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Woodlands in a post-agricultural landscape in New Jersey[1]

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ABSTRACT

WHITE, D. W., W. WORTHEN AND E. W. STILES (Department of Biological Sciences, Rutgers University, Piscataway, NJ 08855-1059). Woodlands in a post-agricultural landscape in New Jersey. Bull. Torrey Bot. Club 117: 256–265. 1990.—To discover how original, deciduous forest has fared in a landscape long-altered by humans, we determined the history, extent, composition, and structure of woods in Franklin Township, Somerset County, New Jersey. This 121 km^2 part of the Piedmont Plateau was converted to agriculture in the early eighteenth century but has begun to be suburbanized only recently. Wooded land increased from 9 to 18% of the township between 1880 and 1943, then declined as development disturbed two-thirds of the woodlands present in 1943. In 1986, 213 woods covered 16% of the township. More than half of these woods consisted of young successional vegetation; mature stands occurred in only 58 woods. Woods were affected directly and indirectly (i.e., by human land use) by differences in slope and soil. Woods on the steep gravel and diabase soils in the southern one-third of Franklin Township were more extensive (32 vs. 8% coverage), larger (median area: 6.2 vs. 2.8 ha), more often mature (49 vs. 21% of woodlands), and less dominated by upland oaks (29 vs. 49% of total importance value) than woods on the easily tilled, gently sloping shale soils in the north. *Quercus borealis* Michx. f., *Q. velutina* Lam., and *Q. alba* L. dominated in mature northern "mixed-oak" woods; *Liriodendron tulipifera* L. dominated southern woods most often, although *Q. borealis* led in mean importance value overall. Riparian floodplains were extensively wooded (53% coverage) with *Fraxinus* spp., *Q. palustris* Muenchh., and *Acer saccharinum* L. dominating. Riparian woods were often well developed but young. In contrast, parts of many upland woods may have been continuously wooded. Nevertheless, in comparison with a well protected relic oak woods, few upland stands appeared near structural equilibrium. Precolonization species compositions may have been most nearly approached in former woodlots in northern uplands, the region where mature woods were rarest and in most jeopardy.

Key words: Deforestation, forest history, forest composition, New Jersey.

As vestiges of the indigenous forest, woodlands are important in the preservation of biological diversity in human-modified, temperate landscapes (Forman *et al.* 1976; Burgess and Sharpe 1981; Lynch and Whigham 1984; Peterken and Game 1984). The conservation value of a given wooded patch may depend on many factors, including the woodland's size, disturbance history, maturity, and similarity to original vegetation. These attributes have been evaluated often for individual old woods (e.g., Buell 1957; Forman and Elfstrom 1975), but rarely for all woods on a regional scale. For this reason, research and preservation efforts lack a context; we cannot say if a given woods is botanically representative or environmentally exceptional.

We examine here the woodlands of Franklin Township, Somerset County, New Jersey, a 121 km^2 region with a three century history of post-settlement human disturbance. We concentrate on three related issues. First, what is status of woods in the township? To define status, we examined woodland extent (number, size and coverage), maturity, and disturbance history. Second, has the physical environment, in interaction with historic patterns of human land use, affected the status of woodlands? And third, what is the species composition and vegetational structure of mature woodlands in this long-modified landscape, and how closely might these extant woods resemble presettlement forest?

Description of the Study Area. Located on the Piedmont Plateau physiographic province (Wolfe 1977) just west of New Brunswick, New Jersey, Franklin Township, Somerset County, is bound-

