Effect of Timber Harvest Practices on Populations of *Cornus florida* and Severity of Dogwood Anthracnose in Western North Carolina

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ABSTRACT

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Stand composition and severity of dogwood anthracnose, caused by *Discula destructiva*, were measured on 39 plots located at the Coweeta Hydrologic Laboratory in western North Carolina. The 0.08-ha plots were selected along transects across watersheds previously clearcut, partially harvested, or not harvested. Basal diameter, percent leaf area with dogwood anthracnose symptoms, and percent branch dieback were estimated for *Cornus florida*. Dogwood anthracnose was most severe on partially harvested watersheds and least severe on the clearcut watershed. Density of *C. florida* was greatest on the clearcut watershed, and the number of dogwood stems was inversely correlated ($r = -0.31$, $P = 0.05$) with disease severity. Dogwood basal area, species importance value, and stand basal area were not significantly affected by harvest treatment and were not correlated with disease severity. In a second study, anthracnose severity was rated in 21 plots of yellow poplar near Asheville, North Carolina, that had been thinned to varying densities in the early 1960s. Among these 0.1-ha plots, thinning intensity did not affect disease severity. Disease severity was inversely related to dogwood size.

Dogwood anthracnose, caused by *Discula destructiva* Redlin (14), is a serious threat to flowering dogwood (*Cornus florida* L.) in the northeastern United States and southern Appalachians (6,7) and to Pacific dogwood (*C. nuttallii* Audubon) in certain areas of the Pacific Northwest (14). Although the development of resistant trees represents the best long-range hope for disease control, preliminary evaluations indicate that highly resistant germ plasm is not readily available in *C. florida* (18). Repeated fungicide applications can repress disease development in urban settings (17,21,23), but they are neither practical nor environmentally desirable in forests. Currently, no disease management strategies exist for forested areas.

In their description of dogwood anthracnose in 1988, Hibben and Daughtrey (6) reported greater disease severity in understory than in semiopen locations. Chellemi and Britton (2) related greater disease severity to lower evaporative potential in understory locations than in semiopen locations.

Aspect and both absolute and relative density of *C. florida* were the best predictors of disease severity among several site factors examined in a previous study (3). Disease severity was inversely related to dogwood density, suggesting that site or stand conditions favoring dogwood populations were less conducive to disease development.

Dogwood is considered a shade-tolerant tree, and maximum photosynthesis has been reported at 30% of full sunlight (8). However, Chellemi and Britton (2) found that only 1% of ambient photosynthetically active radiation (PAR) penetrated the overstory to dogwoods in hardwood stands undisturbed since 1927. Thus, low light penetration to understory dogwoods may have resulted in minimal carbohydrate reserves and a limited ability to regenerate leaves following defoliation by anthracnose.

We suspected that partial harvest of overstory hardwoods might reduce disease severity by reducing competition or by increasing evaporative potential in the understory. The studies described here were designed to determine whether partial harvests in the 1950s and 1960s resulted in any long-term change in canopy structure that increased dogwood populations or reduced the severity of dogwood anthracnose.

MATERIALS AND METHODS

Disease and stand conditions were inventoried on two sets of research plots that had received various harvest treatments during the 1950s and 1960s.

