

During 1981, 41 male gypsy moths were trapped in Santa Barbara County. Lesser numbers were trapped in other southern and northern California counties—Los Angeles (3 moths), Marin (7), San Diego (3), Santa Cruz (2) and Ventura (2). Capture of male moths in traps does not prove that the gypsy moth has become established; those found may have developed from eggs or pupae brought into the state on vehicles and camping equipment from infested areas in the eastern United States. However, intensive surveys in Santa Barbara during the fall and winter revealed four egg masses, indicating that a breeding population of the gypsy moth exists there. Surveys for egg masses at the other locations have been negative to date, so it is unclear if those trap catches indicate establishment.

The gypsy moth, *Lymantria dispar* (L.), is not new to California. Over 400 egg masses were found in Santa Clara County in 1976, and the California Department of Food and Agriculture mounted an apparently successful eradication program against that infestation using two aerial applications of the insect growth regulator diflubenzuron (Dimilin).

Gypsy moth as a pest

The impact the gypsy moth might have upon California's forest and shade trees, if not eradicated from Santa Barbara or elsewhere in the state, can't be predicted precisely, because our climate and vegetation are different from those in the northeastern United States, where this pest has occurred for over a century. However, the gypsy moth is likely to be a serious pest in California, because it readily colonizes new areas and is the most important defoliating insect pest of hardwood forests in the Northeast. Since its introduction from Europe into Massachusetts in the late 1860s, the moth has repeatedly defoliated hundreds of thousands of acres of forest. It spread from its initial infestation site throughout Maine, New Hampshire, Vermont, Rhode Island, and Connecticut. During the 1960s and '70s it moved into eastern Canada, New York, New Jersey, Maryland, Virginia, North Carolina, West Virginia, Pennsylvania, Michigan, Wisconsin, Illinois, and Ohio. Infestations have been found recently in British Columbia, Washington, and Oregon. Natural spread of the gypsy moth is relatively slow, but it is moving rapidly, because of its ability to hitchhike with people traveling from infested areas.

In New England, the moth is ignored when present in low densities, but public notice is taken when populations enter their two- to three-year outbreak phase, partially or completely defoliating forest and shade trees. In an outbreak phase, the gypsy moth may defoliate thousands to millions of acres and,



Gypsy moth caterpillar feeds on oak foliage, favored food among its many host plants. Caterpillars grow from about $\frac{1}{8}$ inch to 3 to 4 inches long during development.

The gypsy moth — here again

Marjorie A. Hoy

This pest of forest and shade trees has invaded California in the past and may become a periodic problem.

apart from this aesthetic impact, are a direct nuisance to humans: the large caterpillars in dense populations become unusually active, crawling up and down trees, and often moving in large numbers onto lawns, lawn furniture, or up the sides of houses. Swimming pools or patios may become covered with fecal material (frass). The caterpillars have long hairs that cause allergenic responses in some people. Outbreaks occur more frequently during the first 20 years or so after this pest invades a new area. After that, outbreaks tend to occur at eight- to ten-year intervals.

The gypsy moth may kill forest trees, particularly in newly invaded areas, and thereby change forest composition. For example, studies at the Melrose Highlands Laboratory in Massachusetts showed that, in one heavily infested region, 30 percent of the dominant favored host trees (oaks, *Quercus* spp.) died between 1912 and 1921. Their average annual defoliation rate was 37 percent. Unfavored host trees (those on which the caterpillars feed only to a limited extent, and only as larger larvae) also were killed (7 percent), even though average annual defoliation was only 7 percent. More trees were defoliated on

ridge tops or on poor growing sites than on better sites; many died as a result of defoliation or increased susceptibility to diseases such as armillaria root rot or other insect damage.

Even when trees were not killed, their annual growth was retarded, particularly in drought years. Vigorously growing hardwoods on a good site in the eastern United States usually withstand one complete defoliation and put out new leaves later the same year, although conifers often die if they are completely defoliated once. The effect of the gypsy moth feeding on California oaks and other vegetation is unknown but could be more damaging than in the East because of the lack of summer rain here.

Food plants

The gypsy moth feeds on over 300 species of plants. Some are favored food for larvae of all ages, and newly hatched caterpillars can feed successfully on them; others are favored only after the young caterpillars develop partially; some are not favored, but a few of the larger caterpillars may develop successfully on them. Some unfavored plants are unsuitable for small larvae and may escape being



In periodic gypsy moth outbreaks, the caterpillars have defoliated millions of acres of forest trees. This wooded area in Connecticut was partially defoliated during June.



