# Response of Ground-level Wildlife Food Plants to Canopy Defoliation by the Gypsy Moth

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*Abstract:* We studied changes in ground-level vegetation (shrubs, herbs, vines, trees) in a deciduous forest before (1984) and after (1987) the initial stages of a gypsy moth (*Lymantria dispar*) invasion. Seventeen of 18 plant species known to be important wildlife food plants increased in percent cover from 1984 to 1987. Total percent ground cover and plant species richness also increased. At the same time, the number of snags and snag basal area increased but not significantly, implying that the gypsy moth can be used as a management tool to enhance understory vegetation without harvesting trees. By 1988, however, tree mortality had significantly increased. A variety of options, therefore, exists for wildlife managers faced with a gypsy moth invasion, including no action, halting the outbreak with pesticides, or silvicultural treatment prior to invasion. Advantages and disadvantages of each depend on management objectives and budgetary and environmental constraints.

The introduced gypsy moth has become the most important insect pest of eastern deciduous forests. In 1987, 538,300 ha of forest were defoliated by the gypsy moth, mostly in the northeast and mid-Atlantic states (U.S. Dep. Agric. 1985). Additional defoliation and subsequent tree mortality were prevented in

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many other areas with pesticides. Gypsy moths are costly to the forest industry, and most forest managers consider their control necessary.

Habitat perturbations such as forest thinnings, clearcuts, and prescribed fire benefit certain wildlife species because they promote growth of annual and perennial herbs and shrubs which provide food and shelter. Similarly, defoliation by gypsy moths opens the forest canopy allowing increased light and water penetration (Collins 1961, Campbell and Sloan 1977, Allen and Bowersox 1989, Hix et al. 1991). Habitat enhancement for forest wildlife may, however, reach a point of diminishing returns if substantial canopy tree mortality results from defoliation (McConnell 1988). In the central Appalachian states, host trees are likely to be oaks (*Quercus* spp.) which are both preferred foods of gypsy moths and sources of mast for white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*), and other wildlife (Martin et al. 1951).

We examined the response of understory plant species, known to be important wildlife foods, to canopy defoliation caused by gypsy moths during the initial stages of a first outbreak.

## Methods

The study area was the Sleepy Creek Public Hunting and Fishing Area (PHFA) which straddles the intersection of Sleepy Creek and Third Hill Mountains at elevations of 270–610 m in Morgan and Berkeley counties, West Virginia. In 1984, at study initiation, Sleepy Creek PHFA contained 8,000 ha of contiguous oak-hickory forest. Dominant canopy species included white (scientific names appear in Table 1), chestnut, and red oaks; hickories; and yellow poplar. Common understory trees included red maple, black gum, sassafras, and black birch. Gypsy moths were present but not abundant in 1984. While defoliation occurred on the study area in 1985, only about 5 ha of forest was defoliated enough to be obvious. Moderate defoliation ($\bar{x} = 40.6\%$, SE = 3.8, $N = 62$ of overstory chestnut oaks) occurred over much of the study area in 1986 (P. J. Martinat, unpubl. data). By 1987 most of the study area was defoliated (50%–100% defoliation of individual overstory oaks), and many overstory oaks were dead by spring 1988.

In 1984, 36 sampling stations were established on Sleepy Creek Mountain with the purpose of estimating bird populations and various vegetation parameters

prior to and during a gypsy moth outbreak (Thurber 1992). Understory vegetation sampling from 15 May – 15 June measured understory cover prior to that year's defoliation, which had to be measured after gypsy moth pupation (usually after 15 Jun) but before substantial refoliation occurred (usually by 1 Jul). Vegetation was sampled on 5 0.04 ha circular plots at each station (1 at the station center and 1 randomly located 26–125 m from the center in each of 4 90° quadrants for a total of 180 plots). Using a sighting tube and procedures described by Cooper et al. (1987) for estimating canopy cover, 20 point intercept samples of ground cover vegetation were recorded on each plot. Sometimes taller vegetation (1–3 m) had to be moved aside to view the ground cover vegetation. In that case, the shrub or tree moved aside also was counted as having been intercepted, and together with ground cover was considered as understory vegetation. Percent coverage by each plant species was estimated on each plot as a percentage of all points that intercepted foliage of that species. Basal area was calculated for each species from diameter at breast height (dbh) values measured for every live and dead tree in each plot. Also, each tree in the plot was assigned to 1 of 4 defoliation levels (0 = no defoliation, 1 = 1%–33% defoliation, 2 = 34%–67% defoliation, 3 = >67% defoliation).

