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Forest Insect and Disease Leaflet 1

Western Pine Beetle

Introduction

The western pine beetle, *Dendroctonus brevicomis* LeConte (Coleoptera: Curculionidae, Scolytinae), is a bark beetle native to parts of western North America. The beetle colonizes and kills ponderosa *(Pinus ponderosa)* and Coulter *(P. coulteri)* pines.

Western pine beetle prefers to colonize larger diameter trees (>20 inches [50 centimeters (cm)] diameter at breast height [DBH]) but will attack and kill trees of most ages and sizes during outbreaks. Rarely is slash or other logging debris colonized. The beetle may cause mortality of 60 to 90 percent of host trees in some landscapes (fig. 1). The most recent notable outbreak occurred in the central and southern Sierra Nevada Range in California from 2014 to 2017, causing mortality of millions of ponderosa pines. This outbreak, as with

Figure 1. Ponderosa pine mortality caused by western pine beetle. Photos by Christopher Fettig, USDA Forest Service.

many other outbreaks of western pine beetle, was incited by drought and supported by landscapes of high-density host trees. The frequency and severity of droughts are expected to increase likely influencing the frequency and severity of future western pine beetle outbreaks.

Western pine beetle serves important roles in its native habitat influencing the structure, composition, and function of forests. The beetle often causes tree mortality in forests that are overly dense, over-mature, or both. Trees that are diseased or weakened by drought, fire, lightning, or mechanical injuries are more susceptible to attack. Killing of weakened trees is an important ecosystem function fulfilled by the beetle during endemic (low) populations.

During outbreaks, western pine beetle can cause significant economic losses. Dense stands of ponderosa pine 8 to 20 inches (20 to 50 cm) DBH are highly susceptible to colonization. Tree mortality resulting from outbreaks in recreational sites and in the wildland urban interface is undesirable given concerns regarding hazard trees, fire risk, and protection of critical infrastructure.

Western pine beetle occurs from British Columbia southward through Washington, Oregon, Nevada, and California; eastward to Montana, Idaho, Utah, Colorado, Arizona, New Mexico, and West Texas; and southward into northern Mexico (fig. 2). Recent work suggests populations in Nevada, Utah, Colorado, Arizona, New Mexico, Texas,

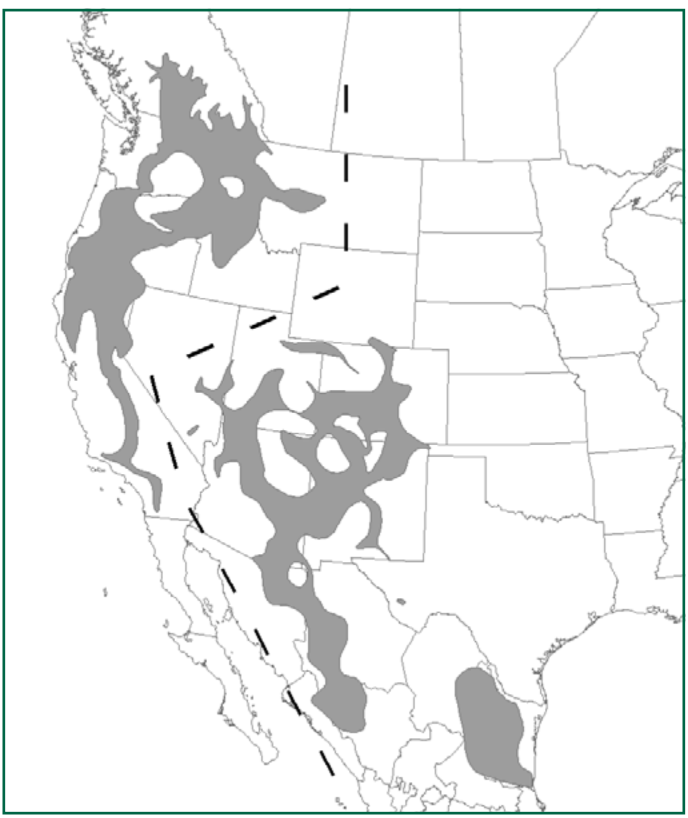

Figure 2. Distribution of western pine beetle *(Dendroctonus brevicomis)* with a dashed line indicating the potential separation of *D. brevicomis* (west of line) and *D. barberi* (east of line). The distribution of western pine beetle in northeastern Mexico is not well resolved. Map by Ross Gerrard, USDA Forest Service.

and Mexico may be *Dendroctonus barberi* Hopkins based on differences in morphological characteristics and other evidence. However, this split would have few management implications, and the authors consider these species to be the same species for purposes of this publication. Of note, little has been published on *D. barberi.* Outbreaks of western pine beetle tend to be most severe in California and Oregon. The beetle is most commonly found at elevations of 2,000 to 6,000 feet (600 to 1,800 meters [m]).

