Forest structure comparison of Hutcheson Memorial Forest and eight old woods on the New Jersey Piedmont

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Forman, Richard T. T., and Bruce A. Elstrom. (Dep. Botany, Rutgers Univ., New Brunswick, N.J. 08903). Forest structure comparison of Hutcheson Memorial Forest and eight old woods on the New Jersey Piedmont. Hutcheson Mem. Forest Bull. 3:44-51. 1975.—Compared with 8 nearby oak woods, the William L. Hutcheson Memorial Forest is higher in number of tree species, percent exotic species, percent understory, subcanopy and large shrub layer species, seedlings of *Fraxinus americana*, *Acer platanoides* and the red oak group, saplings of *Fraxinus americana*, trees of *Cornus florida* and *Quercus alba*, and range of soil moisture conditions. HMF is typical in the number of soil types present and the percents of canopy, edge, central closed canopy, and lowland species. It is lower than usual in seedlings, saplings and trees of *Acer rubrum*, *A. saccharum* and *Fagus grandifolia*, seedlings of *Prunus serotina*, and trees of *Quercus velutina*. Relative to the other woods, at HMF *Fraxinus americana* and *Acer rubrum* are likely to continue their unusual importances, *Cornus florida* is likely to become more typical, and *Acer platanoides* and *Prunus serotina* more atypical. Relative to the present HMF structure *Acer saccharum* is likely to increase in importance, and *Quercus alba*, *Carya* spp. and *Prunus avium* decrease. The higher tree species diversity at HMF, characterized by species of lower forest strata and many exotics, may be related to higher people use. Community coefficient values and composition of dominant species indicate Hutcheson Memorial Forest is broadly representative of the forests on the upland red shale New Jersey Piedmont.

An exceptional amount of research has been done at the William L. Hutcheson Memorial Forest in the last 25 years, with over 80 published papers and reports based on work in the woods and adjacent fields (Small 1973). The forest structure has been described as a mixed *Quercus* canopy, *Cornus florida* understory, and *Viburnum* shrub layer (Bard 1952; Buell 1957; Monk 1957, 1961a; Sulser 1971). Vascular plant species diversity includes 40 trees, 39 shrubs and 232 herbs (Frei and Fairbrothers 1963). Fifteen percent of the tree species and 22% of the total species are exotic (alien) species, some of which are increasing in dominance (Frei and Fairbrothers 1963; Ambler 1965; Sulser 1971). The species abundances of the forest edge are relatively distinct from the closed canopy, which, however, contains numerous gaps (Wales 1972). Though this old forest has apparently been unburned for 3 centuries and uncut, major windstorms and perhaps pest outbreaks have caused pulses of change in the woods, and it is suggested that maples, beech and ash are slowly increasing at the expense of oaks and hickories (Buell 1957; Monk 1961b; Reiners and Reiners 1965; Sulser 1971). Are these forest characteristics and changes representative of the woods on the red shale Piedmont of New Jersey, or is this an atypical woods for the region?

The region is broadly classified as oak-chestnut forest in a study of the eastern United States (Braun 1950) or mixed oak forest in a study of New Jersey (Robichaud and Buell 1973). Detailed studies of forest structure in Cushetunk Mountain (Cantlon 1953), Voorhees State Park (McDonough and Buell 1956), Watchung Reservation in Union Co. (Baird 1956), Herrontown Woods, Princeton (Kramer 1971), and the Institute Woods, Princeton (Horn 1971, 1975) are all on distinct geologic substrata and soils adjacent to the red shale Piedmont. Lowland woodlands in the Piedmont are described for the Raritan River (Buell and Wistendahl 1955; Wistendahl 1958), Millstone River (VanVechten and Buell 1959) and Stony Brook (Horn 1971, 1975). In the apparent absence of detailed studies in other woods of the upland, red shale Piedmont, Hutcheson Memorial Forest (HMF) has been assumed to be representative of this region.

The objectives of this study are to (a) compare the Hutcheson Memorial Forest with other woods for numbers, types, composition and importances of tree species, and (b) look for evidence of relative future changes between HMF and the other woods, as well as within Hutcheson Memorial Forest itself.

Methods

Eight woods surrounded by fields, in addition to Hutcheson Memorial Forest, were selected in a rural New Jersey area approximately 32 km in diameter and bounded by New Brunswick, Oldwick, Flemington and Princeton. The woods are 20-100 m elevation in a Triassic red shale region of the Piedmont (Lewis and Kummel 1915; Widmer 1964). Soils are predominantly silt and shaly loams of the Penn (including Norton) series of the Brunswick formation (Tedrow 1963; Ugolini 1964; U.S. Soil Conservation Service 1958-1967). The climate is mild, with approximately 100 cm precipitation relatively evenly distributed through the year, average annual temperature 11.7°C, and an average monthly temperature range of 0.0-24.0°C (Biel 1958; U.S. Weather Bureau 1959).

Criteria for woods selection were the presence of mature trees (60-100 cm dbh, diameter measured 1.5 m above ground level) over the entire woods, all forest structural layers (canopy, subcanopy, understory, shrub and herb), discreteness from the surrounding fields, approximately isodiametric shape, mature edges, large size, slope not exceeding 10°, well drained soil, lack of disturbance (recent fire, cutting, etc.), absence of streams, and distance from population centers and pollution sources. Three size classes were used, 7.5 ha, 10 ha and 24 ha, and one woods of each size was selected in the northern portion of the study area, one of each size in the central portion, and one of each size in the southern portion. Hutcheson Memorial Forest is the 24 ha woods in the central portion. In the following descriptions of the woods, location and soils are given, plus any exceptions to the above listed criteria for woods selection.

