Assessment of Residual Stand Quality and Regeneration Following Shelterwood Cutting in Central Appalachian Hardwoods

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ABSTRACT: *Partial cutting to develop two-age stands* is *a relatively new practice in the central Appalachian region, and forest managers need quantitative information in order to evaluate how well it meets management objectives. Typically, this practice leaves a residual overstory of* 1 *0 to 40 ft² per ac of basal area and leads to regeneration of desirable shade-intolerant species which comprise the second age class. 1n this study we evaluated residual tree quality and regeneration* 2 *to* 5 *yr after cutting in 20 stands on the Monongahela National Forest in West Virginia. Tree grades were not significantly affected by the cutting. The largest grade reductions, due primarily to epicormic branching and logging wounds, occurred with large white oak sawtimber* (11 %) *and white ash small sawtimber (10%). Epicormic branching following the cut was greatest for white oaks in the suppressed and intermediate crown classes. Across all species, the trees in the lower crown classes produced the greatest number of epicormic branches. Overall, epicormic branching on the 16ft butt logs of dominant and codominant trees was low. For white oak* (Quercus alba), 64% *of these trees produced no epicormic branches. But* 75% *of yellow-poplars* (Liriodendron tulipifera), 82% *of black cherries* (Prunus serotina), 78% *of northern red oaks* (Quercus rubra), *and* 89% *of white ashes* (Fraxinus american a) *produced no epicormic branches on butt logs. Logging wounds occurred on45% of the residual trees across the 20 stands, but* 21 *% had large, wounds over 100 in2. Regeneration of both shade-intolerant and tolerant species was prolific following the cutting. Total numbers of tree seedlings and sprouts ranged from* 8,217 *stems/ac in the mixed oak stands of the Ridge and Valley Province to 30,845 stems/ac in the beech-cherry-maple stands in the Allegheny Mountains. The birches, primarily sweet birch* (Betula lenta), *comprised the most abundant species across the study area, but species composition varied depending on forest cover type. Regeneration numbers were lowest in the mixed oak stands in the Ridge and Valley Province. North. J. Appl. For. 15(4):203-210.*

Traditionally, c1earcutting has been an important silvicultural method of regeneration for central Appalachian hardwoods on eastern national forests. The open conditions following c1earcutting satisfy the light and seedbed requirements for a host of hardwood species, leading to prolific regeneration from seeds and sprouts, and increased growth of established seedlings. However, from an aesthetic viewpoint, c1earcutting has been much maligned.

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Public opposition to clearcutting has led foresters to seek other alternatives that provide adequate tree regeneration, but are more visibly acceptable to the general public (Smith et al. 1989). In addition, concepts of ecosystem management are challenging foresters to meet multiple objectives, often requiring alternative practices (Bartuska 1994, Heisenbuttel 1996).

A silvicultural practice that leads to the development of a two-age structure is one such alternative. A two-age structure is created when a portion of the overstory is removed, leaving 15 to 20 codominant residual trees occupying 10 to 40 ft^2 of basal area per ac. Regeneration develops beneath the residual stand, as a separate age class; hence the term *two-age*. It is essential for the main crown canopy to be sufficiently open to allow the developing younger age class the space it needs to grow. At some point in time the younger age class trees will have heights similar to those in the older age class. The residual overstory may remain intact for as long as the entire next rotation, perhaps 80 years (Miller and Shuler 1995). This form of cutting has received many names, including shelterwood with reserves, irregular shelterwood, deferment cutting, and two-age cutting.

Preliminary studies in Appalachian hardwood forests have shown that partial overstory removal resulted in a spectrum of regeneration that was similar to that of clearcutting (Miller and Shuler 1995, Beck 1986). While epicormic branching of residual trees was found to be most pronounced during the first 2 yr after harvest, most residual trees maintained their original stem quality (Miller 1996). However, evaluations to date have been conducted based on a limited number of research sites in West Virginia, and residual trees were selected to achieve timber production objectives. The present study was established to evaluate the quality of the residual stand and regeneration from a series of operational cuts on the Monongahela National Forest in West Virginia, where residual trees were chosen to meet the multiple objectives of timber, wildlife, and aesthetics. Information from actual field operations could prove very useful in helping to refine the existing guidelines under which such cuts are applied.

