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HERE COMES THE GYPSY MOTH[1]

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Abstract. The gypsy moth was introduced to North America in 1869 in Medford, MA. During the last 15 years, it has expanded its range rapidly, moving south and west through Pennsylvania and into the Appalachian ridge and valley system. With time, it is likely to invade most of the suitable forest type in the country. The life cycle of the insect is described, as are naturally-occurring controls and applied protection measures and control practices which are available. The urgent need for continued basic and applied research, leading to improved pest management programs, is recognized.

In 1869, the gypsy moth (*Lymantria dispar* (L.)) was introduced to North America from Europe when Leopold Trouvelot, a French scientist, brought this known forest pest to his laboratory in Medford, MA. His desire was to cross this species in experimental studies with various native silkworms. Following the accidental escape of some insects, he alerted the public to a potentially serious problem but little was done to combat it. By the early 1890's, locally severe outbreaks were evident around Medford (3); during the first several decades of the 1900's, spread occurred rather slowly throughout much of New England, particularly to the north and east of the point of introduction. Since then the major expansion of the range of this most serious pest of our hardwood forests in the northeastern U.S. has been generally to the west and south; the rate of spread has been accelerating over the last decade or so (see Fig. 1). Recent information indicates that all counties in Pennsylvania and Maryland, and over 25 in Virginia, now are included within the established range; the leading edge of the infestation has advanced across Pennsylvania at an average rate of ca. 15 miles each year since the late 1960's. With the pest well established in the Appalachian ridge and valley system, there is every reason to expect this spread to continue down through even larger areas of susceptible oak forests.

Life Cycle

We have vast areas of essentially unbroken forest land which provides a veritable banquet for the gypsy moth throughout the oak-hickory type. Typically, as populations invade new areas, they cause heavy defoliation for a couple of years. The gypsy moth is a problem not only in our forested lands but also in urban and residential areas (Fig. 2). A very real nuisance factor exists for several weeks in late spring or early summer. At that time of year the caterpillars may crawl into homes, drop their fecal material onto backyard barbeques, and generally make life unpleasant when their numbers are high. The insect destroys the ambience of our summer homes in wooded areas as a result of its defoliating activity. Larvae that die as a result of the virus disease may cause unsightly staining of our buildings. Suddenly, a "forest" pest has become of concern in the urban and suburban environment.

From approximately July or early August until the hardwood buds are breaking the following spring (approximately 8-9 months of the year), the gypsy moth is in the egg stage. Egg masses are commonly deposited on the trunks of trees, but may be laid almost anywhere — in backyard woodpiles, in the hollow legs of lawn furniture, under "No Trespassing" signs, or in just about any concealed place. Large egg masses, perhaps the size

