Forest Insect & Disease Leaflet 184

August 2017

U.S. Department of Agriculture • Forest Service

Western balsam bark beetle

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Introduction

The western balsam bark beetle (*Dryocoetes confusus* Swaine, is an important mortality agent of subalpine fir (*Abies lasiocarpa*) in western North America. The beetle is less aggressive than tree-killing bark beetles in the genus *Dendroctonus* (mountain pine beetle, *D. ponderosae*; spruce beetle, *D. rufipennis*; or Douglas-fir beetle, *D. pseudotsugae*) and usually attacks weakened (e.g., drought stressed) or downed trees. Commonly, less than five percent of trees in a forest stand are attacked in a year, but the cumulative impacts of chronic infestations over time can result in most of the mature subalpine fir within a stand being killed. Outbreaks can result in high numbers of trees being killed in a single year (Figure 1).

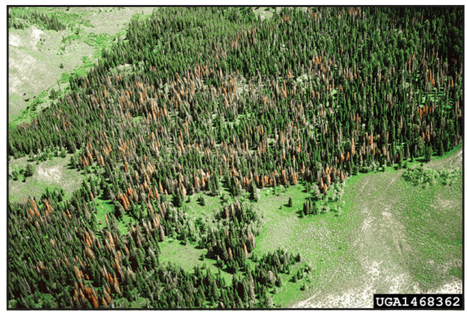

Figure 1. Subalpine fir mortality caused by western balsam bark beetle.

Western balsam bark beetle infestations have been reported since forest surveys began in the early 20th century. Outbreaks have affected the subalpine fir type throughout many areas of British Columbia with estimated losses of more than 423 million ft^3 (12 million m^3) occurring in the Prince Rupert Region between 1956 and 1965. More recently, area affected averaged 100,000 acres (250,000 hectares) during 2003-2013 in southern British Co-

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lumbia with mortality from this beetle as high as 70 percent in certain biogeoclimatic zones. Similarly, western balsam bark beetle infestations affected nearly 700,000 acres (1.7 million hectares) annually from 2001-2010 across the western US, with most subalpine fir mortality recorded in Colorado and Wyoming. An outbreak in the Bighorn Mountains of Wyoming killed more than 70 trees/acre (173 trees/hectare) over a 6-year period reducing tree density more than 60 percent in infested stands. Corkbark fir (*A. lasiocarpa* var. *arizonica*) stand basal area was reduced by 5 to 70 percent during a late 1990's outbreak in the Pinaleño Mountains of southern Arizona.

Western balsam bark beetle has a close association with a fungus (*Grosmannia dryocoetidis = Ceratocystis dryocoetidis*) that is transmitted to trees it colonizes. During a 1957 survey of subalpine fir stands, only about 35 percent of tree mortality could be directly credited to western balsam bark beetle damage. Remaining trees survived attack by beetles, but apparently succumbed to coalescing lesions caused by introduced fungal infection that girdled the trees. Subsequent inoculation tests confirmed the pathogenicity of introduced fungi. Although host defenses often prevent initial beetle attacks, decreased tree vigor caused by fungal infection may also result in subsequent beetle attacks that are successful. Western balsam bark beetle also frequently colonizes trees weakened by root disease fungi (*Armillaria* spp., *Heterobasidion* spp.).

Hosts and Distribution

Western balsam bark beetle is common through much of the range of its primary hosts, subalpine fir and corkbark fir. Its distribution extends from southeast Alaska, British Columbia and Alberta south to Arizona and New Mexico, and from Colorado westward to Oregon (Figure 2). Western balsam bark beetle occasionally attacks Pacific silver fir (*A. amabilis*), grand fir (*A. grandis*) and white fir (*A. concolor*), and rarely Engelmann spruce (*Picea engelmannii*), white spruce (*P. glauca*) and lodgepole pine (*Pinus contorta*) during outbreaks occurring in mixed species stands with subalpine fir.

External Evidence of Infestation

Needles of infested trees fade from green to yellowish-red the year following successful attack by western balsam bark beetle. Needles will then turn a brick-red color for approximately two years on dead trees (Figure 3). Eventually needles become dull-red for

Figure 2. Distribution of western balsam bark beetle based on the range of its primary host trees subalpine fir and corkbark fir.

