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Forest Insect and Disease Leaflet 162

Spongy Moth

Spongy moth, *Lymantria dispar dispar* (Linnaeus) (Lepidoptera: Erebidae), (formerly known as gypsy moth) is an exotic invasive species introduced from Europe that is spreading south and west in North America. In spring and early summer, spongy moth caterpillars feed on the leaves of many different tree species, especially oaks. During outbreaks, caterpillars defoliate entire forests. Most broadleaf trees produce new foliage in response to defoliation more than 50 percent, allowing them to resume photosynthesis. Defoliation weakens trees, which renders them more susceptible to secondary mortality agents. Spongy moth can also directly kill trees, especially if severe defoliation persists for multiple successive seasons. In some years, outbreaks can be massive with defoliation exceeding several million acres. If extensive tree mortality occurs, outbreaks can contribute to shifts in forest species composition toward dominance by immune host species.

Several related moth species, including *L. albescens, L. mathura, L. monacha, L. postalba, L. umbrosa,* and two other subspecies of spongy moth, *L. dispar asiatica and L. dispar japonica,* do not have established populations in North America. Of these, the Asian subspecies *L. dispar asiatica* and *L. dispar japonica* have been the most frequently intercepted and accidentally introduced subspecies in North America. Surveillance and eradication of the Asian subspecies have been particularly critical because these subspecies have broader host ranges than their European counterpart, and unlike the European subspecies, females are capable of flight.

Spongy moth caterpillar.
Photo by Tom W. Coleman, USDA Forest Service.

Identification

From fall through early spring, spongy moth exists as eggs in brown to cream-colored hairy masses (approximately 1.5-inches long and 0.75-inches wide) located on tree trunks and large branches or other objects such as rocks, logs, homes, motor vehicles, and outdoor furniture (fig. 1). In spring, young caterpillars hatching from egg masses first appear dark and hairy, then develop characteristic markings on their dorsal (upper) surface as they increase in size (five and six pairs of raised blue and red spots, respectively, fig. 2). Mature caterpillars can range from 1.5 to 2.5 inches long and frequently seek sheltered areas to rest and ultimately pupate. Pupae are dark brown and affixed with silken thread to trees, rocks, and other structures (fig. 1B). Pupal cases and old egg masses can remain on trees and other surfaces long after the moths have emerged. Adult moths appear from early June to early October throughout its current range and are sexually dimorphic. Males are mottled brown in color with feathery antennae and black wing markings, whereas females are white or cream-colored with distinct black markings on the wings and thin, wire-like antennae (fig. 3). Females are larger than males with a wingspan of about 2.5 inches, compared to the 1.5 inch wingspan of males. Though they have wings, females do not fly.

Figure 1. A high density of spongy moth egg masses laid at the base of a tree (A) and laid under a human-made structure (trailhead sign) (B). Old pupal cases secured with silk webbing can be seen near the egg masses under the shelter in the photo (B). Photo (A) by Chris Foelker, Wisconsin Department of Agriculture, Trade, and Consumer Protection; photo (B) by Tom W. Coleman, USDA Forest Service.

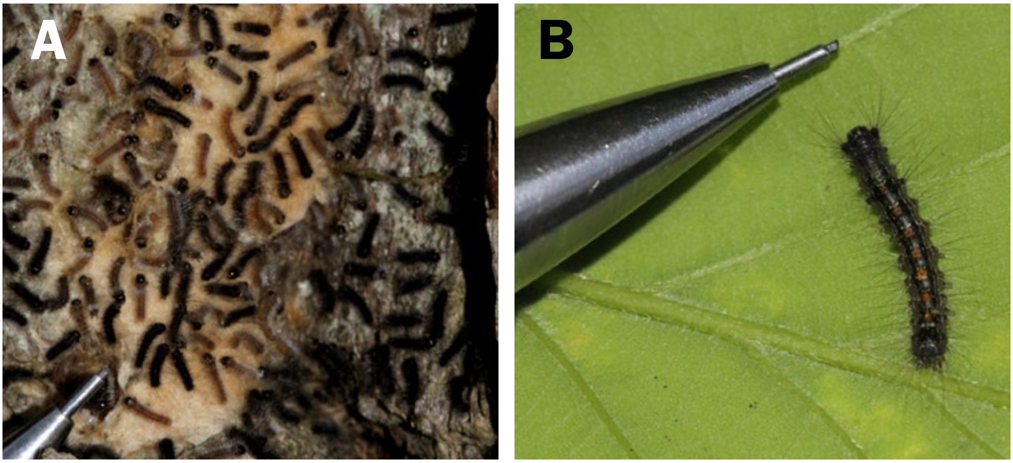

Figure 2. Newly hatched first-instar caterpillars resting on their egg mass (A), a dark-colored second-instar caterpillar (B) lacks the distinct red- and blue-colored markings possessed by fourth-, fifth-, and sixth-instar caterpillars (C). Photos by Tom W. Coleman, USDA Forest Service.

Figure 3. Adult female spongy moths lay eggs on the bark surface or in crevices. Note the brown to cream coloring of the egg mass under each female and at the bottom of the image. A brown-colored male moth can be seen mating with the white-colored female on the stem of a tree (inset). Female and male moths can lose their coloration on their forewings, as seen in the main image of the females, as they age and become more drab-colored. Photos by Chris Foelker, Wisconsin Department of Agriculture, Trade, and Consumer Protection.

