The Evolving Use of Insecticides in *Gypsy Moth Management*

The gypsy moth, an exotic defoliating insect, persists in the United States despite 100 years of attempts at eradication and management using many insecticides. Efforts to eliminate the pest in the Northeast eventually gave way to containment and suppression strategies using broad-spectrum, persistent insecticides. Those products have since been replaced by biologically based technologies that have fewer environmental impacts. With continued expansion of the gypsy moth into the South and Midwest—and with valuable forests at risk—there are renewed efforts to slow its spread with environmentally acceptable insecticides and to eradicate isolated outbreaks in new habitats far from the infested area.

By Andrew Liebhold and Michael McManus

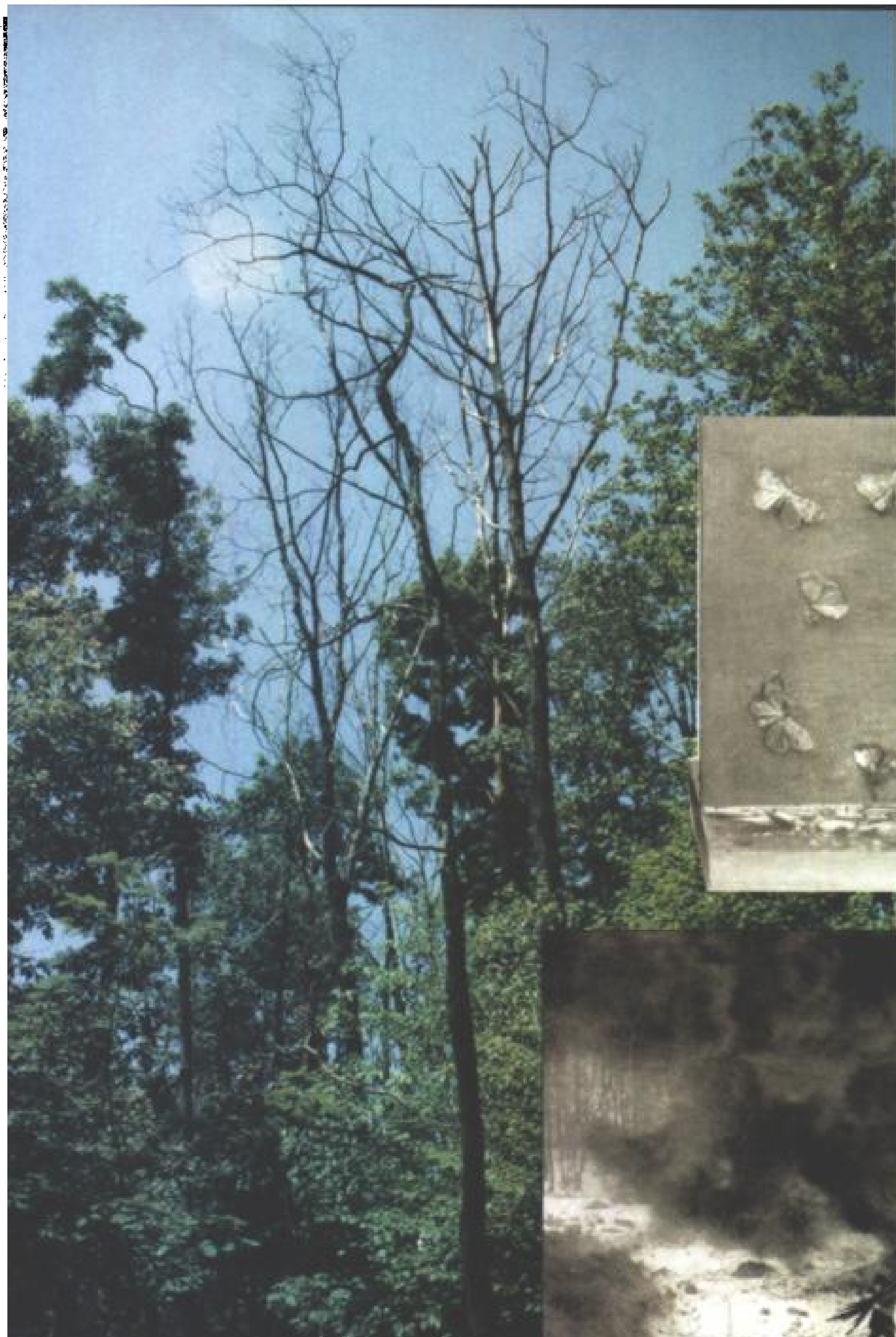
Since the time it was introduced into North America in 1869 near Boston, the gypsy moth has been recognized as the most destructive forest defoliator in the United States. Repeated attempts to eradicate the initial population failed, and the gypsy moth continues to slowly expand its range into uninfested states to the south and west. Insecticides have played a significant role in managing gypsy moth populations, beginning with the eradication programs in the 1890s in Massachusetts and continuing through the eradication, suppression, and containment programs of the 20th century. During the past 100 years, there has been a considerable change both in the insecticides used and in the objectives of their use.