Figure 3. Subalpine fir mortality caused by western balsam bark beetle. Trees with bright, brick red needles indicate trees attacked 1 to 2 years previously. Older attacked trees have dull, red needles or have lost their needles and appear gray.

another 2 to 3 years, resulting in 4 to 5 years of dead needle retention. Trees that successfully pitch out attacking beetles but are killed by pathogenic fungi may take more than one year to fade. The prolonged sequence of fading can make accurate assessment of new tree mortality during aerial surveys problematic. Moreover, in areas where root disease or balsam woolly adelgid occur, it may be difficult to distinguish between mortality caused by beetles versus these other agents. In addition, secondary bark beetles may contribute to subalpine fir mortality in trees already attacked by western balsam bark beetle.

External evidence of attack on tree boles is not readily apparent, making identification of recently infested trees difficult. During late summer, entrance holes and reddish-brown boring dust in bark crevices and around the base of freshly attacked trees may be visible; however, precipitation will often remove these signs by the next spring. The majority of attacks often

Figure 4. Pitch streaming indicative of subalpine fir tree under attack by western balsam bark beetle. Beetles are often unsuccessful in colonizing trees that exhibit such heavy pitch streaming.

occur well above breast height and into the upper crown, which also hinders diagnosis of beetle presence. Numerous streams of clear pitch can be evident, and may indicate unsuccessful attacks (Figure 4). Pitch streams full of boring dust are a sign of successful attack.

Occasionally fir engraver beetles, *Scolytus ventralis*, will also attack subalpine fir and corkbark fir; however, their horizontal egg galleries are easily distinguished from those created by western balsam bark beetle (see description in next section). Numerous secondary bark beetles may also be found on dead or dying subalpine fir, but they are generally smaller and have different egg gallery patterns than western balsam bark beetle.

Figure 5. Male (left) and female (right) western balsam bark beetles. Female western balsam bark beetles are identified by the denser and thicker setal brush located on the forehead.

Identification and Life History

Adult western balsam bark beetles are shiny reddish-brown, and approximately 1/6 inch (3.4 to 4.3 mm) long (Figure 5). Their thorax is evenly convex, and hardened forewings are abruptly rounded without spines. Both male and female beetles have numerous "hairs" on the front of their foreheads (frons); however, this setal brush is more prominent on females and resembles a "crew-cut". Late-instar larvae are 1/7 inch (3-4 mm) long with pale-tan head capsules and yellow-white bodies that are characteristically c-shaped and wrinkled. Pupae are the same size as adults, are yellow-white, and many adult features such as legs and wing covers are recognizable.

Although development studies on western balsam bark beetle demonstrate a 2-year life cycle, it has been speculated that a one-year cycle may occur under appropriate environmental conditions. Adult beetle flight typically begins in early summer after daytime temperatures exceed approximately 60-68º F (15-20º C), but it can occur as early as late May. Male beetles initiate attacks on boles of susceptible hosts; boring into the phloem, excavating a nuptial chamber and releasing a pheromone that attracts females. Males are polygamous, mating with more than one female. Mated females construct egg galleries that radiate away from the nuptial chamber, forming a stellate or star-shaped gallery pattern (Figure 6). These egg galleries may score the outer sapwood. Females can produce up to three separate broods with the first occurring during initial gallery construction in mid-summer. Many females overwinter and extend their egg galleries the following spring to create a second brood. Some then emerge in summer to produce a third brood, either in the same or another tree.

Figure 6. Stellate (star-shaped) egg galleries of western balsam bark beetle on the inner bark (A) and etched on the outer sapwood (B) of infested trees. Larval feeding galleries are smaller in width and perpendicular to egg galleries (seen in A).

Upon hatching, larvae tunnel away from egg galleries to feed throughout the summer and into fall until freezing temperatures occur. A range of larval instars is found overwintering beneath the bark. Larval development continues the next spring and summer with the second winter spent as adults.

