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The *Butler University Botanical Studies* journal was published by the Botany Department of Butler University, Indianapolis, Indiana, from 1929 to 1964. The scientific journal featured original papers primarily on plant ecology, taxonomy, and microbiology. The papers contain valuable historical studies, especially floristic surveys that document Indiana's vegetation in past decades. Authors were Butler faculty, current and former master's degree students and undergraduates, and other Indiana botanists. The journal was started by Stanley Cain, noted conservation biologist, and edited through most of its years of production by Ray C. Friesner, Butler's first botanist and founder of the department in 1919. The journal was distributed to learned societies and libraries through exchange.

During the years of the journal's publication, the Butler University Botany Department had an active program of research and student training. 201 bachelor's degrees and 75 master's degrees in Botany were conferred during this period. Thirty-five of these graduates went on to earn doctorates at other institutions.

The Botany Department attracted many notable faculty members and students. Distinguished faculty, in addition to Cain and Friesner , included John E. Potzger, a forest ecologist and palynologist, Willard Nelson Clute, co-founder of the American Fern Society, Marion T. Hall, former director of the Morton Arboretum, C. Mervin Palmer, Rex Webster, and John Pelton. Some of the former undergraduate and master's students who made active contributions to the fields of botany and ecology include Dwight. W. Billings, Fay Kenoyer Daily, William A. Daily, Rexford Daudenmire, Francis Hueber, Frank McCormick, Scott McCoy, Robert Petty, Potzger, Helene Starcs, and Theodore Sperry. Cain, Daubenmire, Potzger, and Billings served as Presidents of the Ecological Society of America.

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CORRELATION OF MICROCLIMATIC FACTORS WITH SPECIES DISTRIBUTION IN SHENK'S WOODS, HOWARD COUNTY, INDIANA

By Ray C. Friesner and Charles M. Ek

In furtherance of the plan of the Botany Department of Butler University to place on record as rapidly as possible analyses of as many of the remnants of the forest primeval as can be studied before the woodsman's saw and ax make it too late, we here present an additional study in which certain microclimatic factors seemed to show a sharp, if not causal, correlation with the distribution of both woody and herbaceous species. Previous papers published as a part of this plan are those of Potzger and Friesner (1, 2, 3) and Potzger Friesner and Keller (4).

Shenk's woods is a tract of approximately 100 acres and is the first woods north of Sycamore Street road 6.5 miles east of Kokomo. At first sight the area very obviously supports two sharply differentiated forest types and this led to the additional study of causal relationships. The data upon which study was made were collected during the year 1941.

PHYSIOGRAPHY AND SOIL FEATURES

Shenk's woods occupies an area of almost flat and level land. Surface drainage is practically negligible though the site occupied by the Acer-Quercus-Fagus community is, at its extreme elevation, 1-2 feet higher than the lowest part of the area occupied by the Quercus-Ulmus community. Wildcat Creek has cut a valley 25-30 feet deeper than the level of this woods and paralleling it a mile to the south and so probably receives, via underground drainage, what drainage the area has.

The soil of the woods is a heavy clay loam underlain at considerable depth by glacial gravels. That occupied by the Acer-Quercus-Fagus community is somewhat less compact in texture with somewhat larger particles as evidenced by a lower moisture equivalent. A number of kettle-hole bogs as well as usable gravel deposits are within a few miles of the area.

METHODS

Sixty-five 100-square meter quadrats were used for securing the quantitative data; 25 being in area A, and 20 each in areas B and C. A stout cord divided by loops into four 10-meter sections, rolled on a reel, was used for outlining the limits of the quadrats. The loops were hung over sharpened wooden stakes forced into the ground and facilitated rapid demarkation of the areas. Quadrats were evenly spaced in rows which in turn were spaced so as to give a uniform distribution of the quadrats over each of the entire areas. During the procedure one person laid out the quadrats, another called the species and measured all stems 1-inch DBH. or above, a third worker recorded the stems as called, while a fourth wound up the cord, pulled stakes of completed quadrats and carried apparatus forward to the worker who laid out the quadrats. Such a team of 4 workers could readily complete as many as 100 quadrats in a day of work. All stems of young trees less than 1 inch DBH. but 1 meter high or over were also counted and recorded. From the data so compiled any size class could be used for whatever purpose it might later be needed in drawing conclusions. For example: basal areas computed from stems of tall tree species 3 inches DBH. and over would give a fair quantitative estimate of percentages in the crown cover; numbers of stems below 1 inch DBH. and 1 meter high or over were considered to present a reasonably accurate picture of reproduction.

