

Gypsy Moth Role in Forest Ecosystems: The Good, the Bad, and the Indifferent

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Abstract.—Despite a century of attempts to control populations of the gypsy moth, it remains one of the most destructive forest pests introduced to North America. Research has yielded valuable, albeit sometimes conflicting information about the effects of gypsy moth on forests. Anecdotal accounts and scientific data indicate that impacts of gypsy moth defoliation can range from inconsequential to devastating. When defoliation caused by the gypsy moth results in widespread mortality, successional patterns may be modified substantially and species composition may be altered. The most notable change in Eastern forests is a transition from oak dominated forests to those consisting largely of early successional species. Forest-level changes also modify habitats, thereby influencing populations including but not limited to birds, mammals, and invertebrates; but effects of the gypsy moth seem to be forest-specific and organism-specific. Attempts to limit the influence of gypsy moth defoliation by silvicultural methods appear to have promise in maintaining the overstory and possibly diversifying the understory, but it may be difficult to distinguish the effects of defoliation from the effects of thinning on vegetation as well as invertebrate populations.

INTRODUCTION

Since its accidental introduction near Boston, MA, in 1869, the gypsy moth (*Lymantria dispar* L.) has expanded its range in all directions, moving most notably southward and westward. Projections suggest that the expansion will proceed relatively unabated into varying forest types (Liebhold and others 1992). Roughly 80 % of the forests of North America is likely to experience some degree of defoliation. The earliest accounts of gypsy moth defoliation (Forbush and Fernald 1896) indicate the potential destructiveness of the gypsy moth, and information accruing since then also suggests that substantial changes in forests may be attributed to the gypsy moth.

Despite the numerous significant effects of gypsy moth defoliation, in this paper we will limit our

discussion to the effects on forest vegetation and forest arthropod communities. We will also address the use of silviculture to moderate the ecological or biotic effects of gypsy moth.

However, the numerous abiotic effects warrant mention. Among the less obvious consequences of gypsy moth are social, recreational and aesthetic problems such as reduced visitation due to an increased nuisance factor. Economic considerations are also important, because changes in the timber base can have negative ramifications for local economies. Effects of the gypsy moth on abiotic components, such as nutrient cycling, can cause irreparable changes in water quality and reduced soil productivity, and both can be detrimental to forested ecosystems. Studies in the Shenandoah Mountains of VA demonstrated an increased loss of cations from defoliated watersheds, exacerbating effects of acid deposition (Webb and others, unpublished data).

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EFFECTS ON FOREST VEGETATION

Overstory

Although many trees and shrubs may be utilized as a food source, gypsy moth larvae exhibit a distinct preference for certain species. Consequently, forest trees are categorized as "susceptible", "resistant" or "immune" to defoliation (Montgomery 1991, Twery 1991). The extent to which a forest is dominated by trees of each of these categories will then determine its relative susceptibility and vulnerability (Smith 1986). Stand susceptibility is described as the likelihood that defoliation will occur if the gypsy moth is present (Gottschalk 1993). Prior research indicates that pure stands of preferred food species such as oaks (*Quercus* spp.) are more susceptible to defoliation than mixed stands (Gottschalk and Twery 1989, Houston and Valentine 1977). Mortality of overstory trees occurs in direct proportion to defoliation (fig. 1), so the degree of stand susceptibility largely determines the extent of mortality.

A seminal work describing gypsy moth effects on forest composition and structure was published by Campbell and Sloan (1977). They found in-

creases in mortality among preferred overstory species, particularly when defoliation was not severe. In general, the loss of preferred species resulted in a subsequent forest that is less susceptible to gypsy moth. This was due primarily to the increasing dominance of red maple (*Acer rubrum* L.), considered resistant to the gypsy moth. This successional pattern characterizes many gypsy moth post-defoliated stands in the East.

The most obvious forest structural changes caused by gypsy moth defoliation include loss of high canopy cover (>39 ft), increase in low canopy cover and an increase in shrub cover (Thurber 1992). Campbell and Sloan (1977), however, reported that repeated heavy defoliation resulted in changing stand structure and loss of vertical stratification. The structural changes from defoliation and mortality may present favorable consequences for wildlife, but can create stocking level and regeneration problems.

