

**WOODY VEGETATION AND FUEL SURVEY FOR
EVALUATING WILDFIRE HAZARD IN
SPOTSYLVANIA BATTLEFIELD**

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Abstract

Woody vegetation was surveyed during the summers of 1989 and 1990 in 28 forest stands at Spotsylvania Battlefield, Virginia to examine forest composition and structure in relation to stand age and edaphic features. Detrended Correspondence Analysis (DCA) and overstory importance values were used to separate stands into 4 forest types: pine, pine-oak, oak-pine, and mature oak. Two surveyed stands were planted loblolly pine (*Pinus taeda* L.) plantations, and thus, were not included in the DCA due to their artificial conditions. DCA axis 1 represented a successional continuum, as it was positively correlated with stand density and negatively correlated with stand age. Young pioneer stands consisted primarily of Virginia pine (*Pinus virginiana* Mill.), which had relative importance values that exceeded 50%; whereas, mid-successional stands contained a mixture of pine and hardwood species including white oak (*Quercus alba* L.), tulip poplar (*Liriodendron tulipifera* L.), and sweetgum (*Liquidambar styraciflua* L.). Older late successional stands were dominated by oak and hickory (*Carya*) species, as well as dogwood (*Cornus florida* L.) and tupelo (*Nyssa sylvatica* Marsh.) in the understory. Historical data suggest that white oak and red oak (*Q. rubra* L.) dominated presettlement forests in the area. The study area experienced large-scale agriculture, logging, and subsequent land abandonment following settlement. Radial growth analysis indicated that all stands were initiated within the last 150 years. The oldest stands experienced a lack of adequate oak regeneration and contained a scarcity of later successional species which could potentially replace oaks. Fuel surveys conducted in representative stands of each forest type revealed low wildfire hazards throughout a majority of the battlefield.

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Introduction

Oak-hickory forests have traditionally been considered the climax vegetation type throughout a majority of the Eastern Deciduous Forest Biome (Oosting 1942; Braun 1950). Oak (*Quercus*) and hickory (*Carya*) dominance were recorded in many presettlement forests of the northeast, Mid-Atlantic, and central states regions (Spurr 1951; Russell 1981; Whitney and Somerlot 1985; Loeb 1987; Abrams and Downs 1990; Glitzenstein et al. 1990). Frequent fire, initiated by Indians or lightning, was presumably important in maintaining oak species in many of these forests (Buell et al. 1954; Lorimer 1985; Christensen 1981). Occasional fires eliminated shade tolerant species and permitted fire-resistant oaks to replace themselves (Anderson and Adams 1978). Due to canopy closure and decreased fire and logging disturbance, many mature oak forests on mesic (moist) and dry-mesic sites are currently experiencing replacement by more shade tolerant species (Anderson and Adams 1978; Abrams 1986; Pallardy et al. 1988; Seischab 1988; Abrams and Downs 1990; Nowacki et al. 1990). The principal cause of oak regeneration failure appears to be their sluggish seedling growth, which allows more shade tolerant species to overtop them at an early age (Lorimer 1989). However, oak populations may be more stable on xeric (dry) sites, since the invasive ability of shade tolerant species is more limited and the speed of succession and subsequent replacement is slower on these sites (Nigh et al. 1985; Abrams 1986; Host et al. 1987).

In contrast to other areas of the Eastern Deciduous Biome, there has been little documentation of presettlement vegetation in the Piedmont Plateau of Virginia. Upon European settlement, forests in the Piedmont Plateau of Virginia were severely altered by various disturbance events including agriculture and large-scale logging for charcoal production (Mansfield 1977; Felder 1982). Vegetational changes continued as a majority

of agricultural land was abandoned in the 1800s, facilitating large increases in pine (*Pinus*) densities (Gemborys 1974; Cooper 1989). In addition, many areas experienced logging during the late 1800s and early 1900s, resulting in the present day mosaic of forests in different stages of successional development.

There remains a scarcity of information on mature oak forests and their historical development in the northern Virginia Piedmont (Farrell and Ware 1991). Therefore, little is known about how past land use in the area has affected present day forest structure and composition (cf. Glitzenstein et al. 1990). Due to a long history of disturbances in the study area, we would predict that oak species are better adapted than other hardwood species to the various site conditions found in the northern Virginia Piedmont. Moreover, since severe soil erosion and nutrient leaching resulted from poor agricultural practices, we would further expect the process of oak replacement to proceed at a much slower rate. This study was initiated to: 1) trace the historical development of oak forests in this area, 2) examine the successional changes of forests in the northern Virginia Piedmont, 3) determine the ecological status of oak-hickory forests in the region and predict future trends, and 4) evaluate wildfire hazards associated with the different forest types within Spotsylvania Battlefield.

Study area

Spotsylvania Battlefield is one of four Civil War battlefields associated with the Fredericksburg and Spotsylvania National Military Park and comprises approximately 475 ha of forested land. The area is located 81 km southwest of Washington, D.C., in Spotsylvania County, Virginia (38°12' N. Lat. and 77°36' W. Long.). The climate of Spotsylvania County is warm continental with relatively mild winters and hot, humid summers. Mean annual temperatures average 13 °C, while winter and summer daily mean temperatures are 2 °C and 23 °C, respectively (Elder 1985). Precipitation averages 102 cm annually and is well distributed throughout the year. The average frost-free period extends from April 23 to October 17, a total of 178 days (National Park Service 1986).

Physiography and soils

Spotsylvania Battlefield is located within the Piedmont Plateau physiographic province. The general topography is gently rolling with elevations of 61-91 m above sea level (U. S. Geological Survey 1984). Bedrock of the area consists of a mixture of crystalline rocks, including granite, granite gneiss, and hornblende gneiss of the Paleozoic and Precambrian ages (Robinson et al. 1961). Soils are members of either the Appling-Wedowee-Emporia association or the Appling-Louisburg-Wedowee association, which are deep, well-drained sandy loams with clayey or loamy subsoils. These soils are categorized as being medium-textured, strongly acidic, and low in fertility (Elder 1985).

Past land use

Spotsylvania County was inhabited by Indians prior to European settlement, which started in 1721 (Mansfield 1977; Felder 1982). The vegetation at the time of settlement was composed of a mixture of deciduous trees, mainly oak and hickory species (Braun 1950; Silver 1990). Following settlement, the landscape changed rapidly, as many of the forests were cleared for the lucrative tobacco industry or for charcoal iron production (Cappon 1945; Mansfield 1977). Agricultural lands became severely eroded due to poor cultivation practices and therefore much of the land was abandoned (Craven 1965). These lands eventually became reforested, but portions were logged again during the Civil War and in the early 1900s. The battlefield became a unit of the National Park System in 1927 and has since been relatively undisturbed (National Park Service 1986).

Methods

Vegetation

During the summer of 1989 a reconnaissance of the entire Spotsylvania Battlefield was conducted with the aid of aerial photographs. All distinct vegetational units from the photographs were traced onto an acetate overlay which served as a preliminary cover map. Acreage of the vegetational units was estimated with a digital planimeter. Twenty-eight individual stands larger than 4 hectares (ha) and consisting of relatively homogeneous vegetation were chosen for formal inventory (Figure 1). Upon completion of the formal analysis, all remaining stands were assigned a forest type based on visual reconnaissance. Woody vegetation was surveyed and classified as trees (≥ 8 cm diameter breast height, dbh), saplings (tree species < 8 cm dbh and taller than 1.4 m), seedlings (tree species < 1.4

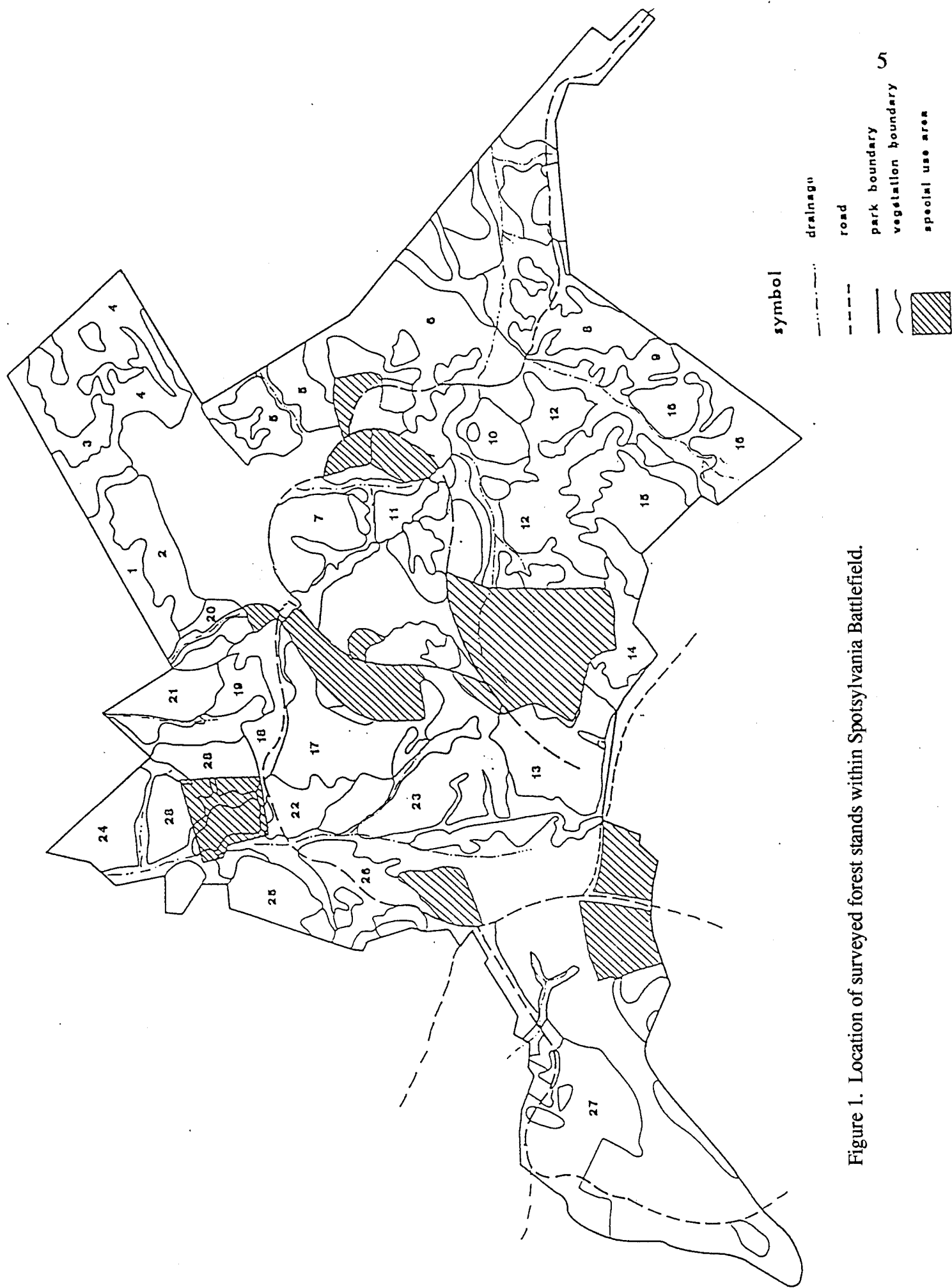


Figure 1. Location of surveyed forest stands within Spotsylvania Battlefield.

m tall), or shrubs (multiple-stemmed, non-tree woody species). Within each stand, trees were tallied by dbh and species in 20, one-tenth ha circular plots. Each tree was also assigned a canopy position as follows: Dominant- tree crowns that extended above the general level of the forest canopy and which received full light from above and partly from the sides; Codominant- tree crowns that formed the majority of the canopy layer and which received full light from above but little light from the sides; Intermediate- tree crowns which were partially below the general canopy layer and which received no light from the sides; and Overtopped- tree crowns which were entirely below the general canopy layer and which received no direct light from above or from the sides.

Vegetation plots were systematically located along transects at 30 to 40 m intervals, depending on stand size (range = 4.0 -17.8 ha) and were permanently marked with metal stakes. Permanent plot locations are on file at the park office. Transects were oriented through representative portions of each stand in a manner that avoided edge effect. Two selected trees per plot were bored at 1.4 m for age determination and radial growth analysis. Saplings and seedlings were tallied by species at each plot using nested (i.e. same plot center) circular plots of 9 m² and 5 m², respectively. Shrub cover was visually estimated in each 5 m² plot using cover classes established by Daubenmire (1959) as follows: Class 1: 0-5%; Class 2: 6-25%; Class 3: 26-50%; Class 4: 51-75%; and Class 5: 76-100%. Average total shrub cover was determined in each stand by averaging the mid-points of the class values for each plot. Aspect and slope were recorded several times in each stand for general stand descriptions.

Age versus diameter graphs were produced for each stand from tree core ages to examine species recruitment patterns. Tree cores of the 3-5 oldest individuals in selected stands were measured for annual radial growth to the nearest 0.1 mm with a dissecting scope and an ocular micrometer. Individual ring width data from each core were standardized via linear regression and division of each measured width by the product of

the ring year and the value of the fitted line (Fritts and Swetnam 1989). Ring width indices were averaged for each stand to construct stand site chronologies, which represented the average life-history growth rates of the oldest trees on a particular site.

Presettlement forest composition was depicted with the use of metes and bounds land survey records housed at the Spotsylvania County Court House. Witness trees, which were used to mark section corners, were recorded by species from the surveys examined to determine which species were present before and during settlement. One hundred fourteen witness trees were tallied from 10 surveys taken between 1713 and 1773, and 75 witness trees were tallied from 9 surveys taken between 1800 and 1866.

Numerical analysis

Importance values (IVs) were calculated for tree species in each stand (Cottam and Curtis 1956). In each stand:

$$\text{Relative density} = \frac{\text{\# of individuals of a particular species}}{\text{Sum of individuals of all species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{\# of plots in which a species occurs}}{\text{Sum of plot occurrences of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of a particular species}}{\text{Sum of basal areas of all species}} \times 100$$

$$\text{Relative IV} = (\text{Relative density} + \text{Relative frequency} + \text{Relative dominance})/3$$

These relative IVs were then subjected to Detrended Correspondence Analysis (DCA) using DECORANA, a computer ordination program (Hill 1979; Hill and Gauch 1980). DCA graphically displays forest stand information in 2 or more dimensions so that any important

environmental relationships can be determined. In addition, different forest types will be spatially separated because stands of similar species composition will be located closer together on the graph than stands of dissimilar composition. Simple correlation was used to determine relationships between DCA stand axis scores and stand characteristics such as species importance values, seedling and sapling densities, basal area, and physical site factors. Analysis of variance tests were performed using the General Linear Modelling (GLM) procedure in SAS (SAS Institute Inc. 1985).

Fuel survey

Upon completion of the vegetative survey, a fuel survey was conducted in two representative stands for each successional stage/forest type located within the battlefield. Successional stages included were young pine (*Pinus virginiana* or *P. taeda* L.), pine-oak, oak-pine, and mature oak. Fuel surveys were conducted along ten 35 foot transects as outlined by Brown (1974). Fuel was recorded according to type (pine or hardwood) and diameter size (0-1", >1-3", and >3"). Fuel in the 0-1" class was counted along the first 6 feet of each transect. Fuel in the 1-3" and >3" classes was recorded in the first 12 feet and 35 feet of the transect, respectively. Fuel >3" was measured for diameter and recorded as sound or rotten.

Results

Stand classification

Oak (*Quercus*) species constituted the highest importance values (IVs) in 17 of the 28 surveyed stands, while Virginia pine (*Pinus virginiana* Mill.) comprised the highest IVs

in 9 stands (Table 1). Two surveyed stands not included in the DCA were planted loblolly pine plantations. DCA separated the 2 major groups, designated as oak or pine, into 4 distinct groups along DCA axes 1 and 2 (Figure 2). Stands within these 4 groups were classified as being pine, pine-oak, oak-pine, or oak according to the species in each stand with the highest importance values. Pine and oak were used as a second designation in certain stands (i.e. pine-oak and oak-pine) when their relative IV was greater than 10%. Tulip poplar (*Liriodendron tulipifera* L.) comprised high IVs in virtually all stands and therefore, was not used in stand designations. DCA axis 1 represented a successional continuum, as it was positively correlated with stand density (range = 363 - 1080 trees/ha) and negatively correlated with stand age (range = 22 - 174 yr) from oak to pine forests. Stand basal area (range = 23.8 - 48.5 m²/ha) was also positively correlated with axis 1 (Table 2). Overstory importance values of white oak (*Quercus alba* L.), mockernut hickory (*Carya tomentosa* Nutt.), pignut hickory (*Carya glabra* Sweet), and black oak (*Quercus velutina* Lam.) decreased along DCA axis 1, while Virginia pine importance increased. No meaningful environmental relationships were associated with DCA axis 2, although importance values of beech (*Fagus grandifolia* Ehrh.), tulip poplar, and pignut hickory decreased along this axis, suggesting a possible moisture gradient. Stand density was positively correlated with stand basal area and negatively correlated with stand age.

Understory composition

No significant relationships existed between seedling density or sapling density and DCA axis stand scores. Total seedling density increased with overstory pignut hickory importance and decreased with overstory beech importance. Differences in seedling species composition were apparent between stand groups (Table 3). Seedling densities of American holly (*Ilex opaca* Ait.), sweetgum (*Liquidambar styraciflua* L.), and southern red

TABLE 1. Mean relative importance values ($\pm$ S.E.) of principal tree species of 26 stands organized by ecological group.

Species	Pine (n=9)	Oak (n=17)
<i>Carya glabra</i>	1 $\pm$ 0 ^a	6 $\pm$ 1 ^b
<i>Carya tomentosa</i>	1 $\pm$ 0 ^a	4 $\pm$ 1 ^b
<i>Cornus florida</i>	5 $\pm$ 1 ^a	5 $\pm$ 1 ^a
<i>Fagus grandifolia</i>	3 $\pm$ 1 ^a	4 $\pm$ 1 ^a
<i>Ilex opaca</i>	2 $\pm$ 1 ^a	2 $\pm$ 0 ^a
<i>Liquidambar styraciflua</i>	6 $\pm$ 1 ^a	3 $\pm$ 1 ^b
<i>Liriodendron tulipifera</i>	13 $\pm$ 2 ^a	15 $\pm$ 1 ^a
<i>Nyssa sylvatica</i>	4 $\pm$ 1 ^a	5 $\pm$ 1 ^a
<i>Pinus virginiana</i>	44 $\pm$ 3 ^a	6 $\pm$ 2 ^b
<i>Quercus alba</i>	8 $\pm$ 2 ^a	31 $\pm$ 2 ^b
<i>Quercus falcata</i>	5 $\pm$ 1 ^a	5 $\pm$ 1 ^a
<i>Quercus rubra</i>	2 $\pm$ 0 ^a	5 $\pm$ 1 ^b
<i>Quercus velutina</i>	2 $\pm$ 0 ^a	5 $\pm$ 1 ^b
Others ¹	0 $\pm$ 0	0 $\pm$ 0

Values in a row with the same letter are not significantly different at $P < 0.05$.

¹ Seventeen additional species were found in pine stands and 15 additional species were found in oak stands.

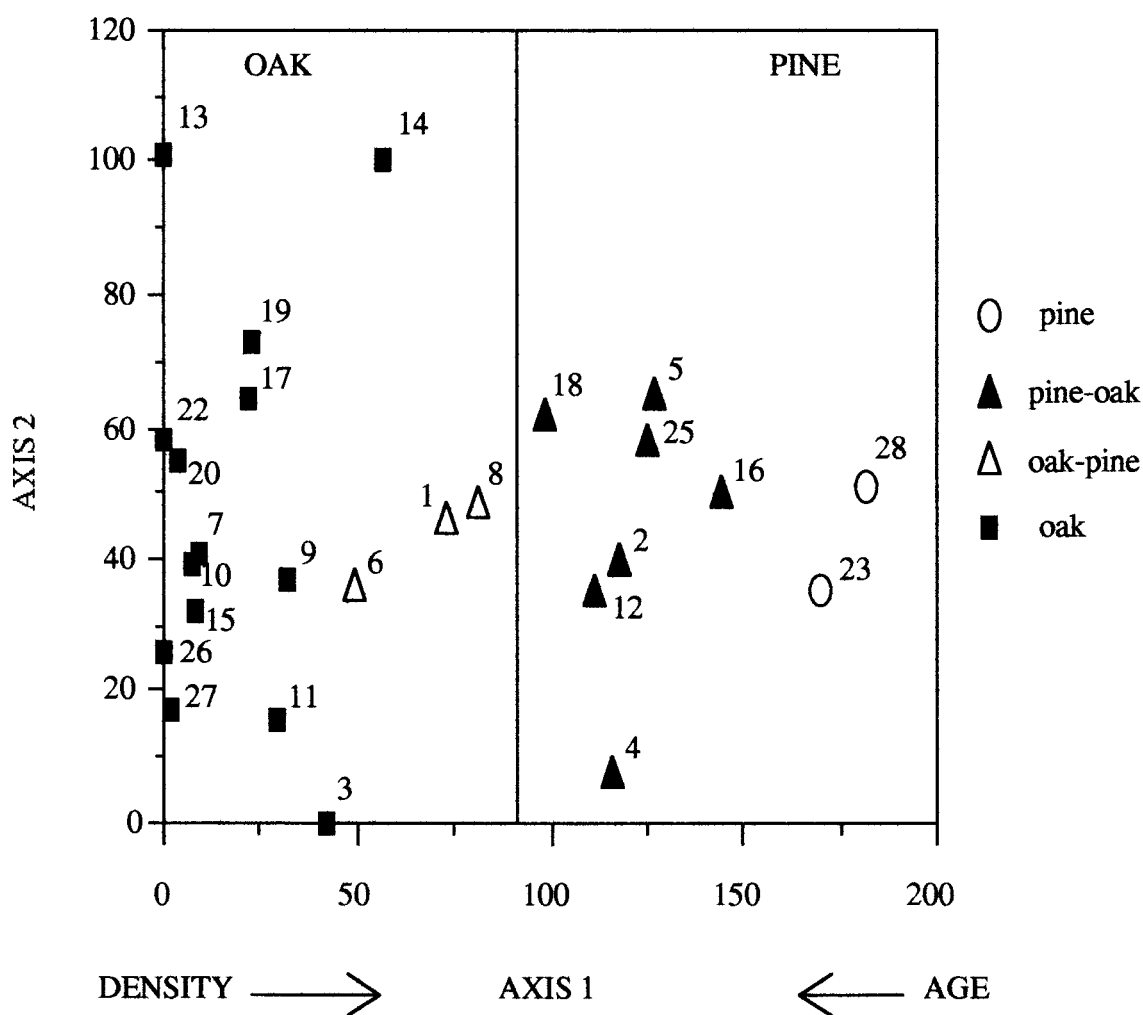


Figure 2. Detrended Correspondence analysis axis 1 and axis 2 for 26 forest stands in Spotsylvania Battlefield.

Table 2. Mean tree density, basal area, maximum ages, and shrub cover ($\pm$ S.E.) of 26 forest stands in Spotsylvania battlefield organized by ecological group.

	Pine	Oak
Number of stands	9	17
Density (trees/ha)	897 ± 42^a	565 ± 34^b
Maximum ages	74 ± 2^a	110 ± 4^b
Total shrub cover (%)	14 ± 2^a	12 ± 1^a
Basal area (m^2/ha)	36 ± 1^a	29 ± 2^b

Values in a row with the same letter are not significantly different at $P < 0.05$.

TABLE 3. Mean seedling density (#s/ha $\pm$ S.E.) of major species and mean totals for the 2 ecological groups.

Species	Pine (n = 9)	Oak (n = 17)
<i>Acer rubrum</i>	3002 $\pm$ 511 ^a	2875 $\pm$ 443 ^a
<i>Carya</i> spp.	1638 $\pm$ 506 ^a	2507 $\pm$ 420 ^a
<i>Cornus florida</i>	8838 $\pm$ 1581 ^a	8858 $\pm$ 1222 ^a
<i>Fagus grandifolia</i>	790 $\pm$ 309 ^a	709 $\pm$ 227 ^a
<i>Ilex opaca</i>	2392 $\pm$ 448 ^a	804 $\pm$ 147 ^b
<i>Liquidambar styraciflua</i>	2416 $\pm$ 975 ^a	798 $\pm$ 193 ^b
<i>Liriodendron tulipifera</i>	682 $\pm$ 221 ^a	918 $\pm$ 114 ^a
<i>Nyssa sylvatica</i>	742 $\pm$ 111 ^a	1045 $\pm$ 177 ^a
<i>Quercus alba</i>	1662 $\pm$ 395 ^a	10745 $\pm$ 1750 ^b
<i>Quercus falcata</i>	1400 $\pm$ 586 ^a	228 $\pm$ 99 ^b
<i>Quercus rubra</i>	837 $\pm$ 189 ^a	1412 $\pm$ 225 ^a
<i>Quercus velutina</i>	1184 $\pm$ 207 ^a	1058 $\pm$ 175 ^a
<i>Sassafras albidum</i>	1268 $\pm$ 364 ^a	1273 $\pm$ 328 ^a
Other	4437 $\pm$ 1720	1710 $\pm$ 238
Total	31287 $\pm$ 2637 ^a	34940 $\pm$ 2435 ^a

Values in a row with the same letter are not significantly different at $P < 0.05$.

oak (*Quercus falcata* Michx.) were higher in the pine group, while white oak seedling densities were higher in the oak group.

There were few differences in sapling species composition between stand groups (Table 4). Southern red oak was the exception, as it obtained higher sapling densities in the pine dominated group. Northern red oak (*Quercus rubra* L.), black oak, and white oak were poorly represented as saplings in both stand groups. Total shrub cover, which ranged from 5.4 - 26.0 %, was not significantly correlated with DCA axis scores and it did not differ between stand groups (Table 2).

Canopy structure

White oak was the most abundant species of the overstory (dominant, codominant, and intermediate canopy positions) in oak stands and the most abundant species of the overtopped canopy position in both oak and pine stands (Figure 3). Virginia pine was the most abundant species of the overstory canopy positions in pine stands. Tulip poplar was well represented in all canopy positions of both forest types. Hickory species had intermediate abundance in all canopy positions of oak stands, whereas tupelo (*Nyssa sylvatica* Marsh.) was abundant in the overtopped canopy position of both stand groups. Beech obtained minor understory importance in both stand groups, although it was poorly represented in the overstory of all stands.

Fuel loading

Fuel loading in tons/acre was calculated (Table 5) according to Brown (1974). The majority of stands within Spotsylvania Battlefield consisted of fuel loads which correspond to Fire Behavior Fuel Models 8 and 9 (Lynch & Horton, 1983), which predict slow

TABLE 4. Mean sapling density (#/ha $\pm$ S.E.) of major species and mean totals for the 2 ecological groups.

Species	Pine (n = 9)	Oak (n = 17)
<i>Acer rubrum</i>	36 $\pm$ 18 ^a	51 $\pm$ 21 ^a
<i>Carya glabra</i>	24 $\pm$ 10 ^a	48 $\pm$ 25 ^a
<i>Carya tomentosa</i>	42 $\pm$ 22 ^a	48 $\pm$ 15 ^a
<i>Cornus florida</i>	562 $\pm$ 75 ^a	900 $\pm$ 119 ^a
<i>Fagus grandifolia</i>	108 $\pm$ 36 ^a	51 $\pm$ 16 ^a
<i>Ilex opaca</i>	215 $\pm$ 47 ^a	234 $\pm$ 51 ^a
<i>Liquidambar styraciflua</i>	90 $\pm$ 40 ^a	54 $\pm$ 18 ^a
<i>Liriodendron tulipifera</i>	102 $\pm$ 44 ^a	73 $\pm$ 24 ^a
<i>Nyssa sylvatica</i>	138 $\pm$ 39 ^a	212 $\pm$ 32 ^a
<i>Quercus alba</i>	36 $\pm$ 13 ^a	51 $\pm$ 19 ^a
<i>Quercus falcata</i>	84 $\pm$ 48 ^a	6 $\pm$ 4 ^b
<i>Quercus rubra</i>	0 $\pm$ 0 ^a	13 $\pm$ 7 ^a
<i>Quercus velutina</i>	24 $\pm$ 24 ^a	13 $\pm$ 10 ^a
<i>Sassafras albidum</i>	30 $\pm$ 18 ^a	10 $\pm$ 5 ^a
Other	113 $\pm$ 36	98 $\pm$ 87
Total	1603 $\pm$ 170 ^a	1861 $\pm$ 167 ^a

Values in a row with the same letter are not significantly different at $P < 0.05$.

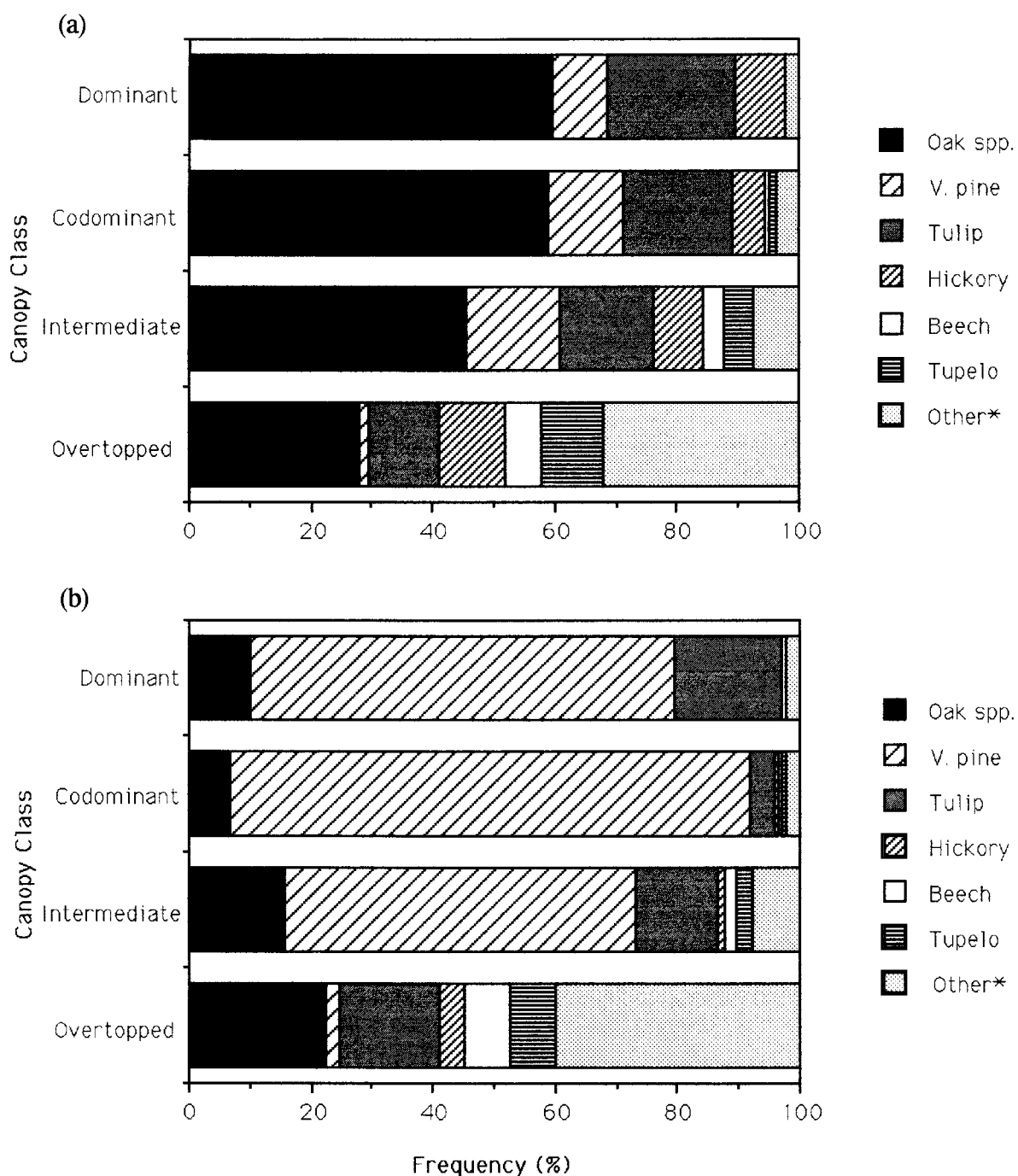


Figure 3. Canopy percentage of major tree species in (a) oak stands and (b) pine stands in Spotsylvania Battlefield.

