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Coping with the Gypsy Moth on New Frontiers of Infestation

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*ABSTRACT. Forest managers on new frontiers of infestation are searching for better ways to cope with the gypsy moth (*Lymantria dispar*). Presented here are information and guidelines for remedial action to minimize future losses. Methods for assessing potential stand defoliation (susceptibility) and mortality (vulnerability), monitoring insect populations, and selecting action alternatives are discussed. With due consideration of management objectives, we address the primary concerns of managers who lack previous experience with the pest.*

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It is hard to find two forest managers who share identical concerns about the gypsy moth. There's the district forester in Pennsylvania who worries about how, where, and when to salvage dead timber left in the wake of a 2- to 3-year outbreak. In Virginia, the supervisor of a park frets over potential effects on a delicate plant community. And a municipal watershed manager in New Jersey wonders about possible consequences to water yields and quality. Problems in areas threatened by the gypsy moth are as varied as the perspectives of owners and managers of the millions of acres of hardwood forest in the East. But no matter who you are or what your perspective, your course of action for coping with gypsy moth will be guided by your understanding of how much tree defoliation may occur, what mortality levels are expected, how the expected damage will affect management objectives, and what action alternatives are at your disposal (Figure 1).

Infestations in the 1970s and 1980s were monitored closely in several areas. Information about the impact of gypsy moth has been assembled, and rule-of-thumb guides for predicting tree defoliation and subsequent mortality have been developed. Selected plot variables, from a major study area, provide a general description of the preoutbreak condition of the infested stands:

Item	Mean	Range
Basal area per acre (ft^2)	90	15–190
Basal area in oaks (%)	68	0–100
Average dbh (in.)	7.4	3.8–13.4
Site index (ft—upland oaks)	61	25–100
Stand Age (yr)	71	15–175
Stocking (%)	81	20–158
Slope (%)	24	0–67
Elevation (ft)	1,535	575–2,450
Volume per acre (bf)	5,500	0–28,200

These characteristics are fairly typical of millions of acres of susceptible forest in West Virginia, Virginia, Kentucky, North Carolina, and other new frontiers of infestation.

The rule-of-thumb label is appropriate for the guides since they by no means account for all of the variation in damage caused by the gypsy moth. What actually happens in the forest will be affected by many interrelated factors such as the frequency and intensity of defoliation, individual-tree stress, the action of secondary organisms such as shoestring root rot and the two-lined chestnut borer, the influence of

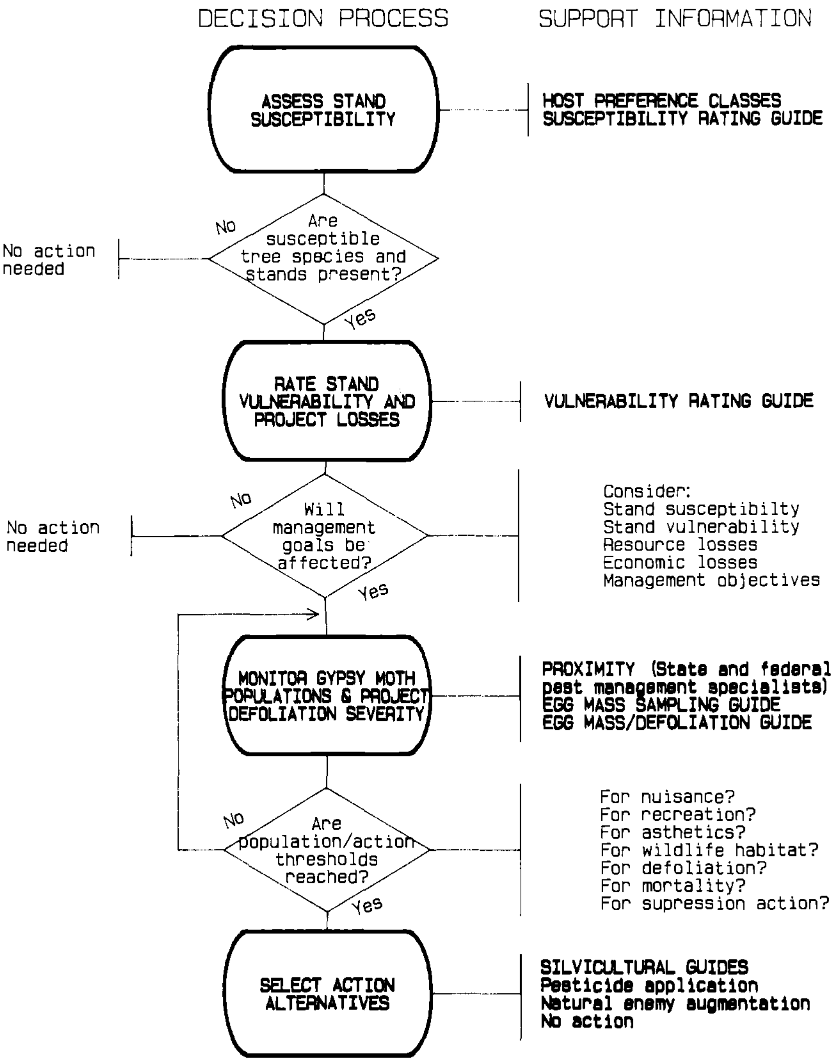


Figure 1. Pathway to better decisions for coping with gypsy moth.

gypsy moth parasites and predators, the effectiveness of control measures, and certainly weather conditions. Most of these factors are in themselves difficult to predict. Although it is not perfect, the following information gives managers an indication of what to expect from gypsy moth infestations. It should remove some uncertainty and lead to improved management decisions as the pest advances into new areas.

