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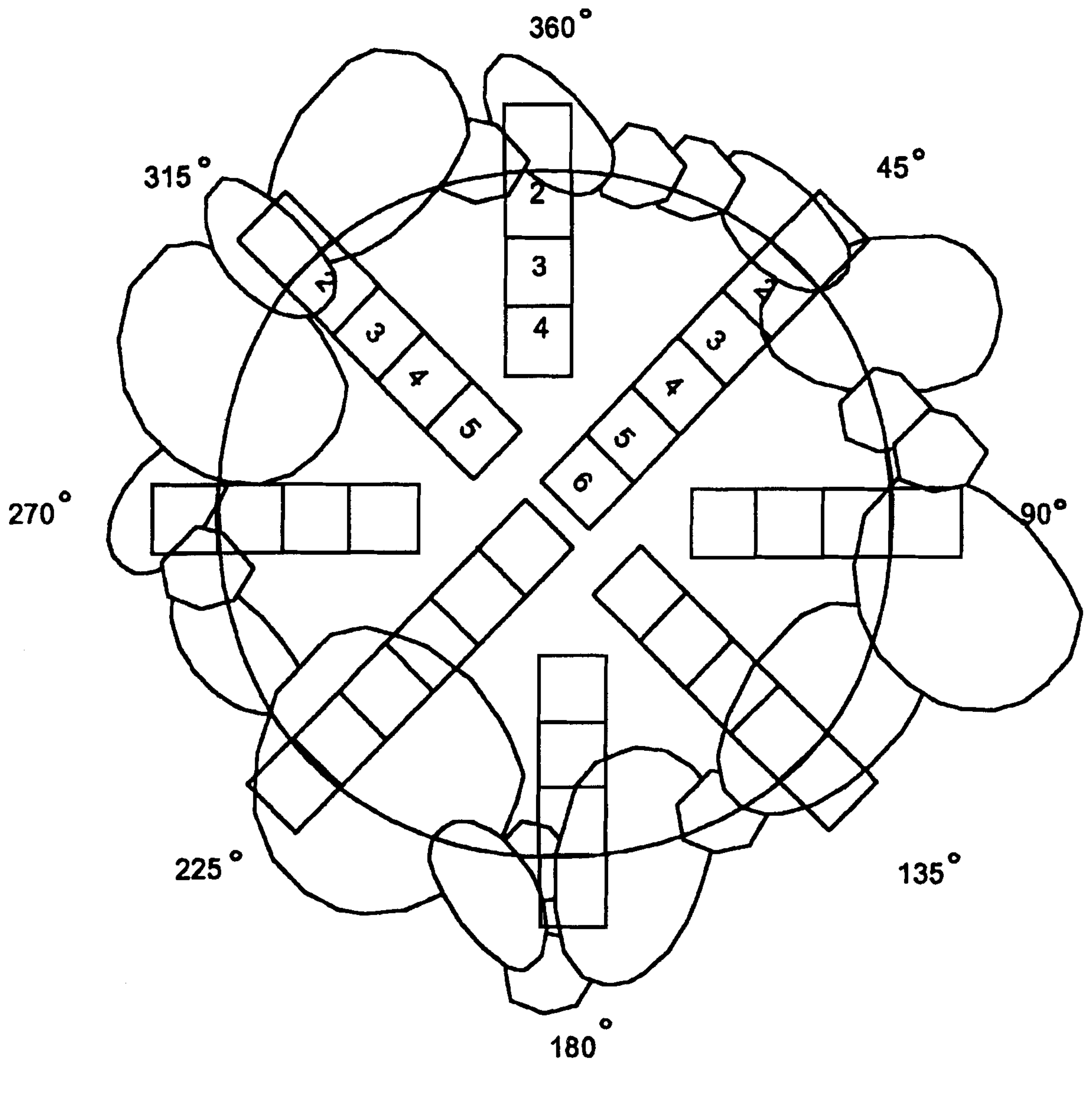
Size of Clearcut Opening Affects Species Composition, Growth Rate, and Stand Characteristics

Martin E. Dale
H. Clay Smith
Jeffrey N. Pearcy



Abstract

In the late 1950's and early 1960's, a series of studies was installed in the central hardwood forest to determine if size of clearcut opening affects the growth rate and species composition of new stands. In 1991, about 30 years after cutting, stand data were collected in 89 openings ranging in size from 0.04 to 1.61 acres. Species composition varied from locations in West Virginia to those in Illinois and from Ohio to Kentucky. For example, there were more maple and birch in West Virginia than in Illinois, regardless of opening size. Some of the difference in species composition and growth rate is related to site quality but there also are differences due to size of opening. Most of the oak and hickory were on the poorer sites while yellow-poplar was more abundant on the better sites. The number of stems per acre increased with opening size; however, the number of stems of shade-tolerant species constituted a greater proportion of the stand in small openings (< 0.5 acre), while the proportion of intolerant species increased in larger openings. Basal area and volume of the current stands seem to increase markedly with opening size for openings up to at least an acre. The greatest reduction in growth is nearest the border of the opening, though some effect on growth extends at least 100 feet into the opening. There also is a strong interaction between border effect and opening size. Productivity is greater at a given distance from the border for larger openings. Opening size has a major influence on stand characteristics after about 30 years.

The Authors

MARTIN E. DALE (retired), joined the USDA Forest Service in 1957, specializing in forest management and silviculture research at Berea, Kentucky. In 1973, he received a Ph.D. degree in forest biometry from Iowa State University, and since 1970 had been assigned to the Northeastern Forest Experiment Station's research unit on timber measurement and management planning at Delaware, Ohio.

H. CLAY SMITH (retired) was principal silviculturalist at the Northeastern Forest Experiment Station's Timber and Watershed Laboratory at Parsons, West Virginia. He received B.S. and M.S. degrees from West Virginia and Purdue Universities, and joined the Northeastern Forest Experiment Station in 1962.

JEFFREY N. PEARCY, research associate, received B.S. and M.S. degrees in forestry from Ohio State University. He worked at the Northeastern Forest Experiment Station, at Delaware, Ohio, in 1992 before returning to the School of Natural Resources at Ohio State University.

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USDA FOREST SERVICE
5 RADNOR CORP CTR STE 200
PO BOX 6775
RADNOR PA 19087-8775

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Introduction

Due to concerns about the adverse effects of clearcutting on species diversity, wildlife habitat, and aesthetic values, forest managers are seeking alternative timber harvesting techniques, including individual-tree partial cuts or the use of small openings for reproducing forests. Silviculturalists have long known that various cutting methods can be used to control light and moisture conditions and thus to create environments that favor or discriminate against a particular species. Small openings can provide a pleasing and suitable environment for some purposes. However, managers interested in timber production are equally concerned about the potential loss of production and certain tree species from these alternate methods compared with what could be achieved with some form of clearcutting.

Small openings in the canopy created by harvesting single trees or clearcutting small openings up to 2 acres in size have caused a shift in species composition (Walters and Nyland 1989). Also, small clearcuts have a much larger proportion of their total area influenced by the surrounding forest than larger clearcuts (Marquis 1965). The increased competition for sunlight and moisture from this edge effect is likely to further reduce tree growth. Reduced height growth of new regeneration has been reported near the opening edge for at least 10 to 20 years after small group-selection cuts (Sander and Clark 1971; Minckler and Woerheide 1965; Willison 1981). Although reduced height and diameter growth has been reported, little is known about the magnitude of this reduction or how far into the opening this border effect extends.

Our objective in this investigation was to determine the magnitude of this border effect for small forest openings created 30 years ago in mature upland oak stands. Also, we wanted to learn if the size of opening affected species composition and growth rates (productivity), and how far the border effect extended into the opening. Thirty years is a relatively short interval in the life of a forest stand and we realize that forest stand conditions are subject to change. The results presented here represent what has occurred after 30 years.

Methods

In the late 1950's and early 1960's, a series of regeneration studies was installed at five locations in the upland oak type in West Virginia, Ohio, Kentucky, and Illinois (Fig. 1) to determine if size of opening or site quality affected the growth rate and/or species composition of newly regenerated stands. These initial efforts encompassed 198 circular plots that ranged in size from 0.04 to 5 acres. These early efforts had essentially the same study objective but there were differences in the initial species composition, site quality, age of stand, and opening size created at each location, and in treatments applied. We did not perform statistical tests of location differences because of unequal samples by site and opening size at each location. Despite these differences, we believe that the similarity in pattern of response with respect to size of opening and border effect justify combining results to look at the generalized response about 30 years after treatment.

Figure 1.—Location of study areas.

Table 1.—Characteristics of openings by location, 1991

Location	Number of openings: Original	Number of openings: Remeasured	Site index	Stand age	Opening size: Range	Opening size: Mean	Height of border trees
				Years	---------*Acres*--------		*Feet*
Fernow	72	29	Fair to Good	25	0.04 to1.29	0.46	89
Vinton	36	15	Fair to Good	31[a]	0.15 to 1.17	0.56	88
Robinson	36	15	Fair		0.06 to 1.31	0.46	91
Baldrock	36	14	Fair to Good		0.18 to 1.61	0.82	90
Kaskaskia	18	16	Fair to Good	32	0.04 to 0.75	0.20	74
Total	198	89					

[a]Cutting was extended over 3 years, so some plots were 30 and some 32 years old.