Life History

Spongy moth has one generation per year and the seasonal timing of its life cycle can vary across its wide range in North America depending on climate (table 1). Eggs hatch in early spring (fig. 2A) in synchrony with the bursting of tree leaf buds. Caterpillars grow 1,000-fold in weight as they progress through five (males) or six (females) larval instars (stages) during their 6- to 8-week development period. After hatching, first-instar caterpillars are strongly photo-positive and crawl upward; some spin downward on long silken threads and disperse as their silken thread carries them on the wind. This behavior is called ballooning and typically transports caterpillars for short distances (less than a mile) but sometimes further on strong wind currents. Young caterpillars chew holes in leaves in the upper canopy during the day and rest at night on foliage. Older caterpillars consume all leaf tissue aside from the midrib (fig. 4A) and actively feed at night, crawling downwards to protected resting sites on or near the base of trees during the day. A significant fraction of late-instar larvae crawl to the forest floor, resting under objects such as rocks, stumps, and logs, and may crawl up a different tree the next morning. During outbreaks, caterpillars will feed throughout the day because of the competition for declining foliage. In early summer, spongy moths enter the pupal stage for 1 to 2 weeks, typically located in their last larval resting site. These resting sites (fig. 1B) are generally in branch and bark crevices and under rocks and human-made structures, but during outbreaks when caterpillar densities are high, pupation may occur anywhere. Adults emerge from pupal cases in mid-summer and are active for 1 to 7 days. Males detect the female-produced sex pheromone [(+)-disparlure] to locate females and mate. Male adult spongy moths are diurnal (daytime) flyers and have a distinct erratic flight pattern. Flightless females lay eggs near where they pupated. In mid- to late summer, females lay 100–1,000 eggs in a brown to cream-colored hairy mass on tree trunks or on other objects. Spongy moth overwinters as a fully developed larva within the egg (embryos develop into larvae in 4 to 6 weeks but remain in the eggs over winter). Dense hairs, the red and blue coloration on caterpillars, lack of web- or tent-building, and feeding primarily during the early growing season can distinguish spongy moth larvae from other leaf-feeding forest pests in the Eastern United States, such as tent caterpillars, spanworms, cankerworms, and webworms.

Table 1. Approximate seasonal occurrence of spongy moth life stages in the established areas of North America (A), approximate timing of various monitoring methods (B), and suppression techniques (C).

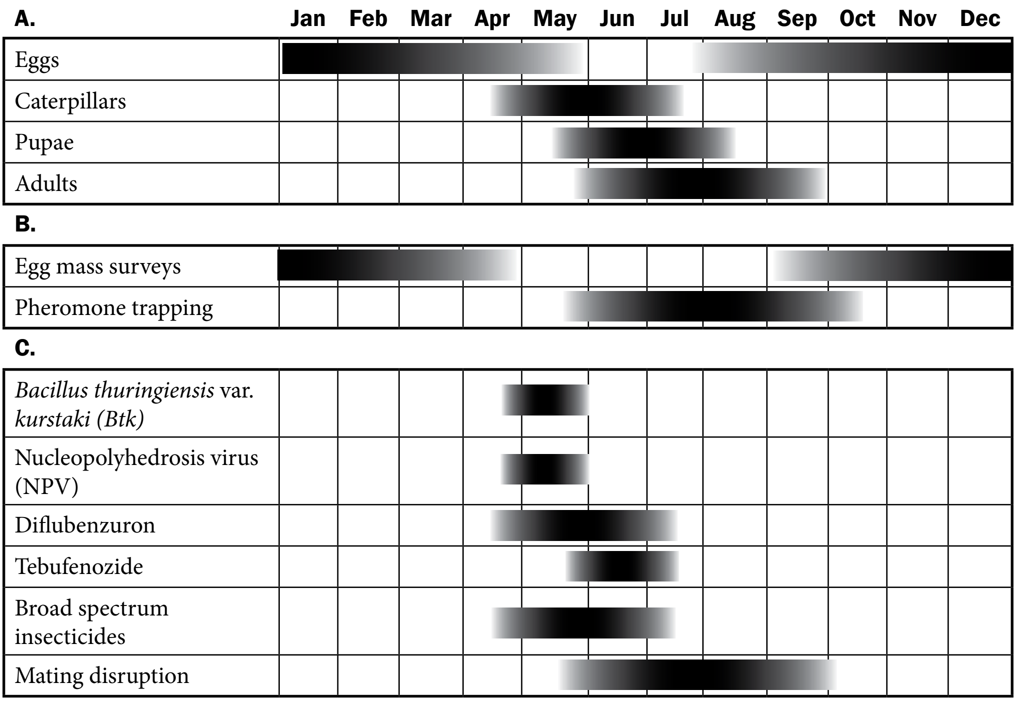

Table 1 Long Description. Egg life stage occurs all year except June and July. Caterpillars occur April to July. Pupae and adults occur May to August, with adults extending into late September. Egg mass surveys occur September to April and pheromone trapping occurs May to October. Suppression techniques all occur between April and July with slight variances, with the exception of mating discruption which ocurrs May to September.

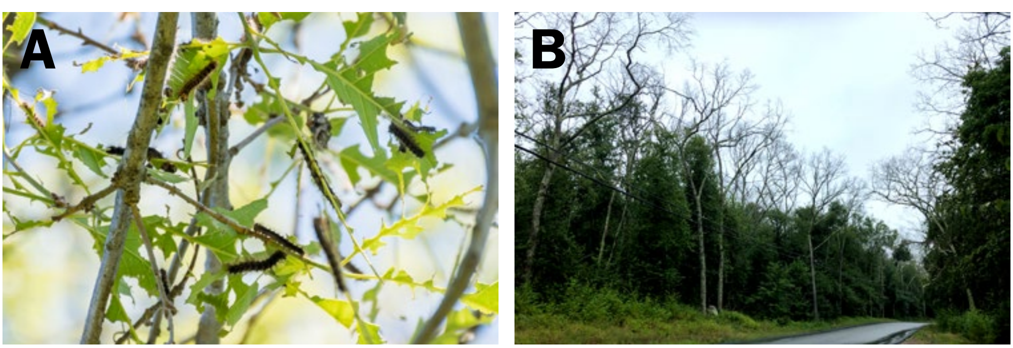

Figure 4. Mature caterpillars can feed extensively on oak leaves (A) and cause severe defoliation and tree mortality, especially of oaks (B). Uninjured resistant and immune host species can be seen in the understory (B) following a spongy moth outbreak in the Northeastern United States. Photo (A) by Karla Salp, Washington State Department of Agriculture, Bugwood.org; photo (B) by Kevin Dodds, USDA Forest Service.

