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Past and present influences on reproduction in the William L. Hutcheson Memorial Forest, New Jersey

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MONK, CARL D. (U. Florida, Gainesville.) Past and present influences on reproduction in the William E. Hutcheson Memorial Forest, New Jersey. Bull. Torrey Bot. Club 88(3): 167–175. 1961.—White oak and black oak collectively contribute 68 per cent to total basal area of canopy tree species; seedlings of these species are fairly common while saplings are rare. On the other hand, sugar maple and Norway maple collectively contribute less than 1 per cent to total basal area, but seedlings of these two maples are common and their saplings are more common than oak saplings. Sapling growth data for the 1956–58 seasons show that sugar maple saplings grew better in the shaded areas of the forest than did other species studied. The pre-colonial fires appear to have favored the oaks but excluded sugar maple. With the cessation of fire after settlement sugar maple seeded in from a nearby source on the flood plain or, as with Norway maple, from shade tree plantings.

The William E. Hutcheson Memorial Forest is a mature oak forest on the Piedmont of New Jersey (40°30'N, 74°34'W). Its history extends back to pre-colonial times (Buell et al. 1954, Buell 1957). The principal disturbance by white man has been the removal of fallen trees and some wind-damaged trees (Monk 1957). Considerable change in the forest has apparently occurred in the last 250 years or so, since protection from fires has permitted many natural changes, and some introduced species have been successful (Adjemovitch 1958). A description of this forest has recently been published (Monk 1961).

The objective of this paper is to examine past and present influences of shade and fire on the reproduction of trees within the forest.

METHODS: A tree census of the forest was made during the winter of 1956–57. With the exception of dogwood (*Cornus florida*), all individuals in the forest stand over 1 in. d.b.h. were measured. This was accomplished by establishing parallel strips 10 to 15 m. wide across the forest. Individuals less than 1 in. d.b.h. were counted in quadrats. A total of 53 20-square-meter quadrats were used to sample saplings (>1 ft. high and <1 in. d.b.h.). One hundred and six 1-square-meter quadrats were used to sample seedlings (<1 foot high).

The nomenclature follows Gray's Manual (Fernald 1950).

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RESULTS

Distribution in size classes.—The census showed that in the larger size classes white oak (*Quercus alba*), black oak (*Q. velutina*), and red oak (*Q. rubra*) are the principal contributors to basal area. Others are red hickory (*Carya ovalis*), white ash (*Fraxinus americana*), red maple (*Acer rubrum*), pin oak (*Q. palustris*), sweet cherry (*Prunus avium*), black gum (*Nyssa sylvatica*), American elm (*Ulmus americana*), swamp white oak (*Q. bicolor*), beech (*Fagus grandifolia*), shagbark hickory (*C. ovata*), sugar maple (*A. saccharum*), Norway maple (*A. platanoides*), and scarlet oak (*Q. coccinea*).

The various species reach maximum numbers in different size classes (Table 1). The species can be placed into two general categories: Group 1,

TABLE 1. *Size class distribution of individuals over 1 in. d.b.h. for trees on upland (U) and lowland (L) sites in Hutcheson Memorial Forest. All trees over 1 in. d.b.h. were measured on 53.3 acres of upland forest and 11.4 acres of lowland forest. These data have been adjusted to a per acre basis.*

Species		TREES PER ACRE IN D.B.H. SIZE CLASSES							
		1–4	5–9	10–14	15–19	20–24	25–29	30	Total
Quercus alba	U	0.8	3.4	8.2	10.3	5.4	1.2	0.3	29.6
	L	1.0	2.8	1.8	3.7	2.8	1.1	0.1	13.3
Quercus velutina	U	0.9	1.9	3.8	3.4	2.3	0.7	0.2	13.2
	L	0.2	0.5	1.8	0.4	—	—	—	2.9
Quercus rubra	U	3.5	3.5	2.4	1.8	1.1	0.4	0.1	12.8
(and *Q. coccinea*)	L	3.2	2.9	1.8	1.1	0.8	0.1	—	9.9
Carya ovalis	U	3.0	0.7	1.2	1.4	0.5	t*	—	6.8
	L	4.7	0.7	0.2	0.2	0.1	—	—	5.9
Fraxinus americana	U	17.5	3.4	0.7	0.2	t	t	—	21.8
	L	30.5	10.7	4.3	1.4	0.5	0.1	—	47.4
Acer rubrum	U	13.7	3.1	0.6	0.1	t	—	—	17.5
	L	44.1	13.7	3.0	1.1	0.1	0.2	0.1	62.3
Prunus avium	U	3.9	4.1	0.2	—	—	—	—	8.2
	L	0.9	0.2	—	—	—	—	—	1.1
Fagus grandifolia	U	1.3	0.3	0.1	0.1	—	—	—	1.8
	L	1.5	0.4	0.1	—	0.1	—	—	2.1
Carya ovata	U	0.4	0.2	0.2	t	t	—	—	0.8
	L	1.6	1.5	0.6	—	—	—	—	3.7
Ulmus americana	U	0.5	0.4	t	t	—	—	—	0.9
	L	6.1	3.0	1.5	0.2	0.2	0.1	—	11.1
Quercus palustris	U	t	0.1	t	t	—	—	—	0.1
	L	1.0	1.6	3.0	0.8	0.5	0.1	0.2	7.2
Acer saccharum	U	1.6	0.1	0.1	—	—	—	—	1.8
	L	0.1	0.1	—	—	—	—	—	0.2
Acer platanoides	U	1.4	0.2	—	—	—	—	—	1.6
	L	0.1	0.2	—	—	—	—	—	0.3
Nyssa sylvatica	U	0.3	0.2	—	—	—	—	—	0.5
	L	16.0	9.6	1.6	0.2	—	—	—	27.4
Quercus bicolor	U	—	—	—	—	—	—	—	—
	L	0.1	0.5	0.4	0.2	0.4	0.1	0.2	1.9
Totals	U	48.8	21.6	17.5	17.3	9.3	2.3	0.6	117.4
	L	111.1	47.8	20.1	9.3	5.5	1.8	0.6	196.2

