

Best Practices for Managing Douglas-fir Beetle

Douglas-fir Beetle and Wildfire

Introduction

Fire plays a major successional role in British Columbia (B.C.) ecosystems. Flames and smouldering stumps are merely the beginning of the subsequent numerous biological and physical processes, which can occur in fire-affected landscapes. One of the most noticeable of these processes is the assemblage of insects post-fire.



2017 fire, Princeton, B.C. – flames erupt in gully with young, regenerating pine.



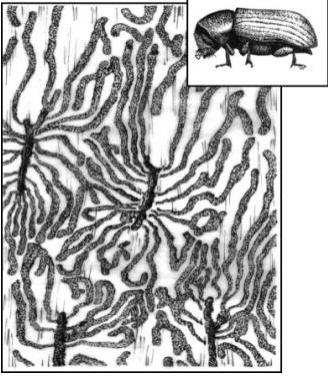
Aerial view of 2017 Elephant Hill fire – mature forests and young pine plantations burnt.

Fires are a frequent occurrence in B.C.'s summer months, burning both high and low elevation stands, which contain a preponderance of Douglas-fir (*Pseudotsuga menziesii*; Fd), Ponderosa pine (*Pinus ponderosa*; Py) and lodgepole pine (*Pinus contorta*; Pl) mixed with spruce (*Picea sp.*; Sx) and other species. The possibility of insect damage and build-up must be considered when developing management plans for burnt areas.

Many bark beetles (Scolytinae), woodborers (Cerambycidae, Buprestidae), ambrosia beetles (Scolytinae) and wood wasps (Siricidae) are attracted to fires and fire damaged hosts. These insects typically attack and breed in weakened, stressed, damaged or recently killed trees. Trees become weakened or stressed in a number of ways including drought, lightning, windthrow, mechanical injury, disease, insect attack or **fire**. Each type of insect (e.g., bark beetle or woodborer) has its own “signature” impact on its host tree or stand, and is attracted to a particular degree of fire damage.

Woodborers ambrosia beetles and wood wasps damage the sapwood portion of burnt trees. The trees must be severely stressed or dead for these insects to attack. Bole symptoms include reddish boring dust (woodborers) or white sawdust (ambrosia beetles), which could be mistaken for bark beetle attacks; therefore, one should check to see if the attacking insects have entered the sapwood. They will not affect living, vigorous trees.

Numerous secondary insects such as the engraver beetles may colonize fire-damaged trees or those trees under attack by primary bark beetles such as DFB. Bole symptoms are similar to DFB so identification of the attacking species must be verified by checking under the bark. These beetles seldom build to numbers that pose a threat to green, healthy trees.

		
Douglas-fir pole beetle galleries and adult.	Douglas-fir engraver beetle gallery and adult.	Woodborer galleries.

Bark beetles will infest recently fire-killed trees and fire-scarred trees that are still alive. These beetles have the potential to move onto and attack healthy, live trees. Bark beetles that are most likely to be active in fire-impacted areas are western pine beetle (*Dendroctonus brevicomis*), mountain pine beetle (*Dendroctonus ponderosae*; MPB), and turpentine beetle (*Dendroctonus valens*) in Ponderosa pine; and, Douglas-fir beetle (*Dendroctonus pseudotsugae*; DFB) in Douglas-fir. Mountain pine beetle and turpentine beetle also attack lodgepole pine, but lodgepole pine is less fire tolerant than Ponderosa pine and therefore is more likely to be killed outright by wildfire or reach an “unacceptable” stage by the time of MPB flight the following year. Therefore, only lightly charred or weakened lodgepole pine may still be susceptible to attack in years following wildfires. The issues surrounding post-fire beetle kill will be addressed separately for Ponderosa pine and Douglas-fir.

