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# Mountain Pine Beetle

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# Mountain Pine Beetle

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## Introduction

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins (*Coleoptera: Curculionidae, Scolytinae*) is a member of a group of insects known as bark beetles. Its entire life cycle is spent beneath the bark of host trees, except when adults emerge from brood trees and fly in search of new host trees.

*Mountain pine beetle-killed whitebark pine in Yellowstone National Park, 2004.*

Mountain pine beetles can reproduce in all species of pine within their range. Outbreaks often develop in dense stands of large-diameter (>8 inches), older (>80 years-old) lodgepole pine and dense stands of mid-sized (8-12 inches diameter) ponderosa pine. When weather is favorable for several consecutive years, severe outbreaks can occur in high-elevation stands of whitebark and limber pine. Widespread outbreaks develop over several years and can result in millions of dead trees. Periodic losses of high-value, mature sugar and western white pine are less widespread, but also serious.

Extensive tree mortality associated with a mountain pine beetle outbreak can significantly influence successional pathways and forest community

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composition. Many ecosystems have become dependent on mountain pine beetle disturbance events and subsequent wildfire for forest renewal. However, outbreaks can also deplete commercial pine forests. Late successional tree species that are less commercially valuable, such as subalpine fir, often replace more valuable pioneer species, such as lodgepole pine, that have been killed by mountain pine beetle. Many wildlife species may benefit from mountain pine beetle outbreaks, including birds that feed on developing larvae and nest in dead trees. However, in the short-term, composition and distribution of others, such as elk and deer, may be affected by a reduction in hiding and thermal cover. Other forest processes such as water yield and wildfire extent and severity can also be affected in the long- and short-term by tree mortality associated with mountain pine beetle outbreaks.


*Figure 1. The range of mountain pine beetle generally follows its major host pine species throughout western North America (shown in green). Current range of mountain pine beetle extends from northern Baja California, Mexico and southern Arizona, US to central British Columbia, Canada. In recent years, mountain pine beetle outbreak populations (shown in red) have been found further north into British Columbia and east into Alberta than had been observed in historical records, including an outbreak in 1985.*

## Range and Hosts

Mountain pine beetles are native to pine forests of western North America. They are found from the Pacific Coast east to the Black Hills of South Dakota, and from central British Columbia and western Alberta to northern Baja California, Mexico (Figure 1). Their habitat ranges from near sea level in British Columbia, to 11,000 feet in southern California.

Major hosts of mountain pine beetle include lodgepole, ponderosa, western white, sugar, limber and whitebark pines. All pine species within in their range, including Coulter, foxtail, pinyon, and bristlecone pines, can also be infested and killed. Scotch and Austrian pines, introduced into North America as ornamentals, Christmas trees and/or forest plantations, are also susceptible to attack. Douglas-fir, true firs, western larch, incense-cedar and western hemlock are occasionally attacked, but because they are not true hosts, broods rarely develop. Recently, mountain pine beetle has been found producing viable brood in spruce. Attacks on trees other than pines usually only occur when nearby pines are heavily infested and beetle population levels are high.

## Evidence of Infestation

Mountain pine beetle typically initiates attacks on the lower 15 feet of a tree bole, although the crown of large trees, particularly sugar pine, may be attacked first. During outbreaks, a tree is generally "mass-attacked" and killed by girdling of the phloem (i.e., layers of cells just inside the bark that transport photosynthate within the tree) by beetles of a single generation. When population levels are low, partial attacks around the bole's circumference referred to as "strip attacks," may result in two or more generations of beetles before the tree is killed. Strip–attacked trees may survive for many years.

Signs of a mountain pine beetle attack include "pitch tubes" which are made when female beetles bore into the tree's bole. On successfully attacked trees, pitch tubes are cream to dark-red masses of resin mixed with phloem boring dust, and are about one-fourth to one-half inch in diameter. When beetles are not present in sufficient numbers to overcome a tree's defenses, enough resin is produced at the attack site to "pitch out" beetles as they attempt to bore into the inner bark. Pitch tubes on unsuccessfully attacked trees are larger, three-fourths to one-inch in diameter, generally generally lighter in color, and widely scattered over the trunk (Figure 2).