The basic treatment applied to all openings on the Vinton Furnace Experimental Forest in southeastern Ohio was to remove all merchantable material by conventional commercial logging, and then fell or girdle all remaining stems more than 4.5 feet tall. Essentially the same treatment was used at Kaskaskia Experimental Forest in southern Illinois except that all stems more than 1.5 feet tall were cut (Minckler et al. 1973). At the other three locations, the amount of site preparation varied somewhat but basically consisted of removing various amounts of vegetation following conventional commercial logging. On the Fernow Experimental Forest in north-central West Virginia, all stems 5.0 inches and larger in d.b.h. were cut. On some plots, 2,4,5-T herbicide mixed in fuel oil was used as a basal spray and applied to residual trees 1.0 to 4.9 inches d.b.h. (Smith 1981). Small trees on other plots at Fernow also received the basal spraying treatment with herbicide; all recently cut stumps of undesirable timber species also were sprayed to prevent resprouting.

On the University of Kentucky's Robinson Experimental Forest in eastern Kentucky, the basic treatment consisted of logging and then killing all trees 3 to 12 inches d.b.h. by frilling and using 2,4,5-T herbicide mixed in fuel oil (Hill 1987). In addition, some plots on the Robinson Forest received a more intensive treatment designed to kill all trees smaller than 3 inches d.b.h., with the herbicide mixture applied as a basal spray; on still other plots, only the undesirable species for timber received this more intensive spray treatment. On the Baldrock Experimental Forest in southeastern Kentucky, the basic treatment was the same as for the Robinson plots for trees larger than 3 inches. Three additional treatments were applied to control vegetation less than 3 inches d.b.h., including basal spraying the 2,4,5-T herbicide mixture with hand sprayers; mist blowing the understory before logging with 2,4,5-T using a Solo[1] backpack mist blower; or using a bulldozer to scrape away the vegetation and expose mineral soil over most of the plot (Sander and Clark 1971). Although some of these site-preparation treatments have been reported to increase the amount of yellow-poplar, such treatments generally did not increase the amount of oak regeneration, nor did they effectively reduce the number of undesirable trees (Sander and Clark 1971). However, some of these treatments influenced the amount and development of stems of sprout origin. We did not detect differences due to site-preparation treatment in the trends reported here with respect to opening size and extent of edge effect.

In 1991, only 89 of the original 198 plots were sampled, primarily because of limited funds. Criteria for plot selection were based on plot size and site. Plots selected at each location were: Fernow Experimental Forest (29 plots); Vinton Furnace Experimental Forest (15); Robinson and Baldrock Experimental Forests (15 and 14, respectively); and Kaskaskia Experimental Forest (16) (Table 1). The distribution of sample plots by opening size, site, and location is given in Appendix Table 10.

Our current sample of plots ranged in size from 0.04 to 1.61 acres: the sites were typical of the upland oak type (site index 55 to 80 for black oak). At the Vinton, Fernow, and Baldrock locations, the original study design attempted to locate openings on two general site classes:

[1]The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

fair (site index 56 to 65) and good (site index 66 to 75) for black oak. In Illinois, openings were located on three topographic positions: a northeast slope, a southwest slope, and a cove. Thus, site index again encompassed a range of sites from fair to good. Only one general site class was covered at the Robinson location, where all plots were established on the south side of a main ridge between two watersheds. Site index at the Robinson location generally was fair and ranged from 55 to 65 for oaks. In selecting our sample from the original plots, we tried to sample across the range of sites and opening sizes available at each location as well as across various site-preparation treatments. At the Baldrock location, most of the original plots were destroyed by subsequent clearcutting, so the actual selection of plots was limited; however, we were able to cover all plot size and site conditions.

Sampling Design

In all except the smallest openings, eight transects were established along the cardinal and off-cardinal directions (Fig. 2). Along each transect, 20.9- by 20.9-foot square subplots (0.01 acre) were established that extended from the opening's border toward its center. On the smaller plots, only the off-cardinal transects were used to prevent overlap of the 0.01-acre subplots. The edge of opening was estimated for each transect so as to fall on the arc formed between stems of the original border trees (Fig. 2). From this beginning point, each transect was extended an additional 20.9 feet into the surrounding forest. Subplots were then numbered consecutively from this outside plot toward the opening center. Normally, we would continue to establish subplots along the off-cardinal transects until the center was reached. Subplots along the cardinal direction transects were established until they began to overlap with adjacent subplots along the off-cardinal transects.

Along the transects we recorded average percent slope and distance from the border to the opening's center, as well as percent slope, aspect, and elevation of each subplot. In later analyses, slope measurements were used to determine the precise horizontal subplot acreage; in turn, these values were used to compute stand characteristics on per-acre basis for each subplot. We also recorded the distance from the opening border to the two tallest trees on each subplot. Total height of these sample trees was measured.

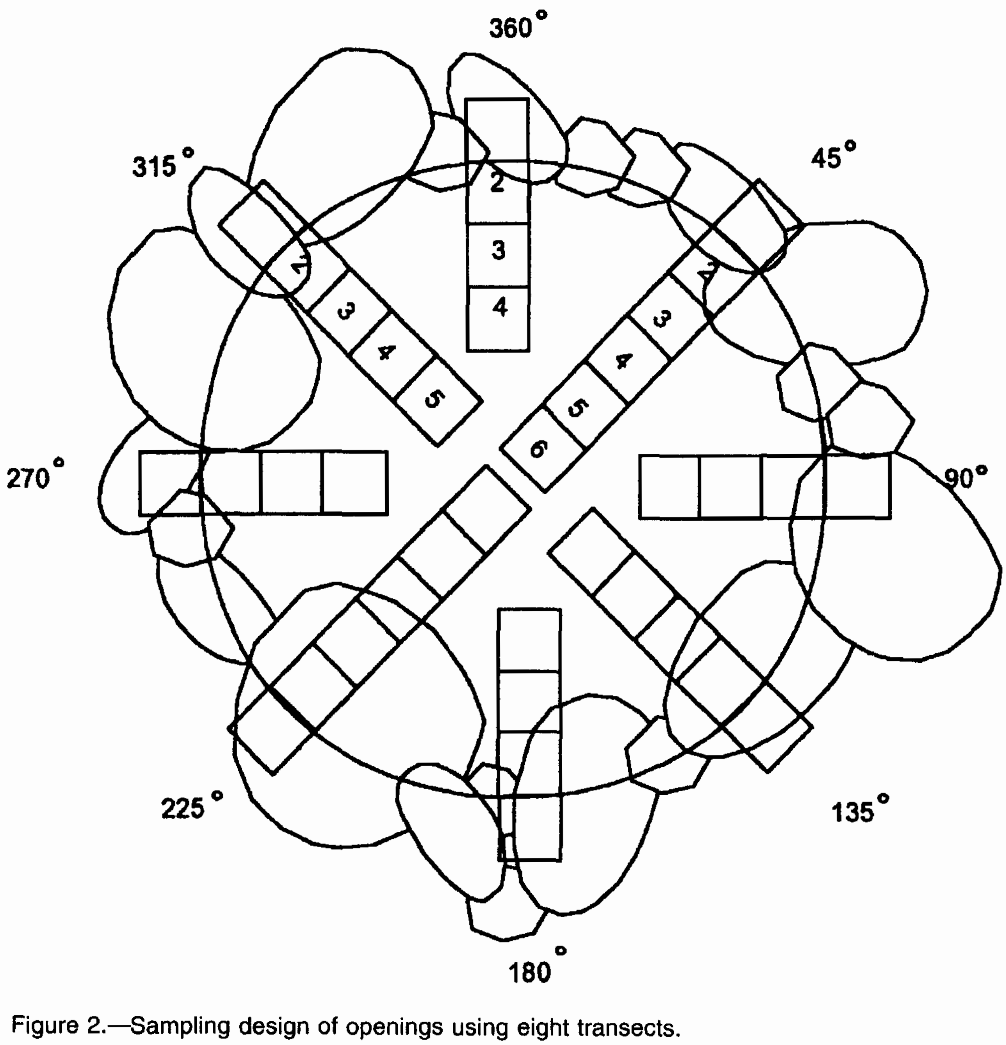

Figure 2.—Sampling design of openings using eight transects.

Table 2.—Distribution of subplots by distance from border and opening size

Group no.	Opening size	Subplot position[a] 1	2	3	4	5	6	7	8	9	Total
	Acres	*Number*									
1	0.0-0.1	72	65	1							138
2	0.1-0.3	75	74	36	2						187
3	0.3-0.5	106	106	98	47						357
4	0.5-1.0	82	80	82	66	35	6	2			353
5	1.0-1.8	128	120	120	119	103	29	18	4	1	642
6	>3.0							32	32	32	96
Total		463	445	337	234	138	35	52	36	33	1773

[a]Position 2 extended 20.9 feet from the opening perimeter toward the plot center, with a midpoint distance of 10.4 feet from the edge of the opening. Position 1 extends 20.9 feet into the surrounding forest stand, thus, -10.4 feet. Midpoint distances for positions 3 through 9 are 31.3, 52.2, 73.1, 94.0, 114.9, 135.8, and 156.7 feet, respectively.

To determine how far the crown of adjacent border trees extended into the opening, we estimated the point at which the projected vertical crown edge of the border tree would intersect the center line of the transect, and measured this distance from the opening edge. These measurements were used to compute the portion or acreage of opening currently receiving direct overhead sunlight. In ecological literature, these openings are defined as extended gaps (Runkle 1990). Although the extended gap does not indicate the size of opening receiving direct sunlight from above, it is an objective and consistent measurement over time.

Variables measured on each subplot included species, diameter at breast height (all trees larger than 2.5 inches d.b.h.), crown class, and the height and distance from border of the two tallest sample trees on each 0.01-acre subplot. In addition, we identified all dominant and codominant trees that were potential crop trees based on species and quality characteristics such as stem straightness, number of branches, sweep, crook, and forking.