Method

Study Area

During 1996,20 stands were identified on the Monongahela National Forest in West Virginia (Table I). The stands had all received a shelterwood cut intended to create a two-age stand structure 2 to 5 growing seasons prior to measurement. All residual stems 1 to 5 in. dbh were cut during or soon after logging in each stand. Previous studies have shown that butt log epicormic branches and logging wounds appear within 2 yr after cutting, and change little over the next 8 yr (Smith et al. 1994, Miller 1996); thus, it was felt that an evaluation after 2 growing seasons would be sufficient to evaluate residual quality. The study stands were located on four ranger districts, and were part of the ongoing timber sale program on the forest. Stands ranged from 8 to 25 ac in size and occurred in two physiographic provinces and three forest cover types (Table 1). Eleven stands occurred in the beech-cherry-maple cover type at the higher elevations in the Allegheny Mountains, eight on the north end of Middle Mountain (Greenbrier Ranger District), and three on Spruce Knob Mountain (Potomac Ranger District). Five stands were located west of the Allegheny Front in mixed Appalachian hardwood stands (Greenbrier, Cheat, and Marlinton Ranger Districts), while four were located in the Ridge and Valley physiographic province with mixed oaks dominating the overstory (Potomac Ranger District).

Table 1. General description for 20 shelterwood-with-reserves cuts on the Monongahela National Forest.

Stand	Ranger district	Area (ac)	Physiographic province	Forest cover type	Site index[1]	Year harvested	Management objectives[2]
I	Greenbrier	15	Allegheny Mts.	Beech-cherry-maple	78	1993	TWA
2	Greenbrier	13	Allegheny Mts.	Beech-cherry-maple	89	1994	TWA
3	Greenbrier	15	Allegheny Mts.	Beech-cherry-maple	80	1992	TWA
4	Greenbrier	10	Allegheny Mts.	Beech-cherry-maple	70	1993	TWA
5	Greenbrier	10	Allegheny Mts.	Beech-cherry-maple	89	1993	TWA
6	Greenbrier	13	Allegheny Mts.	Beech-cherry-maple	81	1992	TWA
7	Greenbrier	22	Allegheny Mts.	Beech-cherry-maple	69	1993	TWA
8	Greenbrier	13	Allegheny Mts.	Beech-cherry-maple	74	1992	TWA
9	Greenbrier	25	Allegheny Mts.	Mixed Appal. hdwds.	72	1995	TWA
10	Potomac	24	Allegheny Mts.	Mixed Appal. hdwds.	85	1993	TA
11	Potomac	14	Ridge & Valley	Mixed oaks	60	1993	T
12	Potomac	14	Ridge & Valley	Mixed oaks	65	1992	T
13	Potomac	13	Ridge & Valley	Mixed oaks	60	1992	T
14	Potomac	8	Allegheny Mts.	Beech-cherry-maple	58	1992	WA
15	Potomac	33	Ridge & Valley	Mixed oaks	54	1994	TA
16	Potomac	13	Allegheny Mts.	Beech-cherry-maple	58	1992	W
17	Potomac	9	Allegheny Mts.	Beech-cherry-maple	58	1992	W
18	Cheat	10	Allegheny Mts.	Mixed Appal. hdwds.	65	1994	T
19	Cheat	10	Allegheny Mts.	Mixed Appal. hdwds.	75	1994	W
20	Marlinton	24	Allegheny Mts.	Mixed Appal. hdwds.	58	1994	WA

1 Site index is average hI. in ft of dominant and codominant trees at 50 yr of age.

2 Management objectives are timber (T), wildlife (W), and aesthetics (A).

Residual Tree Measurements

Within each stand, individual tree measurements were made on up to five trees in each of the following species groups and size classes:

<u>Measured Suecies</u>
Northern red oak *(Quercus rubra)*
White oak *(Q. alba)*
Chestnut oak *(Q. prinus)* Sugar
maple *(Acer saccharum)*
Red maple *(A. rubrum)* Black
cherry *(Prunus seratina)*
Yellow-poplar *(Liriodendron tulipifera)*
White ash *(Fraxinus americana)*
American basswood *(Tilia americana)*

<u>Size Classes</u>
Poletimber (5-10 in. dbh)
Small sawtimber (12-16 in. dbh)
Large sawtimber (18 in.+ dbh)

Trees were selected at random from these species and size classes as they were encountered in the stand. The theoretical maximum number of trees that could be sampled in a given stand was 135 (9 species x 3 size classes x 5 trees). However, in practice, not all species and size class combinations occurred in each stand. Each individual tree was measured for dbh, merchantable height, current tree grade, estimated initial tree grade prior to cutting, number and area of logging wounds, and number of epicormic branches by 16 ft log sections up to 33 ft. In a retrospective study such as this, it was not possible to exactly measure tree response to a treatment such as shelterwood cutting, since the trees were not measured prior to the cut. However, it was possible to reasonably reconstruct certain tree variables. For example, each tree was graded using the USDA Forest Service tree grade specifications (Hanks 1976, Miller et aI. 1986). The initial grade prior to the cut was estimated by ignoring logging damage obviously caused by the cut and epicormic branches that developed following the cut. Obviously, the determination of which branches developed following the cut is difficult. In doubtful cases the branches were pruned and aged to determine their year of origin.

Regeneration Measurements

Within each stand, fixed-area regeneration plots were systematically established, one per ac, with a minimum of25 and a maximum of 50 per stand. Regeneration stems (all woody stems < 1.0 in. dbh) were tallied by species and height class on 1/1,000 ac plots. The height classes were: (a) < 0.5 ft; (b) 0.5-0.9 ft; (c) 1.0-2.9 ft; (d) 3.0-4.9 ft; and (e) ~ 5.0 ft1.0 in dbh.

Data Analysis

To compare the log grade distributions before and after cutting, a chi-square analysis was used, with a significance level of 0.05. Differences in numbers of epicormic branches between crown classes were assessed using analysis of variance, followed by Tukey's HSD at the 0.10 level as a mean separation procedure. The same procedure was used to determine differences in logging wound numbers and area, and percentage of trees wounded among the three harvest seasons. Percent data were transformed prior to analysis.

Results and Discussion

Residual Stand Quality

Throughout the 20 study stands, a total of 768 individual trees representing nine commercial species were evaluated for tree grade, logging damage, and epicormic branches (Table 2).

Tree Grade.-Tree grades provide an objective assessment of saw log quality for trees of various sizes (Hanks 1976, Miller et al. 1986). Based on tree size, surface defects, and cull deductions, the grades effectively categorize trees into three quality classes. As a young tree ages and increases in diameter, it should increase in grade as well. Logging wounds and epicormic branches resulting from a partial cut are the major culprits in causing a stagnation or reduction in tree grade.

Table 2. Distribution of sample trees for quality measurements by species and size class.

Species	Poletimber (5-10 in. dbh)	Small sawtimber (12-16 in. dbh)	Large sawtimber (> 18 in. dbh)	Total
	No. of trees			
Yellow-poplar	5	23	11	39
Black cherry	33	59	38	130
N. red oak	31	43	32	106
White oak	16	19	9	44
Chestnut oak	23	22	15	60
Sugar maple	77	61	20	158
Red maple	55	49	10	114
White ash	21	41	20	82
A. basswood	15	17	3	35
Total	276	334	158	768

Each *of* the 768 measurement trees were graded based *on* their current condition. In addition, the grade prior to the cut was estimated by ignoring wounds and branching that occurred following the cut. All poletimber trees received a grade of 4, since they are too small for grade 3 trees (Hanks 1976). Most species showed the same distributions following the cutting (Table 3). Chestnut oak and American basswood both had identical distributions prior to and following the cut, for all sawtimber trees. Grade reductions, when they occurred, were generally minor and none were significant using the chi-square test at the 0.05 level. Percent reductions ranged from 0 to 10 for small sawtimber and 0 to 11 for large sawtimber. The greatest reductions occurred with white ash small sawtimber (10%) and white oak large sawtimber (11 %). In only four cases did the grade reductions involve more than a single grade (one red oak and three black cherries).

