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Pine Butterfly

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Pine butterfly, *Neophasia menapia menapia* (C. Felder & R. Felder, 1859), is a serious defoliator of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) as well as other conifers throughout western North America (Figure 1). It is transcontinental and can be found throughout the range of ponderosa pine from southern British Columbia through northern New Mexico, and from the Rocky Mountains westward to the eastern slopes of the Cascades and the Sierra Nevada mountain ranges.

The habitat also includes some mixed-conifer types where ponderosa pine is dominant. Several disjunct populations of ponderosa pine in southeastern Arizona, southwestern New Mexico, and the northern portions of the Sierra Madres in Mexico are suspected to host pine butterfly in addition to a related species, *Neophasia terlooii* Behr 1869. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), especially along the northwestern coastal areas of the Olympic Peninsula in Washington State, southwestern British Columbia and Vancouver Island, was identified as a host for several Pacific Northwest coastal pine butterfly outbreaks since

Ponderosa pine defoliated by pine butterfly in the Prairie City Ranger District, Malheur National Forest, 2011.

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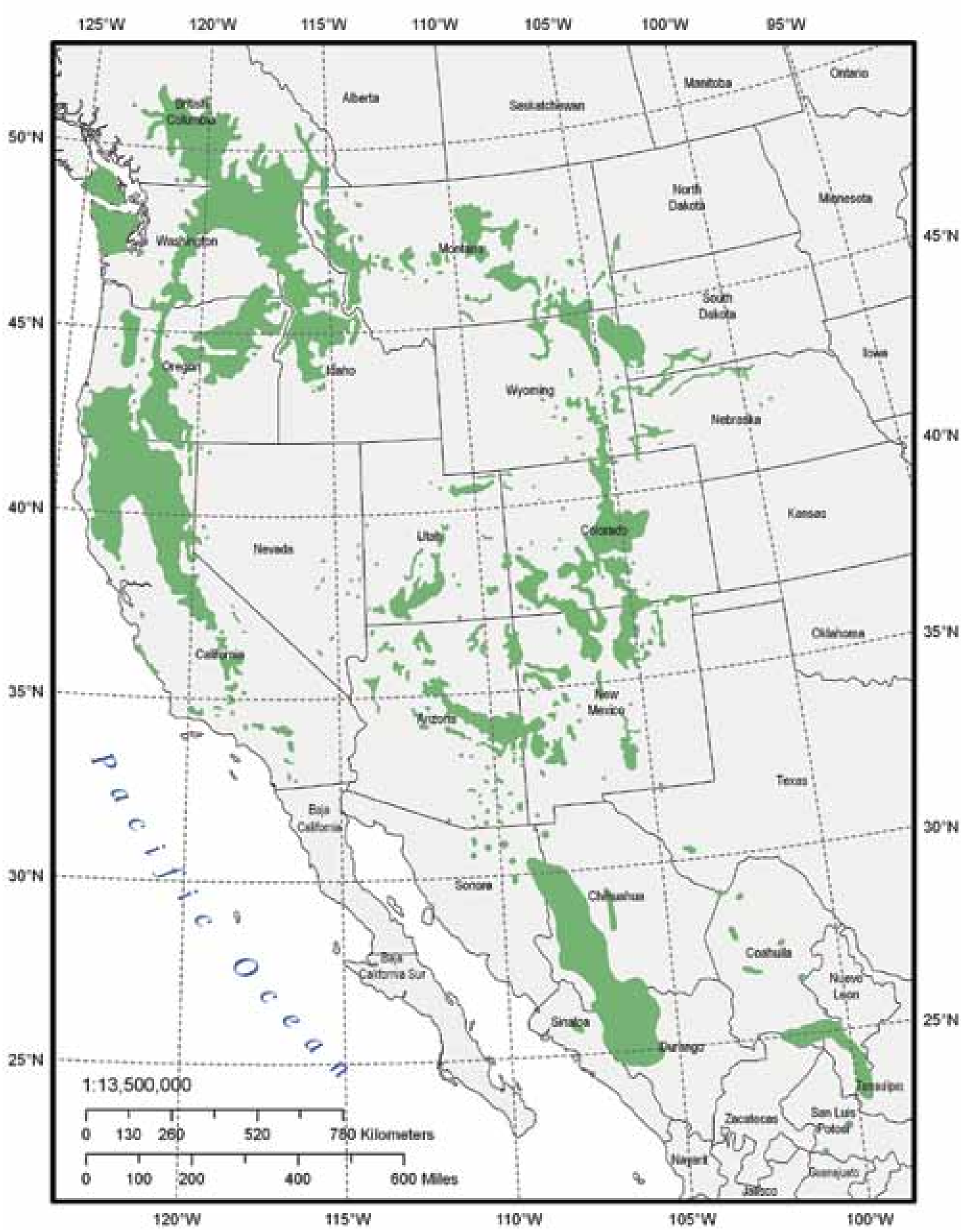