The following null hypotheses were tested regarding understory response to defoliation: (1) there was no difference in percent cover of individual understory plant species between 1984 and 1987; (2) there was no difference in understory species richness between 1984 and 1987; and (3) there was no difference in numbers or basal area of snags between 1984 and 1987. All of the above hypotheses were tested using the Wilcoxon signed rank test (Hollander and Wolfe 1973). If the percent cover was 0 in both 1984 and 1987 for a particular plot, it was not included in the analysis.

## Results

Defoliation was patchy, and ranged from an estimated 0% to 100% for individual plots in 1987. Defoliation level in 1987 was 1.02 (SE = 1.01) for the entire study area, or approximately 33%. Each of the understory shrub, vine, herbaceous, and tree species examined except flowering dogwood increased significantly ($P < 0.05$) in percent cover from 1984 to 1987 (Table 1). Total percent understory cover also increased from 1984 to 1987 and was not uniform over the entire study area. Understory species richness also increased from 1984 to 1987 ($P < 0.001$, Table 2).

Individual plant species formed dense patches of undergrowth in some locations. Of the 180 plots sampled, the number of plots containing >50% ground cover of a single species were: Virginia creeper (*Parthenocissus quinquefolia*), 33; sassafras, 29; blackberry, 10; greenbriar, 8; blueberry, 3; black cherry, 3; red maple, 2; and beaked hazelnut, 2. Three species, blackberry, sassafras, and Virginia creeper formed 100% ground cover on at least 1 plot.

The number of snags on individual plots increased from 1984 to 1987, but not significantly (Table 2). When only large (>22.9cm dbh) snags were considered, however, the difference was significant, translating to a difference of <0.5 snags/

**Table 1.** Wildlife food plants (plots occupied $N$ and mean % cover) in 1984 prior to gypsy moth caused defoliation and in 1987 after 1 year of moderate defoliation and during a year of heavy defoliation, at the Sleepy Creek PHFA, West Virginia.

| Species (Scientific name) | $N$ plots[a] 1984/1987 | 1984 | | 1987 | | $P$[b] |
|---|---|---|---|---|---|---|
| | | $\bar{x}$ | SE | $\bar{x}$ | SE | |
| Shrubs/vines | | | | | | |
| Blueberry (*Vaccinium spp.*) | 72/92 | 9.86 | 1.10 | 18.61 | 1.75 | <0.001 |
| Greenbrier (*Smilax rotundifolia*) | 44/59 | 8.71 | 1.45 | 18.71 | 2.59 | <0.001 |
| Blackberry (*Rubus spp.*) | 39/57 | 7.29 | 0.94 | 18.61 | 0.95 | <0.001 |
| Wild grape (*Vitis spp.*) | 24/56 | 2.95 | 0.65 | 9.77 | 1.03 | <0.001 |
| Mapleleaf viburnum (*Viburnum acerifolium*) | 19/40 | 2.36 | 0.51 | 11.04 | 1.82 | <0.001 |
| Beaked hazelnut (*Corylus cornuta*) | 5/57 | 0.60 | 0.28 | 14.40 | 1.60 | <0.001 |
| Trees | | | | | | |
| Sassafras (*Sassafras albidum*) | 109/132 | 11.57 | 1.01 | 28.46 | 1.96 | <0.001 |
| Red maple (*Acer rubrum*) | 52/112 | 3.57 | 0.50 | 14.33 | 1.17 | <0.001 |
| Chestnut oak (*Quercus prinus*) | 36/90 | 2.33 | 0.36 | 16.12 | 1.41 | <0.001 |
| Red oaks[c] (*Quercus spp.*) | 30/102 | 1.67 | 0.28 | 10.42 | 0.72 | <0.001 |
| Blackgum (*Nyssa sylvatica*) | 22/62 | 1.94 | 0.39 | 9.17 | 0.98 | <0.001 |
| Flowering dogwood (*Cornus florida*) | 21/14 | 7.88 | 1.45 | 5.58 | 1.58 | >0.500 |
| Hickory (*Carya spp.*) | 17/53 | 2.00 | 0.53 | 8.08 | 0.91 | <0.001 |
| Black birch (*Betula lenta*) | 10/27 | 2.58 | 1.02 | 6.97 | 1.06 | <0.001 |
| American chestnut (*Castanea dentata*) | 7/26 | 1.17 | 0.39 | 6.67 | 0.88 | <0.001 |
| White ash (*Fraxinus americana*) | 6/27 | 2.14 | 0.94 | 8.75 | 0.95 | <0.001 |
| White Oak (*Quercus alba*) | 6/16 | 1.59 | 0.61 | 5.00 | 0.87 | 0.014 |
| Black cherry (*Prunus serotina*) | 3/16 | 2.19 | 1.58 | 25.63 | 5.59 | <0.001 |

