GYPSY MOTH IMPACTS IN PINE-HARDWOOD MIXTURES

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Abstract.—Gypsy moth has affected pine-hardwood mixtures, especially oak-pine stands, since the late 1800's. Several old and new studies on impacts in mixed stands are reviewed. When pines are heavily defoliated, considerable growth loss and mortality can occur. Mortality is heaviest in understory white pine trees. Impact information is used to suggest silvicultural management actions to minimize damage in northern mixed stands. Suggestions for pre-infestation treatments in southern mixed stands are made.

INTRODUCTION

Since its introduction into the United States in 1869, the gypsy moth has affected millions of acres of forest in the northeastern and middle Atlantic states. Many of these forested areas were mixtures of hardwoods and conifers, especially mixtures of oak and pine. These mixtures have been located primarily in southern New England. Information on the impacts of gypsy moth on these mixed stands has been collected by a number of people over a number of years. Our intent is to summarize these reports and suggest silvicultural treatments to minimize gypsy moth related impacts in these stands.

SUSCEPTIBILITY TO DEFOLIATION

The susceptibility to defoliation is the primary determinant of whether or not gypsy moth will affect a stand. Without heavy defoliation levels, there will be no significant impacts. Susceptibility will be considered on both the species and stand level.

Species Level

Gypsy moth feeding preferences are quite pronounced. Some species are favored as food by gypsy moth larvae (notably oaks, aspen, birch, and sweetgum), while other species are unfavored and are rarely fed upon (table 1.; Mosher 1915). All pines that have been tested have been intermediate; young larvae will not eat their needles, but older larvae will readily eat pine foliage. Larvae prefer the older needles of both pitch and white pine; only rarely do they eat the new needles of pitch pine, but new needles of white pine are eaten more readily (Hall 1935; Mosher 1915). Because of this feeding pattern, many of the current year needles are not damaged or only lightly fed on unless populations are very heavy. White pine growing in the understory of mixed or pure stands is much more susceptible to defoliation than trees growing in the overstory (figure 1). In contrast to pine, gypsy moth larvae prefer the new foliage of hemlock, so older needles are usually the ones left on the tree (Mosher 1915).

Most species tested for gypsy moth suitability have been northern species or southern species that reach their northern limit in southern New England. Loblolly, pitch, Virginia, and shortleaf pine are the only southern pines that have been tested and all are intermediate (Barbosa and others 1983, 1986; Mosher 1915). In general, soft (white) pines are generally preferred over hard (yellow) pines. Sweetgum is the only southern hardwood other than oak which has been found to be highly preferred (Martinat and Barbosa 1987; Barbosa and others 1983). Many other hardwoods are intermediate, while most southern hardwoods, especially understory species, have not been tested.

Stand Level

Susceptibility on a stand level is determined by species composition and site factors (Bess and others 1947; Houston and Valentine 1977; Herrick and Gansner 1986). By far the most important factor is species composition. As the percentage of basal area in highly preferred species increases, the susceptibility of the stand increases (table 2, figure 2). Pines growing in mixed stands are more susceptible than pines growing in pure stands because the availability of preferred foliage allows the young larvae to survive to the stage where they can then feed on pine foliage. In figure 1, overstory and understory white pines were more heavily defoliated when growing in oak-pine stands (50 percent oak), than in pine-oak stands (2 percent oak), which were in turn higher than pure pine stands (90 percent pine) (Brown and others 1988). The timing of defoliation in mixed stands proceeds as follows: first the preferred hosts are defoliated; as they approach moderate to heavy defoliation, understory pines are beginning to be fed on; as the preferred hosts are heavily defoliated, the understory pines are approaching moderate to heavy defoliation and the overstory pines have some feeding on them; and finally the preferred species and understory pines are completely defoliated, while the larvae moderately to heavily defoliate the overstory pines. In severe outbreaks, the overstory pines may suffer 1 year of moderate to heavy defoliation, while preferred hosts like oaks may suffer 1 or 2 years of moderate and 1 or 2 years of heavy defoliation.