Figure 1. Approximate distribution of pine butterfly in North America. The range of pine butterfly generally follows the ponderosa pine type (illustrated), and portions of the Douglas-fir range in Washington and British Columbia.

first reported in that host in the late 1890s. Pine butterfly infestations also have been reported as far north as the former Prince Rupert Forest District of British Columbia, as far east as the ponderosa pine communities of the Black Hills of South Dakota and northwestern Nebraska, and from the Banff National Park region of Alberta, Canada.

Populations of pine butterfly typically remain low for many years, sometimes decades, then suddenly increase greatly in numbers over large areas during outbreaks. The immense flights of adults during outbreaks are spectacular with the delicate flight of these butterflies somewhat reminiscent of falling snowflakes. Defoliation during large outbreaks, often with three or more years of heavy larval feeding, can be equally spectacular. Results can be loss of nearly all needles except for partially-consumed current-year needles at branch tips, which produces a candelabra-like appearance (Figure 2, see inset). Ordinarily, pine butterfly larvae feed only on older needles, but during outbreaks they consume both new and old needles. Outbreaks can last from 2 to 6 years, but most collapse within 3 or 4 years.

Although pine butterfly outbreaks have occurred in North America with greater frequency than formerly thought, documentation of smaller ones has been limited and causes of outbreaks are still undefined. Several unpublished reports document less well-known outbreaks occurring on national forests early in the twentieth century. Damage and some tree mortality from defoliation are superficially referenced in some of these reports, while other reports describe outbreaks causing slight needle damage over widespread areas, suggesting that those outbreaks were not very damaging. However, past outbreaks of pine butterfly varied greatly in type and degree of damage they caused. Factors influencing degree of defoliation or tree mortality in a given outbreak may vary. Although knowledge on how to predict damage levels and tree mortality is limited, there is general agreement that defoliated

Figure 2. Severe defoliation of ponderosa pine by pine butterfly. By the third year of an outbreak, larvae have eaten nearly all previous years and older needles, and some of the current-year needles at branch tips, producing a candelabra-like appearance (see inset).

trees typically recover unless bark beetles follow several years of severe defoliation.

Hosts

Ponderosa pine is the preferred host of pine butterfly in interior forests, while Douglas-fir is preferred in coastal forests; however, the insect feeds on a wide variety of conifers, particularly during outbreaks when they are in mixed-conifer stands dominated by ponderosa pine. Pine butterfly has been reported on western white pine (*Pinus monticola* Dougl. ex D. Don), lodgepole pine (*Pinus contorta* Dougl. ex. Loud.), whitebark pine (*Pinus albicaulis* Engelm.), Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.), pinyon pine (*Pinus edulis* Engelm.), introduced Scotch pine (*Pinus sylvestris* L.), Pacific silver fir (*Abies amabilis* Dougl. ex Forbes), white fir (*Abies concolor* (Gord. & Glend.) Lindl. Ex Hildebr.), subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.), and western larch (*Larix occidentalis* Nutt.). Although pine butterflies have the potential to severely defoliate these trees, in most cases they are not seriously damaged.

