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Statistical analysis of the phytocoenose homogeneity. II. Species frequency distribution and frequency distribution of the standing biomass as a function of the area size

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Abstract

Homogeneity of the *Leucobryo-Pinetum* phytocoenose was assessed on the grounds of the species frequency distribution and frequency distributions of the total ground--layer biomass and those of individual species. It was confirmed that: 1) species frequency distribution and frequency distribution of biomass, as well as their statistical characteristics depended on the area size and 2) for analysed phytocoenose the area at which frequency distributions of both measures were symmetrical could be determined. The studies showed that phytocoenose homogeneity was related only to the definite area size, i.e. to the definite scale of its spatial differentiation.

Key words: phytocoenose homogeneity, frequency distribution, biomass distribution

INTRODUCTION

Frequency, as a measure of the chance of finding the species within biochore, to some extent, reflects floristic similarity of different fragments of the patch. If the probability is the same in each point of biochore, phytocoenose can be considered homogeneous. However, under the natural conditions it happens very rarely, only when all species are characterized by high frequency, then J-shaped frequency distribution occurs. In the phytocoenose there is usually a number of occasional species which shift frequency distribution to U-shaped. Guinochet (1954, 1957) assumed U-shaped Raunkiaer's normal frequency distribution as a homogeneity criterion (Raunkiaer 1918, after Daget and Godron 1982).

Further studies have showed that the type of species frequency distribution depend on the quadrat size (Dagnelie 1962, Kwiatkowska 1984). The quadrat size at which species attain symmetrical (U-shaped) frequency distribution can be determined on the grounds of Fisher's γ_1 and Pearson's K coefficients (Dagnelie 1962). The latter assumes null value for symmetrical distributions. Here, it is connected with the same species number in the first and last frequency class (Kwiatkowska 1984).

The paper aims at analysis of homogeneity of the model phytocoenose on the grounds of the species frequency distribution and frequency distribution of standing biomass as a function of the area size. After Guinochet (1954, 1957), U-shaped frequency distribution has been assumed as a homogeneity criterion with respect to qualitative measures (species presence). The normal distribution has been accepted as homogeneity criterion — with respect to quantitative measures — biomass of individual species and the total biomass of the ground layer (Kwiatkowska and Symonides 1980). Phytocoenose can be treated as homogeneous when in various biochore parts probability of finding high and low values of standing biomass is the same from statistical point of view, and not higher than it can be derived the normal distribution.

Paper is the second in the series of works which compare results of studies with respect to quantitative and qualitative measures, as well as different homogeneity indices (Kwiatkowska and Symonides 1985). The studies were caried-out in the *Leucobryo-Pinetum* phytocoenose Mat. (1962) 1973, with the uniform physiognomy. It was composed of pure, even-aged, one-layered forest stand, and floristicly poor ground layer (21 species of vascular and 7 species of sporogenous plants) dominated by dwarf-shrubs. The full its characteristics is given in the first paper of the series on assessment of phytocoenose homogeneity on the grounds of distributions of total species diversity and evenness indices (Kwiatkowska and Symonides 1985).

MATERIAL AND METHODS

In sampling the Greig-Smith's (1952) grid was used. It was composed of 512 square quadrats (sample areas) of side 1 m each. In the period of maximum standing biomass of the ground layer (July) in each quadrat all species were recorded. Then, air-dry standing biomass of above-ground parts of all vascular plants in the ground layer was estimated. The data were arranged in plans of species occurrence and cartogramms of their biomass in the successive quadrats. They served as basic data in the statistical analysis of the phytocoenose homogeneity.