N7.5, (7.5 ha woods in the northern portion), Maryknoll Farm West. Three km north of Whitehouse Station, approximately 0.6 km west of route 523. Soils: 60% Norton loam eroded, 40% Norton loam. Gaps common in portion due to recent cutting, edge indistinct in places.

C7.5, Wohendorf-Perry Woods. Three km south of Whitehouse Station, at end of Edgewood Rd., 1 km east of route 523. Soils: 45% Penn shaly silt loam, 45% Penn shaly silt loam eroded, 10% Reaville silt loam wet. Rectangular shape, temporary stream.

S7.5, Water Tower Woods. Northeast of Blawenburg, approximately 3 km north of route 518, 2 km west of route 206, north side of Sunset Road. Soils: 70% Royce silt loam, 5% Royce silt loam eroded, 10% Lansdowne silt loam, 15% Birdsboro gravelly loam. Understory with non-uniform coverage, some wood cut for firewood, large water tower.

N10, Maryknoll Farm East. Three km north of Whitehouse Station, approximately 0.3 km west of route 523. Soils: 80% Norton loam eroded, 20% Norton loam. Gaps common in portion due to recent cutting, edge indistinct in places.

C10, Reno Farm. South of Whitehouse Station, approximately 2 km north of Pleasant Run, by high tension wires on east side of Cole Road. Soils: 40% Penn shaly silt loam eroded, 40% Reaville silt loam, 20% Penn-Bucks complex. Rectangular in shape, permanent stream, understory with non-uniform coverage, 1972 ground fire in one corner.

S10, Ringoes Corso Woods. Three km west of Ringoes, approximately 0.3 km south of Sergeantsville Rd. Soils: 90% Penn shaly silt loam eroded, 10% Rough broken land, shale (bedrock at surface with patches of thin soil). Permanent stream, edge indistinct in places, house near edge.

N24, Treetops. Two km south of Lamington, south of interstate highway 78, west of Lamington River, and immediately west of Fiddlers Elbow golf course. Soils: 40% Athol gravelly loam, 20% Lansdowne silt loam, 20% Annandale and Edneyville gravelly loam, 10% Athol gravelly loam eroded, 5% Reaville silt loam wet, 5% Norton loam eroded. Standing water, gaps common in portion due to recent cutting, houses near edge, soils mainly developed from glacial till and calcareous conglomerate.

C24, William L. Hutcheson Memorial Forest. One km east of East Millstone, on south side of route 514. Soils: 50% Penn shaly silt loam, 20% Royce silt loam, 15% Croton silt loam, 15% Lansdowne silt loam. Rectangular shape, permanent stream, standing water, gaps common due to blowdowns, western portion beyond the narrows excluded.

S24, Western Electric Woods. One km south of Mt. Rose and 1 km west of route 569. Soils: 70% Reaville silt loam, 8% Penn shaly silt loam, 5% Bowmansville silt loam, 5% Klinesville shaly loam, 5% Doylestown silt loam, 3% Reaville silt loam wet, 3% Reaville silt loam eroded. Permanent stream, standing water, understory non-uniform coverage, and grazed, burned or cleared recently near some edges.

Sampling for tree species was done between August 1972 and September 1973, and 3 methods were utilized: quadrats, transects and reconnaissance. A series of parallel lines, marked with colorful plastic flagging, divided each woods into 30 m wide sections, running perpendicular to the straightest long edge of the woods. Quadrats were located in a stratified random manner throughout the woods (including the edge portions) using the marked sections. Quadrats were 40 x 10 m for trees ($\geq$ 10 cm dbh), 10 x 2.5 m for saplings ($<$ 10 cm and $\geq$ 2.5 cm dbh), and 2.5 x 0.5 m for seedlings ($<$ 2.5 cm dbh). The sapling and seedling quadrats were nested in a constant corner of the tree quadrats. All individuals exhibiting a single-stemmed growth pattern, excluding vines, and a dbh $\geq$ 2.5 cm were included as trees or saplings. All seedlings of those species which at least occasionally attain tree or sapling status in the study area were included. Hutcheson Memorial Forest was sampled with 116 quadrats, *N10* woods with 55, *S7.5* woods with 45, and based on the point where species-area curves for these 3 woods begin to level off, 10 quadrats were done in the remaining woods. Presence and abundance of species were recorded.

Transects were 10 x 90 m running perpendicular to the edge of the woods and from the outer canopy level limbs toward the center of the woods. Transects were located randomly along the straightest east or west edge, but no closer than 30 m from a north or south edge. Presence, abundance and dbh of trees and saplings were recorded. Fourteen transects were sampled at the *N10* woods, 8 at *S7.5*, 4 at *C24* (HMF), and 3 at the remaining woods. In the absence of good east and west edges with well drained woods at Hutcheson Memorial Forest, 2 transects were from the south edge between the trail and the "dog leg" and 2 from the north edge opposite these (see map in Monk 1957).

Reconnaissance was done by walking at approximately 10 m intervals in a zig-zag fashion between the marked lines 30 m apart. Species absent from the quadrats and transects were recorded. Distance traversed and time in reconnaissance sampling were approximately proportional to the area of the woods.