* t = <0.05 trees/acre

those species represented predominantly by large individuals and, Group 2, those present in greater numbers as small individuals. Pin oak and swamp white oak fit in neither of these categories.

Group 1 includes the white and black oak. It is evident that they are best represented by a size class of 10 to 25 in. d.b.h. There is a general decline in numbers both above 25 in. d.b.h. and below 10 in. d.b.h. A few of the larger trees reach 40 in. d.b.h. Below 10 in. d.b.h. both white oak and black oak are represented by comparatively few trees—7.8 trees per acre collectively or less than 5 percent of all canopy tree species that size. This is in contrast to their contribution of over 40 percent of all trees over 10 in. d.b.h.

Seedling and sapling counts indicate the probable reason for the paucity of small white oaks and black oaks. Black oak seedlings were not encountered in a total of 106 1-square-meter quadrats, and saplings of this species occurred in only one of the 53 20-square-meter quadrats. White oak seedlings were absent on poorly-drained areas and saplings on well-drained areas (table 2).

TABLE 2. *Density (D) and Frequency (F) of seedlings and saplings on well-drained and poorly-drained areas.*

Species	Well-drained Areas				Poorly-Drained Areas			
	Seedlings		Saplings		Seedlings		Saplings	
	D	F	D	F	D	F	D	F
Prunus avium	752	8	5	7	298	30	4	8
Fraxinus americana	301	25	145	77	405	18	321	65
Acer rubrum	267	20	22	20	383	23	76	39
Acer saccharum	117	7	2	3	21	2	—	—
Quercus alba	84	8	—	—	—	—	2	4
Acer platanoides	67	5	2	3	21	2	—	—
Quercus rubra (and *Q. coccinea*)	17	2	2	3	21	2	2	4
Ulmus americana	17	2	5	10	—	—	11	17
Carya ovata	—	—	2	3	—	—	9	13
Quercus palustris	—	—	—	—	85	9	2	4
Carya ovalis	—	—	—	—	—	—	7	13
Nyssa sylvatica	—	—	—	—	—	—	4	8
Quercus velutina	—	—	—	—	—	—	2	4

Group 2 includes the remainder of the tree species. It can be further subdivided into two: (a) species whose successful transgressives are associated with windthrow areas, and (b) species whose successful transgressives are not restricted to windthrow areas.

In group 2a red oak is least closely restricted to open sites. It does not grow in the most shaded areas but is successful in moderatly shaded places. That its seedlings and saplings are more successful than those of white oak and black oak in the forest is illustrated in tables 1 and 2. The red oak seedling count is less than for white oak, but red oak has approximately 3 times as many individuals between 1 and 10 in. d.b.h. Another interesting aspect of red oak size class distribution is the moderate decline in numbers of individuals from 1 to 25 in. d.b.h.

Successful transgressives of white ash, red maple, red hickory, sweet cherry, shagbark hickory, and black gum are almost entirely associated with the forest margin, windthrow areas, or the edge of the stream. Seedlings of shagbark hickory, red hickory, and black gum are rare in shaded areas, whereas white ash, red maple, and sweet cherry seedlings are abundant (table 2). The cherry seedlings in shaded areas rarely attain a height of one foot.

Saplings of white ash and red maple are abundant in shaded sites as well as in well-lighted areas. Individuals of these species located in shaded areas grow well and appear healthy until they are 5 to 6 ft. in height. Continued suppression by shade results in the death of the saplings.