Post-wildfire considerations

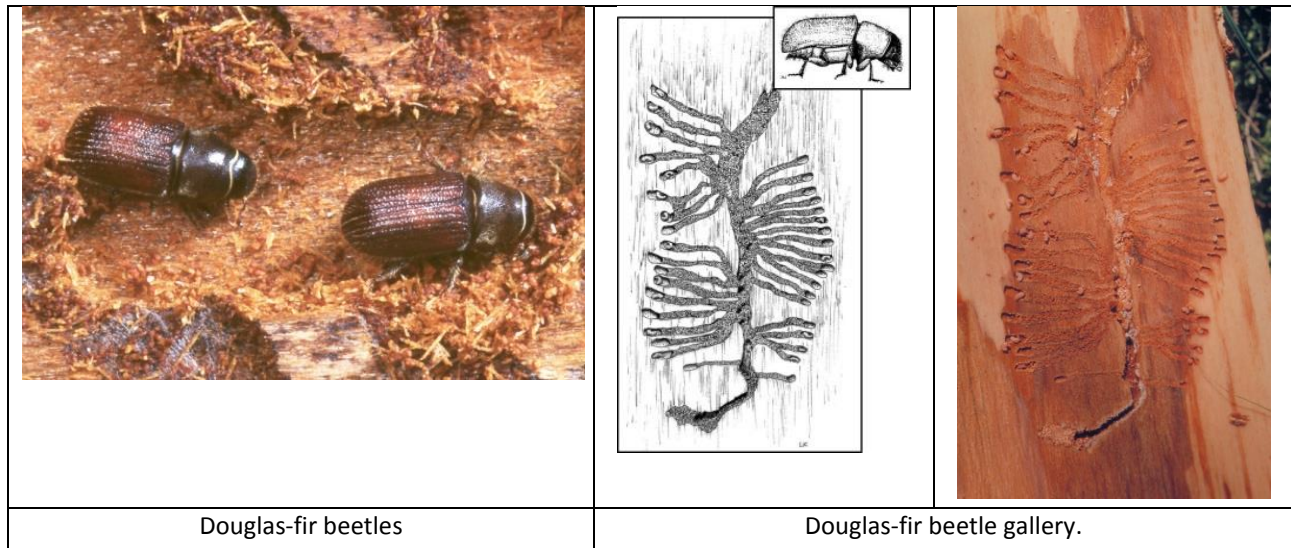
Tree mortality is influenced by many factors following wildfires. In B.C.'s interior, Douglas-fir and Ponderosa pine are fire-tolerant species, due to thick, insulating bark that develops with age and protects the inner cambium from heat injury. Mortality following fire depends not only on species-specific traits and tree age, but also on the type and degree of fire-caused injuries, initial tree vigour, and the post-fire environment. Trees that are only moderately injured by fire and capable of recovery can subsequently be attacked and killed by bark beetles and associated insects. DFB can have a significant influence on post-fire delayed Douglas-fir mortality, killing trees that would otherwise survive fire. Post-fire tree mortality due to DFB is augmented when beetle populations are already present and active near a recent wildfire.

Key forest health objectives post-wildfire:

1. Minimize future tree mortality from insects such as:
 - Bark beetles, including Douglas-fir beetle (DFB);
 - Secondary bark beetles.
2. Facilitate maximum removal of DFB in the salvage of burnt wood.
3. Monitor bark beetle populations within the burn perimeter and within a critical distance outside the burn perimeter.
4. Monitor for secondary bark beetle attack in burn and/or drought-affected areas.

Douglas-fir beetle biology and symptoms

The Douglas-fir beetle is normally present in forests at low densities, breeding in Douglas-fir trees that are injured or have recently died. DFB preferentially attacks freshly downed trees and trees stressed by a variety of factors, including drought and fire. Outbreaks are typically initiated by a stand disturbance, the most common being windthrow, snow breakage or other weather-related phenomena.



DFB adults and larvae create distinctive galleries beneath the bark that distinguish them from other bark beetles. DFB larvae require fresh, moist phloem (inner bark) for food, so trees that have been dead (or down) for more than a year are not suitable habitat. Trees damaged by fire or drought sometimes are attractive for longer periods because they may not be immediately killed by the stress event. Injured or recently killed trees have little or no defensive capabilities making them ideal sites for beetle larvae to feed and develop. Periodically, natural or human-caused disturbances such as windstorms, fire, defoliator outbreaks or logging create an abundance of suitable breeding sites that allow beetle populations to rapidly increase. At high densities, beetles are forced to attack healthy, live trees because there are not enough stressed and dead ones to support the population. By attacking a live tree in large numbers, the beetles are able to overcome the tree's natural defenses and successfully reproduce. If an attacked tree is not killed, then the beetle's eggs and larvae will not survive to the adult stage. Sometimes only a portion of the tree is killed and only the brood in that part of the tree survive. This is commonly referred to as a strip or partial attack. DFB outbreaks typically last for several years and may result in the mortality of many trees.