Tree species were identified with Fernald (1950), Gleason (1962), Harlow (1959) and the Chrysler Herbarium at Rutgers University. We divided the species into 4 growth form categories based on the normal maximum level attained in the forests: canopy, subcanopy, understory and large shrub. Species were classified as edge species, closed canopy species, and lowland species according to Wales (1969), Agriculture Handbook No. 271 (1965), Harlow (1959), and observations of distributions in this study. Species were classified as exotic if not native east of the Appalachian Mountains. More detailed descriptions of study areas, tree and soil sampling are given in Galli (1973) and Elfstrom (M.S. thesis in preparation).

Soil types were determined from detailed maps of the soils in each county (U.S. Soil Conservation Service 1958-1967). All samples for soil moisture were collected on the same day in late May 1973, weighed, dried at 105°C for 48 hrs, and reweighed to determine percent weight loss. Ten samples were taken in each woods. If there were no obviously wet or dry areas, samples were taken in a stratified random manner using the marked lines 30 m apart. When distinctly wetter or drier areas were evident in a woods, 5 samples were taken in the wetter areas and 5 samples in the drier areas, in order to determine the range of soil moisture conditons present.

Results

We encountered a total of 41 species with a dbh ≥ 2.5 cm in Hutcheson Memorial Forest based on quadrat sampling and reconnaissance (table 1). The average total number of species in the other 8 woods was 32.4 (standard deviation = 3.0), or if only the two 24 ha woods equal in size to HMF are considered, 34.0 (sd = 5.7). Therefore species diversity, measured as number of species, appears higher at Hutcheson Memorial Forest than at the other woods in the region. When the quadrat data alone are compared (table 1), based on 10 quadrats selected in a stratified random fashion in all woods, we find: HMF 16 species, 8-woods average 16.9 (sd = 1.3), and 2-woods average 16.5 (sd = 0.7). Thus the greater species diversity at Hutcheson Memorial Forest is due to rare species not encountered in 10 stratified random quadrats.

In examining this difference, first we will consider the types of species and later the particular species present. A notable 14.6% of the total species encountered at HMF are exotic species (table 1). This compares with the 8-woods average of 6.1% (sd = 2.1%). Of the 6 exotic species at HMF, 2 may be considered common, while the average 2.0 (sd = 0.8) exotic species in the other woods are virtually always rare. Thus exotic species are more prevalent at HMF than usual in the region.

Comparing vertical strata in the woods we found 12 canopy species at Hutcheson Memorial Forst (table 1) vs the 8-woods average of 13.5 (sd = 1.2) or the 2-woods average of 14.5 (sd = 0.7), indicating little difference, or perhaps a slightly lower canopy diversity at HMF. There were 11 subcanopy species at HMF vs 7.6 (sd = 2.1) average in the 8 woods or 8.5 (sd = 3.5) in the 2 woods, suggesting a significant difference. Eight understory species at HMF compared with the 8-woods average 5.6 (sd = 0.5) or the 2-woods average 5.0 (sd = 0.0), a notable difference. In the large shrub category HMF had 8 species while the 8-woods average was 5.8 (sd = 0.9) or 2-woods average 6.0 (sd = 1.4), again a notable difference. Therefore the greater species diversity at HMF is due to the greater number of species in the lower strata of the forest. It is notable also that the diversity of HMF canopy is not greater than the other woods.

Some species have distinctly higher relative abundances near the edge of a forest, some in the central closed canopy portion, and some are evenly distributed from the edge to the center. At HMF we found 32.[illegible] of the total species were edge species while the 8-woods average was 31.5% (sd = 4.3); the pattern was similar for species in the quadrats only. Closed canopy species at HMF were 24.4% of the total vs 29.5% (sd = 3.9) in the other woods, with little difference between the two in the quadrats. These results indicate that the percents of edge and closed canopy species are typical at Hutcheson Memorial Forest.

Lowland species, primarily in poorly drained spots or along infrequent streams, comprise 24.4% of the total species at HMF and an average 21.2% (sd = 3.0) in the other woods. The quadrat samples gave 16.0% and 17.6% (sd = 7.1) respectively. Thus lowland species at HMF are of about equal prevalence as in the other woods.

To compare the relative similarity of the total species present at HMF with the other woods we calculated community coefficients (CC) for pairs of woods (Bray and Curtis 1957):

$$CC = \frac{2\,S_c}{S_1 + S_2}$$

S_1 is the number of species at HMF, S_2 the number of species in a second woods, and S_c the number of species common to both woods. The CC's comparing HMF to each of the 8 woods were 0.73 (for the *N7.5* woods), [illegible] (*C7.5*), 0.65 (*S7.5*), 0.76 (*N10*), 0.72 (*C10*), 0.82 (*S10*), 0.76 (*N24*) and 0.79 (*S24*), with an average CC of [illegible] (sd = 0.05). These are high values, considering replicate samples within such woods commonly have a CC of about 0.80-0.85, and indicates that the HMF tree community is quite similar overall to the other woods. The rather low variability indicates further that it is similar to essentially all of the woods.