Evidence of Attack and Infestation

Attacks are most easily identified by the presence of pitch tubes, masses of resin that often contain boring dust. Pitch tubes accumulate at entrance holes on the outer surface of the bark in response to wounding of the tree when females bore into the tree. Pitch tubes range from creamy white to brownish red in color and are approximately ¼ to ½ inch (6 to 12 millimeters [mm]) in diameter (fig. 3). Occasionally, only boring dust will be present on the outer bark. This is most commonly observed during a severe drought when a pine's ability to produce resin is impaired. In these instances, the accumulation of reddish-brown boring dust in bark crevices and around the base of the tree is an indicator of successful attacks.

Unsuccessful attacks can be identified by larger white pitch tubes approximately ¾ to 1 inch (20 to 25 mm) in diameter that are scattered over the bole of the tree. In these cases, the beetle has been

Figure 3. Pitch tubes of successful western pine beetle attack (red circles); pitch tubes are creamy white with red boring dust within the pitch tube and in the fissures of the bark. Photo by Leif Mortenson, USDA Forest Service.

"pitched out" (fig. 4). The presence of predominately white pitch tubes or large streams of resin and the absence of boring dust on the bark suggest the tree may survive the attack.

Initial attacks typically occur midway up the tree bole with later attacks occurring above and below. The beetle requires thick bark to complete its life cycle, so it rarely attacks trees <6 inches (15 cm) DBH, even during severe outbreaks. When attacks do occur on small diameter trees, they tend to be isolated to the lower bole. The mechanism by which host trees die after western pine beetle attack is likely twofold: (1) by "girdling" of host phloem (i.e., the outer layer of wood directly beneath the bark that is responsible for nutrient transport within

Figure 4. "Pitched out" western beetle after an unsuccessful attack. Photo by Christopher Fettig, USDA Forest Service.

the tree) when attacks surround the circumference of the bole; and (2) by blue-stain fungi, *Ophiostoma minus,* carried by western pine beetle which likely have deleterious effects on the host tree, such as limiting water transport within the xylem (fig. 5). However, it is not well understood how blue-stain fungi influence tree mortality.

After a mass attack (i.e., adequate numbers of beetles must attack the tree and overcome its defenses), the foliage begins to change color within weeks to months. These changes occur more rapidly during hot and dry conditions. Initially, the needles fade to a light yellow green and then to red or reddish brown eventually falling to the forest floor. The amount of time it takes for needles to fade and then fall off a tree varies depending on the time of year when beetle attacks occurred, the vigor of the tree, and other factors. Trees attacked in late summer and early fall by the overwintering western pine beetle generation usually will not fade until spring the following year. Maximum beetle emergence generally occurs when needles initially turn red. If needles have completely faded and dropped, the tree no longer contains western pine beetle

Figure 5. Blue-stained wood caused by *Ophiostoma minus,* a fungus associated with western pine beetle. Photo by Christopher Fettig, USDA Forest Service.

brood. Crown fade due to colonization of the tree by western pine beetle will occasionally first occur at the midbole, but often the entire crown will fade uniformly.

Western pine beetle is able to inoculate host trees with various microorganisms including *O. minus*. The fungus appears as blue staining of the sapwood (fig. 5) and as black patches beneath the bark (fig. 6). The beetle carries the fungal spores on its body and the spores are dislodged as the beetle chews through the bark and phloem. *Ophiostoma minus* grows within tree tissues but any benefit to the beetle is unclear. Western pine beetle also carries the spores of other fungal associates in their mycangia, a specialized exoskeletal structure. These fungi grow within galleries providing nutrients to developing larvae.

