Review: Vegetation of Connecticut

Source: *Journal of Ecology*, Vol. 1, No. 4 (Dec., 1913), pp. 306-310+311

Published by: British Ecological Society

Stable URL: <http://www.jstor.org/stable/2255584>

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Journal of Ecology

subformations. The first, characterised by an undergrowth of evergreen xeromorphous diageic chamaephytes, forms a transition to the diageic steganochamaephytium and is often found on the higher parts of slopes; while the second, with undergrowth of evergreen mesomorphous diageic herbs, occupies the bottoms of the valleys and is the most luxuriant form of birch forest.

(9) *Evergreen xeromorphous epigeic chamaephytium (heath) above the Betula limit.* In the region just above the *Betula* limit the chamaephytes continue to produce extensive formations, but higher up the mountains the plants grow scattered and the fell-field replaces the heath. Formation 9 shows two facies, *Dryas* heath and *Empetrum* heath. The *Dryas* heath, rarely met with, is rich in species, numerous herbaceous forms (chiefly hemicryptophytes) occurring along with the chamaephytes. The *Empetrum* heath is very common, with *Betula nana* subdominant and becoming dominant on patches where *Empetrum* is absent.

(10) *Evergreen xeromorphous diageic chamaephytium above the Betula limit.* Where snow water trickles down the slopes and keeps the soil moist, the *Dryas* heath is richer in diageic herbs, and we thus have a formation transitional to Formation 10. Here mosses are more numerous, and as in the case of the corresponding formation below the *Betula* limit there is formed a looser raw-humus which promotes the growth of diageic species.

(11) *Evergreen diageic cryptophytium* is found on more level ground, especially on alluvial plains bordering small streams, and consists of mesomorphous or slightly xeromorphous species, among which geophytes are well represented though hemicryptophytes form the largest class; the preponderance of diageic over epigeic forms is much more marked than in Formation 10.

(12) *Fell-field.* At higher altitudes no continuous vegetation is found. The mountain summits are sprinkled with stones loosened from the rock by weathering processes, and in the fissures of the rock and in the finer gravel the plants grow singly or in small patches. As the author's analyses show, the fell-field is not characterised by any distinctive ecological features, but is composed of diminutive patches of heath, chamaephytium and meadow, or intermediate forms between these types of vegetation.

As the author points out in concluding this interesting paper, the application of the statistical method in a limited area can only show how the growth forms are dependent on differences of soil; it is only when material has been obtained from many areas with different climatic conditions that the effects of the climatic factors can be revealed.

VEGETATION OF CONNECTICUT

- (I) **Nichols, G. E.** "The vegetation of Connecticut. i. Phytogeographical aspects." *Torreyana*, **13**, 1913, pp. 89—112, 6 figures.
- (II) **Nichols, G. E.** "The vegetation of Connecticut. ii. Virgin forests." *Ibid.*, **13**, 1913, pp. 199—215, 5 figures.
- (III) **Nichols, G. E.** "Summer evaporation intensity as a determining factor in the distribution of vegetation in Connecticut." *Bot. Gazette*, **56**, 1913, pp. 143—152.

The first two papers cited above form the beginning of a series in which the author proposes to deal with the various problems presented by the vegetation of Connecticut—a series which promises to be of great general interest and value owing to the comprehensive and detailed manner in which the subject is treated.

The state of Connecticut—bounded on the west by New York, on the north by Massachusetts, on the east by Rhode Island, and on the south by Long Island—shows, for an area of its size (about 4000 square miles), considerable diversity both in topography and in vegetation. The chief rivers (Thames, Housatonic, Connecticut) all flow in a southerly direction through gently undulating lands of no great elevation at any part; the eastern portion of the state consists of hills with deep river valleys, in the north the country is mountainous, but the Connecticut valley is broad and fertile, consisting mostly of Triassic formations, while the greater part of the rest of the state consists of granite and gneiss. Three well-defined regions may be recognised—the Western Highland, the Eastern Highland and the Central Lowland; the boundaries of these

regions are roughly shown in a map (Fig. 41). The surface of the Highlands is mostly very rugged, and in the north, especially in the Western Highland, elevations of 450 m. are common, while there are several hills over 600 m. high. The Central Lowland is characterised on the whole by gentler contours and lesser elevations, the surface being almost level over large areas while the hills rarely attain more than 75 m., but along two trap ridges which traverse the Lowland from north to south there are precipitous cliffs and deep ravines like those found in the Highlands. The Highlands contrast sharply in geology as well as topography with the Lowland, since except for limited limestone areas they are underlain by granites, gneisses and schists, whereas the Lowland rocks are sandstones and shales; but throughout the state the underlying rock is in large part covered by a mantle of glacial drift which in places is more