It is well known that reductions in stand density can negatively influence tree grade. In a study involving six commercial species 10 yr after deferment cutting in West Virginia, which is similar to the cuts evaluated in this study, Miller (1996) found that butt log grade had decreased in 11 % of trees, with yellow-poplar having the lowest reduction (I %) and white oak the highest (24%). White oak large sawtimber had the highest percent grade reduction in our study as well. Sonderman (1987) noted that crop tree release had minimal impact on stem quality for yellow-poplar or mixed oaks in Ohio. However, further studies showed that 7% of grade 2 oaks, 14% of grade 2 yellow-poplar, and 5% of grade 4 red maple declined in grade after heavy thinnings (Sonderman and Rast 1987). The greatest cause of grade changes in these studies was epicormic branching.

Epicormic Branching.-The development *of* epicormic buds into branches following a partial cutting has been well documented, and is a common cause *of* reduced stand quality (Sonderman 1986, Miller 1996, Stubbs 1986). Overall, numbers *of* new epicormic branches in this study were fairly low, with white oak being the most prone to producing new branches (Table 4). Trees that exhibit reduced vigor, such as those with epicormic branches prior to the cut, *or* those in weak crown classes, are more prone to producing new epicormic branches after reduction in

Table 3. Butt log grade distributions for small and large sawtimber trees before (estimated) and after shelterwood-with-reserves cutting on the Monongahela National Forest.

	Sawtimber	Time	No. of	Butt log grade					
Species	size	period	trees	1	2	3	Below grade	X2	Sig. *(P* < 0.05)
				.... No. of trees..................					
White oak	Small	Initial	22	2	5	11	4	-	N.S.
		Final		2	5	11	4		
	Large	Initial	9	3	2	3	1	0.40	N.S.
		Final		2	3	3	1		
Chestnut oak	Small	Initial	22	2	5	11	4	-	N.S.
		Final		2	5	11	4		
	Large	Initial	15	3	6	6	0	-	N.S.
		Final		3	6	6	0		
Red oak	Small	Initial	38	1	18	17	2	0.23	N.S.
		Final		1	17	17	3		
	Large	Initial	32	16	12	4	0	1.04	N.S.
		Final		16	11	4	1		
Yellow-poplar	Small	Initial	23	5	11	5	2	0.31	N.S.
		Final		5	11	4	3		
	Large	Initial	11	10	0	1	0	-	N.S.
		Final		10	0	1	0		
Black cherry	Small	Initial	59	6	26	26	1	0.19	N.S.
		Final		5	25	28	1		
	Large	Initial	38	30	5	3	0	2.07	N.S.
		Final		28	5	3	2		
Sugar maple	Small	Initial	61	1	16	36	8	0.27	N.S.
		Final		1	15	35	10		
	Large	Initial	20	2	4	6	8	-	N.S.
		Final		2	4	6	8		
Red maple	Small	Initial	49	0	8	35	6	-	N.S.
		Final		0	8	34	7		
	Large	Initial	10	0	4	2	4	-	N.S.
		Final		0	4	2	4		
White ash	Small	Initial	41	11	12	18	0	2.08	N.S.
		Final		10	12	17	2		
	Large	Initial	20	10	9	I	0	-	N.S.
		Final		10	9	I	0		
American basswood	Small	Initial	17	1	5	9	2	-	N.S.
		Final		1	5	9	2		
	Large	Initial	3	1	1	0	1	-	N.S.
		Final		1	1	0	1		

Table 4. Epicormic branches found on selected Appalachian hardwood trees of nine commercial species following shelterwood-with reserves cutting on the Monongahela National Forest.

