Chapter 9

Structure, Composition, and Condition of Overstory Trees

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Abstract

The structure, composition, and condition of overstory trees in the four study areas prior to prescribed fire treatments are summarized. Stand initiation dates were similar among the study areas (ca. 1885), and coincided with the decline of the charcoal iron industry in southern Ohio. Tree basal area averaged 26.8m^2/ha and was not significantly different among Integrated Moisture Index classes. Tree density averaged 378 trees/ha and was highest on xeric plots (407/ha). Diameter growth averaged 3.6 mm/year and was greatest in areas with higher concentrations of soil nitrogen or base cations. Branch dieback was 20 percent or less for 96 percent of the 4,894 overstory trees, and foliage transparency was 20 percent or less for about 90 percent of the trees, indicating good crown condition. Twenty-nine species were recorded, the most abundant of which were white oak (79 trees/ha), red maple (52.9/ha), chestnut oak (49.2/ha), hickories (37/ha), and sugar maple (31.6/ha). Despite the abundance of red maple and sugar maple, most of these trees were in the smaller diameter classes (10 to 25 cm d.b.h.), suggesting more recent recruitment in the stands. Although oaks continue to dominate the overstory of these stands, the abundance of shade-tolerant species in the smaller size classes indicates consistent successional trends across the landscape, particularly on intermediate and mesic sites.

Introduction

More than half of the land area in southeastern Ohio is forested, with oak-hickory the most abundant forest type (Griffith et al. 1993). Although located within Braun's (1950) mixed mesophytic forest region, the "Low Hills Belt" in southeastern Ohio is dominated by oak-hickory forests. The assessment of Griffith et al. agrees with the record of witness trees from which Gordon (1969) classified most of southern and eastern Ohio as mixed-oak forest (ca. 1800). Indeed, studies of fossil pollen indicate that oaks have dominated the forests of this region for at least 5,000 years (Ogden 1966; Delcourt and Delcourt 1987; Delcourt et al. 1998). Prior to significant Euro-American settlement in the Ohio Valley, travelers and early settlers frequently described forests that were park-like, with large, widely spaced overstory trees and relatively little undergrowth of woody vegetation (see Chapter 2). The use of fire by Native Americans also was described, so it is likely that many primary forests in the region experienced anthropogenic fires in addition to grazing and browsing by quadrupeds such as deer, elk, and bison (Williams 1989; Whitney 1994; Chapter 2).

Currently, most mature second-growth forests in the Central Hardwoods Region are dominated by a mixed-oak overstory that developed between the mid-1800s and the early 1930s as subsistence farming and charcoal production for iron ore smelting declined (Hicks 2000). The overstory at each of our study areas originated following clearcutting to produce charcoal used in iron smelting in the mid-19th century. The iron industry declined in the late 1800s (Chapter 2).

A dendroecological study of fire scars in a second-growth stand (Vinton County, OH) indicated that dormant-season fires were frequent from 1870 to 1930 (Sutherland 1997); similar results were observed in stands throughout southern Ohio (Sutherland, unpublished). The seedlings, saplings, and trees that survived the fires became today's overstory, which is dominated by oak species on most upland landscapes. The most abundant oak species in the region are white oak (*Quercus alba*), chestnut oak (*Q. prinus*), scarlet oak (*Q. coccinea*), northern red oak (*Q. rubra*), and black oak (*Q. velutina*) (Iverson et al. 1999). These forests also can include 25 or more canopy and subcanopy species other than oaks (Beatley 1959). Other common tree species in the overstory include hickory (*Carya spp.*), yellow-poplar

(*Liriodendron tulipifera*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), ash (*Fraxinus spp.*), and black cherry (*Prunus serotina*) (Griffith et al. 1993).

Recently, species associated with mesic sites and species that are considered sensitive to fire have become more abundant in oak-dominated forests across the region (Abrams 1992). Natural mortality caused by drought, insects, disease, or windthrow is less than 5 percent annually (Stringer et al. 1989). Recruitment of stems into canopy gaps rarely is by oak species (Runkle 1998; McCarthy et al. 2001). In sharp contrast to descriptions of presettlement forests, the secondary forests have a dense midstory layer dominated by maples and other shade-tolerant species (Chapter 9).

Because the observed successional trends in the region have coincided with a decrease in the frequency and spatial extent of fire since the mid-20th century (Yaussy and Sutherland 1993; Sutherland 1997), prescribed burning is being evaluated as a tool to restore the structure, composition, and function to mixed-oak forests. In this chapter we quantify the baseline structure, composition, condition, and productivity of the overstory across a moisture gradient and among the four study areas prior to prescribed fire treatments.

Methods

Study Areas and Experimental Design

The study areas and experimental design are described in detail in Chapter 1. Here a brief overview is provided. The four 75-90 ha study areas are located in Vinton County (Arch Rock and Watch Rock) and Lawrence County (Young's Branch and Bluegrass Ridge). The study areas are within in the Southern Unglaciated Allegheny Plateau, which is characterized by high hills, sharp ridges, and narrow valleys. Sandstones and shales are principle bedrocks. Forests are oak-dominated and the current overstory originated in the late-1800s, after the cessation of clearcutting for the charcoal iron industry.

In each study area, three prescribed fire treatments were established, a control unit (CONT), an infrequent burn unit (INFR), and a frequent burn unit (FREQ). To account for variation in soil moisture and vegetation, a GIS-derived integrated moisture index (IMI) was applied across the dissected landscapes of the study areas (Chapter 3). From the calculated IMI scores, each 30 x 30 m pixel was assigned to one of three soil moisture classes: xeric, intermediate, or mesic. Thus to examine the effects of prescribed fire and account for environmental heterogeneity, a split-plot experimental design was established. The four study areas are replicate blocks, fire treatment units are whole plots, and IMI classes are subplots. The 50 x 25 m vegetation plots (N= 108 total) were established as pseudoreplicates in each IMI class within each fire treatment unit (Chapter 1).

