sierra 15-21	6%	***38%***	19%	13%	25%
Southern 05-14	***91%***	3%	4%	1%	1%
Southern 15-21	***43%***	29%	0%	0%	29%

Table 28: *FFP Notice count and reported acres by ownership type, Forest Practice Area, and year, 2015 through 2021. Rows under each FPA may not add up to 100% due to rounding.*

	Coast		**Cascade**		**Sierra**		**Southern**	
Count	**Small**	**Industrial**	**Small**	**Industrial**	**Small**	**Industrial**	**Small**	**Industrial**
Total	**60%**	**40%**	**60%**	**40%**	**63%**	**38%**	**100%**	**0%**
2015	25%	75%	9%	91%	100%	0%	NA	NA
2016	25%	75%	38%	62%	100%	0%	100%	0%
2017	33%	67%	71%	29%	0%	100%	NA	NA
2018	40%	60%	70%	30%	0%	100%	NA	NA
2019	31%	69%	58%	42%	40%	60%	NA	NA
2020	74%	26%	71%	29%	100%	0%	100%	0%
2021	79%	21%	68%	32%	100%	0%	100%	0%
Acres	**Coast**		**Cascade**		**Sierra**		**Southern**	
Total	**44%**	**56%**	**46%**	**54%**	**28%**	**72%**	**100%**	**0%**
2015	16%	84%	2%	98%	100%	0%	NA	NA
2016	23%	77%	23%	77%	100%	0%	100%	0%
2017	14%	86%	53%	47%	0%	100%	NA	NA
2018	12%	88%	60%	40%	0%	100%	NA	NA
2019	34%	66%	49%	51%	15%	85%	NA	NA
2020	59%	41%	53%	47%	100%	0%	100%	0%
2021	62%	38%	56%	44%	100%	0%	100%	0%

Exemption Inspections and Violations

Table 29: *FFP Notice inspections, showing inspection numbers based on the both the year of the inspection and the year of the FFP. The "**" for 2021 indicates that FFPs accepted in 2021 are potentially still active and ongoing. Data as of June 29th, 2022.*

		Year of Inspection							
		2015	2016	2017	2018	2019	2020	2021	Total
Year of FFP EX	2015	18	17	2	0	0	0	0	37
	2016	-	27	16	3	0	0	0	46
	2017	-	-	10	7	1	0	0	18
	2018	-	-	-	18	21	2	1	42
	2019	-	-	-	-	38	21	7	66
	2020	-	-	-	-	-	25	38	63
	2021	-	-	-	-	-	-	40**	40
	Total	18	44	28	28	60	48	86	

Between 2015 and 2021, a total of 321 inspections occurred on Forest Fire Prevention Exemption, inclusive of those Notices that received multiple inspections. The majority of FFPs had one to two inspections, with a minority receiving three or more inspections. Table 29 shows the number of inspections on FFPs by both the year of the FFP, and total inspections by the year of the inspection itself. Table 29 reflects an increasing number of inspections, concurrent with increasing numbers of FFP Notices (Figure 5, Figure 6). Generally, FFPs receive the most inspections the year of acceptance, followed by the subsequent year when operations may be still active, and then the second year after acceptance, likely as final inspections, or inspections to address previously discovered issues. Likewise, as FFP Notice numbers have increased in recent years, the percent of FFP Notices receiving at least one inspection, per CalTREES, has slightly decreased and plateaued just above 50% (Table 30). This result must be placed into the context of:

- Historic wildfire seasons in 2017, 2018, 2020, and 2021, and Unit staffing impacts
- Overall increasing Exemption and Emergency Notice workloads within each unit
- Priority fire hazard reduction projects as mandated by the Governor's office
- Ongoing active THP/NTMP-related workloads
- Internal and private-external competition for Registered Professional Foresters
- CalTREES data inconsistencies

Table 30: *The percent of FFPs inspected at least one time, by year of the FFP Notice. The "**" for 2021 indicates that FFPs accepted in 2021 are potentially still active and ongoing. Data as of June 29th, 2022.*

	Year of FFP EX	Percent Inspected at least once
Year of FFP EX	2015	86%
	2016	77%
	2017	64%
	2018	69%
	2019	69%
	2020	55%
	2021	48%**
	Total	62%

For FFP Notices accepted by CAL FIRE Between 2015 and 2021, a total of 10 individual FFP Notices received at least one (1) Notice of Violation (data as of June 29th, 2022). This equates to 3.7% of all FFP Notices accepted by CAL FIRE during that time period. During the same 2015-2021 time period, we should note one additional FFP accepted by CAL FIRE in 2014 received a Notice of Violation as well (in 2017). Of the FFP Notices accepted between 2015-2021 that received a Violation, one received two Notices of Violations, and one received three Notices of Violations, based on repeat inspections.

Of the FFP Notices accepted between 2015 and 2021 that received Violations, xx shows the plain language summary of the associated violations. Note, a single Violation may involve multiple FPR infractions.