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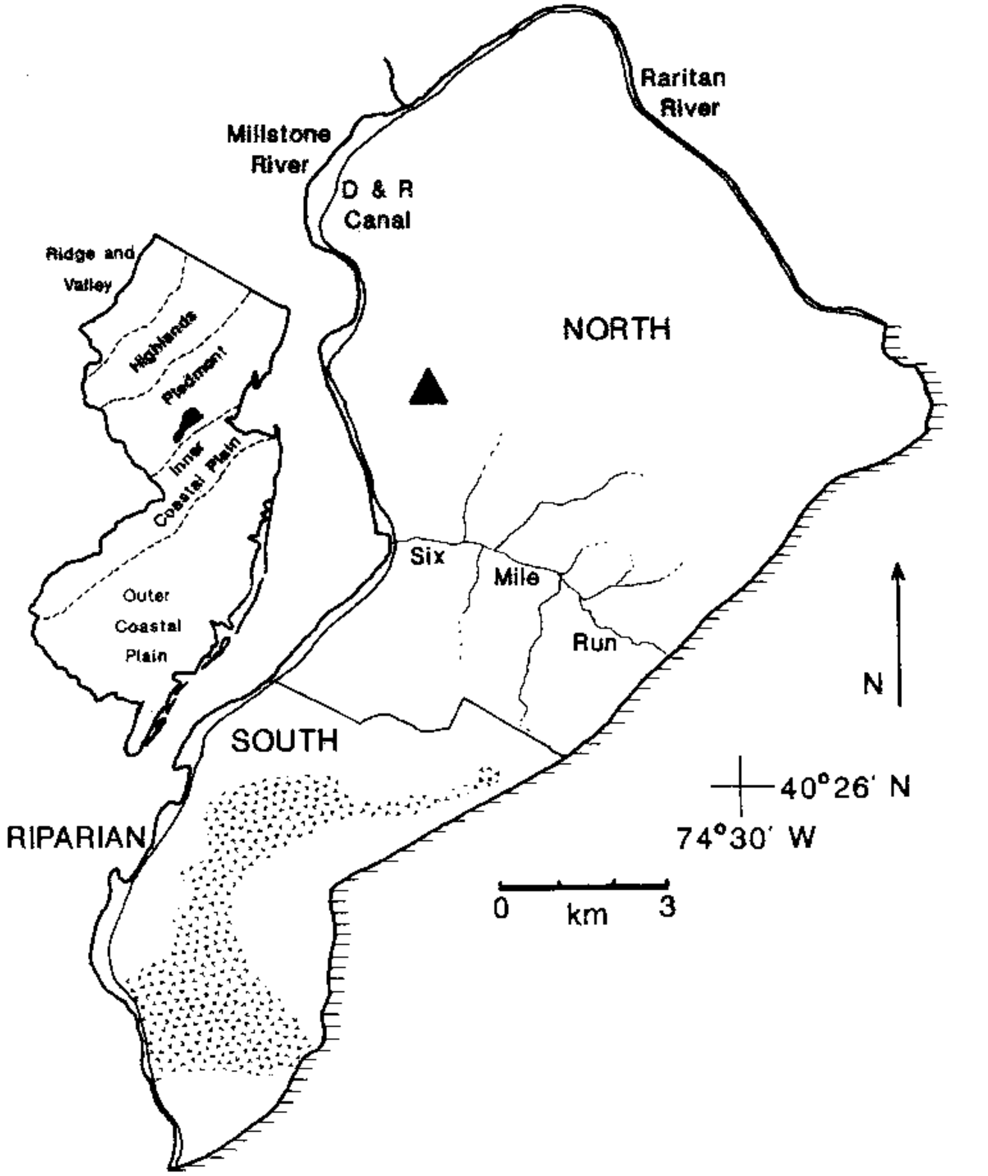

Fig. 1. Franklin Twp., Somerset Co., and its relation to the physiographic regions of New Jersey. The triangle indicates the location of the William L. Hutcheson Memorial Forest. The line dividing North and South regions lies along Butler and Claremont Roads. Stippling shows the position of the Rocky Hill Ridge. Hash marks indicate the township's land boundary.

ed by the Raritan and Millstone Rivers on its north and west and Route 27 on its southeast (Fig. 1). The township has a temperate, subcontinental climate with mean January and July temperatures of −1°C and 24°C, respectively, a 170–180 day frost free period, and 114–118 cm of precipitation spread evenly throughout the year (Robichaud and Buell 1973).

From its settlement in the late 1600's, through the 1940's, Franklin Township was an area of farms and small villages (Menzies 1969). This pattern was broken by one unusual disturbance, the construction of the Delaware and Raritan Canal along the floodplains of the Raritan and Millstone Rivers (Fig. 1). The canal opened in 1834, operated for a century, and has been maintained since 1974 as a state park. The township's population density remained low and relatively stable between 1790 and 1940, averaging about 31 persons per km², then rose sharply, reaching

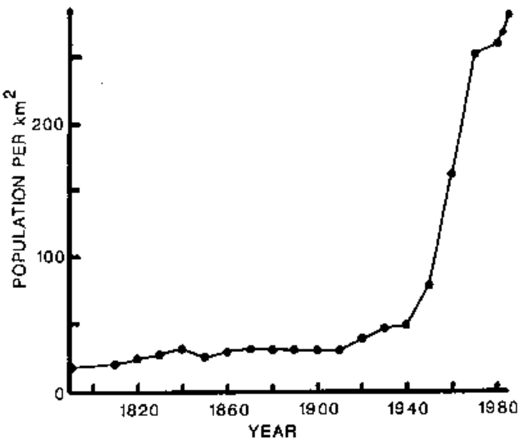

Fig. 2. Human population density of Franklin Twp., Somerset Co., NJ, from the United States census and the New Jersey Department of Labor, Office of Demographic and Economic Analysis.

an estimated 287 persons per km² in 1986 (Fig. 2). In spite of recent population increases, the area's rural aspect persisted because suburbanization was concentrated near the northeastern boundary of the township, land held by speculators and developers was farmed to limit taxes, and the state sequestered land for a planned reservoir in the Six Mile Run drainage in 1970.

