REPRODUCTION IN GROUP SELECTION OPENINGS 8 YEARS AFTER HARVEST IN A BOTTOMLAND MIXED HARDWOOD FOREST

Michael S. Golden[1]

Abstract-Eight-year reproduction was inventoried in permanent plots in 10 small patch cuts in a mixed bottomland forest by the Tombigbee River in western Alabama. Overall, there was adequate reproduction of commercial tree species (1174 stems per acre), but there were some scattered unstocked areas. The overall reproduction of oaks was relatively poor (an average of 340 per acre and less than 20 percent milacre plot stocking) and cherrybark, Shumard, and swamp chestnut oak reproduction was probably not sufficient to recover their proportions that existed in the preharvest overstory. Water/willow oaks were more successful than the other oaks and may attain equal or higher levels in the future stand compared to the preharvest overstory. Understocked areas in the patches resulted primarily from development of heavy woody vine and shrub cover, with grapevine the most important problem. The eight-year stocking of oaks originated primarily from advance reproduction less than one foot tall and from post harvest germination of acorns. The contribution of large advance oak reproduction was very small, due to the very low numbers present before harvest.

INTRODUCTION

The objectives of this paper are (1) to assess natural reproduction success for oaks and other major tree species eight years after harvesting small patches in a river bottomland mixed hardwoods forest; and (2) to examine the relative role of advance reproduction and post-harvest germination in establishing reproduction on this site.

STUDY SITE

The study was established in 1992 in a 75 acre stand of oak-dominated mixed bottomland hardwoods in the floodplain of the Tombigbee River, in Choctaw County, Alabama. The property is owned and managed by Ft. James Corporation. Physiographically, the site is in the Hilly Coastal Plain Province (Hodgkins and others 1979) and is just south of and downstream from the Black Belt.

At the time of cutting, the stand was predominately bottomland mixed oak forest, with the dominant canopy mostly 65-75 years old and 11 O-135 ft tall. The area of the study is a mixture of low, well-drained ridges and moderately to somewhat poorly-drained flats. The dominant soils are of the Mooreville, Urbo, and Una series. Surface horizons are mostly loam to silt loam. Typically, most of the sites are covered by river floodwater for brief periods once or twice during the winter and spring. The flats can also fill with water from rainfall, resulting in their having surface water l-3 inches deep even in late spring.

STUDY DESIGN

Rectangular clearcut patches of 0.8 acre, 132 by 264 ft, were the basic units of the study. These were small clearcuts, but this size falls within acceptable size limits for a group selection regeneration method (Smith and others 1996), since they approximate one tree height wide by two tree heights long. Ten patches, centered among clusters of larger dominants and oriented generally east-west, were delineated.

Five patches were randomly selected and harvested in early June, 1992 and the remaining five were harvested in early October, 1992. These were operational commercial harvests conducted by loggers contracted by Linden Lumber Company of Linden, Alabama. Trees were felled by chainsaws, delimbed and topped where they fell, and pulled by grapple skidders to one of two centrally-located loading decks. Following the commercial harvests, all remaining trees in the openings that were larger than 2 inches dbh were felled. When measured by remaining perimeter trees, all of the cut openings were slightly more than 0.9 acre in size. In aggregate, the ten cut patches totaled approximately 9.1 acres.

DATA COLLECTION AND ANALYSIS

Prior to harvest, all trees in each patch greater than 10 ft tall were inventoried and their locations mapped. Species and dbh were recorded for each tree.

[1]Associate Professor, School of Forestry and Wildlife Sciences, Auburn University, Al 36849.

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Table l-Preharvest stems per acre, basal area, and dbh's for trees larger than 5 inches dbh, all ten patches combined