Hosts

Spongy moth caterpillars are known to feed on the foliage of hundreds of different tree and shrub species. Nevertheless, within North America, there is considerable variation in suitability among tree species, which can be classified as susceptible, resistant, or immune (table 2). Susceptible tree species are those that caterpillars are capable of feeding on from the first instar through completion of larval development. Typical North American susceptible species include oaks, aspen, apple, willow, basswood, hawthorns, and some birches and alders. During outbreaks, susceptible species are generally the most heavily defoliated in mixed stands. Feeding by early instar larvae does not occur on species classified as resistant; most feeding on resistant species is only by late instar larvae, and these hosts are generally only utilized once larvae have depleted most foliage of susceptible trees.

Resistant species include maple, beech, hickory, and black walnut. Immune species include tulip poplar, ash species, American sycamore, and black cherry. Larvae essentially never feed on immune trees and, even during outbreaks, these trees are completely free of defoliation. Most conifers are immune, though some (e.g., hemlock, white pine, blue spruce) are resistant and can be defoliated by late instar larvae; deciduous conifers (e.g., larch, bald cypress) are generally susceptible.

Table 2. Tree and shrub species susceptible, resistant, and immune to spongy moth feeding in the United States. See Liebhold et al. (1995) for a more complete spongy moth host list.

Susceptible	Resistant	Immune
Alder, *Alnus* spp.	Beech, *Fagus* spp.	Arborvitae, *Thuja* spp.
Apple, *Malus* spp.	Dogwood, *Cornus* spp.	Ash, *Fraxinus* spp.
Aspen and poplars, *Populus* spp.	Elm, *Ulmus* spp.	Black cherry, *Prunus serotina*
Basswood, *Tilia* spp.	Hemlock, *Tsuga* spp.	Fir, *Abies* spp.
Paper birch, *Betula papyrifera*	Hickory, *Carya* spp.	Holly, *Ilex* spp.
Hawthorn, *Crataegus* spp.	Maple, *Acer* spp.	Juniper, *Juniperus* spp.
Hazelnut, *Corylus* spp.	Pine, *Pinus* spp.	Locust, *Robinia* spp.
Larch, *Larix* spp.	*Prunus* spp.	Redbud, *Cercis* spp.
Mountain-ash, *Sorbus* spp.	Serviceberry, *Amelanchier* spp.	Sumac, *Rhus* spp.
Oak, *Quercus* spp.	Spruce, *Picea* spp.	Sycamore, *Platanus* spp.
Willow, *Salix* spp.	*Viburnum* spp.	Tulip poplar, *Liriodendron tulipifera*
Witch-hazel, *Hamamelis* spp.	Walnut, *Juglans* spp.	Tupelo, *Nyssa* spp.

Distribution and Spread

The amateur entomologist Éttiene Léopold Trouvelot, an immigrant to the United States from France living in Medford, MA, obtained spongy moth egg masses from Europe and reared spongy moth larvae in cages on trees in the backyard of his home. They escaped in 1868 or 1869. Recognizing the potential for damage, Trouvelot alerted entomologists to this incident, but no action was taken until 1890 when the State of Massachusetts initiated an unsuccessful campaign to eradicate the population. Since then, the spongy moth has been slowly expanding its North American range (fig. 5A). The historically slow rate of spread can be attributed to the lack of female flight as well as to several intensive efforts to limit its spread. Beginning in 1912, the U.S. Department of Agriculture (USDA) implemented a quarantine that limited the movement of objects, such as nursery stock, from the invaded area; this and other management activities (see below) have greatly limited spongy moth range expansion. Spongy moth often colonizes new areas when objects carrying egg masses (e.g., outdoor furniture, firewood, recreational vehicles, and trailers) are transported outside of the generally infested area. As described below, networks of pheromone traps monitored annually by State and Federal agencies are used to detect these populations so that they can be eradicated or contained to prevent additional spread. The current spongy moth range encompasses about one-third of the potentially susceptible forests in the United States (fig. 5B).

Ecological and Economic Impacts

Outbreaks of the spongy moth have primarily impacted susceptible host tree species (fig. 4B). Defoliation from young caterpillars can be difficult to detect, but feeding can resemble small holes in the interior of the leaf. Young caterpillars need foliage from susceptible trees and shrubs to survive and commonly begin feeding on these species in the understory. As caterpillars mature, leaf feeding becomes more extensive and the entire leaf can be consumed. Following low levels of defoliation (less than 50 percent), most broadleaf trees will experience only a minor reduction in radial growth. Healthy trees can withstand 1 or 2 consecutive years of severe defoliation and will frequently re-foliate by mid-summer even after experiencing more than 50 percent defoliation. However, stressed trees and trees with poor crowns are more likely to succumb to high levels of defoliation. Crown dieback can occur following extensive feeding from spongy moth, and tree mortality can result from repeated bouts of severe defoliation (more than 75 percent). Drought and secondary mortality agents on oaks, such as two-lined chestnut borer (*Agrilus bilineatus*) and fungal root diseases (e.g., *Armillaria* spp.), can interact with spongy moth defoliation to cause additional tree mortality 3 to 5 years later. Conifer species (e.g., pines and hemlock), although generally less preferred hosts of spongy moth, are less tolerant of defoliation and can be killed following a

