

Gypsy moth in North America

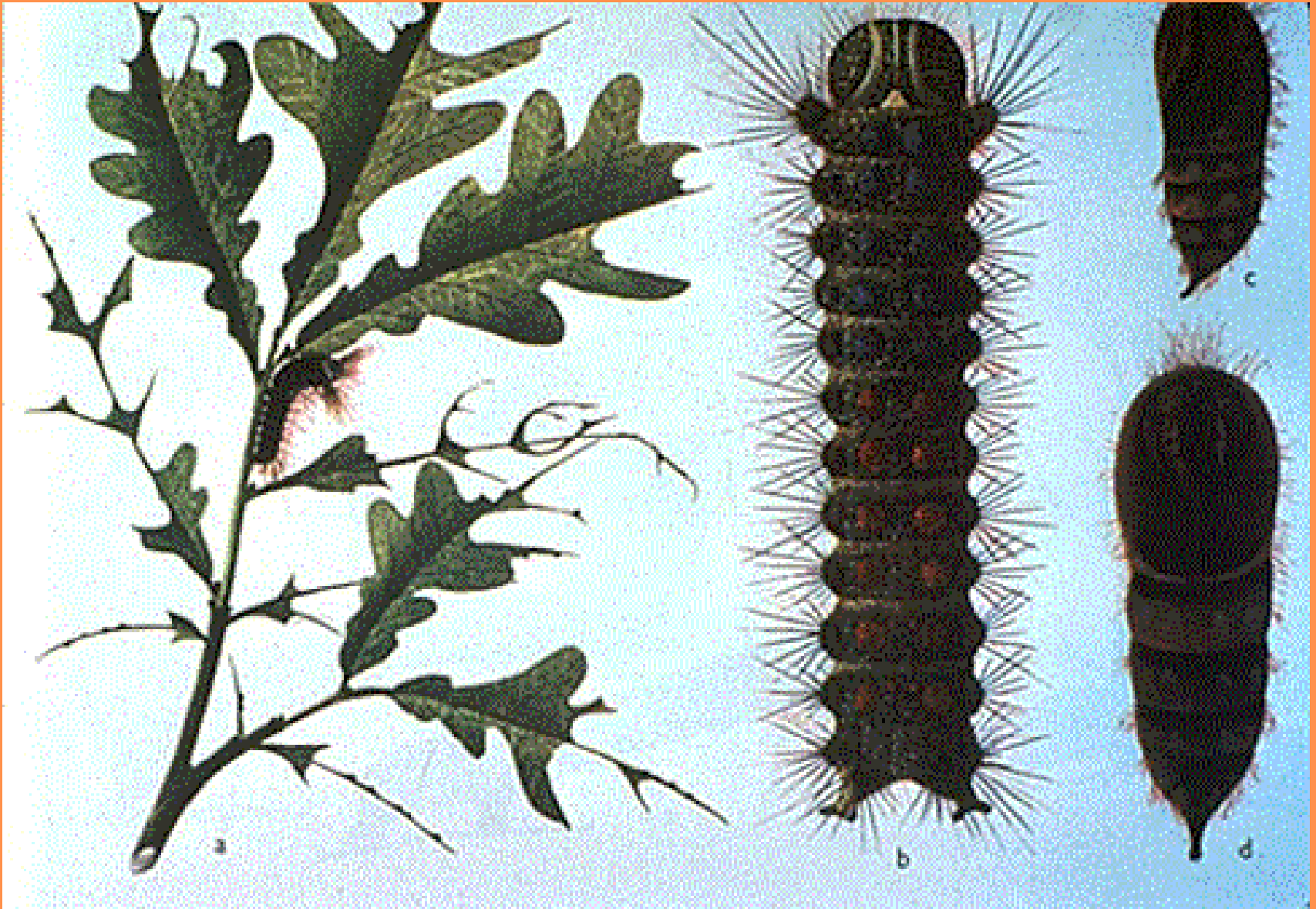


Dr. Vera Krischik

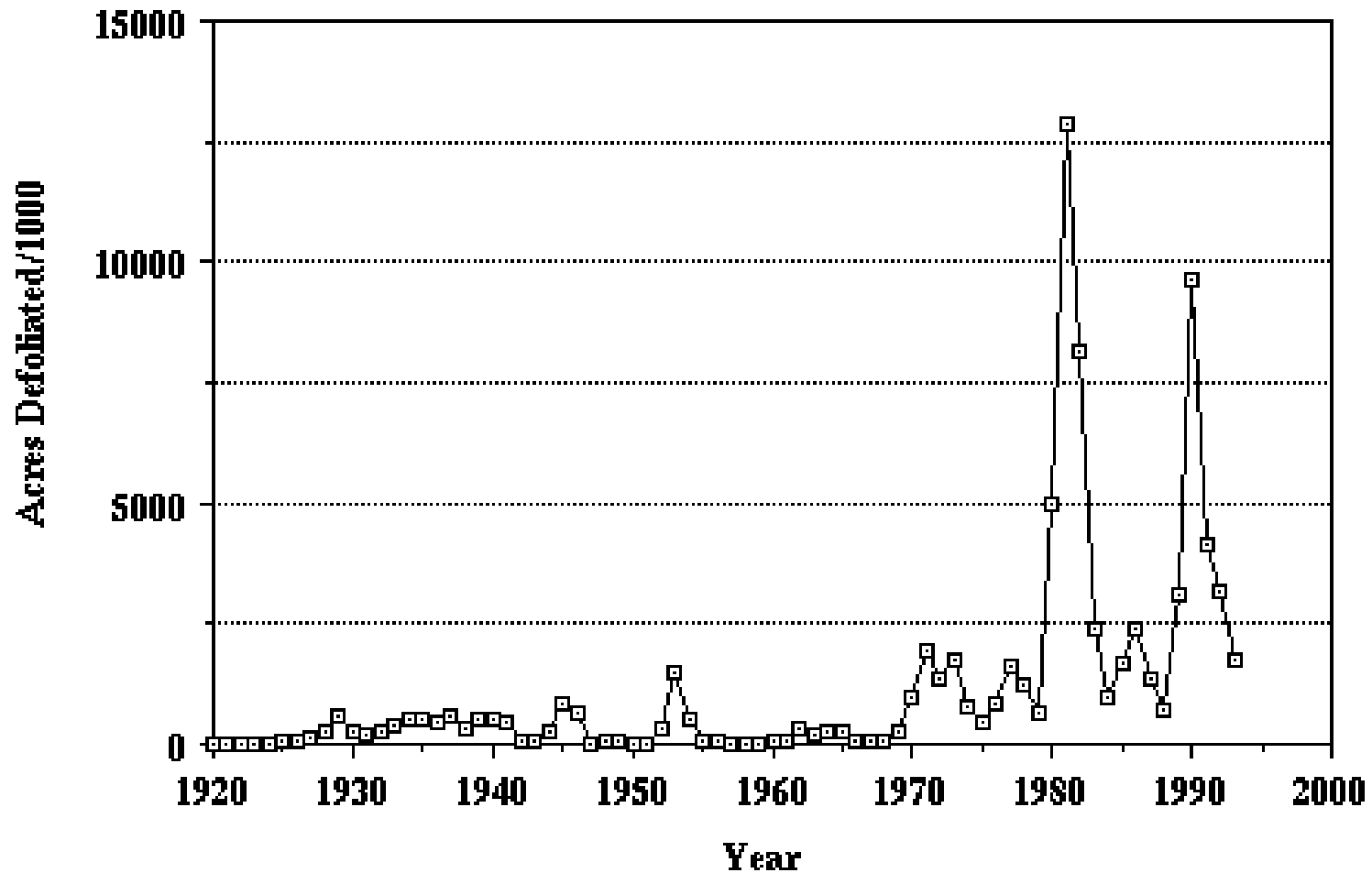
Department of Entomology

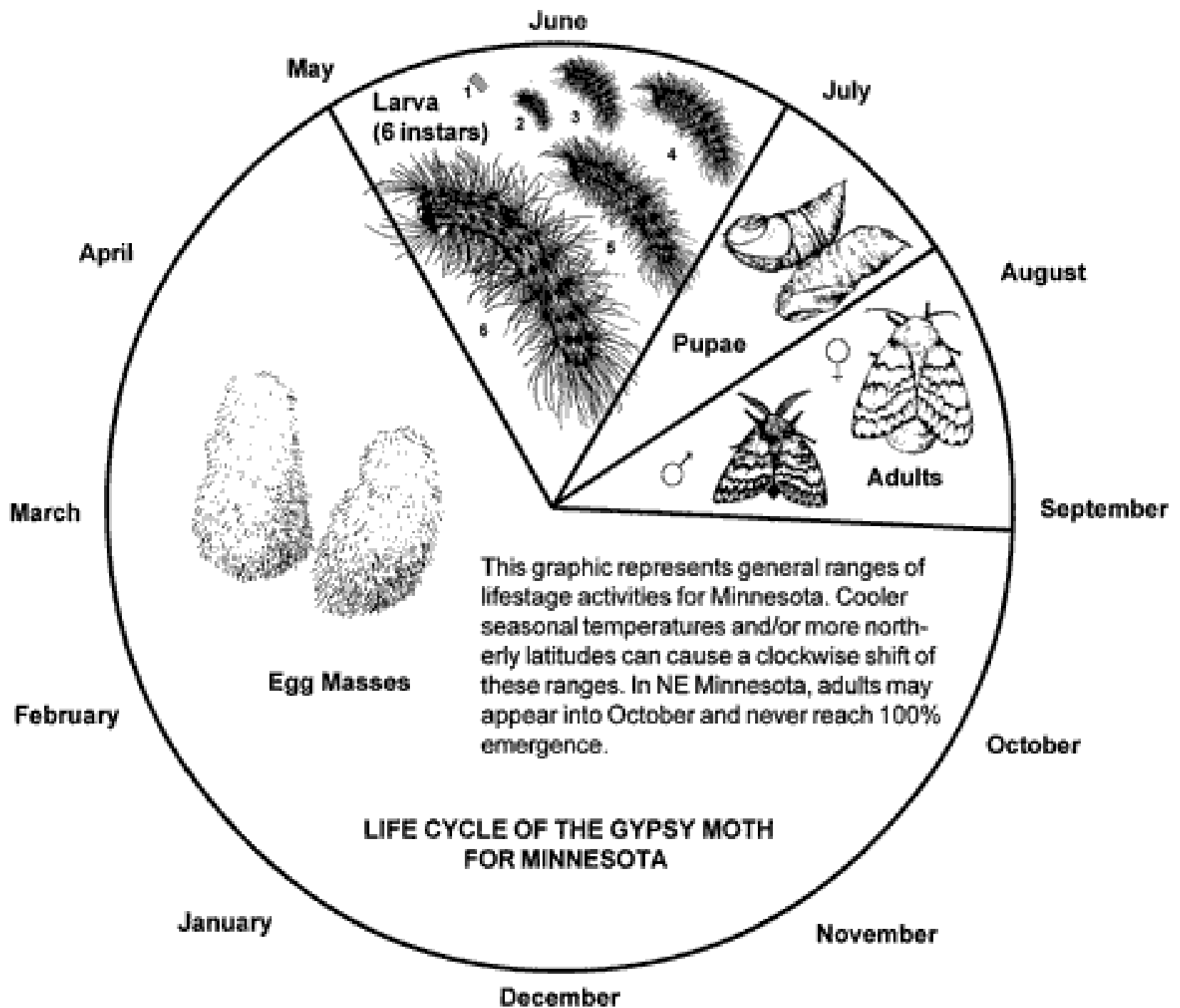
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Gypsy moth in North America



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Gypsy moth in North America



GM egg mass



GM larva



GM pupa



GM male moth



GM female moth

Gypsy moth in North America



Egg mass

Eggs are laid in a fuzzy, tan-colored mass. The egg mass contains an average of 500 eggs and is about the size of a quarter. Eggs are laid during July and August and hatch the following spring from late April through early May. Egg masses may be laid on living and/or inanimate objects. Such as nursery stock, logs, under eaves on roofs, in wheel wells or an outdoor household article.

Gypsy moth in North America



Caterpillars

