REGENERATION IN OAK STANDS FOLLOWING GYPSY MOTH DEFOLIATIONS[1]

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Abstract -- Regeneration was measured in oak stands where defoliation from gypsy moth had created understocked overstories. Abundance and species composition of ground vegetation present in gypsy moth created understocked sawtimber sized stands were determined for two physiographic regions in Pennsylvania. Average abundance for all commercially important species were similar for the two regions (about 28,500 stems/acre) and these species accounted for about 90% of all woody stems inventoried. However there were major physiographic differences in abundance values for specific species. In general: (a) red maple accounted for 90% of stems of commercially important species in the Allegheny Mountain region and 49% in the Ridge and Valley region; (b) birch was most abundant in the Ridge and Valley region, accounting for 29% of the stems of commercially important species whereas in the Allegheny Mountains region birch accounted for 4%; (c) red and white oaks accounted for 16% of the stems of commercially important species in the Ridge and Valley region and 4% in the Allegheny Mountains region.

INTRODUCTION

Between 1969 and 1984, gypsy moth has caused moderate to heavy defoliation to about 6.2 million acres of forestland in Pennsylvania (Quimby 1984). A major moth outbreak in 1981 and below average growing season rainfall amounts from 1980 through 1983 have resulted in substantial tree mortality. Inventories of post-1982 mortality in these defoliated areas have been summarized by Quimby (1984). His study suggests that about 350,000 acres suffered approximately 30% volume loss and about 341,000 acres had greater than 50% volume loss. Most of the mortality was for oak and hickory species. Although stands in the moderate mortality class (15-30% mortality) are likely to regain a fully stocked stand characteristic and can continue to be managed as a unit, the stands with heavy mortality (>50% mortality) are likely to remain understocked until regenerated. Thus the future value of these heavy mortality stands will depend on the nature and characteristics of the post-mortality ground (understory) vegetation.

Numerous authors have summarized the state of knowledge for regenerating non-gypsy moth impacted stands in Pennsylvania (Penn State 1983). Generalized silvicultural guidelines have been developed for regenerating gypsy moth impacted Appalachian hardwood stands (Gottschalk 1988a and 1988b). Information on the composition and abundance of the ground vegetation in stands which have experienced heavy mortality (and possible salvage) have been limited to field observations. These field observations report the ground vegetation to range from "fern-grass savannahs" to "pokeberry-blackberry-blueberry thickets" to an occasional "best red maple-birch regeneration I have ever seen". At this point, we do not have quantitative information on enough stands to develop a point of reference for future cultural activities. Needed is a database on the abundance, composition and structure of ground vegetation in these heavily impacted stands so that forest resource managers can formulate revised plans, if needed.

Heavy mortality has occurred over a wide geographic area and for many edaphic-stand conditions. We selected two physiographic regions for the assessment of regeneration status after gypsy moth related mortality in Pennsylvania. The objective of the study was to determine the abundance and composition of the ground vegetation present in gypsy moth created understocked sawtimber sized stands growing in

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the Allegheny Mountains and Ridge and Valley physiographic regions.

PROCEDURES

Oak dominated sawtimber sized stands that had understocked overstories from gypsy moth defoliation (>30% mortality, volume basis) were selected from Bureau of Forestry (Department of Environmental Resources, Pennsylvania) lands within a seven county area. Bureau of Forestry forestland managers provided guidance and documented that the selected stands were understocked due to gypsy moth related mortality. A total of 90 stands were designed to be selected with 45 located in the Allegheny Mountains physiographic region (Clearfield, Clinton and Centre Counties) and 45 located in the Ridge and Valley physiographic region (Huntingdon, Juniata, Mifflin and Perry Counties) (Figure 1). Within each physiographic region, 20 stands were designed to be selected in Site Productivity Class I, 15 stands in Site Productivity Class II and 10 stands in Site Productivity Class III. This sampling bias favoring the better sites was based on known site dependent regeneration relationships (Bowersox and Ward 1972, Gottschalk 1983) and forest

