Insect Outbreaks

Insects play an important role in structuring the forests of eastern Washington at a variety of scales, ranging from the death of an individual tree, to the elimination of an entire species from a stand, to the near-complete mortality of a forested landscape. With few exceptions, all of the insect species in question are native to eastern Washington and have co-existed with their host tree species for thousands of years.[3] Most damage to forests from insects can be categorized as endemic or epidemic. ***Endemic mortality*** refers to low-level, background mortality that occurs every year with natural variation in the species causing the mortality, population dynamics, and region of impact. ***Epidemic mortality*** refers to rapid, massive, high-mortality outbreaks. While both types of mortality were present in the region prior to Euro-American settlement, epidemic

Figure 38. Engelmann spruce mortality resulting from spruce beetle attack. Such attacks can last for more than a decade.

[3] The balsam wooly adelgid (*Adelges piceae*), a European species that reached the West Coast in 1929, has been responsible for extensive mortality in all true firs (*Abies*), especially Rocky Mountain subalpine fir (*A. bifolia*) populations in eastern Washington.

outbreaks have increased in size and frequency as a result of fire suppression, forest simplification, landscape-level homogenization of forest stands, and the arrival of non-native insect species.

Most of the damage that occurred during the twentieth century is attributed a relatively small number of species, primarily bark beetles of the genus *Dendroctonus.* Each year, several million cubic meters of timber volume succumb to this genus in the western United States. The most damaging species are the mountain pine beetle (*D. ponderosae*), which attacks the four pine species native to eastern Washington, and the western pine beetle (*D. brevicomis*), which attacks primarily mature and old ponderosa pine. Other notable species include the Douglas fir beetle (*D. pseudotsugae*) and the spruce beetle (*D. rufipennis*). As most of the damage is in the form of endemic mortality, proactive management options are limited. The ecological factors that control insect

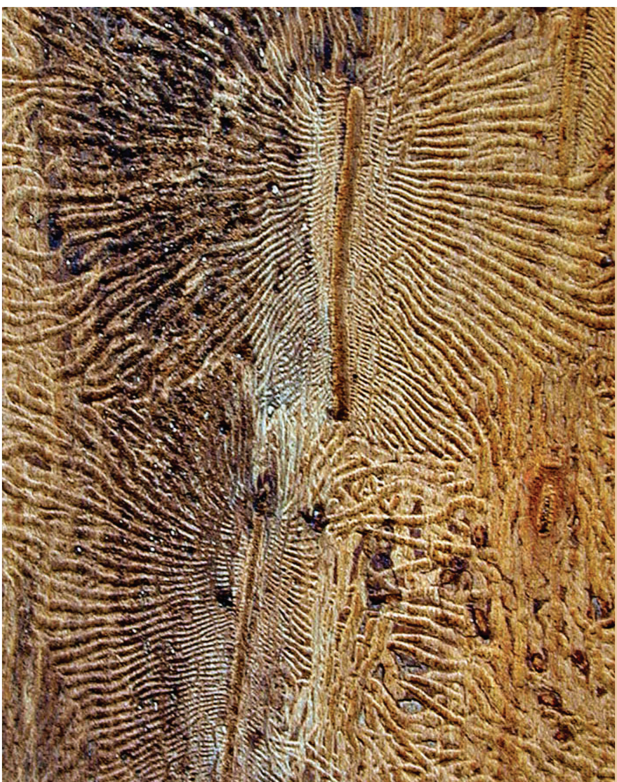


Figure 39. Bark beetle galleries. Adult beetles excavate galleries within the inner bark in which to lay their eggs, and the emerging young excavate galleries of their own. In sufficient numbers, the intricate patterns may have a lethal effect on the host tree.

populations are complex and include a combination of climatic conditions and forest stand structure. Periodically, favorable conditions lead to a rapid growth in bark beetle populations and large numbers of trees are killed over a large area. Such outbreaks do not occur frequently—the time interval often is measured in decades. Following an event, the probability of catastrophic wildfire may increase as the extensive mortality greatly increases fuel loading (Figure 38).