The caterpillar ranges from 1/8 to 2 1/2 inch length depending upon its age. It is dark and hairy. Along its back it has five pairs of blue spots near the head, followed by six pairs of red spots. It actively feeds on plant foliage from early May through early July, when it develops into a pupa.

Gypsy moth in North America

Pupae (cocoons)

The pupa is an inactive stage during which the caterpillar becomes an adult moth. Found during July, it is dark reddish-brown and leathery in appearance. It can range in size from $\frac{3}{4}$ inch to $1 \frac{1}{2}$ inches long.



Gypsy moth in North America



Adult male moth

The adult male moth has feathery (plumed) antennae and can be light beige to dark brown with black jagged bands on its forewings. Its wingspread ranges from $\frac{3}{4}$ to $1 \frac{1}{2}$ inches.

Gypsy moth in North America



Adult female moth

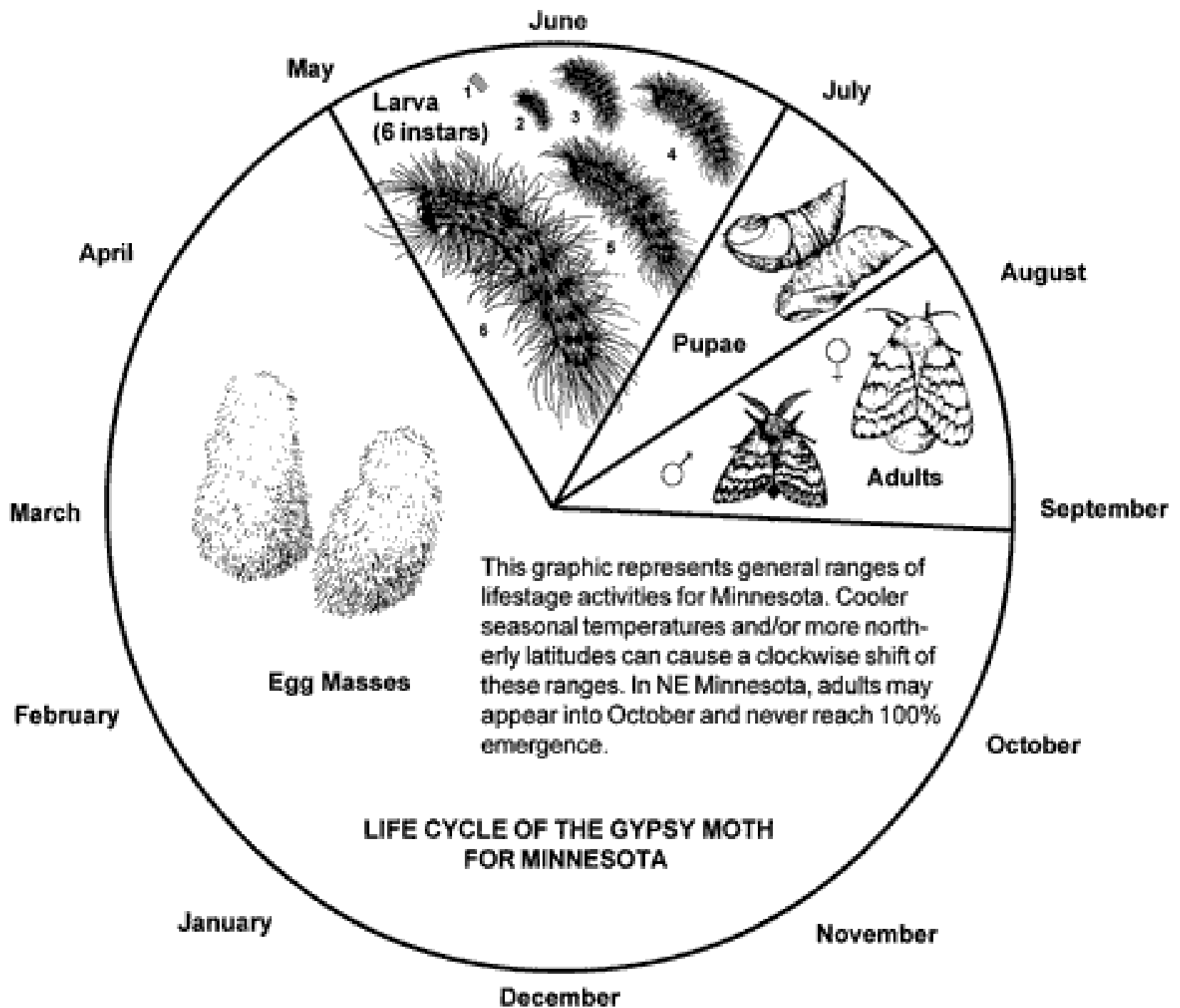
The adult female moth is white with brown zig-zag markings on her wings and narrow antennae. Its wingspread ranges from 1 to 2 inches. Females cannot fly because their bodies are too large and heavy.