ASSESSING POTENTIAL STAND DEFOLIATION (SUSCEPTIBILITY)

To suffer loss from gypsy moth, a tree or stand of trees must first be defoliated. All tree species and forest stands are not equally susceptible. Assessments of potential defoliation require knowledge about feeding preferences and forest stand characteristics.

Host Preferences

Food preferences of the gypsy moth provide a key indicator of potential defoliation. Several studies of host preference have been reported (for example, Mosher 1915, Elkinton 1982, Gansner and Herrick 1985). Vegetation can be sorted into four food preference classes, ranging from Class I—species that are favored as food by gypsy moth larvae (including oaks, aspen, birch, and sweetgum)—through Class IV—unfavored species that are rarely fed upon (including ash, cedar, dogwood, locust, and yellow-poplar) (Table 1).

Rating Stand Susceptibility

Herrick and Gansner (1986) developed a procedure that uses species composition, tree size, and crown condition to rate the susceptibility of forest stands. With this model, stands at risk of heavy defoliation can be separated from those where defoliation is likely to be light. For example, stands with high basal area in oak species, especially black and chestnut oaks, have potential for heavy defoliation (Figure 2).

Table 1. Breakdown of woody plant species by gypsy moth food preference (susceptibility) classes.

Class I: Species that are favored food for gypsy moth larvae during all larval stages.
Overstory: apple, basswood (American linden), bigtooth and quaking aspen, gray, paper (white), and river birch, boxelder, larch (tamarack), American mountain-ash, all oak species, Lombardy poplar, sweetgum, willow.
Understory: alder, hawthorn, hazelnut, eastern hophornbeam, serviceberry, all sumac species, witch-hazel.
Class II: Species that are favored food for gypsy moth larvae after the earlier larval stages
Overstory: chestnut, eastern hemlock, all pine species, all spruce species.
Class III: Nonpreferred species fed upon by later larval stages when preferred foliage is not available.
Overstory: American beech; black, sweet, and yellow birch; blackgum (tupelo); Ohio and yellow buckeye; butternut; sweet and black cherry; eastern cottonwood; cucumbertree; American and slippery elm; hackberry; all hickory species; Norway, red, silver, and sugar maple; pear; silver poplar; sassafras; black walnut.
Understory: blueberries, pin and choke cherry, American hornbeam, paw paw, persimmon, redbud, sourwood, sweetfern.
Class IV: Unfavored species that are rarely fed upon.
Overstory: all ash species, baldcypress, northern catalpa, eastern redcedar, balsam and Fraser fir, American holly, horsechestnut, Kentucky coffeetree, blacklocust and honeylocust, mulberry, sycamore, tuliptree (yellow-poplar).
Understory: all azalea species, dogwood, elderberry, grape, greenbrier, juniper, mountain and striped maple, rhododendron, all rubus species, sheep and mountain laurel, spicebush, sarsaparilla, all Viburnum species.