An initial attack starts with a pioneering beetle on a random flight. A tree is selected using olfactory cues and the adult bark beetle bores into the bark, excavating galleries in the inner bark in which to lay eggs. Upon hatching, the young larvae mine galleries of their own (Figure 39). If enough beetles are present, the tree becomes girdled and dies. Of course, some tree species are more vulnerable than others. A healthy tree may ***pitch out*** the attacking beetle—the hole in the bark begins a flow of pitch in resinous trees, such as ponderosa pine or

Figure 40. Bark beetle mortality. A large ponderosa pine, already stressed by a near fatal wildfire, became easy prey for marauding bark beetles.

western larch, which may discharge the beetle. Upon successfully establishing itself in a tree, the beetle exudes a powerful pheromone, signaling others nearby that a suitable host tree has been located. This triggers a secondary attack which can consist of several dozen beetles. Trees already under stress from drought or fire damage, or those located near large beetle populations established in other recently dead trees, are most likely to be killed (Figure 40).

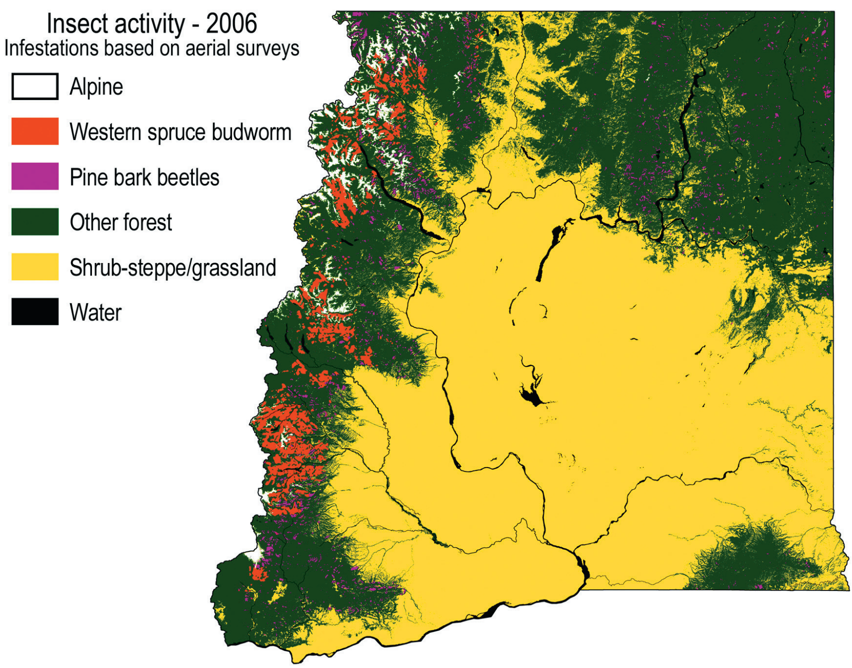
The other primary type of forest insect pests is defoliators. Adult defoliating moths lay their eggs in the buds of trees. The eggs hatch into caterpillars that feed on the emerging new leaves. In sufficient numbers, the caterpillars may eliminate essentially all of a tree's annual production of leaves. Of the many native defoliators in western forests, the two most important in eastern Washington are the western spruce budworm (*Choristoneura occidentalis*) and the Douglas fir

Figure 41. Defoliation by western spruce budworm. An outbreak along the North Cascades highway has taken its toll on the fir and spruce population, leaving the telltale reddish foliage. The few green trees in the photo are pines, which were unaffected.

tussock moth (*Orgyra pseudotsugata*). Both are primarily epidemic species. In eastern Washington, Douglas fir, Engelmann spruce, grand fir, and subalpine fir are the species most susceptible to defoliators (Figure 41). Outbreaks of the Douglas fir tussock moth can be intense, lasting two to four years, before subsiding for many years. Outbreaks of western spruce budworm can last anywhere from a year or two to several decades.

