Major Defoliating Insects of the Intermountain West

Western Spruce Budworm
Douglas fir Tussock Moth

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Western spruce budworm and Douglas fir tussock moth are widespread, native defoliating insects in western conifer forests. These defoliators will taste or nibble almost all western conifers, but Douglas fir and grand fir tend to be the most suitable hosts for successful completion of life cycles. Other somewhat suitable hosts include Engelmann spruce, western larch, and subalpine fir.

In recent decades, forests have become more susceptible to defoliators because thinning and composition control by natural fires has been almost eliminated. At normal low population levels, in "balanced" forest landscapes, defoliators periodically thinned forests helping to eliminate excessive shade tolerant Douglas fir and grand fir. Natural thinning by defoliators and bark beetles, along with natural ground fires, helped reduce the occurrence of large wildfires and insect outbreaks.

Now, after decades of fire suppression and poorly planned timber harvesting, millions of acres of "out-of-balance" forestland are encroached by Douglas fir and grand fir. These overstocked, often layered forests are attractive to defoliators and vulnerable to intense, costly to control wildfire. Insect outbreaks, along with wildfire, are now more likely as forest condition declines across much of the Intermountain West.

Defoliators, along with bark beetles, are perceived as "pest insects". During outbreaks, defoliators can be very destructive to forests infesting hundreds of thousands of acres. However, defoliators are not the problem. The actual problem is millions of acres of fire excluded, out-of-balance forests attractive to insects following their natural role in forest evolution.

Defoliator Infestations—Look For…

- Shriveled, reddish brown damaged needles that soon fall
- Bare branch tips
- Thin crowns and topkill
- Defoliation from top down and outside in
- Grayish-brown forest when viewed from a distance

For spruce budworm specifically…

- Larval feeding primarily on new foliage
- Needles bound together with webbing on individual or adjacent branch tips
- Drab hairless caterpillars
- Topkill or tree death only after several years of severe defoliation

For tussock moth specifically…

- Larval feeding on new and old foliage
- Loose webbing around leaders and multiple branch tips
- Colorful hairy caterpillars
- Defoliated upper crowns in late summer
- Topkill or tree death within 2 years
- Gray woolly cocoons on old foliage and branches

Effects and Impacts of Defoliation

Trees infested by defoliators suffer reduced growth, topkill, and sometimes death. Larvae (or caterpillars) eating needles cause the damage. The amount of sustained damage depends on the initial health and vigor of the tree, and on the intensity and duration of attack. Severely defoliated trees often die, but topkill is usually more common than mortality. Widespread mortality quickly increases fuel loading along with degrading the scenic quality of the landscape.

Defoliation limits the “factory” that drives tree growth causing an immediate reduction in photosynthesis. Food reserves gradually decline along with the capacity to resist the effects of defoliation and to recover.

Spruce budworm larvae prefer new foliage and only reluctantly eat foliage older than one year. Young tussock moth larvae also prefer new foliage, but once new foliage is depleted, maturing larvae readily consume older needles. Tussock moth larvae can completely defoliate and kill heavily infested trees. Trees may be stripped of foliage by late summer where larval populations are high.

Trees weakened by defoliators, particularly tussock moth, become vulnerable to attack by bark beetles. Douglas fir beetles and fir engraver beetles may kill more timber than the defoliator. Smaller trees tend to suffer more from the effects of defoliation, and larger trees tend to suffer more mortality from subsequent bark beetle attack.

Defoliator damage is seldom uniform throughout an infested stand, and it varies with tree species, too. Usually, the more shade tolerant species such as grand fir suffer greater damage than Douglas fir. Note that shade tolerance of Douglas fir varies with site conditions.

In mixed species stands, defoliator infestations tend to cause composition to shift toward nonhost and shade intolerant species such as ponderosa pine, western larch, and, on some sites, Douglas fir. Defoliators “thin” the infested forest favoring growth of nonhost species somewhat compensating for reduced growth of host species.

<u>Growth loss….</u>

Growth loss is a function of diminished height and diameter growth, or volume of wood produced. Volume loss can be quite variable.

- After 5 years of budworm infestation, stand volume growth reduction can range from 1 percent to 20 percent. Repeated infestations may cause much greater cumulative losses.

- A typical tussock moth infestation can reduce average stand volume growth by about 60 percent.

Topkill…

The upper tree crown is most vulnerable to defoliation because it has the most new foliage each year. Severe or repeated defoliation causes topkill resulting in forked tops and stem defects. The length of killed top tends to be quite variable. Topkill induced by spruce budworm requires several years of severe defoliation. Topkill induced by tussock moth can be achieved within 2 years because larvae consume both new and old foliage.

