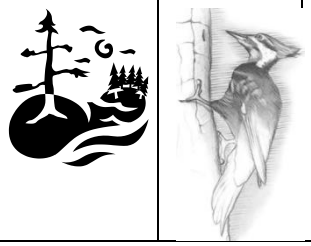
Region One
Vegetation Classification, Mapping, Inventory and Analysis Report



$\bar{x} = \frac{\sum x}{n}$

Report 17-17 v2.0 **December 21, 2017**

Post-fire Assessment of Tree Status

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Overview:

This document provides a compilation of the latest information on assessing when a tree is alive or will imminently die, within three years after fire. For further information, a comprehensive list of citations is included in this document. This document provides an outline on consistently assessing the status of a tree. Readers are encourage to have in field training sessions with fire effects specialists and entomologists in addition to reading this document.

Assessment of species status (live or dead/dying) after fire can be assessed by the following indicators:

1. Percentage of the live crown volume that is still remaining,
2. Circumference and severity of bole char at root collar,

3. Bole circumference infested by bark beetles or wood boring beetles

Survivability of a tree post-fire depends upon the magnitude of severity of all 3 factors. Ryan and Reinhardt (1988) considered both live crown and bark thickness to assess mortality. The extent and severity of charred bark at the root collar, a surrogate for cambium kill, along with crown injury, increases the likelihood of death. For thick-barked species, such as ponderosa pine, Douglas-fir, and western larch, the potential for cambium damage is minimized because thick bark quickly develops as tree diameter increases. For these species, high levels of crown damage (consumption or scorch) are typically required to induce mortality. The cambium at the base of thin-barked species, such as lodgepole pine, Engelmann spruce, and firs, is easily killed by fire even without any crown damage.

Burned trees may take several years to die following fire-injury. In this assessment, trees are considered 'dead' if they have a > 50% likelihood of dying within 3 years post-fire. Appendix A shows the thresholds of percent live tree crown volume remaining, circumference and severity of bole char at the root collar, and the bole circumference infested by bark beetles or wood boring beetles. In order to be considered alive, *all of the criteria* must be met, in order to be considered dead, at least one of the criteria must be outside the thresholds stated. Therefore, trees that exceed the listed thresholds of crown scorch or bark char severity by species and diameter class are considered dead, even though they may have green needles.

Contributors:

Sharon Hood was instrumental in the development of this document and shared extensive literature citations, knowledge, editing, pictures, and research related to effects of wildfires to trees. Forest Health Protection staff: Gregg DeNitto, Joel Egan, Lee Pederson, and Gina Davis provided edits for this report and input on forest insect criteria.

Assessing tree status:

Assessing live vs dead crown:

Crown condition is readily observable and is the most reliable single indicator of post-fire mortality. Tree crowns in the process of 'fading', where all unburnt foliage is transitioning uniformly from green to yellow to red/orange, are considered dead. Otherwise, the degree to which tree foliage is green (unaffected), orange (heat-killed needles), black (burned), or entirely consumed determines live/dead status.

Percent of live crown is the percent of the pre-fire crown volume tree that is alive post-fire. This is <u>not</u> an estimate of live crown ratio. It is determined by first estimating the pre-fire live crown volume, based on: remaining live crown, residual scorched foliage, residual burned foliage, and residual branches that have burned but probably had needles prior to the fire.

To assess pre-fire live crown volume (Hood et al., 2007):

- First, position yourself in such a way that the entire tree crown is visible. Optimum viewing of the crown is at right angles to the direction of the fire spread and against a blue sky. It is important to stand back from the tree to fully view the entire crown.

- Next reconstruct what the crown looked like before the fire. A tree with no bark and charred wood was dead before the fire. Pre-fire crown volume can be estimated by looking at the fine branch structure and needles. Branches lacking fine twigs were likely dead before the fire.

Percent live crown = volume of live crown remaining / total pre-fire crown.

Ponderosa pine (PIPO) and the larch species, sub-alpine larch (LALY) and western larch (LAOC) are assessed in a different manner. PIPO can survive fairly substantial losses to crown if it has intact, viable buds (Fowler et al. 2010, Hood et al. 2010). Therefore, if <10% blackened needles are present, indicating little-to-no portion of the pre-fire crown was consumed, PIPO can survive if ≥15% of the pre-fire crown volume is still green. However, if ≥10% blackened needles are present, then ≥60% of the pre-fire crown volume must be living/green.

Figure 1: Example of assessing live crown (Hood et al., 2007). Douglas-fir with 50 percent crown volume scorched. A) The short, lower branches of this tree were dead before the fire and should not be included when determining crown scorch. Branches that were dead before the fire will not have any fine twigs and will often be broken off. B) Often times, trees have unsymmetrical crown bases as seen in this photo. A trick to determining crown scorch for these trees is to "move" some of the lower branches to the other side of the crown to even out the crown bases. Next, estimate crown scorch based on this new crown shape.