Coweeta survey. The first group of plots was located at the USDA Forest Service Coweeta Hydrologic Laboratory in the Nantahala Mountains near Otto, North Carolina. From a network of 987 rectangular plots established along parallel transects at Coweeta in 1944, 39 plots were selected on the basis of watershed treatment, proximity to roads, and presence of at least 10 dogwood trees. To minimize variation in disease due to aspect, only plots facing NNE to SSE were used. The plots were on watersheds that received the following harvest treatments: 1) clearcut to a 2.5-cm limit in 1939 and again in 1962, no trees removed, $n = 7$; 2) 30–35% of basal area removed in 1956, $n = 14$; and 3) controls undisturbed since 1927, $n = 18$. A complete description of the site and watershed treatments is given by Swank and Crossley (22). The selected plots were inventoried during the winters of 1989–1990 and 1990–1991. All woody stems with diameters at breast height (dbh, i.e., 1.5 m above ground) $\geq$1.25 cm were counted and measured. Measurements of flowering dogwood stems were grouped into 2.5-cm-basal-diameter size classes. Dogwood anthracnose severity was estimated between 24 June and 12 July 1991. The percent existing leaves with symptoms of anthracnose and the percent branches with dieback were estimated separately according to a 12-point scale, in which 0 = healthy, 1 = 1–10% affected, 2 = 11–20%, 3 = 21–30%, 4 = 31–40%, 5 = 41–50%, 6 = 51–60%, 7 = 61–70%, 8 = 71–80%, 9 = 81–90%, 10 = 91–100%, and 11 = dead. Foliar data are specific for anthracnose symptoms. Limb dieback is attributed to a variety of causes and should be considered a measure of general tree health. All plots were rated by the same observers.

A general linear models procedure (19) was used to analyze variation in disease severity and general tree health among watershed treatments. Plot means were weighted to adjust for the number of trees sampled in each plot. Means were separated with t tests using three individual contrast statements. Pearson's correlation coefficients and multiple regression were used to determine the single and combined relationships of four continuous variables on disease severity: stand basal area, number of dogwood stems, dogwood basal area, and species importance value. Importance value was calculated as: [(dogwood basal area/total basal area) + (dogwood stems/total stems)]/2.

To compare stand structure under the different harvest treatments, we ranked species on the basis of proportional abundance from the highest to the lowest in each treatment. To determine whether watersheds were intrinsically

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comparable with respect to woody plant diversity, the cumulative proportion of stems was plotted against the number of species included from one to the maximum number of species in the stand after the method of Patil and Taillie (13). Overstory composition in the different watersheds was compared by calculating the percent stand basal area for all trees with dbh ≥ 8.75 cm.

Bent Creek survey. The second group of plots was located at the USDA Forest Service Bent Creek Research and Demonstration Forest near Asheville, North Carolina. Twenty-one plots, originally established to study growth and yield of yellow poplar (*Liriodendron tulipifera* L.), were inventoried. The 0.1-ha circular plots had been thinned in the early 1960s to initial residual basal areas ranging from 3.7 to 12.1 m^2. Basal areas at the time of this study ranged from 6.0 to 18.9 m^2 (mean = 12.5). Severity of dogwood anthracnose and percent branch dieback were estimated as at Coweeta, except that only 10 arbitrarily selected *C. florida* per plot in each of the following three size classes were rated: 1) dbh < 2.5 cm, 2) dbh 2.5–4.9 cm, and 3) dbh ≥ 5.0 cm.

A matrix of Pearson's correlation coefficients (19) was constructed to assess the effects of initial stand density after thinning, current stand density, site index (1), slope, landform index (11), terrain shape index (10), gradient, and elevation on disease severity. Multiple regression was used to examine partial relationships to disease severity. An analysis of variance was performed to examine the relationship between dogwood size and disease severity; the means for size classes were separated with Duncan's multiple range test.

RESULTS

Coweeta survey. The mean severity of dogwood anthracnose ranged from 10 to 68% and averaged 22%. Limb dieback ranged from 13 to 83% and averaged 47%. These two measures were correlated ($r = 0.82$, $P = 0.0001$).

Disease severity was significantly greater on partially harvested watersheds than on clearcut watersheds and was intermediate on control watersheds (Table 1). Trees growing on partially harvested watersheds also had significantly more branch dieback than trees growing on control watersheds (Table 1).

The number of dogwood stems per hectare was negatively correlated with disease severity over all plots combined, and there were fewer than one-half as many dogwood stems on partially harvested watersheds as on the clearcut watershed (Table 2). Dogwood basal area and species importance value were not affected by harvest treatment (Table 2). However, 90% of the dogwoods in the clearcut watershed were ≤9 cm in basal diameter, compared with 68% in the control and the partially harvested watersheds (Fig. 1).