[a] Number of plots out of 180 measured in which the species was detected.
[b] Probability of no difference among years, Wilcoxon signed rank test.
[c] Includes northern red (*Q. rubra*), scarlet (*Q. coccinea*), and black oak (*Q. velutina*).

plot, but equal to almost 10 large snags/ha. Because of the difference in large snags between 1984 and 1987, the difference in snag basal area, although slight, was significant for all snags and for larger snags only (Table 2).

## Discussion

The likelihood that a stand will be defoliated (stand susceptibility) is related to many factors, including stand composition and stocking level (Gottschalk 1987). Stands with a high component of preferred host species, such as oaks, are most susceptible (Campbell and Sloan 1977, Houston 1981*a*). Defoliation does not kill trees directly. If defoliation is heavy (>60%) then the tree is likely to refoliate that season, stressing the tree by both depleting energy stores and preventing the production of new reserves (Wargo 1981*a*). Stressed trees become more vulnerable to insect and fungal attack and may die (Houston 1981*b*). If the tree is heavily defoliated >1 year, its chances of succumbing are increased (Wargo 1981*b*).

**Table 2.**      Comparisons of understory plant species richness and snag characteristics ($\bar{x} \pm$ SE) on 180 0.04-ha. circular plots in 1984 (predefoliation) and 1987 (postdefoliation) at the Sleepy Creek PHFA, West Virginia.

| Variable | 1984 | | 1987 | | |
|---|---|---|---|---|---|
| | $\bar{x}$ | SE | $\bar{x}$ | SE | P |
| Species richness | 3.81 | 0.13 | 7.16 | 0.19 | <0.001 |
| N snags[a] | 5.62 | 0.37 | 6.36 | 0.42 | 0.09 |
| N large snags[b] | 0.63 | 0.08 | 1.01 | 0.08 | <0.001 |
| Snag basal area[c] | 3.17 | 0.23 | 4.48 | 0.30 | <0.001 |
| Large snag basal area | 1.50 | 0.19 | 2.57 | 0.27 | <0.001 |

[a] Snags >7.62cm dbh and taller than 3m.
[b] Snags >22.9cm dbh.
[c] Expressed as m²/ha.

In eastern Massachusetts oak forests, Campbell and Sloan (1977) compared the effect of defoliation to thinnings that removed subdominant and suppressed trees, opened up the forest canopy, and changed species composition to that with a lower component of oaks. Such changes produced stands of individual trees less susceptible to gypsy moth defoliation. Gypsy moth populations then behaved more like endemic caterpillar populations. Elkinton and Liebhold (1990) also believed that subsequent outbreaks should not be as frequent nor as long as initial invasions.

In our study, most large oaks were still alive after 1 year of moderate defoliation and little refoliation (1986), and 1 year of heavy defoliation (1987). Between 1984 to 1987, percent cover increased for virtually every important browse and soft mast plant species. Only flowering dogwood did not show a positive response, perhaps because of lethal dogwood anthracnose (Hibben and Daughtrey 1988). Understory species richness also increased. Both defoliation and understory growth were patchy in distribution.

