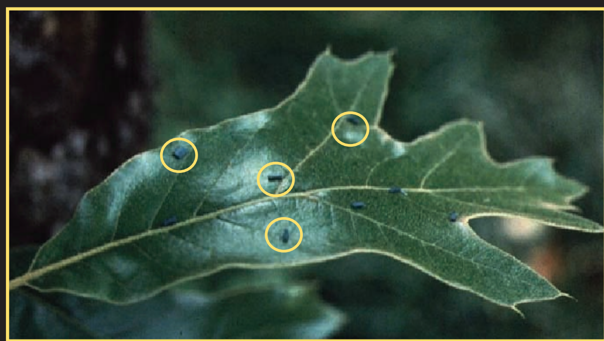
Photos across top of page courtesy of Purdue University and Virginia Tech Departments of Entomology

"SLOW THE SPREAD"

A National Program to Contain the Gypsy Moth



Courtesy of USDA Forest Service

***Above:* Plastic laminated pheromone dispensers (circled in yellow) rest on foliage after aerial application. Mating disruption is one of the key elements in the Slow the Spread program.**

Alexei A. Sharov, Donna Leonard, Andrew M. Liebhold, E. Anderson Roberts, and Willard Dickerson

ABSTRACT

Invasions by alien species can cause substantial damage to our forest resources. The gypsy moth (*Lymantria dispar)* represents one example of this problem, and we present here a new strategy for its management that concentrates on containment rather than suppression of outbreaks. The "Slow the Spread" project is a combined federal and state government effort to slow gypsy moth spread by detecting isolated colonies in grids of pheromone-baited traps placed along the expanding population front from Wisconsin to North Carolina. Detected colonies are treated using *Bacillus thuringiensis* or mating disruption. Analyses to date indicate that this project has reduced spread by more than 50 percent.

Keywords: entomology and pathology; integrated pest management; invasive species

The gypsy moth *(Lymantria dispar)* is probably the most destructive forest defoliator in the United States. More than 81 million acres of forests have been defoliated by the gypsy moth since 1924, and more than 12 million acres have been aerially sprayed to control its populations since 1970 (USDA 1995). During gypsy moth outbreaks, many species of hardwoods may be defoliated; repeated defoliation causes decreased growth, dieback, and tree mortality. Outbreaks often occur in forested residential areas where, in addition to problems associated with defoliation, the presence of large number of caterpillars is the source of considerable nuisance to homeowners.

The gypsy moth problem is a prime example of what can happen if alien species become established outside their native range. Gypsy moth is native to Europe and Asia, and it was accidentally introduced into the United States near Boston in the late 1860s. Since then it has gradually spread West and South *(fig. 1)* (Liebhold et al. 1989, 1992). Early eradication attempts failed, as did efforts from 1923 to 1941 to prevent further range expansion via a barrier zone along the Hudson River valley (McManus and McIntyre 1981).

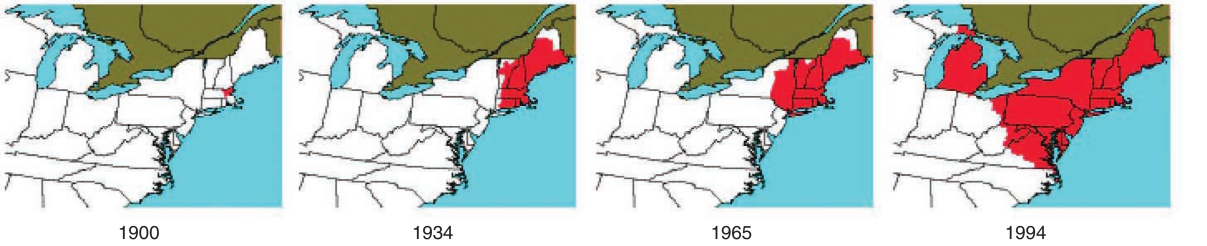


Figure 1. **The dynamics of gypsy moth spread in the United States during the 20th century.**