DFB is consistently associated with fire-injured trees, often attacking larger trees with moderate to high levels of basal bole injury. Logs and other large-diameter debris are also attractive. The most important criteria to DFB and the key factors in the Hazard Rating System are: age (prefers old trees), diameter (prefers large trees) and stand purity (the percentage of total stand basal area composed of Douglas-fir based on all trees with a diameter at breast height greater than or equal to 12.5 cm). Factors predisposing stands to attack by Douglas fir beetle include:

- **Biogeoclimatic zone** - the Interior Douglas-Fir (IDF) is highest hazard;
- **Stand density** - increased stem density increases the hazard;
- **Proportion of Douglas-fir** - the higher the percentage of host trees, the higher the hazard;
- **Diameter of Douglas-fir** - larger diameters preferentially attacked;
- **Aspect and slope** - south facing slopes of > 40 degrees have highest hazard;

- **Drought, fire, or lightning strikes;**
- **Recent windthrow** - highest hazard is full trees blown down or tops broken in winter through spring storms;
- **Recently felled trees** – in road building or along fire guards;
- **Debris piles** left unburned, high stumps, and/or bole damage;
- **Root disease** (*Armillaria ostoyae*) is the most frequently observed pathogen, but laminated root rot (*Phellinus weirii*) may also be a predisposing factor; and,
- **Previous defoliation** (e.g. western spruce budworm, *Choristoneura freemani*).

Most research suggests DFB populations will increase post-fire. The potential for DFB build up depends upon several factors, which include:

- Local proximity to DFB populations (*is there an active and increasing population in close proximity to the fire area?*);
- Amount of susceptible host;
- Extent and severity of wildfires;
- Pre-emptive management actions deployed; and,
- Local weather conditions.

Numerous issues surround the possibility of bark beetle attack post-fire. An aerial classification of burned areas, or burn severity rating, is usually the first activity conducted post-wildfire. General burn classifications that may be useful in predicting risk to DFB attack are listed below:

- **Black:** Tree boles completely blackened, foliage destroyed, boles charred and understorey vegetation burned. These areas are not likely to have significant beetle problems.
- **Black/brown:** Mostly black but some browned foliage. These areas may develop beetle populations in thick barked tree species (e.g. Fd), but not in thin barked trees species (e.g. lodgepole pine, subalpine fir).
- **Brown/black/some green:** Mostly browned foliage, some blackened spots, but some green foliage as well. These areas may have beetle problems because of the occurrence of medium to light fire damage, which may result in significant numbers of trees that are susceptible to attack.
- **Mixed green/brown/black:** mostly green foliage, with brown and black spots, understorey variously burned. Beetle problems in these areas will likely depend on the significance of ground fire effects.

The following section itemizes risk factors and specific actions needed to mitigate the impacts of attack by DFB.

Risk factors and associated mitigation techniques

Typically, management of DFB in a defined geographic setting will take two years or longer. Therefore, anticipate in advance the placement and harvest sequence of harvest block, tree baits, the number and location of trap trees, mass trapping locations and other tactics such as MCH (methylcyclohexenone). Location and timing of these management tools are critical in reducing the number of green Douglas-fir from being attacked and killed by DFB.

Risk factors

1. **Current beetle populations** - Overall risk is reduced if there are no current significant DFB populations in the area. Burnt stands within a 1 km radius of current DFB populations are at high risk. Consult with Forest Health specialists or review the Regional/Provincial Forest Health reports for information on which bark beetles are active in the area. Confirm beetle species, flight times, and stage of life cycle.
2. **Timing and intensity of burn** - These two parameters relate to the acceptability/suitability of trees to DFB. Early season fires occurring prior to beetle flight increase the risk of attack, by increasing tree susceptibility. July-August fires (post-beetle flight) pose a wider range of risks dependent upon the degree of damage: outright mortality; or trees are still alive, but have incurred various levels of charring. Trees, killed by the fire, are unlikely to be attacked because the phloem will be dry by the following year's beetle flight. The trees, which have survived the fire and are not overly charred, may sustain attack the following year when the beetles fly in the spring. Generally, DFB will not attack Douglas-fir with crown and stem injury that is >80%. Douglas-fir exhibiting exfoliated bark and dry phloem are not colonized by beetles.

Surviving large diameter Douglas-fir is at highest risk of attack. The following criteria may be used to estimate the risk:

- Trees are at highest risk, the first summer post-fire. The risk decreases in the second year. Largest diameter trees are attacked first.

