The Gypsy Moth

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History

The gypsy moth was brought into the United States from France by a naturalist, Leopold Trouvelot, who was performing experiments with silk-producing caterpillars. Escaping from the Trouvelot home in Medford, Massachusetts in 1868 or 1869, the gypsy moth caterpillars initially went unnoticed. Twenty years later, however, their numbers had increased substantially, trees were being defoliated, and the gypsy moth was recognized as a nuisance.

The first outbreak occurred in Medford in 1889. Mrs. Belcher of Medford was to serve as a harbinger of an oft-repeated event when she wrote of that outbreak, "My sister cried out one day, 'They (the caterpillars) are marching up the street.' I went to the front door, and sure enough, the street was black with them, coming across from my neighbor's, Mrs. Clifford's, and heading straight for our yard. They had stripped her trees, but our trees at that time were only partially eaten."

The first gypsy moth collected in Connecticut was found in Mystic in 1905. Immediate efforts were made to eradicate the infestation; but by 1915, the gypsy moth had spread to 20 towns. By 1922, the insect was recognized to be in Connecticut to stay. It was present throughout Windham, Hartford, and Tolland Counties, most of New London County, five towns in Litchfield County and two towns each in New Haven and Middlesex Counties.

Early methods of controlling the gypsy moth in Connecticut were essentially those that had been developed and used before in Massachusetts and included (1) cutting and burning of infested brush, (2) pruning trees, (3) placing of burlap skirts on tree trunks with subsequent destruction of caterpillars, (4) burning of stonewalls, stoneheaps and dumps after oil had been spread, (5) banding trees with Tanglefoot to entrap caterpillars, (6) destroying of egg masses, (7) filling and covering of cavities in trees, (8) collecting and placing caterpillars in bottles of alcohol or kerosene, and (9) treating trees with chemical insecticides applied with sprays from the ground. Aerial spraying of pesticides was introduced for the control of gypsy moth in the 1940s but was not used extensively until the 1950s. Over the decades pesticides have changed even as they continue to change today.

Figure 1. An early spraying rig used shortly after the first gypsy moths were discovered in Connecticut.

Federal quarantine

In 1924, the federal government established the "Barrier Zone," a belt 30 miles wide extending from Long Island Sound to the Canadian border. The eastern portion of the zone in Connecticut passed through the eastern part of Litchfield County and swung southward to East Haven. This federal program was supposed to keep western Connecticut free of gypsy moths so that the states to the west would remain uninfested. This quarantine failed completely, and in 1952, the gypsy moth was recognized to be present in all sections of the State.

The gypsy moth has spread northward into Maine, New Hampshire, Vermont and parts of southern Canada; westward throughout most of New York and Pennsylvania and as far south as Maryland and Delaware. An isolated though extensive infestation occurs in Michigan and new introductions from states in the Northeast occur frequently in several presently uninfested states.

The gypsy moth is still under federal quarantine. Many items are regulated and are required to be inspected before they are moved to uninfested states. These items include plants grown out-of-doors, logs and pulpwood, mobile homes and associated equipment, outdoor furniture, and a number of other products and items that may harbor gypsy moth eggs, caterpillars, pupae, or adults. A state or federal plant protection inspector may be called as shown below.

USDA
Groton 443-4946
Wallingford 269-4277
Windsor Locks 623-6376

STATE
Connecticut Agricultural Experiment Station
New Haven 789-7236

The nursery industry, a large segment of agriculture in Connecticut, is particularly affected by the gypsy moth. Aside from protecting his investment in a crop from these leaf eating insects, a nurseryman must have his plants certified to be free of gypsy moths before he can ship them to destinations outside the gypsy moth quarantine area.

Additional copies are available from:
The Connecticut Agricultural Experiment Station
P.O. Box 1106
New Haven, CT 06504

Life cycle

The gypsy moth has one generation per year. Female moths lay their eggs during mid-July to early to mid-August. The eggs are laid in a buff-colored mass that may contain less than 100 to more than 1000 eggs. Eggs are laid in several layers and are covered with hairs from the body of the adult female. The embryo becomes fully formed in 3 weeks and remains quiescent over the winter until it hatches in late April or early May.