Both bark beetles and defoliators have greatly benefitted from past management practices. Fire suppression and high-grade logging techniques have combined to form forests more susceptible to epidemic insect outbreaks. An excessive number of stems creates stress in all of the trees as they compete for limited below-ground resources—including the main canopy dominants. Both bark beetles and

Figure 42. 2006 map of insect pest activity in eastern Washington. Only those infestations detectable via aerial surveys were mapped. Survey conducted jointly by Washington State DNR and U.S. Forest Service.



defoliators can take advantage of these conditions to mount a successful attack. Forest simplification also contributes to the problem by creating ideal conditions across a wider area. A naturally patchy landscape would have susceptible stands separated from each other by more resistant stands, preventing insect populations from reaching epidemic proportions. Surveys conducted jointly by the Washington State Department of Natural Resources and the U.S. Forest Service indicate that the insect currently causing the most extensive mortality is the western spruce budworm (Figure 42).

Mistletoes

Mistletoes are parasitic plants that grow in the crowns of many tree species found in eastern Washington. Leafy mistletoes, such as members of the genus *Phoradendron*, infect crowns of Oregon white oak. Dwarf mistletoes, in contrast, are small, leafless plants that infect the twigs in the outer crowns of trees (Figure 43). The majority of dwarf mistletoe species are host-specific—that is, they infect only one species or a group of similar species. Most members of the pine family are susceptible to dwarf mistletoes of the genus *Arceuthobium*. Unlike leafy mistletoes, these parasitic plants do little photosynthesis themselves—they get most of their food in the form of sugars from photosynthesis of their host tree. The aerial shoots they produce mostly serve a reproductive function.

Figure 43. Dwarf mistletoe on a subalpine fir. The female plant pictured is covered with ripening seeds, which will be explosively discharged when fully ripe. The sticky seeds can travel as far as 15 m (49 ft), and will occasionally land in the crown of a nearby tree, creating risk of a possible future infection.

Figure 44. Broom formation. Many dwarf mistletoes will form *brooms* on the branches of the host tree – dense areas of wood and foliage caused by altering growth hormone concentrations in the vicinity of the infection.

Dwarf mistletoes possess a bizarre seed dispersal mechanism—the seeds are explosively discharged when ripe and coated with a sticky covering that can adhere to the leaves or stems on which they land. Depending on wind conditions and the location of the plant within the tree crown, the seeds can sometimes travel 10-15 m (33-49 ft) away from the parent plant. While impressive, this is a limited distance when compared to other mechanisms of seed dispersal. Gravity limits the upward migration of infections—the heaviest infections typically occur in the lower crowns. Occasional, wider dispersal may occur when the sticky seeds adhere to a bird and are transported to another tree farther away.

Figure 45. Large mistletoe broom in Douglas fir. The brooms of Douglas fir dwarf mistletoe can grow to exceptional size, often severely affecting the growth and health of the tree.

As a parasite, the mistletoe makes use of sugars produced by the host, reducing their availability for tree growth. Hormones produced by the mistletoe also cause excessive, but deformed growth in the vicinity of the infection. These infections often result in ***broom*** formation—dense areas of foliage and branches, which appear as a star-shaped formation easily visible within the crown (Figure 44). Depending on the species, these brooms can grow to be quite large (Figure 45).

Several species of mistletoe infect members of the Pine family in eastern Washington. The size and distribution of these infections can be indirect indicators of tree and stand age. The two most prevalent are the Douglas fir dwarf mistletoe (*A. douglasii* — Figure 46) and the larch dwarf mistletoe (*A. laricis* — Figure 47). Another common species is the lodgepole pine dwarf mistletoe (*A. americanum* — Figure 48). Ponderosa pine is parasitized by the

Figure 46. Extreme Douglas fir dwarf mistletoe infection. In some instances, the dwarf mistletoe will kill all of the non-infected portions of the tree, leaving just the remnants of brooms, as in this heavily infected Douglas fir.

western dwarf mistletoe (*A. campylopodum*), a species that does not readily form brooms, but instead is more common on the main trunks of trees (Figure 49).