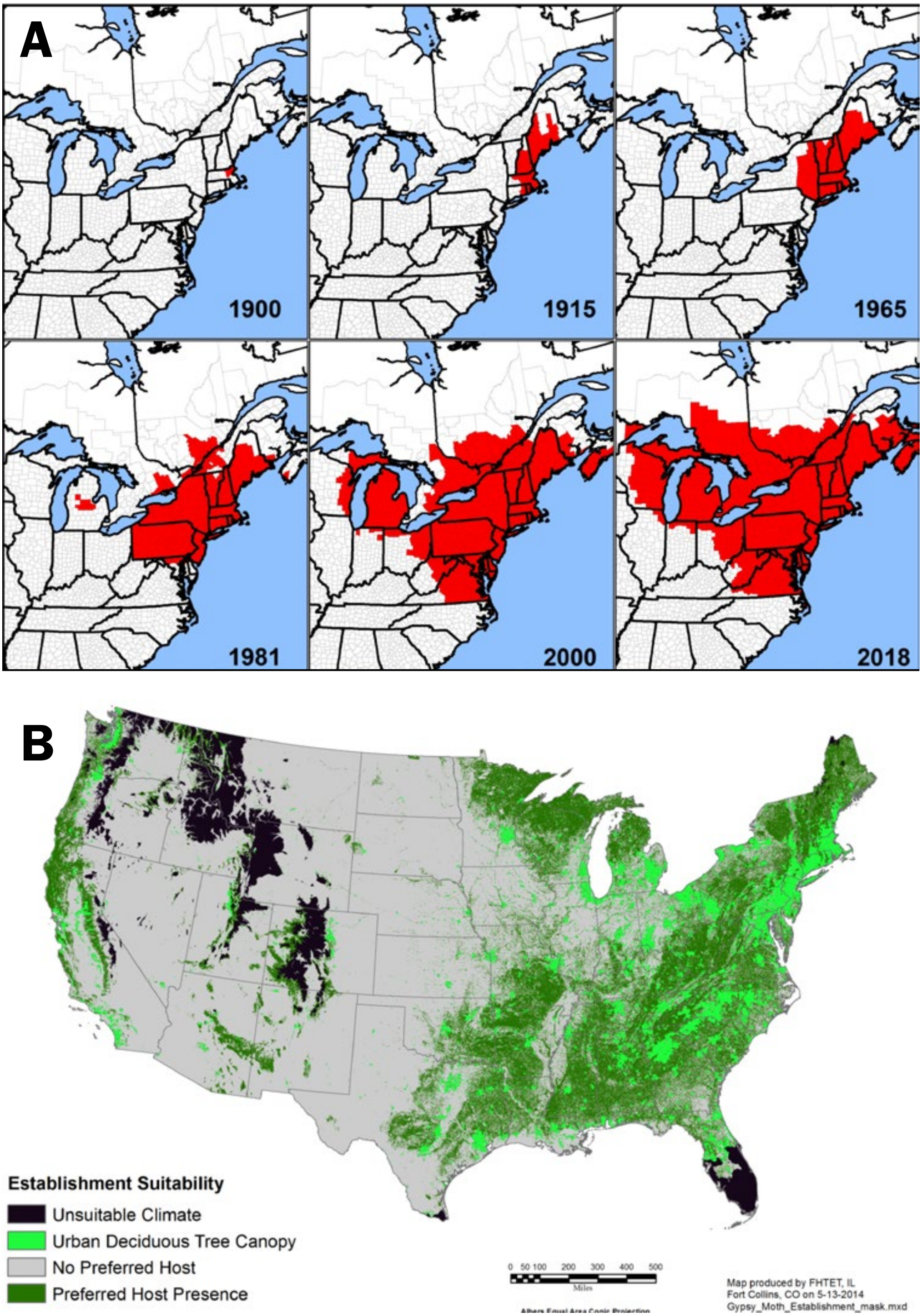

Figure 5. Historical spread of the spongy moth from 1900 to 2018 to the south and west in North America (A); and range of susceptible hosts and habitat suitability of spongy moth found in the United States (B).

single year of complete defoliation. Forest stands dominated by oaks, particularly chestnut oak, or other susceptible hosts (more than 50 percent of the forest canopy), experience the most defoliation and mortality (fig. 6A). In addition, forests located on xeric sites, such as south- and west-facing aspects, and ridge-tops with sandy or rocky soils and a preponderance of hiding places (e.g., bark flaps) for caterpillars can contribute to multi-year defoliations and high-levels of tree mortality caused by spongy moth (fig. 6B). Tree mortality can exceed 90 percent following spongy moth outbreaks when additional stressors (e.g., drought, secondary mortality agents) are present, though, generally, more than 15 percent of the total basal area is lost following most spongy moth outbreaks. Losses to the forest canopy can result in changes in understory vegetation and long-term canopy composition where more shade-tolerant and less susceptible tree species, like red maple, typically gain canopy dominance.

Defoliation and tree mortality from spongy moth can delay mast production in oaks, thus reducing food availability for wildlife such as squirrels, mice, and deer. During and following outbreaks, there may be short-term changes in the microclimate (e.g., higher sun exposure, temperature, and wind) on the forest floor and in water quality because of the substantial loss of canopy cover and the leaching of nutrients with leaf material and frass (insect excrement) to the forest floor and ultimately forest streams.

In North America, regional spongy moth outbreaks typically occur every 8 to 12 years and may persist for 1 to 3 years. From 1920 to 2020, spongy moth has defoliated more than 95 million acres. Economic impacts associated with tree mortality include the loss of timber revenues and removal/replacement costs for homeowners, businesses, and governments. The most serious impacts are felt by private landowners who experience loss of aesthetic and property values when ornamental trees are defoliated or killed. High densities of caterpillars can also be a nuisance when frass rains down from defoliated trees on homeowners and in recreation areas (fig. 7). Hairs from caterpillars can trigger respiratory problems, skin irritations, and allergic reactions in some people.