To trace the effects of flood frequency, topography, soil characteristics and related land use on woodland traits, we divided the township into three regions (Fig. 1; see Kirkham 1976). A Riparian region between the Millstone and Raritan rivers and the Delaware and Raritan Canal is subject to several floods per year (Wistendahl 1955; Frye and Quinn 1979); soils were formed from glacial outwash or other alluvial deposits. Uplands in the North region are nearly level and slow draining to gently sloping; elevations are below 42 m. Soils, derived from Triassic red shale, are shaly and loamy (Ugolini 1964). Uplands in the South are more rolling with areas of moderate to steep slope and elevations of 12–98 m. The South includes part of the Rocky Hill Ridge, one of several diabase sills which rise above the softer sedimentary strata of the Piedmont (Wolfe 1977). Bedrock in wooded areas is usually igneous basalt or diabase trap rock (the object of a large quarry) or metamorphosed shale, and soils may be stony, excessively wet, or both (Tedrow 1986).

Successional and mature floodplain (Buell and Wistendahl 1955; Wistendahl 1955; Frye and Quinn 1979) and upland woods (Bard 1952; Forman and Elfstrom 1975; Pickett 1982) have been studied in or near northern Franklin Township. A local benchmark for relatively undisturbed upland woods is provided by the intensively studied William L. Hutcheson Memorial Forest, located in the northern township 1 km east of East Millstone (Fig. 1; Buell 1957; Monk 1961; Sulser 1971).

Methods. To assess trends in woodland extent and identify continuously wooded areas, observations of woods existing in 1986 were compared with records of woods from 1880, 1943, and 1978. The number and area of historic woods were determined from a topographical map based on 1878–1880 field surveys (Cook and Vermeule 1887), United States Geological Survey topographic maps with woodland areas based on 1943 aerial photography, and 1978 aerial photographs (U.S. Department of Agriculture, Aerial Photography Field Office). Close correspondence existed between the locations of existing mature woodlands and woodlands depicted on the 1887 map, giving us confidence in the 1880 data. Areas were estimated from photographs and maps using a computer graphics tablet; areas of 1986 woods were based on field estimates of changes since the 1978 photographs. Woodlands included land under a natural tree canopy except for those areas where the overstory was intermittent or inconsequential (e.g., fencerows, stream galleries, copses) or the understory was modified (e.g., picnic grounds, residential yards, cemeteries). Woodlands were counted separately if they were divided by paved roads or rights-of-way.

Between 17 October 1985 and 16 July 1986, field reconnaissances were made of all woods. Woods were examined for current area, tree species composition, tree size, and evidence of disturbance. From these observations, woods were classed as young, intermediate, or mature. Young woods originated after 1910–1920 based on absence from 1887 and 1943 maps, small tree size, and, in suitable habitats, presence of successional redcedar (*Juniperus virginiana* L.) or gray birch (*Betula populifolia* Marsh.) in the canopy (see Bard 1952). Mature woods contained one or more stands of large trees (diameter at breast height, dbh >30–46 cm) and occupied a total wooded area of at least one hectare. Intermediate-aged woods fell between these age extremes.

Mature stands were sampled for basal area, frequency, and density of each tree taxon by the Bitterlich, variable-radius plotless method (Shanks 1954) using a 3.03 diopter wedge prism. Ten-point, linear transects were used in all stands of adequate size resulting in samples of ca. 100

Table 1. Number and extent of wooded areas in Franklin Twp., Somerset Co., NJ, listed by region for the years 1880, 1943, 1978, and 1986. Woods are separated by age class in 1986.

		1880		1943		1978		1986					
								Young		Intermediate		Mature	
Region	Region area (ha)	N	Area (ha)	N	Area (ha)	N	Area (ha)	N	Area (ha)	N	Area (ha)	N	Area (ha)
North	8635	43	456	144	925	163	825	88	302	28	122	30	307
South	2970	17	616	34	1027	46	969	18	53	5	39	22	866
Riparian	464	2	55	22	197	21	240	5	37	11	87	6	124

trees per transect. Interpoint spacing was adjusted to the size of the stand. In large woods, multiple stands were chosen for sampling to reflect differences in slope, aspect, or soils. Sampled trees were tallied in 15.2 cm dbh classes to allow calculations of density (see Grosenbaugh 1952). Under the plotless Bitterlich technique, frequency data were recorded to express the frequency of each taxon's contribution to stand basal area, not presence itself. An overall importance value (IV) was determined for each taxon by summing relative density, relative frequency and relative basal area and dividing the total by three. Results for individual stands were reported by White and Worthen (1986).