From these data we developed equations for each of the major species and/or species groups to predict total tree height as a function of d.b.h. Then, for each tree we used this predicted height, or actual height if measured, to predict total and merchantable cubic-foot volume using Demaerschalk's taper and volume functions and parameters (Martin 1981). Totals were summed by species for each subplot and corrected to horizontal per-acre values. Hence, stand characteristics on a per-acre basis were computed for each of the 1,773 subplots. These included basal area, number of trees, total cubic-foot volume, and merchantable cubic-foot volume.

For purposes of this study, each of the openings was grouped in one of five size classes: Group 1 (0.04 to 0.10 acre); Group 2 (0.11 to 0.30 acre); Group 3 (0.31 to 0.50 acre; Group 4 (0.51 to 1.00 acre); Group 5 (1.01 to 1.75 acres). A sixth group consisted of subplots that were established in clearcuts that were larger than 3 acres and where all the subplots were at least 150 feet from the border trees. Thus, the subplots in Group 6 are representative of stands that would develop in large clearcuts used in even-age management. Border trees should have little or no effect on Group 6 subplots. Table 2 shows the distribution of 1,773 subplots by opening size and distance from border or the subplot position.

The stand characteristics cited previously were computed for each opening on a per-acre basis using a weighting procedure commonly used in stratified random-sampling procedures. The mean transect length of each opening, after correcting for slope, was used to compute the total acreage in each opening. Since we knew the distance from border for each subplot, it was easy to compute the strata area or proportion of opening area to be used in the strata weighting procedure. Small openings have a much greater proportion of their total area affected by border trees than large openings. For example, about 78 percent of the area of a 0.10-acre opening is within 20 feet (approximately the width of one subplot) of the border. By contrast, only 15 percent of a 5-acre opening is within 20 feet of the border trees (Table 3). Therefore, when stand characteristics are expressed on a per-acre basis for the entire opening, it is essential that strata means represent the correct proportional area of the opening as given here.

Results and Discussion

Species Number and Relative Frequency

On the 1,310 subplots within openings we recorded 5,327 stems larger than 2.5 inches d.b.h. These stems represented 45 tree or shrub species. On the border (subplots 1) we found 40 species, 35 of which also were found on the interior plots. The 463 subplots on the border had a total of 2,134 stems, approximately 460 stems per acre, compared with about 407 stems per acre in the openings. The 50 different species found in all plots are listed in Appendix Table 11, by common and scientific name, shade-tolerance class, and desirability for timber

Table 3.—Percentage of opening area contained in border zones that are 10, 20, 30, or 40 feet wide[a]

Opening diameter (feet)	Opening area	Proportion of area in border zone for width of:			
		10 feet	20 feet	30 feet	40 feet
	Acres				
50	0.04	0.64	0.96	—	—
75	0.10	.46	.78	0.96	—
100	0.18	.36	.64	.84	0.96
118	0.25	.31	.56	.76	.90
150	0.41	.25	.46	.64	.78
166	0.50	.23	.42	.59	.73
200	0.72	.19	.36	.51	.64
236	1.00	.16	.31	.44	.56
250	1.13	.15	.29	.42	.54
300	1.62	.13	.25	.36	.46
333	2.00	.12	.23	.33	.28
400	2.88	.10	.19	.28	.36
500	4.51	.08	.15	.23	.29
527	5.00	.07	.13	.21	.28

[a]$P = (4w/d)*(1-w/d)$ only if $w<d/2$
where P = proportion of total area in border zone of width (w, in feet) for circular openings with diameter (d, in feet).

products. Assignment to a tolerance class was based on the classification of Trimble (1975). The classification of desirability for timber products depends on local markets, so it is subjective and indicates our preferences. If other resource uses are considered, no doubt this classification would change.

The 50 species that were found were not of equal importance or relative frequency. In Appendix Table 12, we show the relative frequency of the 33 most common species tabulated by shade-tolerance class and desirability for timber products. There were only 20 species with a relative frequency greater than 1 percent; however, these species combined accounted for about 90 percent of all stems. Maple species were most numerous, accounting for about 26 percent of all stems, followed by yellow-poplar with 15 percent. All oaks combined accounted for about 14 percent of the stems, but white and chestnut oak accounted for two-thirds of all oak. Other common timber species each with about 3 to 5 percent of the total were black cherry, hickory, sweet birch, and hemlock. Sassafras and dogwood each represented about 5 percent of the total.

Effect of Site Quality and Study Location on Species Composition

Species relative frequency varied considerably both at a study location and between locations. At a given study location, some of the variation in species composition between openings is related to differences in site quality as well as in opening size and site-preparation treatment. However, we found important differences in species composition between study locations particularly for the Illinois and West Virginia plots. For example, maples were most abundant on the West Virginia subplots: 68 percent of the subplots had one or more maple stems while yellow-poplar was found only on 13 percent of the subplots (Table 4). By contrast, maples were not a major stand component in Illinois but yellow-poplar was the most abundant species, occurring on 43 percent of the subplots. Magnolias and birches were more abundant at the eastern locations while hemlock was found mostly on the better sites in Kentucky. Yellow-poplar, oak, and hickory generally were distributed more widely and found at all locations, but these species seemed to be influenced by site conditions at each location. Maple ranked either first or second in number of stems at every location except Illinois. Red maple dominated the fair sites and sugar maple dominated the good sites. Yellow-poplar was distributed widely, ranking first at Baldrock and in Illinois and no lower than fifth at any location. Sourwood was found at every location in considerable numbers. Sassafras was distributed widely and at the Fernow and Kaskaskia locations was found on a quarter to a third of the sample subplots.

The influence of site quality is evident in the number of stems per acre for five species groups at each location (Table 5). We consistently found more oaks and hickories on the fair sites at all locations, but, as noted in Table 4, the overall distribution of oak and hickories varied with location. Also as expected, we found more yellow-poplar on the better sites at each location. Similar trends for oak-hickory and yellow-poplar were reported for the oak type for other harvest cutting practices (Hilt 1985; Heiligmann et al. 1985).

Although maples were the most abundant species in the openings, they are of lesser importance in terms of stand characteristics such as basal area and cubic or

Table 4.—Percentage of subplots stocked with a species at each study location

Baldrock		Robinson		Vinton Furnace		Fernow		Kaskaskia	
Species	Percent	Species	Percent	Species	Percent	Species	Percent	Species	Percent
Y.-poplar	.561	Maple sp	.598	Maple sp.	.457	Maple sp.	.677	Y.-poplar	.425
Maple sp.	.447	Ch. oak	.221	Hickory	.381	Bl. cherry	.284	Wh. oak	.349
Hemlock	.273	Wh. oak	.218	Dogwood	.262	Sassafras	.225	Sassafras	.336
Magnolia	.229	Hickory	.203	Y.-poplar	.257	Birch sp.	.207	Bl. gum	.240
Sourwood	.202	Y.-poplar	.188	Ch. oak	.195	Y.-poplar	.126	Hickory	.164
Birch	.182	Redbud	.166	Wh. oak	.167	Bl. locust	.066	S. red oak	.151
Dogwood	.178	Sourwood	.140	Sourwood	.133	Magnolia	.066	Sourwood	.137
Wh. oak	.123	Bl. cherry	.103	Bl. oak	.081	Dogwood	.063	Maple sp.	.116
Beech	.111	Ash	.085	N. red oak	.071	Sourwood	.057	Bl. cherry	.048
Sassafras	.059	Bl. gum	.063	Bl. cherry	.067	Ch. oak	.057	Scarlet oak	.041
Holly	.047	Bl. oak	.059	Bl. gum	.067	Bl. gum	.051	Am. beech	.021
		Scarlet oak	.048	Elm sp.	.052				

Table 5.—Number of trees, basal area (ft^2), and quadratic mean diameter (QSD) per acre by location, site class, and species group

Location		Oak-hickory		Yellow-poplar		Maple		Other timber		Nontimber		Total	
		Fair[a]	Good[b]	Fair	Good	Fair	Good	Fair	Good	Fair	Good	Fair	Good
KY	Trees	115	27	41	148	139	65	41	160	62	122	398	522
	BA	24.2	2.8	13.3	23.3	20.0	8.0	6.9	23.8	5.2	12.1	69.6	70.0
	QSD	6.2	4.4	7.7	5.4	5.1	4.8	5.6	5.2	3.9	4.3	5.7	5.0
OH	Trees	158	81	28	54	88	91	40	48	74	64	388	388
	BA	21.6	10.4	4.6	19.5	15.2	19.2	6.2	6.6	5.4	9.1	53.0	64.8
	QSD	5.0	4.9	5.5	8.1	5.6	6.2	5.3	5.0	3.7	5.1	5.0	5.9
WV	Trees	31	1	3	53	142	145	149	136	121	18	446	343
	BA	7.7	0.3	0.7	13.5	25.6	18.6	26.9	20.7	13.7	1.3	74.6	54.4
	QSD	6.7	7.4	6.5	6.8	5.7	4.8	5.8	5.3	4.6	3.6	5.5	5.4
IL	Trees	204	66	19	112	—	31	42	54	106	72	371	335
	BA	19.0	5.7	3.1	26.8	—	3.7	2.0	11.5	6.0	4.4	30.0	52.1
	QSD	4.1	4.0	5.5	6.6	—	4.7	3.0	6.2	3.2	3.3	3.9	5.3
Average	Trees	108	35	27	99	120	86	68	113	83	74	406	409
	BA	19.0	3.8	7.5	20.5	19.1	12.0	11.7	18.0	7.5	7.1	64.8	61.4
	QSD	5.7	4.5	7.1	6.2	5.4	5.1	5.6	5.4	4.1	4.2	5.4	5.3

[a]Black oak site index 56 to 65.
[b]Black oak site index 66 to 75.

merchantable volume. Yellow-poplar constitutes 15 percent of the number of trees (Appendix Table 12), but accounts for 21 percent of the basal area and 37 percent of the merchantable volume. By contrast, 24 percent of the trees are red maple and they represent 23 percent of the basal area and 23 percent of the merchantable volume. Basal area and merchantable volume are not illustrated for individual species; however, they are included in Figure 3, which provides totals by tolerance class and timber class. Overall, there were slightly more tolerant stems than intolerant ones (45 versus 39 percent) (Fig. 3). However, the intolerant preferred species were about equal to tolerant nonpreferred species in basal area, and the intolerant preferred species represented the largest proportion of the stand merchantable cubic volume.