In group 2b, species with successful transgressives in shaded areas, there are only sugar maple, Norway maple, and beech. Seedlings and saplings of beech of seed origin were not found. This species is presently maintained through root sprouts. Such reproduction of beech is quite successful in shaded areas. Sugar maple and Norway maple, though represented by only 2.0 and 1.9 trees per acre respectively over 1 in. d.b.h., are represented by a fair number of seedlings and saplings. The transgressives of sugar maple and Norway maple are largely localized around the few seed trees, though they are not restricted there.

Sapling Growth.—Height growth of saplings of seven species was measured during the 1956–58 growing seasons. This was done by placing an India ink mark on the terminal leader a few cm. below the terminal bud (Kienholz 1941). The distance from the ink mark to the end of the shoot was measured weekly. When possible, saplings of each species for study were selected in windthrow sites and shaded areas. To determine the relative amount of light received by each sapling, light readings were taken with a Weston photometer during the noon hour in late June. The light intensity in an adjoining field was 10,000 f.c. before and after the readings in the forest. To estimate the percentage of light around each sapling, ten readings were taken in the vicinity of each plant. These were added and averaged and expressed in percent of the 10,000 f.c. It was realized that the light intensity around each sapling may change during the day with changes in the position of the sun; however, the relative light intensities were the primary concern.

The sapling growth data are summarized in table 3. It is of interest to note that of the saplings located in shaded areas (white ash, sugar maple,

TABLE 3. *Sapling height growth for the 1956–58 growing seasons.*

Species	Average Growth in mm. for 1956–58	Percent Light Intensity Around Saplings	Number of Saplings Involved
Acer saccharum	151	1–6	4
	375	15–40	3
Fraxinus americana	86	1–6	5
	442	75	2
Acer rubrum	78	5–15	3
	242	35	4
Carya ovata	48	5	1
	240	35	2
Quercus velutina	443	20	1
Quercus rubra	234	30	1
Carya ovalis	124	15	1
	352	35	1
Acer platanoides	355	30	1

red maple, red hickory, and shagbark hickory) sugar maple grew considerably more than any of the others during the three year period.

DISCUSSION: Bard (1952), in considering the Hutcheson Memorial Forest, stated that many of the larger oak trees live 200 years or more and that mortality of these large trees is low, thus requiring only a few seedlings for replacement. In conclusion, she stated that "the consideration of Mettler's Woods [Hutcheson Memorial Forest] as representing a climax community may be warranted". However, evidence obtained from the present detailed stem count of all size classes seems to indicate a general decline in the importance of the oaks, particularly white oak and black oak, and an increase in sugar maple.

A similar situation has been reported by Braun (1936, 1958) in the mature oak forests on the Illinoian till plain in Ohio. There white oaks with diameters of 3 to 4 ft. are not reproducing themselves, but beech is reproducing.

The most convincing evidence for an increase in sugar maple and possibly Norway maple is the relationship between number of seed trees and transgressives. There are about 6 trees of each of these species that are producing seeds. Transgressives are more numerous in the vicinity of these seed trees, but are not confined to such sites. Both of these maples have about 2 individuals per acre between 1 and 5 in. d.b.h. This is more than for the oaks of the same size class. Oak saplings are fewer than the maples while seedling count is about the same, thus indicating that seedling and sapling mortality is less than for the oaks. It is apparent that the sugar and Norway maples are recent additions to the forest since they are still of minor importance. None have reached the 15 in. d.b.h. size class even though both show a high reproductive potential.

The cause of the recent introduction of sugar maple and Norway maple is a matter of conjecture. It may be the result of (1) change in climate, (2) changes resulting from the cessation of fires, or (3) a combination of these. There is no evidence in the long-term Weather Bureau climatological data for New Jersey (100 years of data) that indicates that climate has changed enough to explain satisfactorily such a change in vegetation, although over a longer period of time there may have been a change to more mesic conditions in the northeast (Raup 1937).

The most likely environmental change that could have induced the vegetational change is the cessation of fires. There are reasons to suspect that this has played a major role in the development of the woods since colonial times.

That pre-colonial fires were widespread in the northeastern deciduous forest has been well documented (Day 1953). Day refers to numerous papers which give a general description of the pre-colonial and colonial forests along the eastern coast. The terms "stately oaks" and "park-like" often appeared in the descriptions, and frequent mention was made of the sparse undergrowth which favored travel through the forests. Humphrey (1931) quotes similar descriptions. If these descriptions are valid, the character of the forests has changed considerably since colonial days. The high percentage of shrub cover today certainly does not give the forest a park-like appearance, and traveling on horseback through the woods would be difficult.

