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ON THE PHYTOCOENOLOGICAL VALUE OF A SPECIES

Detailed study of Estonian spruce forests

Introduction

In quite a considerable part of relevant literature each community type is described as having a characteristic composition and structure.

There are, however, different leading assemblages on the basis of the same floristic composition, and our task is to describe the composition of the community quantitatively, as well. The characteristics of number (density), coverage, and pattern (frequency, aggregation) are separate and distinct attributes of the structure of the community, though it is difficult to evaluate them simultaneously by a single estimate, since there are no indications of their informative value. In this respect, the coverage is perhaps of the greatest value, but the exclusive application of coverage at the evaluation does not yield satisfactory results.

It would be desirable to determine the compositional or phytocoenological value for each species on a quantitative basis. One example of such a reflection is the total estimate as employed by the plant sociologists of the Braun-Blanquet school, which is a combination of abundance and coverage estimates (Braun-Blanquet, 1932) on a "semiquantitative" level.

In 1947, Curtis introduced the *DFD* index, based on the sum of the percentage density, percentage frequency, and percentage dominance (coverage).

Somewhat later (1951) a new index, the "importance value" (*IVI*), which differs only in one respect from the *DFD* index, was introduced by Curtis and McIntosh.

Ponyatovskaya and Syrokomskaya (Понятовская, Сырокомская, 1960) suggested an index based on the product of density by cover, and Butorina (Буторина, 1963) claims that a useful measure may be the multiplication of abundance by weighted mean constancy, etc.

Various suggestions have been made to employ certain weighed characteristics, using Czekanowski's (1913, cited by Curtis, 1959) index of similarity (Gleason, 1920; Dagnelie, 1960; Pandeya, 1961), but such an approach is, as pointed out by Greig-Smith (1964), less precise. Among the indices mentioned above, the *IVI* index is likely to be of the greatest interest, although open to criticism, since the way of combining seems quite arbitrary.

Relative density (the proportion of the density of a species to that of the stand as a whole) and relative dominance (the proportion of the basal area of a species to the stand as a whole) have been computed as in the *DFD* index.

The difference is in frequency which is also calculated so as to be a relative rather than a usual direct expression of frequency percentage. In the work by Curtis (1959), Curtis and Cottam (1962), etc., the authors claim that this index is an excellent indication of the vegetational importance of a species within a stand.

Taking the above-mentioned views for granted, we have decided to use the importance-value index in expressing the quantitative relations of the floristic relevé of the ground-layer of spruce communities *(Picea abies* (L.) Karst.) in Estonian forests.

The sampling method used will be described in the second paper of this series.

The basal areas as well as the exact cover estimates of the ground-layer species were impossible or very difficult to determine; however, the wet weight of the surficial parts of herbaceous plants was employed to express the relative dominance, since there were some indications of an actual linear relationship between weight and coverage (Ramenski: Раменский, 1938; Ipatov: Ипатов, 1962).

The results for 10 stands, each containing one sample-area examined by 10 clip quadrats of 1 × 1 sq. m are expressed in table 1.

On the basis of the same data another technique was employed.

Discussion and Results

I. Criticism of Density. Density may be a misleading characteristic, especially relative density, computed on the basis of the sum of the densities of different species. One of the reasons for this is that the relative density of a certain number of individuals is higher when overall density is low, and lower when the entire complement is accordingly more abundant.

At the same time, the densities of certain species cannot be compared with each other. Thus it is impossible to compare *Anemone nemorosa* with *Dryopteris filix-mas* since the weight and the average biomass of the latter exceeds that of the former by ca 20 times. Likewise, both the above-mentioned species noticeably vary in size. The small individuals of *Anemone nemorosa* may be 20 times smaller than the average plant, and those of *Dryopteris filix-mas* may be even 30 times smaller. Finally, the question arises as to whether young seedlings should be taken into consideration since up to 80 per cent of them may be destroyed by the middle of summer.

Unfortunately, the weight of the juvenile plants may turn out quite significant; for instance, in clip quadrat 0079, on June 3 and 18, 1962, there were 12 average and 78 small *Anemone nemorosa* plants. As checked at the beginning of July, the respective figures were 10 and 20.

Lastly, the greatest drawback is that whereas the obtaining of accurate data on the herbaceous species is connected with very complicated, meticulous and hard work, the density of tree species does not contain any particular methodical difficulties. An accurate estimate of the density of the species with vegetative reproduction is impossible. Furthermore, it is difficult to decide where an individual plant begins and where it ends, and what should be taken into account. Thus we must be satisfied with counting the number of shoots. The latter estimations may be only used for a determination and evaluation of the changes in the

Table 1

A comparison of the *IVI* and *FCW* values for most frequent groundlayer species with reference to some other characteristics