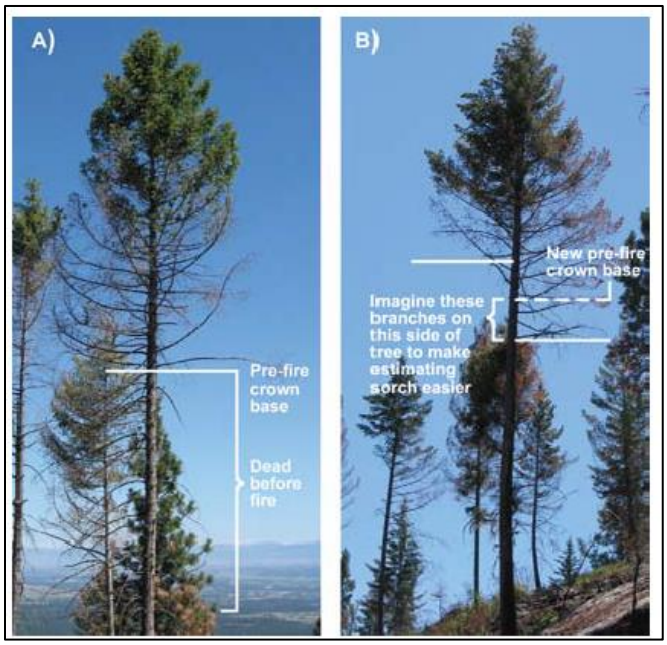


Figure 2. Example of ponderosa pine live crown assessment. Ponderosa pine with 85% pre-fire crown volume scorched but little-to-no (i.e. <10%) needles blackened or consumed. The buds in a large portion of the crown survived the fire, allowing the tree's crown to recover the following year.

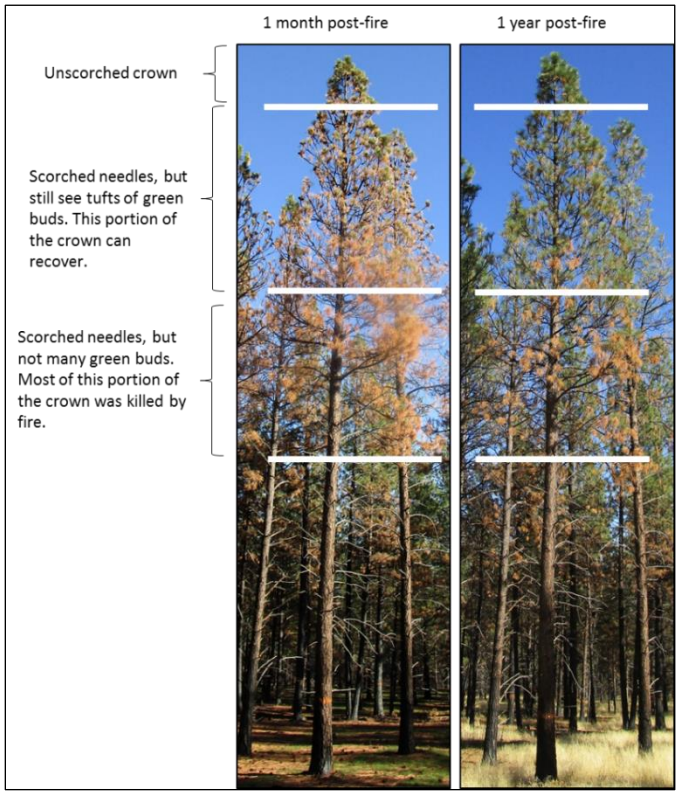
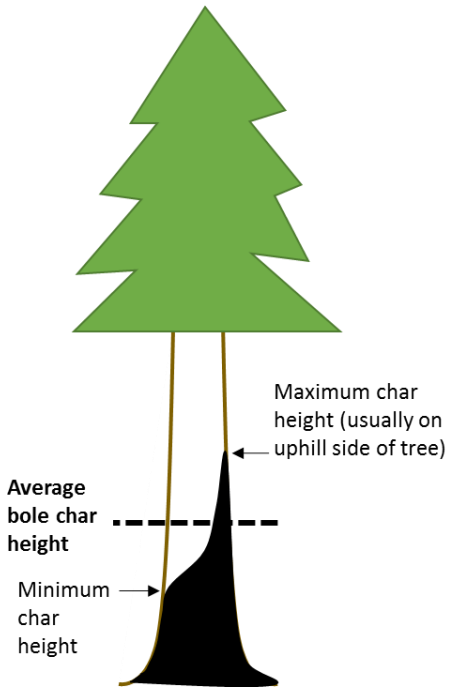


Figure 3. Example of blackened needles and partially consumed crown of a ponderosa pine.

