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A COMPARISON OF STRIP AND QUADRAT ANALYSES OF THE WOODY PLANTS ON A CENTRAL INDIANA RIVER BLUFF

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This report is concerned with the distribution of woody plants on certain river hills in central Indiana. The location is in the vicinity of Blue Bluffs on White river in Morgan county. Most hills, and particularly river hills of a hundred or more feet in height, show certain obvious differences in the woody plants at the top and the bottom. The relative abundance and evenness of distribution of different species, however, is hard to ascertain by ordinary observation, hence various methods of sampling are used to determine more exactly wbat are the distributional relationships of various species. Strip and sample plot methods of timber estimation have long been in use hy the foresters and lumbermen, and out of their methods have grown certain practices of the ecologist. In these studies there has been an effort to compare two methods of statistical analysis of vegetation, (1) sampling by line transects, and (2) sampling by quadrats, or regularly distributed squares.

In the first attempt to determine accurately the distribution of woody species on these river hills, the strip or transect method was used and found to be rapid and easy. The results are interesting and indicative of the conditions of the vegetation, but are not completely satisfactory. The second analysis was made on a basis of quadrats and was found to give more accurate results, but occasioned more work.

If we assume that floristic differences, even of small degree, bave ecological significance, then it would seem that a careful statistical analysis of vegetation becomes one of the problems of first importance in an ecological investigation. In a recent discussion of methods in the floristic study of vegetation, Nichols (4) remarks: "If there is any one set of facts which is more susceptible to direct study and exact characterization than any other, it is the floristic composition of the vegetation." As the casual observer may notice, there are flood plain, slope and ridge types of timber, and it is readily apparent that the moisture and exposure conditions are different at the bottom and the top of a bluff. But, as a special technique is required to ascertain the quantitative differences in soil moisture, soil structure, evaporation, humidity, etc., and to interpret them, so, too, certain technique is necessary quantitatively to determine the presence and distribution of critical or important species in the vegetation. For the student of plant communities, an inadequate description of the floristic composition of the vegetation is as bad as a species description for a taxonomist which would say that a flower was large, or larger, but not how large! Since river hills present abruptly changing habitat differences, they present good plant communities for analysis. A changing habitat means a changing floristic composition of the plant community, and vice versa, so that certain species, at least, we recognize as having considerable ecological significance, while every species must have a certain ecological "equation." In the excellent statement of Nichols, previously quoted, we read: "In general, there can be little question that every species of plant possesses not only a certain more or less definite taxonomic identity, but also a more or less definite ecological individuality. This being true, it follows, as the logical corollary, that any resemblances or differences in the floristic composition of plant communities may be of ecological as well as of taxonomic import."

In the following text the strip transect study will be presented first, and then the analysis by use of quadrats.

STRIP TRANSECT STUDY

A strip was laid out, starting at the bank of White river (West fork), running directly to the top of Rock Hill, a distance of 650 feet in a southwest direction. The immediate river bank has a slope of 25 degrees, followed by a gentle slope of about 5 degrees for 75 feet, from which flood plain the bluff rises at slopes varying from 15 to 30 degrees from the horizontal, the steepest part being near the summit. At the top of the bluff the transect strip turned 45 degrees to the west and descended into a ravine, a distance of 775 feet. The slope of this portion of the line is generally less steep than that on the side of the river bluff, much of it being from 10 to 20 degrees. The line then continued west from the ravine upward for a distance of 500 feet to the top of Blue Bluffs, at a slope of from 14 to 28 degrees. The total length of the line is 1,925 feet, while the top of the bluff is 285 feet above the river.

The data were gathered in the following manner: For an entirely separate purpose of hydrogen-ion studies of the soil, soil samples were taken at intervals of twenty-five feet along the line.[1] At each station where a soil sample was taken, a list was made of the trees and shrubs growing within the twenty-five-foot strip. The result was a large number of lists of species representing the succession of plants as they were encountered from the river valley to the top of the river hills, or from the top down, according to the line.

The direction of the line was controlled by compass, and the angle of slope was determined by use of an Abney Hand-Level. In handling these lists of species, it was decided to divide the lists according to altitudinal zones. This was accomplished by plotting on paper the length and angle of slope of the various segments of the line. On this contour of the hills studied were located the positions of the various soil sample stations and the lists of species accompanying them. Five zones were selected arbitrarily, which represent the five columns in Table I. From the river up they are each fifty feet in altitude, except the hilltop zone, which is slightly over. By thus dividing the strip into horizontal zones, it was possible to determine which stations occurred in each zone and, consequently, which species occurred in each zone. The results are presented in Table I.