Budworm larvae eat new foliage causing partial defoliation. Several years of defoliation are needed before topkill occurs. Note the reddish tinge in the crowns caused by larvae-damaged needles.

(Forestry Images 1678006)

Upper crown defoliation by tussock moth larvae causes topkill within 2 years.

(USFS—Region 6)

Mortality…

Spruce budworm induced mortality is slow to occur, and it is usually light even after several years of defoliation. Mortality tends to be concentrated in smaller trees, especially suppressed trees. Overall, average stand mortality seldom exceeds 5 percent, but losses can be much higher in patches following several years of severe defoliation.

Tussock moth can cause quick and extensive mortality. In heavily defoliated areas, 40 to 70 percent mortality is common.

An overstocked stand defoliated by Douglas fir tussock moth. Note the pine in the foreground has not been damaged.

(Forestry Images 1678036)

Extensive mortality caused by a prolonged outbreak of spruce budworm. Many years of defoliation are needed for this level of damage. Note the fuel hazard increase.

(Forestry Images 0806071)

Conducive Habitats and Predisposing Factors

Forests most susceptible to attack and vulnerable to damage by spruce budworm and tussock moth have common characteristics. These include:

- More than 50 percent host species composition, mainly Douglas fir and grand fir.

  More host trees in a forest increase the food available to support a defoliator outbreak. Adjacent host trees facilitate dispersal of larvae. Lack of nonhost trees delays stand and forest recovery when outbreaks subside.

- Uneven or layered forest structures with large host trees in the overstory.

  Large overstory trees are most susceptible to initial infestation. Larvae disperse from overstory trees and infest smaller understory trees causing often-severe damage. Understory trees suffer the greatest defoliation because maturing budworm larvae descend from upper canopy layers and continue to feed on smaller trees with smaller crowns.

Understory saplings and pole-size trees partially defoliated and suffering topkill caused by spruce budworm. Understory host trees in uneven forests are often severely damaged by older, larger larvae descending from the overstory.

(Forestry Images 0806065)

- Overstocked or “crowded” forests (too many trees for soil conditions).

  Overstocking causes smaller, less vigorous trees with less foliage and smaller tree food reserves. Trees weakened by drought, made worse by overstocking, are less able to recover from partial defoliation.

Natural Controls

At normal ("endemic") population levels, defoliators are held in check by a combination of predators, parasites, and adverse weather. However, natural population controls can't prevent defoliator outbreaks in extensive out-of-balance forests especially during periods of drought.

Natural controls help dampen increasing defoliator populations. For example:

- Birds may consume over 80 percent of budworm larvae at normal population levels. Birds eat defoliator eggs and destroy pupae, too. Protecting and maintaining bird habitat helps support bird populations. An abundance of soft snags is especially beneficial.

- Ants, spiders, and other insects are efficient predators on larvae infesting smaller understory trees. Avoid disrupting ant colonies and down-log ant habitat during logging and thinning.

- Certain small wasps and flies parasitize eggs.

- Late spring frosts may kill large numbers of larvae. Cool, wet weather slows larvae development making them vulnerable to predators for a longer period.

Defoliator outbreaks naturally subside for several reasons including:

- Lack of food. Larvae starve once all available foliage is consumed.

- Lethal diseases infect larvae. For example, dense populations of tussock moth larvae trigger a lethal virus that quickly spreads stopping the outbreak. The virus persists for several years helping keep the tussock moth population in check.

Life Cycles

Understanding defoliator life cycles is not essential for planning effective preventive management, but understanding helps build appreciation for the complexity of these insects. Both defoliator species discussed in this report have roughly similar life cycles from a non-entomologist perspective, but there are important differences. A beginning similarity—spruce budworm and tussock moth each have one generation per year.

Western Spruce Budworm

Spruce budworm outbreaks develop slowly. Outbreaks may last a few years or for more than 30 years.

Adults are small, mottled, rusty-brown moths usually present in mid-summer. Both male and female moths fly.

An adult spruce budworm moth. Both males and females can fly.

(Forestry Images 0806075)

Female moths emit pheromones to attract males. Soon after mating, eggs are deposited in shingle-like masses on the undersides of needles. The light greenish egg masses usually contain 25 to 40 eggs. The adults, having completed the life cycle, then die.

Tiny spruce budworm egg masses on the undersides of true fir needles.

(USFS—Region 6)

Eggs hatch in about 10 days. The newly hatched larvae crawl into protective bark crevices or under bark scales, spin a tiny silken shelter called hibernacula, and remain dormant over winter.