Results. EXTENT AND HISTORY. The number and cumulative area of woodlands at four periods is presented by region in Table 1. At the time of the earliest systematic survey of New Jersey's woodlands in 1880, 62 woods covered only 9% of the 121 km^2 township. Cover had apparently been declining until this period; 30 years earlier, two forest blocks occurred in northern Franklin Township where only fragmented woodlands remained in 1880 (Anonymous 1850). Wooded area nearly doubled between 1880 and 1943, reaching almost 18% coverage, but since then, cover has declined, except in the Riparian region. From 1943–1986, there was a 21% decline in woodland area in Northern uplands; about one half of this decline occurred from 1978–1986. In Southern uplands, coverage declined 7% from 1943–1986. In 1986, 213 woodlands covered 1936 ha or 16% of the township. For the bulk of the township, the northern uplands, woods covered <9% of the land in 1986. Coverage in southern uplands has historically been over three times that in the north.

Reforestation, fragmentation and woodland destruction have, in turn, been major influences on the number of separate woods in the township (Table 1). From 1880–1943, the number of woods more than tripled as many areas were reforested. From 1943–1978, woodland number increased more slowly as existing woods were fragmented, and numbers declined subsequently with the destruction of some northern upland woods.

In 1986, woodlands that included mature stands of trees accounted for about one-quarter of all woods and two-thirds of all wooded area, although the proportion of mature woods in the North was less than half that in the South (Table 1). Within each region, individual young and intermediate-aged woods had about one-third to one-tenth the area of mature woods.

Most mature stands may occupy land which has been continuously wooded. Early woodlands have endured: of 62 woods present in 1880, 52 (84%) remained at least partly wooded in 1986. Absence of cultivation or a long woodland history could also often be inferred from large tree size, the presence of large surface boulders, pit and mount microtopography, sprout-clump origin of large trees, or sprouts of American chestnut (*Castanea dentata* [Marsh.] Borkh.).

Woodlands were small in 1880, and their median and maximum areas have shrunk since then in spite of the increase in overall woodland coverage through 1943. Median woodland area decreased from 6.7 ha in 1880 to 3.3 ha in 1943, 1978 and 1987. In 1986, 90% of woodlands were smaller than 20 ha. Median woodland area in the North was less than half that in the South in 1986 (2.8 vs. 6.2 ha, respectively). From 1880–1986, maximum woodland size shrank from 67 to 39 ha in the North, and from 304 to 190 ha in the South.

DISTURBANCE. To examine the proportion of woods and wooded area which have been disturbed recently, we grouped woods by the type of disturbance each suffered from 1943–1986 (Table 2). When multiple insults were recorded for a single woods, only the most severe and widespread disturbance was considered. We were able to record only the overall areas of the woods affected by each disturbance, not the areas of the

Table 2. Woodlands of Franklin Twp., Somerset Co., NJ, grouped by the major type of disturbance suffered between 1943 and 1986. Disturbance severity tends to decrease from top to bottom; woods with multiple disruptions were assigned to the first applicable class.

Disturbance class	1943 N	1943 Wooded area (ha)	1986 N	1986 Wooded area (ha)
Industry (quarry)	1	408	12	329
Building construction				
Commercial	20	261	22	132
Residential	64	605	61	535
Other development[a]	19	109	21	72
Rights-of-way	26	424	28	438
Vehicle trails, dumping	7	36	6	39
High canopy mortality	4	61	4	76
Undisturbed (except flooding)				
Immature woods	38	111	40	155
Mature woods	21	133	19	160

[a] Parks, golf courses, camps, ponds, and clearing for agriculture.

actual disturbances. Fragmentation of existing woods caused increases in the number woods included in some disturbance classes.

Of the 200 patches present in 1943, almost two-thirds were affected by development sometime over the following 43 years. Residential construction was the most ubiquitous disturbance, although commercial development in the North and expansion of a quarry in the South were each associated with a greater loss in wooded area. Rights-of-way for new roads and utility corridors were a major disturbance in 13% of woods and contributed to the fragmentation of additional woods which were affected primarily by industry and construction. Loss of wooded area to rights-of-way was obscured in the township because many corridors cut through patches which were otherwise expanding through reforestation. Although recent timber harvesting had occurred in four woods, we never judged it to be a leading source of disturbance.