State and Federal Governments have directed more than $282 million from 1980 to 2020 to suppress spongy moth outbreaks on more than 14 million acres. As spongy moth continues to spread south and west from currently infested areas, counties are placed under a Federal quarantine to restrict the movement of spongy moth life stages, resulting in additional costs to governments and business to institute new monitoring, management, and regulatory protocols. Since 2000, Federal and State agencies have contributed more than $7 million annually to monitor and manage low-density spongy moth populations at the transition zone between invaded and uninvaded areas to reduce its natural and human-assisted spread rate through a national program (see below).

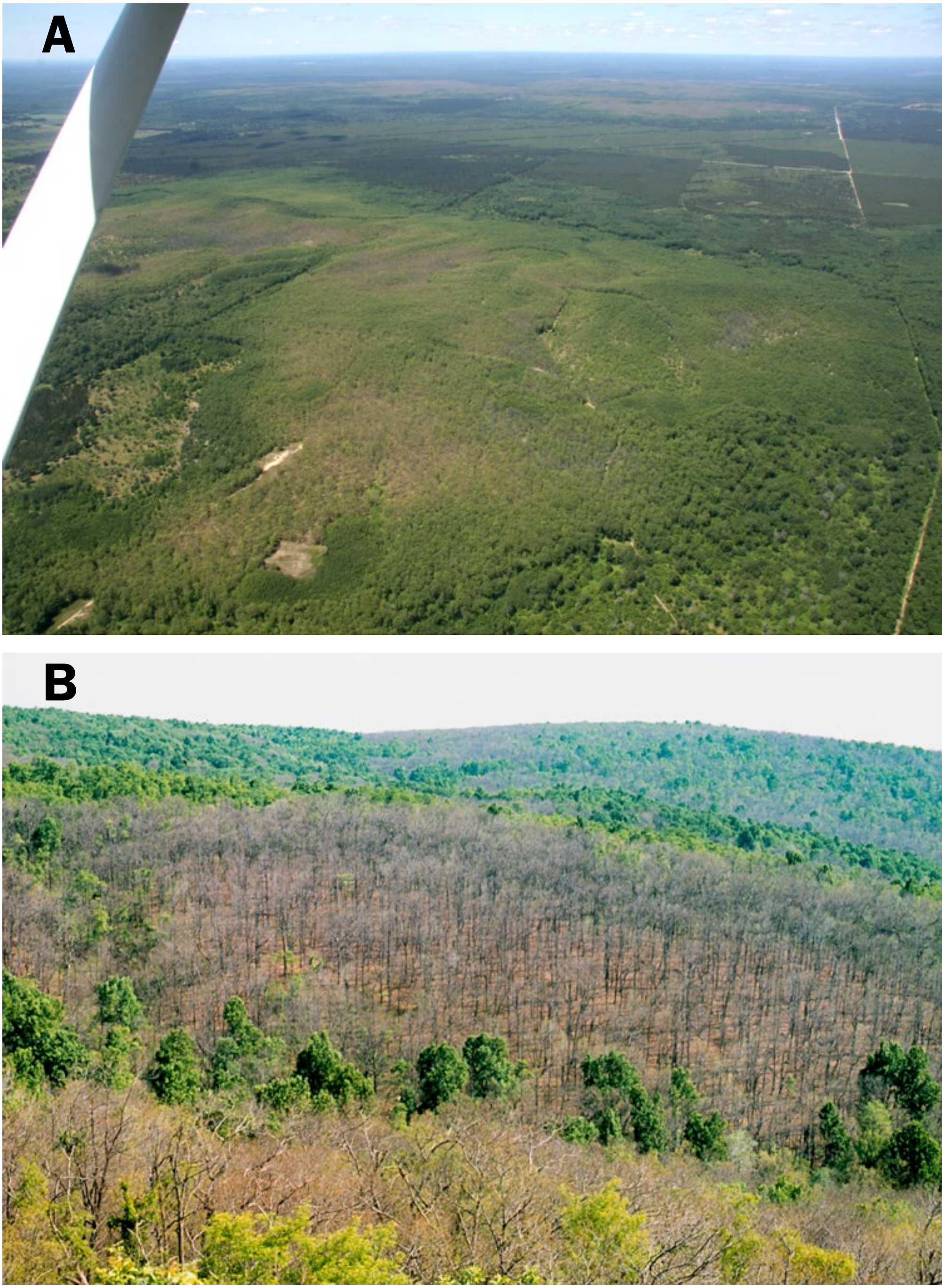

Figure 6. Oak-dominated stands that experience repeated bouts of defoliation can lead to high levels of defoliation and tree mortality (more than 90 percent). Defoliation can be extensive across the landscape. Note the brown patches of trees in the foreground and background of the image (A). Interacting stressors (e.g., insects, disease, and dry sites) can result in tree mortality being delayed for 3 to 5 years following an outbreak (B). Photos by Mark Robinson, USDA Forest Service.

Figure 7. During outbreaks, high densities of caterpillars can be a nuisance and a health concern to homeowners, especially those in or adjacent to forested areas. Photo by Chris Foelker, Wisconsin Department of Agriculture, Trade, and Consumer Protection.

Natural Enemies

There are multiple pathogens, parasitoids, and predators, introduced in the early 19th century from Europe and Asia, that attack spongy moth in North America. The most important mortality agents affecting high-density populations are two diseases: a viral pathogen, spongy moth nucleopolyhedrosis virus (NPV), and a fungal pathogen, *Entomophaga maimaiga* Humber, Shimazu, and R.S. Soper (Entomophthorales: Entomophthoraceae), both of which can contribute to outbreak collapse. Both diseases can infect all stages of larvae and have multiple infection cycles in a season but are typically most prevalent and noticeable with later instar larvae.