In early spring, tiny larvae emerge from hibernaculae and mine into last year's needles or into buds. In mid- to late-spring, the growing larvae begin feeding on new needles. Damaged foliage on branch tips becomes reddish brown. Larvae grow rapidly with new foliage and are fully developed by mid-summer. Larvae feed on older needles only after new foliage is consumed.

A tiny spruce budworm larva (3rd instar) at its entrance hole in a Douglas fir bud—hence the name "budworm". The tiny larva seems to be looking out of its temporary home.

(Forestry Images 1678002)

Defoliator larvae develop through several stages termed "instars". Budworm begins as tiny green larvae and finishes as olive brown hairless larvae about an inch long.

A maturing budworm larva (6th instar), not quite an inch long, in a tangle of webbed needles. Budworm larvae are hairless and rather drab compared to tussock moth larvae.

(Forestry Images 1678009)

Larvae spin webbing around new needles at the ends of branch twigs creating a tiny loose shelter. The larvae continue to feed and develop within the shelter until the new shoot is destroyed. Adjacent elongating shoots may be webbed together causing them to become twisted or stunted.

Needles fed on and webbed together by spruce budworm larvae. Opening the web-tangled needles will reveal larvae.

(Forestry Images 1441045)

Larvae disperse within and between trees. Tiny, newly emerged larvae may be carried on the wind by a silken, thread-like sail. Older larvae descend on silk threads or fall to understory trees and continue feeding. Unlucky larvae that end up on the forest floor or on short understory trees often become food for predatory ants and spiders. Adult moths may be carried long distances by large storms, but this long distance dispersal does not cause new outbreaks. Outbreaks arise in place from endemic populations where forest conditions are conducive.

A spruce budworm larvae hanging on a silken thread. Overtopped trees tend to suffer more damage and mortality because growing budworm larvae fall or "spin down" from the overstory on threads and continue to feed on smaller understory trees.

(Forestry Images 1678012)

Fully developed larvae enter a pupal stage (pupate) lasting 10 to 14 days. Adults emerge from the golden brown pupae, seek a mate, and the life cycle continues.

An olive brown spruce budworm pupa in a mass of webbed needles. Pupation requires 10 to 14 days.

(FIDL 53)

Douglas Fir Tussock Moth

Tussock moth outbreaks develop quickly and usually collapse after 1 or 2 years of defoliation. Beginning to end, outbreaks usually last about 4 years.

Adults are grayish brown to charcoal brown moths. Males have feathery antennae and a wingspread slightly greater than 1 inch. Females, unable to fly, are about ¾ inch long with a large abdomen and tiny wings.

Life size adult Douglas fir tussock moths. Female moths lack useful wings; therefore, they are unable to fly.

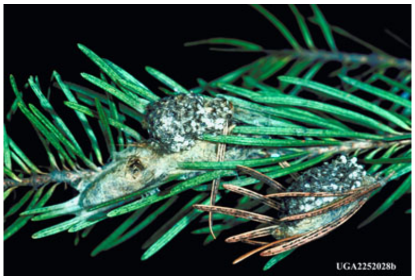
(Forestry Images 2253026)

New moths emerge from pupal cocoons in late summer. Flightless female moths remain on or near their cocoons emitting pheromones to attract males. Tussock moth infestations do not spread far or fast because the female moth cannot fly. Insect dispersal is mainly by windborne larvae. Tiny, almost weightless young larvae are often carried on wind currents by strand-of-webbing sails to nearby trees—a process termed "ballooning". Dispersal by ballooning seldom exceeds ¼ mile and does not cause a new outbreak. Outbreaks arise in place from endemic populations in susceptible forests.

A female tussock moth on her pupal cocoon. Females stay close to the cocoon. Larval hairs give the cocoon a woolly appearance.

(Forestry Images 2254043)

Soon after mating in late summer, eggs are deposited on the cocoon in a grayish, woolly mass about ½ inch across. Up to 350 eggs are contained in the mass. The woolly nature of the egg mass is created by matted hairs from both larvae and the female moth. The adults, having completed the life cycle, then die. Tussock moth overwinters in the egg stage.



Tussock moth egg masses on old pupal cases.

(Forestry Images 2252028)

A tussock moth egg mass with tiny, newly hatched larvae.

(Forestry Images 0949041)

A few days after eggs hatch in late spring, the tiny larvae crawl to new foliage and begin feeding causing needles to shrivel and turn reddish-brown. Young larvae are about ¼ inch long, dark colored, and covered with long fine hair. The young larvae tend to be most abundant in the tops of trees where new foliage is plentiful.

