EFFECT OF PREHARVEST UNDERSTORY TREATMENT AND GROUP OPENING SIZE ON FOUR-YEAR SURVIVAL OF ADVANCE REPRODUCTION IN THE BOSTON MOUNTAINS OF ARKANSAS

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ABSTRACT.—The purpose of this study was to examine survival of regeneration in small openings. Six forest stands were located in 1990 and three understory treatments were applied to each in early 1991. In each stand, six sizes of openings were created in 1992 ranging in size from 0.025 ac to 0.50 ac. Understory treatments consisted of:

1) no control of competing regeneration,
2) mechanical control of competing regeneration (cut stems), and
3) chemical control of competing regeneration (cut stems sprayed with herbicide).

Only northern red oak appeared to exhibit a response to treatments with increased survival as intensity of understory control increased and as opening size decreased. We attribute these results to the wide fluctuation in seedling populations and the short time interval between opening creation and post-treatment measurement.

Maintaining tree species composition in upland hardwood forests has been problematic. Without historic fire regimes or sufficient light in the understory the trend in species dominance will likely continue to move toward shade tolerant trees (Nigh and others 1985, Dodge 1997). In the Boston Mountains of Arkansas, we periodically find carpets of small, less than 1-foot-tall, first-year oak seedlings. Unfortunately these seedlings rarely survive more than 1 or 2 years on moderate to high site index sites without controlling competition and providing sufficient light (Graney 1999). The difficulty of maintaining species composition is especially challenging when balancing what is ecologically suitable for regeneration of oak and the multiple desires of many publics.

Management with low visual impact has led to consideration of using small group openings in the Boston Mountains of Arkansas. However, the effect of group openings of 0.5 acres or less on species composition in the Boston Mountains has not been examined. The long-term objective of this study is to examine the effectiveness of small group selection openings on survival of white oak (*Quercus alba* L.), northern red oak (*Quercus rubra* L.), black oak (*Quercus velutina* Lam.), black cherry (*Prunus serotina* Ehrh.), white ash (*Fraxinus americana* L.), post oak (*Qurecus stellata* Wangenh.), hickory (*Carya* Nutt.), and black walnut (*Juglans nigra* L.). Our short-term objectives are to:

1) determine survival of regeneration 4 years after opening creation in relation to treatments, and
2) examine the usefulness of logistic regression to examine highly unstable short-term seedling survival in relation to treatments.

METHODS

The Boston Mountains are the highest and most southern member of the Ozark Plateau Physiographic province. They form a band 30 to 40 miles wide and 200 miles long from north-central Arkansas westward into eastern Oklahoma. Elevations range from about 900 ft in the valley bottoms to 2,500 ft at the highest point. The plateau is sharply dissected. Most ridges are flat to gently rolling and are generally less than 0.5 mile wide. Mountainsides consist of alternating steep simple slopes and gently sloping benches.

Soils on mountaintops and slopes usually have shallow to medium depth and are represented by medium-textured members of the Hartsells, Linker, and Enders series (Typic Hapludults).

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They are derived from sandstone or shale residuum, and their productivity is medium to low. In contrast, soils on mountain benches are deep, well-drained members of the Nella and Leesburg series (Typic Paleudults). They developed from sandstone and shale colluvium, and their productivity is medium to high. Rocks in the area are alternating horizontal beds of Pennsylvanian shales and sandstones. Annual precipitation averages 46 to 48 inches, and March, April, and May are the wettest months. Extended summer dry periods are common, and autumn is usually dry. The frost-free period is normally 180 to 200 days long.

Study Description

Six upland hardwood stands were located in 1990. Pretreatment inventories of regeneration were done in late 1990 (July through November). Three understory treatments were applied in early 1991:

1) no control of competing regeneration,
2) mechanical control of all competing stems greater than 1 foot tall and less than or equal to 5.5 inches d.b.h. (cut stems), and
3) chemical control of all competing stems greater than 1 foot tall and less than or equal to 5.5 inches d.b.h. (cut stems sprayed with herbicide).

In 1992 (May through September), six sizes of openings were created: 0.025 ac, 0.05 ac, 0.10 ac, 0.20 ac, 0.35 ac, and 0.50 ac. All trees greater than 5.5 inches d.b.h. were removed in the harvest.

Individual stems of the regeneration to be released were tagged with unique identification numbers to examine survival throughout the study. Due to the expense and time of tagging trees, and following them throughout the study period, only species difficult to regenerate successfully and/or intermediate to intolerant of shade were examined. They included white oak, northern red oak, black oak, black cherry, ash, post oak, hickory, and black walnut. Other species were considered competitors.