The species diversity profiles in Figure 2 show that two watersheds were intrinsically comparable. Since the profile for the undisturbed watershed was dominated by the profile for the clearcut watershed and no intersection occurred, the undisturbed watershed was intrinsically more diverse than the clearcut watershed for the 25 most abundant species in each watershed. This ordering was index-free and would be confirmed by any valid diversity index. The clearcut watershed departed from maximum diversity (even distribution of species) with relatively larger proportions of the most abundant species and relatively smaller proportions of the least abundant species.

The sample profiles for undisturbed and partially harvested stands intersected twice. According to Patil and Taillie (13), when two profiles intersect, there exists a pair of diversity indices that order the communities oppositely. Using methods described by these authors, we defined families of diversity indices (I_β) for the partially harvested and undisturbed watersheds with the parametrized function:

$$I_\beta = (1 - \sum_{i=1}^{s} p_i^{\beta+1})/\beta, -1 \leq \beta,$$

where p_i = proportion of total sample stems accounted for by species i in a given watershed. Three of the most commonly used diversity indices are members of each family: the species count ($s - 1$) occurs at $\beta = -1$, Shannon's index occurs at $\beta = 0$, and Simpson's index occurs at $\beta = 1$. Therefore, β may be interpreted as a sensitivity parameter, since I_β is sensitive to rare species for values of β near -1 and it is sensitive to abundant species when β is close to 1.

For each harvest treatment we computed jackknifed estimates (24) of I_β and its standard error for 39 values of β in the range: $-1 \leq \beta \leq 2$. All differences in I_β values for the two treatments were subjected to approximate t tests and found to be nonsignificant ($P > 0.23$), failing to confirm that intersections in cumulative abundance profiles are real. Thus, we conclude that intersections are due to sample variation or our experiment was too small to confirm intersections.

Nearly 90% of the total number of woody stems in each harvest treatment were composed of only 10 species. The most common were: flowering dogwood, yellow poplar, rhododendron (*Rhododendron maximum* L.), red maple (*Acer rubrum* L.), mountain laurel (*Kalmia latifolia* L.), chestnut (*Castanea dentata* (Marsh.) Borkh.), hickory (*Carya tomentosa* (Poir.) Nutt.), black gum (*Nyssa sylvatica* Marsh.), sourwood (*Oxydendrum calendulaceum* (L.) DC.), hemlock (*Tsuga canadensis* (L.) Carrière), sweet birch (*Betula lenta* L.), chestnut oak (*Quercus prinus* L.), northern red oak (*Q. rubra* L.), and black oak (*Q. velutina* Lam.). The relative proportions of the most abundant species based on density and on basal area are shown in Figures 3 and 4. Dogwood was the most abundant species in undisturbed watersheds, whereas rhododendron was the most abundant species in the clearcut and partially harvested watersheds (Fig. 3). In basal area, yellow poplar predominated in the clearcut stand, whereas red maple,

Table 1. Effect of harvest practices on severity of dogwood anthracnose in plots at Coweeta Hydrologic Laboratory in western North Carolina

Previous harvest type[y]	Leaf area infected (%)	Branch dieback (%)
Partial	30 a[z]	58 a
Clearcut	15 b	44 ab
None	23 ab	38 b

[y] Partial harvesting in 1956, clearcut in 1939 and again in 1962, and controls undisturbed since 1927.

[z] Means in columns followed by the same letter do not differ significantly at $P < 0.05$ based on individual t tests of weighted means.