Gypsy moth may be contributing to the role of a regulator of forest ecosystems (Mattson and Addy 1975). Gypsy moth induced mortality preferentially eliminates low vigor trees (Campbell 1979, Houston 1981); hence removal of these individuals may help perpetuate a relatively healthy stand. Such mortality also resembles the effects of thinning from below. As such, a low to moderate level of mortality appears to have little effect on forest conditions. More recent findings from central PA Ridge and Valley plots that have undergone defoliation indicate crown position has a significant influence on amount of mortality (fig. 2). Similar to the findings of Campbell and Sloan (1977), this study indicates that suppressed and intermediate trees are more likely to suffer mortality. These results support the theory that gypsy moth mortality is similar to a thinning.

As Kegg (1973) maintains, however, defoliation effects are not equivalent to a thinning when high levels of defoliation lead to catastrophic mortality levels (>50 to 60% of stand basal area) (Fosbroke and Hicks 1989). Catastrophic mortality levels generally occur on only about 20 to 25% of the landscape (Herrick and Gansner 1987, 1988, Gottschalk 1993).

Understory and Regenerating Species

As with any disturbance causing extensive mortality, areas that have experienced defoliation

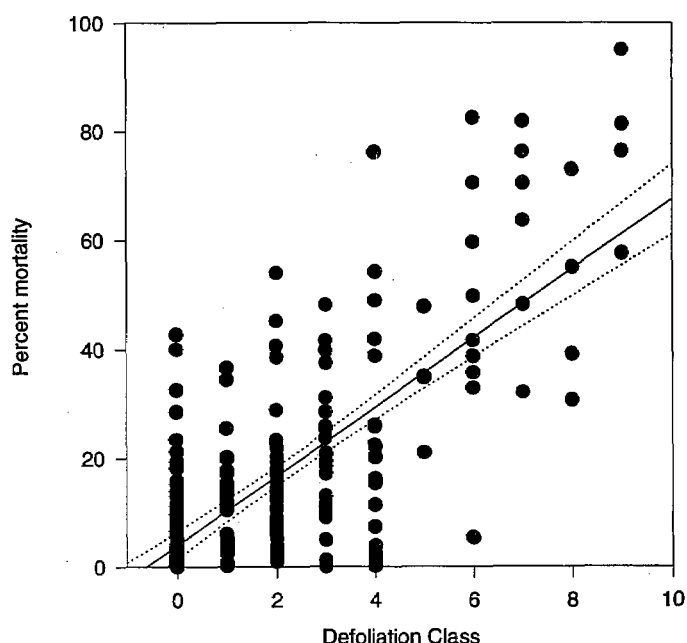


Figure 1.—Regression line (with 95% confidence interval) showing the relationship between percent mortality of stand basal area and defoliation class (Feicht and others 1993). Increasing class is equivalent to increases in defoliation ranging from <30% (class 0) to 4 years of > 60% defoliation (class 9).

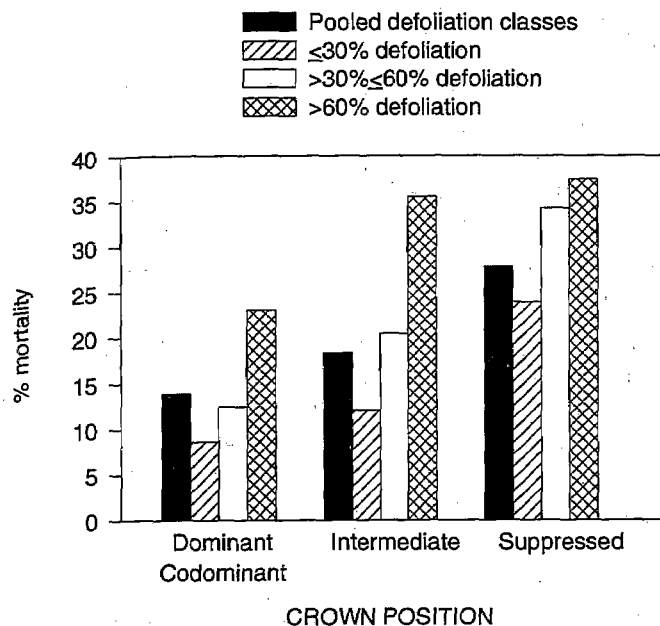


Figure 2.—Percent mortality of trees classified by crown position and defoliation class.