The percentages given in Table I are not based on the total number of stations (and lists of species) along the whole line, but on the number of such stations occurring in the strip within each altitudinal zone above the river. Although the stations are evenly spaced in the line, the regions of the slopes which are more gradual will have more stations within the fifty-foot rise than those regions which are steeper. Thus we find 10 stations in the hilltop zone, and 13, 18, 20 and 16 stations consecutively in the zones down to the one immediately above the river level. The percentage occurrence of a species within a zone depends then upon the number of times it occurred in the separate

[1]See the following paper, page 172.

TABLE I

Distribution and Frequency of Species from River-Bluff Transects

Species	Percentage Occurrence Based on Altitude Classes (Height in feet above the river)				
	200-285	150-200	100-150	50-100	0-50
Gaylussacia baccata	10	....	....	....	....
Populus grandidentata	50	8	....	....	....
Vaccinium vacillans	20	15	....	....	....
Acer rubrum	50	38	11	10	19
Acer saccharum	20	54	15	45	75
Carya alba	10	31	38	10	12
Carya ovata	20	38	22	30	25
Cornus florida	30	46	38	45	25
Fraxinus lanceolata	30	8	15	15	31
Hydrangea arborescens	10	23	11	5	37
Nyssa sylvatica	10	8	5	5	12
Ostrya virginiana	60	61	60	50	62
Quercus alba	10	46	60	45	19
Quercus rubra	70	77	55	60	50
Sassafras variifolium	60	62	60	50	62
Vitis labrusca	....	15	11	....	....
Carya cordiformis	....	8	....	....	6
Quercus velutina	....	46	15	20	....
Fagus grandifolia	....	15	27	60	56
Sambucus canadensis	....	....	5	....	....
Fraxinus americana	....	....	11	....	....
Fraxinus pennsylvanicum	....	....	11	....	....
Morus rubra	....	....	22	10	....
Platanus occidentalis	....	....	5	....	25
Juglans cinerea	....	....	11	5	6
Cornus sp?	....	....	11	15	6
Ulmus americana	....	....	5	15	37
Prunus serotina	....	....	....	5	....
Ribes cynosbati	....	....	....	5	....
Liriodendron tulipifera	....	....	....	5	6
Ulmus fulva	....	....	....	5	19
Rubus allegheniensis	....	....	....	10	19
Carpinus caroliniana	....	....	....	15	44
Cercis canadensis	....	....	....	....	19
Rubus occidentalis	....	....	....	....	12
Acer negundo	....	....	....	....	6
Acer saccharinum	....	....	....	....	6
Benzoin æstivale	....	....	....	....	6
Celastrus scandens	....	....	....	....	6
Cratægus sp?	....	....	....	....	6
Fraxinus nigra	....	....	....	....	6
Gleditsia triacanthos	....	....	....	....	6
Juglans nigra	....	....	....	....	6
Pyrus coronaria	....	....	....	....	6
Smilax glauca	....	....	....	....	6
Number of stations at each height (total 77)	10	13	18	20	16
Number of species at each height (total 45)	15	18	23	24	34

lists for the stations in each zone. Thus, in the hilltop section there are ten stations and *Populus grandidentata*[1] occurs in five of them, having a percentage, as listed, of 50 per cent; and so on through the whole table.

The number of species in each of the zones increases steadily from the top of the hills to the level of the river plain as follows: 15, 18, 23, 24 and 34, consecutively, in the five zones. It may be reasoned that the increase in number of species, or general richness of the flora, lower down may only be apparent and not real, siuce the number of stations is greater than at the top. The ratios between the number of stations and the number of species substantiate this argument except in the lowest zone, where the undoubted greater floristic richness is revealed in the presence of thirty-four species.

