MORTALITY FOLLOWING GYPSY MOTH DEFOLIATION IN THE CENTRAL APPALACHIANS[1/]

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Abstract.--Using stepwise discriminant analysis, an equation was formulated which effectively classifies trees as dead or living in stands that were previously defoliated by gypsy moth. Variables that were most useful in classification were species preference, slope percent, tolerance class, aspect, and site index. Trees that were most vulnerable to mortality were oaks (particularly white oaks), growing on slightly steeper slopes, slightly less tolerant, growing on more southwesterly exposures and on better sites than trees that remained alive. Using this equation, approximately 75% of the trees were correctly classified.

Keywords: *Lymantria dispar*, gypsy moth, tree mortality

INTRODUCTION

The hardwood forests of the Appalachian region have proven to be highly susceptible to defoliation by gypsy moth (Houston 1981). The major forest cover types in the Appalachians contain a substantial oak component (Braun 1950), and oaks are among the most preferred species for defoliation (Houston 1979). The oak-hickory type, which occurs along the parallel ridges extending from Pennsylvania into Alabama, seems particularly susceptible. Damage in the Ridge and Valley section of Pennsylvania has amounted to hundreds of millions of dollars (Quimby 1985), and the prospects for even greater damage exist as the leading edge of defoliation moves south (Gansner *et al*. 1983)

Although defoliation creates a considerable nuisance and detracts from aesthetic values, it is the subsequent tree mortality that is of greatest concern to most forest land managers. Trees die when defoliation weakens them and predisposes them to secondary agents such as shoestring fungus root rot [*Armillaria mellea* (Vahl. : Fr.) Kummer] and two lined chestnut borer [*Agrilus bilineatus* (Weber)] (Wargo 1977). In the Northeast, certain site and stand characteristics were found to be related to tree mortality (Houston 1981, Kegg 1973), and a similar pattern is becoming apparent in the Appalachian region (Gansner 1981, Hicks 1984).

It is the purpose of our research to identify those factors that relate to tree mortality in the Appalachian Plateau and Ridge and Valley Regions as gypsy moth moves south into these important commercial hardwood forests. Once identified, these relationships will be useful to landowners when deciding on a pest management strategy and in formulating silvicultural guidelines for coping with the gypsy moth (Gottschalk 1982).

PROCEDURES

We have established 408 plots, approximately evenly divided between the Ridge and Valley Region of Allegany County, Maryland and the Appalachian Plateau of Cambria and Somerset Counties, Pennsylvania. These areas are typical of their respective physiographic provinces, although somewhat biased toward more gypsy moth susceptible forest types, and are along the leading edge of gypsy moth infestations. Plots

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were placed in stands that had more than 250 gypsy moth egg masses per acre, and the majority were facing significant defoliation for the first time. Areas slated for chemical control of gypsy moth were avoided except in the case of undefoliated control plots. We attempted to sample a representative range of site quality (oak site index 30-100 ft.) and a species mix ranging from about 10% basal area oak to almost pure oak stands.

Tenth-acre plots were centered at 3- to 5-chain intervals. The plot center was marked with a wooden stake, and trees in the plot were numbered in a clockwise direction, beginning with the first tree encountered from due north. Data collected on individual trees included species, dbh, merchantable height, total height, vigor, crown class, and percent defoliation (ocular estimate). Site data included aspect, slope position, slope percent, percentage exposed rock and soil type (from SCS soil survey). Stand age and site index were determined using increment cores and total height from 4 dominant or codominant northern red oaks (if available) in or near the plot. When 4 red oaks were unavailable, scarlet, black, white or chestnut oaks were used and the equations of Wiant and Lamson (1983) were employed to compute site index in all cases.

To facilitate analysis, several variables were derived from the field data, including: species preference, a subjective measure of a species' desirability as a food source; tolerance, a subjective scaling of relative shade tolerance of species; and transformed aspect. An explanation of these variables follows.