Gypsy moth in North America



Adult female moth

Females release a strong sex attractant (pheromone) to attract male moths, which are strong flyers and capable of mating with several females. The female produces one egg mass and dies. Adult moths are typically active from mid-July to early-September.



Gypsy moth in North America



In either 1868 or 1869, the gypsy moth was accidentally introduced near Boston, MA by E. Leopold Trouvelot. About 10 years after this introduction, the first outbreaks began in Trouvelot's neighborhood and in 1890 the State and Federal Government began their attempts to eradicate the gypsy moth.

Gypsy moth in North America



His main interest was in identifying native silkworms that might be used for silk production. In the late 1860's he returned from a trip to France with some gypsy moth egg masses. He was apparently culturing them on trees in back of his house when some of the larvae escaped. Trouvelot understood the potential magnitude of this accident and notified local entomologists but no action was taken.

Gypsy moth in North America



Trouvelot's interest in silkworm-gypsy moth crosses dimmed and he turned his attention to amateur astronomy.

After 1882 the outbreak on Trouvelot's street continued to grow in size, residents of the Boston area became increasingly alarmed about the gypsy moth problem. In 1889 the Massachusetts State Board of Agriculture began a campaign to eradicate the gypsy moth.

Gypsy moth in North America



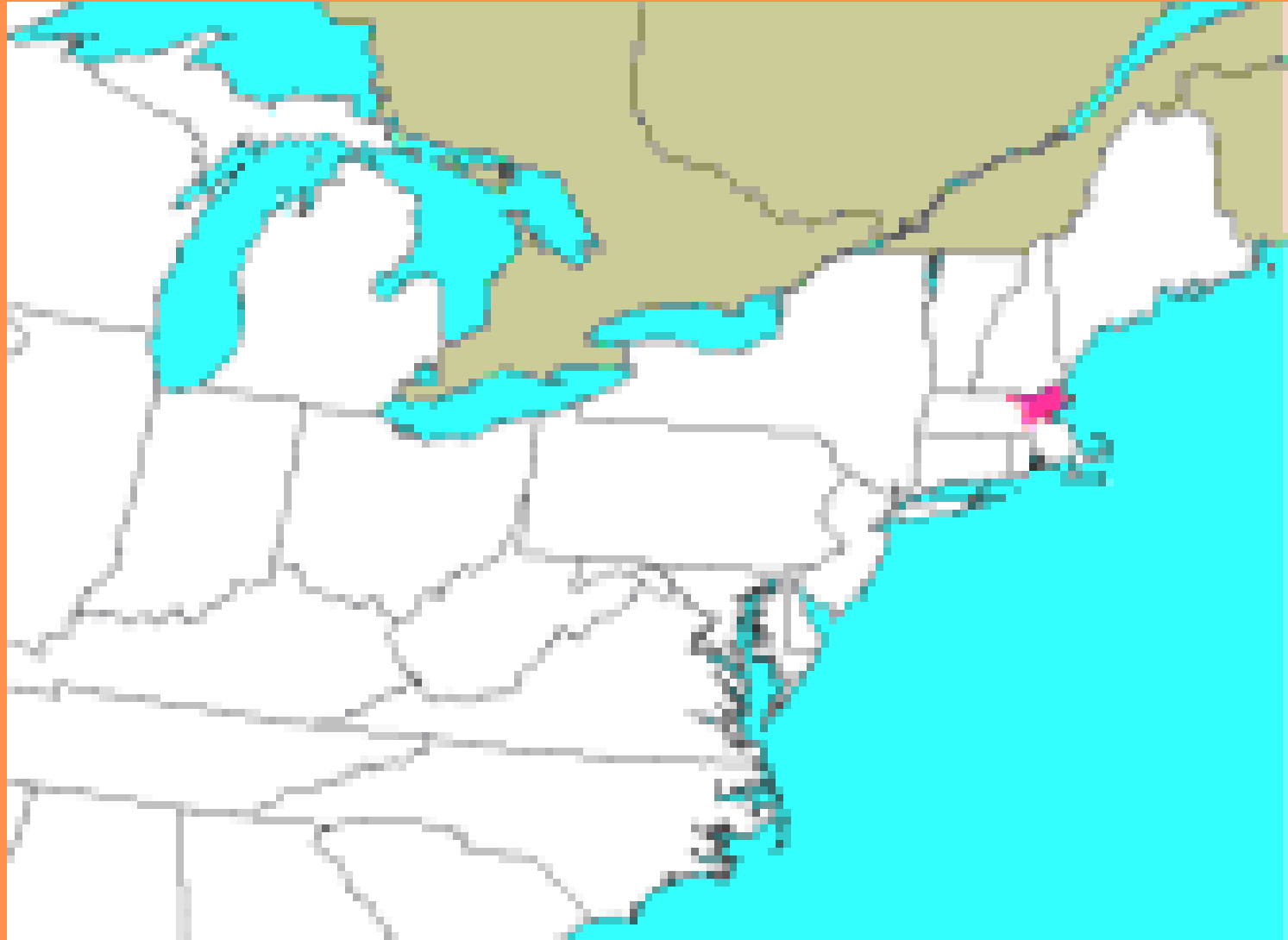
**Picking egg masses
from oaks in 1882.**

