A SOURCEBOOK FOR MANAGEMENT OF THE GYPSY MOTH

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Forestry Canada
Ontario Region
Great Lakes Forestry Centre

1993

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Printing of this publication was funded by Tree Plan Canada

This report is printed on paper
containing recycled material

Canadian Cataloguing in Publication Data

The National Library of Canada has catalogued this publication as follows:
Nealis, Vincent Graham, 1952–
Main entry under title: A sourcebook for management of the gypsy moth
ISBN 0–662–20907–9
DSS CAT. NO. FO42–193/1993E

1. Gypsy moth — Control — Ontario — Handbooks, manuals, etc.
I. Erb, S. (Stephanie).
II. Great Lakes Forestry Centre.

SB945.G9N42 1993 634.9'6781 C93–099651–8

Catalogue No. Fo42–193/1993E
ISBN 0–662–20907–9

Copies of this publication are available at no charge from:
Communications Services
Forestry Canada
Ontario Region
Great Lakes Forestry Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Microfiches of this publication may be purchased from:
Micro Media Inc.
Place du Portage
165, Hotel-de-Ville
Hull, Quebec J8X 3X2

PREFACE

The gypsy moth was accidently introduced to North America near Boston in 1869 by a naturalist hoping to breed a producer of silk. The very attributes that first attracted the naturalist to the gypsy moth are now the bane of pest managers. The high reproductive potential of the gypsy moth and the ability of the caterpillar to feed on a wide variety of common native tree species has facilitated the establishment of the gypsy moth in a broad range of ecological zones from the cool temperate forests of the Great Lakes Basin to the warm, humid forests of the Carolinas. With so many new and diverse areas infested each year, it is difficult to establish any historical or ecological generalisations to predict what will happen next.

Pest managers have tried almost everything in their efforts to control the gypsy moth. Reports of gypsy moth control programs are voluminous, but often unavailable and very nearly indigestible. It is not easy for pest managers to use these reports to guide their own local programs. In contrast, documentation of the impact of the gypsy moth on the forest, and by implication, the benefits of these control programs, has been relatively neglected. There is very little specific information on the short- and long-term impacts of the gypsy moth that can be used to guide the pest manager.

Complicating this management situation is the gypsy moth's intricate relationship with people. Unlike other forest pests, which primarily threaten commercial timber values, the gypsy moth is a pest of semi-urban, shelter-belt and recreational land. This not only challenges the pest manager to incorporate non-traditional notions of forest values into decisions but also obligates the manager to deal with a diverse range of demands and expectations from the public.

It is against this backdrop that communities must devise a management program for the gypsy moth. We hope that this sourcebook helps. It is aimed at professional pest managers as well as municipalities, woodlot owners and cottage association groups that are trying to develop a gypsy moth management strategy at the community level.

It is not our intention to prescribe a particular strategy. Nor have we tried to produce a comprehensive compendium of everything you need to know about the gypsy moth. Instead, we have summarized concepts and information most relevant to local management programs and provided a guide to the sources of specific information. The biology and ecology of the gypsy moth, its impact and the methods used for monitoring populations are covered in chapters 1, 2 and 3. Management activities such as control, public information programs, and integrated pest management are covered in chapters 4, 5 and 6. An annotated bibliography of references follows these chapters. An appendix that lists the addresses of organisations mentioned in the text is found at the end of this publication.

Each chapter consists of text with supporting tables and figures. The text provides general background information and definitions, and explains critical concepts. Bracketed numbers within the text indicate references. For clarity, references within the text are kept to a minimum. Most references are identified by number in the tables and in a separate section at the end of each chapter.

This sourcebook was designed primarily with the gypsy moth situation in Ontario in mind. We hope that others will find it useful. We have drawn heavily on the experience in the United States, and have tried to bring an update of many of the new developments there to as broad an audience as possible.

ACKNOWLEDGMENTS

Much of the groundwork for this sourcebook was done by Darcy Ortiz and Taylor Scarr. We thank Louis Dorais, Bryan Frazer, Gordon Howse, Ed Kettela, Les Magasi, David Roden and Al Schmidt for reviewing all or portions of the sourcebook. Photographs are courtesy of Forestry Canada, Vince Nealis and Ed Czerwinski. Illustrations are by Stephen Kennington, Stephanie Erb, Peter Jakibchuk and Don Wallace. Editing and layout was done by the Publications Unit of Forestry Canada–Ontario Region. This project was funded by Tree Plan Canada and the Ontario Ministry of Natural Resources.

Table of Contents

(continued)

Chapter 5 PUBLIC INFORMATION PROGRAMS

Chapter 6 INTEGRATED MANAGEMENT OF THE GYPSY MOTH

Chapter 1
BIOLOGY AND ECOLOGY OF THE GYPSY MOTH

The gypsy moth, *Lymantria dispar* (L.), is a notorious defoliator of broadleaved trees in temperate regions. It is native to Europe and Asia and a member of a worldwide family of moths that includes other leaf-feeding insects such as tussock moths. In its native range, the gypsy moth is highly variable in appearance and behavior. One of the most striking variations is between the flightless adult female in Europe and the flying adult female gypsy moth in Asia.

The European form of the gypsy moth was introduced accidently to North America near Boston in 1869. Despite the flightless nature of the adult female in this founding population, the gypsy moth has steadily extended its range in North America. By the early 1990s, the gypsy moth inhabited most hardwood forests of eastern North America, as far west as Indiana, north to the Great Lakes Basin, and south to the Carolinas (Photo 6). Isolated infestations, likely caused by inadvertent transport of egg masses by people, have recurred at several locations in North America.

Introduction to Canada

In Canada, occasional collections of the gypsy moth have been made in areas adjacent to infested American locations since the early part of the century. It was not until 1969, however, that the first defoliation was noted in southeastern Ontario. Since then, the area of infestation has increased rapidly. By 1992, the gypsy moth was established throughout all of Ontario to the south and east of Lake Huron and there was evidence of resident populations along the northern shore of Lake Huron, extending to Lake Superior.

Established populations of the European gypsy moth exist throughout the St. Lawrence River and Ottawa River valleys in Québec and Ontario. In spite of quarantine and eradication programs, evidence of new infestations is found annually in New Brunswick, Nova Scotia and British Columbia.

In 1991, Asian gypsy moths were discovered in western North America. Asian gypsy moths differ from European gypsy moths in several biological characteristics, most notably the flight capabilities of the female moth. In this publication, unless otherwise noted, the information presented pertains to the European gypsy moth already introduced and widely distributed in North America. Most of the general management concepts presented, however, will be applicable to the Asian gypsy moth. Sources of information for the Asian gypsy moth are found in the reference list (6, 77, 151).

LIFE CYCLE

The gypsy moth's life cycle is characterized by four distinct stages: egg, larva (caterpillar), pupa and adult. The gypsy moth produces one generation per year (see Table 3.1).

Eggs

The female adult gypsy moth lays all of her eggs in a single, buff-colored egg mass that resembles a sponge or chamois (photos 7 and 8). The number of eggs in one of these masses varies from fewer than 100 to more than 1,000 eggs, with an average of 700 eggs for females feeding on unlimited quantities of preferred foliage. The egg masses are placed in sheltered positions on trees, or on rocks or fallen logs on the ground (Photo 8).

The gypsy moth embryo develops within the egg until it forms a small caterpillar, but does not hatch immediately. Instead, the insect remains in a state of arrested development within the egg mass for the winter. In this stage, the gypsy moth can tolerate temperatures as low as –30°C provided these conditions do not persist for several days. Hibernating gypsy moth need at least 2 months of low temperatures before they can become active again.

Larvae

Gypsy moth larvae or caterpillars emerge from their eggs in early spring (Photo 9). The exact time will vary from place to place and with weather. Most egg hatch will be completed by mid-May in Ontario.

The small, newly hatched caterpillars disperse from the egg mass within one day. They climb to the tops of trees, where they may venture off the branch and hang by a silk thread. Breezes then "balloon" these caterpillars to neighboring trees. This windborne movement is undoubtedly the most important dispersal event in the life cycle of the gypsy moth, as it enables caterpillars from egg masses on non-preferred trees or even on the ground to locate a preferred tree on which to feed.

Once the caterpillars become established on foliage, they feed and grow throughout May and June. The gypsy moth caterpillar passes through a series of progressively larger stages (instars), separated by a molt in which the entire outer skin is shed and replaced with a new one. Male gypsy moths have five, and females have six instars (Photo 10).

Although each instar has a characteristic range in size and in color pattern, the most reliable method of determining the stage of a caterpillar is to measure the width of its head capsule using a microscope equipped with a micrometer (Fig. 1.1). Larger gypsy moth caterpillars feed on leaves at night and rest in sheltered crevices lower on the tree during the day. When gypsy moth population densities are very high, caterpillars may remain in the tree canopy and feed intermittently throughout the day and night. The large, final-instar caterpillar is voracious. Each may consume as much as 1,000 square centimetres of foliage in their lifetime. This represents approximately 10 to 15 entire leaves of red oak.

Pupae

The development of gypsy moth caterpillars is complete by early to mid-summer, at which time the caterpillar finds a sheltered location in which to pupate (Photo 11). Female gypsy moths, with an extra instar and a longer period of development, pupate later and form larger pupae than do the males. The pupal stage lasts approximately two weeks.

Adults

Emerging female gypsy moths are swollen with eggs. Despite full-size wings, the female cannot fly. Instead, the female moth remains near the pupation site and releases a pheromone (odor) that attracts the highly mobile and responsive males (Photo 12). The female mates only once and then lays all of her eggs in a single egg mass (Photo 7).

POPULATION ECOLOGY

Evidence for cyclical outbreaks of gypsy moth has been claimed in both Europe and Asia. In North America, however, the pattern of outbreaks is less clear. Most localities in North America are only recently colonized by the gypsy moth, so the historical

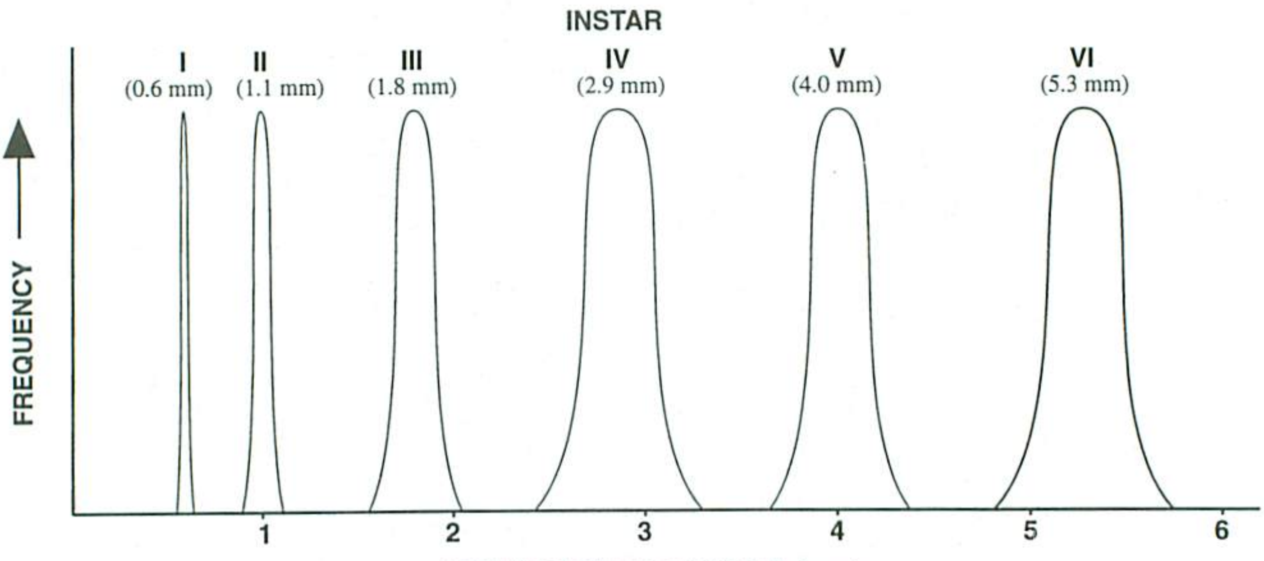


Figure 1.1: Width of head capsules for each instar of the gypsy moth. (Data from reference number 83.)

record is insufficient for general predictions of future patterns.

Temporal Patterns

Many researchers agree that North American populations of the gypsy moth exist either as an *innocuous phase*, in which numbers are maintained at low densities by the action of natural enemies, or as a high-density *outbreak phase,* in which gypsy moth populations become limited by food supply and prone to catastrophic epidemics of disease. The transition between the two phases, the *release phase*, is characterized by high survival of gypsy moth larvae and as much as a 100-fold increase in density in only a few generations (Fig. 1.2). Not all areas infested with gypsy moth, however, will experience such dramatic fluctuations.

In all population phases, mortality of the large larvae appears to have the greatest influence on population trends. The major factors that influence the population ecology of the gypsy moth are summarized in Table 1.1 and Figure 1.2. Natural mortality agents include: *predators* such as insects (Photo 15); small mammals and some bird species (Photo 16) that eat gypsy moth larvae; *insect parasitoids* that kill the gypsy moth by laying their eggs inside the pest (Photo 13); and *pathogens* (disease organisms) such as the nuclear polyhedrosis virus (NPV) (Photo 14).

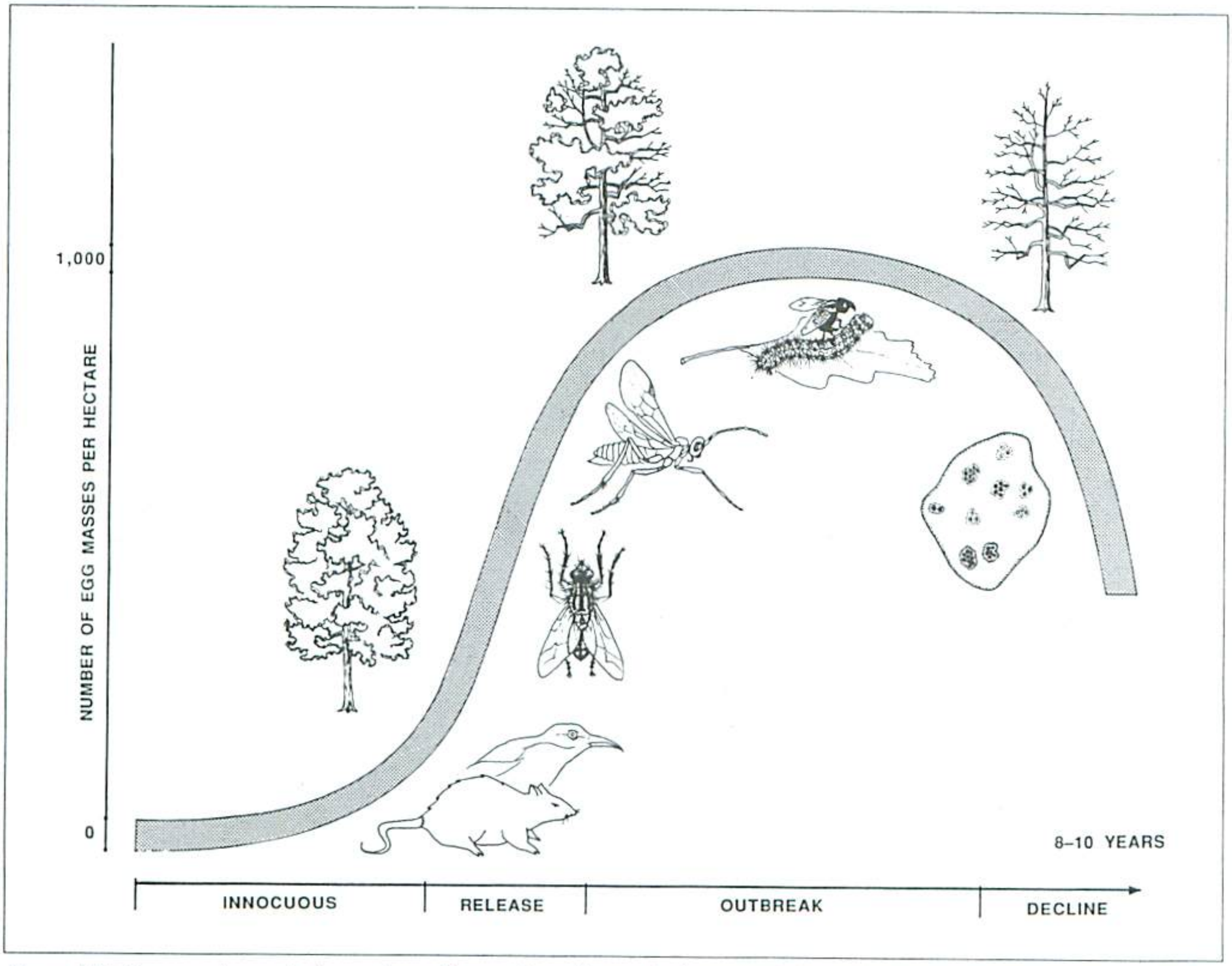


Figure 1.2: Gypsy moth population ecology. The number of insects is determined by the abundance and condition of host trees and the number of natural enemies. Populations increase when suitable foliage is abundant, but severe defoliation limits populations by reducing available foliage. Natural enemies (e.g., predators and parasites) reduce populations at low and moderate gypsy moth densities. Natural viral epidemics cause infestation collapses at high population densities.

Spatial Patterns

Defoliation by the gypsy moth may appear patchy within a region. The pattern of defoliation reflects the particular mix of preferred and non-preferred trees and the topography of the region (photos 3 and 5; see also Chapter 2).

Populations within a region may be in different phases of the outbreak cycle at different times. A consequence of this asynchronous pattern is that even though local outbreaks may subside after a few years, broader outbreaks can persist in a region for several years.

These generalized patterns of population ecology may not be typical in areas newly infested by the gypsy moth. There is evidence that gypsy moth populations along the "leading edge" of the insect's expanding range display exceptionally high densities, low natural mortality, and cause severe defoliation if conditions are suitable.

ADDITIONAL REFERENCES

Additional references on the biology and ecology of the gypsy moth are 14, 18, 27, 37, 44, 48, 59, 67, 70, 96, 98, 131, 135, 153 and 163.

Table 1.1: Factors that affect gypsy moth population dynamics.

Factors	Characteristics	References
Environmental		
Food	• Some tree species are more suitable as food plants than others • Food quality deteriorates after severe defoliation	Table 2.2 50, 128
Dispersal	• Movement by newly hatched larvae is important for local dynamics	25, 50
Weather	• Most effects of weather are subtle and difficult to predict • Activity and development rates increase at warmer temperatures • Weather influences the timing of the appearance of various life stages • Extreme conditions of prolonged cold can kill unprotected eggs	50, 92, 138
Natural enemies		
Predators	• Small mammals (e.g., the white-footed mouse) and larger birds (e.g., the black-billed cuckoo) can have significant local effects • The effect of predators is limited by their relatively low rates of dispersal and reproduction • Impact is greatest when gypsy moth population levels are low • Predators are important at maintaining low population levels of the gypsy moth infestation or reducing habitat susceptibility	25, 28, 50, 66, 136
Parasitoids	• Different species of parasitoids characterize different population phases • Parasitoids have a moderately high capacity for dispersal and reproduction • Parasitoids are widely distributed, but have a variable local impact	Chapter 4, 50, 66, 102 123, 134
Pathogens		
NPV (nuclear polyhedrosis virus)	• This virus is specific to the gypsy moth • It persists at some level in all populations • NPV causes a characteristic "wilted" appearance of caterpillars • NPV causes the most extensive mortality at outbreak levels	50, 71, 166
Entomophaga maimaiga	• This fungus is specific to gypsy moth • It can cause extensive mortality under some environmental conditions • It may persist from year to year in gypsy moth populations	4, 71, 72, 162

Chapter 2
IMPACT OF THE GYPSY MOTH

The gypsy moth represents a new and additional stress to North American forests. Management programs for the gypsy moth will be determined ideally by a prediction of the impact and some assessment of the value of the resource at risk.

SHORT- AND LONG-TERM IMPACTS

The short-term impacts of a gypsy moth infestation, such as defoliation (Photo 5), nuisance and allergic reactions, are the most obvious and alarming impacts to residents. However, the relationship between these immediate impacts and more long-term impacts, including tree mortality, is anything but clear. Many areas may become infested, but the long-term impact may be slight.

Broadleaved trees are, in general, resilient and will survive single bouts of defoliation unless they are already stressed by other factors. Repeated outbreaks of the gypsy moth tend to be restricted to forests dominated by tree species such as oaks on which the gypsy moth prefers to feed (Table 2.1). Within this forest type, long-term impacts including the death of trees are restricted to poor growing sites on which trees have low vigor. Difficulties in determining the exact cause of death of a tree makes it difficult to attribute the death of trees in an area to past infestations of the gypsy moth.

Table 2.1: List of preferred and less-preferred tree species for the gypsy moth. (References: 70, 79, 94)

Most preferred	Intermediate	Least preferred
Alder	Beech	Ash
Apple	Birch, black	Cedar
Aspen, largetooth	Birch, yellow	Fir, balsam
Aspen, trembling	Butternut	Juniper
Basswood, American	Cherry	Locust, black
Birch, gray	Dogwood, flowering	Maple, mountain
Birch, paper	Elm, slippery	Spruce
Hawthorn	Elm, white	Sumac
Mountain-ash	Hemlock, eastern	Sycamore
Oak (all types)	Hickory	Tulip tree
Poplar, Lombardy	Ironwood	Walnut, black
Tamarack	Maple	
Willow	Pine, white	
	Witch-hazel	

Even very low levels of a gypsy moth infestation can cause economic impacts in newly infested areas. Forest products from these areas may be subject to quarantine and require costly inspections before entering the market.