In further result elaboration 6 new "grids" were formed. Each one composed of quadrats with sizes ascended with geometric progression (Fig. 1). For each grid frequency of all species was calculated. Next, the species were grouped into 5 and 8 frequency classes due to the class width:

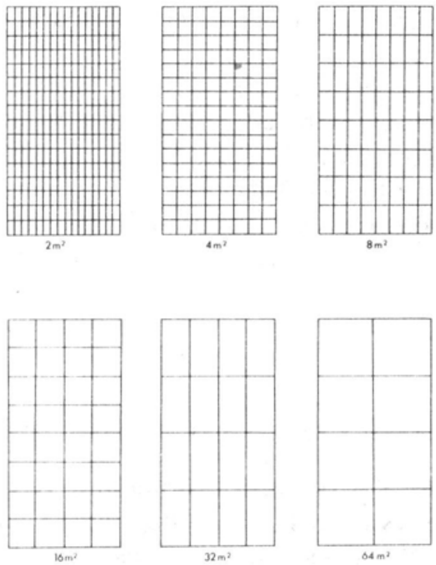

Fig. 1. Grid plan with the quadrat size increasing with geometric progression

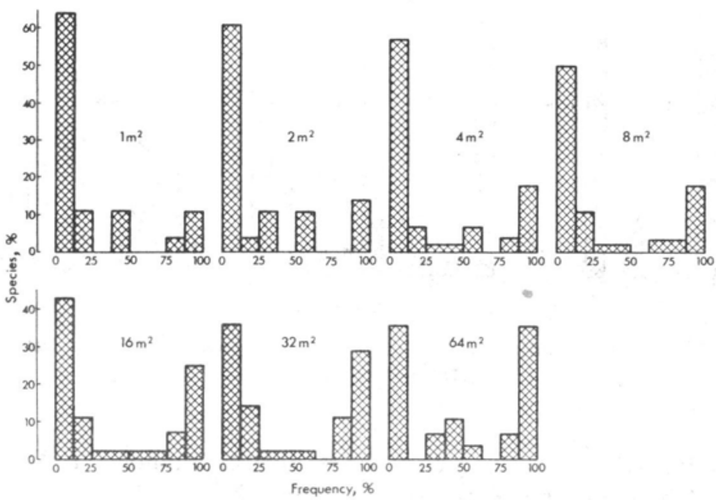

Fig. 2. Effect of the quadrat size on the type of species frequency distribution. Class width — 12.5%

20% (according to Raunkiaer 1918, after Daget and Godron 1982) and 12.5% (according to Dagnelie 1962), respectively. Then, the number and per cent of species in each class was established, at the different quadrat size.

Species frequency distributions related to the quadrat size were characterized with their statistics: arithmetical mean ($\bar{x}$), standard deviation (S.D.) and coefficient of variation (V).

For each grid type standing biomass of the ground layer and its components, plant species, were established. Empirical distributions of the analysed measure were constructed. When distributions did not differ apparently from the normal distribution Chi^2 test of goodness of fit was used, $\alpha = 0.05$. Frequency distributions concerning total biomass of the ground layer and biomass of 6 dominants are given in the paper.

RESULTS

SPECIES FREQUENCY DISTRIBUTION AS A FUNCTION OF THE AREA SIZE

From the analysis of frequency distributions it may be inferred that distribution type changes from L- to U-shaped with the increase in quadrat size, independent of the class number (Figs. 2 and 3). But class width affects the quadrat size at which distribution attains its symmetry.

When species are grouped into 8 classes the distribution is symmetrical for 64 m^2: species number in the first and last class is then identical

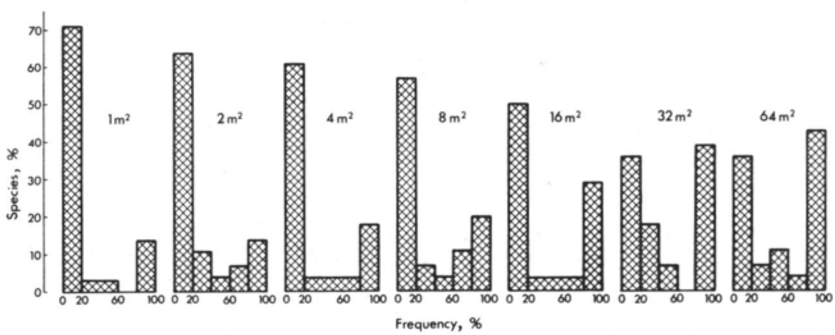

Fig. 3. Effect of the quadrat size on the type of species frequency distribution. Class width — 20.0%

(Fig. 2). For the 20% frequency class species number in the last class is higher than in the first already for 32 m^2 (Fig. 3). The results indicate that it attains its symmetry for the quadrat size between 16 and 32 m^2.

