

The Past and Present Vegetation of High Point State Park, New Jersey

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[Reprinted from *ECOLOGICAL MONOGRAPHS*, 23: 127-148. April, 1953]

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INTRODUCTION

The objective of this paper is to describe and correlate the past and present vegetational patterns and point out future successional trends in the plant communities of High Point State Park. The descriptions of vegetation are intended to be suitable for general use as well as to contribute to the vegetational knowledge of northwestern New Jersey. High Point State Park was selected for the study since no detailed investigations had been made in the region. Furthermore, it represented a delimited area which was relatively free from disturbance since its acquisition as a State Park.

The park is located in Sussex County in northwestern New Jersey. It is an area of 10,935 acres lying just south of the New York State line and saddling the crest of the rocky Kittatinny Mountains for a distance of 8 mi. (Fig. 1). Its southern boundary is contiguous with Stokes State Forest. In width it ranges from 2 to 4 mi. depending upon various irregularities of the boundary. The area has not long been a State Park. It was given to the State of New Jersey by the late Colonel and Mrs. Anthony Kuser in 1923. They had built a 220 ft. monument at the highest point on the ridge which is also the highest elevation in New Jersey (Fig. 1). The monument affords an excellent perspective of the park. During the peak of autumn coloration the differential aspect

of the various communities is pronounced. Light green pitch pine characterizes the rock outcrops of the ridge top, with a colorful oak forest predominating on the slopes. Dark green conifers are conspicuous in the bogs and swampy areas surrounding the lakes (Fig. 2).

The high series of ridges in the park owe their presence to the geological structure of the region. Physiographically, this part of the State lies in the Ridge-Valley Province. The rocks are of Paleozoic age. The limestones, shales, sandstones, and conglomerates were subjected to normal and thrust faulting as well as complex folding during the latter part of the Paleozoic. In Tertiary time, the land was base leveled forming the Schooley peneplain (Kummel 1940). With the uplift of the Schooley peneplain in late Tertiary time, the streams were rejuvenated. The harder strata of sandstone and conglomerate resisted rapid erosion and today persist as ridges while the less resistant shales and limestones form adjacent valleys. East of the Kittatinny ridge, shales and limestones underlie the Kittatinny valley. The ridge is double crested, the eastern part forming the major ridge (Fig. 2, 3). It consists of Shawangunk conglomerate which is primarily quartzitic with small white quartz and slate pebbles embedded in a siliceous matrix. To the east the ridge drops off as a steep, and in places, precipitous escarpment. Toward its base the Martinsburg shale outcrops, its beds dipping northwest under the conglomerate (Salisbury 1902).

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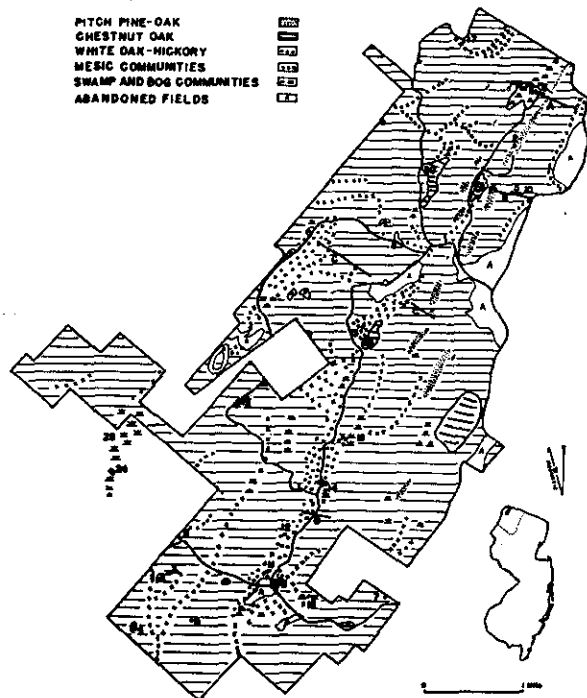


FIG. 1. Vegetational map of High Point State Park. Locations of stands (1-19) studied in detail are designated by solid dot adjacent to the number. Other areas studied in less detail are designated by numbers 20-25. Transects A, B, C, D, E, are indicated by solid lines. Stippled areas in eastern sector of park represent pitch pine-scrub oak community on the conglomerate ridge top. In general these areas correspond to the high rocky outcrops. In most cases, the streams can be located from the pattern of the mesic communities. The mesic communities include the mixed oak-hardwoods and northern hardwoods. Lakes are indicated by wavy lines (20-24). In the east central sector of the park is the Sussex reservoir (Lake Rutherford). Heavy irregular lines indicate roads. High Point Monument is located at the terminus of the road south of stand 2. Lower right outline map of New Jersey with Sussex County and park located.

However, on the ridge top near the park entrance a small lobe of shale extends northward to Lake Marcia. The lower western ridge crest is developed upon the High Falls formation consisting of red, green, and olive-colored sandstone and shale with interspersed beds of conglomerate. The topography is less rugged than where the Shawangunk occurs. Maximum elevations on the two geological formations are strikingly different. The Shawangunk ridge where the High Point Monument is located rises 1803 ft. above mean sea level (Fig. 1). In contrast the highest ridge on the High Falls is only 1480 ft.

During the Pleistocene epoch, the area was glaciated. At least two and possibly three ice sheets advanced southward covering the northern part of the State (Kummel 1940). Each modified the topography by both scouring the highest ridges and elsewhere leaving in its retreat extensive glacial deposits. The pronounced glacial features of the area are due to the most recent glaciation, the Wisconsin—specifi-

cally the Cary substage, the final Mankato advance terminating further north (P. MacClintock, personal communication). The terminal moraines of the Wisconsin extend as far south as a line extending across the State through Perth Amboy, Morristown, Hackettstown and Belvidere. Glacial striae on the scoured conglomerate outcrops indicate that the ice sheet moved across the area of the park in a southwesterly direction. The topography influenced the distribution of the glacial drift. It is estimated to reach 10 ft. or more in depth on the High Falls while along the crest of the Shawangunk ridge it does not exceed 2-3 ft. (Salisbury 1902). Over the latter it is sporadic and interspersed with rock outcrops. The steeper slopes are talus covered as a result of either glacial plucking or the disrupting action of temperature changes in post-glacial time. Glacial lakes formed either by dammed up valleys or scoured out basins characterize the area.

For the most part the soils have been derived from the weathering of glacial drift. On the drift overlying the High Falls the soil has been mapped as the Lackawanna stony loam (Jennings, *et al* 1903). In the depressions on the major ridge, a shallow phase of this type may be recognized. The profile developed is either a true podzol or of the gray-brown podzolic type. The latter is most widespread. It is a brown to reddish-brown loam 5-8 in. deep grading into a yellow-brown to Indian red subsoil. The parent material exposed at a depth of about 2 ft. along the road cut is bouldery clay. It consists of a mottled dark-brown to light-gray matrix containing many boulders and rock fragments.

On the Shawangunk formation rock outcrops are common. Here where soil has formed at all it is by the slow process of the accumulation of organic material and weathering of the parent materials.

The park has an annual mean temperature of 49.5°F. (Sussex, 22-yr. record) with extremes ranging from -20° to +100°F. The frost free season extends from May 7th to October 1st (Culvers Lake). The annual mean rainfall is 45.94 in. (Culvers Lake) with most of it occurring during the summer. Much of the precipitation in winter is in the form of snow with occasional sleet and ice storms. The annual snow cover is 54.5 in. (Culvers Lake) or 10% of the total precipitation. Snow to a depth of 20 in. in one storm is not unusual. The wind direction is southwest during July and August but from the northwest during the rest of the year (U. S. Dept. Agr. 1926).

The park lies in the oak-chestnut forest region which extends southward along the Ridge-Valley and Blue Ridge Provinces (Blodgett 1910; Braun 1950). To the east on the Piedmont of North Carolina, this forest gives way to oak-hickory (Oosting 1942) which also occurs northward on the Piedmont of New Jersey (Bard 1952). To the north and northwest on the Allegheny Plateau, chestnut-oak is replaced by the hemlock-white pine-northern hardwoods as described by Nichols and others (Nichols 1913a, 1935; Lutz 1928, 1930; Bray 1930; Hotchkiss 1932; Hough

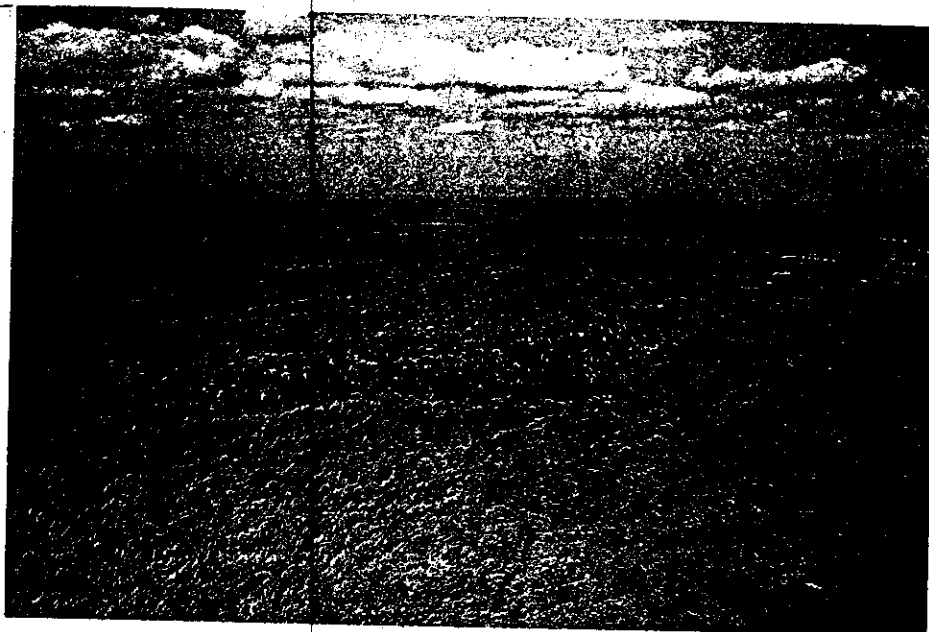


FIG. 2. View north from top of High Point Monument in autumn. On ridge at right, pitch pine-scrub oak community demarked by green areas of pitch pine. Contiguous with it is chestnut oak community represented by orange-yellow coloration. This community also predominates on the adjacent slopes. In center at base of slope, Cedar Bog with dark green coniferous element (hemlock, black spruce, southern white cedar) and interspersed reddish-yellow deciduous element (red maple, yellow birch, black gum). Reddish tinge, at base of slope and especially beyond the bog, indicates the presence of other oak species. Grayish-white areas on ridge top within pitch pine-scrub oak community are conglomerate rock outcrops surrounded by scarlet colored ericaceous shrubs. Dark areas beyond bog are cloud shadows. (This illustration published with funds other than those of Ecological Monographs.)

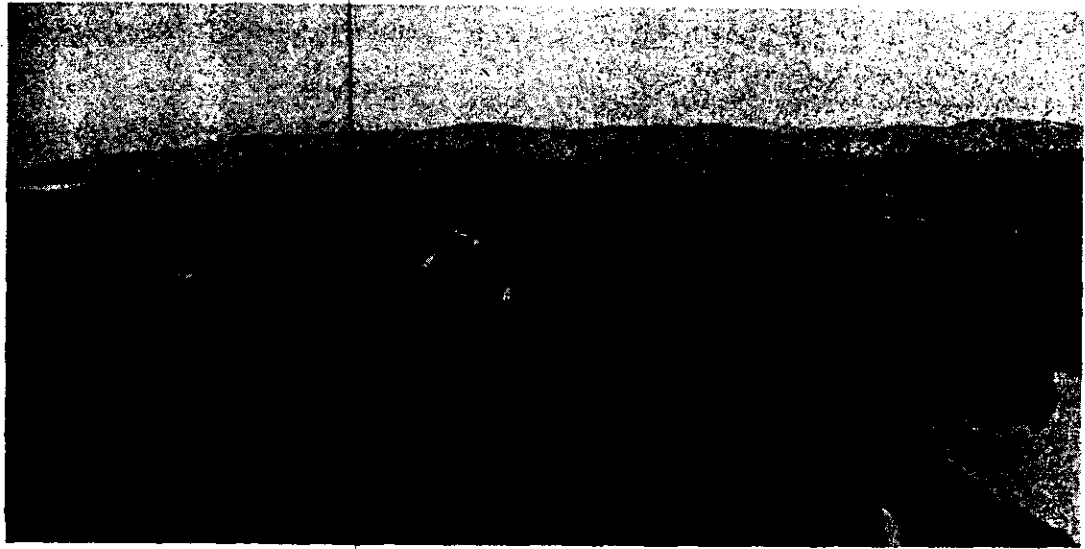


FIG. 3. View south from top of High Point Monument. Shawangunk conglomerate forms major ridge which continues southwestward. Less rugged topography of High Falls formation to right of major ridge. Pitch pine-scrub oak community in foreground left of road (Stand 1). Note burned-over area left of center, indicated by carpet-like area of low shrub vegetation. Lake Marcia at right. Fields are on Martinsburg shale at left. Lake Rutherford and Saw Mill Pond in left and right background respectively.

1936; Gordon 1940; Egler 1940; Hough & Forbes 1943). Bray (1930) studying the vegetation of New York State, points out that the State lies in a transition zone where oak, chestnut, and hickory overlap with the northern hardwoods, the birch, beech, hemlock, and sugar maple. Similar patterns in more detail have been observed by Raup (1938) in the rugged Black Rock Forest of New York and by Jennings (1939) in the mountainous Ridge-Valley Province of Pennsylvania. Within the High Point region, as early as 1884, Britton noted a striking similarity between the pitch pine-scrub oak on the Kittatinny ridge and the Pine Barrens of southern New Jersey. He also observed the presence of a peculiar flora characteristic in part of more northern regions, or in part, the coastal plain of New Jersey. Around 1900 the geological and soil surveys reported a mixed coniferous deciduous forest (Vermeule, *et al* 1900). Jennings and his co-workers found a forest predominantly of oak-chestnut (Jennings, *et al* 1913). Moore (1939) reports a forest primarily of mixed hardwoods in which oak is dominant. Recent comparative studies on the life forms in the pine-oak community compared with those in the Pine Barrens of New Jersey, indicate a greater proportion of hemipterophytes and cryptophytes on the ridge than in the Pine Barrens, which is suggestive of the more rigorous climate of the ridge (Archard 1953, in press).