Species	Stems/ac	Ft²/ac	DBH (in.) Mean	DBH (in.) Maximum
Quercus pagoda	14	46.7	23.6	44.5
Quercus phellos	6	20.6	23.3	38.7
Liquidambar styraciflua	28	20.2	10.6	29.3
Quercus nigra	6	17.6	21.2	40.4
Quercus michauxii	5	8.8	15.1	40.4
Quercus shumardii	1	4.3	22.5	31.1
Fraxinus pensylvanica	5	4.1	11.0	27.6
Celtis laevigata	5	3.3	10.3	20.5
Carpinis caroliniana	12	2.6	6.3	11.9
Quercus lyrata	1	2.1	16.0	32.8
Carya spp.	2	1.9	11.0	21 .o
Carya ovalis	1	1.5	4.1	16.6
Carya cordiformis	2	1.1	5.1	21.8
Carya ovata	2	0.9	8.2	18.1
Quercus laurifolia	<1	0.8	21.2	25.2
Nyssa sylvatica	2	0.6	7.7	12.1
Morus rubra	1	0.4	7.0	9.9
Ulmus Americana	1	0.3	6.8	10.0
Carya tomentosa	1	0.2	7.7	10.8
Ilex opaca	<1	0.2	8.9	12.6
Ulmus spp.	<1	0.1	6.1	6.7
Halesia diptera	<1	0.1	5.9	7.2
Ulmus alata	<1	0.1	6.3	7.4
Ilex decidua	<1	<0.1	6.3	7.2
Crataegus spp.	<1	<0.1	6.0	6.0
Totals	96	134.0		

For inventory and long-term monitoring of reproduction, seven systematically-placed belt transects, each 6.6 ft wide and extending from side to side perpendicular to the long axis, were established in each patch. These were segmented into 1 milacre (6.6 by 6.6 ft) subplots, with 20 subplots in each transect within the patch boundaries, for a total of 140 milacre subplots within each patch. The subplot corners were marked with wire pin flags, which were replaced by plastic pipe stakes after the harvests.

All non-vine woody species were tallied by species and size class within each subplot before harvesting and several times since. The forest surrounding the developing patches was commercially clearcut in late summer, 1999. The last reproduction plot inventory was conducted in early June, 2000, eight years after the first harvests. Tree reproduction in the milacre plots were re-inventoried by species and competitive position class. To characterize and discuss the eight-year reproduction, only those trees considered "non-overtopped" (NOT) were included. This category is composed of trees with no competing trees having live foliage directly overtopping the tip. This includes those judged "free-to-grow", with no taller trees intersecting a 90 degree exclusion angle with the apex at the growing tip (Smith and others 1996) and those with slightly taller, crowding trees nearby, but with no foliage directly overtopping them ("free tip"). It was felt that all of these had at least some chance of ultimately being in the canopy. In the third decade after harvest, cherrybark oak has been found to be able to gain dominance over sweetgums that had earlier crowded them and been taller (Clatterbuck and Hodges 1988). Those trees completely overtopped were excluded from the analyses, regardless of height, and considered to have lost the battle for space in the developing canopy.

At the eight-year inventory, several hundred of the original reproduction plots were judged too heavily damaged by the 1999 timber harvest and were omitted from further analyses. Data from the remaining 954 plots were summarized by species and competition class and compared to preharvest data from the same 954 plots and to the total preharvest overstory inventory.

RESULTS AND DISCUSSION

Preharvest Trees

Before harvest, the overstories of all of the patches were dominated in basal area by oaks. Taken together, the oaks averaged 100.9 ft² per acre. Cherrybark oak *(Quercus* pagoda Raf.) averaged the highest basal area (table 1). It was present in the overstory of all ten of the patches, with a minimum basal area of 17.7 ft^2 per acre and a maximum of 95.1 ft^2 per acre. However, most of the trees were large and its canopy numbers were relatively small, averaging only 14 stems per acre. Willow oak (Q. *phellos* L.) was second in overall dominance (20.6 ft^2 per acre), but it averaged only 6 stems per acre. Water oak (Q. *nigra* L.) was present in the overstories of all ten patches, but was fourth overall in basal area and averaged only 6 stems per acre. Swamp chestnut oak (Q. *michauxii* Nutt.) was present in nine of the ten patches, but was never a leading dominant. Shumard oak (*Q. shumardii* Buckl.) was a leading species in one patch and present in another, but was absent from the other eight patches. Two other oaks, overcup (*Q. lyrata* Walt.) and swamp laurel oak *(Q. laurifolia* Michx.) were present but were scattered and in very low numbers within the patches. Sweetgum (*Liquidambar styraciflua* L.) was third in species average basal area (20.2 ft^2 per acre) and first in average stem density with 28 per acre (table 1). It was present in all patches. Green ash (*Fraxinus pennsylvanica* Marsh.) and sugarberry (*Celtis laevigata* Willd.) were present in most of the patches, but were never among the dominant species.