* Other species include dogwood (*Cornus florida* L.), sweetgum, American holly, sassafras (*Sassafras albidum* (Nutt.) Nees), and red maple (*Acer rubrum* L.).

Table 5. List of fuel loadings for various forest types within Spotsylvania Battlefield.

Forest Type	Stand #	Age* (yrs.)	BA (ft. ² /A)	Fuel loading		Total (Tons/A)	Fuel Model
				<3" (Tons/A)	>3" (Tons/A)		
Pine(Vp)	28	44	155	2.28	1.42	3.71	8
Pine(Lob)	21	26	152	2.79	.94	3.73	9
Oak-pine ¹	8	58	106	2.81	5.26	8.07	9
Pine-oak	2	65	166	2.93	8.49	11.42	9
Oak-pine	6	65	116	4.11	1.25	5.36	9
Oak-pine	1	71	211	2.54	8.98	11.53	9
Oak	7	84	108	2.89	1.19	4.08	8
Oak	13	103	104	1.99	1.91	3.89	8

KEY: Vp=Virginia pine; Lob=Loblolly pine;

* Average age of stand from radial growth analysis

¹ Stand classification took place after fuel survey. Fuel amounts vary in these mid-successional types according to amount of downed pine and subjective placement of fuel transects within each stand.

burning ground fires with low flame heights. There were only 4-6 stands containing areas of heavier fuel concentrations (e.g. areas containing downed overmature pine) that could flare up and result in higher flame heights and possible scorching of trees under excessively dry conditions. These stands included stands 1 and 2 adjacent to the Bloody Angle; stand 8 along the southeastern park boundary; stand 12 located west of the Harrison House ruins; and stand 5 located east of the Bloody Angle salient (refer to Figure 1). Fuel quantities in Spotsylvania mature oak stands (3.89 - 4.08 tons/acre) were lower than the average values found in photo series for similar oak-hickory stands in the northeast (6.7 - 9.4 tons/acre) (Wilcox et al.1982). Fuel loadings in Spotsylvania loblolly (3.73 tons/acre) and Virginia pine stands (3.71 tons/acre) were also lower than average values found in photo series for similar southeastern pine stands (6.0 - 14.7 tons/acre) (Lynch & Horton 1983).

Stand descriptions

See Appendix A for individual stand overstory and understory vegetative composition. The following includes general stand descriptions with predictions of future species composition.

Stand #1 was a 12-acre oak-pine stand located along the park boundary, north of the Bloody Angle. The even-aged stand originated around 1915 from a logging event. White oak, tulip poplar, and Virginia pine comprised 62% of the overstory IV total, while the seedling and sapling layers consisted of dogwood, holly, tulip poplar, and several oak species. Future composition should contain less pine and a mixture of oak, tulip poplar, and beech.

Stand #2 was a 20-acre pine-oak stand located adjacent to stand #1 and the Bloody Angle open field. The even-aged stand originated around 1915 and the overstory composition consisted primarily of Virginia pine and tulip poplar. Holly, dogwood, and tupelo comprised almost 70% of sapling stems. Future composition will contain less pine and an increase in hardwoods such as white oak, tupelo, and tulip poplar.

Stand #3 was an 11-acre oak stand located along the northeastern portion of the park, just north of the Landrum house ruins. The stand was an uneven-aged hardwood mixture consisting of white oak, tulip poplar, beech, and sweetgum in the overstory. Dogwood, tupelo, holly, and white oak comprised 93% of sapling stems. Future composition should continue to contain a mixture of oak, tulip poplar, and beech, as well as hickory and tupelo.

Stand #4 was a 43-acre pine-oak stand located in the northeastern portion of the park, east of the Landrum house ruins. This stand originated around 1915 and half of the overstory stems were an even-aged component of Virginia pine, tulip poplar, and white oak. Several older beech and southern red oak were additional overstory associates, while dogwood, holly, beech, and tulip poplar dominated the sapling layer. Future composition should contain less pine and a mixture of tulip poplar, beech, and oak species.

Stand #5 was a 23-acre pine-oak stand located along the park boundary, just east of the Bloody Angle salient. Approximately 50% of the overstory IV was an even-aged Virginia pine component, which originated from logging around 1915. Shortleaf pine, white oak, and tulip poplar were also present in the overstory, while dogwood, tupelo, and red maple comprised 70% of all saplings. Future overstory composition should contain reduced pine densities and a mixture of oaks, tulip poplar, and sweetgum.

Stand #6 was a 44-acre oak-pine stand located in the eastern portion of the park, north of Burnside Drive. The stand consisted of an uneven-aged overstory, of which 60% was Virginia pine, white oak, and tulip poplar. Dogwood, holly, hickory, and sweetgum

comprised the majority of the sapling density. Future composition should contain a mixture of white oak, hickory, tulip poplar, and tupelo.

Stand #7 was a 20-acre oak stand located south of the Bloody angle salient. This stand experienced several periods of logging which resulted in the uneven-aged component of white oak currently comprising 33% of the overstory IV. Hickory, tupelo, and dogwood shared secondary overstory importance. The sapling layer was comprised of dogwood, tupelo, beech, and several other hardwood species. Future composition should consist of white oak, hickory, tupelo, and beech. This stand contained many trees over 130 years old.

Stand #8 was a 20-acre oak-pine stand located along the southeastern boundary adjoining an agricultural field. This stand originated from logging around 1900 and 70% of the overstory was composed of Virginia pine, white oak, and tulip poplar. Seedling and sapling layer species consisted of dogwood, holly, tulip poplar, sweetgum, and tupelo. Future composition should consist of tulip poplar, tupelo, and several oak species.

Stand #9 was a 13-acre oak stand located in the southeast portion of the park, adjacent to stand #8. The overstory was uneven-aged and over 50% of the stems consisted of white oak and tulip poplar. Hickory and tupelo were additional overstory inhabitants, while important sapling layer species included dogwood, holly, tupelo, and ironwood. Future composition should continue to consist of several oak species, as well as tulip poplar, tupelo, and hickory.

Stand #10 was a 10-acre oak stand located between Gordon Drive and Burnside Drive. This stand was uneven-aged and was dominated by white oak. Additional

overstory species included tulip poplar, hickory, and beech. Dogwood, holly, beech, and tupelo comprised 90% of the sapling layer. Future composition should consist of white oak, red oak, tupelo, hickory, and beech. This stand contained several trees older than 150 years.

Stand #11 was a 14-acre oak stand located within the Bloody Angle salient, along Gordon Drive. The stand was uneven-aged and 60% of the overstory stems were white oak, beech, and tulip poplar. The sapling layer was almost exclusively dogwood (>80%), with a small component of beech, sassafras, and hickory. The overstory should change very little in the future. White oak, beech, hickory, and tulip poplar should share overstory dominance.

Stand #12 was a 37-acre pine-oak stand located south of Gordon Drive and east of the Harrison House ruins. This stand originated around 1915 and consisted of an even-aged overstory component, of which 70% was Virginia pine, white oak, and tulip poplar. Understory saplings consisted exclusively of dogwood, beech, holly, and sweetgum. Future overstory composition should consist of white oak, beech, tulip poplar, and a decreased pine component.

Stand #13 was a 31-acre mature oak stand located at the base of Anderson Drive. The stand originated around 1865 and was dominated (>50% basal area) by white oak. Southern red oak and tupelo were also important overstory species, while hickory, dogwood, tupelo, and black oak comprised the sapling layer. Future stand composition should continue to be composed of oak, tupelo, and hickory species. This stand contained the oldest average tree ages, as the majority of overstory stems were older than 100 years.

Stand #14 was an 11-acre oak stand located southeast of Anderson Drive, along Brock Road. The overstory consisted of an uneven-aged mixture of white oak, southern red oak, tulip poplar, and Virginia pine. This stand appeared to have been disturbed by logging events within the last 75 years. Important sapling species included dogwood, holly, tupelo, white oak, and hickory. Future composition should consist of white oak, black oak, southern red oak, tulip poplar, and hickory.

Stand #15 was a 30-acre oak stand located along the southeastern boundary of the park, north of Brock Road. An uneven-aged mixture of white oak, pignut hickory, dogwood, and tulip poplar comprised over 60% of the overstory density. The sapling layer consisted of dogwood, holly, tupelo, and redcedar. Future composition should consist of hickory, white oak, black oak, and tupelo. Many trees in this stand were older than 100 years.

Stand #16 was a 26-acre pine-oak stand located in the southeast corner of the park adjoining agricultural land that is the future site of Courthouse Crossings development. This stand originated from agricultural abandonment approximately 80 years ago and 50% of the overstory density was Virginia pine. Southern red oak, tulip poplar, and sweetgum were also overstory inhabitants. Dogwood, holly, black oak, and tupelo were important sapling layer species. Future composition should consist of white oak, southern red oak, hickory, and beech, as well as reduced pine densities.

Stand #17 was a 33-acre oak stand located west of the Bloody Angle along Grant Drive (including a portion where Upton's wartime road is located). This stand originated from logging around 1915 and was dominated by an even-aged component of white oak. Southern red oak and tulip poplar were also important overstory inhabitants. The sapling

layer contained a high density of dogwood ($>1000/\text{ha}$), as well as significant numbers of red maple, holly, tupelo, and sweetgum. Future composition should consist of tulip poplar, white oak, tupelo, hickory, and some red maple.

Stand #18 was a 15-acre pine-oak stand located along Grant Drive, west of the Bloody Angle. This even-aged stand originated around 1915 and the overstory was composed of Virginia pine, white oak, southern red oak, and sweetgum. Important sapling species included dogwood, hickory, tupelo, and sweetgum. Future composition should consist of white oak, tulip poplar, hickory, and a decreased number of pine.

Stand #19 was a 16-acre oak stand located in the north-central portion of the park, north of Grant Drive and adjoining stand #18. This stand originated from logging around 1915 and was dominated ($>45\%$ rel. density) by an even-aged white oak component. Sweetgum, tulip poplar, and hickory were also frequent overstory inhabitants. Sapling species included dogwood, tupelo, sweetgum, and red maple. Future composition should include white oak, tulip poplar, tupelo, and hickory.

Stand #20 was an 11-acre oak stand located northwest of the Bloody Angle field. It was an uneven-aged stand that consisted of 120-year old white oak and 70-year old red oak and tulip poplar. Important sapling species included dogwood, tupelo, and oak species. Future composition should include white oak, red oak, hickory, and tupelo.

Stand #21 was an 11-acre loblolly pine stand located in the north-central portion of the park. This stand was artificially planted around 1960 and the overstory consisted of over 80% loblolly pine. Sweetgum and tulip poplar were the only other significant species found in the overstory. The understory contained high sapling densities of many

hardwood species including tupelo, dogwood, hickory, sweetgum, and eastern redcedar. Pine will continue to dominate the overstory, but it will eventually succumb to the invasion of current understory species, especially the oak and hickory. This stand and stand #24 were not included in the formal analysis due to the artificial conditions imposed during their initiation. However, composition can now be monitored for future changes as succession proceeds.

Stand #22 was an 11-acre oak stand located in the north-central portion of the park along Grant Drive, just south of the private inholding. This stand was initiated in 1915 and contained an even-aged mixture of which >70% of the overstory composition was white oak, tulip poplar, and hickory species. The understory contained a high sapling density of dogwood in addition to tupelo, tulip poplar, red maple, and fringetree. Future composition should consist of white oak, southern red oak, hickory, and tupelo.

Stand #23 was a 32-acre pine stand located west of Anderson Drive and adjoining stand #13. This stand was originally agricultural fields which were partially abandoned around 1915, 1940, and 1965. Even-aged Virginia pine components corresponding to the three abandonment dates comprised over 60% of the overstory. Tulip poplar and eastern redcedar were the only other significant overstory species, while dogwood, redcedar, southern red oak, and tulip poplar dominated the sapling layer. Virginia pine will continue to dominate the overstory until mature, after which oaks and other hardwoods will encroach the canopy as codominants.

Stand #24 was a 14-acre loblolly pine stand located in the north central tip of the park, north of the private inholding. This stand was artificially planted with loblolly pine around 1960, although it also contained sweetgum, tulip poplar, and bigtooth aspen in the

overstory. The understory contained a very high sapling density (~2000 stems/ha) of sweetgum in addition to dogwood, tulip poplar, white oak, and tupelo. Pine will continue to dominate the overstory but will eventually be joined and overcome by the current hardwood understory species.

Stand #25 was a 16-acre pine-oak stand located along the northwestern boundary, west of the private inholding. The stand was initiated around 1915 and contained an even-aged overstory mixture of which >80% was Virginia pine, tulip poplar, white oak, and sweetgum. Important sapling layer species included dogwood, holly, and hickory species. Future composition should consist of white oak, tulip poplar, and hickory after the pine component breaks up due to age-related mortality.

Stand #26 was an 18-acre oak stand located just beyond the exhibit shelter along Grant Drive. It was an uneven-aged stand that was initiated in the late 1800s and the overstory consisted of white oak, tulip poplar, and hickory species. The understory sapling layer was dominated by dogwood (~1900 stems/ha), while tupelo, ash, holly, and tulip poplar played minor understory roles. Future composition should consist of hickory, white oak, black oak, and tupelo.

Stand #27 was a 42-acre oak stand located in the southeast portion of the park along Hancock Road. This stand contained the oldest trees in the Battlefield, with several over 160 years old. It was an uneven-aged stand consisting of pignut hickory, white oak, black oak, and tulip poplar in the overstory. Dogwood comprised 62% of the understory sapling density, while holly, tulip poplar, tupelo, and ironwood were minor understory constituents. Overstory composition should change very little in the future, with the exception of increased tupelo densities.

Stand #28 was an 18-acre pine stand located adjacent to the eastern boundary of the private inholding along Grant Drive. The stand was initiated following land abandonment around 1930 and 75% of the overstory density was an even-aged component of Virginia pine. Tulip poplar and sweetgum were the only hardwood species that approached the canopy. Important sapling layer species included dogwood, holly, sweetgum, beech, and southern red oak. Pine will continue to dominate this stand until the understory hardwoods become codominants.

Vegetation cover map

A vegetation cover map was made from delineations derived from the acetate overlay of aerial photographs (Figure 4). Vegetation cover types of forested areas were designated by the most important species in surveyed stands(> 4 ha) or, for non-surveyed stands, upon reconnaissance similarities with inventoried stands. Non-forested stands were delineated by the most abundant vegetation in non-forested areas (e.g. scrub, regrowth). Spotsylvania Battlefield is a mosaic of forest types in different stages of successional development. Pine stands (**P**) were dominated by Virginia pine or loblolly pine, while pine-oak stands (**Po**) consisted of a mixture of Virginia pine and hardwoods such as tulip poplar, sweetgum, and dogwood. Oak-pine stands (**Op**) contained hardwood species such as tulip poplar, southern red oak, and white oak along with a few remaining pine. Oak stands (**O**) were dominated by white oak, but contained many other species such as black oak, red oak, southern red oak, and hickory. Areas designated as special use areas (**cross-hatched** symbol in Figure 4) consisted of scenic restorations (**SR**- areas previously wooded that were clearcut and mowed annually), agricultural regrowth (**Ar**- areas previously mowed annually which have been left to revert to forest), and a private inholding (**IN**- an area within the park boundary which is privately owned). Flood plains (**Fp**) were drainage areas that contained intermittent streams. Certain areas within flood

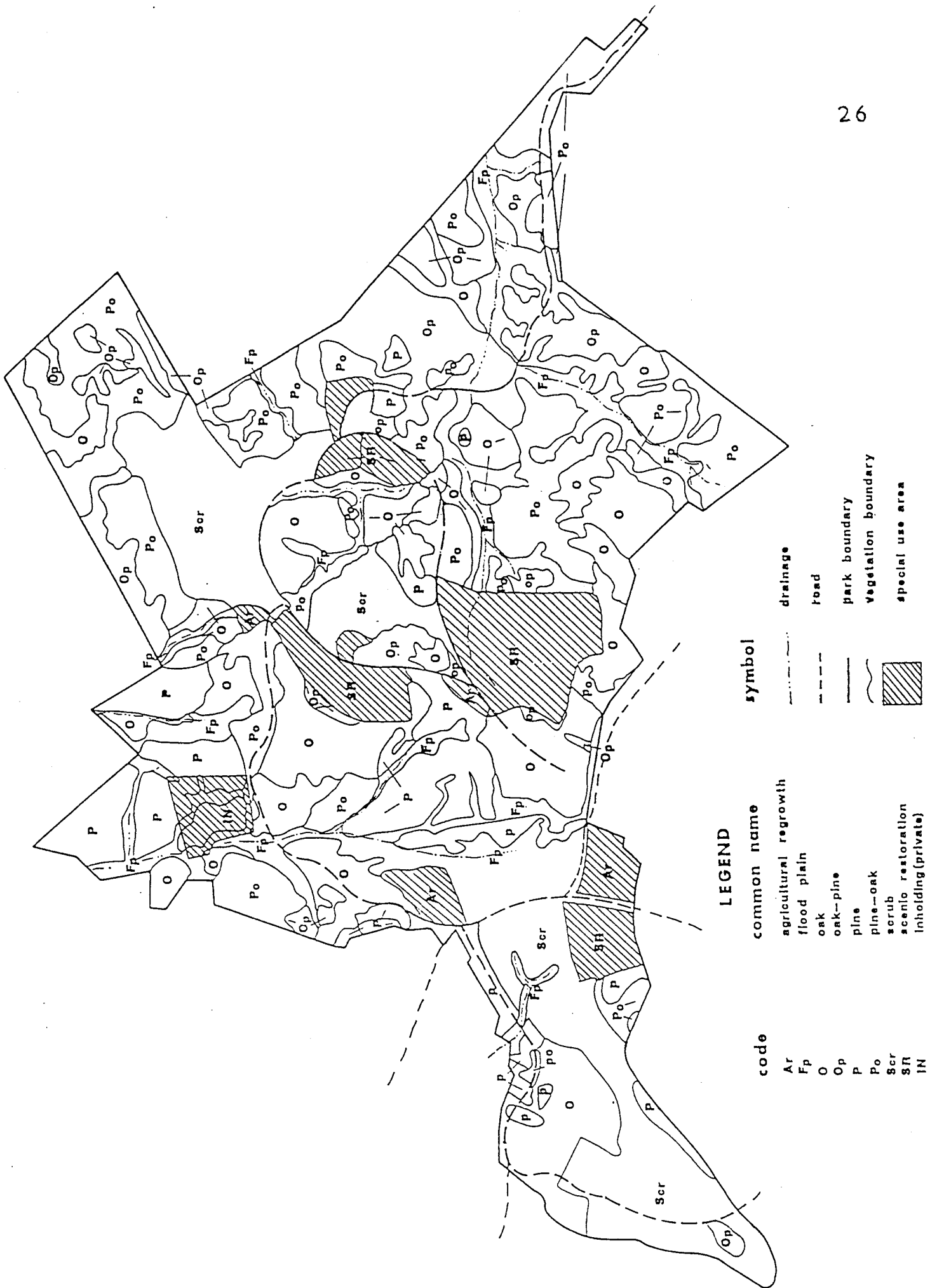


Figure 4. Vegetation cover map of Spotsylvania Battlefield.

plains contained a major component of tree species from adjacent stands. Vegetation described as scrub (Scr) was comprised of a mixture of mowed fields and pasture which contained woody vegetation such as sumac, redcedar, dogwood, and sweetgum. Several neighboring stands delineated on the map are currently composed of the same vegetation type. Since delineation was partially based on a 1980 aerial photograph, these stands may previously have been in different successional stages (e.g. previous pine-oak stands may currently be designated as oak-pine).

Age-diameter data

See Appendix B for age-diameter graphs of each stand. Species age-diameter graphs and radial growth chronologies from representative stands for each successional stage are shown in Figures 3-7. Stand 17 (Figure 5a) and stand 7 (Figure 6a) represent mature, oak dominated stands in which oak and hickory species were the largest and oldest present. Peak recruitment and highest radial growth of most oaks and other tree species in stand 17 occurred soon after 1912, presumably the time of extensive logging (Figure 5b). A second peak in radial growth occurred around 1966, but it was not correlated with precipitation data, logging, or any other known disturbance. Radial growth in stand 7 peaked around 1900 and 1912, probably from a selection cut followed by a clearcut (Figure 6b). These disturbances facilitated the major recruitment of trees in the stand through the release of advanced regeneration or newly formed seedlings. After 1950, there was very little tree recruitment in either stand except for tulip poplar and dogwood.

Stand 8, an oak-pine forest, was initiated from logging around 1900 (Figure 7a). Recruitment of Virginia pine continued for approximately 30 years, after which white oak, southern red oak, and other hardwoods dominated recruitment into the tree size class. Periods of minor release and suppression were apparent in the oldest species throughout this period (Figure 7b).

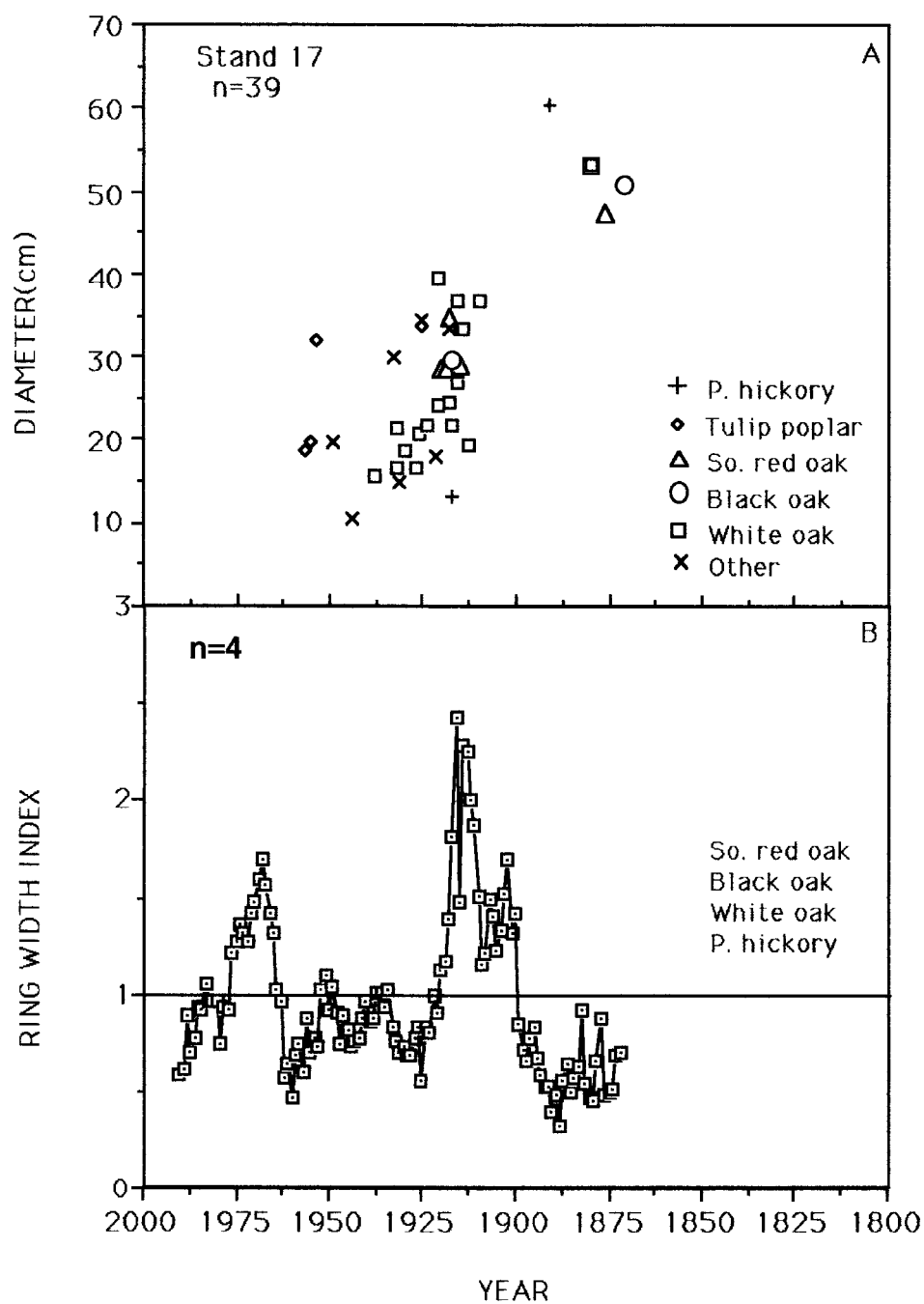


Figure 5. Tree age-diameter and radial growth chronology for stand 17 in Spotsylvania Battlefield. A ring width index of 1 corresponds to the average life history growth rate. Year values are analogous to the year of origin in the age-diameter graph.

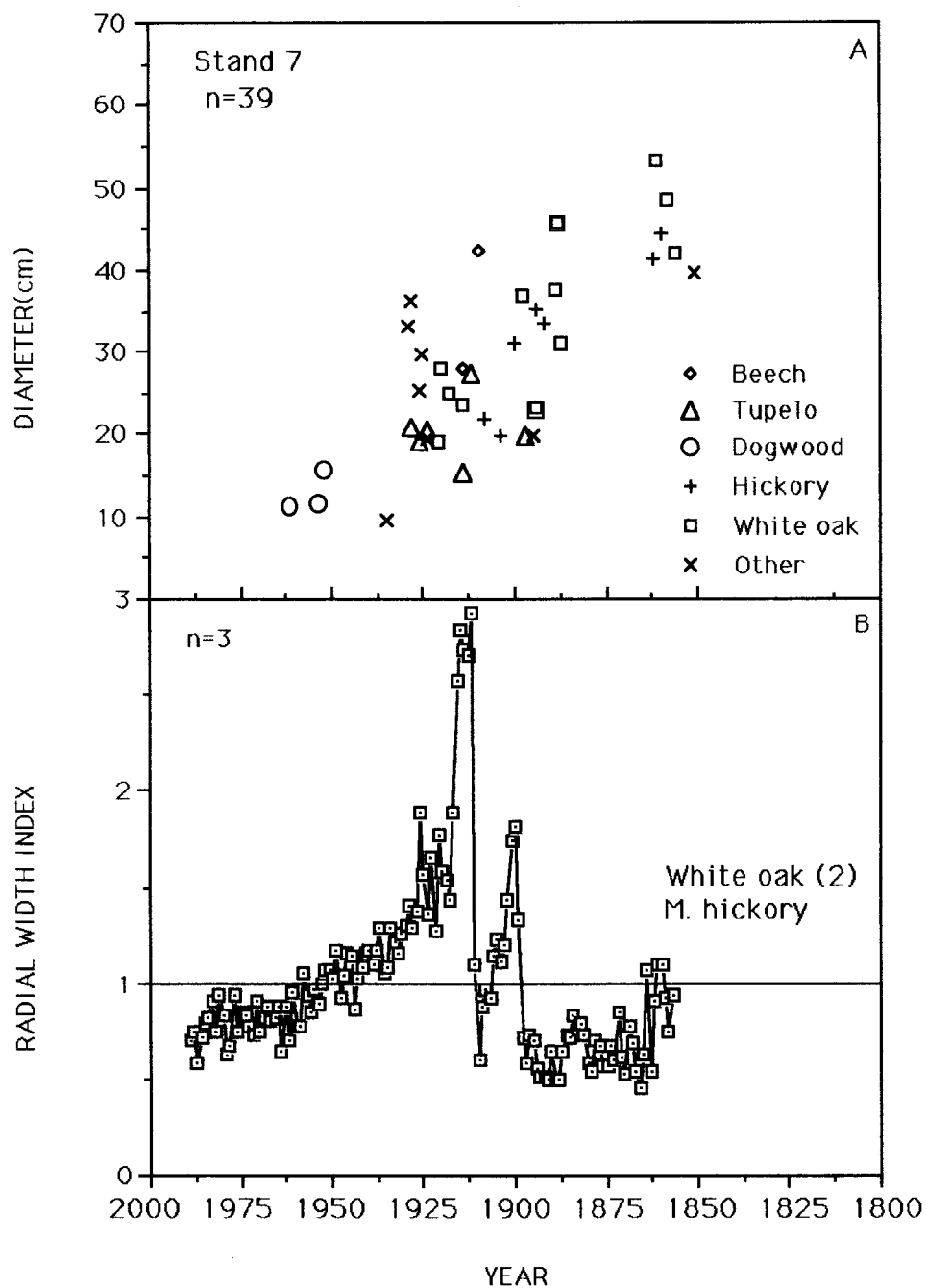


Figure 6. Tree age-diameter and radial growth chronology for stand 7 in Spotsylvania Battlefield. A ring width index of 1 corresponds to the average life history growth rate. Year values are analogous to the year of origin in the age-diameter graph.

