# GYPSY MOTH DEFOLIATION POTENTIAL IN THE OUACHITA/OZARK HIGHLANDS REGION

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**Abstract**—The gypsy moth is expanding its range in North America and is likely to invade the Ouachita/ Ozark Highlands region sometime during this century. A previous analysis indicated that forests in this area are among the most susceptible in North America to defoliation by this insect. We used USDA Forest Service, Forest Inventory and Analysis data to evaluate forest susceptibility in the region. Susceptibility was estimated as the proportion of basal area composed of tree species preferred by gypsy moth caterpillars. Analyses were stratified by ecological land type and land ownership. Forest susceptibility is highest to the north, in the Ozark Highland's area; ca. 80 percent of the forests in this area have high to very high susceptibility to defoliation. Forest susceptibility was lower to the south in the Ouachita region. This trend in susceptibility reflects the increased pine component in southern portions of the region (pine species are not highly preferred by the gypsy moth). South of the Ozark Highlands, in the Boston and Ouachita Mountains, the lower proportion of susceptible forests is lower in land owned by the forest industry, presumably because of more intensive management of softwoods. Most forests in the Ouachita/Ozark region are susceptible to gypsy moth defoliation. Should populations become established in this area, intense defoliation could result in extensive ecological and economic consequences.

## INTRODUCTION

Since the gypsy moth was originally introduced near Boston in 1868 or 1869, it has been slowly expanding its range to include the entire Northeastern United States and portions of Virginia, West Virginia, North Carolina, Ohio, and Michigan (Liebhold and others 1992, 1997a). In many of the forested regions where this insect has become established, outbreaks occur intermittently every 5 to 15 years (Williams and Liebhold 1995). During these outbreaks, defoliation of host trees can be extensive and result in severe ecological and economic effects. It is inevitable that the gypsy moth will continue to spread to the south and west during this century.

The Ouachita/Ozark Highlands region is currently ca. 750 km from the expanding front of gypsy moth defoliation. Based on an historical rate of spread of ca. 21 km/yr (Liebhold and others 1992), we might expect the first defoliation in the region around the year 2035, though it is possible that gypsy moth will be introduced accidentally to the area before then. Isolated infestations have been discovered in the region but eradication efforts to date have been successful. Should future eradication efforts fail or if this strategy is abandoned, defoliating populations likely will appear before 2035. The USDA Forest Service has initiated a program aimed at slowing the spread of the gypsy moth in the Midwest and elsewhere (Leonard and Sharov 1995, Sharov and others 1998). If this program is continued and successful, defoliating populations may not invade the region until well after 2035.

To plan for the management of the gypsy moth, the distribution of susceptible stands must be limited in currently uninfested areas. Liebhold and others (1997a, 1997b) analyzed forest inventory data from across the conterminous United States to evaluate the susceptibility of all forests to gypsy moth defoliation. The analysis indicated that the Ouachita/Ozark Highland's had one of the highest concentrations of forests that are highly susceptible to the gypsy moth. In this paper we provide a more detailed description of projected forest susceptibility to gypsy within this region.

## METHODS

The gypsy moth is a polyphagous insect; North American populations feed on more than 300 different shrub and tree species (Leonard 1981, Liebhold and others 1995). Despite this breadth of host preference, there is considerable variation among Northeastern North American forests in their susceptibility to defoliation. We define susceptibility as the probability or frequency of defoliation given an established gypsy moth population in the area (Gottschalk 1993).

Several studies that have focused on relating various characteristics of forests to susceptibility have yielded susceptibility models of varying levels of complexity. Perhaps the most important factor affecting stand susceptibility is the proportion of basal area represented by species that are highly preferred by the gypsy moth (Herrick and Gansner 1986). Other variables, such as the predominance of chestnut oak, the abundance of tree structural features; e.g., bark flaps, and various site characteristics; e.g., soils, are correlated with susceptibility (Bess and others 1947, Herrick and Gunner 1986, Valentine and Houston 1979). However because of the dissimilarity between forests of the Northeast where the earlier studies were conducted and Ouachita/ Ozark forests; e.g., chestnut oak does not grow there, it is questionable whether previous correlations could be extrapolated for this region. Also, relatively few site and tree characteristics used in earlier studies had been measured in the forest inventory data available to us. As a result, we excluded all plot characteristics except species composition.