An evolution of materials. When the severity of the infestation in Massachusetts was first recognized in 1890, an aggressive eradication program was initiated, using a combination of mechanical methods designed to destroy gypsy moth life stages and applications of Paris green with horse-drawn ground sprayers. In 1893 lead arsenite, a compound developed specifically for use against the gypsy moth, replaced Paris green, and improvements in spray technology were realized. Two developments that revolutionized gypsy moth control in the early 1940s were the use of aircraft for the application of sprays and the allotment by the War Department of 45 kilograms of DDT so that its efficacy against the gypsy moth in Pennsylvania could be evaluated. This insecticide was so effective against the insect that more than 3.7 million hectares in nine states were aerially sprayed with DDT between 1949 and 1960.

By the late 1950s, however, citizens had become concerned about the persistence of DDT residues and other chlorinated hydrocarbons on forage crops and their effects on beneficial organisms, fish, and wildlife. In 1958 a decision was made to gradually phase out the use of DDT in gypsy moth control programs. The publication of *Silent Spring*, by Rachel Carson, in 1962 placed an exclamation point on public concern about DDT and its effects on the environment; in fact, the book is considered by many to represent the birth of the environmental movement in this country.

Beginning in 1959, a new carbamate material, Carbaryl (Sevin®) replaced DDT and was used almost exclusively to control gypsy moth populations during the 1960s and 1970s. In the late 1960s trichlorfon (Dylox®), a broad-spectrum organophosphate insecticide, was registered for use against the gypsy moth and was preferred by some states over Carbaryl because it was less toxic to honeybees. In 1976 two new products were registered by the Environmental Protection Agency acephate (Orthene®) and diflubenzuron (Dimilin®). Orthene was seldom used because of its projected adverse effects on fish and wildlife, but Dimilin, a novel insecticide that killed gypsy moth larvae by disrupting their molting and was highly efficacious at very low dosages, became the product of choice through the 1980s. Unfortunately, Dimilin also adversely affected other nontarget species, aquatic invertebrates, and shellfish in freshwater habitats, and persisted for several months in forested ecosystems.

In the 1980s, at the same time that the general public was becoming disenchanted with areawide spraying of conventional chemical insecticides and their impact on the environment, significant improvements in commercial formulations of the microbial insecticide *Bt* (*Bacillus thuringiensis* var kurstaki) were being realized through extensive research and development



