A Comparison of Forest Dynamics at Two Sites in the Southeastern Ozark Mountains of Missouri

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Abstract: Changes in tree species composition and regeneration patterns were studied in 53 permanent vegetation plots located at two sites (Pioneer Forest and University State Forest) in oak-hickory forests of southeastern Missouri where mortality and decline of red oak species have been identified. The two sites also exhibited differing levels of decline and mortality. Between 1962 and 1991 the importance value (IV) of white oak at University State Forest increased from 20 to 56%, while that of black oak and, to a lesser degree, scarlet oak decreased. Over the same 28 year period, the IV of white oak at Pioneer Forest increased from 36 to 49%, but the importance of black oak remained constant, and the importance value of scarlet oak decreased only slightly. Sapling densities of the red oak species group (black oak, scarlet oak, and southern red oak) ranged from 2-43/ha at University State Forest and from 0 to 30/ha at Pioneer Forest. These densities were low when compared to those of the corresponding white oak species group (white oak and post oak) sapling densities for University State Forest (16-51/ha) and Pioneer Forest (0-148/ha). Recent recruitment does suggest, however, that red oak group species will have a continued importance in these forests; the densities of black oak and scarlet oak seedlings (880-1665/ha at University State Forest and 408-1167/ha at Pioneer Forest) were comparable to those of post oak and white oak (1187-1474/ha at University State Forest and 233-2625/ha at Pioneer Forest).

INTRODUCTION

Since 1980 a considerable increase in red oak group mortality has been observed in the Ozark Mountains of southeastern Missouri (Johnson and Law 1989). As a result, over 35 million board feet of dead and dying oak timber was harvested in salvage sales on the Mark Twain National Forest between 1980 and 1986 (Law and Gott 1988). In addition, there has been much discussion about which management methods best ensure oak regeneration in Ozark forest stands (Sander 1983).

The history of the Ozark region is one of disturbance. Early Native Americans are believed to have shaped the early Ozarks into an open mosaic of forest types through the use of fire (Buckner 1989, Guyette and Cutter 1991). After settlement and the removal of the indigenous people, fire frequency was greatly reduced and the forests of the region became less open (Beilmann and Brenner 1951). The majority of this forest was pine or oak-pine in composition, with *Pinus echinata* Mill. (shortleaf pine) dominating upper slopes and ridges and *Quercus alba* L. (white oak) dominating lower slopes (Cunningham and Hauser 1989).

At the turn of the century large lumber companies logged huge portions of the forest, ultimately removing 1.5 billion board feet of lumber (Schuchard and Kohler 1984). The major focus of this logging was *Pinus echinata* (shortleaf pine), but oak was also cut for use in flooring, barrel staves, and rail road ties (Hill 1949). Of the oak species, *Quercus alba* was the most heavily harvested

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(Hill 1949). This large scale harvest greatly reduced the importance of *Pinus echinata* in the region and allowed the establishment of red oak group species on sites formerly dominated by *Pinus echinata* (Law and Gott 1987).

Over the past two decades much concern has been expressed about oak stands not being replaced by new oak stands after harvest in oak-hickory forests (Loftis 1983). Oak regeneration success is usually dependent upon some sort of disturbance which allows greater light intensities to reach shade intolerant oak seedlings. Stands that have been thinned, or lightly burned generally possess a greater reservoir of oak regeneration that stands that have been left undisturbed (Carvell 1979). In traditionally managed stands, clear-cutting and shelterwood methods often are used to produce higher light intensities to encourage oak regeneration (Johnson 1982).

One can hypothesize that while past disturbances and land use practices have created fairly homogeneous, even-aged stands across much of the Ozark Mountain region, the effect of this phenomenon on species composition and regeneration may vary with differing management strategies. Certain management strategies may serve to decrease the negative effects of oak decline and mortality while improving regeneration. This study compared the vegetation dynamics of 53 permanent plots located at two sites (University State Forest and Pioneer Forest) in southeastern Missouri in which mortality and decline of red oak species have been identified. The permanent plots at University State Forest have essentially been unmanaged since the large scale timber harvest at the turn of the century (J. Dwyer, School of Natural Resources, University of Missouri, personal communication). The permanent plots at Pioneer Forest have been managed through selective cutting and thinning since the 1950's (C. Trammel, Pioneer Forest, personal communication). By comparing the permanent plots at these two sites, a comparison of differences in vegetation composition through time and regeneration was made.

MATERIALS AND METHODS

Two approaches were employed to accomplish study objectives. First, a characterization of mortality present in the Ozark Region and the resulting changes in vegetational composition were completed through the sampling of permanent continuous forest inventory (CFI) plots at University State Forest and Pioneer Forest. In addition, regeneration was determined through the measurement of seedling and sapling densities on these plots. Sampling was completed during the summers of 1990 and 1991 at University State Forest and Pioneer Forest, respectively.

Study Sites

University State Forest

University State Forest is located in Wayne and Butler Counties approximately 16 km north of Poplar Bluff (36° 55' N, 90° 15' W) on the southeastern edge of the Missouri Ozarks. University State Forest has a less rugged topography than is found to the north and northwest. Broad and narrow ridges are common, giving way to steep or gentle side slopes with frequent rock outcrops along major streams and drainages (Nigh 1984). Fragipans are often present on broad level ridgetops, with side slopes displaying varying amounts of chert (Graves 1983).

Pioneer Forest

Pioneer Forest is a large (62,889 ha), privately-owned tract of forested land located in 7 counties of the eastern Ozark Mountains. Stands occupy a wide range of topography, ranging from steep rugged slopes and dissected ridges to gentle slopes and plateaus. CFI plots sampled at Pioneer Forest were located throughout Dent, Shannon, and Reynolds Counties. These three counties contained the best range of red oak species group mortality on Pioneer Forest. CFI plots in this research had experienced light disturbance through selective cutting and understory thinning (C. Trammel, personal communication).