Evidence of Infestation

During endemic years, only a few adult butterflies may appear flittering around tops of individual ponderosa pines during August or September. Eggs are deposited and larvae feed near the tops of taller trees; hence, defoliation is rarely visible during endemic periods. During epidemics, when thousands of adults emerge from chrysalids in late summer, butterflies fill the air and gather throughout host tree crowns while searching for mates or oviposition sites. When tired and hungry, butterflies make short forays down to the forest floor to visit blooming flowering plants used as nectaries (Figure 3), preferring those yellow in color (mostly family Compositae; occasionally Polygonaceae). A few weeks to a month after adults emerge, mortality occurs and dead butterlies may fill stock tanks, ponds (Figure 4), streams, roadside ditches, spider webs,

Figure 3. Adult pine butterfly feeding on nectar.

Figure 4. Stock pond choked with dead pine butterfly adults.

and webbing from fall webworm, *Hyphantria cunea* (Drury) (Figure 5), or other defoliators.

Numbers of butterflies observed flying at tree tops have been used to predict epidemics. If 6 or more butterflies are detected flittering about the top of each tree in August during aerial surveys of large forested areas, or about 24 butterflies per tree from ground observation, epidemic populations and defoliation often can be expected the following year. However, in areas without a history of pine butterfly outbreaks, the presence of high numbers of butterflies may not be indicative of future defoliation although the reason for this disparity is unknown. Concentrations of butterfly during flights in August are often greatest along high ridges.

Figure 5. Pine butterfly adults become entangled in spider webs or webbing from fall webworm (shown here) during mass emergence and flight of adults.

During the period of buildup from low populations, branch defoliation initially appears light as young larvae feed gregariously on individual needles of the previous year, consuming only the fleshy part of the needle. Light feeding is often inconspicuous when scattered through the crown because larvae do not leave behind pieces of partially consumed needles to discolor as with some other defoliators, like sawflies. Later, larvae feed singly and consume nearly the entire needle, leaving only a small stalk within the needle sheath that eventually dries and turns brown. No silken strands are produced during larval feeding. In epidemic years larvae develop over the entire crown and feed on both new and old needles, consuming nearly all needle growth except for some current-year foliage on branch tips. They do not harm new buds during feeding. During these outbreaks, high populations of older larvae can rapidly strip the tree of most needles within only a few weeks. Defoliated trees may be widespread during epidemics, covering thousands to hundreds-of-thousands of acres, including trees of all ages and sizes.

Figure 6. Adult male pine butterflies.

The most severe defoliation may appear first along ridge tops and develop later in valleys between ridges.

The normal habit of female butterflies is to lay eggs on whole, or nearly whole, needles. In areas with severe defoliation of overstory foliage, adults seek out suitable foliage on younger trees on which to deposit eggs, or else they migrate to other undefoliated areas, which can rapidly increase the size of the areas of the outbreak as new areas become infested.

Life Stages

Adult butterflies are delicate and bear some resemblance to the cabbage white (*Pieris rapae* (L.)). Adult pine butterflies have wing-spans of about 1¾-2 inches (44-51 mm). Head and body are black and covered with white hairs. Denser white hairs on the lower side of both head and body make them appear white underneath. Wings of the adult male butterfly (Figure 6) are pure white with black veins on the underside of the hind wings which show through on the upper side. Occasionally, on some males red scales may be present on underside of hind wings, either along the costal margin or a trace along the apex. Hind wings have faint black markings along the tips. Forewings have bold black markings around the apex that enclose white cells along the outer margin. A bold black streak runs along the costal vein and hooks slightly inward a short distance before reaching the apical markings. Markings on the lower side of forewings are generally same as above.