Mean value of the species frequency and its standard deviation change with the increasing quadrat size. In the phytocoenose under study they are directly proportional to its logarithm (Fig. 4). Mode of grouping changes values of both characteristics, but does not affect a nature of the relationship.

Regression equation for the mean frequency is: $y = 4.551\ \lg_2 x + 17.57$ — at 12,5% frequency class, and $y = 4.20\ \lg_2 x + 20.43$ — at 20% frequency

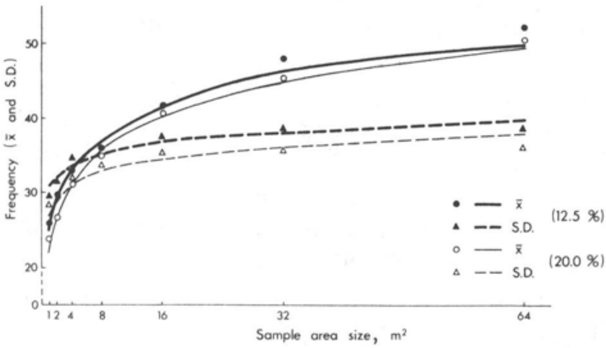

Fig. 4. Relationship between the mean frequency ($\bar{x}$), standard deviation (S.D.) values and the area size. Class width in brackets

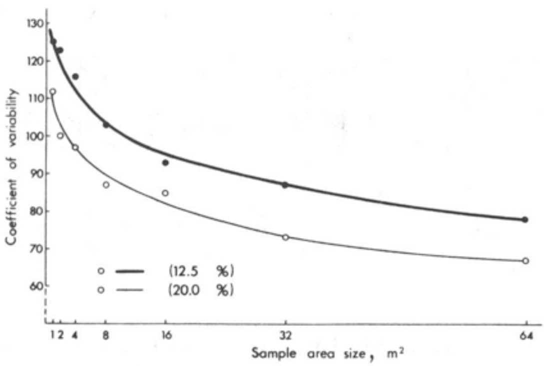

Fig. 5. Coefficient of variation — area size relationship. Class width in brackets

class. Regression equations for standard deviation are: $y = 1.50\ \lg_2 x + 29.21$, and $y = 1.77\ \lg_2 x + 25.57$, respectively. In all equations x designates area size. Concluding, for 8 classes one attains lower values of frequency mean and higher values of standard deviation than for 5 classes.

On the grounds of the analysis of relationship between coefficient of variation and area size it has been found that there is also higher variation in distribution at narrower frequency class. Mode of grouping does not affect the relationship: V is inversely proportional to the logarithm of the area size (Fig. 5). Regression equations for the coefficient of variation are: $y = -8.43 \lg_2 x + 137.28$ (at 12.5% frequency class), and $y = -7.18 \lg_2 x + 117.43$ (at 20% class), where x designates area size.

All analysed statistics are logarithmicly related to the area size. Empirical data show very good fit with regression equations. It is confirmed in values of correlation coefficients ranging from 0.960 to 0.998.

On the grounds of the assumed criterion — whether frequency distribution fits U-shaped distribution — phytocoenose under study can be considered homogeneous only for the large, 32 or 64 m^2, quadrat size.

BIOMASS FREQUENCY DISTRIBUTION AS A FUNCTION OF THE AREA SIZE

Frequency distribution of the ground-layer biomass changes with the increasing quadrat size, however at the assumed level of odds it usually does not fit the normal distribution. Empirical and theoretical distributions agree satisfactorily with each other for the quadrats of 8 and 16 m^2, then probability of null hypothesis of goodness of fit of both distributions is higher than 0.95 (Fig. 6).