LALY and LAOC percent live crown volume must be assessed either before needles drop in the fall of the year of the fire or after bud break the following year post-fire. A tree is considered alive if more than 20% of the pre-fire crown volume remains. If assessment is done when needles are not typically present, then bole char height can be used to determine if a tree is alive or dead. If the average height of char observed on the bole is <80% of the total height of the tree, then it is considered alive.

Figure 4. Bole char height. Assess average bole char height on larch during the dormant season.



When assessing live, green crown (Hood et al., 2007):

- It is difficult to determine scorched crown when the sky is grey, accuracy will decrease.
- Focus on the green needles rather than the orange to determine if enough green is left for the tree to survive.
- Stand back away from a tree, preferably with the sun to your back, to accurately determine crown damage levels. Assessment cannot be done while standing at the tree base.
- For asymmetrical crowns, "move" lower branches to even out the crown base.

Species differ in the amount of crown loss they can survive. Table 1 shows the amount of live crown needed for survival by species, this is also displayed in Appendix A, a rubric which integrates percent live crown, bole char, and presence of insects by species. Appendix B, Table B1 shows the amount of crown loss that will cause mortality. These thresholds are based on several studies of post-fire mortality (Hood et al., 2007a; Hood et al., 2007b; Fowler et al., 2010; Hood et al., 2010; Davis et al., 2012; Grayson et al., 2017).

Table 1: % live crown post-fire needed to survive fire. **Amount of live crown volume remaining needed (as compared to pre-fire live-crown) by species and diameter class to survive fire.**

<table>
<tr><th>SURVIVAL</th><th colspan="5">Diameter Class</th></tr>
<tr><th>Species</th><th>7.0-11.9”</th><th>12.0-16.9”</th><th>17.0-20.9”</th><th>21.0-24.9”</th><th>25.0+”</th></tr>
<tr><td>ABGR: grand fir</td><td>>70% live</td><td colspan="4">>40% live</td></tr>
<tr><td>ABLA: subalpine fir</td><td colspan="3">>70% live</td><td colspan="2">>60% live</td></tr>
<tr><td>BEPA: paper birch</td><td colspan="5">NA</td></tr>
<tr><td>LALY: subalpine larch</td><td colspan="5">If needles off: average height of charring over entire length of bole < 80%;
If needles on: > 20% live crown</td></tr>
<tr><td>LAOC: western larch</td><td colspan="5">If needles off: average height of charring over entire length of bole < 80%;
If needles on: > 20% live crown</td></tr>
<tr><td>PIAL: whitebark pine</td><td colspan="5">> 60% live</td></tr>
<tr><td>PICO: lodgepole pine</td><td colspan="5">> 60% live</td></tr>
<tr><td>PIEN: Engelmann spruce</td><td colspan="3">>70% live</td><td colspan="2">>60% live</td></tr>
<tr><td>PIFL2: limber pine</td><td colspan="5">> 60% live</td></tr>
<tr><td>PIMO3: western white pine</td><td colspan="3">>70% live</td><td colspan="2">>60% live</td></tr>
<tr><td>PIPO: ponderosa pine</td><td colspan="5">If <10% blackened needles present: >15% live crown;
if ≥10% blackened needles present: >60% live crown</td></tr>
<tr><td>POBA2: Balsam poplar</td><td colspan="5">NA</td></tr>
<tr><td>POBAT: Black cottonwood</td><td colspan="5">NA</td></tr>
<tr><td>POTR5: quaking aspen</td><td colspan="5">NA</td></tr>
<tr><td>PSME: Douglas-fir</td><td colspan="4">> 30% live</td><td>> 20% live</td></tr>
<tr><td>THPL: western redcedar</td><td colspan="3">>70% live</td><td colspan="2">>60% live</td></tr>
<tr><td>TSHE: western hemlock</td><td colspan="5">>70% live</td></tr>
<tr><td>TSME: mountain hemlock</td><td colspan="5">>70% live</td></tr>
</table>

Assessing the extent and magnitude of bark char:

Cambium death, caused by high or sustained heating of the tree bole or root collar, is an influential factor in tree mortality following fire. The extent and magnitude of bark char, at the root collar can be used as a surrogate for direct cambium sampling (Ryan, 1982) and varies by species (Hood et al. 2008).

Table 2:Bark Char definitions

Bark char label	Bark Appearance
Unburned	No char
Light	Evidence of light scorching; can still identify species based on bark characteristics; bark is not completely blackened; edges of bark plates charred
Moderate	Bark is uniformly black except possibly some inner fissures; species bark characteristics still discernable
Deep	Bark has been burned into, but not necessarily to the wood; outer bark species characteristics are lost; bark looks smoothed because all ridges are gone

Figure 5. Assess bole char severity at the base of the tree near the root collar. Bole charring may only occur very low on the bole, but if the underlying cambium is killed then the nutrient translocation is still severed from the crown to the roots.