Characteristic / Sample-area No / Species	*IVI* (importance value index)												*FCW* (frequency coefficient of weight)												Total		
	00	01	02	03	04	05	06	07	08	11	*IVI*	Ordination	Ordination	*FCW*	00	01	02	03	04	05	06	07	08	11	*D*	*W*	*F*
																									ind./100 sq.m	g/100 sq.m	percentage of 1000
Galeobdolon luteum Huds.	367	413	506	465	431	598	385	407		605	4,177	2	1	1,769	208	195	229	183	193	253	153	115		235	9,040	4,141.7	83.1
Oxalis acetosella L.	601	516	747	736	794	795	454	853	857	699	7,052	1	2	1,732	189	144	199	171	199	216	118	154	167	175	28,001	3,345.4	98.6
Hepatica nobilis Gars.	80	11	52	313	334	73	72	57	193	195	1,380	4	3	667	52	3	27	170	173	25	34	13	76	94	1,506	1,375.5	43.1
Majanthemum bifolium (L.) Fr. Schmidt	231	106	100	107	129	101	362	410	208	118	1,872	3	4	564	96	44	28	29	42	30	120	94	46	35	4,103	569.8	68.1
Anemone nemorosa L.	214	135	193	156	161	112	25	115	37	54	1,202	5	5	528	126	67	98	73	67	44	5	25	4	19	1,729	646.1	52.7
Dryopteris linnaeana Christens	234	60	44	130	164	31	77	201	95	126	1,162	6	6	482	146	23	17	52	74	10	31	47	16	48	2,139	843.2	36.1
Stellaria nemorum L.	143	232	179	187	20	68			66		895	8	7	353	10	130	99	67	7	22			18		1,070	1,057.7	27.5
Dryopteris spinulosa (Müll.) Ktze.	216	112	150	46	35	75	94	94	43	4	869	9	8	311	117	28	64	9	5	22	40	12	14	+	431	1,648.4	11.5
Rubus saxatilis L.	25	2	60	46	92	63	74	79	126	117	684	11	9	310	12	+	31	18	58	23	42	22	41	63	458	669.8	23.9
Calamagrostis arundinacea Roth.	69		180	13	13		145	309	10	197	936	7	10	292	35		78	3	1		38	78	1	58	2,336	1,090.8	13.6
Luzula pilosa (L.) Wills.	71	82	76	23	25	88	89	57	98	50	659	12	11	264	36	37	45	7	8	33	34	14	26	24	1,073	458.8	25.7
Crepis paludosa (L.) Moench.	54	95	7	19	56	1	220		48		500	16	12	250	30	56	2	7	27	+	120		18		414	961.8	12.6
Asperula odorata L.	19	64	209	32	286		6		174	14	804	10	13	244	4	20	96	8	70		1		43	2	1,572	760.2	17.2
Pulmonaria officinalis L.			23	327	38		6		12	140	546	15	14	229			12	166	12		2		4	33	355	814.8	11.0
Carex digitata L.	65	28	42	32	81		60	41	198	54	601	13	15	209	21	10	18	14	37		25	11	55	18	973	441.7	26.7
Vaccinium myrtillus L.	109	1		21	24	74	271	88		10	598	14	16	206	58	+		3	9	22	97	15		2	654	762.5	13.0
Fragaria vesca L.	48	66	37	20	57	65	35	46	54	34	462	17	17	202	28	40	17	7	31	29	16	12	13	9	474	277.1	25.4
Equisetum pratense Ehrh.	50	96	30	9			33	6	70	124	418	20	18	181	34	48	12	2			13	1	19	52	377	354.3	15.1
Stellaria holostea L.	71		2			244				108	425	19	19	134	14		1			77				42	895	524.3	10.3
Circaea alpina L.	45	167			57	73	77		9	2	435	18	20	132	12	67			21	17	14		1	+	1,369	188.8	17.0
Milium effusum L.	74		122	34	9	21				11	271	24	21	128	39		67	13	2	4				3	394	276.2	10.1
Mercurialis perennis L.			59	53	7		241			1	361	22	22	121			30	15	2		74			+	425	757.9	6.0
Trientalis europaea L.	11	28		36	37	47	41	72	31	23	326	23	23	77	3	8		12	9	13	10	13	4	5	354	51.9	18.5
Athyrium filix-femina (L.) Roth		104	35			69			182		390	21	24	74		32	10			13			29		326	1,095.6	2.9
Veronica chamaedrys L.	7	98	11	9		10				18	153	30	25	61	2	48	4	2		2				3	288	70.9	8.3
Aegopodium podagraria L.	17	14	12	26	17	2	4		10	53	155	28	26	59	7	7	5	6	7	+	1		5	21	175	108.0	9.2
Poa nemoralis L.	32	141	6			28	7	1	2	9	226	25	27	58	9	40	2			6	+	+	+	1	762	62.0	9.5
Ramischia secunda Garcke	4	12		5	15	74	3	63	26	5	207	26	28	58	1	3		1	6	33	+	10	3	1	250	91.5	8.2
Lycopodium annotinum L.				5		84	21		45		155	29	29	50				1		33	3		13		93	290.3	3.2
Dryopteris filix-mas (L.) Schott			65					37		83	185	27	30	47			15					5		27	64	552.6	1.6
Mycelis muralis Rchb.		13	6	1	42	17					79	40	31	31		5	2	+	18	6					63	66.9	4.1
Viola mirabilis L.		3	15	20	16		17	1	11	23	106	36	32	29		1	5	7	6		3	+	2	5	76	74.9	5.3
Linnaea borealis L.	23						62	4		27	116	34	33	27	6						18	+		3	266	48.5	6.5
Deschampsia caespitosa (L.) P. B.		13	6			22	10	4	80	12	147	31	34	26		2	1			4	1	+	17	1	287	72.6	3.8
Paris quadrifolia L.	6	8	8	37	2	18	5		11	26	121	33	35	25	1	1	1	9	+	3	1		2	7	94	27.7	5.0
Dryopteris phegopteris Christens	25	7	3				36	11	46		128	32	36	24	9	2	1				5	1	6		150	58.6	4.4
Geranium silvaticum L.		41	1	28						2	72	41	37	23		14	+	9						+	37	50.7	2.3
Solidago virgaurea L.								5	98		103	37	38	21								1	20		29	63.9	1.8
Veronica officinalis L.	15	5	10	2		21	1	18	2	8	82	38	39	20	5	2	3	+		5	+	4	+	1	90	32.1	4.6
Vaccinium vitis-idaea L.		4	1		22	12	27	6			72	42	40	20		+	+		9	2	8	1			115	70.9	3.0
Viola canina L.	10	19	3	8	9	13	6	1	7	6	82	39	41	18	3	7	+	2	2	2	+	+	1	1	69	32.8	5.7
Lathyrus vernus Bernh.			2	16	23					5	46	47	42	17			+	8	8					1	28	41.9	2.2
Equisetum silvaticum L.		7				2	25	11	14		59	44	43	16		2				+	10	2	2		29	62.8	1.9
Pyrola rotundifolia L.				9		35				2	46	48	44	14				1		13				+	41	30.1	1.8
Brunella vulgaris Moench.	2	41									43	50	45	14	1	13									96	19.7	0.8
Carex silvatica Huds.		41							12		53	46	46	13		11							2		54	57.6	1.5
Dryopteris austriaca (Jacq.) Woynar	43								64		107	35	47	13	8								5		10	121.1	1.1
Ranunculus repens L.		22			13					26	61	43	48	12		6			3					3	64	33.5	2.4
Ranunculus cassubicus L.		23		5	1	2	4		3	6	44	49	49	11		8		1	+	+	+		1	1	28	30.4	2.0
Chrysosplenium alternifolium L.	2	51					1				54	45	50	9	+	9					+				102	5.3	2.3
Geum rivale L.		4							19	6	29	54	51	9		1							7	1	32	37.7	0.9
Melampyrum pratense L.	5			1	2	20		7	3		38	51	52	8	1			+	1	5		1	+		42	11.7	2.6
Poa remota Fors.	10	3	2	2		10			8		35	52	53	7	2	1	+	1		2			1		39	38.7	1.4
Melica nutans L.			4						23	3	30	53	54	5			1						4	+	62	9.1	1.3
Filipendula ulmaria (L.) Maxim.		6					4		3	2	15	54	61	2		1					1		+	+	10	5.0	0.6
Sum for 55 most frequent species	2,998	2,894	3,007	2,979	3,012	2,973	3,000	3,004	2,993	3,008	29,864			10,303	1,417	1,129	1,223	1,076	1,108	969	1,045	649	686	992	64,013	25,398.8	779.0
Number of species present	35	41	37	36	32	34	36	28	39	40	55			55	35	41	37	36	32	34	36	28	39	40	55		
Sum for other 27 species	1	111	3	29	0	32	14	0	8	2	200			34	+	17	+	8	0	6	2	0	1	+	336	90.7	8.2
Number of species present	1	14	2	3	0	3	4	0	2	1	27			27	1	14	2	3	0	3	4	0	2	1	27		
Total *S* — number of species in 10 quadrats of 1 square metre														82	36	55	39	39	32	37	40	23	41	41			82
R — species density (mean number of species in 10 quadrats of 1 square metre; * in 10 sample-areas, and ** in 1000 sections of 0.1 sq. m)														(16.3)	17.3	22.2	17.3	16.6	15.4	14.7	15.6	12.6	14.8	16.5		38.7*	7.87**
D — density (mean number of plant units in 10 quadrats of 1 square metre)														(643)	785	697	768	462	724	770	628	513	444	644	64,349		
M — maturity $\left(\frac{10R}{S}\right)$														(4.7)	4.8	4.0	4.4	4.3	4.8	4.0	3.9	4.5	3.6	4.0			
W — weight (mean wet weight of surface parts in 10 quadrats of 1 square metre, $\frac{g}{1\ sq.m}$)														(255)	323	266	322	248	256	224	300	117	199	235		25,489.5	

abundance of single stands; the assertion of the density, however, results in great errors, especially if performed relatively. Therefore it may happen that a single shoot of *Vaccinium myrtillus* has the same importance as one plant of *Dryopteris spinulosa*.

