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Natural Regeneration Patterns in Even-Aged Mixed Stands in Southern New England

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ABSTRACT. A regeneration survey in southern New England in three different cover types indicated that most of the seedlings present were less than 19.7 in. in height. Although red oak was a principal component of the overstory, it represented a small proportion of regeneration. Black birch and red maple were common regeneration components. There was a general relationship between overstory density and the amount of regeneration. To obtain natural regeneration, a general broad optimum range of overstory densities between 20–80 ft²/ac of basal area is suggested. Successful red oak and sugar maple regeneration was obtained with overstory densities of these species between 20–40 ft²/ac. A higher proportion of these species did not result in more regeneration. White pine regeneration was closely related to the amount of white pine in the overstory, however. The density of mountain laurel seemed to have little effect on the establishment of regeneration. The greater the length of time since last harvest, the more oak seedlings would be present in hardwood stands. The opposite was true for red maple, black birch, and hemlock.

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Natural stands in southern New England are commonly comprised of diverse mixtures of as many as 12–15 commercial tree species. Information on the management of these stands is sparse. Some studies have been published that characterize natural succession patterns in this region (Good and Good 1972), but they do not address management practices or implications. Foresters commonly use silvicultural guides for northern hardwoods (Leak et al. 1987), and a similar guide developed for oak stands in the central states (Gingrich 1967). These guides prescribe intermediate thinnings for the goal of timber production based on optimal stocking but do not address methods of stand regeneration. Other management guides suggest methods, but again these are designed for either oaks in the central states (Sander 1977) or northern hardwoods in northern central states (Tubbs 1977). Currently there is a paucity of applied management information for the mixed stands that are commonly found in southern New England.

Many stands in southern New England are even-aged, and a large proportion are in mature age classes. For example, 56% of Massachusetts' commercial timberland is in the sawtimber size class (Dickson and McAfee 1988). In fact, the area in sawtimber stands has increased by 72% since 1972 (Dickson and McAfee 1988). It is not too early to begin considering the natural regeneration of these stands, but no guidelines exist. It is likely that the regeneration ecology of species in these mixed stands in southern New England may be different from what is observed in other parts of their natural ranges. The possible interactions between these species may represent additional influences that are not otherwise important elsewhere in the natural range.

OBJECTIVES

A study was initiated to characterize natural regeneration patterns in even-aged mixed stands and to identify possible adverse influences on regeneration. Based on observed patterns of establishment and adverse influences such as mountain laurel and hay-scented fern, recommendations for obtaining regeneration and its further research could be made.

METHODS

A regeneration survey was conducted at the Yale-Myers Forest in northeastern Connecticut. Thirty transects were randomly located throughout the 7800-ac tract. Ten circular plots with radii of 13.2 ft were located systematically along each transect. The majority of plots fell in one of the three following cover types: hardwood (predominantly northern red oak, red maple, and black birch, with white ash, sugar maple, white birch, yellow birch, black oak, white oak, pignut hickory, and shagbark hickory; 137 plots), hemlock–hardwood (99 plots), and pine–hemlock–hardwood (30 plots). The remaining plots fell in either swamp or pure hemlock stands. All sampled stands were at least 60–80 years old. They had largely resulted from the clearcutting of white pine stands at the turn of the last century. In the past 30 years, they have received occasional intermediate or improvement harvests.

On each plot, all established regeneration (i.e., including seedling sprouts and stump sprouts) was tallied and classified by species and height (less than 19.7 in., or 19.7 in. and greater, up to 36 in.), and whether or not it was newly established in its first growing season. Using the plot centers as sample points, a BAF 10 prism was used to make an estimate of the overstory density (basal area, in ft²/ac) and the species composition. Occular estimates of the percentage cover of both mountain laurel and hay-scented fern were made at each plot. Finally, based on harvesting records, the number of years since the last commercial timber sale was also identified for each plot. This ranged from 6 to 27 years.

RESULTS

Although regeneration of all species was recorded, data on only the following six species were analyzed, since they represented the principal species present northern red oak, red maple, sugar maple, black birch, eastern hemlock, and eastern white pine.