Advance Reproduction

For the analyses and the discussion here, a broad interpretation of "advance reproduction" will be used, to include all seedlings, saplings, and smaller trees having high stump sprouting potential (Johnson 1993). It has been widely established that hardwood stumps decline in their probability for producing long-lived sprouts as their size increases (Sander and others 1984, Johnson 1993, Belli and others 1999, Golden 1999). A previous study of the sprouts originating on this site (Golden 1999) found that stumps from trees smaller than 12 inches dbh sprouted with high frequency, but those larger produced very few sprouts still alive three years after harvest. Consequently, all trees smaller than 12 inches dbh (including saplings and seedlings) tallied in the reproduction plots were included as advance reproduction. Small seedlings of water oak and willow oak were impossible to reliably distinguish, so all reproduction data for these two oaks will be treated as one class, "water/willow oak".

With all sizes taken together, advance reproduction (AR) of all commercial species combined averaged 12,572 per acre (table 2). Water/willow oak reproduction comprised the majority of these, averaging 7,594 per acre. Cherrybark oak was second in advance reproduction, at 1059 per acre. All other oaks combined averaged less than 100 per acre.

It is noteworthy that more than 95 percent of the advance reproduction for commercial species **was** less than 1 ft tall (small AR), with only 609 per acre taller than 1 ft (large AR) (table 2). For the oaks, only 0.5 percent (45 per acre) of their advance reproduction was taller than 1 ft. For the 952 reproduction plots, cherrybark oak averaged only 6 stems per acre more than 1 ft tall, with 4 per acre of these less than 3 ft tall. There were no cherrybark oaks found in the sizes taller than 3 ft but smaller than 5 inches dbh (table 2). Water/willow oak advance reproduction had somewhat more, but only 26 per acre in large AR, and all of these were less than 3 ft tall. Sweetgum and green ash each had more than 150 stems per acre in large AR, with the large majority of these less than 3 ft tall. Other commercial species, principally sugarberry and elms, comprised more than 230 large AR per acre (table 2).

The small number of large AR for the oaks was apparently due to the heavy shade at the seedling layer, which was created mostly by the midstory and understory layers. Small seedlings were able to establish from strong acorn crops, but failed to continue height growth once food reserves from the acorns were exhausted.

Tree Reproduction After Eight Years

Among the eight-year non-overtopped (NOT) reproduction, commercial tree species averaged 1174 stems per acre, with sweetgum the most abundant (422 per acre) and green ash (301 per acre) second (figure 1). Taken as a group, the oaks comprised about 29 percent (340 per acre) of the NOT reproduction, with water/willow oak having the highest numbers (242 per acre) (figure 1). Cherrybark oak was reduced to 85 NOT trees per acre, and the other oaks (swamp chestnut, shumard, and overcup) together averaged only 14 per acre.

Table 2—Advance reproduction, including all trees up to 12 inches dbh found in the reproduction plots, by size class

Size	Cherrybark Oak	Water/willow oak	Other oaks	Sweetgum	Green ash	Other commercial	Total commercial
				Trees/acre			
4" tall	480	2082	19	66	95	619	3361
>4"<12" tall	573	5486	64	83	503	1893	8602
>1'- 3' tall	4	26	7	112	153	153	453
3'- 10' tall	0	0	0	20	6	13	39
>10' tall - 5" dbh	0	0	4	18	3	50	75
>5"<12" dbh	2	0	2	21	0	17	42
Totals	1059	7594	96	320	760	2743	12572

Table 3-Comparison of oak advance reproduction density and stocking percentages (of 954 plots) to non-overtopped (NOT) reproduction eight years after harvest

Species	All AR	Large AR only	8 year NOT
	-----Stems/acre	(pct. stocking)------	
Cherrybark oak	1112 (37)	6 (1)	85 (6)
Water/willow oak	7977 (56)	27 (2)	242 (14)
Other oaks	101 (7)	14 (1)	14 (1)
Sweetgum	336 (20)	180 (11)	422 (29)
Green ash	798 (34)	70 (12)	301 (21)
Other commercial	2882 (83)	243 (18)	110 (10)

Comparisons Of Preharvest To Eight-Year Species Composition

Advance Reproduction Comparison-in terms of number per acre, when all advance reproduction sizes are taken together, the attrition in numbers from AR to 8-year NOT was most dramatic for water/willow oak, which declined from 7977 to 242 per acre (table 3), for a 33:1 ratio of AR to 8-year stems. This is not surprising, since only 27 per acre of the AR stems were taller than 1 foot. Cherrybark oak numbers also declined drastically, from 1112 to 85 per acre (13:1). Even fewer (6 per acre) of its AR were taller than 1 foot. Only sweetgum showed an increase, from 336 to 422 per acre (table 3).