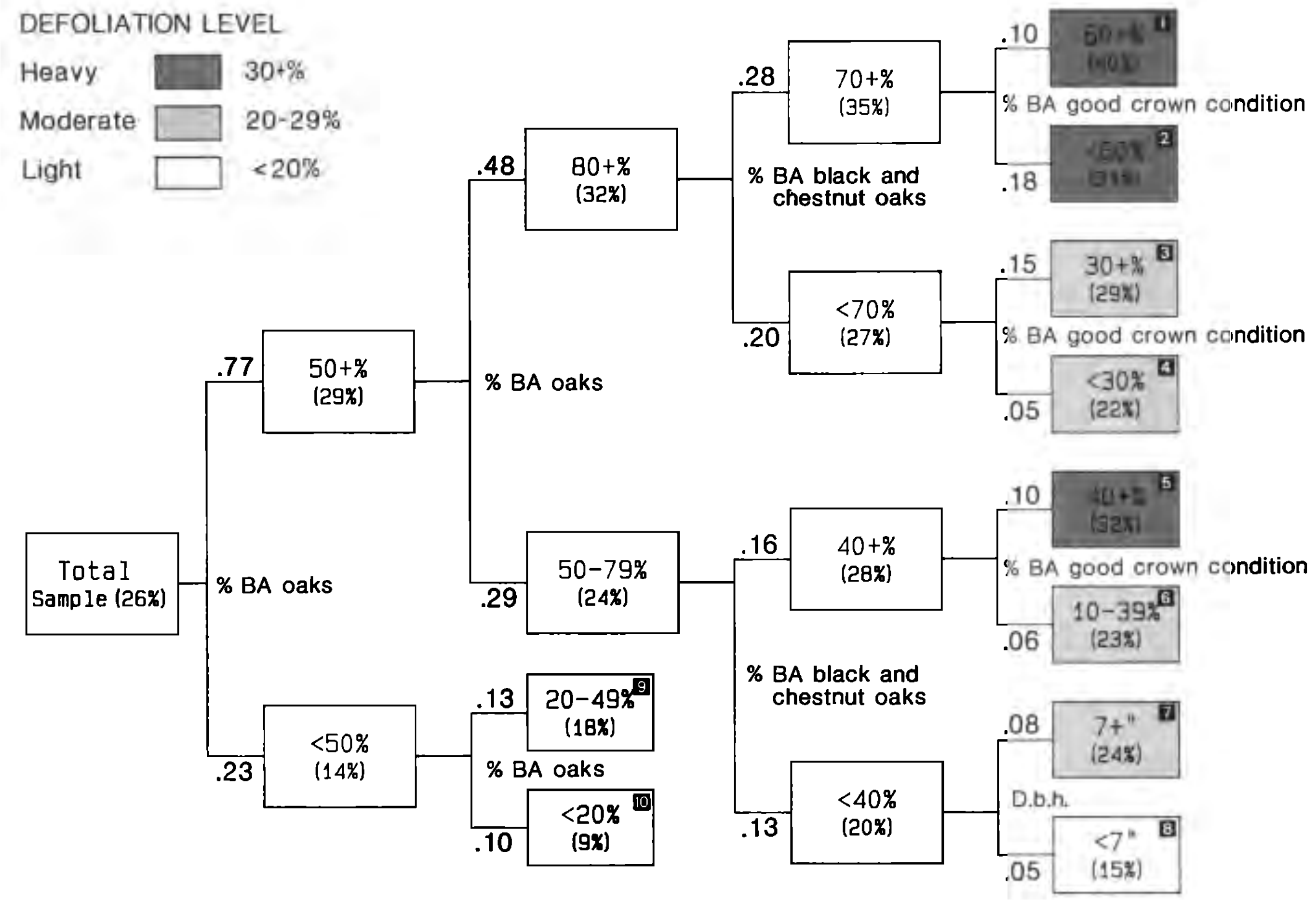


Figure 2. Guide for estimating gypsy moth defoliation potential. Any hardwood stand can be assigned to a defoliation group on the basis of characteristics of the stand. Three-year average defoliation percentages in parentheses from central Pennsylvania sample that is in that group.

ASSESSING POTENTIAL TREE MORTALITY (VULNERABILITY)

As a general rule, gypsy moth infestations result in mortality losses of less than 15% of total basal area. Losses of 15 to 35% are not uncommon, and occasionally levels greater than 50% are reported. Many interrelated factors play a role in determining tree survival following gypsy moth defoliation. The survival of host trees depends on the intensity, distribution, and frequency of defoliation; whether trees refoliate; tree condition prior to defoliation and site factors that affect this condition; environmental conditions immediately before and after defoliation; and extent of disease or other insect invasions. A general understanding of how these agents work can help forest managers appraise probable mortality in defoliated forests.

Defoliation Intensity

Gypsy moth defoliation is commonly classed as light, moderate, or heavy. The term "light defoliation" describes conditions where less than 30% of the foliage has been removed. Stand defoliation in this class cannot ordinarily be detected during routine aerial surveys. A single light defoliation usually causes little damage to trees (Campbell and Valentine 1972). Stands where 30 to 60% of the foliage is removed fall within the "moderate defoliation" class. Damage to these trees will depend primarily on the specific amount of defoliation, and tree vigor before defoliation and during the recovery period. Removal of more than 60% of the foliage places a stand in the "heavy defoliation" class. When defoliated to this extent, trees often refoliate during the same season. When this occurs, a heavy demand is placed on food reserves. Thus, a tree that refoliates can remain under considerable stress during the following weeks and become very vulnerable to other mortality agents.

Defoliation Distribution

Gypsy moths begin feeding on preferred host species within a stand before moving on to less preferred tree species. For example, a "light defoliation" (averaging less than 30%) in a stand composed entirely of preferred species usually means that less than 30% of the foliage was removed from all crowns in the stand; and all trees are subjected to roughly the same amount of stress. In a mixed species stand, light defoliation could include moderate to heavy defoliation on many preferred trees, while less preferred trees would be only slightly affected. Thus, even a light defoliation in mixed stands might cause a significant shift in species composition if many preferred host species are defoliated, stressed, and subsequently die.

Defoliation Frequency

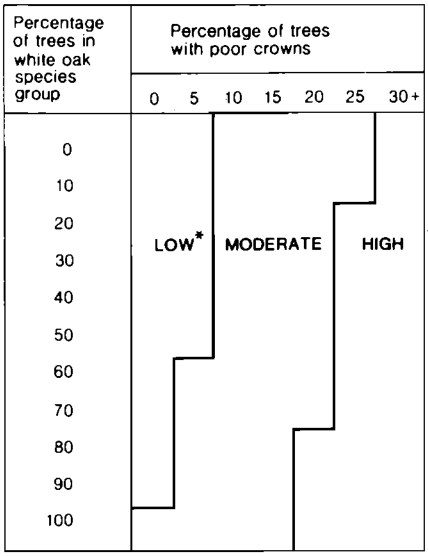
Under normal environmental conditions, a single (even heavy) defoliation does not result in tree mortality (Campbell and Valentine 1972). However, the stress from this defoliation usually weakens a tree and lowers its resistance to mortality in subsequent defoliations. Multiple defoliations have an additive effect and can result in significant loss in timber value.

Tree Condition

Tree vigor prior to defoliation (sometimes expressed in terms of crown condition) has been shown to be significantly related to tree mortality. Low vigor can result from a number of environmental factors; previous attacks from insects and diseases can cause stress, prolonged drought, or excessive moisture, can also have an adverse impact on tree condition. Suppressed trees are especially vulnerable.

Rating Stand Vulnerability

Gansner and Herrick (1984) examined a number of stand and tree characteristics associated with gypsy moth infestation in Pennsylvania and developed a stand vulnerability rating system (Figure 3). The system is based on the percentage of trees in the white oak group (found to be particularly vulnerable) and the percentage of trees with poor crowns (more than 50% dead branches, very thin foliage, reduced leaf size, poor color, or heavy sprouting). Stands with a large percentage of trees with poor crowns and in the white oak species group have a potential for high mortality. Equations underlying development of this guide were used to predict losses in central Pennsylvania. Predicted values were within 2% of actual average loss. Still, these projections are rule-of-thumb estimates; actual mortality in a given situation will depend on the influence of local site and environmental conditions.