Upon hatching, caterpillars may remain on the egg mass for a few days before ascending the tree and beginning to feed on the newly formed leaves. Although only about ¼ inch long at the time of hatching, a fully-grown caterpillar may be almost 2 inches long by the time it completes feeding about July 1. The brownish to black caterpillars have three light stripes along the back and tufts of hairs. Each segment except the first bears a pair of wart-like projections of which the first five pairs are blue and the last six red.

When the caterpillar stops feeding it seeks a protected place to change into a transitional pupa before transforming into a moth. This pupa, which looks like an enlarged brown teardrop, is naked except for a few strands of silk loosely spun around it.

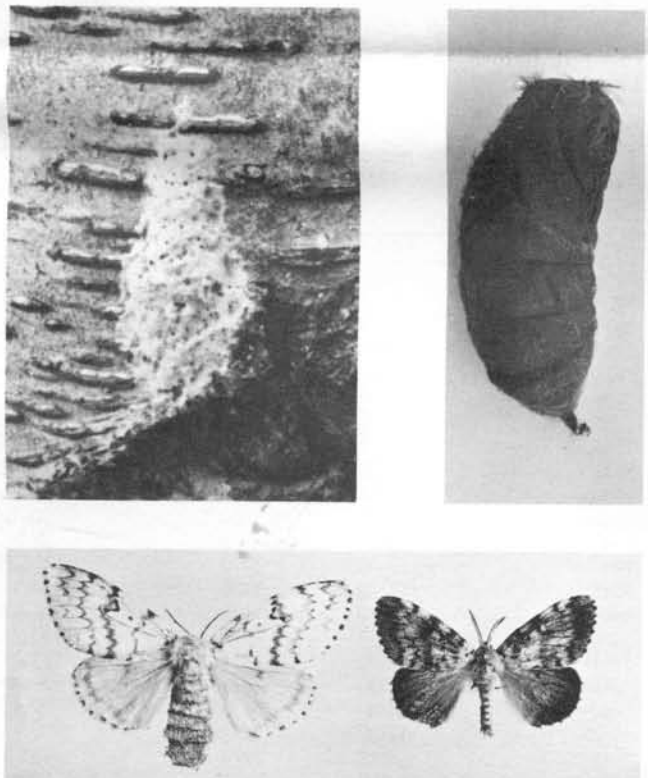

Figure 2. Gypsy moth egg mass, top left; pupa, top right; adult female, bottom left; and adult male, bottom right. The caterpillar stage appears on the cover.

Moths emerge in 10 to 14 days. The males tend to emerge first, are brown and fly in a zigzag manner, usually during the daytime. The female is white with dark markings on her wings, does not fly, and remains near her pupation site and releases a sex attractant (pheromone). Shortly after "calling" a male and mating, she lays her eggs in a single mass and then dies.

Dispersal

Gypsy moth larvae move on the wind or crawl. Young caterpillars deposit silken trails as they crawl. They frequently drop from branches and leaves on silken threads which are then easily broken by the wind. These threads together with the long hairs assist in keeping the insect afloat in air currents that redistribute gypsy moth caterpillars within and between towns.

The larger caterpillars crawl up and down tree trunks, feeding mainly at night and seeking cool, shaded, protected sites to rest during the day. In dense populations, caterpillars may feed continuously day and night and may crawl from place to place anytime. The caterpillars are only capable of crawling short distances over the ground at this stage.

Long range dispersal is aided by man. Man brought the gypsy moth from France to America. Today man inadvertently carries egg masses on vehicles, outdoor furniture, plants, and so forth, from New England to such distant places as Illinois, Minnesota, California, and Florida.

Host plants

Although the gypsy moth may appear at times to eat almost any plant, there are some that it hardly feeds on and others that it relishes. In fact, more than 500 trees, shrubs and vines have been shown to be acceptable hosts. Favored trees include the oaks, apple, basswood, willow, American beech, aspen, gray and paper birch, and tamarack. Less popular although acceptable trees are black and yellow birch, cherry, elm, the hickories, and red and sugar maples. Older caterpillars feed readily on hemlock; and some, though not all, species of pines and spruces. Caterpillars tend to avoid ashes, mountain laurel, tulip tree, sycamore, honey locust, red spruce, American holly, and eastern redcedar.