The gypsy moth's current range extends to portions of North Carolina, Virginia, West Virginia, Ohio, Indiana, Illinois, Wisconsin, and Michigan; this represents less than one-third of the area where extensive impacts are likely to occur once infested *(fig. 2)*. The rate of population spread from 1960 to 1990 was estimated at 13 miles per year (Liebhold et al. 1992). This rate of spread is relatively low compared with other invasive species and can be attributed to the inability of females in North American populations to fly. Most expansion of the infested area is caused by accidental movement of egg masses that are laid on outdoor household articles, nursery stock, and other objects (McFadden and McManus 1991; Liebhold et al. 1992). As a result, isolated colonies become established ahead of the population front; these colonies grow, coalesce, and eventually contribute to further spread of gypsy moth populations (see "Slow the Spread: How It Works," p. 32).

Because the gypsy moth's rate of spread is relatively slow, the full range of the susceptible habitats is not likely to become infested for at least another 100 years. Many years ago, scientists came to realize that elimination of the gypsy moth from North America could never be achieved. Likewise, complete containment of range expansion into new areas is most likely not practical. However, there has been growing recognition that slowing the spread of the gypsy moth is a feasible goal (McFadden and McManus 1991; Reardon 1991).

The economic viability of such an effort is closely tied to the fact that the gypsy moth's impacts are not limited to the time of its initial invasion of an area. Once populations become established in an area, outbreaks occur sporadically, and impacts continue indefinitely into the future. Leuschner et al. (1996) analyzed the economic viability of a program to slow the gypsy moth's spread and showed that the benefits associated with a reduction in future impacts and suppression costs vastly outweighed the costs of implementing a program to reduce spread.

This strategy was initially pilot tested from 1993 to 1998 by the USDA Forest Service along with the USDA Animal and Plant Health Inspection Service (APHIS) and state governments, to demonstrate its feasibility over large regions (Leonard and Sharov 1995). The pilot test of the Slow the Spread strategy was established in three areas along the advancing gypsy moth front: the Appalachian Mountains of Virginia and West Virginia, northeastern North Carolina, and the upper peninsula of Michigan. It adopted and improved strategies developed in earlier programs, most notably the Maryland Gypsy Moth Integrated Pest Management Program (1985–88) and the Appalachian Integrated Pest Management project conducted in 1988–92 (Reardon 1991). Like these programs, the Slow the Spread project uses catch data from grids of pheromone-baited traps deployed just ahead of the advancing population front to detect isolated colonies. Once detected, colonies are further delineated and then treated to eliminate them or retard their population growth. This strategy is designed to nullify the increased rate of spread caused by "leap-frogging" that occurs

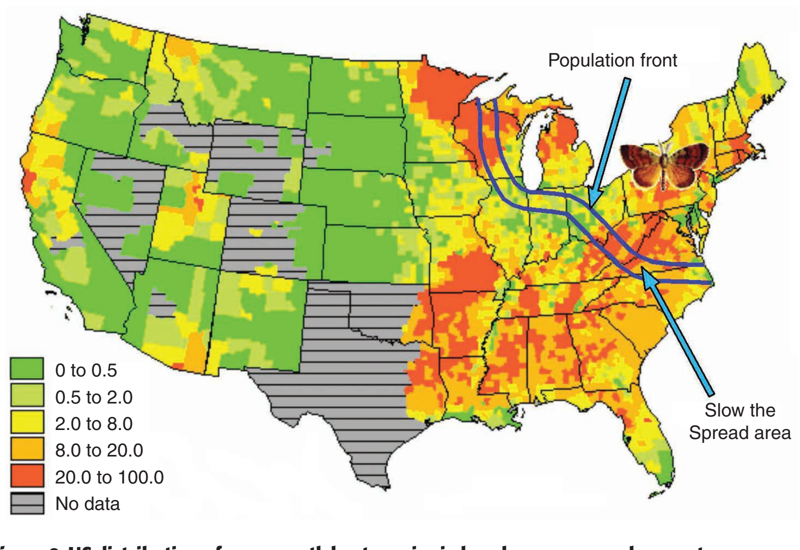
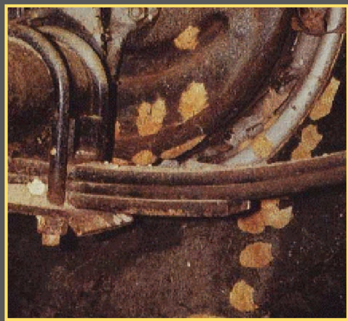