The gypsy moth causes significant impacts other than tree mortality. Large populations of caterpillars can cause temporary allergic reactions in people and reduce the aesthetic and recreational value of infested property.

Not all impacts of the gypsy moth are negative. Thinning of densely stocked stands, release of understory plant species, and acceleration of stand conversion to more desirable species as a result of infestations by the gypsy moth may be regarded as beneficial by some.

The management response to gypsy moth infestations will itself have an impact on the habitat. No response to gypsy moth infestations will permit the outbreak to take its natural course. Aggressive control operations or alteration of the forest to make it less susceptible to the gypsy moth may themselves be dramatic disturbances to the habitat.

We found very few scientific publications that contained actual measurements and analyses of impact of the gypsy moth. Most of the information in Table 2.2 has been generalized from several public information brochures and handbooks.

HAZARD RATING

A good pest management program anticipates impacts. In forestry, the concept of hazard rating is commonly used to rank the risk of forest stands being damaged. Forest fire hazard ratings are familiar examples. Similar hazard rating systems can be devised for the gypsy moth.

Hazard rating systems for the gypsy moth are based on an understanding of the *susceptibility* of trees to becoming infested and their *vulnerability* to significant damage once the infestation occurs.

Table 2.2: Short- to long-term impacts of the gypsy moth on forests and humans.

Time	Impact on forests	References	Impact on humans	References
Short-term	**Trees:** • Defoliation of preferred tree species[a] • Reduced capability to produce food • Increased utilization of food reserves • Deciduous trees may refoliate (additional stress) • Woody growth retarded • Reduced acorn production	14, 26, 37, 44, 48, 70, 96, 116 155	**Physical:** • Allergic reactions in sensitive individuals **Nuisance:** • Defoliation affects aesthetic values • Reduced shade value of amenity trees • Frass may damage finished surfaces • Larvae bothersome to many people	165 14, 44, 48, 78
Short-term	**Wildlife:** • Concentration of specialist predators (e.g., white-footed mouse) • Reduction in cover may affect some bird species • Impact slight and localized • Reduced acorn crop significant for animals such as deer and squirrels	9, 15, 28, 44, 50, 136	**Economic:** • Negative effects on seasonal tourism industry • Quarantine and inspection costs • Protection programs with insecticides may be required • Unanticipated silvicultural treatments may be required	48, 78, 127
Short-term	**Water quality:** • Increase in water temperature and yield • Quality may be influenced by droppings (frass) and cast skins	9		
Short-term	**Soil:** • Change in mineral composition and seasonal distribution of litterfall • Increased soil temperature (can damage tree roots)	64	• Continuing control program may be necessary	
Medium-term	**Trees:** • Twig and branch dieback • Canopy thinned • Mortality of vulnerable trees • Repeated defoliation increases all mortality • Increased risk from secondary pests (e.g., root rot) and wildfire • Increased light to forest floor encourages understory growth • Trees can recover	26, 44, 48, 69, 70, 96, 154, 155	• Loss of valuable trees for timber or ornamental uses	
Medium-term	**Wildlife:** • Increased habitat diversity may favor some species • Loss of food trees adversely affects dependent animals	44		
Long-term	**Trees:** • Shift in tree composition to less preferred species • Acceleration of natural succession, decline of pioneer species (e.g., gray birch, aspen)	9, 19, 26, 70 75	• Composition of managed stand may change, requiring new management objectives and practices	
Long-term	**Wildlife:** • Slow change reflects the replacement of vulnerable tree species	15, 44		

[a] Preferred host species are listed in Table 2.2

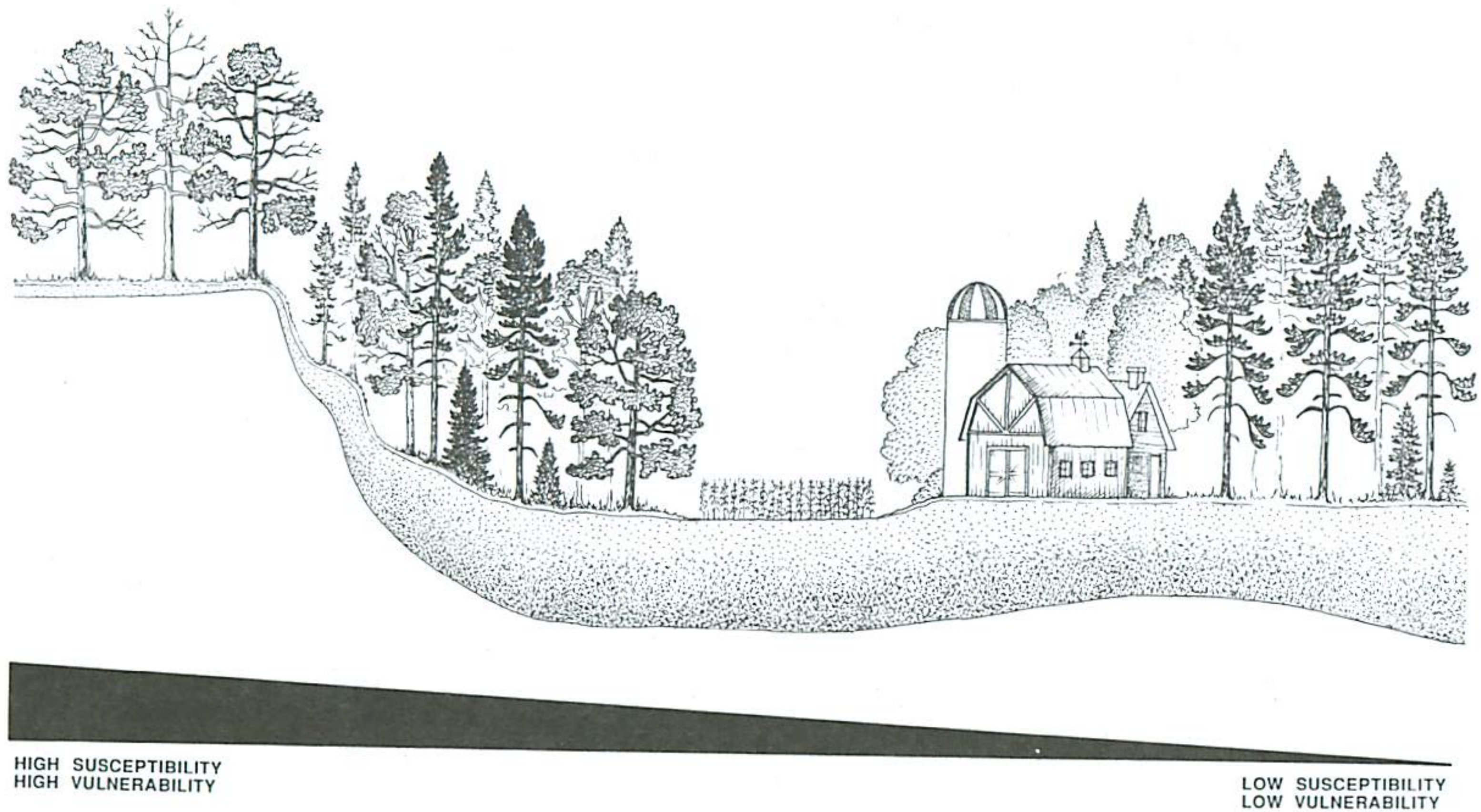


Figure 2.1: Landscape cross-section showing a gradient of habitat ranging from highly susceptible and vulnerable oak trees on ridge tops with shallow soils to less susceptible and relatively invulnerable nonhost trees.

Susceptibility

Susceptibility is the likelihood of a forest stand becoming infested by the gypsy moth. Stand composition is probably the single largest determinant of susceptibility. It has been widely concluded that the gypsy moth prefers to feed on oaks over any other tree species. High-density infestations of the gypsy moth tend to occur where oak species comprise more than 20% of the forest. This generalisation may not hold along the leading edge of the expanding range of the gypsy moth. Forests dominated by other preferred hardwoods such as aspen (*Populus tremuloides*) or white birch (*Betula papyrifera*) may be severely defoliated when the gypsy moth first infests an area. The susceptibility of less-preferred species to defoliation by the gypsy moth increases if these trees are close to an infested forest. The susceptibility of understory trees is particularly high in infested stands. Once the gypsy moth has completely defoliated the oaks, they will move on to and damage trees that in other circumstances would not be considered at risk. An abbreviated list of preferred and non-preferred tree species is given in Table 2.1.

Site factors influence the susceptibility of trees to gypsy moth infestations. Drainage and topography are important. Dry, rocky ridgetops with slow-growing, scrubby oak trees are highly susceptible to infestation by the gypsy moth. Forests in which there is an abundance of healthy, less-preferred tree species growing on deep soils are least susceptible to gypsy moth infestations.

Vulnerability

Vulnerability is a measure of the degree of damage trees will sustain once they become infested by the gypsy moth. Factors that affect the vulnerability of a tree include its species, the severity and duration of the infestation, tree vigor, and site conditions.

Deciduous trees such as oaks store much of their food reserves in their roots. If defoliated, they are capable of refoliating the same year. Severe defoliation stresses the tree but it may take several successive years of defoliation to actually kill it. By comparison, evergreen species such as white pine store food reserves in their needles. These trees are highly vulnerable to severe damage if defoliated. A single year of complete defoliation by the gypsy moth can kill these trees.

The health of the trees influences their vulnerability. Large, dominant trees with full canopies and extensive root systems are capable of withstanding severe and repeated defoliation. They also have a good chance of recovering once the infestation has passed. Understory or suppressed trees may not fare as well.

The health of trees is largely determined by site conditions. Many of the same factors that affect a tree's susceptibility also determine its vulnerability. Any factor that stresses the tree (e.g., poor soils, drought, exposed conditions, other pests) will increase its vulnerability to significant damage. Figure 2.1 summarizes some of the general factors that influence susceptibility and vulnerability of a forest stand to the gypsy moth.

Assessment of the hazard rating of a forested stand in terms of the gypsy moth requires considerable judgment. The hazard rating should be developed with reference to local conditions and the anticipated impact of an infestation on the community. A simple example of a hazard rating system for gypsy moth is a series of questions such as those in Table 2.3. The more times you respond "yes" to these questions, the higher the hazard for the area.

Table 2.3: A simple hazard rating system for the gypsy moth.

- Is the area of concern near existing infestations?
- Have the trees been defoliated previously?
- Is there a large proportion of preferred hosts (i.e., oaks)?
- Are the preferred trees clustered?
- Are the most valued trees understory trees?
- Are the trees showing signs of stress from other factors? (i.e., drought, other insects and diseases)
- Are the trees on dry ridgetops with thin soils?

ADDITIONAL REFERENCES

Additional references on the impact of the gypsy moth are 74, 76, 79, 80, 145 and 146.

Chapter 3
MONITORING THE GYPSY MOTH

The first questions people ask about gypsy moth populations are *"Is there gypsy moth in the area?"* and if so, *"How many?"* Start by consulting federal or provincial forestry offices or other knowledgeable sources (Table 6.2). Forestry Canada's Forest Insect and Disease Survey (FIDS) is a national network that provides information on forest health conditions in Canada. Regional offices of Forestry Canada can be contacted to obtain published information on the current situation and forecasts for the gypsy moth (published in the *Survey Bulletin*). Annual and multi-year summaries are sometimes available (Table 6.1).

SAMPLING

Information about gypsy moth populations can be obtained by employing various *sampling methods*. Sampling is a method of gaining information about an entire population by examining only a part of that population. Public opinion polls are familiar examples of sampling, in which pollsters try to determine national trends by asking only a few thousand people. Sampling information is used by pest managers to assess the current and future status of the pest population in order to make decisions for management. It is essential that the sampling information be reliable.

There are obvious savings of time and money that result from only examining a portion of the population, but the answer gained from sampling is an estimate and subject to errors. It is important to understand these potential errors when using the information from sampling. Different sampling methods may be more appropriate for some purposes than others, but all have limitations.

Accuracy and Precision in Sampling

Errors in sampling are errors of accuracy or precision (Fig. 3.1).

Accuracy relates to how closely the sample estimates the true value of interest. Methods that consistently under- or overestimate the true value are *biased*. An awareness of the degree and direction of bias is critical in interpreting information from sampling. Accuracy in a sampling method is most important when one is trying to find out how severe an infestation is or when one wants to assess the effectiveness of some control measure. Accuracy is less important if you only want to know *if* gypsy moth is present. Finding even one gypsy moth will confirm its presence.

Precision relates to the repeatability of the method. A sampling method that tells you that the number of gypsy moth present is between 10 and 1 million larvae per hectare is neither precise nor useful. Conversely, a method that provides a consistent estimate of between 500 and 1,000 caterpillars per hectare is reasonably precise. Precision can often be improved by increasing either the size or the number of samples.

METHODS OF SAMPLING

The gypsy moth is a difficult insect species to sample accurately. The caterpillar's habit of frequent movement makes definition of a stable sample unit for this feeding stage nearly impossible. The complex association of the gypsy moth with many plant species (Chapter 2) and the tendency of populations to fluctuate between low and high density levels over a relatively short period of time (Chapter 1) make reliable predictions difficult.

The purpose of the sampling program determines the method. Choosing a good sampling method

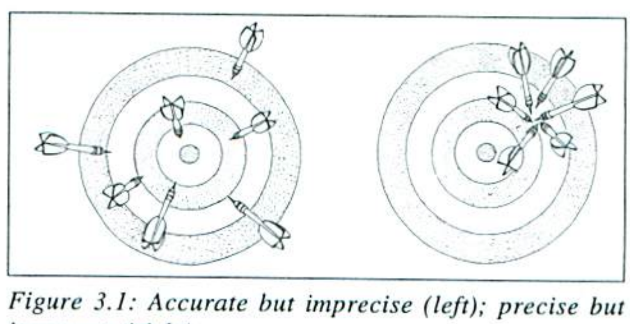


Figure 3.1: Accurate but imprecise (left); precise but inaccurate (right).

requires you to keep objectives, limitations and cost-effectiveness firmly in mind. Management programs must use a variety of sampling methods and then carefully interpret the results of those sampling methods in view of the management objectives.

Methods of sampling gypsy moth populations can be organized by the life stage of the gypsy moth (Table 3.1). Consult Figure 3.2 for the approximate seasonal occurrence of each stage.

Caterpillars (Larvae) and Pupae

The caterpillars and pupae of the gypsy moth can be trapped by girdling the trunks of host trees with a band of dark fabric such as burlap or tar paper. The caterpillars seek shelter by day and so can be found resting under these bands (Photo 2). At the end of the feeding period, many insects pupate in the shelter provided under these bands.

The number of gypsy moth caterpillars trapped under bands can vary greatly from day to day. Weather, the type and size of tree banded, the density of feeding caterpillars and their ages all influence the catch. These factors must be kept in mind when interpreting the results.

The banded tree method is, however, simple and inexpensive if the sampling area is not too large. Fabric bands are useful in early detection of feeding caterpillars in an area because they tend to concentrate the caterpillars in one place. They may also provide a reasonable relative estimate of the trend of the infestation (annual increases or decreases) at moderate levels of infestation if a consistent timing and duration is established for the sampling program. The accuracy of the method is poorest at high population densities.

The population density of gypsy moth caterpillars can also be observed by clipping and examining infested foliage. This method is more time-consuming and destructive than tree banding. The accuracy of this method has not been assessed but it is generally thought to be poor unless combined with other methods of sampling.

The most accurate method of determining the density and stage of development of feeding gypsy moth is by collecting their frass (droppings) in containers placed beneath the tree canopy. Although a well-tested method, collecting frass is time-consuming and requires experience as well as making associated measurements on rates of feeding, etc. Use of this method is restricted to detailed research objectives.

Adult moths

Newly emerged adult female gypsy moths do not fly but release a specific airborne scent, called a *pheromone*, to attract a mate. A synthetic mimic of this mating pheromone can be used to lure male moths to a trap. Pheromone trap designs vary from disposable cardboard traps with a sticky inside surface to various cannister-type or "milk carton" traps made of cardboard or reuseable plastic and that contain an insecticide to kill the moths (Fig. 3.3). A list of commercial suppliers of pheromones and traps can be found in Table 3.2.

Pheromone traps are very efficient at detecting the presence of sparse populations of gypsy moth. They are widely used in survey operations to detect new infestations or after eradication programs to confirm the presence or absence of male gypsy moths.

Very few traps are required to detect the presence of the gypsy moth. In Ontario, two traps are placed in each selected park or campsite. If male gypsy moths are found, more traps are used in subsequent years in an attempt to delimit the potential area of infestation. In these intensive trapping programs, a grid system of trap locations is used.

Pheromone traps are so efficient that they become less useful in areas where gypsy moth populations are well established. The large number of moths caught can saturate the sticky surfaces of the disposable traps or otherwise change the efficiency of the traps. The

Table 3.2: Gypsy moth pheromone trap suppliers.

Company	Trap(s)
Great Lakes IPM	• wing traps (pherocon, scentry) • delta traps (trece, scentry, pherocon) • multipher traps • milk carton traps • single trap kits available
Phero Tech Inc.	• delta traps
Bio–Contrôle Services	• multipher II and lures
Zoecon Industries Ltd.	• pherocon traps and lures
Pest Management Supply Inc.	• multipher II and lures • trap kits (scentry, trece) • single station kits available
Cooper Mill Ltd.	• gypsy moth carton trap
Trece Inc.	• pherocon trap kits and lures

result is that the relationship between the number of moths caught in traps and the size of the population is often weak, and pheromone traps by themselves do not consistently forecast population levels in infested stands. Recent research, however, is improving the accuracy of these predictions.

Male moths caught in pheromone traps can be used to assess the reproductive potential of the population. Larger males with longer wings imply larger, more fecund females in the resident population.

Egg masses

Counting egg masses is the most reliable method of estimating established gypsy moth populations. Unlike the previously mentioned sampling methods, which rely on trapping individuals, egg-mass counts are a direct estimate of the size of gypsy moth populations.

The gypsy moth is in the egg stage for most of the year. This allows a relatively long time during which sampling can be carried out. Egg masses are most readily visible in the autumn after the leaves fall from the trees or in the spring before leaves appear. Care must be taken to count only the current year's egg masses. Old egg masses are softer and have a bleached appearance (Photo 8).

The location of egg masses can be informative. In high-density infestations, most egg masses are located on tree trunks and branches. In low-density populations, a larger portion of the egg masses is found on the forest floor or on man-made objects. Trees at the edge of a forested stand may have more egg masses than trees in the center of the stand. In residential areas, man-made objects have a large number of egg masses. These patterns are, however, generalizations and exceptions have been noted.

The actual size of the egg mass is a vital statistic for assessing gypsy moth populations. Larger egg masses (more than 500 eggs per mass) indicate a healthy, increasing population, whereas smaller egg masses are characteristic of a decreasing population. The number of eggs per mass can be estimated in the field by measuring the length of the egg mass (105).

Timed walk

Early gypsy moth programs estimated the number of egg masses by simply counting all of the egg masses seen on a "five-minute walk" through an area. This method has been shown to be imprecise because of differing capabilities of the observers and variable characteristics of forested stands, residential areas, etc. However, such a quick survey by an experienced observer can provide a good starting point for population assessment in conjunction with other sampling methods. Annual timed walks by the same observer in the same area should give an acceptable relative estimate of the population trend for that area.

Fixed-area plots

The recommended method of estimating the density of gypsy moth egg masses is by counting egg masses within a standardized area, a *fixed-area sample plot*. Using a standard area rather than a standard time to search allows for differences between observers and encourages close examination of the egg masses. Careful examination of egg masses minimizes mistakes as a result of counting egg masses from previous years.

The fixed-area sample plot gives results that are easily translated into an estimate of the number of insects per hectare for comparing different stands or changes in population levels within a stand. The method can be time-consuming and requires more observers than simply walking through the stand. It is, however, the most reliable way of estimating gypsy moth numbers in an area.

There is some variation in the details of conducting fixed-area sampling for gypsy moth egg masses, but all variations attempt to count all of the current year's egg masses within a standard area. Binoculars must be used to observe egg masses high in the tree (Fig. 3.4).

In the United States, fixed-radius plots (5.4-metre radius) of 1/40 acres (0.01 hectares) are used most commonly (Fig. 3.4, left). All egg masses seen on the trunks of all trees within the circle and on the ground are counted. Modifications of this method that are relevant to residential properties have been assessed. In Ontario, a square (10 by 10 metre) fixed-area plot, the modified Kaladar plot (MKP), is used. In this design, all egg masses above ground are counted but only a few 1-square-metre quadrats of the forest floor are examined (Figure 3.4, right).

Fixed- and variable-rate plots are a further modification. These employ a standard area on the ground (20.2 m^2) but examine only those trees of a

Table 3.1: Sampling techniques for the gypsy moth.