Over all locations, basal area on fair sites was about five times greater than on good sites for the oak-hickory group (Table 5). Basal area of yellow-poplar at each location was consistently higher on the better sites. The basal area of maple varied because red maple was found mostly on fair sites and sugar maple mostly on good sites. In general, the quadratic mean diameter of the oak-hickory group was larger than that of the maple group on fair sites but on good sites the reverse generally was true except in West Virginia, where there were few oaks

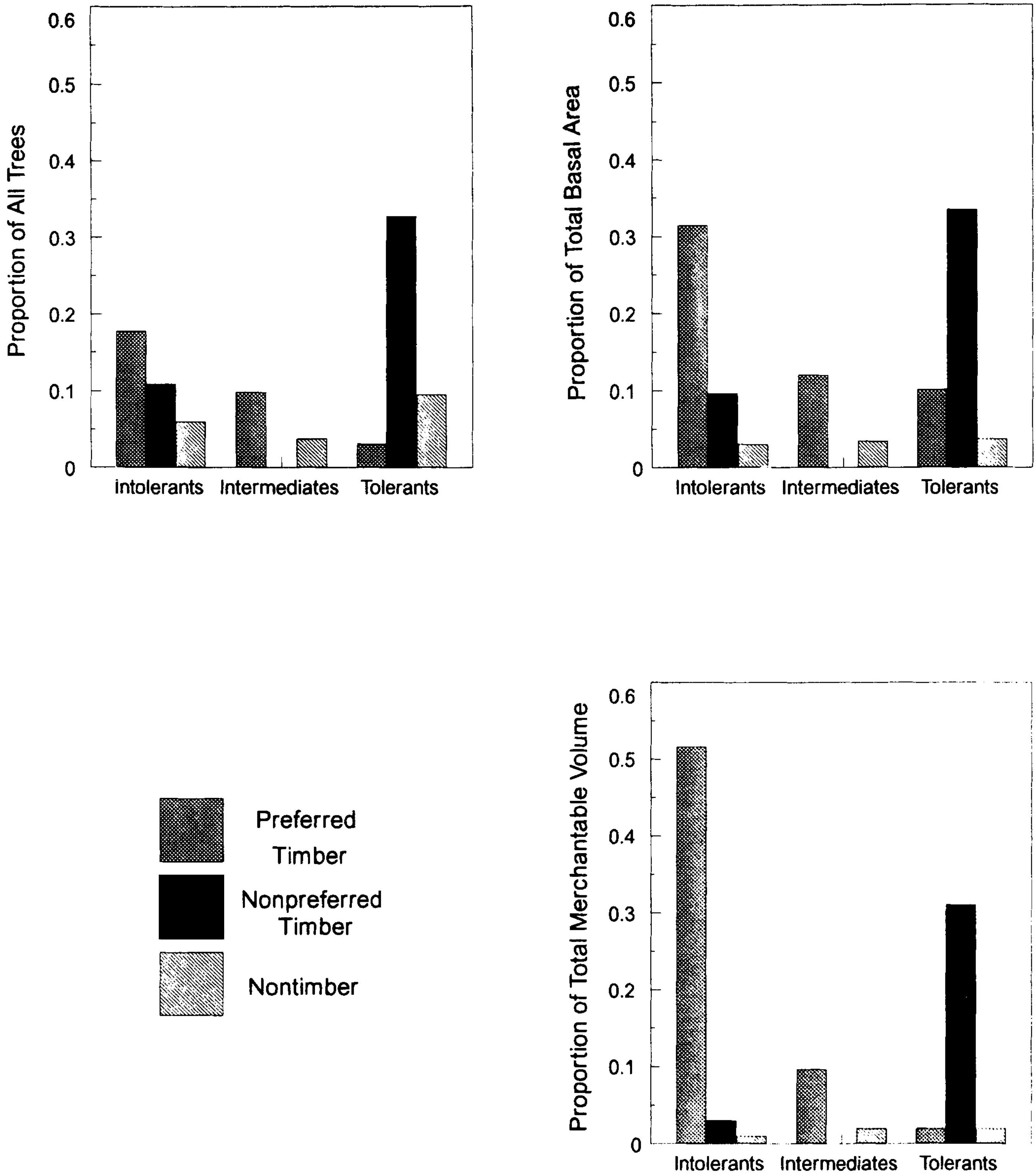

Figure 3.—Proportion of stems by tolerance class and desirability for timber products.

Table 6.—Per acre-stand characteristics by size opening (group)

Size opening (acres)	Number of trees	Basal area	Total volume	Merchantable volume
		Ft^2	----------Ft^3----------	
6 (>3.0)	519.6a	92.0a	2,467a	884a
5 (1.1-1.8)	393.6bc	67.0b	1,790b	630ab
4 (0.51-1.0)	443.9ab	64.8b	1,770b	545bc
3 (0.31-0.50)	358.8bc	49.8c	1,280c	406cd
2 (0.11-0.30)	344.6c	38.2c	893d	225de
1 (0.0-0.10)	241.6d	18.0d	356e	52e

Values in the same column with different letters are significantly different at $P < 0.05$.

on good sites (Table 5). Yellow-poplar was consistently larger than oaks on both fair and good sites. Again, the exception was in West Virginia, where few yellow-poplar were found on fair sites.

Effect of Opening Size on Stand Characteristics

The effect of opening size is obvious from the results presented in Table 6. Mean basal area per acre ranged from 67 ft^2 for the larger openings to 18 ft^2 for the smallest opening. Larger openings (Group 6) had 92 ft^2 per acre. Total volume followed similar trends as 2,467 ft^3 per acre were recorded for Group 6 openings compared with only 356 ft^3 per acre for openings of 0.10 acre (Group 1).

Per-acre values for Group 6 subplots were not adjusted because the proportion of acreage that is affected by border trees is insignificant compared to the total acreage in these large clearcuts. Statistical analysis (ANOVA) of the results indicate that opening size significantly ($P < 0.05$) affects number of trees, basal area, and cubic volumes per acre. In fact, as Table 6 indicates, there were significant differences between several of the size groups. Note that all stand characteristics increase with opening size except for the anomaly in number of trees between opening size 4 and 5. Because the stand characteristics were so highly correlated with opening size, we used nonlinear regression techniques to predict number of trees, basal area, total cubic-foot volume, and merchantable cubic volume as a function of opening size (Fig. 4). The computed regression parameters shown in Figure 4 include all of the subplots from Group 6, though the latter are not shown on the graphs. These equations show a considerable difference in predicted basal area (55 versus 72 ft^2) for 0.5-acre versus 1.0-acre openings. The difference in predicted merchantable cubic volume for openings of this size is even greater, 452 versus 651 ft^3.

Effect of Opening Size on Species Composition

The stand values given in Table 6 are broken down by desirability for timber products and also expressed as a percentage (Appendix Table 13). These values by opening size also are broken down by shade-tolerance class and percentage (Appendix Table 14). Although there is a larger proportion of tolerant species on the smallest opening (< 0.1 acre), the proportion of shade-tolerant stems versus intolerant ones remains about the same for openings larger than 0.1 acre. The effect of opening size on growth is clear from the volumes in Appendix Tables 13 and 14, which indicate that the amount of basal area and stand volume increases rapidly with opening size.

Not only did size of opening affect the stand characteristics but there was an interaction between opening size and distance from the border. The stand values shown in Table 7 indicate that distance from the border has a greater effect on small openings than on larger openings. For example, the mean basal area for all subplots in position 2 (within 20.9 feet of the border) for the smallest openings was only 20 percent (21 ft^2) per acre compared with 43 percent (45 ft^2) per acre for the same position on openings between 1.0 and 1.75 acres (Group 5). From the results in Table 7, it appears that this interaction effect is minimized as opening size increases beyond an acre. It also is apparent that the distance from the edge affects stand characteristics for at least a distance of 100 feet into the opening. The values shown in Table 7 should be interpreted with caution where sample size is fewer than 10 observations per cell (Table 2). The stand values for large clearcuts were based on all of the subplots from the large clearcuts (> 3 acres) plus all subplots that were 105 feet or more from the opening border.

The effect of opening size and distance from the edge on growth and species composition is readily apparent in Figures 5 through 8. These figures show the number of trees, basal area, total volume, and merchantable volume on a per-acre basis by tolerance class and distance from the edge for each size group.