Vio Year/FFP Year	Violation Summary
2015 / 2015	- **LTO harvested trees above diameter limit** - **LTO harvested unmarked trees, contrary to harvest plan**
2017 / 2017	- **RPF failure to identify and/or mark Watercourse Lake Protection Zone (WLPZ) within plan area**
2018 / 2017	- **LTO installed a culvert in a Class II watercourse against regulation**
2019 / 2019	- **RPF marked trees in excess of diameter limit for harvest**
2019 / 2019	- **Archaeological site damaged during operations by LTO**
2019 / 2019	- **RPF failed to verify operational flagging was complete prior to operations resulting in archaeological site damage**
2020 / 2020	- **RPF addendum directed LTO to use impermissible landing within Class I WLPZ** - **RPF misidentified a feature as a private permanent road for operational use** - **RPF failed to map location of Class III tractor crossings used for active log skidding** - **RPF failed to mark Exemption area adequately per FPRs for tree harvesting** - **LTO harvested trees in excess of diameter limit, which were both marked and not marked by the RPF** - **LTO conducted timber operations within a Class I WLPZ, including construction of a tractor road and harvesting of trees within the WLPZ**
2020 / 2020	- **RPF marked trees for harvest in excess of diameter limit that were subsequently harvested by the LTO**
2021 / 2020	- **LTO harvested trees in excess of diameter limit including those marked for retention by the RPF** - **LTO conducted timer operations within a Class I WLPZ including harvesting of trees in excess of the diameter limit** - **RPF failed to mark timber stand accurately per the FPRs** - **LTO failed to treat post-harvest logging slash to be less than 18" depth above the ground**
2022 / 2021	- **Post-harvest logging slash was not treated by the LTO, slash piles left throughout harvest area**

Appendix 2: Canopy Closure Method Comparison

- **Canopy "closure" and "cover" methods gave slightly different results in our tests. Closure, the required measurement per the FPRs, generally was higher than "cover" results, although spherical densiometers are known to over-estimate canopy closure percentages.**
- **The smartphone-based app was able to find significant differences between a coast Redwood stand and mixed conifer stands in the Sierra Nevada and southern Cascades.**
- **In all three forest stand type sites we tested, the spherical densiometer gave significantly higher canopy closure results than the smartphone-based app.**
- **Regardless of forest stand type, the smartphone app recorded the lowest canopy closure results. Closure results for the app when the site tube (canopy "cover") recorded a "miss" were lower than when a "hit" was recorded, and regardless of site tube results, the app recorded lower closure than the densiometer across all forest stand types.**
- **When looking at each forest stand type individually, and assessing closure measurement method types and if a site tube recorded a "hit" or "miss", we found that the app was able to identify the lowest end of canopy closure, and frequently identified the lowest closure values when site tubes also recorded a "miss" (analogous to open areas of canopy).**
- **The smartphone-based app was a reasonable, rapid, objective method to record canopy closure results.**
- **Remotely sensed canopy "cover" results may be a reasonable, office-based way to determine if a project is near or above applicable requirements, and to get a rapid assessment of canopy cover, in order to determine if further field work is needed to quantify post-harvest results.**
- **Compared to remotely sensed canopy "cover" values, the smartphone-app worked best in stands with low canopy cover, full treatment (not singular tree removal), and homogenous stands, and performed less desirably (compared to remotely sensed data) in stands with very high canopy cover, high stand variability, stands with large areas left untreated, and in "plantation" type forest stands.**

Three separate comparisons of canopy closure were made, one in a coastal Redwood stand, one in a mid-elevation Sierra Nevada mixed-conifer stand, and one in a mid-elevation southern Cascade mixed-conifer stand. The closure measurements were made at a one plot-per acre intensity, with basal area measurements using variable radius plots made at varying frequencies for each test site, dependent upon site size. Depending on the method, we compared either "closure" or "cover", with "closure" being the measurement identified in the FPRs, and includes overhead and adjacent cover and all incoming light (spherical densiometer and smartphone app), while "cover" captures immediate cover directly vertically overhead (site tube, remote sensing data).

The methods tested to compare canopy closure measurements were:

- Site tube. Site tubes are held up to the eye, and users record if tree canopy intersects the vertical viewpoint, resulting a Yes/No (or Hit/Miss) result. Total "Yes" or "Hit" points recorded out of all points yields a canopy *cover* result. This is the traditional method employed to assess watercourse lake protection zone (WLPZ) canopy cover in FORPRIEM.

- Spherical densiometer. Users use a concave spherical densiometer and record the number of covered points in the four cardinal directions ten feet from plot center, for an average value.
- Smartphone App. From plot center, users use the HabitApp app to take an upward facing canopy photo, ensuring the phone is flat, and record the closure percentage output. Within-app sensitivity is adjusted by the user as needed to get an accurate canopy closure value.
- Remote Sensing. Gridded raster data from the California Forest Observatory (California Forest Observatory) was extracted in GIS for the site test area, to determine a mean canopy cover value.