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Table 1.--Break down of woody plant species by gypsy moth food preference (susceptibility) classes (adapted from Mosher 1915)

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

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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

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Class III: Nonpreferred species fed upon by later larval stages only 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 coffee-tree, black and honey locust, 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, sarsparilla, all viburnum species

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Table 2.--Average three-year defoliation and stand susceptibility to defoliation as related to species composition of the stand (adapted from Herrick and Gansner 1986).

Preferred species	Three-year average defoliation	Stand susceptibility
pct	pct	
0 to 20	9	low
20 to 50	18	moderate
50 to 80	24	high
80 to 100	32	very high

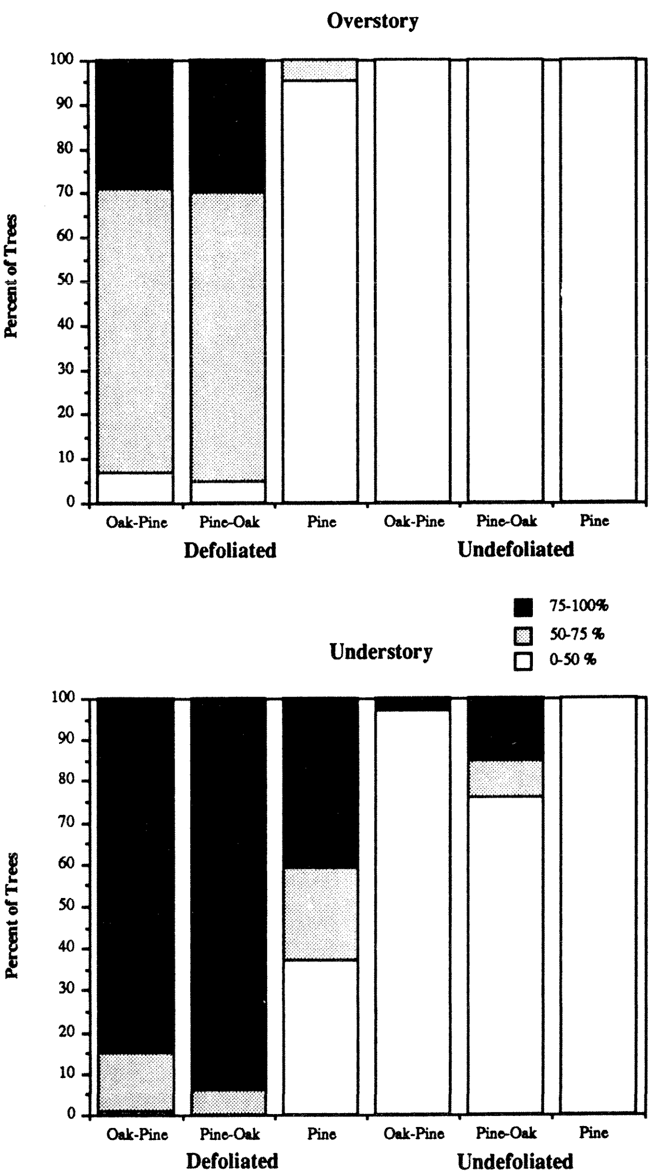


Figure 1.--Distribution of defoliation of white pine trees in the overstory and understory on plots in Rhode Island classed as defoliated and undefoliated in 1981 (Brown and others 1988).