Field Methods

In the first year of data collection (January-April, 1995), species, status (alive or dead) and d.b.h. (diameter at breast height, 1.4 m) were recorded for all standing trees at least 10.0 cm d.b.h. Each tree was marked permanently. For each tree, we also recorded whether it was on the regeneration or the understory subplot. These measurements indicate conditions present at the end of the 1994 growing season and are termed "1994" data. The "1995" measurements were taken from January to April 1996, when measurements were collected to evaluate stand age, diameter growth, stand dynamics (ingrowth, tree mortal status, crown position), tree health (crown condition: foliage transparency and branch dieback), and potential economic value (grade). D.b.h. was remeasured and mortality determined for all trees. Ingrowth trees were identified, painted, and tagged.

Crown class (Helms 1998) and potential tree grade (Yaussy 1993) were recorded for live trees larger than 24 cm in diameter after the 1997 growing season. Stem quality consisted of four grades that each tree would likely attain when it reached a d.b.h. of 40 cm. Grade 1 had the fewest knots, seams, and other defects while grade 4 had the most defects.

Crown condition was evaluated by estimating foliage transparency and branch dieback on all living trees in summer of 1995 following Millers et al. (1991). Foliage transparency is an estimate of the amount of light passing through the crown, and describes crown density for given species as well as accounting for reduced foliage density resulting from herbivory, disease, or other injurious agents. Hence, the foliage density or the amount of light passing through the crown (transparency) for a healthy tree of one species may be considerably lower than that for a healthy tree of another species, so the measure is most useful for within-species comparisons. Branch dieback is a measure of recent branch mortality that begins at the terminal portion of a limb and progresses downward. Presumably, branch dieback reflects some stress (e.g., drought, herbivory) on the tree and is not species-specific, though some species may be more susceptible to a given stress than others.

Increment cores were collected in October and November 1996, to determine the age of the stands and develop tree-ring chronologies from the sites. Two of the largest trees outside the plots but within 10 m of opposite plot corners were selected. Favored in order was the white oak group, the red oak group, and other trees. For each tree, two cores were taken with an increment borer at a height of 1 m; species and d.b.h. also were recorded. The cores were

Table 1.—Summary statistics for overstory variables on the 108 plots in four study areas.

Item	Minimum	25%	Mean	Median	75%	Maximum
D.b.h. (cm)	9.9	14.3	26.5	22.9	36.2	102.0
1-year d.b.h. growth (mm)	0.0	2.0	3.6	3.0	5.0	22.0
Trees/ha (no.)	224.0	320.0	378.2	368.0	424.0	664.0
Basal area (m^2/ha)	16.6	24.3	26.8	27.0	29.2	37.5
Basal area in oak (%)	4.4	57.9	69.3	75.7	88.7	99.1
Foliage transparency (%)	5.0	10.0	11.7	10.0	10.0	100.0
Branch dieback (%)	2.0	10.0	8.1	10.0	10.0	90.0
Crown class	1.0	2.0	3.0	3.0	4.0	4.0
Age (years)	64.0	94.0	110.2	109.0	129.0	154.0
Mortality (1 year) (%)	0.0	1.9	3.9	3.2	5.6	12.8
Tree grade	1.0	2.0	2.4	2.0	3.0	4.0

glued in grooved, wooden mounts and sanded with progressively finer grits of sandpaper for accurate dating and measurement of rings. If the pith was not included in either core (per tree), both cores were used to estimate the pith age in a 5-year class. To determine the age of each plot, we chose the oldest of the two trees sampled unless we judged that the older tree was not representative of the overall stand age. This occurred twice when one tree per plot was more than 200 years old. These were residual trees that were not harvested during the charcoal iron period.

Data Analysis

A mixed-model analysis of variance (ANOVA) was used to test for significant differences in overstory characteristics among the three IMI categories and pretreatment differences among the three treatment units (SAS 1999). The study areas were treated as blocked random effects and IMI and treatment units as fixed effects. Values less than 0.05 were considered significant and P-values greater than 0.05 and less than 0.10 were considered marginally significant.

Results

Age, Structure and Productivity

Of the 216 trees cored (mean d.b.h. = 40.8 cm), 121 were white oak, 39 chestnut oak, 16 black oak, 14 northern red oak, 8 yellow-poplar, 6 scarlet oak, 5 hickory, 4 sugar maple, and 1 each of post oak (*Quercus stellata*), ash, and red maple. Overall, the mean stand age was 110.2 (Table 1). The YB study area had the oldest stands (average plot age = 120.9 years) with nearly half of the plots being at least 140 years old (Table 2). Stand age did not differ significantly among IMI classes (F = 0.38, p = 0.688) but was marginally different among fire-treatment units (F = 3.70, p = 0.088; Table 3).

Tree density and basal area averaged 378.2 trees/ha and 26.8 m^2/ha, respectively (Table 1). Tree density was greatest at YB (416 trees/ha) and on xeric plots (407.1 trees/ha), though the difference among IMI classes was marginally significant (F = 3.24, p = 0.058; Tables 2-3). Tree basal area was similar among the study areas, with WR averaging slightly less (25.3 m^2/ha) than the other sites, which ranged from 27.1 to 27.8 m^2/ha (Table 2). Basal area was not significantly different among IMI classes (F = 0.92, p = 0.418; Table 3) or among fire-treatment units (F = 1.48, p = 0.277). The relative abundance of suppressed trees averaged 39.2 percent versus 27.7 percent for codominant, 17.6 percent for intermediate, 8.6 percent for standing dead, and 6.9 percent for dominant trees (Table 4). The average score for crown class did not differ among IMI classes (F = 1.88, p = 0.180) or fire-treatment units (F = 0.04, p = 0.960) (Table 3).