FIG. 41. Map of Connecticut and part of southern New York, showing location of cedar swamps (•), boundaries between Highlands and Lowland in Connecticut (-----), and position of Ronkokoma (-----) and Harbor Hill (.....) terminal moraines on Long Island. W.H., Western Highland; C.L., Central Lowland; E.H., Eastern Highland. (From Nichols.)

than 50 m. thick. The contrast between Highlands and Lowland has been accentuated by the activity of the glaciers, for in the Highlands the *débris* deposited by the retreating ice sheet as a rule is heterogeneous and very unevenly distributed, while in the flatter Lowland the till has been buried to a large extent beneath layers of stratified sands, gravels and clays so that the structure of the surface soil tends to be much more uniform. Among the chief features of the Lowland, both from a physiographic and an ecological point of view, are the extensive sand plains—broad level stretches which are in places devoid of any but the sparsest and most xerophytic plant growth; such areas are usually populated by a flora which is pre-eminently southern in aspect, the northern element being correspondingly scarce. Various other

examples of similar correlation between physiographic features and the character of the vegetation can be recognised.

From a taxonomic standpoint the flora is adequately summed up in the various bulletins published by the Connecticut Geological and Natural History Survey. Excluding the thallophytes, 1949 species of plants have been recorded, including 463 bryophytes (134 liverworts, 329 mosses), 74 pteridophytes, 13 gymnosperms, 496 monocotyledons, and 903 dicotyledons. Of alien spermatophytes 460 are known, but though qualitatively and even quantitatively abundant they are disregarded in the present discussion since they serve to complicate rather than simplify matters. Nearly 70 per cent. of the indigenous plants are endemic to North America, the remaining 30 per cent. being in large part common to Europe or Asia or both. It is interesting to note how greatly the relative proportions of endemic and extra-continental species vary among and within the great divisions and subdivisions of the vegetable kingdom. While less than 20 per cent. of the bryophytes are endemic, fully 92 per cent. of the gymnosperms (*Juniperus communis* seems to be the sole exception), 80 per cent. of the monocotyledons, and nearly 90 per cent. of the dicotyledons are not known to occur outside of North America. Again, among the pteridophytes only 30 per cent. of the homosporous species, but nearly 80 per cent. of the heterosporous species are endemic; while among the dicotyledons, nearly 30 per cent. of the 37 local Ranunculaceae are extra-continental in range, but 98 per cent. of the 160 Compositae are endemic. The figures show that in the more primitive groups of plants the species tend to have a wider range than in the more advanced groups, or in other words that species in groups of comparatively recent evolutionary derivation are far more restricted in range than species in groups of more ancient origin. With regard to the intra-continental ranges of the various species it is found that while the majority of those known to occur in Eurasia range far to the north in North America, the endemic species show decidedly southward tendencies; for instance, of the 28 endemic Ranunculaceae native to Connecticut only 5 (about 18 per cent.) have been recorded north of New England or Nova Scotia, while at least 5 of the 9 extra-continental species have a more or less boreal distribution. Similarly among the bryophytes 84 per cent. of the endemic species are apparently confined to latitudes south of northern New England.