Table 2. Effects of harvest practices on stand composition variables and their correlation (Pearson's r [P]) with anthracnose severity at Coweeta Hydrologic Laboratory in western North Carolina

Harvest type	Stand basal area[w]	Correlation of stand basal area with disease severity	Dogwood basal area[x]	Dogwood stems/ha	Correlation of dogwood stems/ha with disease severity	Species importance value
Partial	31.4 a[y]	+0.56 (0.04)	0.95 a	338 b	+0.48 (0.08)	0.14 a
Clearcut	33.7 a	−0.46 (0.08)	1.55 a	788 a	−0.61 (0.15)	0.12 a
None	31.2 a	−0.16 (0.57)	1.20 a	488 b	−0.25 (0.28)	0.19 a
Combined[z]	31.7	−0.17 (0.30)	1.27	446	−0.31 (0.05)	0.16

[w] Estimated in square meters as the mean total area per hectare at breast height for all woody species, excluding *Cornus florida*.

[x] Estimated in square meters as the mean total basal area per hectare measured at the base of *C. florida*.

[y] Numbers in columns followed by the same letter are not significantly different at $P < 0.05$ according to Duncan's multiple range test.

[z] Means and correlation coefficients for all plots combined.

chestnut oak, northern red oak, and hickory were the major components of the undisturbed and partially harvested stands (Fig. 4).

Total stand basal area was positively correlated with disease severity on partially harvested watersheds but not on clearcut or control watersheds (Table 2).

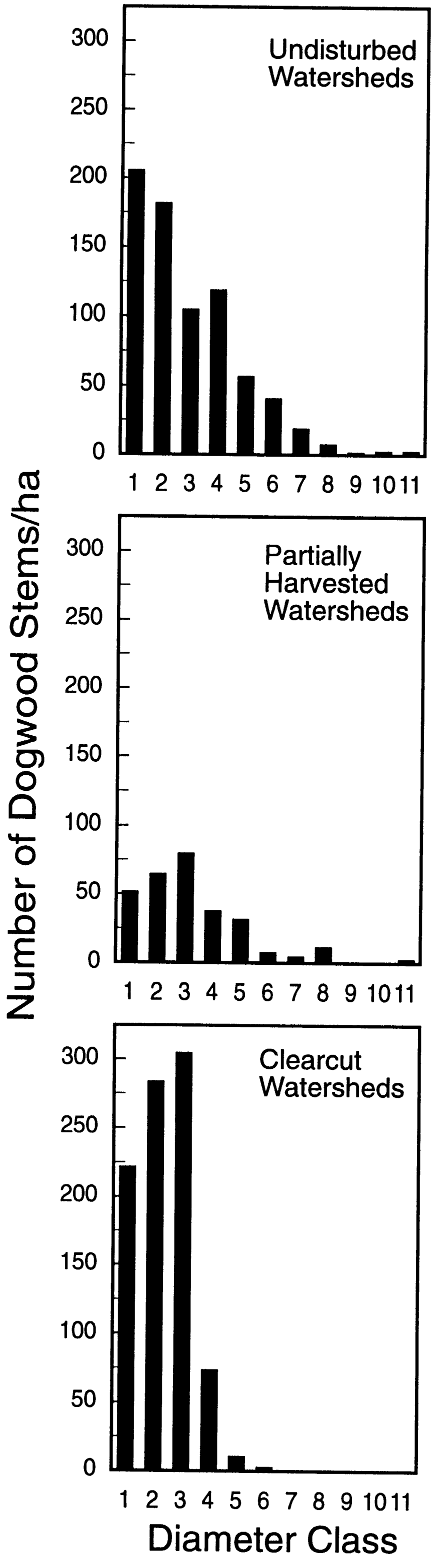

Fig. 1. Dogwood size class distributions (size class interval = 2.5 cm basal diameter) in undisturbed, partially harvested, and clearcut watersheds at Coweeta.

Harvest treatment did not affect current stand basal area. Multiple regression parameter estimates were not significant at $P = 0.15$.

