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ALTERNATIVES TO THE GYPSY MOTH ERADICATION PROGRAM IN MICHIGAN[1]

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ABSTRACT

Responding to questions of what the gypsy moth, *Porthetria dispar*, would do in Michigan forests, a computer simulation model was constructed. The model consisted of three subunits: a submodel of gypsy moth population dynamics, a submodel of forest growth and a submodel of tree defoliation and mortality. Several different policies were simulated for an 80 year period. The eradication policy now employed in Michigan failed due to survival of small portions of the population. Allowing the gypsy moth to become established in Michigan forests and then responding by spraying when defoliation is visible provided a policy with the least economic and environmental cost.

The gypsy moth, *Porthetria dispar* (Linnaeus) (Lepidoptera: Lymantriidae) is not yet a serious pest in Michigan forests. Pheromone trappings in 1973, however, indicated that males were present in 22 counties and that at least 600,000 acres in Michigan were lightly infested (Wallner, 1974). Dense populations such as those experienced in East Coast forests have not yet been observed. In fact, defoliation has not yet been discovered. If outbreaks should occur in Michigan, however, action may have to be taken to preserve oak forests for their high recreational value as well as for the harvestable products they represent.

Control of the insect pest has, in the past, centered around chemical control means. Eradication has been attempted in Michigan during two periods, 1954-1967 and 1973-present. Either low density survival or subsequent reinfestation has left us with widespread, low density populations. The present control strategy of eradication has probably slowed the spread of the gypsy moth, but is only postponing a solution to the problem.

Since 1973, approximately 73,000 acres have been treated in attempts to eradicate the gypsy moth from Michgian. Future plans call for treating larger acreages yearly until the job is completed. For such a program to be successful two assumptions must be met: (1) 100% mortality must be obtained throughout the acreages sprayed and (2) no additional gypsy moths can be introduced from outside the state. Many experienced entomologists feel such assumptions cannot be met, yet Michigan, with its millions of acres of mixed oak forests, is not willing to chance allowing gypsy moth populations to become established because the results are unknown.

Response to resource management problems of this nature has and continues to be largely trial-and-error. The potential for large-scale error is far greater, however, than the potential for problem solution. As Holling et al. (1976) have stated, "The past history of resource management, and indeed applied sciences in general has been essentially one of trial-and-error approaches to the unknown . . . but we now find increasingly that the extensive and intensive nature of our trials can generate errors larger and more costly than society can afford."

METHODS

One alternative to trial-and-error is computer simulation to examine a range of alternatives without risk. Computer simulation, modeling, and the use of system analysis

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techniques has recently come into increasing use in ecological problems (Conway, 1976; Ruesink, 1975). Benefits of the modeling technique are not only the finished model, but also useful information derived from the methodology. The initial phases of modeling require a pooling and organization of existing information relevant to the study. Perhaps even more importantly, data holes are indicated where further research is needed.

Alternative control strategies may be simulated in order to compare short and long-range consequences. User-interaction models can be useful learning and teaching tools in which the outcomes of decision alternatives may be analyzed quickly and efficiently. Models also lend themselves to graphic and visual aids useful in public relations displays, discussions, and conflict resolution.

With all of the uses of models, of whatever form, there are limitations to the modeling technique. Models are only as accurate and as complete as the data base upon which they are built. Conversely, models which accurately represent complex ecological systems are usually very difficult to analyze and comprehend (not to mention build) because of their complexity.

A schematic diagram of the model is given in Figure 1. The model is composed of three sub-units: a submodel of gypsy moth population dynamics, a submodel of forest growth, and a third submodel interacting with the first two in which tree defoliation and mortality caused by the gypsy moth are simulated.

Any modeling effort must begin with a number of basic assumptions upon which model validity and generality are based. In building the model, we tried to maintain model generality. Instead of accurately modeling within-year fluctuations of the gypsy moth we attempted to capture year to year population dynamics as they influence forest growth and mortality.

The site modeling technique of Holling et al. (1976) was used to model small sub-units of a typical Michigan forest which later were combined to represent the whole forest area of interest. We chose as our site size a 1 square mile (640 acres) area of forest. Trees within the site were divided into susceptible (mainly oak varieties) and non-susceptible species. Trees under 20 years of age were assumed somewhat resilient to gypsy moth attack because of their rapid growth rate (this is not a bad assumption since natural mortality due to crowding is high for this age group). The equation of Gingrich

