ting liquid fungicides in elm trees for the control of Dutch elm disease and other disorders. **In** Methods for Evaluating Pesticides for Control of Plant Pathogens, K.D. Hickey, Ed., American Phytopathological Society, St. Paul, MN, pp. 261-265.

Stipes, R.J., R. Cu, J.L. Ratliff, T.D. Myers, T.B. Brenneman, B.J. Stipes, R.L. Fralin and S.V. Overton. 1987. *Comparative translocation of Arbotect injected via root flares or shallow bole pits in large American elms.* Phytopathology 77:990. (Abstr.)

Traux, P.A. and R.J. Stipes. 1981. Comparative systemic distribution of Arbotect 20S, Vanguard, Lignasan BLP, Bloc and nuarimol in *Ulmus americana.*

Zimmermann, M.H. and C.L. Brown. 1971. Trees: Structure and Function. Springer-Verlag, New York. 336 pp.

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AN URBAN FOREST INTEGRATED PEST MANAGEMENT PROGRAM FOR GYSPY MOTH: AN EXAMPLE

by Mark Ticehurst and Stuart Finley[1]

Abstract. An integrated pest management program for gypsy moth was designed, implemented, and evaluated in the urban forested community of Lake Barcroft, Falls Church, VA. The objectives of the program were to reduce or prevent defoliation, tree mortality, and nuisance associated with dense populations of gypsy moth. Intensive surveys of larvae, pupae, adult males, and egg masses were evaluated in 100 sites. Further evaluations were made of eggs per mass, egg viability, parasitism of eggs, larvae, and pupae, sex ratio of pupae, and tree susceptibility to infestation and defoliation. *Bacillus thuringiensis* and Luretape® were selectively applied. The larval parasites, *Cotesia melanoscelus* and *Glyptapanteles flavicoxis* were released throughout the Program area. The objectives were achieved. The cost was approximately $20. per residential lot per year.

Key words: Gypsy moth, integrated pest management, urban forest, implementation, evaluation.

The gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae) is considered to be a forest pest throughout much of the world. The vast majority of the 1.3 million acres defoliated by the gypsy moth in the United States in 1987 (1) occurred on uninhabited forest lands. The economic impact of this pest is primarily recognized in terms of tree mortality. Tree mortality associated with gypsy moth defoliation during a three-year period on 690,000 acres in Pennsylvania was $104.2 million (4).

Currently the gypsy moth is invading the urban forests in the megapolis surrounding Washington, DC. The impact of this defoliator in this area is like-

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ly to be more acute than in the uninhabited forest. The American Forestry Association placed the value of an urban tree at $57,151. Trees can increase real estate values as much as 20% (5). Other impacts on aesthetics and personal well-being are more difficult to assess but are likely to be more intense in the urban forest. Consequently, pest management objectives, thresholds, and the cost/benefit analysis in the urban setting may differ from management of the gypsy moth in the uninhabited forest.

The purpose of this program was to establish, implement, and evaluate an intensive gypsy moth integrated pest management (IPM) system in an urban forested community. The objectives of the IPM program were to prevent or reduce defoliation, tree mortality, and the nuisance associated with dense populations of gypsy moth. The format of this program and presentation of the information is similar to that described by Reardon et al. (6) for the "Maryland IPM Program" in relatively uninhabited forests.

Program Structure

This urban forest IPM program is a cooperative effort among the National Gypsy Moth Management Group, Inc. (NGMMG), the Lake Barcroft Watershed Improvement District (LBWID), and the Fairfax County, Virginia, Gypsy Moth Office (FGMO). The NGMMG is a private organization which specializes in all aspects of gypsy moth management and research, including the commercial production of parasites. This organization designed and evaluated the IPM program, and also implemented several procedures.

Community leaders with the LBWID assisted in defining program objectives. The LBWID newsletter was used as the vehicle to disseminate program information to residents in the community. Most of the funding for IPM program was provided by the LBWID.

The FGMO has responsibility for gypsy moth throughout Fairfax County, and cooperates with the Virginia Department of Agriculture and Consumer Services in the implementation and funding of several gypsy moth projects. In this Urban Forest IPM Program survey and monitoring data, as well as management recommendations, were provided to the FGMO for the purpose of coordination and implementation.