Selection of CFI plots

Individually, plots were selected to offer a broad representation of the varying degrees of oak decline present in each study site. For the purpose of this study, decline and mortality were synonymous. The past data from the CFI plots made this comparison of mortality between plots possible. Although a wide diversity of decline levels was the primary criterion for the selection, plots also were selected to provide an ample representation of the micro-environmental conditions (topography, soil, etc.) present at each study site. Plots exhibiting heavy or recent logging, extremely low basal area and/or extensive management were eliminated from consideration for sampling.

Vegetation Sampling

The CFI plot trees at University State Forest and Pioneer Forest have been measured every five years between 1962 and 1987. Vegetation sampling for this project was completed during the summers of 1990 and 1991. Once a plot was selected, the sampling strategy consisted of two parts: (1) remeasurement of previously established permanent plots, and (2) additional sampling of seedling and sapling layers, which were not included in the permanent plot databases. On each plot dbh of the previously censused and ingrowth trees was measured. In addition, a concentric one-tenth acre (0.04 ha) circular plot was inventoried for the total number of saplings (stems $\geq$ 1 m in height) by species, and four one-thousandth acre (0.00004) circular plots were surveyed for seedling density. These four seedling plots were placed random at distances north, south east, and west from plot center. Thirty-two permanent plots at University State Forest and 21 permanent plots at Pioneer Forest were sampled.

Data Preparation and Analysis

Density (stems/ha), basal area (m^2/ha), and importance value (IV = relative density [species density/total density] + relative basal area [species basal area/total basal area]) were calculated for each remeasurement of the CFI plots. In addition, the density of seedlings and saplings was calculated for each plot.

Quercus velutina and *Q. coccinea* mortality was then quantified. This was accomplished by using CFI plot data to calculate the percent mortality for each remeasurement interval. These intervals were: 1962-1967, 1967-1972, 1972-1977, 1977-1982, 1982-1987, and 1987-1990 (University State Forest) and 1991 (Pioneer Forest). The number of trees that died in an interval was divided by the number of trees living in 1962. Since the sampling of the CFI plots was a 100% census, it was unnecessary to test changes in species mortality, basal area, density, or importance within a site for significance.

RESULTS

Analysis of the mortality of living trees from the 1962 measurement revealed different mortality rates and patterns between University State Forest and Pioneer Forest (Figure 1). University State

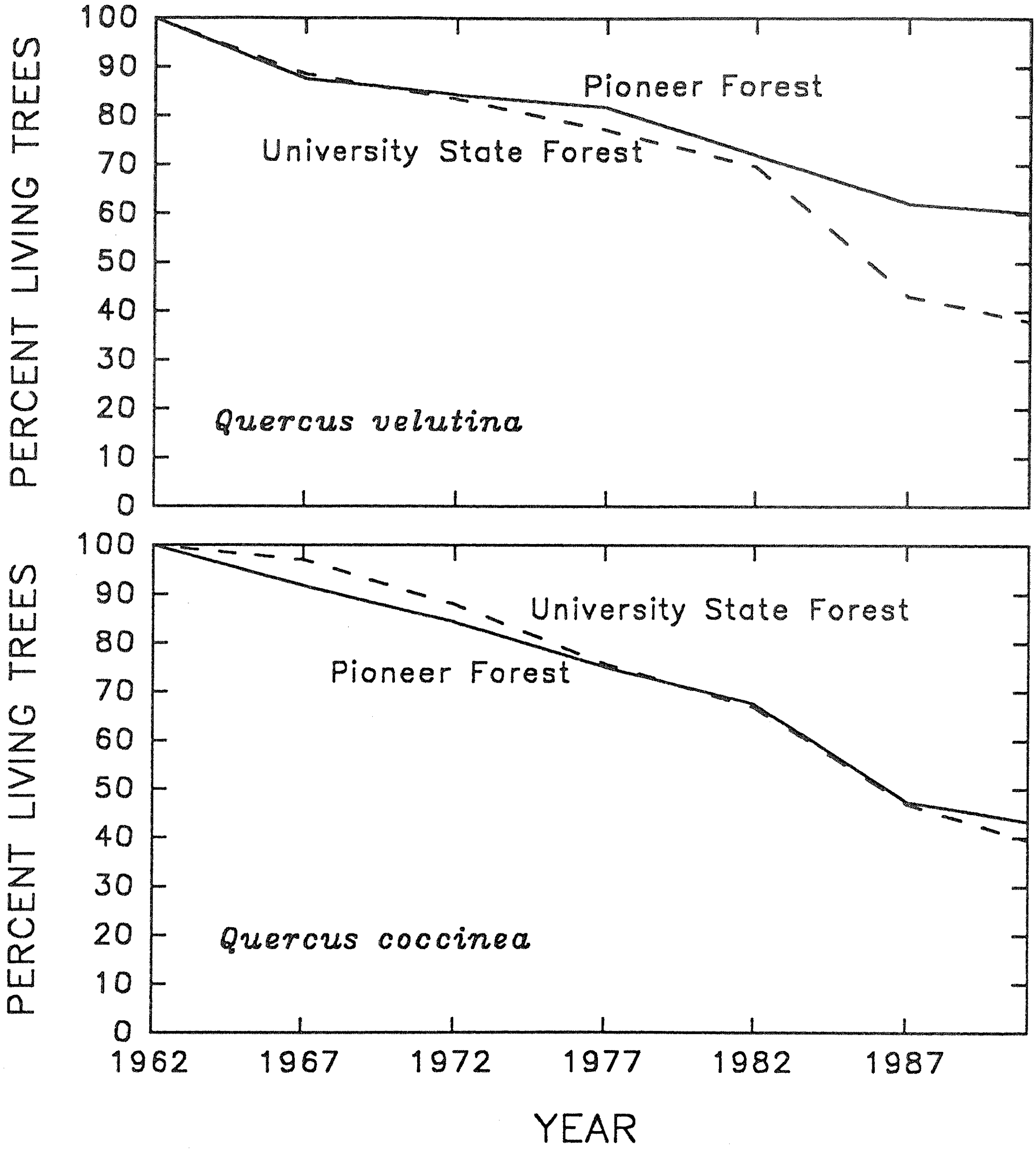


Figure 1.—Comparison of the mortality of *Quercus velutina* and *Q. coccinea* trees which were living at University State Forest and Pioneer Forest in 1962. Plot represents percent of original trees living at each remeasurement.

