EFFECTS OF PREVIOUS STAND MANAGEMENT ON MORTALITY FOLLOWING GYPSY MOTH DEFOLIATION: PRELIMINARY RESULTS”

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Abstract.--Oak-hickory forest stands were sampled for tree mortality using a series of temporary plots. Stands were classified by gypsy moth defoliation and by thinning treatment timing. Thinning of forest stands does accomplish its goal of reducing mortality in undefoliated stands; however, the effect is not clear when stands are defoliated.

INTRODUCTION

Foresters in central Pennsylvania observed that mortality following gypsy moth defoliation was higher in managed stands than in unmanaged stands. If this observation were true, proposed silvicultural treatments for minimizing the impact of gypsy moth (Gottschalk 1987) may increase the impacts. This study was conducted to test the hypothesis that there was no difference in mortality between managed and unmanaged stands.[3] The answer to this question is critical to the future development of silvicultural prescriptions for minimizing the impact of gypsy moth.

Four hypotheses were formulated to determine how thinning treatments might increase mortality following gypsy moth defoliation. The first is the concentration theory. In a thinned stand, the gypsy moth defoliation and mortality are concentrated on the crop trees left after a thinning; while in an uncut stand defoliation and mortality are dispersed across all of the trees. There is also less foliage present immediately after a thinning, so equal gypsy moth populations may cause more damage in a thinned stand.

The second hypothesis is the managerial perception theory. The amount of mortality in thinned--residual basal area (ba) of 60 sq. ft. per acre--and unthinned--ba of 100 sq. ft. per acre--stands could be equal on an absolute basis--20 sq. ft. ba--but very different on a relative basis--20 percent (20/100 sq. ft. ba) in the uncut but 33 percent (20/60 sq. ft. ba) in the thinned. If mortality is equal on a relative basis (20 percent), then it would be greatly different on an absolute basis--20 sq. ft. ba in uncut (0.2 X 100 sq. ft. ba) and 12 sq. ft. ba in thinned (0.2 X 60 sq. ft. ba). The method used to measure mortality influences the forester’s perception of the stand. Twenty percent mortality in an uncut stand does not appear too bad and the stand is still manageable. However, 20 percent mortality in a thinned stand appears devastating and the stand now may be drastically understocked and in need of regeneration.

The third hypothesis is the secondary organism-abundance theory. Most mortality following gypsy moth defoliation comes from secondary organisms that invade and kill the stress-weakened tree. Thinning produces dying root systems and logging damage to residual trees that increase the populations of the two most common secondary organisms: the shoestring root rot, *Armillaria* spp., and the twolined chestnut borer, *Agrilus bilineatus.* With larger populations present at the time of defoliation, more mortality results.

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The timing of cutting relative to defoliation is the key to the final hypothesis, the logging stress hypothesis. Thinning produces logging wounds, exposed roots, soil compaction, crown breakage, and new environmental conditions. This logging activity stresses the trees and may result in lower vigor for several years. The residual trees also change their growth patterns following thinning. They expand their crowns and root systems and may be more vulnerable to attack during this period. Data showing this effect were published for southern pines (Nebeker and others 1983). If a stand is defoliated during the period before it recovers from thinning-imposed stresses, more mortality may occur than in uncut stands or thinned stands that have recovered. Estimates of the time required to recover from this stress range from 1 to 3 years or even as long as 5 years for slower responding oaks (Graney 1987).

OBJECTIVES

The objectives of this study were twofold: 1) to determine if past management practices, especially thinnings, change the tree mortality when the stands are subsequently defoliated by the gypsy moth and 2) to determine if the timing of these cutting treatments relative to &foliation changes the mortality response. Results should indicate if the field observations are true and why.

METHODS

A factorial design with time-of-cutting treatment as one main effect, and defoliation class as the other, was used (table 1). Analysis of variance and individual contrasts were used to test specific hypotheses. Each cell in the design matrix was filled with two to four uniform forest stands or management units ranging from 10 to 90 acres (table 2). Study sites were selected in central Pennsylvania in the Ridge and Valley Physiographic Province on state forest and Glatfelter Pulp Wood Company lands. Stands were identified by the timing of cutting treatment through landowners' records. Only stands that contained greater than 50 percent oak (by basal area including dead trees) at the time of measurement were included. Defoliation intensity and frequency were delineated using either color infrared optical bar photography or aerial sketch maps. Identified stands were classified by treatment and defoliation history and placed in the matrix.