Four species were encountered only at HMF (table 1): *Paulownia tomentosa, Acer negundo, Cornus racemosa* and *Pyrus malus*. One is an exotic, 2 are subcanopy species, 1 understory and 1 large shrub species. The other woods had an average of 1.3 (range 0.3) unique species, those being *Ulmus rubra, Tsuga canadensis, Robinia pseudo-acacia, Pinus virginiana, Platanus occidentalis, Populus tremuloides, Maclura pomifera, Prunus pensylvanica, Rhus copallina* and *Populus grandidentata* were in two or more woods but not encountered at HMF. Of the 13 species only in the 8 woods, one is an exotic, 6 are canopy species, 3 subcanopy, 1 understory, and 3 large shrub species. Therefore, based on rare species either unique to HMF or unique to the other woods, there is a slightly higher number of such species

Table 1. Relative abundances of species in quadrat and reconnaissance sampling. The first line for a species = trees (10 x 40 m quadrats), second line = saplings (2.5 x 10 m quadrats), third line = seedlings (0.5 x 2.5 m quadrats). Relative abundance in %. Species only encountered in reconnaissance = R. The last 24 species were absent from quadrats. Canopy species = CA, subcanopy species = S, understory species = U, large shrub layer species = LS, exotic species = EX, edge species = ED, closed canopy species of center of forest = CL, lowland species = LO. Seedlings of the red oak group were lumped together = *

Size of Woods (ha)	7.5	7.5	7.5	10	10	10	24	24	Average of 8 Woods	24
Portion of Study Area (North, Central, South)	N	C	S	N	C	S	N	S		C (HMF)
Number of Quadrats	20	19	[illegible]	55	10	10	10	10	-	116
No. Species/10 Quadrats	18	17	15	16	19	17	17	16	16.9	16
No. Species all Quadrats	15	17	25	22	19	17	17	16	18.6	25
Total Number of Species (Quads & Reconnaissance)	33	29	30	33	31	35	38	30	32.4	41
Total Number of Trees in Quadrats	177	[illegible]	108	524	108	132	121	121	-	1255
Total Number of Saplings in Quadrats	[illegible]	78	346	450	56	77	90	70	-	1040
Total No. of Seedlings in Quadrats	69	56	173	319	49	75	57	58	-	530
Year Seedlings Sampled	[illegible]	1973	1972	1972	1973	1973	1973	1973	-	1972
Quercus alba L. CA	[illegible]	22.8	18.8	9.1	14.8	7.6	11.6	14.9	15.5	20.5
	0	0	6.1	1.6	7.1	0	0	0	2.1	0.8
	2.9	1.2	1.2	9.9	12.0	0	1.8	0	2.5	0.7
Quercus velutina Lam. CA, *	17.0	19.4	32.5	15.5	26.8	13.6	21.5	14.9	23.0	5.9
	0	0	4.9	0.4	1.9	0	0	4.3	1.6	0.1
	0	0	34.7	7.4	4.0	1.3	8.8	6.9	7.9	26.7
Quercus rubra L. var. *borealis* (Michx. f.) Farw. CA, *	2.8	7.0	3.6	10.9	13.0	6.8	5.8	4.1	7.7	6.4
	0	1.3	0.6	0	1.8	1.3	0	1.4	0.9	0.3
	[illegible]	0	0	0	0	0	0	0	0	0
Fraxinus americana L. CA	2.8	4.4	1.0	0.4	5.6	12.1	0	0	3.8	10.1
	0	3.9	0	0	0	0	0	0	0.6	17.2
	[illegible]	9.3	0	0	14.0	1.3	5.3	6.9	5.7	13.7
Carya spp. CA	[illegible]	7.0	1.6	2.3	6.7	6.1	2.5	10.8	4.6	7.1
	[illegible]	2.6	2.0	0	16.1	0	0	1.4	3.4	1.0
	0	2.3	0	1.6	8.0	0	0	0	1.5	1.3
Acer saccharum Marsh. CA, CL	0	21.9	0.3	0	5.6	12.9		8.3	7.0	0.5
	0	20.5	0	0	0	44.2	R	8.6	10.5	2.5
	[illegible]	23.5	0	3.0	0	60.0		1.7	11.4	6.4
Fagus grandifolia Ehrh. CA, LO	[illegible]	5.5	0.3	27.7	0		19.8	18.2	12.2	0.6
	[illegible]	[illegible]	0	[illegible]	0	R	27.9	12.9	12.3	1.7
	[illegible]	8.1	0	3.8	0		3.5	6.9	3.3	0.5
Liriodendron tulipifera L. CA	[illegible]	0	0.3	0.2	0	0	11.6	0	2.3	0
	0	0	0	0	0	0	0	0	0	0
	0	0	0	1.5	0	0	1.8	0	0.4	0
Ulmus spp. CA, LO	0	0	0	0	0.9	5.3			0.9	0
	0	0	0	0	0	0	R	R	0	0
	0	2.3	0	1.2	0	0			0.4	0.2
Quercus coccinea Muenchh. CA, *			0.7	0.2					0.3	
	R	R	0	0	R	R	R	R	0	R
			0	0					0	
Quercus palustris Muenchh. CA, ED, LO, *		0	1.0			0	0.8		0.3	
	R	0	0	R	R	0	0	R	0	R
		0	0			0	0		0	
Betula lenta L. CA	0.6		0	0		0		0.9	0.2	0
	0.7	R	0	0	R	0	R	1.4	0.3	0
	0		0	0		0		0	0	0
Acer rubrum L. S	21.5	4.4	29.9	23.3	14.8	9.1	17.4	22.3	20.4	6.0
	[illegible]	6.2	37.3	11.9	19.6	3.9	6.7	22.9	16.0	9.7
	13.9	10.4	18.3	7.1	4.0	2.7	5.3	27.6	10.2	2.9

at HMF than the 8-woods average, but the percentage of exotics differs little. All of these species at HMF are species of lower forest strata, while the largest group of such species in the other woods is canopy species.