*Low Hazard = less than 10% mortality
Moderate hazard = 10-25% mortality
High hazard = more than 25% mortality

Figure 3. Guide for rating risk of forest stand mortality to gypsy moth.

CONSIDERING IMPACT ON MANAGEMENT OBJECTIVES

Decisions about specific preventive or remedial actions depend on individual land management objectives. A timber manager may not care about the expected loss of a few trees in an overstocked stand. But the recreation manager may have a very low tolerance for any mortality in a historic or scenic area. Wildlife managers might welcome small openings created by tree mortality but would be concerned if too many mast-producing tree species were killed. The manager of wilderness lands might be indifferent to any natural tree mortality.

The forest manager can decide if preventive or remedial action is justified after determining if the forest or portions of the forest are susceptible to gypsy moth defoliation or vulnerable to tree mortality. If projected amounts of defoliation or mortality are not significant, then the manager might allow the infestation to develop. If, on the other hand, expected damage is not acceptable, some preattack action such as silvicultural cutting or enhancement of biological controls might be considered. As the outbreak continues to develop, insect populations can be monitored to estimate when infestation is likely and what the severity of defoliation might be. If warranted, foliage protection with insecticides can be considered.

MONITORING GYPSY MOTH POPULATIONS

Information about forest stand composition and condition can be used to assess potential defoliation and mortality. Then, as the gypsy moth approaches, managers will want to keep close track of its location and abundance.

Proximity of the Gypsy Moth

Information on the location and spread of gypsy moth infestations is collected by USDA Animal and Plant Health Inspection Service (APHIS), by state forest pest management agencies, and by the Forest Pest Management group within the USDA Forest Service These specialists can provide the best early information on the extent of the infested areas, population levels, trends, and direction and rate of movement.

Egg-Mass Sampling

Once gypsy moth presence has been confirmed in an area, the most useful measure for determining potential populations and need for suppression is the number of gypsy moth egg masses per acre. Egg masses are visible on trees and ground litter for seven to eight months prior to spring defoliation. Early assessment of expected populations provides lead time for planning and organizing treatments. Several egg-mass sampling techniques are used. These include five-minute walks, fixed-radius plots, variable-radius plots, and combined fixed- and variable-radius plots. The best technique depends on population size and the availability of time, personnel, and money.

The five-minute walk is popular because of its simplicity. It is most applicable to areas with high-egg mass densities when a quick population estimate is needed to determine spray threshold conditions. The five-minute walk survey begins in the woods at least two chains from an open area. Time is recorded as the surveyor walks nonstop scanning front to sides and overhead, counting all *new* gypsy moth egg masses. There should be a minimum of two walks per site. Results are averaged. For newly infested areas, egg masses per acre = 20.56 × count from walk + 14.58. Other equations are available for use in areas where populations are building or in older outbreaks (Eggen and Abrahamson 1983).

Predicting Defoliation From Egg-Mass Counts

The number of egg masses on a site can be used to estimate defoliation potential. A method for predicting gypsy moth defoliation percentage based on the number of egg masses per acre is presented in Figure 4 (Gansner et al. 1985). Considering all the factors that can influence defoliation (e.g., host species, larval dispersion, weather), the model works quite well. R^2 for the underlying equation is 0.61.

Determining Action Thresholds

Gypsy moth population tolerance levels vary with particular management goals and specific landowner objectives. Urban and state programs for aerial spraying are often aimed at preventing nuisance caused by caterpillars, or unsightliness of defoliated trees at homesites and recreation areas. A common threshold for nuisance prevention is 250 to 500 egg masses per acre. The threshold for foliage protection to minimize tree mortality and growth loss in forest stands would be much higher. An egg-mass density threshold of approximately 1,400, indicating about 60% potential defoliation, might be considered acceptable (Wargo 1978). Foliage protection for esthetics might have a 30% threshold defoliation level; for wildlife mast-production, it might be only 20%.

SELECTING ACTION ALTERNATIVES

Several action alternatives are available to the resource manager faced with gypsy moth-caused damage. These include silvicultural treatments, insecticide application, enhancement of natural control agents, or just letting nature take its course. Again, the appropriate action depends on projected losses and their impact on management objectives.

Silvicultural Treatments

Appropriate silvicultural prescriptions are determined by the proximity of infestation, coupled with timber stand characteristics and maturity.

If defoliation is not expected within the next five years, there is adequate lead time for taking preventive action. Seven silvicultural prescriptions have been described that may aid in reducing timber losses (Figure 5a). If the stand is poorly stocked (less than C level; 35%), or if the stand is adequately stocked (C level or better; >35%) but is within five years of maturity, stand regeneration may be considered. Shortening the rotation will allow marketing of the current stand, avoid lost value in the salvage of dead material, and assure adequate regeneration through seed production and sprouting from live stumps. If advanced regeneration stocking and stump sprouting potential are adequate, the stand can be regenerated with a *harvest.* For stands where sources of regeneration are not adequate, a *shelterwood* or *conversion* cutting may be considered. If susceptibility or vulnerability of the stand is high, then conversion to nonpreferred host species will help reduce the establishment and spread of the gypsy moth. On lower quality sites, conversion usually will be to a pine species, while higher quality sites can be converted naturally to mixed hardwoods using shelterwood or selection cutting. When susceptibility and vulnerability are low, shelterwood cutting can develop adequate advanced regeneration; drastic change in species composition is not needed.