Stage sampled	Method	Sampling characteristics	Uses	References
Gypsy Moth				
Caterpillars	Burlap banding (mid-June to July)	• Affected by diurnal movements of larvae (in response to weather, population density) • Concentrates larvae; biased • Effectiveness decreases as population increases • Feasible only in small areas	• Early detection of larval populations • Provides a way of monitoring larval development • Provides an estimate of density trends • Demonstration/education	88, 97, 159
	Frass collection (mid-June to July)	• More accurate than burlap bands • Requires special equipment, experience	• Intensive field studies, research	86
Male moths	Pheromone traps (July to August)	• Highly sensitive at low population levels • Concentrates insects; biased • Different trap designs and lure formulations may influence the catch	• Detection of new infestations • Monitoring low-density populations • Identifying priority areas for subsequent egg-mass sampling • Demonstration/education	13, 31, 49 59, 140
Egg masses	Timed walk (Sept. to Nov.)	• Subject to observer and stand variations • Counting efficiency decreases as egg-mass density increases • Effective in combination with other sampling methods	• Confirms presence of breeding population • Gross categorization of population density	1, 90, 114
	Fixed-area plots Sept. to Nov.	• Standardized sampling procedure • Non-constricting time frame • Reliable at high egg-mass numbers • Precision increases as number of sample plots increases	• Precise estimate of population size • Ascertain effectiveness of control methods • General defoliation forecasts	24, 27, 51 52, 85, 121 135, 139
Trees				
July to Aug.	Single-tree defoliation estimates and/or aerial surveys of plots	• Subject to observer errors • Must be carried out after all feeding is complete but before plants recover • Reliable mostly for recording severe defoliation • Covers large areas quickly (aerial)	• Recording leaf loss • Recording refoliation • Providing regional maps of severe defoliation	87, 89

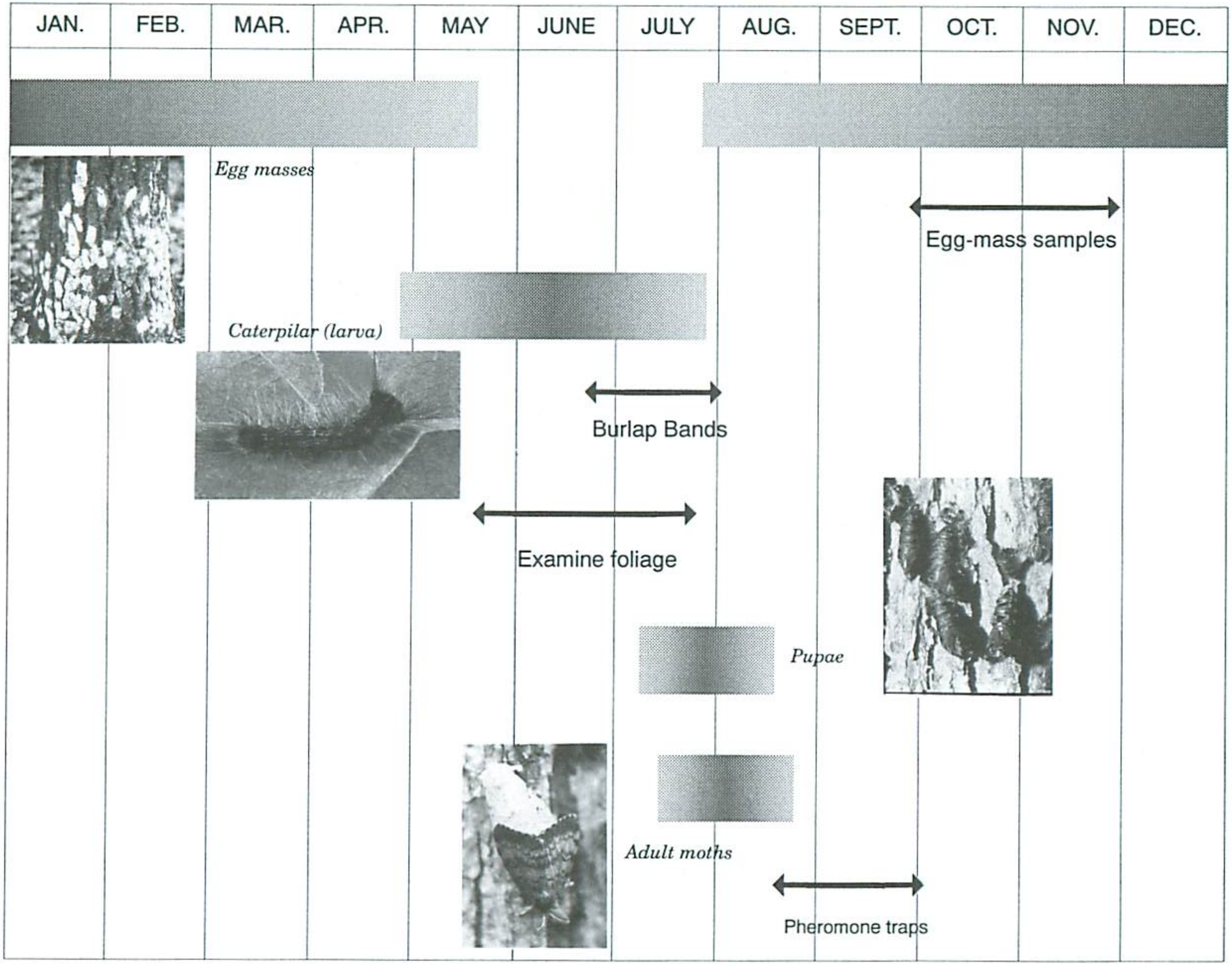


Figure 3.2: Approximate seasonal occurrence of various life stages of the gypsy moth indicating the best time for sampling.

specific size. This method is not intended for forested areas smaller than 10 hectares.

The number of fixed-area plots required to obtain a useful estimate depends on the the size of the gypsy moth population and the level of precision desired.

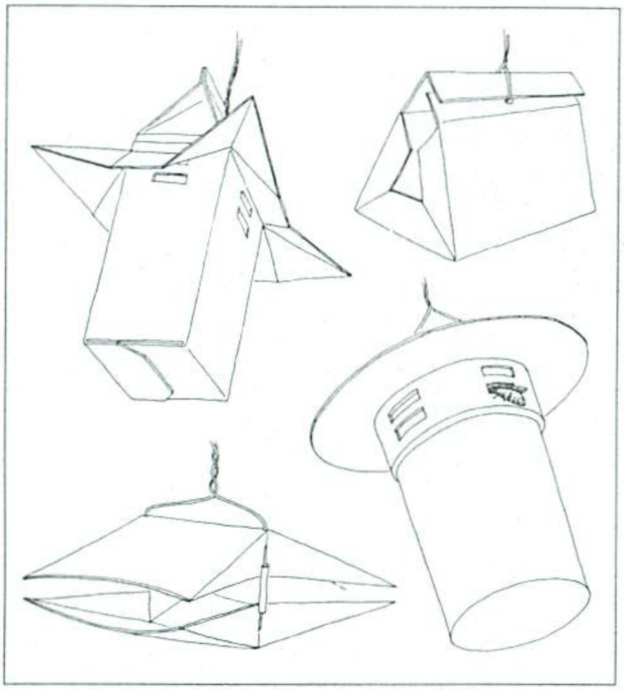


Figure 3.3: Examples of pheromone trap designs used to monitor populations of adult gypsy moths.

Sequential methods have been devised to reduce the number of samples required when population levels are either very high or very low. A minimum of three plots per square kilometre has been suggested. In the United States, four to 10 fixed-area plots per square kilometre are used. In general, the more plots, the more precise the estimate obtained.

Although egg-mass samples provide the best estimate of population levels, they give only approximate forecasts of future defoliation. Several studies have developed equations for relating egg-mass density to defoliation, but these equations are probably specific to the site studied and have limited applicability in new areas.

Defoliation

Direct estimates of defoliation are sometimes desirable. This usually means estimating the percentage of the current year's foliage removed by the gypsy moth. Such a survey should be carried out in late July or August, after feeding has finished.

Rough estimates can be obtained by an examination of the tree crowns with binoculars. This method is vulnerable to the same disadvantages as the timed-walk method of estimating egg masses; the results can be highly variable and dependent on the observer. A more reliable estimate can be obtained by

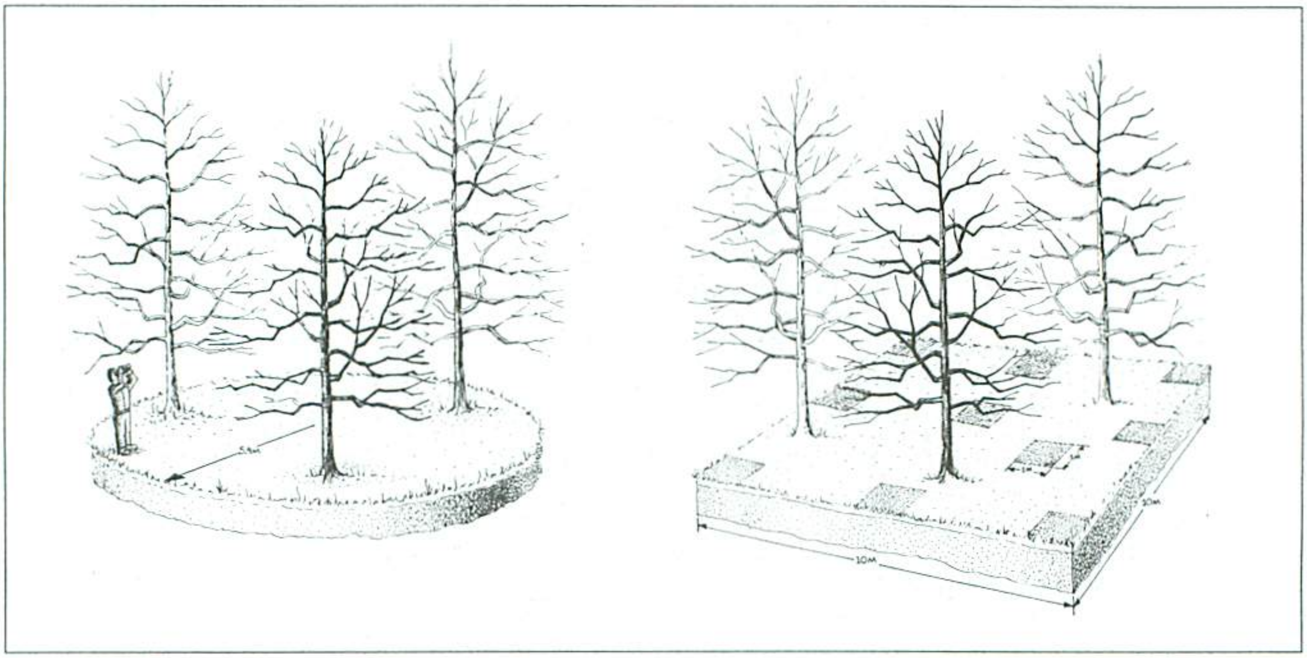


Figure 3.4. Circular and square (MKP) sample plot layouts for estimating gypsy moth egg-mass density in a fixed area.

clipping branches from the trees and actually measuring the percentage of the foliage remaining (or absent) on individual branches. This method is time-consuming and acceptable sample sizes have not been worked out. A reasonable starting point would be to sample trees within the same fixed-area plot employed for egg-mass surveys.

Some agencies, such as Forestry Canada, conduct aerial surveys to estimate the total area defoliated by the gypsy moth. These surveys map only detectable (i.e., moderate-to-severe) defoliation. They do not represent the total area infested by the gypsy moth.

ADDITIONAL REFERENCES

Additional references on monitoring gypsy moth populations are 12, 32, 44, 60, 104, 106, 144 and 163.

Chapter 4
CONTROL

If gypsy moths are found in sufficient numbers to cause concern and the actual or potential impact is considered unacceptable, then control programs may be undertaken to reduce population levels.

OBJECTIVES OF A CONTROL PROGRAM

There are two general objectives of control programs: eradication and suppression of gypsy moth populations.

Eradication

Eradication programs attempt to exterminate the gypsy moth from an area. It is important to understand that eradication can be realized only in isolated infestations of limited size. A gypsy moth eradication program depends on early detection of the arrival of the pest and specific delimitation of the area infested. Both detection and delimitation are greatly aided by the systematic use of pheromone traps (Chapter 3).

To eradicate the gypsy moth in newly infested areas, intensive and aggressive control action may be necessary. Cutting and burning of infested stands or multiple aerial applications of registered insecticides are some of the control measures taken.

Proponents of eradication programs cite the necessity of aggressive control of these isolated infestations in order to prevent the establishment or slow the spread of the gypsy moth. Successful eradication programs are important management victories as they deny or significantly delay establishment of the gypsy moth in new areas. These on-going control programs address long-term pest management objectives.

Suppression

Suppression programs aim to reduce gypsy moth numbers sufficiently to reduce anticipated impacts. Suppression programs are commonly carried out when gypsy moth populations increase to unacceptable levels within the established range of the insect.

Suppression programs vary greatly in scale and cost. There have been large aerial spray programs over 100,000 hectares of forest in Ontario but suppression programs may also be carried out on residential properties or even single trees at no cost outside of the owner's time and effort. The intensity of a suppression program reflects the perceived severity of the pest problem. Repeated control measures or combinations of different control measures are used where any losses would be judged intolerable.

Successful suppression programs are concerned primarily with the protection of foliage. Unless a suppression program involves treatment of a significant proportion of the area infested, suppression programs have little influence on the regional dynamics of the gypsy moth. They are short-term solutions to pest problems.

The total areas treated during various control programs for the gypsy moth conducted in Ontario from 1970 to 1992 are shown in Figure 4.1. Until 1983 most programs involved eradication of small infestations. Thereafter, control programs focused on suppression of established gypsy moth populations over larger areas.

THE COST OF CONTROL OPERATIONS

Pest managers recognize there is always the option of taking no action against a pest. The costs, both economic and environmental, of control operations must be weighed against the consequences of allowing gypsy moth infestations to run their natural course.

Estimating the economic cost of carrying out control operations is relatively easy. It is the cost of resources: materials and labor. Estimating the environmental cost of control operations is more difficult. The concerns are largely ones of public health and of the impact on non-target organisms such as wildlife.

Public health

With insecticides, the public health question is addressed through the concept of lethal dosages.

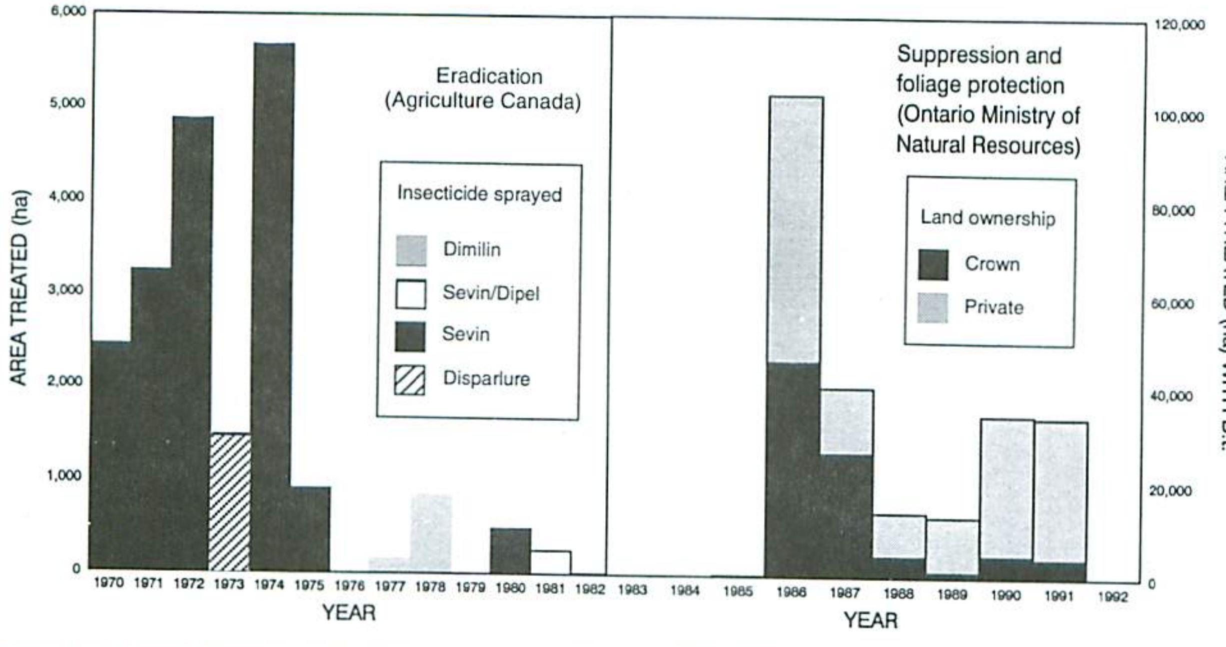


Figure 4.1: Control programs against the gypsy moth in Ontario, 1970–1992.

Groups of test organisms are exposed to varying dosages of the insecticide. The dosage that kills 50% of the group is called the LD_{50}. This value is considered an index of the compound's toxicity to a particular organism. The lower the LD_{50}, the less of the toxin is required to kill an organism (i.e., the more toxic the substance).

Environmental impact

When a control method has a negative impact on a wide variety of organisms, it is considered a *broad-spectrum method.* Insecticides that kill several or all species of insects in the treated area are broad-spectrum. Cutting and burning an infested stand has a similar, broad-spectrum impact on the environment. Conversely, specific control activities such as trapping and destroying gypsy moths or using species-specific pathogens such as NPV (Chapter 1) are *narrow-spectrum methods.* Narrow-spectrum control methods are considered to have less environmental impact than broad-spectrum methods.

CONTROL METHODS

Most control operations seek dramatic and immediate reductions in pest populations. There are, however, some approaches to control that are more subtle and long-term (Table 4.1).

Long-term methods

Quarantine regulations and inspections are intended to prevent the introduction of exotic pests. Gypsy moth pupae and egg masses are readily transported on vehicles and goods. Inadvertent transport of the gypsy moth by vacationers or commodity shippers is often the source of new infestations. Inspection of vehicles from infested areas before entry into uninfested areas is an effective method of keeping the gypsy moth out of an area. Quarantine programs are most effectively coordinated at national ports of entry. Movement within countries and between regions may be regulated but it is difficult to enforce. Interception of the gypsy moth depends on the vigilance and co-operation of a knowledgeable public (Chapter 5).

Silvicultural control methods reduce the susceptibility of forests by converting managed stands to less-preferred tree species (Table 2.1). Tending methods such as thinning or fertilizing reduce vulnerability by improving tree vigor (Chapter 2).

Provision of shelter for important predators of the gypsy moth, such as the white-footed mouse or some bird species, can be considered a long-term cultural control (Chapter 1).

Classical biological control attempts to establish exotic natural enemies from the home range of the pest in the infested areas. The initial impact of this approach

Table 4.1: Techniques for gypsy moth control.

Control method	Objective	Characteristics	References
Quarantine	• Prevent introduction of the gypsy moth to new areas	• Effective only if strictly enforced on a continuing basis • An informed and co-operative public is required	47, 143
Silvicultural	• Reduce susceptibility and vulnerability of stand • Encourage natural enemies such as parasitoids, birds and mammals	• Results are realized over the long-term • Potential for broad, but managed impacts	14, 62, 96, 99
Classical biological control	• Establish new natural enemies of the gypsy moth in an area • Increase overall mortality	• Self perpetuating, natural control • Development costs (exploration and research) may be high • Benefits are long-term • Impact on other organisms can be assessed • May not be complementary with insecticide use • Success may vary according to local population densities and environmental conditions	20, 38, 66, 68 107, 108, 130 160, 161
Finding, trapping and killing gypsy moth	• Reduce local populations	• Minimum environmental impact • Limited effectiveness • Labor intensive • Not feasible for large areas, large trees or high-density populations	70, 96
Barriers	• Protect individual trees	• Minimum environmental impact • Limited effectiveness • Labor intensive • Not feasible for large areas or high-density populations • Can be used in combination with insecticide application to limit reinfestation	35, 36, 70, 96 110
Mass-trapping	• Define the area of infestation • Suppression or eradication	• Narrow spectrum • Not feasible for large infestations • Labor intensive • May be used in conjunction with other methods	14, 93
Mating disruption	• Follow-up to direct control action	see mass-trapping (above)	32, 65, 137
Sterile release	• Suppression	• Same as mass-trapping, except less amenable to combining with other techniques	132

(cont'd)

Table 4.1: Techniques for gypsy moth control (concl.).

Control method	Objective	Characteristics	References
Inundative release of natural enemies, including NPV	• Suppression of outbreak populations	• Narrow spectrum • Effectiveness may be influenced by environmental conditions at the time of treatment • Limited availability of material • Potential for some carryover benefits	41, 58, 66, 82 107, 117, 125
Bacillus thuringiensis* var. *kurstaki	• Suppression or eradication	• Widely available commercial product • Requires applicator's licence and specialized equipment • Low mammalian toxicity • Minimal or no buffer zones required • Some non-target effects on restricted groups of insects (caterpillars) • Multiple applications may be necessary for severe infestations • Effectiveness influenced by ambient weather conditions and physical characteristics of forest canopy	11, 61, 70, 101, 148, 167
Natural plant products	• Suppression or eradication	• Active research area—not yet available for general use • Low mammalian toxicity • Limited commercial development • Specificity depends on particular mode of action	73
Synthetic insecticides	• Suppression or eradication	• Widely available commercial products • Require applicator's licence and special equipment • Reliable efficacy if used as directed • Moderate- to broad-spectrum depending on method of application, mode of action and persistence • Mammalian toxicity may be high • Buffer zones required	21, 30, 70, 129

is low and very localized. Eventually, an ideal biological control agent will spread naturally and attack the gypsy moth over a broad geographic range.