Thus it was decided to avoid the application of density in general and find another procedure in expressing the phytocoenological value of species.

II. The Frequency Coefficient of Weight (*FCW*). The determination of the following data for each component of the floristic composition seems to be sufficient:

1) the biomass of the average plant,

2) the number of plants of the average size.

On the basis of the obtained data, a suitable ordination of the biomass of the species from the point of view of domination could be determined.

Density multiplied by average weight cannot, however, give the desired result because average weight is produced by the ratio of total weight (W) to total density (D); consequently $\frac{DW}{D}$ results in total weight only. Furthermore, average weight involves density, which, as indicated above, is not desirable.

In most cases it is possible to determine the wet weight of the surface parts of a species without any considerable errors. But we cannot, however, see any reason for using relative weight because then the differences in overall densities of separate stands (sample-areas) will disappear.

Another aspect of phytocoenological importance is the manner of distribution of a species within the stand. It is obvious that a highly aggregated particular species with relatively great weight in one locality only, when it is absent in other places (quadrats), will represent a doubtful phytocoenological value. On the other hand, a species with the same weight, but having regular distribution, might be a significant member of the relevé and could be assessed on conclusions with a sufficient rank of phytocoenological importance.

However, usual direct frequency may often result in inaccurate values, and therefore it is reasonable to use the quantitative measurement of the degree of aggregation in addition to frequency. The occurrence of rooted plants within the sample units dispersed at random over the stand may give a different picture if taken on the basis of the same frequency percentage as the degree or manner of aggregation (fig. 1).

We must, of course, recognize the real manner of distribution; but to do this accurately is often very labourious when the calculation of densities is performed with the use of the index developed by McGinnies (1934) and Relations of Frequency to Density Table of Fracker and Brischle (1944), modified by Curtis and Cottam (1962). Various other suggested techniques are discussed in detail by Greig-Smith (1964).

Without any accurate evidence we establish (Frey, 1961) an empirical procedure that appears to be a modification of a somewhat similar approach suggested by Anderson as Frequency Times Presence Index (Anderson, 1954) and introduced by Curtis (1959) as Anderson's factor.

In our practice, constancy, or to be exact, local constancy, is employed instead of presence. This constancy is computed on the basis of 10, located at random, 1×1 sq. m. clip quadrats each containing 10 sections (fig. 1).

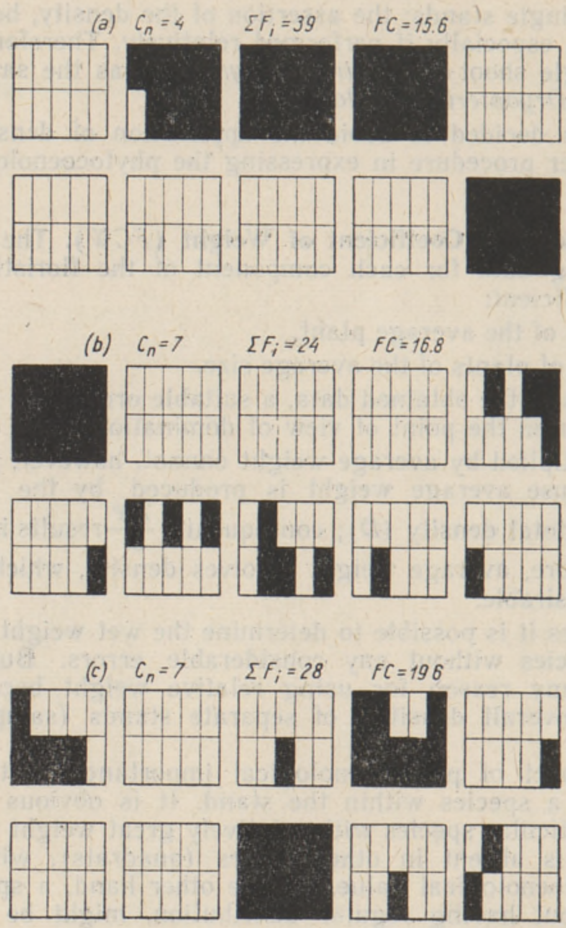


Fig. 1. An example of calculating the *FC* factor. Sample-area No. 04. Pattern shown by (a) *Asperula odorata,* (b) *Carex digitata,* (c) *Circaea alpina.*

For example, *Asperula odorata* in sample-area No. 04 has a constancy value of 40 per cent and a frequency of 39 per cent (fig. 1 (a)).

$$\frac{FC}{\sqrt{100^2}} = \frac{39 \cdot 40}{100} = 15.60.$$

Perhaps a more comprehensive system would be to use index numbers instead of percentages, as follows:

F_i equals the number of sections (out of $N_f = 10$) of the i-th quadrat in which a species occurs.

C_n — the number of quadrats (out of $N_c = 10$) in the j-th sample-area in which this species appears.

Thus the *FC* factor for a single sample-quadrat might be expressed as:

$$FC = \frac{F_i \, C_n}{\sqrt{N_f N_c}}.$$

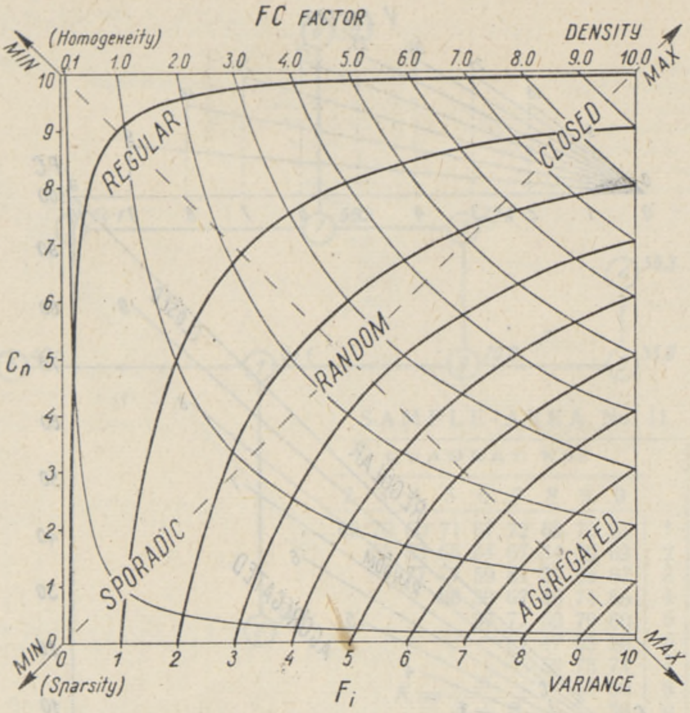


Fig. 2. *Pattern Field,* illustrating the dependence of the *FC* factor on local constancy and frequency index numbers for a single sample.