Gypsy moth in North America

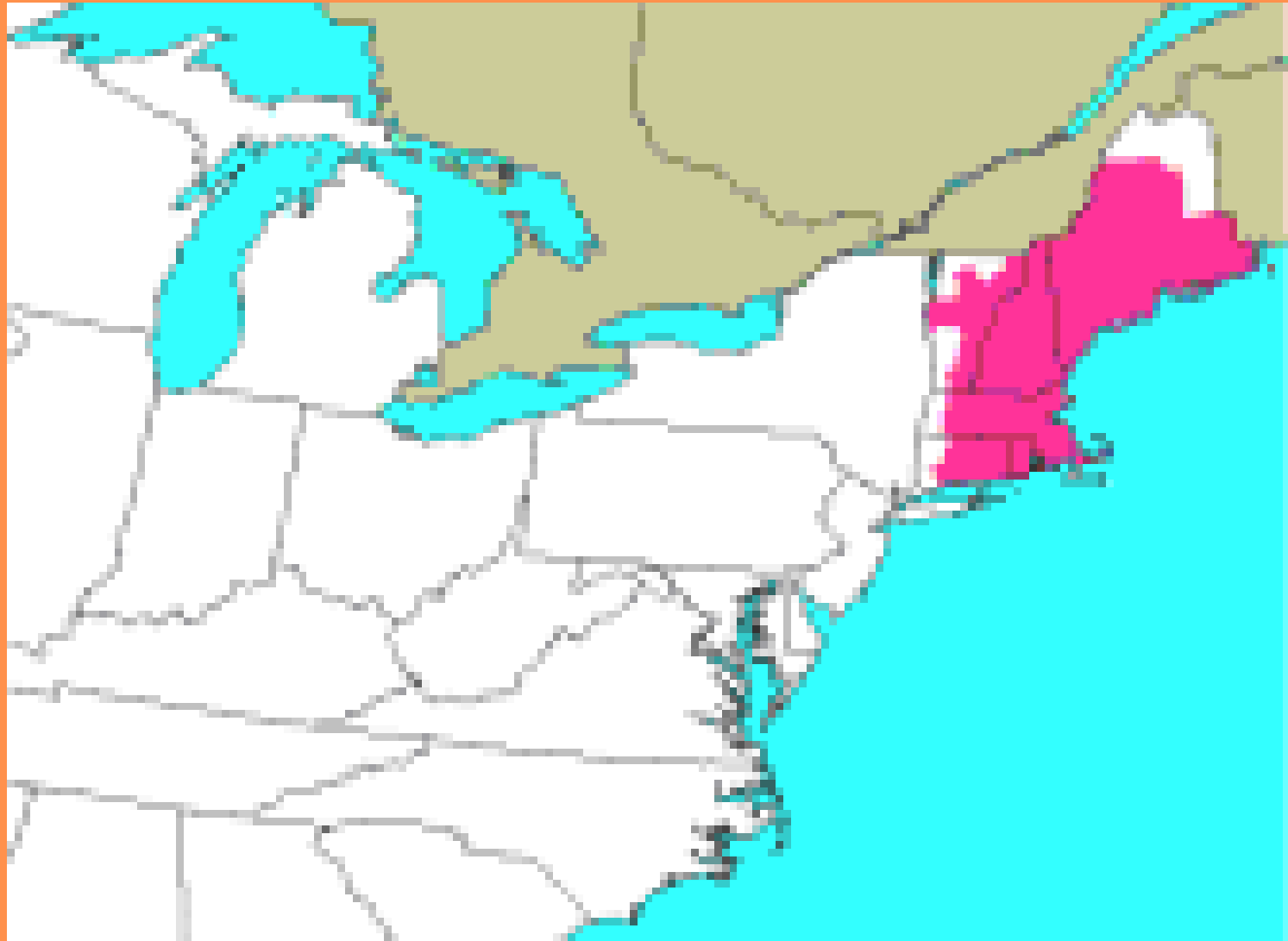


The methods used during the program ranged from manual removal of egg masses, burning infested forests and application of primitive insecticides. Despite the expenditure of considerable money and effort, the gypsy moth infestation continued to expand in size and by 1900 the effort to eradicate this insect was abandoned.