I wish to express my sincere appreciation and thanks to Dr. and Mrs. Murray F. Buell for their continuous encouragement, sincere interest, and helpful criticisms in the preparation of this manuscript. And also to Mr. Howell O. Archard for his assistance during the field work. I am indebted to the following for their identification or verification of species of the following groups: Drs. G. M. Day

(*Picea*); W. E. Manning (*Carya*); E. T. Moul (Mosses); J. W. Thomson (Lichens); H. A. Wahl (*Carex*); and F. W. Woods (*Ilex*).

METHODS

The field work was conducted during the summers of 1950 and 1951. A systematic reconnaissance of the park was undertaken by following a series of compass lines selected on the basis of a study of aerial photographs and topographic maps. Then long transects were established through sections of the park, cutting across successive communities. Along these transects tree cover was measured by the line intercept method (Bauer 1943, Buell & Cantlon 1950). This served to show the relationship of the communities to the topography and to each other. There were five such transects (A, B, C, D, E). Next, individual stands were sampled (Stands 1-19). Locations of transects and stands are shown in Fig. 1. Again the line intercept method was used to determine cover in both the tree and shrub layers. In each community a line of 100 m. was used except where only a single stand of a type was sampled. In the latter case, the size of the sample was increased depending upon the uniformity of the community. For instance, in the mixed oak-hardwoods community a transect of only 160 m. was used. Diameters of all trees which occurred in a continuous 4 m. strip along the transect line were measured. Saplings (including individuals of tree species 1 ft. high or over but less than 1 in. d.b.h.) were counted on a continuous 2 m. strip along the transect line. Herb and moss cover was estimated on $\frac{1}{2} \times 2$ m. quadrats spaced at 5 m. intervals along the transect line. Tree seedlings were counted in the $\frac{1}{2} \times 2$ m. quadrats.

Specimens of all species found were collected and

have been deposited in the Chrysler Herbarium of Rutgers University. Nomenclature for the vascular plants is according to Gray's Manual (8th ed. Fernald 1950); mosses according to Grout (1940).

Soil samples were taken in the communities studied. The pH of the samples was determined with the Beckman pH meter after the soil had been brought into the laboratory. The dry soils were soaked 24 hours before testing using a soil-water ratio of 1:2.5.

Peat samples for pollen analysis were obtained from Cedar and Pine bogs. The samples were taken at 1 ft. intervals with the Davis-type peat sampler. In the laboratory the pollen was separated by the KOH method (Sears 1930). Counts of 150 grains were made except in the lower clay layers where, because of a paucity of pollen, a minimum of 50 grains was counted. Such low pollen samples come from the 33 to 38 and 40 ft. levels of Pine Bog and the 20 ft. level in Cedar Bog. Percentages are based on total tree pollen.

RESULTS

XERARCH SUCCESSION

The earlier stages of primary succession are characterized by the covering of exposed rock surfaces with vegetation and its accompanying soil accumulation. The pioneer invaders on the bare rocks are usually crustose and foliose lichens. The formation of moss-lichen mats occurs in the depressions or from the periphery of the rock outcrops. As soil accumulates within these mats, grasses and sedges are able to become established. With further accumulation ericaceous shrubs and trees of the surrounding forest invade and eventually cover the exposed rock surfaces. This succession is well shown on the exposed outcrops of the ridge top, contiguous with the pitch pine-scrub oak community (Fig. 2). Growing on the dry exposed rock surfaces of the ridge top, crustose lichens must withstand extreme periods of drought. Most conspicuous of them is *Rinodina oreina* (Ach.) Mass. which grows so closely appressed to the rock that it appears to be a part of it and gives the conglomerate a blackish-gray appearance (Fig. 4). Foliose forms such as *Crocynia neglecta* (Ach.) Hue. and *Parmelia conspersa* (Ehrh.) Ach. var. *isidata* (Anzi.) Stizenb. also grow on the bare rock surfaces where they frequently cover and destroy the crustose forms. *Crocynia* appears as irregular gray patches and *Parmelia* forms circular greenish gray patches. In addition two members of the Umbilicariaceae, *Actinogyra mühlenbergii* (Ach.) Schol. and *Lasallia pensylvanica* (Hoffm.) Llano form black scaly masses on the rock surfaces. These lichens do not develop mats upon which higher plants can grow. The soil building pioneers which start in the crevices and depressions or from the periphery of the outcrops here, as in North Carolina (Oosting & Anderson 1937), do not appear dependent upon the presence of crustose lichens. *Bryum capillare* and *Ceratodon purpureus* are the earliest forms to appear in the crevices. They are particularly important on

the ledge near the monument where they occur with *Potentilla tridentata* (Fig. 4). These three, *Bryum*, *Ceratodon*, and *Potentilla* also occur in an admixture of soil and conglomerate fragments surrounding the outcrops. Other mosses which commonly form tufts and mats in the crevices or depressions are *Polytrichum juniperinum*, *P. commune*, *Leucobryum glaucum*, *Dicranum scoparium* and *D. fulvum*. *Cladonia*, especially *C. caroliniana* (Schwein.) Tuck. may occur with any one or combinations of these species and eventually form expanding mats which spread out over the rock surface. Similar mats form from the edge and advance out over the rock. The thickness of the moss-lichen mats increases as the lower portions of the mosses and lichens die and add humus to the organic layer and as dust and dirt sift down into them.

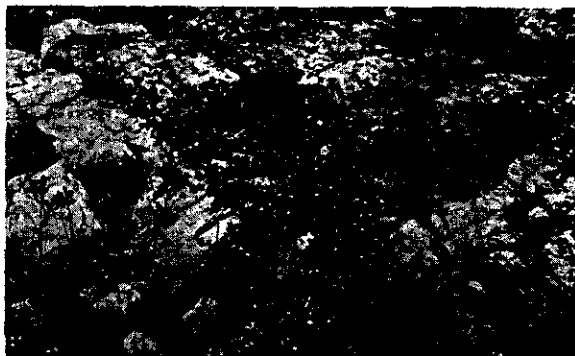


FIG. 4. Xerarch succession on Shawangunk conglomerate at High Point Monument. *Rinodina oreina* gives conglomerate gray tone. Umbilicariaceae form black scaly patches at right. In crevices *Potentilla tridentata* is flowering. Note *Pyrus melanocarpa* at left.

With the increase in thickness of the mat, growing conditions improve, especially moisture holding capacity, and herbs can grow on the mat. *Deschampsia flexuosa* is among the first and along with it may be *Danthonia spicata*, *Panicum depauperatum*, *Andropogon scoparius*, and *Carex pensylvanica*. In crevices on the more exposed sites, *Carex*, *Danthonia*, and *Panicum* frequently occur with the mosses and lichens. During this open herbaceous stage pine seedlings become established. Finally, with further growth of the mats, low shrubs invade either on the periphery or in the center of the mat. In order of decreasing importance on the mats they are *Vaccinium angustifolium*, *Gaylussacia baccata*, *Pyrus melanocarpa*, *Vaccinium vacillans*, *Kalmia angustifolia*, *Amelanchier stolonifera* and *Vaccinium stamineum*. Where soil accumulates in the deeper fissures of the bed rock, shrubs may invade directly. Here *Pyrus* or one or more of the above shrubs is frequently found. Scrub oak (*Quercus ilicifolia*) becomes established on the mat only after it has reached considerable thickness. Herbaceous cover beneath the shrubs is similar to that found in the pitch pine-scrub oak community.

In contrast to the exposed ridge top is the north-

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FIG. 5. Northwest facing talus slope above Cedar Bog. Note sweet birch and white birch. *Rhododendron* is dominant shrub.

west talus slope (Fig. 5). Much of the slope is partially shaded by chestnut oak (*Quercus prinus*), sweet birch (*Betula lenta*), white birch (*Betula papyrifera*), white pine (*Pinus strobus*), striped maple (*Acer pensylvanicum*), mountain maple (*Acer spicatum*) and mountain ash (*Pyrus americana*). Such slopes are strewn with large conglomerate boulders on which the earlier lichen stages are similar to those on the ridge except for an abundance of Umbilicariaceae. Among these *Lasallia papulosa* (Ach.) Llano is dominant, forming large grayish-black scale-like growths. In addition *Umbilicaria mamulata* (Ach.) Llano and *Actinogyra muhlenbergii* are present. Where the boulders are shaded, these species increase in cover so that little of the rock is exposed. On and between the rocks where debris accumulates, mats of *Cladonia rangiferina* (L.) Web. and *C. uncialis* (L.) Web. are common and frequently associated with cushions of *Polytrichum ohioense*, *P. commune*, *Leucobryum glaucum*, and *Dicranum scoparium* which occur in pure or mixed aggregations. In these moss-lichen cushions, or where sufficient leaf litter accumulates, *Polypodium virginianum* and occasionally *Dryopteris marginalis* and *Aralia nudicaulis* are present. Birch seedlings are common on the cushions, as are also such shrubs as *Gaylussacia bacata*, *Vaccinium angustifolium*, *Kalmia latifolia*, and

occasionally *Rhododendron maximum*. The trees which eventually become established grow with their roots spreading through the moss mats. However, as the roots increase in size and portions of the mat are eroded away, the roots become exposed. These roots of the larger trees frequently grow between the boulders. The trees, thus poorly anchored, frequently lean and often exhibit inferior growth form. On most rocky areas this succession long ago reached a forested stage resulting in many rocky woodlands in the park.

HYDRARCH SUCCESSION

Two patterns of hydrarch succession are evident in the park. In the artificial impoundments, filling is occurring primarily by sedimentation and by the invasion of emergent aquatic vegetation. In contrast, lakes of glacial origin are being filled by the encroachment of a floating mat upon which vegetation thrives and which deposits organic material from the under side. However, in both of these patterns, submerged and floating aquatics are present in the deeper water. In the two instances, the filling by encroachment of emergents or by mat formation, different types of forest communities result. In the former the forest is composed primarily of broad-leaved trees (swamp forest), in the latter of conifers and scattered broad-leaved species (bog forest) (Fig. 1).

Both of these successional patterns are found in the park area. The earlier stages of the succession may be observed in the five lakes and two beaver dams. Three of them, Steeny Kill Lake (No. 20), Saw Mill Pond (No. 21), and an unnamed pond (No. 22), are artificial impoundments (Fig. 1). In contrast Lake Marcia (No. 23), and Lost Lake (No. 24), are of glacial origin. Sussex reservoir (Lake Rutherford) although surrounded by park property was not studied.

HYDRARCH SUCCESSION WITHOUT A FLOATING MAT

Aquatic zonation is well illustrated at the southern end of Steeny Kill Lake (Fig. 6). The area occupied by the lake was formerly a swamp forest. The trees were cut and a dam built at the northern end. Stumps project above the water in the southern end of the lake; elsewhere the deeper water has submerged them. *Callitriche heterophylla* and species of *Potamogeton* are the predominant submerged forms. On the exposed stumps grow *Leersia oryzoides* and *Spiraea tomentosa*. In the shallower water, is an emergent zone dominated by *Sparganium americanum* which grows 1-2 ft. in height (Fig. 6). Its associates are *Iris versicolor*, *Leersia oryzoides* and several species of *Scirpus*. On hummocks in this zone *Spiraea* occurs with *Hypericum virginicum*, *H. mutilum* and *Galium tinctorium*. Further back *Juncus effusus* and *Scirpus cyperinus* become the principal species. Between the hummocks of *Carices* and *Osmunda cinnamomea*, *Sphagnum* forms a more or less continuous layer with scattered plants of *Drosera rotundifolia*, *Dryopteris thelypteris*, *Chrysosplenium americanum*, and *Scirpus atrocinctus*. Here and there



FIG. 6. Hydrarch succession at southern end of Steeny Kill Lake. Note concentric zones beginning with *Sparganium americanum* at edge of water and followed by *Juncus-Scirpus* stage, shrub stage, and finally swamp hardwoods community in left background.

are pure stands of *Typha latifolia* in the *Juncus-Scirpus* zone, especially near the shrub zone which is further back.

A shrub zone occurs next to the sedge zone and in it *Alnus rugosa*, *Ilex verticillata*, *Nemopanthus mucronata*, and *Vaccinium corymbosum* are predominant. Less important shrubs are *Rhododendron maximum* and *Rhus vernix*. The shrub layer is from 5 to 10 ft. in height. The wet, hummocky ground is covered with *Sphagnum* and herbs: *Polygonum sagittatum*, *Osmunda cinnamomea*, *Dryopteris thelypteris* and various species of *Carex*. Young trees of red maple (*Acer rubrum*) and gray birch (*Betula populifolia*) are especially common in some parts of the shrub zone.

At other places along the lake shore where the bottom gradient is steeper, the zonation is less conspicuous and somewhat telescoped. In places *Cephalanthus occidentalis* and *Scirpus validus* play an important part in the succession, but are scattered in their distribution.

In contrast, probably because of the rocky substratum, aquatic vegetation is poorly represented in Saw Mill Pond and Lake Marcia. In the former *Sparganium americanum* and *Brasenia schreberi* are sporadic along the shallow lake shores. At Lake Marcia, those plants which occur are restricted primarily to shallow inlets where mucky soil has accumulated. Here one may find patches of *Juncus effusus*, *J. acuminatus*, *Eriocaulon septangulare*, *Ludwigia palustris* and species of *Eleocharis*. Other species that have been found in Lake Marcia but contribute little to the vegetation are *Juncus canadensis*, *Scirpus validus*, and *Eleocharis palustris* (Renlund 1951). Along the rocky shores a dense shrub thicket has developed with *Vaccinium corymbosum*, *Rhododendron viscosum*, *Myrica gale*, *Cephalanthus occidentalis*, *Clethra alnifolia* and *Alnus rugosa* as the principal species.

In the southern sector of the park, a small shallow unnamed pond is surrounded by a dense shrub zone. At the eastern end on the exposed muddy substrate a willow thicket (*Salix sericea*) is dominant, giving

way to *Alnus* toward the upland. In other places along the margin *Rhododendron viscosum*, *Ilex verticillata*, *Vaccinium corymbosum*, *Viburnum recognitum*, *Alnus serrulata*, *Alnus rugosa* and *Cephalanthus occidentalis* form a dense border. In the open water, herbaceous aquatics are relatively sparse. In the shallow water near the shore one finds a few scattered patches of *Ludwigia palustris*.