Multiple regression analysis was used to relate a number of independent variables (percentage cover of hay-scented fern, percentage cover of mountain laurel, total overstory basal area, overstory basal area of a particular species, and time elapsed since the last cut) to the number of seedlings less than 19.7 in. in height (dependent variable). This analysis was done for each species, for each of the three cover types. Statistics resulting from the multiple regression analyses are listed in Table 1.

Table 1. Multiple regression results[a] relating the number of seedlings less than 19.7 inches in height to a number of independent variables.[b]

Species	Laurel	Hay-scented fern	Species overstory BA	Total overstory BA	Time since last cut
Hardwood cover type:					
Red oak	−0.01925	−0.00949	0.02530	−0.02990	0.14214
	0.1175	0.6308	0.1513	0.0678	0.0087**
Red maple	−0.05683	−0.13613	0.03102	−0.04903	−0.63394
	0.1416	0.0323*	0.6946	0.2822	0.0002**
Sugar maple	−0.03829	−0.01183	−0.06321	0.02525	0.47269
	0.2777	0.8304	0.4620	0.5495	0.0017**
Black birch	−0.10314	−0.11158	0.48829	−0.18798	−0.74526
	0.1743	0.3473	0.0697	0.0367*	0.0223*
White pine	−0.01549	−0.00714	0.11748	−0.00742	−0.05438
	0.0002**	0.2668	0.0001**	0.1236	0.0022**
Eastern	−0.00975	−0.01784	0.06483	0.01051	0.01299
hemlock	0.5006	0.4295	0.2798	0.5529	0.8347
Hemlock-hardwood cover type:					
Red oak	0.02818	0.02121	0.00547	0.00711	−0.06526
	0.0504	0.3390	0.7992	0.6415	0.1538
Red maple	−0.01559	−0.00768	0.29387	0.06589	−0.61836
	0.7583	0.9228	0.0179*	0.2014	0.0003**
Sugar maple	−0.01083	−0.00806	0.10255	−0.00465	−0.03231
	0.2346	0.5560	0.0185*	0.6082	0.2573
Black birch	−0.16999	0.21284	−0.29596	−0.23849	−0.83819
	0.0718	0.1073	0.1847	0.0087**	0.0031**
White pine	−0.02106	−0.02630	0.38018	−0.01361	−0.10099
	0.0406*	0.0841	0.0001**	0.1865	0.0038**
Eastern	−0.05872	0.06241	−0.00684	0.00545	−0.30275
hemlock	0.2203	0.3682	0.9329	0.9307	0.0588
Pine-hemlock-hardwood cover type:					
Red oak	−0.03130	−0.06305	−0.00407	−0.01344	−0.02332
	0.1743	0.1395	0.9335	0.6252	0.7760
Red maple	−0.24433	−0.33239	−0.14784	−0.04694	−1.04129
	0.1019	0.2243	0.6244	0.8074	0.0568
Sugar maple	0.02081	0.31222	0.33451	0.03836	0.07192
	0.7485	0.0125*	0.5269	0.6335	0.7507
Black birch	−0.67909	0.81276	0.26700	−0.68199	−1.95144
	0.0376*	0.1765	0.8683	0.0828	0.1104
White pine	−0.54506	−0.47495	0.61479	−0.35721	−1.13097
	0.0092**	0.2061	0.0309*	0.1683	0.1276
Eastern	−0.21303	−0.09049	−0.07662	−0.20472	−0.47237
hemlock	0.0041**	0.4709	0.4928	0.0225*	0.0699

[a] The following model was used:
# of SEEDLINGS = a(% cover MOUNTAIN LAUREL) + b(% cover HAY-SCENTED FERN) + c(SPECIES OVERSTORY BASAL AREA) + d(TOTAL OVERSTORY BASAL AREA) + e(TIME SINCE LAST CUT (years))

[b] Of the paired numbers, the top one is the regression coefficient of the independent variable, and the bottom indicates its significance in the model ($p > t$). Those variables significant at the 95% confidence level are indicated by *; those at the 99% level by **.

Composition of Regeneration

The majority of regeneration present was either red maple or black birch (Fig. 1). Red oak represented a small proportion of the regeneration, despite the fact that it was often a principal component of the overstory (Fig. 2). Most regeneration was less than 19.7 in. in height (Fig. 1). For this reason, data for seedlings greater than 19.7 in. were not analyzed. Further reference to regeneration implies that which is less than 19.7 in. in height.