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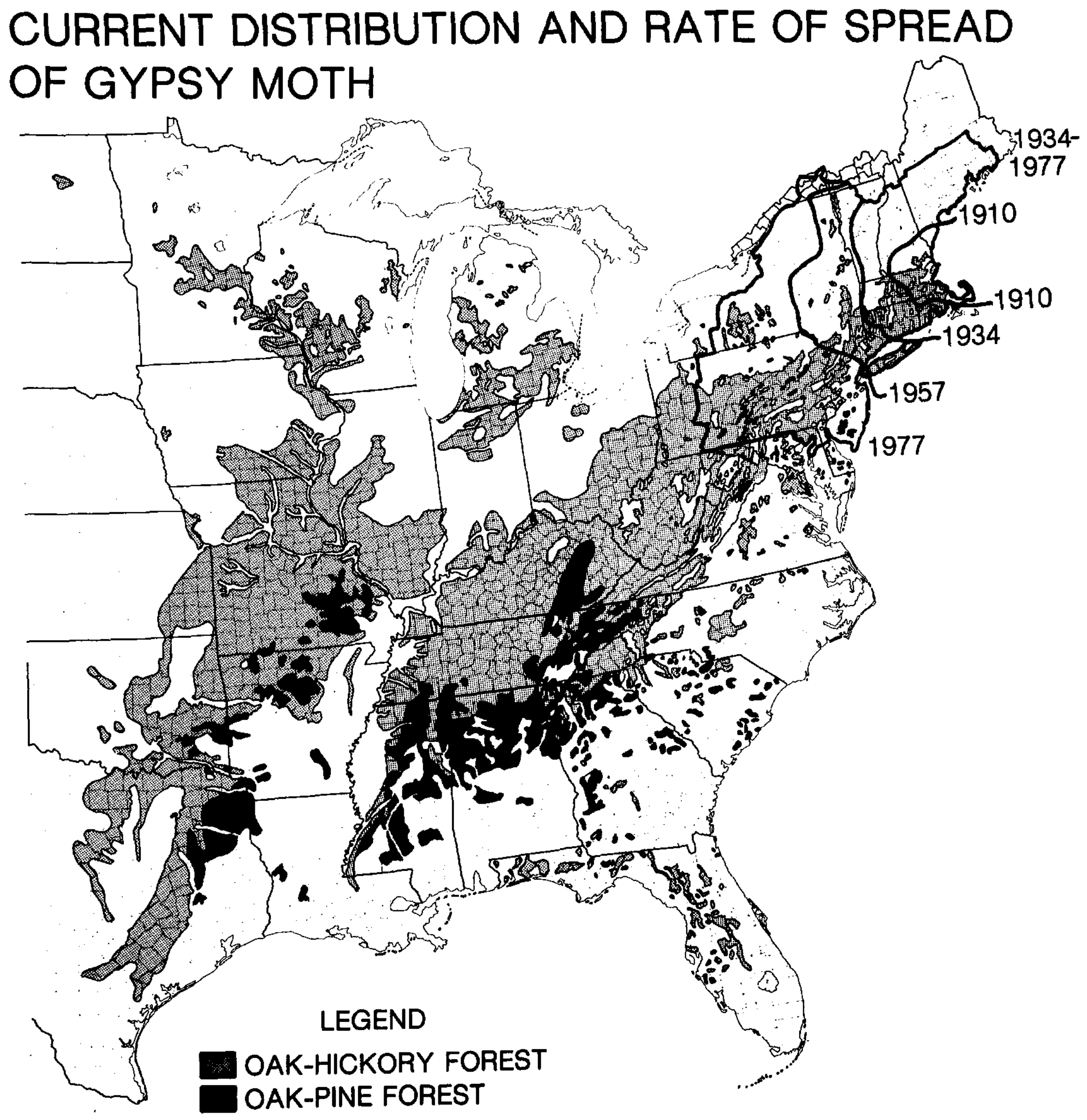

Fig. 1. Spread of the gypsy moth in the northeastern United States. Areas with susceptible forest type are indicated by shading.

of a half dollar and containing 700 to 1,000 eggs, are found in healthy growing populations; in populations that are under stress, those where larvae have had limited food resources as they fed and developed and from which smaller adults were produced, egg masses are about the size of a dime and contain only 100 to 250 eggs.

In the spring of the year, about the time of bud break, the eggs hatch; most of the eggs in a single mass hatch more or less synchronously. Depending on the weather conditions, the young larvae may remain on or near the egg mass for periods of a few hours to several days. At hatch, larvae are photopositive and geonegative; their first movement is an upward-directed response. When they reach the top of the tree, these larvae, approximately 1/8 to 1/4 of an inch long, spin down on silken threads. Long setae densely clothe each larva, adding to its buoyancy. Larvae remain suspended on the silken threads until wafted away by winds. Opinions differ on the distances that individual larvae may be blown; data are scarce. In flatland situations, it is likely that most larvae move only a matter of tens or hundreds of yards. However, in the ridge and valley situation found throughout the Appalachians, the distances that larvae are spread by wind are certainly measured in miles if not tens of miles.

Following dispersal, the larvae molt and begin feeding. Early feeding is referred to as 'shot-hole' feeding, since the leaves are riddled with tiny holes. Most feeding by the small larvae is done during the daytime — early morning and late afternoon. As the larvae grow, they tend to remove larger and larger chunks from the leaves, eventually consuming entire leaves. They are also wasteful feeders. Often they do not consume the leaf material but simply nip the petiole causing the leaf to fall to the ground. As far as the tree is concerned, though, the leaf is lost as a source of photosynthetic activity.

The larvae change behavior about halfway through their development. At about the 3rd or 4th instar, or when the larvae are about ¾" or 1" long, they become nighttime feeders. During the daytime, they crawl down from the crowns of the trees to seek a protected or concealed place during the daylight hours.

Fig. 2. Residential area defoliated in early July. Note heavy defoliation in tops of conifers as well as on hardwoods.

Larval feeding continues through May and June and into early July. The length of the feeding period depends on both the geographic location (how far south or north one is in the range) and altitude. Feeding is more intensive and extensive during these latter instars with larva eventually reaching a length of about 2-3 inches. Complete defoliation of virtually all trees in a forest can occur when populations are heavy; litter on the forest floor increases as a result of the wasteful feeding when leaves are chewed off at the petiole.