	Avg.		Crown class			
Species	dbh (in.)	Log no. (ft)	Suppressed	Intermediate	Codominant	Dominant
Yellow-poplar	15.4	I (1-17)	8.5 a[1]	6.4 a	0.6 b	0.0 b
		2 (17-33)	13.5 a	7.8 ab	2.7 b	0.0 b
Black cherry	14.1	I (1-17)	0.3 b	3.0 a	0.8 b	0.0 b
		2 (17-33)	0.3 b	7.3 a	2.3 b	0.0 b
N. red oak	14.7	I (1-17)	3.9 b	4.2 a	1.4 b	0.4 b
		2 (17-33)	12.3 a	8.2 ab	4.9 b	6.0 ab
White oak	14.0	I (1-17)	13.0 a	6.6 a	1.2 b	5.0 ab
		2 (17-33)	16.7 a	14.9 a	5.0 b	3.5 b
Chestnut oak	13.5	1(1-17)	5.8 a	2.0 b	0.7 b	0.0 b
		2 (17-33)	10.8 a	9.0 a	3.6 b	1.0 b
Sugar maple	11.8	1(1-17)	2.7 a	2.2 a	0.6 b	0.0 b
		2 (17-33)	2.4 a	2.8 a	1.2 a	0.4 a
Red maple	11.7	I (1-17)	2.8 a	2.7 a	0.8 b	
		2 (17-33)	3.7 a	4.6 a	2.4 a	
White ash	13.8	I (1-17)	3.0 a	1.5 a	0.3 b	0.0 b
		2 (17-33)	0.0 b	5.5 a	1.4 ab	0.0 b
A. basswood	11.7	I (1-17)	2.0 a	1.9 a	0.2 b	
		2 (17-33)	3.2 a	7.8 a	4.1 a	

[1] Means within a row followed by the same letter are not significantly different at the 0.10 level using Tukey's HSD.

stand density than dominant or codominant trees with clear stems (Smith 1965, Miller 1996). The data also indicated that lower log sections had fewer branches than upper log sections, consistent with the observations of Sonderman (1987), Miller (1996), and Ward (1966). With the exception of white oak, dominant trees rarely produced epicormic branches on the butt log. Suppressed and intermediate white oaks produced an average of 16.7 and 14.9 new branches on the second 16 ft log, respectively. This is especially important, since tree grade is determined based on butt log features only. For eight of the nine species the number of epicormic branches on codominant trees was significantly less than on intermediate trees (Table 4). Brinkman (1955) also reported this trend, and it may be a strong indicator that trees in lower crown classes are not good candidates for the residual stand if timber is a primary objective. For example, 29% of yellow-poplar suppressed and intermediate trees had clear butt logs, while 75% of the codominants and dominants had clear butt logs. Even with white oak, the most prolific sprouter of epicormic branches, 64% of the codominant and dominant trees had no branches on butt logs. However, only 5% of the suppressed and intermediate white oaks remained free of branches.

Logging Wounds

Wounding can reduce tree grade through the creation of surface defects and by introducing decay, which increases the cull volume, as well as contributes to stem breakage and mortality. Surface defects caused by basal wounds, however, generally do not cause immediate grade reductions, since the butt log grade may be based on the upper 12 ft section of the butt log (Hanks 1976).

In this evaluation of 20 stands, all received some degree of logging damage to the residual trees. On average, 45% of the residual trees had one or more logging wounds (range 23 to 92%). Smith et al. (1994) determined that for many Appalachian hardwood species, surface wounds of 100 in2 or larger are unlikely to heal over 10 yr after logging, while most smaller wounds healed more quickly. Earlier research has shown that wounds of 100 in2 or more are likely to develop decay (Hesterberg 1957, Lavalee and Lortie 1968). In the 20 sample stands, about 21 % of the residual stems had wounds 100 in2 or larger (range 3 to 46%). The majority of these wounds were in the lower 4 ft of the butt log, consisting of rubs or scrapes associated with skidding.

