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Gypsy Moth

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Figure 1 - *Older gypsy moth larvae showing five pairs of raised blue spots and six pairs of raised brick-red spots.*

The gypsy moth, *Lymantria dispar* Linnaeus, (fig. 1) is one of the most notorious pests of hardwood trees in the Eastern United States. Since 1980, the gypsy moth has defoliated close to a million or more forested acres each year. In 1981, a record 12.9 million acres were defoliated. This is an area larger than Rhode Island, Massachusetts, and Connecticut combined.

In wooded suburban areas, during periods of infestation when trees are visibly defoliated, gypsy moth larvae crawl up and down walls, across roads, over outdoor furniture, and even inside homes. During periods of feeding they leave behind a mixture of small pieces of leaves and frass, or excrement.

Gypsy moth infestations alternate between years when trees experience little visible defoliation (gypsy moth population numbers are sparse) followed by 2 to 4 years when trees are visibly defoliated (gypsy moth population numbers are dense).

The gypsy moth is not a native insect. It was introduced into the United States in 1869 by a French scientist living in Massachusetts. The first outbreak occurred in 1889. By 1987, the gypsy moth had established itself throughout the Northeast. The insect has spread south into Virginia and West Virginia, and west into Michigan (fig. 2). Infestations have also occurred in Utah, Oregon, Washington, California, and many other States outside the Northeast.

Life Cycle

The gypsy moth passes through four stages: egg, larva, pupa, and adult (moth stage). Only the larvae damage trees and shrubs.

Gypsy moth egg masses are laid on branches and trunks of trees, but egg masses may be found in any sheltered location. Egg masses are buff colored when first laid but may bleach out over the winter months when exposed to direct sunlight and weathering.

The hatching of gypsy moth eggs coincides with budding of most hardwood trees. Larvae emerge from egg masses from early spring through mid-May (fig. 3).

Larvae are dispersed in two ways. Natural dispersal occurs when newly hatched larvae hanging from host trees on silken threads (fig. 4) are carried by the wind for a distance of about I mile. Larvae can be carried for longer distances. Artificial dispersal occurs when people transport gypsy moth eggs thousands of miles from infested areas on cars and recreational vehicles, firewood, household goods, and other personal possessions.

Figure 3 - *Gypsy moth larvae emerging from egg mass.*

Figure 1 - *Area of general infestation as of 1988.*

Larvae develop into adults by going through a series of progressive molts through which they increase in size. Instars are the stages between each molt. Male larvae normally go through five instars (females, through six) before entering the pupal stage. Older larvae have five pairs of raised blue spots and six pairs of raised brick-red spots along their backs (rig. 5).

During the first three instars, larvae remain in the top branches or crowns of host trees. The first stage or instar chews small holes in the leaves (fig. 6). The second and third instars feed from the outer edge of the leaf toward the center.

Figure 4 - *Gypsy moth larvae suspended on silken threads.*

When population numbers are sparse, the movement of the larvae up and down the tree coincides with light intensity. Larvae in the fourth instar feed in the top branches or crown at night. When the sun comes up, larvae crawl down the trunk of the tree to rest during daylight hours. Larvae hide under flaps of bark, in crevices, or under branches-any place that provides protection. When larvae hide underneath leaf litter, mice, shrews, and *Calosoma* beetles can prey on them. At dusk, when the sun sets, larvae climb back up to the top branches of the host tree to feed.

When population numbers are dense, larvae feed continuously day and night until the foliage of the host tree is stripped (fig. 7). Then they crawl in search of new sources of food.

The larvae reach maturity between mid-June and early July. They enter the pupal stage (fig. 8). This is the stage during which larvae change into adults or moths. Pupation lasts from 7 to 14 days. When population numbers are sparse, pupation can take

Figure 5 - *Gypsy moth egg masses on the trunk and branches of a tree*

Figure 6 - *First instar gypsy moth larvae chewing small holes in leaves*

place under flaps of bark, in crevices, under branches, on the ground, and in other places where larvae rested.

During periods when population numbers are dense, pupation is not restricted to locations where larvae rested. Pupation will take place in sheltered and non-sheltered locations, even exposed on the trunks of trees or on foliage of non-host trees.

The male gypsy moth emerges first, flying in rapid zigzag patterns searching for females. When heavy, egg-laden females emerge, they emit a chemical substance called a pheromone that attracts the males (fig. 9). The female lays her eggs in July and August close to the spot where she pupated (fig. 10). Then, both adult gypsy moths die.

Four to six weeks later, embryos develop into larvae. The larvae remain in the eggs during the winter. The eggs hatch the following spring.