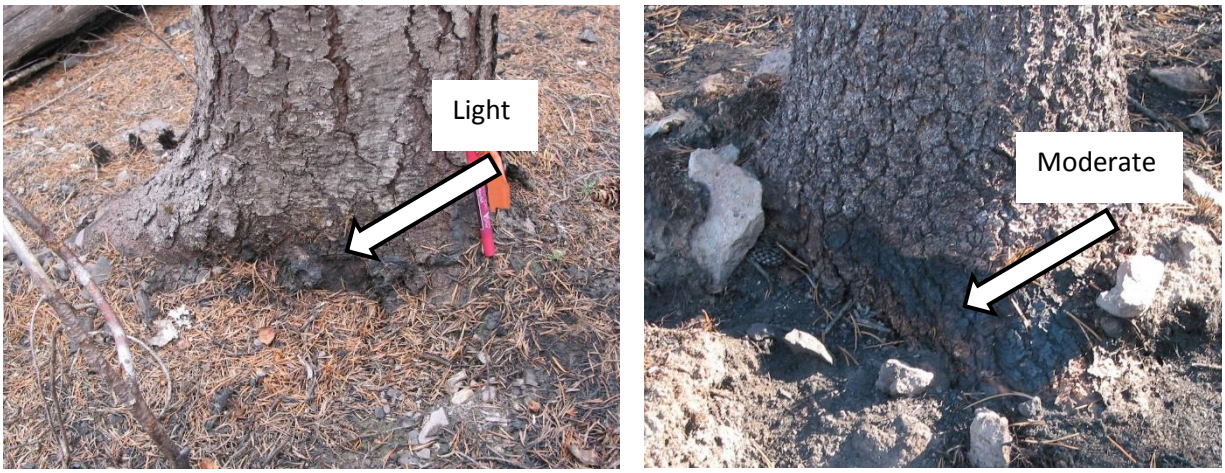


Figure 6. Deep char on Douglas-fir where outer bark species characteristics are lost (left arrow) and completely burned away to expose wood (right arrow).

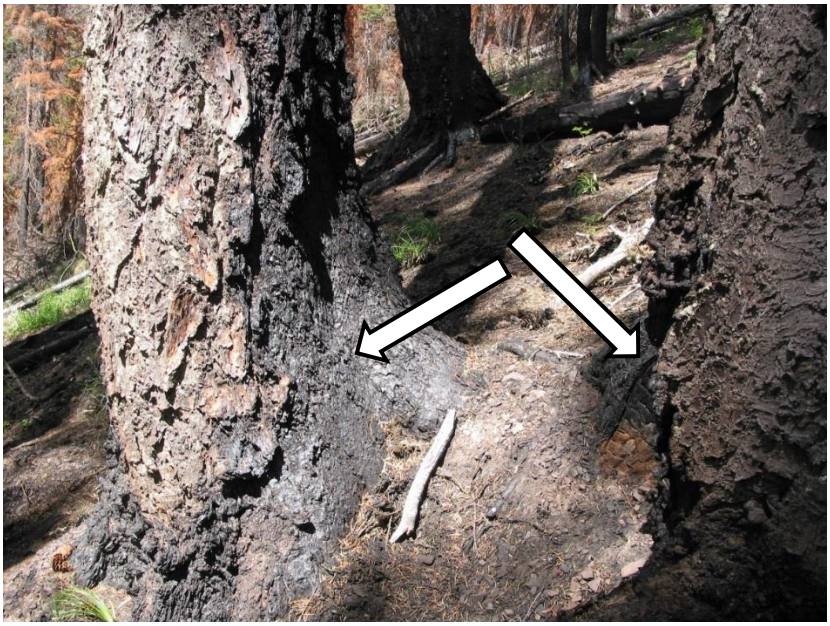
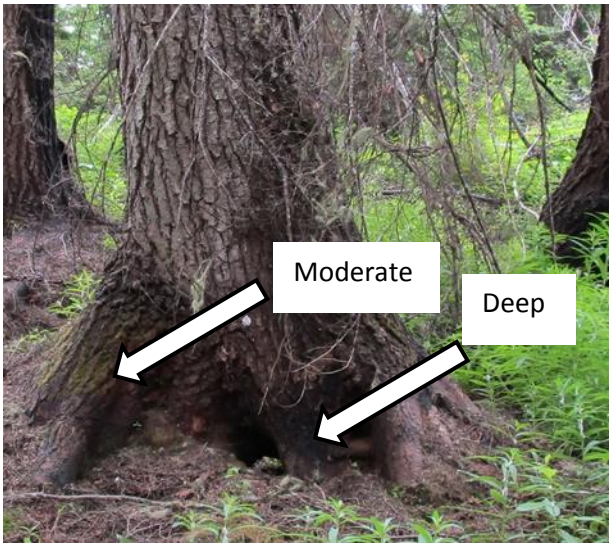


Figure 7. Moderate and deep bole char on western hemlock. Moderate charring has bark that uniformly black except possibly some inner fissures and species bark characteristics are still discernable. Species bark characteristics are lost with deep charring.