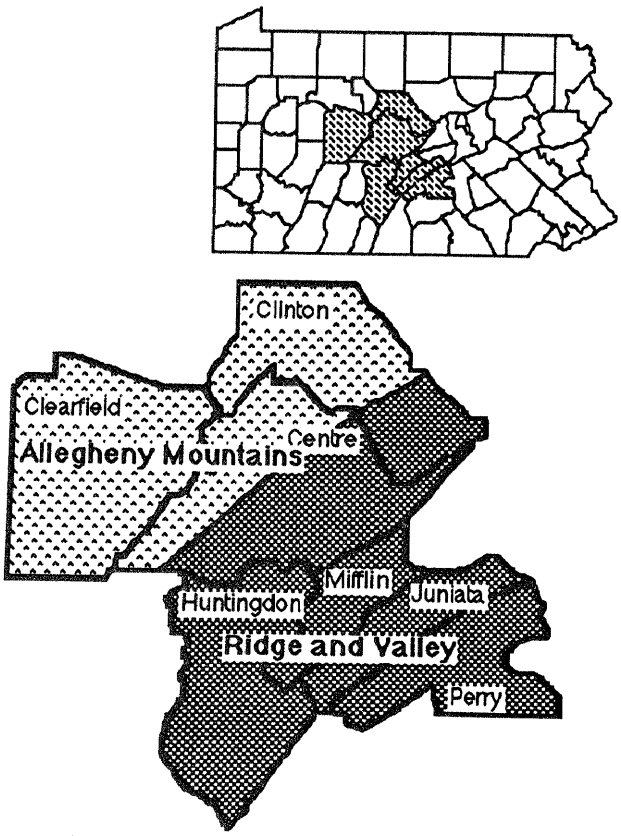

Figure 1. The central Pennsylvania study area and the counties located in the Allegheny Mountains and Ridge and Valley physiographic regions.

management intensity. Site productivity classes were based on expected merchantable sawlog lengths for oak (Class I = 48 ft, Class II = 32 to 48 ft and Class III = < 32 ft; Bureau of Forestry procedures). Study stands met the designed number in each site productivity class except for the Class I sites in the Allegheny Mountains region where only 13 of the desired 20 stands could be located. Prior to gypsy moth defoliations, the mixed oak stands were even-aged and ranged from 80 to 120 years of age and were fully stocked.

At each randomly located potential ground vegetation sample point, a field estimate of overstory stocking level was made to determine if the surrounding stand was below the B level for sample point acceptance. Residual live tree basal area for the ground vegetation inventory points ranged from 0 to 60 $ft.^2$ and averaged about 40 $ft.^2$, mainly oak species (Table 1).

Ground vegetation for six points in each stand were inventoried according to the procedures outlined by Marquis et al. (1984). Commercial and non-commercial species present 6 to 7 years after heavy mortality were inventoried for two height class. They were (a) 0.1-1.0 ft. and (b) >1.0 ft. height but less than 1.0 in. DBH. These inventory procedures also provide a basis for estimating non-woody vegetation and regeneration stocking criteria. Relative density of non-tree species was ocularly estimated, by 10% classes, for each species group and for collective ground cover dominance of each sample plot. The regeneration stocking criteria used (Marquis et al. 1984) required a decreasing number of seedlings with increasing seedling size for determining the likelihood of a 6 ft. radius (113.1 $ft.^2$) plot being stocked. These criteria required higher numbers of seedlings per size class than other regeneration stocking criteria (Sanders et al. 1976 and 1984) to insure success where deer browsing is severe. These criteria do not account for inter-species competition.

Statistical analysis was performed using Statistical Analysis System package programs (SAS 1985). The General Linear Models procedure was used for analysis of variance. Number of stems by species for the individual inventory plots were converted to a per acre basis, and used in the analysis. Sums of squares for stand nested within site productivity class was used as the error term for analysis of variance. If analysis of variance showed statistically significant differences attributable to region or site, means were separated by the Waller Duncan procedure. The 0.05 level of probability was accepted as significant.

RESULTS

Total number of seedling stems averaged about 28,500 per acre for the commercial species and 3,800 per acre for the non-commercial

species. There were no significant differences between the two regions in the abundance of commercial species and non-commercial species for the 0.1 to 1.0 ft. and total height classes (Table 2). However, the Ridge and Valley region had significantly greater abundance values in the >1.0 ft. class for both species groups. The main reason for the regional difference in the large size class was the abundance values for birch and stripped maple (Table 2).