Female (1 1/4" long).



Male (3/4" long).

Gypsy moths have been trapped in six California counties.

fed upon, even by large larvae, during an outbreak.

Favored food plants in the eastern United States include oak, birch (except yellow and black), aspen, beech, larch, linden, willow, box elder, sumac, Lombardy poplar, apple, and apricot. Less favored trees include chestnut, hemlock, pine, and spruce. Least favored are cherry, cottonwood, elm, hickory, maple, and poplar. Ash, azalea, cedar, dogwood, walnut, cypress, grape, holly, juniper, locust, privet, raspberry, sycamore, and tulip trees are unfavored and usually escape attack. Recent work by Drs. Robert Fusco in Pennsylvania and J. Gordon Edwards of San Jose State University showed that gypsy moth caterpillars can feed to some degree on dozens of California plants including coast redwood, eucalyptus, avocado, lemon, pine, and manzanita. The full impact of the gypsy moth in California plants can't be predicted from laboratory feeding studies, because the climate and plant growth patterns will interact to influence their effect. California clearly offers an array of suitable host plants.

Although quarantines may limit the movement of certain commodities because they may support egg masses, the gypsy moth is

unlikely to become a serious pest of those California crops commonly treated with pesticides.

Biology of gypsy moth

The gypsy moth naturally occurs in a broad geographic band across Europe, Russia, Asia, and Japan, although genetic differences between the Japanese and European gypsy moths suggest that they actually may be different species. The moth is a pest of oaks in southern Europe and northern Morocco, where the climate is similar to that in California.

The gypsy moth has one generation each year throughout its range. Females are large, white nonflying moths with dark patterns on their wings. Males are smaller, brown moths and use their feathery antennae to detect the sex lure (pheromone) the female releases. Unlike most moths, the males fly during the day in a zigzag pattern and search up and down tree trunks for females. Apparently males use visual cues as well as odor to locate mates.

After mating, the female deposits a single egg mass, which contains a few hundred to a thousand eggs, on rocks, stumps, houses,

yard furniture, woodpiles, walls, and camping equipment, as well as tree trunks. In New England, females lay eggs during July and early August.

During August, the eggs develop until small larvae are visible through the shells; these unhatched larvae overwinter in diapause (hibernation). A chill is required to terminate diapause; if the eggs receive less than the optimal winter chill, they hatch over a long period in the spring, and some may not hatch at all.

In New England, gypsy moth eggs usually hatch just as oak leaves begin to expand in May. Egg hatch begins earlier in California. In Santa Barbara this year, egg hatch began in mid-February and has continued until this writing (late April), suggesting that the chill was sufficient to ensure hatch, but insufficient to cause the eggs to hatch at the same time. The precise pattern and proportion of eggs that will hatch in California remain to be determined.

If the gypsy moth becomes established in California, it probably will undergo a genetic adaptation to our winter climate, since there is great genetic variability in its diapause characteristics. For example, when I worked with this pest in Connecticut, I was able to select a strain with no diapause after only a few generations of laboratory selection.

After the eggs hatch, the small caterpillars are active for a period before they settle down to feed. They may climb to a branch tip and be blown through the air on silken threads. Cold, rainy weather may kill large numbers and reduces dispersal. Dispersal of the small caterpillars allows the gypsy moth to spread on its own efforts as well as through man's activities.

Newly hatched caterpillars are about 3 mm long but grow to average 50 to 90 mm (3 to 4 1/2 inches) with a 1000-fold increase in weight. To achieve this growth, the larvae must consume substantial amounts of foliage, feeding first on new leaves, particularly on the leaf hairs, then on the epidermis. Later they cut holes in leaf margins.

Small larvae typically feed early in the morning and late in the evening, but remain on the foliage. Larger caterpillars tend to feed at night and seek resting sites other than leaves when not feeding; they move up and down tree trunks, leaving silken trails. Caterpillars feed and molt several times, usually five for males and six for females, before they pupate on trees or other objects.

In the Northeast and in Canada, low winter temperatures may cause high mortality of the gypsy moth, particularly of egg masses unprotected by snow cover. Late spring frosts and cold wet weather when young caterpillars are hatching also exert some mortality. High temperatures when caterpillars are develop-

ing promote rapid growth and allow them to escape some of their natural enemies. There seems to be no reason why the gypsy moth can't adapt to California's climate and become a permanent resident wherever there are suitable host plants.

Control

The gypsy moth has many natural enemies—parasites, predators, and diseases. Although these offer some hope for suppression, the gypsy moth remains a serious pest in most areas of the world where it is found, despite the influence of natural enemies and over 100 years of studies on eradication and control.