Regeneration Measurements

Regeneration was sampled on a series of permanent 0.001-acre (3.72 feet in radius) or 0.002-acre (5.27 feet in radius) plots that were placed in each group opening. Regeneration plots in the 0.025 openings were 0.001-acre while plots in larger openings were 0.002-acre. Each 0.025- and 0.05-acre opening had five regeneration plots in which seedlings were tagged and measured, while larger openings had nine. One plot was placed at the center of the opening while the other plots were placed along the four cardinal directions (North, East, South and West).

Stems less than 1.6 inches d.b.h. were measured in 1990 and again in 1996 on each plot. Measurements included species and ground diameter to the nearest 0.1 inch (measured 1 inch above ground level on the uphill side of the stem). Within each plot, all black oak, northern red oak, and white oak stems were tagged and measured during the first inventory. If less than two stems of an oak species greater than 1 foot tall existed within a plot, then a stem was located and tagged outside the plot, so that at least two stems of each existing oak species was tagged if available within the opening. These additional trees will increase our ability to model long-term survival. In addition, a subset of species including post oak, black cherry, ash, hickory, and black walnut were tagged for each plot. In the subset of species, trees were tagged in proportion to their occurrence and size, with at least two stems of each species being tagged if possible.

Modeling Survival

Logistic regression was used to estimate survival probabilities of tagged regeneration trees. Designed independent variables included three levels of understory weed control and six levels of opening size. The dependent variable is the probability of survival. Although the observed value of the dependent variable is binary (0 or 1) in logistic regression, the resulting probability estimates are continuous and restricted to the interval 0 to 1. To prepare for logistic regression analysis, each tree was assigned either 1 (successful) or 0 (unsuccessful), where mortality of an individual stem by the time of the post-treatment measurement was considered unsuccessful.

For categorical independent variable (understory weed control), standard logistic regression dummy variables were used (Hosmer and Lemeshow 1989). For instance, because there were three weed control treatments, two dummy variables were needed, where the no understory control (U0) was coded 0, 0; manual understory control (U1) was coded 1, 0; and understory control treatment with herbicide (U2) was coded 0, 1.

To evaluate logistic regression model performance, we selected predictors with a p-value of 0.05 or less based on the Chi-square distribution with one degree of freedom. We used the Hosmer-Lemeshow goodness-of-fit statistic (Hosmer and

Lemeshow 1989, p. 140) to test the null hypothesis that the equation described the data. For Hosmer-Lemeshow goodness-of-fit p-values of 0.05 or less (indicating a poor fit of the equation to our data), the null hypothesis was rejected. This means that predictor p-values of 0.05 or less have a different interpretation than the Hosmer-Lemeshow goodness-of-fit p-values of 0.05 or less.

RESULTS AND DISCUSSION

During the post-treatment inventory 4 years after opening creation, 64 percent of the 11,807 tagged seedlings had survived (table 1). White oak, northern red oak, black oak, and black walnut had the highest mortality. The largest proportion of tagged seedlings were represented by white oak at 3,957 seedlings, northern red oak with 2,491 seedlings, and black oak with 1,774 seedlings.

Of the original stems, survival by species was 54 percent white oak, 60 percent northern red oak, 63 percent black oak, 90 percent black cherry, 87 percent ash, 100 percent post oak, 100 percent hickory, and 57 percent black walnut. However, post oak, hickory, and black walnut included only 3, 1, and 19 stems, respectively. Percent survival by understory treatment, species, and opening size does not appear to present any clear consistent trends at this early stage (table 1). We further inspected treatments in relation to survival using logistic regression to determine the usefulness of logistic regression to examine short-term data of this type.

Based on our logistic regression, survival probability of northern red oak increased with increasing intensity of understory control treatment and decreasing opening size. We suspect that the increasing survival with decreasing opening size is due to the large natural fluctuation in young seedling survival and the short time interval between opening creation and post-treatment measurement. The model is:

$$Pnro = 1/(1+EXP(-(0.175-(1.218*O)+U)))$$

where Pnro = the probability of northern red oak survival, O = Opening Size in acres, U = 0 for no understory control, U = 0.458 for mechanical control and U = 0.364 for chemical control.