Not only does the gypsy moth feed on many species of hardwoods, with its preferred hosts being the oaks, but it will also feed on conifers such as white pine, particularly when populations are heavy. Many of the conifers are killed after a single heavy defoliation. On the other hand, there are some trees, such as tulip poplar, and the ashes, that the gypsy moth virtually ignores.

After feeding has been completed, the insect molts and enters the pupal stage for a period of approximately two weeks. Pupae are often clustered on tree trunks, in loosely rolled leaves, or in other partially protected places. Female pupae are characteristically larger and heavier than the males, which have a more tapered and pointed abdomen. It is during this quiescent period that intense physiological changes take place. The foliage-consuming machine that was the larva becomes the reproductive machine that is the adult moth. At about the first of July it is possible to see all four life stages of the insect in the field at the same time: mature larvae, pupae, early emerging adults, and newly laid egg masses.

Shortly after the female adult emerges from the pupa, she emits a pheromone to attract a male for mating. Copulation and fertilization follow in short order, and usually within hours the female deposits her complement of eggs. Death normally follows within a day of egg-laying. Male moths may live for a week or so, successfully inseminating numerous females if the opportunity arises. The newly-laid eggs embryonate within 3-4 weeks; the neonate larvae remain within the egg, entering diapause to pass through the winter and to complete the generation.

Control Measures

There are two broad categories of controls that affect changes in numbers of the gypsy moth. To protect a valuable resource which is imminently threatened, man may apply direct controls. Usually these involve application of chemical or biological pesticides, and the protection lasts only during the year of application. Occasionally mechanical controls may be used. The other group of factors are those which occur naturally, and over which man has little or no direct influence. Here we include the various parasites and predators, and the nuclear polyhedrosis virus (NPV). These factors exert their efforts over longer periods of time, but cannot be relied upon to maintain populations below an economic threshold year in and year out.

Naturally-occurring controls. Adults of a very tiny hymenopteran, *Ooencyrtus kuvanae* (Howard), lay their eggs in the eggs of the gypsy moth. From 5-10% of the eggs in a large gypsy moth egg mass, and as many as 70-80% in small egg masses, may be parasitized. Even though *Ooencyrtus* cannot prevent pest outbreaks, it contributes to extending the number of years between successive peaks of gypsy moth outbreak populations. A number or other species of parasites attack the larvae, and yet others attack the pupal stage of development.

While all of these parasites contribute to the natural control of the gypsy moth, they are not so effective that we are able to exploit them for reliable population regulation. Efforts continue at the federal level and with cooperators in various states to identify still more potentially valuable natural enemies from around the world. Those most promising — and not pests in their own right — will be introduced to our forests to increase the environmental resistance to continued growth of gypsy moth populations. But natural enemies alone are not likely to "solve" our problems. They haven't done so in parts of the world where the gypsy moth is a native, and there is no good reason to believe they would do any better here.

Another very important naturally-occurring mortality factor in heavy populations — perhaps the single most important factor — is the nuclear polyhedrosis virus. In high populations, a virus epizootic commonly occurs, killing many larvae and contributing to population collapse. Frequently one or more species of parasitic flies in the family Tachinidae are present in large numbers at the same time and contribute to the pest population collapse. Indeed, at times there may be as many complaints about the presence of these lazy, non-biting flies as there are about the gypsy moth itself!

Following a population collapse, the normal expectation is a period of several years of relatively little gypsy moth activity, but then an inexorable rebuilding of numbers and renewed defoliation. As the decades go by, the intervals between population peaks tend to get further apart, increasing from 3-4 years with the first few cycles to perhaps 7-10 years as some ecological adjustments and balances occur with time.

Applied control. The long range goal of scientists concerned with managing the resources affected by the gypsy moth is to develop an integrated pest management program. During 1974-1978, an expanded research and development program was mounted by the USDA addressing this goal, and the results of that cooperative effort are reported in a recent USDA Technical Bulletin (1). Indeed, that Bulletin is the single best comprehensive reference work on the gypsy moth available anywhere.

While there is much emphasis on naturally-occurring controls in the forest at large, Man most frequently intervenes directly when a specific valuable resource is threatened. The threat may be of tree mortality in prime timber; of loss of recreation, wildlife support or aesthetic values; of nuisance created by hordes of unwanted larvae; or even of entomophobic concern in some people. The most common intervention Man employs is the application of pesticides.

Under forest conditions, aerial application of one of half a dozen or more registered chemical pesticides is the most commonly used option; carbaryl and trichlorfon are the materials most often used. Over the next five years or so, there is a high probability that several new pesticides may become available, ones in the same class as diflubenzuron which disrupts the molting process and causes death in that way.