Regeneration With Respect to Overstory Composition

There appear to be relationships between the degree to which a species is present in the overstory and the amount of regeneration of that species in the understory. Red oak and sugar maple regeneration, for example, seem to be most abundant when these species are not greatly represented in the overstory (Fig. 3). A basal area of 20–60 ft^2/ac appears to be the general optimal range. A higher proportion of oak or sugar maple in the overstory (e.g., basal area greater than 60 ft^2/ac) does not result in more abundant regeneration of these species in the understory. Red maple seems to exhibit a similar pattern of regeneration.

Black birch exhibits a clear pattern of regeneration with respect to its presence in the overstory. Basal areas of 40–60 ft^2/ac result in the greatest amount of black birch regeneration (Fig. 3). Stands with greater than 40–60 ft^2/ac of black birch overstory result in little establishment of black birch regeneration.

Unlike the previously mentioned species, both white pine and hemlock seem to produce the greatest amounts of regeneration under conditions where these species comprise a higher proportion of the overstory. Hemlock regeneration, for example, was most abundant when this species comprised 80–100 ft^2/ac of the overstory. Hemlock was also found to regenerate under conditions of greater parent tree overstory densities (up to 140 ft^2/ac) as compared to the other species. This is perhaps because of its greater shade tolerance. White pine shows an erratic pattern of regeneration, whereby it is abundant both under moderate overstory density (40–60 ft^2/ac) and under much higher pine overstory densities (80–100 ft^2/ac). The low number of pine seedlings in the 60–80 ft^2/ac basal area overstory pine class suggests an artifact in the data. Multiple regression analysis showed that white pine regeneration is positively and significantly related to the amount of white pine in the overstory, in all three cover types (Table 1). No other species demonstrated this relationship between overstory composition and regeneration.

Regeneration With Respect to Total Overstory Density

There seems to be a broad range of total overstory densities beneath which it is possible to establish natural regeneration. A total overstory density of approximately 60–80 ft^2/ac seems to be the optimum (basal area level BA3, Fig. 4). Since cutting took place as long as 27 years beforehand in some cases, this density probably represents a broad maximum, or at least a condition that permits survival of regeneration.

Some interesting species-specific patterns emerge from the analysis The most abundant black birch regeneration, for example, can be found with a total overstory density of 60–80 ft^2/ac. Red oak is present in low numbers across the spectrum of densities and is less abundant only beneath overstory basal areas of greater than 140 ft^2/ac. Red maple can regenerate under relatively dense overstory conditions (as high as 120 ft^2/ac) Hemlock was found to be regenerating under high overstory density