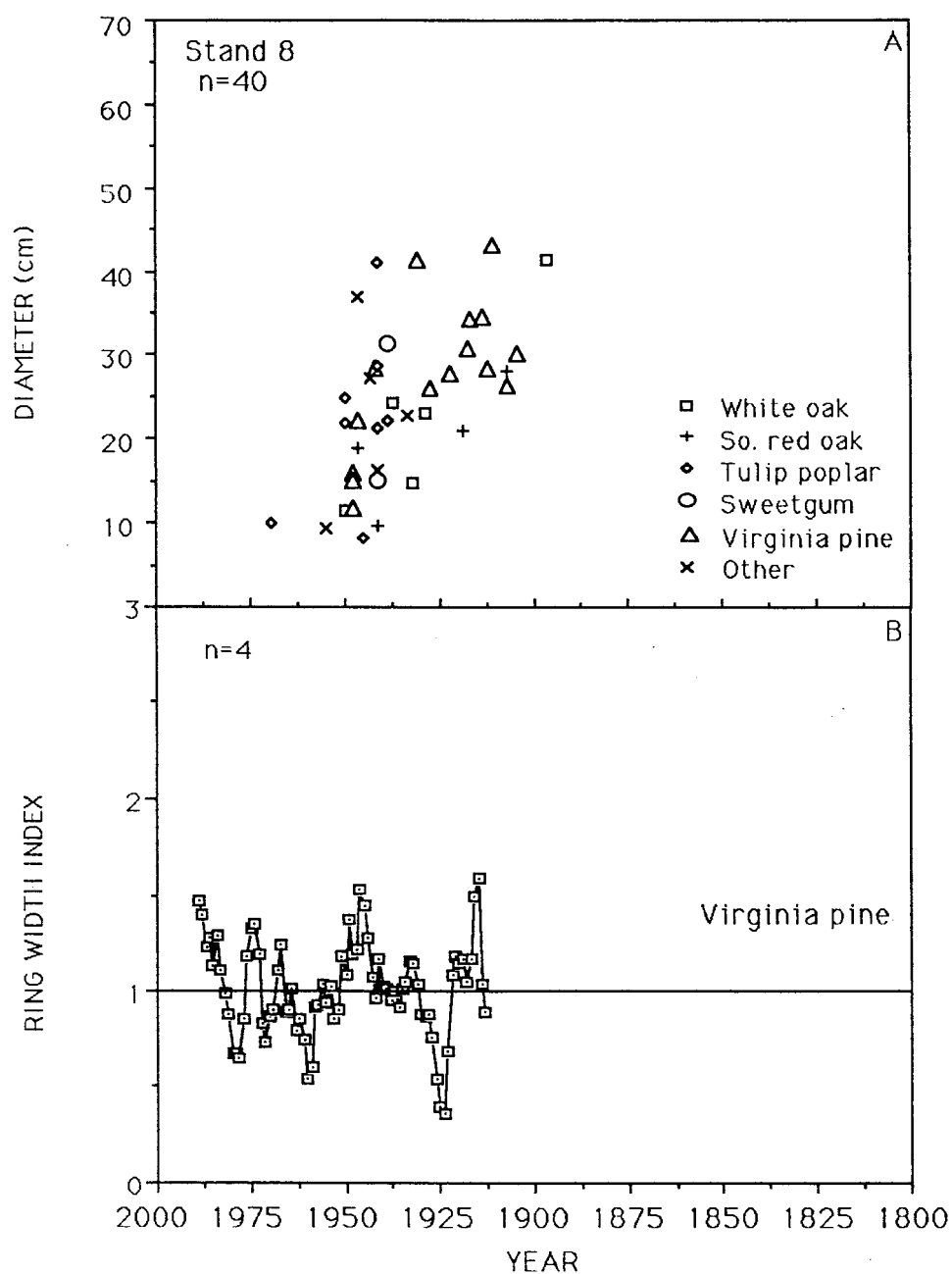


Figure 7. Tree age-diameter and radial growth chronology for stand 8 in Spotsylvania Battlefield. A ring width index of 1 corresponds to the average life history growth rate. Year values are analogous to the year of origin in the age-diameter graph.

Stand 18 is an even-aged pine-oak stand that developed after a logging event around 1915, the year of highest radial growth (Figure 8). Major recruitment of red oak, white oak, and Virginia pine ensued for approximately 25 years following stand initiation, after which there was very little species recruitment. Virginia pine dominated stand 28 following land abandonment in 1930, at which time radial growth was highest (Figure 9a). Recruitment of Virginia pine, along with individuals of sweetgum and tulip poplar, proceeded for approximately 30 years.

Historical data

Land survey records suggest that the forests in the vicinity of present day Spotsylvania Battlefield were dominated by white oak and red oak during the period 1713 - 1773 (Table 6). Hickory, birch, and black oak had only minor importance in the forests at that time. During the 1800s, farming and iron production became less important, while logging and land abandonment became more frequent. As a result, white oak and red oak again had the highest witness tree percentages, although pine importance increased to 12% during the period, probably due to the increased disturbance frequency. Present day composition of 7 mature oak stands in Spotsylvania Battlefield were compared to presettlement data, since forests at that time were described as mature oak-hickory forests (Appendix C contains a complete woody species list of present day composition). White oak had the highest densities in present day mature stands, while poplar, gum, and dogwood obtained secondary importance (Table 6). In contrast, red oak was much less abundant in present day forests. For all stands presently surveyed in the battlefield, pine had the highest density, followed by white oak, tulip poplar, and gum species.

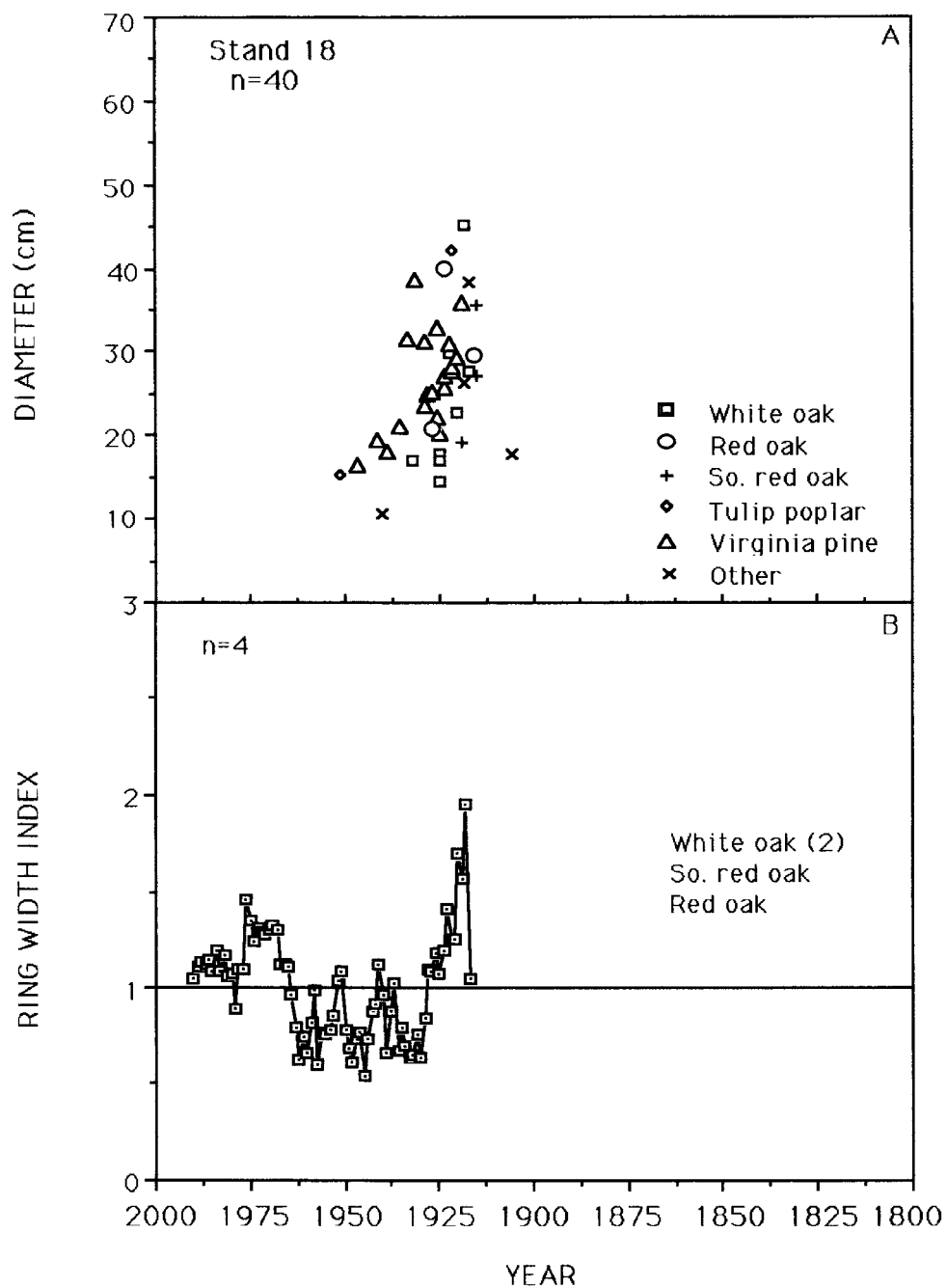


Figure 8. Tree age-diameter and radial growth chronology for stand 18 in Spotsylvania Battlefield. A ring width index of 1 corresponds to the average life history growth rate. Year values are analogous to the year of origin in the age-diameter graph.

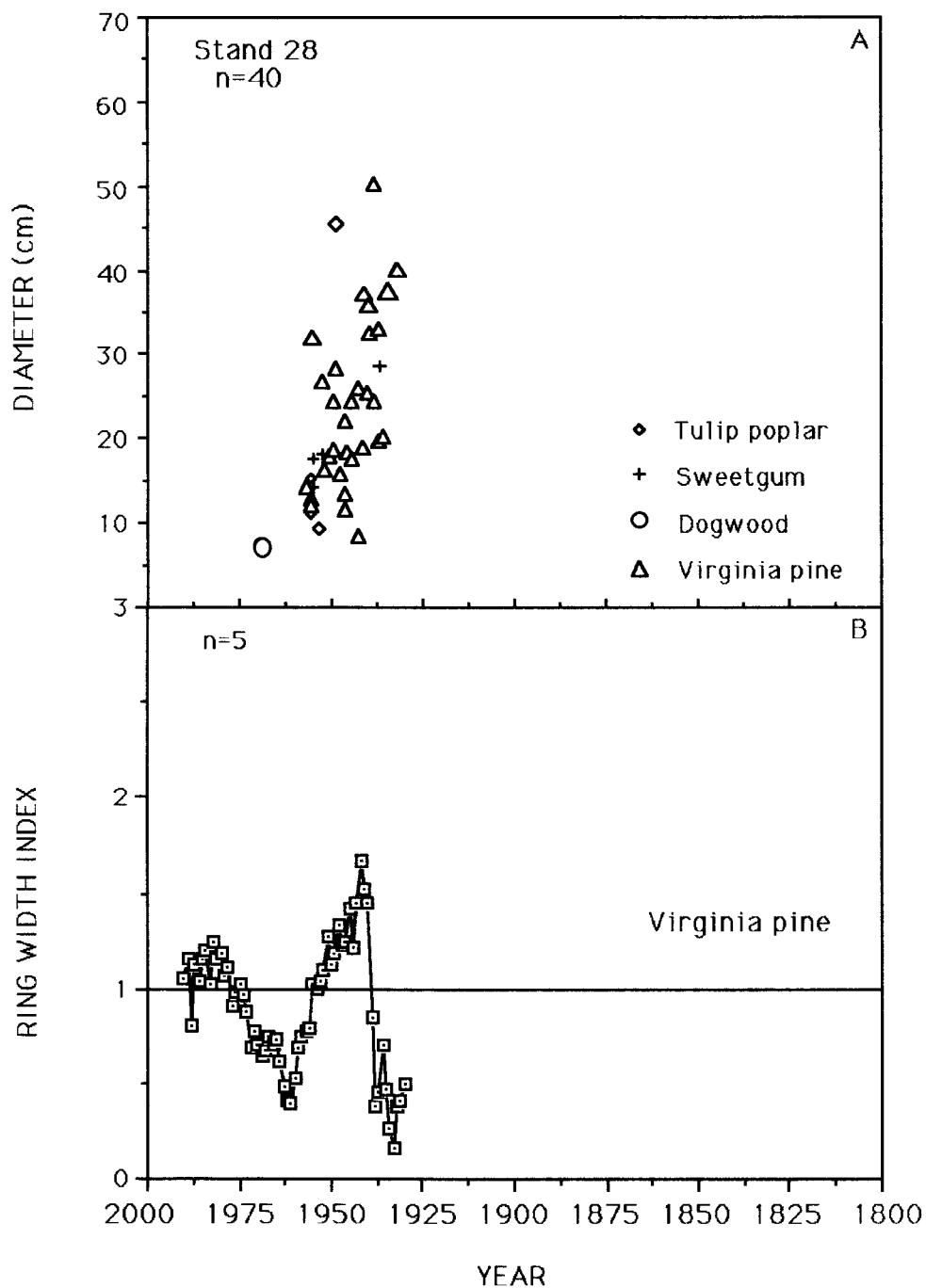


Figure 9. Tree age-diameter and radial growth chronology for stand 28 in Spotsylvania Battlefield. A ring width index of 1 corresponds to the average life history growth rate. Year values are analogous to the year of origin in the age-diameter graph.

Table 6. Percent species composition of presettlement forest witness trees versus present-day mature oak stand tree densities and total stand tree densities in Spotsylvania Battlefield.

SPECIES	1713-1773 % Total (n = 114)	1800 -1866 % Total (n = 75)	1990 Mature oak Stands*	1990 All Stands
White oak	49	27	33	21
Red oak	25	24	4	2
Black oak	4	0	4	2
Willow oak	3	0	0	0
Spanish (red) oak ¹	2	8	2	3
Post oak	0	8	0	0
Blackjack oak	0	1	0	0
Hickory	5	8	9	5
Birch	4	0	0	0
Pine	3	12	2	26
Maple ²	2	3	1	1
Poplar	2	0	11	13
Dogwood	1	1	11	6
Gum ³	1	0	11	9
Persimmon	1	0	0	0
Cedar	0	5	1	1
Sassafras	0	3	0	0
Cherry	0	1	0	0

* From 7 mature oak stand totals

1 southern red oak

2 red maple

3 sweetgum + blackgum

Discussion

European settlement of Spotsylvania County started in 1721. Indians of the Saponi, Manahoac, and Algonquin tribes previously inhabited the area, and early settlers noted that Indians frequently burned forests in the region (Mansfield 1977). Although the extent of Indian burning has been debated by some (Russell 1983), it certainly affected forest composition on a local scale (Buell et al. 1954; Christensen 1981; Pyne 1983; Lorimer 1985; Abrams 1985; Abrams and Downs 1990). Fire presumably played an important role in determining presettlement composition of the study area. Since Virginia pine is extremely fire sensitive (Slocum and Miller 1953; Williams 1990), frequent fires caused by lightning or Indians should have favored the more resistant oaks with their thick bark and prolific sprouting ability (Anderson and Adams 1978; Christensen 1981; Lorimer 1985). Periodic fires in presettlement forests may also have eliminated later successional species such as beech, maple, dogwood, and gum.

Few studies have examined presettlement composition in the Virginia Piedmont. However, Spurr (1951) published George Washington's survey notes from the mid-1700s which provided information on similar forests in western Virginia. These forests were dominated by white oak, red oak, and hickory species, with lower importance of dogwood, tulip poplar, and gum, similar to those of the Spotsylvania Battlefield. These data are also in agreement with Braun (1950) and Silver (1990), who stated that presettlement forests in the Virginia Piedmont were dominated by open stands of oak and hickory species. The open, park-like nature of those stands was indicative of a frequent fire regime.

Within 2 years after settlement, Spotsylvania County had 3 operating iron furnaces within 10 miles of the present day study area (Cappon 1945). Since each furnace required

the charcoal produced from approximately 0.4 ha of woodland per day to operate (Mansfield 1977), it is likely that much of Spotsylvania Battlefield was logged during the 40-year period of peak iron production in the early to mid-1700s. Most of the land not cut for charcoal production was cleared and planted with tobacco, the county's principal crop throughout most of the mid-1700s (Felder 1982). Abusive farming practices led to severe erosion after only 3 or 4 rotations, resulting in widespread land abandonment by the late 1700s (Craven 1965). This period of logging, land clearing, abandonment, and eventual reforestation led to the increase in pine importance seen in the 1800s. Second-growth forests initiated during this time were either partially cleared during the Civil War or logged in the late 1800s and early 1900s. Therefore, all present day forests within the battlefield were second- or third-growth.

Ordination of 26 present day stands in Spotsylvania Battlefield indicated 2 major ecological groups comprising a total of 4 forest types. Forest stands were grouped along a successional gradient from young pine stands to mature oak stands with increasing time since past land disturbance. The youngest stands rapidly became established following land abandonment within the last 60 years and consisted almost exclusively of Virginia pine and eastern redcedar (*Juniperus virginiana* L.). Redcedar rapidly lost importance during pine canopy closure due to its shade intolerance (Fowells 1965). Oak and other hardwoods became established as seedlings at this time, although most did not enter the overstory until canopy gaps from pine mortality became available. Tulip poplar and sweetgum were the first hardwoods to enter the pine canopy. Since Virginia pine is relatively short lived and subject to windthrow with maturity (Fenton and Bond 1964), oaks began to replace pine as these stands began to break up after 60-70 years.

Pine-oak and oak-pine stands were mid-successional stands that contained Virginia pine, tulip poplar, and various oak species as canopy codominants. These stands were formed in the early 1900s from either land abandonment or previous logging events. Even-

aged stands were indicative of logging, as a mixture of oaks and pine recruited into the overstory for a period of approximately 30 years. Uneven-aged stands were a consequence of secondary succession following agricultural abandonment. Virginia pine initially became established in these stands for a period of 25-30 years, depending upon several factors including field size and seed source proximity (McQuilken 1940). Oaks and other hardwoods entered the overstory after pine canopy recruitment stopped. A few stands of this transitional forest type were initiated from logging but experienced recruitment patterns similar to post-agricultural stands. The present overstory of these stands consist of mature pine which have not yet been fully replaced by hardwoods.

The oldest stands within Spotsylvania Battlefield originated following logging during the late 1800s and were dominated by white oak, black oak, southern red oak, and tulip poplar. Major cutting cycles occurred in 1880, 1900, and 1912, as seen in the tree ring indices of the oldest stands. White oak and hickory recruitment followed each cutting for approximately 15-25 years, while recruitment of species such as tulip poplar, tupelo, dogwood, and holly continued for an additional 20-30 years. Although stands located on xeric (dry) sites maintained oak recruitment for periods up to 60 years after logging, oak recruitment ceased in most stands following the initial wave of establishment.

White oak was the leading overstory dominant in the majority of present day mature stands. Tulip poplar also obtained high importance in most of the stands examined in this study due to its ability to invade soon after field abandonment (Monette and Ware 1983) or in canopy gaps associated with treefalls (Buckner and McCracken 1978; Skeen et al. 1980). Therefore, tulip poplar should continue to be an important constituent of mature forests in the future (cf. Abrams and Downs 1990). Tupelo should also be an important associate of future forests (cf. Farrell and Ware 1991; Gemborys 1974), as it obtained the highest sapling density of species with canopy potential and it is rated as a shade tolerant

species (Fowells 1965). In addition, tupelo importance was exceeded only by white oak importance in several of the oldest stands.

Despite overstory dominance and high seedling numbers of oak species in mature stands, sapling densities and recent recruitment of these species to the tree size class were relatively low. Oaks in Spotsylvania Battlefield were also not being replaced by more shade tolerant species at any significant rate. The scarcity of oak replacement species such as beech and red maple in the study area is one of the most striking features of present day composition. The fact that beech and maple constitute such minor overstory importance values suggests that these forests are rather unique within the Eastern Deciduous Biome. Beech was present in the overstory of some Spotsylvania Battlefield stands, although it was not structurally important. Beech importance may increase on some sites, despite low seedling and sapling densities (Keever 1973; Kasmer et al. 1984; Abrams and Downs 1990). Red maple obtained low densities in the overstory and sapling layers despite relatively high seedling densities. This appears to be somewhat unique in Virginia, although DeWitt and Ware (1979) also found red maple to be only locally important. Moreover, since presettlement records indicate that red maple densities were apparently always low, it does not appear that this species will be an important constituent of future mature stands.

Soil and site characteristics may play a key role in retarding the development of later successional species in the region. The sandy, acidic characteristics of soils at the study area, combined with varying moisture and nutrient availability could drastically affect the speed of succession. Since the majority of soils in the study area were highly susceptible to erosion, past abusive farming practices and weathering probably reduced the soil nutrient status of most stands. Nutrient and moisture levels may be further depleted on some sites due to increased root competition of overstory species (Coile 1940). Thus, successional progression in mature stands will probably continue to proceed at a slow rate.

On the most xeric sites, conditions may prevent significant recruitment of most later successional species, except in protected microsites.

Silvicultural prescriptions

The present composition of Spotsylvania Battlefield is intrinsically related to past disturbance. The majority of stands were 80-90 years old, resulting from either logging or agricultural abandonment. The stands dominated by oaks and hickories were still ecologically young, with only a few trees older than 150 years. Present and presettlement forests were dominated by white oak, which maintained dominance despite varying disturbance regimes. In presettlement times, we assume that fires occurred relatively frequently, maintaining open canopies and eliminating more shade-tolerant species. Due to the current mosaic of forest stands in different stages of successional development and the mild terrain (average slopes < 12%) associated with the battlefield, the chance of uncontrollable wildfire in these fuel types is presently low under normal weather conditions. Therefore, silvicultural prescriptions are not deemed necessary to maintain healthy forest conditions. Stands with higher pine concentrations contain hardwood understories of low flammability, and thus, the chance for crown fires is minimal. In addition, many pine stands are surrounded by hardwood stands with depauperate ground vegetation, further lowering the threat of widespread fire occurrence. Mature oak stand fuel loadings should remain low in the future, while succession will bring pine and pine-oak stands to a non-hazardous hardwood mixture in the near future. Moreover, there were no prevalent insect problems encountered during the course of this study. We believe these forests will develop naturally to mature, mixed-oak stands without representing a significant wildfire threat to the park or surrounding community.

In conclusion, today's dominance of white oak resulted from recruitment following periodic logging that occurred in the late 1800s and early 1900s. Moreover, secondary succession initiated from land abandonment eventually favored oaks and hickories over the initial pine invaders. Currently oaks are recruiting poorly in mature stands due to canopy closure and reduced fire and logging disturbance. Due to the present lack of adequate oak regeneration and the apparent scarcity of later successional species, the ecological status of oak remains unclear. With a scarcity of species displaying a potential to replace oaks, the climax composition (i.e. stable, self-perpetuating populations which are in equilibrium with the environment) of Spotsylvania Battlefield will probably consist of a mixture of oaks, hickories, tulip poplar, beech, and tupelo on the better sites. On the more xeric sites, oak and hickory species may represent an edaphic or soil controlled climax, capable of self-maintenance in the absence of further disturbance.

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Appendix A

STAND VEGETATIVE COMPOSITION

Stand # 1. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	2.8	2.7	4.1	3
<i>Carpinus caroliniana</i>	0.0	0.3	0.8	0
<i>Carya glabra</i>	1.3	1.7	3.3	2
<i>Carya tomentosa</i>	0.3	1.4	3.3	2
<i>Cornus florida</i>	0.1	1.0	1.6	1
<i>Fagus grandifolia</i>	0.3	0.7	1.6	1
<i>Fraxinus americana</i>	1.6	0.7	1.6	1
<i>Fraxinus pennsylvanica</i>	0.1	0.3	0.8	0
<i>Ilex opaca</i>	0.2	1.4	3.3	2
<i>Liquidambar styraciflua</i>	3.4	4.7	7.4	5
<i>Liriodendron tulipifera</i>	32.2	20.9	15.6	23
<i>Nyssa sylvatica</i>	1.6	3.4	6.6	4
<i>Pinus virginiana</i>	24.8	27.7	13.1	22
<i>Quercus alba</i>	14.4	19.9	16.4	17
<i>Quercus coccinea</i>	4.0	2.7	4.1	4
<i>Quercus falcata</i>	2.2	1.4	3.3	2
<i>Quercus prinus</i>	0.1	0.3	0.8	0
<i>Quercus rubra</i>	4.8	4.1	4.9	5
<i>Quercus stellata</i>	0.5	0.3	0.8	1
<i>Quercus velutina</i>	5.3	4.4	6.6	5

Total tree density (#s/ha) = 731
 Total basal area (m²/ha) = 48.5

Avg. stand age (yrs.) = 71

Species	Understory density (#s/ha)	
	Seedling	Sapling
<i>Acer rubrum</i>	3230	54
<i>Carpinus caroliniana</i>	109	--
<i>Carya</i> spp.	967	--
<i>Cornus florida</i>	8935	751
<i>Fagus grandifolia</i>	539	215
<i>Ilex opaca</i>	1184	430
<i>Juniperus virginiana</i>	--	54
<i>Liquidambar styraciflua</i>	1937	--
<i>Liriodendron tulipifera</i>	430	215
<i>Nyssa sylvatica</i>	1507	54
<i>Quercus alba</i>	3551	269
<i>Quercus falcata</i>	215	--
<i>Quercus rubra</i>	2800	108
<i>Quercus velutina</i>	1077	--
<i>Sassafras albidum</i>	754	--
Totals	27235	2150

Average total shrub cover (%) 12.5

Acreage 12

Stand # 2. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carya glabra</i>	0.3	1.5	3.3	2
<i>Carya tomentosa</i>	0.2	0.9	1.7	1
<i>Cornus florida</i>	0.5	2.3	5.8	3
<i>Fagus grandifolia</i>	1.9	3.2	8.3	4
<i>Ilex opaca</i>	0.3	2.1	4.2	2
<i>Liquidambar styraciflua</i>	1.5	3.5	6.7	4
<i>Liriodendron tulipifera</i>	21.7	19.4	15.8	19
<i>Nyssa sylvatica</i>	2.7	3.8	7.5	5
<i>Pinus echinata</i>	0.5	0.3	0.8	1
<i>Pinus virginiana</i>	51.1	47.2	16.7	40
<i>Quercus alba</i>	4.8	8.2	10.8	8
<i>Quercus coccinea</i>	0.6	0.6	1.7	1
<i>Quercus falcata</i>	3.7	3.8	8.3	5
<i>Quercus rubra</i>	3.6	1.2	3.3	3
<i>Quercus velutina</i>	2.6	2.1	5.0	3

Total tree density (#s/ha) = 843

Avg. stand age (yrs.) = 65

Total basal area (m²/ha) = 38.2

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	2152	--
<i>Castanea dentata</i>	109	--
<i>Carya</i> spp.	1077	54
<i>Cornus florida</i>	5491	377
<i>Fagus grandifolia</i>	324	161
<i>Ilex opaca</i>	2367	323
<i>Juniperus virginiana</i>	--	54
<i>Liquidambar styraciflua</i>	645	54
<i>Liriodendron tulipifera</i>	324	108
<i>Nyssa sylvatica</i>	860	323
<i>Prunus serotina</i>	215	--
<i>Quercus alba</i>	1937	54
<i>Quercus phellos</i>	324	--
<i>Quercus rubra</i>	754	--
<i>Quercus velutina</i>	1614	--
<i>Sassafras albidum</i>	539	--
Totals	18722	1508
Average total shrub cover (%)	<u>16.8</u>	Acreage <u>20</u>

Stand # 3. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carpinus caroliniana</i>	0.2	1.4	3.1	2
<i>Carya glabra</i>	6.2	5.1	6.3	6
<i>Carya tomentosa</i>	3.8	3.3	5.2	4
<i>Cornus florida</i>	0.3	2.8	1.0	1
<i>Fagus grandifolia</i>	6.5	18.2	18.8	15
<i>Ilex opaca</i>	0.3	1.4	2.1	1
<i>Liquidambar styraciflua</i>	5.8	12.1	9.4	9
<i>Liriodendron tulipifera</i>	31.7	21.0	14.6	22
<i>Nyssa sylvatica</i>	0.4	1.4	3.1	2
<i>Pinus virginiana</i>	4.6	5.6	6.3	6
<i>Quercus alba</i>	27.4	20.1	16.7	21
<i>Quercus coccinea</i>	2.1	1.4	3.1	2
<i>Quercus rubra</i>	7.7	4.7	7.3	7
<i>Quercus stellata</i>	1.4	0.5	1.0	1
<i>Quercus velutina</i>	1.7	0.9	2.1	2

Total tree density (#s/ha) = 529

Avg. stand age (yrs.) = 74

Total basal area (m²/ha) = 38.9

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	3230	--
<i>Carya</i> spp.	1077	54
<i>Cornus florida</i>	7101	377
<i>Fagus grandifolia</i>	1937	--
<i>Fraxinus pennsylvanica</i>	215	--
<i>Ilex opaca</i>	754	108
<i>Liquidambar styraciflua</i>	645	--
<i>Liriodendron tulipifera</i>	860	--
<i>Nyssa sylvatica</i>	324	108
<i>Prunus serotina</i>	430	--
<i>Quercus alba</i>	3983	108
<i>Quercus falcata</i>	215	--
<i>Quercus rubra</i>	860	--
<i>Quercus velutina</i>	539	--
<i>Sassafras albidum</i>	324	--
Totals	22494	755
Average total shrub cover (%)	<u>6.8</u>	Acreage <u>11</u>

Stand # 4. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carpinus caroliniana</i>	0.6	1.0	1.9	1
<i>Carya glabra</i>	0.9	1.4	3.7	2
<i>Carya tomentosa</i>	1.5	0.7	1.9	1
<i>Cornus florida</i>	1.4	7.1	8.4	6
<i>Fagus grandifolia</i>	9.5	14.2	13.1	12
<i>Fraxinus pennsylvanica</i>	0.2	0.7	0.9	1
<i>Ilex opaca</i>	0.2	1.0	2.8	1
<i>Liquidambar styraciflua</i>	5.4	4.4	9.4	6
<i>Liriodendron tulipifera</i>	21.6	18.2	15.9	19
<i>Nyssa sylvatica</i>	3.3	4.1	7.5	5
<i>Pinus virginiana</i>	45.1	36.8	17.8	33
<i>Quercus alba</i>	4.2	8.1	11.2	8
<i>Quercus falcata</i>	4.5	0.7	1.9	2
<i>Quercus rubra</i>	1.5	1.4	2.8	2
<i>Sassafras albidum</i>	0.1	0.3	0.9	0

Total tree density (#s/ha) = 731

Avg. stand age (yrs.) = 71

Total basal area (m²/ha) = 30.9

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	539	54
<i>Carya</i> spp.	430	--
<i>Castanea dentata</i>	109	--
<i>Cornus florida</i>	11624	430
<i>Fagus grandifolia</i>	3015	108
<i>Fraxinus pennsylvanica</i>	215	--
<i>Ilex opaca</i>	1077	161
<i>Liquidambar styraciflua</i>	1614	54
<i>Liriodendron tulipifera</i>	969	108
<i>Nyssa sylvatica</i>	1292	54
<i>Quercus alba</i>	1184	--
<i>Quercus falcata</i>	969	--
<i>Quercus phellos</i>	109	--
<i>Quercus rubra</i>	645	--
<i>Quercus velutina</i>	324	--
<i>Sassafras albidum</i>	324	--
Totals	24439	969

Average total shrub cover (%)

15.3Acreage 43

Stand # 5. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carpinus caroliniana</i>	0.0	0.3	0.9	0
<i>Carya glabra</i>	0.3	1.3	1.8	1
<i>Carya tomentosa</i>	0.2	0.3	0.9	0
<i>Cornus florida</i>	0.3	1.9	4.4	2
<i>Fagus grandifolia</i>	1.7	3.2	7.0	4
<i>Ilex opaca</i>	0.2	1.0	1.8	1
<i>Liquidambar styraciflua</i>	1.2	3.2	5.3	3
<i>Liriodendron tulipifera</i>	10.7	9.7	14.0	11
<i>Nyssa sylvatica</i>	3.0	7.7	10.5	7
<i>Pinus echinata</i>	3.0	2.3	2.6	3
<i>Pinus virginiana</i>	56.2	48.7	17.5	41
<i>Populus deltoides</i>	1.0	0.3	0.9	1
<i>Quercus alba</i>	4.9	10.0	12.3	9
<i>Quercus falcata</i>	13.4	5.8	10.5	10
<i>Quercus rubra</i>	2.0	0.6	1.8	1
<i>Quercus stellata</i>	0.4	0.6	1.8	1
<i>Quercus velutina</i>	1.6	2.6	5.3	3
<i>Sassafras albidum</i>	0.0	0.3	0.9	0

Total tree density (#s/ha) = 766

Avg. stand age (yrs.) = 71

Total basal area (m²/ha) = 36.3

Species	Understory density (#s/ha)	
	Seedling	Sapling
<i>Acer rubrum</i>	4090	161
<i>Carya</i> spp.	754	--
<i>Cornus florida</i>	10655	539
<i>Fagus grandifolia</i>	539	--
<i>Ilex opaca</i>	1722	108
<i>Juniperus virginiana</i>	--	54
<i>Liquidambar styraciflua</i>	1831	--
<i>Liriodendron tulipifera</i>	860	108
<i>Nyssa sylvatica</i>	430	161
<i>Quercus alba</i>	1292	54
<i>Quercus falcata</i>	1292	--
<i>Quercus prinus</i>	969	--
<i>Quercus rubra</i>	430	--
<i>Quercus velutina</i>	2046	--
<i>Sassafras albidum</i>	645	54
Totals	27555	1239