Turning to the relative importance of species within the woods, we see all woods are dominated by three oaks *Quercus velutina*, *Q. alba* and *Q. rubra* which together comprise 28.0-54.9% of the trees ≥10 cm dbh in a woods (table 1). Each woods has 1-3 other species with more than 10% relative abundance, the primary species in

Table 1 continued.	N7.5	C7.5	S7.5	N10	C10	S10	N24	S24	$\bar{X}$ of 8	C24
Prunus avium L. S, ED, EX	2.3	0	0.7	1.9	0	0.8			0.6	6.2
	0	0	0	0.4	0	0	R	R	0	1.3
	2.9	3.5	0.6	0	[illegible]	0			[illegible]	2.7
Sassafras albidum Nutt. S, ED	0	0.9	1.0	0.6	0.9	4.5	[illegible]	9.6	1.5	0.8
	0	1.3	1.2	2.2	0	0	0	0	0.7	0.5
	2.9	1.2	[illegible]	4.1	4.0	6.7	0	19.3	3.7	1.1
Acer platanoides L. S, EX	0	0	0		0	0	0	0	0	2.1
	[illegible]	0	0	R	0	0	0	0	0.1	2.2
	0	0	0		0	0	0	0	0	3.3
Prunus serotina Ehrh. S, ED	0.6	0	0	0.2	0.9	0.8	0	2.5	0.7	0.2
	0	0	0	1.5	0	0	0	2.9	0.6	0
	7.2	7.0	6.5	6.5	20.0	1.3	13.8	5.4	8.5	1.5
Nyssa sylvatica Marsh. S, ED, LO	2.3	1.8	1.0	2.7	0	0.8	1.7	0	1.3	0
	1.4	2.6	0.9	4.2	0	0	4.4	1.4	1.9	0
	0	7.7	2.0	1.2	0	1.3	0	0	1.6	1.3
Acer negundo L. S, LO	0	0	0	0	0	0	0	0	0	0.5
	0	0	0	0	0	0	0	0	0	0.9
	0	0	0	0	0	0	0	0	0	0.2
Juglans nigra L. S			0		0	1.5		0	0.2	
	R	R	0	R	0	0	R	0	0	R
			0		0	0		0	0	
Ailanthus altissima (Mill.) Swingle S, ED, EX		0	0	0	0			0	0	0.2
	R	0	0	0	0	R	R	0	0	0.2
		0	0	0	0			0	0	0
Cornus florida L. U	13.6	1.8	6.8	5.0	5.6	18.2	5.8	2.5	8.6	36.5
	61.8	56.4	42.8	56.7	37.5	48.1	60.0	32.9	49.5	55.7
	52.2	[illegible]	30.6	55.2	12.0	14.7	45.6	6.9	29.3	24.1
Amelanchier arborea (Michx. f.) Fern. U, CL	0	[illegible]	0	0	2.8	0		0	1.0	0.2
	0.7	2.6	0.3	0.7	3.6	1.3	R	1.4	1.3	0.5
	0	0	0	0	2.0	0		1.7	0.5	0
Juniperus virginiana L. U, ED			0		1.9				0.2	0
	R	R	0.3	R	1.8	R	R	R	0.3	0
			2.3		2.0				0.5	0.2
Castanea dentata (Marsh.) Borkh. U, CL		0	0.3	0.2	0	0	0	0	0.1	0
	R	0	0.3	3.3	0	0	1.8	0	0.5	0
		0	0.6	1.5	0	0	0	0	0.3	0
Carpinus caroliniana Walt. U, CL, LO			0	0.2			0		0.0	
	R	R	1.7	0.2	R	R	1.1	R	0.4	R
			0	0			1.8		0.2	
Morus alba L. U, EX	0	0	0	0	0	0	0		0	0.1
	0	0	0	0	0	0	0	R	0	0.1
	0	0	0	0	0	0	0		0	0.2
Celtis occidentalis L. U, CL, LO	0		0		0		0	0	0	
	0	0	0	R	1.8	R	0	0	0.2	R
	0		0		0		0	0	0	
Pyrus malus L. U	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0.2
Lindera benzoin (L.) Blume LS, CL, LO			0.3		0	0	0	0	0.0	0
	R	R	0	R	1.8	1.3	0	1.4	0.6	0.4
			0		0	8.0	3.5	6.9	2.3	3.7
Viburnum prunifolium L. LS	0	0		0	0				0	0
	0	0	R	0	3.6	R	R	R	0.5	3.6
	1.4	5.8		2.1	4.0				1.7	5.3
Hamamelis virginiana L. LS, CL	0		0	0	0	0	0	0	0	0
	0	R	1.7	0.9	1.6	0	0	7.1	1.7	0
	0		0	9.9	6.0	0	5.3	20.7	4.1	0
Crataegus spp. LS, ED	0	0	0	0	0		0		0	0
	0	0	0	0	0	R	0	R	0	0
	0	1.7	0	0	2.0		0		0.4	0.2
Sambucus canadensis L. LS, LO	0	0	0	0		0		0	0	
	0	0	0	0	R	0	R	0	0	R
	0	0	0	0		2.7		0	0.3	
Rhus glabra L. LS, ED			0	0					0	0
	R	R	0	1.1	R	R	R	R	0.1	0
			0	0					0	0

order being *Acer rubrum*, *Fagus grandifolia*, *Cornus florida*, *Acer saccharum* and *Fraxinus americana*.