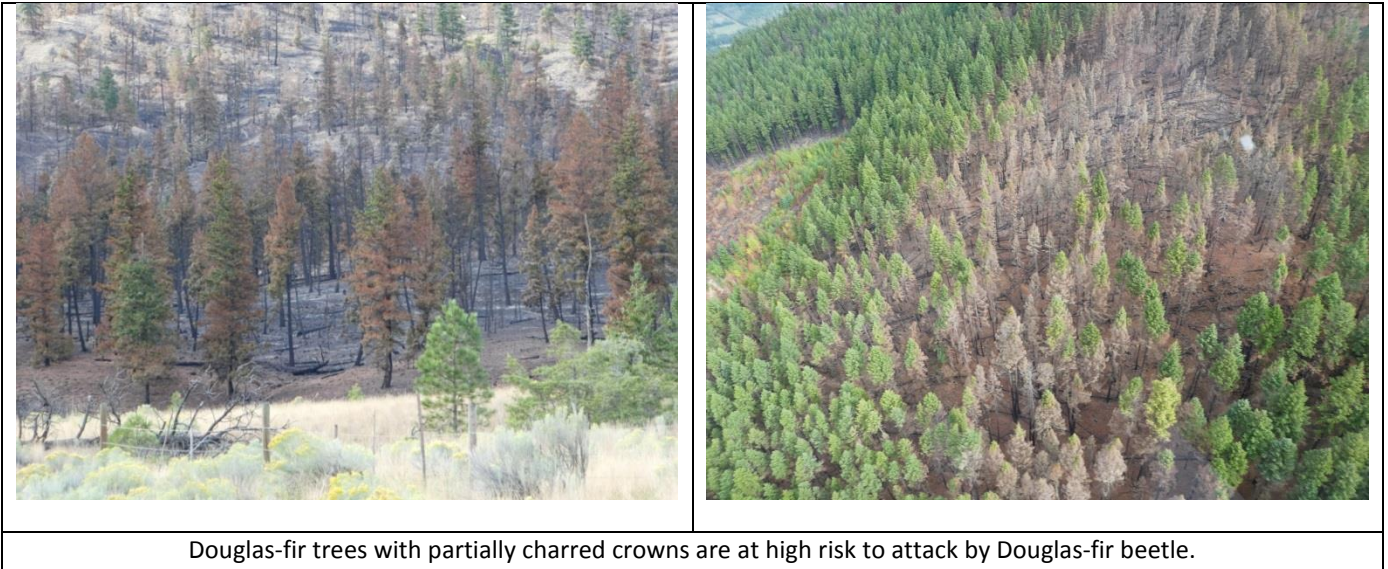
Douglas-fir beetle Hazard Rating System

Diameter (cm)	Lowest to highest hazard
<29.9	0.3
30.0 – 39.9	0.8
≥ 40	1.0

- Douglas-fir with (high) 60-80% bole char and/or crown volume scorch are most likely to be attacked in Year 1;
- Largest Douglas-fir will produce the most beetles; therefore priority should be given to removing or disposing of these trees first;
- Douglas-fir with (moderate) 50-60% bole char and/or crown volume scorch are selected by DFB in Year 2; and

- Total crown defoliation (**100% crown scorch**) dramatically **decreases** the likelihood of DFB attack.

The first year following a wildfire DFB will select the largest of the fire-impacted trees. In subsequent years, smaller diameter trees may be attacked and killed by DFB and secondary bark beetles.



Bole scorch on Douglas-fir can be at high risk to Douglas-fir beetle attack



Dry (red) or intact foliage on fire-scorched trees = good habitat for Douglas-fir beetle

3. **Timing of falling live Douglas-fir (e.g. fireguards)** - Douglas-fir may require up to one year to dry out (due to thick bark) and become unacceptable to beetles. Therefore, any large diameter Douglas-fir felled during summer wildfires will likely be exposed to at least one beetle flight. Douglas-fir burned or felled from August through late fall and winter are at higher risk of attack than those felled earlier in the year. Douglas-fir burned or felled prior to August will be at lower risk, but could still be attacked by DFB depending on piece size and phloem moisture.

Live Douglas-fir felled while making fire guards or fighting fire should be decked for easy extraction either prior to, or after the next year's DFB flight. These trees may be used as trap trees. However, if they sustain DFB attack, **they must be removed** prior to beetle emergence the following year. Limbing and exposing the bole of felled trees to direct sunlight to dry the phloem will make them less attractive to beetles.

Any Douglas-fir left on-site must be checked for beetle attack/emergence and follow-up control actions **must be implemented**.

4. **Fire-fighting activities that create host material for DFB (e.g. fireguards, decks)** - The size of current beetle populations, values at risk, phloem condition and total available suitable bark surface area are key considerations. In general:
- The most important consideration is the amount (tree size and condition) of Douglas-fir at risk— is the wood scorched or relatively fresh?
 - 1 - 3 trees down and left in a spot will not be a problem, provided there are not many spots, and they are spaced at ≥ 500 m apart.
 - 5 - 10 trees down and left in a spot will probably cause some mortality in adjacent trees for up to two years. Up to 40 trees may be killed if the area has active beetle populations, but likely fewer trees will be affected. Could treat adjacent, at risk Douglas-fir with MCH.
 - 50+ dispersed downed trees at < 400 m spacing in a shaded stand are termed “scattered blowdown”. This creates a very high risk scenario and significant numbers (10s to 100s) of trees could be killed, with mortality continuing for 2-6 years.
5. **Piece size** – Fresh, uninfested, **shaded** Douglas-fir as small as firewood size (15 cm x 50 cm) can attract and produce beetles. In general, pieces ≥ 20 cm diameter and ≥ 2 m length may be attacked. Smaller pieces can be left if exposed to all-day sun. Bucking felled Douglas-fir trees into 2 m shaded sections will not significantly disrupt the bark surface area suitable for beetle attack. **Keep stumps low** (30 cm height maximum). In very sensitive situations, **peel stumps**.