Forest sustained much greater relative mortality of the original *Quercus velutina* living trees than did Pioneer Forest. Only 38% of the *Q. velutina* trees originally measured at University State Forest in 1962 were still living in 1991, compared to 60% for Pioneer Forest. The mortality rate of *Q. velutina* at University State Forest mirrored that at Pioneer Forest until the 1982 remeasurement, but between 1982 and 1990 the mortality rate of this species at University State Forest was significantly greater ($p = 0.05$) then at Pioneer Forest. The two sites showed no significant differences in the mortality of *Q. coccinea* trees from the 1962 measurement. Approximately 40% of the *Q. coccinea* trees measured in 1962 were still living in 1991 at both sites.

Analysis of IV over the 29-year period revealed several changes in the species composition of both sites (Figure 2). The IV of *Quercus velutina* showed a sharp decrease at University State Forest since the 1982 measurement, but no such decrease was apparent at Pioneer Forest. At both sites there was a slight decrease in the IV of *Q. coccinea*. Significantly, there was an increase in *Q. alba* IV at both sites. This increase was more notable at University State Forest, which showed a sharp increase in *Q. alba* IV after 1982, corresponding to the drop in *Q. velutina* IV over the same time period.

These different trends in oak species composition can be better explained by examining changes in basal area, density, relative basal area, and relative density (Figures 3-6). At University State Forest there were sharp declines in both mean plot basal area and mean plot density of *Quercus velutina* following the 1982 remeasurement, with mean density also declining steadily before 1982. This trend held true when relative basal area and relative density of *Q. velutina* were considered, but the declines were not as steep nor as sudden. Pioneer Forest experienced no such declines in *Q. velutina* mean density, and a small but steady increase in mean basal area. The relative density and relative basal area of *Q. velutina* at Pioneer Forest exhibited similar trends.

As previously stated, the decline in *Q. coccinea* IV was slight at both sites. The mean density of *Q. coccinea* has declined steadily at University State Forest since 1967, but the rate of decline increased after 1982. There also was a decrease in mean *Q. coccinea* basal area following 1982, after a steady increase since 1962.

Consideration of *Q. coccinea* relative basal area and relative density at University State Forest revealed that these declines in basal area and density were not as severe when compared to the basal area and density of all species. A decline in *Q. coccinea* relative density was evident, but the extent was considerably less than was suggested by absolute density. In addition, there was little if any discernible decrease in *Q. coccinea* relative basal area. These findings suggest that the decline in *Q. coccinea* density is being compensated by an increase in the basal area of living trees.

Pioneer Forest has experienced only a slight decease in *Quercus coccinea* mean density since 1982, and has experienced an increase in *Q. coccinea* mean basal area over the same time period. In addition, no discernible changes in relative density or relative basal area have occurred since 1982, and only a slight overall decrease has occurred since 1962. *Quercus alba* appears to be only one of the dominant canopy species increasing in importance at both sites. The large increase in mean density, combined with a slight increase in mean basal area, suggest that this increased importance is due to an increase in smaller *Q. alba* trees. This trend is supported by the relative density and relative basal area of *Q. alba* at both study sites. At University State Forest a rapid increase in relative density of *Q. alba* is evident following the 1982 remeasurement. An increase in relative basal area after 1982 also was evident, but the magnitude of increase was reduced in comparison to that of relative density. Pioneer Forest also experienced an increase in *Q. alba* relative basal area and relative density.