Studies from across the range of western balsam bark beetle suggest there are two principal flight periods each year; the first typically larger and comprised of newly emerged young adults and the second being primarily re-emerged second-year females. Initial flight is dominated by male beetles followed by an increasing percentage of females or a relatively equal number of both genders. In British Columbia, peak flights occurred in mid- to late-June and in mid-August through early September depending on latitude and moisture regime. Adult flight in northern Idaho and western Montana generally began in early- to mid-June and continued through September; with peak flights occurring in late-June/early-July and late-July/early-August. In northern Utah, peak flights occurred between mid-June to early-July, then 4-7 weeks later in August. In north-central Wyoming, adult flight initiated in early-July with peak flight activity observed in mid-July and late-August. In a five-year study of adult flight in Colorado, beetles commonly began dispersing in early- to mid-June with first peak flight occurring in early- to mid-July. Occurrence of a second peak varied between years and elevation. Based on limited studies in northern Arizona, flight initiation occurred the first week of July and peaked in mid-July.

Factors affecting tree and stand susceptibility and outbreaks

Generally, this bark beetle attacks small groups of host trees at a somewhat low, but steady level each year in infested stands. During endemic population phases, western balsam bark beetle infests old, stressed or damaged trees and fresh host material on the ground, such as wind breakage and blowdown. Outbreaks typically begin as a result of certain environmental conditions (extended drought) or large-scale disturbances such as windthrow (Figure 7).

Susceptibility of individual trees to attack by western balsam bark beetles may be related to specific traits. In a comparison of attacked and unattacked subalpine fir in British Columbia, successfully attacked trees typically had slower growth and smaller crowns and were older, but not necessarily bigger. Increased susceptibility of older trees seemed to be associated with effects of senescence and declining host vigor. Trees with low vigor are slower growing and produce less secondary resin which results in beetles having higher successful attack rates compared to vigorous, faster growing trees with more resin production. Pioneering male beetles attacking vigorous trees may be overwhelmed by host defenses and therefore unable to release aggregation pheromones needed to successfully colonize trees. Although western balsam bark beetle may show preference for larger-diameter size classes/ older trees; during intense outbreaks or as larger diameter host trees are depleted, smaller-diameter trees may also be attacked. This pattern of attack is typically observed during periods of prolonged drought when host tree resin production has been significantly reduced. In addition, smaller diameter

Figure 7. Dense stands of corkbark fi r impacted by western balsam bark beetle during an extended drought on the Sandia Mountains, New Mexico.

trees can be attacked as a result of spillover from successful attacks on neighboring large-diameter trees.

Tree mortality caused by western balsam bark beetle may also be related to forest stand conditions and site characteristics. Significant positive linear relationships were found between the amount of tree mortality and percentage of subalpine fir trees in a stand, subalpine fir basal area, and subalpine fir stand density index following a western balsam bark beetle outbreak during the late 1990s and early 2000s in the Bighorn Mountains of Wyoming. These findings suggest that inter-tree competition caused by high tree density and basal area results in increased susceptibility to western balsam bark beetle. Forest stands impacted during the outbreak in Wyoming were dominated by subalpine fir (>80 percent), which may also explain the high rate and level of mortality (>50 percent of subalpine fir tree density and basal area). In stands with a smaller component of subalpine fir (<50 percent), factors such as abundance of large-diameter host trees and level of root disease may be more important in determining the amount and rate of tree mortality. During a similar timeframe in southern British Columbia, the highest levels of tree mortality occurred in the driest, coldest Engelmann spruce-subalpine fir biogeoclimatic zone compared with wetter, warmer sites.

Disturbance events (windthrow, avalanches) and host stress caused by drought, defoliation and root disease have all been implicated in the initiation of western balsam bark beetle outbreaks or maintaining chronic levels of infestation. Corkbark fir basal area was reduced by more than 50 percent in many stands due to a western balsam bark beetle outbreak in southeastern Arizona following defoliation caused by looper defoliation, *Nepytia janetae*, and winter storm damage. Similarly, western balsam bark beetle population increase and associated tree mortality was observed following a 1993 storm that caused windthrow and tree breakage over a large area in northern Wyoming. Egg galleries were observed in all diameter classes of fir blowdown greater than 4 inches (10 cm). Felled trees in Colorado had highest attack rates on bole sides and, to a lesser extent, on the underside during endemic conditions, although there was no surface preference for attack on felled trees exposed to high populations in British Columbia.