To decrease susceptibility of logs and debris, leave them exposed and de-limb to maximize exposure to the sun. Although limbing is helpful, it still leaves the underside half of a log suitable for beetle attack and is not effective in shaded situations.

6. **De-barking** - Labour intensive. This technique is effective in situations where Douglas-fir beetle larvae are present at the sapwood surface. However, starting about **21 July**, DFB

moves into the bark to overwinter and can survive the winter in bark pieces on the ground. Therefore, when Douglas-fir is peeled from late summer on, the bark pieces **must be burned**.

7. **Number of pieces** - One tree felled in the shade will not start an epidemic. "Endemic" level DFB typically occurs in widely (1 - 5 km) scattered spots of 1-2 fallen trees, which result in patches of 1-5 dead trees before the spot subsides. Higher levels of DFB will likely result in more standing tree mortality. Therefore, remove or dispose of fireguard wood and debris quickly and thoroughly post-fire.
8. **Natural windthrow following wildfires** - Studies have noted that Douglas-fir windthrow (green trees) in and around fires during the winter-spring months after the fire become infested by DFB. This indicates that both fire-scarred trees and fresh windthrow is attractive to DFB.

DFB mitigation techniques

1. **Anti-aggregation pheromones** can successfully repel DFB from vulnerable areas and are used to help protect small, high-value stands. The anti-aggregation pheromone **MCH** (methylcyclohexenone) is used to disrupt or prevent DFB attack. It is most effective when the number of infested or susceptible trees is low and is applied before annual beetle flight occurs (typically May-June but can be as early as April) on blowdown (or fireguard) trees; large, susceptible trees; and damaged or severely stressed trees. Stapling the pheromone packages on adjacent standing trees or at 2 or 3 m spacing on felled logs might significantly reduce/eliminate attack by DFB.
2. **Trap trees** - This is a management tactic used in conjunction with traditional or salvage harvesting. Because DFB prefers freshly downed trees to standing trees, trap-tree programs are often employed at an operational level to suppress beetle populations. Live, healthy, large diameter Douglas-fir are felled in early spring and remain on the ground throughout the beetle flight. Trap trees are then removed and processed before beetle flight the following year.

Trap trees should be felled prior to beetle flight in early spring (by April 1). Trap trees may also be felled in fall, if done sufficiently late in the season, to ensure that the phloem does not significantly dry out before the following spring. Trees should be dropped in the shade and left unlimbed and unbuckled. Trees left in the sun, or where a major portion of the bole receives direct sunlight, will not attract beetles as effectively as those lying in a shaded environment. Trap trees should be left on site until about late summer to attract beetles throughout their flight period.

In standard harvest (no burnt wood), trap trees are the preferred option because they attract beetles from outside as well as inside block boundaries. In fire-impacted stands, trap trees may not be an option. There are many competing susceptible host resources and any remaining live, green Douglas-fir may be a priority for protection. In this scenario, the use of trap trees or other options such as tree baiting should be considered.

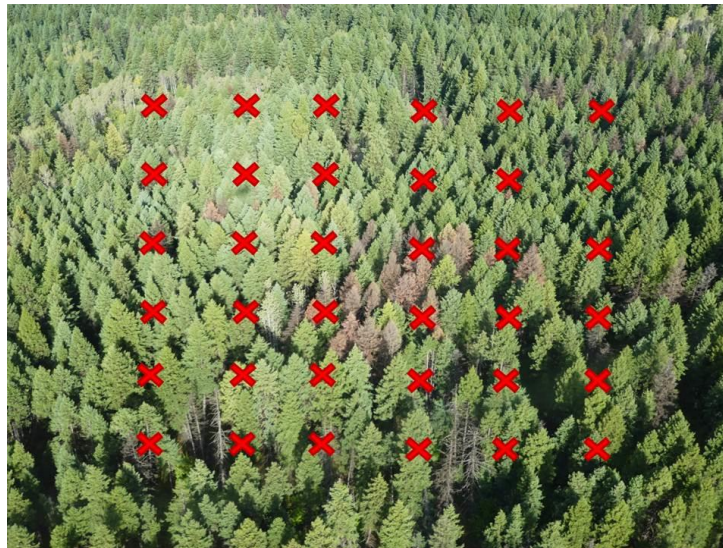


Trap trees should be placed within stand and not limbed.