Recent deaths of large trees significantly altered the canopies and understories of 22 woods, although this was a leading disturbance in only four woods. A well documented example is the Hutcheson Memorial Forest. In 1969, the Forest had a basal area of 27 m^2/ha (Sulser 1971), but in 1986, following the death of some canopy oaks and understory flowering dogwoods (*Cornus florida* L.), basal area had dropped to 18 m^2/ha, plus 5 m^2/ha of standing dead timber (White and Worthen 1986). A woods 0.4 km to the east showed the greatest damage; it had 7 m^2/ha standing dead wood (other large boles had recently fallen), equivalent to 35% of its predamage basal area. Basal area of standing dead trees averaged 2 m^2/ha in 44 mature woods with recorded damage, an average 9% loss in predamage basal area. On average 22 standing dead trees >15.2 cm dbh occurred per hectare, equal to 8% of the predamage tree population in this size range. Insect defoliation and disease for *Cornus florida* were the major apparent causes of tree mortality, followed by flooding and shading; however, potential pollution and climate effects were not determined. Both Hutcheson Memorial Forest and its neighbor had been completely defoliated by gypsy moths (*Lymantria dispar* L.) in 1981, and gypsy moth damage in a mixed-oak forest in the Highlands province led to mortality rates (22 trees/ha; 7% of the population) similar to those in Franklin Township (Ehrenfeld 1980). Canopy destruction by insects is not a novel disturbance, however, and New Jersey woods with intact understories may be resilient compositionally to gypsy moth damage in the long term (Ehrenfeld 1980).

Fewer than one-third of the woods (representing one-sixth of 1986 wooded area) were disturbance-free during the last four decades. Two-thirds of the woodlands without recent human or natural disturbance were young or intermediate-aged woods originating from post-agricultural succession or recovering from heavy cutting. Thus, little-disturbed mature woods occupied only 1% of the township and accounted for less than 9% of all woodlands and wooded hectares.

SPECIES COMPOSITION AND WOODLAND STRUCTURE. Description of the region's upland forest type as "mixed oak" (Buell 1957; Monk 1961; Robichaud and Buell 1973; Forman and Elfstrom 1975) is well supported (Tables 3, 4). Township-wide, red (*Quercus borealis* Michx. f.), white (*Q. alba* L.), and black oak (*Q. velutina* Lam.) together accounted for one third of the averaged IV total, and one or another of these species dominated in 30 of 56 upland stands. These three oaks also provided the largest individual trees sampled. Five *Quercus* species characteristic of upland mixed oak forests (*Q. borealis*, *Q. alba*, *Q. velutina*, *Q. prinus* L., and *Q. coccinea* Muenchh.) accounted for a median 39% (range: 0–82%) of the IV total in upland stands (see Fig. 3). Pin oak (*Q. palustris* Muenchh.)

Table 3. Survey of trees in 30 stands in Northern uplands of Franklin Twp., Somerset Co., NJ. Species are ranked by importance value.[a] + = <0.5%.

Tree species	Number of stands present (dominant)	Relative density (%)	Relative frequency (%)	Relative basal area (%)	Importance value (%)
Quercus borealis	29 (10)	21	17	21	20
Quercus alba	28 (6)	14	14	17	15
Quercus velutina	26 (7)	14	12	15	14
Fraxinus spp.[b]	22 (4)	14	10	12	12
Acer rubrum	26 (2)	10	10	9	10
Carya spp.[c]	29	10	10	7	9
Cornus florida	26	1	8	5	5
Prunus avium L.	17	5	4	3	4
Quercus palustris	11 (1)	4	3	3	3
Acer saccharum Marsh.	12	1	2	2	2
Fagus grandifolia Ehrh.	9	2	2	1	1
Ulmus rubra Muhl.	10	1	2	1	1
Prunus serotina Ehrh.	6	2	1	1	1

[a] Fifteen species had importance values <1.0%: *Sassafras albidum* (Nutt.) Nees., *Quercus coccinea, Celtis occidentalis, Quercus bicolor, Nyssa sylvatica* Marsh., *Amelanchier arborea* (Michx. f.) Fern., *Acer negundo* L., *Acer platanoides* L., *Juglans nigra* L., *Betula lenta* L., *Acer saccharinum, Ailanthus altissima* (Mill.) Swingle, *Ostrya virginiana* (Mill.) K. Koch., *Juniperus virginiana*, and *Paulownia tomentosa* (Thunb.) Steud.

[b] *Fraxinus americana* L. and *F. pennslyvanica* Marsh.

[c] *Carya cordiformis* (Wang.) K. Koch., *C. tomentosa* (Poir.) Nutt., *C. ovata* (Mill.) K. Koch., *C. ovalis* (Wang.) Sarg., and *C. glabra* (Mill.).

contributed 1–50% (median: 5%) of the IV in 28 stands, and swamp white oak (*Q. bicolor* Willd.) occurred in four stands.

Beyond the broad mixed-oak pattern, major floristic and community differences existed between upland woods on gravel and diabase soils in the South and those on red-shale soils in the North. Upland oaks were more important in the North than in the South (mean percent of stand IV: 49 ± 18 vs. 29 ± 18%, respectively; $F = 17.20$, $P < 0.0001$). Three of the nine species which were dominants in Southern stands, tulip poplar (*Liriodendron tulipifera* L.), sweet gum (*Liquidambar styraciflua* L.) and chestnut oak (*Q. prinus*), were not observed in the North. Similarly, before its elimination by an introduced fungal blight by about 1920 (Korstian and Stickel 1927), *Castanea dentata* had been locally im-

Table 4. Survey of trees in 26 stands in Southern uplands of Franklin Twp., Somerset Co., NJ. Species are ranked by importance value.[a] + = <0.5%.