Woodpeckers often target trees colonized by western pine beetle to feed on western pine beetle larvae, pupae, and adults. When searching for prey, woodpeckers make holes in the bark to feed in the inner bark or chip (flake) away large portions of the bark to feed in the outer bark (fig. 7). Among the major tree-killing bark beetle species, migration of larvae to the outer bark is unique to western pine beetle. As such, chipping (flaking) of bark by woodpeckers can often be used to distinguish pines killed

Figure 6. Galleries of western pine beetle; black patches are caused by *Ophiostoma minus* carried by western pine beetle. Photo by Leif Mortenson, USDA Forest Service.

Figure 7. Bark removed by woodpeckers feeding on western pine beetles in late larval, pupal, and newly molted (teneral) adult life stages. Photo by Christopher Fettig, USDA Forest Service.

by western pine beetle from some distance. Following bark sloughing or bark removal, the winding S-shaped galleries of western pine beetle are unique to this species (fig. 6). Western pine beetle may also co-occur in the same host tree with other bark beetle species such as red turpentine beetle *(Dendroctonus valens),* mountain pine beetle *(Dendroctonus ponderosae),* and *Ips* spp., among others.

Life History and Identification

Most of the western pine beetle's life cycle occurs beneath the bark except when adults disperse in search of host trees. Individuals pass through four developmental stages: egg, larva (fig. 8a), pupa (fig. 8b), and adult (fig. 8c).

Western pine beetle may have one to four generations per year. Parent females may produce one to two generations in a season, resulting in overlapping life cycles. The beetle's life cycle may take 2 to 10 months to complete. All life stages may be found overwintering due to the overlapping generations. However, larvae are the most common life stage to overwinter. The generation time (voltinism) is dependent largely on temperature. In the northern part of its range and at higher elevations, western pine beetle generally has two generations per year with peak flight periods occurring in June and late August. However, voltinism increases in the southern part of its range and at lower elevations where three to four generations may occur per year. Attacks occur as early as March and as late as December in parts of the range.

Temperatures associated with flight initiation and flight cessation vary. However, flight initiation tends to occur when daily maximum temperatures frequently exceed 60° F (15° C) and

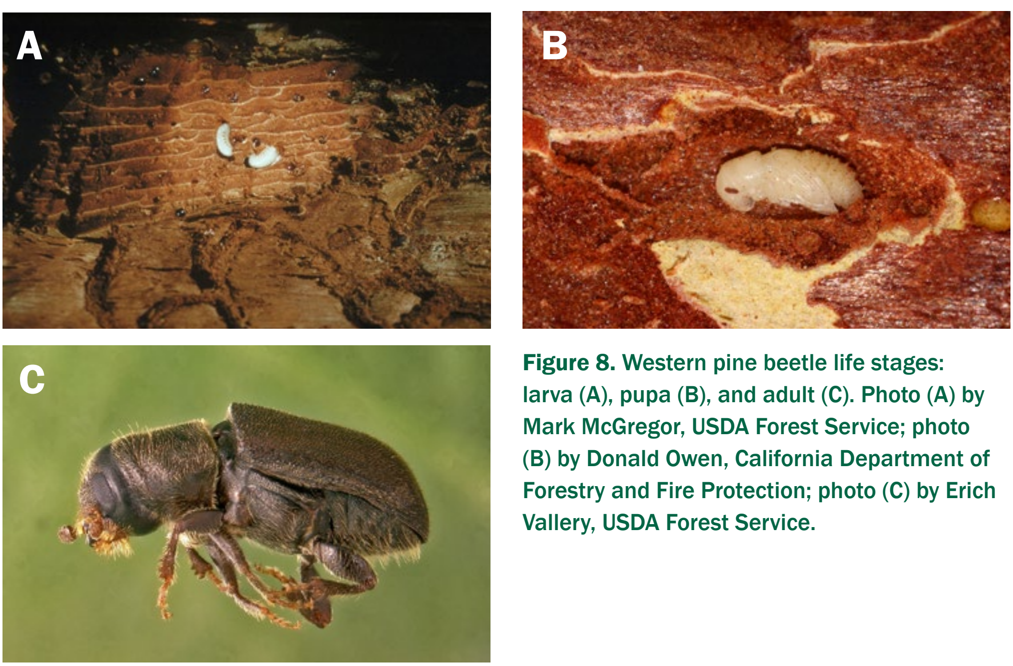

Figure 8. Western pine beetle life stages: larva (A), pupa (B), and adult (C). Photo (A) by Mark McGregor, USDA Forest Service; photo (B) by Donald Owen, California Department of Forestry and Fire Protection; photo (C) by Erich Vallery, USDA Forest Service.