Bent Creek survey. The severity of anthracnose ranged from 13 to 36% and averaged 23%. Limb dieback ranged from 30 to 71% and averaged 47%. These two measures were correlated ($r = 0.82$, $P = 0.0001$). However, none of the stand or site variables was significantly correlated with anthracnose severity or dieback, and multiple regression parameter estimates were not significant at $P = 0.15$. Smaller dogwoods were more severely diseased than larger trees (Table 3).

DISCUSSION

These studies are of interest because partial harvesting of overstory trees had been considered for dogwood anthracnose control in forests. We hypothesized that partial harvesting would reduce dogwood anthracnose severity due to reduced competition and to long-term changes in canopy structure that would promote evaporative potential, light penetration, and the vigor of understory dogwoods. However, the results of these studies support the rejection of this hypothesis.

At Coweeta, partial harvesting did not reduce disease severity or promote dogwood population development. In fact, the clearcut watershed had more dogwood stems per hectare and also had the lowest disease severity. Neither stand nor dogwood basal area was significantly different from those on undisturbed control plots 29–34 yr after harvest. However, the relative abundance of dogwood was greatest on control plots.

Neither initial residual basal area nor current stand basal area affected disease severity in plots at Bent Creek thinned to a wide range of densities. The high level of disease in these plots, the close correlation between ratings for foliar symptoms and limb dieback, and the consistent significant differences in disease severity found among the different size classes of dogwoods in these plots argue that the measures used were sufficiently sensitive to detect a long-term effect of thinning on disease severity. Thus, both studies failed to show any beneficial effect of partial harvesting, and the Coweeta data suggest that thinning may actually be detrimental in the long term.

Dogwoods are generally cut or damaged during thinnings, but they regenerate readily from stump and root sprouts. The energy costs of regeneration may reduce the ability of the tree to compartmentalize invading hyphae of facultative pathogens such as *D. destructiva* (20). In clearcut stands, these costs may be offset by release from competition for light. In lightly thinned stands such as the partially harvested watersheds at Coweeta, rapid closure of the overstory may reduce the vigor of regenerated dogwoods and reduce the ability to survive infection. Light quality may also vary among these stands, as species regenerate in different proportions. Transmitted light spectra vary within the canopy of different plant species (9,16), and the quality of light has a greater influence on plant growth than the quantity of light (4). Overstory plants can absorb as much as 89% of the visible and PAR light range, transmitting and reflecting mostly wavelengths <400 nm and >750 nm (5,9). In response to lower light quality, both shade-tolerant and shade-intolerant species decrease leaf thickness, root/

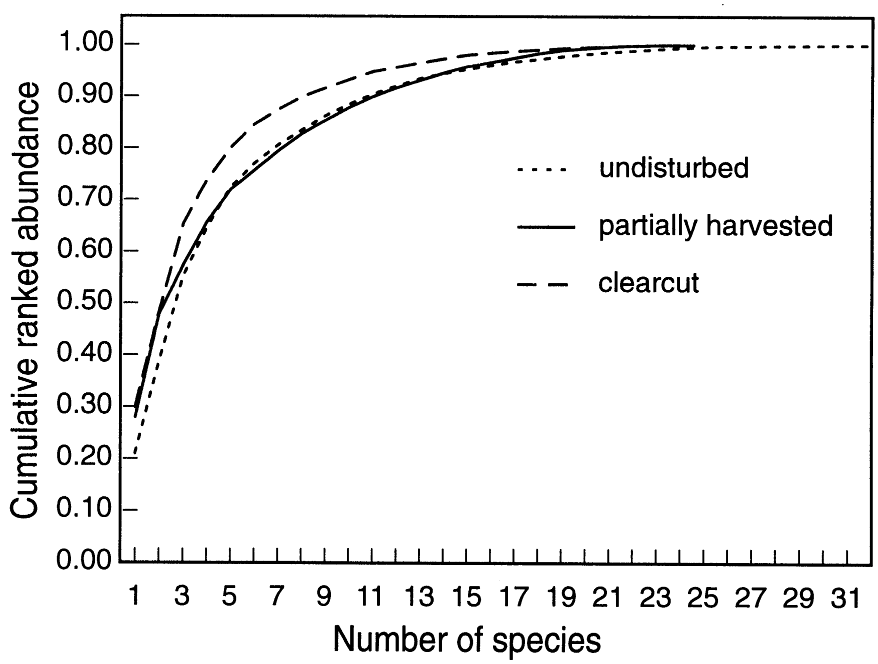

Fig. 2. Cumulative ranked abundance of species in undisturbed, partially harvested, and clearcut watersheds at Coweeta.