Species preference - Preference classes are based on those reported by Houston (1979) and are as follows:

SPECPREF 1 (most preferred) - white oak, chestnut oak
SPECPREF 2 (preferred) - northern red, black and scarlet oak
SPECPREF 3 (intermediate) - American basswood, quaking and bigtooth aspen, hawthorn
SPECPREF 4 (less preferred) - slippery and American elm, black gum, black walnut, black cherry, flowering dogwood, cucumbertree, witch-hazel, serviceberry, pin cherry, sassafras, red maple, yellow and sweet birches, pignut, shagbark, mockernut and bitternut hickories, pitch, Virginia and table-mountain pines
SPECPREF 5 (non-preferred) - yellow-poplar, white ash

Tolerance - Subjective tolerance classes are those reported in Fowells (1965) and Smith and Linnartz (1980) as follows:

TOL 1 (very intolerant) - quaking and bigtooth aspen, pin cherry, hawthorn
TOL 2 (intolerant) - pignut, shagbark, mockernut and bitternut hickories, black cherry, black gum, black walnut, pitch, Virginia and table-mountain pines, yellow-poplar, scarlet oak
TOL 3 (intermediate) - American and slippery elms, yellow and sweet birches, northern red oak, chestnut oak, cucumbertree, serviceberry, white ash, white oak, black oak
TOL 4 (tolerant) - American basswood, red maple, witch-hazel
TOL 5 (very tolerant) - flowering dogwood, sassafras

Transformed aspect - The method used by Auchmoody and Smith (1979) was used to produce transformed aspect values with a maximum value of 2.00 for northeast aspects and a zero value for southwest aspects. Other aspects have intermediate values (fig. 1).

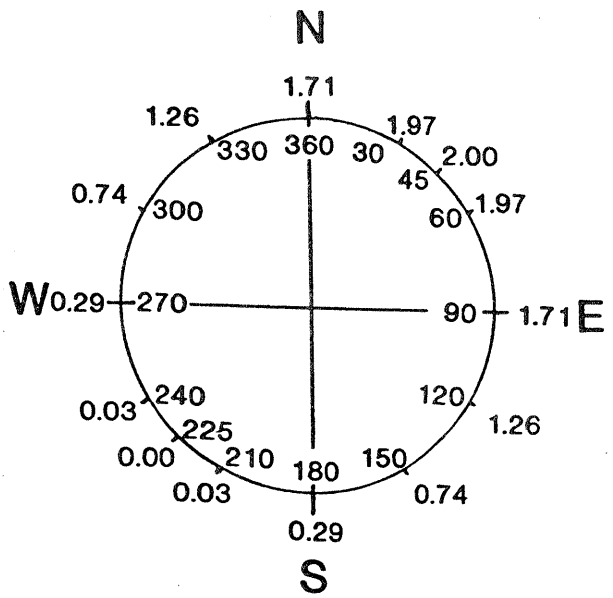

Figure 1.--Azimuth values (inside circle) and transformed aspect values (outside circle).

Stepwise discriminant analysis was used to determine the site and stand factors associated with tree mortality. The stepwise procedure permits the selection of variables that are effective in differentiating between subpopulations. The discriminant function was computed by dividing the trees in the 17 defoliated plots into two populations: living and dead. Of the 532 trees in the sample, 204 (38.3%) were dead and 328 (61.7%) were living.

RESULTS

Variables identified by stepwise discriminant analysis that were most effective in partitioning trees into living and dead categories were (in decreasing order of importance) species

preference, slope percent, tolerance, transformed aspect, and average site index. In general, trees in the dead category were in the more preferred host classes, occurred on steeper slopes, were slightly less tolerant, occurred on slightly less mesic aspects, and were on sites having higher site index values (Table 1).

Table 1.--Means and standard deviations for variables included in stepwise discriminant analysis, by live/dead class for the Appalachian Plateau plots.