Biological control was one of the principal gypsy moth control methods in the earlier part of the century. At least 12 species of parasitoids, predators, and pathogens have been either purposefully or fortuitously established in North America as controls against the gypsy moth. New introductions are being considered by research laboratories.

Each of these cultural control methods implies some level of impact on the environment. Silvicultural methods purposefully change the ecology of the stand. Biological control adds new insect species to the habitat. The changes that result from these actions can, however, often be anticipated and therefore managed.

Short-term methods

The most specific control methods are those which affect only gypsy moths. Scraping and destroying egg masses, and trapping and killing caterpillars and pupae under fabric bands (Chapter 3) have essentially no negative environmental impact.

Various *barriers* such as sticky bands have been used to protect specific trees, although these barriers do not stop windborne, ballooning caterpillars. Some resins used as barriers can also be toxic to plants.

The deployment of a large number of high-capacity pheromone traps to capture moths is a method of *mass-trapping* gypsy moths. Since only male moths fly to the traps, the idea is to reduce the number of male moths available for mating. A modification of this idea is *mating disruption*, in which pheromones are applied directly to the infested area. The abnormally high local concentration of pheromones confuses the male so that he cannot locate a mate.

A genetic control method developed for the gypsy moth is the *release of sterile individuals*. These laboratory-produced insects develop naturally and mate, but are sterile and do not produce offspring. As with the mass-trapping and mating-disruption methods, this method is species-specific. The impact on other organisms is minimal.

None of the narrow-spectrum control methods discussed so far are feasible for large areas or severe infestations. Manual searches for gypsy moth life stages are labor-intensive and trapping and mating-disruption methods become less effective as the population density of the gypsy moth increases.

INSECTICIDES

For effective control over larger areas (greater than 10 hectares), some commercial control product, usually applied by licenced applicators using specialized equipment, is required. Recommendations on organizing an aerial spray program for gypsy moth can be found in the publication *Gypsy Moth in Ontario* (70).

From an operational point of view, any organism or compound applied to an area for the purpose of killing gypsy moths can be considered an insecticide. By this definition, naturally occurring microbial pathogens, synthetic pheromones, insect growth regulators, and conventional chemical products are all insecticides if applied to an area by pest managers with the goal of reducing gypsy moth population levels.

Two broad classes of insecticides can be identified. *Biological insecticides* include microbial pathogens of the gypsy moth and extracts of natural plant products. *Synthetic insecticides* are the conventional products of the pesticides industry.

Biological insecticides

Biological insecticides have the virtue of being relatively specific (narrow-spectrum). This is particularly true of micro-organisms such as the nuclear polyhedrosis virus (NPV) and the fungus *Entomophaga maimaiga*. These natural pathogens affect only the gypsy moth (Table 1.2). The mass release of insect parasitoids (biological control by *inundation*) can be considered another case of using a biological agent as an insecticide.

The technology for production and application of these biological insecticides is largely in the research stage. The availability of material and consistency of its effect are limited compared with synthetic insecticides. In the United States, a formulation of natural NPV called Gypchek is available. In Canada, a similar product, Disparvirus, has been developed at the Forest Pest Management Institute (see Table 6.2).

Development of natural plant products and nematodes as insecticides is still largely in the research stage. The bacterium *Bacillus thuringiensis* var. *kurstaki (Bt)*, however, has been fully developed as a commercial, operational biological insecticide.

Bt (Bacillus thuringiensis)

Bt is a common soil bacterium. It can be mass-produced using fermentation technology. Early field results with *Bt* were highly variable, but steady improvements in strain selection and application techniques have resulted in improved control results. *Bt* is now the insecticide of choice against the gypsy moth in most public jurisdictions in North America.

It is not the ingested *Bt* bacterium that produces the lethal effect but a protein crystal produced by the bacterium. The expression of the toxin in the crystal occurs only under particular conditions. The gut of foliage-feeding caterpillars meets these conditions. For this reason, *Bt* effects only a relatively narrow range of organisms (i.e., caterpillars). *Bt* is, however, toxic to a wide range of caterpillars and is therefore less specific than other microbial agents such as NPV.

Synthetic insecticides

The least-specific (broadest-spectrum) of all insecticides are the synthetic insecticides. These compounds differ somewhat in their toxicological properties and, in turn, in the range of organisms that they affect. The common property of most of these synthetic compounds is that they act both as ingested and contact poisons; the insecticide enters the insect either by being eaten or simply by contacting the surface of the insect.

Once inside the insect, there are a variety of modes of action. *Insect growth regulators*, for example, interfere with the normal molting process of the insect whereas organophosphates such as *acephate* and carbamates such as *carbaryl* disrupt the normal functioning of the insect's nervous system.

REGISTRATION OF INSECTICIDES

The use of pesticides in Canada is regulated by the federal Pest Control Products Act. This act is administered by the Plant Industry Directorate of Agriculture Canada. Each province has similar legislation that can further restrict, but not liberalize the federal law. In Ontario, this is the Pesticides Act, administered by the Ministry of the Environment.

Regulatory authorities specify a process leading to *registration* of a pesticide for use. The process is largely concerned with public health and consumer protection. Regulators want to ensure that commercial products are safe and effective when used as directed (Table 4.2).

To obtain registration of a pesticide, manufacturers must provide data on its *toxicity*, its *effectiveness*, and on any *residue products*, among other details. These data are reviewed by Agriculture Canada and other departments, including Health and Welfare. Any department may request additional information to address specific concerns.

Table 4.2: Classification of pesticides. (Reference: 30)

	Pesticide schedule		
	Restricted	Commercial	Domestic
	• Products for which several regulatory limitations have been imposed	• Products for use in commercial operations such as agriculture and forestry	• Products eligible for sale for non-commercial use in and around the home
	• Compliance with the described restrictions is the responsibility of the licenced user	• More toxic products than domestic class	• Inadvertent exposure is less likely to result in severe effects
	• Penalties for misuse	• Users must be licenced, equipped and more knowledgeable in safe use and disposal	• Disposal of container and product via regular garbage collection poses low risk
LD_{50} Acute oral	<50 mg/kg	>50 mg/kg	>100 mg/kg
LD_{50} Acute dermal	<100 mg/kg	>100 mg/kg	>1,000 mg/kg
Environ-mental effects	May be significant	Possible, but limited	Minimal under directed use

Registration of a pesticide results in its classification into one of three categories: *restricted, commercial,* or *domestic* (Table 4.2). Information about a registered pesticide is referenced by its *Pest Control Product Number (PCP No.)*. The *product label* specifies technical information about the product: the crops or pests on which it can be used, methods of storage and disposal, toxicological information, and procedures to follow in the event of an accident. The product label is a legal document and its provisions must therefore legally be followed.

Common limitations include the method of application (ground or aerial spray) and the establishment of obligatory no-spray buffer zones around water sources or inhabited areas. These limitations are usually based on the concepts of human toxicity and broad-spectrum versus narrow-spectrum effects. Insecticides with broad-spectrum activity or that pose a significant risk to humans will have the most severe restrictions.

All insecticides registered for aerial application in forested areas are classified as restricted irrespective of their toxicity. This is because of the special requirement for provincial use permits for aerial application of any insecticide used in forest and woodlands management. The use of commercial or restricted pesticides requires an applicator's licence. In Ontario, these licences are obtained by successful completion of a course approved by the Ministry of the Environment.

A list of insecticides registered for commercial or restricted use against the gypsy moth in Canada and the manufacturers is given in Table 4.3. These lists are current as of April 1993. They represent descriptive information only and are not intended to be endorsements of a product. Information on all registered pesticides can be obtained by contacting the Pesticides Directorate of Agriculture Canada at 1–800–267–6315 or (613)993-4544.

Table 4.3: Registered pest control products for the gypsy moth in Canada.

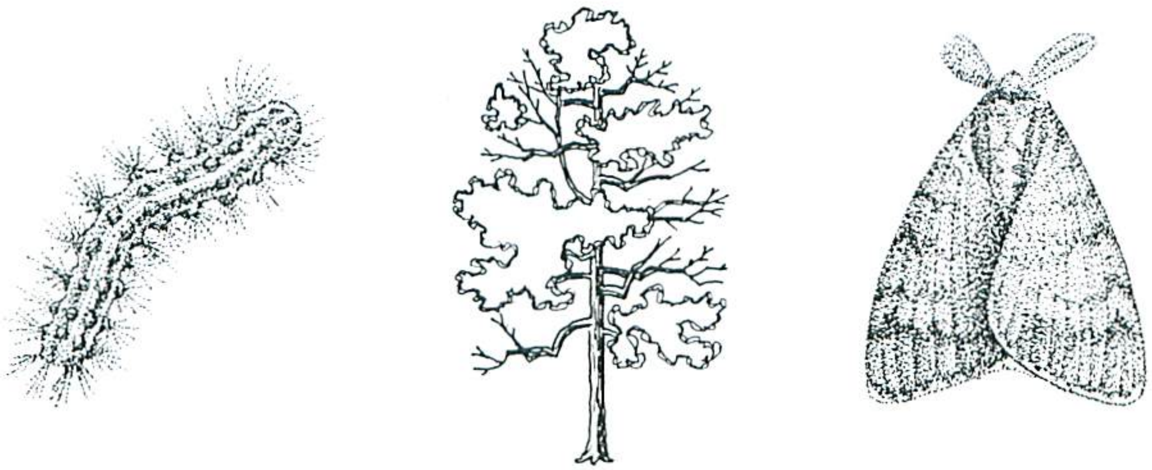
Common name	Trade name	PCP No.[a]	Pesticide schedule	Manufacturer[b]
Bacillus thuringiensis	Dipel 88	16873	Restricted	Abbott Laboratories Ltd.
	Dipel 132	17954	Restricted	Abbott Laboratories Ltd.
	Dipel 48 AF	20861	Restricted	Abbott Laboratories Ltd.
	Dipel 64 AF	21526	Restricted	Abbott Laboratories Ltd.
	Dipel 176	20599	Restricted	Abbott Laboratories Ltd.
	Thuricide 48 LV	17980	Restricted	Zoecon Industries Ltd.
	Thuricide HPC	11302	Commercial	Sandoz Agro-Canada Inc.
	Futura XLV–HP	21484	Restricted	Novo Nordisk Bioindustrial
	Foray 48 B	21464	Restricted	Novo Nordisk Bioindustrial
	Foray 76 B	22403	Restricted	Novo Nordisk Bioindustrial
	Bactospeine	17781	Restricted/Commercial	Novo Nordisk Bioindustrial
Acephate (ACP)	Orthene Forest Spray Concentrate	14226	Restricted	Chevron Chemical (Canada) Ltd.
	Orthene Tree & Ornamental Spray	15559	Commercial	Chevron Chemical (Canada) Ltd.
Carbaryl	Sevin 4 Oil Carbaryl Insecticide Liquid Suspension	11115	Restricted	Rhone–Poulenc Canada Inc.
	Sevin 50 W	6839	Restricted/Commercial	Rhone–Poulenc Canada Inc.
	Sevin 80 s	8151	Restricted/Commercial	Rhone–Poulenc Canada Inc.
	Sevin XLR	17027	Restricted/Commercial	Rhone–Poulenc Canada Inc.
	Sevin 85 S	7446	Restricted/Commercial	Rhone–Poulenc Canada Inc.
	Sevin XLR Plus	19531	Restricted/Commercial	Rhone–Poulenc Canada Inc.
Diflubenzuron	Dimilin 25% WP Insecticide	13816	Restricted	Solvay Duphar B.V.
Trichlorfon	Dylox Liquid Solution	8950	Commercial	Chemagro Ltd.
	Sylox 80% Soluble Powder	9827	Restricted/Commercial	Chemagro Ltd.
	Sylox 420 Liquid Insecticide	16387	Restricted/Commercial	Chemagro Ltd.
	Danex (Trichlorfon) 80 SP	15319	Commercial	Makhtechim–Agan (NA) Inc.

[a] Pest Control Product Number

[b] The addresses of these manufacturers are listed in Appendix 1.

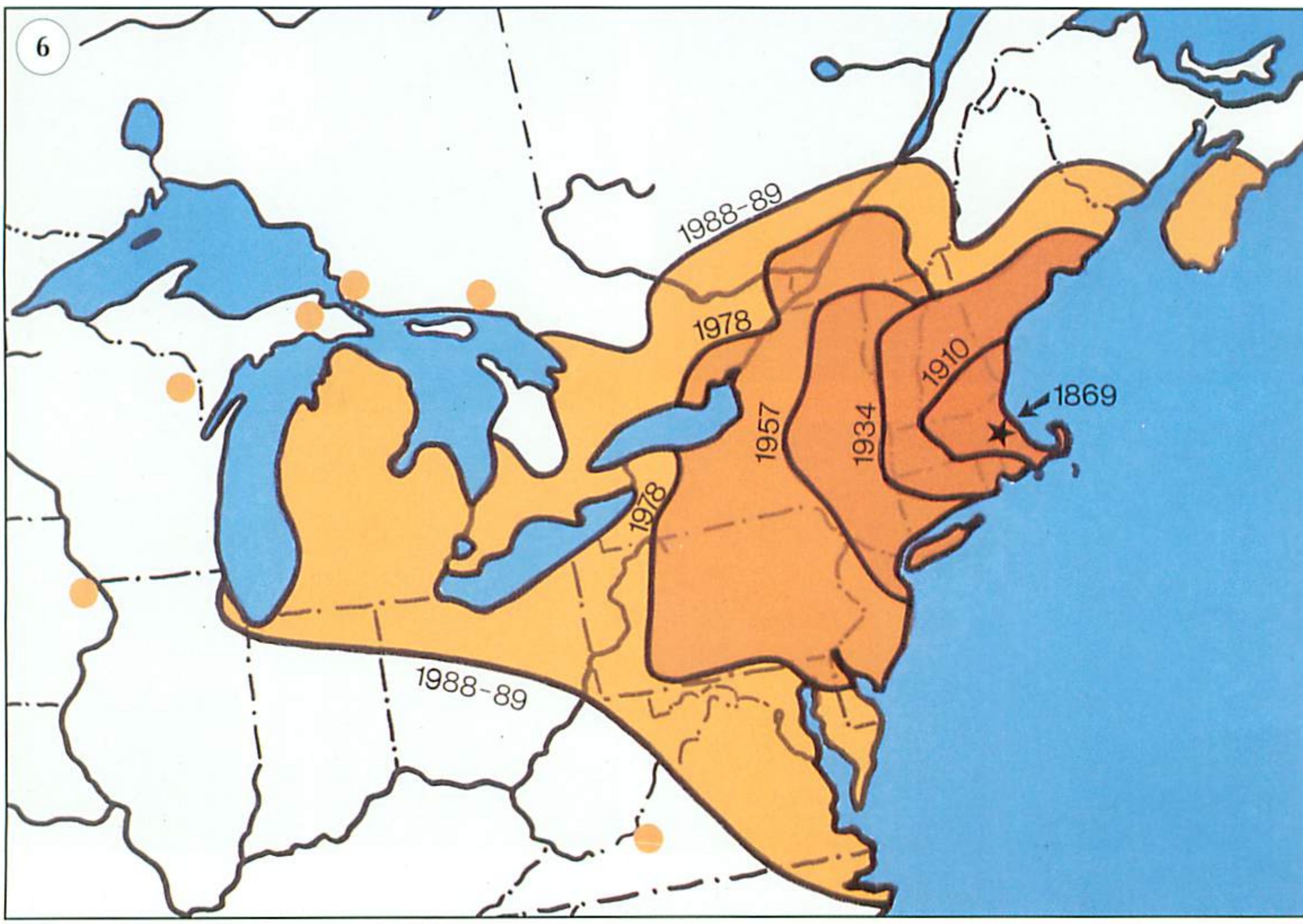
References: Agriculture Canada hotline, 30

The Gypsy Moth



1. Gypsy moth larva. 2. Larvae resting under fabric bands. 3. Aerial view of defoliation.

4. Final-stage larva on white pine.
5. Hardwood species, especially oak, are most susceptible to defoliation.
6. Spread of gypsy moth in eastern North America (1869–1989)
7. Female moths laying eggs in summer.
8. Gypsy moth egg masses after the winter.
9. Hatching gypsy moth larvae in the spring.
10. Larvae resting on bark.
11. Pupae in summer.
12. Adults mating in summer: male is brown, female is white.

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13. Parasitic insect emerging from a gypsy moth larva.
14. Gypsy moth killed by the nuclear polyhedrosis virus (NPV).
15. An insect predator of the gypsy moth.
16. The black-billed cuckoo, a predator of the gypsy moth.

Minor use

Under some circumstances, pest managers may apply for a "User Requested Minor Use Label Expansion". These applications are managed by the Minor Use Program Coordinator of Agriculture Canada and are reviewed by provincial coordinators. The intent of the Minor Use Registration is to obtain temporary registration for the use of a product in limited amounts and areas. Several criteria must be met. The product should already be evaluated and registered for other purposes and there should be reasonable grounds to expect it will work for the current intended use. There must also be a demonstrable need. The producer is required to amend the label to include the proposed use.

All pesticides, however scheduled, interfere with some biological process. They should be handled with all due precaution and only used under the conditions specified on the label.

ADDITIONAL REFERENCES

Additional references on methods of controlling the gypsy moth are 9, 15, 18, 21, 37, 44, 45, 46, 48, 96, 111, 113, 118, 144 and 158.

Chapter 5
PUBLIC INFORMATION PROGRAMS

NEED FOR A PUBLIC INFORMATION PROGRAM

The gypsy moth's capacity for widespread defoliation in urban, recreational, timber-producing and wilderness areas causes concern in a wide variety of interest groups. There are bound to be conflicting opinions on how to deal with the gypsy moth because of the different values placed on the forest resource by these different groups. Public information programs, therefore, are one of the most important aspects of gypsy moth management. A misinformed or apprehensive public will not contribute positively to the development of a management program but will certainly generate opposition to the best-laid plans.

Successful public programs ensure that all concerned citizens are given the opportunity to become aware of the gypsy moth, the management policies of the responsible agencies, the management options, and the potential consequences of specific actions or of inaction. Public information programs also offer the opportunity for public input to the decision-making process. These programs should provide mechanisms for resolution of conflicts between the management agency and the public as well as among different community groups with opposing points of view. Public information programs are the first step in enlisting public assistance and support for the management program. Many monitoring and control programs, such as quarantine inspections to prevent movement of the gypsy moth (Chapter 3), rely heavily on public participation.

With insecticide control programs, there are explicit legal requirements for certain kinds of public information. Progressive public information programs, however, go beyond the legal requirements for notification in an effort to enlist public support for long-term management objectives. Through their influence on legislators, a supportive public will be a strong ally in defining objectives and securing financial support for resource management.

CARRYING OUT A PUBLIC INFORMATION PROGRAM

Public information programs must identify and target their audience to ensure that communications are appropriate and easily understood. The information program should be driven by objectives, rather than techniques. Some objectives, such as developing a general awareness of the gypsy moth and its impact, may apply to all residents in an area. Other objectives such as the communication of detailed control options, will be aimed more specifically at managers responsible for public or private land.

The timing of communications is important. General information about the gypsy moth can be distributed years before defoliation actually occurs. Specific information about control operations, on the other hand, will not be made until just before the action is taken.

Four phases of a public information program can be distinquished with respect to their audience, objectives, methods and timing.

Interpretation

Interpretive programs attempt to raise general public awareness about the gypsy moth, its impact on the environment, and the potential control options available. This interpretive phase is extensive and aims for the broadest possible audience. Brief, factual information about the gypsy moth is communicated mainly by print and video media (Table 5.1).

Published information on the gypsy moth can be distributed by mail or in person. Interpretive programs in parks are ideal opportunities to inform recreationists. Pheromone trap monitoring systems (Chapter 3) in parks, for example, are excellent demonstration aids for informing the public about the gypsy moth. Information on the identification of gypsy moth egg masses and the dangers of inadvertent transport of these egg masses from infested to uninfested areas is a key aspect of quarantine programs (Chapter 4).

Table 5.1: Methods of communication.

Method	Commercial media[a]	Public meetings	Telephone	Conventional and electronic mail
Interpretive	• Informative articles (newspapers, magazines, cottage newsletters, etc.)	• Park interpretive programs • Trapping demonstrations	• General information supplied by informed agencies at all times • Public opinion polls	• Ongoing information available via bulletin boards • Targeted mass-mailings
Decision-making	• Interviews with experts	• Workshops (homeowners, woodlot owners) • Open houses	• Contacting those leaving areas infested by the gypsy moth • Informing specific groups about spray operations	• Distribution of any written information • Limited mailings
Notification	• News releases and public service announcements • Paid advertisements	• Seminars to inform interested parties of progress	• Informing specific groups about spray operations • Hotlines	• Mail to affected parties
Report	• Follow-up articles (newspapers, newsletters, etc.)	• Seminars for those interested in control results	• Contact those affected or involved in decision-making to discuss results, or arrange follow-up	• Distribution of written material regarding spray results, recommendations, etc.

[a] Special types of publications are listed in Table 5.2.