Table 31: *Comparison of canopy closure/cover results for three test sites in California, using different methodologies.*

	Basal Area (Feet^2 Ac^{-1})	***"Cover"*** Site Tube Method	***"Cover"*** Remote Sensing Method	***"Closure"*** Spherical Densiometer Method	***"Closure"*** Smartphone App Method	***Cover Mean***	***Closure Mean***
Coast Redwood	**106 ft^2 ac^{-1}**	**69%**	**75%**	**77%**	**56%**	**72%**	**67%**
Sierra Nevada Mixed Conifer	**140 ft^2 ac^{-1}**	**44%**	**43%**	**54%**	**44%**	**44%**	**49%**
Southern Cascade Mixed Conifer	**117 ft^2 ac^{-1}**	**47%**	**40%**	**58%**	**42%**	**44%**	**50%**
All	**121 ft^2 ac^{-1}**	**53%**	**53%**	**63%**	**47%**	**53%**	**55%**

Comparative results indicate a difference in "cover" and "closure", with "closure" results generally greater than or equal to "cover" results, with the exception of remotely sensed canopy cover in the coast Redwood stand. This last result is likely due to the influence of incoming sunlight, and more detailed, ground-based measurements, relative to coarser satellite imagery used to determine where canopy is present and the physical structure of Redwood crowns. In both mixed conifer stands, the test sites were chosen within thinned areas at the lowest end of the FPR canopy closure requirements (40%), in order to determine if the app-based approach could identify closure at the lowest level.

Generally, smartphone-app based closure results, with respect to satellite-based cover estimates, performed best when canopy cover was lower, forest units are fully treated (as opposed to spatially varying treatments, or minimal tree removal), and where stands were homogenous. The smartphone-app approach to closure did not perform as well, with respect to cover estimates from satellite, when canopy cover was very high (the ability of light to still penetrate and be captured in small amounts, versus overhead views of the canopy), where stands had high variability, and where there were large untreated portions of a forest stand (multiple age/size class trees present, or high canopy cover but ability of light to still penetrate), and in plantations (limited vertical development of trees, not captured by below canopy "closure" estimates versus overhead "cover" estimates).

Visual results of a comparison between the two methods on select FFP Notices is shown in Figure 76.

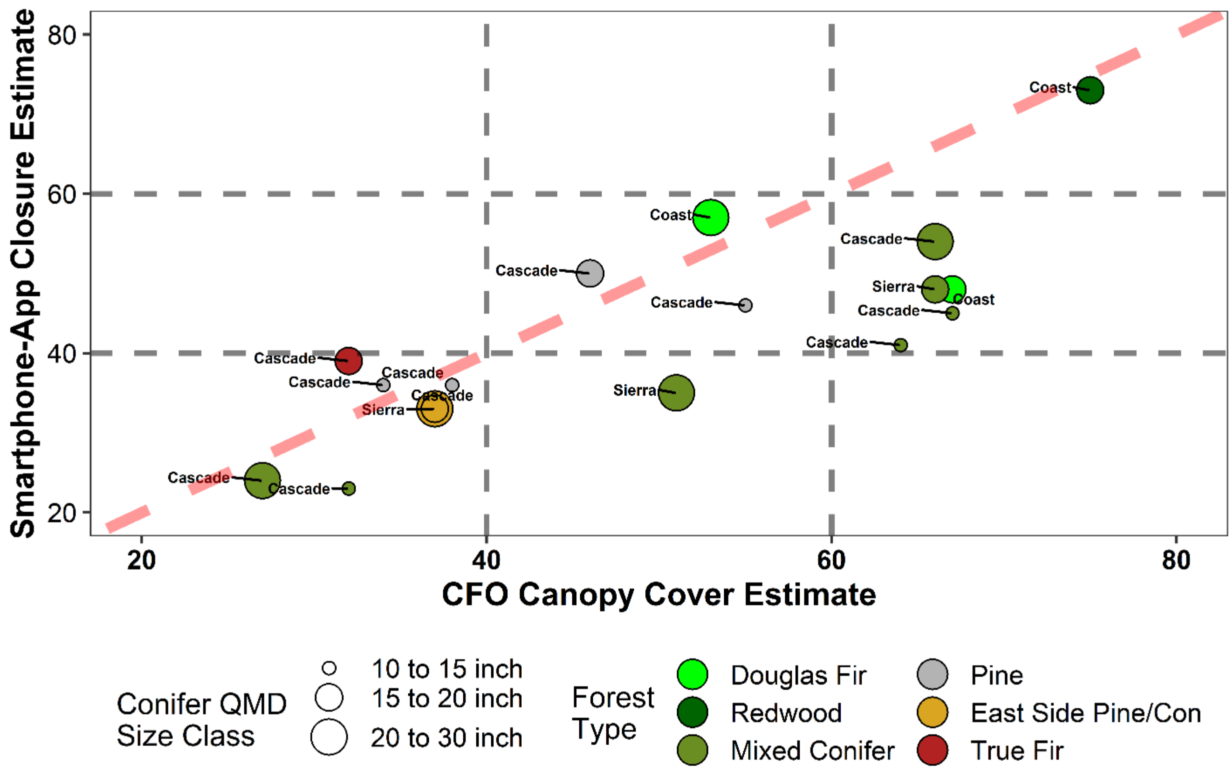

Figure 76: *CFO Canopy Cover Estimates versus field based smartphone-app based "closure" estimates on select FFP Notices. Point size indicates the post-harvest conifer QMD size class, point color indicates the forest type, and points have the Forest Practice Area labeled. Dashed gray lines show the 40% and 60% thresholds, and the dashed red line shows the 1:1 line. Points below the red line indicate a higher CFO cover estimate relative to the closure estimate, while points above the red line indicate the closure value was higher than the remotely sensed cover value. Points closest to the line are closest to equal values.*

Statistical comparisons[31] between methods measuring canopy closure and forest types indicated that the smartphone HabitApp found a significant difference between the coast Redwood closure and both mixed conifer sites ($p<0.0001$), while there was no statistical difference between either mixed conifer sites (three percent difference, $p = 0.45$) (Figure 77).