Table 1.--Classifications used for treatments in two-way 'factorial design

Class	Cutting treatment timing
	--relationshin to defoliation or measurement--
1	Uncut stands
2	Thinned 1-3 years before
3	Thinned 4-6 years before
4	Thinned 7-10 years before
5	Thinned 10- 15 years before
6	Thinned >15 years before
7	Thinned 1-3 years after

Class	Defoliation history
1	Undefoliated (none >30% in any year from 1979-1985)
2	Defoliated (≥1 year moderate--3O-60% or heavy--60-100% from 1979-1985)

Table Z--Number of stands and total acreage measured in each classification cell

Cutting treatment	Defoliation historv	
	Undefoliated	Defoliated
Class 1	3 stands 70 acres	3 stands 162 acres
Class 2	2 stands 50 acres	3 stands 133 acres
Class 3	3 stands 101 acres	4 stands 134 acres
Class 4	3 stands 145 acres	2 stands 52 acres
Class 5	3 stands 101 acres	2 stands 55 acres
Class 6	0 stands 0 acres	3 stands 127 acres
Class 7	Not applicable	3 stands 117 acres
Subtotal	14 stands 467 acres	20 stands 780 acres
Total	34 stands 1247 acres	

Each stand was sampled using lo-factor variable-radius plots. A minimum of 15 plots were taken per stand, with an additional plot for each 8 to 10 acres over 20 acres. Additional plots were added, as necessary, to achieve a 90 percent confidence limit within 10 percent of the mean. Plots were laid out on systematic transects throughout the stands. Data were recorded using the SILVAH data collection protocol for all live and standing dead trees larger than 1" dbh. Information collected included tree species, dbh (in 2" classes), tree quality, and tree vigor (live or dead). Regeneration plots were measured also. Stand summaries were computed using the SILVAH computer program (ver. 2.3, Marquis and others 1984).

Mortality is defined and calculated as a percent by taking basal area of standing dead trees divided by the total basal area of all live and standing dead trees multiplied by 100. By using a percentage of basal area, the second hypothesis can be tested by looking at differences in relative mortality. Stand summaries or means were used as variables in statistical analyses.

RESULTS

Mortality in uncut, undefoliated stands was 12.1 percent, while in thinned, undefoliated stands it ranged from 3.6 to 7.2 percent. Mortality in uncut, defoliated stands was 30.9 percent, while in thinned, defoliated stands it ranged from 8.4 to 48.5 percent (table 3). Significant differences occurred between defoliated and undefoliated stands in cutting treatment classes 1, 3, and 4, but not in classes 2 and 5 (table 3). Individual contrasts between treatment classes within defoliation classes showed highly significant differences for the undefoliated stands (table 4). For the defoliated stands, only class 7, the postdefoliation cutting treatment, had significant differences.

Table 3.--Mortality of oak-hickory stands and independent t-tests of defoliated versus undefoliated classes within cutting treatment classes

Cutting treatment	Defoliation history		T-test
	Undefoliated	Defoliated	
	--percent of basal area/acre--		--t(>T)--
Class 1	12.1	30.9	.001
Class 2	4.1	42.2	.187
Class 3	3.6	37.6	.007
Class 4	4.3	29.9	.000
Class 5	7.2	17.1	.106
Class 6	---	48.5	---
Class 7	---	8.4	---

Analysis of variance of two-way unbalanced design

Source	df	Mean square	F-ratio	P(>F)
Cutting treatment	6	438.483	4.898	0.002
Defoliation history	1	2946.291	32.910	0.000
Error	26	89.526		

Table 4.--ANOVA table and individual contrasts for comparing cutting treatments within defoliation classes

Analysis of variance

Some	df	Mean square	F-ratio	P(>F)
Yndefoliated stands				
Between cutting treatment classes	4	36.677	11.917	0.001
Error	9	3.078		
Defoliated stands				
Between cutting treatment classes	6	529.282	3.783	0.027
Error	11	139.896		

Individual contrasts

Contrast	Defoliation class	
	Undefoliated	Defoliated
	--P(>F)--	
Class 1 vs. all managed	0.001	0.959
Class 1 vs. class 2	0.001	0.327
Class 1 vs. class 3	0.000	0.504
Class 1 vs. class 4	0.000	0.925
Class 1 vs. class 5	0.007	0.226
Class 1 vs. class 6	---	0.101
Class 1 vs. class 7	---	0.040
All managed vs. class 7	---	0.005

Because defoliation effects seemed so much stronger than treatment effects in defoliated stands, I reanalyzed the data from defoliated stands by defoliation intensity and frequency (table 5). When the stands are reclassified in this way and cutting treatment is ignored, then a highly significant linear pattern is evident (table 6, fig. 1). As defoliation intensity and frequency increases, mortality increases.