Experienced agencies advocate beginning the interpretive phase of the program as much as two years before a noticeable infestation is expected. This gives time to prepare the public for potential action and to raise the general level of understanding about the situation while there is still time for discussion and clarification. Not informing the public adequately until control action became urgent was a major criticism of many of the earlier gypsy moth eradication programs.

Decision-making

Decisions are needed whenever action against the gypsy moth is required. Decisions for active management, particularly control programs, need this more detailed public information phase.

This phase also uses print and video media but its information content can be expanded because the audience is more restricted and is directly affected by the management action. Public meetings during this phase are indispensible. Planners should decide on an agenda for these meetings, including the topics to be covered. Workshop formats permit input from public interest groups.

Having experts available at public meetings to answer questions is effective. Printed material can be handed out to reinforce the understanding of the participants. Specialized and detailed reports and videos are useful at this stage (Table 5.2).

Notification

Notification of the decisions reached is the next phase of the public information program. Once again, an open house or other public forum for the announcement allows planners to explain their decisions and to answer questions.

Decisions that require rapid notification (e.g., changes in control programs) use news releases to inform the public. Identifying a single spokesperson to the media is a good way of ensuring a clear and consistent interpretation of management decisions. Providing more than one contact may sometimes be desirable, as the media often seeks another perspective on the same story. In this case, it is important that a consistent overall message is communicated.

Telephone hotlines are an effective means of keeping a dialogue open and reassuring the public.

Reporting

Reports on the results of control programs must be made public as soon as possible. This enhances public awareness and increases the credibility of the management program. New publications may be prepared to explain the decision and the results, and to promote subsequent, ongoing management programs.

METHODS OF COMMUNICATION

Pest managers have many methods available to them to communicate information about their programs. The choice of a particular method or combination of methods will depend on the intended audience and the phase of the public information program (Table 5.1).

Existing communication media such as newspapers, magazines, radio and television, conventional and electronic mail, and the telephone should be used to their full advantage. The advice of an individual who understands the effective use of these commercial media is strongly recommended in public information programs. In addition to commercial media, supplementary publications and public meetings to communicate the specific details of the management program are desirable.

It is important to remember that communication is a two-way activity. Most of the methods discussed in this chapter can also be used to solicit public opinion on management options. Opinion polls and surveys are useful tools to ascertain the success of any particular approach to public information and of pest management in general.

ADDITIONAL REFERENCES

Additional references on public information programs for gypsy moth management are 43, 127 and 142.

Table 5.2: Examples of public education materials.

Material	Objective	Characteristics	References
Brochures/fact sheets	• Communicate specific facts about gypsy moth identification, life history and control to broad cross-sections of the public at minimum cost	• Text is brief, simple and factual • Question and answer format is effective • Often rely heavily on illustrations or photographs • Can be mass-distributed	2, 3, 29, 34, 111, 112, 113, 145
Educational material	• Encourage participation of educators in communicating information about the gypsy moth	• Can vary from activity books and board games for young children to exercises in monitoring populations for forestry students	7, 8, 81, 103
Information reports, handbooks, proceedings	• Communicate detailed information to citizen groups and homeowners with a high interest level • Explanation and promotion of a particular pest management objective	• May run to several pages of information and require high levels of reader interest • Technical information may be presented as graphs or tables • Often includes specific recommendations for control	10, 16, 37, 82, 96, 98, 100, 109
Audio-visual productions	• see Information reports etc.	• see Information reports etc. (above)	5, 33, 55, 56, 147

Chapter 6
INTEGRATED MANAGEMENT OF THE GYPSY MOTH

JURISDICTION

Wherever the gypsy moth has gone, it has raised questions over who should be responsible for its management. The first few chapters of *The Gypsy Moth* by Forbush and Fernald (54), which describe the original infestations in Massachusetts, reveal that this problem of jurisdiction was as prominant in the 19th century as it is today. An understanding of the roles of the various agencies involved (Table 6.2) is a prerequisite to the development of an effective gypsy moth management program.

In Canada, the federal government is responsible primarily for regulation, detection, eradication, and research in the context of insect pests. Research may be carried out in federal research laboratories or by funding research at universities. Provincial governments are responsible for the operational management of pests on Crown land. This includes setting policies for management and conducting control programs where appropriate. Pest infestations on private land are, in principle, the responsiblity of the landowner. Gypsy moth, however, does not distinquish among landowners, and infestations are usually the concern of a broad range of public and private groups. A high level of coordination among these groups is crucial.

Canada

In regions of Canada where the gypsy moth is not considered to be established, control action is authorized under the Plant Protection Act. This federal Act of Parliament is intended "to prevent the introduction or spreading of pests injurious to plants". The Act is administered by Agriculture Canada.

If a new, isolated infestation by the gypsy moth is found, Agriculture Canada can carry out control programs to eradicate or contain the pest. Agriculture Canada cooperates closely with federal and provincial forestry agencies to implement detection and control programs in each region.

At a certain point after a pest becomes established, quarantine and eradication are no longer realistic options. Responsibility for management of the pest is intended to pass from the level of national interest specified by the Plant Protection Act to a more local level of management; i.e., to provincial, municipal, or private landowners. A brief history of the gypsy moth in Ontario will clarify the different responsibilities.

Ontario

Gypsy moth egg masses were discovered near Kingston in 1969. Throughout the 1970s, surveys and localized spray programs were carried out by Agriculture Canada in the St. Lawrence region (Fig. 4.1). Despite these efforts, the infested area in Ontario continued to expand. The eradication spray program was eventually abandoned by Agriculture Canada, although monitoring throughout the area continued.

In 1981, Forestry Canada's Forest Insect and Disease Survey mapped 1,000 hectares of defoliation near Kaladar. The Ontario Ministry of Natural Resources (OMNR) recognized the potential for an even larger area of infestation and planned an aerial spray program for 1982. Public opposition, however, effectively led to cancellation of the 1982 spray program. No spray programs were undertaken by the OMNR in either 1983 or 1984. Over this period, the area of moderate-to-severe defoliation by the gypsy moth in Ontario increased from just over 1,000 hectares in 1981 to nearly 250,000 hectares in 1984 (Fig. 6.1).

In 1985, a limited spray program was carried out in infested provincial parks. By this time public opinion had changed and there was considerable public support for a suppression program. The OMNR expanded its spray program in 1986 to cover approximately 100,000 hectares of Crown and private land. The 1986 decision to include private land in the OMNR's spray program led directly to the Private Land Spray Program of 1988. This three-year agreement clearly defined the roles of OMNR and various landowners. A procedure to plan and implement the spray program was developed through consultation. Only *Bt* was used in these spray programs (Fig. 4.1).

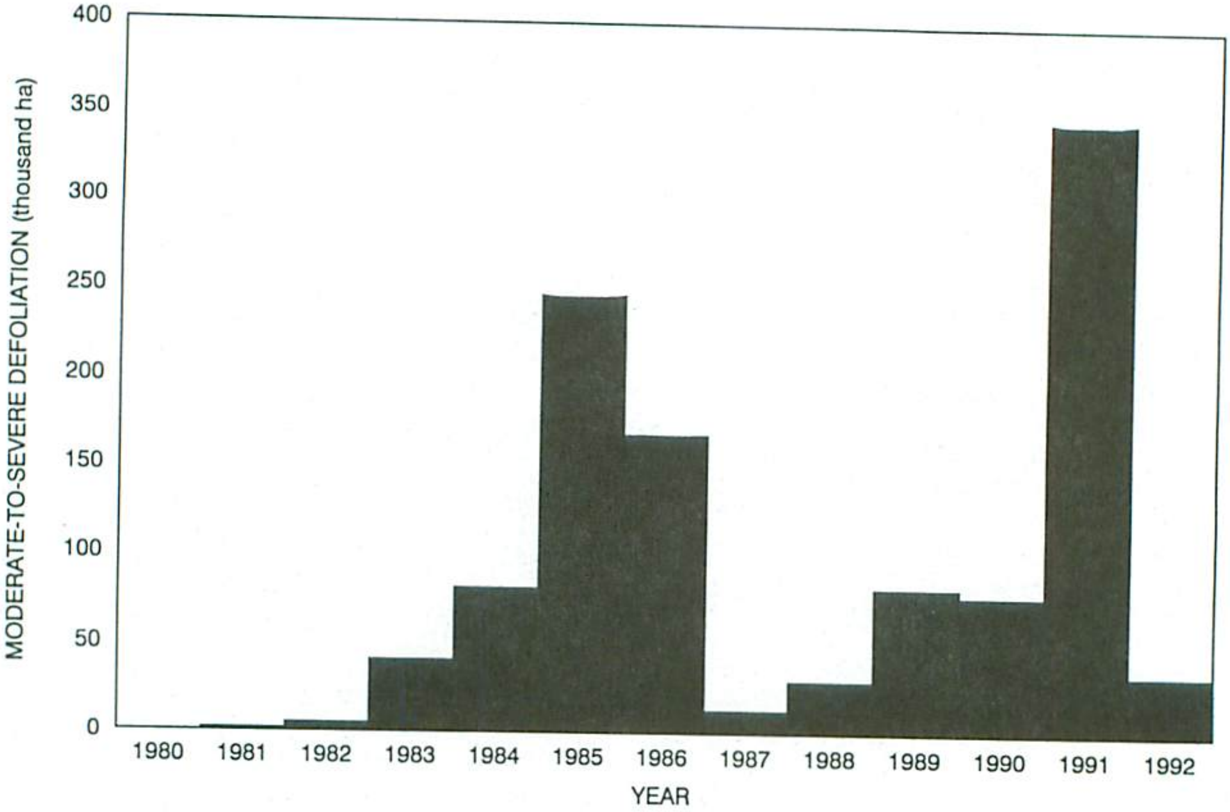

Figure 6.1: Moderate-to-severe defoliation by the gypsy moth in Ontario.

As the area of gypsy moth infestation in Ontario increased, it became more costly and difficult to continue to subsidize the ever-increasing amount of private land sprayed. In 1992, all provincial forest spray programs were cancelled and the Private Land Spray Program for gypsy moth was not renewed.

As of 1993, it appears that management of the gypsy moth on private and municipal land in Ontario will be the direct responsibility of municipalities and landowners, with advice provided by federal and provincial agencies (Table 6.2).

In 25 years, the gypsy moth in Ontario has gone from a pest for which the federal government conducted eradication programs to one for which there is increased reliance on local communities of landowners for management.

United States

The administrative structure for pest management in the United States has some similarity to that already described for Canada in that the American federal government maintains responsibility for regulation, quarantine and research. In the United States, APHIS (the Animal and Plant Health Inspection Service), a branch of the United States Department of Agriculture (USDA), is the agency responsible for regulation, quarantine and eradication. Other federal agencies, including the Agricultural Research Service, are responsible for research.

Control programs within the established range of the gypsy moth in the United States are largely the responsibility of the affected owners. These owners may be the federal government (e.g., the USDA Forest Service), in the case of national parks and forests, or state, county and private landowners. Often research and control of the gypsy moth in the United States are co-operative ventures among several levels of government and with extension services at state universities (e.g., 149, 150).

A brief chronology of programs in the United States to 1978 can be found in *The Gypsy Moth: Research Toward Integrated Pest Management* (44). A review of current (to 1995) research and development programs sponsored by the USDA Forest Service is available in *Gypsy Moth News* (95).

The results of research sponsored by the USDA are presented at an annual meeting (the USDA

Interagency Gypsy Moth Research Review) and the proceedings are published in the General Technical Report series of the Northeastern Forest Experimental Station (e.g., 63).

One of the largest recent (1987–1992) collaborative programs was the Appalachian Integrated Pest Management Demonstration Project (AIPM). This initiative was intended to minimize the further spread and impact of gypsy moth within the Appalachian Region and to evaluate control methods for isolated infestations.

Unlike most suppression programs undertaken to mitigate ongoing damage, the AIPM objectives included pre-emptive action against increasing populations of the gypsy moth. The AIPM project was also explicitly directed to develop a working integrated pest management program structure that included co-ordination of federal, state and county participants (9).

INTEGRATED PEST MANAGEMENT

Since the 1960s, pest managers have attempted to replace their previous reliance on insecticides with the concept of *integrated pest management* (IPM). Simply put, integrated pest management is an approach that recognizes that pest problems are ecological problems and require ecological solutions. The management approach implied by integrated pest management is that many different control tactics, including the absence of any control action, should be considered. Decisions are made in the context of local socioeconomic objectives and values.

It is important to recognize that insecticides may still be used in an integrated pest management program. However, the choice of insecticide and the rate, timing and area of application will be made with reference to the broader concerns of environmental management rather than with the single objective of killing the pest.

A consequence of the integrated pest management approach is that more specific and diverse sources of information must be incorporated into the decision-making process. In fact, it is likely that significant improvements in the effectiveness of an integrated pest management program will come more from increasing the number of components in the program than by increasing the detail or precision of any one component. With large-scale management programs, the decision-making can be quite complex (Fig. 6.2).

Recent advances in computer technology for processing and displaying information and for incorporating expert knowledge are used increasingly in making decisions in pest management. These *decision-support systems* vary from simple programs that match current gypsy moth population levels with forest inventory and site information or the use of weather data to predict seasonal development of the gypsy moth, to more complex applications that utilize extensive database management, simulation models and optimal resource allocations.

Coordination

Integrated pest management programs require more than the recognition of multiple objectives and the use of alternative control techniques. They also demand strong coordination among all interested parties. The distinct roles identified for different agencies means that an explicit effort must be made to ensure that information and resources gained at one level are available and utilized effectively at other levels in the management program. Published bulletins and newsletters are one means of achieving this coordination (Table 6.1).

A national survey of gypsy moth management programs in the United States (120) found that the ties between, for example, research and implementation, were weak. Research information was often not used

Table 6.1: Newsletters for the exchange of information on the gypsy moth.

Newsletter	Organisation[a]
FIDS Survey Bulletin	Forestry Canada: • Forest Pest Management Institute • Maritimes Region • Newfoundland and Labrador Region • Northwest Region • Ontario Region • Pacific and Yukon Region • Quebec Region
Gypsy Moth News	USDA Northeastern Area State and Private Forestry
Gypsy Moth Update	Virginia Department of Agriculture and Consumer Service Office of Plant Protection
National Gypsy Moth Management Group	National Gypsy Moth Management Group Inc.
Gypsy Moth Exotica	USDA Forest Service, Northeastern Forest Experiment Station

[a] Addesses for these organisations can be found in Appendix 1.

in control decisions and operational survey data were not used by researchers. This survey identified the need for strong leadership and coordination at all levels of gypsy moth management. It recommended the formation of functional working groups with representatives from both research and implementation organizations. These groups would develop regional management strategies that included standardized sampling methods and comparative databases. Working groups would also identify a range of appropriate control actions (e.g., 157).

In Canada, this working group structure has been used to some extent. In the Maritimes, for example, the Gypsy Moth Coordinating Committee comprises research and survey personnel from Forestry Canada, Agriculture Canada, the provincial ministries of

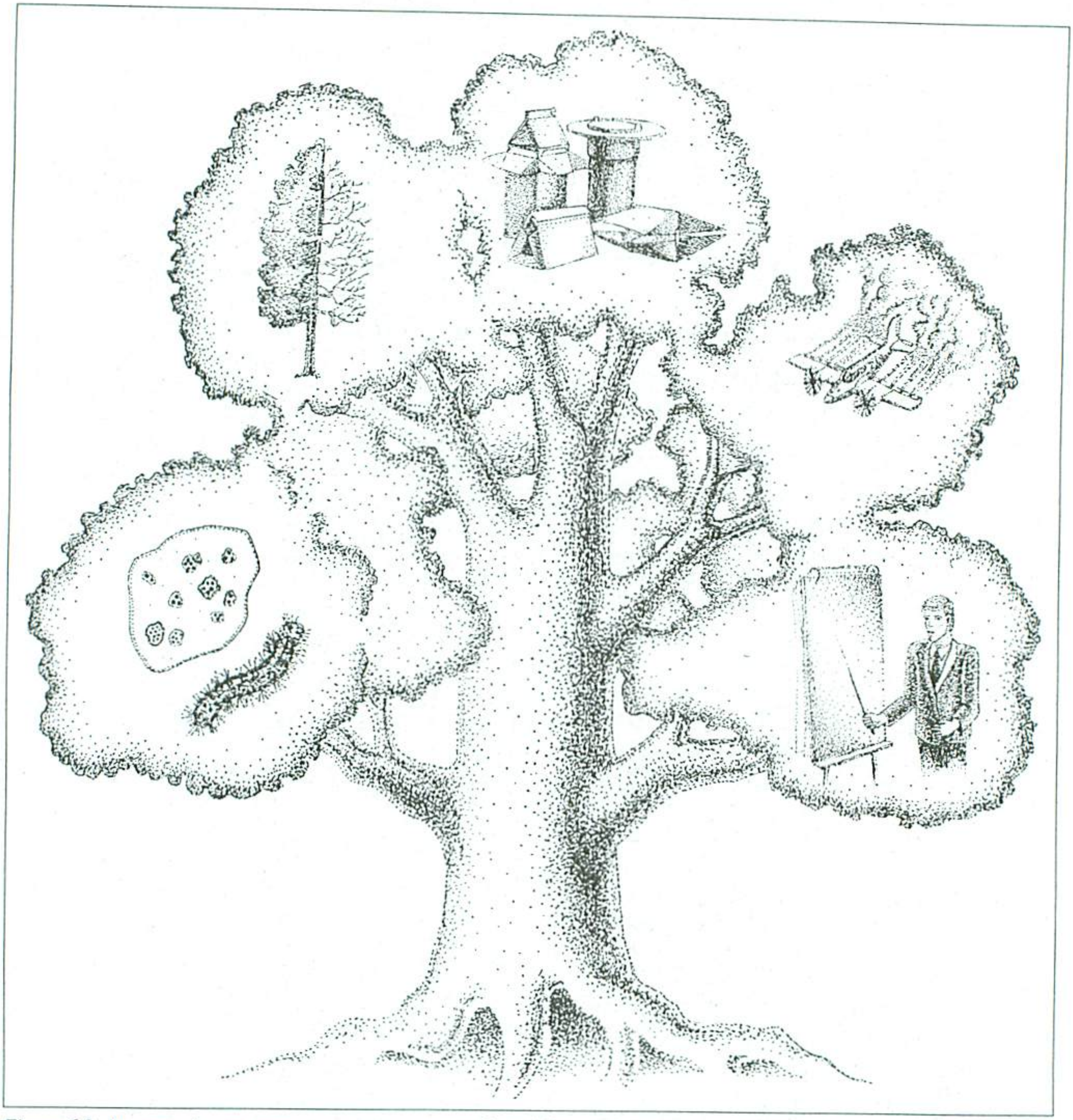

Figure 6.2: Integrated pest management programs use knowledge of the pest's biology, consider its potential and actual impacts, monitor the pest, assess control options and communicate plans and results.

Natural Resources and Agriculture, and affected municipalities. In other provinces, strategies for management of the gypsy moth may be developed on an *ad hoc* basis by subcommittees of larger advisory councils. In Ontario, this is the Ontario Region Plant Pest Advisory Council. In British Columbia, the Plant Protection Advisory Council has been active in coordinating the gypsy moth eradication programs in that province.

These Canadian groups have been mostly concerned with the coordination of specific and short-term control operations, in particular, detection and eradication of gypsy moth populations from their respective regions. There has been very little coordination at any level for more comprehensive and long-term management of the gypsy moth. The reasons for this are many and varied. They include conflicting or non-overlapping jurisdictions, limited budgets, and difficulty in reaching a consensus on the severity of the problem and what would constitute reasonable and effective action.

CONCLUSIONS

In the preface to this sourcebook, we state that solutions for management of the gypsy moth are not simple. We believe, however, that the starting point for management is at the community level. Communities are best able to identify their own resource management priorities and to address the concerns of local groups who may demand or oppose control action. It is also at the community level that the strongest support can be gained for continuing research to provide the specific knowledge and tools necessary for the development of a management strategy. Application of this knowledge in the community will provide the necessary link between research and implementation.

This publication is intended to expose individuals and community groups interested in gypsy moth management to this knowledge. No matter how simple or complex the local gypsy moth situation, effective management of this pest will rely on integrating the information from the basic subject areas summarized in this sourcebook: biology and ecology, impact, monitoring, control and public involvement. Other sources of information are listed in Table 6.2.

ADDITIONAL REFERENCES

Additional references for various aspects of gypsy moth management are 6, 15, 17, 18, 22, 33, 40, 42, 44, 46, 51, 53, 58, 91, 104, 109, 115, 122, 124, 133, 146 and 156.

Table 6.2: Sources of additional information. (Addresses are listed in Appendix 1.)

Agency	Responsibilities with respect to gypsy moth
Canada	
Agriculture Canada Sir John Carling Building (library)	• Quarantine, pesticide use in Canada • Library services
Ontario	
Forestry Canada, Forest Pest Management Institute	• Research on pest control products
Forestry Canada, Ontario Region Great Lakes Forestry Centre	• Research • Forest Insect and Disease Survey
Forestry Canada Petawawa National Forestry Institute	• National database on forest insects
Ontario Ministry of Natural Resources, Provincial Entomologist	• Pest control policy, advice • Spray programs
Ontario Ministry of the Environment	• Information regarding pesticide use in Ontario • Commercial spray licensing

(cont'd)

Table 6.2: Sources of additional information (concl.). (Addresses are listed in Appendix 1.)