The minimum value of the factor would be $\frac{1}{\sqrt{N_f N_c}}$ and the maximum one $\sqrt{N_f N_c}$ respectively.

For quadrats these values are (fig. 1(a)):

$$F_1C_4 = \frac{0 \cdot 4}{10} = 0; \; F_2C_4 = \frac{9 \cdot 4}{10} = 3.6; \; F_3C_4 = \frac{10 \cdot 4}{10} = 4.0;$$

$$F_4C_4 = \frac{10 \cdot 4}{10} = 4.0; \; F_5C_4 = \frac{0 \cdot 4}{10} = 0 \text{ etc.}$$

The product on the presence basis ($F \cdot P$ factor) is named as an index of the commonness of the plant and is claimed to be directly related to the chances of finding that particular species at any given point in any stand of the community (Curtis, 1959).

The *FC* factor must therefore be related to chances of finding a particular species at any given point of a sample-area and may be named as the frequency-rank index, which ranges from 0.1 to 10.0 for a single sample-quadrat and from 0.1 to 100.0 for a sample-area. The latter may be expressed as the sum of the former or as the average frequency index in a sample-area multiplied by the constancy index number:

$$\overline{FC}_n = \frac{\sum_{i=1}^{10} F_i C_n}{N_f}.$$

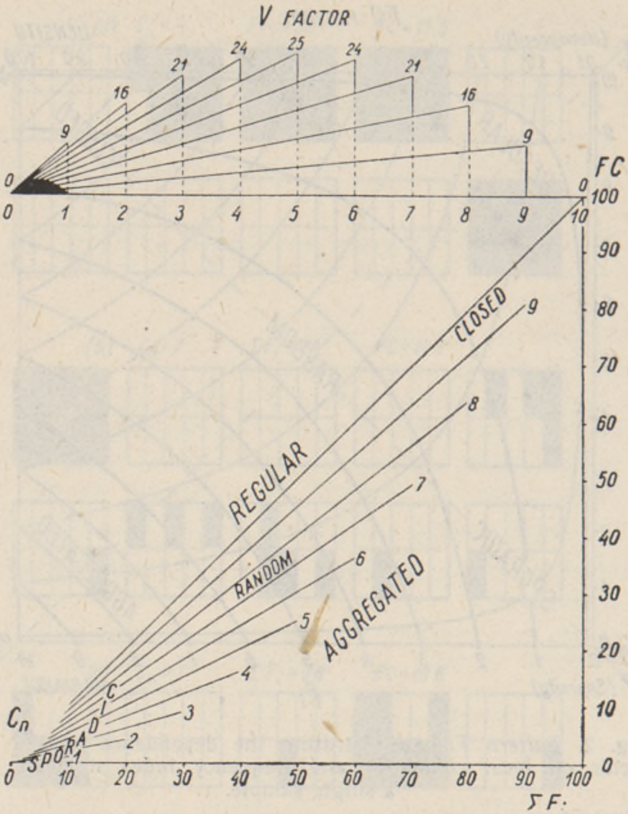


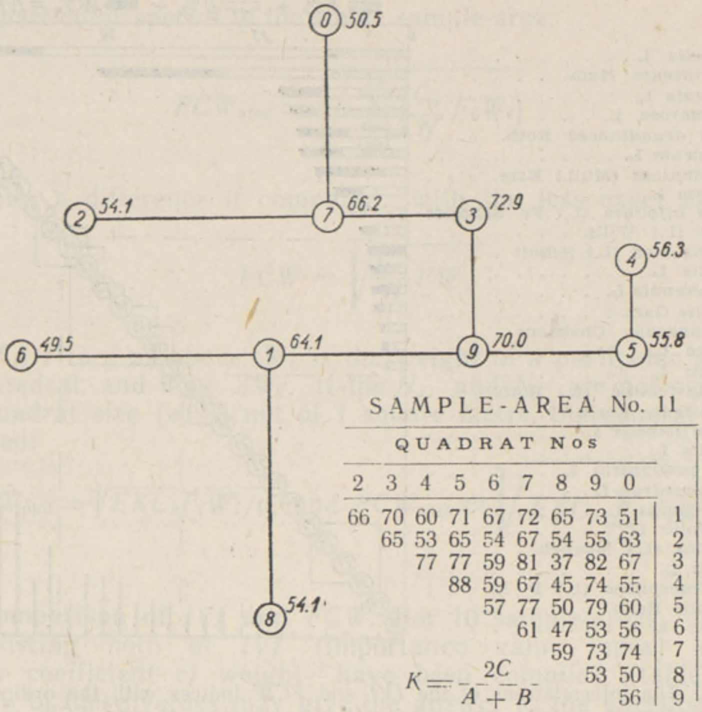
Fig. 3. Interrelations of the *FC* factor, local constancy and frequency for a sample-area.

The value of the *FC* factor likewise refers to the manner of distribution as it is shown in fig. 1. The maximum value can be obtained if the species has a regular manner of distribution, and the minimum one — if it is aggregated. Thus a species with a known frequency, for example — 43, may have a regular distribution and occur in all 10 quadrats, or be aggregated with the occurrence in a minimum number (5) of quadrats, i. e. this particular species may have the frequency-rank ranging from 5, 6, to 9, 10.

For a single quadrat the manner of distribution may be taken into consideration in a similar way (see fig. 2).

Furthermore, it is possible to define some other aspects of distribution as sporadic if a species occurs at very few points only; and as closed if this species occurs almost at all localities (points), and random distribution. The sample data on the frequency and constancy of the whole sample-area, expressed as *FC* factor, for 10 quadrats separately, give the general picture of the manner of distribution for a particular species (see fig. 3) on a given sample-area. (Compare with figs 18 and 19 in Hopkins, 1955!).