Poor trap tree deployment – trees are overexposed to sunlight and drying.

3. Baiting stands – DFB tree baits (containing attractive pheromones) are deployed in a grid within a block at 50-meter intervals. Tree baits are stapled onto the bole of host trees. They are intended to contain beetle populations within the baited area, and do not usually attract beetles from outside block boundaries. Baiting harvest blocks in fire-impacted stands is a good option because it is often difficult to determine how much pre-existing attack exists in a post-fire block, and baiting will contain the population and may hold beetles that fly through the block from outside block boundaries. Baits must be placed prior to April 1st and all attacked trees must be removed prior to April 1st of the following year.



Grid-bait infested stands to prevent DFB from leaving block.

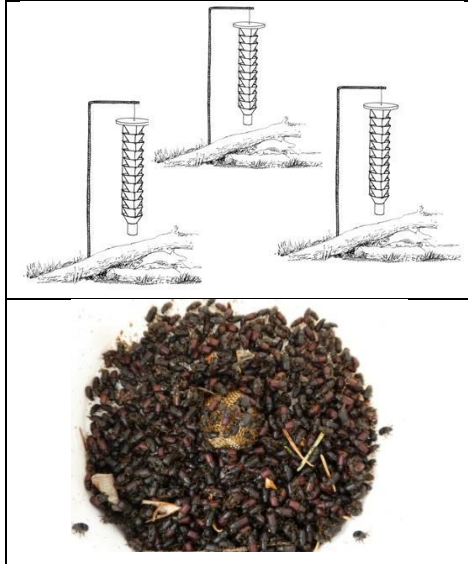
- 4. Trap trees and secondary beetles** – when the DFB population is declining or trap trees are placed incorrectly, or in less than optimal locations, secondary beetles may attack. Often when trap trees are limbed or left in direct sunlight, secondary beetles will displace DFB in the trap trees.

Douglas-fir pole and engraver beetles are known as secondary beetles and typically attack small-diameter Douglas-fir trees and the tops of larger trees. They prefer to attack trees injured by fire scorch, defoliation, blowdown, or root disease. Stand conditions and weather can also strongly influence beetle populations. Under drought conditions, they have been known to attack and kill Douglas-fir as large as 30 cm in diameter. Because Douglas-fir pole beetles and engraver beetles are secondary insects associated with trees under stress, enhancing tree/stand quality will help to prevent attacks. The best management approach is to promote stand vigour by thinning and promptly removing wind thrown trees or trees damaged by other stand disturbances.

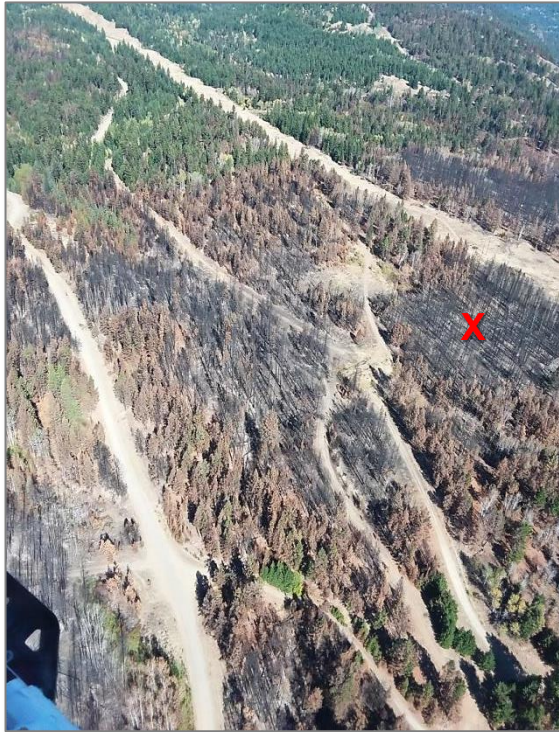
		
Boring dust and frass from Douglas-fir beetle or secondary bark beetle attack.	Douglas-fir beetle galleries.	Fire-scorched Douglas-fir with <i>Cryptoporus</i> fungi

- 5. Mass Trapping Douglas-fir beetle with Lindgren® funnel traps** - Where harvest is not an option or where trees are not available to use as trap trees, the use of funnel traps baited with DFB pheromone and host odor is considered.