Tree species	Number of stands present (dominant)	Relative density (%)	Relative frequency (%)	Relative basal area (%)	Importance value (%)
Quercus borealis	25 (5)	17	13	17	15
Liriodendron tulipifera	23 (7)	15	12	17	13
Acer rubrum	21 (1)	11	9	9	10
Fraxinus spp.	21 (2)	10	9	8	9
Carya spp.	22 (1)	10	8	7	8
Quercus alba	25 (2)	7	9	8	8
Fagus grandifolia	19 (2)	5	6	5	5
Quercus velutina	20	3	6	4	4
Quercus palustris	13 (1)	4	4	5	4
Liquidambar styraciflua	5 (3)	5	3	4	4
Cornus florida	21	1	6	4	4
Acer saccharum	11 (1)	3	4	3	3
Prunus avium	11	2	3	2	2
Nyssa sylvatica	14	2	2	2	2
Sassafras albidum	16	2	2	1	2

[a] Fifteen species had importance values <1.0%: *Quercus prinus* (dominant in one stand), *Ulmus rubra, Prunus serotina, Quercus coccinea, Ailanthus altissima, Quercus bicolor, Acer negundo, Juglans nigra, Populus grandidentata* Michx., *Juniperus virginiana, Carpinus caroliniana* Walt., *Betula lenta, Ostrya virginiana, Robinia pseudoacacia* L., and *Tilia americana* L.

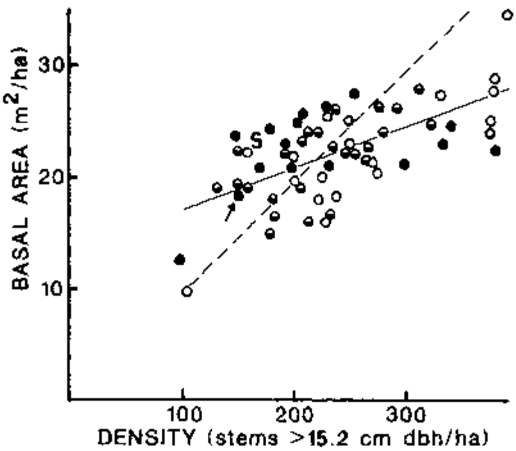

Fig. 3. Scatter plot of 61 stands by basal area and density of stems >15.2 cm dbh. Symbol shading indicates the cumulative importance of five upland oaks: *Quercus borealis*, *Q. alba*, *Q. velutina*, *Q. prinus*, and *Q. coccinea* (open symbols, <25% of total importance; half filled, 25–50%; filled, >50%). The dashed line shows the relation between basal area and density assuming all trees had average basal area (986 cm^2); above the dashed line, trees were larger on average. The solid line is for the regression equation, basal area = 13.3 + 0.037 × density. The arrow indicates Hutcheson Memorial Forest, and the "S" shows the Forest with standing dead trees included.

portant in the South but absent in the North (Vermeule and Pinchot 1899: 90–91); *Castanea* sprouts were observed only in three Southern stands. Ash (*Fraxinus* spp.), red maple (*Acer rubrum* L.), and hickory (*Carya* spp.) were important components of woods in both regions. Overall, 41 tree taxa were sampled in 61 mature stands (Tables 3 and 4), and ten additional species were noted in sampled or reconnaissance-only woods. Upland stands in the North and South had broadly similar tree species compositions (indices of similarity: IS_J = 66% based on species presence, IS_E = 65% based on relative IVs [Mueller-Dombois and Ellenberg 1974]). Tree species richness per sampling point and per stand were greater in the South than the North although overall diversity was similar in the two regions (Table 5).

Riparian floodplain woods differed from upland woods in dominance pattern, diversity, and tree density. Three tree taxa were dominant overwhelmingly in the five surveyed Riparian stands: *Fraxinus* spp. (34% IV), *Q. palustris* (26% IV), and silver maple (*Acer saccharinum* L.; 23% IV). The thirteen additional tree taxa surveyed were of minor importance: *Acer negundo* (6% IV) and *Carya* spp. (3% IV); others with ≤1% IV, *Gleditsia triacanthos* L., *Quercus bicolor*, *Platanus occidentalis* L., *Crataegus* spp., *Prunus serotina*, *Acer rubrum*, *Acer platanoides*, *Ulmus rubra*, *Salix* sp., *Maclura pomifera* (Raf.) Schneid., and *Diospyros virginiana* L. Upland oaks were absent. The index of similarity of tree species between Riparian and upland stands was only IS_J = 24% and IS_E = 49%. Riparian woods contained fewer species per stand and fewer species overall than upland woods (Table 5). Riparian woods had about half as many small stems (<15.2 cm dbh) per hectare as upland woods, perhaps as the result of damage during flooding. However, large trees (>15.2 cm dbh) which typically withstand floods occurred at relatively high densities in Riparian woods, perhaps because of high moisture availability (see Frye and Quinn 1979). Overall, mean tree diameter and concentration of basal area in trees >30.5 cm dbh, did not vary significantly among regions (Table 5).