Diameter growth averaged 3.6 mm from the 1994 to 1995 growing seasons (Table 3). Diameter growth was marginally different among the IMI classes (F = 3.39, p = 0.051). Trees in the intermediate plots had a higher growth rate (4.0 $\pm$ .07 mm/yr [mean $\pm$ 1 SE]) than those in the mesic (3.5 $\pm$ .07 mm/yr) and xeric (3.3 $\pm$ .06 mm/yr) plots (Tables 2, 4). Diameter growth was also higher at WR (4.2 $\pm$ .08 mm/yr) and BR (4.1 $\pm$ .09 mm/yr) than at AR (3.1 $\pm$ .06 mm/yr) and YB (3.1 $\pm$ .07 mm/yr). One-year rates of mortality (1994-1995 growing seasons) averaged 3.9 percent and were not significantly different among IMI classes (F = 1.00, p = 0.383) or fire-treatment units (F = 0.33, p = 0.719) (Tables 3-4). However, mortality was highest at AR, averaging 5.3 percent compared to 3.3 to 3.8 percent in the other study areas (Table 2).

Table 2.—Means for overstory variables among the four study areas and three IMI classes.

Item	WR	AR	BG	YB	Xeric	Interm.	Mesic
D.b.h. (cm)	25.94	27.39	27.54	25.44	26.20	27.04	26.35
1-year d.b.h. growth (mm)	4.18	3.09	4.09	3.13	3.29	4.04	3.45
Trees/ha (no.)	368.00	374.81	354.07	416.00	407.06	366.95	362.89
Basal area (m^2/ha)	25.30	27.18	27.11	27.82	27.17	27.36	26.01
Basal area in oak (%)	68.89	72.47	68.98	67.05	87.05	71.07	50.81
Foliage transparency (%)	13.22	13.36	10.34	9.85	12.21	11.24	11.51
Branch dieback (%)	13.58	14.04	11.40	10.81	13.09	12.29	11.86
Crown class	3.05	2.92	2.96	3.05	2.95	2.98	3.03
Age (years)	111.78	107.70	100.30	120.85	113.12	110.45	107.06
Mortality (1 year) (%)	3.75	5.28	3.42	3.32	3.30	4.06	4.42
Tree grade	2.42	2.40	2.37	2.40	2.50	2.31	2.37

Species Composition

We recorded 29 tree species (Table 5), the most abundant of which were white oak (79 trees/ha), red maple (52.9/ha), chestnut oak (49.2/ha), hickory (37/ha), sugar maple (31.6/ha), black oak (24/ha), and yellow-poplar (20.7/ha). White oak, sourwood (*Oxydendron arborea*), and black oak had the most standing dead trees/ha, averaging 7.4, 5, and 3.7, respectively.

The relative abundance of white oak was high in all moisture classes and in the larger size classes but it exhibited lower relative abundance in the 10- to 30-cm size classes, particularly in the mesic areas (Fig. 1). Despite the abundance of red maple in all study areas and IMI classes, nearly all of the trees were less than 25 cm in d.b.h. Sugar maple showed a similar size distribution but was rare on xeric plots. Chestnut oak was most abundant on xeric plots but uncommon in the 10-to 20-cm class. Hickories (*Carya glabra*, *C. tomentosa, C. cordiformis, C. ovata*) were more abundant on intermediate and mesic sites and in the 20- to 40-cm d.b.h. class. Black oak was abundant in all moisture classes but uncommon in size classes less than 30 cm d.b.h.

Although other species were common in the smaller and intermediate size classes, oaks accounted for a high percentage of the stand basal area (overall mean = 69.3 percent) due to their high relative abundance in the larger size classes (Table 1, Fig. 1). The proportion of basal area in oak was significantly different among IMI classes ($F = 30.2$, $p < 0.001$), averaging 87.1, 71.1, and 50.8 percent on xeric, intermediate, and mesic plots, respectively (Tables 2-3). The percentage of basal area in oak did not differ significantly among fire-treatment units ($F = 1.48$, $p = 0.277$).

Differences in size class distributions among species also are evident in the relative percentages of trees in the four crown classes. For the white oak group (white oak and chestnut oak) and the red oak group (black oak, northern red oak, scarlet oak) nearly 50 percent and nearly 75 percent of the trees, respectively, were codominant or dominant (Fig. 2). Yellow-poplar was the only other common species with half or more of its trees in these two classes. Among the common species that can attain dominant or codominant status, half or more of the stems of red maple, sugar maple, ash, blackgum, and miscellaneous overstory species (e.g., beech, [*Fagus grandifolia*]) were in the suppressed category (Fig. 2).