Program area. The program was initiated in the urban forested community of Lake Barcroft in March 1986. Lake Barcroft is about 850 acres in area, envelopes a 140 acre lake, is a 15 minute drive from the White House, and situated in Falls Church, Virginia. Development of the community began in 1950. Currently, 1000 homes exist on 1020 lots. The area is composed of mixed hardwoods, predominantly oak species, with intermittent groves of naturally occurring tulip poplar. Ornamental plantings of several deciduous and coniferous vegetation occur throughout the community. Overall, the urban forest at Lake Barcroft is very susceptible (2) to gypsy moth infestation and defoliation.

The community exists along the southern defoliation front of the gypsy moth infestation in North America. No defoliation, tree mortality, or severe nuisance associated with the gypsy moth had been observed in this or adjacent communities prior to this time. However, dense pest populations and defoliation in nearby Alexandria, Virginia, indicated an imminent threat.

Program components. The program was composed of the following components:

—Public information and education
—Intensive biological survey and monitoring
—Decision making
—Intervention
—Evaluation

Public Information and Education. Residents of Lake Barcroft were informed of biological facts, ecological relationships, program time tables, and other program details through public meetings and a month newsletter. The newsletter was published by LBWID. Questions, concerns, and suggestions from residents were received by a LBWID coordinator and directed to the NGMMG. Additional information was provided by the FGMO through the State University Extension Service.

Intensive Biological Survey and Monitoring. The purpose of this effort was to define the abundance, condition, and distribution of the gypsy moth infestation at Lake Barcroft. Surveys were conducted in 100 of the 1020 lots. Sites were determined by overlaying a map of lots with a regular grid of lines. An element of bias was included in the selection of sites. Lots without

susceptible trees were excluded. Lots closest to the excluded sites and with susceptible trees were then selected.

The following surveys were conducted:

1. Larval and pupal density. One burlap band was installed around the circumference of a dominant or codominant oak tree at breast height at each survey site. All larvae and pupae on or under the bands were counted at weekly intervals.

2. Parasite evaluation. All larvae and pupae observed above were collected and individually reared in 1 oz cups at the NGMMG laboratory. Parasites reared from these individuals were identified and recorded.

3. Sex ratio. All healthy gypsy moth were reared to the adult stage. Males and females were recorded.

4. Male moth density. One male trap was installed at each survey site. The number of males in each trap was determined in August following the cessation of flight activity.

5. Egg mass density. Surveys for egg masses were conducted in two plots about 1/40th acre each at each survey site. Surveys were taken in September through October.

6. Egg density. The number of eggs per egg mass and parasitism (%) and viability (%) of eggs was determined for ca. 10% of all egg masses observed.

7. Tree susceptibility. The susceptibility of trees to infestation and defoliation was characterized by criteria described by Houston and Valentine (2). Each lot is in the process of being evaluated.

The NGMMG was responsible for site selection and the collection and analysis of data.

Decision Making. Survey results were presented to the LBWID for review and discussion in October. A prognosis was developed by the NGMMG to predict the impact of the gypsy moth on the community in terms of defoliation, tree mortality, and nuisance for the following season. Scenarios were developed with the implementation of various IPM tactics. Resultant impacts and costs were predicted. Recommendations were designed which were consistent with program objectives and which were environmentally and economically acceptable.

Program objectives in the urban forest dictated preventative actions. When egg mass density was greater than 20 per acre, eggs per mass greater than 500, and egg viability greater than 70%, aerial application of an insecticide was recommended as one component. In this situation the treatment was designed to reduce population growth, reduce the potential for dispersal, and permit growth of natural enemy populations.

Much emphasis was put on the establishment of natural enemies. Relatively low levels of natural enemies exist along the leading front of the infestation. Parasites are considered to be key factors which influence of the regulation of gypsy moth populations, although some controversy exists as to their specific role (3). Consequently, efforts to enhance the establishment of natural enemies were attempted at all population levels in this urban forest.

Intervention. Mechanical and biological techniques were employed in the Urban Forest IPM Program.

1. The mechanical techniques included the physical removal and destruction of all gypsy moth life stages. This procedure would be completely impractical and insignificant in the uninhabited forest. Burlap bands were available to all residents. Residents were encouraged to destroy all larvae and pupae. Egg masses were collected and destroyed from November through March following the egg mass surveys in early fall. Residents were not encouraged to climb trees. Egg masses were removed by LBWID staff upon request.