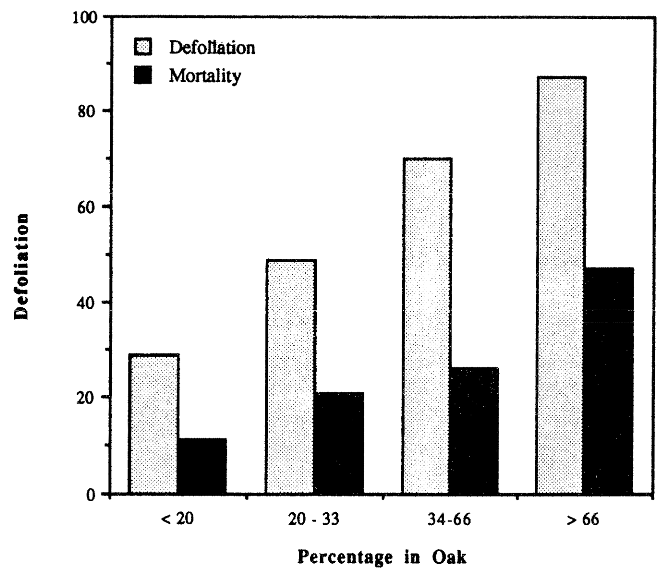


Figure 2.--Defoliation and mortality between 1912 and 1921 on Melrose Highlands plots in New England, classed by percentage of oak (basal area) in the stands (Campbell and Sloan 1977).

IMPACTS ON PINE-HARDWOOD STANDS

While the gypsy moth has many socio-political impacts in addition to its biological impacts on forest stands, we are only considering the impacts on timber production in mixed pine-hardwood stands in this paper. Vulnerability is the probability of a tree (or stand) suffering impacts, such as mortality of trees, growth loss, and changes in species composition, once it has been defoliated.

Mortality

Numerous papers have been written on the vulnerability to mortality of oaks to gypsy moth (Campbell and Sloan 1977; Quimby 1987; Herrick and Gansner 1987a). However, we would like to bring together the literature on vulnerability of white pine and hemlock in New England. Pitch pine, and to a smaller extent Virginia pine, have also been studied. Pitch pine is covered in another paper in these proceedings (Montgomery and others 1989).

As shown in figure 2, mortality of oaks is directly related to defoliation, although many other factors influence the process. As with oaks, defoliation intensity is a major factor determining vulnerability of white pine. Baker (1941) studied mortality of white pines defoliated between 1912 and 1921 (figure 3). When only a trace of defoliation occurred on old needles, mortality was less than 5 percent. When all old needles were completely eaten and new foliage was defoliated between 0 and 80 percent, mortality was around 10 percent. Only when defoliation of new foliage was greater than 80 percent, did mortality increase threefold. In 1953, similar results were obtained for both white pine and hemlock; mortality increased when defoliation surpassed 80 percent and hemlock mortality was 74 percent when completely defoliated (figure 4, House 1960). Similar and even more dramatic results were obtained for white pine and hemlock defoliated in 1981, where 94 percent of the completely defoliated hemlock trees died (figure 5, Stephens 1988). The difference in mortality rates between white pine and hemlock are related to the defoliation patterns. Since new foliage is consumed first for hemlock and it has no capacity for refoliation, complete defoliation causes severe mortality. White pine still has many new needles left and they have not yet completed elongation when gypsy larvae pupate, so they continue to develop some additional foliage and survive better.

Crown class and position also affect the defoliation and subsequent mortality of white pine and hemlock. Stephens (1988) found that understory white pine and overstory hemlock tended to be defoliated

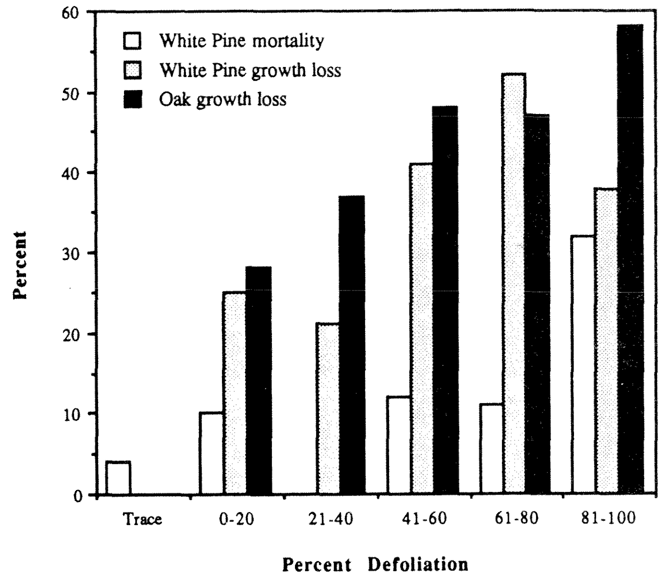


Figure 3.--Mortality and growth loss of oak and white pine between 1912 and 1921 in New England, classed by percent defoliation of study plots. Trace defoliation represents old foliage present. All other categories have all old foliage eaten and various degrees of defoliation on new foliage (Baker 1941).