Agency	Responsibilities with respect to gypsy moth
Québec	
Forestry Canada, Québec Region Laurentian Forestry Centre	• Research • Forest Insect and Disease Survey
Ministère des Fôrets	• Forest Pest Survey
SOPFIM, Societé de protection des forêts contre les insectes et les maladies	• Spray program operations
Maritimes	
Forestry Canada, Maritimes Region	• Research • Forest Insect and Disease Survey
New Brunswick Department of Natural Resources	• Pest control policy, spray programs
Nova Scotia Department of Lands and Forests	• Pest control policy, spray programs
Prince Edward Island Department of Energy and Forestry	• Pest control policy, spray programs
Forestry Canada, Newfoundland and Labrador Region, Newfoundland Forestry Centre	• Research • Forest Insect and Disease Survey
Newfoundland Department of Forestry and Agriculture	• Pest control policy, spray programs
British Columbia	
Forestry Canada, Pacific and Yukon Region Pacific Forestry Centre	• Research • Forest Insect and Disease Survey
British Columbia Ministry of Forests	• Pest control policy, spray programs
Alberta	
Forestry Canada, Northwest Region Northern Forestry Centre	• Research • Forest Insect and Disease Survey
Alberta Forest Service	• Operational management of forests
Saskatchewan	
Saskatchewan Parks and Renewable Resources	• Operational management of forests
Manitoba	
Manitoba Department of Natural Resources	• Operational management of forests
United States	
United States Department of Agriculture Forest Service	• Research and management of federal lands
United States Department of Agriculture Extension Service	• Communication, education, natural resource programs (in cooperation with the Forest Service)
Northeastern Area State and Private Forestry (field office of Forest Service)	• Forest pest management, cooperative forestry, forest health protection
United States Department of Agriculture Northeastern Forest Experiment Station	• Research and experimentation, forest monitoring • Administers programs such as the Appalachian Integrated Pest Management project

Note: Most state departments of agriculture (plant protection or regulatory division) are listed in the state government sections of the telephone directory. Federal government sections provide numbers for APHIS and USDA extension services (county extension agents).

REFERENCES

The number of articles written about the gypsy moth is staggering. The references in this sourcebook have been selected for content and availability. The annotations should assist in deciding to track down the original source. References in the list are in alphabetical order (by author) and are numbered for reference to the text.

The availability of scientific publications is generally good. The libraries of universities with an applied science department or of government research laboratories (e.g., Forestry Canada, Agriculture Canada) should have most. If not, interlibrary loans can be arranged. The John Carling Library at the Central Experimental Farm in Ottawa has all of these periodicals.

Government publications and magazine articles sometimes can be obtained through a library, but some articles, particularly ones published by American state government agencies, may require writing directly to the author or agency. Be prepared to send postage.

1. Abrahamson, L.P. 1987. Five-minute walk method of sampling gypsy moth egg mass densities. Gypsy Moth News, July 1987, 14: 4-6.

   Describes the timed-walk method of estimating gypsy moth egg-mass density.

2. Agriculture Canada. 1987. Gypsy moth. A destructive pest of forest and shade trees. Agriculture Canada, Ottawa, Ontario. Publication 1811/B. 1 p. (ISBN 0–662–54562–1)

   Brochure describing the life cycle of the gypsy moth, with photographs. (English and French)

3. Agriculture Canada. 1991. European gypsy moth. Agriculture Canada Pesticides Directorate, Ottawa, Ontario. Pest Note 91–8. 4 p.

   Pest note handout briefly describing gypsy moth life cycle, damage, and control.

4. Andreadis, T.G. and Weseloh, R.M. 1990. Discovery of *Entomophaga maimaiga* in North American gypsy moth, *Lymantria dispar*. Proceedings of the National Academy of Science, USA. 87: 2461–2465.

   Description of a pathogenic fungus released more than 75 years ago and only recently becoming important.

5. Anne Arundel County Department of Public Works. Gypsy moth in Anne Arundel county. 1990. Anne Arundel County Department of Public Works. Annapolis, Maryland. (Video, 12 minutes)

   A detailed presentation of a county spray program to combat the gypsy moth. An explanation of life history and impact is followed by a discussion of aerial spraying techniques and post-spray surveys. Good images of various life stages.

6. Anonymous. 1992. Asian gypsy moth in the Pacific Northwest Region. Gypsy Moth News, July 1992, 29: 8–9.

   Discusses the development of cooperative federal/provincial/state committees in the United States and Canada to attempt to combat the Asian gypsy moth invasion. Presents a summary of 1992 control efforts, and post-spray evaluation techniques.

7. Appalachian Integrated Pest Management. (year unknown) AIPM gypsy moth field exercise. Burlap banding of trees for gypsy moth caterpillars. USDA Forest Service, Appalachian Integrated Pest Management, Morgantown, West Virginia. 1 p.

   Outline for an educational exercise relating to gypsy moth management.

8. Appalachian Integrated Pest Management. (year unknown) AIPM gypsy moth field exercise. Tree identification. USDA Forest Service, Appalachian Integrated Pest Management, Morgantown, West Virginia. 1 p.

   Outline for an educational exercise relating to gypsy moth management.

9. Appalachian Integrated Pest Management (AIPM). 1989. Gypsy moth demonstration project. Final Environmental Impact Statement. USDA Forest Service, Southern Region, Atlanta, Georgia. Management Bulletin R8–MB 33. 404 p. including appendices.

   Voluminous documentation of an environmental analysis of several alternative management strategies for gypsy moth, including no action.

10. Ascerno, M.E., Carroll, M. and Hayes, E. 1984. Gypsy moth in Minnesota: the early years. Agricultural Extension Service, University of Minnesota, Department of Entomology, St. Paul, Minnesota. AG–FO–2363. 7 p.

    A very good example of an information brochure that provides factual and detailed public information before infestations of the gypsy moth became widespread.

11. Beegle, C.C. and Yamamoto, T. 1991. History of *Bacillus thuringiensis* Berliner research and development. The Canadian Entomologist 124: 587–616.

    History of the discovery of Bt's insecticidal properties.

12. Bellinger, R.G., Ravlin, F.W. and McManus, M.L. 1989. Forest edge effects and their influence on gypsy moth (Lepidoptera: Lymantriidae) egg mass distribution. Environmental Entomology 18: 840–843.

    Trees at the edge of the stand had more egg masses than trees in the center of the stand. Egg-mass samples taken from edge trees will overestimate true density.

13. Bellinger, R.G., Ravlin, F.W. and McManus, M.L 1990. Predicting egg mass density and fecundity in field populations of the gypsy moth (Lepidoptera: Lymantriidae) using wing length of male moths. Environmental Entomology 19: 1024–1028.

Establishes a relationship between wing length of male moths caught in pheromone traps and the number and size of egg masses in the next generation.

14. Benoit, P. and Lachance, D. 1990. Gypsy moth in Canada: behavior and control. Forestry Canada, Corporate and Public Affairs, Ottawa, Ontario, Information Report DPC–X–32. 21 p.

Reviews gypsy moth biology and control in Canada. Includes photographs of pheromone traps and burlap bands used to trap gypsy moths. (Also available in French as "La spongieuse au Canada: Mœurs et répression.")

15. Bolgiano, C. 1989. Taking AIPM at the gypsy moth. American Forests 95 (March–April): 37–41.

Summarizes the principle objectives of the Appalachian Integrated Pest Management demonstration project.

16. British Columbia Ministry of Forests. 1981. Public Involvement Handbook. British Columbia Ministry of Forests, Victoria, B.C. 134 pages + maps. (ISBN 0–7719–8788–9)

Guidelines for carrying out a public information program for general forestry-related activities. Contains an example of an actual public meeting.

17. British Columbia Plant Protection Advisory Council. 1985. Understanding the gypsy moth threat. The proceedings of an information symposium, 5 November 1985, Robson Media Centre, Vancouver, B.C., sponsored by British Columbia Plant Protection Advisory Council.

Proceedings of an information session held to develop a policy and procedure for dealing with introductions of the gypsy moth to British Columbia.

18. Brown, G.S. 1975. Gypsy moth. pages 208–212 *in* M.L. Prebble (editor). Aerial Control of Forest Insects in Canada. Department of the Environment, Ottawa, Ontario.

Brief review of early introductions, and control attempts, of gypsy moth in Canada.

19. Brown, J.H. Jr., Halliwell, D.B. and Gould, W.P. 1979. Gypsy moth defoliation: impact in Rhode Island forests. Journal of Forestry 77(1): 30–32.

Evaluated the impact of a 3-year infestation of gypsy moth in oak and mixed-oak stands. Mortality was greatest to oak in the mixed stands.

20. Burgess, A.F. and Crossman, S.S. 1929. Imported insect enemies of the gypsy moth and the brown-tail moth. United States Department of Agriculture, Washington, D.C. Technical Bulletin 86. 147 p.

Detailed description of the classical biological control program in the earliest, but most active, stage of research and implementation. Excellent figures and descriptions of the biology of the natural enemies.

21. Butler, L. 1992. Non-target impact of Dimilin and *Bacillus thuringiensis*. Gypsy Moth News, February 1992, 28: 4–5.

Describes some of the non-target species directly affected by Bt and Dimilin, as well as the indirect effects on forest food webs. Briefly discusses two ongoing studies in Virginia that are attempting to expand knowledge of non-target effects.

22. Cameron, E.A. 1991. The gypsy moth: how integrated is pest management? Forest Ecology and Management 39: 113–118.

**A critique of the Appalachian Integrated Pest Management (AIPM) project.*

23. Campbell, N. 1990. Building a public relations program. Gypsy Moth News, July 1990, 23: 3–4.

This article provides solid advice, based on experience, on a public information program for gypsy moth.

24. Campbell, R.W. 1973. Forecasting gypsy moth egg-mass density. USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania, Research Paper NE–268. 17 p.

A comprehensive, early attempt to provide equations that would relate egg-mass density to weather variables and stand characteristics. The specific results are of limited use but the approach and discussion are informative.

25. Campbell, R.W. 1976. Comparative analysis of numerically stable and violently fluctuating gypsy moth populations. Environmental Entomology 5: 1218–1224.

Survival of larval stages is most important determinant of population trends. Dispersal of early-stage larvae helps to initiate and maintain local outbreaks. Predation of later stages can help maintain innocuous population levels.

26. Campbell, R.W. 1979. Gypsy moth: forest influence. USDA Forest Service, Washington D.C., Agricultural Information Bulletin 423. 44 p.

One of the few studies that examines long-term impacts of gypsy moth. Clear text, useful illustrations.

27. Campbell, R.W., Miller, M.G., Duda, E.J., Biazak, C.E. and Sloan, R.J. 1976. Man's activities and subsequent gypsy moth egg-mass density along the forest edge. Environmental Entomology 5: 273–276.

At low densities, gypsy moth egg masses were found most frequently along the forest edge and particularly on man-made objects. Increases in gypsy moth populations may occur most often in areas disturbed and occupied by people.

28. Campbell, R.W. and R.J. Sloan. 1976. Influence of behavioral evolution on gypsy moth pupal survival in sparse populations. Environmental Entomology 5: 1211–1217.

Native North American predators such as the white-footed mouse had a major impact on sparse populations of gypsy moths. Management implications are discussed.

29. Canadian Forestry Service. 1983. The gypsy moth. A potential threat to the Maritimes. Forestry Canada, Maritimes Region, Fredericton, New Brunswick. 1 p.
Public information brochure to aid in identification of the gypsy moth.

30. Canadian Pulp and Paper Association and Forest Pest Management Institute. 1992. Insecticides registered for forest and woodlands management. Forest Pest Management Institute, Sault Ste. Marie, Ontario. Technical Reference (unnumbered). 6 p.
A very useful summary of insecticides used in forestry. Includes Pest Control Product Number, trade names, manufacturers and their addresses. (Aussi disponsible en francais.)

31. Carter, M.R., Ravlin, F.W. and McManus, M.L. 1992. Effect of defoliation on gypsy moth phenology and capture of male moths in pheromone-baited traps. Environmental Entomology 21: 1308–1318.
The number of male moths caught in pheromone traps placed in new infestations did not reflect the level of defoliation in the stand.

32. Cooper Mill Ltd. (year unknown) Pheromones explained. Cooper Mill Ltd., Agricultural Division, Madoc, Ontario. 7 p.
Clear explanation of pheromones and their use as tools for detection, monitoring, and controlling insect pest populations.

33. Cooperative Extension Service, Michigan State University. 1990. Living with the gypsy moth in Michigan. Michigan State University, East Lansing, Michigan. (Video, 23 minutes)
A good review of the gypsy moth presence in Michigan with professionals discussing the life cycle, ecology, natural control factors and homeowner control strategies. Also presents comments from concerned citizens. Emphasizes the concept of minimizing the impact of a forest insect that is new to Michigan.

34. Cooperative Extension Service, Michigan State University. 1991. A comparison of the gypsy moth, eastern tent, and forest tent caterpillars. Michigan State University, East Lansing, Michigan. Extension Bulletin E–2299. 1 p.
A pictorial guide to distinquish the gypsy moth from other common forest caterpillars.

35. Cooperative Extension Service, Michigan State University. 1991. Barrier bands to suppress the gypsy moth. Michigan State University, East Lansing, Michigan. Extension Bulletin E–2301. 1 p.
Leaflet showing preferred method of using sticky barriers on trees.

36. Cooperative Extension Service, Michigan State University. 1991. Cloth banding trees to suppress the gypsy moth. Michigan state University, East Lansing, Michigan. Extension Bulletin E–2300. 1 p.
Preferred method of banding trees to trap gypsy moth caterpillars.

37. Cooperative Extension Service, Michigan State University. 1991. Gypsy moth in Michigan homeowner's guide. Michigan State University, East Lansing, Michigan. Extension Bulletin E–2302. 8 p.
Good example of homeowner information on gypsy moth control in newspaper format.

38. Coulson, J.R., Fuester, R.W., Schaefer, P.W., Ertle, L.R., Kelleher, J.S. and Rhoads, L.D. 1986. Exploration for and importation of natural enemies of the gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae), in North America: an update. Proceedings of the Entomological Society of Washington 88: 461–475.
A useful update on the classical biological control programs in North America since 1960.

39. Coulson, R.N. and Saunders, M.C. 1987. Computer-assisted decision-making as applied to entomology. Annual Review of Entomology 32: 415–437.
Reviews the application of computer technology and expert systems to insect pest management problems.

40. Cram, W.A. 1990. Gaining support for British Columbia's gypsy moth wars 1978–1988. A case study in public relations. British Columbia Ministry of Forests, Victoria, B.C. Pest Management Report Number 12. 26 p. (ISSN 0710–7935).
Discussion of the history and public process of gypsy moth eradication programs in British Columbia.

41. Cunningham, J.C., Kaupp, W.J. and Howse, G.M. 1991. Development of nuclear polyhedrosis virus for control of gypsy moth (Lepidoptera: Lymantriidae) in Ontario. I. Aerial spray trials in 1988. The Canadian Entomologist 123: 601–609.
Results of double application of a formulation of gypsy moth virus in Ontario. Significant reduction of defoliation in the area treated and evidence that overall population levels of gypsy moth were reduced in treated plots.

42. Czerwinski, C. and Isman, M.B. 1986. Urban pest management: decision-making and social conflict in the control of gypsy moth in west-coast cities. Bulletin of the Entomological Society of America 32 (Spring): 36–41.
Review of social conflict in early eradication programs for gypsy moth in Vancouver, Seattle and Santa Barbara. The authors conclude that there was insufficient recognition of the importance of public discourse. They make recommendations for future programs.

43. Dahlsten, D.L. and S.H. Dreistadt. 1991. Forest pest management sociopolitics. Forest Ecology and Management 39: 289–297.

Discussion of the importance of social and political influences on pest management programs. Recognizes that forest pest managers are often not familiar with communication methods or the necessity of addressing these issues.

44. Doane, C.C. and McManus, M.L. (editors). 1981. The gypsy moth: research toward integrated pest management. USDA Forest Service, Science and Education Agency, Washington, D.C. Technical Bulletin 1584. 757 p.

An extensive review of information up to 1978 on gypsy moth bioecology, population dynamics, detection and evaluation, impact, and several types of control alternatives. Discusses the history of research in the United States and further outlines research and development needs to improve methods of coping with the pest.

45. Dreistadt, S.H. 1983. An assessment of gypsy moth eradication attempts in Michigan (Lepidoptera: Lymantriidae). The Great Lakes Entomologist 16: 143–148.

Argues that the gypsy moth has been established in Michigan for several years but that environmental factors limit outbreaks. Control efforts should focus on suppressing outbreaks rather than eradication.

46. Dreistadt, S.H. and Dahlsten, D.L. 1989. Gypsy moth eradication in Pacific coast states: History and evaluation. Bulletin of the Entomological Society of America 35: 13–19.

Reviews eradication programs on the Pacific coast including descriptions of control methods, success, and public issues.

47. Eiber, T. 1991. Enhancement of gypsy moth management, detection, and delay strategies. Gypsy Moth News, June 1991, 26: 2.

Specific recommendations on how to make the public aware of the dangers of inadvertently transporting gypsy moth into an area.

48. Elkinton, J.S. 1982. The biology and management of the gypsy moth in Massachusetts. Massachusetts Agricultural Experiment Station, University of Massachusetts at Amherst. Bulletin Number 677. 16 p.

Reviews gypsy moth biology, history, impact, and control.

49. Elkinton, J.S. and Childs, R.D. 1983. Efficiency of two gypsy moth (Lepidoptera: Lymantriidae) pheromone-baited traps. Environmental Entomology 12: 1519–1525.

Low-volume sticky pheromone trap designs were more efficient at catching male moths than milk carton traps. Sticky traps, however, become saturated and the size of the catches become less meaningful at moderate population levels of the gypsy moth.

50. Elkinton, J.S. and Liebhold, A.M. 1990. Population dynamics of gypsy moth in North America. Annual Review of Entomology 35: 571–596.

Comprehensive review of gypsy moth population biology. Many references.

51. Fleischer, S., Carter, J., Reardon, R. and Ravlin, F.W. 1992. Sequential sampling plans for estimating gypsy moth egg mass density. Appalachian Integrated Pest Management, USDA Forest Service, Northeastern Area, Morgantown, West Virginia. 14 p.

Reviews and compares egg-mass sampling techniques. Explains sequential sampling methods and provides decision charts for forested and urban landscapes.

52. Fleischer, S.J., Ravlin, F.W. and Reardon, R.C. 1991. Implementation of sequential sampling plans for gypsy moth (Lepidoptera: Lymantriidae) egg masses in eastern hardwood forests. Journal of Economic Entomology 84: 1100–1107.

Compared timed-walk and fixed-area plot methods of estimating egg-mass density. Concluded that the timed-walk method is less consistent. Demonstrated that sequential sample plans can save time with an acceptable loss of precision.

53. Fleischer, S., Roberts, A., Young, J., Mahoney, P., Ravlin, F.W. and Reardon, R. 1992. Development of geographic information system technology for gypsy moth management within a county: an overview. USDA Forest Service, Northeastern Area, Morgantown, West Virginia. Report NA–TP–01–93. 24 p.

Summarizes the use of geographic information systems for development of maps containing data on gypsy moth populations, forest inventories, and suppression activities.

54. Forbush, E.H. and Fernald, C.H. 1896. The gypsy moth. Wright and Potter Printing Co., State Printers, Boston, Massachusetts. 495 p. + appendices.

Original report on the first attempts to contain and eradicate the gypsy moth in Massachusetts. This book has high historical value. It also contains much insight into the problem of management that is still relevant.

55. Forest Pest Management Institute. 1993. Virus: A natural choice for gypsy moth control. Forest Pest Management Institute, Sault Ste. Marie, Ontario. (slide presentation)

A 48-slide presentation of the gypsy moth life cycle, ecology, impact on forests, and control with nuclear polyhedrosis virus. Information on viral replication, rearing gypsy moth for virus production, aircraft spraying and post-spray surveys is also provided. A script accompanies the slide show.

56. Forestry Canada. 1993. Virus: a natural choice for gypsy moth control. Forestry Canada, Forest Pest Management Institute, Sault Ste. Marie, Ontario. (Video)

A discussion of gypsy moth life history, impact, and homeowner controls is presented in a question/answer *format. A map of the spread of infestation in Ontario is provided, as well as a detailed discussion of formulating and testing the nuclear polyhedrosis virus as a specific control alternative. (Aussi disponsible en francais.)*

57. Frey, T. The ingredients of a successful gypsy moth public involvement program. Gypsy Moth News, July 1990, 23: 6–9.

    This article provides a good discussion of what a successful gypsy moth management program should accomplish, and how it is defined.

58. Fuxa, J.R. 1987. Ecological considerations for the use of entomopathogens in IPM. Annual Review of Entomology 32: 225–251.

    A thorough review, with references, of the general issues surrounding the use of pathogens in insect control.

59. Gage, S.H., Wirth, T.M. and Simmons, G.A. 1990. Predicting regional gypsy moth (Lymantriidae) population trends in an expanding population using pheromone trap catch and spatial analysis. Environmental Entomology 19: 370–377.

    The authors combined data on pheromone trap catches with records of defoliation using a geographic information system to predict areas of high, medium, or low risk of future defoliation.