Frequency distributions of individual species biomass much more differ

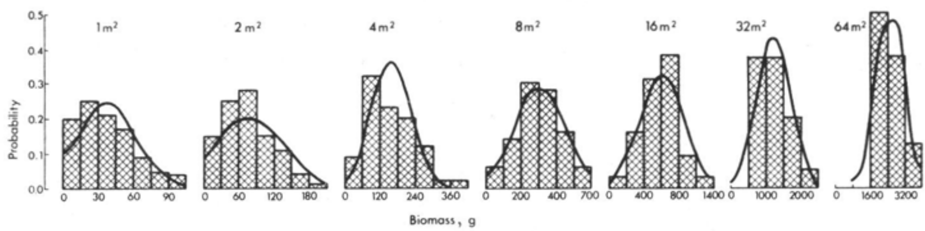

Fig. 6. Relationship between the type of frequency distribution of ground-layer biomass and the area size

from the normal distribution than the frequency distribution of the total ground-layer biomass. For small quadrats they are clearly asymmetrical, positively skewed, independent of species. Also effect of the quadrat size on the type of frequency distribution of biomass does not depend on species. On the other hand, the nature of changes in the distributions of individual species biomass occurring with increasing quadrat size is different (Figs. 7 and 8).

For *Vaccinium myrtillus* L. distribution changes from positively skewed (for 1, 2, 4 m^2) into relatively symmetrical (for 8 m^2) and becomes negatively skewed for 64 m^2 (Fig. 7a). Distributions of *Vaccinium vitis-idaea* L.

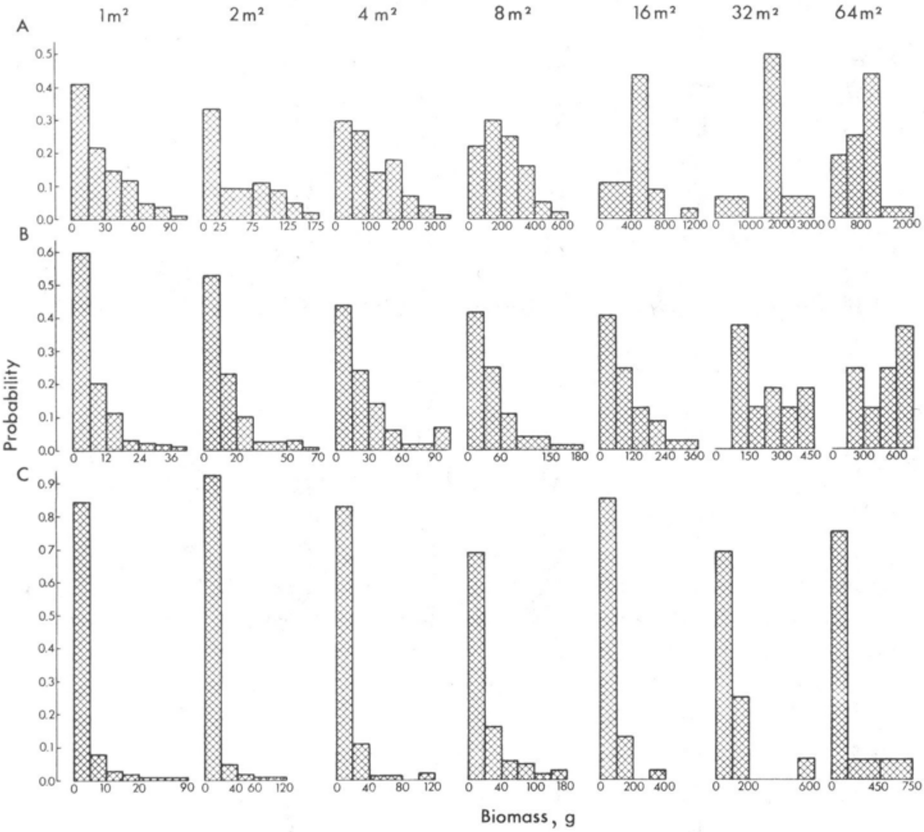

Fig. 7. Relationship between the type of frequency biomass distributions of *Vaccinium myrtillus* (A), *Vaccinium vitis-idaea* (B), *Calluna vulgaris* (C) and the area size