Based on relative abundance of trees in an intensive 116 quadrats 10 x 40 m at HMF the dominants in order are *Cornus florida*, *Quercus alba* and *Fraxinus americana*. Comparing relative abundances at HMF with the averages for the 8 woods indicates that (a) *Cornus florida* is much more abundant at HMF than in the other woods, (b) *Quercus alba*, *Fraxinus americana* and *Prunus avium* are somewhat more abundant than in the others, (c) *Acer rubrum* and *A. saccharum* are somewhat less abundant, and (d) *Quercus velutina* and *Fagus grandifolia* are much less abundant than in the others.

Table 1 continued.

	N7.5	C7.5	S7.5	N10	C10	S10	N24	S24	X̄ of 8	
Prunus pensylvanica L. LS, ED	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
	0	0	1.2	0	0	0	0	0	0.2	0
Ligustrum vulgare L. LS, ED, EX	0	0	0	0	0	0		0	0	0
	0	0	0	0	0	0	R	0	0	0
	0	0	0	0	0	0		0	0	0.2
Carya cordiformis (Wang) K. Koch CA, CL, LO	R	0	0	0	0	R	0	0	-	0
Carya glabra (Mill.) Sweet CA, CL	R	R	0	R	R	R	R	R	-	R
Carya ovalis (Wang) Sarg. CA, CL	R	R	R	R	R	R	R	R	-	R
Carya ovata (Mill.) K. Koch CA, CL	R	R	R	R	R	R	R	R	-	R
Carya tomentosa Nutt. CA	0	0	R	R	R	R	0	0	-	0
Paulownia tomentosa (Thunb.) Steud. S, ED, EX	0	0	0	0	0	0	0	0	-	R
Pinus virginiana Mill. S, ED	0	0	0	0	0	0	R	0	-	0
Platanus occidentalis L. CA, LO	0	0	0	0	0	0	R	0	-	0
Tsuga canadensis (L.) Carr. CA, CL	0	0	0	R	0	0	0	0	-	0
Ulmus americana L. CA, LO	0	R	0	R	R	R	R	R	-	R
Ulmus rubra Muhl. CA, LO	0	0	0	0	0	0	0	R	-	0
Betula populifolia Marsh. S, ED	R	0	0	R	R	0	R	R	-	0
Diospyros virginiana L. S, ED, LO	0	0	0	0	0	0	R	0	-	R
Populus grandidentata Michx. S, ED	0	0	0	R	R	0	0	0	-	[illegible]
Populus tremuloides Michx. S, ED	0	0	0	0	0	0	R	0	-	0
Robinia pseudo-acacia L. S, ED	0	0	0	0	0	R	0	0	-	0
Tilia americana L. S, CL	0	0	0	0	0	R	0	0	-	0
Corylus americana Walt. LS, ED	0	0	R	0	0	0	R	0	-	R
Cornus racemosa Lam. LS	0	0	0	0	0	0	0	0	-	R
Maclura pomifera (Raf.) Schneid. U, ED, EX	0	0	R	0	0	0	0	0	-	0
Ostrya virginiana (Mill.) K. Koch U, CL	0	R	0	0	R	R	0	0	-	R
Rhus copallina L. LS, ED	R	0	0	0	0	0	0	0	-	0
Rhus typhina L. LS, ED	R	0	R	R	0	R	0	0	-	R
Spiraea tomentosa L. LS, ED	0	0	R	0	0	0	0	0	-	0

Some differences are seen when we compare the relative basal areas of species at HMF and the average for the 8 woods (table 2). (a) *Cornus florida* is much higher in basal area than in the other woods, (b) *Quercus alba* is somewhat higher, (c) *Quercus velutina, Carya* spp., *Fagus grandifolia, Acer saccharum*, and *Liriodendron tulipifera* are somewhat lower, and (d) *Acer rubrum* is much lower in basal area than in the others. Therefore, based on relative abundance and basal area of trees at HMF, 2 species, *Cornus florida* and *Quercus alba*, are more important than in the other woods, and at least 4 species, *Acer rubrum, Quercus velutina, Fagus grandifolia*, and *Acer saccharum*, are less important than usual.

The differences in successional status of species may be suggested by the relative abundances of saplings and seedlings (table 1). Sapling data at HMF show (a) *Fraxinus americana* is much more abundant than the 8-woods average, (b) *Acer rubrum* and *A. sacchar[um]* somewhat less abundant, and (c) *Fagus grandif[olia]* much less abundant than the other woods.

In contrast, seedling data at HMF (table 1) show the red oak group seedlings much more abundant than the other woods, (b) *Fraxinus americana* and *Acer p[la]tanoides* somewhat more abundant, (c) *Acer sacchar[um]*, *Prunus serotina, Fagus grandifolia* and *Hamamelis [vir]giniana* somewhat less abundant, and (d) *Acer rubr[um]* much less abundant than the 8-woods average.

We now examine the changes at Hutcheson Memo[rial] Forest relative to the other woods, suggested by the tree, sapling and seedling results. *Fraxinus americ[ana]* which is presently more important at HMF than the 8-woods average in all 3 categories, may continue to maintain or increase its higher relative importance. The striking difference in the number of large *Cornus flo[rida]* trees and to a lesser extent *Quercus alba* at HMF vs the other woods may disappear through time, since the sapling and seedling relative abundances are similar. *Acer rubrum, A. saccharum*, and *Fagus grandifolia*, presently less important in all 3 categories at HMF than elsewhere, may continue at a lower level than in the other woods. The relatively low importance of *Quercus velutina* at HMF compared with the other woods may disap[pear]

Table 2. Relative basal areas of species in transects. Based only on trees ≥10 cm dbh. Transects 10 x 90 m from edge toward center of woods. Relative basal areas in %.