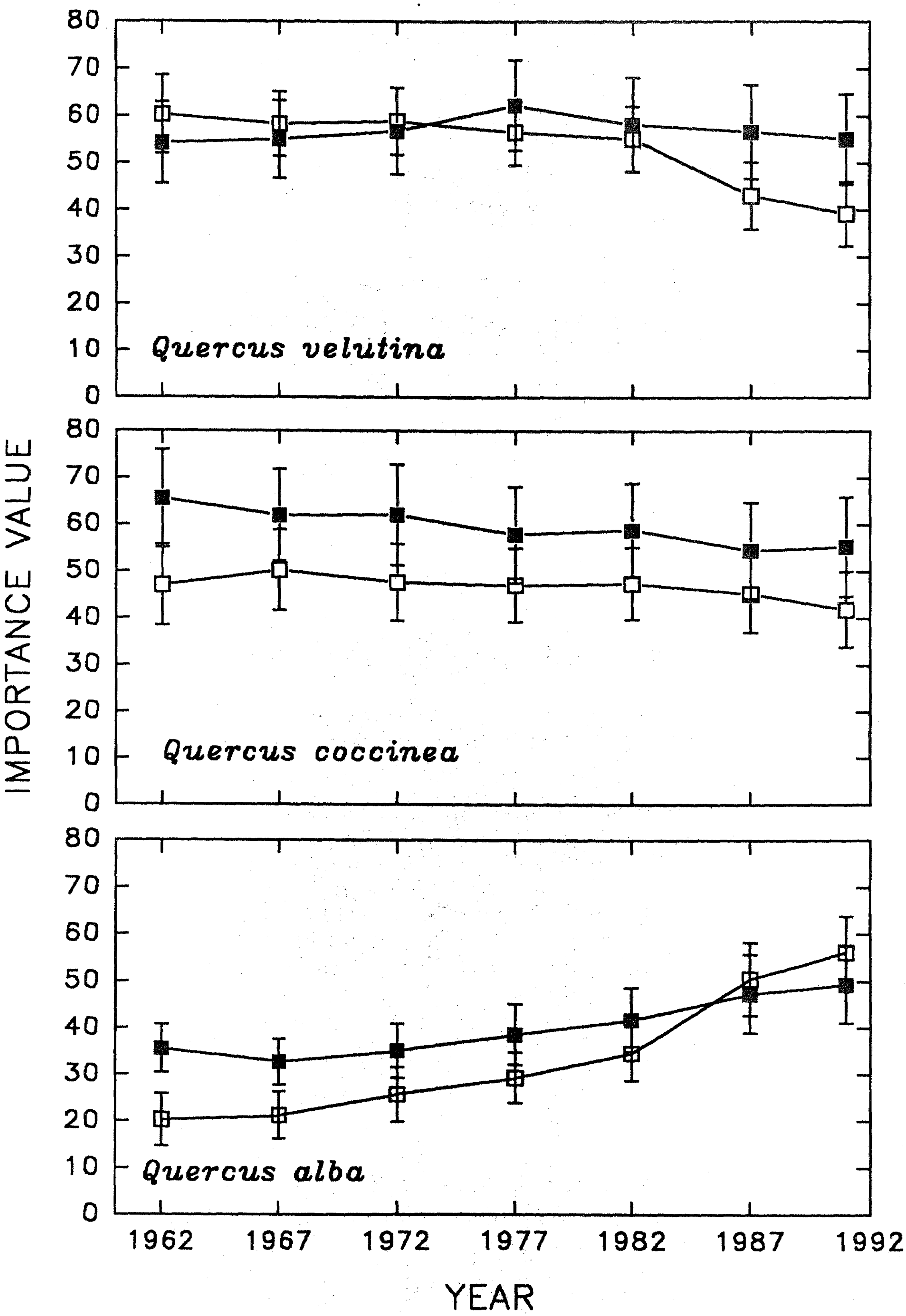


Figure 2.—Comparison of importance value of major *Quercus* species at University State Forest and Pioneer Forest between 1962 and 1991. Bars represent ± 1 S.E.

□ University State Forest
■ Pioneer Forest

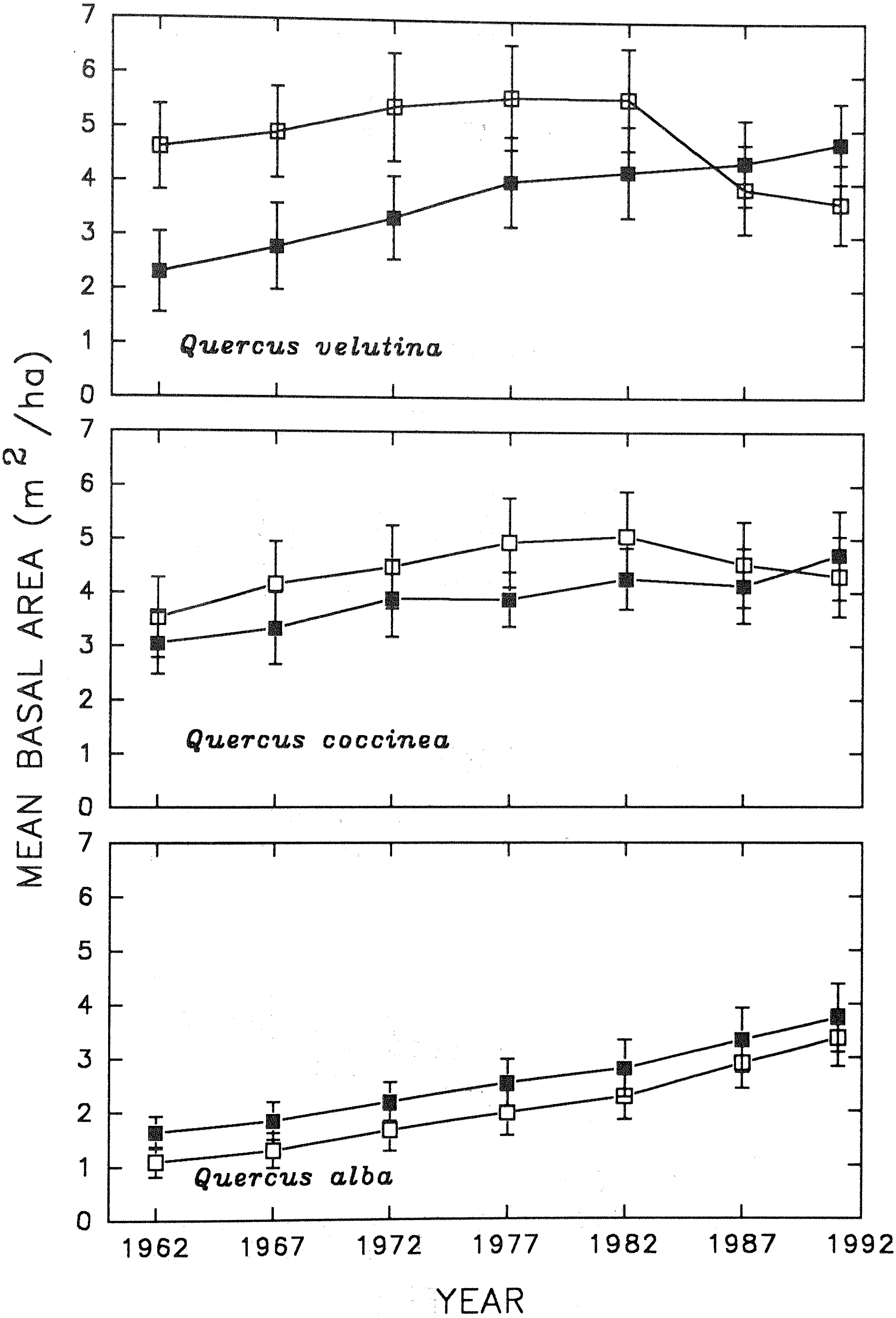


Figure 3.—Comparison of mean plot basal area of major *Quercus* species at University State Forest and Pioneer Forest between 1962 and 1991. Bars represent ± 1 S.E.
□ University State Forest
■ Pioneer Forest