In the southern part of the park, beavers have built a dam, forming a pond in a low swampy area, and killing many swamp hardwood species. Along the pond margin *Typha latifolia* grows in sporadic clumps. On the surface of the water one frequently finds a dense covering of *Lemna minor*. In the central part of the park, beavers have recently flooded a low swampy area and the surrounding oak forest. Some of the trees are dead and others are dying either due to flooding or the activities of the beavers girdling the bases of the trees. Aquatic vegetation is sparse due to the recency of the disturbance; however, near the shore *Lemna minor* frequently covers the surface of the water.

Another area, at one time inundated by the activities of beavers and since abandoned, has been drained and today Big Flat Brook flows through it. The area shows evidence of having been pastured before flooding. After its use as a pasture ceased gray birch, red maple and hawthorn (*Crataegus* spp.) invaded. The flooding produced by beaver activities killed the birch and hawthorn. Since the withdrawal of water, a dense willow thicket now grows along much of the stream. Rushes, sedges, and grasses are also important along the stream and on the exposed lake bed along with species of *Eleocharis* and other herbs. In some areas the herbs give way to shrubs—*Viburnum dentatum*, *V. lentago*, *Lyonia ligustrina*, and *Alnus rugosa*.

All of these earlier stages in hydrarch succession appear to be leading toward a swamp hardwoods community. Stands representing this community occur in poorly drained areas, chiefly along the tributaries of Big Flat Brook. Here two stands (14, 15) were studied in detail (Fig. 1).

The forest floor is wet and boggy. In one stand (15) a mixture of woody, sedge, and sphagnum peat extends to a depth of 3 ft. This is underlain by yellow-brown sedge peat which gives way to gray clay at a depth of 9 ft.

The tree canopy is composed of two more or less distinct layers, below which is a sporadic shrub layer and fairly continuous herb and moss layers. In the tree layer, red maple and yellow birch (*Betula lutea*) are the dominant species, contributing up to 70% of the total tree cover in the two stands. In one stand, yellow birch is most important; whereas in the other, red maple is predominant. Associates are black ash (*Fraxinus nigra*), white ash (*Fraxinus americana*), basswood (*Tilia americana*), and tulip tree (*Liriodendron tulipifera*) (Fig. 6, 13). The tree canopy covers 94% of the total area. Most of the trees are 4-9.9 in. d.b.h. although larger ones attaining 16-18 in. d.b.h. are represented. In gen-

eral, the trees are shallowly rooted and somewhat elevated above the frequently water-filled depressions on the forest floor. The average height of the forest is 65 ft. In the understory hornbeam (*Carpinus caroliniana*) is most important, with hop hornbeam (*Ostrya virginiana*) and transgressives of the dominants. Yellow birch, red maple, white ash, and hop hornbeam are all reproducing themselves. Yellow birch seedlings are most abundant followed by red maple and white ash.

In the sparse shrub layer, covering 16% of the total area, there is considerable variation. In one stand (14) *Hamamelis virginiana* and *Vaccinium corymbosum* contribute 71% of the total shrub cover. In the other (15) *Viburnum dentatum* and *Viburnum lentago* contribute 57%. Shrubs present in both stands are listed in figure 14.

The herb layer is relatively continuous, covering about 70% of the area. The three most important herbs in each stand are *Osmunda cinnamomea* with a 33% contribution to the cover, *Carex stricta* with 29%, and *Symplocarpus foetidus* with 5%. *Carex* and *Osmunda* form characteristic hummocks on the forest floor with *Sphagnum* occupying the wetter depressions between them. Other herbs are listed in figure 15.

Bryophytes occupy 31% of the area. *Sphagnum* is most important, contributing about 21% cover. Others, in order of decreasing importance, include *Thuidium delicatulum*, *Mnium punctatum* var. *elatium*, *Mnium cinclidioides*, *Tetrapis pellucida*, *Dicranum scoparium*, *Bazzania trilobata* and *Trichocolea tomentella*. They are usually found on the elevated tree roots and sedge hummocks.

Near Lake Rutherford the swamp hardwoods community occurs with red maple, black gum (*Nyssa sylvatica*), and sporadic white pine which towers above the deciduous species. *Vaccinium corymbosum*, *Rhododendron viscosum*, *Alnus rugosa*, and *A. serrulata* are the dominant shrubs there and gray birch forms a conspicuous border. Frequently hemlock (*Tsuga canadensis*) and black gum are mixed in with the other broad-leaved species as at the northern and southern ends of Steeny Kill Lake. In other poorly drained areas, swamp-white oak (*Quercus bicolor*) is also present.

HYDRARCH SUCCESSION WITH A FLOATING MAT

The second pattern of hydrarch succession is associated with the formation of a floating mat. This is best illustrated by Pine Bog (locally referred to as Pine Swamp) located on the southwestern boundary of the park, 1200 ft. above sea level (Fig. 1, No. 25). It was formed as a result of glacial drift blocking the drainage of a mountain valley (Waksman, et al 1943). In the southern part of the bog, an open body of water (Lost Lake) is surrounded by a floating sedge and sphagnum mat (Fig. 7). On the mat, *Chamaedaphne calyculata* is the dominant shrub and along with it are *Andromeda glaucophylla*, *Kalmia polifolia*, *K. angustifolia*, and *Vaccinium oxycoccos*. Here small trees of black spruce (*Picea mariana*) and

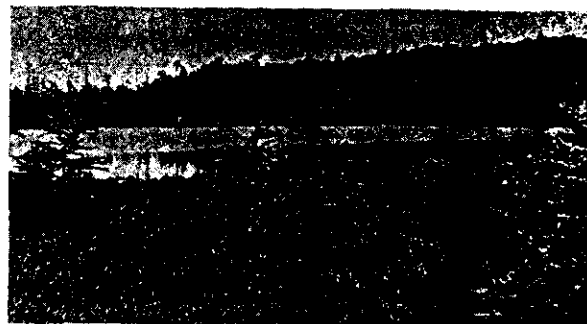


FIG. 7. Lost Lake in Pine Bog surrounded by a floating mat on which *Chamaedaphne calyculata* is the dominant species. Tamarack and black spruce in foreground. Peat samples were taken on the opposite side of the lake where the person is standing.

tamarack (*Larix laricina*) have been seeded in from the surrounding tree and shrub zone. The tamarack is restricted primarily to the open mat; the black spruce is not only on the mat but throughout the greater portion of the more mature bog. Along with black spruce, red maple, black gum, yellow birch and sporadic white pine and hemlock form a very open forest rising above a dense shrub layer. The shrubs are mostly *Vaccinium corymbosum*, *Rhododendron viscosum*, *Alnus rugosa* and species of *Ilex*. *Rhododendron maximum* forms a border along the edge of the bog.

A later stage in bog succession is illustrated by Cedar Bog (locally called Cedar Swamp), which is located at the northern park boundary approximately 1500 ft. above sea level (Fig. 1 Stand 19). It is probable that this was a lake that filled in the same way as Pine Bog. However, the encroachment on the lake is complete and no open water remains. The area is now completely covered by a forest of coniferous and deciduous species. Although it is mostly a rather closed forest, the southwest portion is like much of Pine Bog with red maple, yellow birch, black gum and occasionally white pine and black spruce, scattered throughout a shrubby matrix.

Where the bog forest is most mature (Stand 19) it consists of distinct tree, shrub and moss layers. There are very few herbs. In the tree canopy, hemlock and red maple are dominant, contributing 55% of the total tree cover. Other trees contributing cover are southern white cedar (*Chamaecyparis thyoides*) with 14% cover, yellow birch 12%, black spruce 10% and black gum 9% (Fig. 8, 21). Cover in the tree layer is 89% with only 11% represented by openings in the canopy. The larger hemlocks and cedars are approximately 90 and 140 years of age respectively. The tops of many cedars and hemlocks are broken or dying back as a result of wind and ice storms. Others, especially hemlock, are branched on the side opposite the prevailing winds. Windfalls are occasionally found with the shallow root systems of the fallen trees tipped up on edge. Logs in various stages of decomposition furnish an excellent substrate for establishment of seedlings. Dead stand-



FIG. 8. Cedar Bog. Crowns of *Chamaecyparis thyoides* most conspicuous. Road crosses bog at this point. Young cedars are common along the road.

ing trees, especially cedars, are scattered throughout; one cedar measured 25" d.b.h. Some cedars up to 30" in diameter have been cut.

The trees differ in their ability to complete their life cycle. Hemlock and red maple are most successful. Cedar seedlings are sparse except in the openings. Those that become established in dense shade usually die when 3-4 in. in height. Cedar is destined to be of less importance in the future as a result of competition from the more shade tolerant hemlock and red maple. Only locally is it increasing in importance. For example, along a road recently constructed across the bog, white cedar shows vigorous reproduction with an abundance of seedlings and saplings and larger trees 3-4 in. d.b.h. Black spruce reproduction is also poorly represented, it, like the cedar being more important in the less mature parts of the bog. Reproduction of yellow birch and black gum indicates that they will maintain their present status in the community.

The shrub layer is 93% complete, there being only 7% of the area unoccupied. Of this shrub cover, *Rhododendron maximum*, which occurs primarily in deeper shade, forms a dense undergrowth contributing 64%. Its seedlings are abundant on the moss-covered hummocks and root systems. The remaining 36% of the shrub cover is contributed by *Ilex laevigata*, *I. verticillata*, *Nemopanthus mucronata*, *Vaccinium corymbosum* and *Alnus serrulata* which occur primarily in the openings. In the southwest portion of the bog where it is more open *Rhododendron maximum* frequently decreases in importance. Here in addition to those shrubs previously mentioned *Rhododendron viscosum*, *Alnus rugosa* and *Lindera benzoin* form an almost continuous shrub layer.

In the mature forest, herbs are widely scattered. *Osmunda cinnamomea* contributes 5% cover, *Calla palustris* 3%, and *Symplocarpus foetidus* 1%. These are most important in the openings. Of the remaining 13 herbs each contributes less than 1% cover. Beneath the shrubby matrix in the more open portions of the bog, tussocks of *Osmunda cinnamomea* covered with *Sphagnum* are characteristic. Along the road across the bog, *Sphagnum* supports a distinctive herbaceous flora including species such as *Calla*

palustris, *Sarracenia purpurea*, *Drosera rotundifolia*, *Scirpus cyperinus*, *Eriophorum* sp., *Juncus effusus* and species of *Carex* and *Eleocharis*.

DEPOSITS OF PINE BOG AND CEDAR BOG

Samples of the sediments now filling the lake basins of Pine and Cedar Bogs were obtained to a depth of 40 ft. and 30 ft. respectively. In the lowest levels, the deposits consist of 8-10 ft. of gray clay. These are overlain by gyttja which is formed in the open lake waters as a result of benthic fauna reworking planktogenic detritus (Lindeman 1941). The gyttja varies from fine detritus ooze in the lower levels to coarse detritus ooze in the upper levels (Deevey 1939). Its depth ranges from 10-15 ft. in the two bogs. The upper layers of sedge and sphagnum peat were formed by dead material of sphagnum, sedges, and associated plants falling from the underside of the mat. As this is continuously built up by fresh deposits, it compresses the underlying gyttja. In Pine Bog 17 ft. of sedge-sphagnum peat has accumulated. In Cedar Bog there are 4 ft. of sedge peat containing fragments of wood, overlain by 6 ft. of woody peat.

ABANDONED FIELDS

Most of the former farm land is now abandoned to the invasion of native vegetation, and various successional stages are evident leading to an oak or oak-hickory forest community (Fig. 1). Along the lower southeast escarpment, on the Martinsburg shale, abandoned fields are more or less continuous. Erosion there has removed much of the glacial drift, exposing the shale so that the vegetation there is directly influenced by the underlying geological formation. On the High Falls and Shawangunk formations, throughout the rest of the park, the old fields are more scattered. Where there are old fields, glacial drift covers the bed rock. Agricultural use of the land has ceased, except for several fields seeded with timothy and clover a few years ago and still mowed each summer.

PERENNIAL HERBACEOUS STAGE

There are no fields just abandoned, but on those with good drainage in which cultivation has most recently ceased, *Poa compressa*, *Daucus carota*, *Solidago graminifolia*, and *Hypericum perforatum* are the dominants (Fig. 9). Next in importance are *Hieracium pratense*, *H. aurantiacum*, *Trifolium pratense*, *T. repens*, *Linaria vulgaris*, *Agrostis alba*, *Phleum pratense*, and about 34 other herbaceous species scattered through the vegetation. *Andropogon scoparius* is not very important in the succession except in fields whose soils are derived from the shale. Fields in this early stage of succession are commonly bordered by hedgerows of gray birch, trembling aspen (*Populus tremuloides*), black cherry (*Prunus serotina*), scarlet oak (*Quercus coccinea*), and red maple (Fig. 9). From this border the trees spread out into the field and one finds young plants among the herbs near the edge of the field.

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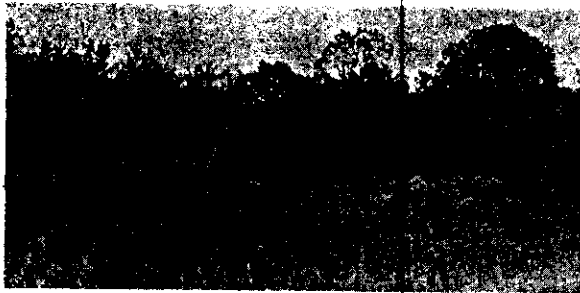


FIG. 9. Perennial herbaceous stage. *Daucus carota* and *Solidago graminifolia* are dominant herbs. Gray birch and trembling aspen at left and oaks at right form border along hedgerow.

drained Papakating silt loam, *Potentilla simplex*, *Iris versicolor* and species of *Carex*, *Juncus*, *Solidago*, and *Agrostis* are dominant in the fields that have not been plowed for some time. Other species present are *Linaria vulgaris*, *Hypericum perforatum*, *Cirsium arvense* and *Phleum pratense*. Woody species of *Spiraea* and *Clethra* are invading this community.