Average total shrub cover (%)

25.3Acreage 23

Stand # 6. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	0.9	1.2	2.7	2
<i>Carpinus caroliniana</i>	0.9	0.8	1.8	1
<i>Carya glabra</i>	8.0	4.6	5.4	6
<i>Carya tomentosa</i>	3.5	2.7	4.5	4
<i>Cornus florida</i>	0.6	3.1	7.1	4
<i>Fagus grandifolia</i>	2.2	4.2	5.4	4
<i>Fraxinus pennsylvanica</i>	0.2	0.8	0.9	1
<i>Ilex opaca</i>	0.5	2.3	5.4	3
<i>Juniperus virginiana</i>	0.8	1.5	3.6	2
<i>Liquidambar styraciflua</i>	1.0	3.1	4.5	3
<i>Liriodendron tulipifera</i>	21.0	16.2	13.4	17
<i>Nyssa sylvatica</i>	2.4	3.5	7.1	4
<i>Pinus echinata</i>	2.4	0.8	1.8	2
<i>Pinus virginiana</i>	15.4	16.2	8.0	13
<i>Quercus alba</i>	30.0	31.3	16.1	26
<i>Quercus coccinea</i>	1.4	0.4	0.9	1
<i>Quercus falcata</i>	4.4	4.2	4.5	4
<i>Quercus phellos</i>	0.1	0.4	0.9	0
<i>Quercus rubra</i> -	4.5	2.7	6.3	4

Total tree density (#s/ha) = 640

Avg. stand age (yrs.) = 65

Total basal area (m²/ha) = 26.8

Species	Understory density (#s/ha)	
	Seedling	Sapling
<i>Acer rubrum</i>	3230	--
<i>Carpinus caroliniana</i>	539	--
<i>Carya</i> spp.	1937	108
<i>Cornus florida</i>	11518	700
<i>Fagus grandifolia</i>	1399	54
<i>Fraxinus pennsylvanica</i>	1831	54
<i>Ilex opaca</i>	1399	592
<i>Liquidambar styraciflua</i>	2152	108
<i>Liriodendron tulipifera</i>	1077	54
<i>Nyssa sylvatica</i>	860	108
<i>Prunus serotina</i>	109	--
<i>Quercus alba</i>	5382	54
<i>Quercus falcata</i>	1614	54
<i>Quercus rubra</i>	430	--
<i>Quercus stellata</i>	430	--
<i>Quercus velutina</i>	324	--
<i>Sassafras albidum</i>	109	--
Totals	34340	1886

Average total shrub cover (%)

10.5Acreage 44

Stand # 7. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	1.4	1.9	3.3	2
<i>Carya glabra</i>	4.7	4.3	5.4	5
<i>Carya tomentosa</i>	6.8	4.9	6.5	6
<i>Cornus florida</i>	2.6	19.1	16.3	13
<i>Fagus grandifolia</i>	5.4	7.4	6.5	6
<i>Ilex opaca</i>	0.3	2.5	1.1	1
<i>Juniperus virginiana</i>	0.3	1.9	3.3	2
<i>Liquidambar styraciflua</i>	0.9	1.1	2.2	1
<i>Liriodendron tulipifera</i>	3.6	3.7	5.4	4
<i>Nyssa sylvatica</i>	5.7	16.0	17.4	13
<i>Pinus virginiana</i>	0.7	0.6	1.1	1
<i>Quercus alba</i>	48.1	29.0	20.7	33
<i>Quercus falcata</i>	0.5	0.6	1.1	1
<i>Quercus rubra</i>	9.4	2.5	4.4	5
<i>Quercus velutina</i>	9.4	4.3	5.4	6

Total tree density (#s/ha) = 400

Avg. stand age (yrs.) = 84

Total basal area (m²/ha) = 24.8

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	754	--
<i>Carya spp.</i>	3875	54
<i>Cornus florida</i>	3445	484
<i>Fagus grandifolia</i>	645	161
<i>Fraxinus pennsylvanica</i>	539	54
<i>Ilex opaca</i>	109	54
<i>Juniperus virginiana</i>	--	54
<i>Liriodendron tulipifera</i>	215	54
<i>Nyssa sylvatica</i>	1507	484
<i>Quercus alba</i>	14962	54
<i>Quercus rubra</i>	1077	--
<i>Quercus velutina</i>	1077	--
<i>Sassafras albidum</i>	1292	54
Totals	29497	1507

Average total shrub cover (%) 16.0Acreage 20

Stand # 8. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	0.6	1.5	2.8	2
<i>Carya glabra</i>	4.0	2.6	5.7	4
<i>Carya tomentosa</i>	1.6	1.8	3.8	2
<i>Cornus florida</i>	0.5	2.2	3.8	2
<i>Fagus grandifolia</i>	0.5	1.5	3.8	2
<i>Fraxinus pennsylvanica</i>	0.2	0.7	1.9	1
<i>Ilex opaca</i>	0.2	1.1	2.8	1
<i>Liquidambar styraciflua</i>	1.7	2.2	4.7	3
<i>Liriodendron tulipifera</i>	19.9	21.2	17.0	19
<i>Nyssa sylvatica</i>	2.2	3.6	5.7	4
<i>Pinus echinata</i>	0.4	0.4	0.9	1
<i>Pinus virginiana</i>	35.9	29.9	15.1	27
<i>Quercus alba</i>	20.7	23.0	18.9	21
<i>Quercus coccinea</i>	0.9	0.7	1.9	1
<i>Quercus falcata</i> -	6.2	4.4	5.7	5
<i>Quercus phellos</i>	0.3	0.4	0.9	1
<i>Quercus rubra</i>	3.2	2.6	3.8	3
<i>Quercus velutina</i>	0.8	0.4	0.9	1

Total tree density (#s/ha) = 677

Avg. stand age (yrs.) = 58

Total basal area (m²/ha) = 24.5

Species	Understory density (#s/ha)	
	Seedling	Sapling
<i>Acer rubrum</i>	3660	54
<i>Carya</i> spp.	1831	--
<i>Castanea dentata</i>	645	--
<i>Cornus florida</i>	8612	753
<i>Fagus grandifolia</i>	1184	54
<i>Fraxinus pennsylvanica</i>	754	108
<i>Ilex opaca</i>	1184	592
<i>Liquidambar styraciflua</i>	645	161
<i>Liriodendron tulipifera</i>	969	269
<i>Nyssa sylvatica</i>	215	161
<i>Prunus serotina</i>	539	--
<i>Quercus alba</i>	3015	--
<i>Quercus falcata</i>	109	--
<i>Quercus rubra</i>	430	--
<i>Sassafras albidum</i>	109	--
Totals	23901	2152

Average total shrub cover (%) 17.5Acreage 20

Stand # 9. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	1.6	1.0	1.1	1
<i>Carpinus caroliniana</i>	0.6	4.1	2.1	2
<i>Carya glabra</i>	1.7	2.0	4.2	3
<i>Carya tomentosa</i>	7.0	7.7	8.4	8
<i>Cornus florida</i>	1.5	10.7	10.5	8
<i>Fagus grandifolia</i>	0.4	1.5	3.2	2
<i>Fraxinus pennsylvanica</i>	0.1	0.5	1.1	1
<i>Ilex opaca</i>	0.1	1.5	2.1	1
<i>Liriodendron tulipifera</i>	27.5	20.4	16.8	22
<i>Nyssa sylvatica</i>	2.8	8.2	9.5	7
<i>Pinus echinata</i>	1.8	1.0	1.1	1
<i>Pinus virginiana</i>	6.8	5.1	6.3	6
<i>Populus deltoides</i>	0.7	0.5	1.1	1
<i>Quercus alba</i>	36.7	29.6	21.0	29
<i>Quercus falcata</i>	5.1	2.6	5.3	4
<i>Quercus rubra</i>	0.9	2.0	4.2	2
<i>Quercus velutina</i>	4.6	1.5	2.1	3

Total tree density (#s/ha) = 484

Avg. stand age (yrs.) = 68

Total basal area (m²/ha) = 26.8

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	3983	--
<i>Carpinus caroliniana</i>	324	215
<i>Carya</i> spp.	2691	108
<i>Cornus florida</i>	16791	1184
<i>Crataegus</i> spp.	109	--
<i>Fagus grandifolia</i>	2800	54
<i>Fraxinus pennsylvanica</i>	1399	54
<i>Ilex opaca</i>	430	377
<i>Juniperus virginiana</i>	324	54
<i>Liquidambar styraciflua</i>	1292	--
<i>Liriodendron tulipifera</i>	1399	--
<i>Nyssa sylvatica</i>	324	377
<i>Prunus serotina</i>	754	--
<i>Quercus alba</i>	4413	--
<i>Quercus falcata</i>	109	--
<i>Quercus phellos</i>	109	--
<i>Quercus rubra</i>	754	--
<i>Quercus velutina</i>	539	54
<i>Sassafras albidum</i>	215	--
Totals	38759	2477

Average total shrub cover (%) 13.0Acreage 13

Stand # 10. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carya glabra</i>	3.4	5.8	7.7	6
<i>Carya tomentosa</i>	3.6	4.5	6.4	5
<i>Cornus florida</i>	0.5	5.8	10.3	6
<i>Fagus grandifolia</i>	1.5	9.0	7.7	6
<i>Ilex opaca</i>	0.3	3.2	5.1	3
<i>Juniperus virginiana</i>	0.1	0.6	1.3	1
<i>Liquidambar styraciflua</i>	0.5	1.3	1.3	1
<i>Liriodendron tulipifera</i>	17.2	10.9	11.6	13
<i>Nyssa sylvatica</i>	1.5	5.8	5.1	4
<i>Pinus virginiana</i>	2.9	2.6	3.9	3
<i>Quercus alba</i>	51.8	39.1	23.1	38
<i>Quercus coccinea</i>	3.4	1.9	2.6	3
<i>Quercus falcata</i>	3.8	2.6	5.1	4
<i>Quercus rubra</i>	5.3	4.5	6.4	6
<i>Quercus velutina</i>	4.2	2.6	2.6	3

Total tree density (#s/ha) = 385

Avg. stand age (yrs.) = 84

Total basal area (m²/ha) = 31.2

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	1077	--
<i>Carpinus caroliniana</i>	--	54
<i>Carya</i> spp.	1831	54
<i>Castanea dentata</i>	2261	--
<i>Cornus florida</i>	10764	861
<i>Fagus grandifolia</i>	430	161
<i>Ilex opaca</i>	324	215
<i>Liquidambar styraciflua</i>	215	54
<i>Liriodendron tulipifera</i>	969	--
<i>Nyssa sylvatica</i>	109	108
<i>Prunus serotina</i>	860	--
<i>Quercus alba</i>	10225	--
<i>Quercus falcata</i>	109	--
<i>Quercus rubra</i>	1399	--
<i>Quercus velutina</i>	1077	--
<i>Sassafras albidum</i>	324	--
Totals	31964	1507

Average total shrub cover (%) 13.1Acreage 10

Stand # 11. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	1.7	1.8	1.1	2
<i>Carpinus caroliniana</i>	0.0	0.6	1.1	1
<i>Carya glabra</i>	2.4	3.6	5.7	4
<i>Carya tomentosa</i>	2.4	3.0	4.6	3
<i>Cornus florida</i>	1.3	12.5	10.3	8
<i>Fagus grandifolia</i>	10.8	17.9	16.1	15
<i>Ilex opaca</i>	0.2	1.8	2.3	1
<i>Juniperus virginiana</i>	0.3	0.6	1.1	1
<i>Liquidambar styraciflua</i>	0.4	0.6	1.1	1
<i>Liriodendron tulipifera</i>	17.2	10.7	11.5	13
<i>Nyssa sylvatica</i>	1.0	3.0	5.7	3
<i>Pinus echinata</i>	0.6	0.6	1.1	1
<i>Pinus virginiana</i>	3.1	3.0	4.6	4
<i>Quercus alba</i>	48.6	32.7	19.5	34
<i>Quercus falcata</i>	2.3	2.6	4.6	3
<i>Quercus prinus</i>	0.5	0.6	1.1	1
<i>Quercus stellata</i>	0.5	0.6	1.1	1
<i>Quercus velutina</i>	6.6	4.2	6.9	6

Total tree density (#s/ha) = 415

Avg. stand age (yrs.) = 77

Total basal area (m²/ha) = 29.7

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	4522	--
<i>Carya</i> spp.	3445	54
<i>Cornus florida</i>	5491	699
<i>Fagus grandifolia</i>	2582	54
<i>Ilex opaca</i>	430	--
<i>Liquidambar styraciflua</i>	109	--
<i>Liriodendron tulipifera</i>	109	--
<i>Nyssa sylvatica</i>	109	--
<i>Prunus serotina</i>	754	--
<i>Quercus alba</i>	14100	--
<i>Quercus rubra</i>	860	--
<i>Quercus velutina</i> -	430	--
<i>Sassafras albidum</i>	860	54
Totals	33801	861

Average total shrub cover (%) 11.6Acreage 14

Stand # 12. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carya glabra</i>	1.8	1.7	2.7	2
<i>Carya tomentosa</i>	0.3	0.8	1.8	1
<i>Cornus florida</i>	1.0	5.5	9.9	5
<i>Fagus grandifolia</i>	1.0	2.2	4.5	3
<i>Ilex opaca</i>	0.3	1.1	3.6	2
<i>Juniperus virginiana</i>	0.1	0.3	0.9	0
<i>Liquidambar styraciflua</i>	1.1	1.9	6.3	3
<i>Liriodendron tulipifera</i>	17.4	18.0	16.2	17
<i>Nyssa sylvatica</i>	1.4	5.2	10.8	6
<i>Pinus echinata</i>	1.6	0.8	0.9	1
<i>Pinus virginiana</i>	57.9	44.2	17.1	40
<i>Quercus alba</i>	6.6	13.8	14.4	12
<i>Quercus coccinea</i>	1.8	0.8	1.8	1
<i>Quercus falcata</i>	1.9	0.6	1.8	1
<i>Quercus rubra</i>	4.3	2.2	4.5	4
<i>Quercus velutina</i>	1.5	0.8	2.7	2

Total tree density (#s/ha) = 895

Avg. stand age (yrs.) = 68

Total basal area (m²/ha) = 34.5

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	2046	--
<i>Carpinus caroliniana</i>	109	--
<i>Carya</i> spp.	3551	--
<i>Castanea dentata</i>	324	--
<i>Cornus florida</i>	10199	914
<i>Fagus grandifolia</i>	754	161
<i>Ilex opaca</i>	4090	109
<i>Liquidambar styraciflua</i>	1831	54
<i>Liriodendron tulipifera</i>	539	--
<i>Nyssa sylvatica</i>	430	--
<i>Prunus serotina</i>	109	--
<i>Quercus alba</i>	1077	--
<i>Quercus falcata</i>	430	--
<i>Quercus phellos</i>	324	--
<i>Quercus rubra</i>	539	--
<i>Quercus velutina</i>	969	--
<i>Sassafras albidum</i>	2152	--
Totals	29393	1238
Average total shrub cover (%)	<u>15.8</u>	Acreage <u>37</u>

Stand # 13. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carya glabra</i>	0.3	2.0	3.1	2
<i>Carya tomentosa</i>	0.3	3.4	6.2	3
<i>Cornus florida</i>	0.4	3.4	7.7	4
<i>Ilex opaca</i>	0.2	0.7	1.5	1
<i>Juniperus virginiana</i>	0.0	0.7	1.5	1
<i>Liquidambar styraciflua</i>	0.1	0.7	1.5	1
<i>Liriodendron tulipifera</i>	2.0	1.4	3.1	2
<i>Nyssa sylvatica</i>	5.7	21.8	23.1	17
<i>Pinus echinata</i>	0.4	0.7	1.5	1
<i>Quercus alba</i>	51.1	43.5	30.8	42
<i>Quercus coccinea</i>	3.0	2.0	3.1	3
<i>Quercus falcata</i>	15.9	8.8	12.3	12
<i>Quercus rubra</i>	14.0	6.1	10.8	10
<i>Quercus velutina</i>	6.7	4.8	9.2	7

Total tree density (#s/ha) = 363

Avg. stand age (yrs.) = 103

Total basal area (m²/ha) = 24.1

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	430	--
<i>Carya</i> spp.	1184	645
<i>Cornus florida</i>	1614	484
<i>Ilex opaca</i>	323	--
<i>Liquidambar styraciflua</i>	215	--
<i>Liriodendron tulipifera</i>	1077	--
<i>Nyssa sylvatica</i>	2046	269
<i>Prunus serotina</i>	1292	--
<i>Quercus alba</i>	10010	--
<i>Quercus falcata</i>	430	--
<i>Quercus rubra</i>	2152	--
<i>Quercus velutina</i>	2691	161
<i>Sassafras albidum</i>	645	--
Totals	24109	1559

Average total shrub cover (%) 16.0Acreage 31

Stand # 14. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	2.0	4.9	5.4	4
<i>Betula nigra</i>	0.1	0.7	0.9	1
<i>Carya glabra</i>	0.0	0.3	0.9	0
<i>Cornus florida</i>	0.1	0.7	1.8	1
<i>Fagus grandifolia</i>	1.0	2.3	3.6	2
<i>Ilex opaca</i>	0.7	2.3	5.4	3
<i>Juniperus virginiana</i>	0.2	0.7	1.8	1
<i>Liquidambar styraciflua</i>	5.9	6.2	7.1	6
<i>Liriodendron tulipifera</i>	14.6	13.4	11.6	13
<i>Nyssa sylvatica</i>	2.8	6.5	9.8	6
<i>Pinus virginiana</i>	6.4	13.7	8.0	9
<i>Quercus alba</i>	34.4	24.2	15.2	25
<i>Quercus falcata</i>	18.3	13.7	10.7	14
<i>Quercus phellos</i>	0.1	0.3	0.9	0
<i>Quercus rubra</i>	6.1	2.0	3.6	4
<i>Quercus stellata</i>	0.8	2.6	5.4	3
<i>Quercus velutina</i>	6.4	4.6	7.1	6
<i>Sassafras albidum</i>	0.2	1.0	0.9	1

Total tree density (#s/ha) = 756

Avg. stand age (yrs.) = 60

Total basal area (m²/ha) = 24.9

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	3230	109
<i>Carpinus caroliniana</i>	109	--
<i>Carya spp.</i>	324	161
<i>Cornus florida</i>	1722	808
<i>Fagus grandifolia</i>	109	--
<i>Ilex opaca</i>	2152	376
<i>Liquidambar styraciflua</i>	2152	109
<i>Liriodendron tulipifera</i>	430	54
<i>Nyssa sylvatica</i>	1184	215
<i>Prunus serotina</i>	109	--
<i>Quercus alba</i>	4198	215
<i>Quercus falcata</i>	754	54
<i>Quercus phellos</i>	109	--
<i>Quercus rubra</i>	2046	54
<i>Quercus stellata</i>	860	54
<i>Quercus velutina</i>	1507	--
<i>Sassafras albidum</i>	2780	--
Totals	23795	2209

Average total shrub cover (%) 10.3Acreage 11

Stand # 15. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carya glabra</i>	11.8	8.8	8.7	10
<i>Carya tomentosa</i>	5.4	3.1	4.8	4
<i>Cornus florida</i>	2.4	16.6	15.4	11
<i>Fagus grandifolia</i>	0.4	2.1	2.9	2
<i>Ilex opaca</i>	1.7	8.8	10.6	7
<i>Juniperus virginiana</i>	0.3	2.1	3.9	2
<i>Liriodendron tulipifera</i>	6.3	9.8	9.6	9
<i>Nyssa sylvatica</i>	2.4	9.3	10.6	7
<i>Pinus virginiana</i>	4.7	2.6	2.9	3
<i>Quercus alba</i>	49.5	27.5	19.2	32
<i>Quercus falcata</i>	1.9	0.5	1.0	1
<i>Quercus rubra</i>	2.5	4.1	3.9	4
<i>Quercus velutina</i>	10.6	4.1	5.8	7
<i>Sassafras albidum</i>	0.1	0.5	1.0	1

Total tree density (#s/ha) = 477

Avg. stand age (yrs.) = 82

Total basal area (m²/ha) = 23.8

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Carya</i> spp.	7964	--
<i>Castanea dentata</i>	645	--
<i>Cornus florida</i>	11409	754
<i>Fagus grandifolia</i>	215	--
<i>Fraxinus pennsylvanica</i>	109	--
<i>Ilex opaca</i>	430	324
<i>Juniperus virginiana</i>	109	161
<i>Liriodendron tulipifera</i>	430	--
<i>Nyssa sylvatica</i>	215	215
<i>Prunus serotina</i>	430	--
<i>Quercus alba</i>	30678	--
<i>Quercus rubra</i>	2691	--
<i>Quercus velutina</i>	2476	--
<i>Sassafras albidum</i>	1937	--
Totals	59748	1454
Average total shrub cover (%)	<u>6.6</u>	Acreage <u>30</u>

Stand # 16. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	0.5	1.6	2.7	2
<i>Carpinus caroliniana</i>	0.1	1.0	1.8	1
<i>Carya tomentosa</i>	0.3	0.6	1.8	1
<i>Cornus florida</i>	1.1	5.8	8.0	5
<i>Fagus grandifolia</i>	3.2	9.3	11.6	8
<i>Ilex opaca</i>	0.4	2.2	3.6	2
<i>Juniperus virginiana</i>	0.0	0.3	0.9	0
<i>Liquidambar styraciflua</i>	2.8	6.1	7.1	5
<i>Liriodendron tulipifera</i>	5.3	6.1	8.9	7
<i>Nyssa sylvatica</i>	1.0	3.5	7.1	4
<i>Pinus echinata</i>	0.4	0.3	0.9	1
<i>Pinus virginiana</i>	69.5	47.3	17.9	45
<i>Quercus alba</i>	1.9	2.6	4.5	3
<i>Quercus falcata</i>	11.7	7.7	10.7	10
<i>Quercus phellos</i>	0.5	1.9	2.7	2
<i>Quercus rubra</i>	0.2	0.6	1.8	1
<i>Quercus stellata</i>	0.3	1.3	2.7	1
<i>Quercus velutina</i>	0.7	1.6	4.5	2
<i>Sassafras albidum</i>	0.0	0.3	0.9	0

Total tree density (#s/ha) = 773

Avg. stand age (yrs.) = 64

Total basal area (m²/ha) = 36.3

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	1937	--
<i>Carpinus caroliniana</i>	969	54
<i>Castanea dentata</i>	754	--
<i>Carya spp.</i>	754	109
<i>Cornus florida</i>	3768	376
<i>Fagus grandifolia</i>	1399	54
<i>Ilex opaca</i>	1937	269
<i>Liquidambar styraciflua</i>	539	--
<i>Liriodendron tulipifera</i>	215	--
<i>Nyssa sylvatica</i>	969	161
<i>Pinus virginiana</i>	6566	--
<i>Prunus serotina</i>	430	--
<i>Quercus alba</i>	754	54
<i>Quercus falcata</i>	1399	109
<i>Quercus phellos</i>	430	109
<i>Quercus rubra</i>	539	--
<i>Quercus stellata</i>	430	--
<i>Quercus velutina</i>	430	215
<i>Sassafras albidum</i>	2906	--
Totals	27125	1510
Average total shrub cover (%)	<u>6.4</u>	Acreage <u>26</u>

Stand # 17. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	2.1	3.3	2.6	3
<i>Carpinus caroliniana</i>	0.1	0.7	0.9	1
<i>Carya glabra</i>	3.5	3.0	4.3	4
<i>Carya tomentosa</i>	1.0	2.0	5.2	3
<i>Cornus florida</i>	1.3	6.0	9.5	6
<i>Fagus grandifolia</i>	0.6	0.3	0.9	1
<i>Fraxinus pennsylvanica</i>	0.5	1.0	2.6	1
<i>Ilex opaca</i>	0.7	4.0	7.8	4
<i>Juniperus virginiana</i>	0.3	1.3	3.5	2
<i>Liquidambar styraciflua</i>	2.5	7.7	7.8	6
<i>Liriodendron tulipifera</i>	16.2	17.7	13.8	16
<i>Nyssa sylvatica</i>	0.3	1.3	2.6	1
<i>Pinus virginiana</i>	0.2	0.3	0.9	0
<i>Quercus alba</i>	41.4	37.3	17.2	32
<i>Quercus coccinea</i>	2.0	0.7	1.7	1
<i>Quercus falcata</i>	13.9	7.0	8.6	10
<i>Quercus rubra</i>	9.8	5.0	7.8	8
<i>Quercus velutina</i>	3.6	1.3	2.6	3

Total tree density (#s/ha) = 741

Avg. stand age (yrs.) = 69

Total basal area (m²/ha) = 28.2

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	3120	324
<i>Carpinus caroliniana</i>	539	109
<i>Carya</i> spp.	2906	109
<i>Castanea dentata</i>	324	--
<i>Cornus florida</i>	10440	1077
<i>Fraxinus pennsylvanica</i>	324	--
<i>Ilex opaca</i>	1831	324
<i>Liquidambar styraciflua</i>	860	215
<i>Liriodendron tulipifera</i>	1399	54
<i>Nyssa sylvatica</i>	969	324
<i>Prunus serotina</i>	109	--
<i>Quercus alba</i>	6889	54
<i>Quercus falcata</i>	109	--
<i>Quercus rubra</i>	2800	--
<i>Quercus velutina</i>	969	--
<i>Sassafras albidum</i>	969	54
Totals	34557	2634

Average total shrub cover (%) 9.5Acreage 33

Stand # 18. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	0.1	0.3	0.8	0
<i>Carya glabra</i>	0.2	0.5	1.6	1
<i>Carya tomentosa</i>	1.0	3.5	6.5	4
<i>Cornus florida</i>	1.6	9.6	13.7	8
<i>Ilex opaca</i>	0.8	4.3	6.5	4
<i>Juniperus virginiana</i>	0.1	0.5	0.8	0
<i>Liquidambar styraciflua</i>	3.2	8.6	9.7	7
<i>Liriodendron tulipifera</i>	9.1	5.8	8.9	8
<i>Nyssa sylvatica</i>	0.2	0.8	1.6	1
<i>Pinus echinata</i>	0.7	0.5	1.6	1
<i>Pinus virginiana</i>	50.7	36.7	15.3	34
<i>Quercus alba</i>	13.7	18.5	15.3	16
<i>Quercus coccinea</i>	1.6	0.5	1.6	1
<i>Quercus falcata</i>	9.7	6.1	8.9	8
<i>Quercus phellos</i>	0.4	0.3	0.8	0
<i>Quercus prinus</i>	1.5	0.5	0.8	1
<i>Quercus rubra</i>	3.8	1.5	3.2	3
<i>Quercus velutina</i>	1.8	1.5	2.4	2

Total tree density (#s/ha) = 976

Avg. stand age (yrs.) = 65

Total basal area (m²/ha) = 38.0

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	5491	54
<i>Carpinus caroliniana</i>	539	161
<i>Carya spp.</i>	2906	163
<i>Cornus florida</i>	13885	484
<i>Fagus grandifolia</i>	109	--
<i>Ilex opaca</i>	2046	--
<i>Juniperus virginiana</i>	215	--
<i>Liquidambar styraciflua</i>	1831	161
<i>Liriodendron tulipifera</i>	215	--
<i>Nyssa sylvatica</i>	1077	269
<i>Prunus serotina</i>	215	--
<i>Quercus alba</i>	2367	--
<i>Quercus falcata</i>	215	--
<i>Quercus phellos</i>	109	--
<i>Quercus prinus</i>	215	--
<i>Quercus rubra</i>	1077	--
<i>Quercus stellata</i>	1184	--
<i>Quercus velutina</i>	1399	--
<i>Sassafras albidum</i>	1831	--
Totals	36926	1292
Average total shrub cover (%)	<u>12.5</u>	Acreage <u>15</u>

Stand # 19. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	0.7	0.8	2.0	1
<i>Carya glabra</i>	0.9	2.7	4.0	3
<i>Carya tomentosa</i>	3.1	5.5	7.0	5
<i>Cornus florida</i>	0.3	1.6	4.0	2
<i>Fagus grandifolia</i>	0.2	0.8	2.0	1
<i>Ilex opaca</i>	0.9	4.7	7.0	4
<i>Juniperus virginiana</i>	0.6	1.6	3.0	2
<i>Liquidambar styraciflua</i>	5.2	12.5	13.0	10
<i>Liriodendron tulipifera</i>	9.1	8.6	12.0	10
<i>Nyssa sylvatica</i>	1.4	2.0	3.0	2
<i>Pinus taeda</i>	0.6	0.8	1.0	1
<i>Pinus virginiana</i>	4.0	3.5	6.0	5
<i>Populus grandidentata</i>	0.9	0.4	1.0	1
<i>Quercus alba</i>	59.2	45.7	20.0	42
<i>Quercus falcata</i>	6.6	3.9	7.0	6
<i>Quercus rubra</i>	0.1	0.4	1.0	0
<i>Quercus velutina</i>	6.2	4.7	7.0	6

Total tree density (#s/ha) = 633

Avg. stand age (yrs.) = 67

Total basal area (m²/ha) = 25.6

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	6566	161
<i>Carpinus caroliniana</i>	215	54
<i>Carya</i> spp.	2152	54
<i>Castanea dentata</i>	324	--
<i>Cornus florida</i>	5597	484
<i>Fraxinus pennsylvanica</i>	215	--
<i>Ilex opaca</i>	1184	109
<i>Juniperus virginiana</i>	--	54
<i>Liquidambar styraciflua</i>	1937	161
<i>Liriodendron tulipifera</i>	969	54
<i>Nyssa sylvatica</i>	1507	215
<i>Pinus virginiana</i>	109	--
<i>Quercus alba</i>	18407	54
<i>Quercus phellos</i>	324	--
<i>Quercus stellata</i>	109	--
<i>Quercus velutina</i>	645	--
<i>Sassafras albidum</i>	109	--
Totals	40369	1400
Average total shrub cover (%)	<u>14.5</u>	Acreage <u>16</u>

Stand # 20. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carya glabra</i>	2.0	5.3	9.6	6
<i>Carya tomentosa</i>	1.7	5.3	6.4	4
<i>Cornus florida</i>	0.8	8.0	7.4	5
<i>Ilex opaca</i>	0.1	0.5	1.1	1
<i>Liquidambar styraciflua</i>	1.0	3.2	3.2	2
<i>Liriodendron tulipifera</i>	14.0	12.8	16.0	14
<i>Nyssa sylvatica</i>	0.6	4.8	7.4	4
<i>Pinus virginiana</i>	3.8	4.8	4.3	4
<i>Quercus alba</i>	47.4	36.7	19.1	34
<i>Quercus coccinea</i>	6.8	4.3	3.2	5
<i>Quercus falcata</i>	4.3	2.1	3.2	3
<i>Quercus rubra</i>	13.6	6.9	10.6	10
<i>Quercus stellata</i>	0.9	1.1	2.1	1
<i>Quercus velutina</i>	3.2	4.3	6.4	5