In addition to pitch tubes, successfully infested trees will have dry, reddish-brown boring dust, similar to fine sawdust, in bark crevices along the tree bole and around the tree base (Figure 3). Infested trees may also have boring dust but no apparent pitch tubes. These trees, referred to as "blind attacks," are more common during periods of drought when trees may be stressed and capable of producing little pitch.

*Figure 2: Unsuccessful mountain pine beetle attack—commonly called a "pitchout."*

Needles on successfully infested trees begin changing color several months to a

*Figure 3: Pitch tubes and boring dust—indicative of a successful mountain pine beetle attack in lodgepole pine.*

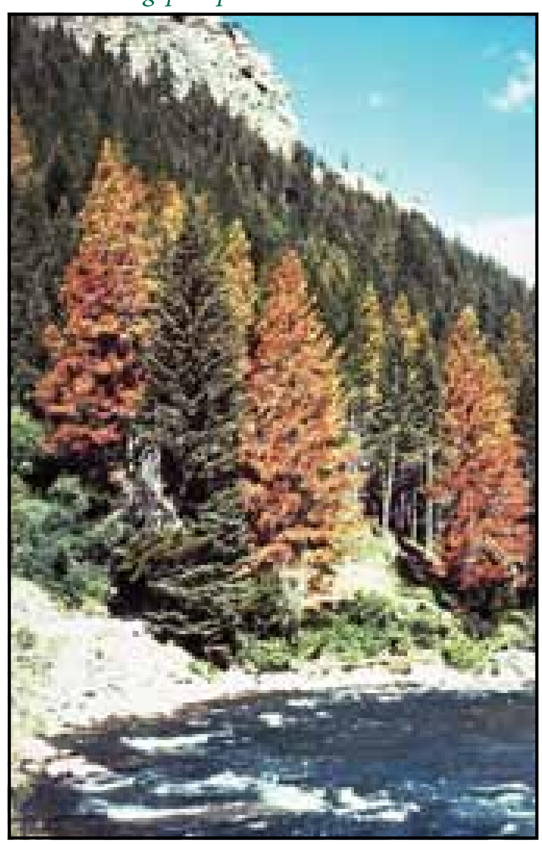

*Figure 4. Fading mountain pine beetle-killed lodgepole pines. Trees generally fade 8-10 months after being attacked.*

*Figure 5. Blue-stained sapwood of a mountain pine beetle-killed tree.*

year after attack. In unusually dry years, foliage may begin to fade within a few weeks. Needles change from green to yellowish green, then sorrel, red, and finally rusty brown (Figure 4, see page 3). Fading often begins in the lower crown and progresses upward in lodgepole pine, but may vary somewhat with other hosts. In large-diameter, tall sugar pines, for example, upper crown fading may be the first sign of an infestation.

Mountain pine beetle is associated with several fungal species including *Ophiostoma montium* and *Grosmannia clavigera*. Attacking beetles carry spores of the fungi on their bodies and in specialized structures called mycangia. Fungi are inoculated into the tree by adult beetles, and developing larvae and new adults obtain vital nutrients by feeding on fungal structures that spread throughout the phloem and sapwood. In addition to providing nutrients for developing brood, fungi can also alter patterns of water and resin flow in the tree, aiding in tree death. One to several months after the tree is infested, the sapwood discolors to a bluish tint caused by these "bluestaining" fungi (Figure 5).

Woodpeckers often feed on developing or overwintering larvae beneath the bark, and in doing so can make holes in thick barked trees such as ponderosa pine, or may completely remove the bark from thinned bark trees such as lodgepole and whitebark pine. These signs, plus resulting piles of bark flakes around a tree base, can also be evidence of mountain pine beetle infestation.

## Life History

Beetles develop through four stages: egg, larva, pupa, and adult. Except for a few days during the summer, when adults emerge from brood trees and fly to attack new host trees, all life stages are spent beneath the bark.