Between the two types of closure measurement methods (app and spherical densiometer), our tests found that in all three forest type sites, the spherical densiometer gave significantly higher closure readings ($p < 0.0001$), with marginal differences between 9% and 21% (Figure 78).

[31] R Statistical Software, standard analysis of variance between forest types, the lme4 package for mixed-effects models, and the emmeans package for comparisons, used to perform pairwise comparisons of results from the analysis of variance results, using a statistical significance of $p < 0.05$, and a Tukey adjustment for multiple comparisons. Models were built using Forest Site Type as the random effect.

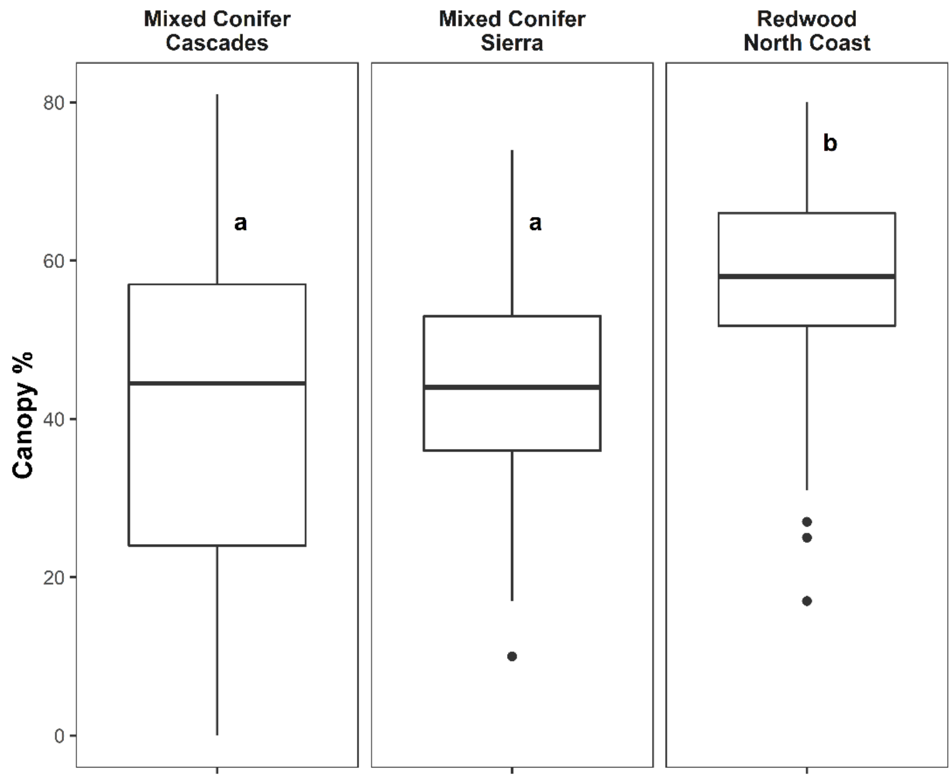

Figure 77: *Smartphone based HabitApp canopy closure results for the three different test sites. Different letters in each panel indicate significant differences.*

Splitting closure measurement results by both type and if the results was associated with a site tube Hit/Miss, our tests found that closure results were significantly lower with the HabitApp when a site tube recorded a “miss”, relative to HabitApp “hits” and the spherical densiometer for both site tube results (Figure 79).

Lastly, we assessed within each forest type site differences in canopy closure cover by method and site tube Hit/Miss. Within the Cascade mixed conifer stand, closure measured by the app, when a site tube recorded a miss, was significantly less than both app-measured cover when a site tube hit was recorded, and both site tube results for the densiometer (Figure 80); while the densiometer result under a site tube hit was significalty higher than all other closure results and site tube results. Meanwhile, the Sierra Nevada mixed conifer site, the app closure result was lower than all other site tube results and closure methods, the other of which had no significant differences (Figure 80). Lastly, in the coast Redwood stand, all four types of results (app versus densiometer, site tube hit or miss) were significantly different from each other (Figure 80).

The overall findings of this test exercise are that the smartphone-based app was able to accurately determine, in a rapid, objective, and recordable way (via photographs), known differences in forest stand types in different locations, identify the lowest end of canopy closure (overhead and adjacent aerial cover, incoming solar radiation), accurately identify canopy gaps (site tube “misses”), and was consistent across forest types and locations. The remotely sensed CFO data may be a reliable data source and methodology in the future to assess pre- and post-harvest canopy cover, knowing that values at the lowest end of FPR requirements, under current regulations, may need field verification. Field verification in enforcement-oriented situations may need to make use of more accurate hemispherical photography methods.