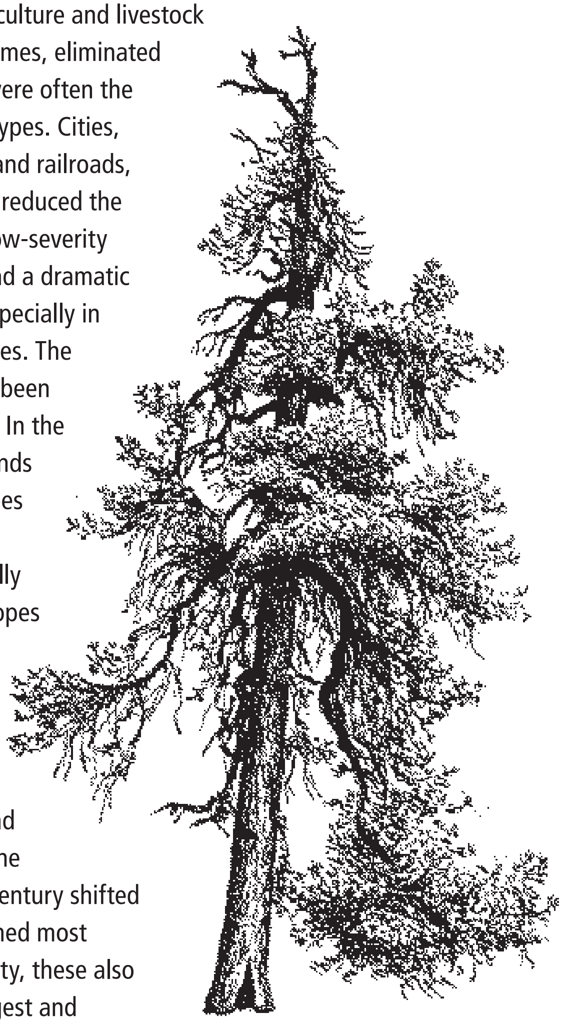
Figure 47. Severe larch dwarf mistletoe infection. All non-infected portions of these two trees are dead. The outlook of such trees is bleak.

Figure 48 above. Lodgepole pine dwarf mistletoe. Ripening seeds of the female plant.

Figure 49 left. Western dwarf mistletoe. The male plant (above) and female plant (below) are both growing out of the main trunk of this young ponderosa pine.

Landscapes, Stands, and Individual Trees

In eastern Washington, fire suppression, logging patterns, and livestock grazing have altered the natural disturbance cycles that originally shaped stand development and the fate of individual trees, leading to forest simplification and homogenization at the landscape level. Beginning in the mid nineteenth century, Euro-American activity began to reduce or eliminate fire from many landscapes. Agriculture and livestock grazing reduced and, sometimes, eliminated the abundant grasses that were often the source of fires in dry forest types. Cities, with their associated roads and railroads, fragmented areas and often reduced the extent and connectivity of low-severity fires. These changes have had a dramatic effect on forest structure, especially in low-elevation, dry forest types. The most significant change has been an increase in stand density. In the absence of frequent fire, stands became thick with young trees and grew to resemble the dense, wetter forests naturally occurring on north-facing slopes or at higher elevations.



Early Euro-American logging used ***highgrading***—the practice of removing only the largest and most valuable trees. While the focus during the twentieth century shifted to the removal of trees deemed most susceptible to beetle mortality, these also tended to be among the largest and oldest trees in a stand. Together, these practices simplified and homogenized forests in our region. Furthermore, excessive grazing by both cattle and sheep eliminated much of the natural grass cover that offered competition to tree seedlings, further contributing to denser stands. Additional grazing impacts include soil compaction, reduced vegetation cover, increased shrub/grass ratio, and increased soil erosion.