by the gypsy moth are likely to undergo dramatic changes in species composition and structure. Early successional species replace a largely oak overstory in the East. Studies by Allen and Bowersox (1989), Ehrenfeld (1980), Feicht and others (1993), and Hix and others (1991) have examined regeneration following gypsy moth defoliation and indicate a reduced regeneration of previously dominant overstory species. Even in moderately defoliated areas, most of the regeneration consists of exploitive species, particularly red maple; and there is little evidence to suggest that shade tolerant trees replace the overstory in low to moderately defoliated areas.

Studies in the Ridge and Valley of PA, and the Appalachian Plateau of WV have yielded comparable results in terms of woody species regeneration following defoliation. Figure 3 demonstrates the overwhelming dominance of red maple in the regeneration as well as the variation among species between the two physiographic provinces. Black cherry assumes a more significant role in the Appalachian Plateau than in the Ridge and Valley, and Muzika and Twery (1995) have shown that this species dominates in size, although not numerically, in post-defoliated stands. The size advantage may be sufficient to dominate red maple in Appa-

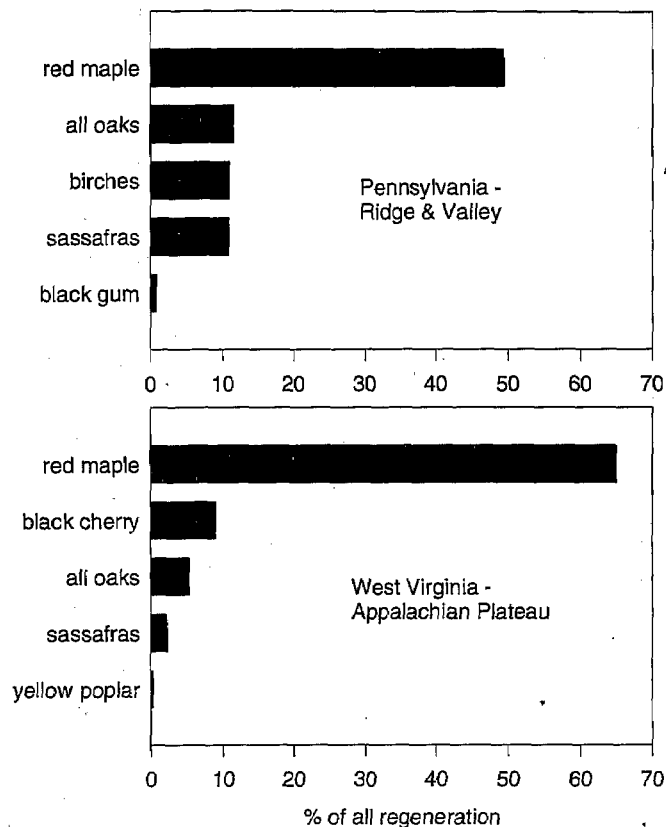


Figure 3.—Percent regeneration of major species in post gypsy moth defoliated stands. Data represent regeneration in areas surveyed 3 to 4 years subsequent to defoliation and includes all individual stems >0.1 ft in height, but ≤2.49" dbh.

lachian Plateau forests. For example defoliated stands had an average of 512 trees/acre > 5 ft tall. Oak constitutes a small portion of the regeneration in the Ridge and Valley and Appalachian Plateau forests, and probably will account for a minimal component in the future forest overstory.

EFFECTS ON FOREST ARTHROPODS

Arthropods are among the more poorly understood components of most ecosystems, and forests are not an exception. These organisms play critical ecological roles and in forests infested with gypsy moth, can account for substantial predation. Thus, maintaining healthy populations of soil, ground-dwelling, and arboreal arthropods is critical not only from the standpoint of biological diversity, but also as a means to control populations of forest pests (Smith and Lautenschlager 1978).