- Hang traps in groups of three
- Hang traps in the shade (if possible)
- Hang traps 2.5 m-3.0 m above ground to avoid damage from bears, cattle or humans
- Place traps at least 100 m away from standing, live, mature Douglas-fir in order to avoid spill-over attack
- Maintain collection cups periodically (empty and destroy captured beetles)

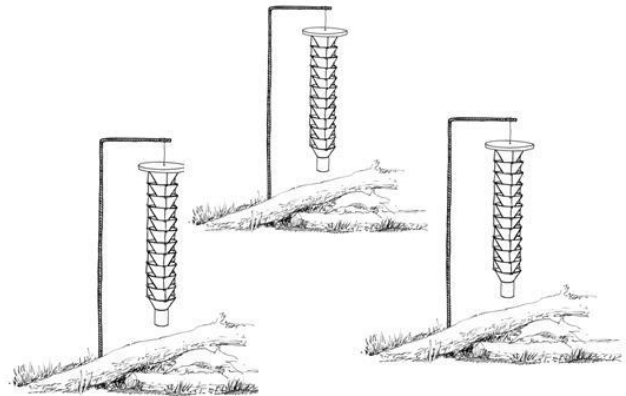


Multiple funnel traps for mass trapping are usually arranged in clusters of 3 or 4, about 10 meters apart.
Lower left, view of collection cup filled with DFB.



Mass trapping options:

- place 1-3 traps in key management areas
- place traps in severely burned areas or clearings where spillover is less of a problem (in these circumstances it may be a good thing!)



Management with funnel traps & pheromones:

- Both ♂(♀) attracted to traps
- traps can run all summer
- traps catch 2-3 times DFB as a single trap tree
- **Spillover!!** May not be an issue in post-fire scenarios if placed in severely burnt areas
- Place at least 100m from live Fd; optimize use of severely scorched sites
- maintain bi-weekly
- replace with new baits ~mid-June



Surveying fire damaged stands

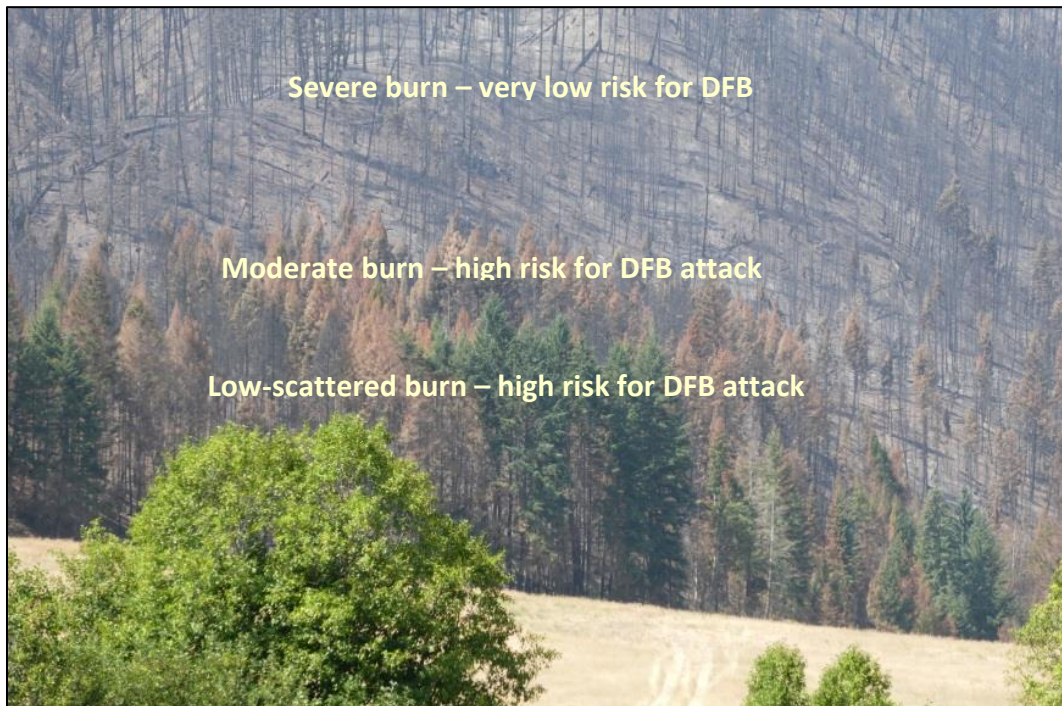
Canopy fires that cause complete defoliation usually result in complete scorching of the inner bark so that trees are not suitable for beetle infestation. However, light ground fires can have less obvious and longer-term effects (3-4 years) concerning DFB susceptibility.

The following list gives a classification of burned areas. These criteria may assist in estimating the severity of fire damage.

1. **Black:** Tree boles completely charred and blackened, foliage destroyed, and understorey vegetation burned. These areas are not likely to have significant beetle problems.

2. **Black/brown:** Mostly black but some browned foliage. These areas may develop DFB populations.
3. **Brown/black/some green:** Mostly browned foliage, some blackened spots, but also some green foliage. Beetle problems may arise due to the occurrence of medium to light fire damage. There may be significant numbers of trees susceptible to attack.
4. **Mixed green/brown/black:** Mostly green foliage, with brown and black spots, understory variously burned. Beetle problems in these areas will likely depend on the significance of ground fire effects.