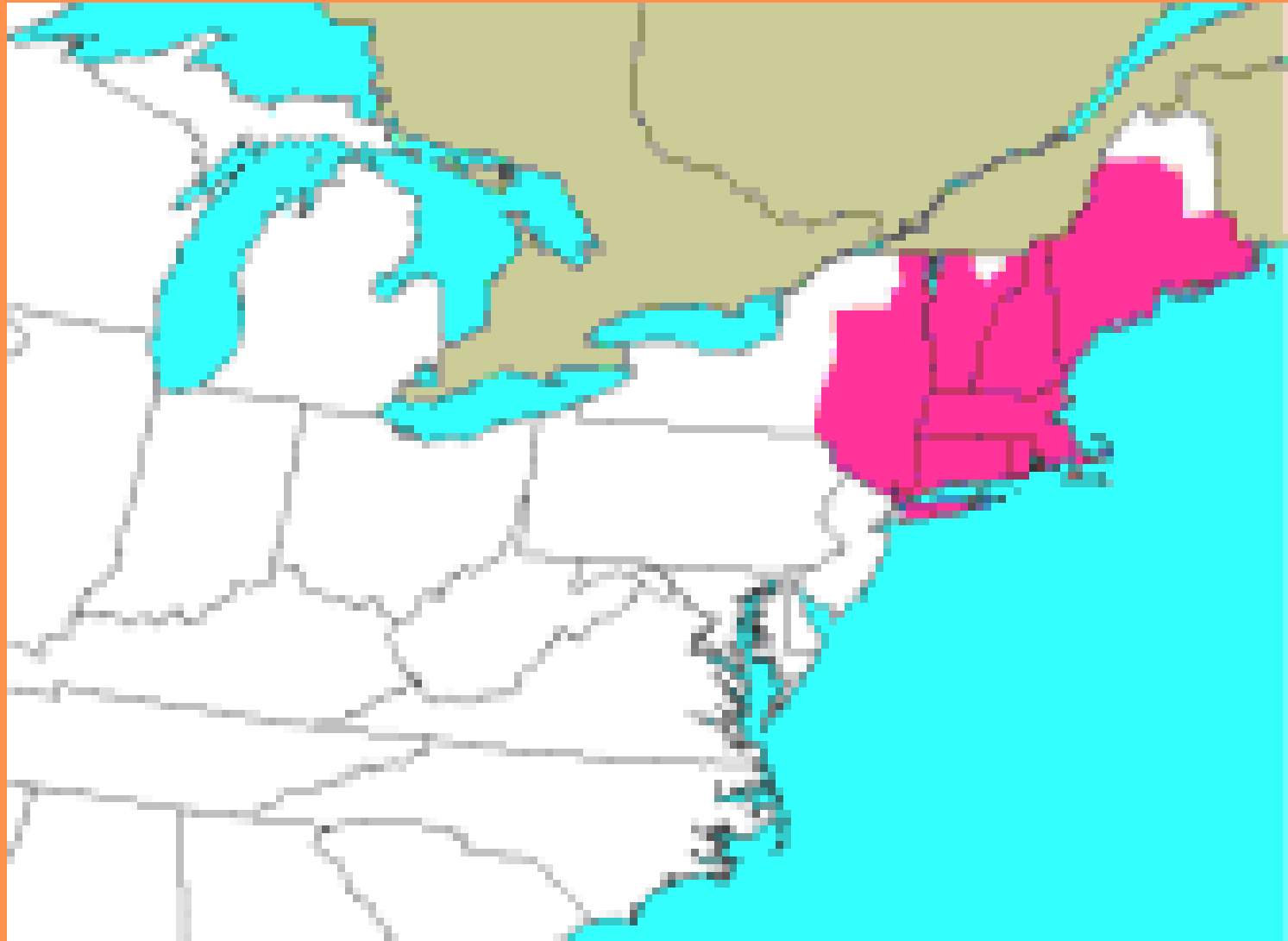
Gypsy moth in North America 1900



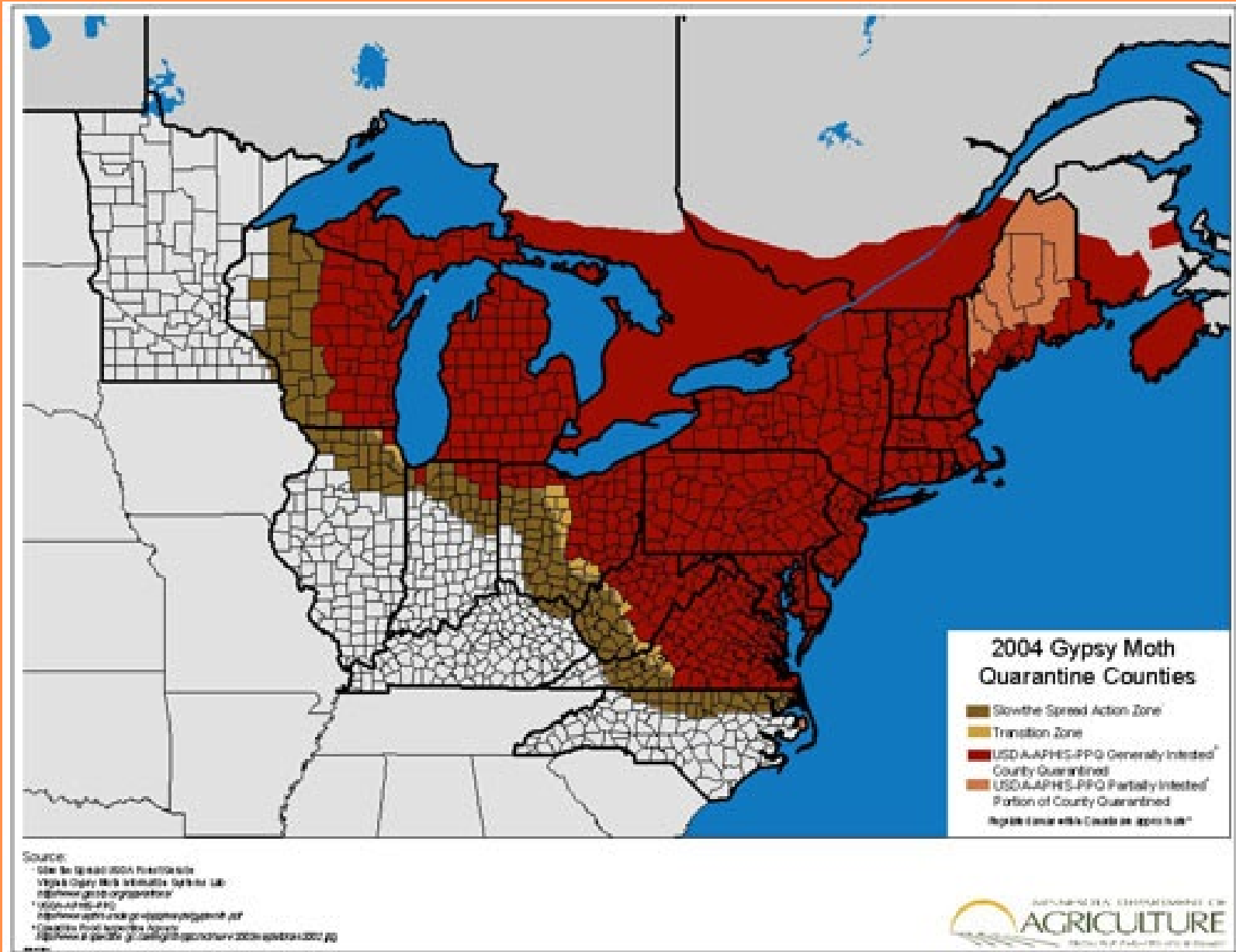
Gypsy moth in North America 1935



Gypsy moth in North America 1965



2004 Gypsy moth infested quarantine counties



Gypsy moth in North America



Female gypsy moths cannot fly and have the habit of depositing their eggs on objects near the trees on which they were feeding as caterpillars.

These objects might be picnic tables, car wheel wells, grills or any outdoor household article or lawn ornaments. When these objects are moved from an infested area, the gypsy moth eggs “hitchhike” into other areas, hence the name gypsy moth.

Gypsy moth in North America



The United States government realized early on that this insect would be a serious problem.

In the early 1900s, a federal quarantine was placed on all trees in the infested area. Nurseries wanting to transplant trees from the quarantined area had to conduct a careful inspection to ensure the moth wasn't hitching a ride. Since the female moth cannot fly and the larvae can only move a few miles on the wind, the quarantine kept the moth isolated to the northeast United States for decades.

Gypsy moth in North America



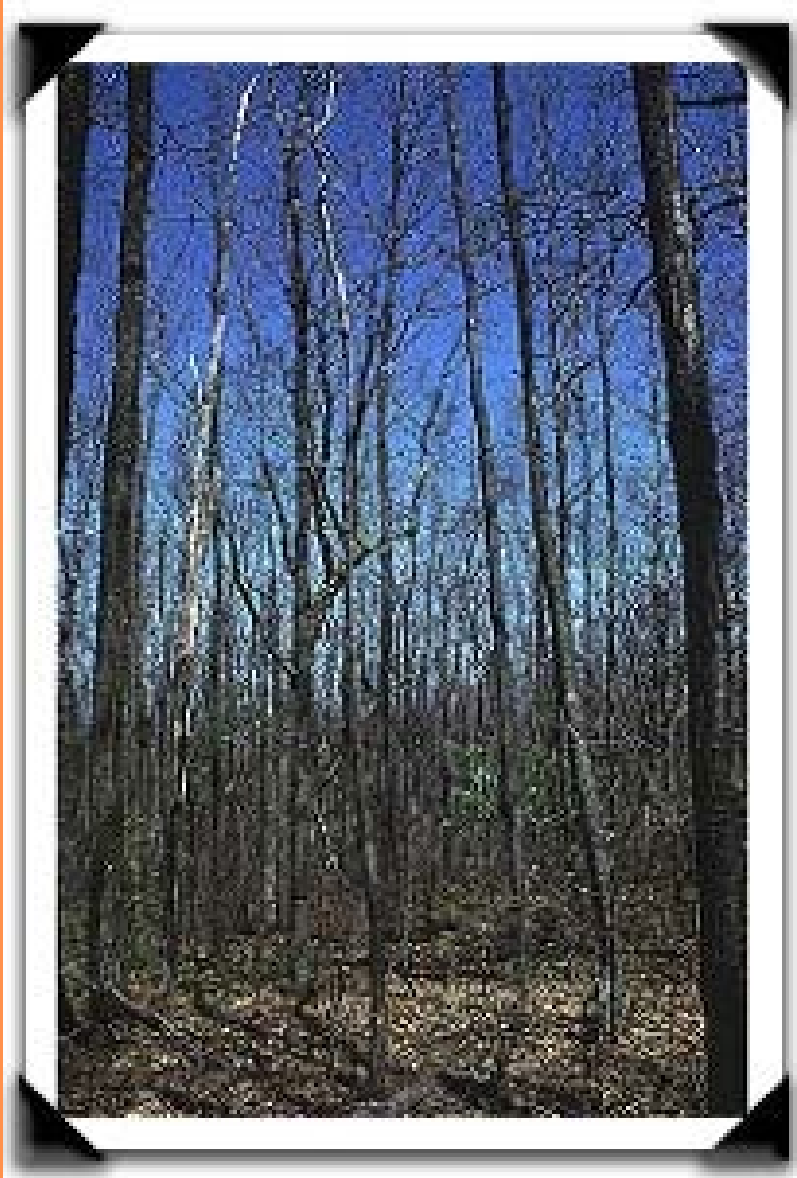
But with a helping hand from people, the moth has expanded its territory in recent years, from western Pennsylvania all the way through Ohio, Michigan and Illinois, and into central Wisconsin. Because of the way the moth deposits eggs, people camping in infested areas during prime egg-laying periods (July through mid-August) are particularly susceptible to carrying the pest home on camping gear or even in the wheel wells of their cars. Fortunately, the moth has not arrived en masse in Minnesota - yet.

Gypsy moth in North America



One caterpillar can eat up to one square meter of vegetation during its development. They can eat all the leaves on an adult tree in a matter of days. The tree is then weak and susceptible to diseases and other insects. In northeastern states, gypsy moth have been known to defoliate entire forests. When gypsy moth becomes established, property values can decrease, large sums of money are spent by state and federal governments to control it. Much of the beauty of the natural forested landscape is threatened or lost.

Gypsy moth in North America



Gypsy moth larvae can defoliate entire trees and forests.

Gypsy moth in North America



Minnesota Department of Agriculture, in cooperation with the USDA, has had an annual gypsy moth trapping program in place since 1973. This program is designed to protect Minnesota's forests from this tree pest already established in Wisconsin and other eastern states.