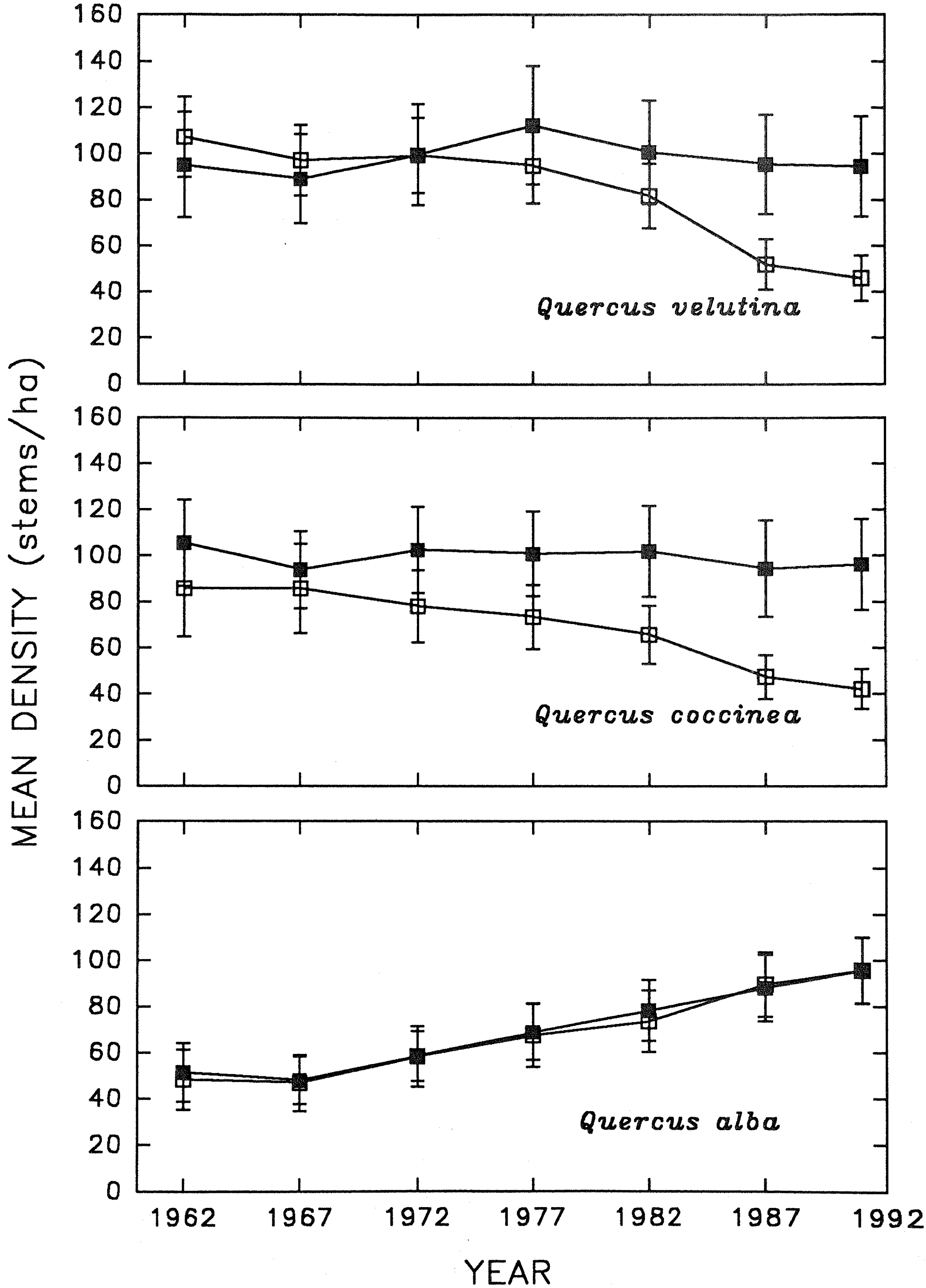
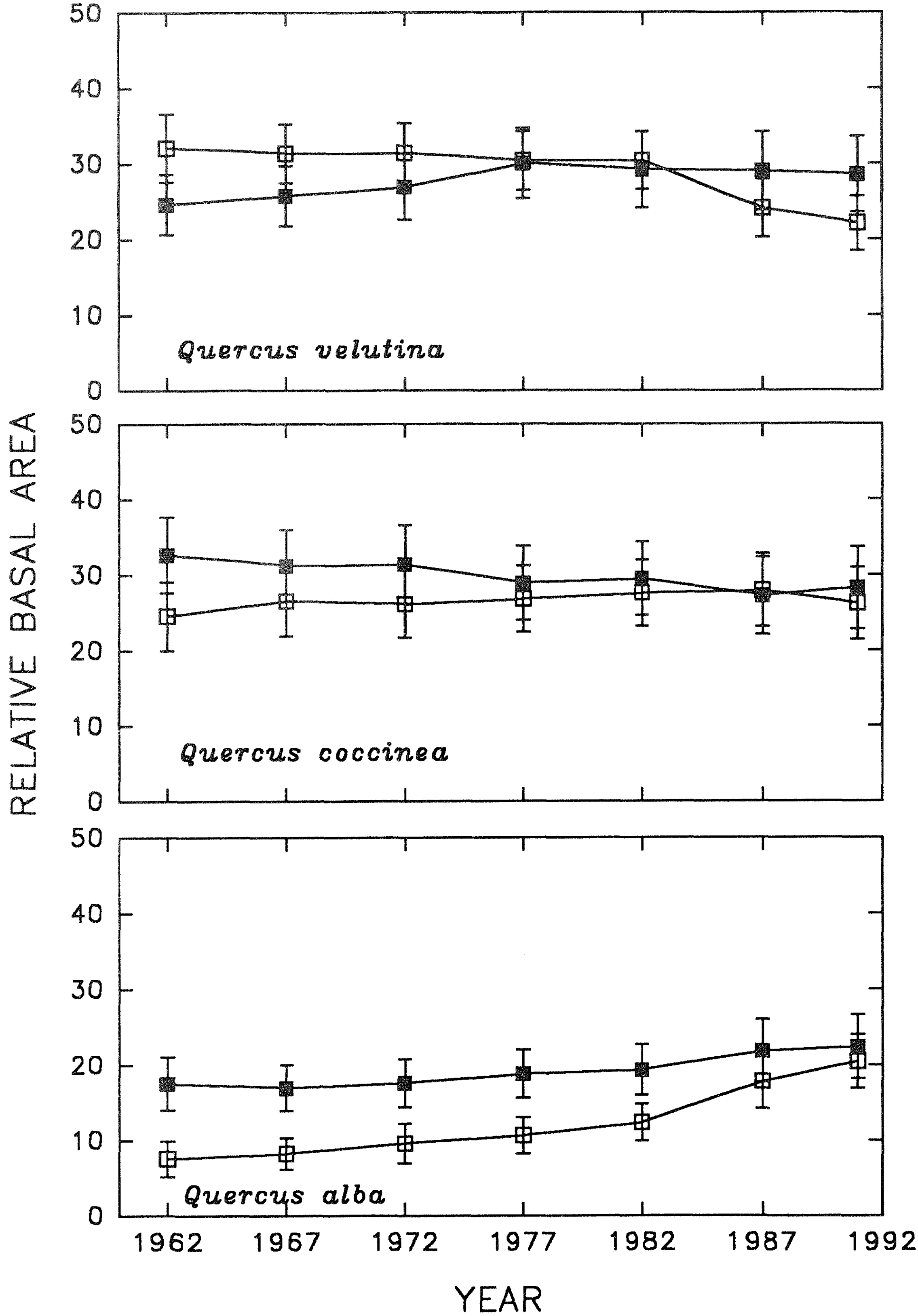