Figure 2. **US distribution of gypsy moth host species in basal area per acre by county (adapted from Liebhold et al. 1997), the current population front, and the location of the Slow the Spread project.**

Slow the Spread: How It Works

Because female gypsy moths are unable to fly, natural spread is very limited; Liebhold et al. (1992) estimated that range expansion due to larval dispersal alone is only expected to be about 1¼ miles per year. The higher rate of spread of 13 miles per year that was observed from 1960 to 1990 is most likely the result of introductions that occur when humans accidentally move gypsy moth life stages into the transition or uninfested zones on outdoor household articles, nursery stock, vehicles, and other objects. These life stages found colonies that reproduce and expand over successive years. Eventually these "spot" infestations coalesce with the continuously infested area, which produces a high rate of spread.



These gypsy moth egg masses have become attached to the wheel of a trailer. Accidental conveyance of egg masses can result in isolated colonies establishing themselves ahead of the population front.

Grids of pheromone-baited traps spaced at 2-km intervals are used for detecting isolated colonies in the transition zone, a band 100 kilometers wide spanning the entire length of the generally infested area in the United States *(fig. 3).* When moth captures in traps indicate a possible colony, a delimiting grid with 0.5-km intertrap distance is set to delineate the boundary of the colony prior to treatment. This ensures aerial treatments are accurately targeted.

Areas to be delimited or treated are initially determined by a computer algorithm designed to analyze moth capture patterns according to project standards and priorities. Then maps of the recommendations are posted on the Internet, which are used by federal and state representatives to begin planning actions that will be taken in the following year. Plans are discussed, prioritized, and finalized at the project level. The finalized plan of action is then compared to the initial computer recommendations to ensure compliance with project standards.

Widespread use of mating disruption, a noninsecticidal treatment that is specific to the gypsy moth, is one of the key elements in the Slow the Spread project. Mating disruption is based on the application of controlled-release dispensers that emit an insect sex pheromone for several months. The cloud of pheromone emitted by the dispensers interferes with the normal mate-searching behavior of males. As a result, females are not mated and lay nonviable eggs. Plastic laminated flakes (Disrupt II®) impregnated with the gypsy moth synthetic pheromone are used to disrupt mating (Reardon et al. 1998). These flakes are mixed with a sticker and applied from aircraft.

The traditional dose of 30 grams per acre has been demonstrated to suppress mating in low-density populations (Reardon et al. 1998; Sharov et al., in review). Recent experiments indicated that mating can be suppressed at even lower doses of 15, 6, and 3 grams per acre (Reardon et al.1998; Sharov et al., in review). Thus, the recommended dose in the Slow the Spread project was recently reduced to 15 grams per acre. The cost of treatment at this dose is approximately $17 per acre, which compares favorably with alternative treatments such as double applications of *B. thuringiensis* ($26–$28 per acre) or a single application of diflubenzuron ($12–$15 per acre).

Mating disruption is equally efficacious in control of isolated gypsy moth colonies as *B. thuringiensis* treatments (Sharov et al., in review), and the scope of its use in the project has increased dramatically *(fig. 4).* Target-specific tactics such as mating disruption will continue to be critical in Slow the Spread to protect unique habitats and rare, threatened, or endangered species that occur within the project area.

when isolated colonies become established in front of the general infestation (see "Slow the Spread: How It Works").