Natural enemies

Natural enemies include insect parasites and predators, microbial pathogens, birds, and mammals. Ten exotic parasites have been introduced and established in North America; six are wasps and four are parasitic flies. Two parasitize eggs, two attack small caterpillars, four parasitize large caterpillars, and the remaining two parasitize pupae. The most common parasite is the small, black wasp, *Ooencyrtus kuwanai*; although numerous, it destroys only the outermost eggs in a mass.

Predators include two large ground beetles that prey upon larvae and pupae as do birds and small- and medium-sized mammals. Shrews and white-footed mice are also predators.

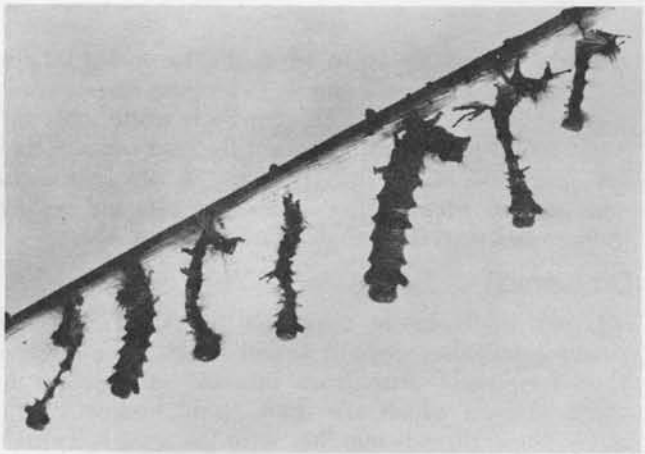

Figure 3. A group of caterpillars that were killed by the nuclear polyhedrosis virus (NPV). They are hanging in a manner characteristic of death from the disease.

A nuclear polyhedrosis virus (NPV) and a streptococcus bacterium are two known microbial pathogens. The NPV is by far the more important and is the major cause along with starvation for the end of outbreaks. This virus may remain viable in the forest for more than one year.

In summary, all natural enemies are important and without them outbreaks would occur more frequently, and they would last longer. Nevertheless, they have not been sufficient to prevent many outbreaks from occurring nor have they always been adequately abundant to terminate them quickly.

Outbreaks

Although in Connecticut the first gypsy moth was caught in 1905, the first time 1000 or more acres of woodland were defoliated was in 1938. Thousands of acres were often defoliated annually in the 1950s and 1960s (Table 1). Defoliation peaked in 1971 when 654,000 acres were noticeably defoliated by the gypsy moth and elm spanworm. The outbreak of the latter insect totally collapsed two years later because of an egg parasite. Gypsy moth populations steadily declined in the 1970s until no defoliation was recorded in 1977. Caterpillars affected 3,800 acres in 1978; defoliation increased modestly to 8,600 acres in 1979, and in 1980, caterpillars defoliated more than 370,000 acres. This substantial increase was caused in part by caterpillars that dispersed from outbreaks in New York and possibly Massachusetts. There also seems to have been a general increase of the gypsy moth in various parts of Connecticut that was independent of this dispersal. The pattern of defoliation in 1980 is shown in Figure 4 and the number of acres defoliated is shown by county in Table 2.

Caterpillar outbreaks in the past have tended to collapse in 2 or 3 years. One town, however, recorded defoliation within its boundaries for eight consecutive years, and several other towns recorded it for 4 to 6 years. Outbreaks have tended to follow a northerly and easterly path because the prevailing southerly and westerly winds are the main means of dispersal for the small caterpillars.

Effect of defoliation on trees

The forest is one of the enduring features of our landscape. Although we have cut and burned our forests, cleared land for farms, and released insect and disease plagues upon our trees, Connecticut remains forested. Cut-over land, burned woodland and unmanaged farmland have reverted to forest and diseased trees have been replaced by others.

The gypsy moth began to defoliate thousands of acres of woodland in Connecticut in the 1950s. Outbreaks continued into the 1960s, 1970s and 1980s. The effect of these outbreaks on our forest when measured over a decade has been small. Experiment Station studies show that a single defoliation does not increase tree mortality in the forest. Repeated defoliation increased mortality and resulted in the death of some large trees, but over a decade, mortality has not been more than twice that which would have occurred without gypsy moth outbreaks. Mortality can be high (up to 79%) in some localized areas such as on dry ridges or upper slopes where thin rocky soils present an inhospitable environment for trees under stress.