THICKET STAGE

Gray birch spreads out over most fields relatively fast (Fig. 9). Along with it appear the shrubs—*Rhus typhina*, *R. glabra*, *Quercus ilicifolia* (scrub oak), *Rubus* spp. and various heaths. The herbs of this thicket stage are primarily *Agrostis alba*, *Potentilla simplex*, *Solidago graminifolia*, *Hypericum perforatum*, *Linaria vulgaris*, *Solidago rugosa* and *Poa compressa*. As the succession continues considerable variation is evident. Gray birch may form a relatively uniform and continuous, tree layer growing in clumps and ranging from 1-4 in. d. b. h. With it may be found scattered black cherry, red maple, and white ash as well as saplings of red oak (*Quercus rubra*), white oak (*Quercus alba*), red maple, and scarlet oak. Species of *Rubus* commonly form a dense tangle 3-4 ft. in height. The dominant herbs are *Solidago rugosa* and *Potentilla simplex*.

On the other hand, gray birch and red maple may be co-dominant in which case the shrub layer may consist of *Quercus ilicifolia*, *Vaccinium angustifolium*, *V. stamineum*, *Viburnum recognitum*, *Hamamelis virginiana* and species of *Rubus*. In such stands *Lycopodium complanatum* and *Polytrichum commune* frequently form continuous mats over the ground. Where rock outcrops in the thicket, *Polytrichum commune*, *P. juniperinum* and *Danthonia spicata* cover the area. Sometimes white pine and pitch pine (*Pinus rigida*) are associated with red maple and gray birch. Saplings of hickory (*Carya* spp. including *C. glabra* and *C. ovalis*; *Carya ovata*) red, white, scarlet, and black oak (*Quercus velutina*) are also common. On the Martinsburg shale red cedar (*Juniperus virginiana*) is occasionally associated with gray birch and red maple but does not occur in the other areas.

FOREST STAGE

Eventually a forest of oak or of one dominated by oak and hickory gains ascendancy over the birch

(Fig. 10). Some of the same shrubs found in the thicket persist but there is a change in the herb composition. The principal ones are *Lycopodium complanatum*, *Pteridium aquilinum*, *Lysimachia quadrifolia*, and *Medeola virginiana*. The resulting forest is dominated by either red oak, chestnut oak, white oak and hickory or by white oak and hickory alone.



FIG. 10. Approaching forest stage. Gray birch and pitch pine still present. Larger trees are oaks.

Other trees common in the young forest are black oak, red maple, and scarlet oak.

PITCH PINE-OAK COMMUNITIES

The pitch pine-oak communities occur on the Shawangunk conglomerate as a depauperate pine-scrub oak community (Fig. 11) and on the drift overlying the High Falls sandstone as a pitch pine-arborescent oak community. Four stands of the pine-oak community were studied, two (Stands 1, 2) on the Shawangunk conglomerate and two (Stands 3, 4) on the High Falls sandstone. The former will be referred to as the pine-scrub oak and the latter as the pine-oak.



FIG. 11. Pitch pine-scrub oak community. Note heaths in crevices of conglomerate. Chestnut oak community is contiguous with pitch pine at right (Stand 2).

PINE-SCRUB OAK

On the ridge where the pine-scrub oak community occurs, the soil is very thin and rock outcrops are common (Fig. 11). Often mats consisting primarily of organic material bound together with roots cover the rock surfaces. The pH is approximately 4.

The tree and herbaceous layers are open, in contrast to a shrub layer that furnishes practically com-

plete cover (Fig. 13, 14, 15). The pitch pines, the dominant trees contributing 76% of the total tree cover, are rather widely spaced. Species associated with the pine in order of decreasing importance are red maple, gray birch, juneberry (*Amelanchier arborea*, *A. laevis*), and sweet birch. The tree layer averages 18-20 ft. in height with the larger pines 8-10 in. d. b. h. and approximately 70 years of age. The pines typically have broken tops or tops with gnarled or twisted branches. The open aspect of the woods is evidenced by the 54% unoccupied space in the tree layer (Fig. 13).

Pine seedlings and saplings are occasionally found in the rock crevices or moss mats where sufficient soil is present. Seedlings of red maple are frequently found. Saplings of sassafras (*Sassafras albidum*), juneberry, red maple, and sweet birch are scattered throughout the stands. Although a chestnut oak community always borders it, chestnut oak saplings are rarely found in the pitch pine community of the ridge top.

The shrubs are conspicuously two-layered, covering 92% of the area. The taller shrubs are scrub oaks which often form a dense thicket 3-10 ft. high. The lower layer is dominated by heaths, of which *Vaccinium angustifolium* and *Gaylussacia baccata*, typically two feet or less in height, are most important contributing 57% cover. Low shrubs of less importance are *Pyrus melanocarpa*, *Vaccinium vacillans*, *Kalmia angustifolia*, *Amelanchier stolonifera* and *Comptonia peregrina*, *Diervilla lonicera*, *Prunus pennsylvanica*, *P. pumila*, *Rhus copallina*, and *Pyrus americana*.

The herb layer, in contrast, covers about 20% of the ground. Of the 21 species of herbs *Maianthemum canadense*, *Pteridium aquilinum*, and *Aralia nudicaulis* together contribute approximately 20% cover in this layer. All the others contribute a total of less than 1%. The moss layer is sparse covering less than 1% of the area.

Evidence of browsing by deer is conspicuous. Plants most frequently browsed include pitch pine, sassafras, juneberry, mountain ash saplings and certain herbaceous species. Evidence of fire in the recent past is indicated by the fire scars on the base of the tree trunks.

PINE-OAK

The pine-oak occurs on some of the hilltops of the High Falls formation. The soil is a podzol, the A horizon ash-gray in color underlain by a yellow-brown B horizon. The pH of the soil is about 4.5.

The tree canopy frequently consists of two more or less distinct layers. The uppermost layer is dominated by occasional pitch pine extending 10-15 ft. above the lower oak canopy. The pitch pine contributes approximately 24% cover. The deciduous lower layer of red maple, scarlet (*Quercus coccinea*), white, and chestnut oaks represents about 65% of the total tree cover (Fig. 13). Trees of minor importance are black gum (*Nyssa sylvatica*), black oak (*Quercus velutina*) and sassafras. There is about 20% unoccu-

pied space in the tree layer compared to about 50% in the pine-scrub oak community of the ridge top (Fig. 13). The larger pines are 17-19 in. d. b. h. and about 140 years of age. Most of them are over 10 in. d. b. h. The hardwoods are most abundant in the small size classes. Pine snags and rotting pine logs occasionally are present. White oak, scarlet oak, chestnut oak, and red maple are reproducing, and chestnut sprouts are present. Pine seedlings are rare and saplings are completely absent.

In the shrub layer, *Gaylussacia baccata* is dominant, contributing about 60% of the cover. Other heaths represented are similar to those found on the ridge (Fig. 14). Scrub oak contributes about 15% of the cover and occurs in clumps, where ample light reaches it. The shrub layer is rather dense, covering about 85% of the area.

Ten herbs were found. They occupy only about 15% of the area (Fig. 15). *Pteridium aquilinum* has an average of 9% cover. None of the others furnish over 1% cover. Principal among them are *Gaultheria procumbens*, *Aralia nudicaulis*, and *Medeola virginiana*. Mosses occupy less than 1% of the area.

CHESTNUT OAK COMMUNITY

The chestnut oak community is the characteristic community of the park. It forms a matrix in which all the other communities are found (Fig. 1). A total of 6 stands was studied. Four (5, 6, 7, 10) of the stands were selected on the Shawangunk formation; two (5, 10) on the southeast escarpment below the monument; another (6) on the northwest slope above Cedar Bog and the remaining (7) on the ridge above, where it occupies a slight depression. The two stands on the High Falls (8, 9) are located on gently undulating topography overlain by glacial deposits (Fig. 1).

On the upper and mid-slopes and many sites along the ridge top of conglomerate where the soil is very rocky, the most xeric aspect of the chestnut oak community is characteristic (5, 6). Here an organic layer consisting of 3-6 cm of leaf litter overlies a mor humus layer which forms a mat over the rocky substratum. Depressions along the ridge top, filled with soil, constitute a more favorable environment for this community (7). An especially favorable site for the community is on the High Falls formation where the soil is relatively deep overlying the bed rock (8, 9). On the lower slopes, although the ground is very rocky, the interstices are filled with finer soil resulting in an even more favorable soil mantle than upon the slopes and ridge tops (10). In this community the soil pH is 5.0.

Within the chestnut oak community, there is a progression from the most xerophytic aspect (5, 6) (Fig. 12), to the deeper soils, especially on the High Falls and depressions on the ridge top (7, 8, 9), to the lower slopes of the conglomerate which represent the most mesophytic phase (10) (Fig. 13, 14, 15).

On the rocky slopes, the forest consists of two more or less distinct tree layers, a relatively continuous shrub layer and sparse herb and moss layers.

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FIG. 12. Chestnut oak community along road to Cedar Bog. The most xeric aspect characteristic on rocky slopes.

In the tree layer, chestnut oak is by far the most important, contributing over 55% of the total cover. The principal associate is red oak. Black oak and sweet birch are occasionally present. Although the total cover in the tree layer is over 90%, the tree crowns are thin, transmitting a considerable amount of light.

Most of the trees fall into 1-3.9 in. and 4-9.9 in. size classes, but larger specimens are scattered throughout the stand. Two or more trees growing

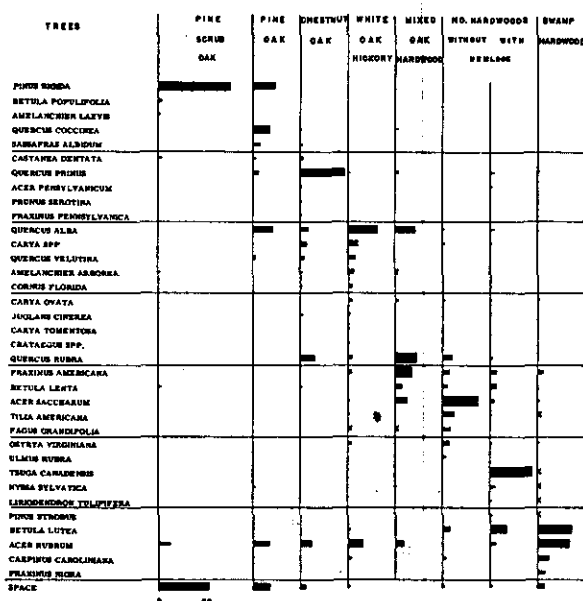


FIG. 13. Tree cover and frequency for forest communities. Length of bar represents % of total cover, width of bar represents % frequency of occurrence on 20 m segments along the transect lines in all stands sampled of each community. For example, in the pine-scrub oak community *Pinus rigida* is dominant contributing 76% of the total tree cover and representing 93% frequency. The (X) indicates that the species was present in the community but not occurring on the transects. Space refers to the portion of the canopy between the crowns of the trees. For example, in the pine-scrub oak community, where the gaps in the canopy are greatest, space is equal to 54% of the total area, in contrast with the mixed oak-hardwoods where the canopy is completely closed. *Carya* spp. include *C. glabra* and *C. ovalis*.

from a single root system are common. The larger chestnut oak are 9-14 in. d. b. h. and approximately 95 years of age.

The average height of the forest is 50 ft. The understory consists of red maple, sassafras, chestnut sprouts, and young trees of hickory and oak. All species are reproducing themselves although chestnut oak is most successful. Oak reproduction is primarily of sprout origin. Chestnut sprouts are common. Numerous fire scarred chestnut snags litter the forest floor.

The shrub layer covers 40% of the area. The uniform distribution of shrub stems forms a fairly continuous layer. In one stand *Gaylussacia baccata* and *Vaccinium vacillans* are most important, whereas, in the other *Kalmia latifolia* and *Rhododendron nudiflorum* predominate. Other shrubs of importance include *Vaccinium angustifolium* and *Kalmia angustifolia*. Of the 12 shrubs present 7 are ericads which furnish over 90% of the cover in this layer.

The herb layer is extremely sparse, the total cover in this layer being less than 10%. Of the 17 species present in the herb layer only two, *Aralia nudicaulis* and the sub-shrub *Gaultheria procumbens*, were estimated as contributing more than 1% cover. Others occasionally present are *Carex pensylvanica*, *Pteridium aquilinum* and *Melampyrum lineare*. Mosses contribute approximately 2% cover. The principal species, *Polytrichum ohioense* and *Leucobryum glaucum* frequently occur between exposed rocks where the leaf litter is relatively thin or absent.

This xeric phase extends onto the ridge tops wherever the soil is very rocky. Here the trees are smaller with low gnarled branches. They frequently occur in clumps of 3-6 from a single root system. In addition to the characteristic ericaceous shrub layer, clumps of scrub oak occupy the openings in the tree canopy.

On the ridge top where considerable drift has been deposited in the depressions (7) and over most of the undulating topography of the High Falls (8, 9) where the soil is relatively deep, oaks such as white, red, and black are associated with the chestnut oak.

On these more favorable sites chestnut oak contributes about 43% cover while its associates contribute 24%. The trees fall primarily into the 1-3.9 in. and 4-9.9 in. size classes except on the High Falls where the 10 in. or over size class is of equal or greater importance. The larger trees on the ridge are 8-9 in. d. b. h. and 60-70 years of age while those on the High Falls are 15-16 in. d. b. h. and 110 years old. The average height of the forest is 45 ft. on the ridge and 65 ft. in the High Falls stands.

A distinct understory of red maple and oak transgressives contributes the greatest cover in the understory although sassafras, hickory, and junberry are also present. All species appear to be reproducing themselves, yet most of the reproduction is of sprout origin. Chestnut sprouts are common. Many hickory saplings exhibit inferior growth due to the dying back of the terminal buds. Many of the larger

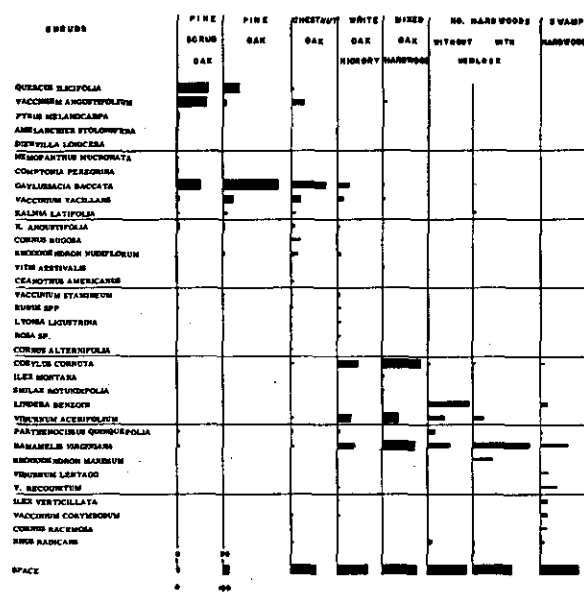


FIG. 14. Shrub cover and frequency for forest communities. For explanation see legend for figure 13. *Rhododendron roseum* is present in chestnut oak community but it was not recorded in the transect data.

chestnut oaks are not healthy, and in fact dead trees are occasionally found throughout the stand.