The distribution in the intermediate zones of the various species we must consider more a matter of chance, but there are certain species whose ecological characteristics are so marked that we may consider them as "hilltop" or "flood plain" species. For example, *Gaylussacia baccata* is confined to the top zone, while *Vaccinium vacillans* and *Populus grandidentata* are confined to the upper two zones. In some other work on the distribution of species (in relation to soil acidity and topography), Cain and Friesner (2) have called attention to the presence of these species and others on ridge tops and upper slopes, where they are considered "xerophytic-acid-boreal relics." In the lower flood plain zone there are twelve species which were not encountered elsewhere in this strip transect. Since the lower zone included more than the flood plain proper, it is not to he expected that these twelve species are strictly peculiar to the lower altitude. As a matter of fact, the strip transect fails to reveal the truly flood plain species as such, although one familiar with the trees of the region would know that of the twelve species, *Gleditsia triacanthos, Fraxinus nigra, Acer saccharinum* and *Acer negundo* are primarily flood plain and river bottom species. Two other species are worthy of note in this connection. *Ulmus fulva* and *Platanus occidentalis* are essentially flood plain species, although they frequently occur on lower slopes as here encountered.

Twelve species occur at all heights on these river hills from the bottom to the top of the ridges. They are *Acer rubrum, Acer saccharum, Carya alba, Carya ovata, Cornus florida, Fraxinus lanceolata, Hy-*

[1]Nomenclature after Gray's Manual, 7th Ed.

drangea arborescens, Nyssa sylvatica, Ostrya virginiana, Quercus alba, Quercus rubra and *Sassafras variifolium.* If we add to this list *Fagus grandifolia,* which occurred in all zones but the top, the list includes the most important woody species of the upland forest. In the particular region under study, the most characteristic species is *Quercus rubra,* ranging from the top of the hills to the bottom with the following high percentages: 70, 77, 55, 60 and 50 per cent, respectively.

Oak-hickory development is dominant here and in many places in Morgan county, but, given physiographic stability and freedom from the ax, the beech-maple climax will develop over the vast second-growth areas, as evidenced by many stands of almost pure beech-maple on a wide range of soils and slopes in the region. Most conspicuous among the small under-trees are *Ostrya virginiana* and *Sassafras variifolium,* each with a frequency of 50 per cent or over throughout the strip transect.

Of the twelve species ranging from the top to the bottom of the river hills, some occur with greater frequency on the lower slopes and some on the upper slopes. For example, *Acer saccharum,* as is true of its codominant, *Fagus grandifolia,* has a frequency of 20 per cent at the top and 75 per cent at the bottom of the hills. Other species show a greater tendency towards a higher frequency at the top of the hills, as *Acer rubrum,* with 50 per cent at the top and 19 per cent at the bottom. Still others are more common away from the extremes of the ridge tops and the flood plain, as *Quercus alba,* with percentages as follows: 10, 46, 60, 45, 19, respectively. As already suggested, floristic differences such as these are indicative of environmental differences, since species have more or less characteristic ecological requirements. The hilltops are considerably more xerophytic than the lower slopes and the flood plain; evaporation is greater as a result of higher temperatures and increased wind movement, while the soil is conspicuously better drained and, in the dry summer periods, becomes dry and crusted. In contrast, the flood plain is essentially hydrophytic, while the middle slopes represent more nearly the average mesophytism of the region, without the more extreme physiographic influences.

In conclusion, the strip method can be shown to have certain advantages. First, the data can be easily and rapidly obtained. The present transect was laid out in two short working days and the lists of species completed. Prerequisite, of course, is a familiarity with the species encountered in such a survey, otherwise the time requirement would be greater. Secondly, the result of such a survey gives a considerably more definite idea of the vertical distribution of the woody species on the river hills than could be obtained by unaided observation.

QUADRAT STUDY

When an attempt was made to determine the frequency of individual species in the woodland from the percentages derived by the strip transect studies (in the strict usage of the term "frequency"), it was found that the data were inadequate, although the strip was equivalent to about seventy-seven quadrats, twenty-five feet on a side, laid out in a line. Consequently, it was decided to go into the field again and collect data from the same region by the use of regularly spaced quadrats (or sample squares), for purposes of comparison with the strip transect method and to obtain true "frequency" data. The river hills were again divided into zones on a basis of height above the river. Seven zones were selected. The lowest flood plain zone ranged from the river level to fifteen feet above, while the second zone was from fifteen to fifty feet above the river. The first zone includes the flood plain proper. This subdivision separates the lower slope from the true flood plain, which was not the case in the first study. The other zones were fifty feet in height, except the top one, which was only fifteen feet in height. In each of these seven zones ten quadrats were laid out which were fifty feet on a side and regularly spaced from one another. In each of these quadrats (seventy in all) the total woody flora was listed. The results of this survey are presented in Table II.