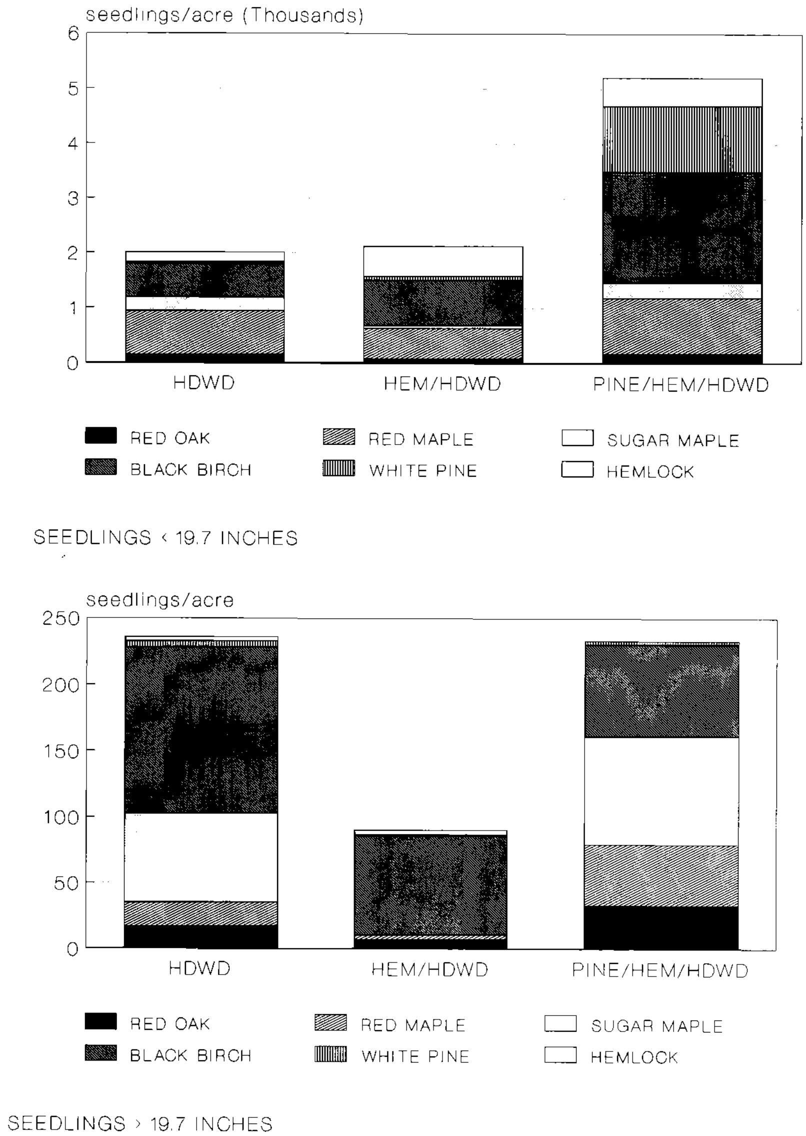

Fig. 1. Species composition of regeneration by cover type for seedlings <19.7 in. (top) and >19.7 in. (bottom).

conditions, due perhaps to its extreme shade tolerance.

As might be expected from the broad range of basal areas beneath which regeneration could be established, the total overstory basal area was not an important independent variable in the multiple regression analysis. Black birch was the only species to have this independent variable play a significant role in the analysis. As might be expected, it was negatively related, based on its relative shade intolerance.

Time Since Previous Harvest

The independent variable in the multiple regression analysis that seemed to have the most conspicuous effect on regeneration was the amount of time that has elapsed since the last timber sale (this time ranged from 6 to 27 years). The amount of red oak and sugar maple regeneration in hardwood stands is significantly and positively related to the amount of elapsed time (Table 1). This suggests that the longer one waits following a partial cut, the more oak or sugar maple will accumulate in the understory. This positive relationship is nonexistent, however, for red oak and sugar maple regeneration in the hemlock–hardwood and pine–hemlock–hardwood stands (Table 1). Perhaps the presence of hemlock adversely affects oak and sugar maple regeneration accumulation in the understory because of shade or allelopathy, or a combination thereof (Ward and McCormick 1982).

On the other hand, the amount of red maple, black birch, white pine, and eastern hemlock regeneration is often significantly and negatively related to the amount of elapsed time since the last cut (Table 1). Figure 5 shows the relationship between the time since the last cut and the regeneration less than 19.7 in. in height of the various species in all cover types. There seems to be a peak in abundance of regeneration of these species between 5 and 14 years since the last cut. After this, there is a notable decrease. In this case, it may be assumed that either the seedlings are growing out of the <19.7 in. class, or they are not surviving. Given the lack of seedlings in the >19.7 in. class (Fig. 1), the latter explanation is suggested.

Influence of Mountain Laurel

The results of the multiple regression analysis indicate that white pine regeneration is particularly sensitive to the presence of mountain laurel. In all three cover types (hardwood, hemlock–hardwood, and pine–hemlock–hardwood), the percentage cover of laurel was a highly significant, negative variable in the regression (Table 1). Black birch and eastern hemlock were also negatively affected in the pine–hemlock–hardwood cover type. In general however, the presence of mountain laurel does not seem to have an adverse effect on regeneration (Fig. 6). This is contrary to current ideas that suggest laurel inhibits regeneration establishment (Phillips and Murdy 1985).