If the stand is fully stocked but will not reach maturity for another 6 to 15 years, it is advisable to *defer cutting for 6 to 15 years, and reexamine* for possible protection, early harvest, or salvage if mortality has occurred. Younger fully stocked stands (16 or more years from maturity) with less than 80% stand density may best be handled by *deferred cutting for 10 to 15 years and reexamining* their status as defoliation becomes an immediate threat. Experience suggests that stresses created by thinning or cutting can remain for 3 to 5 years after treatment. Reduced vigor resulting from this stress, coupled with defoliation stress, could result

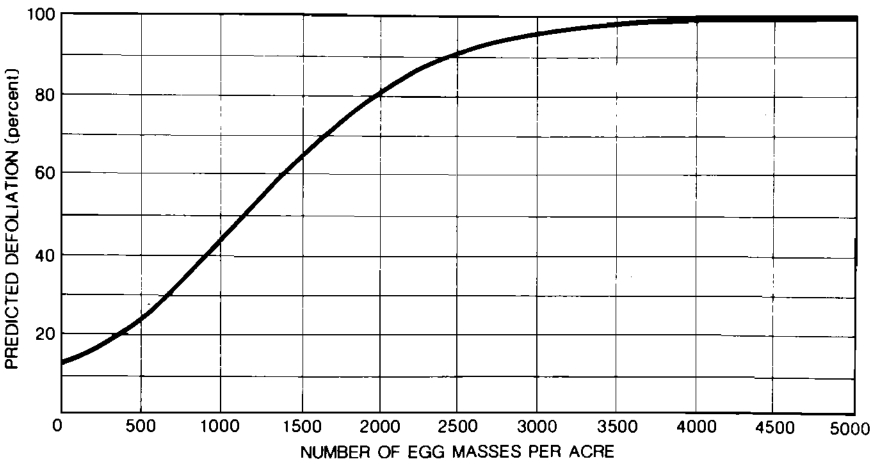


Figure 4. A graph for predicting gypsy moth defoliation from egg mass counts.

A. Defoliation not imminent for longer than 3 to 5 years.

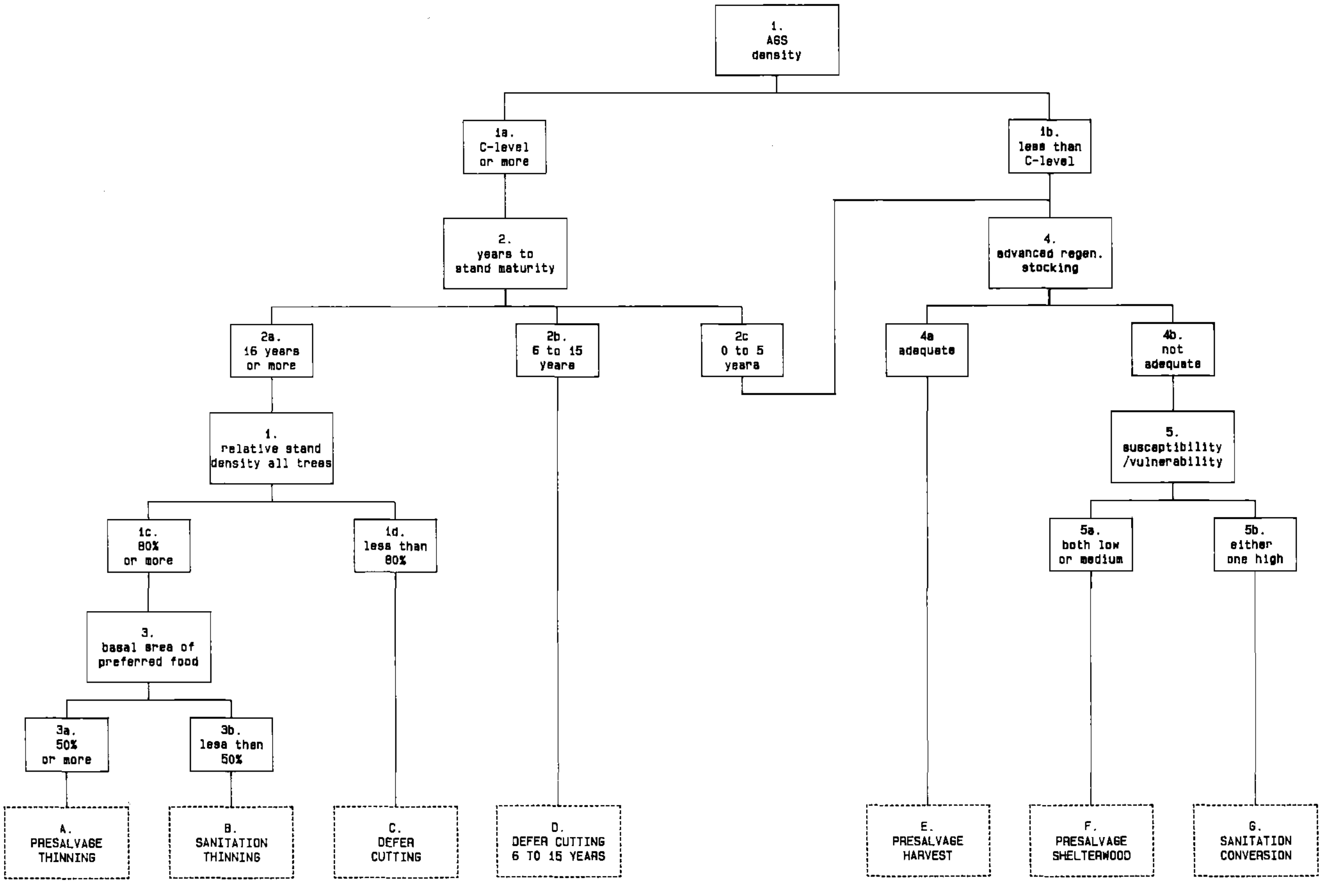


Figure 5a. Silvicultural prescriptions for areas where defoliation is not expected for 5 or more years.

in high mortality. High value, highly stressed stands should be observed closely and are good candidates for chemical spray protection if an outbreak is expected during the recovery period.