Among hardwoods, oaks die more readily than other species groups; white and chestnut oaks being the most susceptible. Within the conifers, hemlocks are particularly susceptible as evidenced by the almost complete mortality of large hemlocks in a portion of Cromwell which was completely defoliated for one season in 1962.

Table 1. Acreage noticeably defoliated by the gypsy moth in Connecticut, 1935-1980.

Year	Acres	Year	Acres
1935	67	1958	117
1936	0	1959	6,000
1937	0	1960	20,000
1938	1,131	1961	15,800
1939	1,759	1962	83,300
1940	0	1963	40,140
1941	0	1964*	93,552
1942	0	1965*	86,009
1943	0	1966*	15,895
1944	14	1967	2,731
1945	16	1968	16,416
1946	496	1969*	52,635
1947	0	1970*	425,039
1948	0	1971*	654,102
1949*	0	1972	508,460
1950	475	1973	333,215
1951*	200	1974	120,980
1952*	1,500	1975	63,411
1953*	20,000	1976	9,809
1954*	14,000	1977	0
1955*	6,842	1978	3,835
1956*	3,458	1979	8,619
1957*	4,800	1980	372,216

* An additional 1000 or more acres of forested land were treated with insecticide.

Table 2. Intensity of defoliation in Connecticut counties, 1980.

County	Acres/Percent Defoliation				Total Defoliation	County Acreage
	10-25	26-50	51-75	76-100		
Litchfield	5,070	17,433	19,422	23,712	65,637	607,168
Hartford	6,162	14,625	17,160	28,197	66,144	480,128
Tolland	2,340	1,443	0	0	3,783	268,848
Windham	19,539	507	8,190	897	29,133	332,740
Fairfield	9,633	22,269	35,412	29,952	97,266	422,031
New Haven	4,758	19,617	31,239	25,545	81,159	399,016
Middlesex	3,861	10,725	3,744	312	18,642	248,028
New London	10,452	0	0	0	10,452	448,508

Most white pines have survived up to 70% defoliation; about 75% have survived following 100% defoliation.

Effects of defoliation on the tree are direct and indirect. The direct effect is one of reducing the food reserves of the tree. Such stressed trees are then predisposed to attack by organisms such as the shoestring rootrot fungus and the twolined chestnut borer, which may further weaken or even kill trees. Defoliation also affects trees by decreasing growth and by causing twig and branch dieback, which may deform trees. Defoliated yard or street trees may benefit from judicious watering and fertilizer application.

In summary, defoliation is detrimental to trees, but most affected trees have survived in Connecticut. In the forest, defoliation may be hastening the reduction of oaks and their replacement with maples and birches. For a homeowner, a dead ornamental tree can create an aesthetic as well as a financial loss.

Egg mass surveys

Outbreaks are forecast from surveys of (1) the numbers of egg masses per acre, (2) the size of the egg masses, (3) the proportion of trees that are favored host plants, and (4) the history of the gypsy moth in the area. By our survey methods (5 minutes of counting), the presence of 150 or more large (1¼ × ¾ inches) egg masses per acre of forest supporting an abundance (50% of the leaf area) of favored trees usually indicates a pending outbreak.

Surveys may be made at any time between August to mid-April, but are easier to conduct when the leaves are off the trees in fall, winter or early spring. New egg masses may be distinguished from old by their lighter color and firmer texture.

A state-wide survey of egg masses was not completed when this was written, but available data indicated that the gypsy moth would be abundant in Connecticut in 1981. Extensive defoliation is expected in western, central and parts of eastern Connecticut.

Control programs

Section 22-91 of the General Statutes enables a town to conduct a control program against the gypsy moth, to be reimbursed by the State for up to 50% of the cost of such a program and to assess landowners for not more than one-half of the cost to the municipality. Under this statute, a sum not to exceed $37,500 may be shared by all towns conducting control programs. A decision on whether to embark on a town-wide control program is a responsibility of the town government. Often, the pros and cons of spraying are well-debated before a decision is reached.

Thirteen towns undertook control programs in the 1970s. All other towns left control to individual residents or landowners.