Temperature has a significant influence on mountain pine beetle development and survival. Populations across the beetle's wide range have adapted to local temperature regimes, resulting in variability in the time required to complete a generation as well as timing of individual life-stage development. In low elevation stands and in warm years, mountain pine beetle require one year to complete a generation. At higher elevations, where summers are typically cooler, life cycles may vary from one to two years.

Female beetles initiate attacks. During the process of chewing into the inner bark and phloem, aggregating pheromones are released attracting hundreds of male and female beetles to the same tree within a few days. More attacking beetles produce more attractant pheromones, resulting in a mass attack that overcomes the tree's defenses. Male beetles also produce pheromones, including anti-aggregating pheromones that help regulate the number of attacks on an individual tree to prevent overcrowding. This dynamic combination of pheromones also results in attacks on adjacent live trees, producing groups of dead trees across a landscape.

Mating occurs under the bark, after which females construct straight, vertical egg galleries. Packed with boring dust, these galleries are mostly in the phloem, or inner bark, although they often slightly score the sapwood. Galleries may range from 4-48 inches in length, depending on attack density, but average about 10 inches (Figure 6).

Tiny, pearl-white eggs are laid in niches along both sides of egg galleries. Timing of egg laying is dependent on temperature and geographic location, but typically occurs from late June to late August. Eggs hatch in 10-14 days, although they may take longer in cooler weather (Figure 7).

Eggs may also be laid in late spring by females that survived winter. Surviving females and males may either re-emerge and attack new trees or merely extend egg galleries in the same tree where they overwintered.

*Figure 6. Mountain pine beetle egg and larval galleries.*

*Figure 7. Mountain pine beetle adult and eggs in egg gallery.*

Larvae are legless white grubs with brown heads that feed in the phloem, constructing galleries that extend at right angles to the egg gallery. Development through four larval stages (instars) is temperature dependent and therefore highly variable from year to year and site to site. The final larval instar excavates an oval cell where pupation occurs and the new adult is formed. New, immature adults spend a period of time maturation feeding on fungal spores and associated tree tissue before emerging. When several feeding chambers coalesce, adults may be found in groups, and one or more beetles often emerge from the same exit hole. Within one or two days of emerging, adults seek out and attack new trees, to resume the yearly cycle (Figures 8, 9, 10).

## Factors Affecting Outbreaks

Mountain pine beetle populations can exist at low levels in pine ecosystems for decades infesting and killing stressed trees, resulting in scattered and often insignificant levels of tree mortality. Eruption to an outbreak population and subsequent widespread tree mortality are dependent on a number of factors, including favorable climatic and stand condi-

*Figure 8. Mountain pine beetle larvae in feeding galleries.*

*Figure 9. Larvae transform to pupae within cells constructed at end of feeding gallery.*

*Figure 10. "Callow" or immature adults darken before emerging to complete life cycle.*

tions as well as proximity to an existing beetle population.

***Temperature.*** Mountain pine beetle population success is influenced by temperature in several ways. Cool temperatures may retard development, resulting in longer lifecycles and/or a disruption of critical timing of summer emergence necessary for a coordinated and successful mass attack. Also, excessively warm temperatures could speed up development and similarly disrupt emergence timing. Cold temperatures can directly affect mountain pine beetle survival. Although mountain pine beetles have mechanisms that enable survival in sub-freezing conditions, unseasonably low temperatures for extended periods of time in winter can cause excessive mortality in all lifestages. In particular, dramatic temperature drops in autumn and spring can result in death of many individuals.

***Tree Resistance.*** To reproduce, mountain pine beetles must successfully locate and colonize suitable hosts. Colonization requires overcoming tree defenses and can only be accomplished by recruitment of a critical minimum number of beetles, which varies with changes in host vigor. When the number of mountain pine beetles emerging to attack new trees is low, healthy trees may produce sufficient resin to prevent successful attacks. Beetles either drown in toxic resins as they bore into the inner bark, or abandon the tree. If a large number of beetles are available to attack a tree within a short time period, even a relatively healthy tree can be overcome. Several factors can influence tree resistance including precipitation, temperature, stand density, and pathogen infections.