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**Table 1—Number of FIA plots used in the analysis**

| State | Year of inventory | Number of forested plots |
|---|---|---|
| Arkansas | 1995 | 2,796 |
| Missouri | 1989 | 6,645 |
| Oklahoma | 1993 | 663 |

FIA = Forest Inventory and Analysis.

Thus we adopted proportion of basal area represented by preferred species as the measure of forest susceptibility. Montgomery's (1991) three-way classification (susceptible, resistant, immune) was used to categorize each tree species. This classification was based on a summary of field and laboratory studies, as well as extrapolations based on taxonomic affinity. It is described in detail in Liebhold and others (1995). In a previous study in which similar data were used (Liebhold and others 1997b), proportion of basal area was highly correlated with defoliation frequency at the county level for States located within the infested area.

Assessment of forest susceptibility was based on USDA Forest Service, Forest Inventory and Analysis (FIA) data compiled in the Eastside Forest Data Base (Hansen and others 1993). These data are collected in statewide inventories conducted every 10 years. Inventory data are collected at permanent plots located throughout forested areas of each State. We selected data from the 9,777 plots in Arkansas, Missouri, and Oklahoma that fell within the Ouachita/Ozark Highlands (table 1) (fig. 1).

Summaries of forest susceptibility were stratified using an ecological land type classification developed by Keys and others (1995). Expanded, from an earlier classification by Bailey (1995) the hierarchy of Keys and others begins with domain at the global ecoregion level and can be refined to the landscape and land unit, which can be hundreds to < 10 ha in size. Provinces are regional ecological delineations. The areas of interest for this study in the Ozark-Ouachita area fall within four provinces. The Ozark Highlands section is categorized within the Eastern Broadleaf Forest (continental) Province. The Boston Mountains section is the only one within the Ozark Broadleaf Forest—Meadow Province. The Arkansas Valley section is one of seven sections within the Southeastern Mixed Forest Province. The Ouachita Mountains section is the only one in the Ouachita Mixed Forest—Meadow Province. Twenty subsections fall within these four sections (table 2). The location of each FIA plot within a subsection was determined by comparing approximate survey plot locations with the digital map version of the Keys and others (1995) classification using a GIS. When plots fell near the margin of a subsection, final classification into the appropriate subsection was determined by subjectively comparing individual plot locations with a digital elevation model of the region (Foti and Bukenhofer 1999).

All inventory data contained information about individual trees and plots. Individual tree records were used to sum total basal area by species for each plot. These plot records were then expanded (using appropriate factors) to subsection-level estimates of basal area per acre. This information was then used to estimate the proportion of forested land in each subsection that fell into one of four susceptibility classes based on the percentage of basal area composed of preferred tree species: 0 to 20 percent = low, 20 to 50 percent = moderate, 50 to 80 percent = high, 80 to 100 percent = very high. We used this susceptibility classification scheme in our earlier analysis (Liebhold and others 1997b) because historical patterns of defoliation seem to be closely related to these classes (Gottschalk 1993). The type of land owner is recorded at all FIA plot locations, so we estimated the proportion of land falling in each of the four susceptibility classes for public forest, forest industry, and other private land for each subsection.