Management Options

Vegetation management

Generally, subalpine fir grows at high-elevation sites with a limited season for vegetation management activities. Lack of accessibility can prevent removal of currently infested trees to suppress building beetle populations. In addition, difficulty in identifying currently infested trees can affect timely removal. If sanitation treatments are implemented, they should occur following flight activity in August or before adult flight in June. Prompt removal or destruction of host material generated from windthrow or logging slash is recommended to prevent population increase or suppress populations. Similarly, removing trees weakened by causes other than root disease will mitigate successful attacks. Caution should be exercised in areas of known root disease pockets because partial cutting can increase root disease spread.

Because western balsam bark beetle prefers less vigorous trees, silvicultural treatments that improve tree growth and vigor may be an effective management strategy. Treatments that lower subalpine fir basal area or stand density index, percentage of fir in a stand, and stand age could reduce inter-tree competition for limited resources, increase individual tree vigor and lower stand susceptibility to damage caused by western balsam bark beetle. Increasing age class diversity and promoting younger age classes would also presumably limit stand level impacts caused by western balsam bark beetle. Because subalpine fir stands over 100 years old in British Columbia sustain continuous attack from western balsam bark beetle, it is recommended to use a rotation age less than 100 years. Although encouraging a healthy fir component through active management in high-value sites such as developed ski areas makes intuitive sense, specific silvicultural guidelines in fir dominated stands that result in lowering susceptibility to beetle attack have yet to be fully developed. Furthermore, thinning in spruce-fir stands can increase windthrow risk thereby providing a preferred habitat for western balsam bark beetle development.

Pheromones

Pheromones may provide another alternative for managing beetle populations. Pheromones for western balsam bark beetle have been identified and shown to be effective in manipulating beetle populations and dispersal. Commercially available attractant pheromone lures or baits containing *exo*-brevicomin can be used to monitor beetle flight or concentrate dispersing beetles into stands scheduled for harvest. Based on studies in British Columbia, baiting two trees per active spot is recommended for containment and concentration of small isolated infestations, while baiting trees on a 164 foot (50 meter) grid is recommended for larger areas. One study demonstrated that stands can be successfully co-baited for both western balsam bark beetle and spruce beetle when trying to manage populations of both bark beetle species. Baited trees less than 8 inches (20 cm) in diameter were not typically attacked. Therefore, select larger, older or less-vigorous trees for baiting.

Although a trap out strategy to suppress western balsam bark beetle populations has not been documented, high quantities of beetles collected in funnel traps and attraction of beetles to freshly felled trees suggest this might be a feasible tactic. This suppression strategy could be used to address a small, local population of insects. All baited standing trees, felled trap trees and adjacent infested trees from spillover effects must be removed or treated on site (e.g., burned or bark peeled) to kill all beetle life stages before adult flight occurs.

Western balsam bark beetle response to its aggregation pheromone, *exo*-brevicomin, was inhibited by *endo*-brevicomin in both laboratory assays and field studies. *Endo*-brevicomin is not commercially available and additional field studies are required to determine its efficacy and deployment methods. Combining non-host volatiles with *endo*-brevicomin may enhance repellency effects but further research is required to document the effectiveness of this technique. If pheromones are used for manipulating behavior or distribution of beetles, treatments should be deployed by early-June for the northern Rockies and late-June for the central Rockies and Southwest.

Acknowledgements

Earlier drafts of this leaflet were improved through thoughtful reviews provided by Kathy Bleiker, Ken Gibson, Matt Hansen, Lorraine Maclauchlan and Art Stock.

Photo Credits

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Sandra Kegley (Figure 4), Joel McMillin (Figure 6A)

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Published by USDA Forest Service, Pacific Northwest Region (R6), Portland, Oregon

FS/R6/RO/FIDL#184-17/XXX