The color of scales on female butterfly wings is pale yellow (Figure 7); other black markings resemble those on the male, except black occurs along the entire apical margin on both sides of the forewings. Apical markings along the tips of the upper and lower sides of hind wings are also bolder than in the male, as are the black lines along the veins on the underside. Most females also have bright orange-red triangular-shaped spots along the underside apical margin of the hind wings.


Figure 7. Adult female pine butterflies and eggs.

Eggs are emerald-green in color and measure approximately 1 mm wide by 1½ mm long (0.04 x 0.06 inch). They are laid near the tip of the needle in single rows of 5 to 20 or more per needle in shingle-like fashion at an angle of about 45º, and firmly cemented together with the upper ends pointing toward the needle tip (Figure 8). The eggs are vase-like in shape with a round but slightly flattened base, being widest near the middle and tapering to the narrow, depressed top. The top is ringed with 8-11 tiny porcelain-white bead-like structures and sides are adorned with about 20 faint, thin vertical ribs.


Figure 8. Eggs of pine butterfly.

Newly-hatched larvae are olive green with black shiny heads, and are about 2 mm (0.08 inch) in length. These newly-hatched pine butterfly larvae may be confused with newly-hatched

Figure 9. Mature larvae of pine butterfly.

The pupae are slender, 18 – 20 mm (0.7-0.8 inch) in length, and either dark brown or green (Figure 10), depending on the substrate on which they pupated: green-colored pupae are usually found on foliage, while brown-colored pupae are found on tree trunks and barked portion of branches. Pupal color is not sex-related as originally thought, nor does it necessarily indicate parasitized or diseased conditions. Both brown and green pupae have white stripes running down each side, and a narrower white dorsal stripe; stripes on brown pupae become less conspicuous as transformation to adult nears completion. The head case is prolonged into a straight, slender, conical spur, and the eyes and wing cases are prominent. The wing cases are rounded down to the abdomen, which is slender and conical.

pine sawfly larvae which are very similar in appearance and hatch at about the same time. However, the presence of hatched pine butterfly eggs near the tips of needles, or the presence of pine sawfly egg punctures along the mid-length of pine needles, may aid in distinguishing between them. Mature pine butterfly larvae are about 25 mm (1.0 inch) long, and have pale green heads covered with small white points, each supporting a short hair. The body is clear green tinged with purple, displaying two yellowish-white lateral stripes along each side (Figure 9), and is covered with fine, closely set hairs; it tapers towards the anal shield, which contains similar white points as found on the head. Starting with the fourth instar, the posterior end of the anal shield forms two short, blunt, well-separated fleshy projections.

Life History and Habits

Pine butterfly has one generation per year and overwinters in the egg stage on current year needles of host conifers. Time of egg hatch in late spring or early summer varies, depending on elevation and climate. Egg hatch can begin as early as mid-May or as late as early July. Generally, egg hatch roughly corresponds to the time when

Figure 10. Green (left) and brown (right) pupae of pine butterfly.

new shoots of ponderosa pine are approximately 1-2 inches (2½ - 5 cm) in length. Both egg hatching and needle growth are directly affected by spring weather: warm temperatures result in early hatching, while cool, wet weather in late spring delays egg hatch. Egg hatch in the 2009-2012 outbreak in eastern Oregon was recorded at elevations ranging from 5,193-5,293 feet when accumulated heat units beginning on April 1st reached an average of 149.7 growing degree-days at a base temperature of 50oF.