2. The biological tools included the application of microbial insecticides, release of gypsy moth parasites, and application of male moth attractants.

a. The microbial insecticide, *Bacillus thuringiensis* (Bt), was applied when egg mass populations exceeded 20 per acre. This bacterium is a common component of several government and private gypsy moth programs. Approximately 80 acres were sprayed with Bt in 1986 and 100 acres in 1987.

b. Three species of parasites were released and a fourth is expected in 1988. *Cotesia melanoscela, Glyptapanteles flavicoxis,* and *Meteorus pulchricornis,* all tiny braconid wasps, attack the larval stage. *Ooencyrtus kuvanae,* an

even smaller encyrtid wasp, parasitizes the eggs. Releases were made at most survey sites. Approximately 31,000 parasites were released in 1986 and 135,000 in 1987. This may be the most intensive release program on record.

c. Luretape® , a tape which contains a synthetic formulation of disparlure, was applied to 80 acres in 1986 following the aerial application of Bt. Disparlure is emitted from the tape and disrupts the ability of the male moths to find and mate with females. Schwalbe et al. (7) observed that disparlure is most effective at low gypsy moth populations.

Evaluation. This Urban Forest IPM Program was evaluated in terms of its effectiveness and cost during the first two years of operation.

All program objectives were achieved; no defoliation, tree mortality, or nuisance associated with the gypsy moth was detected in Lake Barcroft in 1986 or 1987. The egg mass density in Lake Barcroft for 1988 is two per acre. Compare this with 1,423 and 1,229 egg masses per acre in the two immediately adjacent communities of Sleepy Hollow Woods and Ravenwood.

The cost for the Urban Forest IPM Program was $20,000 each year for 1986 and 1987. Homeowners were assessed about $20 per year. Most of this fee was paid to the NGMMG for program design, collection and analysis of data, coordination with government agencies, and for the production and release of gypsy moth parasites.

Summary

The management of the gypsy moth in the urban forest appears to be technically, environmentally, and economically feasible. Preliminary results indicate that the Urban Forest IPM Program achieved the program objectives of preventing defoliation, tree mortality, and nuisance with primarily biological approaches. Many immediately adjacent communities are scheduled to be treated with chemical insecticides in 1988 by the Virginia Department of Agriculture and Consumer Services, in cooperation with the FGMO. Chemicals were proposed because gypsy moth population levels exceeded limits where microbial insecticides, including Bt, are effective. No insecticidal treatment is recommended for the program area in 1988.

The long-term success of the Urban Forest IPM Program will be determined at a later time. However, preliminary evidence suggests that gyspy moth management at low levels with biological approaches can be effective.

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Literature Cited

1. Anonymous. 1987. *Gypsy moth defoliated areas in the USA.* Gypsy Moth News November (15): 1.
2. Houston, D.R. and H.T. Valentine. 1977. *Comparing and predicting forest stand susceptibility to gypsy moth.* Can. J. For. Res. 7: 447-461.
3. Leonard, D.E. 1981. **In** The Gypsy Moth: Research Toward Integrated Pest Management (C.C. Doane and M.L. McManus, eds.), pp. 9-29. U.S. Dept. Agric. Tech. Bull. 1584, 757 pp.
4. Quimby, J.W. 1986. Impact of gypsy moth defoliation on forest stands. 1986 Gypsy Moth Review. December. pp. 186-193.
5. Payne, B.R., W.B. White, R.E. McCoy, and R.R. McNichols. 1973. Economic analysis of the gypsy moth problem in the northeast. II. Applied to residential property. USDA FS Res. Paper NE 285. 6 pp.
6. Reardon, R., M. McManus, D. Kolodny-Hirsch, R. Tichenor, M. Raupp, C. Schwalbe, R. Webb, and P. Meckley. 1987. *Development and implementation of a gypsy moth integrated pest management program.* J. Arboric. 13(9): 209-216.
7. Schwalbe, C.P., E.C. Paszek, B.A. Bierl-Leonhardt, and J.R. Plinamer. 1983. *Description of gypsy moth (Lepidoptera: Lymantriidae) mating with disparlure.* J. Econ. Entomol. 76: 841-844.

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