This picture will be also indicated in fig. 2, and in addition to the *FC* factor, a second variable is determined. The parameter (*V*) corresponds to the increasing variability within a stand, from regular, random and aggregated distribution respectively, and may be called the variance coordinate. As the *FC* factor can be regarded as an indication of an



SAMPLE-AREA No. 11

QUADRAT Nos

2	3	4	5	6	7	8	9	0	
66	70	60	71	67	72	65	73	51	1
	65	53	65	54	67	54	55	63	2
		77	77	59	81	37	82	67	3
			88	59	67	45	74	55	4
				57	77	50	79	60	5
					61	47	53	56	6
						59	73	74	7
							53	50	8
								56	9

$$K = \frac{2C}{A+B}$$

Fig. 4. An ordination of quadrats by the method of dendrit according to the matrix of Czekanowski's formula. The corresponding values of the *FC* factor are indicated on ordination.

increasing overall density, or biomass, in the succession of sporadic, random to closed distribution, or a density co-ordinate (T), the two factors may be used as co-ordinates with a biological meaning to determine the position of sample quadrats in relation to the possible distributions. The variance co-ordinate (V) has a similar distribution as the *FC* factor, although along the heterogeneity diagonal. The co-ordinates for a whole sample-area simultaneously can be expressed as:

$$T = F_n C_n E \quad \text{and}$$

$$V = \frac{F_n K}{C_n N_f} - T, \quad \text{where}$$

$E = \frac{K}{N_f N_c^2}$, $F_n = \sum_{i=1}^{n} F_i$ and $K = 10$ is the constant of the resulted scale, i. e. the maximum value of the co-ordinates.

Thus it is a very rapid procedure of rough estimation of manner of distribution, by using the frequency and local constancy index numbers as variables related to co-ordinates of the pattern field. The exactness of results, however, depends on the intensity of the sampling used, with the scale of pattern reflected, which is dependent on the employed size of sampling units.

The *FC* factor ratings for single sample-quadrats (plots) in a master list may be totalled. The result is an excellent measure of the character-

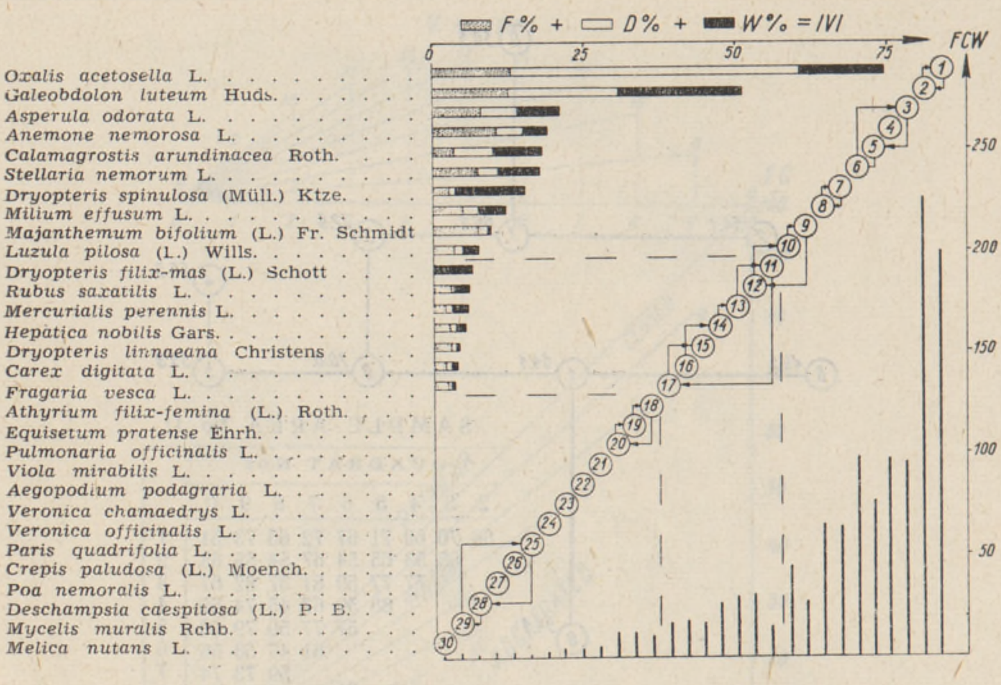


Fig. 5. The interrelations of the *IVI* and *FCW* indices with the ordination of complement species and reordination according to the *FCW* values. Sample-area No. 02.

istic value of a particular quadrat as a member of a whole sample-area. The quadrat with the maximum value of the *FC* factor has a floristic composition with a maximum degree of similarity in the floristic composition of a whole sample-area. So the quadrats may be ordinated according to the *FC* factor. We must, however, draw attention to the fact that such a position of quadrats is correct if it is contemplated in a multidimensional universe. Then the quadrats with the maximum value of the *FC* index would be located in the centre of the grouping and the quadrats having small values would be dispersed in the external sphere of the grouping.

For a better understanding, the same quadrats were compared (see fig. 4) on the basis of Czekanowski's $\frac{2w}{a+b}$ formula (Curtis, 1959), with the ordination of result values by the method of dendrit. The absolute value of the *FC* index total simultaneously refers, of course, to overall density in quadrats.

As stated above, the total weight of a particular species may contain a sufficient portion of incidence. A considerably better expression may be the multiplication of the weight of a particular species by its frequency rank, which should give a desired index. Since the values of such a multiplication may range from practically zero to about 5,000 (in the herbaceous layer of the Estonian spruce forests), we decided to compress the scale proportionally by using the square root. So the *FCW* index for particular species in a single sample-plot can be expressed by the following formula:

$$FCW_{\text{plot}} = \sqrt{\frac{C_n F_i W_i}{N_f}}$$

and for a particular species in the whole sample-area:

$$FCW_{\text{area}} = \sqrt{\sum_{i=1}^{10} \left(\frac{C_n}{N} F_i W_i \right)}$$

which shows a difference if compared with the less exact expression:

$$FCW = \sqrt{\frac{C_n}{N} \bar{F} W_n} ;$$

here C_n, F_i, $\bar{F}$ are as above, W_i is the weight of a particular species on a single quadrat, and $W_n = \Sigma W_i$. If the N_c and N_f are not equal to 10, and the quadrat size (a) is not of 1 square metre, the general formulae are required:

$$FCW_{\text{plot}} = \sqrt{EKC_n F_i W_i / a}, \text{ and } FCW_{\text{area}} = \sqrt{EKC_n \sum_{i=1}^{N_c} F_i W_i / a} .$$

III. Comparison of *IVI* and *FCW*. For 10 sample-areas, the master lists consisting both of *IVI* (importance value index) and *FCW* (frequency coefficient of weight) have been compiled (table 1). The comparison of these values may give the answer to the question of *FCW* as a new conception of phytocoenological value. Consequently, a graphical example of interrelations of *IVI* and *FCW* (fig. 5) is added. Thus we may conclude that there exists a correlation between *IVI* and *FCW*. The ordinations of complement species according to *IVI* and *FCW* values show no great differences.

Nevertheless, there are some relatively great leaps in the order of species, but it is possible to dispute them.

The first deviation shown by *Oxalis acetosella* and *Galeobdolon luteum* occurred due to the *IVI* value of *Oxalis acetosella* containing about 48 (out of 74) units of density, while the frequency proportions of both species were practically equivalent. At the same time, *Galeobdolon luteum* had an essentially higher value of weight as well as coverage than *Oxalis acetosella*. What, then, is of greater importance, the number of small specimens, or the real dominance?