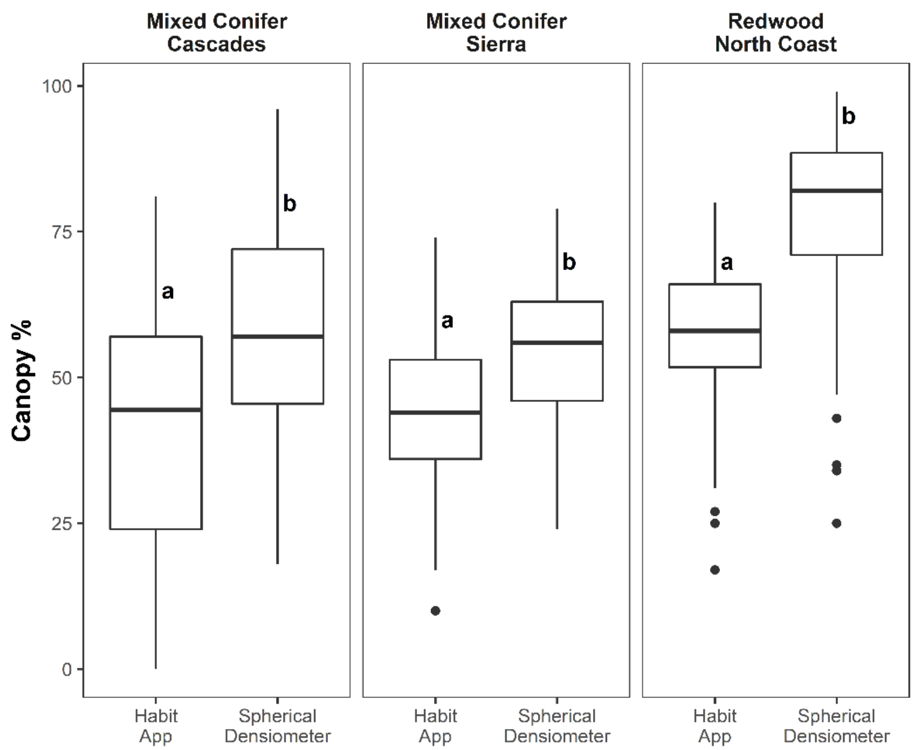

Figure 78: *HabitApp versus spherical densiometer canopy measurements for each of the three test sites. Within each panel, different letters indicate significant differences in canopy closure between each method, for each forest type site.*

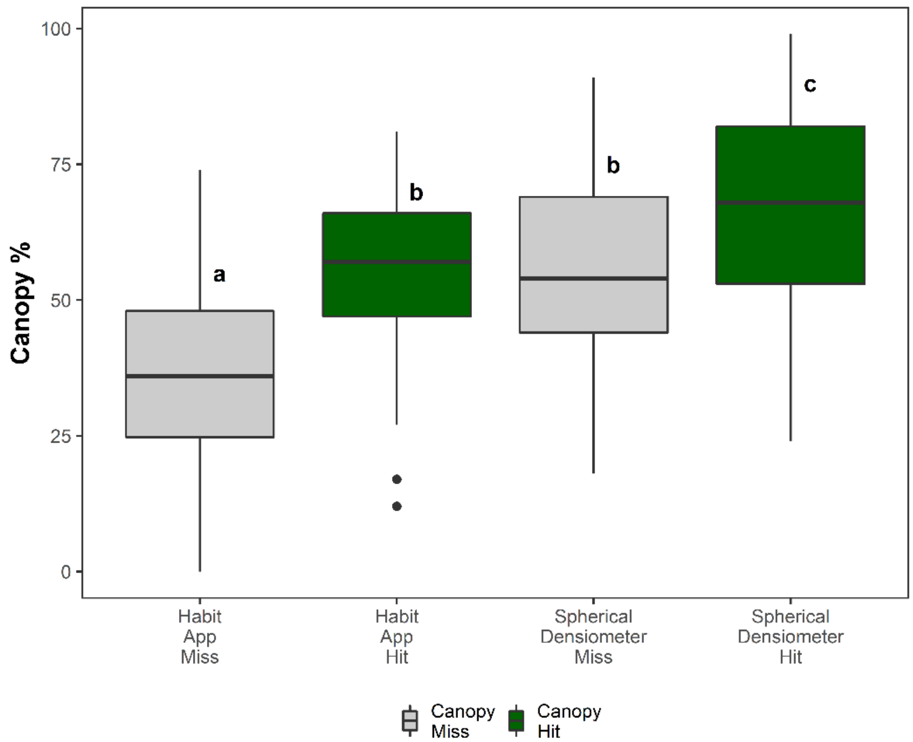

Figure 79: *App and densiometer based results, separated by measurement type and if each point was associated with a site tube method Hit/Miss. Different letters indicate significantly different canopy closure results.*