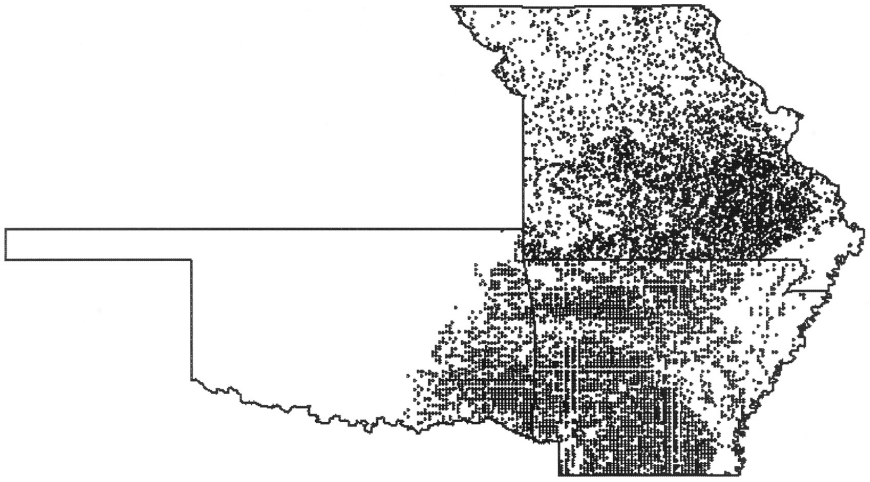

Figure 1—Location of USDA Forest Service, Forest Inventory and Analysis plots in Missouri, Arkansas, and Oklahoma.

**Table 2—Characteristics of ecological landtype subsections in the Ouachita and Ozark Highland's region[a]**

| Section | Subsection | Number of plots | Preferred species |
|---|---|---|---|
| | | | *% BA* |
| Ozark Highlands (222A) | | | |
| St. Francis Knobs and Basins | 222Aa | 256 | 64 |
| Central Plateau | 222Ab | 921 | 70 |
| Osage River Hills | 222Ac | 279 | 75 |
| Gasconade River Hills | 222Ad | 211 | 66 |
| Meramac River Hills | 222Ae | 301 | 71 |
| Current River Hills | 222Af | 417 | 66 |
| White River Hills | 222Ag | 605 | 59 |
| Elk River Hills | 222Ah | 87 | 74 |
| Black River Ozark Border | 222Al | 210 | 67 |
| Springfield Plain | 222Am | 215 | 65 |
| Springfield Plateau | 222An | 225 | 65 |
| Boston Mountains (M222A) | | | |
| Boston Mountains | M222AA | 157 | 55 |
| Boston Hills | M222AB | 374 | 51 |
| Arkansas Valley (231G) | | | |
| Eastern Arkansas Valley and Ridges | 231GA | 127 | 39 |
| Mount Magazine | 231GB | 115 | 40 |
| Western Arkansas Valley and Ridges | 231GC | 127 | 51 |
| Ouachita Mountains (M231A) | | | |
| Fourche Mountains | M231AA | 372 | 38 |
| West Central Ouachita Mountains | M231AB | 239 | 34 |
| East Central Ouachita Mountains | M231AC | 232 | 38 |
| Athens Piedmont Plateau | M231AD | 132 | 23 |

BA = basal area.

[a] Subsection codes in parentheses.

## RESULTS AND DISCUSSION

The Ouachita/Ozark Highlands region is a hilly to mountainous area that differs from the surrounding area both in topography and geological origin. The Highlands consist of two ecological sections—the Ozark Mountains in southern Missouri, northern Arkansas, and northeastern Oklahoma; and the Ouachita Mountains in western Arkansas and eastern Oklahoma. Table 2 shows the estimated percentage of basal area composed of tree species preferred by the gypsy moth in each of these sections. As stated earlier, we used this percentage as our metric of forest susceptibility to the gypsy moth. The Ozark Highlands section (222A) generally had the most susceptible mixtures of species of the four sections. These same data were mapped graphically (fig. 2) and clearly show a trend with increasing proportions of susceptible species, particularly oaks, in the northern portion of the region. Examination at a coarser scale of forest type reveals a north-south trend in forest type that reinforces our analysis (fig. 3).