Figure 4.—Comparison of mean plot density of major *Quercus* species at University State Forest and Pioneer Forest between 1962 and 1991. Bars represent ± 1 S.E.

□ University State Forest

■ Pioneer Forest



;ure 5.—Comparison of relative basal area of major *Quercus* species at University State Forest d Pioneer Forest between 1962 and 1991. Bars represent ± 1 S.E.

□ University State Forest

■ Pioneer Forest

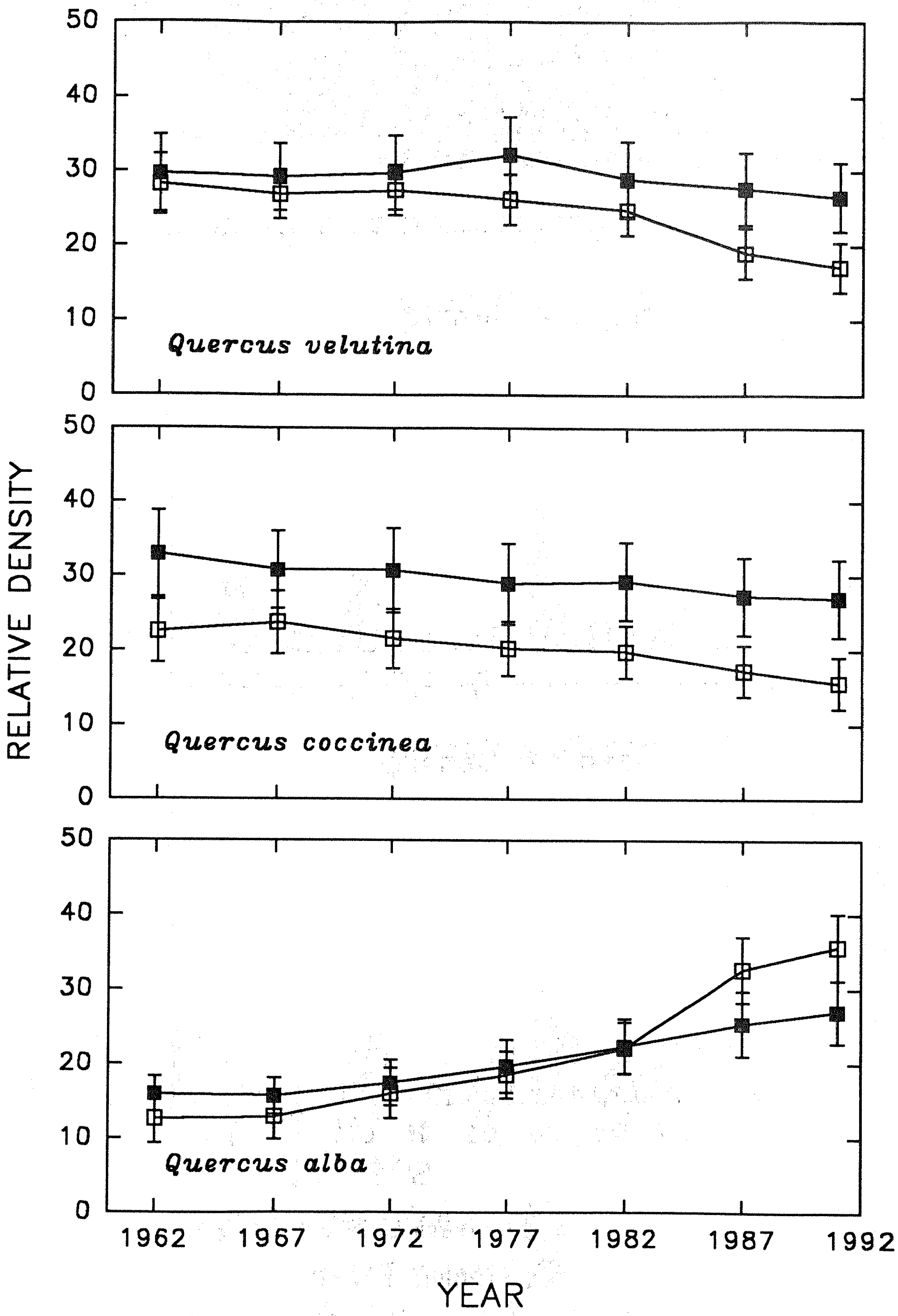


Figure 6.—Comparison of relative density of major *Quercus* species at University State Forest and Pioneer Forest between 1962 and 1991. Bars represent ± 1 S.E.

□ University State Forest

■ Pioneer Forest

The dominance of red oak group species observed in the canopy stratum of the two sites was not evident in the sapling layer (Figure 7). Across both sites *Quercus coccinea* sapling densities were significantly lower (p = 0.05) then those of *Quercus alba*. The sapling densities of *Quercus velutina* across the two sites were also lower then those of *Q. alba*, but the differences were not significant. Overall, *Cornus florida* was the dominant sapling layer species across the study sites (254 stems/ha), followed by *Sassafras albidum* (106 stems/ha), *Carya texana* (98 stems/ha), *Nyssa sylvatica* (83 stems/ha), and *Q. alba* (80 stems/ha), respectively.