Crown Condition

Foliage transparency was 20 percent or less in virtually every tree (mean = 11.7%). Branch dieback also was 20 percent or less in 96 percent of trees (mean = 8.1%). These low percentages were found across all size and crown classes (Tables 2, 5). Foliar transparency was higher at WR and AR (13.2 and 13.4 percent, respectively) than at YB and BR (9.9 and 10.3 percent) and was significantly different among IMI classes ($F = 4.99$, $p = 0.019$) but not fire-treatment units ($F = 0.72$, $p = 0.525$) (Tables 2-3). Branch dieback showed the same pattern, i.e., higher at WR and AR (13.6 and 14.0 percent) than at YB and BR (10.8 and 11.4 percent), and marginally different among IMI classes ($F = 3.50$, $p = 0.051$), but not fire-treatment units ($F = 0.51$, $p = 0.625$). For both transparency and dieback, average values were highest on xeric plots (Table 2). Most species had a majority of trees in the excellent class for transparency and dieback, though less than half of the trees in the red oak group were in the excellent category for both variables (Figs. 3-4). Tree grades were significantly higher (indicating more defects) on xeric plots ($F = 7.29$, $p = 0.005$) but did not differ significantly among fire-treatment units ($F = 1.82$, $p = 0.214$) (Table 3).

Table 3. -Analysis of variance for significant differences in overstory variables among the treatment units, IMI classes, and interactions.

Item	Source	F-value	p-level
D.b.h. (cm)	Treatment	2.52	0.104
	IMI	0.37	0.698
	Trt*IMI	1.58	0.216
1-year d.b.h. growth (mm)	Treatment	1.72	0.201
	IMI	3.39	0.051
	Trt*IMI	1.12	0.373
Trees/ha (no.)	Treatment	3.08	0.066
	IMI	3.24	0.058
	Trt*IMI	0.40	0.805
Basal area (m2/ha)	Treatment	0.20	0.825
	IMI	0.92	0.418
	Trt*IMI	2.72	0.065
Basal area in oak (%)	Treatment	1.48	0.277
	IMI	30.19	0.000
	Trt*IMI	1.91	0.158
Foliage transparency (%)	Treatment	0.72	0.525
	IMI	4.99	0.019
	Trt*IMI	1.49	0.248
Branch dieback (%)	Treatment	0.51	0.625
	IMI	3.50	0.051
	Trt*IMI	0.28	0.888
Crown class	Treatment	0.04	0.960
	IMI	1.88	0.180
	Trt*IMI	0.30	0.872
Age (years)	Treatment	3.70	0.088
	IMI	0.38	0.688
	Trt*IMI	0.05	0.996
Mortality (1 year) (%)	Treatment	0.33	0.719
	IMI	1.00	0.383
	Trt*IMI	1.44	0.253
Tree grade	Treatment	1.82	0.214
	IMI	7.29	0.005
	Trt*IMI	0.33	0.855

Discussion

The majority of the even-aged stands on the four study areas originated in the mid- to late-1800s, which coincides with the decline in the charcoal iron industry across the region. Because the forests have developed on terrain with similar geomorphology and land use, it is not surprising that forest structure and composition are similar across the study sites.

Tree basal area averaged 27 m^2/ha, which was nearly identical to second-growth stands of similar age in southeastern Ohio (Goebel and Hix 1996) and somewhat less than the 30 to 32 m^2/ha values reported for several old-growth oak-hickory forests in the Midwest (Whitney 1994). Tree density, which averaged 378 trees/ha, was greater than that reported for old growth oak-hickory forests (320 to 350 trees/ha). However, the density of presettlement forests may have been lower than current old-growth forests based on early descriptions of more open-structured forests.

By definition, mesic plots had higher predicted soil moisture, and also had more available inorganic N (NH_4 and NO_3), and higher pH than intermediate plots (see Chapter 5), but diameter growth was significantly greater on intermediate plots. However, the latter had more soil Ca, Mg, and P than mesic plots. This might explain the greater diameter-growth rates (e.g., Long et al. 1997).

Differences in diameter growth among the study areas may also be related to soil fertility. Diameter growth was about 35 percent higher at WR and BR than at AR and YB despite similar average IMI values for the plots among the study areas (Chapter 3). The soils data suggest that greater soil N availability drove higher diameter growth at WR. For a variety of oak forests, Reich et al. (1997) showed a strong and positive linear relationship between nitrogen availability (nitrogen mineralization rate) and productivity. At BR, higher diameter growth may be related to significantly greater soil Ca, Mg, and Ca:Al ratios, the result of the interbedded limestone strata at that site (Chapter 4). However, the higher diameter-growth rates on intermediate plots and at WR and BR did not result in greater basal area at those sites.

Stand structure did not differ significantly across the moisture gradient, though, as expected, patterns of species abundance differed among IMI classes. For the most abundant species, white oak and red maple were ubiquitous across the landscape, while chestnut oak and black oak were the most abundant on xeric and xeric/intermediate sites, respectively. Hickory, sugar maple, and yellow-poplar were most abundant on intermediate and mesic sites. Compositional change across the IMI classes was evident in the tree regeneration layer (Chapter 8), and particularly in the understory vegetation layer (Chapter 7). Aspect-driven gradients in species composition are typical for forests in the region (Hutchins et al. 1976; Muller 1982; Goebel and Hix 1996).