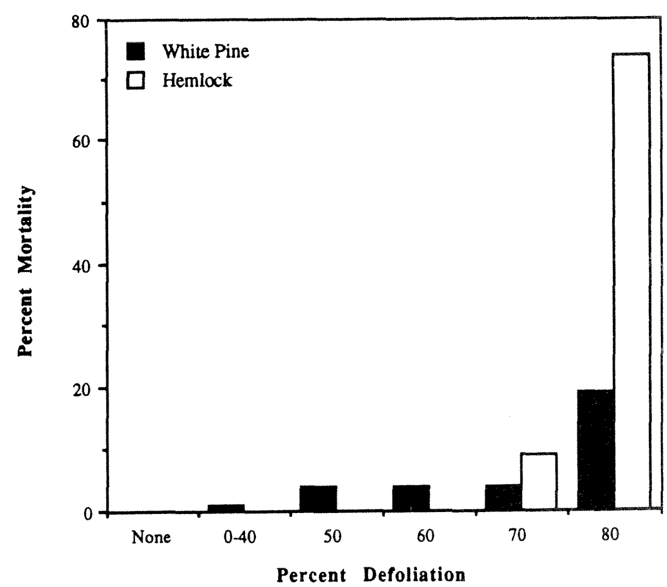


Figure 4.--White pine and hemlock mortality after different levels of defoliation in 1953 in New England (House 1960).

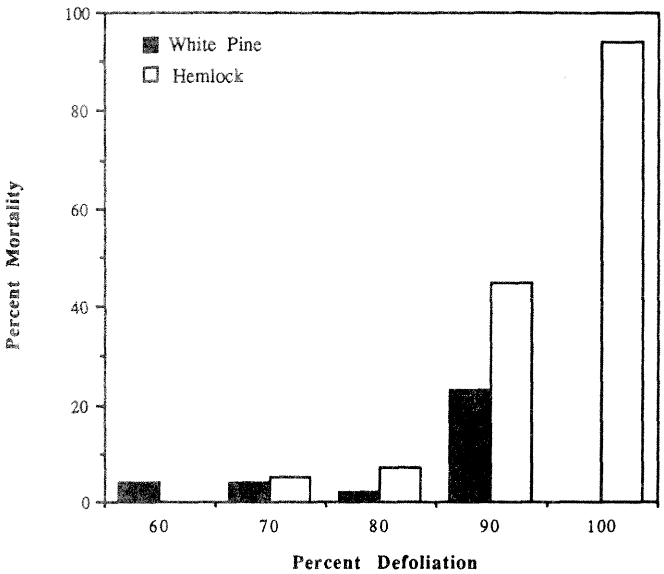
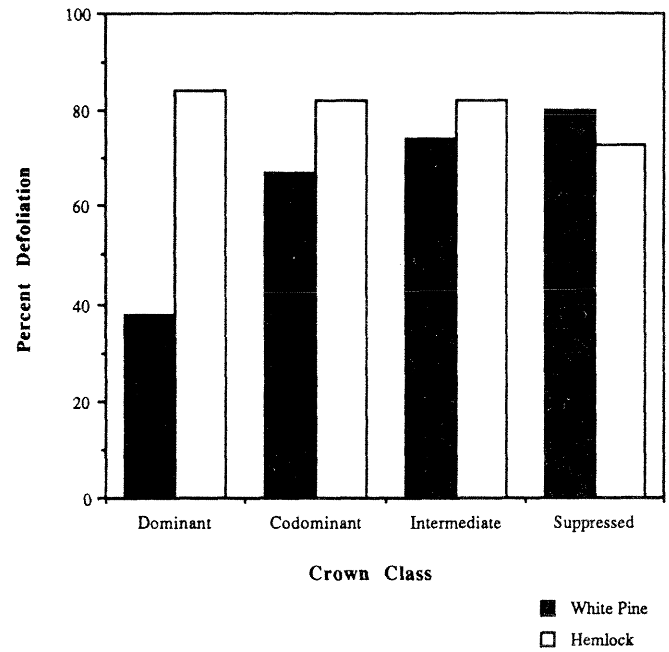