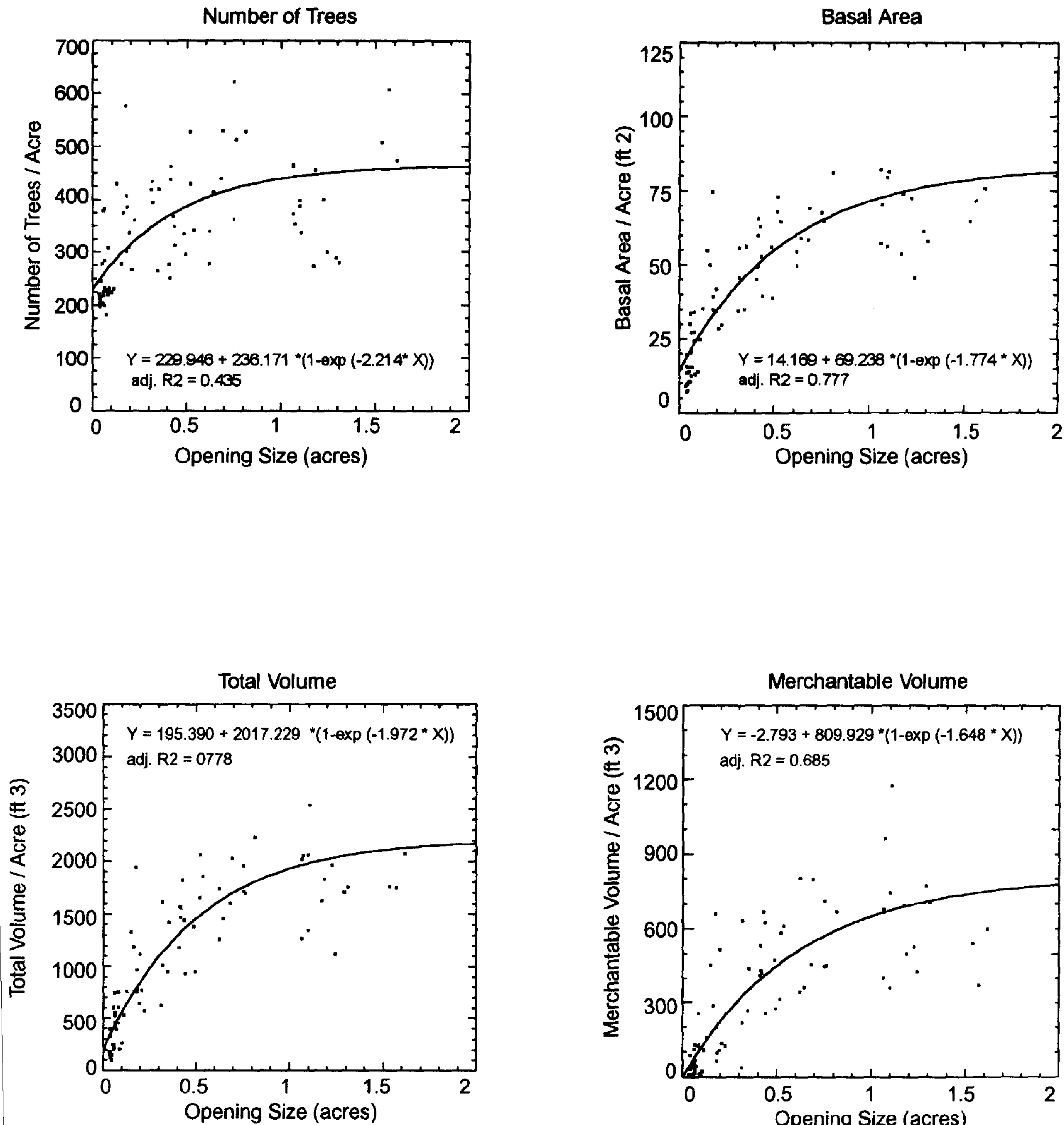

Figure 4.—Effect of opening size on stand characteristics (data for opening Group 6 are not included).

Table 7—Percentage of trees, basal area, merchantable cubic volume, and total cubic volume, by opening size and distance from border (edge) compared to interior of large clearcuts

Distance from edge (feet)	Size of opening 0.0-0.1 acre	0.1-0.3 acre	0.3-0.5 acre	0.5-1.0 acre	1.0-2.0 acre
			Trees/Acre[a]		
21	48	54	57	66	58
42		87	75	91	79
63			78	88	83
84				89	84
105					77
			Basal Area/Acre[b]		
21	20	32	38	42	43
42		47	58	67	68
63			67	80	80
84				101	93
105					88
			Merchantable Cubic Volume/Acre[c]		
21	6	19	27	21	27
42		22	46	42	62
63			59	73	68
84				132	95
105					107
			Total Cubic Volume/Acre[d]		
21	13	26	32	34	35
42		36	51	59	61
63			60	78	71
84				107	87
105					92

[a]557 for large clearcut (> 3.0 acres).
[b]105 ft^2 for large clearcut.
[c]1,113 ft^3 for large clearcut.
[d]3,124 ft^3 for large clearcut.

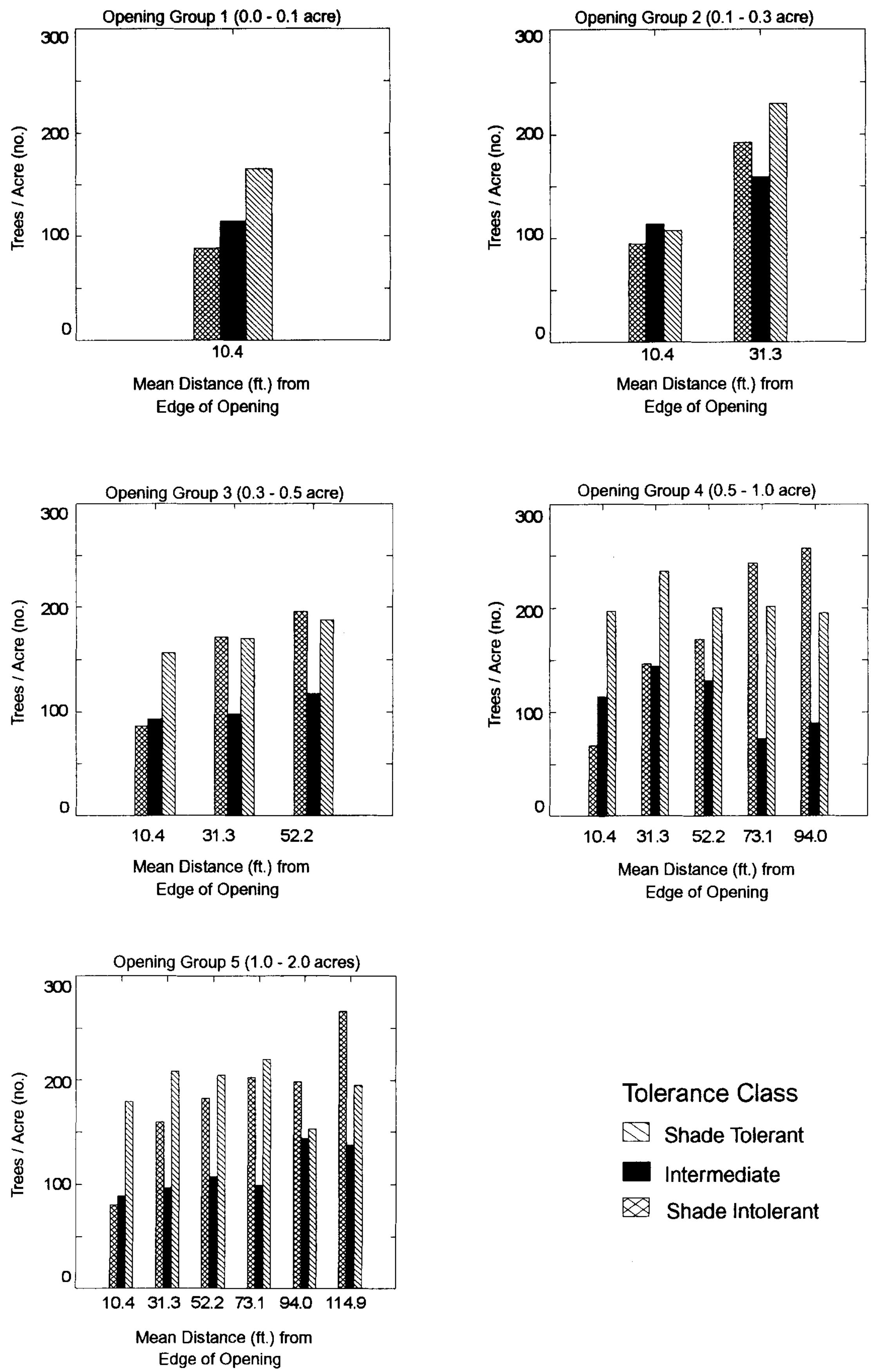

Figure 5.—Variation in trees per acre by subplot position and tolerance class.