Trees differ in their resistance to fire. In parts of the country this is being capitalized upon by foresters through a prescribed burning program in an attempt to produce or maintain a forest in a subclimax state that may be more valuable economically than the climax vegetation. Garren (1943), in his review of fire in the southeastern conifer forest, points out numerous species that increase with repeated fire and decrease with cessation of fire. The effects of fire in maintaining pine as the dominant tree in the Pine Barrens of New Jersey has been shown by Little and Moore (1949). Buell and Cantlon (1953) reported a great reduction in shrub cover with frequent prescribed burns in the pine region of New Jersey. The reduction in shrub cover would tend to convert the appearance of the forest to park-like, as mentioned in early descriptions of the eastern deciduous forest.

There is considerable agreement that protection from fires favors sugar maple. Daubenmire (1936), in his study of the "Big Woods" of Minnesota, stated: "the behavior of sugar maple, the most fire sensitive species, at the western edge of the Big Woods is particularly noteworthy. It is completely absent in those places where fire barriers are so ineffective that they have served only to lessen the intensity of burning. In such places a gradual transition occurs from pure maple-basswood forest to bur oak savanna, and it is always the sugar maple which is the first to drop out.''

Cottam (1949) found that the bur oak savanna of southwestern Wisconsin could be transformed to dense woods in 100 years. Cottam considered that the ''cessation of these fires at the time of settlement enabled the oak openings to grow into oak woods, and unless further catastrophes interfere, the woods seem destined to become a climax Acer-Tilia woods.''

In a comparison of surveyors' records with present day forest composition in Wisconsin, Ward (1956) found that there has been a great increase in the importance of sugar maple. Evidence is given by him which suggests that fire does eliminate sugar maple except in protected sites. In mesic forests in Wisconsin, Eggler (1938) found that ''under conditions following immediately after severe burning oaks would be more successful in reproduction than maples.'' That oaks are more fire resistant than sugar maple was pointed out also by Starker (1934). Dix (1957) studied the vegetation in the National Zoological Park, Washington, D. C., which had been protected under the National Park Service for the past 67 years, and found sugar maple to be the principal understory species. Dix attributes this increase in sugar maple to protection from grazing and fire, and to the removal of the chestnut.

Bromley (1935) thought the extensive oak-chestnut-hickory-pine forest type of southern New England may have been due to frequent fires. He considered that this forest type was yielding to the white pine-hemlock climax in which sugar maple would be an important member.

Raup (1937) recognized a southward shift of the ecotone between the northern and southern hardwood forests of New England. He felt that the ''fires helped to maintain it [pre-colonial oak-chestnut-hickory type] against the competition of the more mesophytic forests to the northwest, but that fires were the sole factor in maintaining it is difficult to believe.'' He attributed the apparent change to a cooler and more moist trend in the climate within the past 3000 years.

From the above references it is apparent that a recent increase in sugar maple is not restricted to the Hutcheson Memorial Forest. It is apparent that these areas of increase are situated on the periphery of the main distribution of sugar maple. Perhaps, in all these, sugar maple was restricted by fire until 100 or 200 years ago.

It has already been shown that the Hutcheson Memorial Forest has had a past history of fire. Buell et al. (1954) found that the forest was burned at approximately 10-year intervals, before and during early colonial days. The date of the last fire recorded was in 1711. This report is significant in that it shows that fires of sufficient intensity to scar tree bases occurred only before or in the first years of colonization.

Below the canopy of the pre-colonial forest the subordinate vegetation was evidently much less dense than that at present. Hence, the greater amount of light would have created more favorable conditions for survival of young oaks.

The present size class distribution of the oaks, concentrated around 15 in. d.b.h., suggests that conditions were more favorable for them earlier. Annual ring counts of ten windthrown oaks revealed that trees of this size class are between 200 and 225 years of age. The open conditions created by the frequent pre-colonial fires were probably still existing some years after the last recorded fire in 1711 when many of the present oaks got started. With the cessation of fire and the subsequent increase in the density of the vegetation, the ability of the oaks to maintain their high level of dominance began to decline. Today the oaks are still dominant and will remain so for a long time. However, the low survival rate of transgressive oaks and the successful introduction of the shade tolerant maples suggest a trend toward a forest with more maple.

The Norway maple, of course, is an introduction from Europe. It is a favorite shade tree in central New Jersey and, hence, there has been an abundant seed source. Although Dansereau (1957) reports it to be generally unsuccessful in North America, in Hutcheson Memorial Forest it equals sugar maple as an aggressive species. The sugar maple in the forest may also have had shade plantings as a seed source although it does occur naturally on the local flood plains (Buell and Wistendahl 1955).

That the difference in success of certain of the tree species in the Hutcheson Memorial Forest is related to their different responses to low light intensities is suggested by data in Table 3. Sugar maple shows the best growth at low light intensities of all species tested. This ability of sugar maple to grow in low light intensities is supported by the work of Burns (1923).

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