***Predators and Parasites.*** Nematodes, worm-like internal parasites, can hinder or prevent egg production. Other nematodes feed on eggs after they are laid.

A dolichopodid fly and two species of checkered beetles are common predators of both adults and immature beetles. Parasitic wasps are also prevalent in mountain pine beetle populations. All may reduce beetle populations substantially in individual trees, but none have been shown to significantly influence mountain pine beetle populations during outbreaks.

Many species of woodpeckers feed heavily on developing or overwintering larvae. In their search for larvae, woodpeckers make holes or large openings in the bark causing the remaining bark to dry more quickly, subsequently killing additional larvae. Woodpeckers can significantly influence beetle mortality during endemic populations, but are not considered important in regulating outbreaks (Figure 11).

***Competition.*** Mountain pine beetle larvae compete for food and space not only with each other, but with larvae of other insect species. For example, larvae of

*Figure 11. Woodpecker feeding on overwintering larvae typically has little effect on outbreak populations.*

wood boring beetles, which are also found within the inner bark, can canabilize large numbers of mountain pine beetle brood. Other bark beetles with faster development time and/or attack timing can utilize the food resource ahead of slower developing mountain pine beetle.

***Stand and Landscape Characteristics.*** Weather, host trees and community associates are important to rapid expansion of mountain pine beetle populations. Spread of a population across a landscape, however, is also dependent on a variety of stand and landscape characteristics that may differ by ecosystem. Stands with characteristics susceptible to mountain pine beetle population outbreaks are referred to as high "hazard." Generally, adequate food (host trees), of a suitable size and age are required across large areas for a widespread outbreak to occur.

Mountain pine beetle outbreaks in lodgepole pine develop and are sustained in areas with an average age >80 years, average tree diameter (at breast height) >8 inches, stand stocking between 300-600 trees per acre, and at an elevation/latitude combination suitable for beetle survival (Figure 12). When the majority of larger-diameter lodgepole pines have been infested and killed, beetles tend to infest smaller and smaller trees. Phloem is thinner and dries more quickly in such trees and fewer offspring are produced. Once the food supply has been exhausted and/or weather becomes unfavorable, populations decline.

In second-growth ponderosa pine stands in the Black Hills and Rocky Mountains, highly susceptible stands are generally those that are densely stocked (i.e., for average stand diameter of 10-12 inches, >150 square feet basal area per acre), have an average diameter >10 inches, and are even-aged and single-storied. The role of mountain pine beetle in ponderosa pine stands at some western locations may be secondary to that of western pine beetle (*D. brevicomis* LeConte), particularly in larger diameter (>12 inches in diameter) trees. Occasionally, mountain pine beetle infestations are confined to small-diameter (<12 inches diameter) ponderosa pines with single trees or small groups of trees being killed. In all cases, a stand may remain uninfested for decades until conditions are suitable for beetle population growth.

## Management Options

Management options for mountain pine beetle populations are scale and time-dependent. Options include: 1) short-term prevention techniques, aimed at manipulating beetle populations, 2) long-term prevention techniques targeted at the stand and landscape, and 3) restoration of affected landscapes.

*Figure 12. A "high-hazard" lodgepole pine stand, very susceptible to mountain pine beetle infestation.*

### *Short-term Prevention*

Insecticides. Preventive treatments, applied before trees are infested by beetles, are an

effective use of insecticides to protect individual high-value trees. Useful in campgrounds, around home sites, or to protect valuable seed-producing trees, preventive sprays can effectively, efficiently, and economically protect trees from beetle attack. However, if stand conditions contributing to outbreaks are not changed, periodic treatments will be necessary as long as epidemics exist in the area
(Figure 13).

Insecticides are registered and periodically reviewed by the U.S. Environmental Protection Agency. Persons contemplating the use of insecticides should contact pest control or forest health professionals to ensure proper use.

<u>Pheromones</u>. As noted previously, beetles produce both aggregative and anti-aggregative pheromones that are used to manipulate their populations to their advantage. Many of these "message-bearing" chemicals have been identified, and their production synthesized. Forest health professionals and resource managers can use these chemicals to manipulate beetle populations to our advantage.