Ryan (1982) states that, in the absence of significant crown injury, most trees survive up to 25% basal girdling, but few trees survive more than 75% girdling. Extensive root collar damage on thin barked species will most likely result in death, regardless of percent of pre-fire live crown remaining (Hood 2010).

The extent of bark char is based on the percent of the circumference of the root collar of the tree burned. Table 3 displays the magnitude and extent of bark char observed at the root collar for a species to survive a fire. Appendix B, Table B2 displays the magnitude and extent of bark char observed at the root collar for a tree to suffer cambium death. These thresholds are based on Hood et al., 2007a; Hood et al., 2008; Hood et al., 2010; Davis et al., 2012; Grayson et al., 2017.

Table 3: Maximum extent and severity of bark char, at root collar, for tree survival

SURVIVAL	**Diameter Class**				
Species	**7.0-11.9"**	**12.0-16.9"**	**17.0-20.9"**	**21.0-24.9"**	**25.0"+**
ABGR: grand fir	≤ 50% bole circumference, moderate or deep charring				
ABLA: subalpine fir	≤ 50% bole circumference, *any* bole charring				
BEPA: paper birch	≤ 50% bole circumference, *any* bole charring				
LALY: subalpine larch	≤75% bole circumference, deep charring				
LAOC: western larch	≤75% bole circumference, deep charring				
PIAL: whitebark pine	≤ 50% bole circumference, *any* bole charring				
PICO: lodgepole pine	≤ 50% bole circumference, *any* bole charring				
PIEN: Engelmann spruce	≤ 50% bole circumference, *any* bole charring				

<table>
<tr><th>SURVIVAL</th><th colspan="5">Diameter Class</th></tr>
<tr><th>Species</th><th>7.0-11.9"</th><th>12.0-16.9"</th><th>17.0-20.9"</th><th>21.0-24.9"</th><th>25.0"+</th></tr>
<tr><td>PIFL2: limber pine</td><td colspan="5">≤ 50% bole circumference, any bole charring</td></tr>
<tr><td>PIMO3: western white pine</td><td colspan="5">≤ 50% bole circumference, any bole charring</td></tr>
<tr><td>PIPO: ponderosa pine</td><td colspan="5">≤75% bole circumference, deep charring</td></tr>
<tr><td>POBA2: Balsam poplar</td><td colspan="5">≤ 50% bole circumference, any bole charring</td></tr>
<tr><td>POBAT: Black cottonwood</td><td colspan="5">≤ 50% bole circumference, any bole charring</td></tr>
<tr><td>POTR5: quaking aspen</td><td colspan="5">≤ 50% bole circumference, any bole charring</td></tr>
<tr><td>PSME: Douglas-fir</td><td colspan="2">≤ 50% moderate or deep charring</td><td colspan="3">≤75% bole circumference, deep charring</td></tr>
<tr><td>THPL: western redcedar</td><td colspan="3">≤ 50% bole circumference, any bole charring</td><td colspan="2">≤75% bole circumference, any bole charring</td></tr>
<tr><td>TSHE: western hemlock</td><td colspan="5">≤ 50% bole circumference, any bole charring</td></tr>
<tr><td>TSME: mountain hemlock</td><td colspan="5">≤ 50% bole circumference, any bole charring</td></tr>
</table>

Assessing bark beetle and wood boring beetle infestation status:

Bark beetle and wood boring beetle infestations within fire-injured trees are common following wildfire events. Trees may be mass-attacked by aggressive bark beetles and/or colonized by secondary bark and wood boring beetles opportunistically taking advantage of dying host. Fire-injured trees create a pulse resource of habitat suitable for insect colonization that typically lasts 2-3 years following fire-injury (Davis et al. 2012). Multiple studies have documented presence of insect infestations within fire-injured trees substantially increases probability of mortality (Denitto et al. 2000; Weatherby et al. 2001; Hood et al. 2007a; Hood and Bentz 2007; Hood et al. 2010).

Infestations can be classified by evaluation of trees having no insect activity, unsuccessful-attacks, strip-attacks, or mass-attacks. Only mass-attacked trees are used when designating dead tree status.