Another aspect became manifest in the case of *Asperula odorata*. This species had more individuals and likewise higher weight than, for example, *Anemone nemorosa*. In spite of these values, *Asperula odorata* fell in the fifth place in ordination because this species had a markedly aggregated distribution on the mentioned sample-area and was not such an important member of the community showing a relatively high frequency (63 per cent), but being of a minimal rank $\left(\frac{7}{10} \cdot 63 = 44.1 \text{ only} \right)$. For the same reasons *Dryopteris filix-mas* fell into the 11th to 17th place, and *Athyrium filix-femina* from the 18th to 20th one.

Stellaria nemorum, with practically similar values of frequency and weight as *Asperula odorata*, having bigger average individuals and a lower density respectively, rose from the 6th to the 3rd place because its distribution over the sample-area was rather random.

These leaps were partially the result of the errors of the evaluation of

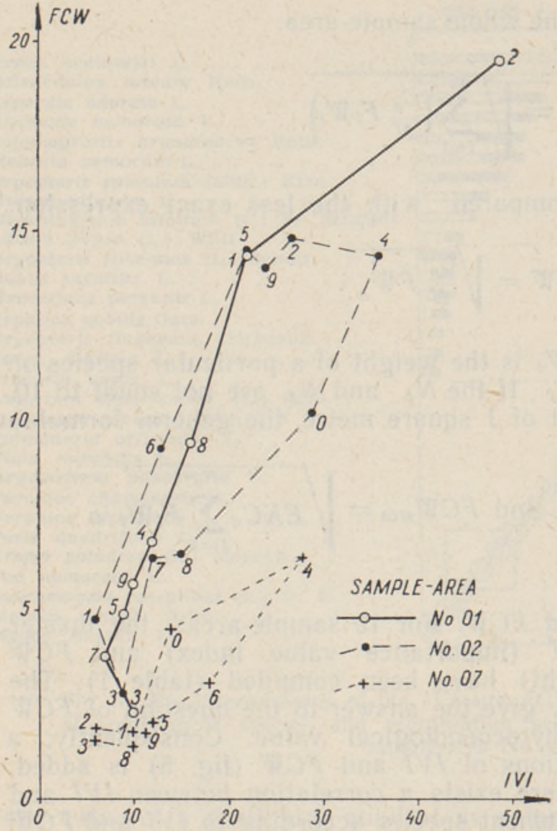


Fig. 6. The relationship between *FCW—IVI* correlation (table 2).

the actual values by *IVI* itself, since the same actual value turned into a higher relative value when overall density (i. e. biomass as well as species density) was low, and a considerably lower value in cases of a denser and richer herbaceous layer. Extremely great errors would result where vegetation is very sparse.

Approximately the same conclusions might be made, if the interrelations of *IVI* and *FCW* of a particular species were examined. For example (fig. 6), in the case of *Anemone nemorosa* there is a relationship between the overall density and the *IVI*-*FCW* correlation.

On sample-area No. 01, where the species density, as the mean value of 10 quadrats of 1 square metre, was 22.2, a practically linear relationship might be obtained between *FCW* and *IVI*. Only quadrats 3 and 2 with minimum species density and with a relatively small sum of *FC* ratings show somewhat higher *IVI* values. The study of sample-areas Nos 02 and 07 yielded similar results, etc., with clear reference to the fact that the species density and the sum of *FC* values of a quadrat were the determinants of the *IVI* value-deviations (see fig. 6 and table 2).

For *Anemone nemorosa,* for example, the ratio between *FCW* and *IVI* was as follows:

$FCW = 0.6\ IVI$, or $y = ax$, with the most frequent values for the coefficient from 0.54 to 0.65. For the whole species complement the coefficient ranges from 0.17 to 0.65.

IV. The Advantages of the ***FCW*****.** The *FCW* index, being a new conception, ought to have some clear advantages if widely employed by ecologists.

In comparison with the prevailing importance value index, the *FCW* index has, as mentioned above, a series of advantages based on the fact that the *IVI* may often be a misleading characteristic since it contains relative, and not actual values. The frequency, density as well as dominance (weight) values are directly related to the species density, as well as frequency, density and the biomass totals of herbaceous as well as tree layers, especially if the species density is low (as in the tree layer of the Estonian spruce forests where we find only 3—5 species simultaneously, and not 20—25 as in the North-American deciduous

Table 2

Data on the *FC* factor and corresponding species density

Sample-area No. 01

Quadrat Nos	4	7	5	1	9	8	0	6	2	3
Σ *FC*	96.7	88.4	86.9	85.4	77.2	77.1	(70.6)	(63.7)	57.7	50.6
Species density 22.2	12.9	10.9	11.2	10.4	10.0	10.1	(9.5)	(8.3)	7.4	5.8

Sample-area No. 02

Quadrat Nos	6	1	9	7	5	2	8	0	3	4
Σ *FC*	89.9	86.8	73.4	72.0	68.7	64.9	54.7	51.4	50.8	49.8
Species density 17.3	12.2	12.4	9.1	8.9	9.0	8.7	6.3	5.7	6.1	5.6

Sample-area No. 07

Quadrat Nos	2	0	4	1	3	5	8	7	9	6
Σ *FC*	67.8	61.9	55.5	52.6	51.7	51.3	48.6	(40.9)	38.5	36.7
Species density 12.6	10.0	8.5	6.5	6.2	5.9	5.8	6.0	(4.9)	5.2	4.3

forests or in rainy forests). If the species density is high, we can obtain a clear correlation between *IVI* and *FCW*.

These advantages are discussed above. Moreover, we must draw the following conclusions: for *FCW* it is unnecessary to count densities, and this is very important for reducing the duration of field work. On the other hand, the differences between investigations in, for example, meadows and forests become slighter.

The use of the *FCW* index instead of *IVI* likewise reduces computer operations. For *IVI* it is necessary to prepare three tables (frequency, density and dominance) with cumbersome additions, whereas for the *FCW* index only two are necessary. The calculations of the *FC* factor can be carried out without computers, and it is possible to prepare the *FC* times *W* multiplications in the time required for the third table.

Further, it is necessary to prepare three tables with a relative characteristic for the *IVI*. All this work is not required for the *FCW* index. During the time needed for the addition of relative values of the *IVI*, the student, using the tables of square roots, can compute the *FCW* indices. In this way about 40 per cent of labour will be saved (the latter value also depends on the species density). We should like the *FCW* index to be worthy of the attention of other ecologists as a quantitative measure of phytocoenological value of community components. This index, however, should not be used without criticism; its advantages and disadvantages should be considered in relation to the vegetation being examined.

Summary

By combining two or more different quantitative characteristics into a single item, various workers have attempted to use resulting indices as a more comprehensive estimate for expressing the phytocoenological value of a species in a stand. Among such indices, the *IVI*, being the most likely one to be correct, has been employed in the study of Estonian spruce forests. At the same time, a new concept, the *Frequency*

Coefficient of Weight (*FCW* index) is suggested as having some advantages if compared with the *IVI* index.

The correlation between *IVI* and *FCW* values is discussed, and some examples of discrepancies considered. The *FCW* index is proposed as a measure of the phytocoenological value of a species.