Influence of Hay-Scented Fern

The results of multiple regression analysis indicate very little effect of

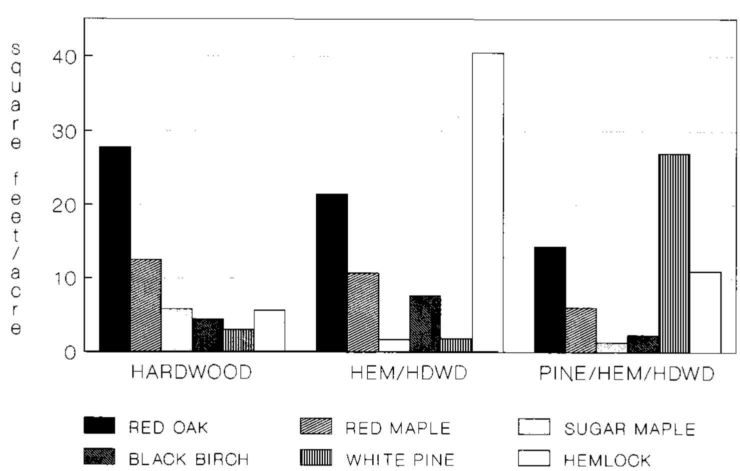

Fig. 2. Overstory species composition.

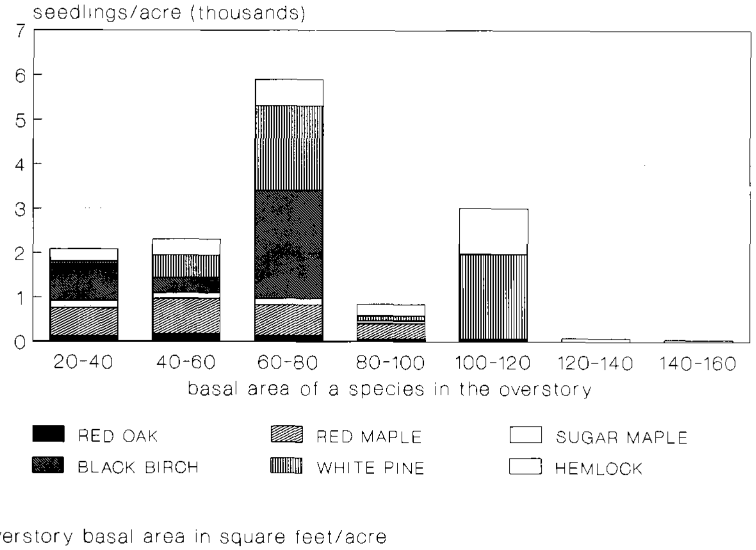

Fig. 3. Species composition of regeneration by overstory species composition.

hay-scented fern on regeneration. In only one case was regeneration significantly and negatively affected (red maple regeneration in the hemlock–hardwood stand), despite the fact that hay-scented fern cover ranged from 0–100%. This is in contrast to results reported by Horsley (1988), which indicated oak seedling mortality when planted in dense fern cover, compared with seedlings planted in areas maintained in a fern-free condition. The influence of hay-scented fern clearly needs more investigation.

APPLICATIONS

Future Species Composition

Based on the species composition of the regeneration observed in these study plots, one might first conclude that these stands would ultimately be dominated by red maple and black birch, with red oak playing a much less important role than it does today. This may not necessarily be the case, however.

Studies of the historic development of these stands (Oliver 1978) indicate that while they may be dominated by red maple and black birch in the first 20 years, after 40 years the height growth of these species begins to slow, and red oak may assume a dominance in the canopy, as it continues to grow in height at a constant rate. The result is an even-aged stand with a stratified canopy of oak in the dominant position and other species in more subordinate positions. Based on full stocking at the seedling/sapling stage of development, Oliver (1978) hypothesized that as few as 60 oaks/ac could ultimately result in a well-stocked stand of oak and mixed hardwoods. In fact, the presence of red maple and black birch saplings and poles in the early stages of stand development is actually beneficial, as they act as trainers and encourage straight bole development in the oaks that will eventually dominate the stand. Heiligmann et al. (1985) also studied the development of mixed hardwood stands. Even when oak-hickory stands in southeastern Ohio seemed to be converting to more of a mixed hardwood stand with a predominance of red maple, they estimated that there was a sufficient amount of oak in the mixture to become a significant part of the future stand. The results of the regeneration study reported here indicate approximately 200 oak seedlings/ac less than 19.7 in. in height, in the three different cover types.