Measures of woodland structure were correlated among stands. Significant positive correlation existed between stand basal area and density of stems >15.2 cm dbh (r = 0.651, P < 0.0001); however, the increase in basal area with

Table 5. Characteristics of woods in 1986 in three regions of Franklin Twp., Somerset Co., NJ. Values are means ± 1 standard deviation. Mean tree diameter was calculated from total basal area and density of stems >15.2 cm dbh for each stand. F values are for ANOVA among regions (*, P < 0.05; **, P < 0.01; ***, P < 0.0001).

Trait	North	South	Riparian	F
Number of stands	30	26	5	
Density (stems/ha)				
Trees <15.2 cm dbh	760 ± 320	780 ± 300	410 ± 100	3.39*
Trees >15.2 cm dbh	220 ± 60	250 ± 70	300 ± 80	3.36*
Basal area (m^2/ha)	21 ± 4	24 ± 3	22 ± 4	4.21*
Mean tree diameter (cm)	35 ± 4	36 ± 4	31 ± 2	2.84
Percent BA in trees >30.5 cm dbh	56 ± 15	59 ± 12	53 ± 4	0.60
Tree species/point	3.8 ± 0.5	4.5 ± 0.6	3.0 ± 0.5	21.69***
Tree species/stand	9.4 ± 1.5	11.2 ± 2.9	7.4 ± 2.9	7.50**

increasing density was less than expected if tree size had remained constant, suggesting that low-density stands are ones that have thinned as they matured (Fig. 3). Across stands, average tree size varied with the importance of upland oaks representative of "mixed-oak" forests. Stands where upland oaks accounted for >50% of total IV had larger than average trees more frequently than did stands that were less oak-dominated ($G_{Yates} = 4.69$, $P < 0.05$). Furthermore, significant positive correlation existed between average tree dbh (derived from the ratio total basal area : density of trees >15.2 dbh) and upland oak IV ($r = 0.399$, $P < 0.002$).

Notwithstanding the general interregional patterns outlined above, individual stands presented a large variety of species assemblages and dominance relationships. When 61 stands were classed by their first and second dominant tree species, 38 unique dominance pairs were represented. The most common combination, *Q. borealis* and *Fraxinus*, occurred only seven times. Of the 41 tree taxa encountered, 13 taxa from 7 genera led in importance in at least one stand (Tables 3 and 4). For the six most frequently dominant trees, significant correlation existed between species importances in only 8 of 15 possible pairs (Table 6). Significant negative correlation existed between *Q. palustris* which occurred on floodplains and poorly drained uplands and all other leading dominants except *Fraxinus*. Upland oaks appeared decreasingly mesic from *Q. borealis* to *Q. velutina* to *Q. alba* based on their interrelations and variation with *Fraxinus* (see Ehrenfeld 1982). Stand-to-stand heterogeneity may have arisen from independent variation in drainage, soils, topography, and disturbance history and from chance regeneration patterns in small, long-isolated patches.

Table 6. Pearson correlation coefficients for importance values of the six most frequently dominant taxa in stands in Franklin Twp., Somerset Co., NJ. Only pairs with significant r values ($P < 0.05$) are shown.

	Q. velutina	*Fraxinus*	*Q. palustris*
Quercus borealis	0.324		−0.524
Q. alba	0.573	−0.397	−0.395
Q. velutina		−0.508	−0.423
Liriodendron			−0.253

Discussion. The history of Franklin Township woodlands mirrors the general postsettlement history of forests in the northeastern United States. Central to these histories was the waxing and waning of local agriculture and the demand for wood (Robichaud and Buell 1973; Wacker 1975; Russell 1980; Ehrenfeld 1982). First, in an early agricultural period, forests were either cleared for crops, hay, or pasture, or exploited for fuel, lumber or woodland grazing (see Cronon 1983). For central New Jersey, woodland status in 1880 appeared to be representative of the end of this clearance period. Next, in a late agricultural or regeneration period, agriculture declined regionally because of competition from farms to the west and south, soil deterioration, and economic downturns. Disturbances to forests eased as coal and oil supplanted wood. Remnant woods matured, and neglected agricultural land became reforested. Finally, a post-agricultural period began with the expansion of residential and commercial development which was indifferent, or attracted, to wooded land. The transition point between the late- and post-agricultural periods in central New Jersey may be well represented by 1943 conditions. Now, after three centuries of intense human disturbance, about 16% of Franklin Township is wooded, and 58 woods support mature stands.