Three options are available to towns that wish to have a community program. These options are to (1) aerially spray town-owned and/or private lands, (2) ground spray roadsides, and (3) ground spray town-owned and/or private lands.

Non-insecticidal control

Destruction of egg masses—Egg masses may be destroyed by scraping them into a can containing kerosene or by coating each egg mass with creosote colored with lampblack. Eggs may also be destroyed by burning. It is not sufficient to scrape the eggs onto the ground because many will probably survive. Limitations of this method include (1) inaccessibility of egg masses attached to high branches or deposited in secluded places, and (2) wind-blown caterpillars reinfesting areas cleared of egg masses.

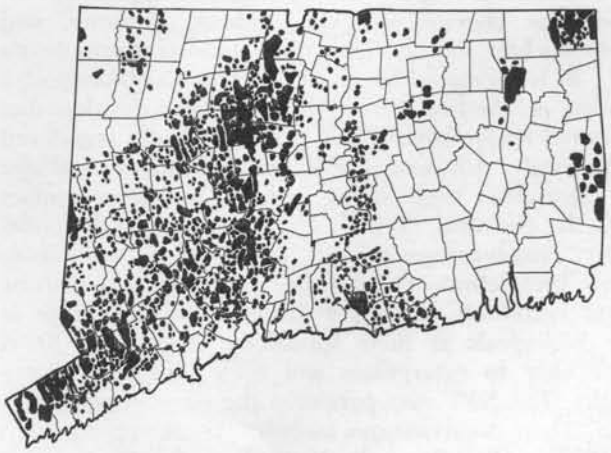

Figure 4. The areas of Connecticut that were defoliated 10 percent or more during 1980.

Use of burlap skirts—Large caterpillars may be attracted by placing skirts of burlap on the trunks of trees. The burlap provides cool, damp shade for caterpillars resting during the day. These caterpillars can be removed and destroyed.

Sticky bands—Sticky bands prevent caterpillars from climbing trees. They are most effective on uninfested or sprayed trees. A band may be prepared as follows: (1) place a 4-inch wide piece of nonabsorbent cotton around the trunk, 4 to 5 feet above the ground to prevent caterpillars from crawling beneath the band, (2) tie a 6- to 12-inch wide piece of tarpaper around the cotton, (3) smear the surface with a sticky material such as Tanglefoot, (4) replace the sticky material when needed until mid-July. Grease should not be used because it may disfigure or even kill trees.

Traps—The sex attractant of the gypsy moth has been identified, synthesized and named disparlure. Traps containing this attractant help detect new infestations outside the quarantine area, but there is no evidence disparlure can be used to control the gypsy moth.

Forest management—Much of the present hardwood forest is 40 to 50 percent oak, and oaks are most susceptible to defoliation by the gypsy moth. Control by removing susceptible trees and encouraging less or nonsusceptible species is a possible long-range means of reducing the nuisance and damage caused by the gypsy moth. In the unmanaged forest, which includes most of our woodland, this trend away from oak and toward species less susceptible to defoliation is occurring slowly, but steadily. Deliberate removal of susceptible oaks may reduce the biological problem of defoliation, but unfortunately, it also reduces the economic value of the forest. A homeowner may consider replacing dead or dying oaks with aesthetically pleasing trees that are less palatable to gypsy moth caterpillars.

Insecticidal control

The application of insecticides is probably the most direct means of protecting foliage. Insecticides registered by the Department of Environmental Protection for the control of gypsy moth by ground application include the chemicals—Sevin, Imidan, Orthene, and methoxychlor, and the biological, *Bacillus thuringiensis (Bt)*. *Bt* is registered for aerial use. Another biological, a nuclear polyhedrosis virus (NPV) has been developed as an aerial spray; however, it is not presently registered in this state. Advantages of chemical pesticides include: (1) caterpillars begin dying within hours after contact with the chemical, (2) high efficiency, and (3) dependability. Disadvantages are: (1) toxicity of the residue to many invertebrate animals and (2) toxicity to man or other vertebrate animals if misused. An advantage of the biologicals is their specificity: essentially *Bt* is toxic only to caterpillars and NPV kills only gypsy moths. The NPV may persist in the environment for a year. Their disadvantages include: (1) caterpillars die 3 to 10 days after *Bt* application, (2) moderate effectiveness, (3) need for more critical timing of application, and (4) possible need for two applications about 10 days apart.