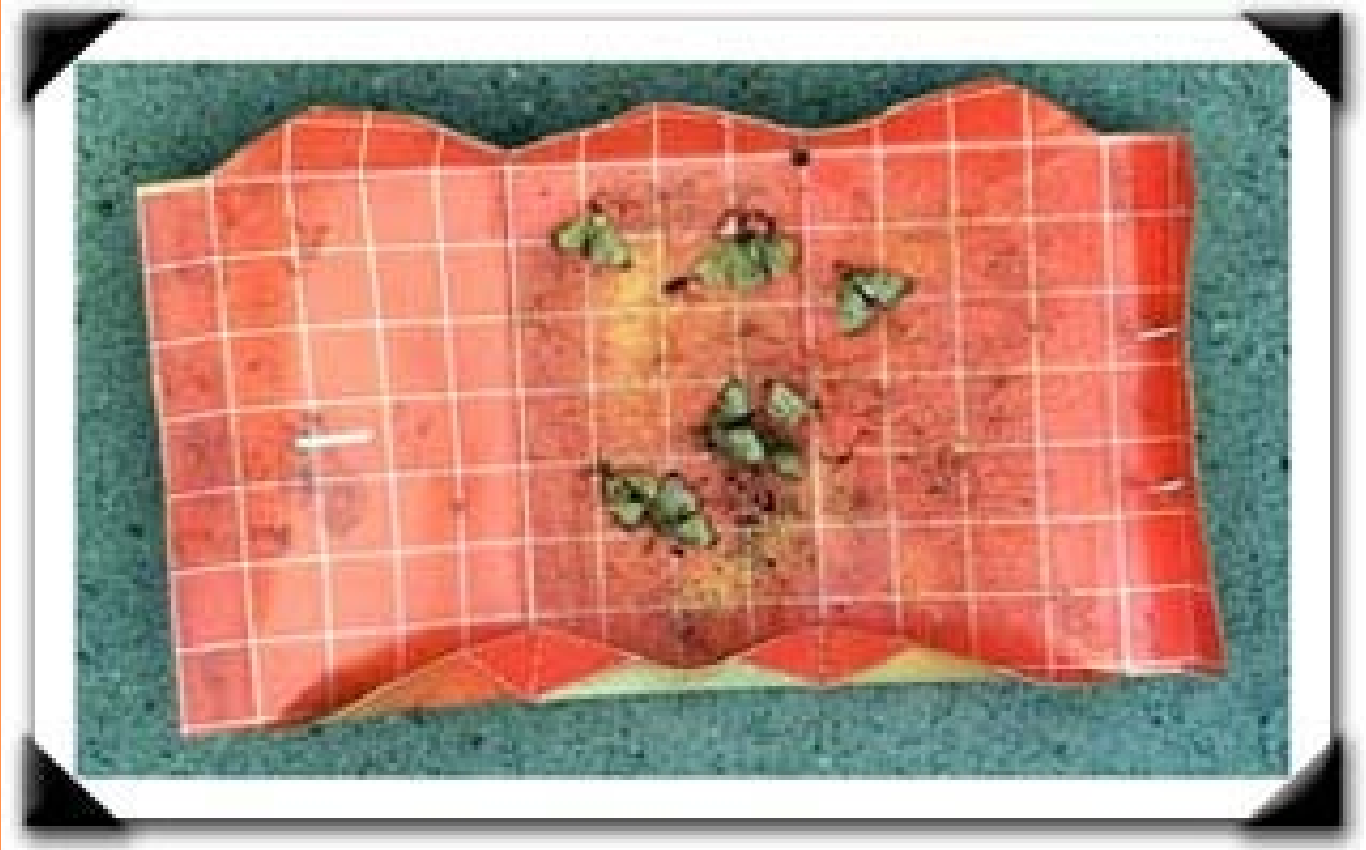
Gypsy moth in North America



Each summer, MDA workers fan out across the state to set about 16,000 gypsy moth traps. Known as Delta traps, they are triangular, 5 x 6 inch pup tent-shaped pieces of cardboard that are stapled or tied to trees and poles.

Each trap contains a pheromone designed to lure adult male gypsy moths. These pheromones are nontoxic to humans or animals. Once inside, the moth becomes entangled in a sticky substance coating the trap's interior.

Gypsy moth in North America



Delta traps attract male gypsy moths with the pheromone of the female. The trap has been opened and laid flat to show the male moths.

Gypsy moth in North America



To detect new infestations, traps are placed at a rate of either one trap every 1500 meters or one trap every 3 kilometers, depending on the risk of introduction.

They are placed at higher rates in areas where male moths were caught in previous years. Traps are placed on public property, public rights of way and private property.

Gypsy moth in North America



Depending on the number of moths caught in a location, the MDA moves in to combat the pest with chemical and behavioral management techniques.

So far, these spot treatments have kept the moth from getting a foothold in Minnesota.

Gypsy moth in North America



The MDA follows up the treatments with a mass trapping effort. This means 36 or more delta traps are set per square mile to determine if the population was eradicated. If no additional moths are caught, the treatment is considered successful.

The MDA will continue to monitor the site with heavy trapping for two years following a treatment. If traps remain empty for those two years, the MDA goes back to regular trapping.

Gypsy moth chemical management



Gypsy moth in North America



Chemical management

- ***Bacillus thuringiensis* var. *kurstaki***: only affects lepidoptera, conserves beneficial insects; Kills larvae by lysing gut with protein crystal; not toxic to mammals
- **Green plastic flakes containing female pheromone**: Disparlure; distributed by plane; 3-4 flakes per foot
Disrupt mating; males can not locate females.

Gypsy moth in North America



Chemical management

- Dimilin, IGR (insect growth regulator) prevents GM larvae from molting. Can cause mortality to aquatic insects, do not spray near water.

***Bacillus thuringiensis var. kurstaki* (Btk)**

Dipel

Thuricide

Protein crystal

Mode of action: Naturally-occurring microorganism that is a stomach poison to moths and butterflies. Feeding ceases and then death occurs.

Duration: No more than 1 week

Caution: Will kill some other butterflies and moths.

diflubenzuron

(not available for homeowner use)

Dimilin

IGR

Mode of action: Stops insect growth and development.

When to apply: When eggs have hatched and leaves are expanded. Apply when young caterpillars are present.

Duration: 3 months on foliage

diflubenzuron

(not available for homeowner use)

Dimilin

IGR

Caution: Cannot be applied over water courses or ponds. Will affect any animals that produce chitin (e.g., crawfish and insects).

tebufenozide

Mimic

IGR

Mode of action: Stops insect growth and development.

When to apply: When eggs have hatched and leaves are expanded. Apply when young caterpillars are present.

Duration: 3 months on foliage

cyfluthrin
Tempo
pyrethroid

Mode of action: Stomach and contact insecticide.

When to apply: When eggs have hatched and leaves are expanded. Apply when young caterpillars are present.

Duration: 2-3 weeks

Caution: Highly toxic to honey bees. Also toxic to many other insects and aquatic organisms.

azadirachtin

Neemix

botanical

Mode of action: Growth regulator.

Duration: No more than 1 week

Caution: Will kill some other butterflies and moths.

acephate

Orthene

organophosphate

Mode of action: Stomach poison. Broad spectrum insecticide. Cholinesterase inhibitor.

When to apply: When eggs have hatched and leaves are expanded. Apply when young caterpillars are present.

Duration: 1-1.5 weeks

Caution: Toxic to birds, bees. Do not apply over water.