Mortality rates were highest in the pole size class in undefoliated stands, while defoliated stands had greatest mortality in the small, medium, and large sawtimber-size classes (fig. 2-6).

Table 5.--Classifications used for defoliation history only

Class	Defoliation frequency and intensity
1	1 year of moderate (30-60%)
2	1 year of heavy (60-100%)
3	1 year of moderate + 1 year of heavy
4	2 years of heavy
5	3 or more years of heavy

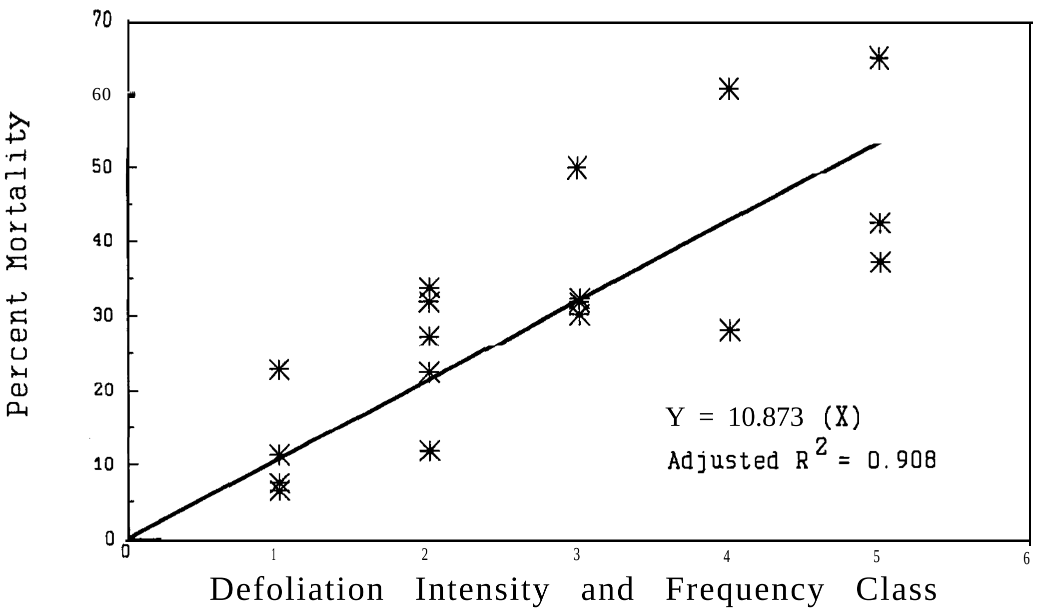

Figure 1.--Regression of reclassified defoliation versus percent mortality.

Table B.--Mortality of oak-hickory stands by reclassified defoliation history and ANOVA of defoliation frequency and intensity classes

Defoliation history	Mortality
	--percent of ba/acre--
Class 1	12.0
Class 2	25.4
Class 3	36.1
Class 4	44.7
Class 5	48.2