No previous information is available to describe potential effects of gypsy moth defoliation and mortality on forest arthropod communities. Over a 4-year period we examined the changes in populations of carabid beetles, spiders, phalangids, and ants to determine the extent to which gypsy moth defoliation affects these invertebrates. These four groups are important predators of the gypsy moth. The study took place on the West Virginia University Experimental Forest, located in Preston and Monongalia Counties, in north-central WV. In 1989, sixteen stands (20–30 ac) were located, baseline information was gathered, and eight of these were thinned in the winter of 1989. During 1990 and 1991, six stands were defoliated by gypsy moth. Large-capacity pitfall traps were used to trap, kill, and preserve invertebrates during an 11-week period beginning in late May to early July, from 1989–1992.

The average number of individuals captured, each year by group in defoliated stands is shown in Table 1. Analysis of covariance (1989 data as the covariate), showed that the total number of ants, spiders and beetles changed significantly from the pre-defoliation year. However, ant and beetle populations decreased, but spiders increased. Although these populations probably were influenced by the effects of gypsy moth defoliation, it is difficult to discern whether such effects alter patterns of natural variation in populations.

THE ROLE OF SILVICULTURE

Overstory

The use of silviculture to deal with forest pests has been expressed and explored for most of the

Table 1.—Average number of individuals per trap collected in pitfall traps in defoliated stands by year and group. Defoliation occurred in 1990 and 1991. Analysis of the spider data for 1992 has not been completed.

	Year			
	1989	1990	1991	1992
Ants	104	86	68	53
Phalangids	10	11	13	5
Spiders	73	93	120	NA
Carabid beetles	63	28	33	40

century (see Gottschalk 1993 for complete references on this topic). An obvious role for silviculture is stand manipulation to change stand susceptibility, hence, reduce the likelihood that gypsy moth will cause substantial damage. Information is not available to verify the effectiveness of silvicultural treatments for gypsy moth. The West Virginia University Forest study described earlier has begun to yield some information about the potential benefits of thinning in advance of gypsy moth defoliation.

Initial results suggest that thinning may be an effective way to prevent excess loss of overstory basal area and particularly oak basal area. In stands with comparable defoliation, 5 years after thinning, the thinned stand lost 46% of the total basal area and 54% of the oak basal area, whereas the unthinned stand lost 63% total basal area and 85% of the oak basal area (fig. 4).

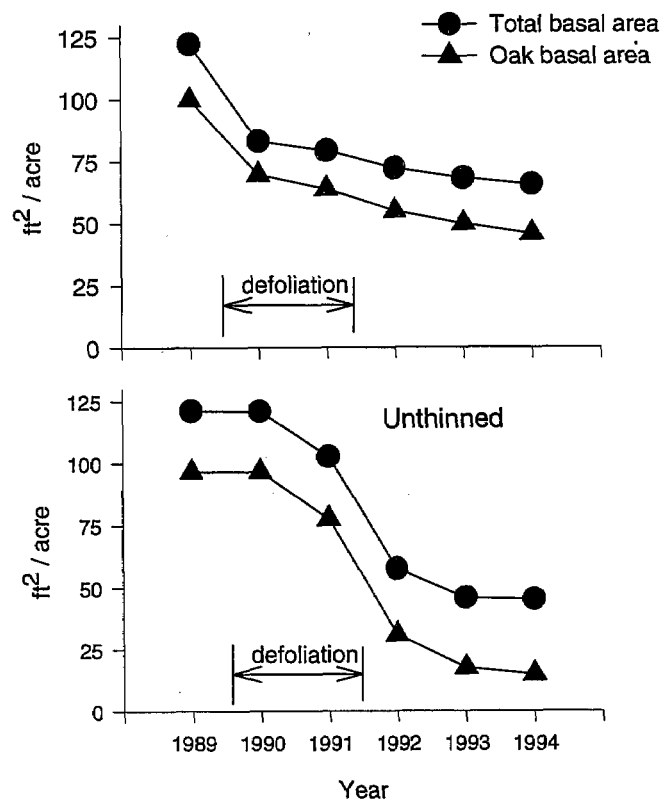


Figure 4.—Reduction in basal area (total and oaks only) over time in thinned and unthinned stands defoliated by gypsy moth. Stands were thinned in winter 1989–90 and defoliation occurred in 1990 and 1991. Basal area values were derived from stems >2.49" dbh.