Synthesized aggregative pheromones can be used as tree "'baits" and in traps to attract and contain small spot infestations, thus reducing probability of spread into nearby susceptible stands. To be effective, aggregative pheromones must be used in combination with removal of infested trees. Anti-aggregative pheromones, such as verbenone, show promise in preventing attacks on high-value sites. Both strategies may be used to manipulate beetle populations to our advantage until silvicultural treatments can be implemented to reduce stand susceptibility, or beetle populations naturally return to endemic levels (Figure 14).

Synthetically produced pheromones are registered and periodically reviewed by the U.S. Environmental Protection

*Figure 13. Preventive treatments can successfully protect susceptible hosts from mountain pine beetle attacks.*

*Figure 14. Verbenone can be an effective preventive treatment in some situations.*

Agency. Persons contemplating the use of pheromones should contact a forest health professional to ensure proper use. Inappropriate use can result in unintended tree mortality.

### *Long-term Prevention*

Stand conditions associated with mountain pine beetle outbreaks have been quantified for several pine types. Several hazard rating models are available for identifying stands that are most likely to be infested, and to predict expected levels of beetle-caused tree mortality should an outbreak occur. Although less certain, models also have been developed for predicting stand risk, an estimate of when a stand will become infested. Risk models include a measure of the proximity of an active mountain pine beetle population. Resource managers can use available models to incorporate mountain pine beetle information into planning processes, so appropriate action can be taken prior to outbreak initiation.

Silviculture. Silvicultural measures, such as thinning (Figure 15), have been shown to minimize mountain pine beetle-caused tree mortality in some lodgepole and ponderosa pine stands if performed prior to outbreak initiation. Opening the stand through thinning influences beetle populations by 1) changing microclimate and wind patterns within the stand, 2) allowing beetle-produced pheromones to dissipate through opened crowns, and 3) providing more growing space, nutrients, and water for remaining trees.

Patch-cutting in lodgepole pine landscapes creates a mosaic of age and size classes, which reduces acreage of lodgepole pine that will be highly susceptible to mountain pine beetle attack at any one time. Where clear- or patch-cutting is not an option, selective harvesting can help reduce beetle-related damage. Susceptible trees can be removed selectively in riparian zones, along roads, in campgrounds, and in scenic vistas.

Salvage can retrieve timber that would otherwise be lost, and if infested trees are removed and disposed of before beetles emerge, some reduction in beetle populations will be realized. However, salvage logging of infested trees, while a large outbreak is underway, is generally not effective for reducing subsequent levels of mountain pine beetle-caused tree mortality. Additionally, beetle-infested trees and resultant snags and woody debris are important for many species of wildlife, nutrient recycling and tree regeneration.

Silvicultural strategies to reduce stand susceptibility to mountain pine beetle outbreaks in host species other than lodgepole and ponderosa pines have not been developed.

*Figure 15. Silvicultural treatments offer the best long-term means of protecting susceptible stands from mountain pine beetle infestation.*

Prescribed fire is an additional option for altering stand density to reduce overall susceptibility to mountain pine beetle attacks. However, sublethal heating of critical plant tissue during prescribed burns can stress residual trees, which then may become more susceptible to bark beetle attack. Care should be taken to reduce fire-caused injury to desirable trees, especially in thin-barked species.

### *Restoration*

Forest landscapes comprised of diverse tree species, ages, and size classes may be less susceptible to widespread levels of mountain pine beetle-caused tree mortality. Restoration efforts emphasizing diversity, especially at landscape scales, are viable management strategies. Such efforts will require an understanding of host-site relationships, and may entail manipulation of stand density and species composition through silvicultural means.

## Additional Information

Private landowners can get more information about mountain pine beetle ecology and management from local Cooperative Extension agents, State agricultural experiment stations, county Extension offices, and Forest Health Protection staffs, USDA Forest Service. Federal or State resource managers should contact the Forest Health Protection office—either Federal or State—in their area.

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