tend to cease when the maximum daily temperature is below 60° F. After the flight period has initiated, it may be abruptly interrupted if there is a substantial drop in average temperature. Flight occurs during the day and there are two diurnal peaks in flight (in California): midmorning and the last 2 to 3 hours of daylight. The multivoltinism of western pine beetle, with more generations in warmer climates, suggests climate change may influence future population dynamics.

Female western pine beetles initiate host colonization and release aggregation pheromones attracting males and other females, which may incite mass attack. When mass attack occurs, the beetles are often able to overcome the tree's defenses (pitch production, among others), which eventually leads to tree death. Males also release aggregation pheromones and both sexes release anti-aggregation pheromones, which function as "no vacancy" signs to prevent overcrowding of the host tree by western pine beetle. Pheromones released from one tree often lead to adjacent trees being attacked, resulting in groups of dead trees.

When western pine beetles successfully attack a tree, they bore through the bark to the phloem where they mate. The female then bores a winding, maze-like gallery packed with frass laying approximately 60 eggs in small niches along the sides of the gallery. Occasionally, females will reemerge and reattack the same tree or attack another nearby tree. Egg incubation takes 1 to 2 weeks before hatching. Once larval hatch occurs, larvae feed on the phloem for 10 to 15 days while excavating small galleries. The larvae then move to the outer bark where they complete their development. Larvae go through four stages (instars) before pupation. Newly formed (teneral) adults feed in the middle and outer bark where *O. minus* spores are encountered and mycangial fungi are collected. The mature adult beetles then emerge from the tree to begin another generation.

Factors Affecting Outbreaks

For a western pine beetle outbreak to develop, there must be susceptible host trees present and suitable weather (e.g., warm and dry) conducive to beetle population growth.

Weather

Weather has both direct and indirect effects on western pine beetle populations. Winter temperatures can negatively affect brood development. However, temperatures must drop below -20° F (-29° C) for several days for significant mortality to occur, which rarely occurs throughout much of the range of western pine beetle. Furthermore, due to the thick bark of trees they infest, western pine beetles are well insulated from lethal cold temperatures when overwintering. Western pine beetle is vulnerable to fluctuations in weather during flight. A sudden storm or significant drop in temperature will arrest flight and may lead to beetle mortality. Both events are common during the spring and fall dispersal periods. Indirect effects are mediated through host trees and community associates. Of note, severe drought stress (whether resulting from elevated temperatures, reductions in precipitation, or both) inhibits tree defenses, increases susceptibility to mass attack, and favors western pine beetle brood development.

Host Tree Susceptibility

For a tree to be successfully colonized by western pine beetle, an adequate number of beetles must attack the tree and overcome its defenses. Western pine beetle generally attacks unhealthy trees with low vigor as healthy pines are able to resist western pine beetle attack by producing enough resin to either "pitch out" the beetles, or soak the phloem surrounding the egg galleries with resin which prevents eggs from hatching. However, even a healthy pine can be overwhelmed by large numbers of western pine beetles.

Predators and Parasites

There are numerous species that prey on and parasitize western pine beetle. Woodpeckers are significant predators of western pine beetle. *Temnochila chlorodia* (Coleoptera: Trogossitidae) is one of the primary invertebrate predators that is attracted to *exo*-brevicomin, the female western pine beetle aggregation pheromone. Additionally, two checkered beetles, *Enoclerus lecontei* and *Enoclerus sphegeus* (Coleoptera: Cleridae), commonly prey on western pine beetle (fig. 9). *Enoclerus lecontei* and *E. sphegeus* are attracted to ipsdienol, an anti-aggregation pheromone released by male western pine beetle. A possible early sign of attack is the presence of predaceous checkered beetles hunting on the bark surface for western pine beetle adults.

Parasitic wasps also commonly attack western pine beetle. Together, predators and parasites may play an important role in regulating endemic populations but are ineffective at suppressing epidemic populations.