The dominant forest type group in the northern portion of the Ouachita/Ozark Highlands is oak-hickory while the loblolly-shortleaf pine type group dominates in the southern portion of the region. Each of the forest type groups in figure 3 represents many different specific forest types (Eyre 1980). Nevertheless, these maps depict a real trend in the region; that is increased dominance of oak to the north and increased dominance of pine to the south. Analyzing FIA data from the Ouachita/Ozark Highland regions Guldin and others (in press) found that the proportion of stands in the oak-hickory forest type group was greater in the Ozark Mountain section (north) and that the proportion of stands in the loblolly-shortleaf type group was greatest in the Ouachita Mountains section.

The observed trend from oak-dominated to pine-dominated forests from north to south in the Ouachita/Ozark regions reflect in part an historical anomaly. At one time much of the forested area of the Missouri Ozark Mountains currently dominated by oak-hickory forests were dominated by pure shortleaf pine or mixed pine-oak forests. Before 1880, pine and oak-pine cover types were estimated at 6.6 million acres in Missouri (Liming 1946). Extensive logging and changes in fire frequency have resulted in shifts in species composition (Batek and others 1999).

Our results were derived from summaries pooled across all inventory plots in land type subsections. The question arises: how is susceptibility to gypsy moth distributed among individual stands? Figure 4 shows estimates of the percentages

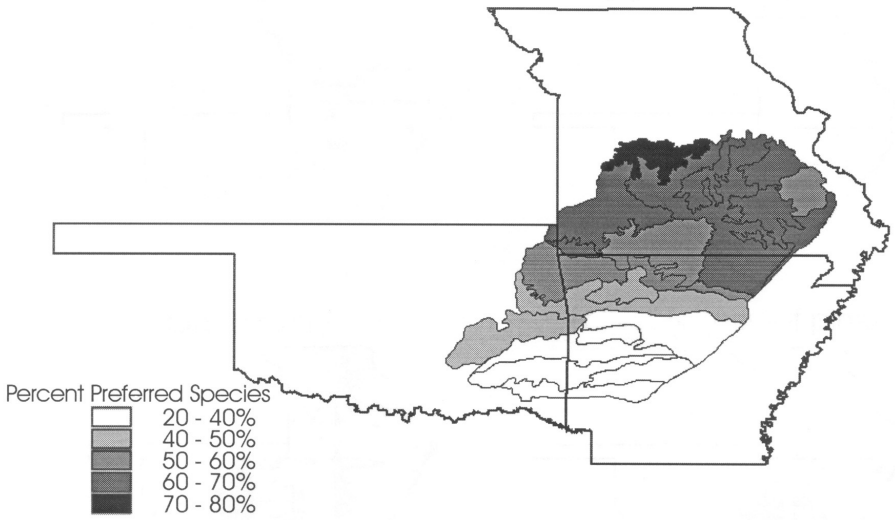


Figure 2—Map of the Ouachita and Ozark Highlands region showing the proportion of basal area composed of tree species susceptible to the gypsy moth by ecological subsection.