Over time, the above practices greatly reduced the differences between the (formerly) low-severity fire regime forests and those that were naturally denser. Large-scale forest simplification has led to forest patch sizes that are larger than those found in pre-Euro-American landscapes. Whether this change is irreversible is still being debated, but the imposed pattern has led to the current situation of large-scale insect epidemics and catastrophic loss due to wildfire, which only serve to exacerbate the problem.

In western Washington, where stand-replacing fires are the norm, the ages of the oldest trees in the stand are usually representative of the age of the stand itself. This is not often the case in the dry mixed-conifer forests of eastern Washington where many of the oldest trees, especially fire-resistant species, will have survived one or more previous fire events. The older the cohort of trees, the more diffuse these old trees will be across the landscape. At such low densities, aging the stand becomes problematic. A series of overlapping, low severity disturbances may lead to the establishment of multiple cohorts. What is the age of the stand in such a scenario? Or perhaps, more appropriately, how does one define the stand? In forests that experience low- and/or mixed-severity fire regimes, the concept of a stand begins to have little relevance in discussions of mature and old forests. Instead, it is the individual tree that determines the presence of old-growth conditions. This cohort of older, scattered legacy trees will serve as the foundation of any restoration plan.

However, in wetter forests that experience infrequent, stand-replacing fires, the stand is still the primary unit of concern—as it is in western Washington. Therefore, depending on the forest type and fire regime under consideration, the landscape, the stand, or the individual tree will be the focus.

Actual and Relative Shade Tolerance

An understanding of shade tolerance and its role in vegetation zones, tree interactions, and successional stage is essential in a guide devoted to determining the age of trees and stands of trees. While shade tolerance may at first seem only marginally related to determining age, it is actually a core concept of vegetation zones and how different tree species interact. Successional status, which will ultimately lead us to tree and stand age, is inseparably linked to an understanding of shade tolerance.

Shade tolerance can be thought of in two ways—actual and relative. ***Actual shade tolerance*** refers to the light level at which a tree can photosynthesize. At low light levels, photosynthesis may be insufficient to balance leaf respiration. With many trees, this balance point, known as the ***compensation point***, occurs at light levels of 2–3 percent of full sunlight (Figure 50). With light levels above this, photosynthesis increases nearly linearly up to a threshold, called the

Figure 50. A generalized view of leaf photosynthesis with increasing light levels. Peak photosynthetic efficiency occurs at the saturation point.

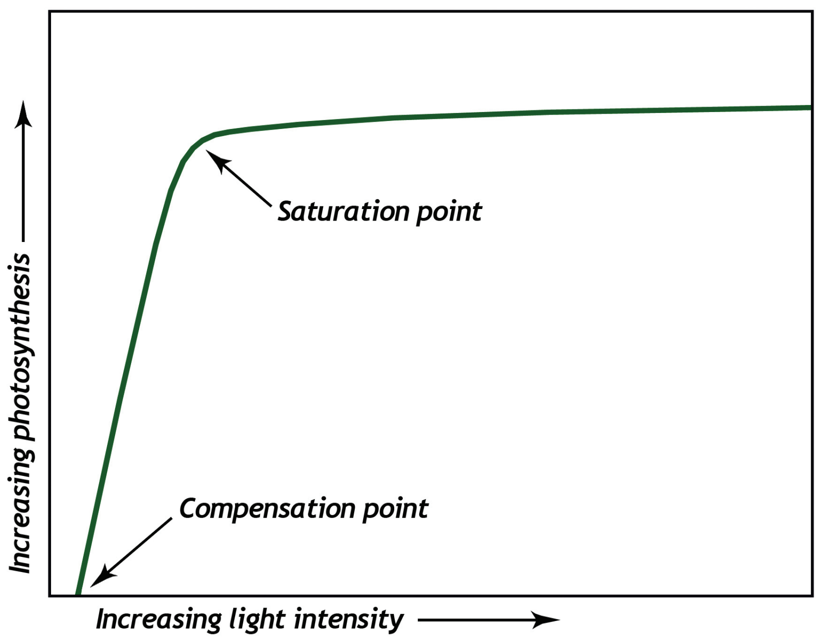


Figure 51. Leaf arrangement in response to light. Left – a fully illuminated shoot from the top of a noble fir tree showing aggregated leaves and self-shading. Below – a shaded shoot from the same stand with minimal self-shading and a high silhouette area ratio (SAR).