However, published predictive methods for oaks emphasize that larger AR, at least 1 foot tall, have much higher probabilities for reproduction success (Sander 1984, Johnson and Deen 1993, Belli and others 1999). If only those larger AR are considered, the oaks increased their numbers substantially - cherrybark oak from 6 to 85 per acre and water/willow oak from 27 to 242 per acre. This clearly indicates that large AR alone did not account for the majority of successful oak reproduction.

One of the most informative values in assessing reproduction success is stocking percentage. From the practical standpoint of comparing importance of a species among tree reproduction, distribution is perhaps as important as sheer numbers, since having a given number of widely distributed seedlings is a more advantageous situation than when they are concentrated in dense clusters.

Distribution is customarily assessed in silvicultural applications by determining the percentage of well-distributed sample plots that are "stocked". This gives information that is highly related to both density and distribution. For a specific species, a stocked milacre reproduction plot had at least one suitable individual of the species present. Stocking for "all AR" was determined using presence of any stem less than 12 inches as the criterion, but stocking using just "large AR" (that less than 1 ft tall excluded) was also determined.

With all sizes considered, AR stocking for cherrybark oak was somewhat low (37 percent), while water/willow oak was moderate (56 percent), and other oaks was very low (7 percent) (table 3). The stocking with large AR oaks was extremely low (1, 2, and 1 percent, respectively, for cherrybark, water/willow, and other oaks). When AR stocking was compared to that of 8-year NOT, the data exhibited a pattern similar to that for stems per acre, differing primarily in degree. The ratio of all AR stocking to 8-year was about 6:1 for cherrybark oak, 4:1 for water/willow oak, and 7:1 for other oaks (table 3). Unfortunately, the stocking levels were very low in the 8-year stand for the oaks, only 6, 14, and 1 percent for cherrybark, water/willow, and other oaks, respectively. Again, sweetgum exhibited an increase from preharvest to eight-year stocking (table 3). So, using plot stocking as the criterion, oak reproduction success would be judged to be very poor.

Preharvest Overstory Comparison-Another test of reproduction "success" for a specific species is whether it held its own or increased in proportion compared to its proportion in the preharvest overstory. In other words, has a species gained or lost in relative importance in the new stand compared to the harvested one?

When the species proportions in the preharvest overstory (all trees more than 5 inches dbh) numbers were compared to their proportions among the 8-year NOT trees (figure 2), the greatest gain achieved was for green ash, which increased more than fourfold, from 5 to 22 percent of stems. Water/willow oak gained slightly (13 up to 17 percent) and sweetgum remained almost the same (about 30 percent). However, cherrybark oak and other oaks lost substantially in proportions, dropping to less than half and to one-eighth, respectively (figure 2). Cherrybark oak comprised only 6 percent of the 8-year NOT trees, down from 14 percent in the preharvest overstory.

Table 4-Sources of plots stocked with non-overtopped oak reproduction after eight years

Source	Cherrybark oak	Water/willow oak	Other oaks
	Number (pct.) of plots		
All AR, <12" dbh	37 (62)	104 (78)	0 (0)
AR, 1' tall-12" dbh	2 (3)	8 (6)	4 (40)
Post-harvest germination	21 (35)	21 (16)	6 (60)
Totals	60(100)	133(100)	10(100)