Predictors for opening size and post-treatment are significant at $\alpha = 0.05$ ($pO < 0.001$, $pU < 0.001$). Based on the Hosmer-Lemeshow goodness-of-fit statistic, differences between estimated probabilities and observed responses are not significant ($p = 0.480$). The model is based on 2,491 observations. Any model describing this early stage of development in small openings should be viewed with skepticism due to the high instability of early reproduction in these systems resulting in large fluctuations in population density. For instance, in the case of northern red oak, 40 percent of the trees had died by the time of the second measurement.

Table 1.—*Percent survival by understory treatment, species and opening size. Numbers in parenthesis indicate number of tagged seedlings prior to treatment.*

Understory Treatment	Species	Opening Size (acres) 0.025	0.050	0.100	0.200	0.350	0.500
None	Ash	100(29)	98(23)	98(35)	85(49)	84(38)	77(56)
Mechanical	Ash	89(19)	98(18)	82(42)	86(33)	84(49)	95(58)
Chemical	Ash	90(11)	94(16)	87(22)	91(20)	82(56)	57(44)
None	Black cherry	89(26)	96(21)	99(50)	92(72)	81(82)	90(77)
Mechanical	Black cherry	91(33)	94(42)	93(47)	97(84)	95(88)	86(102)
Chemical	Black cherry	97(23)	83(38)	85(63)	94(61)	86(74)	76(72)
None	Black oak	47(40)	63(29)	69(148)	68(90)	53(161)	55(151)
Mechanical	Black oak	76(37)	51(27)	69(126)	53(101)	62(243)	54(148)
Chemical	Black oak	76(38)	76(51)	78(76)	54(70)	67(102)	67(136)
None	N. red oak	67(93)	63(68)	66(237)	56(122)	33(149)	61(174)
Mechanical	N. red oak	69(70)	62(124)	73(138)	54(194)	61(274)	49(288)
Chemical	N. red oak	77(40)	60(57)	63(91)	61(65)	62(137)	48(170)
None	White oak	51(77)	47(113)	48(85)	61(163)	49(298)	60(259)
Mechanical	White oak	52(110)	50(102)	62(327)	54(453)	54(315)	50(535)
Chemical	White oak	67(46)	44(120)	64(213)	57(223)	60(222)	54(295)

Northern red oak seedling mortality was highest for small diameter trees. For instance 1,512 of the 2,491 seedlings tagged and measured were 0.1 inch in diameter, and 62 percent of these died. However, for seedlings greater than or equal to 0.2 inches in diameter, only 22 percent had died by the time of remeasurement. Of the 0.1 inch diameter seedlings, 97 percent were less than 1 foot tall, the height class most likely to die within 1 or 2 years. It is likely that many of these trees died prior to opening creation.

Due to the low sample size for post oak, hickory and black walnut, it was not possible to develop a survival model for them. Survival of white oak, black oak, black cherry, and ash showed no relationship with treatments using logistic regression. At this early stage, many of the regenerating trees consist of very small (less than 1 foot tall) seedlings that typically have high mortality rates and sporadic cycles of first-year seedlings being recruited into the regeneration pool.

Seedlings greater than 1 foot tall have successfully been used to examine the impact of silvicultural treatments on tree species dynamics (Loftis 1990). It is also possible that a response has not been observed due to the small size of our openings. Oak reproduction in small openings of less than 0.5 acres will have a relatively large proportion of the reproduction affected by the surrounding stand and could favor development of more shade tolerant species (Sander and Clark 1971, Smith 1981, Sander and others 1983). Thus, the relative capacity of oaks to compete may be diminished.

However, increasing public concern over visual impact of large openings on public lands will likely place further constraints on maximum opening size. To effectively manage uneven-aged upland hardwood stands and maintain an acceptable stocking of oaks and other desirable species, public land managers will require information on the minimum opening size for successful growth and development of reproduction. This information will provide the tools to help balance both the wants of their publics and the growth and development needs of the forest.

CONCLUSIONS

It was not possible to detect any change in survival of white oak, black oak, black cherry, and ash in relation to treatments over the 4-year period after overstory removal. At this time it is difficult to determine if the lack of response is due to the small size range of openings, natural high mortality of small seedlings, or the short time interval between overstory removal and the following regeneration measurements. Remeasurement of these trees during and after the stem exclusion phase of development should determine effectiveness of the treatments.

Future hardwood opening size studies should consider including somewhat larger openings. This would increase the probability of capturing the minimum opening size to successfully regenerate oaks and other species intermediate to intolerant of shade. Additionally, a remeasurement of regeneration close to the time of opening creation will help determine how much mortality has occurred prior to treatment, making analysis of short term post-harvest data easier to interpret.

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