An outline of *Pattern Field*, a new concept, having two co-ordinates, has been introduced in connection with the factors controlling the co-ordinates.

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REFERENCES

Anderson, O., 1954. The phytosociology of dry lime prairies of Wisconsin. Ph. D. thesis, University of Wisconsin. Quotations from Curtis, 1959.

Braun-Blanquet, J., 1932. Plant Sociology. New York.

Curtis, J. T., 1947. The palo verde forest type near Gonivaves, Haiti, and its relation to the surrounding vegetation. *Caribbean For.*, 8: 1—26.

Curtis, J. T., 1959. The Vegetation of Wisconsin. An ordination of plant communities. Madison.

Curtis, J. T. and G. Cottam, 1962. Plant Ecology Workbook. Minneapolis.

Curtis, J. T. and R. P. McIntosh, 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecology*, **32**: 476—496.

Czekanowski, J., 1913. Zarys metod statystycznych. Warsaw.

Dagnelie, P., 1960. Contribution á l'étude des communautés végétales par l'analyse factorielle. *Bull. Serv. Carte phytogéogr., Sér.* **B**, **5**: 7—71; 93—195.

Fracker, S. B. and H. A. Brischle, 1944. Measuring the local distribution of Ribes. *Ecology*, **25**: 283—303.

Frey, T., 1961. Salukuusikute tüüpide jä alustaimestiku sõltuvus ökoloogilistest tingimustest Venevere metskonnas. MS. Tartu.

Gleason, H. A., 1920. Some applications of the quadrat method. *Bull. Torrey Bot. Club*, **47**: 21—33.

Greig-Smith, P., 1964. Quantitative Plant Ecology. London.

Hopkins, B., 1955. The species-area relations of plant communities. *J. Ecol.*, **43**: 409—426.

McGinnies, W. G., 1934. The relationship between frequency index and abundance as applied to plant populations in a semi-arid region. *Ecology*, **15**: 263—282.

Pandeya, S. C., 1961. On some new conceps in phytosociological studies of grasslands. II. Community coefficient *(F×C) ICC. J. Indian Bot. Soc.*, **40**: 267—273.

Буторина, Г. Н., 1963. Эколого-ценотический анализ кустарничково-травяного яруса лесных ассоциаций. В сб.: Типы лесов Сибири: 30—51.

Ипатов В. С., 1962. О корреляции между проективным покрытием и весом травянистых растений. *Ботан. ж.*, **47**: 991—992.

Понятовская, В. М. и И. В. Сырокомская, 1960. Опыт сравнительной оценки участия вида в строении лугового сообщества. *Геоботаника*, **12**: 171—180.

Раменский, Л. Г., 1938. Введение в комплексное почвенно-геоботаническое исследование земель. М.

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LIIGI FÜTOTSÖNOLOOGILISEST VÄÄRTUSEST

Detailuurimusi Eesti arukuusikutes

Resümee

Fütotsönoloogilise väärtuse indeks *(IVI)* koosneb arvukuse, dominantsuse (katteväärtus või rinnaspind) ja frekventsuse andmeist, mis kõik on väljendatud protsentides kogu proovipinna summaarse suhtes ja seejärel summeeritud. Et kirjanduses (Curtis, 1959; Curtis, Cottam, 1962; Greig-Smith, 1964) on esitatud tõendusi selle indeksi eeliste kohta, on seda kasutanud ka J. Kaasik (ENSV TA Zooloogia ja Botaanika Instituut) Eesti arukuusikute kohta kogutud andmete ümbertöötamisel (vt. tab. 1), kusjuures ta dominantsuse mõõduks võttis toorkaalu, tuginedes vihjetele lineaarse seose olemasolust toorkaalu ja katteväärtuse vahel (Раменский, 1938; Ипатов, 1962). Samade lähteandmete baasil on käesoleva töö autor rakendanud teistsugust menetlust (tab. 1) ja seda alljärgnevatel kaalutlustel:

1. Arvukus (indiviidide arv pinnaühikul) on ebasobiv näitaja, sest, iseäranis rohurindes, pole eri liikide indiviidid, nagu *Dryopteris spinulosa* ja *Anemone nemorosa*, oma biomassi poolest võrreldavad. Sama liigi indiviidid võivad üksteist toorkaalus kuni 30-kordselt ületada. Pealegi on üksiku indiviidi eristamine vegetatiivselt paljunevate liikide puhul metoodiliselt vähe usaldusväärne. Eraldi peatumata arvukuse loendamise töökulul tuleb rõhutada, et *IVI*-indeksis kasutatav suhteline arvukus oleneb nii taimkatte tihedusest kui ka liigirikkusest, mistõttu erinevate proovialade võrdlemine kaotab mõtte. Sama kehtib ka teiste suhtarvude puhul.

2. Üldiselt peaks olema küllaldane, kui saab väljendada liigi biomassi osatähtsust kogu taimkattes. Üksnes toorkaalust ei piisa. Fütotsönoloogilise väärtuse teine aspekt on liigi sagedus ja jaotumisviis (joon. 1—3). On selge, et suhteliselt suure toorkaalude summaga liiki, mis kasvab üksiku laiguna (agregatsioonjaotumus) ja puudub prooviala ülejäänud osades, tuleks antud koosluses vaadelda võimaliku juhusliku liigina. Teiselt poolt on sama toorkaalude summaga, kuid kogu proovialal ühtlaselt jaotunud (regulaarjaotumus) liik sellele kooslusele ilmselt iseloomulik, mistõttu ta peaks saama kõrgema fütotsönoloogilise osatähtsuse hinde kui eelmine liik. Et frekventsuse jaotumine toorkaalu jaotusega üldjoontes ühtib, tuleb tavalise frekventsuse asemel sageduse mõõduna kasutada mingit jaotumusviisiga seotud näitajat. Kui valmistati proovialade liigilise koosseisu võrdlustabelid Czekanowski (1913) sarnasuskoefitsiendi alusel (tsit. Curtis, 1959), selgus, et üksiku kirjelduse tüüpilisust kogu prooviala suhtes iseloomustab näitaja, mis väljendab liigi sagedust *(F)* antud ruudus ja konstantsust *(C)* sama prooviala eri ruutudes (joon. 4).

Neil kaalutlustel leiti, et sobiva sagedushinnangu annab frekventsuse ja lokaalkonstantsuse korrutis ehk *FC*-faktor, mis sõltub jaotumusviisist ja üldisest sagedusest (joon. 2 ja 3). Teiste sõnadega, *FC*-faktori väärtus on võrdeline liigi üldise biomassi hulgaga (joon. 2), olles maksimaalne maksimaalsel tihedusel (*closed distribution,* liitejaotumus), keskpärane juhusliku ja minimaalne sporaadilise jaotumuse puhul. Tiheduse ruutudevaheline varieeruvus on aga minimaalne regulaarjaotumusel, keskpärane juhusliku ja maksimaalne agregatsioonjaotumuse korral. Seega on varieeruvustelg risti tihedusteljega ja varieeruvuse aste väljendub faktoris $V = F - \frac{FC}{10}$.