60. Gansner, D.A., Herrick, O.W. and Ticehurst, M. 1985. A method for predicting gypsy moth defoliation from egg mass counts. Northern Journal of Applied Forestry 2: 78–79.

    Provides an empirical equation that explains 60% of the defoliation on the basis of egg-mass density estimates.

61. Gill, S.S., Cowles, E.A., Pietrantonio, P.M. 1992. The mode of action of *Bacillus thuringiensis* endotoxins. Annual Review of Entomology 37: 615–636.

    Technical review of the toxicity of Bt to insects.

62. Gottschalk, K.W. 1991. Gypsy moth: silvicultural options. Gypsy Moth News, June 1991, 26:7.

    Silvicultural methods for management of the gypsy moth.

63. Gottschalk, K.W. and Twery, M.J. (editors). 1992. Proceedings, U.S. Department of Agriculture Interagency Gypsy Moth Research Forum 1992. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. General Technical Report NE–170. 60 p.

    Reports from the third annual research forum describing results of research funded by the USDA Forest Service.

64. Grace, J.R. 1986. The influence of gypsy moth on the composition and nutrient content of litter fall in a Pennsylvania oak forest. Forest Science 32: 855–870.

    Detailed study of short-term changes to characteristics of the litter layer in a forest defoliated by the gypsy moth. Argues that changes in nutrients following defoliation should be viewed as a further stress.

65. Grant, G.G. 1991. Development and use of pheromones for monitoring lepidopteran forest defoliators in North America. Forest Ecology and Management 9: 153–162.

    Discusses the use of pheromones in monitoring programs for several forest pests.

66. Griffiths, K.J. 1976. The parasites and predators of the gypsy moth: a review of the world literature with special application to Canada. Canadian Forestry Service, Sault Ste. Marie, Ontario. Report 0–X–243. 92 p.

    Extensive and annotated bibliography to 1976.

67. Griffiths, K.J. 1980. A bibliography of gypsy moth literature: vol–I and vol–II. Canadian Forestry Service, Sault Ste. Marie, Ontario. Report O–X–312. 350 p.

    Comprehensive bibliography of the world literature on the gypsy moth. Contains 4,140 citations, with excellent coverage of European literature.

68. Griffiths, K.J. and Quednau, F.W. 1984. *Lymantria dispar* (L.), gypsy moth (Lepidoptera: Lymantriidae). pages 303–310 *in* J.S. Kelleher and M.A. Hulme (editors) Biological Control Programmes Against Insects and Weeds in Canada 1969–1980. Commonwealth Agricultural Bureau, Farnham Royal, U.K. (Also available from Research Branch, Agriculture Canada, Ottawa, Ontario.)

    Reviews biological control of the gypsy moth in Canada up to 1980.

69. Gross, H.L., Roden, D.B., Churcher, J.J., Howse, G.M. and Gertridge, D. 1992. Pest-caused depletions to the forest resource of Ontario, 1982–1987. Forestry Canada, Ontario Region, Sault Ste. Marie, Ontario, Joint Report 17. 23 p.

    Estimates losses attributed to gypsy moth in Ontario, by year and by region affected.

70. Gypsy Moth Management Committee. 1991. Gypsy moth in Ontario. Facts about protecting property against gypsy moth infestations. Ontario Ministry of Natural Resources. 16 p. (ISBN 0–7729–8656–8)

    One of the best general information brochures on gypsy moth biology, impact, and control for homeowners. Especially good sections on Bt and carbaryl. (Aussi disponsible en francais.)

71. Hajek, A.E. and Snyder, A.L. 1992. Natural enemies: Tools for integrated pest management. USDA Forest Service, Northeastern Area, Durham, New Hampshire. Report NA–PR–02–92.

    Photographs of whole-insect symptoms, and microscopic characteristics of gypsy moth pathogens.

72. Hajek, A.E. and Soper, R.S. 1992. Temporal dynamics of *Entomophaga maimaiga* after death of gypsy moth (Lepidoptera: Lymantriidae) larval hosts. Environmental Entomology 21: 129–135.

Describes specific conditions governing the release of the infective stages of this gypsy moth pathogen. Suggests that the disease may persist in populations for more than one year.

73. Helson, B. 1992. Naturally derived insecticides: prospects for forestry use. The Forestry Chronicle 68: 349–354.

Reviews research on plant-derived insecticides and their potential use in forestry.

74. Herrick, O.W. and Gansner, D.A. 1987. Mortality risks for forest trees threatened with gypsy moth infestation. USDA Forest Service, Northeastern Forest Experiment Station, Broomall, Pennsylvania. NE–RN–338. 4 p.

Simple guidelines to assign relative mortality risks to individual trees threatened by the gypsy moth.

75. Herrick, O.W. and Gansner, D.A. 1988. Changes in forest condition associated with gypsy moth on new frontiers of infestation. Northern Journal of Applied Forestry 5: 59–61.

Extensive and repeated defoliation reduced the oak component in stands but the overall average stocking rate did not change greatly. Losses from tree mortality were offset by growth of surviving trees.

76. Hicks, R.R. Jr. 1991. The role of hazard rating in forest health protection. Gypsy Moth News, June 1987, 26: 6.

Succinct description of the concept of hazard rating for gypsy moth.

77. Hofacker, T. and Flanigan, T. 1992. The Asian gypsy moth. Gypsy Moth News, February 1992, 28: 2–3.

A brief summary of the inadvertent introduction of the Asian gypsy moth into North America, and the response of the USDA to this invasion. Provides a comparison of some features of Asian and North American gypsy moths.

78. Hollenhorst, S.J., Brock, S.M., Freimund, W.A. and Twery, M.J. 1992. Predicting the effects of gypsy moth on near-view aesthetic preferences and recreation appeal. Forest Science 39: 28–40.

A test using photographs of defoliated forests showed that a person's impression of the forest was negatively affected at only the highest levels of defoliation.

79. Houston, D.R. 1979. Classifying forest susceptibility to gypsy moth defoliation. USDA Combined Forest Pest Research and Developent Program, Washington, D.C. Agriculture Handbook No. 542. 23 p.

Handbook describing preliminary attempts to develop a classification system for susceptibility of stands to the gypsy moth. Good illustrations and a clear description of principles.

80. Houston, D.R. and Valentine, H.T. 1977. Comparing and predicting forest stand susceptibility to gypsy moth. Canadian Journal of Forest Research 7: 447–461.

Multivariate statistical techniques were used to classify stands according to their susceptibility to the gypsy moth. Stands that have previously experienced high oak mortality now seem less susceptible.

81. Hylbom, M.M., Held-Phillips, D. and Goff, G. 990. The gypsy moth. A workbook about Michigan's newest insect. Clare County Cooperative Extension Service. 22 p.

Workbook and teacher's guide on gypsy moth designed for youths involved in 4–H activities.

82. Jamieson, K.B. (editor). 1993. Virus: A natural control choice for the gypsy moth. Forest Pest Management Institute, Sault Ste. Marie, Ontario. 18 p. (unnumbered report) (ISBN 0–662–20521–9)

A good example of an illustrated information booklet providing brief descriptions of the life history and control methods for gypsy moth. Discusses nuclear polyhedrosis virus as a specific control method.

83. Jobin, L., Hébert, C. and Bourassa, J–P. 1992. Head capsule width of larval populations of the gypsy moth (Lepidoptera: Lymantriidae) in Quebec, with reference to Dyar's hypothesis. Environmental Entomology 21: 89–93.

Tables and figures showing distribution of gypsy moth infestations in Quebec and Ontario and frequency distributions of head capsule widths to aid in distinquishing various stages of the gypsy moth caterpillar.

84. Kolodny–Hirsch, D.M. 1986. Evaluation of methods for sampling gypsy moth (Lepidoptera: Lymantriidae) egg mass populations and development of sequential sampling plans. Environmental Entomology 15: 122–127.

Compares two sizes of fixed-area plots and variable-area plot methods of estimating egg-mass density. The author found the 0.01-ha fixed-area plot most efficient. Also describes a sequential sample plan based on this sample unit.

85. Liebhold, A. 1992. New approaches to sampling for decision making. Gypsy Moth News, July 1992, 29: 10–13.

Discusses limitations of current egg-mass sample techniques and possible improvements to aid management decisions.

86. Liebhold, A.M. and Elkinton, J.S. 1988. Techniques for estimating the density of late-instar gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae), populations using frass drop and frass production measurements. Environmental Entomology 17: 381–384.

Title is self-explanatory. This method, though more accurate than simpler methods of estimating larval density, is most likely to be used where information is required for research purposes.

87. Liebhold, A.M. and Elkinton, J.S. 1989. Characterizing spatial patterns of gypsy moth regional defoliation. Forest Science 35: 557–568.

Analysis of aerial sketch maps of defoliation shows a very patchy distribution of defoliation. Different areas within a region (here, the state of Massachusetts) also showed variable timing of infestations.

88. Liebhold, A.M., Elkinton, J.S. and Wallner, W.E. 1986. Effect of burlap bands on between-tree movement of late-instar gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae). Environmental Entomology 15: 373–379.

    The tendency for gypsy moth larvae to accumulate under fabric bands biases this method of population estimation.

89. Liebhold, A.M., Simons, E.E., Sior, A. and Unger, J.D. 1993. Forecasting defoliation caused by the gypsy moth from field measurements. Environmental Entomology 22: 26–32.

    Egg density (the number of egg masses times the number of eggs per egg mass) was the best single variable for predicting defoliation.

90. Liebhold, A., Twardus, D. and Buonaccorsi, J. 1991. Evaluation of the timed-walk method of estimating gypsy moth (Lepidoptera: Lymantriidae) egg mass densities. Journal of Economic Entomology 84: 1774–1781.

    Demonstrates the inconsistency of the timed-walk method of estimating egg-mass density. Concludes that 0.01-ha fixed-area plots are more precise and can be more economical.

91. Lyons, D.B. and Lysyk, T.J. 1988. Development and phenology of eggs of gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae), in Ontario. pages 351-365 *in* W.E. Wallner and K.A. McManus (editors). Lymantriidae: a comparison of features of New and Old World tussock moths. USDA Forest Service, Northeastern Forest Experiment Station, Broomall, Pennsylvania. General Technical Report NE–123.

    Uses a rate-summation model to predict the time of hatch of gypsy moth larvae from overwintered egg masses.

92. Madrid, F.J. and Stewart, R.K. 1981. Ecological significance of cold hardiness and winter mortality of eggs of the gypsy moth *Lymantria dispar* L., in Quebec. Environmental Entomology 10: 586–589.

    Field collections of gypsy moth eggs in Quebec indicated good overwinter survival, even above the protective snow cover.

93. Marshall, P.T. 1989. Mass trapping—an eradication tool? Gypsy Moth News, December 1989, 21: 5.

    Promotes mass trapping as part of an integrated approach to suppressing or eradicating new infestations.

94. Mauffette, Y., Lechowicz, M.J. and Jobin, L. 1983. Host preferences of the gypsy moth, *Lymantria dispar* (L.), in southern Quebec. Canadian Journal of Forest Research 13: 53–60.

    Host-tree preferences of newly established gypsy moth populations in the St. Lawrence River Valley.

95. McFadden, M. 1992. The gypsy moth research and development program—alive and well. Gypsy Moth News, November 1992, 30: 3–8.

    Describes research objectives sponsored by the USDA Forest Service and identifies collaborators under each objective.

96. McManus, M.L., Houston, D.R. and Wallner, W.E. 1979. The homeowner and the gypsy moth: guidelines for control. USDA, Combined Forest Pest Research and Development Program, Washington, D.C. Home and Garden Bulletin No. 227. 34 p.

    Illustrated information on gypsy moth biology and ecology. Gives some recommendations for homeowners.

97. McManus, M.L. and Smith, H.R. 1984. Effectiveness of artificial bark flaps in mediating migration of late-instar gypsy moth larvae. USDA Forest Service, Northeastern Forest Experiment Station, Hamden, Connecticut. Research Note NE–316. 4 p.

    Compares different kinds of material for banding and discusses the uses and limitations of the method.

98. McManus, M.L. and Zerillo, R.T. 1978. The gypsy moth: an illustrated biography. USDA, Washington, D.C. Home and Garden Bulletin No. 225. 15 p.

    Life history of gypsy moth with very good photographs.

99. Mech, R. and Simmons, G. 1990. The gypsy moth in Michigan: a guide for homeowners and small woodlot owners. Cooperative Extension Service, Michigan State University, East Lansing, Michigan, Extension Bulletin E–1983, File 27.35. 6 p.

    A well-produced introduction to the gypsy moth management for homeowners and owners of small woodlots. Useful summaries of several control methods including silvicultural practices.

100. Midland County Gypsy Moth Suppression Program. 1988. The Midland county gypsy moth story. Midland County Gypsy Moth Suppression Program, Midland, Michigan 25 p.

    Excellent example of a local county program including rationale, results and a financial report.

101. Miller, J.C. 1990. Field assessment of the effects of a microbial pest control agent on nontarget Lepidoptera. Bulletin of the Entomological Society of America 36: 135–139.

    Populations of several species of nontarget Lepidoptera were reduced following application of Bt against the gypsy moth in Oregon.

102. Mills, N.J. 1990. Are parasitoids of significance in endemic populations of forest defoliators? Some experimental observations from gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae). pages 265–274 *in* A.D. Watt, S.R. Leather, M.D. Hunter and N.A.C. Kidd (editors) Population Dynamics of Forest Insects. Intercept Ltd., Hampshire, U.K.

Experimental results examining the role of insect parasitoids in low-level populations of gypsy moth with a discussion of the applicability to biological control.

103. Mollenhauer, E. 1990. The gypsy moth in the classroom: a school-based approach to gypsy moth education. Gypsy Moth News, July 1990, 23: 1–3.

An educator's description of projects for school children involving gypsy moth.

104. Montgomery, M.E. 1990. Role of site and insect variables in forecasting defoliation by the gypsy moth. pages 73–83 *in* A.D. Watt, S.R. Leather, M.D. Hunter and N.A.C. Kidd (editors) Population Dynamics of Forest Insects, Intercept, Andover, U.K.

Combines egg mass sample data with site characteristics and measures of fecundity for improved forecasts of defoliation.

105. Moore, K.E.B. and Jones, C.G. 1987. Field estimation of fecundity of gypsy moth (Lepidoptera: Lymantriidae). Environmental Entomology 16: 165–167.

Provides an equation for estimating the number of eggs per egg mass based on egg-mass length.

106. Moore, K.E.B. and Jones, C.G. 1992. Estimating field hatch of gypsy moth (Lepidoptera: Lymantriidae). Environmental Entomology 21: 276–280.

Describes a method for estimating the proportion of larvae hatching from the egg-mass.

107. National Gypsy Moth Management Group. Facts about gypsy moth parasites. National Gypsy Moth Management Group, Landisburg, Pennsylvania. 1 p.

Brief description of the biocontrol agents available through this company.

108. Nealis, V.G. and Wallace, D.R. 1988. A biological control program for gypsy moth in Ontario. Forestry Newsletter, Forestry Canada, Ontario Region, Sault Ste. Marie, Ontario. Summer 1988, p. 7.

Describes recent classical biological control program in Canada.

109. Nichols, J.O. 1980. The Gypsy Moth. Bureau of Forestry, Commonwealth of Pennsylvania, Harrisburg. 34 p.

Comprehensive information on the gypsy moth, with useful addresses of sources of information in Pennsylvania.

110. Onken, B.P. 1989. Improving treatment efficacy of Luretape®. Gypsy Moth News, December 1989, 21: 6.

Reports limited success using barriers to protect trees.

111. Ontario Ministry of Natural Resources. 1990. Suggested gypsy moth control methods for the landowner. Ontario Ministry of Natural Resources, Toronto, Ontario. Resources Report, March 1990. 2 p.

Fact sheet offering brief advice on gypsy moth control.

112. Ontario Ministry of Natural Resources. 1990. Gypsy moth—fact and fiction. Ontario Ministry of Natural Resources, Toronto, Ontario. Fact Sheet, February 1990. 4 p.

Fact sheet using question-and-answer format to inform the public on issues of common concern related to the gypsy moth.

113. Ontario Ministry of Natural Resources. 1990. Pesticides—some basic facts. Ontario Ministry of Natural Resources, Toronto, Ontario. Fact Sheet. March 1990. 3 p.

Informative fact sheet answering commonly asked questions concerning pesticides and their use.

114. Ontario Ministry of Natural Resources. (year unknown) Gypsy moth egg mass survey for the woodlot owner. Ontario Ministry of Natural Resources, Toronto, Ontario. 1 p.

Instructions to carry out a timed walk for estimating gypsy moth egg-mass density in a woodlot.

115. Oregon State University Extension Service. 1986. The gypsy moth in Oregon. Potential effects and management options. Oregon State University, Corvallis, Oregon. Report EM 8315. 16 p.

A well-organized and clearly written publication on aspects of gypsy moth biology and management from the perspective of newly infested areas.

116. Peterson, N.C. and Smitely, D.R. 1991. Susceptibility of selected shade and flowering trees to gypsy moth (Lepidoptera: Lymantriidae). Journal of Economic Entomology 84: 587–592.

Examines the susceptibility of selected horticultural varieties of shade and ornamental trees on residential properties to the gypsy moth.

117. Podgwaite, J.D., Reardon, R.C., Walton, G.S., Venables, L. and Kolodny-Hirsch, D.M. 1992. Effects of aerially applied Gypchek on gypsy moth (Lepidoptera: Lymantriidae) populations in Maryland woodlots. Journal of Economic Entomology 85: 1136–1139.

Significant reductions in egg-mass densities were observed in stands treated with Gypsy moth NPV (Gypchek) and various additives to enhance the efficacy of the virus. Protection of foliage by this treatment was greatest in the most heavily infested stands.

118. Rafats, J. 1992. Gypsy moth (*Lymantria dispar*) and its control. USDA National Agricultural Library, Beltsville, Maryland, Quick bibliography series QB 92–17. 57 p.

A compilation of citations referring to chemical and biological control of the gypsy moth. All references are from the National Agriculture Library's AGRICOLA database. Instructions on obtaining reference articles through libraries, electronic mail and direct requests are provided.

119. Ravlin, F.W. 1991. Development of monitoring and decision-support systems for integrated pest management of forest defoliators in North America. Forest Ecology and Management 39: 3–13.

Effective monitoring systems are the basis for effective decision-support systems in pest management.

120. Ravlin, F.W., Bellinger, R.G. and Roberts, E.A. 1987. Gypsy moth management programs in the United States: status, evaluation, and recommendations. Bulletin of the Entomological Society of America 33: 90–98.

A national survey was used to determine the status of gypsy moth management programs in the United States. The authors conclude that better coordination among participating agencies is required for effective management programs at the regional level. The report recommends working groups and the use of common survey and analytical tools as a framework for improved coordination.

121. Ravlin, F.W., Fleischer, S.J., Carter, M.R., Roberts, E.A. and McManus, M.L. 1990. A monitoring system for gypsy moth management. pages 89–95 *in* K.W. Gottschalk, M.J. Twery and S.I. Smith (editors) Proceedings: U.S. Department of Agriculture Interagency Gypsy Moth Research Review 1990. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. General Technical Report NE–146.

Description of a monitoring system that integrates pheromone trap data and egg mass samples to support pest management decisions.

122. Ravlin, F.W., Logan, J.A., Schaub, L., Rutherford, S.L. and Fleischer, S. 1990. GYPSES: a knowledge-based environment for decision support in gypsy moth management. pages 43–49 *in* Proceedings: Application of GIS simulation models, and knowledge-based systems for land use management. Virginia Polytechnical Institute and State University, Blacksburg, Virginia.

Presents the concept of a decision-support system specific to gypsy moth management.

123. Reardon, R.C. 1976. Parasite incidence and ecological relationships in field populations of gypsy moth larvae and pupae. Environmental Entomology 5: 981–987.

Parasite populations have limited ability to reduce the gypsy moth's rate of increase.

124. Reardon, R.C. 1991. Appalachian gypsy-moth integrated pest-management project. Forest Ecology and Management 39: 107–112.

Description of objectives and structure of the Appalachian Integrated Pest Management (AIPM) project.

125. Reardon, R.C., Kaya, H.K., Fusco, R.A. and Lewis, F.B. 1986. Evaluation of *Steinernema feltiae* and *S. bibionis* (Rhabditida: Steinernematidae) for suppression of *Lymantria dispar* (Lepidoptera: Lymantriidae) in Pennsylvania, U.S.A. Agriculture, Ecosystems and Environment 15: 1–9.

Reports preliminary research data on nematode effectiveness. Highly effective in laboratory assays, less effective in field trials.

126. Reardon, R., McManus, M., Kolodny–Hirsch, D., Tichenor, R., Raupp, M., Schwalbe, C., Webb, R. and Meckley, P. 1987. Development and implementation of a gypsy moth integrated pest management program. Journal of Arboriculture 13: 209–216.

Describes an integrated gypsy moth management program in Maryland that relies heavily on information on monitoring and hazard rating for prescribing action.

127. Roden, D.B. and Surgeoner, G.A. 1986. Public concerns about the gypsy moth (*Lymantria dispar,* Lepidoptera: Lymantriidae) in Ontario. Bulletin of the Entomological Society of Canada 18: 58–63.

Reports the results of a survey of cottage and commercial resort owners in Ontario, asking their opinion on potential management strategies. Most respondents favored some kind of spray program but wanted more information.