Our results indicate that the current composition of the overstory is similar to that of the presettlement forests in the area, which were dominated by several oak (especially white oak) and hickory species (Chapter 2). However, strong successional trends also are apparent as shade-tolerant species including red maple, sugar maple, and

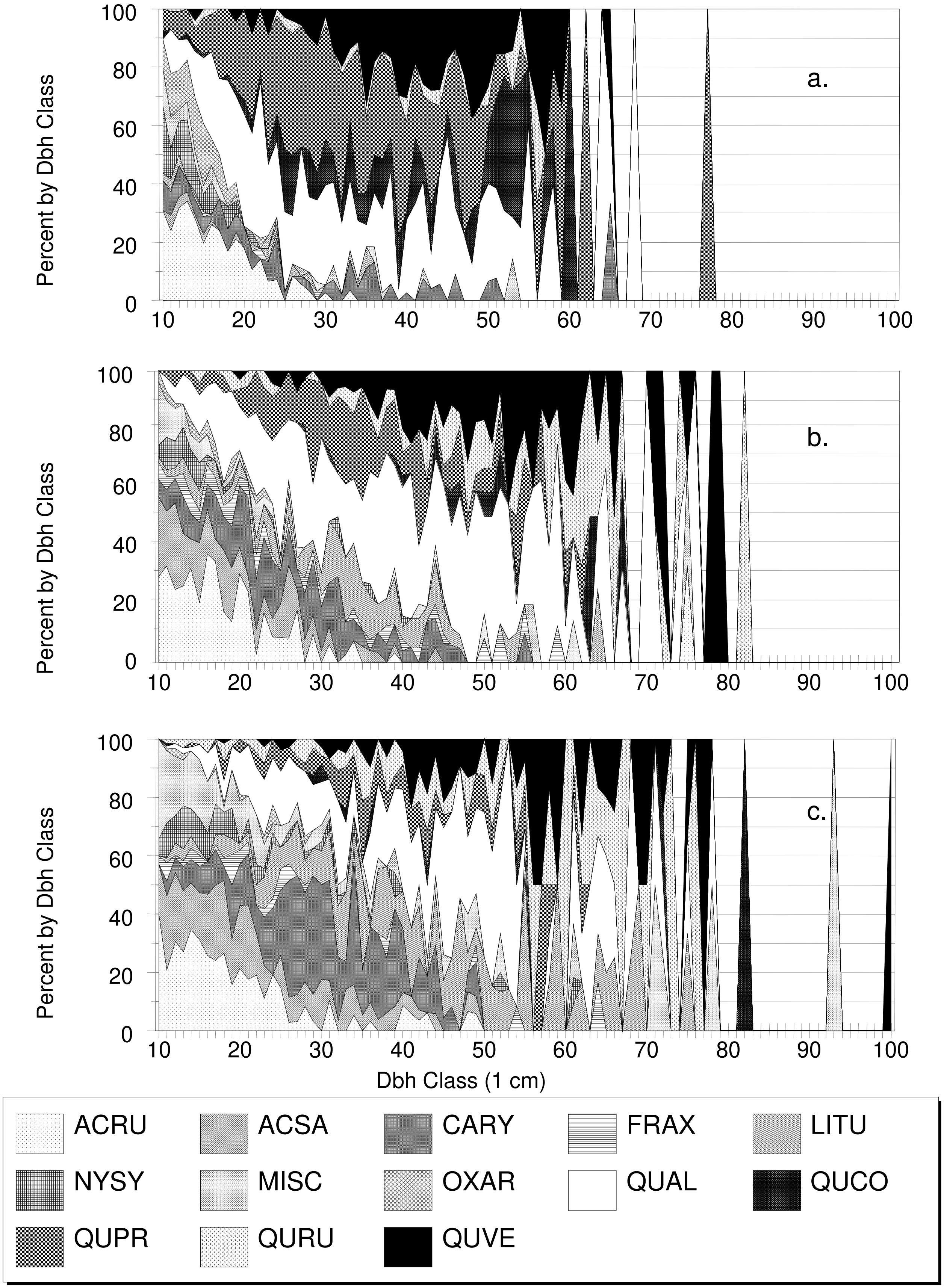

Figure 1.—Percentage of trees by diameter class (1 cm) and IMI class, (a=xeric, b=intermediate, c=mesic). Species included in the miscellaneous group are listed in Table 5.