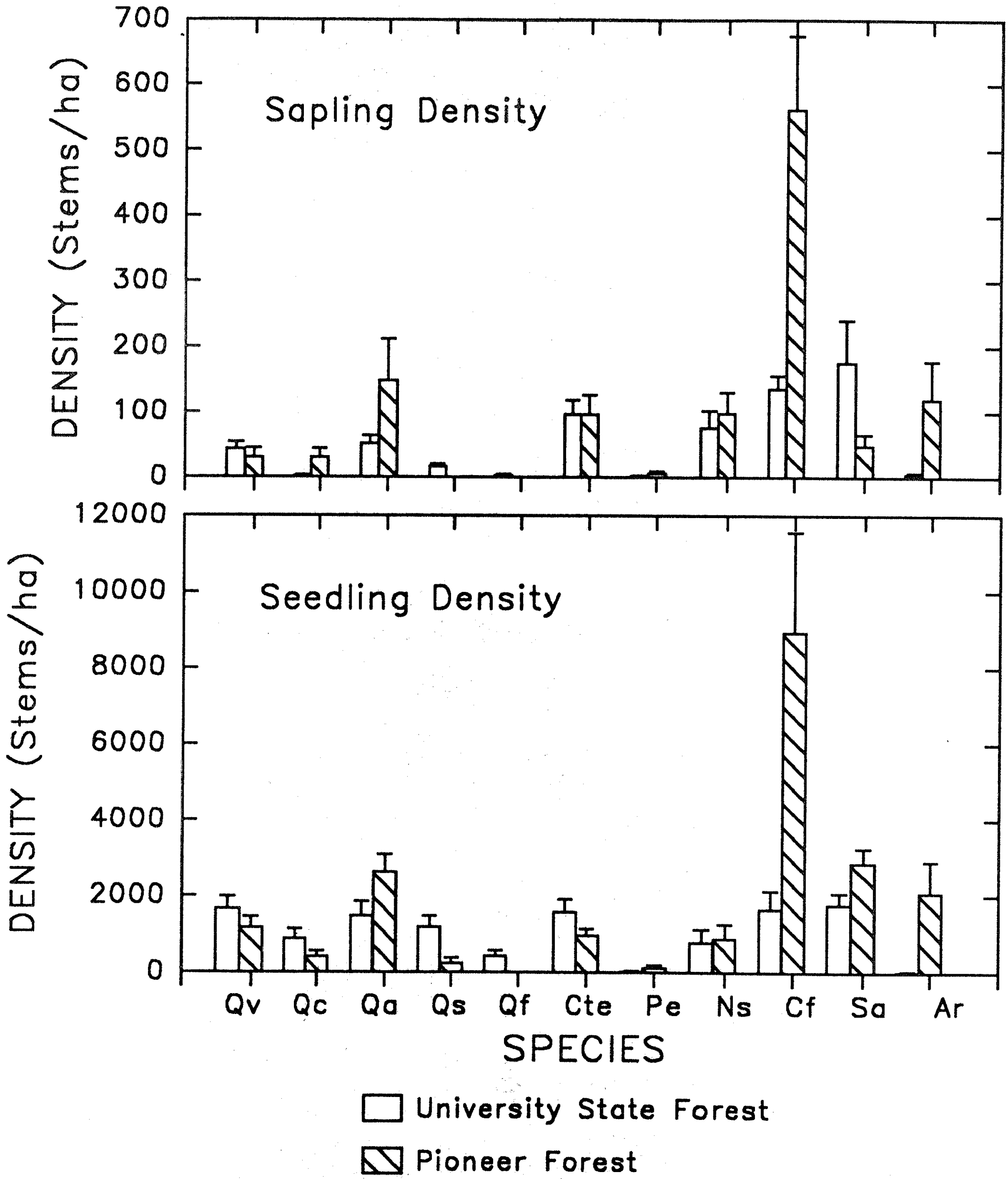


Figure 7.—Mean sapling and seedling densities for the 0.08 ha plots. Bars represent ± 1 S.E.
Qv = *Quercus velutina*, Qc = *Q. coccinea*, Qa = *Q. alba*
Qs = *Q. stellata*, Qf = *Q. falcata*, Ct = *Carya texana*,
Pe = *Pinus echinata*, Ns = *Nyssa sylvatica*, Cf = *Cornus florida*, Sa = *Sassafras albidum*, Ar = *Acer rubrum*.

Analysis of sapling densities by site suggested differences in sapling layer composition between study sites (Figure 7). Pioneer Forest appeared to have a greater density of *Q. alba* saplings than University State Forest. Pioneer Forest had a significantly greater ($p = 0.05$) *Q. coccinea* sapling density than University State Forest. Although University State Forest had the higher *Q. velutina* sapling density, the difference between sites was not significant. Pioneer Forest had a significantly greater ($p \leq 0.01$) *Cornus florida* sapling density than the other two sites. Dominance of *Cornus florida* in the sapling and seedling layers was stated as a management problem in some Pioneer Forest stands (C. Trammel, personal communication).

The three study sites exhibited differing seedling densities for the major seedling layer species. Pioneer Forest exhibited a significantly higher ($p = 0.05$) *Quercus alba* seedling density than University State Forest. Plots of the two study sites exhibited no significant differences in *Q. velutina* seedling density. The *Quercus stellata* density at University State Forest was significantly greater ($p = 0.05$) than that of Pioneer Forest. The three sites also differed in the seedling densities of non-oak species. Pioneer Forest's *Cornus florida* seedling density was significantly greater ($p= 0.01$) than that of University State Forest. This high seedling density, combined with the high *C. florida* sapling density, indicated that this species is dominant in the Pioneer Forest understory.