Analysis of variance

Source	df	Mean square	F-ratio	P(>F)
Class	4	740.276	5.488	0.008
Error	13	134.880		

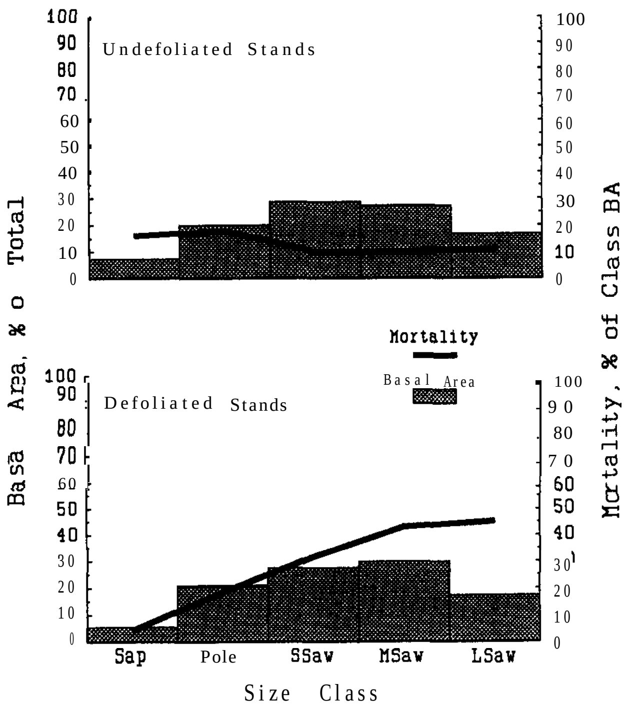

Figure 2.--Size-class distribution and mortality by size class in uncut stands.

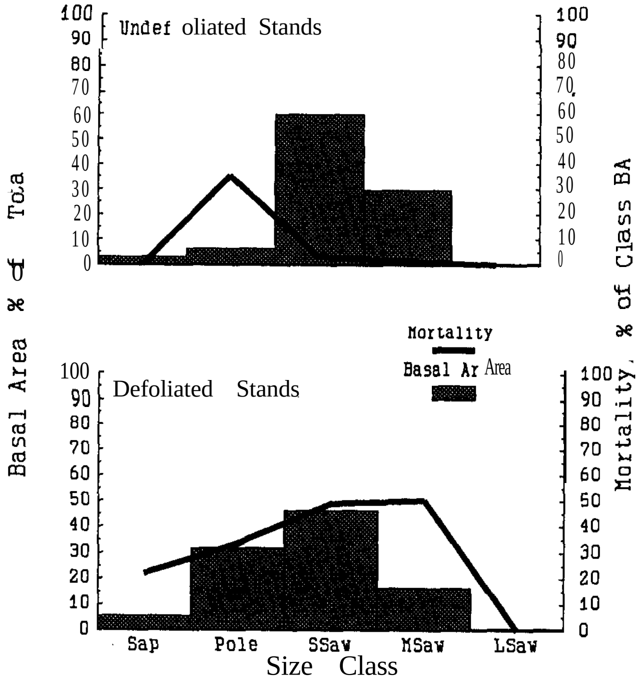

Figure 3.--Size-class distribution and mortality by size class in stands thinned 1 to 3 years before defoliation or measurement.

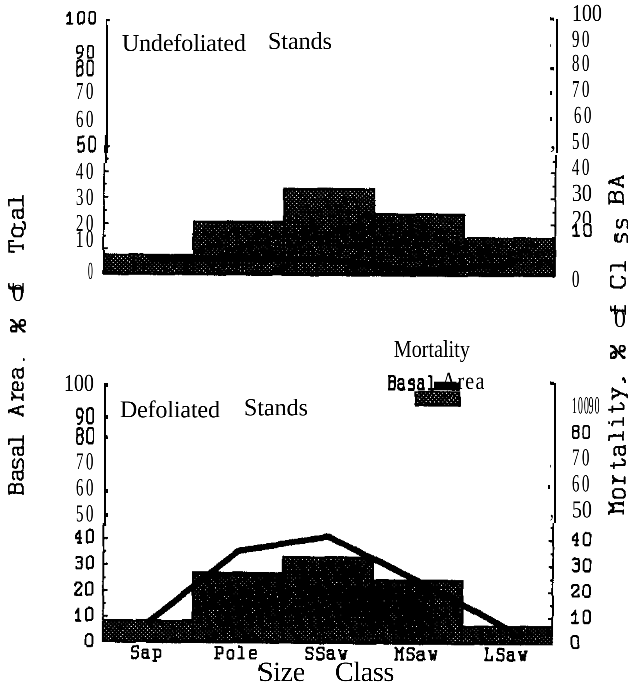

Figure 5.--Size-class distribution and mortality by size class in stands thinned 7 to 10 years before defoliation or measurement.