Crown Class

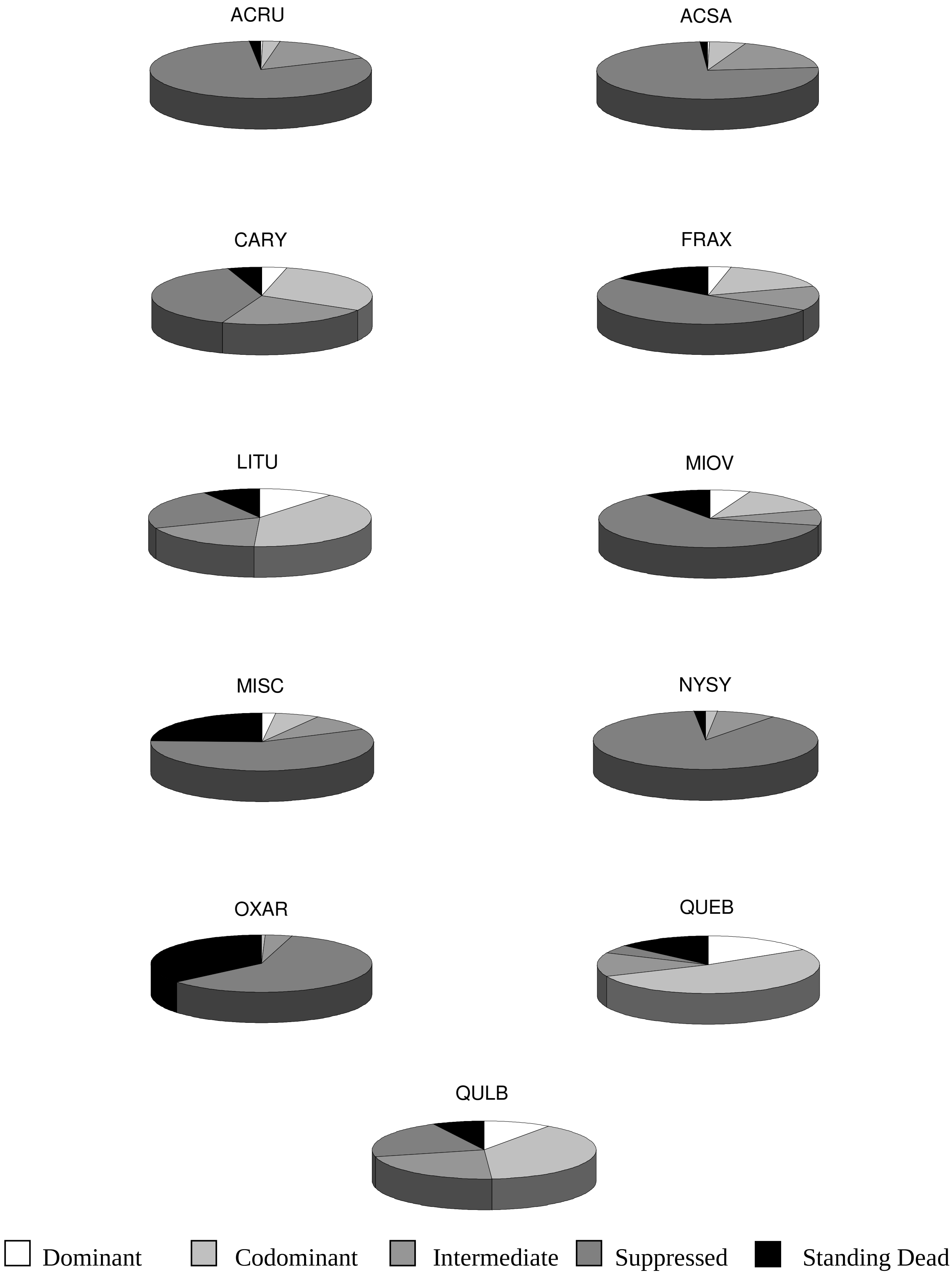

Figure 2.—The relative abundance of trees in the five crown classes for the species groups defined in Table 5.

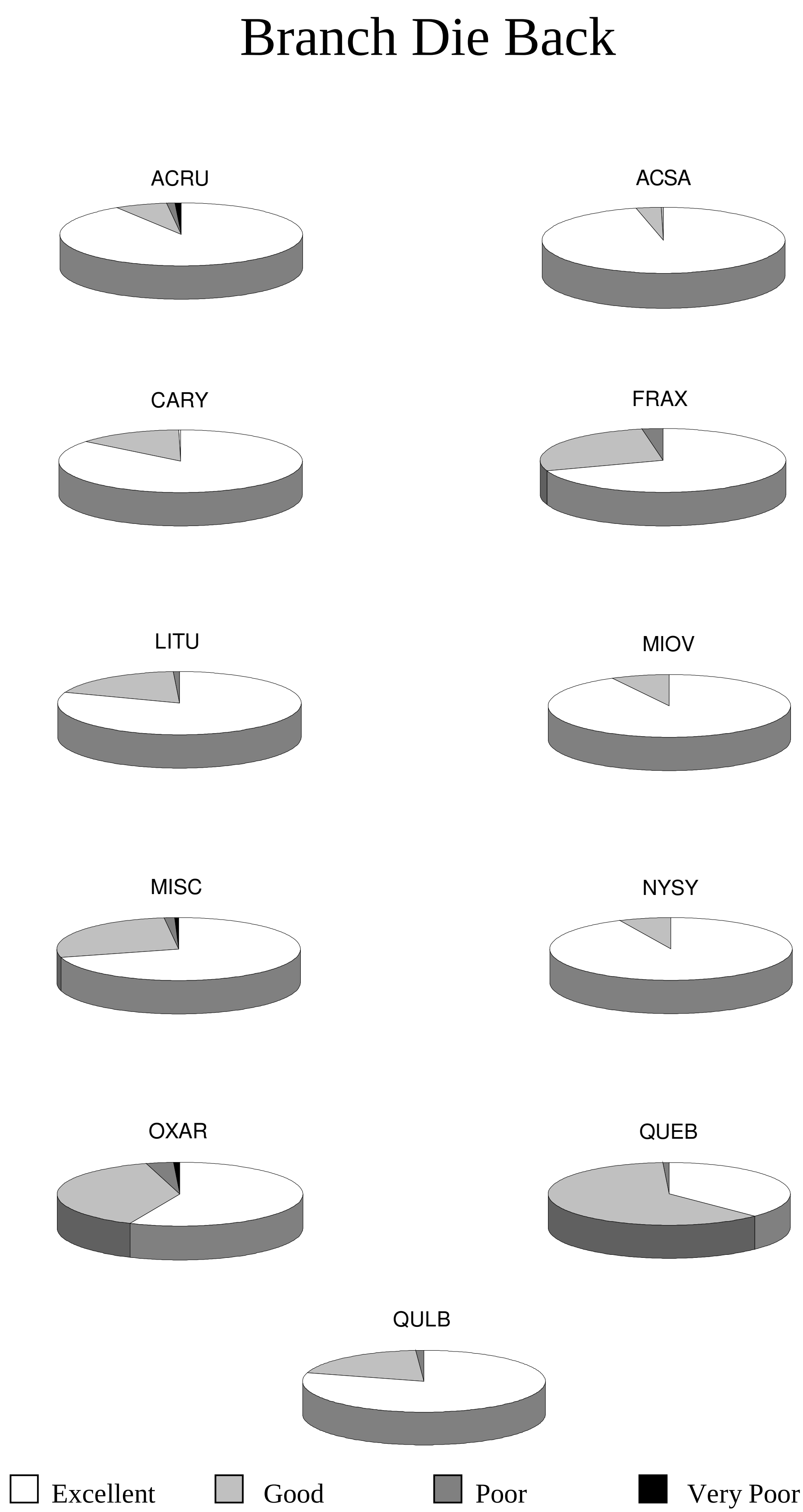

Figure 3.—The relative abundance of tree species groups (see Table 5) for classes of branch die-back. The classes are defined as excellent (<15%), good (15-44.9%), poor (45-74.9%), and very poor (>=75%).