In common with other glaciated regions the modern era of plant life in Connecticut dates back to the period when the continental glaciers receded towards the pole, but in order to apprehend clearly not only the origin of the flora but also its affinities to that of other regions, one must look back to preglacial times when there was continuity between the continental land-masses of the northern hemisphere and the climate in the present subarctic regions was mild enough to permit the circumpolar migration of temperate plants—in no other manner can the similarity of certain components, notably the bryophytes, in the vegetation of Europe and North America be accounted for. With the advent of the climatic changes which caused or accompanied the development of the continental ice sheet, great transformations in the vegetation were induced; as the glaciers advanced southward the temperate plants slowly retreated, their places being taken progressively by arctic species which during the warmer period of the early Tertiary had apparently been confined to extreme polar regions. The southward margin of the ice sheet in the eastern United States is marked by the terminal moraine which now forms a part of the "backbone" of Long Island, reaching thence westward through Staten Island and northern New Jersey; the entire state of Connecticut was buried beneath ice and snow, and its vegetation completely annihilated. The terminal moraines on Long Island indicate two distinct glacial epochs in this region, and it is probable that a tundra vegetation existed at any rate south of the southernmost (Ronkokoma) moraine during the last period of glaciation, with coniferous forest on the higher levels. As the ice retreated northward the tundra formation doubtless followed in its wake, with the coniferous forest following in the rear; as a milder climate returned, temperate plants from the south invaded the area and eventually the arctic flora was in large part either exterminated or forced northward, with the exception of a few forms which had taken refuge in bogs where their descendants still survive. While practically all the species now comprising the flora have been derived from the south, many of them—certainly those which to-day are common to Europe—must have existed in preglacial times not only here but also far to the north. Many forms now endemic to North America, e.g. tulip-tree and sassafras, are known to have been native to Europe in preglacial times, but it is equally certain that

numerous endemic American species have never occurred in Europe—either they attained their present evolutionary development since the discontinuance of the circumpolar land bridge, or else they were restricted until comparatively recent times to the warmer parts of North America so that the opportunity to migrate into Europe was never afforded them.

The author discusses the segregation in the southeastern part of Connecticut of a group of plants characteristic of the Atlantic coastal plain from Long Island and New Jersey southward, which present a problem for which existing factors of topography, soil and climate do not seem to offer a satisfactory solution; in the same category are two other groups of coastal plain plants, one made up of species which have their centre of distribution in the southeast but may extend for some distance westward along the coast or northwestward into the valley of the Connecticut River, the other of species which occur locally in other parts of the state but are frequent or common in the southeastern section. The coast white cedar, *Chamaecyparis thyoides*, as the only aborescent form among these species, is selected as fairly typifying in its range the whole group; like all the plants mentioned (46 species of spermatophytes and 2 of bryophytes), except *Arctostaphylos Uva-ursi*, it is endemic to North America. It grows usually in swamps, with *Rhododendron maximum* often forming a dense undergrowth; as shown in the map (Fig. 41) there is an almost continuous chain of these swamps in Long Island, and they are abundant in the eastern but scarce in the western portion of Connecticut. There are apparently no pronounced climatic, topographic, or soil differences to account for the presence of this unique flora in southeastern Connecticut and eastward, and the most satisfactory solution seems to rest on the assumption that in postglacial time there has been a land bridge which connected eastern Long Island with the adjacent mainland and across which northbound coastal plants could readily pass without entering western Connecticut. The probability that such a formation once existed was urged by Hollick ("Plant distribution as a factor in the interpretation of geological phenomena," *Trans. N.Y. Acad. Sci.*, **12**, 1893) as an explanation for the occurrence of certain coastal plain plants in Rhode Island and southeastern Massachusetts, and Fernald ("A botanical expedition to Newfoundland and Labrador," *Rhodora*, **13**, 1911) adduced botanical evidence showing that for some time after the recession of the glaciers a more or less continuous land connection probably stretched northward as far as Newfoundland. The isolation in southeastern Connecticut of such an appreciable colony of coastal plain plants, 75 per cent. of which are common both to Long Island and New Jersey, affords strong confirmation of the views advanced by Hollick and Fernald.

In this first paper, the author outlines briefly the general distribution of various types of vegetation in the state, but these will be dealt with more fully in later papers.