Figure 7 - *A tree stripped by gypsy moth larvae.*

Figure 8 - *Gypsy moth pupa.*

Figure 9 - *Male gypsy moth.*

Hosts

Gypsy moth larvae prefer hardwoods, but may feed on several hundred different species of trees and shrubs. In the East the gypsy moth prefers oaks, apple, sweetgum, speckled alder, basswood, gray and white birch, poplar, willow, and hawthorn, although other species are also affected. The list of hosts will undoubtedly expand as the insect spreads south and west.

Older larvae feed on several species of hardwood that younger larvae avoid, including cottonwood, hemlock, southern white cedar, and the pines and spruces native to the East. During periods when gypsy moth populations are dense, larvae feed on almost all vegetation: To date, the gypsy moth has avoided ash, yeflow-poplar, sycamore, butternut, black walnut, catalpa, flowering dogwood, balsam fir, red cedar, American holly, and shrubs such as mountain laurel, rhododendron, and arborvitae.

Effects of Defoliation on Trees

The effects of defoliation depend primarily on the amount of foliage that is removed, the condition of the tree at the time it is defoliated, the number of consecutive defoliations, available soil moisture, and the species of host.

If less than 50 percent of their crown is defoliated, most hardwoods will experience only a slight reduction (or loss) in radial growth.

If more than 50 percent of their crown is defoliated, most hardwoods will refoliate or produce a second flush of foliage by midsummer (rigs. 11, 12). Healthy trees can usually withstand one or two consecutive defoliations of greater than 50 percent. Trees that have been weakened by previous defoliation or been subjected to other stresses such as drought are frequently killed after a single defoliation of more than 50 percent.

Figure 10 - *Female gypsy moth laying eggs.*

Figure 11 - *Tree Before Defoliation.*

Figure 12 - *Tree after refoliation.*

Trees use energy reserves during refoliation and are eventually weakened. Weakened trees exhibit symptoms such as dying back of twigs and branches in the upper crown and sprouting of old buds on the trunk and larger branches. Weakened trees experience radial growth reduction of approximately 30 to 50 percent.

Trees weakened by consecutive defoliations are also vulnerable to attack by disease organisms and other insects. For example, the *Armillaria* fungus attacks the roots, and the two-lined chestnut borer attacks the trunk and branches. Affected trees will eventually die 2 or 3 years after they are attacked.

Although not preferred by the larvae, pines and hemlocks are subject to heavy defoliation during gypsy moth outbreaks and are more likely to be killed than hardwoods. A single, complete defoliation can kill approximately 50 percent of the pines and 90 percent of the mature hemlocks.

Factors That Affect Gypsy Moth Populations

Natural enemies play an important role during periods when gypsy moth populations are sparse. Natural enemies include parasitic and predatory insects such as wasps, flies, ground beetles, and ants; many species of spider; several species of birds such as chickadees, bluejays, nuthatches, towhees, and robins; and approximately 15 species of common woodland mammals, such as the white-footed mouse, shrews, chipmunks, squirrels, and raccoons.

The Calosoma beetle, a ground beetle of European origin, cuckoos, and flocking birds, such as starling, grackles, and red-winged blackbirds, are attracted to infested areas in years when gypsy moth populations are dense.

Diseases caused by bacteria, fungi, or viruses contribute to the decline of gypsy moth populations, especially during periods when gypsy moth populations are dense and are stressed by lack of preferred foliage.

Wilt disease caused by the nucleopolyhedrosis virus (NPV) is specific to the gypsy moth and is the most devastating of the natural diseases. NPV causes a dramatic collapse of outbreak populations by killing both the larvae and pupae. Larvae infected with wilt disease are shiny and hang limply in an inverted "V" position (fig. 13).

Figure 13 - *Larvae infected by the nucleopolyhedrosis virus (NPV) hanging in an inverted "V" position.*

Weather affects the survival and development of gypsy moth life stages regardless of population density. For example, temperatures of -20 OF. (-29 OC.) lasting from 48 to 72 hours can kill exposed eggs; alternate periods of freezing and thawing in late winter and early spring may prevent the overwintering eggs from hatching; and cold, rainy weather inhibits dispersal and feeding of the newly hatched larvae and slows their growth.

Managing the Gypsy Moth

A number of tactics have the potential to minimize damage from gypsy moth infestations and to contain or maintain gypsy moth populations at levels considered tolerable. These tactics include monitoring gypsy moth populations, maintaining the health and vigor of trees, discouraging gypsy moth survival, and treating with insecticides to kill larvae and protect tree foliage. The tactic or combination of tactics used will depend on the condition of the site and of the tree or stand and the level of the gypsy moth population. Tactics suggested for homeowners are probably too costly and too labor intensive for managers to use in forest stands.

Tactics Suggested for Homeowner

Homeowners might want to consider one or more of the following tactics when gypsy moth populations are sparse. These activities do not guarantee a reduction or elimination of gypsy moth populations, nor will the activities guarantee to reverse the trend of an infestation of the gypsy moth. These activities are more practical for homeowners to use on individual yard trees than for land managers to use in forest stands.