Red maple dominated the commercial species abundance values in both regions with a total of 13,563 and 25,895 stems per acre in the Ridge and Valley and Allegheny Mountains regions, respectively. The abundance values for total stems (above), and the 0.1 - 1.0 ft. stems (10,954 and 22,743 per acre for the Ridge and Valley and the Allegheny Mountains, respectively) were significantly different (Table 2). The regional difference in the >1.0 ft. red maple stems between the 2,609 per acre in the Ridge and Valley and the 3,152 per acre in the Allegheny Mountains was not significant. Red maple was most dominant in the Allegheny Mountains region, accounting for 90% of all commercial species stems. In the Ridge and Valley region, red maple accounted for 49% of all commercial species stems.

Species specific abundance values for birch, red oak and white oak were greater in the Ridge and Valley region than in the Allegheny Mountains region. The differences were significant for all size classes of white oak, the 0.1 - 1.0 ft. class of red oak and the >1.0 ft. class of birch (Table 2). The abundance value for ash, black cherry, yellow-poplar and other commercial species were not analyzed because of the low abundance values and infrequent occurrence.

Abundance values of non-commercial species were low in both regions, collectively accounting for about 12% of the average total woody stems in each region (Table 2). Sassafras with 1,776 stems per acre was the most abundant non-commercial species in the Allegheny Mountains region; and stripped maple with 1,964 stems per acre was the most abundant species in the Ridge and Valley region. Although the abundance of non-commercial stems was low in comparison to the total woody stems, these non-commercial stems may have an impact on commercial species diversity. Individually, two of the three non-commercial species in the Allegheny Mountains region had abundance values equal to or greater than the abundance values for red oak, white oak and other commercial species. Collectively, the non-commercial total abundance of 3,530 stems per acre was greater than all commercial species less red maple (3,038 stems/acre). In the Ridge and Valley region, the abundance value for stripped maple was greater than the values for red oak and other commercial

Table 1. Average overstory basal area in the sample stands for the two physiographic regions, by site productivity classes[1] and species group.

Physiographic Region/County	Site Productivity Class[1] I	II	III	Weighted Average
	(- - - - - - square feet per acre - - - - -)			
Allegheny Mountains				
Red oak	20	15	11	16
White oak	5	14	19	12
Red maple	16	13	6	12
Others	4	2	3	2
Total	45	44	39	43
Ridge and Valley				
Red oak	19	12	18	16
White oak	10	14	20	13
Red maple	5	3	2	4
Others	3	3	6	4
Total	37	32	46	37

[1] Site productivity classes were primarily based on expected merchantable saw log lengths, for oak I = 48 ft, II = 32 to 42 ft. and III = <32 ft.

Table 2. The average[1] abundance of species groups in the two physiographic region, by height class.

Species Group	Height Class	Allegheny Mountains	Ridge and Valley
	(- - - - - - - - - - stems/acre	- - - - - - - - - - -)	
Red oak	0.1 - 1.0	530 a	1,160 b
	> 1.0	177 a	338 a
	Total	707 a	1,498 b
White oak	0.1 - 1.0	397 a	2,471 b
	> 1.0	61 a	570 b
	Total	458 a	3,041 b
Red maple	0.1 - 1.0	22,743 a	10,954 b
	> 1.0	3,152 a	2,609 a
	Total	25,895 a	13,563 b
Birch	0.1 - 1.0	1,073 a	2,590 a
	> 1.0	71 a	5,396 b
	Total	1,144 a	7,986 b
Stripped maple	0.1 - 1.0	39 a	794 b
	> 1.0	103 a	1,170 b
	Total	142 a	1,964 b
Witch-hazel	0.1 - 1.0	466 a	429 a
	> 1.0	199 a	375 a
	Total	665 a	804 a
Sassafras	0.1 - 1.0	1,192 a	603 b
	> 1.0	584 a	238 a
	Total	1,776 a	841 b
All[2] commercial	0.1 - 1.0	25,239 a	18,091 a
	> 1.0	3,694 a	9,861 b
	Total	28,933 a	27,952 a
All non-[3] commercial	0.1 - 1.0	2,476 a	2,010 a
	> 1.0	1,064 a	2,066 b
	Total	3,530 a	4,076 a
Total	0.1 - 1.0	27,715 a	20,101 a
	> 1.0	4,748 a	11,909 b
	Total	32,463 a	32,000 a

[1] Physiographic region means, within species and size class, with the same letter were not significantly different at the 0.05 level.