also change towards negative skewness, but contrary to *V. myrtillus*, no symmetrical distribution has been detected (Fig. 7b). Biomass distributions of *Calluna vulgaris* (L.) Salisb. are positively skewed, independent of the quadrat size (Fig. 7c).

At 64 m^2 typically positively skewed frequency distribution of *Melampyrum pratense* L. biomass changes into uniform, whereas frequency biomass distribution of *Pinus sylvestris* L. — into symmetrical close to the normal distribution (Figs. 8a and c). Case of *Molinia coerula* (L.) Moench is still different, distribution, first positively skewed, shifts with the increasing quadrat size to bimodal distribution (Fig. 8c).

According to the assumed homogeneity criterion — whether empirical distribution fits the normal distribution — phytocoenose under study can be considered homogenous with respect to the standing biomass of the ground layer for the quadrats of 8 and 16 m^2.

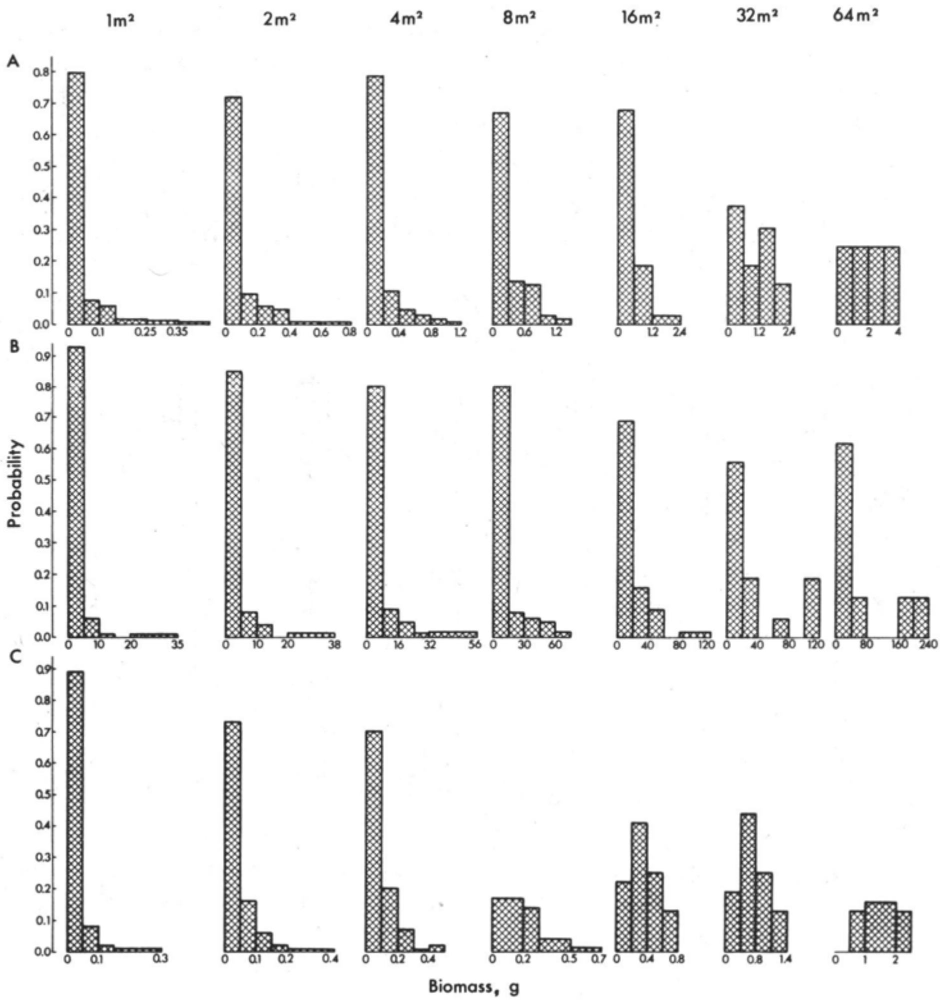

Fig. 8. Relationship between the type of frequency biomass distributions of *Melampyrum pratense* (A), *Molinia coerulea* (B), *Pinus sylvestris* (C) and the area size

DISCUSSION

From the analysis of the relation of the types of species frequency distribution and frequency distribution of biomass to the area size it may be inferred that: 1) the type of species frequency distribution and its statistical characteristics ($\bar{x}$, S.D., V) and the type of frequency distribution of biomass depend on the area size and 2) in phytocoenose the area size at which distributions of both analysed measures are symmetrical

(U-shaped, normal or close to normal) can be determined. The studies confirm conclusions of the investigations into homogeneity of other plant communities, i.e. grass community with *Brachypodium ramosum* (Callèja 1962, Dagnelie 1962, Gounot 1962, Gounot and Callèja 1962), and forest communities — *Tilio-Carpinetum* Tracz. 1962 and *Potentillo albae-Quercetum* Libb. 1933 (Matuszkiewicz and Wydrzycka 1972, Kwiatkowska 1984), with respect to qualitative measures. Homogeneity has been always a function of the area size, independent of the assumed criterion.

The fact that relation of frequency distribution parameters ($\bar{x}$ and S.D.) to the area size differs from that given by authors quoted above is worth noting. In the phytocoenose under study both mean frequency and standard deviation values are directly proportional to the logarithm of the quadrat size. In Dagnelie's (1962) and Kwiatkowska's (1984) works this has been true for mean value only, while standard deviation of species frequency has changed negatively parabolicly with the increasing quadrat size. It may be concluded that the type of relation of analysed parameters can be different, dependent on the phytocoenose type.