Young larvae grow slowly at first feeding only on nutritious new foliage. By mid-summer, larvae are larger and eating more. Current needles remain the preferred food, but older needles are eaten, too. Mature larvae easily survive and grow on a diet of older foliage and buds. Larvae produce silk-like threads as they crawl around seeking fresh needles. The threads form a loose mass of webbing around branch tips.

Tussock moth larvae encase branch tips in loose webbing as they search for needles to eat.

(USFS—Region 6)

Mature larvae are about 1¼ inch long, hairy, and very colorful. The middle part of the caterpillar body is covered with blonde to buff or brownish colored hairs along with several tufts of rusty red tipped white hairs. Two long black tufts project forward from near the head. A similar black tuft projects from the rear. Contact with larval hairs may cause skin irritation or even a serious rash, but the hairs are not poisonous.

Brightly colored Douglas fir tussock moth larvae. Tufts of hair (tussocks) define the larvae. Note the black tufts extending from either end of the caterpillar. Beware—the hairs may irritate your skin.

(Canadian Forest Service)

In late summer, mature larvae pupate inside a thin cocoon of silken webbing and larval hairs. Cocoons are usually attached to foliage and twigs, but they may be found on other surfaces during outbreaks. Cocoons are mottled gray and about 1 inch long. The pupal stage lasts about 2 weeks, adults emerge, and the life cycle continues.

Management

Achieving long-term improvement in forest resistance to defoliators requires simple strategies, but the strategies must be flexible and follow a basic guiding principle:

Maintain appropriate diversity within stands and across forest landscapes.

Preventing outbreaks by treating forest condition is the best way to manage defoliators. Forest composition, structure, and stocking are the basic factors that influence susceptibility and vulnerability to all forest pests. These basic factors must be considered when planning silvicultural activities to maintain and improve long-term stand and forest resistance to insect outbreaks.

- **Composition: Limit the fir component to less than 50 percent.**

  In mixed species stands, shift composition away from grand fir and Douglas fir toward a greater component of ponderosa pine and, on suitable sites, western larch or lodgepole pine. If the stand is attacked, losses in the host component will be at least partially replaced by greater growth in the nonhost component. Avoid trying to eliminate all grand fir. Grand fir becomes soft snags that provide essential habitat for birds that prey on budworm larvae.

- **Structure: Shift stand structure toward evenness especially in host species dominated stands.**

  Evenly structured stands (a single crown layer) of host species tend to be less vulnerable to defoliator damage than are unevenly structured stands (multiple canopy layers). When properly spaced, evenly structured stands are less vulnerable to wildfire, too. Perfect structural evenness is not necessary, nor is it desirable.

- **Stocking: Maintain proper stocking for site conditions with carefully applied thinning.**

  Trees in appropriately stocked stands tend to be vigorous with large crowns and lots of needles. Healthy trees with large food reserves are better able to recover from partial defoliation compared to stressed trees in unthinned stands. Thinning reduces competition for soil moisture and nutrients. Tree stress can be further reduced by minimizing soil and leave tree damage during thinning and harvesting.

Insecticides

Insecticides, usually applied by helicopter, are sometimes used to suppress defoliator outbreaks especially where silvicultural treatments are difficult to apply (inaccessible terrain, roadless areas). Insecticides are convenient suppression tools, but they provide only temporary relief. Insecticides include chemical, bacteriological, and viral sprays.

Some insecticides, such as B.t. (Bacillus thuringensis), are promoted as "benign" or "environmentally friendly". B.t. is probably the most commonly applied defoliator insecticide, but it is toxic to all moths and butterflies, not just spruce budworm and tussock moth. Moths and butterflies are essential pollinators in forests, and they are an important food source for birds and bats. Applications of B.t. to non-forest areas such as meadows and to riparian areas should be avoided if nontarget moths and butterflies are a concern. Repeated applications of B.t. across large blocks of forestland may damage or temporarily destroy local non-target moth and butterfly populations.

Pheromone Trapping—The Early Warning System

Defoliator trends can be determined by monitoring the population of adult males. Sometimes, larvae or pupal cocoons are sampled and counted, too.

Adult numbers are estimated by attracting flying males to sticky traps baited with a synthetic pheromone. In mid-summer, sticky traps are hung from branches in susceptible forests. Male moths enter the sticky trap, attracted and fooled by the pheromone scent, hoping to find a female. Instead, their wings get stuck to the gooey adhesive on the sides of the trap. Traps are collected after the male moth flight period has ended. Moths stuck to the sides of the trap are counted to give an indication of insect numbers, population trends, and the potential for defoliation the following year.

A delta-shaped trap hanging from a tree limb, baited with a pheromone attractant, lures male moths. Captured moths are counted to predict population trends.

(Forestry Images 1441055)