Scenarios 3 and 4 pose the highest risk for DFB attack.



Severity of fire damage in Douglas-fir presents varied levels of risk for Douglas-fir beetle attack.

Recent windthrow

Windthrow or top breakage occurring in the winter or spring poses the highest risk to attack by DFB. All windthrow should be mapped during detailed survey flights and identified for follow-up survey. Where possible, windthrow should be incorporated into harvesting plans or follow-up treatment if attacked by DFB. The amount of windthrow and degree of attack should be quantified and prioritized for treatment.

Windthrow occurring more than one year in the past will no longer be at risk to DFB attack. Other secondary bark beetles or woodborers may still utilize this material. Surveys should be conducted in proximity to these older patches of windthrow to identify any new patches of attack.

Post-fire management sequence and techniques to mitigate further effects of Douglas-fir beetle

1. Overlay burn severity, DFB Hazard Rating and most recent DFB attack (proximity and size of attack centres)
2. Within fire perimeters DFB will still select the largest Douglas-fir trees to attack; therefore, optimize harvest blocks based on ecosystem requirements, timber values and hazard to DFB
3. Locate, assess and treat all recently downed Douglas-fir (felled during firefighting activities, road construction, as trap trees, or natural windthrow and breakage) – remove or destroy prior to spring beetle flight if infested with DFB
4. Harvest block location and timing (harvest sequence) should maximize beetle removal and burnt wood salvage – concentrate DFB in the burnt wood scheduled for harvest
5. Scorched trees are a very attractive host for DFB, so conventional trap trees may be less effective within a burn perimeter, and are likely a rare resource (2018 research project)
6. Two or more years post-burn, the use of freshly felled, large, green Douglas-fir trap trees should be utilized outside the fire perimeter to optimize DFB management
7. Deploy in-block tree baiting to hold beetles in proposed blocks and to attract DFB populations that are adjacent or dispersing
8. Monitor DFB flight period with funnel traps throughout priority salvage areas
9. Optimize use of mass trapping techniques in very severely burned areas or clearings near active DFB populations
10. MCH – applied to protect live, green trees from DFB in *special areas*

Selected References

- Amman, G.D. and K.C. Ryan. 1991. Insect infestation of fire-injured trees in the Greater Yellowstone Area. USDA Forest Service, Intermountain Forest and Range Experiment Station, Research Note INT-398.
- Cunningham, C.A., M.J. Jenkins and D.W. Roberts. 2005. Attack and brood production by the Douglas-fir beetle (Coleoptera: Scolytidae) in Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Pinaceae), following a wildfire. Western North American Naturalist 65: 70–79.
- Furniss, M.M. 1965. Susceptibility of fire-injured Douglas-fir to bark beetle attack in southern Idaho. Journal of Forestry 63: 8-11.
- Harvey, B.J., D.C. Donato and M.G. Turner. 2014. Recent mountain pine beetle outbreaks, wildfire severity, and postfire regeneration in the US Northern Rockies. pnas.org/cgi/doi/10.1073/pnas.1411346111.
- Hood, S. and B. Bentz. 2007. Predicting postfire Douglas-fir beetle attacks and tree mortality in the northern Rocky Mountains. Canadian Journal of Forest Research 37: 1058-1069.

- Hood, S., B. Bentz and K. Ryan. 2003. Douglas-fir beetle attack and tree mortality following wildfire. Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula MT. 6 pp.
- Hood, S. and D.C. Lutes. 2017. Predicting post-fire tree mortality for 12 western US conifers using the First Order Fire Effects Model (FOFEM). *Fire Ecology* 13: 66-84.
- Jenkins, M.J. 1990. The relationship between fire and bark beetle attack in western North American forests. pp. C1101-C1112 in: *Proceedings of the Symposium of Forest Fire Research. International Conference of Forest Fire Research*, November 19-22, 1990, Coimbra, Portugal.
- Seidl, R. and W. Rammer. 2017. Climate change amplifies the interactions between wind and bark beetle disturbances in forest landscapes. *Landscape Ecology* 32: 1485-1498.
- MFLNRORD. 2017. Bark Beetle Susceptibility Rating.
<https://catalogue.data.gov.bc.ca/dataset/bark-beetle-susceptibility-rating>
- Weatherby, J.C., P. Mocettini and B.R. Gardner. 1994. A biological evaluation of tree survivorship within the Lowman Fire boundary, 1989-1993. USDA Forest Service, Intermountain Forest and Range Experiment Station, Report R4-94-06. 9 pp.