The Influence of the Overstory

The amount of established regeneration in the understory bears some relation to both the total overstory density and the species composition of the overstory. The data from this study suggest a very broad spectrum of acceptable overstory basal areas of between 60 and 80 ft^2/ac to obtain the most abundant regeneration of mixed species. Higher basal areas would result in a regeneration composition that has a lower proportion of black birch and red maple, and almost an equivalent proportion of red oak. It is important to note that red oak regeneration was present at relatively low overstory densities of 20–40 ft^2/ac. This suggests that some degree of opening in the overstory may be advisable.

It is apparently not necessary to have a high proportion of a given species in the overstory in order to obtain established regeneration of that species in the understory. Overstory basal areas as low as 20–40 ft^2/ac of red oak, for example, are perfectly adequate for securing red oak regeneration in the understory. This is not the case with white pine, however, whose regeneration success was highly related to the amount of white pine in the overstory.

The fact that the amount of oak regeneration in the understory seems greatest in stands with a relatively low proportion of oak in the overstory may be due to the possible influence of wildlife in scattering and distributing acorns. Healy (1988), for example, in a review of the effects of seed-eating birds and mammals on Appalachian hardwood regeneration cited numerous examples of the scattering and hoarding of seeds and nuts. In one case (Darley-Hill and Johnson 1981), blue jays transported and cached 133,000 acorns from an oak stand in 28 days. Jays can apparently move acorns up to 2.5–3 1 miles. Squirrels can move nuts 660 ft from beneath parent trees (Barnett 1976). Given the potential movement of acorns due to wildlife, it is not surprising that despite the heavy-seeded strategy, the amount of oak regeneration is not necessarily the greatest under conditions of high oak density in the overstory.

Another possible explanation of the

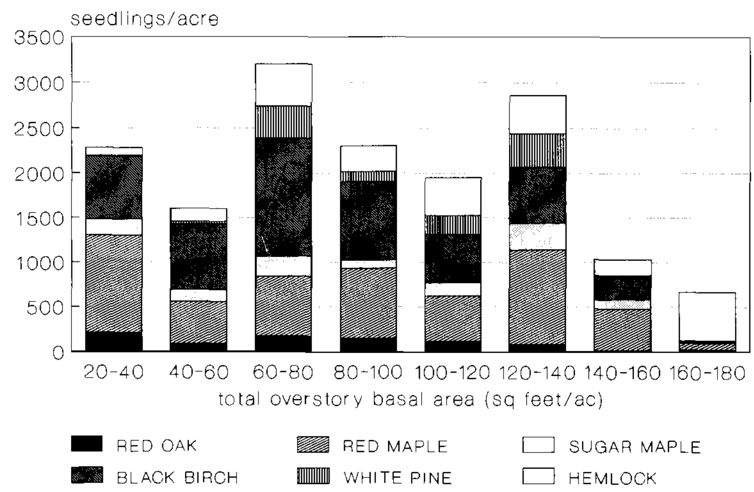

Fig. 4. Species composition of regeneration by total overstory density.

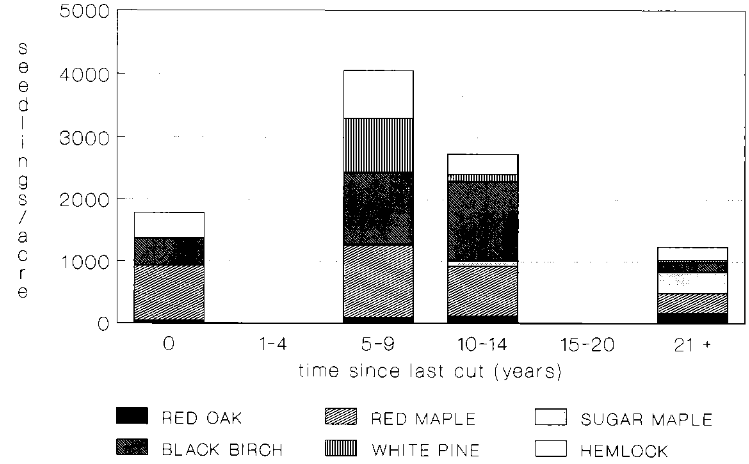

Fig. 5. Regeneration composition by time since last cut.

observation that the highest amounts of red oak regeneration are found beneath overstories with a low proportion of oak is that the crowns of individual oaks under these conditions are larger and produce more mast. Also, germination and initial growth is often retarded or impeded in stands with high basal areas because of the relative shade intolerance of oak (Ashton, in prep.).