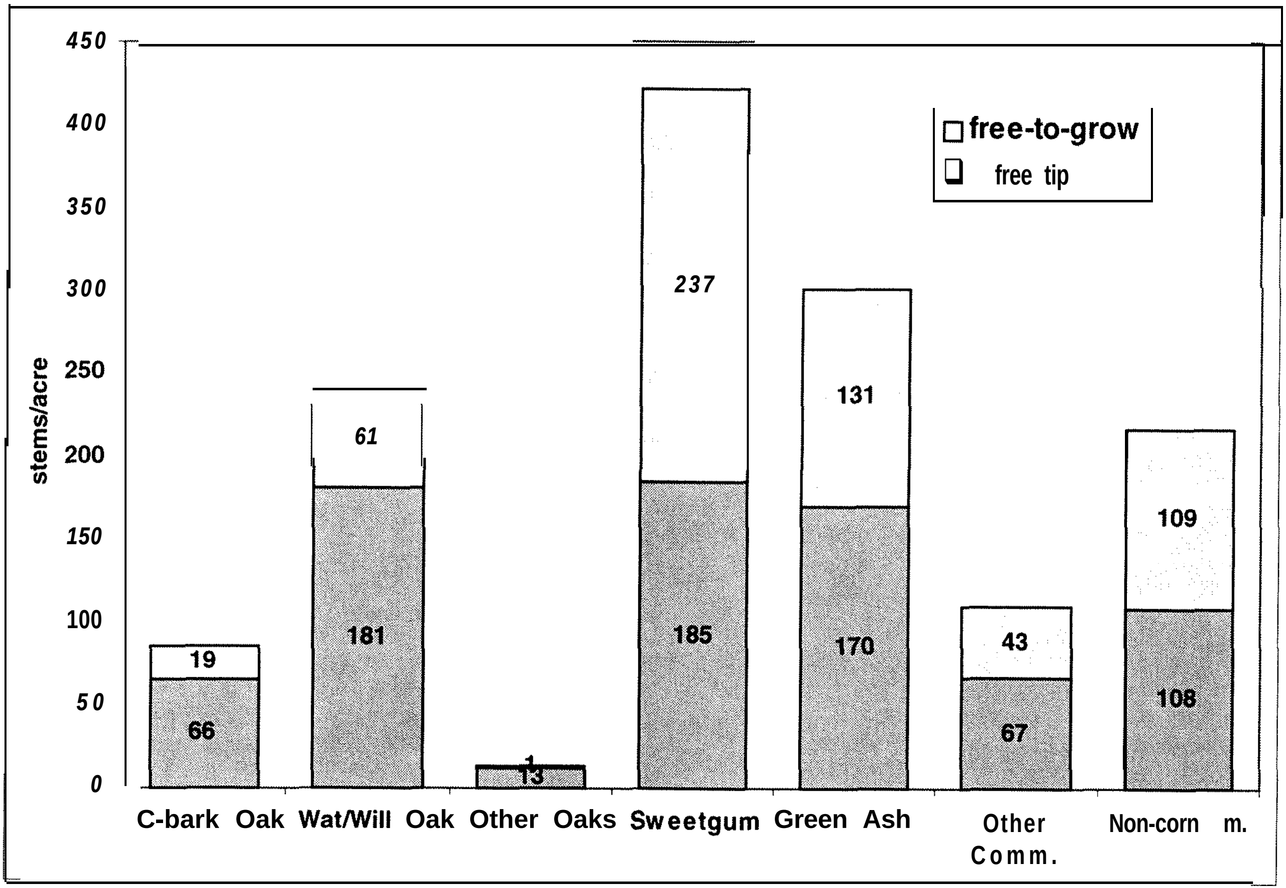

Figure l-Eight-year non-overtopped (NOT) reproduction.

Origins Of Eight-Year Oak Stocking

Since it was obvious from the previous analyses that most of the successful (non-overtopped) oak regeneration at eight years could not have come from large advance reproduction, where did it come from? Conventional wisdom is that oak regeneration must come almost entirely from advance reproduction, and so postharvest germination of seed plays little or no role (Johnson 1993). Although individual seedlings were not tagged in this study, the careful inventory of precisely relocated small plots allowed me to develop some conservative assessments of the role of post-harvest germination (PHG) in providing successful stocking at eight years.

For this, I examined for each oak species just those plots that were stocked with at least one NOT tree at the eight-year inventory. For these, if a plot had not been stocked with any size AR, it was assumed that the source of that plot's stocking at 8 years was PHG. If it had any AR, the stocking was assumed to have originated from that. For those stocked plots that had contained AR, they were assumed to have originated from large AR if any stems taller than 1 foot were present for the species at the preharvest inventory. Otherwise, they were assumed to have originated from small AR, less than 1 foot tall. Thus this approach produced estimates of PHG and small AR that are minimums relative to AR and large AR, respectively.

The results indicate that PHG contributed substantially to the eight-year NOT stocking for the oaks. For cherrybark oak, 35 percent of its stocking (21 of 60 plots) was from post-harvest germination (table 4). The proportion was smaller for water/willow oak, 17 percent, but still substantial. Only 10 plots were stocked with other oaks, but 6 of these were from PHG.