The quadrat study revealed sixty-eight species, in contrast to forty-five species which were encountered in the strip transect survey. The number of different species encountered in the separate altitudinal zones is interesting in comparison with the first survey, where there was a steady increase in number of species in successively lower zones. Here the largest numbers of species were found to be in the intermediate regions. From top to bottom the number of species in each zone were as follows: 34, 36, 53, 40, 47, 44, 21. Apparently, fewer species can compete in the flood plain, where the drainage and aeration are poor during most of the year, and, conversely, relatively fewer species can compete with those adapted for life on the hilltops, where the soil becomes dry and baked during the hot summer season. This is a very

TABLE II

Distribution and Frequency Percentage of Species on a River Bluff. Data from Quadrats in Seven Zones

Species	Height Classes in Feet Above the River 250-285	200-250	150-200	100-150	50-100	15-50	0-15	Average of All Quadrats
Rhus copallina	30	....	....	....	....	....	....	4
Juniperus virginiana	10	....	....	....	....	....	....	1
Vaccinium vacillans	30	20	20	....	....	....	....	10
Viburnum acerifolium	20	10	10	....	....	....	....	6
Amelanchier canadensis	20	10	10	....	....	....	....	6
Populus grandidentata	30	10	10	....	....	....	....	7
Quercus velutina	80	100	40	....	....	....	....	30
Rubus odoratus	20	70	20	20	....	....	....	19
Nyssa sylvatica	30	....	10	10	....	....	....	7
Quercus alba	60	40	40	40	20	....	....	29
Carya alba	20	10	40	20	10	....	....	14
Fraxinus americana	10	40	70	80	70	....	....	39
Celastrus scandens	40	20	30	....	10	....	....	14
Acer saccharum	100	100	100	100	100	100	....	86
Sassafras variifolium	100	80	70	50	80	90	....	67
Rubus allegheniensis	70	40	40	10	20	70	....	36
Hydrangea arborescens	60	80	30	40	40	40	....	41
Carya ovata	60	50	60	40	40	20	....	39
Quercus rubra	60	50	90	50	50	70	....	53
Acer rubrum	60	30	40	....	20	30	....	26
Fagus grandifolia	40	60	70	30	90	50	....	49
Ostrya virginiana	40	80	80	50	60	40	....	50
Rubus occidentalis	40	10	30	10	30	50	....	24
Prunus serotina	30	....	10	10	50	60	....	23
Ulmus fulva	30	50	20	50	40	80	....	37
Morus rubra	20	40	60	80	40	70	....	44
Evonymus atropurpureus	10	....	30	20	20	20	....	14
Liriodendron tulipifera	10	20	20	20	50	50	....	24
Vitis labrusca	80	50	90	70	90	50	20	64
Rhus toxicodendron	60	50	90	70	100	60	70	71
Cornus florida	60	100	80	60	80	50	10	63
Fraxinus lanceolata	60	80	90	50	70	90	70	73
Carya cordiformis	10	30	20	40	60	70	10	34
Tilia americana	10	60	30	10	....	10	10	19
Fraxinus quadrangulata	....	10	30	....	10	....	....	7
Juglans cinerea	....	20	60	20	70	40	....	30
Ulmus americana	....	20	30	50	70	20	....	27
Celtis occidentalis	....	40	40	20	30	100	....	33
Æsculus glabra	....	10	10	20	10	50	....	14
Asimina triloba	....	20	40	50	60	50	10	33
Sambucus canadensis	....	10	20	10	40	50	30	37
Quercus coccinea	....	....	10	....	....	....	....	1
Prunus virginiana	....	....	10	....	....	....	....	1
Gymnocladus dioica	....	....	40	20	....	....	....	9
Crategus sp?	....	....	10	20	50	....	....	11
Benzoin æstivale	....	....	40	30	40	30	....	20
Juglans nigra	....	....	30	10	....	60	....	14
Cercis canadensis	....	....	30	30	50	60	....	24
Rhus glabra	....	....	20	....	10	20	....	6