Faktorid *FC* ja *V* kui jaotumusvälja koordinaadid on sel viisil väga mugavaks vahendiks jaotumusviisi esialgsel määramisel, kusjuures arvutuste maht on keerukamate meetoditega võrreldes praktiliselt null.

Liigi fütotsönoloogilise osatähtsuse indeksina võib ülaltoodu alusel esitada *FC*-faktori korrutist vastava toorkaaluga *(FCW)*. Näitaja väärtuste proportsionaalseks kokkusurumiseks rakendati ruutjuurteisendust.

Võrreldes *FCW*-indeksi ja *IVI*-indeksi rakendamise tulemusi, ilmneb üldine seaduspärasus (vt. joon. 5 ja 6). Kõiki lahkuminekuid saab vaadelda *FCW* eelistena, eriti selgesti aga neil juhtudel, kus liigitihedus (*resp.* liigirikkus) on madal, millele vastavalt esineb *IVI* suhtarvudes suur juhuslikkuse moment. Kõrge liigitiheduse ja ülepinnalise arvukuse (tiheduse) puhul on *IVI* ja *FCW* väärtuste vaheline seos praktiliselt lineaarne ja suure osa liikide puhul (vt. joon. 6 ja tab. 2) väga sarnane sirge võrrandiga. Välitööde ajakulu seisukohalt on oluline, et *FCW* ei vaja arvukuse andmeid. Samuti väheneb arvutuste maht umbes 40% võrra, sest *FC* leitakse peastkorrutamisega ja ruutjuur — tabelitest. *IVI* puhul tuleb aga valmistada 6 tabelit, millele lisanduvad veel liitmised.

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ФИТОЦЕНОТИЧЕСКАЯ РОЛЬ ВИДА

Детальные исследования ельников Эстонии

Резюме

Индекс *IVI*, или индекс фитоценотической роли, составляется из данных о численности (густота стояния), доминантности (покрытие или сумма площадей сечения на высоте груди) и частоты встречаемости, которые выражаются в процентах от суммарной для пробной площади, а затем суммируются. Так как в литературе (Curtis, 1959; Curtis, Cottam, 1962; Greig-Smith, 1964) имеются данные, что индекс *IVI* отражает роль вида в фитоценозе, этот индекс был применен Ю. Каасик (Ин-т зоологии и ботаники АН ЭССР) для обработки данных об эстонских ельниках, произрастающих на минеральных почвах. При этом (табл. 1) мерилом доминантности служил вес надземных частей растений в сыром виде, поскольку, согласно данным литературы (Раменский, 1938; Ипатов, 1962), между сырым весом и проективным покрытием существует линеарная зависимость. Автор настоящей статьи также опирался на эти данные, но пользовался иным методом расчета, что объясняется следующими соображениями.

Во-первых, численность (число индивидуумов на единице площади) не может служить достаточно убедительным показателем, так как индивидуумы различных видов травянистого яруса (напр., *Anemone nemorosa* и *Dryopteris spinulosa*) не сравнимы по своей биомассе. Индивидуумы же одного вида могут превосходить друг друга по весу до 30 раз. Во-вторых, расчленение отдельного индивидуума в случае вегетативно размножающихся видов методически не достоверно. Не останавливаясь отдельно на вопросе о трудоемкости пересчета численности, необоходимо подчеркнуть, что применяемая в индексе *IVI* относительная численность зависит как от общей густоты стояния травянистого яруса, так и от видовой насыщенности, вследствие чего сравнение различных пробных площадей теряет смысл. То же самое можно сказать и о других относительных величинах.

В общем для расчета достаточно, если удается выразить значение биомассы данного вида в растительном покрове. Применение же одного только веса недостаточно. Другим аспектом фитоценотической роли является частота встречаемости и характер распределения рассматриваемого вида (рис. 1—3). Ведь ясно, что вид, имеющий сравнительно высокий суммарный вес, но произрастающий отдельным пятном и отсутствующий на остальных участках пробной площади (агрегационное распределение), следует рассматривать как возможный случайный член данного сообщества. С другой стороны, вид с такой же суммой веса, но произрастающий равномерно по всей пробной площади (регулярное распределение), мы вправе считать истинным членом этого сообщества, и вряд ли возникнут возражения, если мы при оценке фитоценотической роли последнего дадим ему более высокую оценку, чем первому виду. Однако поскольку распределение частоты встречаемости в общих чертах совпадает с распределением веса растений, то вместо обычной частоты встречаемости как мерила частоты возникает необходимость найти какой-то иной показатель, связанный с характером распределения.

После составления таблиц сравнения видового состава пробных площадей на основе формулы Чекановского (1913, цит. по Curtis, 1959) выяснилось, что типичность отдельного описания в сравнении с пробной площадью, как целой, характеризуется показателем, базирующимся на частоте встречаемости (F) вида в данном квадрате и постоянстве того же вида (C) на отдельных квадратах рассматриваемой площади (рис. 4).

Таким образом, наиболее пригодную оценку частоты дает произведение частоты встречаемости на локальное постоянство, или фактор FC, зависящий от характера распределения и общей частоты встречаемости (рис. 2 и 3). Иными словами, величина фактора FC соответствует общей биомассе вида (рис. 2), максимальной при наибольшей густоте (слитное распределение, closed distribution), промежуточной при случайном (random) распределении и минимальной при спорадическом распределении, когда вероятность нахождения одного индивидуума определяется законом редких событий Пуассона. Изменчивость же густоты внутри квадратов (рис. 2) минимальна при регулярном распределении, промежуточна при случайном и максимальна при агрегационном распределении. Таким образом ось изменчивости (мозаичности) перекрещивается с осью густоты, а степень изменчивости определяется величиной фактора V:

$$V = F - \frac{FC}{10}.$$

Применение факторов FC и V как координат поля распределения является, таким образом, вполне удовлетворительным способом первоначального определения характера распределения, причем объем вычислений по сравнению с более сложными методами практически ничтожен.

На основе вышеизложенного мы предлагаем в качестве индекса фитоценотической роли вида в сообществе использовать произведение фактора *FC* на соответствующий сырой вес *W*. С целью сокращения величин индекса *FCW*, из них извлекается квадратный корень.

При сравнении отдельных величин индексов *IVI* и *FCW* проявляется общая закономерность (рис. 5 и 6). При этом все расхождения можно считать преимуществом индекса *FCW*, особенно в случаях низкой видовой насыщенности, когда в относительных величинах индекса *IVI* проявляется большой момент случайности. При высокой видовой насыщенности и общей численности (густоты стояния) зависимость между величинами индексов *IVI* и *FCW* практически линеарна и у значительной части видового состава очень близка к уравнению прямой (рис. 6 и табл. 2).

С точки зрения объема полевых работ важно, что индекс *FCW* не нуждается в данных о численности. Также уменьшается (примерно на 40%) объем вычислений, так как величины фактора *FC* находятся путем устного умножения, а квадратный корень извлекается при помощи таблиц. Для обработки же величин *IVI* необходимо составить шесть таблиц и совершить сложения.

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