Application of insecticides—Proper timing and thorough coverage of the foliage with the spray are essential. Insecticides are apt to be most efficient if applied (1) after all larvae have hatched, (2) after most of the larvae have settled down to feed and have ceased being blown by the wind, and (3) before the caterpillars have fed excessively on the leaves. This period usually occurs between mid-May and mid-June. If defoliation becomes noticeable in mid-June or evergreens are being attacked, it may still be beneficial to spray at that time. Although a single, properly-timed application is often sufficient to protect trees, more than one application may sometimes be required when the trees to be protected are adjacent to heavily infested woodland.

Ground spraying—Ground application of insecticides with a mist blower or hydraulic sprayer has been effective in controlling gypsy moths and protecting foliage on shade trees. Sprays work best if thoroughly applied to leaves at the top as well as in the middle and bottom of a tall tree. Incomplete coverage may require a second application.

Aerial spraying—The application of insecticides by aircraft is the only practical means for controlling cater-

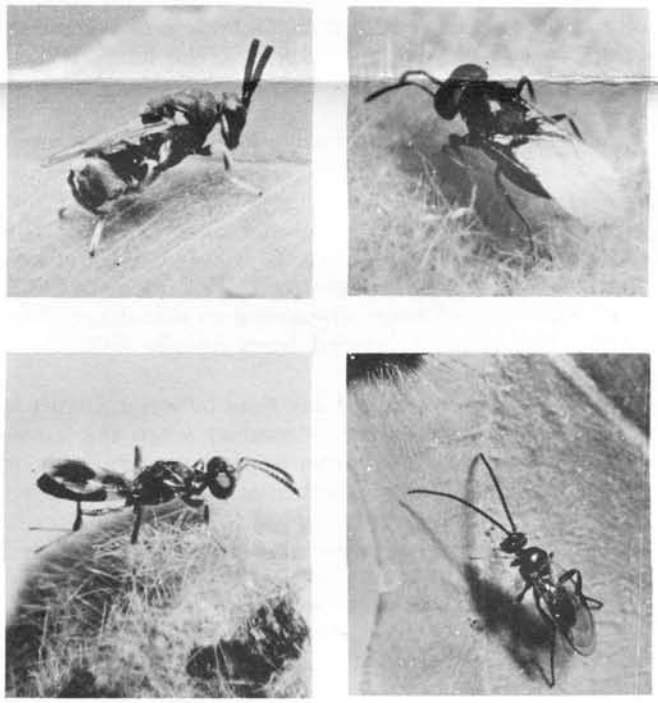

Figure 5. Several wasp parasites of the gypsy moth. At the top left is *Brachymeria lasus*, a parasite of pupae that was introduced into Connecticut during 1979 and 1980; at the top right is *Ooencyrtus kuwanai*, a parasite of eggs; at the bottom left is *Anastatus disparis*, a parasite of eggs; and at the bottom right is *Apanteles melanoscelus*, a parasite of small caterpillars.

pillars on large areas of forested land. *B. thuringiensis* is registered by the Department of Environmental Protection for application by aircraft on forested land. Nurserymen may aerially apply Sevin or methoxychlor to their crop.

Research

The Experiment Station has studied gypsy moth biology and control and the effect of this insect on the forest. Major efforts have included (1) determination of effectiveness of chemical and biological insecticides, (2) releasing new parasites, (3) studying the biology of established parasites, (4) attempting to improve parasites by cross-breeding closely related species, (5) developing an artificial diet and a strain of gypsy moth that could be bred continuously in the laboratory, (6) investigating the role of microbial pathogens in ending outbreaks, (7) studying the diffusion of disparlure and its effect on gypsy moth behavior, (8) determining effects of defoliation on the Connecticut forest, and (9) monitoring defoliation in Connecticut. In spite of these efforts and those of others, gypsy moth outbreaks cannot yet be prevented, nor can their duration be shortened over wide areas.

Current research at the Experiment Station emphasizes biological controls. Attempts are being made to establish parasites imported from Japan in northeastern and southwestern Connecticut. Parasites already established in the state are being studied in an effort to develop methods of increasing their effectiveness. Microbial pathogens applied by aircraft will be reevaluated in 1981.

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