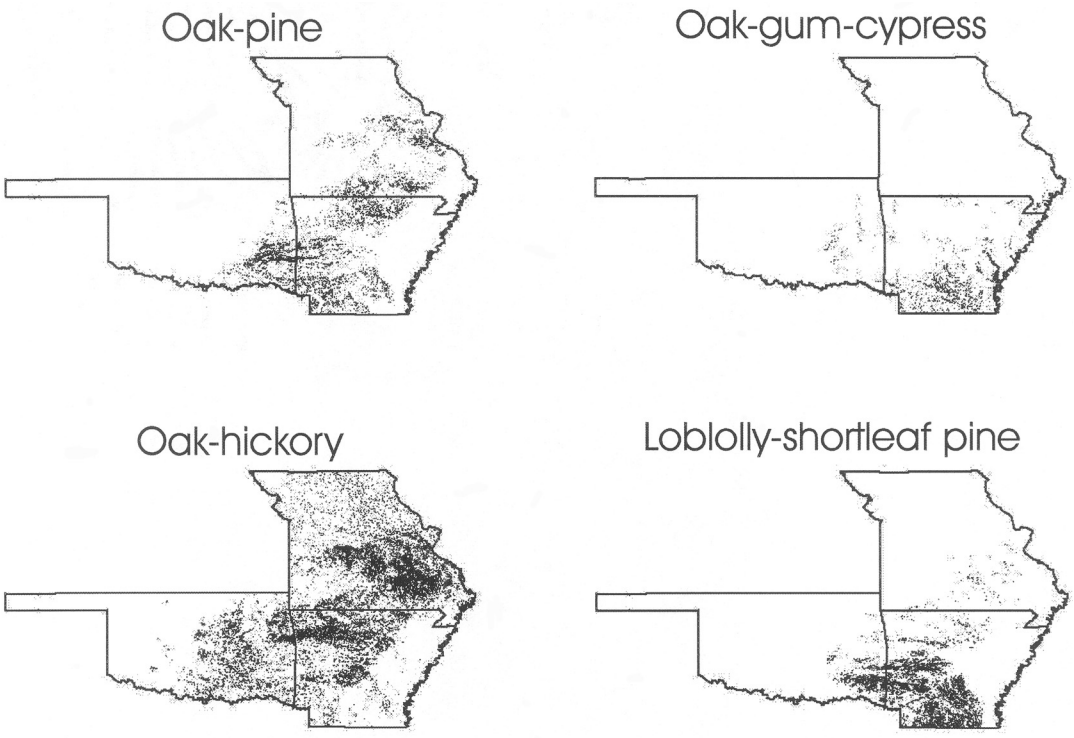


Figure 3—Distribution of four major forest types in the Ouachita and Ozark Highlands region. Maps were modified from maps described in Zhu and Evans (1992).

of land area covered by forest of varying levels of susceptibility. These data indicate that the Ozark Highlands had the greatest area in highly susceptible stands and the Ouachita Mountains section had the highest area in stands with low susceptibility. This reflects the same latitudinal trend seen in figure 2 and presumably is due to the higher pine component in the more southerly subsections.

Separate analysis of susceptibility by ownership in the Boston and Ouachita Mountains revealed a lower proportion of susceptible forests on forest industry lands (fig. 5). Much of the industry land in these sections is managed for softwood production. This higher pine component would explain the lower susceptibility in these sections compared to public and other private lands. Guldin and others (in press), by contrast, forest industry land in the Ozark Highlands is largely

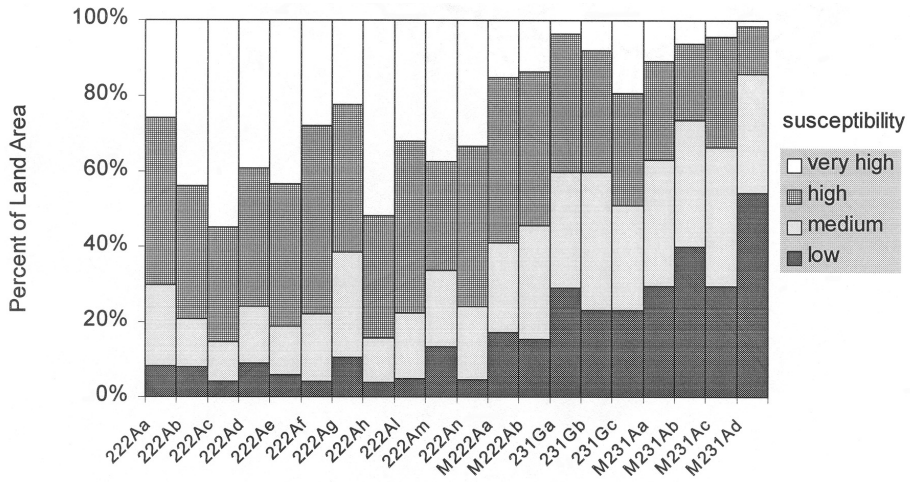


Figure 4—Percentages of forest land area falling into each of four gypsy moth susceptibility classes for each subsection. Susceptibility classes were based on percent basal area composed of species preferred by the gypsy moth: low = 0 to 20 percent, medium = 20 to 50 percent, high = 50 to 80 percent, and very high 80 to 100 percent.