saturation point, at which peak photosynthetic efficiency occurs. Leaves cannot use all of the light from a fully illuminated position, so once the photosynthetic apparatus of the leaf is saturated, additional photons are converted to heat. Too much heat can be lethal to the leaf. Although the details will differ among species, the general form of this curve is common to all leaves.

Most trees, including many of the coniferous species, arrange their leaves differently around the stem under contrasting light conditions. For example, noble fir, a shade-intolerant species of subalpine forests in the south Cascades, displays dramatic differences in shoot morphology between branches growing under fully sunlit conditions and those found in the shade (Figure 51). Leaves at the top of the tree receive much more light than they can possibly use and aggregate themselves to provide self-shading. The leaves are oriented in such a way that no individual leaf is fully illuminated. In contrast, leaves in the deep shade exist in lighting conditions well below their saturation point, so aggregation and self-shading would not be beneficial. Instead, heavily shaded leaves are often oriented so that there is maximum exposure to the few photons that do reach them. In other words, these leaves minimize self-shading by orienting themselves perpendicularly to the sun's rays to maximize light interception. In many of our closed-canopy forests, only 1–5 percent of the available light reaches the ground, and most of this arrives in the form of diffuse light. Many of the understory species found in these forests, such as vanilla leaf (*Achlys triphylla*) or vine maple (*Acer circinatum*), orient their leaves parallel to the ground to get maximum exposure to the small amount of diffuse light available.

Each species varies with respect to its ability to aggregate and disperse its leaf orientation. Pines, in general, lack the ability to orient their leaves perpendicularly to the sun's rays or to minimize self shading. As a result, leaves from pines cannot exist in low-light levels. Firs, in contrast, are quite adept in this regard. A common measure of the ability of a shoot to maximize exposure is known as the Silhouette Area Ratio (SAR). SAR is the ratio of the projected area of a shoot to the projected area of all of the leaves individually. Pines typically have low SAR values of 0.3–0.5, indicating a high level of self-shading. The shade shoots of our most shade-tolerant tree species, including western hemlock, Pacific silver fir, western redcedar, grand fir, and Pacific yew (*Taxus brevifolia*), can have very high SAR values (0.95–0.99), indicating almost no self-shading (Figure 52). Shade-tolerant species are thus able to hold foliage lower in their crowns than other trees, often resulting in deeper, denser crowns. As a consequence, the shade cast by shade-tolerant trees is often much darker than that of their shade-intolerant associates.

Relative shade tolerance refers to the shade tolerance of one tree species when compared to its neighbors. Douglas fir, for example, will not grow in the shade of western hemlock or western redcedar. In such cases, its foliage will only exist in areas with high light levels, which in an older forest will be the upper canopy. All of the lower canopy levels, including regenerating trees in the understory, will be occupied by the leaves of shade-tolerant species. Throughout much of the forested parts of eastern Washington, however, where Douglas fir commonly grows with ponderosa pine and western larch, it behaves as a shade-tolerant species. These species of pine and larch have an even lower shade tolerance. In many of these forests, the understory environment is too dark for successful regeneration of the main canopy species. Instead, Douglas fir often is the species that occupies the lower canopy levels and regenerates in the understory. For these reasons, it is important to distinguish between actual and relative shade tolerance when discussing the shade tolerance of tree species.

Figure 52. Grand fir has one of the highest known silhouette area ratios (SAR), with values up to 0.99, indicating almost no self-shading of leaves.