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Introduction
Aerial and ground surveys of tree mortality in Napa and Lake Counties in December 2021 and Jan 2022 revealed widespread conifer mortality. Herein we report our findings and recommendations based on these surveys. Additional surveys are planned for 2022.

Drought: The current drought is the underlying cause of conifer mortality in Lake County. High levels of water stress render trees vulnerable to attack by both insects and pathogens. Mortality caused by these factors is often delayed, and may not become apparent until after the drought conditions have eased. Stress is highest at the top of the crown, which is therefore the part of the tree initially most vulnerable to insect attack.
Fire: Fire damage, specifically scorching of bark and cambium, can cause tree mortality for years after the event. Scorching combined with drought can continue to kill trees for 5 years or more, and repeated evaluation within burn scars may be required.
Insect Damage: Mortality among conifers due to insect attack is most often the result of either direct damage to the cambium or through vectoring of wilt disease fungi that block the water conducting woody tissue (xylem). Bark beetles are the most damaging conifer pests and are responsible for the vast majority of the mortality seen in Lake County through aerial and ground surveys in 2021 and January 2022. Each tree species is attacked by different species of bark beetles as presented below. Currently in Lake County widespread and severe mortality is occurring in three conifer species, ponderosa and knobcone pines and Douglas-fir, and patchy and less widespread mortality in gray pine. All of the beetles discussed below are native to California, and under non-drought conditions, do not cause extensive tree mortality.
Ponderosa Pine (*Pinus ponderosa*): The Western Pine Beetle (WPB: *Dendroctonus brevicomis*) is the most destructive pest of ponderosa pine in California. Attacks are initiated in the spring and there are two generations/yr. Mortality is primarily the result of the blue-stain fungus *Ceratocystis minor* which is vectored by WPB and girdling of the cambium by adult and larval tunneling. Attacks initiated by the overwintering brood and the first generation between April and July usually lead to rapid decline and tree death in as little as two months. Attacks by the second generation, initiated in late summer and fall, can result in delayed mortality due to slower growth of the blue-stain wilt fungus. Mortality may occur in winter or spring depending on the temperature. In Lake County the temperatures remain high enough for much of the mortality to occur during the winter months, while at high elevations mortality is often delayed until after the spring thaw. In addition to WPB ponderosa pines are also susceptible to top kill

by the pine engraver, *Ips paraconfusus*, which also weakens the trees and facilitates attack by WPB.

Knobcone Pine (*Pinus attenuata*): This species is dependent on fire for regeneration; heat opens the closed cones on knobcone pine stems and branches and releases large numbers of seeds at once, resulting in large stands of the same age. This species is generally short-lived, and most stands degrade at 40-80 yrs. Historically fires occurred more frequently, and senescent stands would have been less common than they are today. Within Lake County many stands are over 40 years old and are susceptible to attack by the pine engraver *Ips paraconfusus*.

Douglas-fir (*Pseudotsuga menziesii*): The Douglas-fir engraver (*Scolytus unispinosus*) and the flatheaded fir borer (*Phaenops drummondi*) are the two most important pests of this species in California. The engravers weaken the trees by attacking the upper crowns, and the flatheaded borers initiate attacks on the main bole, 10-15 feet above ground. Populations and attacks by both of these species are currently high in Lake and the surrounding counties.

Gray Pine (*Pinus sabiniana*): Mortality in this species appears to be much less widespread and intense than in the above three species. This may be due to a greater drought tolerance. Outbreaks of the pine engraver, *Ips spinifer*, in Lake County are currently patchy and are causing high levels of mortality within small, geographically dispersed, areas.

Recommendations

Due to the widespread nature of the conifer mortality in Lake County actions should consider the degree of development, topography, and other site-specific conditions.

Within communities

<u>Hazard Trees:</u> Removal of hazard trees threatening health and property should be determined and prioritized by a licensed arborist or other qualified professional. Dead and dying trees along roadways and right-of-ways, and within parks and other public properties should be addressed by the responsible jurisdictions. (Smith & Cluck 2011, Owen et al. 2015, Cluck 2015, Addendum 2021)

Private Timberlands

More detailed recommendations for protection of valuable individual trees or stands of trees and for harvest or regeneration of damaged stands can be developed in consultation with Cal Fire forest health professionals.

Undeveloped properties

<u>Fire breaks:</u> Given the large scale of the mortality observed in Lake County the most cost-effective method of protecting property is through the construction of fuel breaks (CalFire 2019).

<u>Fuel reduction:</u> Fuel reduction projects within and adjacent to population centers could, in some cases, enhance the effectiveness of fire breaks. Fuel reduction projects should be evaluated on a case-by-case basis (CalFire 2021).

References

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Forest Health Protection
Pacific Southwest Region

Fire-injured tree marking guideline considerations for drought and elevated bark beetle populations

Summary

The current drought is unprecedented in many areas of California. In the most severely affected areas, drought and bark beetles are causing high levels of tree mortality in nearly all conifer species. This includes fire-injured trees in recently burned areas which are now at a higher risk of mortality than would be expected under more normal precipitation conditions.