DISCUSSION

Differences in vegetational composition and temporal trends were evident between the two study sites. University State Forest and Pioneer Forest exhibited similar *Quercus coccinea* mortality, but University State Forest exhibited much greater *Q. velutina* mortality. In addition, changes in IV between 1962 and 1991 suggest that, with regard to vegetation composition, the two sites are moving in different directions. University State Forest has experienced a decline in *Q. velutina* IV since 1980, while the IV of this species at Pioneer Forest has remained stable. Both University State Forest and Pioneer Forest showed a slight decrease in *Q. coccinea* IV between 1980 and 1987, but after this period the IV of *Q. coccinea* at Pioneer Forest increased, while at University State Forest importance of this species continued its gradual decline. At both sites there has been an increase in *Q. alba* IV, but at Pioneer Forest the rate of increase has been constant since 1967 while at University State Forest *Q. alba* IV has increased dramatically since 1982.

This large scale cutting of timber over a relatively short period resulted in mostly even-aged stands at both sites. The even-aged nature of these stands has possibly increased the importance of cohort senescence in the region. According to Mueller-Dombois (1988), a forest that consists of a mosaic of even-aged stands, stand segments in advanced age states, or senescing cohort stands can be expected to die more or less synchronously, when an environmental or biotic trigger is provided. In Missouri, drought appears to have been this trigger (Law and Gott 1987, Jenkins 1992). While cohort senescence has been described as a natural phenomenon (Mueller-Dombois 1987), the previous land use practices in the Ozarks may have abnormally enhanced its probability and produced a predisposition to large scale oak decline and mortality.

Differences in the management of the two sites may in part explain their differences in forest composition and red oak group mortality resulting. The stands in which permanent plots were studied at University State Forest have been essentially unmanaged since they were first harvested at the turn of the century. Pioneer Forest (including the CFI plots), however, has been managed through the use of selective cutting and thinning. Thinning is conducted in immature stands to reduce competition as the stand matures. When enough trees within a stand are of sufficient size for harvest, these larger trees are selectively cut. The cutting of these trees may explain the lower *Quercus velutina* mortality at Pioneer Forest. The observed reduction in natural mortality of this species may be because of harvesting of the larger trees before they die. When mortality at Pioneer Forest resulting from selective cutting and thining was combined with that resulting from natural causes, University State Forest still exhibited significantly greater ($p = 0.05$) mortality after 1982.

However, the difference in mortality between the two sites was greatly reduced. In addition, the harvesting of these larger, slower-growing trees may allow the younger, faster-growing trees to grow with reduced competition for light, water and nutrients. This increased availability of light may also explain why Pioneer Forest has shown no major decrease in the density of *Q. velutina* and *Q. coccinea*, two species that are considered shade intolerant (Hinckley et al. 1979). Finally, the selective cutting employed at Pioneer Forest may be creating more uneven aged stands, which would therefore be less susceptible to synchronous mortality associated with cohort senescence as described by Mueller-Dombois (1987).

Selective cutting has long been criticized for not allowing sufficient oak regeneration (Sander and Clark 1971). However, the results of this study indicate that oak regeneration on Pioneer Forest is certainly comparable, and perhaps superior, to that of University State Forest. *Quercus velutina* and *Q. coccinea* seedling densities were not significantly different on the two sites. Pioneer Forest, however, did have a significantly greater density of *Q. alba* seedlings. In addition, Pioneer Forest had significantly greater *Q. coccinea* and *Q. alba* sapling densities than did University State Forest. These results suggest that uneven-aged management of oak-hickory forests in the Ozarks might provide sufficient regeneration to perpetuate oak species in subsequent stands.

While the two sites have exhibited different trends in mortality, vegetational composition, and regeneration, there are several overall trends that are evident at both sites. As stated earlier, both sites have shown increased numbers of small *Quercus alba* trees. A similar trend was observed by Johnson and Law (1987) in a declining *Q. coccinea* stand on the Fristoe Unit of Mark Twain National Forest. This result suggests that *Q. alba* is going to have increased importance in the future canopy as the red oak group trees die.

In addition, both sites exhibited *Quercus* sapling densities which were lower than those of other species, while exhibiting seedling densities comparable to those of other species. Cho and Boerner (1991) observed such a sparse representation of *Quercus* species in the sapling layer in an Ohio "old-growth" forest, although *Quercus* species seedling density was relatively high. More mesic, shade tolerant species such as *Acer saccharum* and *Fagus grandifolia* dominated the sapling layer, suggesting that there was insufficient light reaching the forest floor to facilitate the release of the seedlings present. Since *Quercus alba* is more shade tolerant then *Q. coccinea* and *Q. velutina*, the other dominant species found on the forest floor of the xeric Ozark Mountains, one can speculate that it is best able to survive under a canopy that is less dense than that of the Ohio "old growth" forest. Johnson (1992) also observed an occurrence of low red oak group and high white oak group sapling density in two xeric ecosystems in Michigan. These sites were not undergoing accelerated mortality, and therefore the light levels required to release red oak group species regeneration on the forest floor may not have been present. From these findings one can suggest that in the Missouri Ozarks red oak group mortality may be allowing a new cohort of red oak group species to ultimately reach the canopy.

Even without frequent disturbance, oak regeneration usually is not a problem on xeric sites (Loftis 1983). These sites tend to support relatively stable communities that show little evidence of succession to more shade-tolerant, mesic species (Pallardy et al. 1988, 1991, Johnson 1992). Stands of oak species growing on xeric sites tend to accumulate reproduction in their understory in the form of sprouts and acorns, often for 50 years or longer (Johnson 1992). These ecosystems, characterized by such "auto-accumulating" reproduction, are therefore often self-sustaining (Johnson 1979, 1992).

The release of this accumulated reproduction often is dependent upon some source of reduction in canopy shading (Walters 1990). The mortality of *Quercus velutina* and *Q. coccinea* trees in the canopy could provide the increase in light needed by the shade intolerant oak seedlings. Under such conditions, sapling-sized individuals would likely be sparse relative to those in the seedling and canopy layers because of the lack of light reaching the forest floor prior to red oak group mortality (P.S. Johnson, personal communication).

In addition, red oak group mortality may also result in the release of advanced regeneration of *Q. alba* now present in the seedling layer. Therefore, it appears that both red oak group species and *Q. alba* will continue to dominate forest composition.

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