Spongy moth NPV is specific to spongy moth and has been present in North America since the early 1900s. It likely arrived from Europe with parasitoids introduced for biological control. Spongy moth NPV infects developing caterpillars upon ingestion of viral bodies present on the leaf surface or residing on the surface of egg masses. After being consumed, the virus quickly replicates and ruptures cells throughout the internal organs of the caterpillar, resulting in death. The virus is transmitted when the dead caterpillar's cuticle ruptures and viral bodies are either spread by rainfall or drop onto leaves below. These viral bodies are then eaten by uninfected caterpillars. The diagnostic symptom of NPV-caused mortality in spongy moth caterpillars is an inverted “V” body position (fig. 8A). Interactions between NPV and host spongy moth populations are considered to be one of the main drivers of the quasi-periodicity of moth outbreaks. Spongy moth NPV has been formulated into an aerially applied biopesticide, Gypchek. This product is costly and time-consuming to produce because it requires the large-scale rearing of virus-infected caterpillars. Gypchek is used only in USDA Forest Service-sponsored treatment areas where there are concerns about nontarget effects, particularly to threatened or endangered native butterflies and moths (Lepidoptera).

Entomophaga maimaiga is a fungal pathogen largely specific to spongy moth and was first documented causing significant mortality in Eastern North America in 1989. The introduction date and origin of this important pathogen are unknown; it may have been introduced accidentally or intentionally at an earlier date but remained undetected for many years. Infection by *E. maimaiga* is facilitated by wet conditions, especially during early spring, which are ideal for spore propagation and caterpillar infection. This fungus produces two types of spores: large resting spores that overwinter in the soil and are viable for more than 10 years and smaller, short-lived conidia which disperse in the wind. Caterpillars are infected upon contact by airborne conidia after which the fungus begins consuming the caterpillar. Mortality typically occurs within a few days and four to nine cycles of infection can occur within one season. The general diagnostic symptom of *E. maimaiga*-caused mortality in late-instar spongy

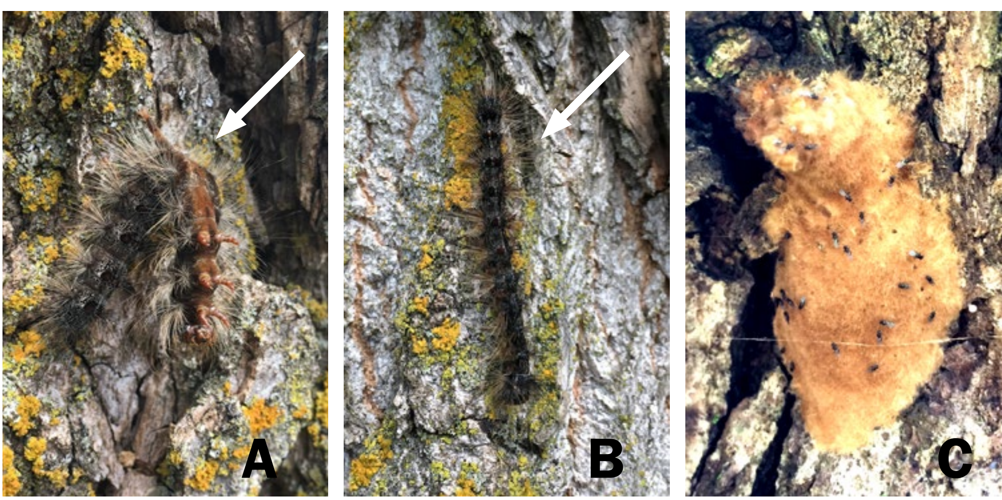

Figure 8. General symptoms of caterpillars killed from spongy moth nucleopolyhedrosis virus (A), the arrow points to the “V” shape of the infected caterpillar and the fungal pathogen *Entomophaga maimaiga* (B), the arrow notes the straight and limp infected body. These symptoms are not definitive nor mutually exclusive as co-infection by both pathogens can occur, as well as attack by parasitoids (C), eggs parasitized by an introduced wasp, *Ooencyrtus kuvanae*. Photos by Chris Foelker, Wisconsin Department of Agriculture, Trade, and Consumer Protection.

moth are thin, shriveled caterpillars in a downward facing position (fig. 8B).

Early spongy moth management efforts in North America included introducing a variety of insect natural enemies (e.g., parasitic flies and wasps and predatory beetles). At that time, there was little regulation or research on the effectiveness or nontarget effects of these introduced natural enemies. At least 10 species established, and several of them were generalist predators and parasitoids that offered little control of spongy moth. However, some were specialist parasitoids that may contribute to regulation of low-density spongy moth populations (fig. 8C).

Small mammals, particularly white-footed mice, feed on both larvae and pupae, and are typically the most important cause of spongy moth mortality in low-density spongy moth populations. Temporal and spatial variation in their abundance, which may be related to timing of mast seeding, appears to be associated with the release of low-density populations to outbreak levels.

Management and Treatment Options

There are many management tactics available to suppress spongy moth populations and reduce risk of tree mortality from repeated spongy moth defoliation. When developing a management plan, it is important to consider the extent, severity, and context of the outbreak. For homeowners, direct manual control measures targeting outbreak populations may be feasible for protecting high-value trees but are generally ineffective at changing the course of regional spongy moth outbreaks. Management of outbreak spongy moth populations has been conducted for over a century in North America. Many previous treatment options (e.g., broad spectrum insecticide applications, branch pruning, egg mass removal and destruction, tree banding, egg mass treatments, sterile male release, augmentation biological control, and mass trapping) have been deemphasized because they are too tedious and economically impractical over large areas, ineffective for controlling spongy moth populations or reducing defoliation, or environmentally unacceptable (fig. 9). Pesticides are an effective choice for treating invading or outbreak spongy moth populations. Ground applications are appropriate for small acreages; otherwise, most pesticides are applied aerially via helicopter or fixed-wing aircraft. Large-scale aerial treatments for spongy moth are typically conducted in areas of high recreation value, residential neighborhoods, high-value timber, along the leading edge of spongy moth expansion, or in State/Federal cooperative programs (table 3).