Competition

Western pine beetle's ability to obtain nutrients is most critical during the larva stage. Larvae compete with other larvae from their brood or with other phloem-feeding insects. They are also preyed on by larvae of some predacious insects.

Figure 9. *Enoclerus lecontei* (in black circle), an important western pine beetle predator. Photo by Donald Owen, California Department of Forestry and Fire Protection.

Stand and Landscape Characteristics

Stand and landscape characteristics are important factors influencing western pine beetle outbreaks. Outbreaks are less likely to occur in heterogeneous forests with high tree species diversity and low stocking compared to dense, homogenous forests. Forests with high stand densities and abundant hosts are the most susceptible to western pine beetle (fig. 10). Throughout the range of western pine beetle, host tree density has increased greatly over the past century due to fire suppression, historic logging, and other factors. High stand densities increase competition among trees while reducing tree growth rates and tree vigor. They also create beneficial microsite conditions for the beetle by reducing windspeeds, moderating temperatures, and increasing the stability and directionality of pheromone plumes used in host selection and colonization.

Throughout the southern Cascade and Sierra Nevada Ranges, forest susceptibility to western pine beetle infestations substantially increases at stand densities around 150 ft^2 of basal area per acre (34 m^2/hectare [ha]) or a stand density index (SDI, a measure of stocking based on the number of trees per unit area and DBH of the tree of average basal area) around 230. Susceptible forests in the interior West generally exhibit increased susceptibility at lower stand densities (i.e., around 120 ft^2 of basal area per acre [27 m^2/ha]). Due to climate change manifesting hotter and drier conditions, however, ponderosa pine forests in general may be more susceptible today to western pine beetle at even lower stand densities than their historical counterparts. For example, some recent data suggest stand density levels <100 SDI are required to promote high levels of resistance (≥90 percent pine survival), and those <150 SDI are required to promote moderate levels of resistance (≥70 percent pine survival).

Western pine beetle outbreaks can have substantial impacts on forests and the ecosystem goods and services obtained from forests. The duration of outbreaks

Figure 10. A dense stand of ponderosa pine susceptible to high levels of tree mortality by western pine beetle. Photo by Crystal Homicz, University of California, Department of Entomology and Nematology.

varies with outbreak intensity and stand and landscape characteristics. Severe outbreaks may result in large amounts (i.e., >50 percent) of tree mortality but only last 2–3 years due to rapid depletion of suitable host trees. Less severe outbreaks may result in similar levels of tree mortality accumulated over longer periods. While outbreaks lower stand density, they also cause shifts in forest structure and composition. Forest structure may be greatly altered as average tree size is reduced due to western pine beetle preferentially attacking larger trees. Following outbreaks there are often large increases in surface and ground fuels, especially after periods of peak snag fall (fig. 11), which may influence wildfire behavior and impacts.

Management Options

There are two strategies for managing western pine beetle: direct control and indirect control. Direct control is indicative of short-term tactics designed to treat current infestations through manipulating beetle populations with sanitation harvests, chemical applications (i.e., insecticides and pheromones), or both. Indirect control involves preventive measures designed to decrease the probability and severity of future western pine beetle infestations by reducing tree density, increasing tree vigor, and encouraging tree species and structural diversity. Information on the severity and extent of western pine beetle infestations necessary to develop management strategies requires accurate detection and survey methods. These range from simple ground-based surveys to aerial detection surveys using digital sketch mapping technology.

Insecticides

Insecticides may be a viable option for protecting uncolonized individual high-value trees in recreational or residential sites. These include contact insecticides

Figure 11. Left: Heavy surface fuel loads about 5 years after a western pine beetle outbreak. Photo by Crystal Homicz, University of California, Department of Entomology and Nematology. Right: Snags in an area of heavy ponderosa pine mortality caused by western pine beetle. Photo by Christopher Fettig, USDA Forest Service.

applied directly to the tree bole (bole sprays) or systemic insecticides injected directly into the tree (bole injections) near the root collar. Several formulations are available and highly effective (90 to 100 percent) when properly applied. Most provide two field seasons of protection with a single application. If conditions contributing to outbreaks do not change, preventative insecticide applications will be required until western pine beetle populations collapse. Lists of insecticide products registered for protecting trees from western pine beetle can be obtained online from State regulatory agencies.