Variable	Class	
	Live	Dead
Species preference	3.34 ± 1.02	2.53 ± 1.02
Slope percent	4.29 ± 1.57	5.15 ± 2.14
Tolerance class	3.61 ± 0.56	3.21 ± 0.52
Transformed aspect	1.18 ± 0.37	1.10 ± 0.35
Site index (oak)	48.64 ± 6.99	49.12 ± 5.31

Using the five variables selected in the stepwise process, the discriminant function was computed. The 534 trees were classified as living or dead based on the computed prior probability of an individual belonging to either class. Results of this procedure showed that of the 204 dead trees, 148 (72.55%) were correctly classified as dead while of the 328 living trees, 243 (74.09%) were correctly classified.

These results are encouraging in that about 3/4 of the trees in either category were correctly classified using discriminant analysis. For the most part, the variables represent data readily available for managed forest stands. Thus, forest managers should be able to make more informed decisions regarding what course of action to pursue when confronted with gypsy moth defoliation.

DISCUSSION

These results represent only 17 plots from the Appalachian Plateau Province that were heavily defoliated by gypsy moth four years prior to measurement. We have no data on the severity of defoliation of individual trees. Since species preference was a primary variable in predisposing trees to mortality, one might assume that dead trees were defoliated more heavily and thus subjected to greater stress. Although we have no way of assessing this, we suspect that it is probably true.

Although we have limited understanding of the biological relationships involved in vulnerability of trees to mortality, in a practical sense, the findings of this research demonstrate that it is possible to assign dead or living classification of trees based on measured site and stand variables with a fair degree of confidence. Although our information is somewhat preliminary and based on a relatively few plots, the data set contains over 500 trees which constitutes a reliable sample size. The discriminant model correctly classified the status of about 75% of the trees. It remains to be seen how effective this model will be when validated with other data sets, but an interesting comparison with similar data from the Ridge and Valley Province of West Virginia is afforded by the work of Crow (1985). Crow analyzed data from 2508 trees defoliated by insects in the looper complex. Using stepwise discriminant analysis, the same variables were identified as useful in classification of living versus dead trees as in the present study, except that the number of years defoliated replaced slope and dbh replaced tolerance in Crow's results (Table 2).

Table 2.--Means and standard deviations for variables included in stepwise discriminant analysis, by live/dead class for looper-defoliated stands in the Ridge and Valley Province Crow (1985).

Variable	Class	
	Live	Dead
Species preference	1.33 ± 0.72	1.04 ± 0.24
Transformed aspect	1.11 ± 0.59	1.21 ± 0.57
Dbh	8.16 ± 4.65	8.76 ± 3.96
Site index (oak)	64.85 ± 11.74	66.96 ± 13.35
Years defoliated	2.02 ± 0.80	2.10 ± 0.75

In Crow's results, both species preference and site index had a similar relationship to live/dead classification as in the Appalachian Plateau plots. Aspect had the reverse relationship which may not be important since the Plateau data set represented a series of plots taken along a relatively level hilltop and essentially had very little variation in aspect. Species preference was the most important classifying variable from both Crow's and our results, with the most preferred species (oaks, particularly white oaks) being most prone to mortality. Mortality was also associated with slightly higher site index in both studies. As in our study, Crow's discriminant equation correctly classified 73% of the dead trees in the sample. However only 47% of the live trees were correctly classified in Crow's study.

Since the biology of tree mortality

following defoliation is not completely understood, these empirical studies can serve as a foundation for hypotheses regarding the underlying causes of mortality. For example, we might speculate that certain species such as oaks, in addition to being preferred by defoliating insects, are also more susceptible to secondary organisms that ultimately cause mortality. This is certainly true for the two-lined chestnut borer and may also be true for Armillaria mellea (shoestring fungus). The relationship of site index to vulnerability is open to speculation. One might propose that more mesic sites provide a better habitat for Armillaria than xeric sites and thus defoliation in mesic stands would predispose trees to this fungus. Alternatively, one might propose that the more vulnerable tree species grow on the better sites.

Whatever the underlying mechanisms, we believe it is possible to rate the vulnerability of trees to mortality with a fair degree of confidence, and that such a rating has the potential of being an effective forest management decision-making tool.

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