Newly hatched larvae initially feed on the empty eggshells prior to moving to tips of needles, where they then feed gregariously through the first three instars. Eggshell feeding appears to be critical to survival of neonate larvae. At the tips of the needles, young larvae align themselves parallel with each other, encircling the needle with their heads pointing toward the tip of the needle as they feed (Figure 11). Larvae reverse their orientation on the needle, with heads pointing away from the tip, when they temporarily stop feeding and rest. New larvae consume only the fleshy part (epidermis, hypodermis, mesophyll, and some of the endodermis) of the needle, leaving vascular tissue in the center of the needle intact. After their first molt larvae may consume the entire needle, leaving only fascicle and needle base within, or a small portion of the needle extending out of the fascicle. After the third instar, they cease feeding in clusters around a needle and feed individually, although occasionally two or more larvae may feed on the same needle. During epidemics, larvae often consume entire needles. In smaller infestations, larvae may destroy approximately one-half of a needle.

The larval stage lasts for 6 to 8 weeks, with each instar lasting about a week. When larvae reach maturity, many migrate to bark crevices, limbs, or twigs. Others lower themselves to the ground by a silken thread, sometimes from heights of 75 feet or more. They pupate by forming chrysalids on almost any type of ground vegetation and other objects, including grasses, weeds, shrubs, and forbs; broken branches; fence posts, signs, and other structures; tree limbs and tree trunks; and on the foliage of trees. They attach themselves to the pupation site

Figure 11. Young pine butterfly larvae feed gregariously on individual needles and consume only the tissues surrounding the vascular portion of the needle.

completely expanded and dried. Within a few hours after mating, the female begins depositing eggs near the tips of whole or nearly whole current-year needles on ponderosa pines. Eggs do not hatch until the following spring. Newly emerged females produce an average of 97 eggs. Peak flight of the butterfly occurs around mid-August. Flight of adults can continue into September. Some adults remain active into the early part of October.

with a few silken strands around their middle and at the tip of the abdomen. The pupation period can range from 10-20 days.

At some locations, male butterflies may begin emerging from the chrysalis during the second half of July. Large numbers of males usually emerge about a week before females. During this period, males actively patrol crowns of trees, awaiting appearance of the first females to secure as mates; they also frequent various blooming plants to feed on nectar. The fragile wings on these males soon become ragged and tattered from lumbering into and between needles looking for females. When females finally emerge, mating occurs almost immediately, sometimes before their wings have

Air turbulence and wind during times of butterfly emergence and flight can cause redistribution of large numbers of butterflies and help spread infestations to new areas. During outbreaks, sometimes the immense numbers of butterflies in the air can present special safety hazards to low-flying aircraft. During a large pine butterfly outbreak in northeastern Oregon in 2011, pilots of fire suppression aircraft attempting to provide aerial support to a small fire within the outbreak area encountered so many insect strikes from the pine butterflies that they had trouble seeing out their windshields. Due to safety concerns, they were forced to return to the airport without dropping their retardant payloads, to wash the splattered butterflies from their windshields.

Ecological Impacts

Epidemics of pine butterfly vary in size, intensity, and frequency of occurrence. Most, but not all, infestations in ponderosa pine have occurred on cycles averaging 8 or 9 years. Not all infestations have become widespread or resulted in serious defoliation—many have gone largely unnoticed without any ecological effects documented. Ecological impacts are difficult to predict as they depend upon the severity of defoliation and other factors that influence recovery, including factors that may encourage subsequent attacks by bark beetles on defoliation-weakened trees. Growth and vigor of trees before defoliation may help determine how well they may recover afterwards. In some epidemics, older, decadent trees seem to have greater difficulty than younger trees in recovering from pine butterfly defoliation, and some trees eventually die or are attacked and killed by bark beetles. Buds are not injured by pine butterfly feeding, so each year trees replace foliage lost during defoliation, although the repeated defoliation decreases photosynthetic capacity. Most trees contain adequate carbohydrate reserves to get them through a few years with reduced photosynthesis.

Serious impacts on tree growth and mortality have been noted for several well-documented outbreaks. Generally, loss of increment, rather than actual tree mortality, has resulted in the greatest economic loss in previous epidemics on ponderosa pine in the northwest.