Sharov and Liebhold (1998) performed a detailed analysis of historical gypsy moth spread in the mountains of Virginia and West Virginia. The period analyzed begins in 1980 prior to the start of management of isolated colonies and ends in 1995, which includes three years of management under Appalachian Integrated Pest Management (1990–92) and three years under the Slow the Spread pilot project (1993–95). They found that during this period, the rate of gypsy moth spread decreased from 13–16 miles per year (which corresponds to the historical spread rate from 1960–90) to 5¼ miles per year in 1990–95 *(fig. 5, p. 34).* The reduction in the rate of spread was close to a value predicted using a model of gypsy moth spread (Sharov and Liebhold 1998) and confirmed the feasibility of slowing gypsy moth spread on a large scale.

Based on the success of the pilot project, the Slow the Spread strategy was integrated into USDA's national program for managing the gypsy moth in 1999. The national program now includes three strategies called "suppression," "eradication," and "slow the spread." These strategies are implemented in different geographic areas and have different objectives. Suppression projects are implemented in the area where gypsy moth is permanently established to reduce the damage caused by outbreaks. Eradication projects are conducted to eliminate isolated infestations of the insect that are detected in areas where the gypsy moth is not a permanent resident. Beginning in 1999, the Slow the Spread strategy was implemented along the entire length of the gypsy moth population front *(fig. 2).* The project consists of a coordinated effort by the USDA (Forest Service and APHIS) and nine state