Suppression strategies

Bacillus thuringiensis var. *kurstaki* (Btk) is a naturally occurring soil bacterium that has been formulated into a commercial biological insecticide for spongy moth control. It is favored in many large-scale treatment programs because it is effective against high-density populations and has limited nontarget effects. This product primarily targets foliar-feeding, early instar Lepidoptera and is active in the environment for less than 2 weeks. Btk is typically applied from aircraft but can also be applied to the canopy from the ground, such as in small eradication projects. Gypchek, which has a greater specificity, has similar impacts and application timing as Btk and can be used in treatment programs where impacts on sensitive species of Lepidoptera are a concern (tables 1 and 3).

Insect growth inhibitors (e.g., diflubenzuron and tebufenozide) are also effective at suppressing high spongy moth populations (tables 1 and 3). When ingested or contacted by caterpillars during molting, diflubenzuron inhibits the formation of chitin, a major component of the insect exoskeleton. Tebufenozide is also active at disrupting molting, but it mimics the action of a molting hormone in various terrestrial and aquatic insects; however, moths are generally more sensitive to the insecticide than nontarget insects and arthropods.

Application of broad spectrum insecticides to the tree crown can be used to target feeding caterpillars, but these materials are rarely used in large-scale treatment programs. Immediate and persistent toxicity may make these products ideal for homeowners, but the

Figure 9. Many historical treatment options for spongy moth, e.g., insecticide fogging (A), branch pruning and egg mass removal (B), tree banding (C), egg mass treatments, sterile male release, biological control augmentation, and mass trapping, are no longer extensively used primarily because more effective and environmentally safe measures are available. Photos (A) and (B) are historic photos by USDA Forest Service, Bugwood.org; photo (C) by Scott Bauer, USDA Agricultural Research Service, Bugwood.org.

Table 3. Frequently applied treatment options for spongy moth population suppression.

Treatment Option	Timing of Application	Nontarget Effects	Biological Pesticide (Y/N)	Mode of Action and Comments
Bacillus thuringiensis var. *kurstaki* (Btk)	Mix of 1st and 2nd instars	Feeding caterpillars of all butterflies and moths	Y	A naturally occurring soil bacterium that breaks down the gut lining of feeding caterpillars. Bacteria must be ingested to cause mortality. Applications have a short period of efficacy; commonly applied twice in a season.
Spongy moth nucleopolyhedrosis virus (NPV)	Mix of 1st and 2nd instars	None, specific to spongy moth	Y	Formulation of the naturally occurring spongy moth nucleopolyhedrosis virus (Gypchek) that ruptures internal organs. Manufacturing can be costly and time-consuming as it requires the rearing of live caterpillars. Product is only available for use in USDA Forest Service-sponsored programs.
Diflubenzuron	3rd instar	Especially toxic to aquatic invertebrates	N	A commercially available insect growth regulator that prevents caterpillars from molting.
Tebufenozide	1st to 3rd instars	Feeding caterpillars of all butterflies and moths	N	A commercially available insect growth regulator that prevents caterpillars from molting.
Broad spectrum insecticides (carbaryl, bifenthrin)	All larval instars	Most arthropods that contact the insecticide	N	Broad spectrum contact insecticides that inhibit normal function of the nervous system. These products are no longer used in large-scale treatment programs.
Mating disruption	Pupation, prior to moth emergence	Nonlethal, specific to spongy moth in North America	Y	Pheromone-based product that limits male moth ability to locate females. Used in the National Gypsy Moth Slow the Spread program and occasionally in eradication; effective primarily for low density populations.

nontarget effects of these insecticides on arthropods makes them unfavorable for use in larger treatment programs.

Broad spectrum insecticides were used frequently in earlier spongy moth treatment programs but have not been used in large spongy moth treatment programs since the late 1980s. Mating disruption is a nonlethal control strategy that saturates an area with a species-specific, synthetically produced sex pheromone to inhibit mate finding and subsequent reproduction. This control strategy is only effective in areas with low and isolated populations and is used primarily along the invading edge of the infestation in the national Slow the Spread (STS) program (see below).

Prevention strategies

Preventative silvicultural measures are a component of an effective long-term management strategy for larger woodlots, particularly within generally infested areas with a history of spongy moth defoliation or in high-risk stands adjacent to the spongy moth invasion front. Specific plans should be tailored more precisely for an individual site, though general strategies to reduce the risk of outbreak include thinning to reduce basal area of susceptible host species (e.g., oak, paper birch, aspen) and increasing basal area of resistant and immune species (e.g., conifers, maple, black cherry, black walnut). Maintaining general tree vigor is also important for reducing stand vulnerability to tree mortality following outbreaks. Intermediate cuttings targeting trees with poor crowns can reduce stand vulnerability. Homeowners can water trees during periods of drought stress and remove ailing or undesirable understory that are susceptible hosts.

National Monitoring and Management Programs

There is a comprehensive U.S. national monitoring and management program for both the European spongy moth and the Asian subspecies. The USDA rogram is comprised of four strategies: (1) suppress building populations of European spongy moth in quarantined areas, (2) slow the spread of new populations of European spongy moth along a 62-mile (100 km) wide action area along the expanding invasion front, (3) eradicate all new populations of the Asian subspecies and new populations more than 62 miles from quarantined areas for the European subspecies, and (4) monitor and regulate the movement of the European subspecies life stages from quarantined areas with regulatory inspections and certifications (fig. 10). The Forest Service and State agencies cooperate to suppress spongy moth outbreaks in quarantined areas across all land ownerships (though not all States participate), whereas the Forest Service and USDA Animal and Plant Health Inspection Service (APHIS) and State agencies cooperate to slow the spread of European spongy moth and eradicate new populations of both subspecies. The Forest Service manages the STS program, which is carried out in collaboration with multiple State agencies in the Central and Eastern United States, a nonprofit foundation, two universities, and APHIS. The STS program, implemented in 2000, represents a culmination of several previous pilot programs during which the monitoring and management protocols used in STS were developed.