An outbreak that occurred on nearly 150,000 acres on what is now known as the Yakama Nation in Washington State from 1893 to 1895 is considered to be the most serious of the outbreaks to date. That outbreak resulted in profound ecological changes to the magnificent, mature, park-like ponderosa pine forest that once grew in Cedar Valley. Pine butterfly and subsequent western pine beetle (*Dendroctonus brevicomis* LeConte) infestations created islands of dying trees that reseeded into sites having exposed mineral soil from heavy sheep trampling of the forest floor during annual sheep drives. These insects converted a mature forest into a mosaic of even-aged groupings of younger ponderosa pine which within 4 to 5 decades after the outbreak became overstocked due to fire exclusion. In the absence of fire thinning, the reseeded stand developed to pole-sized trees which grew more acutely overstocked. Entomologists during this period believed the suppressed tree growth in these overstocked stands posed risks to these stands from future epidemic attacks of other bark beetle species. In addition, tree mortality from insect attacks contributes to hazardous fuel accumulations which may be followed by wildfire.

Volume estimates in the Yakima Nation outbreak placed losses of the mature ponderosa pine forest at nearly one billion board feet. The outbreak caused destruction of up to one-half of the original pine stands, with losses in some stands ranging up to 90 percent of host trees. Most of the tree mortality was believed to have been caused by western pine beetle. Other pine butterfly outbreaks in Idaho also have resulted in tree mortality, though not as severe. Entomologists believed that were it not for the attraction of bark beetles to defoliation-weakened trees resulting in the killing of those trees, most trees that died in the 1920 to 1923 outbreak in northern Idaho likely would have recovered.

Growth reductions on surviving trees were noted in the Yakima Nation outbreak, as well as in other outbreaks. In the Yakima outbreak, subnormal ring width began in 1893 and continued until 1907, 12 years after the outbreak ended. In the outbreak that occurred in the Payette Lakes area of central Idaho in 1920 to 1923, the duration during which many trees failed to add basal increment growth varied from 1 to 11 years. In a 1952 to 1954 pine butterfly outbreak in southern Idaho, the annual loss due to pine butterfly defoliation was over 39 percent of the normal growth increment when measured over a period of 7 years (1952-1959).

In general, pine butterfly outbreaks demonstrate considerable synchrony of occurrence based on outbreak chronologies in the Pacific Northwest. An outbreak detected in 2009 in eastern Oregon was followed by outbreaks in central and southern Idaho, and the Bitterroot Valley region of Montana in subsequent years. Earlier outbreaks in Washington, Idaho, and Montana were similarly synchronized; all occurred within a year or two of one another. The expansion of outbreaks of this insect is rapid, largely due to the wind dispersal of adults over large areas. In the most recent Oregon outbreak, the acres defoliated by pine butterfly increased exponentially for the years 2009-2011. Acreage defoliated increased 6-fold from 3,857 acres in 2009 to 24,062 acres in 2010. In 2011, this outbreak increased 10-fold more when aerial insect detection surveys mapped a total of 250,325 defoliated acres.

Natural Control

Endemic levels of pine butterfly are maintained by various biotic and abiotic factors, but most are imperfectly known. During epidemics, biotic factors and starvation function as the most

Figure 12. The ichneumonid parasitic wasp, Theronia atalantae fulvescens*, is a major parasite on pupae of pine butterfly.*

important mechanisms for ending pine butterfly infestations. Several parasites, predators, and disease organisms help terminate outbreaks and keep populations under control. The ichneumonid wasp that parasitizes pupae, *Theronia atalantae fulvescens* (Cresson), has been credited with the decline of several past outbreaks. Although this parasite has a diverse array of Lepidopteran hosts and is active in most western forest habitats, population buildup frequently lags 1 to 2 years behind buildup of the butterfly. When this parasite finally appears, it appears in such great numbers, and so successfully locates pine butterfly pupae within which it deposits an egg (Figure 12), that few pupae seem to escape being parasitized. The following year, defoliation is often greatly curtailed in areas where populations of this parasite have highly increased.