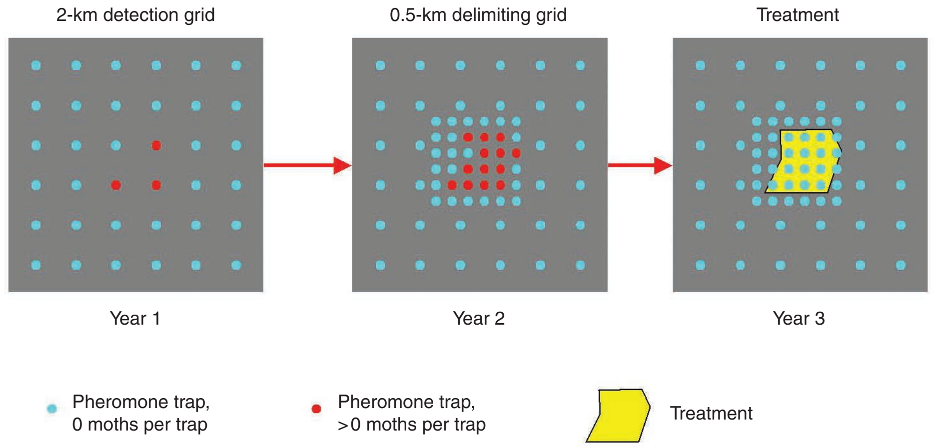


Figure 3. **Steps in detecting and treating an isolated gypsy moth colony.**

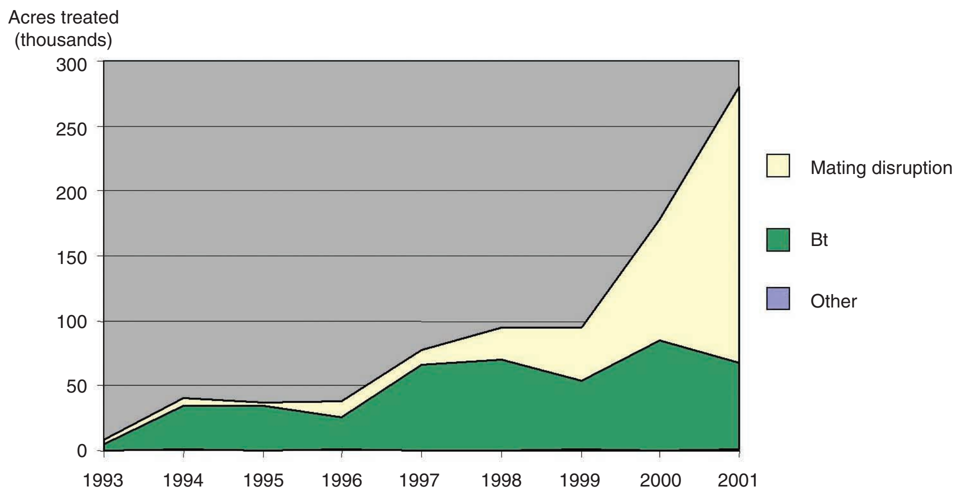


Figure 4. **Area treated in the Slow the Spread project, 1993–2001.**

governments: North Carolina, Virginia, West Virginia, Kentucky, Ohio, Indiana, Illinois, Michigan, and Wisconsin. The annual cost to deploy approximately 80,000 traps and treat approximately 275,000 acres is just under $11 million. Implementation of Slow the Spread is expected to decrease the new territory invaded by the gypsy moth each year from 15,600 square miles to 7,800 square miles or less *(fig. 6, p. 34)*. The benefits associated with the reduction in the rate of spread outweigh the cost of implementation by a ratio of at least 3 to 1 (Leuschner et al. 1996).

The advent of Slow the Spread as part of USDA's national strategy to manage the gypsy moth represents a major innovation in forest pest management. In contrast with traditional gypsy management programs, Slow the Spread is preventive. As with any areawide pest management program whose goal is to contain spread, Slow the Spread will be only as successful as its weakest link. Therefore, the project has a strong focus on standardized protocols for data collection, analysis, decisionmaking, and allocation of funds among the various cooperators. Major technical and organizational innovations that account for the project's success include the following:

• Slow the Spread is a large-scale project and it demands teamwork that crosses administrative and geographic boundaries. The Slow the Spread Foundation, a nonprofit organization directed by representatives from major stakeholders in the program, manages the project and oversees the budget. This novel organizational structure provides a formal framework for cooperation among the many state and federal agencies involved in project implementation. Another advantage to this management structure is that federal resources can be easily shifted from one state to another depending on priorities and biological need.

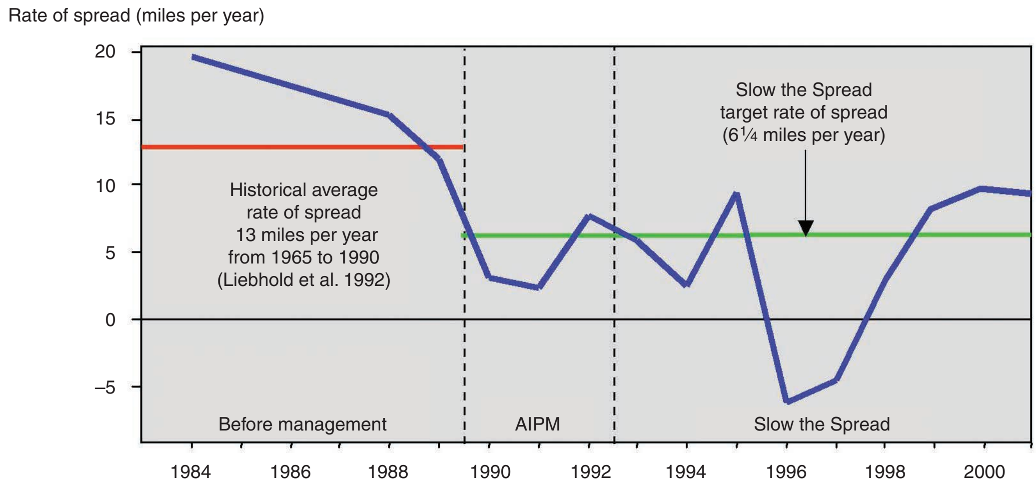


Figure 5. **Historical rates of gypsy moth range expansion in the central Appalachian area of Virginia and West Virginia.**