Drought, bark beetles and fire injuries are contributing to ongoing tree mortality in the footprints of the American Fire (TNF 2013), Barry Point Fire (MDF 2012), Reading Fire (LNF 2012) Chips Fire (PNF, LNF 2012), and likely others in the Region. Most noticeable is the high level of mountain pine beetle-caused mortality of fire-injured sugar pine.

Based on these observations:

1) land managers may want to survey previously salvaged wildfire areas to capture additional mortality depending on management objectives.
2) for restoration projects planned for 2014 and current year wildfires, land managers should consider selecting a lower probability of mortality threshold to compensate for the potential increase in fire-injured tree mortality or plan to extend contracts to capture additional delayed mortality.
3) land managers are advised to use additional marking guideline criteria such as cambium kill and the presence of red turpentine beetle attacks for sugar pine.
4) please consult Forest Health Protection staff for assistance.

The marking guidelines developed for most R5 salvage and hazard tree abatement projects are based on *Marking guidelines for fire-injured trees in California* (Smith and Cluck 2011) and *Hazard Tree Guidelines For Forest Service Facilities and Roads in the Pacific Southwest Region* (Angwin et al. 2012). The probability of mortality (Pm) typically selected is 0.7 for salvage and roadside hazard units. In roadside units, trees are also evaluated for structural defects and marked if they meet high failure potential thresholds. Cambium sampling is generally not conducted due to time constraints and the additional work load relative to the small increase in guideline accuracy using this variable provides. Red turpentine beetle attacks are often not assessed due to the timing of timber marking occurring before the first post-fire beetle flight.

A Pm of 0.7 is a relatively conservative guideline in that a land manager can be fairly certain that a tree marked at this level is likely to die within the next 5 years. As a result, many trees that have a Pm of 0.1 to 0.6 are left on the landscape and could ultimately die whether it is from fire-injury alone or a combination of fire-injury, bark beetle attack and drought. Sale contracts that allow for additional volume and time have enabled land managers to keep removing trees as they die to successfully meet post-fire management objectives. Contracts that are less flexible have resulted in an inability to remove the delayed mortality and an excessive number of dead trees on the landscape.

Another aspect of how well a Pm of 0.7 will meet post-fire management objectives is simply the number of fire-injured trees that will remain post-initial harvest. Fires that are mostly high severity and kill trees immediately may have very few low and moderate severity burned acres, so there is less likelihood of higher levels of delayed mortality. Fires that have a large number of acres of low to moderate severity have a higher probability of experiencing higher levels of delayed mortality over several years. Fire-injured trees are stressed trees and the available soil moisture (pre- and post-fire) as well as the amount of bark beetle activity in the area can play a significant role in post-fire mortality. Therefore, depending on the type burn severity and post-fire management objectives, choosing a lower probability of mortality threshold may be warranted under current drought conditions.

High levels of mountain pine beetle activity have been observed over the past few years in sugar pine, and even more so in fire-injured sugar pine. To help capture some of this mortality during fire restoration projects, land managers should consider utilizing the cambium kill criteria as well as the red turpentine beetle criteria in marking guidelines. High levels of cambium kill have been observed by FHP on larger diameter sugar pine in most wildfire areas over the past 15 years and trees that have extensive cambial injury are highly attractive to mountain pine beetles, even at lower levels of crown kill. Sugar pine can generally sustain higher levels of cambium kill than other tree species but can be particularly vulnerable to mountain pine beetles at higher injury thresholds. Hood et al. (2010) found that when holding crown injury constant, sugar pine mortality increased only slightly until all cambium quadrants sampled were dead (CKR = 4), which follows past findings that sugar pine is capable of withstanding more extensive cambial injury than other California conifers (Wagener 1961). Hood et al. (2010) also observed that mountain pine beetles attacked 81% of the subset of sugar pines (170 of 210 assessed trees) that subsequently died in the Power Fire (ENF 2004). The Region 5 FHP fire-injured tree marking guidelines for sugar pine highlight how a high level of cambium injury affects sugar pine survival. These guidelines show that with up to three dead cambium samples (CKR=3) the crown kill criteria for sugar pine need to be adjusted up 5% for a given probability of mortality. That means a tree with that level of cambium injury would require 5% more crown injury to be marked for removal. However, when a tree has four dead samples (CKR=4), the crown criteria need to be adjusted down by 20%. Crown criteria are also reduced with the presence of red turpentine beetle.