shoot weight ratio, dry matter content, net CO_2 assimilation rate, and relative growth rate, while increasing dark respiration (4). The architecture of the predominant overstory species also affects both the quality and the quantity of light penetration, with more diffuse radiation penetrating clearcut stands because of their irregular vertical structure (12). This results in a more favorable red/far-red ratio in pioneer stands than in old growth (12). In addition to the effects on host physiology, the microclimate in the canopy is influenced by the amount, duration, and spatial distribution of solar energy directly, as well as indirectly through its effects on evaporation and transpiration (15). The data presented here suggest that increased light, as provided temporarily in the clearcut watershed, is more beneficial than the increased water and nutrients made available through partial harvest.

Although the Bent Creek data indicate that small trees were more severely infected than large trees, it should be noted that size is not necessarily correlated with age. At Coweeta, most trees in the clearcut stand were <9 cm in basal diameter and the oldest was 28 yr. Many trees in the partially harvested and control watersheds were considerably older. Small trees in the clearcut watershed were relatively young and in general appeared vigorous. Trees of similar size in the partially harvested and control stands could have been older but growing in suppressive conditions affecting both regeneration and susceptibility.

Chellemi et al (3) reported a negative correlation between dogwood density and disease severity in stands undisturbed since 1927. A similar relationship was observed in the present study. However, in thinned plots, disease severity tended to increase with dogwood density. Although confirming earlier conclusions that denser dogwood populations had less disease overall, the current study demonstrates that this conclusion cannot be generalized to thinned stands.

Dogwood anthracnose has been considered an introduced pathogen because of its rapid spread on hosts native to North America and because the earliest reports of infection originated near ports of entry on both coasts in the mid- to late 1970s (14). Thus, the fungus was probably not present in the surveyed stands during the first few years after treatment, when the theoretical beneficial effects of thinning would be greatest. It therefore remains possible that dogwoods in stands infected with *D. destructiva* might benefit temporarily from thinning. Further studies are required to examine the effects of harvest practices in stands where anthracnose is present. However, based on the studies reported here, stand thinning did not result in the long-term development of a canopy structure that favored dogwood populations or reduced anthracnose severity.

Table 3. Influence of dogwood size on anthracnose severity in mature yellow poplar stands at Bent Creek, North Carolina

Dogwood dbh (cm)	Leaf area infected (%)	Branch dieback (%)
<2.5	33 a[z]	69 a
2.5–4.9	23 b	43 b
≥5.0	17 c	29 c

[z] Data points represent mean disease ratings of 10 trees per size class from each of 21 plots. Means in columns followed by different letters differ significantly at $P < 0.05$ according to Duncan's multiple range test.