In the center of each quadrat used for study of woody species in areas A and B there was also laid out, during the dormant season, a 1-meter quadrat which was later used for enumeration of the spring, summer and autumn herbaceous flora. The quadrats were delimited by heavy wire stakes at each of their four corners. When enumeration of the herbaceous flora was in progress a heavy cord slipped into loops at the top of each wire stake definitely laid off each quadrat from the surrounding area. Having thus been laid off during the dormant season, there was no chance for prejudice or selection in choosing more or less heavily populated sites for the quadrats. Such a procedure was followed in earlier work by Potzger and Friesner (5) in studies on the herbaceous species in different types of forest areas and found to be highly satisfactory.

Five atmometer stations were established in each of areas A and B and readings of evaporation loss were taken weekly from May 29 to September 20 inclusive. Atmometers were standardized at the beginning and the end of the season and all evaporation data were standardized to the mean coefficient of each atmometer which yielded them.

At the same time that atmometer data were being collected samples of soil were obtained within a radius of 10 meters of each atmometer and placed in air-tight containers for determination of soil moisture. Samples were taken in duplicate from surface (i.e., immediately under the duff layer), 6-inch and 12-inch depths. Percentage of moisture present in each sample, each week from May 1 through October 3, was determined by weighing the soils before and after dessication in a constant temperature oven at 103° C. The wilting coefficient of each soil was also obtained and from these two sets of figures the percentage of growth water in each sample for each week was obtained. Wilting coefficient was obtained by the formula $W.C. = \frac{ME}{1.84}$ where M.E. is the percentage of water remaining in soil previously saturated after centrifuging at 2440 revolutions per minute for 20 minutes.

RESULTS

WOODY FLORA

Results from quadrat studies of woody flora are tabulated and summarized in tables I and II. A study of these tables will show that area A and C may be considered Quercus-Ulmus areas and area B an Acer-Quercus-Fagus area. In area A, 48.61% of the crown cover (determined by the percentage of basal area of stems 3 inches and over DBH. among the tall tree species, i.e., excluding from consideration all under-story species) is made up of 4 of the more mesophytic species of Quercus, viz. *Q. bicolor, Q. borealis* var. *maxima, Q. macrocarpa* and *Q. muhlenbergii;* and 22.95% comprises 2 species of Ulmus, viz. *U. americana* and *U. fulva.* None of the Quercus species show a high frequency and all of them combined show an F. I. of only 48%. *Ulmus americana,* on the other hand, shows an F.I. of 84% and *U. fulva,* 40%. These differences are correlated with striking differences in the number of stems in smaller and larger size classes. Whereas in Quercus there are few stems below 16 inches DBH., in Ulmus 73% of the stems are below 3 inches DBH. Other species worthy of note in area A are *Acer saccharum,* 5.03% of the crown cover; *A. saccharinum,* 7.59;

Fraxinus americana, 6.03; *Platanus occidentalis*, 4.66. These data are presented in tabular form in table II.

Area C shows results quite similar to area A. The differences most worthy of note being a 4% increase in Quercus and the relative positions in crown cover between *Ulmus americana* and *U. fulva* being reversed. In addition, *Tilia americana* has made more than a fair showing and *Fagus grandifolia* shows a considerable increase.

In area B, on the other hand, a striking contrast is seen. Here *Acer saccharum* becomes the dominant species, occupying 58% of the crown cover while Quercus, still showing 16.97%, entirely lacks *Q. bicolor*, its most mesophytic form of area A. *Fagus grandifolia* occupies 9.88% of the crown cover in area B with other species as follows: *Ulmus fulva, 7.21%*; *Tilia americana,* 6.78% and *Fraxinus americana,* 6.78%.

HERBACEOUS FLORA

Study of the herbaceous flora in the two areas reveals some very striking differences (table III) which reflect the habitat differences and thus throw light upon the edaphic relations of the forest associations. It will be noted from the table that the early spring-flowering species are in low frequency or entirely absent in the Quercus-Ulmus area. Only 4 vernal species reach a frequency index above 20% and only one of these is very early in their time of flowering. They are *Arisaema atrorubens, Galium aparine, Osmorrhiza claytoni,* and *Viola eriocarpa.* The Acer-Quercus-Fagus area, on the other hand, contained 9 species with F.I. above 20% and the species present include the common early-flowering species of the region, e.g., *Claytonia virginica, Dentaria laciniata, Dicentra cucullaria, Erythronium americanum, Hydrophyllum appendiculatum, Ranunculus abortivus,* and *Viola eriocarpa.*