Total tree density (#s/ha) = 465

Avg. stand age (yrs.) = 87

Total basal area (m²/ha) = 29.5

Species	Understory density (#s/ha)	
	Seedling	Sapling
<i>Acer rubrum</i>	4198	54
<i>Carpinus caroliniana</i>	1184	--
<i>Castanea dentata</i>	754	--
<i>Carya</i> spp.	2046	54
<i>Cornus florida</i>	6889	539
<i>Ilex opaca</i>	109	--
<i>Liquidambar styraciflua</i>	109	--
<i>Liriodendron tulipifera</i>	1292	--
<i>Nyssa sylvatica</i>	2476	324
<i>Pinus virginiana</i>	109	--
<i>Prunus serotina</i>	324	--
<i>Quercus alba</i>	18513	54
<i>Quercus rubra</i>	2691	54
<i>Quercus velutina</i>	645	--
<i>Sassafras albidum</i>	4952	--
Totals	46291	1079

Average total shrub cover (%) 26.0Acreage 11

Stand # 21. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	0.0	0.1	1.1	0
<i>Cornus florida</i>	0.0	0.1	1.1	0
<i>Juniperus virginiana</i>	0.0	0.1	1.1	0
<i>Liquidambar styraciflua</i>	2.8	6.4	19.4	10
<i>Liriodendron tulipifera</i>	3.6	4.0	15.1	8
<i>Pinus taeda</i>	90.7	81.2	21.5	64
<i>Pinus virginiana</i>	1.0	2.8	14.0	6
<i>Populus grandidentata</i>	0.2	0.1	1.1	0
<i>Quercus alba</i>	1.0	3.1	12.9	6
<i>Quercus falcata</i>	0.1	0.3	2.2	1
<i>Quercus rubra</i>	0.3	1.0	6.5	3
<i>Quercus stellata</i>	0.1	0.3	2.2	1
<i>Quercus velutina</i>	0.2	0.3	2.2	1

Total tree density (#s/ha) = 1734

Avg. stand age (yrs.) = 26

Total basal area (m²/ha) = 35.0

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	1507	--
<i>Aralia spinosa</i>	645	54
<i>Castanea dentata</i>	109	--
<i>Carya</i> spp.	860	645
<i>Cornus florida</i>	4413	754
<i>Fagus grandifolia</i>	215	--
<i>Ilex opaca</i>	109	215
<i>Juniperus virginiana</i>	--	269
<i>Liquidambar styraciflua</i>	1937	484
<i>Liriodendron tulipifera</i>	109	109
<i>Nyssa sylvatica</i>	969	808
<i>Pinus taeda</i>	--	54
<i>Pinus virginiana</i>	--	109
<i>Prunus serotina</i>	109	54
<i>Quercus alba</i>	1831	109
<i>Quercus falcata</i>	430	54
<i>Quercus phellos</i>	1184	109
<i>Quercus rubra</i>	645	109
<i>Quercus stellata</i>	539	--
<i>Quercus velutina</i>	215	--
<i>Sassafras albidum</i>	1507	109
Totals	17323	4036
Average total shrub cover (%)	<u>11.4</u>	Acreage <u>11</u>

Stand # 22. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	1.3	1.6	1.9	2
<i>Carpinus caroliniana</i>	0.1	0.3	0.9	0
<i>Carya glabra</i>	1.8	5.7	10.4	6
<i>Carya tomentosa</i>	1.5	5.1	12.3	6
<i>Cornus florida</i>	0.4	2.5	5.7	3
<i>Fagus grandifolia</i>	0.1	0.6	1.9	1
<i>Ilex opaca</i>	0.2	1.0	2.8	1
<i>Liquidambar styraciflua</i>	1.3	3.5	4.7	3
<i>Liriodendron tulipifera</i>	19.4	15.6	17.9	18
<i>Nyssa sylvatica</i>	1.0	1.6	4.7	2
<i>Quercus alba</i>	59.7	53.2	18.9	44
<i>Quercus falcata</i>	7.0	5.1	9.4	7
<i>Quercus rubra</i>	3.3	1.9	3.8	3
<i>Quercus stellata</i>	0.3	0.3	0.9	0
<i>Quercus velutina</i>	2.8	1.9	3.8	3

Total tree density (#s/ha) = 776

Avg. stand age (yrs.) = 69

Total basal area (m²/ha) = 29.7

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	5167	109
<i>Carpinus caroliniana</i>	109	--
<i>Carya spp.</i>	1507	54
<i>Chionanthus virginicus</i>	324	109
<i>Cornus florida</i>	5597	1292
<i>Fagus grandifolia</i>	109	54
<i>Ilex opaca</i>	645	--
<i>Juniperus virginiana</i>	--	54
<i>Liquidambar styraciflua</i>	860	109
<i>Liriodendron tulipifera</i>	1614	109
<i>Nyssa sylvatica</i>	1292	376
<i>Pinus virginiana</i>	215	--
<i>Prunus serotina</i>	215	--
<i>Quercus alba</i>	11841	54
<i>Quercus falcata</i>	215	--
<i>Quercus rubra</i>	860	--
<i>Quercus velutina</i>	969	--
<i>Sassafras albidum</i>	754	--
Totals	32292	2320

Average total shrub cover (%)

10.9Acreage 11

Stand # 23. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carya glabra</i>	0.3	1.0	5.0	2
<i>Carya tomentosa</i>	0.2	0.5	2.5	1
<i>Cornus florida</i>	2.6	9.6	8.0	7
<i>Ilex opaca</i>	0.1	0.2	1.3	1
<i>Juniperus virginiana</i>	4.3	10.9	13.8	10
<i>Liquidambar styraciflua</i>	0.5	1.2	5.0	2
<i>Liriodendron tulipifera</i>	8.6	5.9	15.0	10
<i>Nyssa sylvatica</i>	0.8	2.2	5.0	3
<i>Pinus taeda</i>	0.1	0.2	1.3	1
<i>Pinus virginiana</i>	80.3	64.7	25.0	57
<i>Platanus occidentalis</i>	0.3	0.5	1.3	1
<i>Prunus serotina</i>	0.2	0.5	2.5	1
<i>Quercus alba</i>	0.2	0.5	1.3	1
<i>Quercus falcata</i>	0.2	0.2	1.3	1
<i>Quercus velutina</i>	0.8	0.2	1.3	1
<i>Sassafras albidum</i>	0.5	1.5	6.3	3

Total tree density (#s/ha) = 1000

Avg. stand age (yrs.) = 47

Total basal area (m²/ha) = 32.0

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	3983	--
<i>Carpinus caroliniana</i>	109	--
<i>Carya</i> spp.	645	54
<i>Cornus florida</i>	16037	430
<i>Ilex opaca</i>	1507	161
<i>Juniperus virginiana</i>	--	270
<i>Liquidambar styraciflua</i>	860	--
<i>Liriodendron tulipifera</i>	645	430
<i>Nyssa sylvatica</i>	324	--
<i>Pinus virginiana</i>	2261	54
<i>Prunus serotina</i>	969	--
<i>Quercus alba</i>	430	--
<i>Quercus falcata</i>	2476	376
<i>Quercus phellos</i>	969	--
<i>Quercus rubra</i>	754	--
<i>Quercus stellata</i>	1507	--
<i>Quercus velutina</i>	1831	--
<i>Sassafras albidum</i>	2582	161
Totals	37889	1936

Average total shrub cover (%)

5.4Acreage 32

Stand # 24. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Fraxinus americana</i>	0.2	0.6	3.7	2
<i>Juniperus virginiana</i>	0.1	0.2	1.2	0
<i>Liquidambar styraciflua</i>	4.7	13.2	23.4	14
<i>Liriodendron tulipifera</i>	4.7	7.1	23.4	12
<i>Pinus taeda</i>	83.8	69.4	24.7	59
<i>Pinus virginiana</i>	0.5	1.1	4.9	2
<i>Populus grandidentata</i>	5.7	7.2	11.1	8
<i>Prunus serotina</i>	0.2	0.8	3.7	2
<i>Quercus alba</i>	0.1	0.3	2.5	1
<i>Quercus falcata</i>	0.1	0.2	1.2	0

Total tree density (#s/ha) = 1576

Avg. stand age (yrs.) = 25

Total basal area (m²/ha) = 35.6

Species	Understory density (#s/ha)	
	Seedling	Sapling
<i>Acer rubrum</i>	1507	109
<i>Carpinus caroliniana</i>	645	215
<i>Carya</i> spp.	109	108
<i>Cornus florida</i>	3230	808
<i>Fagus grandifolia</i>	324	54
<i>Fraxinus americana</i>	109	54
<i>Ilex opaca</i>	109	--
<i>Juniperus virginiana</i>	324	54
<i>Liquidambar styraciflua</i>	2691	1992
<i>Liriodendron tulipifera</i>	--	484
<i>Nyssa sylvatica</i>	109	324
<i>Prunus serotina</i>	539	54
<i>Quercus alba</i>	1722	484
<i>Quercus falcata</i>	215	--
<i>Quercus phellos</i>	324	--
<i>Quercus rubra</i>	430	215
<i>Quercus stellata</i>	109	109
<i>Quercus velutina</i>	860	54
<i>Sassafras albidum</i>	215	--
Totals	13561	5108

Average total shrub cover (%)

11.4Acreage 14

Stand # 25. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	0.2	0.7	1.7	1
<i>Carya glabra</i>	0.1	0.5	0.8	0
<i>Carya tomentosa</i>	0.1	0.7	1.7	1
<i>Cornus florida</i>	0.8	4.6	10.9	5
<i>Fagus grandifolia</i>	0.2	0.2	0.8	0
<i>Ilex opaca</i>	0.1	0.7	2.5	0.1
<i>Juniperus virginiana</i>	0.0	0.2	0.8	0
<i>Liquidambar styraciflua</i>	6.7	11.2	14.3	11
<i>Liriodendron tulipifera</i>	16.7	15.3	16.0	16
<i>Nyssa sylvatica</i>	1.3	3.2	7.6	4
<i>Pinus echinata</i>	0.5	0.2	0.8	0
<i>Pinus virginiana</i>	59.9	44.6	16.0	40
<i>Populus grandidentata</i>	0.7	0.2	0.8	1
<i>Quercus alba</i>	9.7	14.2	14.3	13
<i>Quercus falcata</i>	1.7	2.1	5.9	3
<i>Quercus rubra</i>	0.4	0.7	2.5	1
<i>Quercus stellata</i>	0.6	0.2	0.8	1
<i>Quercus velutina</i>	0.2	0.5	1.7	1

Total tree density (#s/ha) = 1080

Avg. stand age (yrs.) = 64

Total basal area (m²/ha) = 42.4

Species	Understory density (#s/ha)	
	Seedling	Sapling
<i>Acer rubrum</i>	4198	--
<i>Carpinus caroliniana</i>	430	--
<i>Carya</i> spp.	4305	215
<i>Castanea dentata</i>	215	--
<i>Cornus florida</i>	5706	969
<i>Fagus grandifolia</i>	430	161
<i>Fraxinus pennsylvanica</i>	1507	--
<i>Ilex opaca</i>	5167	430
<i>Juniperus virginiana</i>	215	161
<i>Liquidambar styraciflua</i>	2582	109
<i>Liriodendron tulipifera</i>	109	54
<i>Nyssa sylvatica</i>	754	54
<i>Prunus serotina</i>	539	--
<i>Quercus alba</i>	4413	54
<i>Quercus falcata</i>	215	--
<i>Quercus phellos</i>	430	--
<i>Quercus prinus</i>	--	54
<i>Quercus rubra</i>	2261	--
<i>Quercus stellata</i>	215	--
<i>Quercus velutina</i>	1399	--
<i>Sassafras albidum</i>	109	--
Totals	35199	2261
Average total shrub cover (%)	11.3	Acreage 16

Stand # 26. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Carya glabra</i>	8.3	15.5	14.8	13
<i>Carya tomentosa</i>	4.7	6.0	8.3	6
<i>Cornus florida</i>	2.1	9.5	11.1	8
<i>Fraxinus americana</i>	0.3	0.4	0.9	1
<i>Ilex opaca</i>	0.0	0.4	0.9	0
<i>Juniperus virginiana</i>	0.7	1.2	2.7	2
<i>Liquidambar styraciflua</i>	0.1	0.8	1.9	1
<i>Liriodendron tulipifera</i>	18.8	17.1	13.9	17
<i>Nyssa sylvatica</i>	4.4	6.3	8.3	6
<i>Pinus virginiana</i>	1.4	0.8	1.9	1
<i>Quercus alba</i>	44.3	30.2	16.7	30
<i>Quercus coccinea</i>	1.0	2.0	2.7	2
<i>Quercus falcata</i>	0.4	0.4	0.9	1
<i>Quercus prinus</i>	0.1	0.4	0.9	0
<i>Quercus rubra</i>	4.5	4.4	6.5	5
<i>Quercus velutina</i>	8.7	4.8	7.4	7

Total tree density (#s/ha) = 623

Avg. stand age (yrs.) = 66

Total basal area (m²/ha) = 28.2

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	1614	--
<i>Carya</i> spp.	3336	--
<i>Castanea dentata</i>	215	--
<i>Chionanthus virginicus</i>	539	--
<i>Cornus florida</i>	15392	1937
<i>Fagus grandifolia</i>	109	--
<i>Fraxinus americana</i>	539	54
<i>Fraxinus pennsylvanica</i>	539	54
<i>Ilex opaca</i>	215	54
<i>Juniperus virginiana</i>	109	54
<i>Liquidambar styraciflua</i>	324	--
<i>Liriodendron tulipifera</i>	754	54
<i>Nyssa sylvatica</i>	1507	109
<i>Prunus serotina</i>	860	--
<i>Quercus alba</i>	12163	--
<i>Quercus rubra</i>	1292	--
<i>Quercus velutina</i>	1722	--
<i>Sassafras albidum</i>	2261	--
Totals	43490	2316
Average total shrub cover (%)	<u>6.6</u>	Acreage <u>18</u>

Stand # 27. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	0.1	1.0	2.1	1
<i>Carpinus caroliniana</i>	0.0	0.5	1.0	1
<i>Carya glabra</i>	14.4	14.8	14.6	15
<i>Carya tomentosa</i>	1.4	2.5	4.2	3
<i>Cornus florida</i>	0.5	4.9	7.3	4
<i>Fagus grandifolia</i>	0.1	0.5	1.0	1
<i>Ilex opaca</i>	0.5	12.3	7.3	7
<i>Liquidambar styraciflua</i>	1.5	3.4	4.2	3
<i>Liriodendron tulipifera</i>	25.5	20.7	15.6	21
<i>Nyssa sylvatica</i>	1.2	5.4	9.4	5
<i>Quercus alba</i>	38.6	25.1	19.8	28
<i>Quercus rubra</i>	4.7	4.9	6.3	5
<i>Quercus velutina</i>	11.6	3.9	7.3	8

Total tree density (#s/ha) = 502

Avg. stand age (yrs.) = 88

Total basal area (m²/ha) = 31.3

Species	Understory density (#s/ha)	
	<u>Seedling</u>	<u>Sapling</u>
<i>Acer rubrum</i>	860	--
<i>Carpinus caroliniana</i>	324	161
<i>Carya spp.</i>	3551	109
<i>Castanea dentata</i>	754	--
<i>Cercis canadensis</i>	324	--
<i>Chionanthus virginicus</i>	109	--
<i>Cornus florida</i>	19267	2098
<i>Fagus grandifolia</i>	--	54
<i>Fraxinus pennsylvanica</i>	539	54
<i>Ilex opaca</i>	969	430
<i>Liquidambar styraciflua</i>	109	--
<i>Liriodendron tulipifera</i>	1614	324
<i>Nyssa sylvatica</i>	1614	161
<i>Prunus serotina</i>	645	--
<i>Quercus alba</i>	10334	--
<i>Quercus rubra</i>	860	--
<i>Quercus velutina</i>	1292	--
<i>Sassafras albidum</i>	3230	--
Totals	46395	3391
Average total shrub cover (%)	<u>6.5</u>	Acreage <u>42</u>

Stand # 28. Overstory and understory vegetative composition.

Species	Relative Dominance	Relative Density	Relative Frequency	Relative I.V.
<i>Acer rubrum</i>	0.2	1.0	4.2	2
<i>Albizia julibrissin</i>	0.1	0.2	1.4	1
<i>Cornus florida</i>	0.8	3.7	11.1	5
<i>Fraxinus americana</i>	0.0	0.2	1.4	1
<i>Ilex opaca</i>	0.0	0.2	1.4	1
<i>Juniperus virginiana</i>	0.1	0.5	2.8	1
<i>Liquidambar styraciflua</i>	6.9	11.8	23.6	14
<i>Liriodendron tulipifera</i>	4.9	5.7	15.3	9
<i>Nyssa sylvatica</i>	0.2	1.0	5.6	2
<i>Pinus taeda</i>	0.8	0.2	1.4	1
<i>Pinus virginiana</i>	85.5	74.7	27.8	63
<i>Quercus falcata</i>	0.2	0.7	4.2	2

Total tree density (#s/ha) = 1006

Avg. stand age (yrs.) = 44

Total basal area (m²/ha) = 35.7

Species	Understory density (#s/ha)	
	Seedling	Sapling
<i>Acer rubrum</i>	2582	54
<i>Albizia julibrissin</i>	539	--
<i>Carpinus caroliniana</i>	--	54
<i>Carya</i> spp.	324	--
<i>Cornus florida</i>	2261	539
<i>Fagus grandifolia</i>	539	324
<i>Ilex opaca</i>	1614	376
<i>Liquidambar styraciflua</i>	10010	376
<i>Liriodendron tulipifera</i>	2261	109
<i>Nyssa sylvatica</i>	539	215
<i>Pinus virginiana</i>	11518	--
<i>Prunus serotina</i>	645	--
<i>Quercus alba</i>	1507	109
<i>Quercus falcata</i>	5597	269
<i>Quercus phellos</i>	2152	--
<i>Quercus rubra</i>	539	--
<i>Quercus stellata</i>	754	--
<i>Quercus velutina</i>	645	--
<i>Sassafras albidum</i>	324	54
Totals	44350	2479

Average total shrub cover (%)

20.6Acreage 18

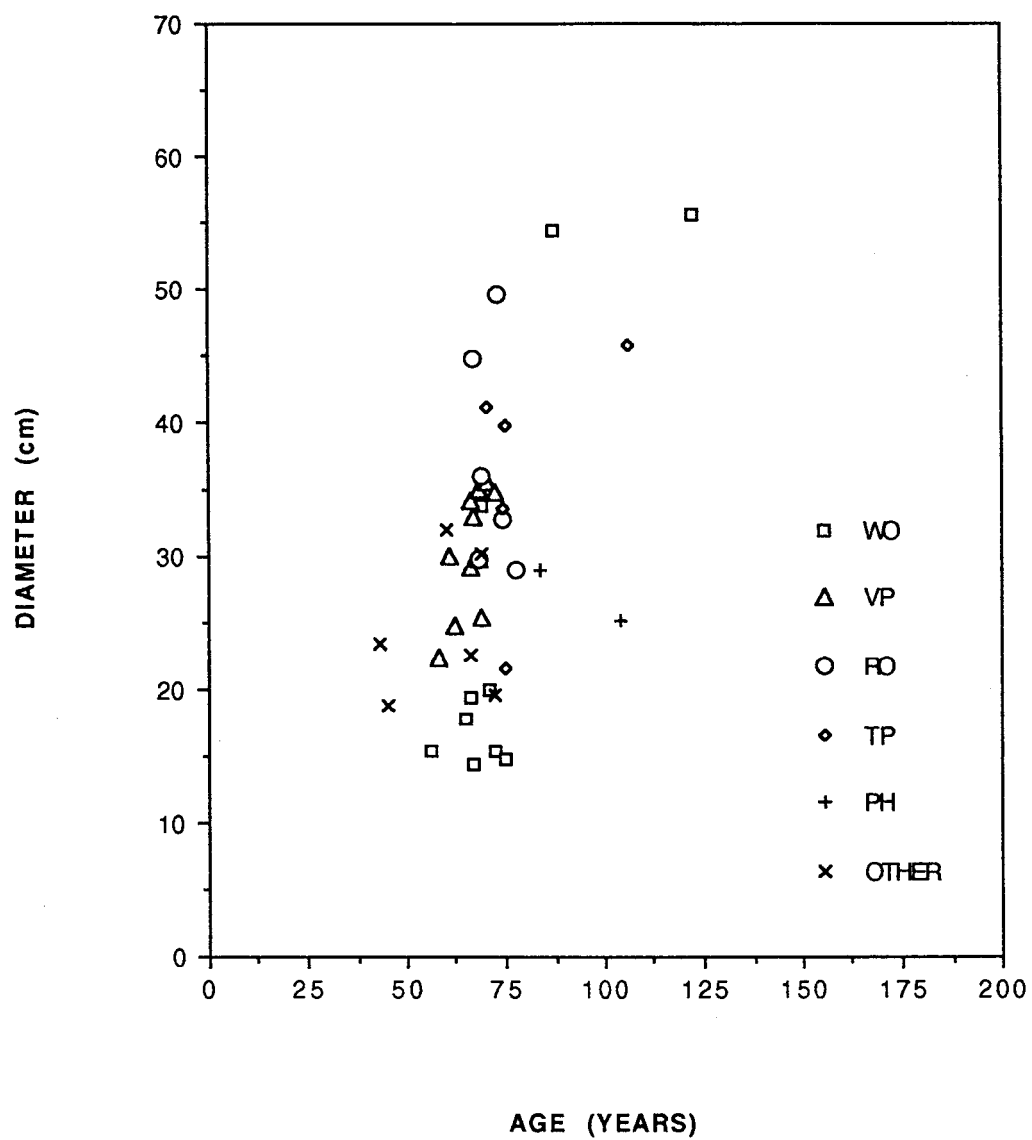
Appendix B

STAND AGE-DIAMETER GRAPHS

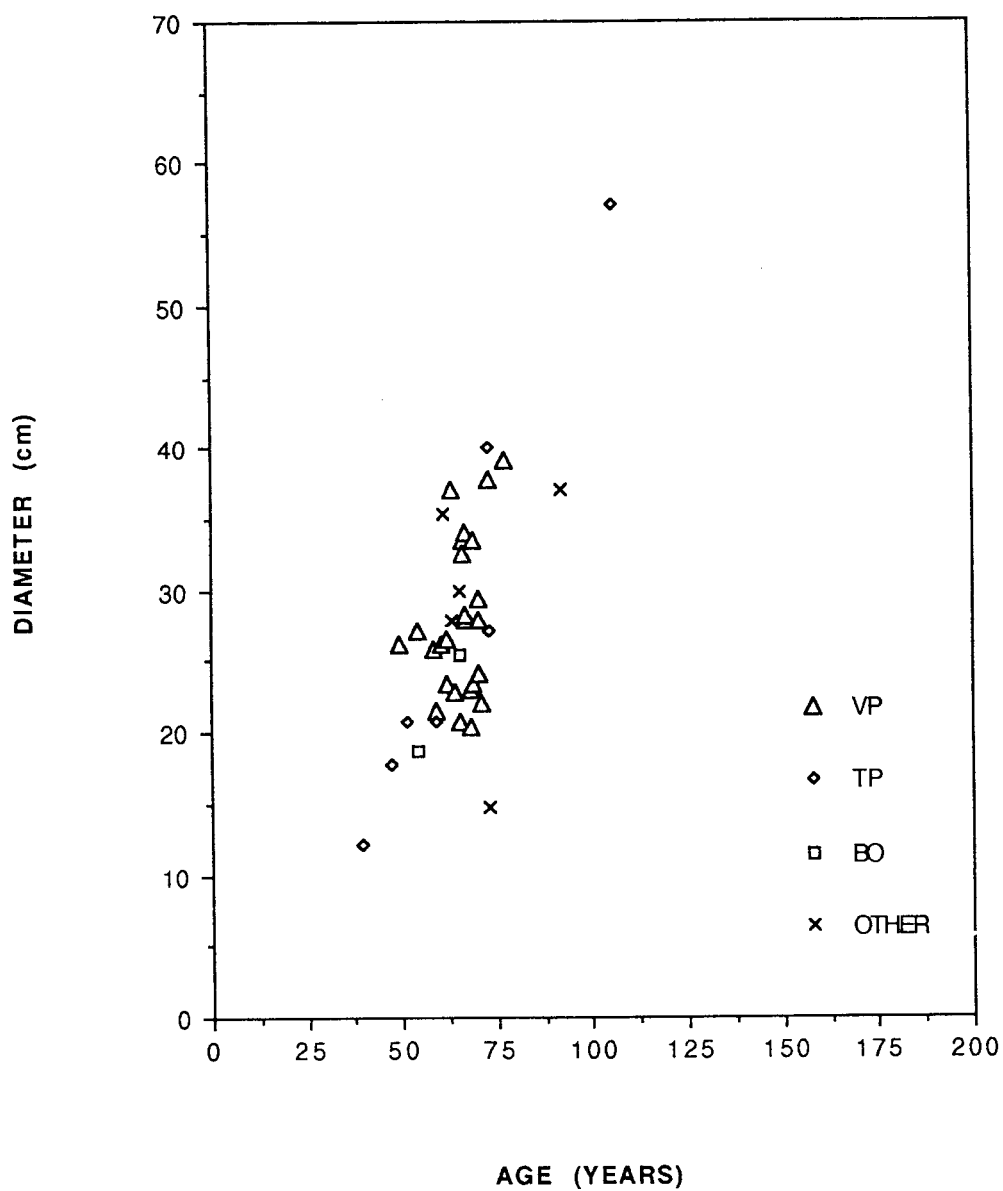
AGE-DIAMETER GRAPH KEY

<u>SYMBOL</u>	<u>SPECIES</u>
ASPEN	Bigtooth aspen
BG	Blackgum
BO	Black oak
DOG	Dogwood
ERC	Eastern redcedar
HICK	Hickory spp.
LOB	Loblolly pine
MH	Mockernut hickory
PH	Pignut hickory
RO	Red oak
SG	Sweetgum
SLP	Shortleaf pine
SRO	Southern red oak
TP	Tulip poplar
VP	Virginia pine
WO	White oak