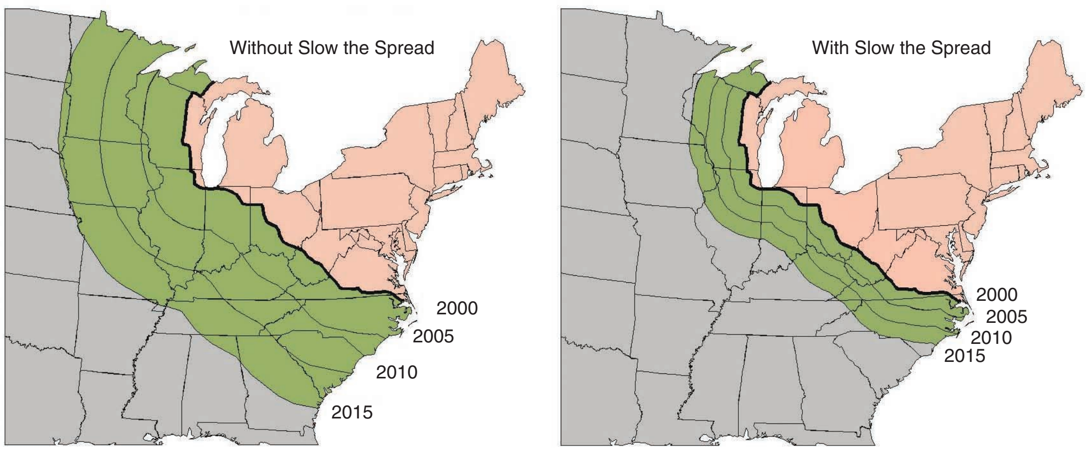


Figure 6. **Projected gypsy moth spread with and without the Slow the Spread project.**

• Data from 80,000 pheromone-baited traps deployed in grids across the 55-million-acre project area are used for pretreatment detection and delineation, to run the computer algorithm, and for posttreatment evaluations (see "Slow the Spread: How It Works"). Surveying with traps is effective and inexpensive and has replaced traditional egg mass surveys, which are labor intensive and too expensive to use in a large-scale project.

• Slow the Spread is technology-based and data-intensive. Integration of the multistate effort has been facilitated by development of database standards, computer algorithms, and immediate data availability over the Internet (www.ento.vt.edu/STS). The database and results of analyses are updated weekly. Development of automated data processing and map posting has been a key element to this rapid turnaround of data.

• Development of mating disruption as an efficacious, target-specific tactic to control gypsy moth has been a key element to the success of Slow the Spread. Aerial applications of pheromone flakes that disrupt mating are used in most of the low-density colonies that are typically found in the Slow the spread area (Liebhold and McManus 1999). Moderate-density populations are sometimes treated using aerial applications of *Bacillus thuringiensis* or diflubenzuron.

• Quantitative evaluations have been developed for all actions taken in the project and are conducted annually.

• Public access to all data, actions, and results is available at the project's website (www.ento.sts.edu/STS).

The success of the Slow the Spread strategy has been demonstrated in several ways. First, the rate of spread was reduced by more than 50 percent in the Appalachian Mountains when treatment of isolated colonies in the transition area was implemented beginning with the Appalachian Integrated Pest Management project and continuing in the Slow the Spread project. Preliminary results indicate similar decreases in spread rates elsewhere in the national project. Second, most treatments have been successful

(Sharov et al., in review), and most of the colonies treated in the project never appear again. Treatment impacts may be enhanced due to reduced mating success of females in low-density populations (Sharov et al. 1995). If gypsy moth populations are suppressed below the density threshold that supports mating and population growth, then populations may go extinct without further intervention.

Third, there is a strong scientific foundation to the strategy implemented in Slow the Spread, and model predictions match well with actual project results (Sharov and Liebhold 1998). USDA expects that integration of the strategy into the national gypsy moth management program will hold spread rates of this exotic pest at less than 6 miles per year and protect thousands of square miles from becoming newly infested each year. Given the success of the project and the various technical and organizational innovations, the same general strategy could be applied to some other established alien pest species.