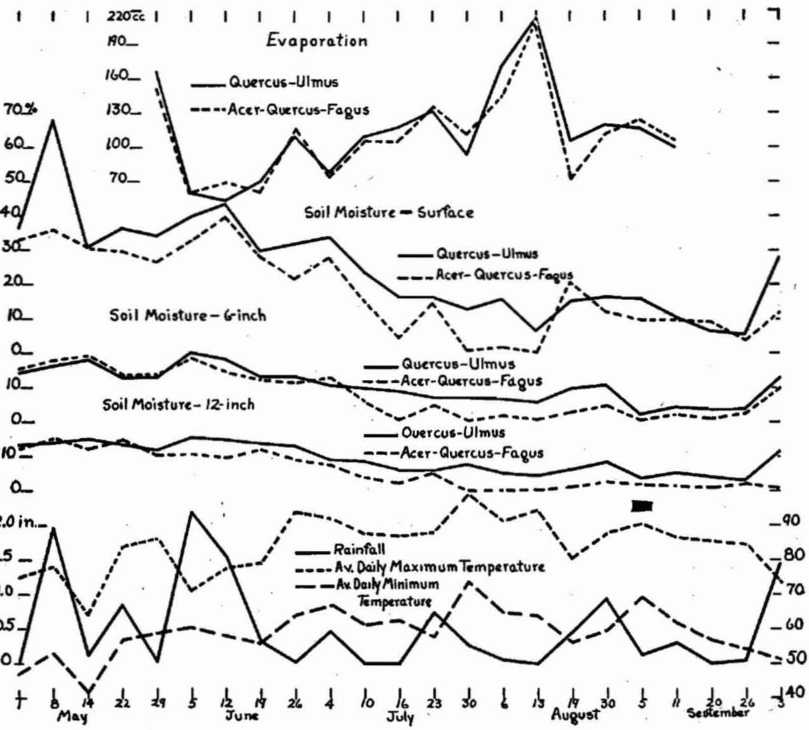
These differences in the vernal herbaceous flora are correlated with soil differences between the two areas. The soil of the Quercus-Ulumus area is much more compact, is composed of much more finely divided particles, and has a higher growth-water content in addition to a higher wilting coefficient than that of the Acer-Quercus-Fagus area. These differences would also seem to indicate a lower air content and a slower spring warming of the soil in the Quercus-Ulmus area.

The aestival species do not reveal any major differences of diagnostic value. The presence of *Impatiens biflora* (table II), in the Quercus-Ulmus area and its absence in the Acer-Quercus-Fagus area, together with the greater frequency of *Campanula americana* and *Osmorrhiza longistylis* in the former area, are the chief indicators among the aestival species.

The autumnal species are few and strikingly low in frequency but the high frequency of *Polyonum virginianum* in the Quercus-Ulmus area may have indicator value.

EVAPORATION DATA

Evaporation data collected from 5 atmometers stationed in each of the forest areas from May 22 to September 11 are shown in fig. 1. It will be seen that the curves (showing standardized results) very



closely parallel each other emphasizing the correlation of the curves with weekly differences in meteorological data. If there are any differences worthy of note between the data of the two areas they are the fact that when the evaporation rate is very high (e.g., weeks ending May 29 and August 6, 13) it is a little higher in the Quercus-Ulmus area than in the Acer-Quercus-Fagus area and that during 9 of the 16 weeks the rate of loss is higher in the former area while during 6 weeks it is higher in the latter area. In considering these differences it should be pointed out that the Quercus-Ulmus area occupies the northern part of the woods and the Acer-Quercus-Fagus area is in the southern portion. This, taken with the fact that the prevailing winds come from the southwest would, other things being equal, lead us to expect a generally higher loss in the Acer-Quercus-Fagus area. The slightly greater loss during the larger number of weeks in the Quercus-Ulmus area is associated with smaller frequency of understory species, the higher forest canopy and thus a more open area which permits better air circulation.