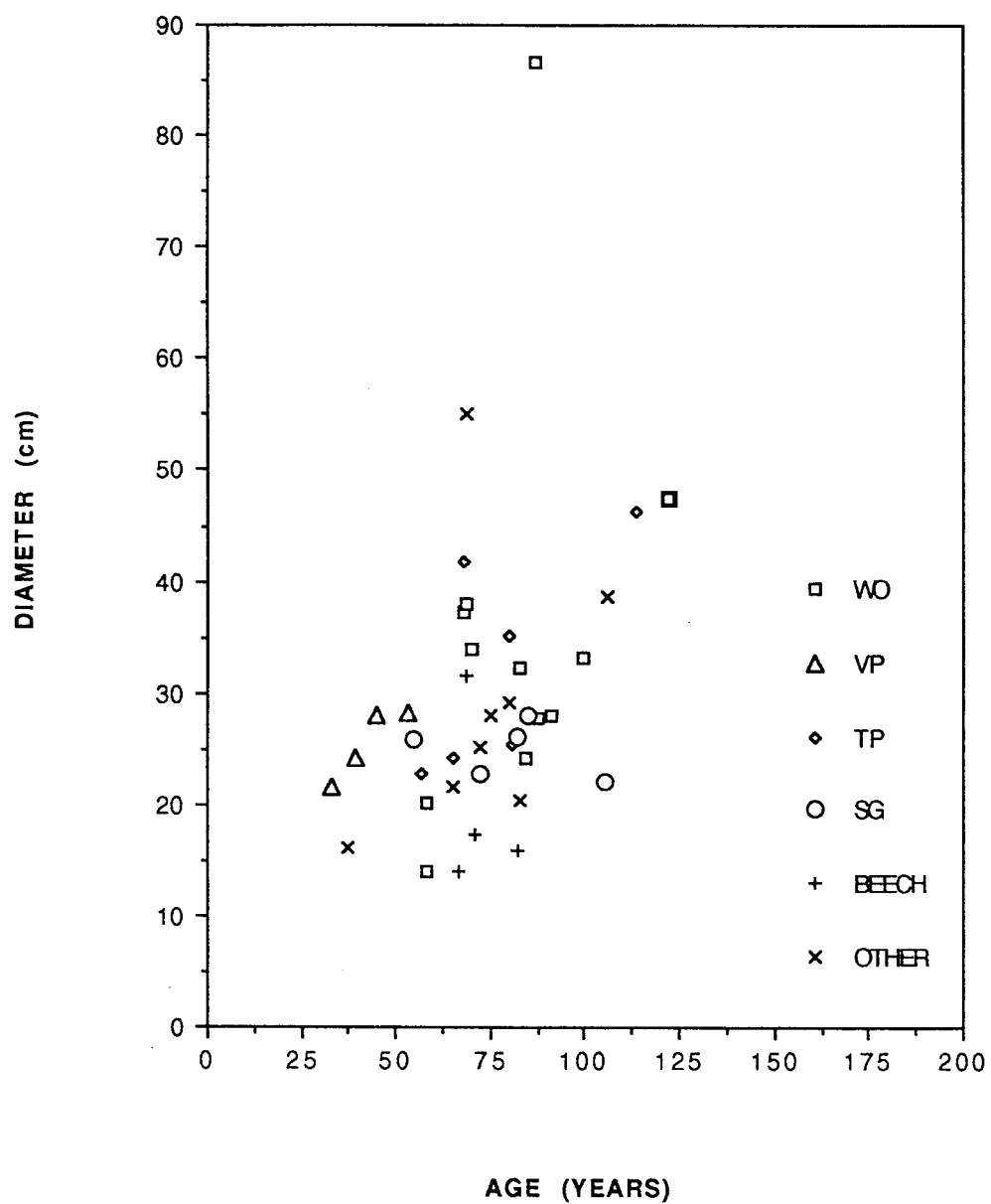
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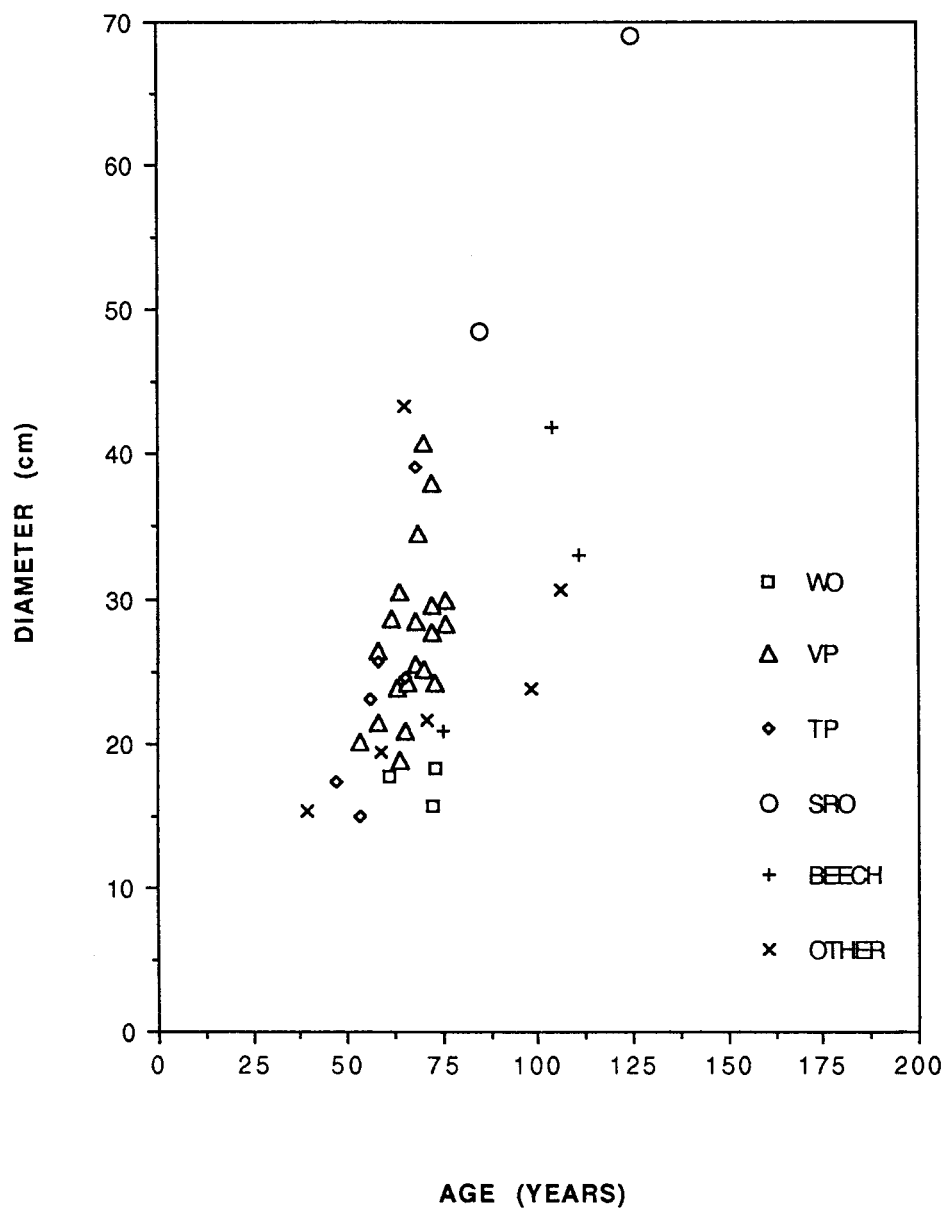
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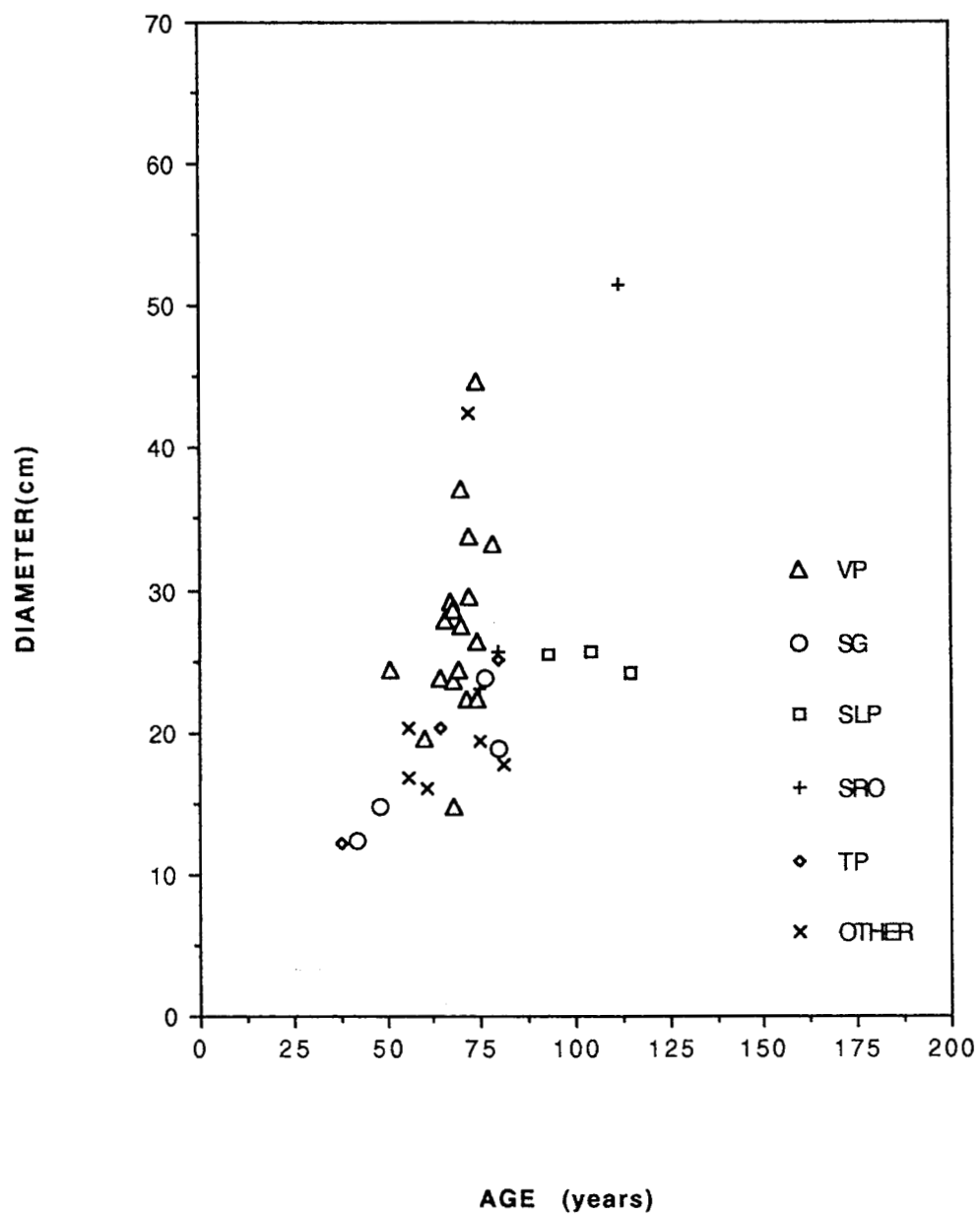
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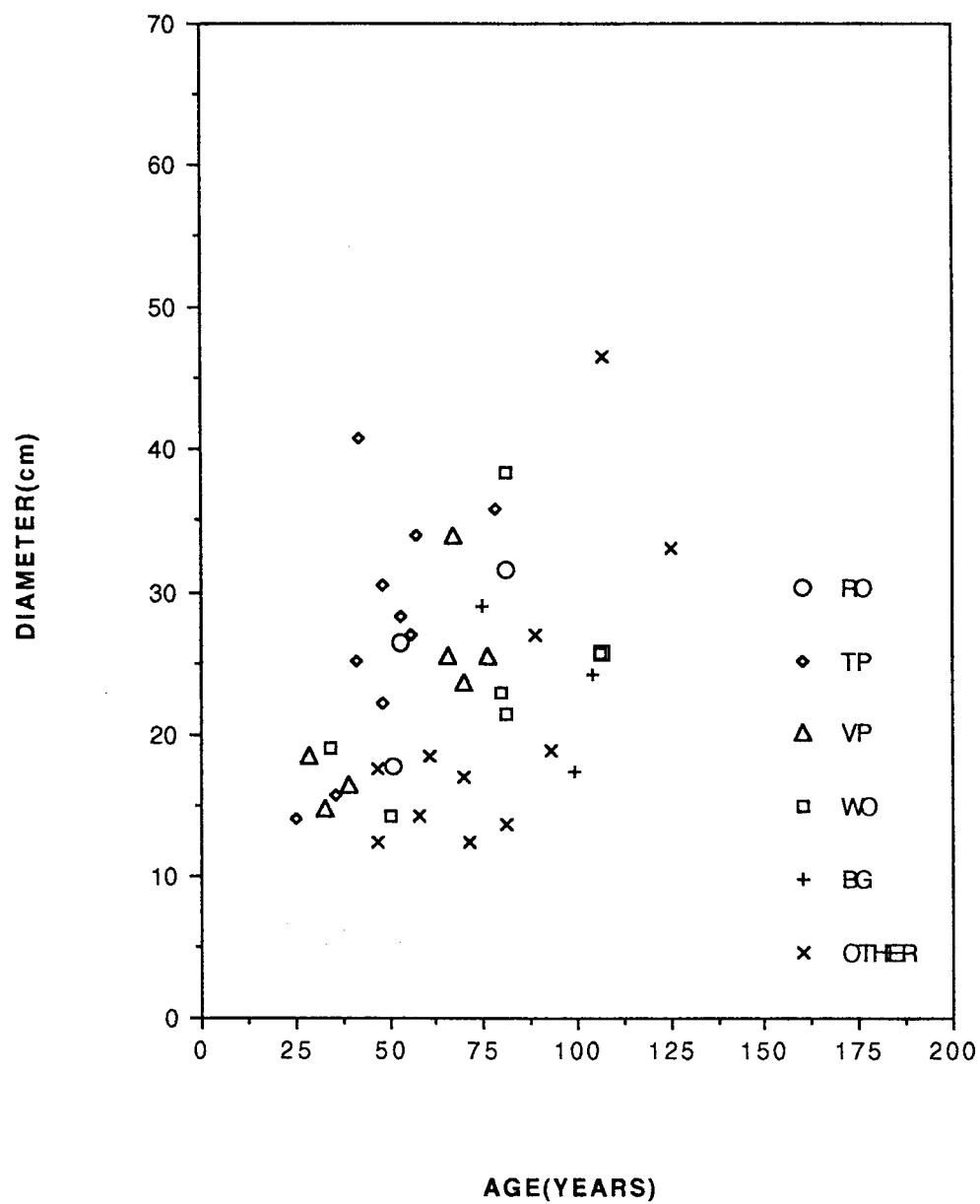
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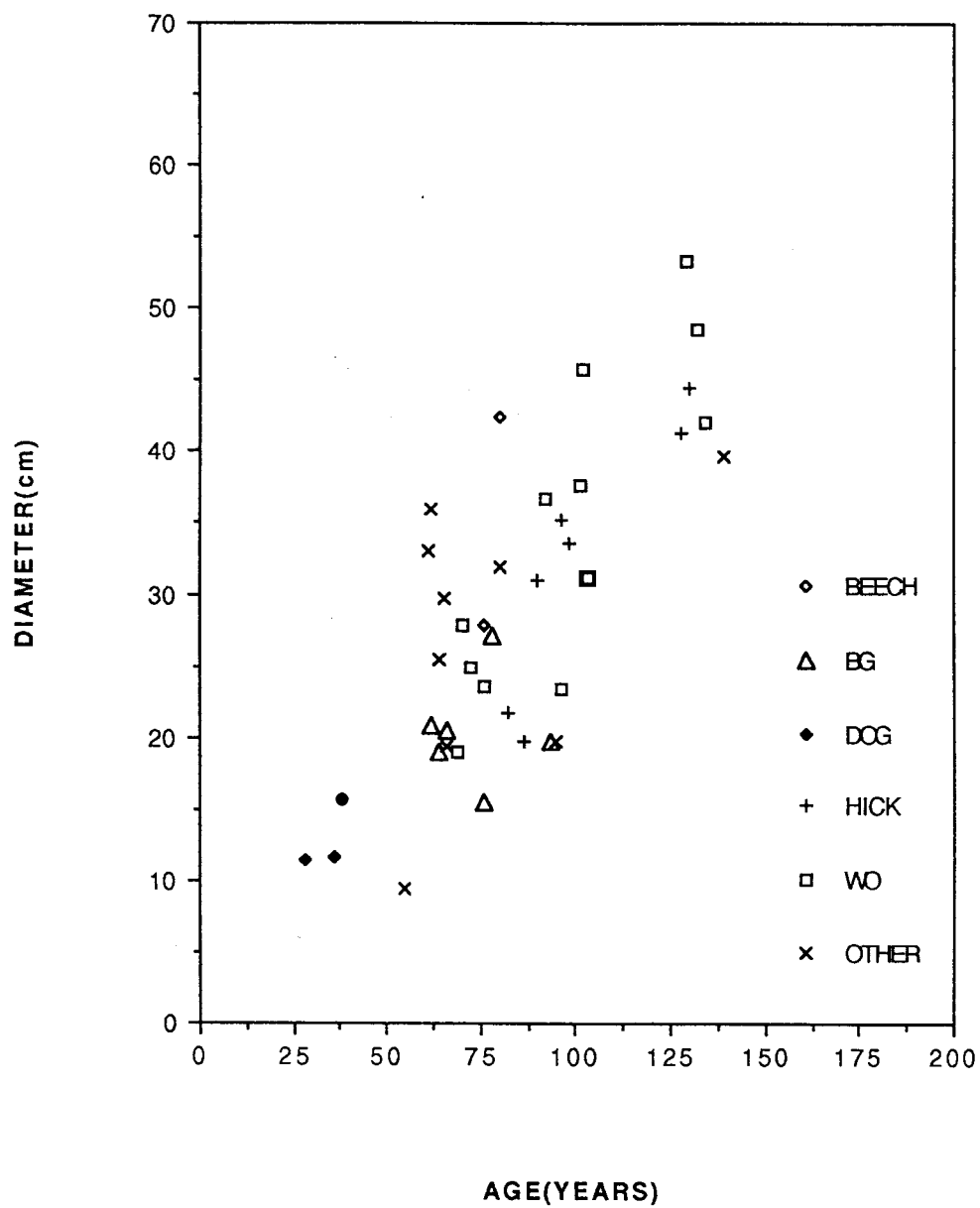
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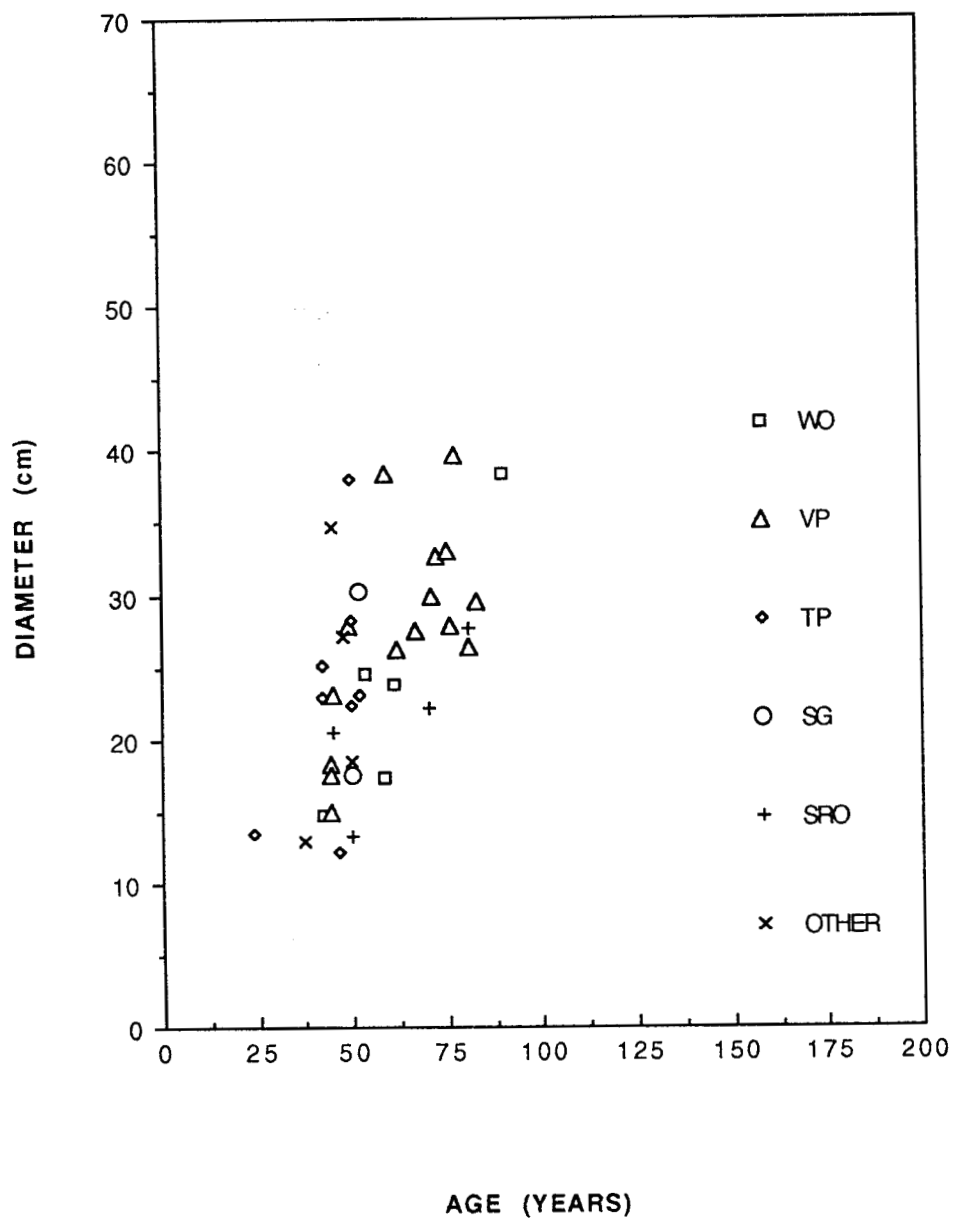
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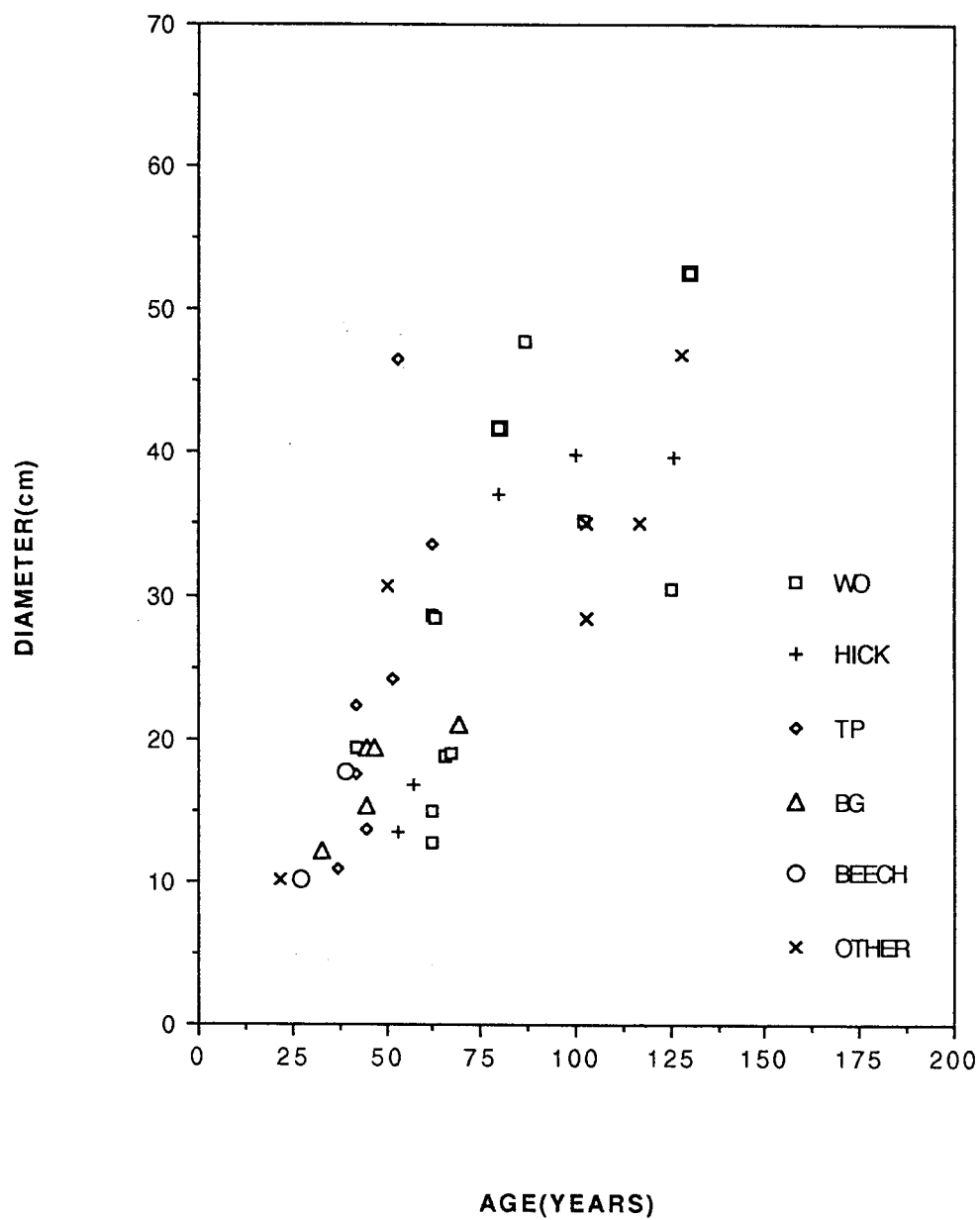
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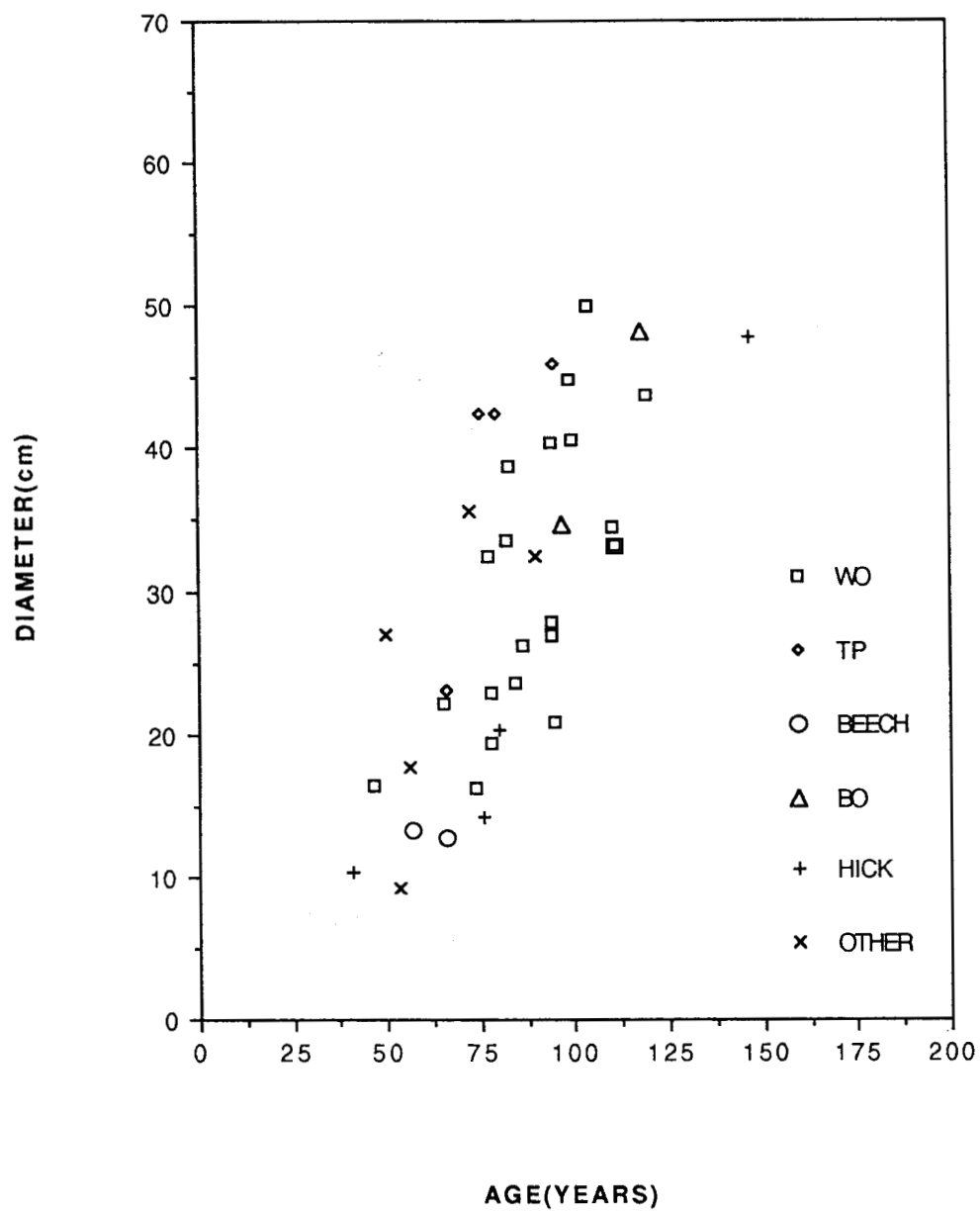
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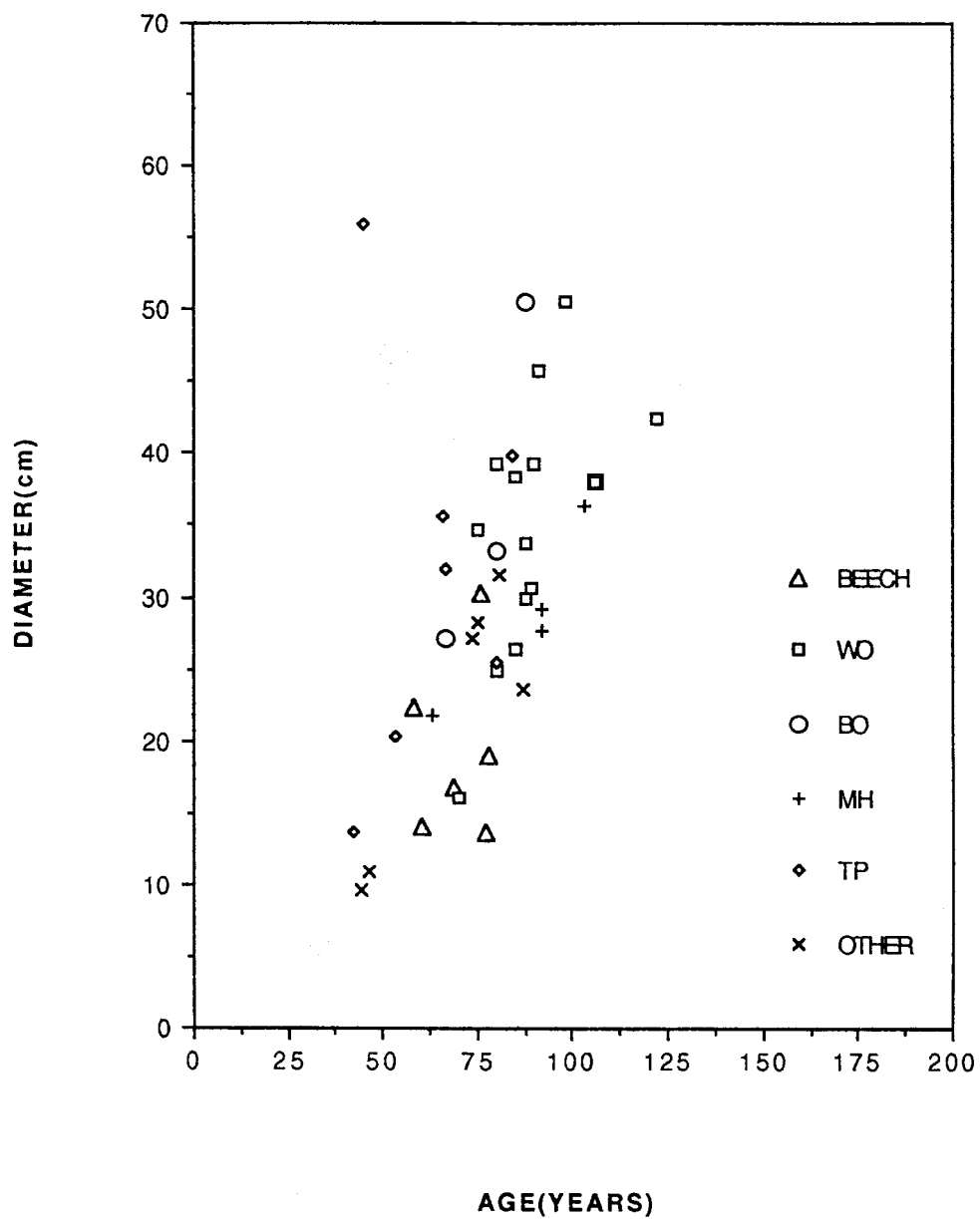
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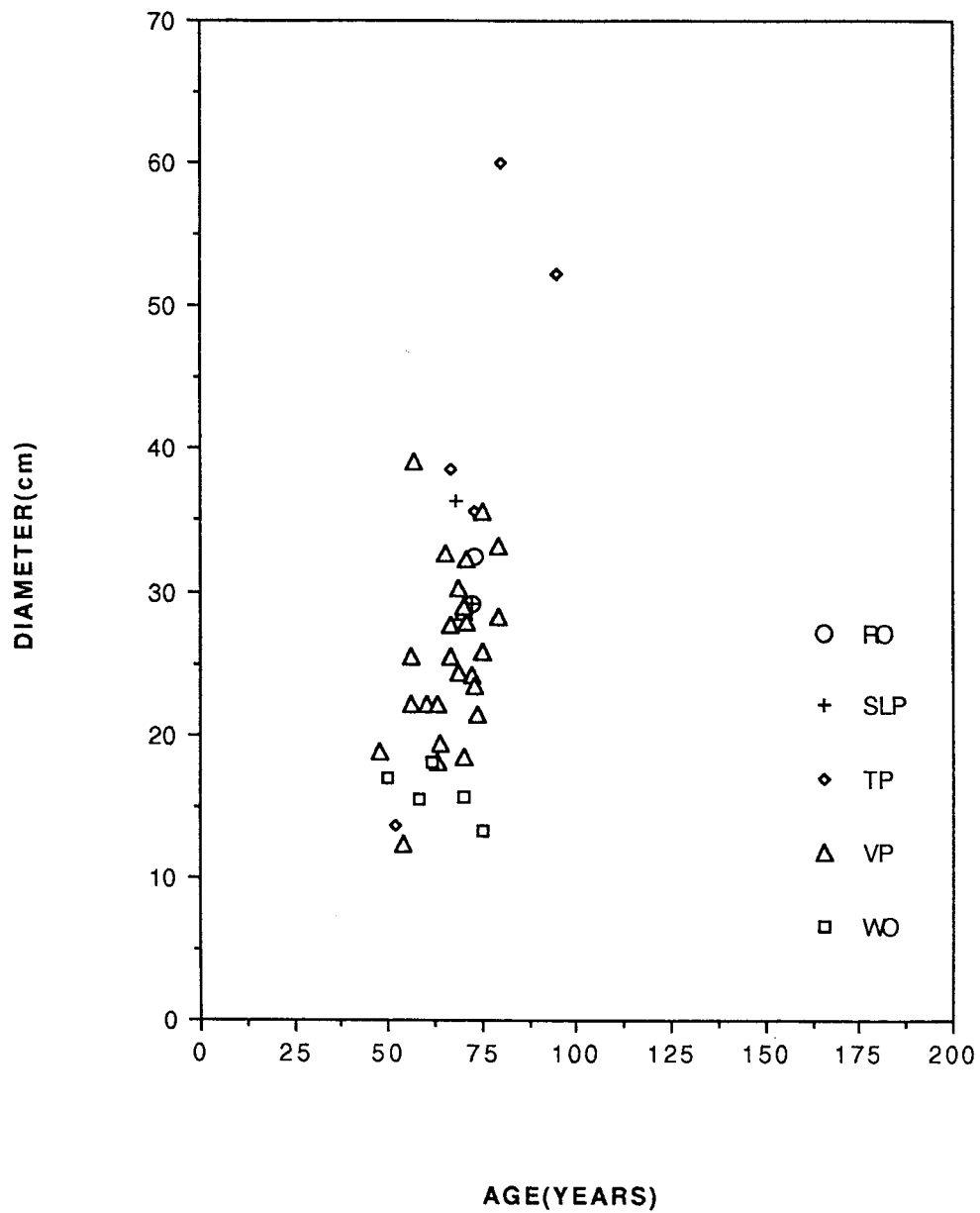
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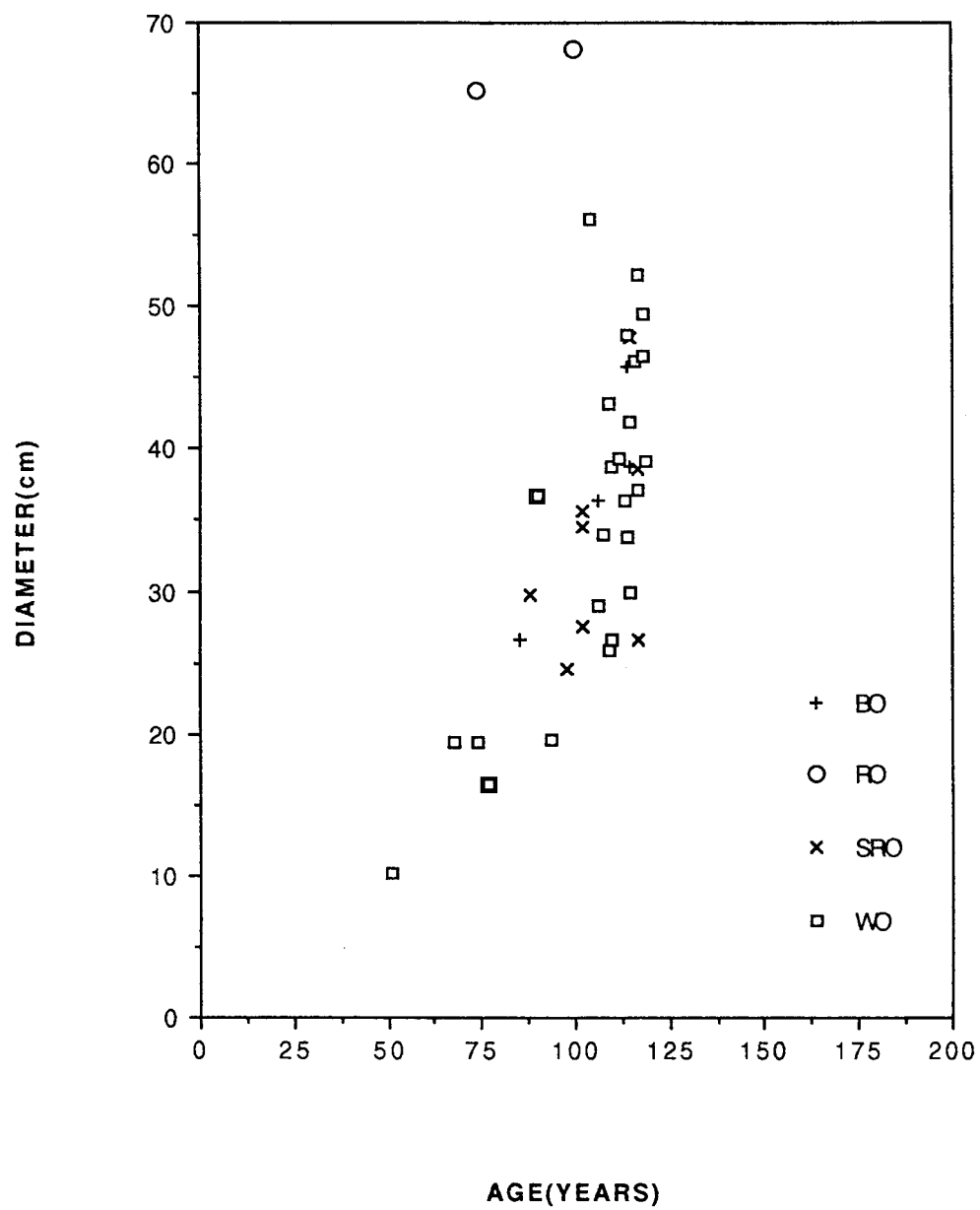
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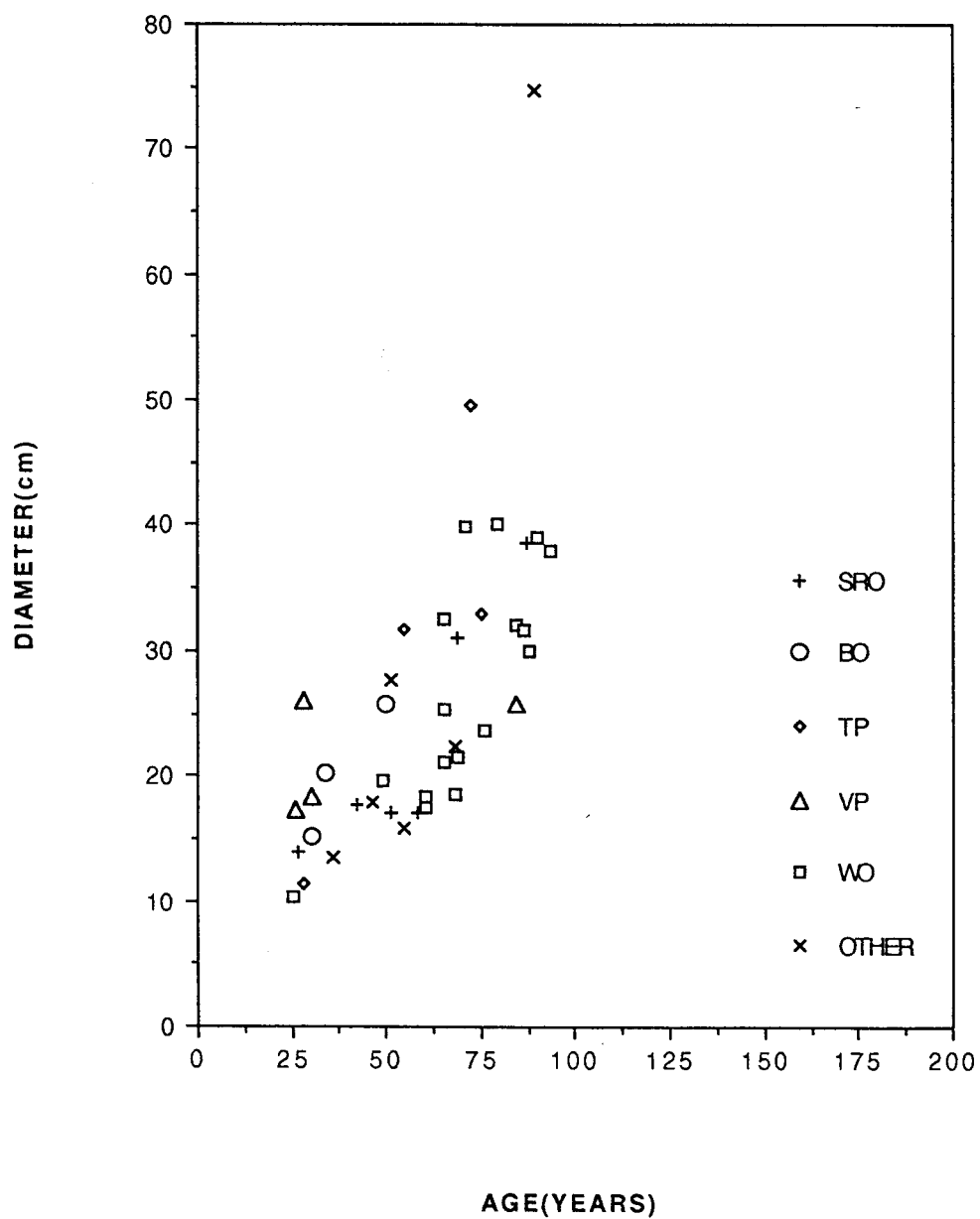
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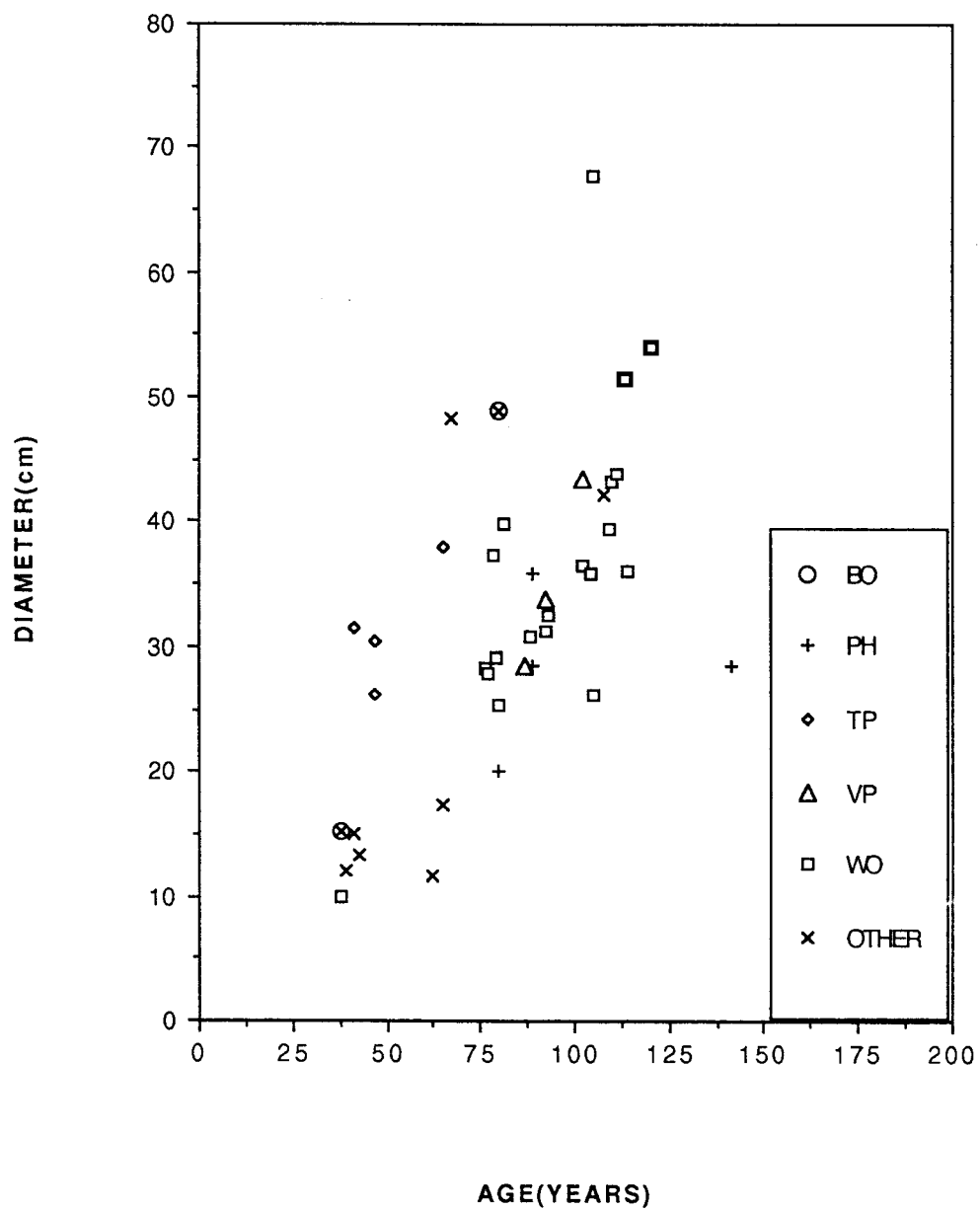
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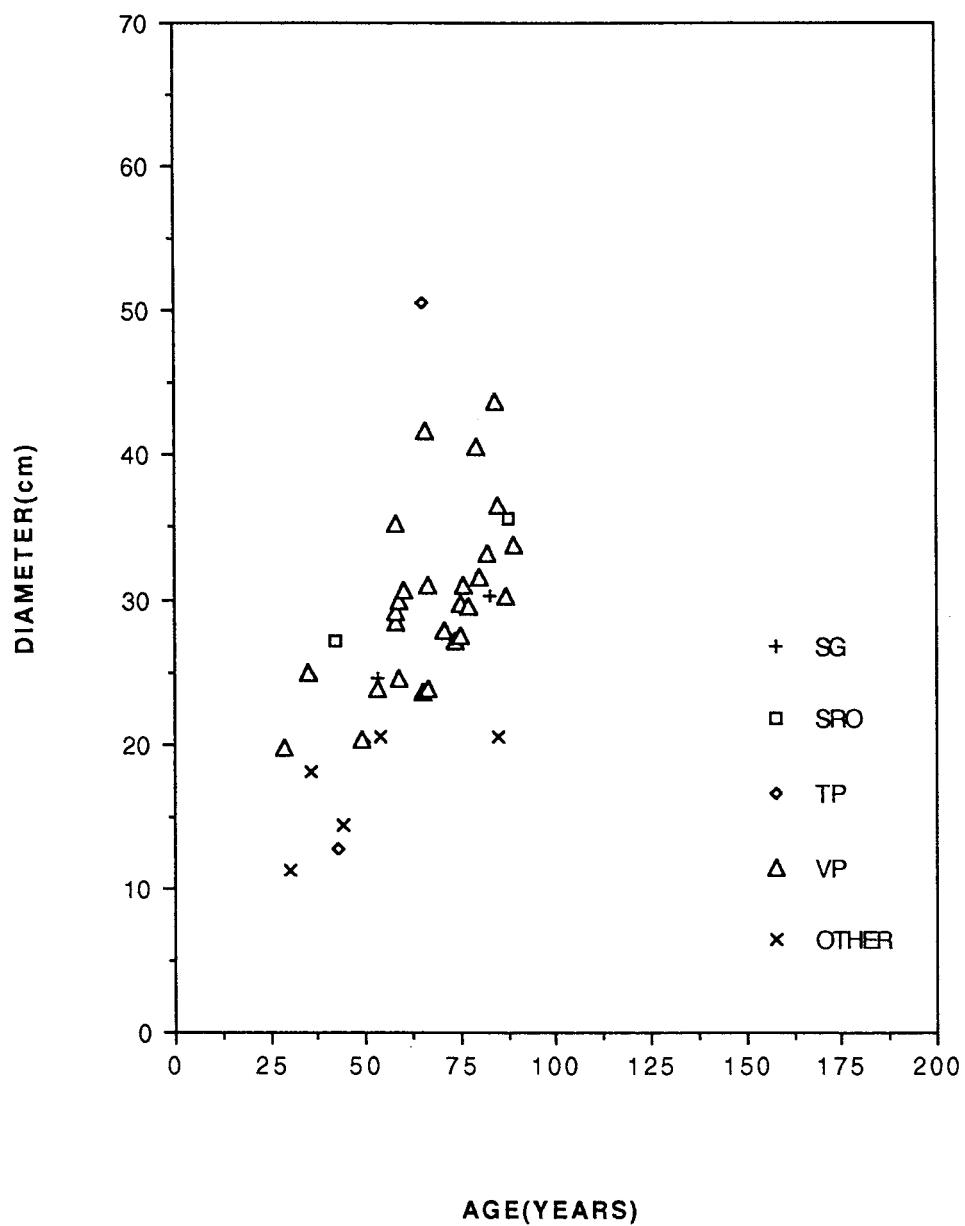
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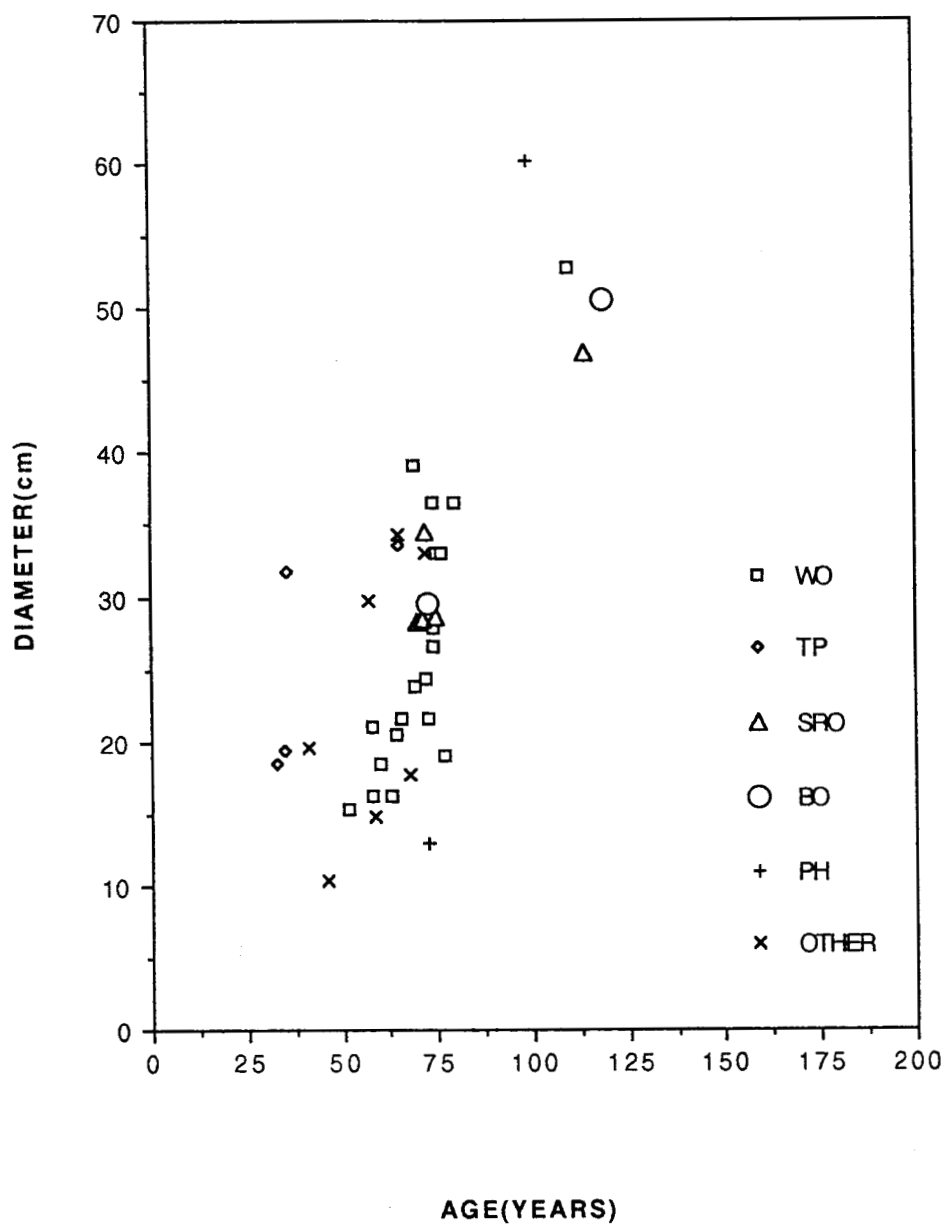
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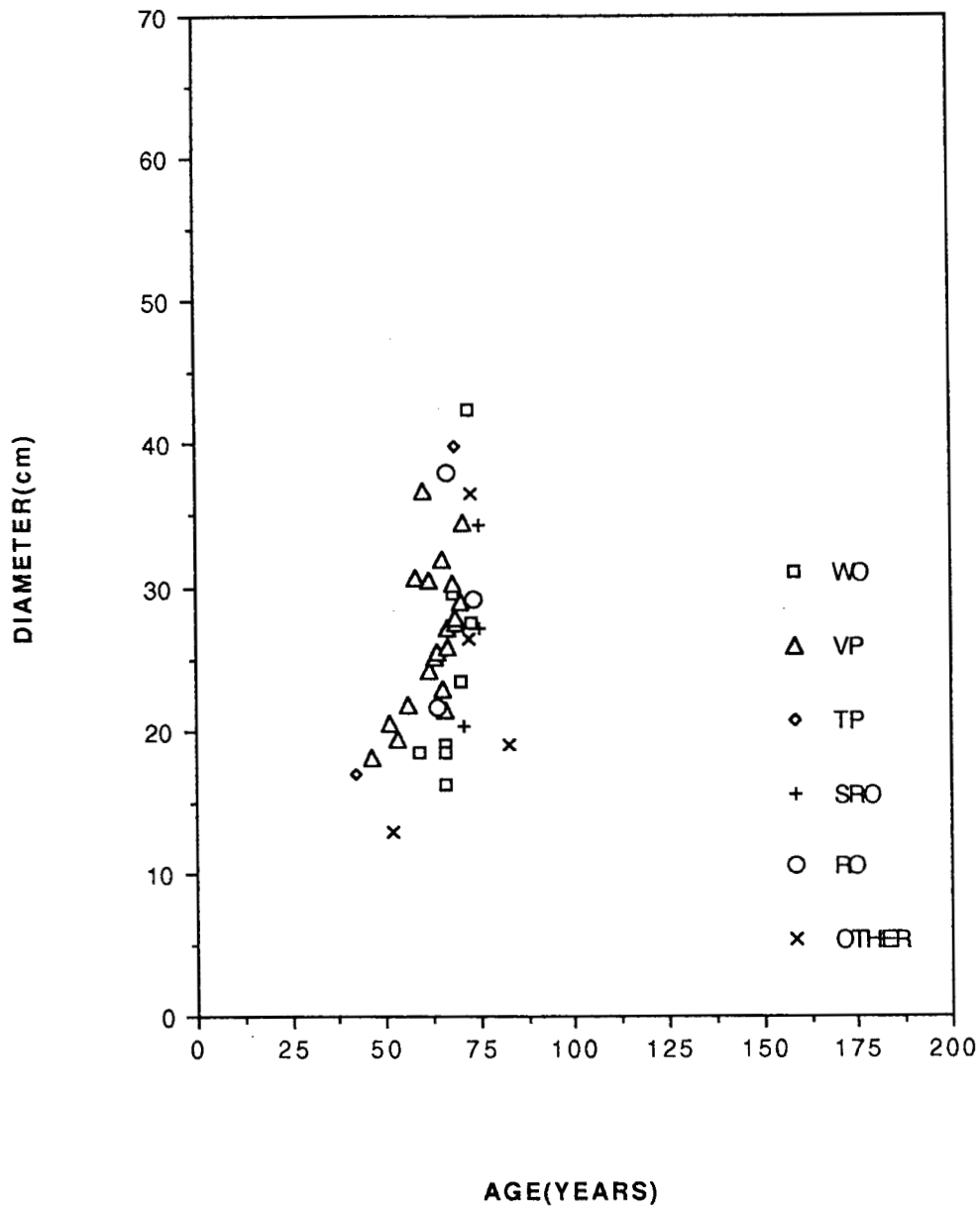
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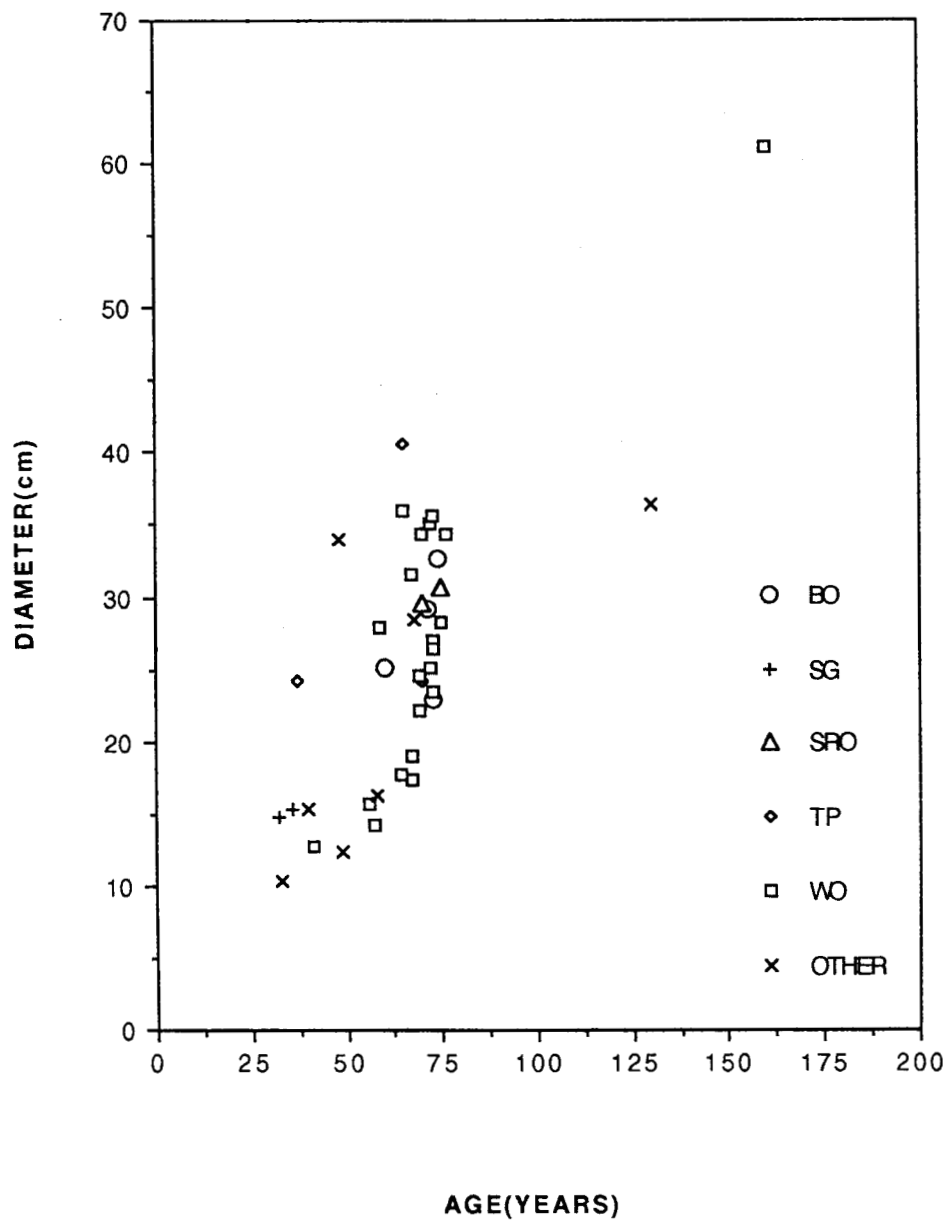
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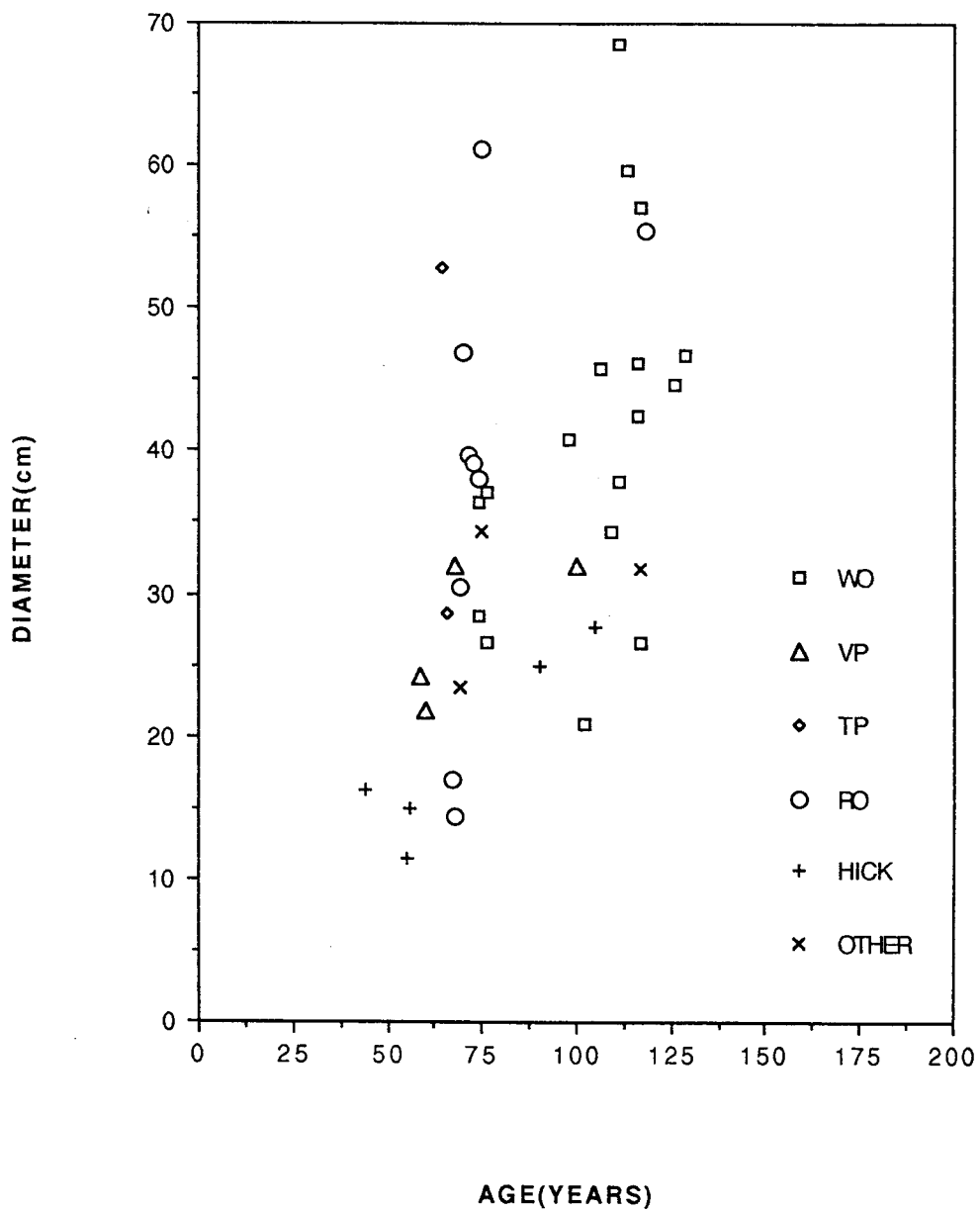
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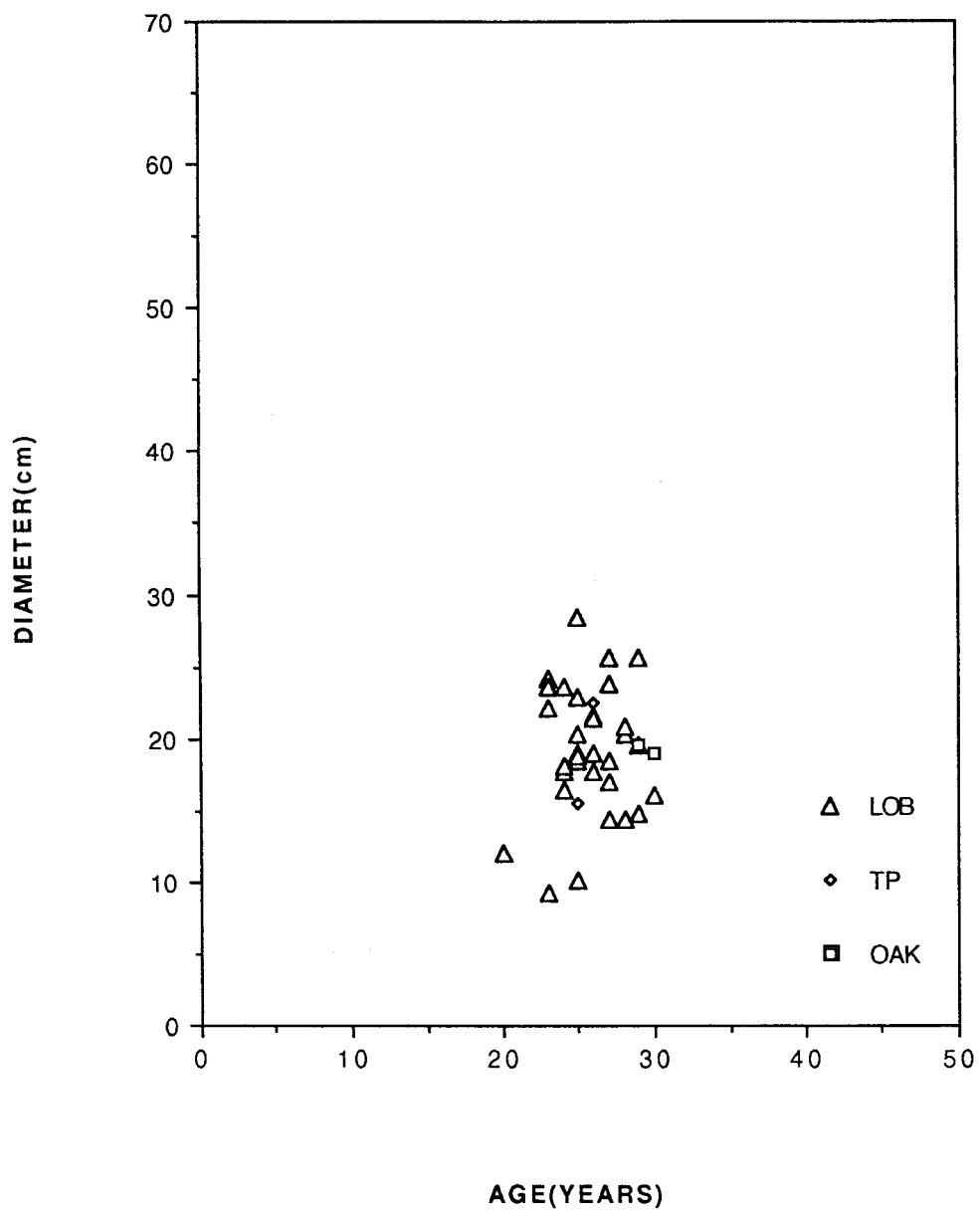
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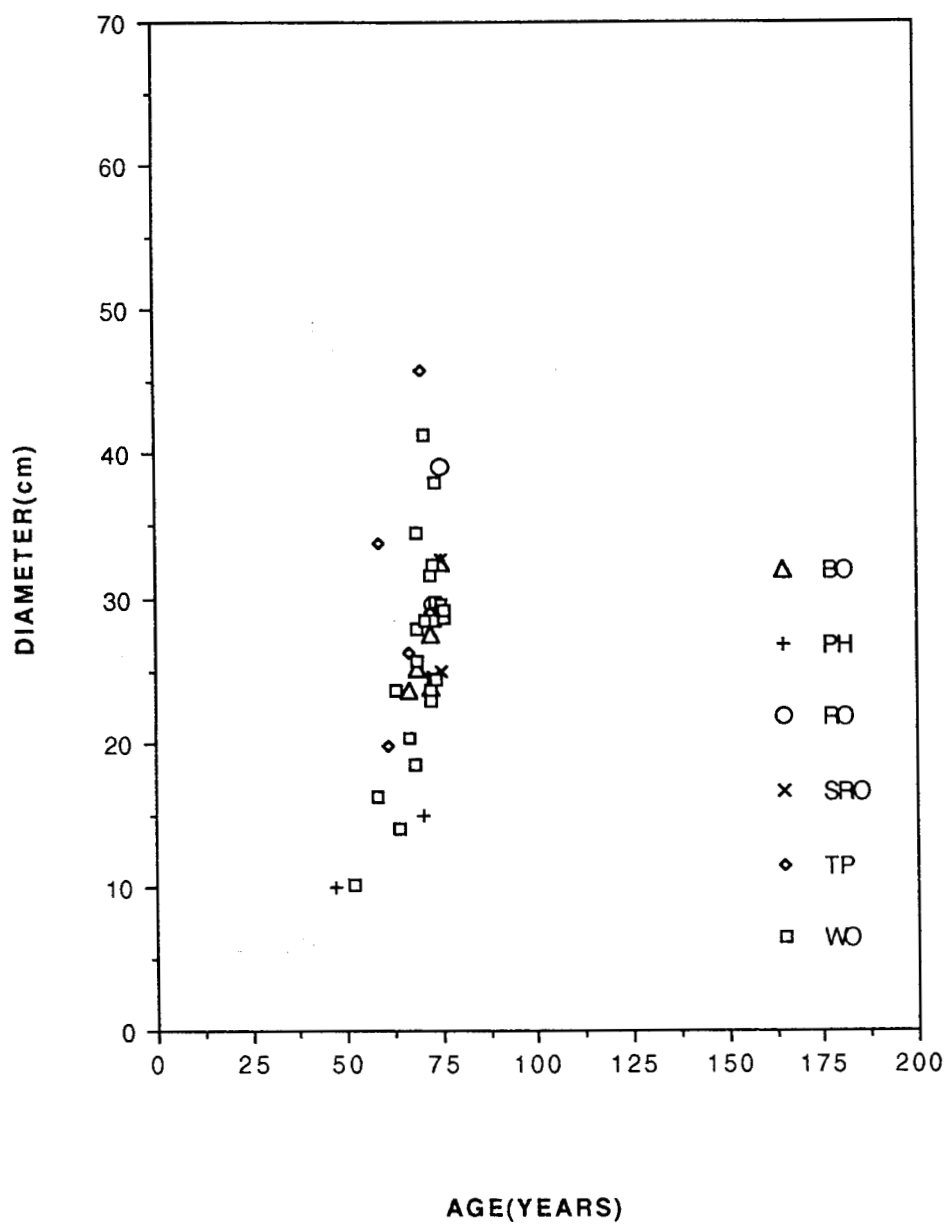
AGE-DIAMETER STAND #20