Once it was recognized that eradication of the gypsy moth was impossible in New England, 40 parasites were imported from Europe and Asia. Of these, 10 have become established in North America: two parasites of gypsy moth eggs (*Anastatus disparis* Ruschka, *Ooencyrtus kuwanai* [Howard]), two of small larvae (*Apanteles melanoscelus* Ratzeburg, *Phobocampe disparis* [Viereck]), four of large larvae (*Blepharipa pratensis* [Meigen], *Compsilura concinnata* [Meigen], *Exorista larvarum* [L.], *Parasetigena silvestris* [Robineau-Desvoidy]), and two of pupae (*Monodontomerus aereus* Walker, *Brachymeria intermedia* [Nees]). Although these biological control agents are widespread in the United States, they have not been able to suppress gypsy moth to an acceptable level, and controversy about their effectiveness exists. During the past 10 years, additional parasites have been imported from Asia and Europe, but no establishments have been achieved.

The gypsy moth is susceptible to a number of diseases, most notably a nucleopolyhedrosis virus that attacks caterpillars. This disease becomes prevalent during outbreaks when caterpillars are crowded and stressed from lack of food, but does not seem to prevent outbreaks. A commercial product containing the virus (Gypchek) has been registered for use in suppressing gypsy moth populations, but only limited quantities are available. Other pathogens of gypsy moth under natural conditions include bacteria, fungi, and nematodes. The microbial insecticide *Bacillus thuringiensis* (Thuricide, Dipel) is registered for use against the gypsy moth; when properly timed, it can suppress populations and protect foliage.

In Europe, some birds, such as cuckoos, are believed to be useful predators. Small mammals, such as mice and shrews, take their toll of larvae and pupae in northeastern United States.

Insecticides registered for control of gypsy moth include Dimilin (diflubenzuron), Sevin (carbaryl), Orthene (acephate), Dylox (trichlorfon), Imidan, malathion, methoxy-



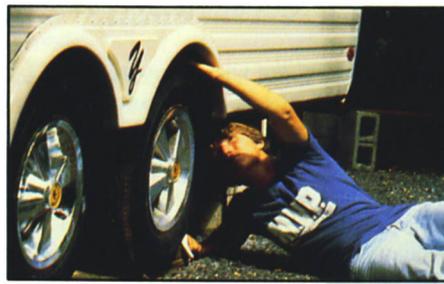
Egg masses are laid on tree trunks and other surfaces, stationary and mobile.

chlor, and biological insecticides Gypchek and *Bacillus thuringiensis*. Experimental control techniques include release of irradiated sterile males, release of the synthetic sex pheromone to disrupt the normal mating behavior of moths, and use of large numbers of pheromone traps to reduce or trap out males in an area.

The gypsy moth has rarely been kept isolated within an infested area. Eradication has been even more rarely achieved, and probably can be accomplished only where the infested area is small and localized. Whether the gypsy moth can be eradicated from California this time is open to debate and probably depends on the size of the infestation and measures that can be used.

The future

Visual searches of wooded areas for gypsy moth egg masses, larvae, or pupae are difficult, particularly if the population is small. However, any unusual caterpillars or egg masses found and suspected to be gypsy moth should be given to the local county agricultural commissioner's office for identification. Quarantine stations at state borders are charged with detecting and eliminating gypsy moth on vehicles and household goods entering the state, and require the cooperation of residents and visitors.



Mike Pendrak

Gypsy moth eggs are carried long distances by cross-country travelers.

A large number of traps will be deployed throughout California during 1982 to detect gypsy moths. The sticky traps contain a syn-



Parasite exit holes on egg mass (size of mass: about 1" x ¾").

thetic sex pheromone (disparlure), which attracts male moths. Because egg masses are hard to find, especially when present in low densities, the traps are useful for detecting new infestations. It is not clear, though, how far moths can fly to reach the traps.

Eradication of the Santa Barbara infestation is being attempted during 1982 through a combination of three techniques: aerial application of the bacterial insecticide *B. thuringiensis*, mass trapping of male moths with disparlure, and ground application of carbaryl in a half-mile radius around the egg mass finds. Even if eradication succeeds again, the gypsy moth is a very successful invader and we can expect it to enter California periodically. Our climate is favorable, we have abundant favored host plants, and gypsy moths are constantly imported into the state from infested areas. Only very careful quarantine and eradication measures will keep gypsy moth from becoming a permanent destructive California resident.

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