Gypsy moth in North America

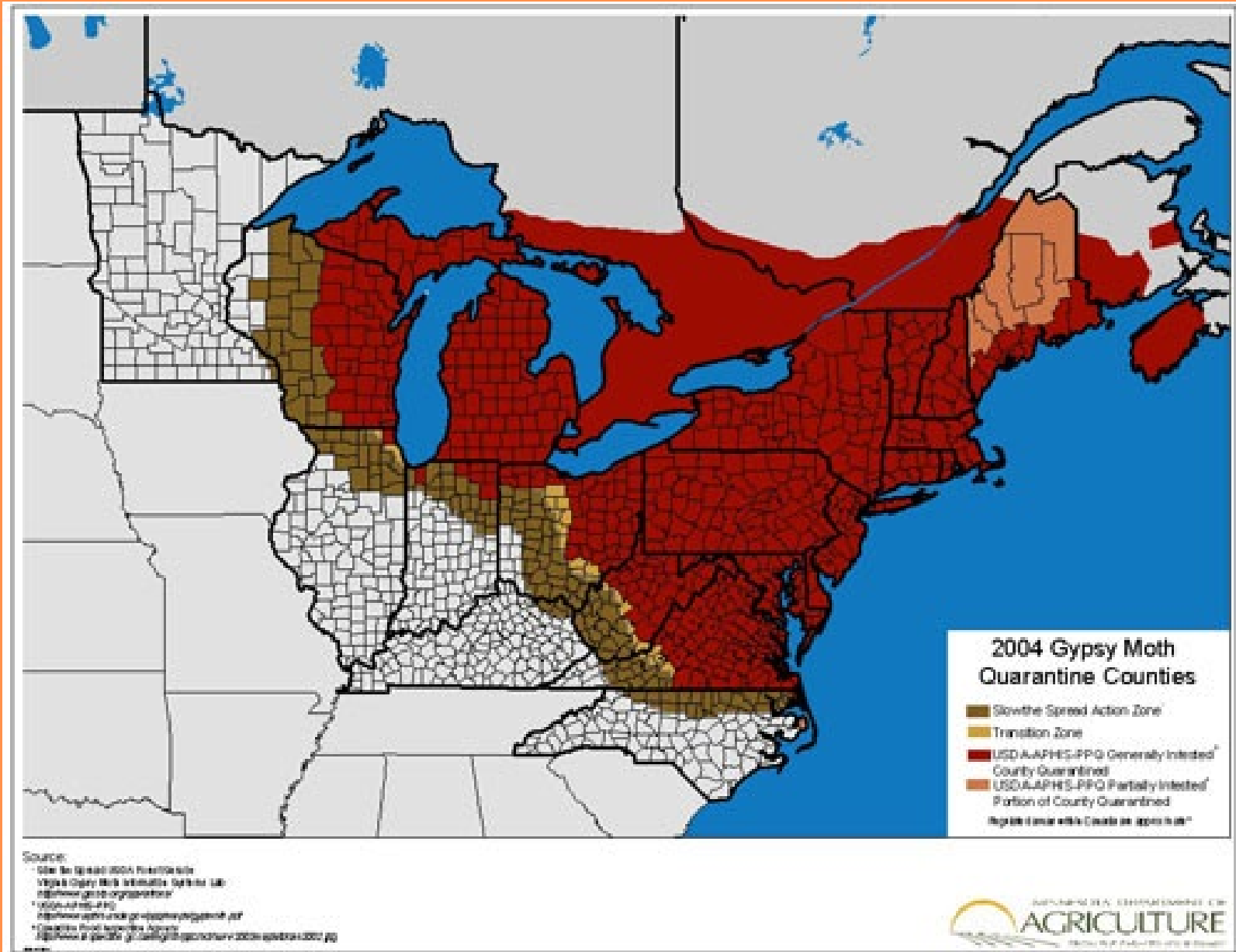


Slow the spread program (STS) Chemical management

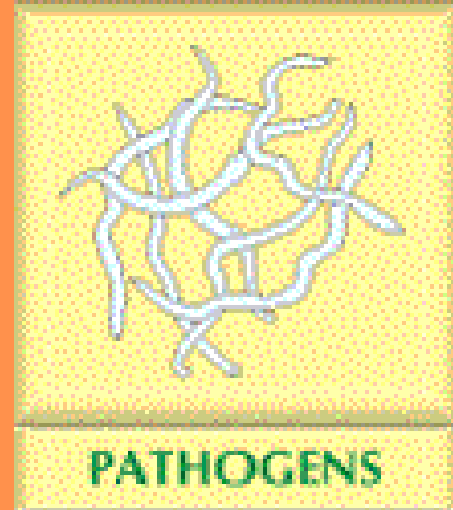
The goal of the STS project is to determine the feasibility of using IPM strategies to slow the spread of the gypsy moth over a large geographic area. The objectives for STS are to:

- 1) demonstrate that new and current technology can slow the rate at which gypsy moth populations are spreading,
- 2) assess the technological, economic, ecological, and environmental viability of implementing an operational STS program.

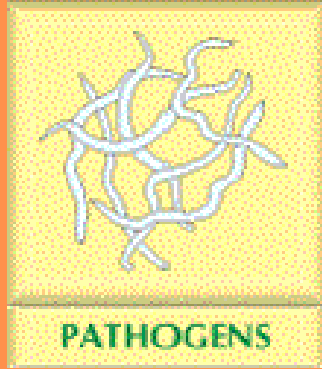
2004 Gypsy moth infested quarantine counties



Gypsy moth virus and fungus



NPV: Nucleopolyhedralosis virus



A naturally occurring virus called the “wilt” has resulted in massive mortality of caterpillars causing populations to collapse in areas of severe defoliation.

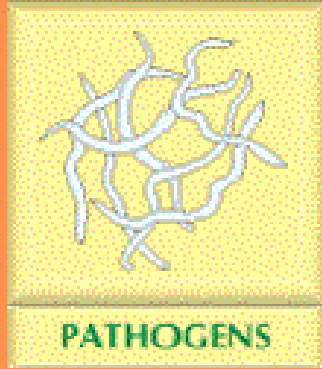
Although the virus is always present, it seldom affects the larval stage until they are under stress, due to overcrowding or reduced food availability.



NPV virus death

The bodies of dead caterpillars are soft, filled with a brown liquid and disintegrate rapidly. Usually, they hang limply in an inverted “V” position.

Entomophaga maimaiga fungus



Although *Entomophaga maimaiga* was introduced in the United States from Japan in 1910 and 1911, its 1989 appearance in Connecticut, New Hampshire, Vermont, northeastern Pennsylvania, New Jersey, southeastern New York, and Massachusetts is a mystery:

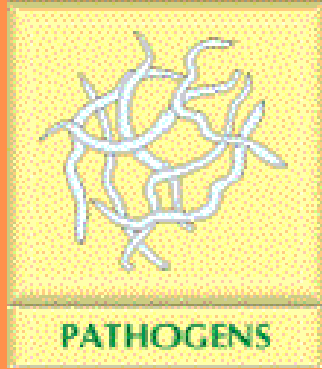
If its presence is due to the original introduction, why wasn't it detected during the years between 1911 and 1989?

***Entomophaga maimaiga* fungus**



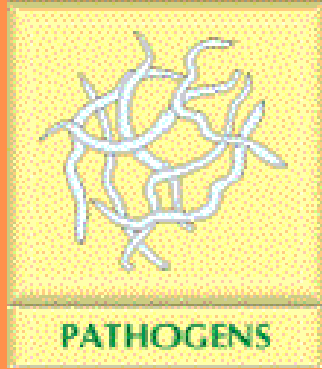
***E. maimaiga* passes the winter as a tough, thick-walled “resting spore” in the soil and on tree bark. In May or June, resting spores germinate and produce sticky spores at the end of a stalk that grows just above the soil surface. Gypsy moth caterpillars come into contact with these spores as they search for suitable leaves to feed on. The fungus digests its way through the exoskeleton of the caterpillar and grows inside the body of the caterpillar. Infected caterpillars may die within one week.**

Entomophaga maimaiga fungus



When young caterpillars are affected early in the summer, the fungus will produce a second type of spore called conidia. These microscopic spores are spread by the wind and can infect other caterpillars. The cycle of conidia production and infection may occur four to nine times during the summer. When the fungus develops in large caterpillars, it produces the overwintering resting spores.

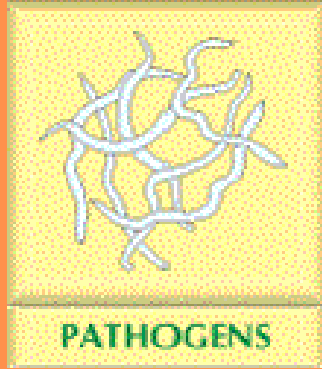
***Entomophaga maimaiga* fungus**



In recent years during wet spring weather, the fungal insect pathogen, *Entomophaga maimaiga*, has caused collapse of heavy infestations of gypsy moth.