Size of Woods (ha)	7.5	7.5	7.5	10	10	10	24	24	Average of 8 woods
Portion of Study Area (North, Central, South)	N	C	S	N	C	S	N	S	
Number of Transects	3	3	8	14	3	1	1	3	-
Number of Trees	82	96	127	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Total Basal Area (cm²)	2016	2379	3581	8075	1858	1664	1891	2195	-
Cornus florida	3.6	2.3	1.8	10.[illegible]	0	13.9	9.8	0	6.0
Quercus alba	4.6	22.6	25.7	13.5	25.5	7.5	12.2	14.5	18.0
Quercus rubra	6.5	23.2	3.1	22.4	32.9	10.4	0	21.2	17.[illegible]
Quercus velutina	22.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fraxinus americana	[illegible]	11.8	0.8	0.2	0	16.5	0	5.3	5.0
Prunus avium	0	2.5	1.6	1.0	0	5.4	0	0.6	1.5
Carya spp.	2.0	11.7	1.2	10.9	6.5	5.5	5.1	8.7	3.3
Acer platanoides	0	0	0	0	0	0	0	0	0
Sassafras albidum	1.1	4.1	0	0.6	0	2.9	0	0.5	1.3
Ulmus spp.	0	0	0	0.3	0	0	0	0	0.0
Acer rubrum	14.9	5.5	11.4	10.6	8.7	1.9	25.6	11.4	12.8
Fagus grandifolia	17.2	0	1.3	10.4	0	0	10.8	6.5	6.6
Acer saccharum	0	0.9	0	0.6	0	20.8	2.5	13.4	5.8
Liriodendron tulipifera	7.4	0	0	0.8	0	0	22.9	1.8	4.7
Quercus palustris	5.4	0	0.7	1.1	0	0	0	4.5	1.7
Quercus coccinea	4.7	0	0	0	0	1.9	0	2.7	1.3
Juglans nigra	5.2	0	0	0	0	1.1	0	0	0.8
Prunus serotina	0.5	0	0	0.7	0	0.8	0	0	0.2
Betula populifolia	0.6	0	0	0	0	0	0	0	0
Nyssa sylvatica	1.5	0	0.3	1.3	0	0	0	1.8	1.0
Amelanchier arborea	0.5	4.3	0	0	1.6	0	0	0	0.8
Castanea dentata	0	0	0	0.1	0	0	0	0	0.0
Ailanthus altissima	0	0	0	0	0	0	0	0	0

Table 3. Soil type and soil moisture conditions in the woods. Soil types determined from county soil maps. Soil mositure in percent by weight based on 10 samples per woods with the wettest and driest areas in a woods sampled when evident. All samples taken in one day.

Size of Woods (ha)	7.5	7.5	7.5	10	10	10	24	24	Average of 8 woods	24
Portion of Study Area (North, Central, South)	N	C	S	N	C	S	N	S		C (HMF)
Total Number of Species	33	29	30	32	31	35	38	30	32.5	41
Number of Soil Types	2	5	1	2	1	2	6	7	3.5	4
Maximum Soil Moisture %	32.5	42.2	37.0	31.3	40.0	44.0	43.3	52.6	40.3	55.9
Minimum Soil Moisture %	23.0	20.0	28.0	24.5	24.5	29.7	25.5	33.5	26.1	24.7
Range of Soil Moisture %	9.5	22.2	9.0	6.8	15.5	14.3	17.8	19.1	14.3	31.3

pear in time, if many of the red oak group seedlings are this species, but this remains uncertain. The seedling values for the red oak group and *Acer platanoides* at HMF are higher than in the other woods, such that these species may become relatively more important. Similarly *Prunus serotina* may become less important at HMF compared to elsewhere. Note particularly that these trends for HMF are relative to the other woods, i.e. in comparison with the trends in the 8-woods averages.

The suggested trends within HMF itself, based on comparing the tree data of tables 1 and 2 with the seedling-sapling data (table 1), of course are different. Here *Cornus florida, Fraxinus americana,* the red oak group (primarily *Quercus rubra* and *Q. velutina*), and the less common species may change little in relative importance. However, *Acer saccharum* may increase in relative importance, while *Quercus alba, Carya* spp. and *Prunus avium* may decrease within Hutcheson Memorial Forest.

Two environmental factors, soil type and soil moisture, were studied to see if they correlated with the higher species diversity at HMF than the other woods. The 4 soil types encountered at HMF (table 3) are essentially the same number as the average 3.5 (sd = 1.9) for the other 8 woods, and slightly less than the 2-woods average of 6.5 (sd = 0.7). If the number of soil types and the number of species per woods are compared for all 9 woods, there is a slight positive correlation, but with high variability. However, if the number of soil types and species per woods are compared within the 3 (woods) size groups separately (7.5 ha, 10 ha and 24 ha), in each case there is a slight negative correlation (indicative of a size-soil type interaction). We conclude therefore that the number of soil types at HMF and the other woods is unimportant in determining the difference in species diversity.

The range of soil moisture conditions (table 3) within HMF, 31.3%, exceeds the 8-woods average range of 14.3% (sd = 5.4) and the 2-woods range of 18.5% (sd = 0.9). Caution should be exercised in interpreting these results since soil moisture is measured as percent by weight, without measurements of soil texture. A plot of soil moisture range vs number of species for the 9 woods would show a positive correlation, but with an exceedingly large variation. If these are plotted separately for the 3 (woods) size groups however, two of the correlations are negative and one positive, again with considerable variation. These results indicate that, though the range of soil moisture conditions appears greater at HMF than in the other woods, this is likely no more than a minor contributing factor to the higher species diversity at Hutcheson Memorial Forest.