Insect mass-attacks within a tree are designated by presence of pitch tubes and/or characteristic boring dust around ≥ 50% of the circumference of the lower bole of a tree (Hagle et al. 2003).

Pitch tubes may be present in infested pine and spruce trees, but will not occur within Douglas-fir, true fir, or other species. Pitch tubes are popcorn-sized globs of resin ranging from white to reddish in coloration (Figure 8). Large pitch tubes caused by red turpentine beetles (RTB) in pines do not signify mass-attacks that will directly cause mortality and should be ignored. RTB pitch tubes are typically larger than a quarter, are deep-red, and found in the lower 4-feet of a tree's bole (Figure 9).

Pitch streamers may occur within true fir, Douglas-fir, and occasionally other hosts but are not specific enough for an insect-attack diagnosis (Figure 10); thus, further evidence of insect-attack should be investigated.

Boring dust with reddish-brown or white coloration found within bark furrows and in the upper root collar area of a tree's lower bole is diagnostic for insect-attack within all tree species (Figure 11).

Further information about diagnostics of insect mass-attack can be found in Forest Health Protection's Field Guide to Diseases and Insect Pests of Northern and Central Rocky Mountain Conifers (Hagle et al. 2003).

Figure 8. Example of popcorn-sized pitch tubes symptomatic of bark beetle-attack within pines or spruce. Pitch tube coloration can vary from white/tan to pink/red in hue.

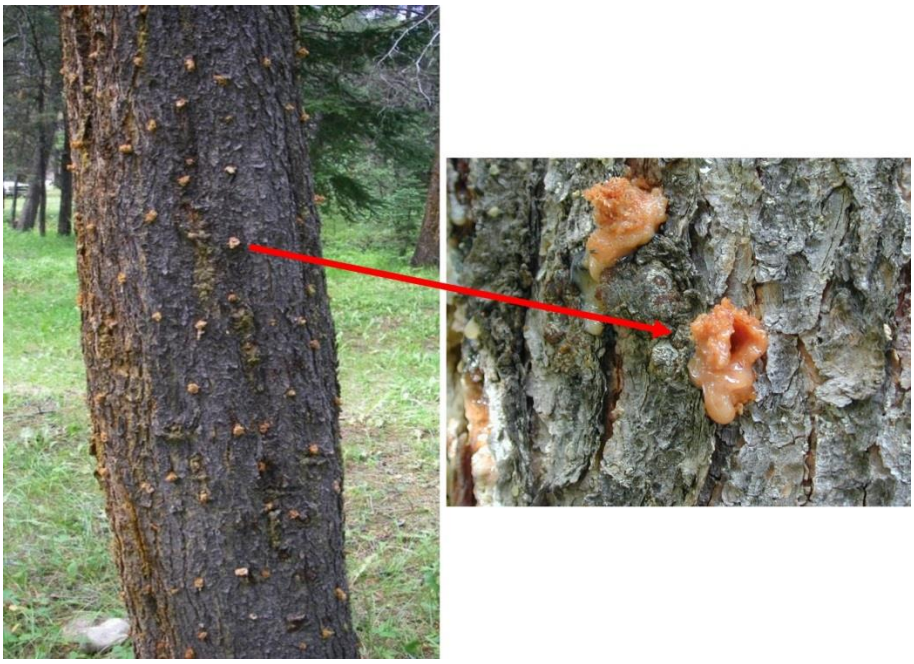


Figure 9. Red turpentine pitch tubes that are not diagnostic of tree mortality and should be ignored when determining mass-attack status.