Figure 5.--Mortality in white pine and hemlock between 1981 and 1984 after defoliation in 1981 in Connecticut (Stephens 1988).

more heavily than overstory white pine and understory hemlock, although hemlock was much more uniform that white pine (figure 6). Mortality rates showed that while dominant hemlocks were defoliated slightly more, they died at half the rate of codominant, intermediate, and suppressed trees (figure 6). The only mortality in white pine occurred in understory trees, dominant and codominant trees were defoliated less and did not die because they suffered less than 80 percent defoliation (figure 6). Brown and others (1988) showed similar patterns of heavy mortality in understory white pine in mixed and pure pine stands that were defoliated, while undefoliated stands had much lower mortality rates (figure 7). Quimby (1987) reported mortality rates in Pennslyvania of 39 to 44 percent in pulpwood-sized conifers. Sawtimber-sized trees had mortalities of 3, 12, 9 to 17, and 0 percent for white pine, hemlock, pitch pine, and red pine, respectively. In New Jersey, mortality was 31 percent for hemlock and 20 percent for white pine (Kegg 1974). Heavy defoliation causes mortality in both white pine and hemlock. Overstory hemlock dies at a lower rate than understory hemlock. Hemlock dies at a higher rate than white pine. Overstory white pine rarely dies, but understory white pine is very vulnerable.

<u>Growth Loss</u>

Since many pines do not die following defoliation, the question of impacts on growth rate arises. What does the defoliation of needles do to the growth of pines? Baker (1941) examined increment cores from many oaks and white pines that were defoliated to various degrees. He found 20 to 60 percent losses in radial growth of both white pine and oaks (figure 3). The losses in general increased with increasing defoliation intensity and were similar between the two groups of trees. House (1960) also looked at diameter growth losses of white pine and of hemlock (figure 8). Five-year diameter growth losses (compared to previous 5-year diameter growth) were not different from undefoliated trees for defoliation intensities up to 80 percent. For trees defoliated 80 to 100 percent, diameter growth losses were double the normal



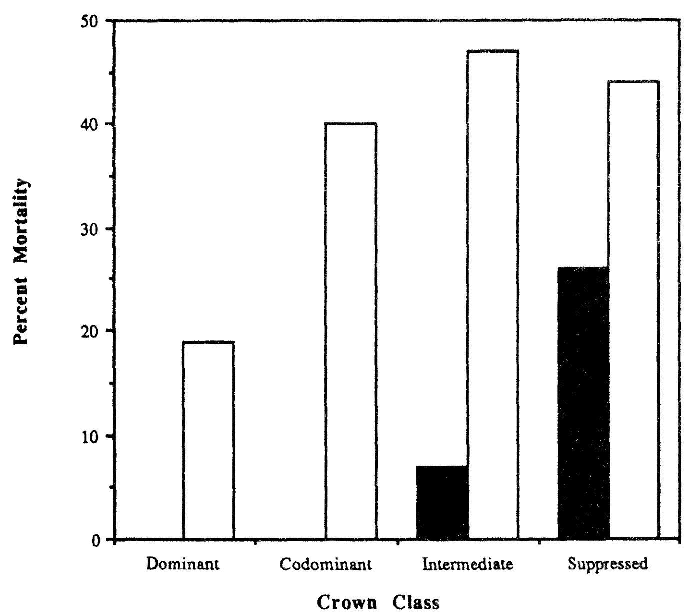


Figure 6.--Mortality and defoliation in white pine and hemlock by crown class after 1981 defoliation in Connecticut (Stephens 1988).