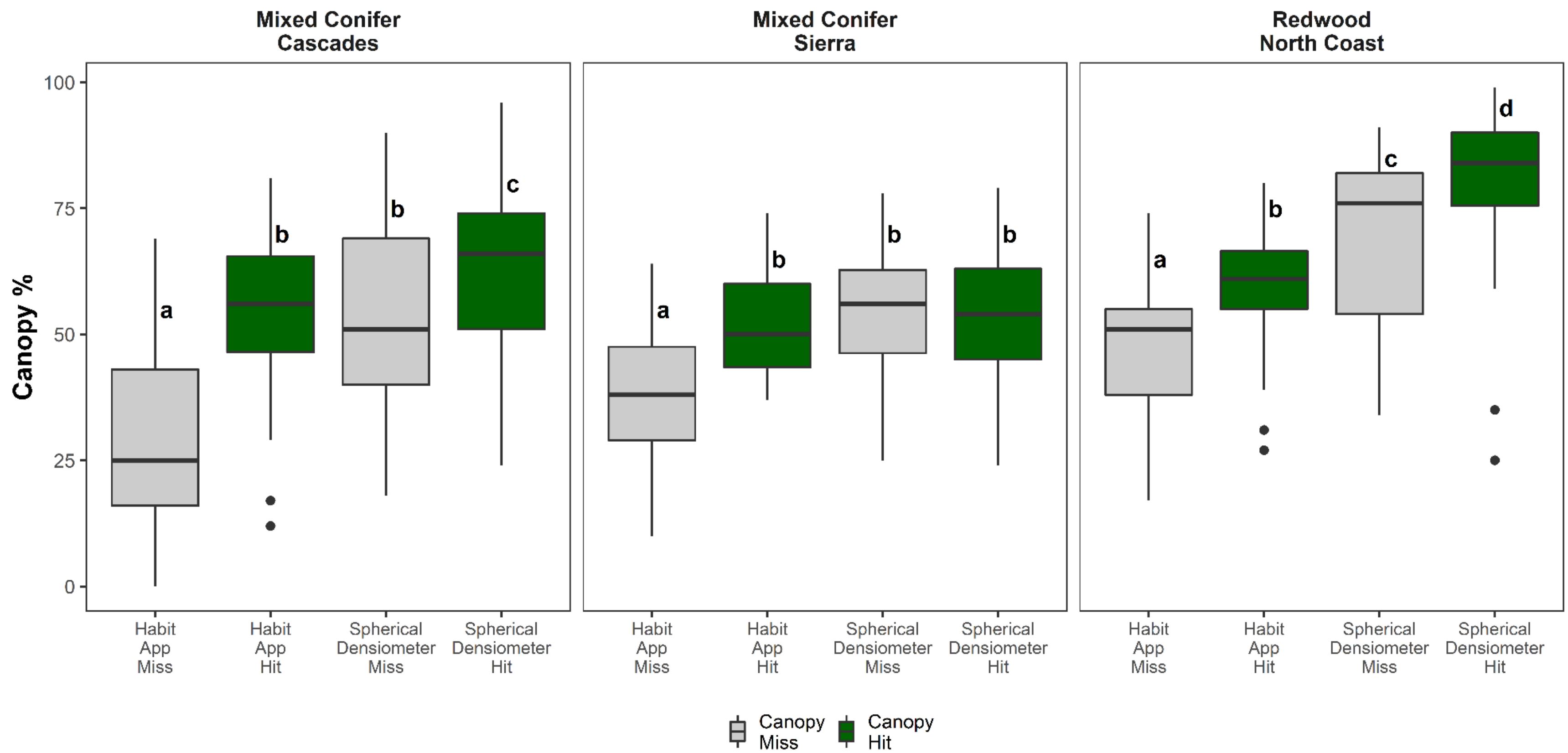

Figure 80: *App and densiometer based results, separated by measurement type and test site locations, and if each point was associated with a site tube method Hit/Miss. Within each panel, different letters indicate significant differences between methods for canopy closure results.*

Appendix 3: QMD Change Calculation

Equation for stump diameter to diameter at breast height, non-redwood conifer species:

DBH = $e^{-0.170+0.966[\ln(\text{stump\_diameter})]+(0.002557)}$

Maranto, C., 2007. "Report findings on QMD rule compliance for EX #4-05EM-058-CAL". *California Department of Forestry and Fire Protection, Forest Practice Administration.* Sacramento, CA. 13 p.

Equation for stump diameter to diameter at breast height, redwood conifer species:

DBH = 0.8759*(stump_diameter)-0.6486

Howe, R.A. 2014. "Coast Redwood Response to Herbicide Treatment of Tanoak". MS Thesis, Humboldt State University, Arcata, CA.

Equation for stump diameter to diameter at breast height, hardwood species:

DBH = stump_diamater – [(stump_dimater/10)+1]

Horn, A.G., and Keller, R.C. 1957. Tree diameter at breast height in relation to stump diameter by species group. Technical Note 507. *US Department of Agriculture, Forest Service, Lake States Forest Experiment Station*. St. Paul, MN. 2 p.