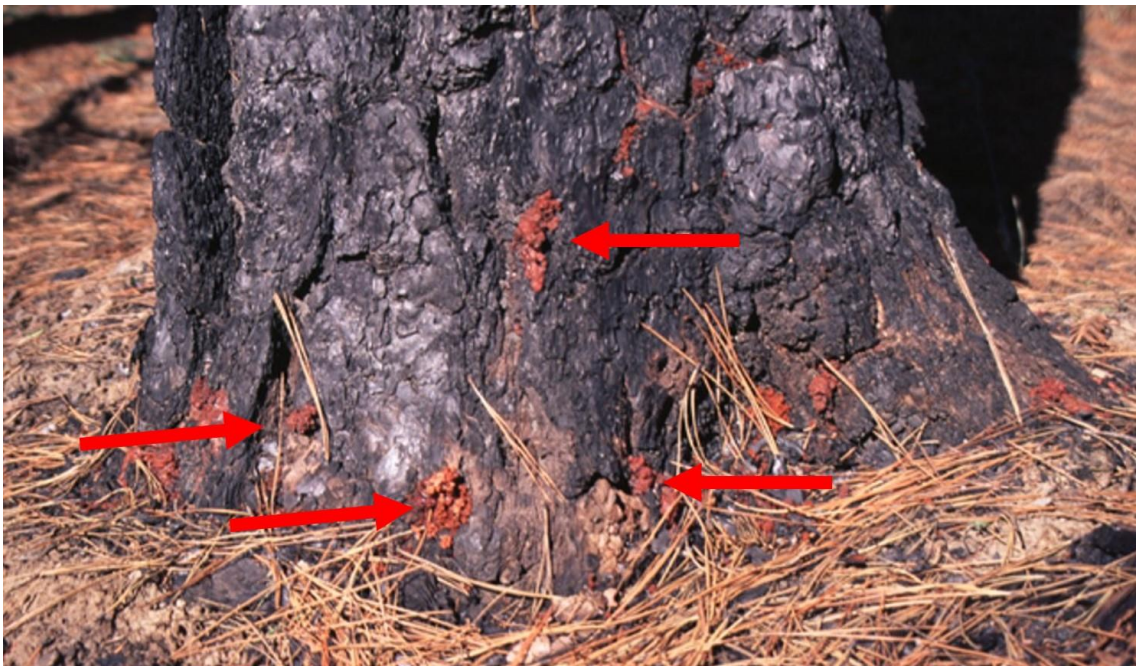


Figure 10. Pitch streamers that are not diagnostic of insect mass-attack. Presence should trigger further investigations to detect diagnostic insect boring dust.

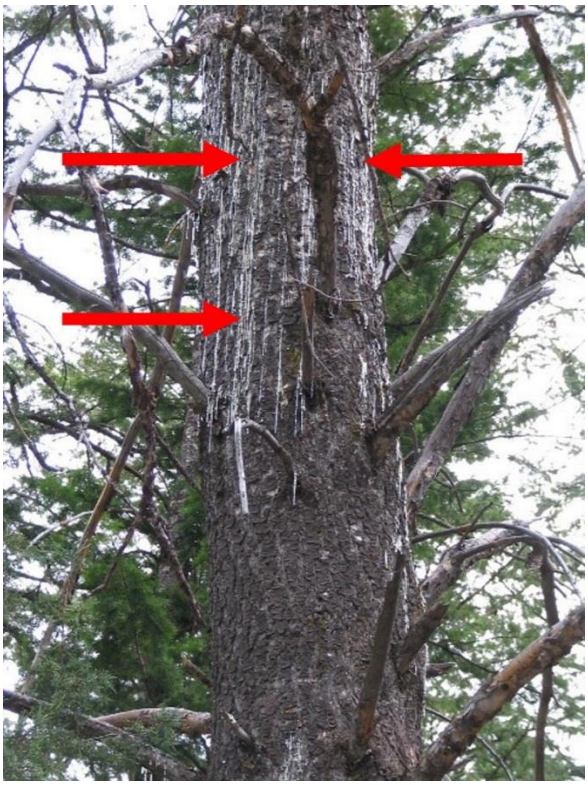


Figure 11. Boring dust example from a mass-attacked Douglas-fir that is diagnostic of insect-attack.

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Appendix A: Species Rubric for assessing live tree status

Thresholds for bark char severity and circumference of root collar (bole char), percent live crown remaining (live crown), and beetle mass-attack status are used to designate live trees. To be considered live, the evaluation tree must have **all** conditions met. To be considered dead, the evaluation tree needs to be outside at least one of the criteria.

		Diameter Class				
Species		**7.0-11.9"**	**12.0-16.9"**	**17.0-20.9"**	**21.0-24.9"**	**25.0"+**
ABGR: grand fir	bole char	≤ 50% moderate or deep charring of the bole				
	live crown	>70% live	>40% live			
	beetle/wood borer	boring dust across ≤ 50% bole circumference				
ABLA: subalpine fir	bole char	≤ 50% *any* charring of the bole				
	live crown	>70% live			> 60% live	
	beetle/wood borer	boring dust across ≤ 50% bole circumference				
BEPA: paper birch, **POBA2:** Balsam poplar, **POBAT:** Black cottonwood, **POTR5:** quaking aspen	bole char	≤ 50% *any* charring of the bole				
	live crown	Not Applicable				
	beetle/wood borer	Not Applicable				
LAOC: western larch, **LALY:** subalpine larch	bole char	≤75% deep charring of the bole				
	live crown	If needles off: average height of charring over entire length of bole ≤ 80%; If needles on: > 20% live crown				
	beetle/wood borer	boring dust across ≤ 50% bole circumference				
PIAL: whitebark pine, **PICO:** lodgepole pine, **PIFL2:** limber pine	bole char	≤ 50% *any* charring of the bole				
	live crown	> 60% live				
	beetle/wood borer	pitch tubes (not RTB) and/or boring dust across ≤ 50% bole circumference				
PIEN: Engelmann spruce	bole char	≤ 50% *any* charring of the bole				
	live crown	> 70% live			> 60% live	
	beetle/wood borer	pitch tubes and/or boring dust across ≤ 50% bole circumference				
PIMO3: western white pine	bole char	≤ 50% *any* charring of the bole				
	live crown	> 70% live			> 60% live	
	beetle/wood borer	pitch tubes (not RTB) and/or boring dust across ≤ 50% bole circumference				
PIPO: ponderosa pine	bole char	≤75% deep charring of the bole				
	live crown	If <10% blackened needles present: >15% live crown; if ≥10% blackened needles present: >60% live crown				
	beetle/wood borer	pitch tubes (not RTB) and/or boring dust across ≤ 50% bole circumference				
PSME: Douglas-fir	bole char	≤ 50% moderate or deep charring of the bole		≤ 75%deep charring of the bole		
	live crown	> 30% live				> 20% live
	beetle/wood borer	boring dust across ≤ 50% bole circumference				
THPL: western redcedar	bole char	≤ 50% *any* charring of the bole			≤ 75% any charring of the bole	
	live crown	>70% live			>60% live	
	beetle/wood borer	Not Applicable				
TSHE: western hemlock, TSME: mountain hemlock	bole char	≤ 50% *any* charring of the bole				
	live crown	>70% live				
	beetle/wood borer	Not Applicable				