Attractants and Repellants

Commercial western pine beetle lures and baits are available. The lures are composed of the female aggregation pheromone (*exo*-brevicomin), the male aggregation pheromone (frontalin) and myrcene, a volatile emitted by ponderosa pine. However, monitoring western pine beetle populations with pheromone-baited traps is not an effective method to predict tree mortality or outbreak potential.

Anti-aggregation pheromones and repellants may be useful to protect individual trees or small groups of trees. Recent research has demonstrated that verbenone (the beetle's anti-aggregation pheromone) in combination with nonhost volatiles ("Verbenone Plus") is an effective repellant although not currently registered for operational use. Verbenone as a stand-alone repellant is ineffective for protecting ponderosa pine from western pine beetle.

Silvicultural Practices and Sanitation

Western pine beetle impacts can be mitigated through short- and long-term silvicultural treatments. Stands with appropriate spacing among host trees provide some resistance to infestation. Encouraging tree species and size class diversity also increases resistance. Thinning practices that reduce average stand density to <90 ft^2 of basal area per acre (21 m^2/ha) or <230 SDI that also produce multistoried stands are considered the most effective indirect control treatments (fig. 12). As indicated above, however, ongoing research

Figure 12. A low-density stand of ponderosa pines with increased resistance to western pine beetle. Photo by Leif Mortenson, USDA Forest Service.

suggests that substantially lower stand densities are required to maintain adequate levels of resistance in contemporary forests due to recent increases in host stress (associated with climate change) and western pine beetle populations.

Prescribed fire may also be used to reduce stand density, or it can be used in tandem with thinning. However, shortly after prescribed fire, some trees may be weakened and more susceptible to western pine beetle attack. Removing duff and litter around the root collar of large (>30 inches [76 cm] DBH) ponderosa pines may reduce burn severity, which will reduce susceptibility to western pine beetle.

Sanitation treatments that remove or destroy trees infested by western pine beetle may be effective for limiting levels of tree mortality caused by western pine beetle at small spatial scales (e.g., several acres) if most of the infested trees are sanitized. It is best to remove infested trees during the fall or winter before beetle emergence occurs in spring. Sanitation is ineffective during large-scale outbreaks.

Restoration

Restoring forests impacted by western pine beetle requires a flexible approach with management decisions influenced by landowner objectives, severity of tree losses, and the overall condition and location of the affected area. In most forests, little or no restoration may occur. However, in the wildland urban interface removal of hazard trees may be important to protect human lives and critical infrastructure. Fuel treatments, such as prescribed fire, chipping, mastication, and thinning of trees, may be necessary in some forests. Planting of ponderosa pines, other drought-tolerant trees, or both may be necessary in areas of heavy tree mortality that lack adequate seed sources to rely on natural regeneration. Restoration provides an opportunity to create a more heterogeneous landscape increasing overall resistance to western pine beetle outbreaks and other disturbances.

Assistance

Forest landowners can obtain more information on western pine beetle, treatment options, and technical assistance concerning the use of pesticides in the United States from a pest control advisor, their local university cooperative extension office, the county agricultural commissioner's office, or their local U.S. Department of Agriculture (USDA), Forest Service, Forest Health Protection program representative (http://www.fs.fed.us/foresthealth/). This publication and other Forest Insect and Disease Leaflets are available online (https://www.fs.fed.us/foresthealth/publications/fidls/index.shtml).

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References

Fettig, C.J. 2016. Native bark beetles and wood borers in Mediterranean forests of California. In: Lieutier, F.; Paine, T.D., eds. Insects and diseases of Mediterranean forest systems. Switzerland: Springer International Publishing: 499–528. Chapter 18.

Fettig, C.J. 2019. Socioecological impacts of the western pine beetle outbreak in southern California: lessons for the future. Journal of Forestry, 117: 138–143.

Fettig, C.J.; Egan, J.M.; Delb, H.; Hilszczański, J.; Kautz, M.; Munson, A.S.; Nowak, J.T.; Negrón, J.F. 2021. Management strategies to reduce bark beetle impacts in North America and Europe under altered forest and climatic conditions. In: Gandhi, K. and Hofstetter, R.W., eds. Bark beetle ecology, management and climate change. New York: Elsevier Publishing: 345–394.