<u>References:</u>

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Post-fire salvage and hazard tree projects in Region 5 have begun to transition from individual tree marking by US Forest Service and/or private contractor crews to designation by damage where cut trees are selected by purchasers and/or operators at the time of removal. This has resulted in later assessments of fire-injured trees beyond the recommended timeframes as stated in the R5 *Marking guidelines for fire-injured trees in California* (Smith and Cluck 2011). The Smith and Cluck (2011) guidelines still represent the best available science for predicting fire-injured conifer mortality in California and can and should be used beyond the original recommended timeframe as needed. However, later fire-injured tree assessments must account for changes in crown condition that could affect accuracy. Failure to account for crown changes such as scorched needle loss will likely result in an underestimation of crown injury, potentially leaving trees that would otherwise be harvested to meet project objectives.

The Fire-injured Tree Guidelines are recommended for use right after a fire and until the beginning of the second post-fire winter (*see* Fire-injured Tree Guidelines page 1). This timeframe was based on subjective observations of many fire-injured trees over time to determine at what point the shedding of scorched needles may reduce the ability to accurately determine the original pre-fire crown length or volume. The pre-fire crown length or volume measurement is needed to make an accurate assessment of percent crown scorch or kill that determines whether a tree will be harvested or retained (*see* Fire-injured Tree Guidelines page 2). How long fire-injured trees retain scorched needles varies between tree species. White fir may retain scorched needles for several years while yellow pines tend to shed them by the end of the second post-fire year. Scorched needles within live portions of the crowns of yellow pines tend to shed within one year. Shedding of scorched needles typically increases during the second post-fire winter aided by wind, rain and snow.

The normal process of post-fire individual tree marking in preparation for subsequent salvage sales and hazard tree abatement has fit well within the recommend timeframe. Tree marking typically starts soon after a fire and is completed no later than the following summer. However, the recent transition from individual tree marking to designation by damage, where cut trees are selected by the operator/purchaser at the time of harvest, has pushed the need for fire-injured tree assessments beyond the current recommendations. Designation by damage operations often begin the summer after the year of the fire, upon completion of the environmental review, and may extend beyond the second post-fire winter into the following summer.

The use of the Fire-injured Tree Guidelines beyond the original recommended timeframe is supported by Forest Health Protection to complete designation by damage harvest treatments. Even when applied at later dates, the guidelines still represent the most accurate tool for predicting conifer mortality in California. However, later application requires consideration of the scorched needle loss that has likely occurred in fire-injured trees. The most likely result of this crown change would be an under estimation of pre-fire live crown length or volume. This in turn would lead to an under estimation of the percent crown length or volume killed and potentially leaving a tree that should be harvested to meet project objectives. For fire-injured trees that are partially green but have begun to shed scorched needles, extra attention needs to be placed on fine branching to help determine the original pre-fire crown length or volume. Fine branching is currently used in the guidelines as a surrogate when needles are missing from portions of the crown that were alive pre-fire (*see* Fire-Injured Tree Guidelines page 2). Fine branching can be relatively easy to identify for some species such as Douglas-fir but more difficult for species such as yellow pine where fine branches can be relatively large and resemble branches that were dead before the fire. Some fine branches within fire-killed portions of the crown may also start to drop off, especially with strong winds and snow. Looking for remnant cones can also help determine pre-fire live crown in some cases. If fine branching, or other evidence such as cones, are not present or difficult to identify, do not assume they were or are there. Trees should be evaluated, and decisions should be made, only with the visible indicators available.

In addition to emphasizing fine branching in later post-fire crown assessments, other indicators may be present that were not available immediately after the fire. These include increased evidence of significant bark and/or woodboring beetle activity and epicormic growth. Bark and woodboring beetle activity within fire areas often increases over the first two to three post-fire years contributing to fire-injured tree mortality. During this time, there will likely be an increase in the number of green-infested trees present during harvest operations that may not meet crown kill criteria thresholds for removal. Careful examination of tree boles for evidence of insect activity will help identify these dying trees (*see* Fire-Injured Tree Guidelines page 8). Epicormic growth may occur on white and Douglas-fir after the first post-fire year. Epicormic growth originates as new branches from the bole on white fir and as new shoots on the branches of Douglas-fir. Epicormic growth occurs in response to tree stress and injury and generally contributes little to live crown volume or length. The influence epicormic growth has on fire-injured tree survival is unknown. Nonetheless, if epicormic growth is visible during designation by damage harvest operations, it can be included as live crown volume or length following the crown evaluation procedures described in the guidelines. This will account for gaps in crown foliage between areas of epicormic growth and surviving live crown by visually "moving" lower branches up to fill in empty areas (*see* Fire-Injured Tree Guidelines page 2).

It important to remember that for many fire-salvage and post-fire hazard tree projects, most trees within designated harvest units are dead (no green needles), either killed outright during the fire or recently from fire-injuries and/or insect attack. These types of trees do not require predictive tree mortality guidelines or additional considerations of crown condition. The timeframe for harvesting these trees is still dictated by the need to process them into lumber before deterioration and degradation reduces economic value and in the case of hazard trees, to remove them before they fail and potentially cause damage or injury.