Discussion

The results of tree, sapling, seedling and soil sampling indicate a higher species diversity, especially of species in lower forest strata (of which many are exotics), at Hutcheson Memorial Forest than the other woods. However, with the exception of a minor effect of soil moisture, the data give few clues on the reason for the higher diversity. Two possibilities require evaluation: sampling methods and unsampled factors.

Since the number of species in 10 quadrats at HMF (16 species) and the other woods (16.9 species, sd = 1.3) is the same, the diversity difference comes in the subsequent sampling. The number of species added after the 10 quadrats is: 25 at HMF based on 106 more quadrats plus reconnaissance, 15 at *S7.5* based on 35 more quadrats plus reconnaissance, 17 at *N10* based on 45 more quadrats plus reconnaissance, and an average 15.3 (sd = 3.6) in the remaining 6 woods based on reconnaissance alone. Thus in the other 8 woods the number of species added is about the same whether based on quadrats plus reconnaissance or reconnaissance alone, and is considerably less than at HMF. There is little difference in the number of added species in the 106 quadrats at HMF (9 species) and the 35 at *S7.5* (8 species) or 45 at *N10* (6 species), which combined with the previous point indicates that the large increase in diversity at HMF is not due to the intensive sampling of the 106 additional quadrats. We conclude that sampling differences between HMF and the other woods contribute little, if anything, to the higher diversity recorded at HMF.

The unsampled factors which seem most important to us are people use and proximity to population centers. People usage at HMF includes approximately 40-50 group tours annually which are limited to the 1.5 km path at the eastern end. A few dozen research projects, strictly limited usage by small advanced classes, and caretaking of the property bring people throughout the woods on a fairly regular basis. Though the numbers have varied, this usage has continued for approximately two decades. We know far less about people usage of the 8 woods, other than our own observations during year-round sampling in this and 6 associated studies. The major uses appear to be hunters during a few weeks in the fall, hikers infrequently, children infrequently, and at *N24* horseback riders infrequently. People may carry seeds, presumably involuntarily, into the forest and the expected result would be in most cases, few individuals of tree species. Since people usage is believed greater in the past 20 years than earlier, trees introduced by people would mostly be less than 20 years old. This hypothesis gibes with the observed results where most of the additional species at HMF are rare, composed of individuals <10 cm dbh and in the lower strata of the forest.

We note that limiting people usage is an important management priority at the William L. Hutcheson Memorial Forest.

The number of exotic species at HMF might be related to proximity to population centers where exotic species are of greatest importance. However, HMF is 11 km from New Brunswick and Somerville and the 8-woods average is 11.0 km (sd = 3.5) from the nearest major population center (New Brunswick, Somerville, Flemington or Princeton). Therefore distance from population centers does not correlate with the higher diversity at HMF. It might be noted that the large areal spread of housing developments around these population centers, where exotic plantings are abundant, has taken place in the last 2 decades.

The distance from small villages which originated as much as two centuries ago might also be examined, since HMF is only 1 km east of such a village, East Millstone. Distances from each of the 8 woods to its nearest village are 1, 2, 3, 3, 3, 3, 3, and 4 km. Therefore HMF is significantly closer to such a village than the 8-woods average, 2.8 km. This could be a contributing factor to the higher species diversity, but the importance of this is unknown.

The indicated changes for the future of the woods are based on the assumption that the relative proportions of species as seedlings and saplings will be important in determining relative proportions of future canopy species. Unfortunately we know too little about the effects of pulses of tree reproduction and growth, subtle climatic changes, air pollution, changes in herbivore populations, and fire history. Thus we must cautiously live with this assumption for predictions, and hope that studies of a few decades in the lifetime of trees are representative.

Though the actual species composition of the HMF canopy may change, the diversity may not, since the higher diversity at HMF is of species which only reach to lower strata. This assumes these species, including several exotics, do not prevent other species from reaching the canopy. Studies such as those of Horn (1971, 1975) showing differential reproduction under each tree species seem particularly valuable.

The disparate data for *Acer rubrum* at HMF in tables 1 and 2 are due to the relative absence of the species in the central portion of the forest where the transects were done. Table 1 is representative of *Acer rubrum* for the entire forest. We are uncertain of future trends in the red oak group in any woods because the seedlings were not separated by species. Also the red oak group is the only case where there may be a significant difference in the production of seedlings between 1972 and 1973 (table 1). Based on the relative abundance of trees, the seedlings are probably almost all *Quercus rubra* and *Q. velutina*. At HMF the two species are about equal in abundance, but in all of the other woods *Quercus velutina* is more abundant, and often many times more abundant, than *Q. rubra*. Differential changes in the two species probable but unpredictable.

The future changes in species composition to be pected at HMF based on intensive sampling through the woods at one time, agree overall with Sulser's sig cant study (1971), based on sampling one portion comparing data with a similar sample 20 years ear Differences for some individual species are evident expected since the present study includes a broader and $>20\%$ of the forest area.

The predicted increase in northern hardwoods spe like *Acer saccharum* and *Fraxinus americana* at the pense of oak forest species like *Quercus alba* and C spp. in these 9 woods on the upland red shale Piedm agrees also with results on other geologic substrata in Piedmont and to the North in New Jersey (Buell et 1966). Such a change in forest structure over a br area would have major ecological implications.

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