The shrub layer is more or less continuous, but considerable variation occurs among the dominants in the different stands. The total cover contributed by the shrubs in approximately 56%. On the ridge, *Vaccinium angustifolium* and *Gaylussacia baccata* contribute over 80% of the shrub cover, whereas on the High Falls the latter, and *Vaccinium vacillans* occupy over 75% of the area. Other shrubs represented included *Rhododendron nudiflorum*, *Vaccinium stamineum* and *Kalmia angustifolium*. As in the previous stands, ericads contribute over 90% to the shrub cover.

The herbaceous layer is sporadically developed. A total of 29 herbs occupy less than 7% of the area. *Aralia nudicaulis*, *Carex pensylvanica*, *Pteridium aquilinum* are the only species representing over 1% cover. Those present in all stands are *Aralia nudicaulis*, *Uvularia sessilifolia*, *Lysimachia quadrifolia*, and *Hypoxis hirsuta*.

The mosses are restricted to rocky outcrops and the bases of tree trunks. Between the rock outcrops *Polytrichum ohioense*, *Leucobryum glaucum* and *Dicranum scoparium* are most important. *Thelia asprella*, *Leucobryum glaucum* and occasionally *Rhododendron roseum* cover the bases of tree trunks, especially those of white oak.

On the lower slopes of the conglomerate where the soils are more continuous, red oak and hickory are associates with the chestnut oak (10). Together these species with the chestnut oak contribute 80% of the total tree cover. Other associates of minor importance are red maple, black oak, sweet birch, black cherry, butternut (*Juglans cinerea*) and red ash (*Fraxinus pensylvanica*). On these better sites the

tree canopy contributes 97% cover in contrast to 90% on the upper slopes. The larger trees are chiefly oaks ranging from 17-23 in. d. b. h. Red oak exhibits the best growth with straight boles and well developed crowns. In contrast, the larger hickories frequently are somewhat decayed at the base and the tops are often broken. The average height of the forest is 60 ft. as compared to 50 ft. further up the slope.

The understory is similar to the poorer stands except for the pronounced increase in hickory transgressives and the presence of flowering dogwood (*Cornus florida*) and striped maple. Hickory, chestnut oak, and red maple are reproducing themselves, with hickory most abundant. Saplings of ash and sweet birch are present. Sprouts of sassafras and chestnut are common. Red oak is absent in the seedling class but present in all other size classes. Hickory and chestnut oak are the only species in all size classes.

The shrub layer covers 50% of the area. Of the 12 shrubs present *Cornus rugosa* contributes 62% of the cover. Others of less importance are *Corylus cornuta*, *Vaccinium vacillans*, *V. stamineum*, *Cornus alternifolia*, and species of *Rubus*. Two vines, *Parthenocissus quinquefolia* and *Vitis aestivalis*, contribute 9% and 4% cover respectively.

The herbaceous layer covers only 12% of the area. Of the 30 species represented not one contributes over 1% cover. *Collinsonia canadensis*, *Solidago caesia*, *Desmodium nudiflorum*, and *Smilacina racemosa* contribute a total of 3% cover. Other herbs, in order of decreasing importance, include *Amphicarpa bracteata*, *Uvularia perfoliata* and *Galium lanceolatum*.

In considering the three aspects of this community, chestnut oak is the characteristic species and along with it are varying amounts of red oak, white oak, black oak, red maple, and hickory (Fig. 13). The shrub layer is typically ericaceous with *Gaylussacia baccata*, *Vaccinium angustifolium*, and *Vaccinium vacillans* most common (Fig. 14). Those herbs which contribute the greatest cover are *Aralia nudicaulis* and *Pteridium aquilinum* (Fig. 15).

WHITE OAK-HICKORY COMMUNITY

The white oak-hickory community is characteristic in the wide valley floors along Big Flat Brook, on the moister upland sites of the High Falls Formation (Fig. 16), and occasionally in the later stages of old field succession. Two stands representing this community were studied in detail, one (No. 11) located near Big Flat Brook in the southern portion of the park, the other (No. 12) on a moist southeast facing slope above Big Flat Brook (Fig. 1).

In both stands the soil is rocky. A thin mor humus overlies a grayish-black A horizon which blends into a yellow-brown layer, the B horizon. The soil pH is approximately 5.

In this community, the forest consists of two more or less distinct tree layers, a shrub layer, and sparse herb and moss layers (Fig. 13, 14, 15). In the tree layer, white oak contributes about 32% and hickory

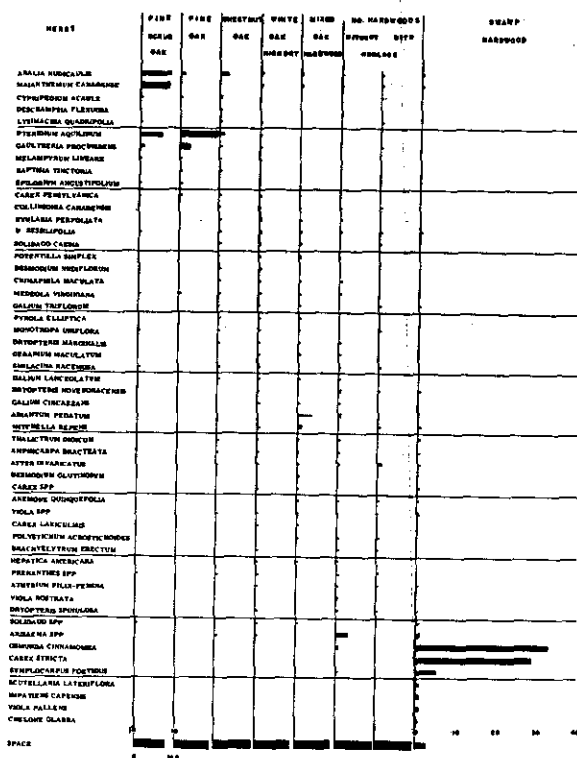


FIG. 15. Herb cover and frequency for forest communities. Length of bar represents % cover contributed by each species and the width of the bar represents the frequency of occurrence based on the total number of herb quadrats in all stands sampled of each community. The (X) indicates that the species was present in the community but not occurring in the quadrats. Space represents the amount of unoccupied area in the herbaceous layer.

about 15% of the total tree cover (Fig. 16). The importance of hickory varies considerably throughout the community. Other associates are black oak, red maple and beech (*Fagus grandifolia*). Sugar maple (*Acer saccharum*) and yellow birch frequently border the streams where they flow through this community. Sugar maple and white ash are most abundant in the smaller 1-3.9 in. size class, whereas white oak, hickory and black oak are most common in the larger size classes. The trees are tall and straight. There is no evidence of sprout origin. The height and diameter of a few of the larger trees are white oak, 26.7 in. d. b. h. (85 ft.), hickory (*Carya glabra*) 20.9 in. (80 ft.) and black oak 15.8 in. (74 ft.) (Stand 12). Chestnut, hickory, and white oak logs are found on the forest floor in various stages of decomposition (Stand 12). Red maple, junberry, dogwood, white ash, and young trees of the dominant species comprise the understory. Nearer the streams hornbeam and hop hornbeam increase in importance (Stand 11). The dominant trees are reproducing themselves. Both seedlings and saplings of sugar maple, birch, and white ash are common (Stand 11).

About $\frac{1}{3}$ of the shrub layer is occupied by shrubs. *Corylus cornuta* contributes an average of 24% of



FIG. 16. White oak-hickory community along road to Life Camp in southern part of the park.

the cover, *Hamamelis virginiana* 17% of the cover and *Viburnum acerifolium* 16%. A few others present are listed in figure 14.

In the herbaceous layer a very small amount, about $\frac{1}{10}$ of the area, is occupied. Of the 54 species present, none contributes more than 1% cover. Those most frequently found include *Utricularia perfoliata*, *U. sessilifolia*, *Potentilla simplex*, *Solidago caesia*, *Aralia nudicaulis* and *Maianthemum canadense* (Fig. 15).

The moss layer is poorly developed. On and between the rocks, *Dicranum scoparium*, *Thuidium delicatulum* and *Polytrichum ohioense* were estimated as contributing a cover of 4%.

MIXED OAK-HARDWOODS COMMUNITY

The broad sloping valleys between the ridges and hills are occupied by the mixed oak-hardwoods community (Fig. 1). A stand studied in detail representing this community is located above Saw Mill Pond on a gentle east facing slope (Fig. 1, Stand 13). The soil there is relatively rocky with an organic layer of 1-3 cm. This organic layer appears to be rapidly incorporated into the underlying soil. Moist spots are common, whose degree of mesophytism is dependent to some degree upon the drainage from the upper slopes.

The forest consists of two distinct tree layers, a shrub layer and sparse herb and moss layers. It is often difficult to designate a single dominant since many tree species contribute significantly to the canopy. Those represented contribute the following cover: white oak 21%, red oak 22%, white ash 17%, sugar maple 12% and red maple 9%. Other trees interspersed among these are shagbark hickory (*Carya ovata*), chestnut oak, scarlet oak, black gum and beech. Junberry and young trees of the main canopy comprise the understory. The tree layer is continuous, with no gaps in the canopy (Fig. 13). The larger trees are 14-16 in. d. b. h. and attain a height of 65 ft. The dominant trees are reproducing themselves. The white and red oak, while most important in the tree layer, are less successful in the reproductive stages. Red maple, sugar maple and white ash are reproducing prolifically.

The sparsely developed shrub layer contributes a total of only 24% cover. Among those represented, *Corylus cornuta* contributes 42% of the cover, *Hamamelis virginiana* 35%, and *Viburnum acerifolium* 16%. Others of less importance are listed in figure 14.

In the herb layer, 38 species contribute 13% cover (Fig. 15). Those contributing most to the cover are *Adiantum pedatum* with 3% and *Mitchella repens* with 1%. Others commonly present are listed in figure 15. Mosses cover only 1% of the area. They occur on the moist exposed soil and between the outcropping rocks. *Thuidium delicatulum* and *Polypodium ohioense* are most common.

NORTHERN HARDWOODS COMMUNITIES

NORTHERN HARDWOODS WITHOUT HEMLOCK

The northern hardwoods community without hemlock is very restricted in its distribution in the park (Fig. 1.) The best stand is located in a narrow rocky valley in the southern portion of the park (Stand 16, Fig. 17). The ground consists mostly of rounded boulders which are often covered with an organic layer. In places on the valley floor, the boulders are exposed, since the organic material is frequently washed away by spring flood waters. Where not subjected to such flooding, the humus layer is 2-3

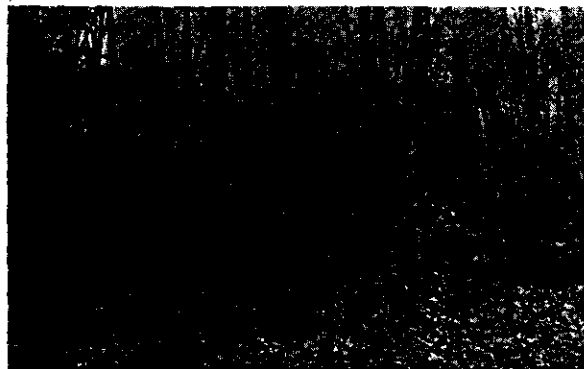


FIG. 17. Northern hardwoods without hemlock. Forest floor densely covered with sugar maple saplings. (Stand 16.)

cm in thickness covering the rocky surface. Where soil is present among the rocks, it consists of a fine light yellow-brown clay loam with a pH of about 5.0.

The forest is composed of two distinct tree layers and sparse shrub and herb layers. The tree canopy is nearly complete with very few openings. Most of the trees are tall and straight. In the upper story are sugar maple and its associates—basswood, red oak, beech, yellow birch, white oak and sweet birch (Fig. 13). Locally beech and sugar maple are most important. Large sporadic white pine towering above the other trees are sometimes present. Chestnut was formerly an important element as indicated by the huge logs on the forest floor. Yellow birch is restricted primarily to the stream margins. The dominant trees vary from 75 to 94 ft. in height; for example one sugar maple 29 in. d.b.h. measured 94 ft., a basswood 12.4 in. 73 ft.; and a white ash 19.4 in., 75 ft. Hornbeam and hop hornbeam with young sugar maples constitute a sub-canopy layer. The trees differ in their reproductive potential. Sugar maple is abundantly reproducing itself (Fig. 17). Small plants 1-2 ft. in height are most common, a total of 784 such individuals were recorded in 400 sq. meters. Yellow birch seedlings are abundant, but saplings are absent. Basswood reproduction is relatively sparse, and beech is reproducing chiefly by root sprouts. White ash reproduction is important in both seedling and sapling stages.

The shrub layer is sparse, occupying only 14% of the total area (Fig. 14). To this 14% cover, *Lindera benzoin* contributes 46%. The other 5 species in order of decreasing importance are *Hamamelis virginiana* with 24% of the cover, *Viburnum acerifolium* with 18%, *Parthenocissus quinquefolia* with 7%, *Rhus radicans* with 3%, and *Corylus cornuta* with 2%.

The herbaceous layer is also sparsely developed, only 9% of the area being occupied. The two most important species are *Arisaema* sp. with 3% cover and *Symplocarpus foetidus* with 1%. Of the thirty-five others that occur, those most frequently present are listed in figure 15. Those present but not recorded in the quadrats are *Allium tricoccum*, *Adiantum pedatum*, *Osmunda cinnamomea*, *O. claytoniana* and *Dryopteris noveboracensis*.