Species	Height Classes in Feet Above the River							Average of All Quadrats
	250-285	200-250	150-200	100-150	50-100	15-50	0-15	
Carpinus caroliniana......	....	....	10	70	50	60	20	30
Smilax glauca....	....	....	20	....	60	60	10	36
Rosa setigera	....	....	10	....	20	40	10	11
Gleditsia triacanthos......	....	....	40	....	10	10	20	11
Acer negundo..................	....	....	20	20	60	70	60	33
Platanus oecidentalis.	....	....	10	30	20	40	70	24
Quercus macrocarpa......	....	....	....	10	....	30	....	6
Betula nigra	....	....	....	....	10	....	....	1
Hamamelis virginiana....	....	....	....	....	10	....	....	1
Ribes cynosbati..............	....	....	....	....	10	30	....	6
Quercus muhlenbergii....	....	....	....	....	10	30	....	6
Acer nigrum....................	....	....	....	....	10	30	10	7
Ulmus racemosa......	....	....	....	....	10	80	70	23
*Fraxinus nigra...............	....	....	....	....	....	30	....	4
Cornus sp?	....	..	. ..	....	....	40	20	9
Acer saccharinum	....	....	....	....	....	....	100	14
Salix nigra	....	....	....	....	....	....	70	10
Populus deltoides...........	....	....	....	....	....	....	60	9
Tecoma radicans........ ...	....	....	....	....	....	....	20	3
Quadrats in each belt ...	10	10	10	10	10	10	10	....
Species in each belt ..... (Total 68)	34	36	53	40	47	44	21	....

widespread and well-known ecological situation: the more rigorous habitats, whether dry or wet, characteristically have fewer species than the intermediate typically mesophytic habitats.

Essentially the same species were found by the quadrat study to characterize the hilltops, but the more extensive quadrat survey reveals three new characteristic species, *viz., Rhus copallina, Juniperus virginiana* and *Amelanchier canadensis*.

The flood plain proper was found to contain twenty-one woody species, of which four were encountered nowhere else. They are *Acer saccharinum, Populus deltoides, Salix nigra* and *Tecoma radicans*. Five additional species occur in 60-70 per cent of the flood plain quadrats: *Fraxinus lanceolata, Rhus toxicodendron, Platanus occidentalis, Acer negundo* and *Ulmus racemosa*.

In a quadrat survey, the question of frequency of species and the indication of dominants are among the interesting results. In their admirable "Vocabulaire de Sociologie Vegetale," tbird edition, Braun-Blanquet and Pavillard (1) have this to say about "frequency" (freely translated):

"Frequency is a statistical idea (expression) which is derived by complete floristic lists from a certain number of sample areas (quadrats) of equal dimensions and disseminated as much as possible throughout the extent of the individual example of the association. The *frequency* of a species is then expressed in per cent by the relation between the number of quadrats which contained it and the total number of areas analyzed in the particular example of the association.

"The species are then usually divided into five *Classes of Frequency*, according to their percentages."

Strictly speaking, "dominance" is also a matter of degree, yet certain most characteristic species of considerable coverage are often referred to as "dominants." In Braun-Blanquet and Pavillard's vocabulary we find:

"To evaluate *dominance* one must be able to assign figures to each species with the exact significance as follows: 1, covering very slightly; 2, species covering between 1/20 and ¼ of the area of the association; 3, species covering between ¼ and ½ of the surface; 4, species covering between ½ and ¾ of the surface, and, 5, species covering more than ¾ of the surface."

Very little work has been done in the United States which would enable the investigators to assign degrees of dominance in this manner. Increasing attention should be paid to the methods of quantitative statistical analysis of vegetation which have been developed in the various European schools of ecology. Many American ecologists have followed the practice of referring to species of "high" frequency as "dominants," whereas, a species may be present in 100 per cent of the quadrats laid out in an association and still not be dominant because of its low surface coverage. The conception of which species are dominant is usually derived by observation unaided by the quantitative statistical methods of plant sociology. Our present field data do not permit the exact reference to any species as dominants, since the extent of coverage of each species in each quadrat was not determined. However, when we find, for example, that *Acer saccharum* has 100 per cent frequency in all zones except the flood plain, it must also be dominant.