For younger fully stocked stands with more than 80% stand density, *sanitation thinning* or *presalvage thinning* may be considered, depending on the percentage of the basal area that is in preferred food species. Sanitation thinning is best applied in stands where less than 50% of stand basal area is in preferred food species, and where other management objectives make it appropriate. This treatment is designed to reduce the spread and establishment of gypsy moth by removing trees that are refuges and preferred food species. Presalvage thinning is best suited for stands that have more than 50% of the basal area in preferred food species. This treatment reduces defoliation-caused losses by removing the most vulnerable trees before they are defoliated and die. Trees that are considered most vulnerable are oaks with poor crown condition, followed by other species with poor crown condition, then trees with fair crowns, particularly on poorer, drier sites. Trees with good crowns are least likely to die (Herrick 1982).

If defoliation is currently taking place or expected within the next five years, the appropriate actions are to protect with *insecticide application,* closely monitor and evaluate through *stand examinations,* or move ahead with *stand regeneration* plans (Figure 5b). Priorities for chemical application can be based on stand maturity, condition, and value of the stand; the severity of the gypsy moth threat; and planned management objectives. Under conditions of low stand value or low risk, the best course of action may be to delay treatment and reexamine the stand after defoliation to assess extent of damage, and salvage potential.

If defoliation has recently occurred, wait one to three years for any subsequent mortality. At that time, the stand can be reevaluated to consider *regeneration cutting* (based on damage level and stocking condition); *deferred cutting* (as determined by stocking level, amount of damage, and stand maturity); and *salvage cutting or thinning* (again determined by stocking, stand condition, and damage level) (Figure 5c). A more complete guide for silvicultural treatment has been developed by Gottschalk.[1]

[1] Gottschalk, K. W. Silvicultural guidelines for forest stands threatened by gypsy moth USDA For. Serv. Northeast. For. Exp. Stn Gen. Tech. Rep. In preparation.