The Influence of Mountain Laurel

It is surprising that the percentage cover of mountain laurel did not inhibit regeneration. It only had a significant, negative effect on pine regeneration, based on the multiple regression analysis. A study by Chapman (1950) offers an explanation of this lack of a relationship. He investigated the influence of mountain laurel on environmental conditions and oak reproduction in southern Connecticut. He found oak regeneration scattered throughout areas with a laurel understory, and measured light conditions in plots where laurel was removed, in dense laurel thickets, and in spaces in the laurel understory between actual thickets. The mean light intensity in the areas cleared of laurel was 9% of full sun, with periodic sun flecks casting almost full sun. In the understory with laurel, he recorded 5% of full sun between the thickets, with periodic sun flecks, as well. In the actual dense laurel thickets themselves however, he measured 2% of full sun with virtually no sun flecks. Since the circular plots used in the current study were 13.2 ft in size, it is very possible that even if laurel occupied as much as 80 or 90% of the cover, oak regeneration could be established in the plots. Hence the poor relationship between laurel cover and regeneration. Apparently, only the extremely dense thickets themselves are prohibitive to regeneration establishment. The same effect of plot size and distribution of cover may also explain why hay-scented fern had little effect on regeneration.

The Influence of Time Since the Last Harvest

It is important to note the interesting effect of time on the occurrence of regeneration. Previous studies have shown that oak seedlings have the ability to die back and resprout in the understory over long periods of time (Sanders et al. 1971). Thus, to achieve adequate regeneration stocking levels using a shelterwood system, time can elapse between when an intermediate harvest is made and when the final cut is made, while the amount of regeneration accumulates in the understory (Hannah 1987). Actually, this time period is necessary for successful oak regeneration development. Sander (1979) pointed out that advance oak regeneration could be inadequate if they were too small to grow fast enough to compete. Sufficient root development (acquired over time) seems to be critical to compete successfully. These studies were conducted in the central states (i.e., Missouri, Ohio, Illinois, Indiana), yet based on the results of this study, oak seems to behave similarly in mixed hardwood stands in southern New England. The implication is that one must have patience in attempting to regenerate a mixed stand with a successful component of oak. As previously discussed, as few as 60 stems/ac may be adequate.

In contrast to the behavior of oak regeneration, red maple and black birch regeneration were negatively related to the amount of time elapsed since the last intermediate harvest. This actually suggests that as time progresses following a cut, the overstory fills in, and less regeneration of these species becomes established.

It is interesting to note the significant negative relation between the amount of established hemlock regeneration and time since the last harvest. One might expect this relationship to be positive, since hemlock is so shade-tolerant, and thus would be uninfluenced by the stand becoming progressively dense over time. The significant negative relationship implies that as time progresses, less and less hemlock regeneration becomes established. This may actually be due to the apparent requirement of soil scarification for successful hemlock regeneration establishment (Ward and McCormick 1982). As time progresses following a cut and the disturbed soil becomes covered by litter, surface conditions for hemlock seedling establishment may become progressively unfavorable (Olson 1954).

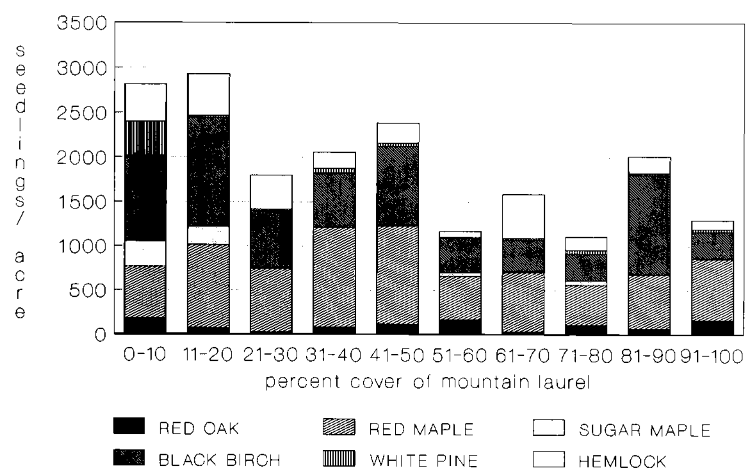

Fig. 6. Regeneration composition by percentage cover of mountain laurel.