It is moved from state to state by state and federal officials through cadavers or infected larvae.

Entomophaga maimaiga fungus



Soil can contain spores, but it can contain other pathogens, so cadavers are the best choice for transporting the fungus.

Entomophaga maimaiga fungus



A. Hajek
UNIVERSITÄT GÖTTINGEN

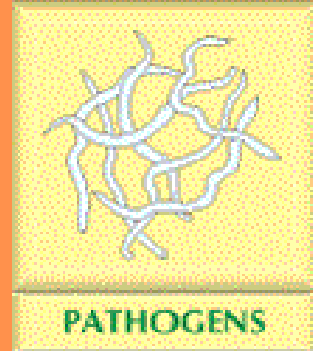
Right: *E. maimaiga*
conidia.



Left: *E. maimaiga*
resting spores.

A. Hajek

Entomophaga maimaiga fungus



Donald Specker

***Entomophaga maimaiga* death Caterpillars killed by *E. maimaiga* will also remain attached to tree stems or branches. However, the bodies tend to be stiff and straight, and the legs extend stiffly from the body. Some of the dead caterpillars may have tiny white conidia attached to the hairs on the body. The cadavers may remain on the stem well into the winter.**

Gypsy moth parasitoids, predators, and deer mice



Gypsy moth parasitoids: *Compsilura concinnata*



Gypsy moth parasitoids: *Compsilura concinnata*



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Gypsy moth parasitoids: *Compsilura concinnata*

Compsilura concinnata
(Diptera: Tachinidae) is a parasitoid native to Europe. This parasitoid is an extreme generalist, attacking over 200 different hosts from three insect orders, including Lepidoptera, Coleoptera and Hymenoptera.



B. Cooper

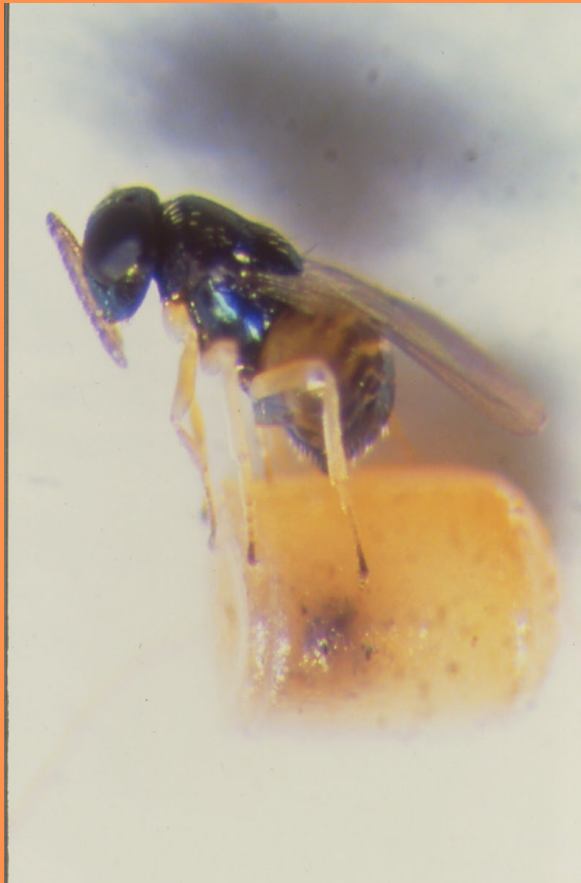
Gypsy moth parasitoids: *Compsilura concinnata*

***Compsilura* was initially introduced into North America in 1906 to combat gypsy moth. Numerous releases of this parasitoid were made thereafter for a variety of lepidopteran pests. In Minnesota, *Compsilura* was released, dating back to 1937, for biological control of the fall cankerworm, *Alsophila pometaria*.**

Gypsy moth parasitoids: *Compsilura concinnata*

These early releases allowed for a sort of “anticipatory” biological control for the gypsy moth. What this means is that, since *Compsilura* has the ability to attack so many different host species, *Compsilura* could become established on alternate hosts before the gypsy moth arrived in Minnesota. Furthermore, the biological control offered by *Compsilura* has “spilled over” from the forest systems into other habitats such as agricultural crops, including cabbage. Unfortunately, *Compsilura* appears to be attacking native, non-pest insects too.

Gypsy moth parasitoids: *Ooencyrtus kuvanae*



***Ooencyrtus* sp.**

<http://www.daapv.unipd.it/promoth/parasitoids.htm>



Ooencyrtus kuvanae

Wisconsin DNR

Gypsy moth parasitoids: *Ooencyrtus kuvanae*

***Ooencyrtus kuvanae* (Hymenoptera: Encyrtidae) is a small encyrtid wasp that was first introduced to the eastern United States in 1909 from Japan as an egg parasitoid for control of the gypsy moth.**

Females overwinter in the leaf litter, and become active around mid-April. Each oviposits on gypsy moth egg masses for about 4 to 6 weeks, with each female laying an average of 200 eggs.

Gypsy moth parasitoids: *Ooencyrtus kuvanae*

Females are good fliers, and they actively search out gypsy moth egg masses on tree trunks and tree branches. The females may locate the egg masses through scents released from the egg masses themselves, or they may be able to detect pheromones of gypsy moth females, and therefore locate egg masses as they are being laid.

Field rates of parasitism by *O. kuvanae* average around 20-30%. Parasitoid presence is noted by a tiny round emergence hole.

Gypsy moth parasitoids: *Cotesia melanoscela*



Gypsy moth parasitoids: *Cotesia melanoscela*

This braconid wasp (Hymenoptera: Braconidae) was one of the first parasitoids introduced from Europe early in this century to control the gypsy moth. There are actually two strains of the wasp in the U.S. now. The European strain was brought from Italy in 1912, while the Asian strain was introduced from India in 1977 and from South Korea in 1983. This species is now widespread and abundant where gypsy moth is established, and is one of the principal parasitoids attacking early-instar gypsy moths in North America.

Gypsy moth parasitoids: *Cotesia melanoscela*

Adults emerge when gypsy moth caterpillars start hatching from their overwintering eggs. Each female lays 500 to 1,000 eggs, which she places singly in first and second instar gypsy moth larvae.

Oviposition itself may be enough to kill small caterpillars. During the second generation, the females oviposit in third instar caterpillars as well, but later instars are not easily parasitized because of their long hairs and vigorous defensive movements. When the larvae complete their development, they tear a hole in the side of the caterpillar and emerge from their hosts.

Gypsy moth parasitoids: *Cotesia melanoscela*

They spin silken cocoons on the foliage, tree bark, or any other objects the caterpillars crawled onto before dying.

The overwintering generation of *C. melanoscela* is attacked by many hyperparasites, which reduce the effectiveness of this wasp. These other parasitoids can parasitize up to 80-90% of the overwintering *C. melanoscela* cocoons. Although this high mortality does not prevent the wasp from establishing and sustaining a population, it does reduce the ability of *C. melanoscela* to suppress gypsy moth populations.

Gypsy moth predators: *Calosoma sycophanta* beetles



***Calosoma sycophanta*, (Coleoptera: Carabidae) a large, bright metallic green beetle, was imported from Europe to New England for the biological control of the gypsy moth in 1905.**

Gypsy moth predators: *Calosoma sycophanta* beetles



The larva feeds day and night, consuming 50 caterpillars during its two-week developmental period. The adult will eat several hundred caterpillars during a life span of two to four years. A native species, *Calosoma scrutator*, also feeds on caterpillars.

Gypsy moth predators: *Calosoma sycophanta* beetles



Unfortunately predators don't exist in sufficient numbers to have a large impact on the gypsy moth caterpillars' numbers.

Gypsy moth predators: deer mice



Most birds avoid gypsy moth caterpillars, but small rodents will feed on them, especially when populations are high. Unfortunately predators don't exist in sufficient numbers to have a large impact on the gypsy moth caterpillars' numbers.