Other important natural enemies of pine butterfly include the fly *Agria housei* Shewell, which parasitizes pupae, and at least two species of true bug, *Podisus serieventris* Uhler and *Apoecilus bracteatus* (Fitch), which feed on all life stages except adult butterflies (Figure 13). In addition, several other predators and parasites are known to feed on various stages of pine butterfly, including a snake fly (eggs), robber fly (adults), yellow jacket wasps and baldfaced hornets (adults), thomisid spiders (larvae), the stilt bug, *Neoneides muticus* (Say) (eggs), a *Simulium* sp. (larvae and pupae), and a few other parasitic wasps and flies which parasitize pupae. A nucleopolyhedrosis virus, a microsporidian, a *Streptococcus* sp. bacterium, and a couple of different varieties of the bacterium, *Bacillus thuringiensis* Berliner (*B.t.*), also have been identified in larval populations of pine butterfly.

Figure 13. The true bug, Apoecilus bracteatus, *feeds on all stages of pine butterfly except adults.*

Avian predators are conspicuously absent in pine butterfly epidemics. Only one brief report of pine butterfly predation by birds is documented in the literature: a flycatcher (Tyrannidae) was observed in British Columbia catching and eating three pine butterfly adults in succession. The reason birds are not found in abundance where a potential food source is so readily available during pine butterfly outbreaks is unclear. The needles of Pinaceae contain piperidine alkaloids and other phyto-chemicals known to be poisonous or unpalatable to vertebrates, and these chemicals may be sequestered in pine butterfly when they feed on pine and other host plant foliage, rendering them unpalatable to birds. Additional research will be needed to determine whether pine butterflies are avoided by birds due to sequestered secondary plant substances, or if some other factor is involved.

Management

Stands that are healthy and growing vigorously prior to an infestation are best suited to withstand and recover from a pine butterfly outbreak. Thinning stands to maintain desirable stocking levels, reducing dwarf mistletoe (*Arceuthobium* spp.) incidence, and providing species diversity where appropriate will enhance stand vigor and resistance, and should also minimize growth loss and tree mortality in stands where outbreaks may develop. In areas with high populations of bark beetles within the vicinity of treatment areas, conducting silvicultural activities during, or immediately after, a pine butterfly epidemic is not recommended as these actions may promote bark beetle infestations in trees weakened by defoliation.

Management of pine butterfly outbreaks using pesticides can be difficult due to the unpredictable, eruptive nature of outbreaks, as populations can spread rapidly, have short outbreak cycles, and there is a high potential for reinvasion. Chemical insecticides are disruptive to natural enemies that ultimately suppress and help terminate outbreaks; hence, they should not be the first choice of intervention.

Application of the biological insecticide, *Bacillus thuringiensis* Berliner (*B.t.*), either from the ground or air, is an effective direct control strategy for reducing loss of foliage if done early in the season while larvae are still immature. Small-scale applications of *B.t.* to high-value sites during severe outbreaks can protect foliage and reduce growth loss and tree mortality; however, applications must be repeated annually until the outbreak subsides due to reinvasion by adults.

Additional Information

Private landowners can obtain more information, including currently registered and effective insecticides, from County Extension Agents, State Forestry Departments, or State Agriculture Departments. Federal resource managers should contact USDA, Forest Service, Forest Health Protection (www.fs.fed.us/foresthealth/). This publication and other Forest Insect and Disease Leaflets can be found at www.fs.usda.gov/goto/fhp/fidls.

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Figure credits: Distribution map (Figure 1) was prepared by Melanie Sutton. Figure 4 was taken by Annie Kellstrom and Figure 7 was taken by Will Brendecke. All other photos were taken by the author. All are

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Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels. Store pesticides in original containers under lock and key--out of the reach of children and animals--and away from food and feed. Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues. Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container. If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly. Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides. Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

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