The moss layer covers 2% of the area. Those most common on the rocks are *Thuidium delicatulum*, *Dicranum fulvum* and *Grimmia apocarpa*.

NORTHERN HARDWOODS WITH HEMLOCK

The northern hardwoods community with hemlock present is also restricted in its distribution. It occupies steep bouldery ravines (Stand 17) and low islands between streams (Stand 18). One stand studied in detail is located in the northwestern part of the park and another is situated $\frac{3}{4}$ mi. south of Saw Mill Pond.

The soil of the two sites varies considerably. On the steep, rocky, ravines, it consists chiefly of organic material which accumulates between the boulders. However, some of the accumulating humus is con-

DEPTH IN FEET

FIG.
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stantly removed by flood waters in the narrow ravines and by erosion on the steep slopes.

An exception to this occurs just outside the park, east of Lake Marcia. There a stand lies at the base of the southeast escarpment on a north facing slope, where the conglomerate gives way to the underlying shale. At this point a stream has cut a deep ravine. The soil in this hemlock stand is derived from the shale and is relatively free of rocks. Where the community occurs on islands between streams, the soil is a rocky clay loam with a podzol profile. An organic layer overlies an ash gray A horizon (pH 4.2) below which is a yellow-brown B horizon (pH 4.8).

In the rocky ravines, hemlock and yellow birch are the important species, contributing 57% of the total cover of the forest canopy (Stand 17). Other main canopy associates in order of dominance are sweet birch, white ash, red maple, sugar maple, basswood, tulip tree, and white pine (Fig. 13). Hemlock is more important on the island sites and on the shale slope (Fig. 20). Here, along with the above associates, white oak, chestnut oak, and black gum may be present. The larger trees vary from 12 to 32.5 in. d. b. h. The larger hemlocks are 80-100 years old. The average height of the forest is 70 ft. An understory tree layer is poorly developed, with striped maple, hop hornbeam and transgressives of the dominant species contributing the most. All trees are reproducing, although oak is least successful. Hemlock and birch seedlings are most abundant. Occasionally hemlock seedlings are so abundant on the forest floor that they produce a green tinge. The seedlings of birch and hemlock occur chiefly on hemlock litter and on rotten logs. There is some evidence that this community may in time occupy a greater area, since in at least three stands, hemlock saplings are present not only within the stand, but also in the surrounding chestnut oak

forest, as well as in abandoned fields and former pasture land.

The shrub layer of this community is relatively open, shrubs occupying not more than 25% of the area, usually less. Those shrubs which most frequently occur are *Hamamelis virginiana* and *Viburnum acerifolium* (Fig. 14). *Rhododendron maximum* is only locally important.

Herbs are sporadic occupying about 6% of the area. Those which are found most frequently include *Aster divaricatus*, *Maianthemum canadense*, *Trientalis borealis* and *Mitchella repens* (Fig. 15). *Lycopodium lucidulum* was present but it was not found in the quadrats.

Mosses cover 9% of the area in the moss layer, the rest being either litter or bare rock. Those present are *Hylocomium splendens*, *Dicranum scoparium*, *Climacium americanum*, *Mnium affine*, *M. punctatum*, and *Trichocolea tomentella*. In the stream flowing through one hemlock stand (17), are mats of *Eurhynchium rusciforme* and *Sematophyllum carolinianum* covering the rock surfaces.

POLLEN ANALYSIS

In general, the pollen record reveals an initial spruce-pine-fir-oak forest succeeded by a period of spruce-pine-fir and then a brief period of pine dominance. This was followed by a deciduous complex in which oak predominated. During the latter, two periods of hemlock maxima were separated by an intervening hickory maximum.

Although the two bogs show the same general trends, they do not correlate in the lower levels (Fig. 18, 19). Some of the records revealed in the bottom levels of the Pine Bog profile are absent in the profile obtained from Cedar Bog. What is especially conspicuous in the Cedar Bog profile, is the shortness of the spruce and fir record compared with

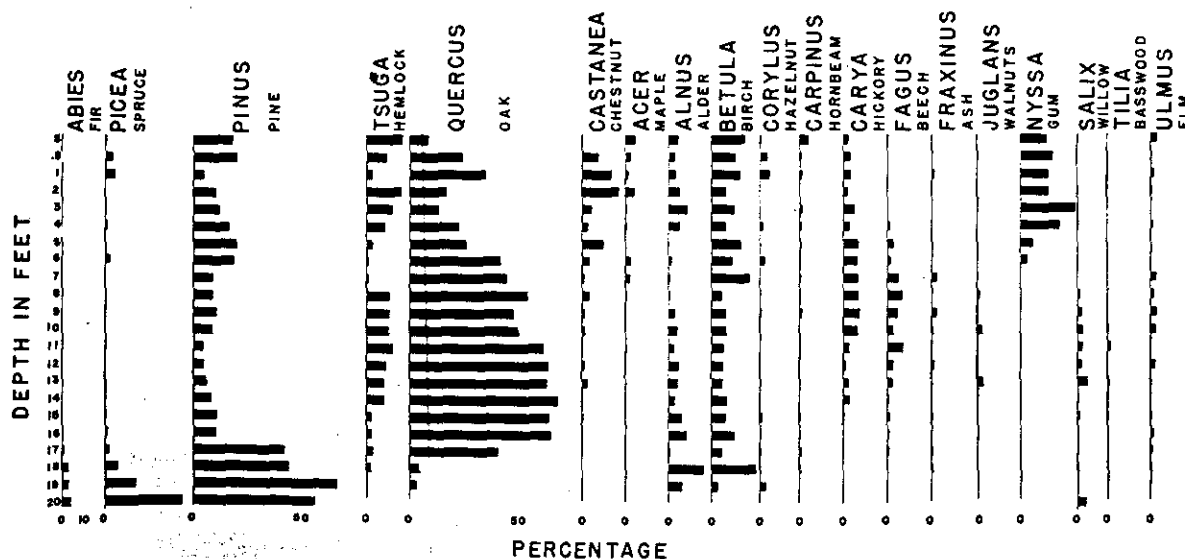


FIG. 18. Cedar Bog pollen spectrum. Length of the bar represents % of total tree pollen. For example, Pinus represents 18% at the surface(s) and 68% at the 19 ft. level. Chamaecyparis (cedar) is found only at the surface where it represents 10% of the total tree pollen.

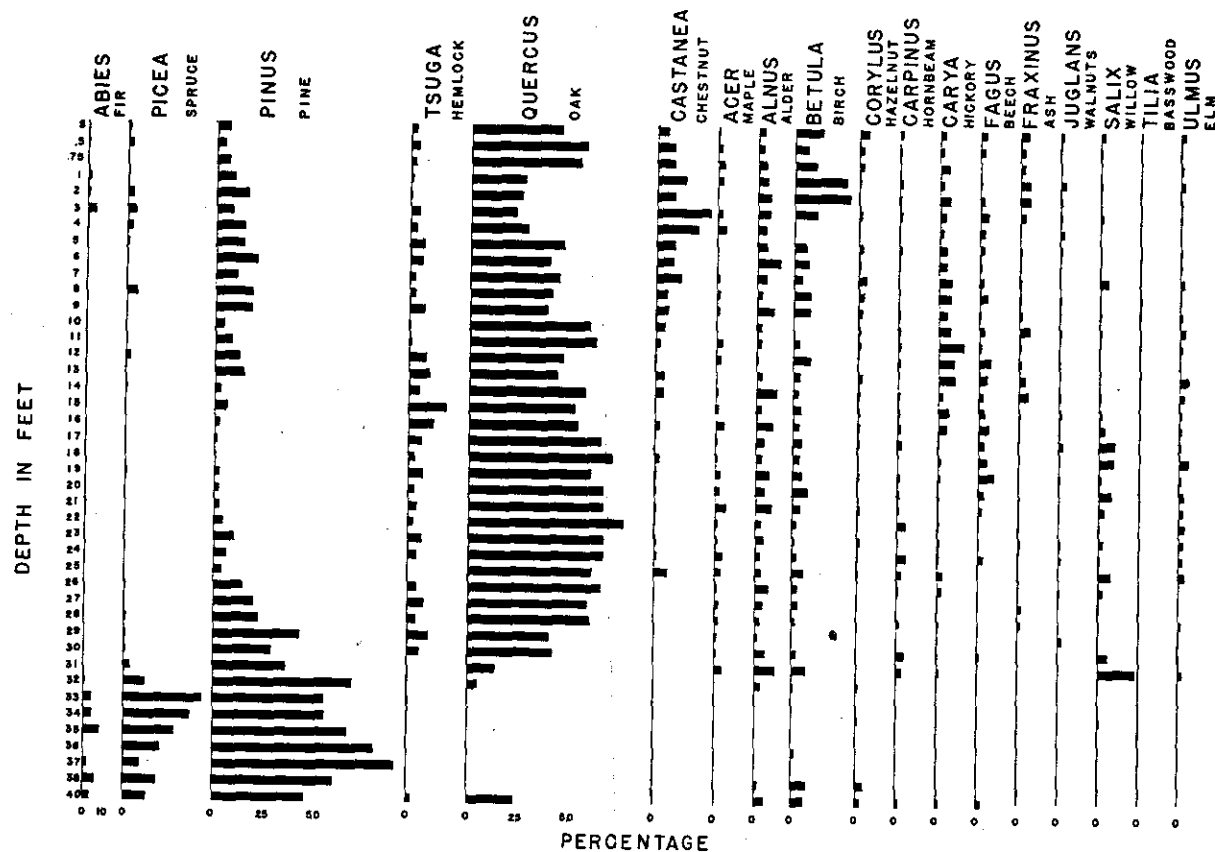


FIG. 19. Pine Bog pollen spectrum. Length of the bar represents % of total tree pollen. For example, *Pinus* represents 7% at the surface(s) and 46% at 40 ft. level. No pollen was found in the 39 ft. sample.

that of Pine Bog. In Cedar Bog, the 20 ft. level is comparable to the 33 ft. level in Pine Bog. The record found in the bottom 7 ft. from Pine Bog is absent from the Cedar Bog profile. Failure to find the deepest part of Cedar Bog may be the explanation for the incomplete profile there (Patzger & Wilson 1944). Although samples were obtained to a depth of 30 ft. in Cedar Bog, those from 21-30 ft. were sterile, except for a few pine and spruce pollen grains at about the 25 ft. level.

In the bottom levels (37-40 ft.) of Pine Bog, spruce, fir, pine and deciduous species occur. This is followed by a spruce maximum in which the deciduous element is practically absent. A pine period, which has been often shown to be very pronounced in eastern North America (Patzger & Otto 1943; Deevey 1939, 1943), if represented in these profiles was of short duration being recorded only in the 32 ft. level in Pine Bog and the 19 ft. level in Cedar Bog. This is succeeded by a long oak-hemlock-pine and mixed broadleaved period during which two hemlock maxima occurred. The first of these maxima (around the 15 ft. and 11 ft. level) is accompanied by a decrease in pine and oak. Between them, there occurred a period in which there was a decrease in hemlock and an unmistakable increase in hickory. The second hemlock maximum (5 ft. and 2 ft.) is accompanied by an increase in chestnut and spruce,

and the reappearance of fir. Beech increased also during the hemlock maxima. Surface samples of Pine Bog, which presumably reflect the present day conditions, show oak and birch to be most important with a slight decline in pine and a rise in hemlock. In contrast, oak is much less important in Cedar Bog, where it is accompanied by an increase in hemlock, birch, maple and pine along with appearance of *Nyssa* and *Chamaecyparis*.

Small quantities of non-tree pollen were found throughout the profile. In the 1-4 ft. levels of Pine Bog, Compositae, especially *Ambrosia*, represents up to 20% and in the lower levels sedges and grasses were present. In the top levels of Cedar Bog, *Chenopodium* and *Rumex* occur.

DISCUSSION

That climate controls vegetation has long been recognized, the major vegetational patterns being determined by the regional climates (Tansley 1949; Weaver & Clements 1938). Within any region, one encounters plant communities whose presence and distribution are determined by local climate and edaphic conditions, as for example a ravine compared with an exposed ridge, or a site with a thin soil mantle over rock compared with a deep fertile soil. It is evident, therefore, that superimposed upon the

pervading influence of the regional climate are both physiographic and edaphic conditions which locally influence the vegetational pattern. Hence, in any regional vegetational pattern, there will be a matrix of vegetation in which the regional climate appears to have the principal control, but within which pronounced local variations occur. The whole pattern is subject to change as changes in the regional climate occur.

PAST VEGETATION

One might expect, as Transeau (1903) did, that tundra vegetation first occupied the area after the ice melted. However, no evidence for such was found, although Deevey (1951) reports pollen evidence of tundra vegetation being found in Maine and possibly in Connecticut bogs. The beginning of the record in Pine Bog shows the presence of deciduous species accompanied by pine and a low representation of spruce. This suggests a period of moderate climate at the start of the record. Since the area lies within the Cary moraine and about 100 mi. south of the Mankato moraine (P. MacClintock, personal communication) it suggests that considerable climatic amelioration occurred following the Cary. This was followed by a disappearance of the deciduous forest species and a spruce dominance which may be correlated with the readvance of the Mankato substage. Deevey (1939, 1943) found a similar fluctuation in Connecticut which he correlated with recession and advance of Early and Late Mankato substages. However, from recent studies in Maine, Deevey (1951) suggests a different interpretation. In these studies he considered the rise in spruce as recording the actual invasion of spruce into the region, but below the spruce maximum he considers the tree pollen wind-borne from a distance. However, this does not seem to be a likely interpretation at High Point State Park since there is a paucity of non-tree pollen.

Pine becomes important early in the profile, as compared with the vegetational sequences illustrated by profiles in the midwest; a phenomenon that may be the result of climate under more maritime conditions (Potzger & Otto 1943). Climatically the spruce-pine-fir period was cool and moist. The subsequent brief period of pine dominance suggests drier conditions (Sears 1948). It is of much shorter duration than the pine period recorded by most bogs studied in the Northeast: in New Jersey (Potzger & Otto 1943), in Connecticut (Deevey 1939, 1943, 1951) and in New Hampshire (Krauss & Kent 1944). However, it is comparable with Deevey's Linsley Pond (L-9 and L-10) profiles. Radiocarbon studies show the time of attainment of the pine period in North America to vary roughly with latitude. In West Virginia it was attained about 9,000 years ago, in Connecticut 8,000 and in Maine 6,000 years (Flint & Deevey 1951). Since these bogs are located relatively near Connecticut the pine period probably occurred around 8,000 years ago in northern New Jersey.