SOIL MOISTURE RELATIONS

Soils for determination of moisture conditions were taken weekly from May 1 to October 3 at 5 stations in each of the forest areas. They were taken at surface, 6-inch and 12-inch depths. Figures 2, 3 and 4 present the percentage of growth water, i.e., the percentage of water in each soil above the wilting coefficient for that soil. It will be noted that the wilting coefficient is higher at all horizons in the Quercus-Ulmus than in the Acer-Quercus-Fagus areas though the difference becomes successively less with increased depth of soil. In spite of the higher wilting coefficient, the remaining available soil moisture is considerably higher at all horizons for nearly every week during the season in the Quercus-Ulmus area than in the Acer-Quercus-Fagus area. This is especially true during the driest part of the season when the available moisture is lowest and the evaporation is highest. Thus during the critical part of the season when the demands of the atmosphere upon the vegetation for moisture are greatest the available supply in the soil is higher in the Quercus-Ulmus area.

CORRELATION OF FLORISTIC AND EDAPHIC FACTORS

From the foregoing it is apparent that the Shenk woods area falls sharply into two parts which differ materially both floristically and edaphically. The Quercus-Ulmus portion of this woods contains a forest camopy in which 4 of the more mesophytic species of Quercus and 2 species of Ulmus occupy 71.56% of the crown cover and from which the early spring herbaceous species are conspicuously absent. The soil is more compact with more finely divided particles and has a higher wilting coefficient, a higher total moisture content and a higher available moisture with a correspondingly lower air content. The few vernal-flowering herbaceous species present are those which flower later in the season, correlated with a slower spring warming of the soil, and whose subterranean organs can tolerate a less aerated soil.

The second portion of this woods contains a forest canopy in which *Acer saccharum* occupies 58% with Quercus and *Fagus grandifolia* occupying an additional 26.85% of the crown cover and in which the common early spring flowering species of this region are present. The soil is less compact with less finely divided particles, a lower wilting coefficient, a lower total moisture and lower available moisture content with a correspondingly higher aeration and more rapid warming rate in the early spring.

The data at hand do not clearly indicate whether the critical and determining edaphic factor differentiating the site for the Quercus-Ulmus area from that for the Acer-Quercus-Fagus area is soil moisture or soil air content. It is probable, since both areas contain nearly the same species of Quercus, though in considerably different percentages of crown cover, that the differentiation results from (1) the fact that Quercus and Ulmus occupy sites which *Acer saccharum* cannot tolerate (areas A and C) and (2) *Acer saccharum* finds more suitable edaphic conditions in area B where Quercus is present also but kept to a lower percentage by competition. This is to say, Quercus-Ulmus form a slightly more hydrophytic pre-climax and occupy sites which are not quite suitable for the climax species, *Acer saccharum* and *Fagus grandifolia.* There is a strong tendency as one studies this forest to conclude that soil aeration (the inverse of soil moisture and soil compactness) is the critical edaphic factor which limits the location of the Acer-Fagus association and, of course, indirectly through competition, also delimits the Quercus-Ulmus community.

CONCLUSIONS

1. The Shenk woods are is sharply differentiated into two types of forest communities, viz. Quercus-Ulmus and Acer-Quercus-Fagus.

2. The Quercus-Ulmus community occurs on soils which are

more compact, comprising more finely divided particles; with a higher wilting coefficient, higher growth water content and lower air content.

3. The Acer-Quercus-Fagus community occurs on soils which are less compact, with less finely divided particles; with a lower wilting coefficient, lower water content and higher air content.

4. Soil aeration is probably the critical factor limiting Acer and Fagus: Quercus and Ulmus occurring on sites with a lower air content than the former can tolerate and on sites with the former but in strong competition with them.

5. The vernal herbaceous flora shows a striking correlation with the woody species and with the edaphic conditions: the early flowering species being almost entirely absent in the Quercus-Ulmus communities where aeration is low, drainage poor and soil warming in the spring is late, but abundant in the Acer-Quercus-Fagus community.

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TABLE I

Woody flora in 25 quadrats of area A and 20 quadrats each in areas B and C

													Stems 3-in. or more	
Species	Area	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-25	26-30	Above 30 in.	Total 1 in.+	F. I.	Basal Area	% Crown Cover
Quercus alba	A	0										0	0	0
	B	0										0	0	0
	C	0	2		1				1	5	9	30	7140.07	30.4
Q. bicolor	A	0						5	4	1	10	20	5742.84	28.71
	B	1									0	5	0	0
	C	2					1		2	1	4	25	2446.53	10.3
Q. borealis var. maxima	A	2					5	1			8	24	2234.46	11.17
	B	9					1	1			2	35	663.66	4.65
	C	0									0	0	0	0
Q. macrocarpa	A						1			1	2	8	1332.04	6.66
	B									1	1	5	1320.26	9.42
	C								1	1	2	10	1237.79	5.3
Q. muhlenbergii	A						1	1			2	8	415.48	2.07
	B											0	0	0
	C											0	0	0
Q. shumardii	A											0	0	0
	B							1			1	5	415.48	2.90
	C							2	1		3	10	1611.64	6.9
Quercus—all species	A	2					7	6	6	3	22	48	9724.82	48.61
	B	10					1	2	0	1	4	50	2399.40	16.97
	C	2	2		1		1	2	5	7	18	65	12436.03	53.0
Ulmus americana	A	21	62	18	3	4	3	1	2	1	95	84	3776.53	18.88
	B	89	1	1							2	30	7.07	.05
	C	2	12	5	0	1	0	1	1		20	65	1324.19	5.67