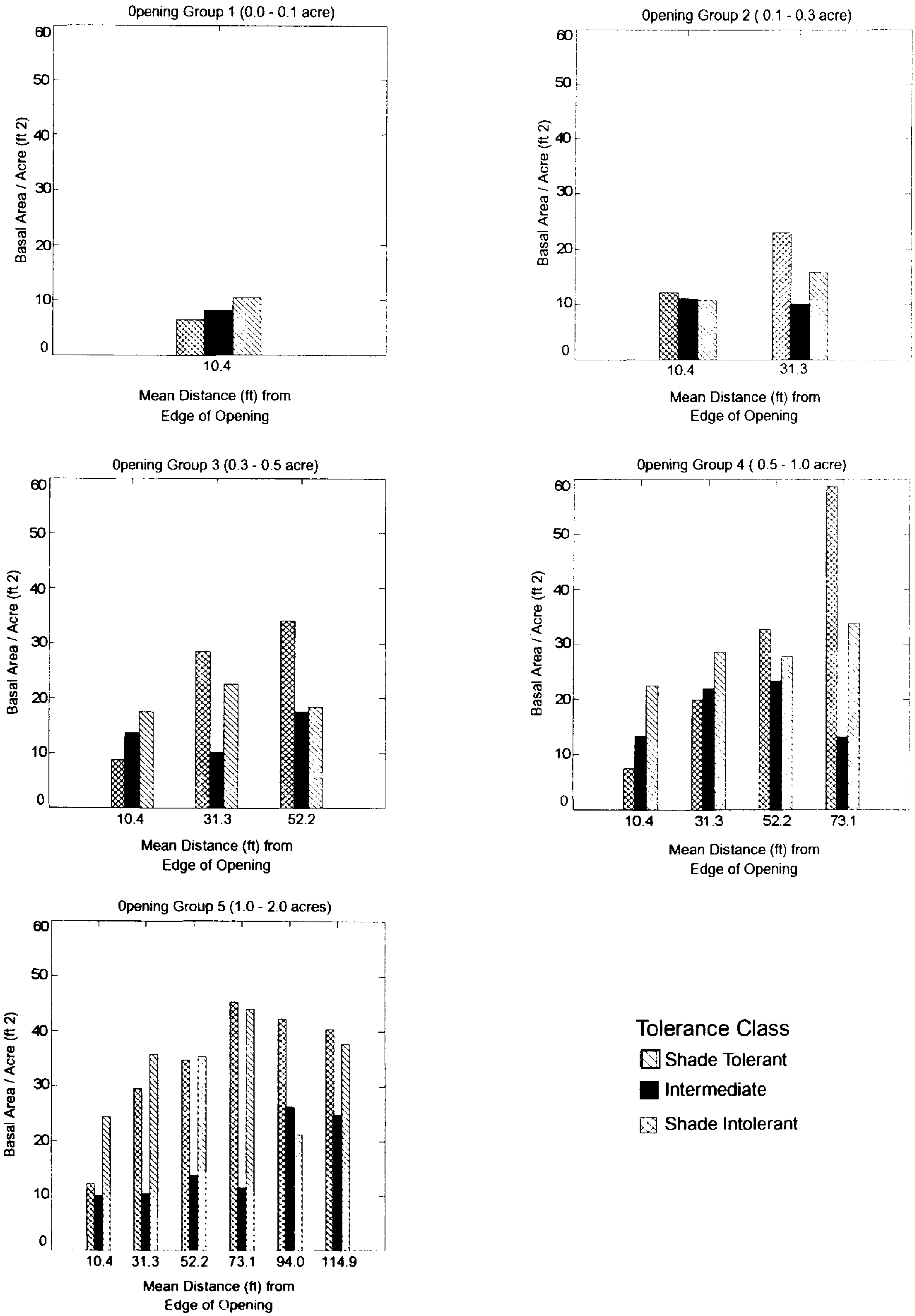

Figure 6.—Variation in basal area per acre by subplot position and tolerance class.

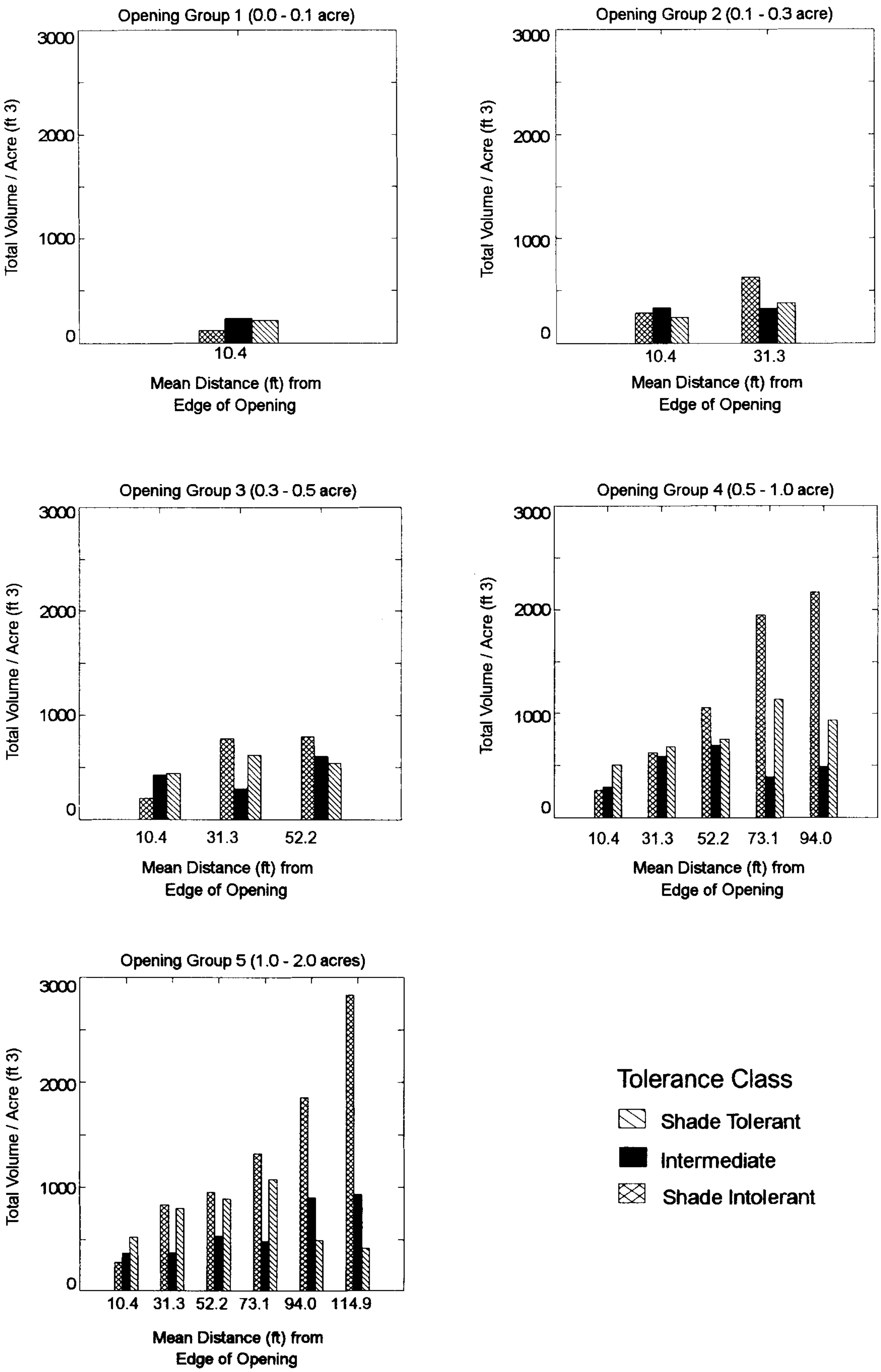

Figure 7.—Variation in total volume cubic foot volume by subplot position and tolerance class.