Following the pine period deciduous species, espe-

cially oak, rapidly became important and have persisted until the present. This change is suggestive of a warmer climate. Associated with these deciduous trees there appeared the hemlock. Its history is accented by two periods of greater importance. These two periods may be interpreted as times of increased moisture (Potter 1947). This interpretation is further strengthened by a correlated decrease in hickory at the hemlock maxima. Between the hemlock maxima a rise in hickory is indicative of drier and possibly warmer conditions. This level probably marks what has been known as the last xerothermic period which had widespread effects upon eastern North America (Sears 1942; Raup 1937; Transeau 1935; Gleason 1923). From samples obtained in Connecticut the date of the hickory maximum has been tentatively set by the radiocarbon method at about 1800 ± 500 years ago (Flint & Deevey 1951). The second hemlock maximum was accompanied by an increase in chestnut and a decline in hickory which together indicate a return to more mesic conditions. Evidence for such a shift is strengthened by the reappearance of spruce and fir.

And indication of the historical period is suggested toward the top of the profiles. In Pine Bog the local influence of a developing bog forest may to some extent mask the true picture of upland conditions. It is possible that the increase in pine near the top may be evidence of such an influence. The appellation Pine Swamp along with the presence of white pine and dead snags in the bog today would suggest that pine was probably more important in recent time than at present. The pronounced rise in birch accompanied by a decline in hemlock suggests the temporary dominance of gray birch as a result of fires and man's activity.

The surface levels of Pine Bog reflect the present upland vegetation dominated by oak and other deciduous species. Hemlock has increased slightly, but its still restricted distribution in the most mesic sites is reflected in the surface layers. In contrast in Cedar Bog, the upland forest is partly masked by the mature bog forest covering much of the bog today. This is shown by the increase in hemlock, birch, and maple along with the appearance of gum and cedar.

An interesting correlation results when Pine Bog is interpreted in terms of Sears (1948) suggested correlation between northeastern pollen profiles and climatic fluctuations since early Wisconsin time. The substage advances may be correlated with an increase in hemlock or spruce, and retreats with a rise in pine, or oak and hickory, concurrent with a decrease in hemlock or spruce. Beginning at the top of the profile, the low percentage of hemlock and higher percentage of oak may reflect the retreat of the Alpine-Alaskan, although the historical period with man's influence may be equally or more important. The increased importance of hemlock between the 3-9 ft. levels may be correlated with the Alpine-Alaskan advance. The retreat of the Cochrane is suggested at the hemlock minimum and hickory maximum (10-11); and its advance may be correlated

with the preceding rise in hemlock, reaching a maximum at the 15 ft. level. The previous decline in hemlock is suggestive of the Agassiz-Campbell retreat, and it is preceded by a slight increase which may be correlative with the advance of Agassiz-Campbell. The brief pine period may be correlated with the retreat of the Mankato.

The Mankato advance is suggested by the spruce maximum. The bottom sediments represent the period after the retreat of the Cary, which may have been accompanied by pronounced climatic amelioration indicated by the presence of oak. If these correlations are valid then this pollen profile supports MacClintock's belief that the bog has been developed on drift of Cary age (MacClintock, personal communication).

PRESENT VEGETATION-HISTORY

With the arrival of man, new influences were superimposed upon those previously controlling the vegetational pattern. Man's activities that affected vegetation were cutting the forests, carelessness with fire and cultivating the land. These activities resulted generally in more xeric conditions and therefore a retrogression in the vegetational development (Nichols 1913a).

The initial anthropic influence upon the region began with the Indian, who depended mainly upon fruits and animals for his existence. He is known to have frequently set fires either accidentally or purposely to facilitate hunting (Little 1946, Vermeule, *et al* 1900). Later as white man entered the region he gradually cleared the areas suitable for agriculture. Later, industry grew up and this was accompanied by increasingly intensive harvesting of wood from the remaining forested areas. The dependence of industry upon forest resources reached its maximum during the middle 1800's. Large quantities of wood were required to supply iron furnaces scattered throughout northern New Jersey. During this period trees 20-25 years of age were cut and utilized as charcoal. Much wood was also used for many other purposes such as railroad ties, hoop poles, and domestic fuels. Around 1850 when anthracite blast furnaces were introduced, the utilization of forest resources began to decrease (Vermeule, *et al* 1900). However, by this time portions of the adjacent New Jersey Highlands were completely denuded of forest vegetation. Along with the intensive cutting were severe forest fires. During the special survey of forests from 1894-1899, Vermeule, *et al* (1900) pointed out that pitch pine as well as mixed coniferous and deciduous forests of the Kittatinny Mountains suffered considerably. Although a permanent organization to control fires was established as a result of this survey, frequent fires have since plagued the region. Present residents recall several large fires in more recent time, one or more of which burned over large areas along the major ridge within the park.

Today the effects of man's activities are evident everywhere: in the prevalence of sprout growth typi-

cal of cut-over oak woods, in the evidence of fires, and in the secondary succession patterns from old fields through gray birch to as yet unstabilized forest.

VEGETATIONAL PATTERN

The dominant community is the chestnut oak with its characteristic ericaceous shrub layer. It forms a matrix in which all the other communities are found (Fig. 1, 20). It is relatively stable on most sites, but on some of the lower slopes it is yielding to the northern hardwoods. Since the disappearance of chestnut, natural replacement by oaks has followed. In Stokes State Forest, Korstian & Stickel (1927) noticed this trend.

The typical community of the rocky ridge top is the pitch pine-scrub oak community (Fig. 20, 21). Fires in the past have probably aided in perpetuating this community by stimulating sprout growth of scrub oak and furnishing favorable conditions for pine reproduction (Lutz 1934; Conard 1935; Little & Moore 1949). In fact, the vegetation resembles that found in parts of the Pine Barrens of southern New Jersey where frequent fires occur. With the exclusion of fire in the pitch pine-scrub oak community on the ridge top, the evidence indicates that both pines and arborescent oaks have great difficulty becoming established, and that shrubs may continue to dominate over considerable portions. Those pines

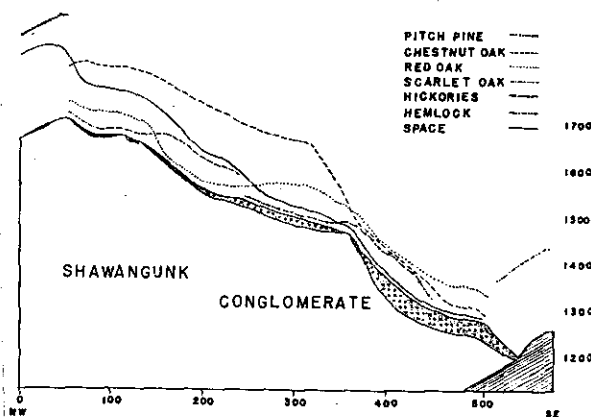


FIG. 20. Transect representing tree cover (Fig. 1, Transect B). The distance of each line representing the species above the topographic profile indicates the % of tree cover represented by the species at different points along the transect line. For example, on the ridge top (0-50) pitch pine contributes 88% of the total tree cover and open space in the tree canopy is at its greatest (70%). Other species are present but altogether contribute only 12% of the cover and are omitted here. On the slopes, chestnut oak contributes 62% cover, reaching a maximum of 71% (190), followed by an abrupt decrease to 25% on the lower slope (360-460). Chestnut oak on the lower slope is accompanied by approximately equal percentages of hickory and red oak. Scarlet oak is restricted primarily to the upper slopes (60-250). Numbers at the bottom refer to horizontal distance in meters and at right, refer to altitude in feet above mean sea level. Glacial drift overlying the geological formations is shown by stippled area with larger dots. Talus slopes are represented by small angular blocks. The Martinsburg shale is shown at right by oblique lines.

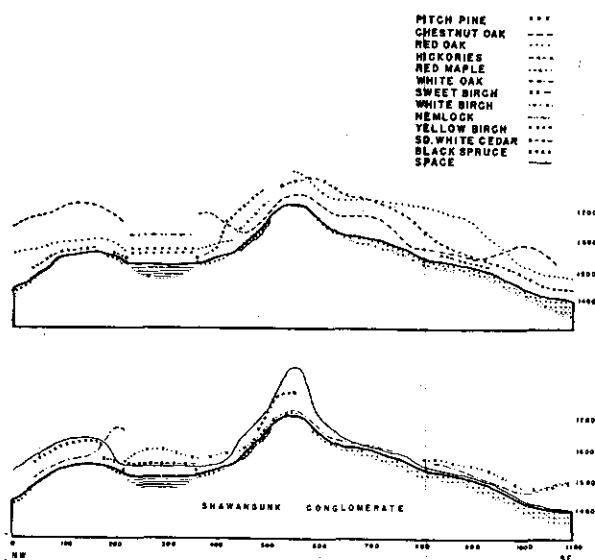


FIG. 21. Transect representing tree cover (Fig. 1, Transect A). See Figure 20 for guide in interpretation. Cedar Bog deposits are represented by parallel lines. Break in line across Bog (210-360) indicates that only a portion of bog was sampled. The letter (R) on either side of the bog indicates location of road.

present are primarily in the open early stages of primary succession. This community will probably continue to be represented as long as primary vegetational succession is still in the process of covering the bare rocky ledges, and as long as fires are allowed to sweep across the ridge.

In contrast, the pine-oak community as it occurs today, on the deeper soils derived from glacial drift, is an advanced successional stage approaching oak forest. Sporadic pines frequently tower above the arborescent oaks and the oaks are reproducing prolifically compared to the pine. Evidence of greater importance of pine in the past is indicated by rotten pine logs on the forest floor, by the occurrence of a podzol soil profile and by sporadic clumps of scrub oak. Very similar to this are late successional stages in the Pine Barrens of New Jersey (Buell & Cantlon 1950). In the absence of further pyric and anthropic influences, the pine will form only a small part of the stands if present at all (Little & Moore 1949).

The white oak-hickory community occurs on the valley floors or in more mesic upland sites (Fig. 21, 22, 23). The presence of chestnut logs in some stands indicates that where hickory is present today both species, along with white oak once shared dominance. At present this community shows a successional trend toward the northern hardwoods. There is an increasing importance of the northern hardwoods in the smaller size classes. The mixed oak-hardwoods community in the same way is yielding to the northern hardwoods. The established northern hardwoods are at their maximum development in deep narrow valleys (Fig. 20, 23). Further aggressiveness by the more mesic species is evidenced by the young hemlock which is in the adjacent chestnut oak community.

Where land has been cultivated at some time in the recent past, gray birch is now common. Raup (1937) found the same situation in the Black Rock Forest of New York. Red cedar also occurs, but is not abundant. It is primarily restricted to the shale. In southern New England, Lutz (1928) and Raup (1940) describe both red cedar and gray birch in secondary succession. Bard (1952) found red cedar abundant and little gray birch on the Triassic shales of the Piedmont of New Jersey. The birch and cedar, which are relatively short lived, are replaced by an oak forest.

Since the recession of the ice sheet, primary succession has been continuously occurring on the scoured ledges of the ridge and in the glacial lakes. In fact, there is still bare rock to be covered and water to be filled in with vegetation. The earlier successional patterns were probably not unlike those operative today. The species concerned may well have been different; but the earlier the stage in the succession, presumably the more nearly the present vegetation resembles that of early post-glacial time. Plants that suggest this are lichens, mosses, and certain flowering plants such as *Deschampsia flexuosa* and *Potentilla tridentata*.

The process of primary succession is much the same for all rock surfaces although the ultimate vegetation which becomes established depends upon the exposure. On the ridge tops it leads to pitch pine-scrub oak or possibly to chestnut oak. In contrast, on the northwest slopes are northern species such as white pine, white birch, sweet birch, mountain ash, striped maple, and mountain maple associated with chestnut oak.

The early stages of bog succession at High Point, as in the rock succession, reflect the early boreal environment shown to have existed in the area by the pollen record. For example, species such as *Andromeda glaucophylla*, black spruce, tamarack and associated vegetation appear as relicts around which more southern species have become established as Transeau (1903) long ago pointed out. He believed that the presence of either a coniferous bog or broadleaved swamp vegetation depends upon the period in post-glacial time when a suitable habitat became available. Although both occupy the same kind of habitat today, the coniferous bog has been gradually losing out. Only where the conifer vegetation has been reasonably undisturbed has it persisted. Elsewhere, the swamp hardwoods have replaced it, and even without disturbance the succession appears to lead to a swamp hardwood forest with hemlock.