TABLE I (Continued)

Woody flora in 25 quadrats of area A and 20 quadrats each in areas B and C

Species	Area	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-25	26-30	Above 30 in.	Total 1 in.+	F. I.	Stems 3-in. or more	
													Basal Area	% Crown Cover
U. fulva	A	20	8	2	1	5	1				17	40	914.54	4.07
	B	248	2	1		1	3				7	95	1026.51	7.21
	C	25	32	17	4	1	0	1	1	1	57	80	2688.74	11.5
Fraxinus americana	A	59	18	11	3		1		1		34	92	1207.39	6.03
	B	13				1					1	50	153.94	1.09
	C	19	5				1	1	1		8	65	1279.42	5.65
F. quadrangulata	A	0	1			1					2	4	113.10	.56
	B	0									0	0	0	0
	C	0				1					1	5	132.73	0.57
Acer saccharum	A	59	13	2	2	2	2				21	76	1007.33	5.03
	B	297	10	2	5	24	12	5			58	100	8113.22	58.00
	C	141	50	2	3	4		1			60	100	796.48	3.40
A. saccharinum	A	15	12	12	1		1	1	1		28	36	1518.98	7.59
	B	0	1								1	5	0	0
	C	2	0	1							1	15	7.07	.03
A. negundo	A	13	4								4	8	0	0
	B	1									0	5	0	0
	C	1	1	1							2	10	7.07	.03
Fagus grandifolia	A	0	1			1					2	8	176.72	.88
	B	7	15		1	3	1		1		21	25	1383.10	9.88
	C	1	1			3	1	1			6	30	1183.60	5.05
Celtis occidentalis	A	18	23	9	1		1				34	64	128.03	.64
	B	5	2								2	15	0	0
	C	10	14	2							16	55	26.71	.11

TABLE I (Continued)
Woody flora in 25 quadrats of area A and 20 quadrats each in areas B and C

Species	Area	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-25	26-30	Above 30 in.	Total 1 in.+	F. I.	Stems 3-in. or more: Basal Area	Stems 3-in. or more: % Crown Cover
Carya cordiformis	A	11	3				1				4	36	254.47	1 27
	B	2									0	10	0	0
	C	7	1		1	1					3	35	255.26	1.09
C. ovata	A	6	1		4	1					6	36	288.23	1.44
	B	2									0	5	0	0
	C	1	2			1	1				4	25	490.88	2.10
Tilia americana	A	10	10	3			1				14	28	14.14	.07
	B	19	14	1				2			17	60	950.34	6.78
	C	6	11	3	4	1	5	1			25	40	2194.62	9.41
Liriodendron tulipifera	A	0	1	1	1						3	8	58.13	.29
	B	0									0	0	0	0
	C	0									0	0	0	0
Prunus serotina	A	0	1								1	4	0	0
	B	8									0	25	0	0
	C	4	7	2							9	40	25.14	.11
Juglans nigra	A	0									0	0	0	0
	B	1									0	5	0	0
	C	0									0	0	0	0
J. cinerea	A	1									0	4	0	0
	B	0									0	0	0	0
	C	0									0	0	0	0
Gymnocladus dioica	A	1									0	4	0	0
	B	0									0	0	0	0
	C	0	1								1	5	490.88	2.10

TABLE I (Continued)