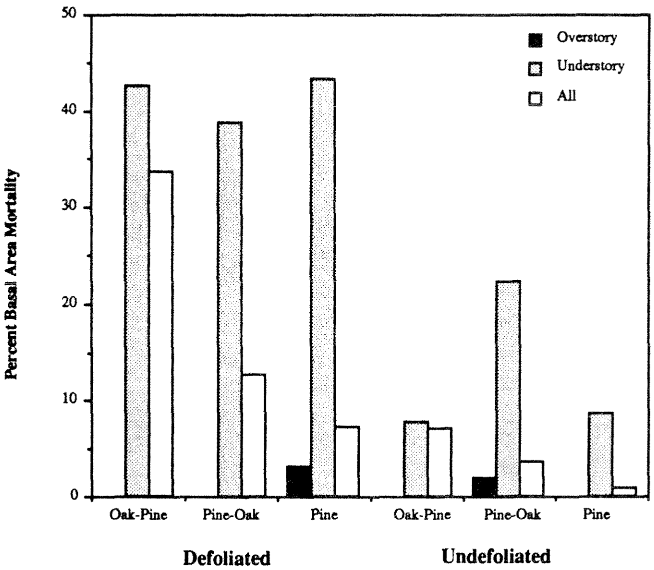


Figure 7.--Mortality in white pine between 1981 and 1983 after defoliation in 1981 in Rhode Island (Brown and others 1988).

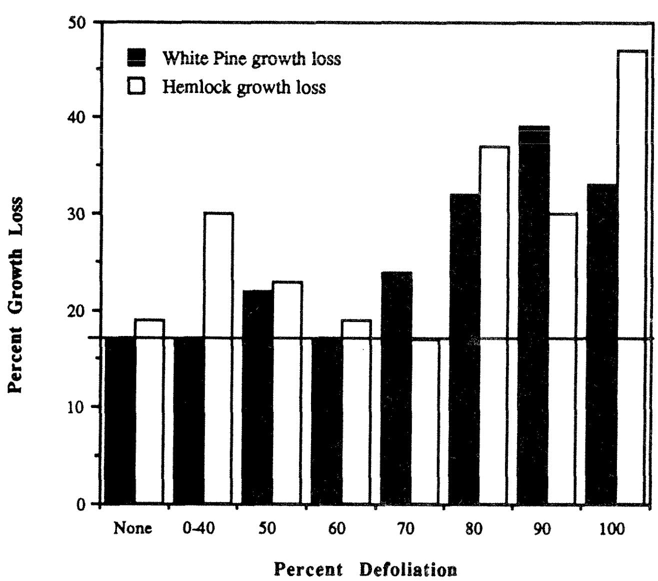


Figure 8.--Five-year diameter growth loss in white pine and hemlock after different levels of defoliation in 1953 in New England. The horizontal bar is a reference line representing baseline growth loss compared to the previous five years (House 1960).

loss. These studies suggest that growth losses can be as serious as mortality for trees that receive heavy defoliation levels. In an interesting study of oak-pitch pine mixtures, Campbell and Garlo (1982) showed mortality and decline in growth of defoliated black oaks in the stand and a corresponding increase in growth of pitch pines which were only lightly defoliated. Because pitch pine was more valuable than black oak, this infestation actually increased stand value. Management of mixed stands may be affected by differential stand growth and developmental patterns resulting from differential defoliation patterns.

Change in Species Composition

When mortality or differential growth occurs in mixed stands, it is possible for the species composition to shift. In oak-white pine stands, greater mortality in the oaks may shift the stand to more dominance by white pine initially but with less pine in the long run due to loss of understory pines. In oak-hemlock stands, a purer oak stand may result from the heavy mortality in hemlock. When an oak shelterwood stand with white pine regeneration is defoliated, the pine can be almost eliminated preventing the conversion to pine or mixed oak-pine. It is also possible for a stand to remain at the same relative composition due to mortality in both groups (Brown and others 1988).