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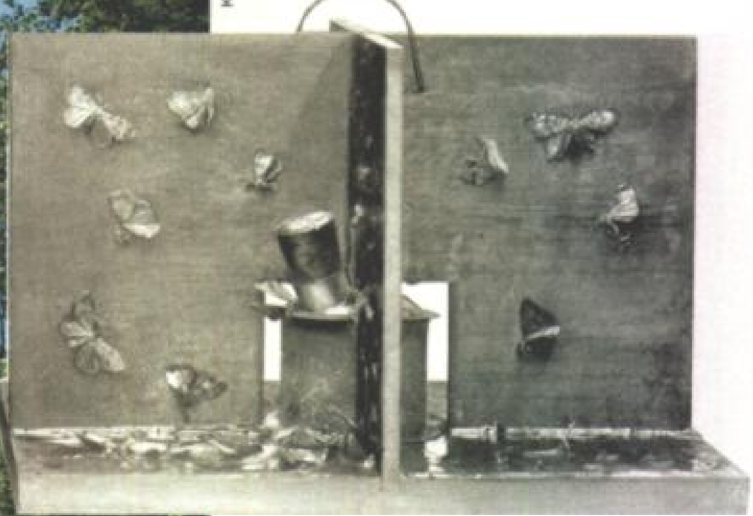

Top: **A live female gypsy moth was placed in the cage in the center, and males attracted to her were trapped on sticky material on the wooden vanes. This early type of pheromone trap was used to detect new populations. *Above:* In 1895 workers in Woburn, Massachusetts, cut and burned a forest infested with the gypsy moth; at the time, eradication of the exotic pest seemed possible.**

Not as efficacious as Dimilin, *Bt* did not persist in the environment, and its use increased dramatically in the late 1980s; *Bt* was the exclusive choice of many state-federal programs in the 1990s. Even though it affects only species of Lepidoptera, its potential impacts on nontarget Lepidoptera raise concerns, especially in habitats where threatened, endangered, or sensitive species are known to occur. Therefore, more specific and environmentally acceptable insecticides to control the gypsy moth are still being sought.

The most likely candidates that meet these specifications are Gypchek, the registered gypsy moth nucleopolyhedrosis virus *(see page 16)*, and Disrupt II, a registered slow-release product that contains a synthetic version of the gypsy moth female sex pheromone and is used to disrupt mating communication and behavior. More recently, Tebufenozide (Mimic II), a product similar in action to Dimilin but with apparently less effect on aquatic invertebrates, has been registered for use against the gypsy moth, and more effective and target-specific strains of *Bt* are being developed and evaluated. It remains to be seen which of these products will be used most frequently in future state-federal gypsy moth management programs.

An evolution of objectives. In 1881, when the importance of the gypsy moth infestation in the Boston area was recognized, Massachusetts began

Historical photos from E.H. Forbush and C.H. Fernald. 1896. *The gypsy moth.* Boston: Wright & Potter.

an aggressive and expensive program to eradicate the species. This program lasted until 1900, when the state legislature, believing that the pest had been eradicated, discontinued the project. Entomologists of the time lacked such technology as synthetic pheromone lures and traps and were therefore unable to detect incipient infestations. Within the next five years, gypsy moth populations increased again in Massachusetts and in three adjacent states. Between 1920 and the 1950s there were several large-scale "barrier" programs designed to prevent the westward spread of the gypsy moth beyond the Hudson River, and to assist in this effort, a federal domestic quarantine was enacted in 1912. The quarantine remains in effect today and is credited with greatly reducing the long-range transport of gypsy moth life stages throughout the United States. Although the barrier-zone concept helped slow the spread of the insect, complete containment failed, and further efforts were stopped. By 1960 any hope of eradicating the gypsy moth had been abandoned, and management objectives shifted to suppressing damaging populations and preventing severe defoliation.

***Left:* In the 1890s workers encircled trees with burlap bands—daytime resting sites for gypsy moth caterpillars. This inexpensive and easy way to detect larval populations is still employed today. *Below:* Hand-pumped sprays were drawn by horse to infested trees; Paris green was the insecticide of choice.**

Although the most serious outbreak on record occurred in 1981, when 5 million hectares were defoliated, more than 0.6 million hectares of forestland were aerially sprayed in 1990 in nine states and the District of Columbia to prevent defoliation; four states far removed from the generally infested area conducted programs to eradicate isolated infestations that had been accidentally introduced.