CONCLUSIONS

The results of this study indicate that red oak regeneration in southern New England can accumulate in the understory of mixed hardwood stands over time, similar to the documented pattern of behavior found in the central states. Red maple and black birch do not behave in the same way, and their numbers can be expected to be fewer and fewer in the understory as time progresses following an intermediate harvest. This suggests that the forester exhibit patience in regenerating a mixed stand, allowing the proportion of oak to accumulate and develop in the understory. This attitude, combined with the knowledge that as the stand develops over time the oak will ultimately express dominance (Oliver 1978), should provide good guidance to those considering the regeneration of these mixed stands.

Although one would expect to the contrary, the results from this study suggest that mountain laurel and hay-scented fern are not significant, negative factors in the establishment of regeneration. In the case of mountain laurel, this is probably due to the ability of oak to become established in the gaps between dense thickets, as discussed by Chapman (1950). Since hay-scented fern occurs in dense, continuous cover, this explanation may not apply.

A significant amount of a given species in the immediate overstory is not apparently necessary in order to achieve abundant regeneration of that species in the understory. This is true even for heavy-seeded species such as oak and may possibly be explained by the influence of wildlife species in transporting acorns. White pine seems to be an exception, however. Its regeneration success is closely related to the amount of white pine in the immediate overstory. If pine is desired in the next stand, there is something to be said for leaving seed trees. Reliance on seed blowing in from adjacent stands may be unwise.

In general, a broad range of total overstory densities of between approximately 20–80 ft^2/ac seems to be the best for securing regeneration. Oak can regenerate at relatively low densities and develop over time. This is similar to the advice reported by Hannah (1987), based on studies in the central states and unpublished work in central Massachusetts. □

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North American Aspen: Timber Supply, Utilization, and Research

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ABSTRACT. Bigtooth and quaking aspen are the two most important white poplar species in North America, comprising 11.9 million ac in the Lake States, 4.4 million ac in western United States, and an estimated 100 million ac in Canada. Lake States aspen utilization increased greatly in the last 10 years and during the period 1982–87 accounted for 47–55% of the total pulpwood harvest. In 1987, removals were estimated at 286 million ft^3 and growth at 282 million ft^3. Canadian aspen utilization has also increased dramatically since 1980 and is expected to expand as demand for structural flakeboard and hardwood pulp increases. Even with increased use, less than 10% of the Canadian allowable cut is being utilized. Despite evidence on the importance of aspen on the economy of the U.S. Lake States and Canada, only a minor amount of research has been undertaken in the last 10 years to genetically improve and/or maintain the existing aspen resource.

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Bigtooth and quaking aspen are the two Section Leuce (white) poplars that are most important to the economy of North America. Quaking aspen, an aggressive pioneer species, is the most widely distributed tree in North America and grows from Newfoundland and Labrador west across northern Canada and to northwestern Alaska. The southern boundary of quaking aspen extends from New Jersey westward to Iowa and northwest to British Columbia. In western North America, quaking aspen grows from northern Mexico to Alaska. Extensive stands are found at 6500 to 9800 ft in Colorado, Arizona, New Mexico, and in some areas in the northern Rocky Mountains and Canada (USDA For. Serv. 1965).

Bigtooth aspen has a range restricted to northeastern North America, extending from Cape Breton Island, Nova Scotia, west to southeastern Manitoba, and from Maryland west to Iowa. Locally, bigtooth aspen is found in western Tennessee and in the mountains of western Virginia and North Carolina. In eastern Canada it is found along the St. Lawrence Valley (USDA For. Serv. 1965).

ASPEN WOOD RESOURCE

United States Lake States

Large areas of natural aspen stands occur in the Lake States Region (Michigan, Wisconsin, and Minnesota). The