Foliage Transparency

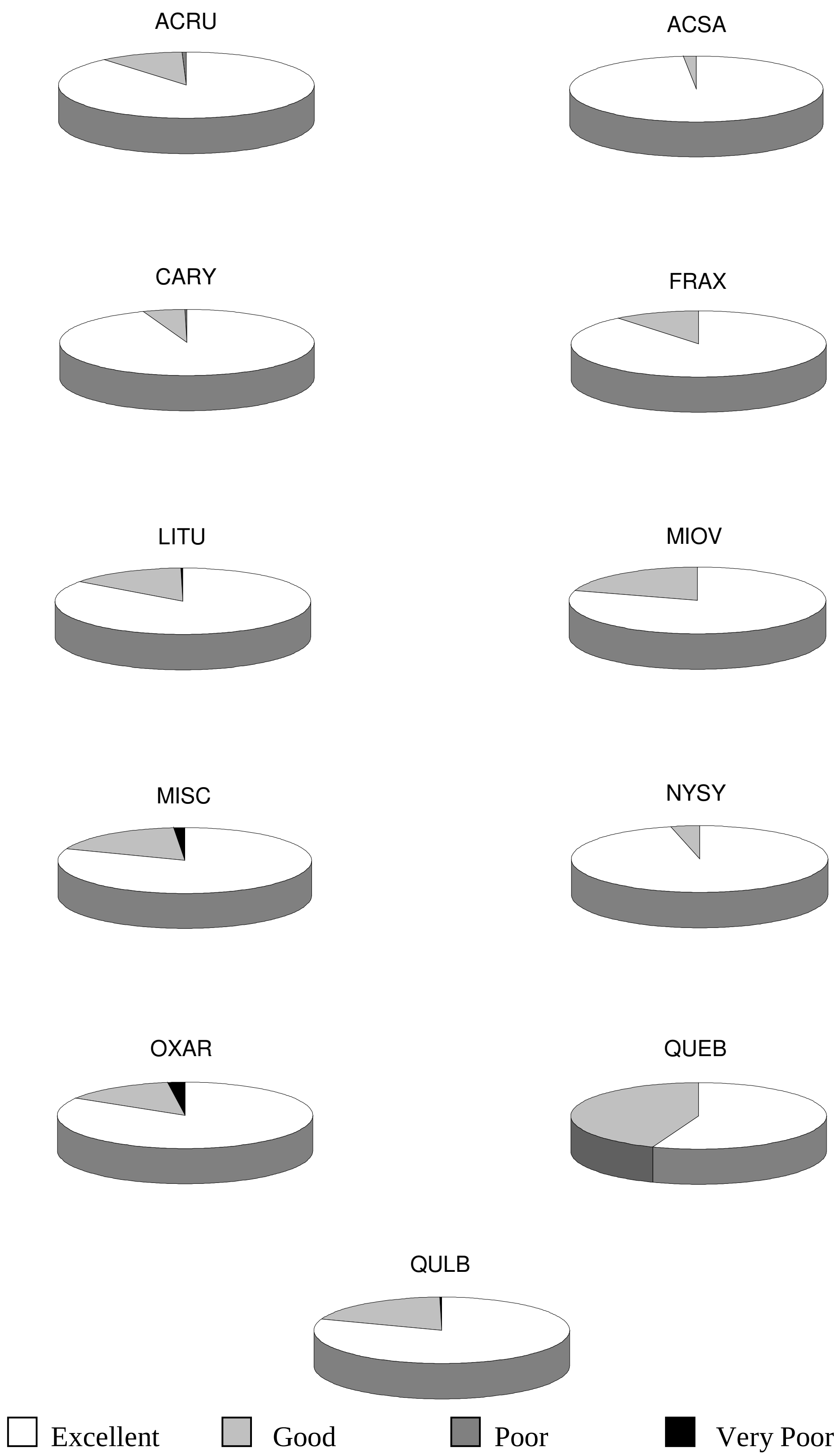

Figure 4.— The relative abundance of tree species groups (see Table 5) for four classes of foliage transparency. The classes are defined as excellent (<15%), good (15-44.9%), poor (45-74.9%), and very poor (>=75%).

Table 4.—Crown condition of overstory trees by size class.

Item	10 to 24.9	25 to 39.9	40 +	Total
	D.b.h. (cm)			
	Percent			Percent
Crown class				
Dominant	0.00	0.51	6.37	6.88
Codominant	0.69	16.19	10.83	27.71
Intermediate	9.82	7.44	0.36	17.61
Suppressed	38.06	1.11	0.04	39.20
Standing dead	8.13	0.34	0.13	8.60
Total	56.70	25.58	17.73	100.00
Total trees	3026	1365	946	5337
Foliage transparency (%)				
5	7.25	1.70	0.72	9.66
10	39.37	20.33	13.06	72.76
20	6.11	5.31	5.27	16.69
30	0.20	0.10	0.14	0.45
40	0.00	0.04	0.00	0.04
50	0.04	0.00	0.00	0.04
90	0.06	0.02	0.00	0.08
100	0.27	0.00	0.00	0.27
Total	53.31	27.50	19.19	100.00
Total trees	2609	1346	939	4894
Branch Dieback (%)				
5	12.28	1.96	0.57	14.81
10	32.61	18.47	11.73	62.81
20	6.11	6.23	5.95	18.29
30	1.12	0.69	0.88	2.70
40	0.37	0.06	0.02	0.45
50	0.39	0.06	0.02	0.47
60	0.06	0.00	0.02	0.08
70	0.14	0.00	0.00	0.14
80	0.12	0.00	0.00	0.12
90	0.10	0.02	0.00	0.12
Total	53.31	27.50	19.19	100.00
Total trees	2609	1346	939	4894