(II) In the first of these more detailed papers, devoted to the virgin forests of Connecticut, the author deplores the wholesale destruction of forests which has proceeded ever since the seventeenth century when practically the whole state was densely wooded, until at the present time there hardly remain half a dozen patches of reputedly virgin forest, none with an area of more than a dozen acres. The forests as such have not actually been demolished, for more than half the total area of the state is still wooded, but the woodlands of to-day are second-growth and represent crops first, second, third, or even farther removed from the original stands. This paper is mainly occupied by a description of a fine stand of virgin forest fully 300 acres in area which was studied in 1911 but has since then been practically destroyed by lumbering. In this tract, representing the type of climax forest which formerly prevailed over at least the greater part of northwestern Connecticut, the dominant trees are hemlock (*Tsuga canadensis*) and beech (*Fagus grandifolia*), about equally abundant and together comprising at least 55 per cent. of the forest. The most important of the other trees and their percentages are as follows—*Acer saccharum*, 12; *Betula lutea*, 10; *Quercus rubra*, 6; *Castanea dentata*, 6. The undergrowth of most Connecticut woodlands is practically made up of *Kalmia latifolia*, *Gaylussacia baccata*, and *Rhododendron nudiflorum*, but the luxuriance of the undergrowth in this virgin forest forms a striking contrast, for while the *Rhododendron* is abundant there occur in profusion two shrubs which even in northern Connecticut are seldom found in second-growth forests—*Viburnum alnifolium* and *Taxus canadensis*, which evidently fail to survive the effects of lumbering owing to their extreme mesophytism and shallow rooting systems. Other undergrowth constituents in the virgin forest are *Hamamelis virginiana*, *Viburnum acerifolium*, *Cornus alternifolia*, and *Lonicera canadensis*;

while associated with these shrubs and sometimes forming a distinct vegetation story are two small trees, *Acer pennsylvanicum* and *A. spicatum*, rarely more than 6 m. high. The author gives a list of 55 herbaceous vascular plants of which the majority are rather widely distributed in this virgin forest, together with lists of the bryophytes classified according to habitat. No one feature better suggests the intense mesophytism of this forest than the character and distribution of the bryophytes, to which the writer has paid special attention—having made an extensive and critical study of these plants and published in conjunction with Evans a valuable memoir on the bryophytes of Connecticut. Not only do these plants form a rich covering over the ground surface, on roots, logs, stumps, and boulders, but they also plaster the bases of trees and extend up the trunks to a height of 24 m.

Some interesting results are given arising from the study of second-growth woodlands, in localities which almost certainly were once occupied by forests similar to that described above. In most cases such tracts are less mesophytic than the original forest, as shown by the usual presence of *Betula alba papyrifera* and *Pinus Strobus* as characteristic trees, together often with *Carya ovata* and *C. glabra*. The proportion of *Castanea* and *Quercus rubra* is greater here than in the virgin forest, while *Tsuga* is usually much less abundant; the increased percentage of *Castanea* and *Quercus* is doubtless attributable to their prolific sprouting capacity. The xerophytic tendency of the second-growth tracts is also shown in the character of the undergrowth: the *Taxus* and *Viburnum* are sparser and may have vanished, while *Prunus*, *Gaylussacia* and *Vaccinium* spp. have made their appearance; many of the herbaceous mesophytes (*Oxalis Acetosella*, etc.) also have disappeared, being supplanted by *Lycopodium* spp., *Pteris aquilina*, etc.—forms rarely seen in the original forest; while even the bryophytic flora has become greatly modified, mesophytic shade species having given way to forms such as *Polytrichum commune* and *Hypnum Schreberi*.

In Connecticut, as a whole, the ultimate climatic formation is a forest dominated by various deciduous trees and hemlock. Of the virgin forest scattered remains are found but for the greater part the present woodlands are second growth, differing in many respects from the original forests. Still, it seems probable, owing to the sprouting capacity of the majority of the constituent trees, that in favourable cases, except for a decrease in the proportion of hemlock and a corresponding increase in that of chestnut, the general aspect of the forest has not greatly altered during the last three centuries. The composition of this forest, however, was never uniform throughout the state. In northwestern Connecticut the original forest was of the "northern hardwood" type, the dominant trees being hemlock, beech and sugar maple, associated with yellow birch, chestnut, etc.; just how much of the state was covered by this type of forest is uncertain, but it was present over the greater part of the Western Highland and extended southward toward the shore of Long Island Sound, and was probably also characteristic of at least the northern portion of the trap range and of the northernmost section of the Eastern Highland. Along the coast and over the greater part of the Central Lowland the original forest was probably composed largely of chestnut and various oaks; the trees characteristic of the northern hardwood forest were also present here but were relatively less abundant and of more restricted occurrence, and in the forests of this area the tulip tree was frequently an important component. The original forests of the Eastern Highland, except in the northernmost part, probably resembled more closely those of the coast and Lowland than those of the Western Highland; in the present forests the prominent trees are the oaks, especially the white and the red oak, chestnut is present but much less conspicuous than in the Lowland forests, while hemlock, beech and maple are of subsidiary importance.