Logging during the spring often causes greater injury to residual stems due to bark slippage caused by high sap contents (Deitschman and Herrick 1957, Smith et al. 1994). In this study, the stand with the greatest degree of wounding (92% of residual trees, 1.6 wounds per tree, average total wound area per tree of 266 in.2) was cut beginning in June 1992. Overall, the stands cut wholly or in part during the spring months had the greatest average number of wounds per tree and area of wounds, 0.9 and 133 in.2, respectively (Table 5). Those stands harvested during the late fall and winter had fewer wounds, with the late summer to early fall cuts being intermediate. For example, in stands cut during the spring, on average 58% of the residual stems had logging wounds (Table 5). For stands logged during the winter, 34% of residual stems had one or more wounds (Table 5). Of greater concern, however, is the frequency of trees with large wounds over 100 in.2 in size. Here, the differences are not as pronounced, although spring logging still had 28% of trees with large wounds, the highest in this study (Table 5). Often it is not possible to schedule cuts only during the winter, but logging during the spring requires special care to minimize wounding (Smith et al. 1994).

Regeneration

Regardless of size class, the abundance of regeneration was notably higher for the stands in the beech-cherry-maple cover type. For all sizes combined, commercial regeneration averaged 30,845 stems/ac in this cover type, compared to 15,198 stems/ac in the mixed Appalachian hardwood stands,

Table 5. Logging wounds on residual trees following shelterwood-with-reserves cutting on the Monongahela National Forest.

Season of cut	Mean no. wounds per tree	Mean wound area per tree (in.2)	Mean proportion of all trees with wounds	mean proportion of trees with wounds> 100 in.2
			(%)	
Mar-Jun	0.9 a[1]	133 a	58 a	28 a
Jul-Oct	0.7 ab	102 ab	46 ab	23 ab
Nov-Feb	0.5 b	44 b	34 b	14 b

[1]Means, within a column, followed by the same letters, are not significantly different at the 0.10 level.

and 8,182 stems/ac in the mixed oak stands (Tables 6 and 7). The smallest regeneration size class 1.0 ft in height) accounted for 64 to 81 % of the total regeneration pool in these stands, with the higher level in the mixed oak stands. Much of this small regeneration can be considered somewhat ephemeral in nature, and is certainly not yet fully established on the site. The larger size class (1.0 ft in height to 0.9 in dbh) represents a more reliable pool of regeneration from which new saplings may emerge (Table 7).

In the beech-cherry-maple stands, regeneration in this size class was dominated by American beech *(Fagus grandifolia),* black cherry, sweet and yellow birches *(Betula alleghaniensis),* and red and sugar maples. Beech and cherry were the most abundant and the most widely distributed species. Beech was found in 63% of the plots, cherry in 44%. These are also the dominant species in the residual stands.

The mixed Appalachian hardwood stands contained the greatest diversity of species, although birches were the most abundant (2324 stems/ac) and most widely distributed (24% of plots) species (Table 7). Other dominant species included white ash, the maples, and black cherry. The red oaks and white oak were more abundant in these stands compared to other forest cover types.

The four mixed oak stands had a regeneration pool dominated mainly by red and sugar maple, with an average of 556 stems/ac, and located on 14% of the plots (Table 6). Sweet birch, red and white oaks, and miscellaneous species such as hickory *(Carya* spp.), blackgum *(Nyssa sylvatica),* and black locust *(Robinia pseudoacacia),* were also important in these stands. The average abundance of regeneration was noticeably lower in these stands. For example, there was about a sevenfold increase in number of stems/ac between the mixed oak and beech-cherry-maple stands. We observed a much higher level of deer browsing in the mixed oak stands, and perhaps that is a factor affecting the abundance and distribution of regeneration.

The adequacy of regeneration to achieve management objectives can be assessed using relatively broad guidelines developed for similar forest cover types in the Appalachian region. For example, Trimble (1973) suggested that the establishment of 5,000 to 10,000 stems/ac with at least 85% of milacre plots stocked with one or more stems (~ 1.0 ft tall) of a desirable species after 5 yr is satisfactory in Appalachian hardwoods. Alternatively, Marquis (1987) suggested that regeneration is satisfactory when at least 70% of milacre plots are stocked with 10 or more stems (2.0 in tall) of desirable species after 5 yr.