[2] Includes other commercial species not listed.

[3] Includes other non-commercial species not listed.

species. Collectively, the non-commercial species were more abundant than all commercial species, except birch and red maple.

Although the abundance values for all commercial, all non-commercial and all woody species did not differ between the two regions, the abundance values for individual species were greatly different between the two regions. Therefore, the abundance values among the three site productivity classes were analyzed by region. Physiographic region specific site productivity dependent differences in average abundance values (by size class) for individual commercial and non-commercial species were substantial. Differences between the lowest and highest average species specific abundance values among the site productivity classes were frequently greater than a factor of five. However, because of high variability in the database and non-constant error variance, site productivity class was a significant factor in

only five of the 25 analyses. The subjective methods for determining site productivity may have also weakened the analyses. Our analyses are continuing and at this time we can only present the following general trends.

Abundance values of all size classes of red oak, other commercial species, witch-hazel and stripped maple were greater in Site I stands than either Site II or III stands, regardless of region. White oak, red maple, birch and sassafras abundance values in response to site productivity class were dependent on region. Number of stems for all size classes of white oak were most abundant in the Site II stands in the Ridge and Valley region and in Site III stands in the Allegheny Mountains region. Greater white oak numbers on the Site II to III productivity classes may be due to chestnut oak accounting for 80% of all white oak stems. Red maple was most abundant in all size classes in Site I stands in the Ridge and Valley region; and in the Allegheny Mountains region, greatest abundance values for the 0.1-1.0 ft. size were measured on Site II stands and greatest values for >1.0 ft. size were measured in Site I stands. Number of stems for all size classes of birch were most abundant in Site I stands of the Allegheny Mountains region and in Site II stands of the Ridge and Valley region. Stems for all size classes of sassafras were most abundant in Site II stands of the Allegheny Mountains region and in Site I stands of the Ridge and Valley region.

The combined dominance of the surface area by all herbaceous and woody ground vegetation averaged 54% in the Allegheny Mountains region and 22% in the Ridge and Valley region. Over all site productivity classes, ferns were the dominant group in the Allegheny Mountains region (38% coverage) but not in the Ridge and Valley region (6% coverage). There was a tendency for ferns to be more dominant of the ground surface area in Site I stands than Site II or III stands (Table 3). Blueberry (and huckleberry) was the most dominant group in the Ridge and Valley region (21% coverage, overall) and second most dominant in the Allegheny Mountains region (14% coverage, overall). Blueberry group was more dominant in Site II and III stands than in Site I stands. Grasses, laurel, broadleaf weeds and others would occasionally dominate individual inventory plots but their overall coverage values were low (Table 3).

Over all site productivity classes, 72% of the plots in the Allegheny Mountains region and 83% of the plots in the Ridge and Valley region were stocked with commercial species (Figure 2).

Table 3. Relative amount of ground surface occupied by selected plant communities for the two physiographic regions, by site productivity class.

Physiographic Region/Plant Community	Site Productivity Class I	II	III	Weighted Average
	(- - - % of surface area occupied - - -)			
Allegheny Mountains				
Ferns	48	32	35	38
Blueberry	8	11	28	14
Grasses	4	13	4	8
Laurel	1	4	9	4
Broadleaves	0	1	0	0
Others[1]	3	3	2	3
Overall Dominance[2]	55	48	62	54
Ridge and Valley				
Ferns	9	5	1	6
Blueberry	14	27	26	21
Grasses	2	1	0	1
Laurel	0	1	6	2
Broadleaves	7	2	2	4
Others[1]	3	2	2	2
Overall Dominance[2]	20	19	29	22

[1] Include mosses, partridgeberry, strawberry, teaberry and vines.

[2] Overall Dominance - the relative amount of the stand surface area dominated by non-tree species. An independent assessment and not a summation of individual plant communities.