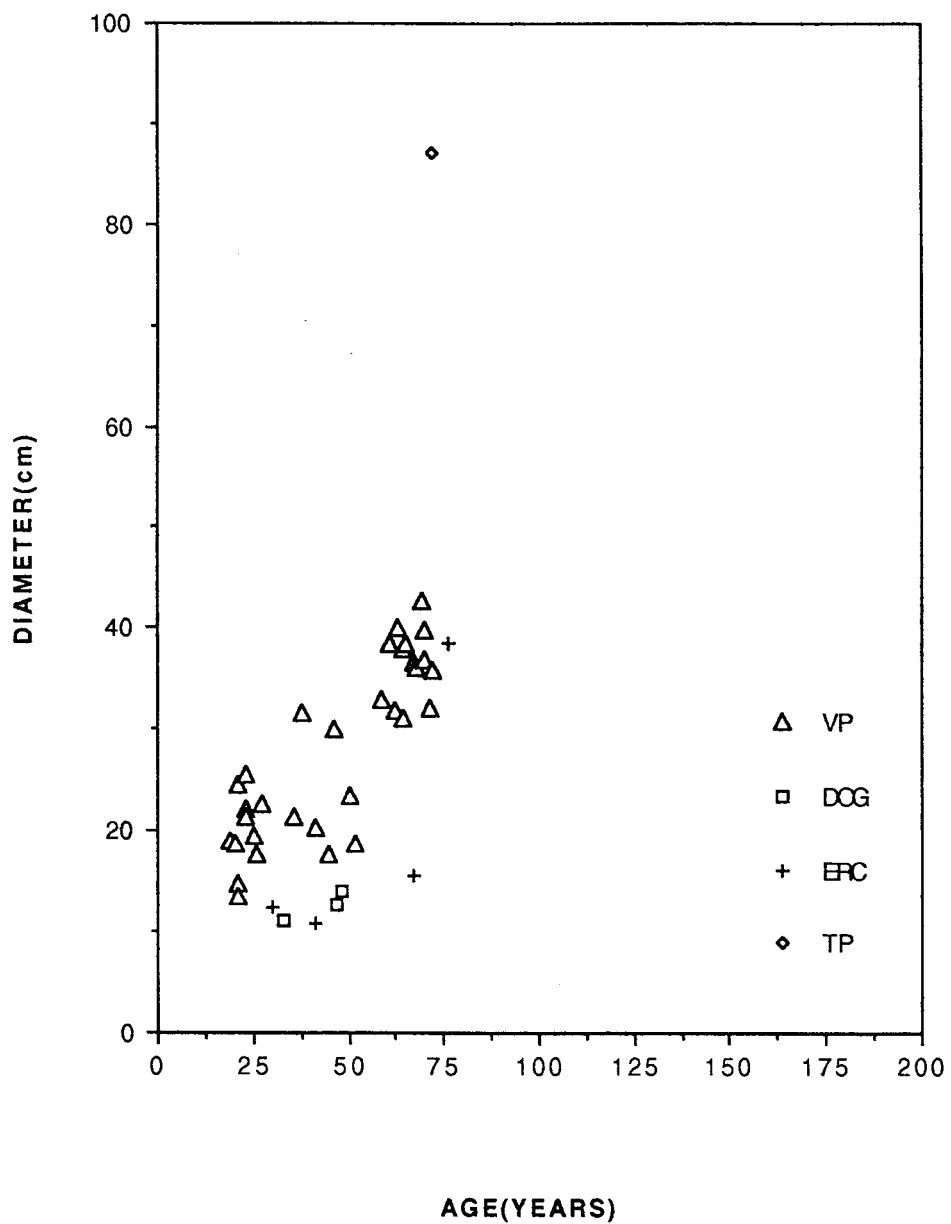
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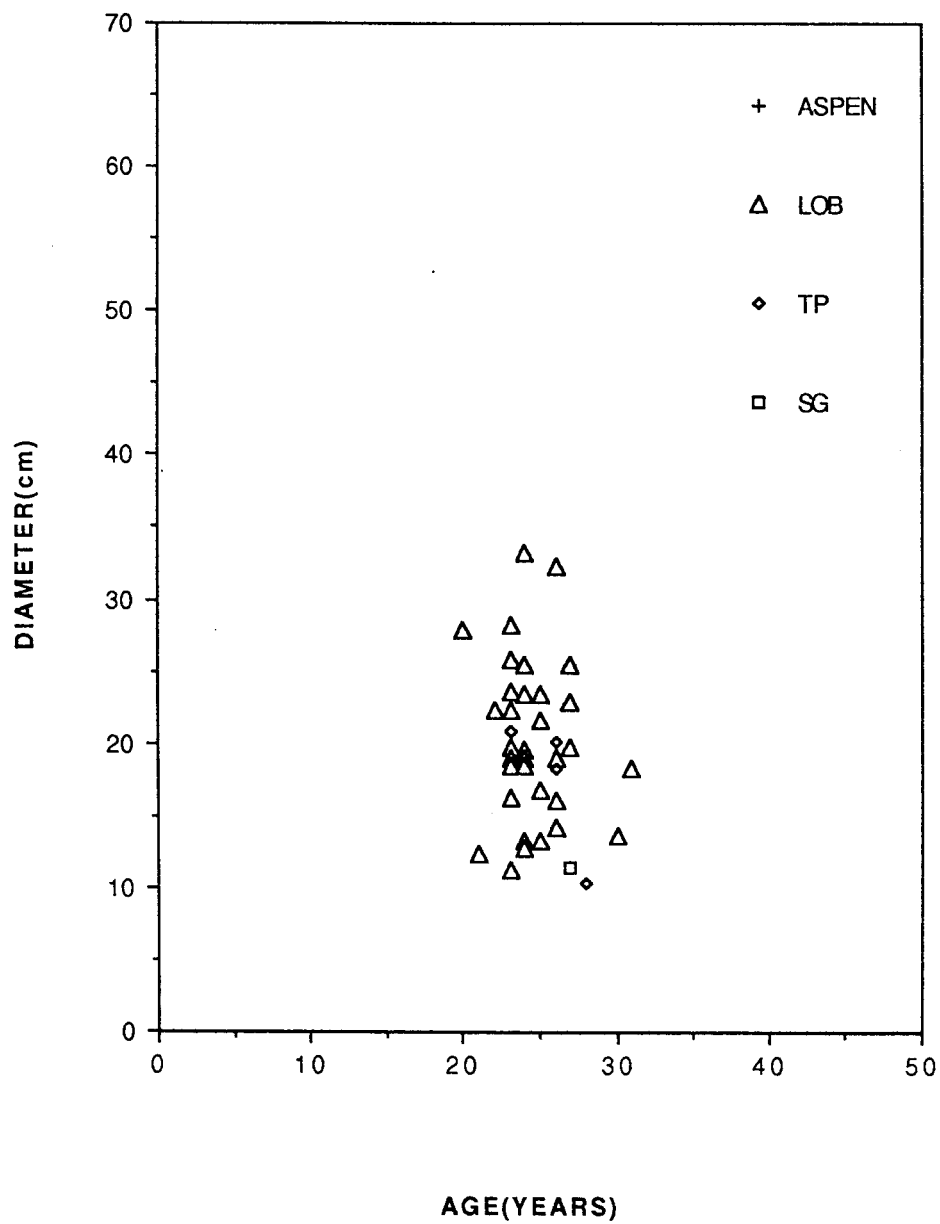
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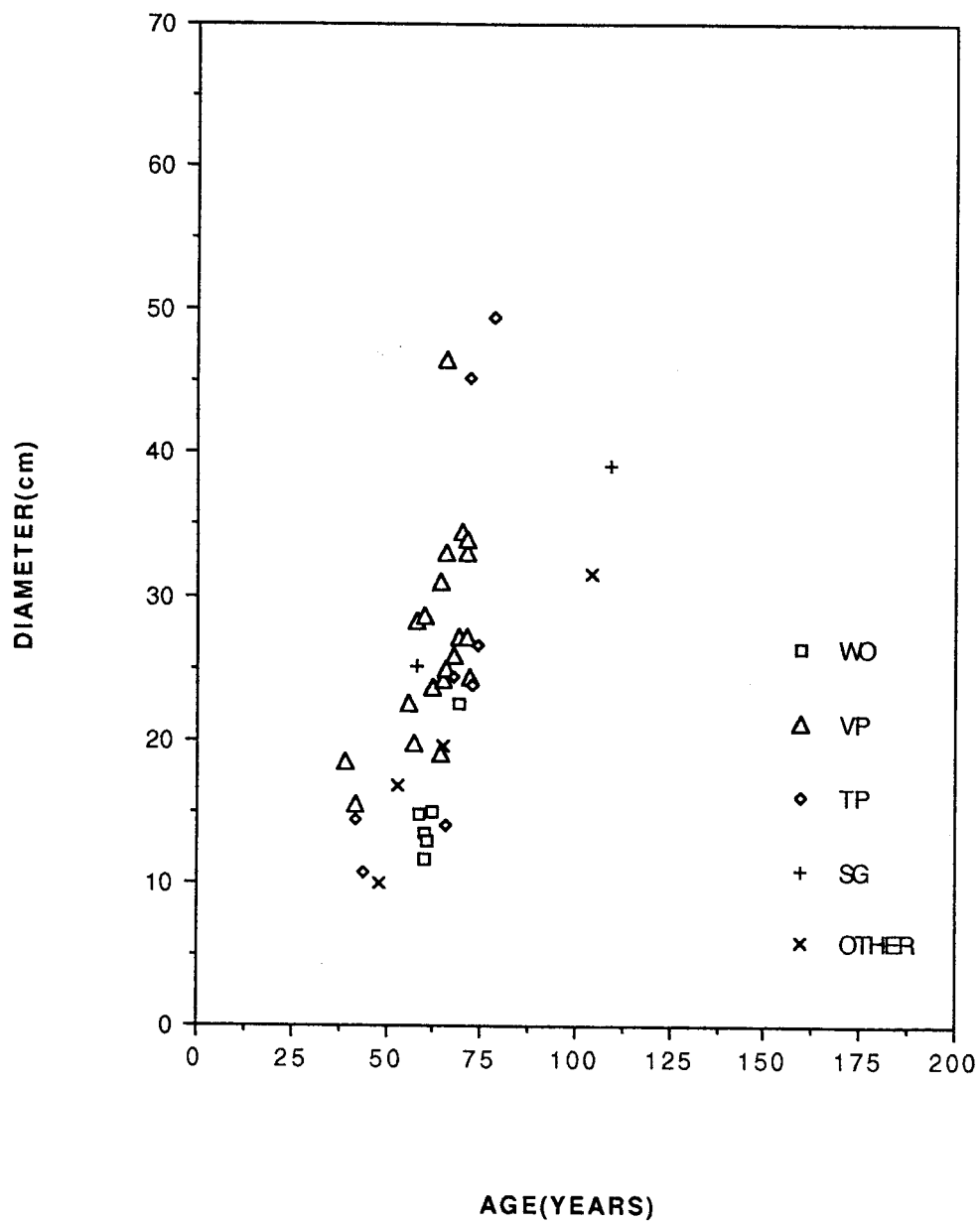
AGE-DIAMETER STAND #23