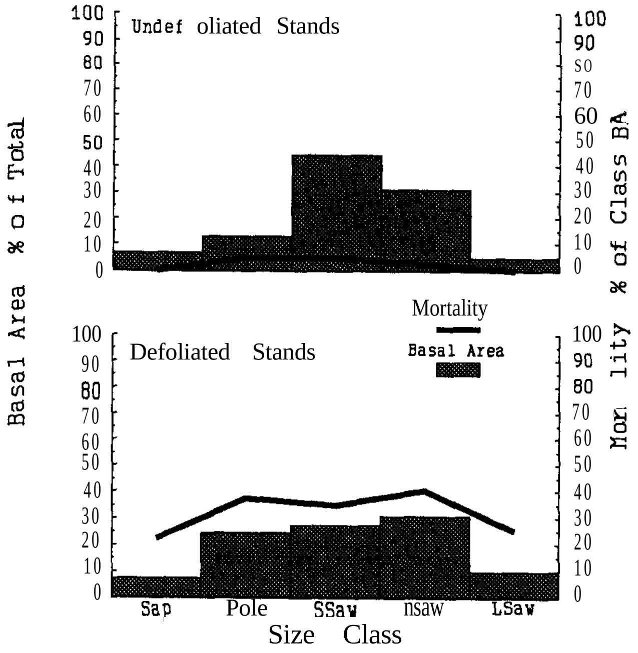

Figure 4.--Size-class distribution and mortality by size class in stands thinned 4 to 6 years before defoliation or measurement.

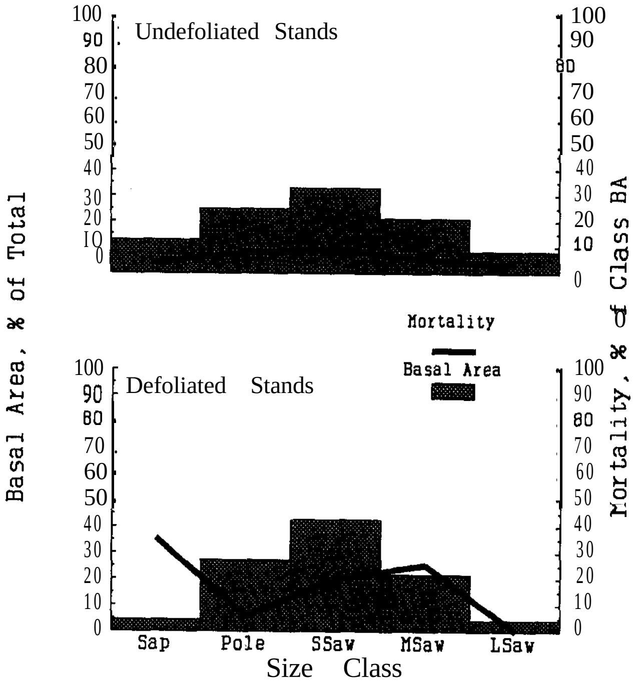

Figure 6.--Size-class distribution and mortality by size class in stands thinned 10 to 15 years before defoliation or measurement.

DISCUSSION

More larger trees die in defoliated than in undefoliated stands. Smaller, weaker trees die as competition becomes intense in undefoliated stands. Defoliation weakens larger trees, making them susceptible to secondary mortality agents, and results in death of many larger trees. Mortality of small trees does not decrease in defoliated stands, but the increases in pole-size mortality are masked by the larger increases in sawtimber-size mortality.

Mortality rates in undefoliated stands show the benefit of thinning in reducing mortality. The tendency for mortality to increase in cutting class 5 suggests that these stands are approaching the point where another thinning is needed. However, since these data are from separate stands and not true chronological series, the increase in mortality in cutting class 5 undefoliated stands could be due to sampling variation. Defoliation overshadows this pattern. Defoliated stands had higher mortality than undefoliated stands, but due to high variability there was no definitive pattern of cutting treatment that changed the mortality relative to uncut stands. This result does not support the casual observations of foresters. One potential reason for the lack of significance in defoliated stands may be the variation in defoliation between stands.

The reclassification by defoliation intensity and frequency does indeed show the importance of variation in these factors in determining mortality. Many of the stands in a thinning treatment cell had the same defoliation pattern, preventing its use as a covariate. To avoid this confounding problem and high variability, additional stands were measured during 1988 to expand the defoliated series into several combinations of intensity and frequency. When analyzed, this expanded sampling design should allow a better evaluation of the effect of cutting treatments on mortality.

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