There are certain other words which are constantly used in descriptions of vegetation which have come to have technical definitions and consequently should not be used laxly any longer. Three such words which might be appropriately considered here are *presence, constance* and *fidelity*. Returning again to the vocabulary cited above, we read: "*Presence* is established according to the existence or absence of a species in different examples (geographically separated) of an association. Certain species are met with a high regularity in all or nearly all the examples of an association encountered; others are lacking in a more or less large number. One can divide them into categories according to different degrees of presence. The *Constance* is an expression relative to presence, referring to selected samples of definite dimensions, but large enough, taken only once in each different stand of the association. In combining the results of constance with frequence, one obtains a synthetic expression of the distribution, more or less uniform, of the species in the different individual examples of the association. It is said to be an expression, more or less approximate, of the homogeneity of the association." *Fidelity* is considered as the extent to which species are confined to a particular plant association, or type of plant community.

In view of these concepts, if we consider the flood plain as a distinct association, four species have a complete fidelity, in that they are confined to the flood plain association in this particular survey. They are *Acer saccharinum, Salix nigra, Populus deltoides* and *Tecoma radicans.* Similarly, considering the upper slope and hilltops to be covered with a black oak association, above about two hundred feet, we find seven species with a high degree of fidelity, *viz., Quercus velutina, Populus grandidentata, Amelanchier canadensis, Viburnum acerifolium, Vaccinium vacillans, Juniperus virginiana* and *Rhus copallina.* The latter two are confined to the topmost zone.

In order to determine constance and presence in the strict technical use of the terms, surveys such as this one would have to be made in other localities where similar associations and situations are to be found. We have here only one instance or example of these river hill associations—one "stand," in the terminology of the foresters.

In a consideration of frequency, only quadrats laid out within the typical portion of the association (of a single association) can be considered in determination of frequence of species. Consequently, our first zone, from the river to fifteen feet above, which includes only the flood plain, must be considered separately and the frequency for the twenty-one species contained therein determined. The results are presented in Table III.

The frequency indices of the various species in the flood plain coincide with the normal expectancy in such work when the conditions of such study are fullfilled: a sufficient number of quadrats of sufficient area distributed throughout the association. That this analysis is ade-

TABLE III

Frequency Classes of the Species of the Flood Plain Association

Species	Raunkiaer's Frequency Classes A 0-20%	B 21-40%	C 41-60%	D 61-80%	E 81-100%
Acer nigrum	x				
Asimina triloba	x				
Carpinus caroliniana	x				
Carya cordiformis	x				
Cornus sp?	x				
Cornus florida	x				
Gleditsia triacanthos	x				
Rosa setigera	x				
Smilax glauca	x				
Tecoma radicans	x				
Tilia americana	x				
Vitis labrusca	x				
Sambucus canadensis		x			
Populus deltoides			x		
Acer negundo				x	
Fraxinus lanceolata				x	
Platanus occidentalis				x	
Rhus toxicodendron				x	
Salix nigra				x	
Ulmus racemosa				x	
Acer saccharinum					x
Number of species (21)	12	1	1	6	1

quate may be decided from a comparison of the results with standard frequency work. Kenoyer (3) has made a critical study of the frequency work, first developed by Raunkiaer (5). Raunkiaer, working on European associations, found that the species in an association, when arranged into five frequency classes, had the following grouping: Class A (1-20 per cent of the quadrats), 53 per cent of the total number of species encountered; Class B (21-40 per cent), 14 per cent of the species; Class C (41-60 per cent), 9 per cent of the species; Class D (61-80 per cent), 8 per cent of the species, and Class E (81-100 per ceut), 16 per cent of the species. In other words, there were two peaks in frequency. First, there was a large percentage of the species which were of low frequency (Class A) being encountered in 20 per cent or less of the quadrats. Second, there was another peak, or large percentage of the species which were of high frequency (Class E), being encountered in 81 per cent or more of the quadrats. This second peak is never as high as the former; in other words, there are fewer species of high frequency than there are of low frequency in an association. The smallest frequency class is usually Class D, although it may be Class

C. Raunkiaer's ratio of frequency classes, 53-14-9-8-16, was derived from an extensive study involving 8,087 percentages.

The work of Kenoyer on American association gives the following ratio: 69-12-6-4-9, showing the same two high points with the difference, as Kenoyer explained, that Class A is larger in American associations, due to the fact that our flora is generally richer in numbers of species.

The flood plain association, from the present analysis, gave the following ratio: Class A, 57 per cent; Class B, 5 per cent; Class C, 5 per cent; Class D, 28 per cent, and Class E, 5 per cent, revealing the two large frequency classes mentioned above. Generally speaking, when the two classes of large size are at either end of the scale, it may be concluded that the number and size of the quadrats is adequate and that a homogeneous association has been dealt with.