Fettig, C.J.; McKelvey, S.R.; Dabney, C.P.; Huber, D.P.W.; Lait, C.G.; Fowler, D.L.; Borden, J.H. 2012. Efficacy of “Verbenone Plus” for protecting ponderosa pine trees and stands from *Dendroctonus brevicomis* (Coleoptera: Curculionidae) attack in British Columbia and California. Journal of Economic Entomology, 105: 1668–1680.

Fettig, C.J.; Mortenson, L.A.; Bulaon, B.M.; Foulk, P.B. 2019. Tree mortality following drought in the central and southern Sierra Nevada, California, U.S. Forest Ecology and Management, 432: 164–178.

Hayes, C.J.; Fettig, C.J.; Merrill, L.D. 2009. Evaluation of multiple funnel traps and stand characteristics for estimating western pine beetle caused tree mortality. Journal of Economic Entomology, 102: 2170–2182.

References (continued)

Huber, D.P.W.; Fettig, C.J.; Borden, J.H. 2021. Disruption of coniferophagous bark beetle (Coleoptera: Curculionidae: Scolytinae) mass attack using angiosperm nonhost volatiles: from concept to operational use. The Canadian Entomologist, 153: 19–35.

Miller, J.M.; Keen, F.P. 1960. Biology and control of the western pine beetle. Misc. Publ. 800. U.S. Department of Agriculture, Washington, DC. 381 p.

Oliver, William W. 1995. Is self-thinning in ponderosa pine ruled by *Dendroctonus* bark beetles?. In: L. G. Eskew, comp. Forest health through silviculture: proceedings of the 1995 National Silviculture Workshop, Mescalero, NM, May 8–11, 1995. Gen. Tech. Rep. RM-GTR-267. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 213–218.

Pureswaran, D.S.; Hofstetter, R.W.; Sullivan, B.T.; Grady, A.M.; Brownie, C. 2016. Western pine beetle populations in Arizona and California differ in the composition of their aggregation pheromones. Journal of Chemical Ecology 42: 404–413.

Six, D.L.; Bracewell, R. 2015. *Dendroctonus.* In: Vega, F.E. and Hofstetter, R.W., eds., Bark beetles: Biology and ecology of native and invasive species, London: Academic Press: 305–350. Chapter 8.

Stark, R.W.; Dahlsten, D.L.; Berryman, A.A. 1970. Studies on the population dynamics of the western pine beetle, *Dendroctonus brevicomis* LeConte (Coleoptera: Scolytidae). University of California, Division of Agricultural Sciences, Berkeley, CA. 174 p.

Steele, R.; Williams, R.E.; Weatherby, J. C.; Reinhardt, E.D.; Hoffman, J.T.; Thier, R.W. 1996. Stand hazard rating for central Idaho forests. INT-GTR-332. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, 30 p.

Stephen, F.M.; Dahlsten, D.L. 1976. The arrival sequence of the arthropod complex following attack by *Dendroctonus brevicomis* (Coleoptera: Scolytidae) in ponderosa pine. The Canadian Entomologist, 108: 283–304.

Sullivan, B.T.; Grady, A.M.; Hofstetter, R.W.; Pureswaran, D.S.; Brownie, C.; Cluck, D.R.; Coleman, T.W. [et al]. 2021. Evidence for semiochemical divergence between sibling bark beetle species: *Dendroctonus brevicomis* and *Dendroctonus barberi.* Journal of Chemical Ecology, 47: 10–27.

Valerio-Mendoza, O.; Armendáriz-Toledano, F.; Cuéllar-Rodríguez, G.; Negrón, J.F.; Zúñiga, G. 2017. The current status of the distribution range of the western pine beetle, *Dendroctonus brevicomis* (Curculionidae: Scolytinae) in Northern Mexico. Journal of Insect Science, 17: 92.

Valerio-Mendoza, O.; García-Román, J.; Becerril, M.; Armendáriz-Toledano, F.; Cuéllar-Rodríguez, G.; Negrón, J.F.; Sullivan, B.T.; Zúñiga, G. 2019. Cryptic species discrimination in western pine beetle, *Dendroctonus brevicomis* LeConte (Curculionidae: Scolytinae), based on morphological characters and geometric morphometrics. Insects, 10: 377

Pesticide Precautionary Statement

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

Caution: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

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