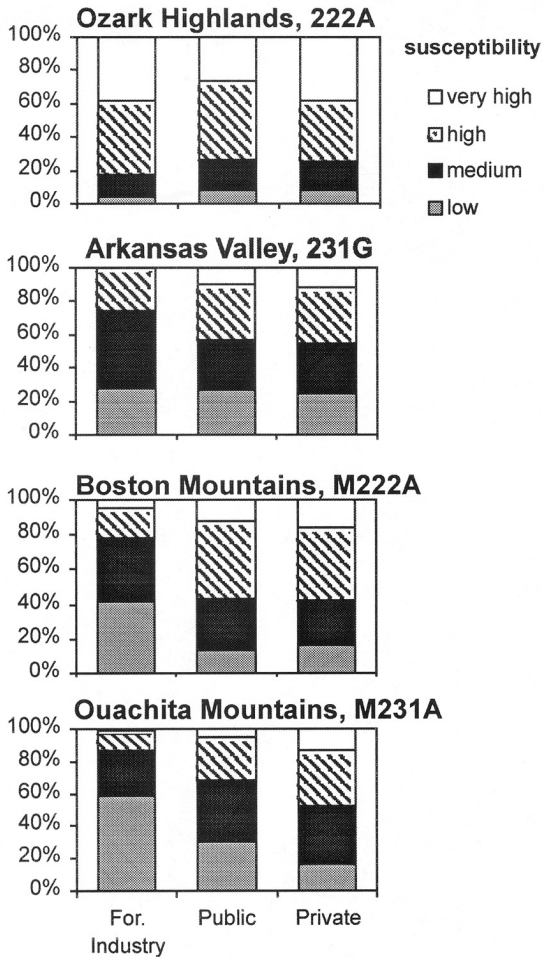


Figure 5—Percentages of forest land area falling into four gypsy moth susceptibility classes for different land ownership classes in each land type section. Susceptibility classes were based on percent basal area composed of species preferred by the gypsy moth: low = 0 to 20 percent, medium = 20 to 50 percent, high = 50 to 80 percent, and very high 80 to 100 percent.

managed for oak and seems to be at least as susceptible as public and other private land (fig. 5).

The classification of forest susceptibility solely on the basis of species composition may not capture all of the differences with respect to the true susceptibility to gypsy moth defoliation. One trend that can be extracted from studies of gypsy moth susceptibility in the Northeastern United States apart from the association with dominance by preferred species is that defoliation tends to be more intense on poor sites (Herrick and Gansner 1986, Valentine and Houston 1979). Guldin and others (2000) found that site quality generally was greater to the south in the Ouachita region and lower to the north in the Ozark Highlands. If forest susceptibility to the gyspy moth continues to be associated with poor sites, as has occurred in the northeast, this would tend to reinforce the trend observed in figures 3 and 4, that is forest susceptibility is greater in the northern portion of the region.

## CONCLUSION

The range of the gypsy moth is likely to continue to expand and defoliating populations are likely to occur in the Ouachita/Ozark Highlands region during this century. An analysis by Liebhold and others (1997a, 1997b) indicated that forests in this area are among the most susceptible in the Nation to defoliation by this insect. The establishment of gypsy moth populations in the region could result in extensive ecological and economic consequences. Our analysis indicates that forest susceptibility is particularly high to the north, in the Ozark Highlands. The data in figure 4 indicate that ca. 80 percent of the forests in this area have high to very high susceptibility to defoliation. It is likely that gypsy moth populations will not become established for another 30 years. Still forest management practices in this area that promote pines or other species not favored by the gypsy moth should reduce the future impact of this insect pest (Gottschalk 1993).

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