Regeneration stocking of desirable species was determined for each stand using the Trimble (1973) and Marquis (1987) guidelines. Desirable species included the oaks, maples, black cherry, white ash, yellow-poplar, and basswood. Based on Trimble's (1973) guideline, the mixed Appalachian hard

Table 6. Numbers of regeneration per acre « 1.0 ft in height) by species and forest cover type following shelterwoodwith-reserves cutting on the Monongahela National Forest.

	Physiography and forest cover type					
	Allegheny Mts. beech-cherry-maple *(n* = 11)		Allegheny Mts. mixed Appal. hdwds. *(n* = 5)		Ridge and Valley mixed oaks *(n* = 4)	
Species[1]	No./ac	Stocking (%)[2]	No./ac	Stocking (%)	No./ac	Stocking (%)
Birches	8,464	62	3,502	39	2,886	25
Maples	1,715	50	1,116	39	2,259	50
Red oaks	9	I	410	24	582	18
White oaks	0	0	80	8	103	6
American beech	2,268	55	83	4	20	0
Black cherry	6,357	68	820	25	40	2
Eastern hemlock	68	3	0	0	0	0
White ash	38	3	829	22	30	2
Yellow-poplar	404	12	3,271	35	367	13
American basswood	0	0	4	I	0	0
Others3	305	16	185	14	299	16
Total	19,628		10,300		6,586	

[1]Birches include sweet birch and yellow birch; maples include red maple and sugar maple; red oaks include northern red oak, scarlet oak, and black oak; and white oaks include white oak and chestnut oak.
[2]Percent stocking is the percentage of mil-ac plots that contained that species.
[3]Other species include blackgum, black locust, bigtooth aspen, cucumber tree, and Fraser magnolia.

Table 7. Numbers of regeneration per acre (:? 1.0 ft in height up to 0.9 in. dbhl by species and forest cover type following shelterwood-with reserves cutting on the Monongahela National Forest.

	Physiography and forest cover type					
	Allegheny Mts. beech-cherry-maple (*n* = 11)		Allegheny Mts. mixed Appal. hdwds. *(n* = 5)		Ridge and Valley mixed oaks *(n* = 4)	
Species'	No./ac	Stocking (%)2	No./ac	Stocking (%)	No./ac	Stocking (%)
Birches	1,989	31	2,324	24	137	9
Maples	641	16	516	19	556	14
Red oaks	3	1	203	11	100	7
White oaks	0	0	254	6	140	3
American beech	4,591	63	162	4	0	0
Black cherry	3,825	44	466	14	45	2
Eastern hemlock	0	0	4	I	0	0
White ash	30	1	499	12	0	0
Yellow-poplar	70	4	62	3	18	2
American basswood	0	0	12	I	0	0
Others3	68	5	396	17	520	20
Total	11,217		4,898		1,516	

1 Birches include sweet birch and yellow birch; maples include red maple and sugar maple; red oaks include northern red oak, scarlet oak, and black oak; and white oaks include white oak and chestnut oak.
2 Percent stocking is the percentage of mil-ac plots that contained that species.
3 Other species include blackgum, black locust, bigtooth aspen, cucumber tree, and Fraser magnolia.

wood stands averaged 43% stocked with an average of 4,898 stems/ac, the beech-cherry-maple stands averaged 51 % stocked with 11,217 stems/ac, and the mixed oak stands averaged 21 % stocked with an average of 1,516 stems/ac (Table 7). Using Marquis' (1987) guideline, the beech-cherry-maple, mixed Appalachian hardwoods, and mixed oak stands were 40%, 31 %, and 14% stocked, respectively.