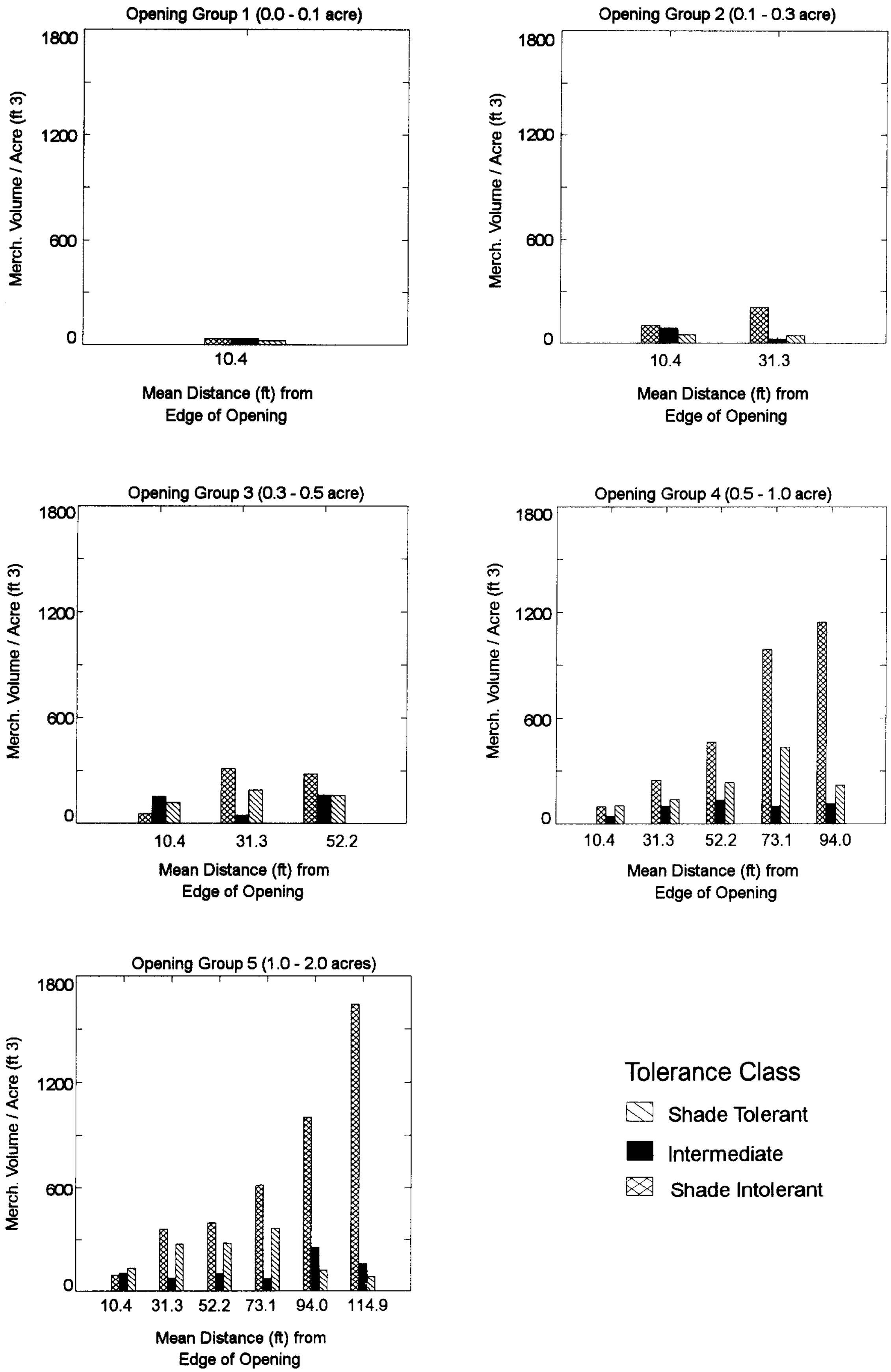

Figure 8.—Variation in merchantable volume by subplot position and tolerance class.

Table 8.—Number of crop trees per acre by site, opening size, and position in opening (spacing between trees was not a consideration)

Opening group	Opening size	Site class	Subplot position 2	3	4	5	6	7	8	9	Mean
	Acres										
1	0.0-0.1	Fair	4	—							4
		Good	5	—							5
2	0.1-0.3	Fair	19	38	—						26
		Good	17	22	—						18
3	0.3-0.5	Fair	11	16	7	—					12
		Good	—	20	11	—					10
4	0.5-1.0	Fair	12	37	37	84	100	—			35
		Good	—	64	78	100	40	100			55
5	1.0-1.8	Fair	13	22	23	45	37	25	—		26
		Good	12	35	71	60	120	164	87		77
6	>3.0	Fair	—	—	—	—	—	50	69	56	58
		Good	—	—	—	—	—	75	88	88	84
Weighted means		Fair	12	27	27	59	42	43	69	56	27
		Good	9	42	56	68	118	127	105	82	46

Crop trees. Available data on crop trees were summarized by site quality, opening size, and opening sample position (Table 8). All crop trees were in the codominant crown class and were selected primarily on the basis of "timber" criteria. Included are trees with vigorous growth characteristics and a potential high quality such as straight stems with few bole branches and no forks or other major defects. Although the best trees were selected for crop trees, other good stems with potential as crop trees were present in the openings. Small openings had few crop trees (about 5 per acre) on both good and fair sites. When opening size was at least 0.5 to 1 acre, the number of crop trees per acre averaged 55 on good sites and 35 on fair sites. Likewise, for openings greater than 3 acres, there were more than 80 crop trees per acre on the good sites compared with about 60 on fair sites.

Characteristics of the individual crop trees, d.b.h., and total height were summarized by species group, opening size, and site class (Table 9). Some crop trees on the fair sites are bigger than those on the better growing sites. For example, the average height of oak crop trees on a fair site (opening 5) was 62.6 feet, while oak crop trees on the good site averaged 56.0 feet. An explanation could be that crop trees of sprout origin were a greater factor on fair than on good sites. Also, the fair sites may be more productive than the initial site class indicates. Another factor in differences in total height could be the age difference among trees on various plots and locations.

The edge effect as well as opening size and site influenced the presence of crop trees. In general, as the number of subplots increased from the opening edge toward the center of the opening, so did the number of potential crop trees (Table 8). Likewise, number of crop trees was consistently higher within a subplot for the good compared with the fair sites. This trend was more pronounced as the opening size increased.

Table 9.—Crop tree d.b.h and height by opening size, site class, and species group

Opening group	Opening size	Site class	Oak-hickory		Yellow-poplar		Maples		Others		All species	
			D.b.h.	Height	D.b.h.	Height	D.b.h.	Height	D.b.h.	Height	D.b.h.	Height
	Acres		*Inches*	*Feet*	*Inches*	*Feet*	*Inches*	*Feet*	*Inches*	*Feet*	*Inches*	*Feet*
1	0.0-0.1	Fair	5.4	44							5.4	44
		Good			9.9	72					9.9	72
2	0.1-0.3	Fair	7.9	64.5	5.8	50.2	8.4	57.7			7.1	55.3
		Good	4.9	45	7.1	56.8			4.5	49	6.3	54.8
3	0.3-0.5	Fair	8.8	72.2	6.8	59	5.6	55.3	6.2	44.5	7	57.2
		Good			10.4	73.8			8.2	58	9.9	69.9
4	0.5-1.0	Fair	8.1	60.6	7.7	67.9	6.3	59.4			7.5	64
		Good			6.7	68.2	4.7	56	8.6	64.6	6.9	68.3
5	1.0-1.8	Fair	10.3	62.6	10.3	74.1	8.6	63.9	7.7	60	8.9	65.4
		Good	6.9	56	6.8	65.9	6.9	59.9	8	61	7.2	63.3
6	>3.0	Fair	7.1	68	13.1	81.7	10.8	78	11	74.2	11.6	77
		Good	7	57.6	6.9	62.3	4.6	53	8.6	61.5	6.9	60.3

Summary

Approximately 30 years ago, a series of studies was installed in central hardwood forests to evaluate the effects of opening size on species composition and stem development of new stands. Study areas were located on five experimental forests—Kaskaskia in Illinois, Robinson and Baldrock in Kentucky, Vinton in Ohio, and the Fernow in West Virginia. The Robinson is administered by the University of Kentucky and the others are maintained by the USDA Forest Service. Sites ranged from fair to good and opening sizes ranged from 0.04 to 1.61 acres. The following are results of a survey of 89 openings.

- In all openings combined, there were 45 different woody species. Twenty species accounted for 90 percent of these stems. Maples, oak, hickory, and yellow-poplar represented 68 percent of all stems.
- Differences in species composition and growth rate were related to site quality. There were more oaks and red maples on fair sites while yellow-poplar and sugar maple dominated the good growing sites.
- Effects of distance from the opening edge varied greatly with opening size. For example, for subplots with a midpoint of 31.3 feet from the edge, stand volume was about three times as large on 1- to 2-acre openings as on 0.1- to 0.3-acre openings.
- Opening size had a tremendous effect on stand productivity. At least for about the first 30 years (short time), four to five times as much basal area and volume per acre can be expected on openings of at least 1.0 acre compared with those of 0.1 acre.
- There was a higher portion of shade-tolerant species in small openings, particularly on those of less than 0.1 acre.
- Reduction in stand growth on smaller openings was attributed to the effect of the border zone (edge) where numbers of trees as well as height and d.b.h. were reduced.
- The greatest reduction was in growth of trees nearest the opening border. However, some effect on growth extended at least 100 feet into the opening.
- There was a strong interaction between border effect and opening size. Growth was greater at a given distance from the border for larger openings.
- As opening size increased at least up to 1 acre, the proportion of shade-intolerant species increased. However, the largest effect of opening size was the increase in total merchantable volume of intolerants as opening size increased.
- Equations were presented for predicting number of trees, basal area, merchantable volume, and total cubic-foot volume for openings up to 2.0 acres in size.
- As opening size increased, the increase in stand volume and basal area was greater for the shade intolerants (yellow-poplar) than the intermediates (oaks-hickories).
- Openings of 0.1 acre or less averaged about five crop trees per acre. Openings of 0.5 to 1.0 acre averaged 55 crop trees per acre on good sites and 35 per acre on fair sites. Openings larger than 3 acres averaged 88 crop trees per acre on the better sites versus 55 on the fair sites.
- Distance from opening edge as well as opening size and site influenced the presence of crop trees. Generally, the number of crop trees increased from the opening edge toward the opening center, and there were more crop trees on good versus fair site. This trend increased with an increase in opening size.

Depending on management objectives, size of clearcut opening has a major influence on future stand characteristics. Species composition, species diversity, productivity, availability of crop trees, available habitat, and edge effects can be manipulated by using openings of different sizes.

Information from this study is based on clearcut openings that were around 30 years old. These new even-aged stands were well established, so there are limited opportunities to manipulate species composition other than using timber stand improvement and crop-tree thinning techniques. Results show that the initial size of a clearcut opening has a major influence on stand development. Thus, users need to be aware of these effects to satisfy individual forest management objectives.

This information should be important to forest managers who are considering small openings as viable alternatives to clearcutting. Forest managers and landowners also need to be aware of stand development and productivity related to opening size. More informed decisions should be possible using this report and related publications to improve the management techniques in central hardwood forests.

Acknowledgments

We gratefully acknowledge the efforts of Ivan Sander and Russ Walters in designing the methodology to collect and record the study data. John Beaton, Robert Ford, Robert Baughman, and Randy Vermell helped collect and/or input the data for computer analyses and summaries. We also thank members of the Northeast Stand Establishment Working Group as well as many others for identifying the need for and helping facilitate this research.