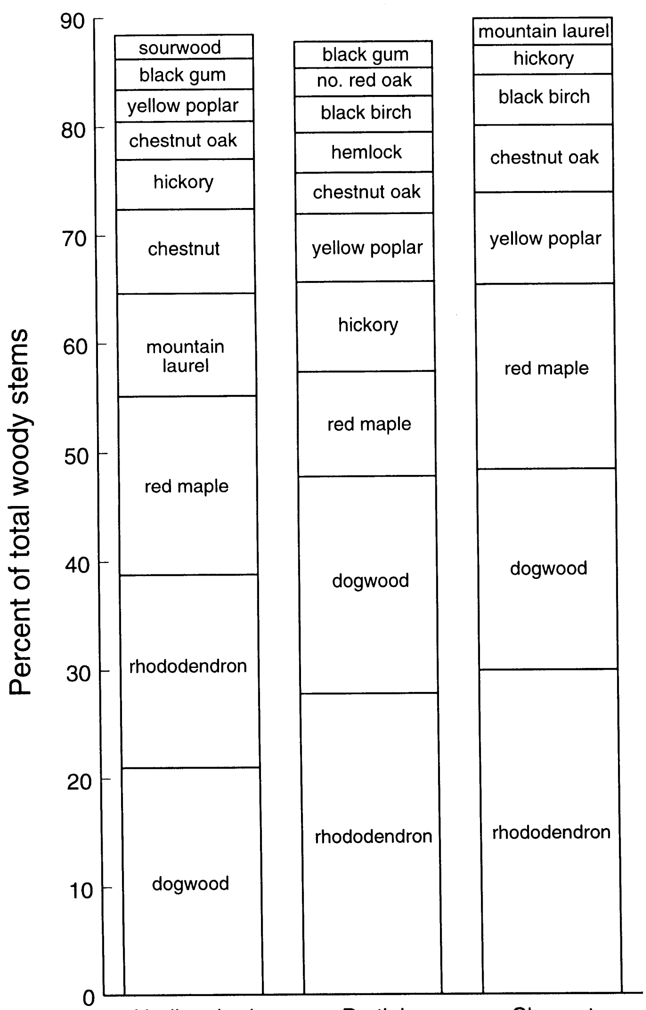

Fig. 3. Densities, based on percentage of total stems, of the 8 most abundant species.

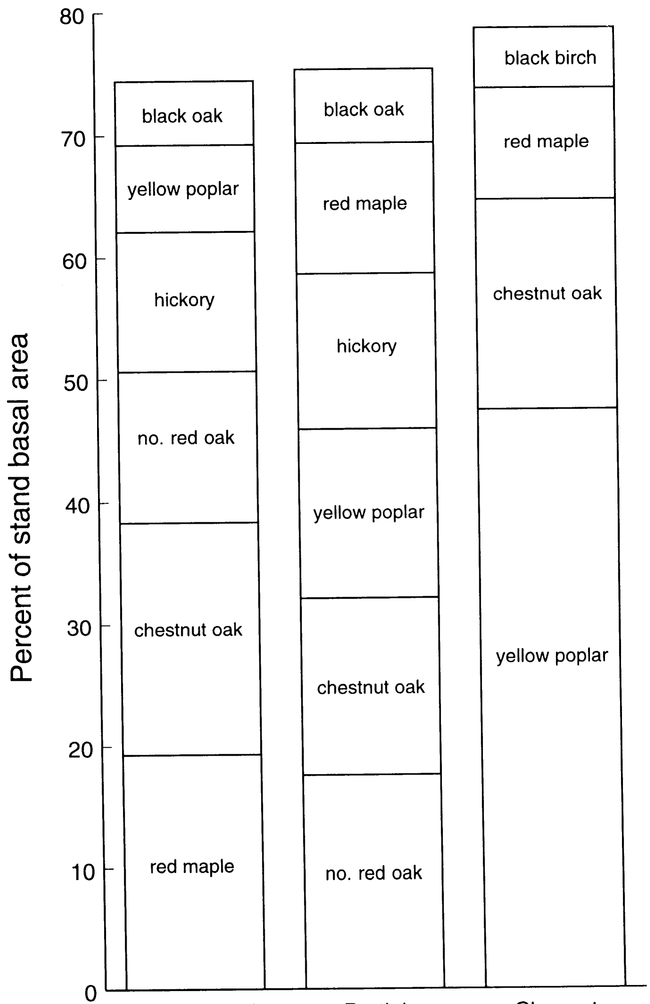

Fig. 4. Overstory composition, based on percentage of stand basal area, for trees with diameters at breast height ≥ 8.75 cm.

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