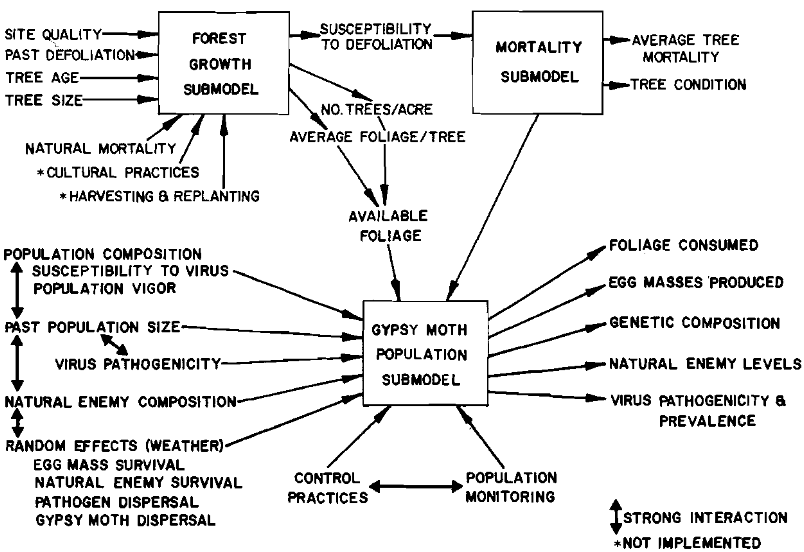

Fig. 1. Submodel interactions for the gypsy moth/forest simulation model.

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(1971) was used to compute yearly increments in tree growth from which tree leaf surface was calculated. Forest sites were sub-classified as to site quality (poor-medium-good) using the criteria of Gysel and Arend (1953). Poor sites were assumed to support less trees/unit area and to be less resilient to defoliation.

In building an accurate population model for the gypsy moth in Michigan, we were faced with a nearly impossible task. At present, the only information available from Michigan on gypsy moth population dynamics is what little we know from yearly pheromone trap catches. Some life table data on both low level stable populations from Eastford, Connecticut, (Campbell, 1969, 1976) and violently fluctuating populations from Glenville, New York, (Campbell, 1976) are available. However, using statistics from two widely separated ecological regions for use in a third region can lead to somewhat invalid results. We therefore decided that instead of precisely modeling population dynamics, we would model the stability properties of the gypsy moth-forest ecosystem. We attempted to mimic the stability behavior of this system by allowing the gypsy moth population to oscillate between an observed low stability region and a high level outbreak (Campbell, 1976).

As diagrammed in Figure 1, the foliage consumed by the gypsy moth divided by the available foliage gives the percent defoliation used to determine tree condition and mortality. Mortality tables (Campbell and Valentine, 1972) were combined with site quality criteria (Gysel and Arend, 1953) in determining mortality figures. Past defoliation history was also taken into consideration. Additional details are available from the authors.

RESULTS

Results of several simulations are plotted in Figure 2. Figure 2B depicts gypsy moth population fluctuation for a poor site (most susceptible to defoliation) with an initial gypsy moth infestation of 40 adults per acre (50:50 sex ratio; 40/acre was chosen as the low level equilibrium density). The model was initiated with trees of uniform age (20 years) and 60% stocking (poor sites). Gypsy moth population levels are represented on the y-axis as the logarithm of actual levels.

As seen in Figure 2B, the gypsy moth population erupts from the low equilibrium level (40/acre = 1.60 on graph) roughly once every 10 years. Peak outbreak levels average around 10,000 moths/acre with outbreaks lasting about four years. Note in years 51 and 76 the occurrence of "mini outbreaks" which were initially controlled by gypsy moth natural enemies. Figure 2A shows tree defoliation corresponding to the population fluctuations in Figure 2B. Tree mortality occurred after several successive years of high defoliation. Near year 64, high cumulative tree mortality resulted in constant 100% defoliation of remaining trees.

Figures 2C-2F show population fluctuations for the same 80 years when gypsy moth

Table 1. Simulations depicted in this study.

Figure	Spray Decision Threshold	Number of Sprays Required	Percent Spray Efficacy	Percent Total Tree Mortality[a]
2a	no spray	–	–	100
2b[b]	no spray	–	–	100
2c	50/acre	12	65	19.52
2d	50/acre	14	95	0.00
2e	1000/acre	6	65	33.92
2f	1000/acre	7	95	5.85
2g	years 1-20	20	99	100