The increases we found probably were caused by canopy openings created by defoliating gypsy moths. Results were consistent with our current knowledge of forest ecology and with other studies (Collins 1961, Campbell and Sloan 1977, Doane and McManus 1981, Allen and Bowersox 1989, Hix et al. 1991), but we cannot be certain of cause and effect because the study lacked control (i.e., undefoliated) plots. Lack of control plots is unfortunate, but pesticides used to keep plots undefoliated would alter the natural arthropod herbivore community.

The understory response we observed is beneficial to many wildlife species. White-tailed deer are known to browse on many of the species listed in Table 1. Soft mast species such as blueberry, huckleberry, blackberries, and wild grape are important foods of wild turkey and ruffed grouse (*Bonasa umbellus*) (Martin et al. 1951). Eastern cottontail (*Sylvilagus floridanus*) and many small mammals use cover provided by understory growth. At the same time, tree mortality was slight enough not to eliminate mast-producing tree species. Even if trees do not die, however, acorn production could decline temporarily from direct consumption of

flowers, abortion of immature acorns from low carbohydrate supply, and lack of flower bud initiation (McConnell 1988).

## Management Implications

The understory response and subsequent benefit to wildlife implies that the gypsy moth could be used as a management tool. If an outbreak can be halted opportunely, such as after the first year of widespread defoliation, then understory growth may be enhanced while saving most overstory oaks and hickories. The estimated 10 large snags/ha would provide canopy openings sufficient to support a continued patchy growth of understory vegetation. If an outbreak is halted only after 2 years of widespread defoliation, however, tree mortality may be substantially higher. For example, basal area losses on Sleepy Creek PHFA exceeded 40% by 1991 (Thurber 1992).

Outbreaks are likely to be halted only by pesticide application. Dimilin®, or diflubenzuron, is particularly effective against gypsy moths while having minimal known negative effects on terrestrial wildlife populations (Cooper et al. 1990). Effects on aquatic systems are a concern (U.S. Dep. Agric. For. Service 1985). *Bacillus thuringiensis* (Bt), a microbial pesticide, is environmentally very safe but is generally less effective than Dimilin®, (Dubois 1981). Interestingly, because partial defoliation is still likely to occur in forests treated with Bt, an understory response similar to the one in our study area might be observed while avoiding substantial tree mortality (Cameron 1989).

Another option that may meet similar objectives while avoiding pesticides is silvicultural treatment to minimize gypsy moth impacts prior to an invasion (Gottschalk 1987). Preoutbreak prescriptions focus on reducing stand susceptibility by increasing stand vigor, removing trees most likely to die, reducing gypsy moth habitat and preferred food sources, and promoting regeneration. Recommended prescriptions include thinnings, harvests, and insecticide applications, and depend upon factors such as stand composition, age, stocking levels, and condition, and projected years to defoliation. These guidelines have yet to be fully tested.

Two points should be emphasized. First, gypsy moth - forest stand interactions are likely to be highly site-specific. What we observed may not be typical of other areas likely to be invaded by the gypsy moth. Second, we are not suggesting this as a preferred course of action, only that it is an option open to forest and wildlife managers. The concept of the gypsy moth as a wildlife management tool will be unpopular with forest managers, because some large overstory trees are likely to be killed. If the outbreak is not halted, oak mortality can be severe. Gansner et al. (1987) stated that gypsy moth infestations generally result in mortality losses of <15% of total basal area. However, more trees may die than expected if unfavorable weather conditions such as drought occur (Campbell and Sloan 1977). Instead of creating snags artificially, tree mortality caused by the gypsy moth may also be used to meet snag management goals.

The gypsy moth has become a permanent component of most eastern deciduous forests. It is not currently known if a completed gypsy moth outbreak will hurt

or benefit wildlife populations, but preliminary data indicate that deer and turkey populations are not declining and may actually be increasing in areas of Pennsylvania that have experienced numerous years of defoliation (A. H. Hayden, Pa. Game Comm., pers. commun.). Impacts are likely to be species and site specific.

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