The occurrence of southern white cedar in Cedar Bog is of particular interest. Its invasion into the area may have occurred during the last xerothermic period or hickory maximum. Several investigators have found evidence to indicate that cedar may have been more important in the recent past (Bartlett 1909; Nichols 1913b; Raup 1937; Heusser 1949). Today it is decreasing and will ultimately give way to the more shade tolerant hemlock and red maple (Little 1950). The broadleaved swamp forest of more recent origin is relatively stable, with little

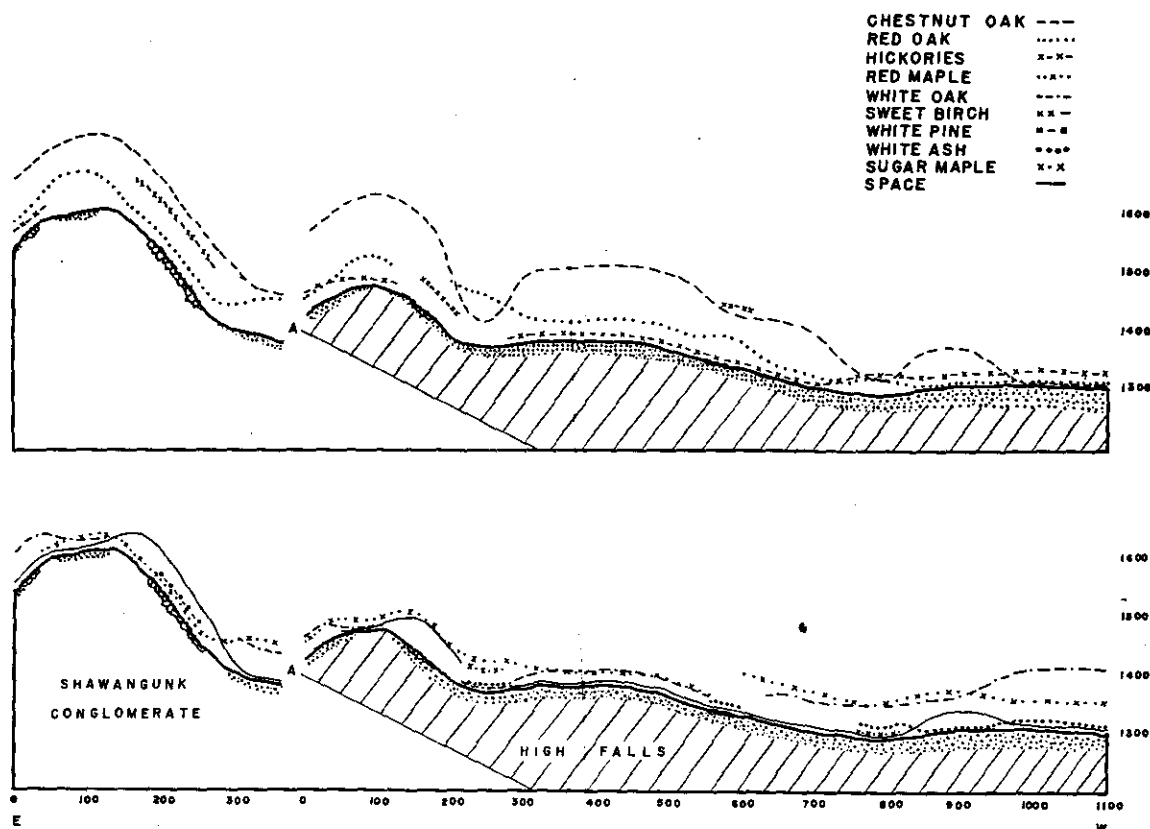


FIG. 22. Transect representing tree cover (Fig. 1, Transect C). See Figure 20 for sample explanation. Break in line A represents abandoned fields.

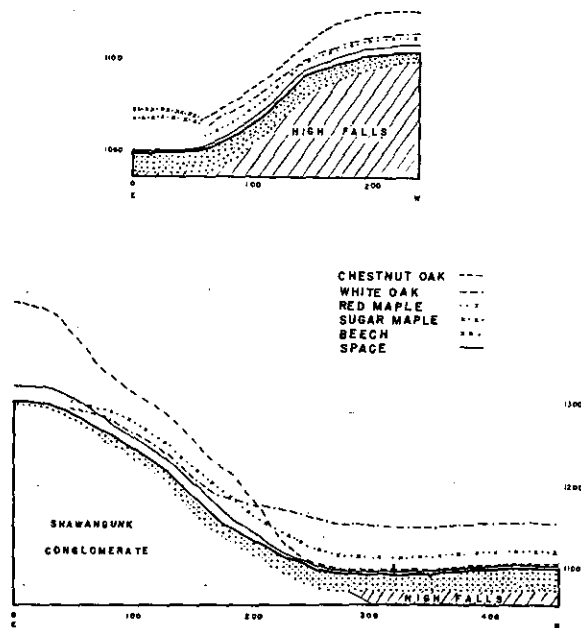


FIG. 23. Transects representing tree cover (Fig. 1 Upper transect E, Lower D). See Figure 20 for sample explanation.

evidence of change except where accumulation of soil has resulted in more mesic conditions. It is interesting to note that relict species whose range is more continuous either further north or south are found in both xerarch and hydrarch primary successions, which offer less competition than other habitats. Today the mosaic of vegetation in High Point State Park is composed of plant communities some of which are relatively stable, while others show successional tendencies. In recent time the activities of man have changed the forest from one which was more mesic, having a larger representation of northern hardwoods, to the more xeric types of today. The northern hardwoods are very restricted in their distribution; however they are expanding into the surrounding oak communities, a trend noted by Raup in the Black Rock Forest (Raup 1938). With protection rather than destruction more mesic conditions will develop, although the physiography and soils will always exert pronounced influences limiting the possible extent of mesophytic development.

SUMMARY

1. The post-glacial history of High Point State Park reveals an initial spruce-pine-fir-oak forest succeeded by a period of spruce-pine-fir and then a brief period of pine dominance. Finally there was a prolonged deciduous complex in which oak predominated. During the latter, two periods of hemlock

maximum with an intervening hickory maximum suggest climatic fluctuations from mesic, to xerothermic, with a return to mesic conditions.

2. Today a chestnut oak community with an associated ericaceous shrub layer is the continuous element of vegetation within the park. In other words, it forms a matrix in which occur all other communities.

3. The dispersed communities within this matrix and their typical sites are: the pitch pine-scrub oak on the rocky conglomerate ridge tops; the pine-oak on hills of the High Falls; the white oak-hickory on many of the valley floors, and some of the moist uplands; the mixed oak-hardwoods on the slopes of broad valleys between the hills; the northern hardwoods in the narrower valleys and deeper ravines; and of course, early successional stages of both primary and secondary succession.

4. Early stages of primary xerarch and hydrarch succession, initiated upon the disappearance of the Pleistocene ice, are continuing now, probably much the same as at their start. This is indicated by the part played by several boreal species.

5. The presence of certain disjunct southern species such as *Chamaecyparis thyoides* suggests relicts of the xerothermic period.

6. Primary hydrarch succession leads to a swamp hardwoods forest with hemlock. Disturbance has hastened the replacement of the northern conifers by this forest.

7. In secondary succession gray birch plays a dominant role. Red cedar, so important in southern New England and further south in New Jersey, is of minor importance. *Andropogon* species are unimportant except on the eastern fringe of the park where the shale outcrops.

8. The present vegetational pattern is a result of man's activities superimposed upon climatic, edaphic, and physiographic conditions. On most sites where they occur the chestnut oak, pitch pine-scrub oak, swamp hardwoods and northern hardwoods communities are relatively stable. The pine-oak, white oak-hickory, mixed oak-hardwoods communities show evidence of change. In the more xeric communities oak is replacing pine and in the more mesic communities the northern hardwoods are replacing the oaks and their associates.

LITERATURE CITED

- Archard, H. O. 1953. A comparison of life-form spectra of three New Jersey pitch pine communities. In press.
- Bard, Gily E. 1952. Secondary succession on the Piedmont of New Jersey. *Ecol. Monog.* 22: 195-215.
- Bartlett, H. H. 1909. The submarine *Chamaecyparis* bog at Woods Hole, Mass. *Rhodora* 11: 221-235.
- Bauer, H. L. 1943. The statistical analysis of chaparral and other plant communities by means of transect samples. *Ecology* 24: 45-60.
- Blodgett, F. L. 1910. Ecological plant geography of Maryland. Midland Zone; upper midland district. *Md. Weather Serv. Spec. Publ.* 3: 221-274.
- Braun, E. Lucy. 1950. Deciduous forests of eastern North America. Philadelphia: Blakiston Co. 596 pp.
- Bray, W. H. 1930. The development of the vegetation of New York State. N. Y. State Col. Forestry. Tech. Publ. 29.
- Britton, N. L. 1884. On the existence of a peculiar flora on the Kittatinny Mountains of northwestern New Jersey. *Torrey Bot. Club Bull.* 11: 126-128.
- Buell, M. F. & J. E. Cantlon. 1930. A study of two communities of the New Jersey Pine Barrens and a comparison of methods. *Ecology* 31: 567-586.
- Conard, H. S. 1935. The plant associations of central Long Island. *Amer. Midland Nat.* 16: 433-516.
- Deevey, E. S., Jr. 1939. Studies on Connecticut Lake sediments. *Am. Jour. Sci.* 237: 691-724.
- . 1943. Additional pollen analyses from southern New England. *Amer. Jour. Sci.* 241: 717-752.
- . 1951. Late-glacial and post-glacial pollen diagrams from Maine. *Amer. Jour. Sci.* 249: 177-207.
- Egler, F. E. 1940. Berkshire plateau vegetation, Mass. *Ecol. Monog.* 10: 145-192.
- Fernald, M. L. 1950. Gray's manual of botany, 8th ed. American Book Co., New York. 1632 pp.
- Fliht, R. F. & E. S. Deevey. 1951. Radiocarbon dating of late Pleistocene events. *Am. Jour. Sci.* 249: 257-300.
- Gleason, H. A. 1923. The vegetational history of the Middle West. *Annals. Assoc. Amer. Geogr.* 12: 39-85 and *Contr. New York Bot. Gard.* 242.
- Gordon, R. B. 1940. The primeval forest types of southwestern New York. *N. Y. State Museum Bull.* 321.
- Grout, A. J. 1940. List of mosses of North America north of Mexico. *The Bryologist* 43: 117-131.
- Heusser, C. J. 1949. A note on buried cedar logs at Secaucus, N. J. *Torrey Bot. Club Bull.* 76: 305-306.
- Hotchkiss, N. 1932. A botanical survey of the Tug Hill Plateau. *N. Y. State Museum. Bull.* 287.
- Hough, A. F. 1936. A climax forest community on East Tionesta Creek in northwestern Penna. *Ecology* 17: 9-28.
- Hough, A. F. & R. D. Forbes. 1943. The ecology and silvics of forests in high plateaus of Penna. *Ecol. Monog.* 13: 300-320.
- Jennings, H., I. L. Owen, I. V. Stone & W. R. Robbers. 1913. Soil survey of the Sussex Area, New Jersey. U. S. Dept. Ag. Bureau of Soils.
- Jennings, O. E. 1939. A contribution toward plant geography of western Penna. *Trillia* 10: 46-81.
- Korstian, C. F. & P. W. Stickel. 1927. The natural replacement of blight-killed chestnut in the hardwood forests of the northeast. *Jour. Ag. Res.* 34: 631-648.
- Krauss, R. W. & G. N. Kent. 1944. Analyses and correlation of four New Hampshire bogs. *Ohio Jour. Sci.* 44: 11-17.
- Kummel, H. B. 1940. The geology of New Jersey. Dept. of Conservation and Devel. Geol. Series Bull. 50.
- Lindeman, R. L. 1941. The developmental history of Cedar Creek Bog, Minn. *Am. Midl. Nat.* 25: 101-112.
- Little, S. 1946. The effects of forest fires on the stand history of New Jersey's pine region. *Northeastern Forest. Exp. Sta. Forest Management Paper* 2.

- . 1950. Ecology and silviculture of white cedar and associated hardwoods of southern New Jersey. *Yale Univ. School Forestry Bull.* 56.
- Little, S. & E. B. Moore. 1949. The ecological role of prescribed burns in the pine-oak forests of southern New Jersey. *Ecology* 30: 223-233.
- Lutz, H. J. 1928. Trends and silvicultural significance of upland forest successions in southern New England. *Yale Univ. School Forestry Bull.* 22.
- . 1930. The vegetation of Hearts Content, a virgin forest in northwestern Pennsylvania. *Ecology* 11: 1-29.
- . 1934. Ecological relations in the pitch pine plains of southern New Jersey. *Yale Univ. School Forestry Bull.* 38.
- Moore, E. B. 1939. Forest management in New Jersey. Dept. of Conservation and Development, Div. Forests and Parks. 54 pp.
- Nichols, G. E. 1913a. The vegetation of Connecticut II Virgin forests. *Torrey* 13: 199-215.
- . 1913b. Vegetation of Connecticut I Phytogeographical Aspects. *Torrey* 13: 89-112.
- . 1935. The hemlock-white pine-northern hardwood region of eastern North America. *Ecology* 16: 403-421.
- Oosting, H. J. 1942. An ecological analysis of the plant communities of Piedmont, North Carolina. *Amer. Midland Nat.* 28: 1-126.
- Oosting, H. J. & L. E. Anderson. 1937. The vegetation of a barefaced cliff in western North Carolina. *Ecology* 18: 280-292.
- Potter, L. D. 1947. Post-glacial forest sequence of north central Ohio. *Ecology* 28: 396-417.
- Potzger, J. E. & J. H. Otto. 1943. Post-glacial forest succession in northern New Jersey as shown by pollen records from five bogs. *Amer. Jour. Bot.* 30: 83-87.
- Potzger, J. E. & I. T. Wilson. 1944. A study of lake filling and bog formation. *Ind. Acad. Sci. Proc.* 54: 79-80.
- Raup, H. M. 1937. Recent changes of climate and vegetation in southern New England and adjacent New York. *Arnold Arboretum Jour.* 18: 79-117.
- . 1938. Botanical studies in Black Rock Forest. *Black Rock Forest Bull.* 7.
- . 1940. Old field forests of southeastern New England. *Arnold Arboretum Jour.* 21: 266-273.
- Renlund, R. N. 1951. Aquatic vegetation of some New Jersey fresh-water lakes. *N. J. Fisheries Survey Rpt.* 1.
- Salisbury, R. D. 1902. The glacial geology of New Jersey. *N. J. Geol. Survey* 5. 802 pp.
- Sears, P. B. 1930. A record of post-glacial climate in northern Ohio. *Ohio Jour. Sci.* 30: 205-217.
- . 1942. Xerothermic theory. *Bot. Rev.* 8: 708-736.
- . 1948. Forest sequence and climatic change in northeastern North America since early Wisconsin time. *Ecology* 29: 326-333.
- Tansley, A. G. 1949. The British Islands and their vegetation I. London: Cambridge Univ. Press. 484 pp.
- Transeau, E. N. 1903. On the geographic distribution and ecological relations of the bog plant societies of northern North America. *Bot. Gaz.* 36: 401-420.
- . 1935. The prairie peninsula. *Ecology* 16: 423-437.
- U. S. Dept. Agr. 1926. Summaries of climatological data by sections. *Weather Bur. Bull. W. No.* 3.
- Vermeule, C. C., A. Hollick, J. B. Smith, J. Gifford & G. Pinchot. 1900. Annual report of the State Geologist for Year 1899. Report on Forests. 327 pp.
- Waksman, S. A., H. Schulhoff, C. A. Hickman, T. C. Gordon & S. C. Stevens. 1943. The peats of New Jersey and their utilization. *N. J. Dept. Conserv. & Devlpmt. Bull.* 55, Part B.
- Weaver, J. E. & F. E. Clements. 1938. Plant ecology. New York: McGraw-Hill Book Co. 601 pp.