Appendix 4: Forest Fire Prevention Exemptions, Biomass Facilities, and Operating Sawmills

Data sources: California Forest Products and Biomass Power Plant Map - Woody Biomass Utilization (ucanr.edu), CAL FIRE Forest Practice GIS Exemption data (accessed December 12, 2022)

Biomass facility data was filtered to only active facilities, and to remove facilities that explicitly would not handle forest residue byproducts. Biomass facilities may have individual requirements or restrictions on the type of forest residue accepted, further limiting results. Likewise, sawmills may be specific to the type of logs accepted (e.g., large diameter or small diameter logs only). Results also do not account for market forces and if facilities pay for material, are paid by users to accept material, or accept material with no monetary exchange. Proximity also does not account for transportation network logistics.

Table 32: Forest Fire Prevention (FFP) Exemptions proximal to active biomass facilities that accept forest residue. Table shows the number of FFPs inside and outside of each buffer size, the corresponding percentage of all FFPs in the GIS dataset, and the percentage of FFPs in each FPA that fell within a buffer size.

	Biomass Facility (10 mile buffer)	Biomass Facility (25 mile buffer)	Biomass Facility (50 mile buffer)
FFPs within buffer	50	187	281
FFPs outside buffer	281	144	50
Percent FFPs within buffer	15%	56%	85%
Percent FFPs not within buffer	85%	44%	15%
Percent of Coast FPA FFPs in buffer	9.4%	53.5%	82.7%
Percent of Cascade FPA FFPs in buffer	20.7%	65.4%	88.3%
Percent of Sierra FPA FFPs in buffer	6.3%	12.5%	62.5%
Percent of Southern FPA FFPs in buffer	0%	0%	88.9%

Table 33: Forest Fire Prevention (FFP) Exemptions proximal to active sawmills. Table shows the number of FFPs inside and outside of each buffer size, the corresponding percentage of all FFPs in the GIS dataset, and the percentage of FFPs in each FPA that fell within a buffer size.

	Sawmill Facility (10 mile buffer)	Sawmill Facility (25 mile buffer)	Sawmill Facility (50 mile buffer)
FFPs within buffer	76	222	292
FFPs outside buffer	255	109	39
Percent FFPs within buffer	23%	67%	88%
Percent FFPs not within buffer	77%	33%	12%
Percent of Coast FPA FFPs in buffer	32.3%	69.3%	97.6%
Percent of Cascade FPA FFPs in buffer	19.0%	73.7%	88.3%
Percent of Sierra FPA FFPs in buffer	6.3%	12.5%	62.5%
Percent of Southern FPA FFPs in buffer	0%	0%	0%