B. Defoliation imminent within 3 to 5 years or now occurring.

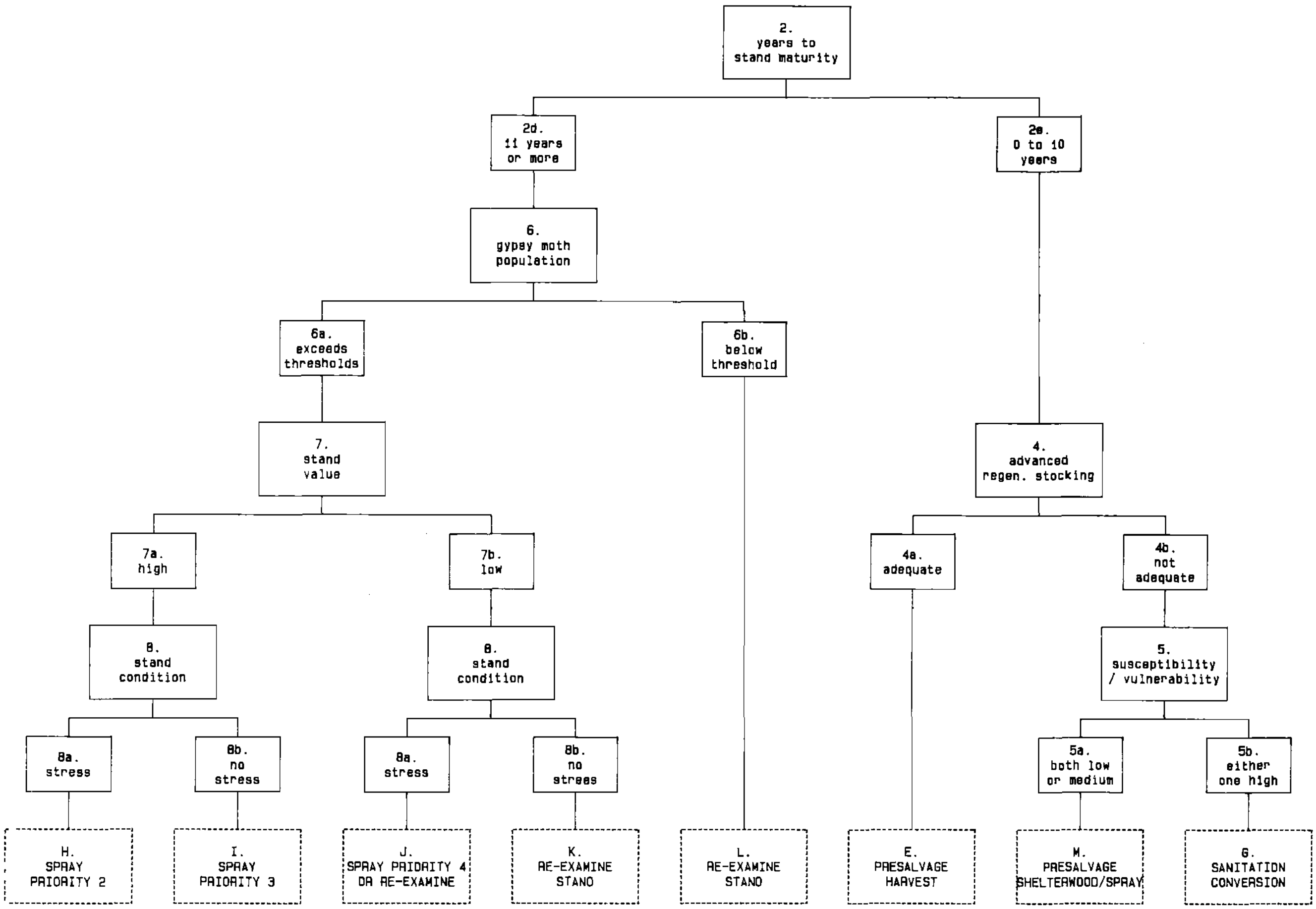


Figure 5b. Silvicultural prescriptions for areas where defoliation is now occurring or expected within the next 5 years.

Pesticide Applications

Seven insecticides, including both synthetic and biological products, used as aerial sprays to control gypsy moth populations have been approved by the Environmental Protection Agency. These products give adequate control when used properly. Most should be applied when larvae are in very early developmental stages and when leaves are about one-third expanded. Pesticide and application costs vary by size of project, type of equipment, materials used, and terrain of the treated area. Total costs in 1985–86 ranged from $4 to $12 per acre for large areas. Additional information and assistance in planning spray projects can be obtained from local forest pest management offices.

No Action

Taking no action at all is sometimes the best choice. If projected effects of gypsy moth are not expected to affect management goals significantly, the prudent manager may elect to take no action and "take a chance." Under these circumstances, no action is probably the most cost-effective option.

A Case Study[2]

Before gypsy moth defoliation begins, foresters on the Lee Ranger District of the George Washington National Forest wanted to know where high levels of mortality are likely to occur. This information would assist them in prioritizing stand harvests, resource allocation (for example, future road construction), recreation planning, and long-term pest management strategies. They used the equation developed by Gansner and Herrick (1984) to estimate potential stand mortality.

The Lee Ranger District has approximately 5,200 timber stands. It was evident from the beginning that they did not want to hazard-rate every stand. Stands were selected by timber type (oak), site index (60+), and timber value (sawtimber class). These criteria reduced the number of stands for hazard rating to 1,000. After collecting needed information on crown condition and species composition, the stands were hazard-

[2] Ghent, J. H. 1985. Estimating forest stand losses to gypsy moth on the George Washington National Forest. Unpublished administrative study on file at USDA Forest Service, R-8, Forest Pest Management, Asheville, NC.