(III) In the third of the papers above cited, the author notes that to a limited extent it is possible to co-ordinate with the phenomena of plant distribution the meteorological data relating to rainfall, evaporation and temperature. He describes a series of experiments which show that, taking as a criterion the ratio between the amount of water precipitated in the form of rain and that lost by evaporation, there is a distinct correlation between the quantity of water theoretically available for plant use during the growing season and the distribution of forest types. It was found that while during the summer period of observation the rate of evaporation throughout the state far exceeded the rate of rainfall, there was an appreciable difference in the ratios between loss and gain in different regions. The estimated ratios were as follows: (a) Western Highland,

0·61; (b) Central Lowland, 0·47; (c) Eastern Highland, 0·42. These regions coincide approximately with (a) northern hardwood area; (b) sprout hardwood area dominated by *Castanea*; (c) sprout hardwood area dominated by *Quercus* spp. Hence it would appear that the area dominated largely by the mesophytic northern hardwood type of forest, and also the strip along the coast, constitute areas of relatively low evaporation intensity; and that the rate of evaporation in the Eastern Highland, where oaks predominate in the forest, is somewhat higher than that in the Central Lowland, where the more mesophytic chestnut is the characteristic tree. Similarly, a plausible explanation is suggested in *temperature* for the restriction of so many southern species to the immediate proximity of the coast, for while the length of the growing season inland averages 148 days, along the shore 177 days intervene between the last killing frost of spring and the first killing frost of autumn.

The author's observations on summer evaporation intensity are of great interest from the fact that—though limited to one season and thus not allowing of final conclusions, as he himself points out—they exhibit on a smaller scale similar relations to those established on a larger scale by Transeau and by Livingston; Transeau's work indicated a general correspondence between the precipitation-evaporation ratios for the whole year and forest distribution, while Livingston showed that the great centres of plant distribution in various parts of the United States are directly related to well-marked differences in the summer evaporation intensity. He points out that in considering the evaporation intensity of the air as a possible factor affecting the distribution of the vegetation it seems reasonable to assume that its effect on plants is felt most keenly during the earlier part of the growing season when growth and development are taking place most rapidly and when the immature tissues and organs are as yet inadequately protected from excessive transpiration. The observations made showed that during June and July the mean weekly evaporation rate far exceeded that maintained during the later months of the season—the period of maximum evaporation coincided approximately with the more critical period of vegetative activity. In view of this correlation and the natural assumption that it is the periods of excessive evaporation that are most influential in determining the character of vegetation, the author has in drawing conclusions disregarded the data obtained during the latter part of the season, when on the whole a uniformly low evaporation rate prevailed throughout the state.

FORESTS OF BRITISH COLUMBIA

MacMillan, H. R. "Report of the Forest Branch of the Department of Lands." Victoria, British Columbia, 1913, 43 pp.

Though this report is devoted to the commercial aspect of the forests of British Columbia, it contains interesting statistics concerning the extent and growth of the forests, and is illustrated by numerous fine plates, two of which we are permitted to reproduce (Plates 25, 26).

Of the total area of British Columbia (about 390,000 square miles), roughly three-fourths (about 290,000 square miles) are occupied by forest, chiefly consisting of coniferous trees—*Pseudotsuga Douglasii*, *Abies canadensis*, *A. Menziesii*, *Pinus rigida*, *P. Murrayana*, *P. Strobus*, *P. monticola*, *Tsuga Mertensiana*, *Juniperus virginiana*, *Cupressus nutkaensis*, etc. The author points out that this province contains one of the few great bodies of forestland left in the world which are not yet materially reduced by destructive lumbering; and that with the possible exception of Siberia, Brazil and the northwestern United States, the timber wealth of British Columbia is unparalleled in any other country. At the present rate of cutting, making no allowance for annual growth, it would take the lumber industry nearly 250 years to use up merely the mature timber now standing; but the annual growth of the forests of British Columbia is even now, before they are adequately protected from fire and waste, not less than five times the present annual lumber cut. Several times as much timber is now going to waste each year through natural decay as is being used in the same year, hence to protect the forests against fire but to lock them up against fuller use would be only in a slight degree less wasteful than not to protect them. The author advocates conservative methods of lumbering, which will not only utilise timber now going to waste but will actually improve the condition of the forests, hence it is advisable to encourage the growth of the lumber industry until it equals the production of the forests.