SILVICULTURAL AND MANAGERIAL RECOMMENDATIONS

Silvicultural treatments to cope with the gypsy moth were suggested very early in New England (Fiske 1913; Clement and Munro 1917). Many of the early New England prescriptions dealt with mixed oak-pine stands and recommended conversion to non-preferred species. The high value of oak stands limits the desirability of conversion. We have refined these prescriptions for northern stands and also suggested some similar treatments for southern stands, although with much less reliable information on which to base them.

Silvicultural Management of Northern Forest Types

There are limited options available to minimize impact of gypsy moth by silvicultural means. These have been practiced with some success in areas where gypsy moth has existed for many years, but they may still not be acceptable for some management objectives. The primary means of affecting the seriousness of gypsy moth outbreaks are to manipulate the species composition away from preferred host species and to maintain the vigor of the stand.

Mixed species conditions. In stands with mixed pine-oak overstories, the pines are at minimal risk. Where stands are white pine and red oak, the pines are often dominant individuals which are rarely fully defoliated and suffer little or no mortality (Stephens 1988). In New Jersey forests of black oak and pitch pine, Campbell and Garlo (1982) found increased growth and vigor of pines when the oaks suffered defoliation and mortality. If pine is the major product desired from stands such as these, little heed need be paid to the gypsy moth. However, if oaks are the primary species of interest, the trees should not be allowed to stagnate, because trees with small crowns and poor vigor are the most vulnerable to gypsy moth outbreaks and the secondary agents which follow.

Many stands in New England have an overstory of oaks with an understory of white pine. These stands are often managed as a shelterwood, with the overstory oak protecting the pines from the white pine weevil until they are over one log tall. The stand is then converted to pine by harvesting the oak overstory. If a gypsy moth outbreak occurs before the oak is removed, the understory pine is at great risk. Many of the understory pines will die when the larvae defoliate them after exhausting their food supply in the overstory. The best alternative for management of such a scenario is to harvest the overstory before an outbreak. If the overstory is not yet ready for harvest, spraying to prevent an outbreak is recommended.

Where the understory is hemlock instead of pine, the trees are at even greater risk. Hemlock does not recover after a full defoliation. However, it is also a less desirable species as timber. The primary situation where it is a desired part of the stand is where it is needed as cover for game species, in which case protection of the stand by spraying is the only recommended method for retaining hemlock in a mixture with oaks.

Stands where pines comprise the overstory and hardwoods the understory are not as common as they are farther south, but this situation does exist in some plantations and old-field stands. The understory hardwoods, however, are generally not those favored by gypsy moth, such as beech, red maple, and viburnum. These stands are generally not at risk from gypsy moth outbreaks. If the understory develops a large proportion of more favored species such as witch hazel, blueberry, or oak, then the situation may change.

Silvicultural options. Reduction of susceptible species in a stand is the most reliable way of reducing the threat from gypsy moth (Gottschalk 1982). Treatments which might be classified as sanitation or presalvage cuttings (Smith 1986) are typical methods of achieving this reduction. In these treatments the proportion of the stand in susceptible or vulnerable trees is reduced sufficiently to decrease the likelihood of an extensive outbreak. The extreme form of this method is stand conversion, which leaves only trees which will not support a gypsy moth population.

If the situation is such that a susceptible species is still the most desired tree, such as in a stand dominated by red oak, the best available method to reduce hazard is to maintain a vigorous stand. The most vulnerable trees, even among favored host species, are those with small crowns or many dead branches within the crown (Herrick and Gansner 1987b). If a stand is maintained in an uncrowded, vigorously growing condition, there is less likelihood that a defoliation will cause mortality (Gottschalk 1982).

Potential Silvicultural Management in Southern Forest Types

Little information and few options are available to minimize impact of gypsy moth by silvicultural means in southern stands. Some success from areas where gypsy moth has existed for many years can be transferred south, but they still may not be acceptable for some management objectives and some conditions. The principal techniques for reducing the impacts of gypsy moth outbreaks farther south are to manipulate the species composition away from preferred host species and to maintain the vigor of the stand.