Until the 1980s, resources had been directed at suppressing high-density populations mainly in urban residential areas. But then the Forest Service embraced the concept of integrated pest management (IPM) to prevent low-density gypsy moth populations from expanding along the advancing front of the infestation. Two pilot programs were initiated during the 1980s to evaluate the concept of managing low-level populations and to develop a more proactive approach using environmentally acceptable methodologies. One, the Maryland IPM Pilot Project (1983–87), used 2-kilometer grids of pheromone traps to identify low-density but increasing gypsy moth populations beyond the generally infested area and developed a database management system to help identify areas where biologically based technologies could then be deployed. The second, the Appalachian Integrated Pest Management Demonstration Project (1987–92), expanded this concept over a much larger region and also assessed the feasibility of slowing the spread of the gypsy moth to uninfested states.

As the area infested by the gypsy moth continues to expand slowly into the South and the Midwest, the frequency at which new isolated colonies are established has increased. Most uninfested states deploy grids of pheromone traps to detect incipient infestations before they become well established. At this stage, infestations can be delimited and eliminated with multiple applications of *Bt.* A serious new threat emerged when the Asian biotype of the gypsy moth was introduced into the ports of Vancouver and Tacoma in 1991 and into North Carolina in 1993. Both of these infestations were eradicated in three to five years using microbial insecticides, at large expenditure of state and federal funds.

Based on the results of those demonstration projects, in 1995 the Forest Service and the Animal and Plant Health Inspection Service developed an environmental impact statement in which they proposed adopting a comprehensive long-term national program to protect the forests and trees of the United States from the adverse effects of the gypsy moth. This consisted of (1) suppressing potentially damaging populations within the generally infested areas, (2) eradicating isolated infestations that are detected beyond the infested area, and (3) slowing the spread of the insect from the area where it is established to delay the impacts and costs associated with managing gypsy moth outbreaks. An in-depth benefit-cost analysis projected that millions of dollars in program benefits could be realized over time if the spread of the gypsy moth could be reduced by 4 to 20 kilometers per year. The feasibility of slowing the spread was demonstrated in a pilot program that began in 1991 in Virginia, West Virginia, and North

Historical photos from E.H. Forbush and C.H. Fernald. 1896. *The gypsy moth.* Boston: Wright & Potter.

Carolina. As with eradication projects, relatively small isolated colonies are delimited and then treated with environmentally acceptable products, such as *Bt* and pheromone flakes for mating disruption.

Outlook for the future. Over the past five years, gypsy moth populations have declined significantly in the Northeast, in part because of a fungus, *Entomophaga maimaiga,* which began reducing larval populations beginning in 1989. This has resulted in a marked reduction in aerial spraying conducted normally through state-federal cooperative suppression programs. A question remains about the behavior of gypsy moth populations in the eastern United States. Will the current absence of outbreak populations, which has been partially attributed to the influence of *Entomophaga maimaiga,* continue, or is this only a lull in an episodic cycle of varying densities?

Although 17 states east of the Mississippi River currently are listed as generally infested, a vast area of valuable commercial hardwood forest that is excellent habitat for the gypsy moth lies to the south and west. Missouri, for example, which is just beyond the currently infested region, has 5.7 million hectares of forestland, 73 percent of which is classified as oak type and thus highly susceptible to defoliation. Despite evidence that the rate of spread of the gypsy moth can be slowed, the insect will continue to expand into new susceptible forestlands, where historically its initial impacts have been most severe. Therefore, it is likely that there will be an increased demand for highly specific, environmentally benign insecticides because of the public's continued concern about the impact of broad-spectrum products on nontarget organisms, human health, and water resources.

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