Table 2.—Number of stems per acre > 5 ft tall, but less than 2.49" dbh, in defoliated stands and defoliated and thinned stands at the West Virginia University Experimental Forest 1989 and 1994.

Species	Defoliated		Defoliated and Thinned	
	1989	1994	1989	1994
Red Maple	34	19	160	79
Sweet Birch	9	11	6	4
Yellow-Poplar	0	0	0	4
Black Gum	30	24	11	0
Black Cherry	62	512	109	715
White Oak	4	4	2	0
Chestnut Oak	9	6	2	6
Northern Red Oak	13	4	2	0

Regeneration

When regenerating species, thinning does not seem to significantly change composition or dominance. In our study, regeneration has been followed since 1989 (pre-treatment) and will continue until 1999. Recent data (Table 2) demonstrate the changing pattern of dominance in the understory and indicate which species are likely to dominate the overstory. Black cherry is the only species with an increasing number in the large regeneration (>5 feet tall; 2.49" dbh) cohort over time since the thinning and defoliation. Thinning somewhat enhances the dominance of black cherry but has little effect otherwise. With the exception of chestnut oak in the defoliated and thinned stands, oaks in general have responded negatively to defoliation and thinning has not moderated that effect. Before defoliation, these stands had as much as 85% of the basal area in oak species, but it is obvious that the future forest will bear little evidence of that oak dominance.

Forest Arthropods

For populations of ants, phalangids, spiders, and carabid beetles, trends in stands that have been thinned and defoliated (Table 3) roughly parallel those of stands that had been defoliated only (Table 1). Thinning slightly elevated phalangid levels in 1990 and 1991 and also increased carabid populations in 1991. An increase in carabid abundance could be particularly significant because members

Table 3.—Average number of arthropods per trap collected in pit-fall traps in defoliated and thinned stands, by year and group.

Arthropod	Year			
	1989	1990	1991	1992
Ants	83	74	64	51
Phalangids	8	10	18	8
Spiders	65	74	115	NA
Carabid beetles	64	26	48	38

of this group are known, active predators of the gypsy moth. The abundance of all groups except spiders decreased over time, and spider abundance increased dramatically with each year.

Species-level analyses are needed to understand the complete effects of defoliation and thinning. Ameliorating potentially detrimental effects may present a more critical problem. In this same study area, for example, in stands that have not been defoliated but only thinned, there are notable changes in species and abundance. Moreover, the effects of defoliation and thinning alter forested ecosystems in a more dramatic way than either effect alone.

SUMMARY

The persistence of gypsy moth effects may go undetected or mistaken for natural processes, especially with the realization that ecosystems rarely attain a steady state. At a certain level, changes caused by gypsy moth may have nominal influence in natural processes. But, the effects of extensive and severe gypsy moth defoliation do not resemble processes of stand dynamics, but rather represent post-disturbance trends. Many such trends are predictable, such as the replacement of the overstory with shade intolerant species. The most dramatic changes in eastern forests reflect the loss in dominance of oak in the forests. In places like the Ridge and Valley Province of Pennsylvania, the full ramifications of changing forest composition may not be realized for decades. As the gypsy moth moves into other regions, e.g. the mixed mesophytic forests, the effects are likely to differ.

Preliminary information on other organisms, such as forest arthropods, indicates that gypsy

moth may influence biological diversity as well as food web dynamics. A more complete understanding of the interaction of other forest arthropods with gypsy moth populations is needed. Furthermore, the effects of defoliation appear to be site specific and have a great deal to do with pre-disturbance conditions, both in terms of vegetation and faunal communities.

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