STS is data intensive. It relies on tens of thousands of sex pheromone-baited monitoring traps (e.g., delta and milk carton) deployed annually in quarantined areas and along the transition zone of infested and uninfested areas (62-mile action area) to monitor population growth and to detect new populations, respectively (fig. 11A). High densities of traps are used in some areas to detect isolated growing populations, delimit treatment boundaries, and assess treatment efficacy. Biorational pesticides are then applied aerially to suppress isolated populations in the transition zone, which reduces the rate of spread (fig. 11B). Trap locations and catch data are used to compute the program boundaries, highlight potential problem areas (i.e., growing populations), adjust trapping densities, and recommend treatment applications. The STS program

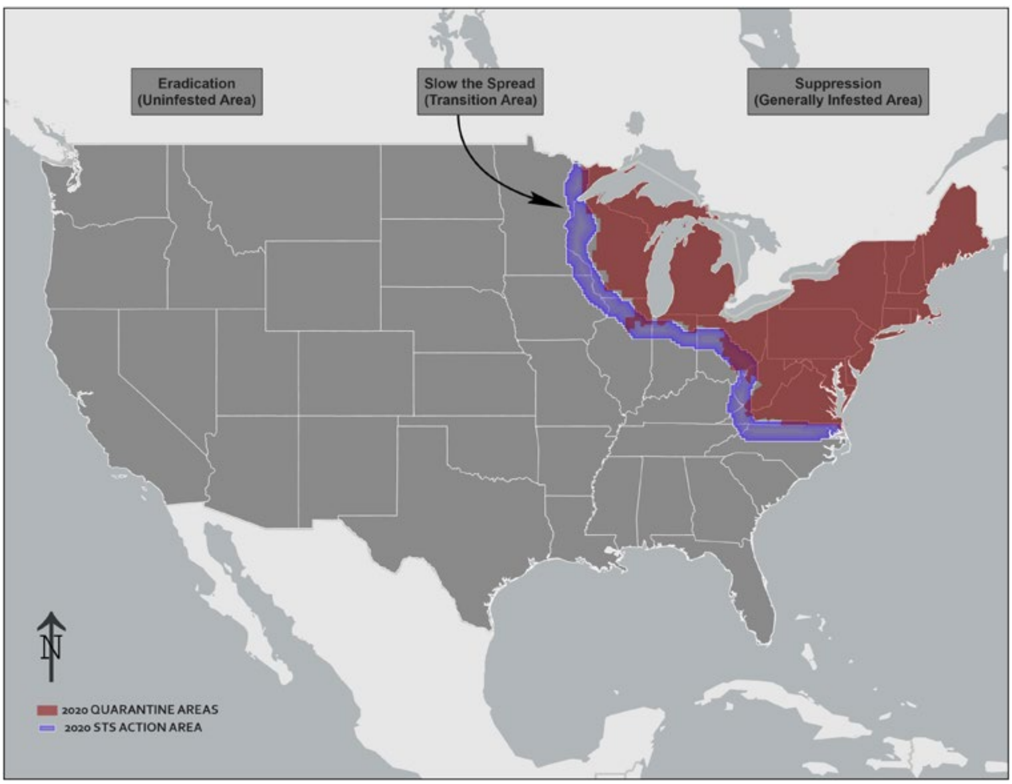

Figure 10. Four strategies of the USDA national program include: (1) suppressing outbreak populations of European spongy moth in quarantined areas, (2) slowing the spread of new populations of European spongy moth along the expanding invasion front, (3) eradicating all new populations of the Asian and European subspecies, and (4) monitoring and regulating the movement of European life stages from quarantined areas (not pictured). Map courtesy of H. Mannin Dodd, Virginia Polytechnic Institute and State University.

has reduced the annual rate of spongy moth spread by more than 60 percent during the 20 years that the program has been in place.

The USDA APHIS collaborates with State agriculture and/or natural resource agencies to detect and eradicate new spongy moth populations outside the quarantined area. Approximately 100,000 pheromone-baited traps are deployed annually nationwide to provide early detection of new populations. Human-assisted dispersal frequently results in the movement of European spongy moth out of quarantined areas in the Eastern United States, whereas egg masses of Asian subspecies are sometimes introduced with cargo and ships originating from eastern Asia. Eradication efforts have successfully eliminated every new population of both subspecies since 1970. Dense trapping grids are typically deployed around newly detected European spongy moth populations in uninfested areas prior to eradication in order to confirm the persistence of populations as well as to delimit their spatial extent. Asian subspecies populations are typically treated the year following detection; these eradication efforts occur most frequently near U.S. ports. APHIS also provides regulatory certification of articles (e.g., nursery stock, shipments of lumber, firewood, plant material, mobile homes, and household items) that may contribute to spread of European spongy moth out of quarantined counties.

Figure 11. Networks of pheromone-baited traps are used to monitor spongy moth populations, direct treatment actions, delineate treatment blocks, and determine treatment efficacy (A). Aerial applications are frequently used to suppress spongy moth populations for the three national program areas (suppression, slow the spread, and eradication) (B). Photos by Tom W. Coleman, USDA Forest Service.

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Acknowledgments

In 2022, the official common name for *Lymatria dispar* and its closely associated sibling species was changed to "spongy moth."

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