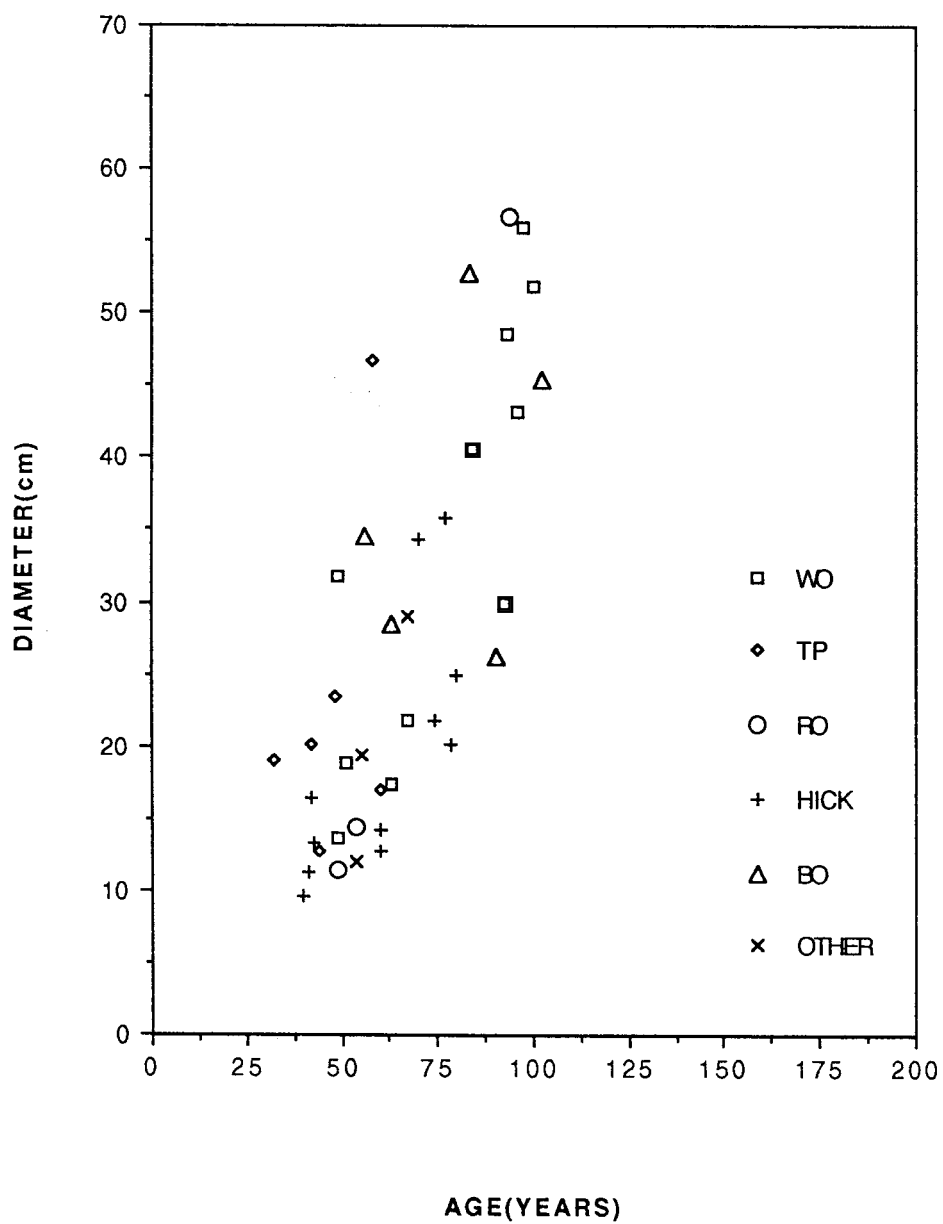
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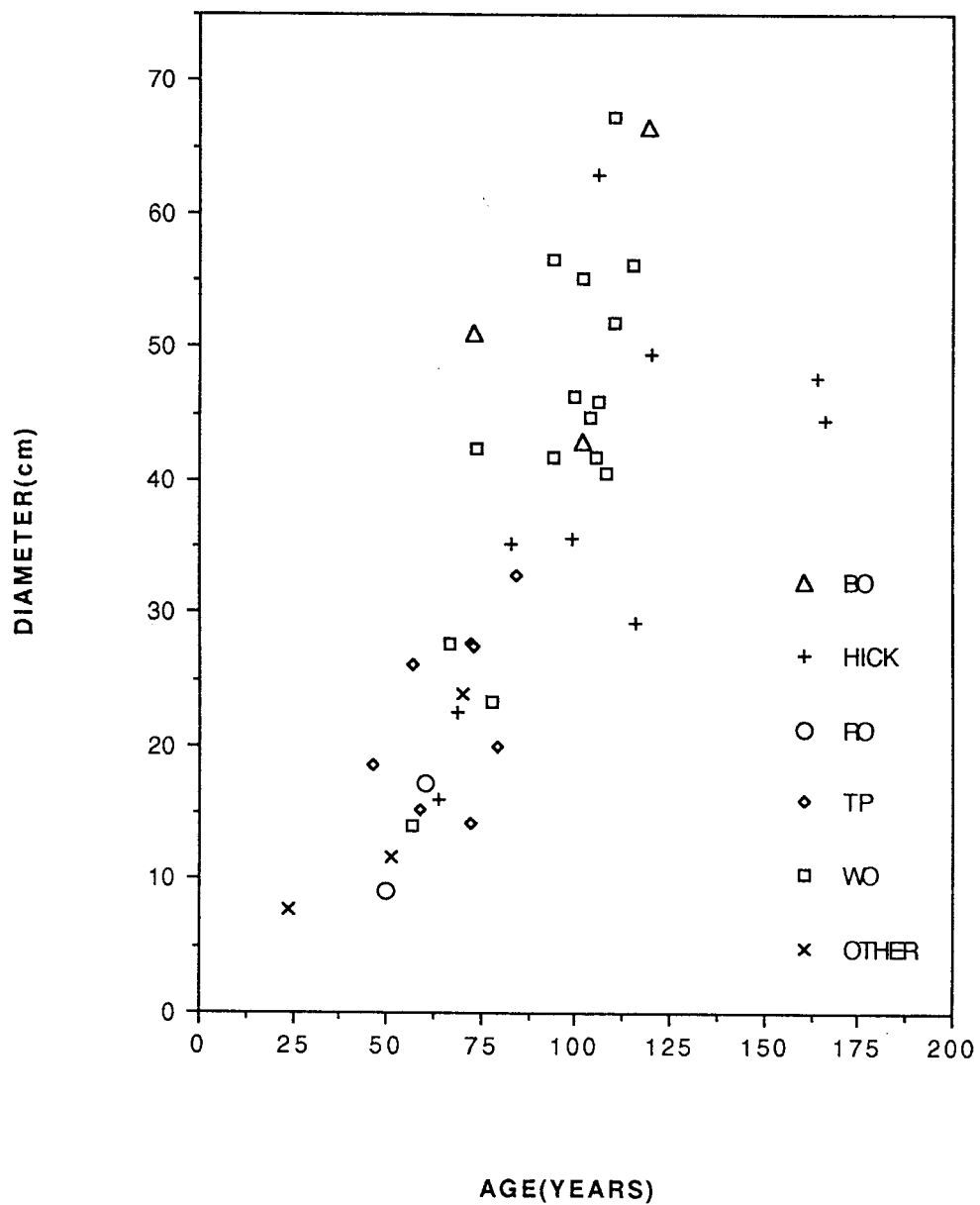
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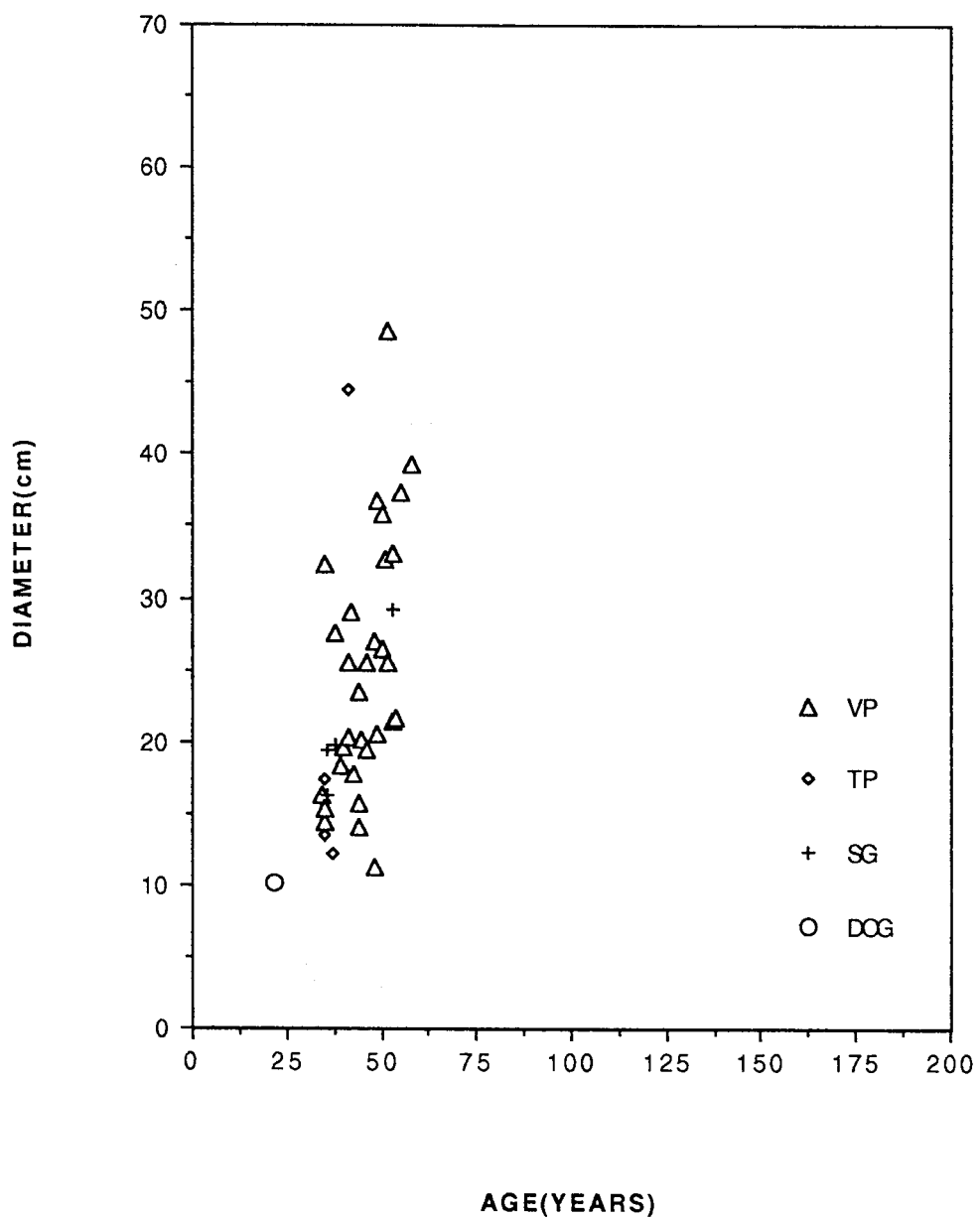
AGE-DIAMETER STAND #26



AGE-DIAMETER STAND #27



AGE-DIAMETER STAND #28



Appendix C

WOODY SPECIES LIST

List of common and scientific names of woody species identified within
Spotsylvania Battlefield.

<u>Common name</u>	<u>Scientific name</u>
Arrowwood	<i>Viburnum dentatum</i>
Ash, green	<i>Fraxinus pennsylvanica</i>
Ash, white	<i>Fraxinus americana</i>
Aspen, bigtooth	<i>Populus grandidentata</i>
Beech, American	<i>Fagus grandifolia</i>
Birch, river	<i>Betula nigra</i>
Blackgum	<i>Nyssa sylvatica</i>
Blueberry	<i>Vaccinium</i> spp.
Cherry, black	<i>Prunus serotina</i>
Chestnut, American	<i>Castanea dentata</i>
Cottonwood, eastern	<i>Populus deltoides</i>
Devil's-walkingstick	<i>Aralia spinosa</i>
Dogwood, flowering	<i>Cornus florida</i>
Fringetree	<i>Chionanthus virginicus</i>
Grape	<i>Vitis</i> spp.
Greenbriar	<i>Smilax</i> spp.
Hawthorne	<i>Crataegus</i> spp.
Hazlenut, American	<i>Corylus americana</i>
Hemlock, eastern	<i>Tsuga canadensis</i>
Hickory, bitternut	<i>Carya cordiformis</i>
Hickory, mockernut	<i>Carya tomentosa</i>
Hickory, pignut	<i>Carya glabra</i>
Holly, American	<i>Ilex opaca</i>
Honeylocust	<i>Gleditsia triaranthos</i>
Honeysuckle, Japanese	<i>Lonicera japonica</i>
Hornbeam	<i>Carpinus caroliniana</i>
Laurel, mountain	<i>Kalmia latifolia</i>
Locust, black	<i>Robinia pseudoacacia</i>
Maple, red	<i>Acer rubrum</i>
Mulberry, red	<i>Morus rubra</i>
Mulberry, white	<i>Morus alba</i>
Oak, black	<i>Quercus velutina</i>
Oak, blackjack	<i>Quercus marilandica</i>
Oak, chestnut	<i>Quercus prinus</i>
Oak, post	<i>Quercus stellata</i>
Oak, red	<i>Quercus rubra</i>
Oak, scarlet	<i>Quercus coccinea</i>
Oak, southern red	<i>Quercus falcata</i>
Oak, white	<i>Quercus alba</i>
Oak, willow	<i>Quercus phellos</i>
Pine, eastern white	<i>Pinus strobus</i>
Pine, loblolly	<i>Pinus taeda</i>
Pine, shortleaf	<i>Pinus echinata</i>
Pine, Virginia	<i>Pinus virginiana</i>
Poison Ivy	<i>Toxicodendron radicans</i>
Redbud	<i>Cercis canadensis</i>
Redcedar, eastern	<i>Juniperus virginiana</i>

Species list (con't.).

<u>Common name</u>	<u>Scientific name</u>
Sassafras	<i>Sassafras albidum</i>
Serviceberry	<i>Amelanchier arborea</i>
Silktree	<i>Albizia julibrissin</i>
Sumac, winged	<i>Rhus copallina</i>
Sweetgum	<i>Liquidambar styraciflua</i>
Sycamore	<i>Platanus occidentalis</i>
Trumpet creeper	<i>Campsis radicans</i>
Tulip poplar	<i>Liriodendron tulipifera</i>
Viburnum, maple-leaf	<i>Viburnum acerifolium</i>
Virginia creeper	<i>Parthenocissus</i> <i>quinquefolia</i>
Walnut, black	<i>Juglans nigra</i>