Mixed Species Conditions. Southern mixed stands have a much broader and more varied composition than northern stands. All across the South, the major mixed stands are oak-pine stands that contain 50 percent or more oak, and 25 to 50 percent southern pines with hickories and blackgum as common associates. In these stands, pine will probably not suffer extensively compared to the oaks. If pine is desired, then gypsy moth will not need to be managed. However, if oaks are important for timber or wildlife habitat, then they should be kept in vigorous condition with large, healthy crowns by thinning. Healthy trees are the least likely to die from gypsy moth defoliation and subsequent secondary organism attack.

In the Piedmont and Coastal Plain, southern pine stands can have up to 40 to 50 percent hardwoods growing with the pines. The variety of species differs widely with site and stand conditions. When enough of the hardwoods are preferred species such as oaks or sweetgum, it is likely that gypsy moth populations will rise high enough to affect the pine. However, since the pine is usually the desired product, loss of the hardwoods may be of little consequence and even benefit the growth and value of the stand. One fear expressed by some southern entomologists, is that enough damage will be done to the southern pines, especially loblolly, to stress the trees sufficiently to cause a southern pine beetle outbreak to start in the stand.[2]

Stands where pines dominate the overstory and hardwoods the understory occur across millions of acres in the South. Many of these southern understory species have not been tested for their gypsy moth feeding suitability. If sufficient numbers of preferred species are present in the understory, it may be possible that enough gypsy moth larvae will survive to a stage where they can move to the pine foliage. Some tests have shown that this situation may enhance the survival of the gypsy moth (Rossiter 1987; Barbosa and others 1986). Again, just enough stress could be placed on these pine trees to trigger other pest problems.

Silvicultural Options

The best silvicultural treatment in mixed oak-pine stands is to reduce the proportion of susceptible species in the stand to a level that places less risk on the stand as a whole; less than 50 percent of the basal area is good, less than 30 percent is better, and less than 15 to 20 percent is best, but hard to achieve in less than two thinnings. The extreme form of this treatment results in stand conversion to non-preferred species, or a gypsy moth-proof stand.

Where is it neither practical nor desirable to convert or reduce preferred hosts sufficiently, then thinnings should be used to increase the vigor of the remaining trees. Development of large, healthy crowns will increase the probability of a tree surviving defoliation. It will also have the often desirable effect of increasing mast production of the oaks.

Many stands may need to be protected with a chemical or biological insecticide. Especially vulnerable are seed tree or shelterwood stands that are in the process of regenerating the stand. Loss of these trees can destroy the entire treatment.

Depending upon the situation with host suitability of understory trees, it may be desirable to remove preferred species from the understories of pine stands to protect them from stress caused by the gypsy moth. This treatment will have the benefit of preventing subsequent pest problems that may arise from stress on the pines at a much lower total cost than treating the secondary pests.

[2]Personal communication, C. Wayne Berisford, Department of Entomology, University of Georgia, Athens GA.

RESEARCH NEEDS

Many unanswered questions exist for mixed pine-hardwood stands, especially for southern forest types. A few of the more important questions are:

1. What are the host feeding preferences of many southern species?

2. What are the species compositions and stand factors that affect stand susceptibility in pine-hardwood mixtures in the South?

3. What are the impacts (mortality and growth loss) in pine-hardwood types in the South?

4. Can appropriate silvicultural treatments minimize gypsy moth impacts in pine-hardwood mixtures in both the North and South?

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Waldrop, Thomas A., ed.
1989. Proceedings of pine-hardwood mixtures: a symposium on management and ecology of the type; 1989 April 18-19; Atlanta, GA: Gen. Tech. Rep. SE-58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 271 pp.

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Cover art by Suzy Mefferd, Clemson, SC.

United States
Department of
Agriculture

Forest Service

Southeastern Forest
Experiment Station

General Technical
Report SE-58

Proceedings of Pine-Hardwood Mixtures: A Symposium on Management and Ecology of the Type

Atlanta, Georgia
April 18–19, 1989