Tactics Directed Against the Gypsy Moth

- Remove objects around the outside of the home that provide shelter for gypsy moth larvae and pupae, such as flaps of bark, dead tree branches, dead trees, boxes, cans, or old tires.
- Diversify the composition of trees and plants on your property to include species not preferred by the gypsy moth, such as tulip or yellow poplar, honeylocust, ash, hickory, dogwood, mountain ash, and many conifers.
- Destroy egg masses found on outbuildings, on fencing, and in woodpiles. Simply scraping egg masses onto the ground will not destroy them. Burn them or soak them in kerosene or soapy water. Caution is urged because the hairs that coat the egg masses can cause allergic reactions. Egg masses can also be destroyed by painting them with commercially available products, such as liquid detergents.
- Place burlap on trees, especially oaks, to provide shade and shelter for older larvae when they seek out protected resting places during the day. The number of larvae and pupae that rest under the burlap provides valuable information about the severity of infestation on your property. When populations are sparse, larvae and pupae beneath burlap can be manually destroyed (fig.

Figure 14 - *Gypsy moth larvae and pupae under burlap..*

14).

- Use barrier bands, consisting of commercially available doublesided sticky tapes, or sticky material such as Tanglefoot, petroleum jelly, or grease, to prevent larvae from crawling up the trunks of susceptible trees. These products should be applied to the surface of an impermeable material, such as duct tape or tar paper, and not applied directly to the bark. Petroleum-based products can cause injury (swelling and cankering) on thinbarked trees.

Maintaining and Enhancing the Health of Trees

- Enhance growth conditions for isolated trees by encircling them with mulch or ground cover plants that do not compete for moisture and nutrients the way dense grass layers do.
- Water shade and ornamental trees in periods. of drought to maximize recovery during refoliation.
- Fertilize shade trees.
- Avoid stressing trees. For example, construction projects tend to compact soil and prevent moisture from penetrating to small feeder roots.
- Avoid applying lime or weed killers around trees. These chemicals can seriously damage shallow tree roots.
- Thin woodlot trees and groups of shade trees between outbreaks to reduce competition.

The Use of Pesticides Against the Gypsy Moth

The decision to use pesticides is influenced by a number of factors:

- The number of visible egg masses.
- The percentage of preferred hosts in a mixed stand of trees (50 percent or more of oak).
- Whether trees already have dead or dying branches, especially near the top branches or crown.
- Whether the property is located adjacent to wooded areas heavily infested with gypsy moths.

During periods when numbers of gypsy moth larvae are dense, pesticides may be the most effective method of reducing the number of larvae and protecting the foliage of host trees. Application of pesticides should be done by a certified appli-

cator, because special equipment is required. Large acreages, such as wooded residential areas and forests, should be treated by aircraft.

Available pesticides fall into two broad groups: microbial or biological and chemical (table 1).

Microbial and biological pesticides contain living organisms that must be consumed by the pest. Microbials include bacteria, viruses, and other naturally occurring organisms; biologicals include manmade synthetics of naturally occurring organisms. These pesticides should be applied before the larvae reach the third stage or instar of development. As they mature, larvae become more resistant to microbial pesticides and are, therefore, more difficult to kill.

Nucleopolyhedrosis virus (NPV), a naturally occurring organism, has been developed as a microbial pesticide. It is presently registered under the name "Gypchek" and is available for use in USDA Forest Service sponsored suppression programs. NPV and Gypcheck are specific to the gypsy moth.

Bacillus thuringiensis (Bt) is microbial and biological. It is the most commonly used pesticide. In addition to being used against the gypsy moth, Bt is used against a number of other pests, including the western spruce budworm, spruce budworm, and tent caterpillar. When Bt is taken internally, the insect becomes paralyzed, stops feeding, and dies of starvation or disease.

Chemical pesticides are contact poisons in addition to being stomach poisons. The timing of the chemical application is less critical to the successful population reduction of the pest than the timing of the apphcation

Table 1 - *Micorbial and chemical pesticides comonly used for gypsy moth control*

Active Ingredient	Representative trade names	Remarks
Bacillus thuringiensis	Dipel, Foray, Thuricide	Registered for aerial land ground application. Available under a variety of trade names. Toxic to other moth and butterfly larvae. Can be used safely near water.
Diflubenzuron	Dimilin	A restricted-use pesticide that can be applied only by certified applicators.
Acephate	Orthene	Registered for aerial and ground application. Available under a variety of trade names. Toxic to bees and some gypsy moth parasites. commonly used from the ground to treat individual trees.
Carbaryl	Sevin	Registered for aerial and ground application. Available under a variety of trade names. Toxic to bees and gypsy moth parasites. At one time, the most widely used chemical in gypsy moth control programs.

of the niicrobials and biologicals. Chemical pesticides can affect nontarget organisms and may be hazardous to human health.