Next we have to consider the wooded slopes of the river hills above the flood plain. These woods are not virgin timber, yet they are relatively undisturbed in comparison to the majority of timbered areas in central Indiana and would be described generally as mixed hardwoods. The hilltops and upper slopes are occupied by what is more nearly an oak-hickory association, while the lower slopes are clothed with a more mesophytic growth, approaching the beech-maple association. The normal woodland succession is usually from the more xerophytic oak-hickory association, with black and red oak playing important roles in the makeup of the vegetation, followed by a white oak stage with an admixture of more mesophytic species, which finally gives way to the beech-maple climax association. The succession, developing towards the beech-maple association, is further along on the lower slopes than on the upper slopes and ridge tops. This can be seen from the following percentages of critical species, Table IV:

TABLE IV

Frequency of More Important Species of the Oak and Beech-Maple Associations

Species	Frequency Per Cent by Altitudinal Zones						
	250-285	200-250	150-200	100-150	50-100	15-50	0-15
Quercus velutina	80	100	40	....	....	....	....
Quercus rubra	60	50	90	50	50	70	....
Quercus alba	60	40	40	40	20	....	....
Carya ovata	60	50	60	40	40	20	....
Carya alba	20	10	40	20	10	....	....
Fagus grandifolia	40	60	70	30	90	50	....
Acer saccharum	100	100	100	100	100	100	....

TABLE V

Frequency Classes of the Hilltop Species

Species	A 0-20%	B 21-40%	C 41-60%	D 61-80%	E 81-100%
	Frequency Classes				
Æsculus glabra	x				
Amelanchier canadensis	x				
Asimina triloba	x				
Carya alba	x				
Carya cordiformis	x				
Celtis occidentalis	x				
Evonymus atropurpureus	x				
Fraxinus quadrangulata	x				
Juglans cinerea	x				
Juniperus virginiana	x				
Liriodendron tulipifera	x				
Nyssa sylvatica	x				
Populus grandidentata	x				
Prunus serotina	x				
Rhus copallina	x				
Sambucus canadensis	x				
Ulmus americana	x				
Viburnum acerifolium	x				
Celastrus scandens		x			
Fraxinus americana		x			
Morus rubra		x			
Rubus occidentalis		x			
Tilia americana		x			
Ulmus fulva		x			
Vaccinium vacillans		x			
Acer rubrum			x		
Carya ovata			x		
Fagus grandifolia			x		
Ostrya virginiana			x		
Quercus alba			x		
Quercus rubra			x		
Rubus odoratus			x		
Rubus allegheniensis			x		
Rhus toxicodendron			x		
Cornus florida				x	
Fraxinus lanceolata				x	
Hydrangea arborescens				x	
Vitis labrusca				x	
Acer saccharum					x
Quercus velutina					x
Sassafras variifolium					x
No. of species (41)	18	7	9	4	3
Percentage	44	17	22	10	7

The hilltops being more nearly representative of the oak-hickory association, the upper two zones (from 200 to 285 feet) were treated so as to reveal the frequencies of the species. These results are expressed in Table V. The ratio of the classes here revealed is not that of the typical Raunkiaerian type. The second peak, represented by the large size of Class E, is absent in the results: 44-17-22-10-7. The conclusion to be drawn, and which had already been anticipated, is that the plant community here dealt with is not a good homogeneous example of the oak-hickory association. Similarly, the lower slopes are approaching the beech-maple association but are not yet typically developed, for, if such were the case, the frequency results would reveal the "dominants" as composing Class E, and also constituting a second peak, *i. e.*, more species falling into Class E than in Class C or D.

SUMMARY

1. This report covers analyses of the woody vegetation of certain central Indiana river hills by two methods: (1) strip transect method; (2) quadrat method, with a discussion of the advantages of each in revealing the content and distribution of the woody flora.

2. The vertical distribution of the species is emphasized, in relation to habitat factors, by a treatment involving altitudinal zones.

3. The question of frequency of the species is considered and certain terms used in plant sociology are discussed.

4. The use of Raunkiaer's and Kenoyer's ratios of frequency classes is considered as to their value in checking the adequacy of the quadrat survey, and whether or not the plant community dealt with is a good example of the association under consideration.

5. The present study is of academic interest only, but many problems of practical importance involve methods of analysis of vegetation here discussed.

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