C. Defoliation has occurred, wait 1 to 3 years for mortality to occur.

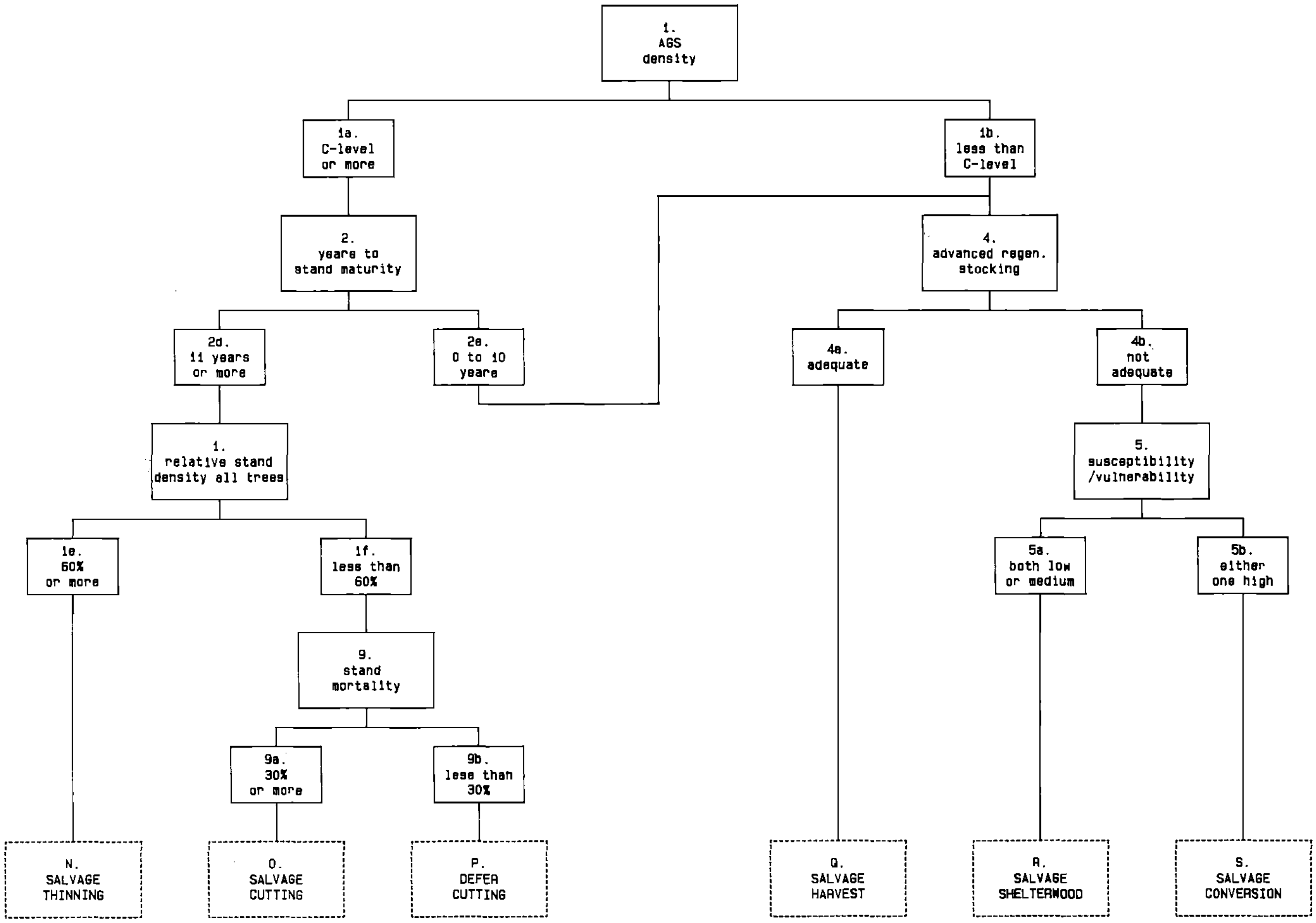


Figure 5c. Silvicultural prescriptions for areas where defoliation has recently occurred.

rated. Mortality predictions ranged from 4 to 53% and averaged 19%. A map of hazard rated stands, showing three levels of predicted mortality—high (30%+), medium (15–30%), and low (<15%), was produced. A computer-based geographic information system (GIS) was used to accomplish both stand stratification and mapping. After the first outbreak of gypsy moth has passed, these stands will be revisited to check the reliability of predictions and, if necessary, improve techniques for estimating and evaluating damage.

CONCLUSION

The gypsy moth has moved south and west from its original confines in New England and has spread out to infest a large portion of the nation's hardwood forests. Repeated outbreaks have left their impact on all sectors of the forest community. The pest has affected recreation, wildlife habitat, water yield and quality, and local timber markets. As the gypsy moth continues its invasion of new areas, new questions and concerns will arise. Information and guidelines presented here provide forest managers with a better understanding of what to expect and a basis for improved decisions for coping with the pest. One finding deserving special mention is the great amount of variability in loss attributed to the insect. It follows that planning for cost-effective gypsy moth control programs should aim at those forest stands most sensitive to heavy damage—with efforts made to identify such areas and hold damage to acceptable levels. □

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Effect of Crown Scorch on Mortality and Diameter Growth of 19-Year-Old Loblolly Pine

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*ABSTRACT. Various levels of crown scorch on 19-year-old loblolly pine (*Pinus taeda L.*) were examined. Scorching and mortality were greatest for small-diameter, suppressed trees. Diameter growth one year after scorching was not diminished for lightly scorched trees but decreased with increasing crown scorch. During the second and third growing seasons after scorching, only trees receiving complete crown scorch exhibited significantly less diameter growth.*

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Crown scorch from prescribed burning can result in tree mortality and decreased diameter growth. But the relationship between scorch severity and tree development among different crown classes is not well understood—particularly the longer term effects on pole-sized loblolly pine. The objective of this study was to assess the effects of various levels of crown scorch on mortality and diameter growth of 19-year-old loblolly pine over three growing seasons.

METHODS

The study was conducted on Louisiana State University's Lee Memorial Forest located in southeastern Louisiana. Eleven 0.5-ac plots in a 19-year-old naturally seeded loblolly pine stand (site index 90) were precommercially thinned in conjunction with hardwood removal during the winter of 1982–1983. Initially the site averaged 450 loblolly stems per acre with an average dbh of 5.2 in. Hardwoods averaged 2,350 trees per acre (tpa) before thinning, with an average dbh of 1.2 in. The pines within the plots were thinned to densities of 200 tpa (3 plots with an average basal area of 52 ft^2/ac), 300 tpa (3 plots with an average basal area of 65 ft^2/ac) and 400 tpa (5 plots with an average basal area of 76 ft^2/ac) with average stand diameters after thinning of 6.9, 6.3, and 5.9 in., respectively. Slash from thinning was left on the site and averaged 1 to 2 ft deep. Since hardwoods comprised the majority of the slash, thinning intensity across the plots did not significantly affect slash depth. After thinning, pines averaged 44.5 ft high, with dominants averaging 52.2 ft.

The plots were prescribe-burned in February 1983 with strip-headfires spaced at 1- to 1.5-chain intervals. Two-and-one-half inches of rain were received at the study site during the 10-day period prior to burning, with one-half inch falling over the 3 days prior to the burn. Temperatures during the burn ranged from the mid 60s to the low 70s F and were accompanied by low relative humidity (51%) and wind speeds. While the fire carried well and initially appeared to be successful, crown scorch was apparent on many trees several days after burning. Scorching was nonuniform across the plots, with damage ranging from complete scorching of the crown to no scorching. Height of bole scorch averaged 3.5 ft, with a maximum of 10.7 ft. Actual crown combustion during the fire was minor or nonexistent, with no evidence of cambial damage.

All trees on the plots had been previously tagged and measured for dbh. After the burn, each scorched tree was placed into one of four crown-scorch classes: one-third of crown length scorched, two-thirds of crown length scorched, all but branch tips scorched, and complete crown scorching. A random sample of nonscorched trees was collected from the burned plots to serve as control observations of diameter growth and mortality. All trees were additionally placed into one of four crown classes: dominant, codominant, intermediate, and suppressed. Diameter measurements were repeated at the end of the first and third growing seasons after the burn.

RESULTS AND DISCUSSION

Distribution of Scorching

The number and percent of trees scorched per acre increased with increasing plot density (Table 1). Plots of 200 tpa had the fewest trees scorched in all four scorch

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