128. Rossiter, M., Schultz, J.C. and Baldwin, I.T. 1988. Relationships among defoliation, red oak phenolics, and gypsy moth growth and reproduction. Ecology 69: 267–277.

Defoliation of oak trees by the gypsy moth affects nutrient quality of the tree. These changes have a negative effect on subsequent growth and fecundity of gypsy moth.

129. Sample, B.E., Butler, L. and Whitmore, R.C. 1993. Effects of an operational application of Dimilin on non-target insects. The Canadian Entomologist 125: 173–179.

The greatest negative effect was shown by butterfly and moth populations sprayed with Dimilin. This study used light traps to sample insects and so represents a conservative estimate of resident populations.

130. Schaefer, P.W., Fuester, R.W., Chianese, R.J., Rhoads, L.D. and Tichenor, R.B. Jr. 1989. Introduction and North American establishment of *Coccygomimus disparis* (Hymenoptera: Ichneumonidae), a polyphagous pupal parasite of Lepidoptera, including gypsy moth. Environmental Entomology 18: 1117–1125.

Introduction and recovery of an introduced parasitoid of the gypsy moth.

131. Schaefer, P.W., Ikebe, K. and Higashiura. Y. 1988. Gypsy moth, *Lymantria dispar* (L.), and its natural enemies in the Far East (especially Japan). Annotated bibliography and guide to the literature through 1986 and host plant list for Japan. Delaware Agricultural Experiment Station Bulletin #476. (Department of Entomology and Applied Ecology, University of Delaware, Newark, Delaware.) 160 p.

A useful introduction to the literature on the gypsy moth in Asia.

132. Schwalbe, C.P., Mastro, V.C. and Hansen, R.W. 1991. Prospects for genetic control of the gypsy moth. Forest Ecology and Management 39: 163–171.
Describes field tests of using inherited sterility as an eradication tool in small, well-delimited infestations.

133. Sheehan, K.A. 1992. User's guide for GMPHEN: Gypsy moth phenology model. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. General Technical Report NE–158. 29 p.
Describes use of a menu-driven computer model to predict the timing of gypsy moth and host development.

134. Simons, E.E., Reardon, R.C. and Ticehurst, M. 1981. Selected parasites and hyperparasites of the gypsy moth, with keys to adults and immatures. USDA Forest Service, Combined Forest Pest Research and Development Program, Washington, D.C. Agriculture Handbook No. 540. 57 p.
Illustrated key to parasitoids that attack the gypsy moth in the United States. Includes a glossary.

135. Skaller, P.M. 1985. Patterns in the distribution of gypsy moth (*Lymantria dispar*) (Lepidoptera: Lymantriidae) egg masses over an 11-year population cycle. Environmental Entomology 14: 106–117.
Extensive data set describing patterns of egg mass distribution in different habitats and at different levels of gypsy moth infestation.

136. Smith, H.R. and Campbell, R.W. 1978. Woodland mammals and the gypsy moth. American Forests, May 1978, 84: 22.
Mammal activity in areas infested by the gypsy moth.

137. Stevens, L.J. and Beroza, M. 1972. Mating-inhibition field tests using disparlure, the synthetic gypsy moth sex pheromone. Journal of Economic Entomology 65: 1090–1095.
One of the earliest attempts to use pheromones for mating inhibition. Showed promise in low-level infestations.

138. Sullivan, C.R. and Wallace, D.R. 1972. The potential northern dispersal of the gypsy moth, *Porthetria dispar* (Lepidoptera: Lymantriidae). The Canadian Entomologist 104: 1349–1355.
Gypsy moth eggs have physiological protection against very cold temperatures. Survival in northern climates is enhanced by snow cover. It is unlikely that severe winter weather on its own will restrict the spread of the gypsy moth.

139. Thorpe, K.W. and Ridgway, R.L. 1992. Gypsy moth (Lepidoptera: Lymantriidae) egg mass distribution and sampling in a residential setting. Environmental Entomology 21: 722–730.
The authors adapted sampling methods to special residential settings and found 0.01-hectare fixed-area plots to be most cost-effective. Whole-property searches were not cost-effective but provided the best estimates.

140. Thorpe, K.W., Ridgway, R.L. and Leonhardt, B.A. 1993. Relationship between gypsy moth (Lepidoptera: Lymantriidae) pheromone trap catch and population density: comparison of traps baited with 1 and 500 µg (+)–Disparlure lures. Journal of Economic Entomology 86: 86–92.
Pheromone trap catches were correlated with subsequent egg-mass densities for both low- and high-concentration lures.

141. Ticehurst, M. and Finley, S. 1988. An urban forest integrated pest management program for gypsy moth: an example. Journal of Arboriculture 14: 172–175.
Describes a local, collaborative project for conducting gypsy moth suppression on urban and private land.

142. Twardus, D.B. and Machesky, H.A. 1990. Gypsy moth suppression in the northeast. USDA Forest Service, Morgantown, West Virginia. Report NA–TP–18. 17 p. including appendices.
A three-year summary of the results of control treatments for the gypsy moth in the United States. An example of public notification of results.

143. United States Department of Agriculture, Animal and Plant Health Inspection Service. 1989. Don't move gypsy moth. USDA Animal and Plant Health Inspection Service, Washington, D.C. Program Aid Number 1329. 11 p.
Brochure explaining how to inspect personal belongings to guard against inadvertent movement of gypsy moths.

144. United States Department of Agriculture, Animal and Plant Health Inspection Service. 1990. Gypsy moth program manual. USDA Animal and Plant Health Inspection Service, Frederick, Maryland. (unnumbered report) 168 p.
Detailed technical recommendations for carrying out quarantine, detection and eradication programs.

145. United States Department of Agriculture Forest Service. Guides for predicting gypsy moth damage for forest landowners. Northeastern Area, Morgantown, West Virginia. NA–FB/P–25. 1 p.
Brochure providing quick and simple methods of calculating potential losses in forest stands.

146. United States Department of Agriculture, Forest Service. 1990. Gypsy moth research and development program. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. 29 p. (unnumbered report)
Reviews research program and provides brief notes and graphs on gypsy moth population biology, impact, management, and integrated control.

147. United States Department of Agriculture, Forest Service 1991. Gypsy moth. A balanced perspective. USDA Forest Service, Southern Region, Forest Pest Management, Atlanta, Georgia. (Video, 18 minutes)

A very good presentation of many aspects of gypsy moth biology, ecology, negative/positive effects of defoliation and the implications for management, through education, future research and homeowner control techniques.

148. van Frankenhuyzen, K. 1990. Development and current status of *Bacillus thuringiensis* for control of defoliating forest insects. The Forestry Chronicle 66: 498–507.

Reviews the development of the operational use of Bt and discusses future prospects.

149. Virginia Cooperative Gypsy Moth Suppression Program. 1990. 1991 guidelines for participation (aerial treatments). State Entomologist, Virginia Department of Agriculture and Consumer Services, Office of Plant Protection, Richmond, Virginia. 45 p.

Guidelines for participation of cooperators. Provides factual information on the gypsy moth and its control as well as the responsibilities of cooperators.

150. Virginia Cooperative Gypsy Moth Suppression Program. 1990. 1991 guidelines for participation (ground treatments and biological control items). State Entomologist, Virginia Department of Agriculture and Consumer Services, Office of Plant Protection, Richmond, Virginia. 34 p.

Guidelines for participation of cooperators. Provides factual information on the gypsy moth and its control as well as the responsibilities of cooperators.

151. Wallner, W. 1992. Comparison of North American gypsy moth (NAGM) and Asian gypsy moth (AGM). Gypsy Moth News, February 1992, 28: 3–4.

A table comparing features of various life stages of Asian gypsy moth and North American gypsy moth is presented. It is stated that Asian gypsy moth possesses more genetic variability than North American gypsy moth.

152. Wallner, W.E., Jones, C.G., Elkinton, J.S. and Parker, B.L. 1990. Sampling low-density gypsy moth populations. pages 40–44 *in* Proceedings: U.S. Department of Agriculture Interagency Gypsy Moth Research Review 1990. USDA Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. General Technical Report NE–146.

A comparison of methods used to monitor gypsy moth populations at low density levels suggests that counting egg masses under fabric bands on host trees is an efficient means of establishing trends in populations.

153. Wallner, W.E. and McManus, K.A. (editors). 1989. Lymantriidae: A comparison of features of new and old world tussock moths. USDA Forest Service, Northeastern Forest Experiment Station, Broomall, Pennsylvania. General Technical Report NE–123. 554 p.

Proceedings of a conference in 1988 reviewing the state of knowledge of the biology of the gypsy moth and related species. Includes sections on taxonomy, genetics, population dynamics, host relationships and control.

154. Wargo, P.M. 1977. *Armillariella mellea* and *Agrilus bilineatus* and mortality of defoliated oak trees. Forest Science 23: 485–492.

Oak mortality was the result of interactions between damage caused by the gypsy moth and these secondary pests.

155. Wargo, P.M. 1978. Defoliation by the gypsy moth: how it hurts your tree. USDA Combined Forest Pest Research and Development Program, Washington, D.C. Home and Garden Bulletin No. 223. 15 p.

Brief answers to common questions about gypsy moth impact. Good color photos of damage and secondary pest effects.

156. Waters, W.E. and Stark, R.W. 1980. Forest pest management: concept and reality. Annual Review of Entomology 25: 479–509.

A relevant review of forest pest management concepts.

157. Webb, R.E., Ridgway, R.L., Thorpe, K.W., Tatman, K.M., Wieber, A.M. and Venables, L. 1991. Development of a specialized gypsy moth (Lepidoptera: Lymantriidae) management program for suburban parks. Journal of Economic Entomology 84: 1320–1328.

Describes a gypsy moth management program designed specifically for use in urban or suburban parks. Provides a guide for decision-making and reports on the results of the subsequent control program.

158. Webb, R.E., Shapiro, M., Podgwaite, J.D., Reardon, R.C., Tatman, K.M., Venables, L. and Kolodny–Hirsch, D.M. 1989. Effect of aerial spraying with Dimilin, Dipel, or Gypchek on two natural enemies of the gypsy moth (Lepidoptera: Lymantriidae). Journal of Economic Entomology 82: 1695–1701.

Interactions between applied control agents (NPV, Dimilin, and Bt) and naturally occurring parasitoids and pathogens.

159. Weseloh, R.M. 1987. Accuracy of gypsy moth (Lepidoptera: Lymantriidae) population estimates based on counts of larvae in artificial resting sites. Annals of the Entomological Society of America 80: 361–366.

The number of larvae found under burlap bands was influenced by weather and biased by other factors. Such data must be interpreted with care.

160. Weseloh, R.M. 1990. Experimental forest releases of *Calosoma sycophanta* (Coleoptera: Carabidae) against the gypsy moth. Journal of Economic Entomology 83: 2229–2234.

Releases of small numbers of adult beetles can, through progeny production, reduce gypsy moth populations.

161. Weseloh, R.M. and Anderson, J.F. 1982. Releases of *Brachymeria lasus* and *Coccygomimus disparis*, two exotic gypsy moth parasitoids, in Connecticut: habitat preference and overwintering potential. Annals of the Entomological Society of America 75: 46–50.

Recent releases of classical biological control agents in the United States.

162. Weseloh, R.M. and Andreadis, T.G. 1992. Mechanisms of transmission of the gypsy moth (Lepidoptera: Lymantriidae) fungus, *Entomophaga maimaiga* (Entomophthorales: Entomophthoraceae) and effects of site conditions on its prevalence. Environmental Entomology 21: 901–906.

Prevalence of this gypsy moth pathogen is dependent on overwintering abundance of the larvae or the fungus and precipitation. Implications for management are discussed.

163. Williams, D.W., Fuester, R.W., Metterhouse, W.W., Balaam, R.J., Bullock, R.H., Chianese, R.J. and Reardon, R.C. 1990. Density, size, and mortality of egg masses in New Jersey populations of the gypsy moth (Lepidoptera: Lymantriidae). Environmental Entomology 19: 943–948.

Size of egg masses was inversely proportional to the size of the population in the previous generation.

164. Wilson, R.W. Jr. and Fontaine, G.A. 1978. Gypsy moth egg-mass sampling with fixed- and variable-radius plots. USDA, Combined Forest Pest Research and Development Program, Washington, D.C. Agriculture Handbook No. 523. 46 p.

Discusses and describes fixed- and variable-radius plots. Provides examples of data sheets for survey crews.

165. Wirtz, R.A. 1984. Allergic and toxic reactions to non-stinging arthropods. Annual Review of Entomology 29: 47–69.

Reviews human allergic reactions to several insect products. Provides a discussion and pertinent references for reactions to gypsy moth.

166. Woods, S.A. and Elkinton, J.S. 1987. Bimodal patterns of mortality from nuclear polyhedrosis virus in gypsy moth (*Lymantria dispar*) populations. Journal of Invertebrate Pathology 50: 151–157.

Mortality from NPV produced two distinct peaks: one early in the season as a result of newly hatched larvae becoming infected from the egg mass and a second peak for larger larvae that results from increased rates of infection in high-density populations.

167. Woods, S.A., Elkinton, J.S. and Shapiro, M. 1988. Effects of *Bacillus thuringiensis* treatments on the occurrence of nuclear polyhedrosis virus in gypsy moth (Lepidoptera: Lymantriidae) populations. Journal of Economic Entomology 81: 1706–1714.

Natural mortality of gypsy moth due to viral (NPV) infections was lower in plots treated with Bt.

Appendix 1. Addresses of organisations mentioned in the text.

Abbott Laboratories Ltd.
1401 Sheridan Road
North Chicago, Illinois
60064
(708) 937–8904

Agriculture Canada
K.W. Neatby Building
960 Carling Avenue
Ottawa, Ontario
K1A 0C6
(613) 996–1665
Pesticides hotline: 1–800–267–6315

Alberta Forest Service
9915–108th Street
Edmonton, Alberta
T5K 2C9
(403) 427–3542
Fax (403) 422–6068

Bio–Contrôle Services
2949 Chemin Ste–Foy
Ste–Foy, Quebec
G1X 1P3
(418) 653–3101

British Columbia Ministry of Forests
1450 Government Street
Victoria, British Columbia
V8W 3E7
(604) 387–5255
Fax (604) 387–8485

Chemagro Ltd.
77 Belfeild Road
Etobicoke, Ontario
M9W 1G6
(416) 614–1053

Chevron Chemical (Canada) Ltd.
3228 South Service Road
Burlington, Ontario
L7N 3H8
(416) 681–2201

Cooper Mill Ltd.
Agricultural Division
RR #3
Madoc, Ontario
K0K 2K0
(613) 473–4847
Fax (613) 473–5080

Forestry Canada, Forest Pest Management Institute
1219 Queen Street East
Sault Ste. Marie, Ontario
P6A 5M7
(705) 949–9461
Fax (705) 759–5700

Forestry Canada, Maritimes Region
P.O. Box 4000
Regent St.
Fredericton, New Brunswick
E3B 5P7
(506) 452–3500
Fax (506) 452–3525

Forestry Canada, Newfoundland and Labrador Region
P.O. Box 6028
Building 304, Pleasantville
St. John's, Newfoundland
A1C 5X8
(709) 772-4117
Fax (709) 772–2576

Forestry Canada, Northwest Region
5320–122nd St.
Edmonton, Alberta
T6H 3S5
(403) 435–7210
Fax (403) 435–7359

Forestry Canada, Ontario Region
1219 Queen Street East
Sault Ste. Marie, Ontario
P6A 5M7
(705) 949–9461
Fax (705) 759–5700

Forestry Canada, Pacific and Yukon Region
506 West Burnside Rd.
Victoria, British Columbia
V8Z 1M5
(604) 388–0600
Fax (604) 363–0775

Forestry Canada, Petawawa National Forestry Institute
1219 Queen Street East
Sault Ste. Marie, Ontario
P6A 5M7
(613) 589–2880
Fax (613) 589–2275

(cont'd)

Appendix 1. Addresses of organisations mentioned in the text (cont'd).

Forestry Canada, Québec Region
P.O. Box 3800, 1055 rue du P.E.P.S.
Sainte–Foy, Québec
G1V 4C7
(418) 648–5850
Fax (418) 648–5849

Great Lakes IPM
102220 Church Rd, NE
Vestaburg, Michigan
48891
(517) 268–5693
Fax (517) 268–5311

Makhtechim–Agan (NA) Inc.
245 Fifth Avenue, Suite 1901
New York, New York
10016
(212) 561–7200

Manitoba Department of Natural Resources
Forestry Branch
300–530 Kenaston Boulevard
Winnipeg, Manitoba
R3N 1Z4
(204) 945–7989
Fax (204) 489–1360

Ministère des Forêts
see: Service de la protection contre les insectes et maladies

National Gypsy Moth Management Group Inc.
Rd 1, Box 715
Landisburg, Pennsylvania
17040
(717) 789–3434

New Brunswick Department of Natural Resources
Hugh John Fleming Forestry Centre
Box 6000
Fredericton, New Brunswick
E3B 5H1
(506) 453–2614

Newfoundland Department of Forestry and Agriculture
Executive Division
Box 8700, 5th Floor Confederation Bldg.–West Block
St. John's, Newfoundland
A1B 4J6
(709) 576–6025
Fax (709) 576–5798

Northeastern Area State and Private Forestry
5 Radnor Corporate Center
100 Matsonford Road, Suite 200
P.O. Box 6775
Radnor, Pennsylvania
19087–4585
(215) 975–4111 (State and Private)
Fax (215) 975–4200
Radnor Experiment Station (215) 975–4222

Nova Scotia Department of Lands and Forests
1701 Hollis Street, Box 698
Halifax, Nova Scotia
B3J 2T9
(902) 424–5935
Fax (902) 424–7735

Novo Nordisk Bioindustrial
33 Turner Road
P.O. Box 1907
Danbury, Connecticut
06813–1907
(203) 790–2600

Ontario Ministry of the Environment
135 St. Claire Avenue, Suite 100
Toronto, Ontario
M4V 1P5
(416) 323–4321
Sudbury office (705) 675–4501

Ontario Ministry of Natural Resources
70 Foster Drive, Suite 400
Sault Ste. Marie, Ontario
P6A 6V5
(705) 945–6602
Fax (705) 945–6667

Pest Management Supply Inc.
311 River Dr.
Hadley, Massachussetts
01035
(413) 549–7246
Fax (413) 549-3930

Phero Tech Inc.
7572 Progress Way
Delta, British columbia
V4G 1E9
(604) 940–9433
Fax (604) 940–9433

(cont'd)

Appendix 1. Addresses of organisations mentioned in the text (cont'd).

Prince Edward Island Department of Energy and Forestry
Forestry Branch
Box 2000
Charlottetown, P.E.I.
C1A 7N8
(902) 368–4700
Fax (902) 892–3420

Rhone–Poulenc Canada Inc.
2000 Argentia Place, Plaza Suite 400
Mississauga, Ontario
L5N 1V4
(416) 821–4450

Sandoz Agro-Canada Inc.
2000 Argentia Place, Plaza Suite 400
Mississauga, Ontario
L5N 1V4
(416) 821–4450

Saskatchewan Parks and Renewable Resources
Forestry Branch
Box 3003
Prince Albert, Saskatchewan
S6V 6G1
(306) 953–2221
Fax (306) 953–2360

Service de la Protection Contre les Insectes et Maladies
1283 Charest ouest
Québec City, Québec
G1N 2C9
(418) 643–9679
Fax (418) 643–0381

Solvay Duphar B.V.
P.O. Box 4
Graveland, 1243 ZG'S
The Netherlands

SOPFIM
Societé de protection des forêts contre les insectes et les maladies
1400 St. Jean Baptiste
Québec City, Québec
G2E 5B7
(418) 877–6844
Fax (418) 877–6846

Trece Inc.
P.O. Box 6278
Salinas, California
93912
(408) 758–0204
Fax (408) 758–2625

United States Department of Agriculture
Extension Service
Washington, D.C. 20250
(202) 720–3377
(Administrator for Extension)

United States Department of Agriculture
Forest Service
14th and Independence, S.W.
P.O. Box 96090
Washington, D.C.
20090-6090
(202) 720–USDA (general information)
(202) 205–0957 (Public Affairs Office)
(202) 205–1532 (Forest and Insect Disease Survey)

United States Department of Agriculture
Northeastern Area State and Private Forestry
5 Radnor Corporate Center
100 Matsonford Road, Suite 200, P.O. Box 6775
Radnor, Pennsylvania
19087
Editors: (304) 285–1541

United States Department of Agriculture
Northeastern Forest Experiment Station
180 Canfield Street
Morgantown, West Virginia
26505
(304) 285–1501
Fax (304) 285–1505
AIPM (304) 285–1563
Entomologists (304) 285–1541

United States Department of Agriculture
Northeastern Forest Experiment Station
Center for Biological Control of North-eastern Forest Insects and Diseases
51 Mill Pond Road
Hamden, Connecticut
06514
Editors: (203) 773–2022 or –2021

(cont'd)

Appendix 1. Addresses of organisations mentioned in the text (concl.).

Virginia Department of Agriculture and Consumer Service
Office of Plant Protection
P.O. Box 1163
Richmond, Virginia
23209
(804) 786–3515

Zoecon Industries Ltd.
P.O. Box 30, Highway 7A
Port Perry, Ontario
L0B 1N0
(416) 985–7377