The most commonly used chemical pesticides currently registered by the U.S. Environmental Protection Agency (EPA) for use against the gypsy moth contain carbaryl, diflubenzuron, and acephate. Malathion, methoxychlor, phosmet, trichlorfon, and synthetic pyrethroids have also been registered by EPA for control of gypsy moth, but are used infrequently.

Diflubenzuron represents a new class of pesticides called insect growth regulators. It kills gypsy moth larvae by interfering with the normal molting process. Diflubenzuron has no effect on adult insects. Aquatic crustaceans and other immature insects that go through a series of molting stages are often sensitive to this pesticide.

Silvicultural Guidelines for Forest Stands and Woodlots

Several interrelated factors determine the vulnerability of forest stands and woodlots to gypsy moth defoliation. An awareness of these factors will enable land managers and woodlot owners to prescribe silvicultural actions that will minimize the impact caused by gypsy moth defoliation. Three of these factors include the abundance of favored food species (mainly oaks), site and stand factors, and tree conditions.

Stands of trees that are predominately oak and grow on poor, dry sites (such as sand flats or rock ridges) are frequently stressed and often incur repeated, severe defoliations. Trees growing under these conditions frequently possess an abundance of structural features such as holes, wounds, and deep bark fissures that provide shelter and habitats for gypsy moth larvae and aid their survival.

Stands of trees that are predominantly oak but grow on protected slopes or on sites with adequate moisture and organic matter are more resistant to defoliation by the gypsy moth.

Slow-growing trees on poor sites frequently survive a single, severe defoliation better than fast-growing trees typically found on well-stocked better sites.

More trees are killed in stands that contain mainly oak species than in oak-pine or mixed hardwood stands.

Subdominant trees are killed more rapidly and more often than dominant trees.

Silvicultural Treatment-What and When?

Appropriate silvicultural treatment will be determined by an anticipated occurrence of gypsy moth defoliation, by characteristics of the stand, and by the economic maturity of the stand. Foresters refer to treatments discussed here as "thinnings." Thinnings are cuttings made in forest stands to remove surplus trees (usually dominant and subdominant size classes) in order to stimulate the growth of trees that remain.

Pre-defoliation treatments: When gypsy moth defoliation is anticipated, but not within the next 5 years, **pre-defollation thinning** to

selectively remove preferred-host trees can reduce the severity of defoliation, increase the vigor of residual trees, and encourage seed production and stump sprouting. Thinnings should not be conducted in fully stocked stands that will reach maturity within the next 6 to 15 years. Thinning results in a short term "shock effect" to residual trees. This shock effect, coupled with defoliati6n-caused stress, renders trees vulnerable to attack by disease organisms such as *Annillaria.*

In fully stocked stands that will reach maturity within the next 16 or more years, two kinds of thinning can be applied. The method of thinning should depend on the proportion of preferred host species present.

If more than 50 percent of the basal area in a stand is preferred host species (mainly oaks), **pre-salvage thinning** should be applied. Pre-salvage thinning is designed to remove the trees most likely to die (trees with poor crown condition) from stress caused by gypsy moth defoliation.

If less than 50 percent of the basal area in a stand is in preferred host species, **sanitation thinning** can be applied to reduce further the number of preferred host trees. This will result in fewer refuges for gypsy moth larvae and in improved habitats for the natural enemies of the gypsy moth.

Treatment during outbreaks: If defoliation is current or is expected within the next 5 years, thinnings should be delayed because of potential "shock effect." High-value stands can be protected by applying pesticides. In low-value stands or those that are at low risk (less than 50 percent basal area in preferred host species), protective treatments are optional.

Post-outbreak treatments: After a defoliation episode, the land manager or woodlot owner should pursue efficient salvage of dead trees, but should delay decisions about additional salvage, regeneration, or other treatments for up to 3 years. At the end of 3 years, most defoliation caused mortality will be complete and the need for treatments can be assessed on the basis of damage level, current stocking conditions, and stand maturity.

Assistance

Homeowners can get advice about identifying and controlling the gypsy moth through the County Cooperative Extension Service, the State Entomologist or State Forester, or from specialists at the State University or Agricultural Experiment Station.

Some communities may qualify for State or Federal cooperative treatment programs. These programs are usually administered through local county or designated State agencies.

Information about regulations concerning the interstate movement of outdoor household articles from areas infested by gypsy moth can be obtained by contacting one of the following:

- The Plant Protection or Regulatory Division of the State Department of Agriculture.
- The Plant Protection and Quarantine Division of the Animal and Plant Health Inspection Service, U.S. Department of Agriculture.

- The County Extension Agent listed in the local telephone directory.

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