[a]excluded natural mortality
[b]defoliation curve

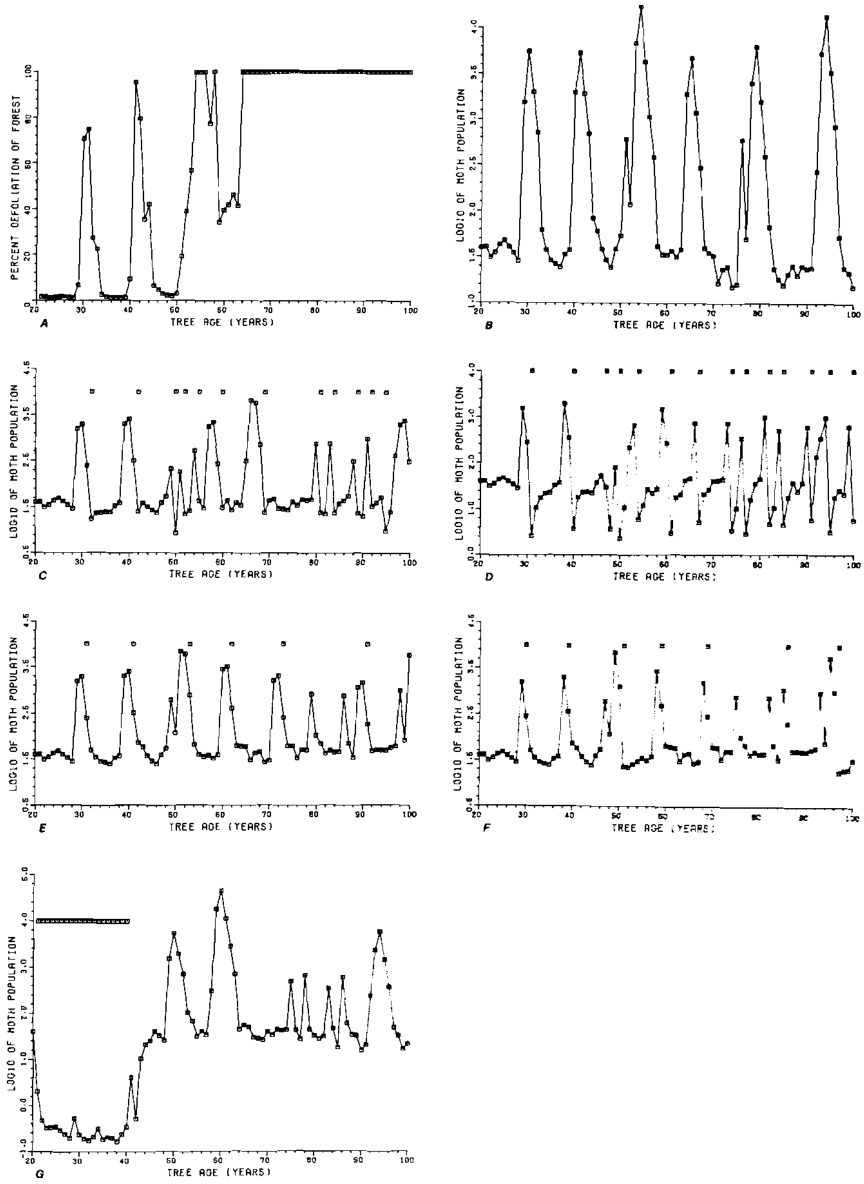

Fig. 2. Results of several different simulations: (A) percent defoliation when gypsy moth is not controlled, (B) population fluctuations of uncontrolled gypsy moth population, (C) population controlled with 65% efficacy when density exceeds 50 adults/acre, (D) population controlled with 95% efficacy when density exceeds 50 adults/acre, (E) population controlled with 65% efficacy when density exceeds 1000 adults/acre, (F) control imposed with 95% efficacy when density exceeds 1000 adults/acre; (G) eradiation policy, 99% mortality achieved each year for the first 20 years, controls relaxed thereafter.

control practices were added. Five contrasting control policies were simulated representing tactics available with current technology.

Two tactics represent responses to slight rises in endemic populations above a low-level equilibrium point. We presumed that such rises, although not detectable by observing defoliation, could be indicated using pheromone traps. The slight rise would "release" the populations from natural enemies enough for the population to reach outbreak level within one to three years. Figure 2C represents a control response using a microbial insecticide such as *Bacillus thuringiensis.* We presumed such a tactic would impose an average of 65% mortality. Figure 2D, by contrast, represents a control response using a chemical insecticide that will result in a mean mortality rate of 95%. In each case, population levels of adult moths were sampled at the end of each development cycle yearly. Such information was used to determine whether a spray should be applied the next year. Population levels (at the end of year of X-1) above the spray decision threshold determined spray action (at the beginning of the year X season). Sprays were timed to affect instars I-III.

Two additional tactics represent responses after population rises sufficient enough for defoliation to be noticeable. Again, the sprays used are (Figure 2E) a microbial insecticide and (Figure 2F) a chemical insecticide. The procedure for determining spray action was similar to that depicted in Figures 2C and 2D except the population density required for response was higher.

Figure 2G shows population level fluctuations for the model run where a spray of 99% efficacy is applied for the first 20 model years regardless of population levels. This simulation represents an eradication policy using a material that would affect 99% mortality, such as a chemical insecticide.

DISCUSSION

As expected, gypsy moth populations, if uncontrolled, result in extreme tree mortality on poorer sites. When spray decisions are based on population levels in the previous year, it is seen that waiting until the population is truly in an outbreak results in fewer total sprays and reasonable tree survival. The results of our "eradication" run are quite revealing. Although model validity can be questioned at the low population levels present in this simulation, our model does suggest that if survivors are left from continuous spraying, it will be only a matter of time before outbreak populations are again present.

Based on the range of tactics we have examined, aside from no control, the eradication policy is perhaps the worst choice available. The eradication approach requires an intensive spray effort, without regard to gypsy moth population density, that inevitably fails. The cost, both economically and environmentally, is the maximum for the tactics examined. Once failure is admitted (likely much earlier in the real world due to taxpayer pressure than was represented by our simulations) another tactic must be selected. A very high economic and environmental price will have already been paid at that point.

The best tactic is given in the simulation represented by Figure 2F. This policy uses a minimum of sprays over an 80 year period and results in very slight tree mortality. The environmental and economic cost is minimum. This does, however, allow the gypsy moth to become established in Michigan forests.

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