Appendix B: Criteria to determine if tree is dead

The following tables provide criteria for trees to qualify as dead. Only one of these criteria needs to be met in order for a tree to be considered dead.

Table B1. % pre-fire live crown loss to trigger mortality. **Amount of pre-fire live crown volume loss by species and diameter class to trigger tree mortality.**

MORTALITY	Diameter Class				
Species	**7.0-11.9”**	**12.0-16.9”**	**17.0-20.9”**	**21.0-24.9”**	**25.0+”**
ABGR: grand fir	≥30% loss	≥60% loss			
ABLA: subalpine fir	≥30% loss			≥40% loss	
BEPA: paper birch	NA				
LALY: subalpine larch	If needles off: average height of charring over entire length of bole ≥ 80%; If needles on: ≥80% loss				
LAOC: western larch	If needles off: average height of charring over entire length of bole ≥ 80%; If needles on: ≥80% loss				
PIAL: whitebark pine	≥40% loss				
PICO: lodgepole pine	≥40% loss				
PIEN: Engelmann spruce	≥30% loss			≥40% loss	
PIFL2: limber pine	≥40% loss				
PIMO3: western white pine	≥30% loss			≥40% loss	
PIPO: ponderosa pine	If <10% blackened needles present: ≥85% loss; if ≥10% blackened needles present: ≥40% loss				
POBA2: Balsam poplar	NA				
POBAT: Black cottonwood	NA				
POTR5: quaking aspen	NA				
PSME: Douglas-fir	≥70% loss				≥80% loss
THPL: western redcedar	≥30% loss			≥40% loss	
TSHE: western hemlock	≥30% loss				
TSME: mountain hemlock	≥30% loss				

*Table B2: Minimum extent and severity of bark char, at root collar, for tree **mortality***

MORTALITY	**Diameter Class**				
Species	**7.0-11.9"**	**12.0-16.9"**	**17.0-20.9"**	**21.0-24.9"**	**25.0"+**
ABGR: grand fir	> 50% bole circumference, moderate or deep charring				
ABLA: subalpine fir	> 50% bole circumference, *any* bole charring				
BEPA: paper birch	> 50% bole circumference, *any* bole charring				
LALY: subalpine larch	>75% bole circumference, deep charring				
LAOC: western larch	>75% bole circumference, deep charring				
PIAL: whitebark pine	>50% bole circumference, *any* bole charring				
PICO: lodgepole pine	> 50% bole circumference, *any* bole charring				
PIEN: Engelmann spruce	> 50% bole circumference, *any* bole charring				
PIFL2: limber pine	> 50% bole circumference, *any* bole charring				
PIMO3: western white pine	> 50% bole circumference, *any* bole charring				
PIPO: ponderosa pine	>75% bole circumference, deep charring				
POBA2: Balsam poplar	> 50% bole circumference, *any* bole charring				
POBAT: Black cottonwood	> 50% bole circumference, *any* bole charring				
POTR5: quaking aspen	> 50% bole circumference, *any* bole charring				
PSME: Douglas-fir	> 50% moderate or deep charring		>75% bole circumference, deep charring		
THPL: western redcedar	> 50% bole circumference, *any* bole charring			>75% bole circumference, *any* bole charring	
TSHE: western hemlock	> 50% bole circumference, *any* bole charring				
TSME: mountain hemlock	> 50% bole circumference, *any* bole charring				