The extent and development of woodlands varied regionally within the township because differences in edaphic conditions and susceptibility to flooding resulted in different patterns of agricultural land use. In the North, where land was most suited for cultivation, deforestation was early and severe and reforestation during the late-agricultural period was limited. Forest survived primarily as small, remnant woodlots. Surprisingly, disturbance to these woodlots may have been light relative to woods elsewhere in the township; woodlots were likely selectively cut and grazed during the early agricultural era, then neglected for a century as agriculture declined. In the South, where soils and topography were less suited to cultivation, clearing for agriculture was less extensive and likely slower, and land was reforested earlier and more widely during agriculture's decline. Paradoxically, disturbance of woods in the South may have been more severe than in the North. The dominance of shade-intolerant species in many mature Southern woods (see below) suggests histories of heavy logging. Riparian land, highly valued as pasture, was apparently cleared extensively soon after settlement (Menzies 1969); construction of a canal on the floodplain likely reinforced disruption of woods there, and a photographic history of the working canal (McKelvey 1975) reveals deforestation of adjacent land. Late-agricultural reforestation has been extensive here, and park status has curtailed recent disturbances.

SIMILARITIES TO ORIGINAL FORESTS. How similar are woods today to precolonization forests in terms of dominant tree species and forest structure? Human disturbance is often assumed to have strongly favored stump-sprouting, fire-hardy, and shade-intolerant tree species over more mesic, shade-tolerant species even on land which has never been cultivated. Under this view, present-day mixed oak woods would represent human-maintained successional artifacts similar to presettlement forests only to the extent that native Indians had had a significant environmental impact (see Buell *et al.* 1966). Recent work has challenged the assumptions of this view. Historical accounts and witness tree records suggest that shade-intolerant species were common in primary forests (see Ehrenfeld 1982; Loeb 1987), and palynological records show that *Quercus* has remained a dominant upland genus since well before settlement (Russell 1980). The long-term stability of the mixed-oak assemblage is further supported by the composition of the relic Hutcheson Memorial Forest and its similarity to nearby upland woods (Forman and Elfstrom 1975).

The township woodlands most closely approximating original conditions may be those on red-shale soils of the gently sloping Piedmont uplands where woodlots have persisted for centuries in an agricultural matrix. This is just the region in which woods are smallest, rarest, most often disturbed, and most rapidly diminishing because of post-agricultural development.

The composition of most woods on Southern uplands, however, may differ substantially from precolonial conditions. Obviously, *Castanea dentata*, one potential dominant of the original forest, has been lost. More generally, regeneration conditions often appear to have been poor for oaks, perhaps because of poorly drained soils. *Liriodendron tulipifera* and *Liquidambar styraciflua*, shade-intolerant species with small, wind-dispersed seeds, dominated 10 of 26 Southern stands in patterns suggesting histories of post-agricultural succession or regrowth following clear cutting (see Horn 1971).

The species composition and development of Riparian woods resembled those of a 60-year-old successional woodland of the Raritan inner floodplain (Frye and Quinn 1979) more closely than they did those of the oldest Raritan bottomland woods (Buell and Wistendahl 1955). Although *Fraxinus* was important throughout, *Q. palustris* and *A. saccharinum* had high relative basal areas in Franklin Township and Raritan successional woods but not in old-growth Raritan bottomlands where *Ulmus americana* L., *Celtis occidentalis* L., and *Acer rubrum* were important. Total basal area of Riparian woods (22 m^2/ha) was nearer to that of successional than old Raritan floodplain woods (21 vs. 28 m^2/ha, respectively). Pioneer trees grow rapidly on the floodplain; through the first 60 years of succession, height and radial growth of floodplain trees is 3× that of upland trees (Frye and Quinn 1979). Thus, relatively young Riparian woods had basal areas and densities of large trees similar to those of mature upland woods (Table 5). This agrees with palynological evidence from northern New Jersey lakes which indicated that since colonization species composition has changed most in wetlands and remained most stable in woodlots on farmed uplands (Russell 1980).

The structural development of present woodlands can be compared to that of the relic Hutcheson Memorial Forest (HMF) as a possible benchmark of local presettlement conditions. Mean tree dbh in HMF, was large, particularly before recent canopy damage, but density was low relative to most stands, and basal area was low (postdamage) to intermediate (predamage) (Fig. 3). Few mature woods had a structure similar to that of HMF, suggesting that most woods are maturing with basal area becoming concentrated in fewer, larger trees.

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