A number of commercial formulations of the bacterially-based pesticide, *Bacillus thuringiensis* (Bt), are also used. While these formulations are considered by many to be "safer" because they are much shorter-lived and have a narrower activity spectrum, they tend to be more expensive, often require repeat applications, and are not as consistently effective as the chemical pesticides. The NPV is also used by aerial application, but so far its registration is still restricted.

In urban and suburban situations, aerial application of pesticides may be used under some conditions, but this may cause an adverse public opinion clamor. Somehow the thought of an airplane spraying pesticides excites people in opposition far more than if ten times as much active ingredient per unit area were applied with ground equipment. Too often pesticides are applied by careless or even incompetent applicators who exploit the public's concern and fan their fears of the possible consequences of gypsy moth activity.

There are additional pesticides and formulations registered for ground application, and these applications may be made in various ways. With thorough coverage of the vegetation, properly timed, there is every reason to expect satisfactory results. Cost, of course, will be far higher than aerial spraying, but ground application allows one to omit 'objectors' from the treated area more easily then aerial application can do.

For a few individual trees in a yard, a homeowner may resort to mechanical control. You will recall that larvae, once they reach 3rd or 4th instar, tend to move down from the foliage during the daytime and seek a concealed resting place. This behavior may be exploited by the homeowner by tying burlap bands, or newspaper or rags or some other material, around the trunk of each tree. Larvae utilizing this shelter must be destroyed each day so they do not return to the canopy to feed at night. I seriously question the "barrier" tapes that have appeared on the market in the last few years. If these do, indeed, act as a barrier, the larvae coming down the tree will not cross them but simply return to the foliage unimpeded. If populations are so high that there is tree to tree migration of large larvae, other control measures would have been needed to protect the tree in any case.

Two other mechanical control measures are commonly used. People frequently seek out egg masses for destruction during the fall and winter. They are easy to locate in a heavy infestation, but frequently are well-concealed in sparse or growing populations. Under those conditions, the masses may be secreted under rocks, in fissures of bark, under loose bark, or in numerous other concealed places. This makes it almost impossible to locate all egg masses, which is another way of saying that simply destroying egg masses mechanically will have very little effect on population control. A number of commercial male moths, tion control. A number of commercial gypsy moth traps, baited with the synthetic pheromone and designed to capture male moths, are on the market. While they do, indeed, capture large numbers of males, there is no assurance at all that they capture the males before they have mated. Male moths normally mate with many females; the numbers game favors the gypsy moth and the trap sellers — not the homeowner.

Another key reason that neither of these two kinds of mechanical control works effectively is related to the behavior of the newly-hatched larvae. The first thing they do is to go through a dispersal phase. In other words, the larvae eating your trees most probably blew in from your neighbor's yard — or from miles away — and what you did last summer to reduce the number of males, or during the fall and winter as you destroyed egg masses, was masked in the total redistribution of populations which took place in ten days or so in the spring.

What is Ahead?

To meet restrictions imposed by the President's 1983 budget, the Animal and Plant Health Inspection Service (USDA) has recently given notice of the possibility of dropping quarantine, survey and eradication programs against the gypsy moth (2). Even if their programs are maintained, they would only slow down the inevitable.

The gypsy moth will continue to spread, eventually infesting areas vastly larger than its current range. It has already reached all three of our west coast states, as well as gulf coast states, in isolated spots. The last two years have seen the two largest outbreaks in our history, providing a tremendous reservoir for spread. Because the insect is often transported over long distances by Man on logs, nursery stock, mobile homes and in other ways, it is likely that the incidence of new isolated infestations will increase drastically. If the federal surveillance program is eliminated, and if each state does not pick up these responsibilities, establishment of population foci will proceed essentially unimpeded.

Eradication of the gypsy moth from North America is impossible; eradication from newly-infested areas remote from the general infestation is possible, but costly and far from certain. Prevention of spread, now that the insect is well-established in the Appalachian ridge and valley system, cannot be achieved.

We urgently need a two-pronged program to cope with the gypsy moth. Even though the insect has been in North America for 113 years, there are still too many key questions unanswered. For example, how far, and under what conditions are the young larvae blown around? A well-supported long-term basic research program is mandatory. The other equally important aim of the program must involve continued improvement in our ability to detect, evaluate, and minimize damage, of whatever kind, caused by the gypsy moth. We have many tools available to us, and substantial progress was made as a direct result of the Expanded R & D program. But we can improve our ability to exploit these control measures in terms of efficacy, need, and cost.

Challenges are before us. We must meet them head-on. Stop-gap exploitive measures will not work. Together, industry and researchers — state, federal, and university — can make headway. To the fray!

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