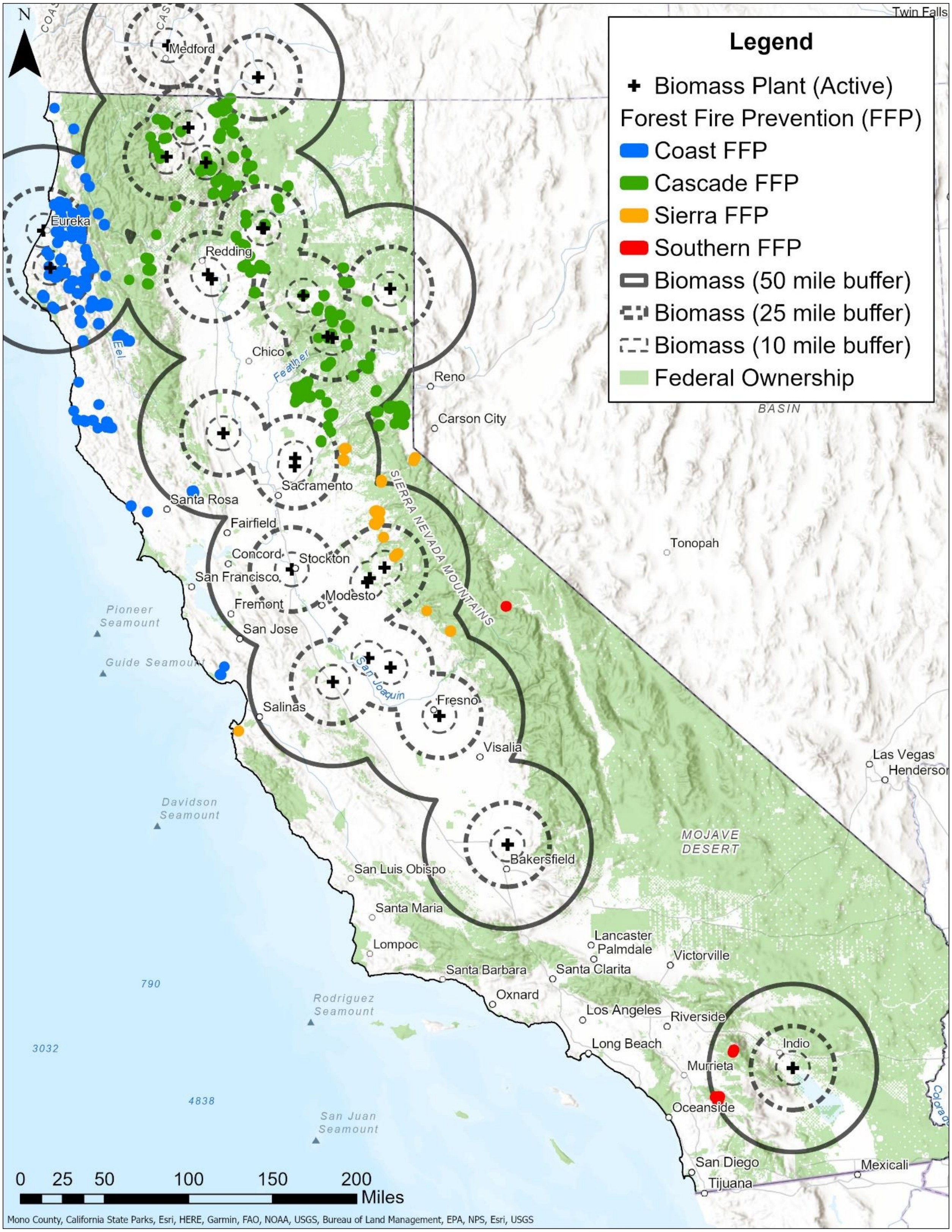

Figure 81: Mapped FFPs proximal to active biomass facilities. FFP colors indicate the Forest Practice Area, and each buffer indicates the 10, 25, and 50 mile radius around each facility. Transparent green indicates federal ownership.

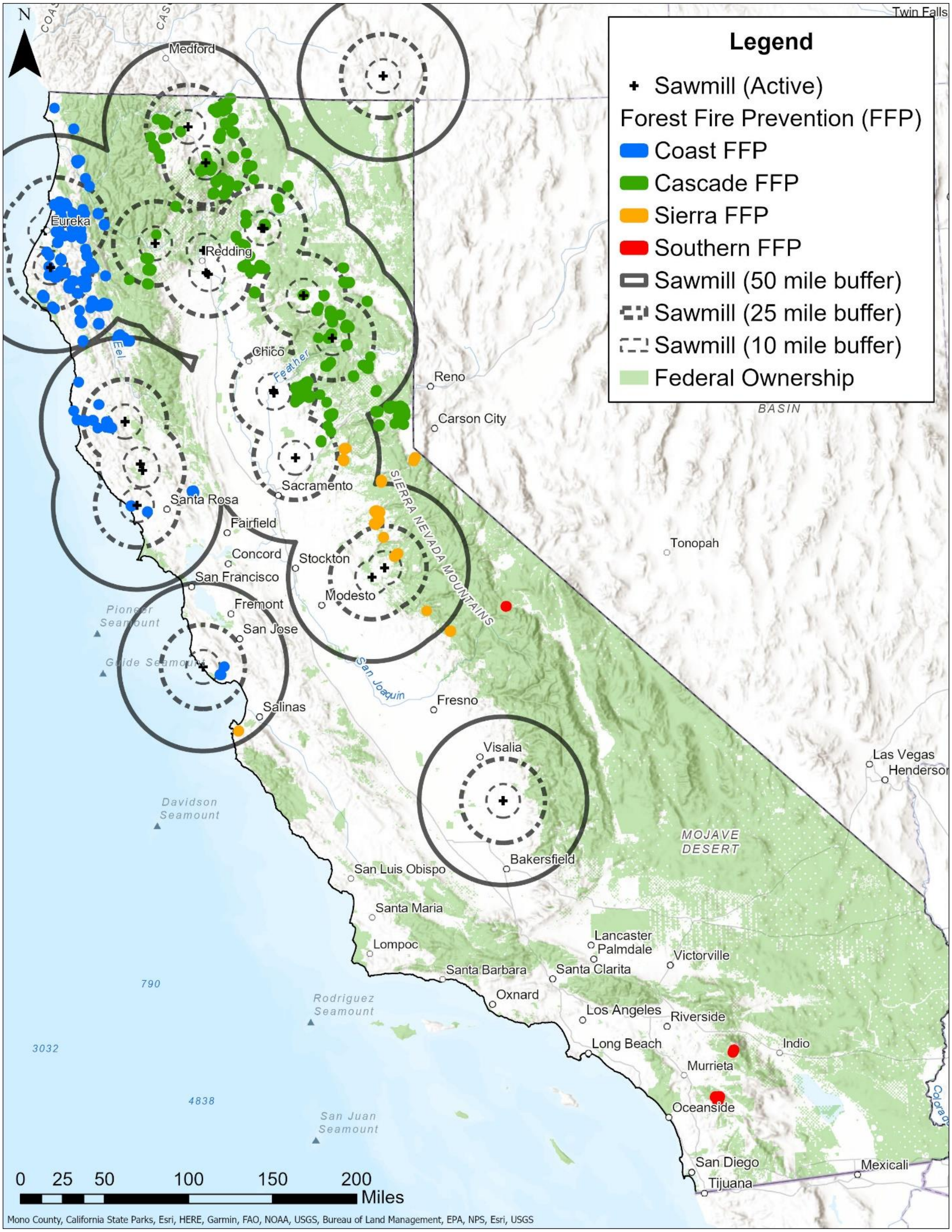

Figure 82: Mapped FFPs proximal to sawmills. FFP colors indicate the Forest Practice Area, and each buffer indicates the 10, 25, and 50 mile radius around each mill. Transparent green indicates federal ownership.