Woody flora in 25 quadrats of area A and 20 quadrats each in areas B and C

Species	Area	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-25	26-30	Above 30 in.	Total 1 in.+	F. I.	Stems 3-in. or more	
													Basal Area	% Crown Cover
Platanus occidentalis	A	0					1		1		2	8	933.84	4.66
	B	0									0	0	0	0
	C	0							1		1	5	706.86	3.03
Aesculus glabra	A	4			1	1					2	16		
	B	10	1			1					2	50		
	C	2	1	1	8						10	50	383.87	
Morus rubra	A	0									0	0		
	B	0									0	0		
	C	1									0	5	0	
Carpinus caroliniana	A	26	9	5							14	44		
	B	1									0	5		
	C	8	3								3	40	0	
Ostrya virginiana	A	2	1	2							3	8		
	B	4									0	15		
	C	12	21	1	2						24	60	73.82	
Asimina triloba	A	42									0	16		
	B	183	63								63	45		
	C	103	6	0	2						8	25	106.81	
Cornus florida	A	0									0	0		
	B	0									0	0		
	C	0	1								1	5		
Crataegus sp?	A	0		1	1						2	8		
	B	0									0	0		
	C	0									0	0		

TABLE I (Continued)

Woody flora in 25 quadrats of area A and 20 quadrats each in areas B and C

Species	Area	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-25	26-30	Above 30 in.	Total 1 in.+	F. I.	Stems 3-in. or more Basal Area	% Crown Cover
Evonymus atropurpureus	A	3									0	4		
	B	2									0	5		
	C	1									0	5		
Viburnum prunifolium	A	0									0	0		
	B	0									0	0		
	C	27									0	15		
Lindera benzoin	A	196									0	60		
	B	19									0	40		
	C	21	2								2	45		
Cornus asperifolia	A	131	6								6	48		
	B	1									0	5		
	C	20	16								16	50		
Smilax hispida	A	2										8		
	B	0										0		
	C	0										0		
Sambucus canadensis	A	1										4		
	B	0										0		
	C	0										0		
Vitis sp?	A	11										8		
	B	0										0		
	C	0										0		

Totals—A—20,116.25
B—14,033.58
C—23,338.82

TABLE II

Percentage of crown cover (based on basal areas of stems 3 inches or over DBH.) occupied by each of the important species of tall trees in each of the 3 areas.

Species of tall trees	Area A	Area B	Area C
Quercus spp.	48.61	16.97	53.00
Acer saccharum	5.03	58.00	3.40
Acer saccharinum	7.59	0	.03
Ulmus spp.	22.95	7.26	17.17
Fraxinus americana	6.03	1.09	5.65
Fagus graudifolia	0.88	9.88	5.05
Tilia americana	0.07	6.78	9.41
Plantanus occidentalis	4.66	0	3.03

TABLE III

Herbaceous species. Showing frequency index in Quercus-Ulmus and Acer-Quercus-Fagus areas.

Species	A. Quercus-Ulmus	B. Acer-Quercus-Fagus
Vernal Species		
Arisaema atrorubens	80	20
Claytonia virginica	16	50
Dentaria laciniata	0	40
Dicentra cucullaria	8	70
Erythronium americanum	0	50
Evonymus obovatus	16	0
Galium aparine	100	30
Geum vernum	16	20
Hydrophyllum appendiculatum	20	100
Osmorrhiza claytoni	60	40
Phlox divaricata	8	0
Ranunculus abortivus	8	30
Trillium recurvatum	0	20
Viola eriocarpa	48	100
Aestival Species		
Agastache nepetoides	0	20
Amphicarpa bracteata	20	20
Blephilia hirsuta	0	20
Campanula americana	60	20
Cryptotaenia canadensis	20	40
Cystopteris fragilis var. protrusa	0	20
Galium circaezans	0	20
G. triflorum	40	40
Geum canadense	100	80

TABLE III (Continued)

Herbaceous species. Showing frequency index in Quercus-Ulmus and Acer-Quercus-Fagus areas.

Species	A. Quercus-Ulmus	B. Acer-Quercus Fagus
Hackelia virginiana	0	40
Impatiens biflora	40	0
Laportea canadensis	40	60
Monarda clinopodia	8	0
Osmorrhiza longistylis	60	20
Oxalis stricta	0	40
Parietaria pennsylvanica	0	80
Phryma leptostachya	60	80
Phytolaca americana	0	40
Pilca pumila	0	80
Prunella vulgaris var. lanceolata	0	20
Sanicula canadensis	60	40
Scutellaria lateriflora	0	20
Atumnal Species		
Aster sp.	20	20
Bidens frondosa	0	20
B. vulgata	20	0
Collinsonia canadensis	0	20
Desmodium paniculatum	0	20
Erigeron canadense	0	20
Hedeoma pulegioides	0	40
Helianthus decapetalus	0	20
Polygonum punctatum	0	20
P. virginianum	80	20
Scrophularia marilandica	0	20
Solanum nigrum	0	20
Solidago altissima	0	20
Verbena urticaefolia	0	20