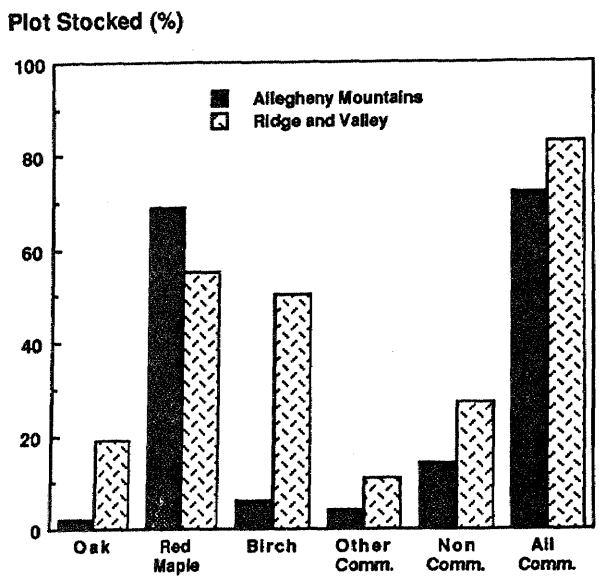

Figure 2. Percentage of plots stocked in the two physiographic regions by species group.

On an individual species basis, red maple was stocked on 69% of the plots in the Allegheny Mountains region, far greater than any other species group (Figure 2). Individual species stocking in the Ridge and Valley region was highest for red maple (55%) and birch (50%). Plots stocked with oak (19%), other commercial (11%) and non-commercial (27%) in the Ridge and Valley region were greater than the species specific values in the Allegheny Mountain region (Figure 2).

DISCUSSION

Initial evaluations in sawtimber stands with heavy gypsy moth related mortality indicate that the stands were developing abundant and well distributed regeneration of commercial species. The regeneration was dominated by red maple in the Allegheny Mountains region and red maple and birch in the Ridge and Valley region. Red and white oaks were very sparse in the seedling component of the Allegheny Mountains region but accounted for about 16% of the commercial species seedlings in the Ridge and Valley region. Competing ground vegetation (particularly ferns) can restrict seedling establishment and growth (Bowersox and McCormick 1987, Kolb et al. 1989). In the oak stands of Pennsylvania, birch, red maple and stripped maple are the most frequent woody stems "observed" to tolerate fern dominated understories. Restricted mixtures of commercial species and greater fern domination of the understory appears to be more prevalent in the Allegheny Mountains region than in the Ridge and Valley region.

Seedling species compositions in the study stands were different from the overstory compositions. The extent of the composition shift caused by the gypsy moth could not be determined because pre-defoliation inventories were not available. Successful natural regeneration of oak species is a mystery throughout the range. In Pennsylvania, quantitative data on regeneration inventories from oak stands are limited to a few research reports. Bowersox and Ward (1972) inventoried 28 undisturbed mixed oak stands in the Ridge and Valley physiographic region and reported that number of woody stems per acre ranged from 2,667 to 79,000 and averaged 26,071. In their database, 5,985 of the stems were of commercial species comprised of 13% red oak, 33% white oak, 43% red maple, 2% birch and 9% other commercial species. Less intense inventories in three Ridge and Valley physiographic region stands that had received shelterwood treatments and then a clearcut found an average of 5,133 stems of commercial species with 6% red oak, 3% white oak, 74% red maple and 17% other commercial species (Bowersox and McCormick 1987). Ferns and grasses dominated the ground vegetation in both the shelterwood and clearcut status of these three stands. Comparatively, the gypsy moth disturbed stands had greater numbers of commercially important seedlings but with similar species composition as stands not disturbed by gypsy moth.

Forest managers desiring to increase the oak component in the developing regeneration need to consider the community differences of the two regions. In the Allegheny Mountains, oak abundance values were sparse and seedlings were smaller in relation to the red maple and non-commercial seedlings. Except in the fern and blueberry dominated unstocked areas, new oak seedling establishment and growth will depend on their ability to compete with the established red maple seedlings. In the Ridge and Valley region where species composition was more diverse, red and white oak was more abundant and seedlings were larger than in the Allegheny Mountains region. Oaks in the Ridge and Valley region accounted for 16% of the commercial species seedlings and were stocked on 19% of the plots. New oak seedling establishment, and growth of the new and existing oak seedlings in the Ridge and Valley region will depend on their ability to compete with birch, red maple and non-commercial seedlings. Knowledge is lacking on the ability of oak to become established and grow in competition with birch and red maple. Once this information is available, practices to increase the oak component can be recommended.

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