blackgum now are abundant in the smaller size classes (10 to 25 cm d.b.h.). Five tolerant species (dogwood [*Cornus florida*], red maple, sugar maple, blackgum, and beech) accounted for more than 80 percent of the stems in the sapling layer (1.4 m tall to 9.9 cm d.b.h.; Chapter 8). Although the age structures of these forests have not been determined, our results suggest that most of dominant and codominant oaks were established during the stand-initiation stage (Oliver and Larson 1996) in the mid- to late-1800s, and the size-class distributions suggest that shade-tolerant species have invaded these stands more recently. Similar trends of maple invasion in second-growth oak forests in the region have been documented (Tift and Fajvan 1999; Schuler and Fajvan 1999). The initiation of maple invasion during this period corresponds with sharp regional decreases in the frequency and spatial extent of fire (Yaussy and Sutherland 1994), suggesting a causal link. The decrease in fire frequency (ca. 1930) was caused at least in part by fire-suppression policies implemented in Ohio and across the Nation (Pyne 1982).

Although 50,000 acres of forest were defoliated by the gypsy moth (*Lymantria dispar*) in northeastern Ohio in 1996 (http://www.hcs.ohio-state.edu/ODNR/Health / gypsymoth.htm), the invasion front has not yet reached southeastern Ohio. The crown condition of these stands was good with respect to measures of foliage transparency and branch dieback (Millers et al. 1991). In similar oak-dominated forests in southwestern Pennsylvania, gypsy moth defoliation caused a 20- to 40- percent increase in mortality of overstory oaks, resulting in subsequent increases in the basal area of red and sugar maple (Fajvan and Wood 1996). The expanding gypsy moth front is projected to reach our study areas soon. In addition to the increasing abundance of maples and other shade-tolerant species at the four sites, gypsy moth defoliation likely will cause these successional trends to accelerate.

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Table 5.—Average density of overstory (≥ 10 cm d.b.h.) tree species present in 1995 in the four study areas (N=5106 live trees, 13.5 ha sampled, in 108 plots).

Scientific name	Common name	Study area[a]	Code[b]	No. live trees/ha	No. standing dead/ha
Acer rubrum	Red maple	A B W Y	ACRU	52.9	1.0
Acer saccharum	Sugar maple	A B W Y	ACSA	31.6	0.4
Aesculus flava	Yellow buckeye	A B W Y	MIOV[c]	1.9	0.0
Amelanchier arborea	Downy serviceberry	A Y	MISC[d]	0.2	0.1
Carpinus caroliniana	American hornbeam	W	MISC	0.1	0.0
Carya spp.	Hickory	A B W Y	CARY	37.0	1.9
Cercis canadensis	Eastern redbud	A B Y	MISC	0.6	0.0
Cornus florida	Flowering dogwood	A B W Y	MISC	4.0	1.3
Fagus grandifolia	American beech	A B W Y	MIOV	6.0	0.1
Fraxinus spp.	Ash	A B W Y	FRAX	8.3	1.3
Ilex opaca	American holly	W	MISC	0.1	0.0
Juglans nigra	Black walnut	A B W	MIOV	0.5	0.0
Liriodendron tulipifera	Yellow-poplar	A B W Y	LITU	20.7	1.9
Nyssa sylvatica	Blackgum	A B W Y	NYSY	17.0	1.3
Ostrya virginiana	Eastern hophornbeam	B	MISC	0.1	0.0
Oxydendrum arboreum	Sourwood	A B W Y	OXAR	10.0	5.0
Pinus echinata	Shortleaf pine	B	MIOV	0.5	0.7
Pinus virginiana	Virginia pine	B	MIOV	0.1	0.1
Platanus occidentalis	Sycamore	B	MIOV	0.1	0.0
Populus grandidentata	Bigtooth aspen	A W Y	MIOV	0.1	0.3
Quercus alba	White oak	A B W Y	QULB[e]	79.0	7.4
Quercus coccinea	Scarlet oak	A B W Y	QUEB[f]	11.8	2.3
Quercus prinus	Chestnut oak	A B W Y	QULB	49.2	2.6
Quercus rubra	Northern red oak	A B W Y	QUEB	13.4	1.5
Quercus velutina	Black oak	A B W Y	QUEB	24.0	3.7
Sassafras albidum	Sassafras	A B W Y	MIOV	2.1	2.1
Tilia americana	American basswood	A W Y	MIOV	4.4	0.0
Tsuga canadensis	Eastern hemlock	A	MIOV	0.1	0.0
Ulmus rubra	Slippery elm	A B W Y	MIOV	2.6	0.1

[a] Denotes presence of each species in four study areas: A = Arch rock, B = Bluegrass Ridge, W = Watch Rock, Y = Young's Branch.

[b] Codes assigned to species with more than 100 live trees (see Figs. 2-4).

[c] Species with potential to produce trees that will occupy the canopy.

[d] Species with no potential to produce trees that will occupy the canopy.

[e] White oak group (subgenus *Lepidobalanus*).

[f] Red oak group (subgenus *Erythrobalanus*).

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