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Appendix

Table 10.—Distribution of sample openings by location, site, and opening size

Location	Site class	Opening size						
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Total
		Number						
Baldrock	Fair	—	—	—	2	—	—	2
	Good	—	3	—	3	4	2	12
Robinson	Fair	6	—	3	3	3	—	15
	Good	—	—	—	—	—	—	—
Vinton	Fair	—	3	3	3	2	3	14
	Good	—	—	—	—	1	—	1
Parsons	Fair	7	—	3	—	3	2	15
	Good	6	—	3	—	3	2	14
Kaskaskia	Fair	2	3	1	—	—	—	6
	Good	3	5	1	1	—	—	10
Total	Fair	15	6	10	8	8	5	52
	Good	9	8	4	4	8	4	37

Table 11.—List of species and assigned class for shade tolerance and desirability for timber products

Common name	Scientific name	Shade tolerance[a]	Desirability for timber[b]
Sugar maple	*Acer saccharum* Marsh	3	1
Red maple	*Acer rubrum* L.	3	2
Ohio buckeye	*Aesculus glabra* Wild.	3	3
Serviceberry	*Amelanchier arbore*a (Michx. F.) Fern.	3	3
Paw paw	*Asimina triloba* (L.) Dunal	3	3
Yellow birch	*Betula alleghaniensis* Britton	2	2
Sweet birch	*Betula lenta* L.	1	2
Hornbeam	*Carpinus carolinians* Walt.	3	3
Hickory	*Carya* sp.	2	2
Hackberry	*Celtis occidentalis* L.	2	2
Eastern redbud	*Cercis canadensis* L.	3	3
Flowering dogwood	*Cornus florida* L.	3	3
Hazelnut/witch hazel	*Corylus* sp./*Hamamelis* sp.	3	3
Persimmon	*Diospyros virginiana* L.	3	3
Beech	*Fagus grandifolia* Ehrh.	3	2
Ash	*Fraxinus* sp.	2	1
Holly	*Ilex opaca* Ait.	3	3
Black walnut	*Juglans nigra* L.	1	1
Sweetgum	*Liquidambar styraciflua* L.	1	2
Yellow-poplar	*Liriodendron tulipifera* L.	1	1
Cucumbertree	*Macnolia acuminata* L.	2	2
Fraser magnolia	*Magnolia fraseri* Walt.	2	3
Magnolia	*Magnolia* sp.	2	3
Blackgum	*Nyssa sylvatica* Marsh. var. sylvatica	3	2
Hophornbeam	*Ostrya virginiana* (Mill.) K.Koch.	3	3
Sourwood	*Oxydendrum arboreum* (L.) DC.	3	3
Shortleaf pine	*Pinus echinata* Mill.	1	2
Pitch pine	*Pinus rigida* Mill.	1	2
Virginia pine	*Pinus virginiana* Mill.	1	2

Continued

Table 11.—Continued

Common name	Scientific name	Shade tolerance[a]	Desirability for timber[b]
Sycamore	*Platanus occidentalis* L.	1	2
Bigtooth aspen	*Populus grandidentata* Michx.	1	2
Black cherry	*Prunus serotina* Ehrh.	1	1
White oak	*Quercus alba* L.	2	1
Scarlet oak	*Quercus coccinea* Muenchh.	1	1
Southern red oak	*Quercus falcata* Michx. var. falcata	1	1
Burr oak	*Quercus macrocarpa* Michx.	2	1
Chestnut oak	*Quercus prinus* L.	2	1
Northern red oak	*Quercus rubra* L.	2	1
Post oak	*Quercus stellata* Wangenh.	1	1
Black oak	*Quercus velutina* Lam.	2	1
Sumac	*Rhus* sp.	1	3
Black locust	*Robinia pseudoacacia* L.	1	2
Sassafras	*Sassafras albidum* (Nutt.) Nees	1	3
Basswood	*Tila americana* L.	3	2
Eastern hemlock	*Tsuga canadensis* (L.) Carr.	3	2
American elm	*Ulmus americana* L.	2	2
Red elm	*Ulmus rubra* Muhl.	2	2
Misc. shrubs		2	3
Misc. trees		2	2

[a]1 = shade intolerant; 2 = somewhat shade tolerant; 3 = shade tolerant.
[b]1 = preferred; 2 = nonpreferred; 3 = others.

Table 12.—Most common species and their relative frequency by shade tolerance and desirability for timber products

Intolerant		Intermediate		Tolerant	
		PREFERRED			
Yellow-poplar	.148	White oak	.051	Sugar maple	.017
Black cherry	.049	Chestnut oak	.045		
White ash	.013	Black oak	.010		
Scarlet oak	.010	N. red oak	.009		
S. red oak	.010				
		NONPREFERRED			
Hickory	.047	Red elm	.004	Red maple	.240
Sweet birch	.043	Cucumber tree	.003	Hemlock	.035
Black locust	.008	American elm	.001	Beech	.027
Aspen	.003	Yellow birch	.001	Blackgum	.025
Virginia pine	.002			Basswood	.003
		OTHER			
Sassafras	.053	Fraser Magnolia	.025	Dogwood	.050
Sumac	.001	Magnolia sp.	.012	Sourwood	.028
				Redbud	.014
				Serviceberry	.005
				Holly	.003

Table 13.—Stand characteristics by opening size and desirability for timber products

Opening group	Opening size	Timber class	Number of trees	Basal area	Total volume	Merchantable volume
	Acres			*Ft²*	*Ft³*	*Ft³*
1	0.0-0.1	Preferred	63 (26)[a]	6.7 (37)	139 (39)	35 (67)
		Nonpreferred	111 (46)	7.5 (42)	160 (45)	15 (29)
		Other	68 (28)	3.8 (21)	57 (16)	2 (4)
2	0.1-0.3	Preferred	145 (42)	21.4 (56)	545 (61)	189 (84)
		Nonpreferred	90 (26)	8.8 (23)	196 (22)	27 (12)
		Other	110 (32)	8.0 (21)	152 (17)	9 (4)
3	0.3-0.5	Preferred	136 (38)	24.4 (49)	666 (52)	260 (64)
		Nonpreferred	154 (43)	20.4 (41)	512 (40)	138 (34)
		Other	69 (19)	5.0 (10)	102 (8)	8 (2)
4	0.5-1.0	Preferred	162 (41)	32.4 (50)	956 (54)	354 (65)
		Nonpreferred	161 (41)	25.3 (39)	673 (38)	169 (31)
		Other	71 (18)	7.1 (11)	141 (8)	22 (4)
5	1.0-1.8	Preferred	142 (32)	29.5 (44)	877 (49)	391 (62)
		Nonpreferred	213 (48)	28.8 (43)	716 (40)	195 (31)
		Other	89 (20)	8.7 (13)	197 (11)	44 (7)
6	>3.0	Preferred	187 (36)	44.2 (48)	1283 (52)	575 (65)
		Nonpreferred	234 (45)	36.8 (40)	913 (37)	265 (30)
		Other	99 (19)	11.0 (12)	271 (11)	44 (5)

[a]Parentheses indicate percent.

Table 14.—Stand characteristics by opening size and shade-tolerance class

Opening group	Opening size	Tolerance class	Number of trees	Basal area	Total volume	Merchantable volume
	Acres			*Ft²*	*Ft³*	*Ft³*
1	0.0-0.1	Intolerant	58 (24)[A]	4 (24)	96 (27)	17 (33)
		Intermediate	48 (20)	4 (28)	93 (26)	18 (35)
		Tolerant	135 (56)	10 (48)	167 (47)	17 (32)
2	0.1-0.3	Intolerant	145 (42)	18 (46)	429 (48)	139 (62)
		Intermediate	69 (20)	8 (22)	196 (22)	43 (19)
		Tolerant	131 (33)	12 (32)	268 (30)	43 (19)
3	0.3-0.5	Intolerant	151 (42)	21 (43)	551 (43)	187 (46)
		Intermediate	57 (16)	10 (21)	269 (21)	85 (21)
		Tolerant	151 (42)	18 (36)	461 (36)	134 (33)
4	0.5-1.0	Intolerant	130 (33)	25 (38)	743 (42)	311 (57)
		Intermediate	83 (21)	15 (23)	389 (22)	76 (14)
		Tolerant	181 (46)	25 (39)	637 (36)	158 (29)
5	1.0-1.8	Intolerant	182 (41)	31 (46)	859 (48)	353 (56)
		Intermediate	58 (13)	9 (14)	251 (14)	63 (10)
		Tolerant	204 (46)	27 (40)	680 (38)	214 (34)
6	>3.0	Intolerant	223 (43)	43 (47)	1209 (49)	504 (57)
		Intermediate	94 (18)	15 (16)	394 (16)	97 (11)
		Tolerant	203 (39)	34 (37)	864 (35)	283 (32)

[A]Parentheses indicate percent.

Dale, Martin E.; Smith, H. Clay; Pearcy, Jeffrey N. 1995. **Size of clearcut opening affects species composition, growth rate, and stand characteristics.** Res. Pap. NE-698. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 21 p.

In the late 1950's and early 1960's, a series of studies was installed in the central hardwood forest to determine if size of clearcut opening affects the growth rate and species composition of new stands. In 1991, about 30 years after cutting, stand data were collected in 89 openings ranging in size from 0.04 to 1.61 acres. The number of stems per acre increased with opening size; however, the number of shade-tolerant species constituted a greater proportion of the stand in small openings (< 0.5 acre), while the proportion of shade-intolerant species increased in larger openings. Basal area and volume of the current stands increased markedly with opening size for openings up to at least 1 acre. Results of this study indicate that opening size has a major influence on stand characteristics after about 30 years.

Keywords: Central hardwoods, opening size, species composition, stand productivity

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