Most of the stocking for cherrybark and water/willow oaks originated from small advance reproduction, comprising 62 and 78 percent, respectively, of stocked plots (table 4). Only about 3 and 6 percent of the stocking originated from AR taller than 1 foot for cherrybark and water/willow oaks respectively. This is primarily a reflection of the lack of large advance reproduction in the stand.

Major Limitations To Successful Reproduction

Muscadine grape (*Vitis rotundifolia*) proved to be a major problem on this site. It did not appear to be particularly abundant before the harvest, although vines were common and small seedlings were scattered throughout. Between the three-year assessment (not reported) and the eight-year inventory, a large number of seedlings and saplings were completely covered by grapevines, and many were bent or even broken over by the weight of the heavy vines. Rattan-vine (*Berchemia* scandens) also covered and broke seedlings in some areas. Erect blackberries (*Rubus* spp.) formed tall, dense thickets in

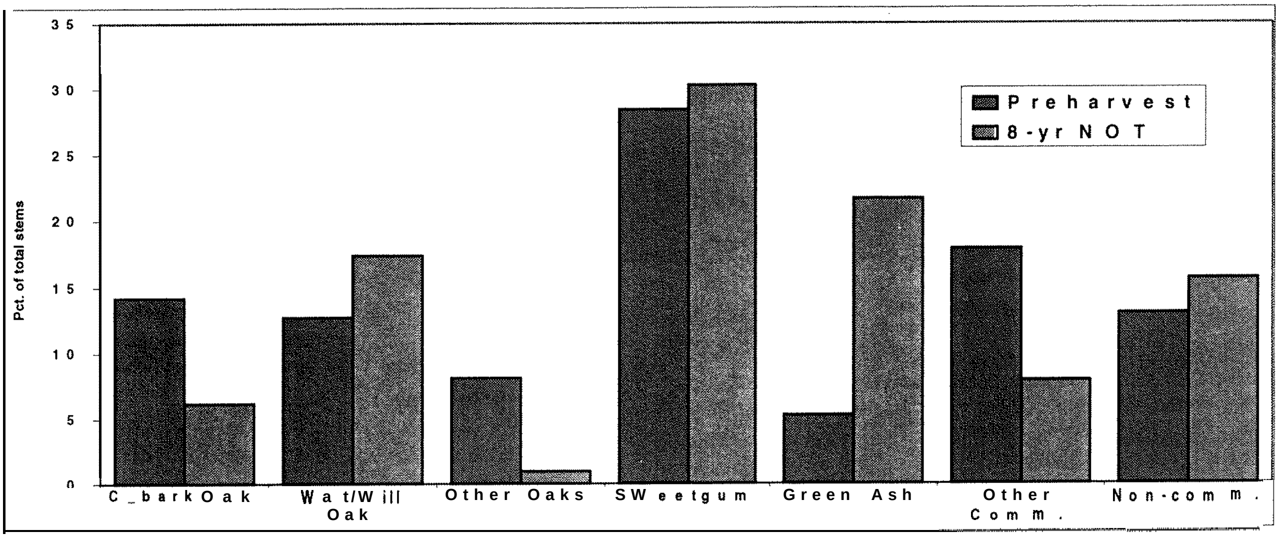

Figure 2-Percentage of total stems, by species, for preharvest trees (>5" dbh) vs 8-year non-overtopped.

some areas. Some of these created sufficient shade to cause mortality of developing oaks. The blackberries also provided support for the woody vines, producing a tent-like effect in some areas.

CONCLUSIONS

Eight years after harvesting small clearcut patches in a riverbottom mixed forest, there was adequate reproduction of commercial tree species overall (1174 per acre), but there were some scattered unstocked areas. The overall reproduction of oaks was relatively poor (340 per acre and less than 20 percent milacre plot stocking) and cherrybark, Shumard, and swamp chestnut oak reproduction was probably not sufficient to recover their proportions that existed in the preharvest overstory. Water/willow oaks were more successful than the other oaks and may attain equal or higher levels in the future stand compared to the preharvest overstory. Understocked areas in the patches resulted primarily from development of heavy woody vine and shrub cover, with grapevine the most important problem. The eight-year stocking of oaks originated primarily from advance reproduction less than one foot tall and from post harvest germination of acorns. The contribution of large advance oak reproduction was very small, due to the very low numbers present before harvest.

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