In general, regeneration stocking of desirable species was relatively low. In most stands, regeneration was surveyed 2 to 4 yr after cutting, thus the percent of plots stocked will likely increase as the height of reproduction increases. Many plots that lacked a desirable timber species were otherwise stocked with birch and beech, a valuable wildlife species (Table 7). As a result, regeneration in the beech-cherry-maple and mixed Appalachian hardwood stands was marginally satisfactory at the time data were collected. However, regeneration stocking in the mixed oak stands was relatively low compared to the other forest cover types. The mixed oak stands are located in the drier Ridge and Valley province, where climatic factors may contribute to the slow development of regeneration. Marquis (1987) observed that excessive deer browsing also can impede the height growth of new regeneration and result in unsatisfactory stand stocking levels.

Miller and Schuler (1995) evaluated regeneration in four mixed Appalachian hardwood stands two years following partial cutting. They observed from 5,024 to 12,260 stems/ac of commercial species. Dominant species included American beech, red maple, black cherry, sugar maple, and yellowpoplar. A long-term study of diameter limit cutting in this region resulted in from 2,500 to 6,000 stems/ac between 1.0 ft in height and 0.9 in dbh, depending on year (Miller and Smith 1993). Smith et al. (1989) reported 6,000 to 18,000 commercial stems per acre 5 yr following deferment cutting in central Appalachian hardwood stands. After following regeneration in two-age stands in the southern Appalachians for 20 yr, Beck (1986) concluded that the regeneration was similar in size and composition to that in nearby clearcuts. In the same area in North Carolina, McGee (1975) reported from 6,436 to 16,874 total stems per acre in two stands 3 yr following partial cutting in which 33 ft² of residual basal area per acre was left.

Shelterwood with Reserves: Meeting the Goals?

The purpose of this study was to evaluate a shelterwoodwith-reserves cutting practice from a timber perspective. This is still a relatively new practice, and future applications will depend on knowledge and experience developed by the current practitioners. Nine of the 20 stands, or 45%, were left with a residual overstory above the prescribed goal, indicating that foresters are reluctant to mark the stands heavily. In some stands, clumps of trees were left for wildlife purposes. In these areas the potential for regenerating desirable shadeintolerant species is relatively low. Maintaining a large residual overstory is likely to require future treatments to insure adequate growing space for the regeneration, since overhead competition is known to reduce the growth and vigor of the regeneration (Loftis 1983, Young et al. 1993). For example, if 40 trees, each 14 in. in dbh, were left per acre as a residual, the stand would be at the upper limit of 40 ft²/ ac basal area. Assuming no mortality and an average growth rate of 2 in. per decade, after 40 yr each tree will have a dbh of 22 in., or a basal area of 2.64 ft². This represents a stand basal area of 106 ft²/ac, a fully stocked condition with no room for a younger age class of intolerant species struggling to reach the main canopy. While certain tolerant species such as sugar maple, American beech, and eastern hemlock could survive and grow under these conditions, the most valuable timber species such as northern red oak, black cherry, and yellow-poplar could not.

Epicormic branching reduced tree quality for some species, particularly white oak, but was mostly associated with the suppressed and intermediate trees that were left. The relatively low loss in butt log grades, less than 11 %, was also encouraging. Evidence from this evaluation shows that shelterwood-with-reserves cutting can effectively lead to regeneration of desirable commercial species, and preserve the quality of the residual overstory. However, it must be noted that these stands were not cut as heavily, on average, as current guidelines suggest.

Summary and Application

- Suppressed and intermediate trees should not be left as residual trees for future timber value, particularly white oak, due to losses in quality resulting from epicormic branching. Epicormic branching was generally low for dominant and codominant stems. For all species except white oak, at least 75% of the butt logs for dominant and codominant stems had no epicormic branching.
- Log grade reductions due to epicormic branching and logging wounds were not common. For all species, the log grade distributions prior to and following cutting were not statistically different.
- The spring months of March through June should be avoided for harvesting, if possible. Logging wounds were greater in number and size in stands harvested during these months.
- .Although grade reductions due to logging wounds were minor, wounds were common, with 21 % of residual stems having large wounds of 100 in.2 or larger. Special care should be taken to reduce the number of large wounds during logging.
- . Regeneration following shelterwood-with-reserves cutting resembles that observed following clearcutting. A mix of shade-intolerant and tolerant species makes up the regeneration pool.

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