Literature Cited

LEONARD, D.S., and A.A. SHAROV. 1995. Slow the Spread project update: Developing a process for evaluation. In *Proceedings, US Department of Agriculture Interagency Gypsy Moth Research Forum 1995*, eds. L.C. Fosbroke and K.W. Gottschalk, 82–85. General Technical Report NE-213. Washington, DC: USDA Forest Service.

LEUSCHNER, W.A., J.A. YOUNG, S.A. WALDEN, and F.W. RAVLIN. 1996. Potential benefits of slowing the gypsy moth's spread. *Southern Journal of Applied Forestry* 20:65–73.

LIEBHOLD, A., and M. MCMANUS. 1999. The evolving use of insecticides in gypsy moth management. *Journal of Forestry* 97(3):20–23.

LIEBHOLD, A., V. MASTRO, and P.W. SCHAEFER. 1989. Learning from the legacy of Leopold Trouvelot. *Bulletin of the Entomological Society of America* 35:20–21.

LIEBHOLD, A.M., J. HALVERSON, and G. ELMES. 1992. Quantitative analysis of the invasion of gypsy moth in North America. *Journal of Biogeography* 19:513–20.

LIEBHOLD, A.M., K.W. GOTTSCHALK, D.A. MASON, and R.R. BUSH. 1997. Forest susceptibility to the gypsy moth. *Journal of Forestry* 95(5):20–24.

MCFADDEN, M.W., and M.E. MCMANUS. 1991. An insect out of control? The potential for spread and establishment of the gypsy moth in new forest areas in the United States. In *Forest insect guilds: Patterns of interaction with host trees*, eds. Y N. Baranchikov, W.J. Mattson, F.P. Hain, and T.L. Payne, 172–86. General Technical Report NE-153. Washington, DC: USDA Forest Service.

MCMANUS, M.L., and T. MCINTYRE. 1981. Introduction. In *The gypsy moth: Research toward integrated pest management,* eds. C.C. Doane and M.L. McManus, 1–7. Technical Bulletin 1584. Washington, DC: US Department of Agriculture.

REARDON, R.C. 1991. Appalachian gypsy-moth integrated pest-management project. *Forest Ecology and Management* 39:107–12.

REARDON, R.C., D.S. LEONARD, V.C. MASTRO, B.A. LEONHARDT, W. MCLANE, S. TALLEY, K. THORPE, and R. WEBB. 1998. *Using mating disruption to manage gypsy moth: A review*. Report FHTET-98-01. Washington, DC: USDA Forest Service.

SHAROV, A.A., and A.M. LIEBHOLD. 1998. Model of slowing the spread of gypsy moth *(Lepidoptera: Lymantriidae)* with a barrier zone. *Ecological Applications* 8:1170–79.

SHAROV, A.A., A.M. LIEBHOLD, and F.W. RAVLIN. 1995. Prediction of gypsy moth *(Lepidoptera: Lymantriidae)* mating success from pheromone trap counts. *Environmental Entomology* 24:1239–44.

SHAROV, A.A., D. LEONARD, A.M. LIEBHOLD, and N. CLEMENS. In review. Evaluation of preventive treatments in low-density gypsy moth populations. *Journal of Economic Entomology.*

US DEPARTMENT OF AGRICULTURE. 1995. *Gypsy moth management in the United States: A cooperative approach. Final Environmental Impact Statement*. Washington, DC.

Alexei A. Sharov (sharov@vt.edu) is research scientist and E. Anderson Roberts is senior research associate, Department of Entomology, Virginia Polytechnic Institute and State University, Price Hall, Blacksburg, VA 24061; Donna Leonard is manager, Slow the Spread, USDA Forest Service, Forest Health Protection, Asheville, North Carolina; Andrew M. Liebhold is research entomologist, USDA Forest Service, Northeastern Forest Experiment Station, Morgantown, West Virginia; Willard Dickerson is director, Plant Industry Division, North Carolina Department of Agriculture and Consumer Services, Raleigh.