Changes in the type of species frequency distribution with the increasing area size cannot be interpreted unequivocally. Investigations have showed that distribution becomes symmetrical for the different area size, dependent on the mode of species grouping (i.e. width of the frequency class). Therefore, the type of frequency distribution is not a sufficiently precise indicator of the homogeneity, especially in floristicly poor phytocoenoses. It is clear that in the patch where few species are present, with the apparent dominance structure, even occasional occurrence of one species is important from the statistical point of view and affects results of the homogeneity analysis.

Phytocoenose homogeneity has not been studied so far with respect to the standing biomass. Thus, results can be compared only with some homogeneity indices of the ground-layer biomass (Chojnacki 1974). This paper has proved that the types of frequency distribution of total ground-layer biomass and those of individual species are a function of the area size. They fit the normal or uniform distribution only for some, relatively large areas (quadrats). The area size differs for qualitative and quantitative measures, as well as kind of the quantitative measure analysed. All this may be explained with the contagious type of spatial structure of the total ground-layer biomass, as well as biomass of its components — plant species. It will be discussed in the third paper of the cycle.

Summing-up, the investigations have showed that empirical distributions of the analysed qualitative and quantitative measures fit appropriate model of the symmetrical distribution only at the definite area size. Thereby, conclusion on the phytocoenose homogeneity can concern only definite scale of its spatial differentiation.

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Statystyczna analiza jednorodności fitocenozy. II. Rozkład frekwencji i rozkład wartości stanu biomasy jako funkcja wielkości powierzchni

Streszczenie

Praca jest częścią szerszych studiów nad problemem homogeniczności fitocenozy, mających na celu paralelizację wyników uzyskanych dla cech jakościowych i ilościowych, z zastosowaniem różnych wskaźników homogeniczności. Do badań wytypowano fizjonomiczne jednorodną fitocenozę *Leucobryo-Pinetum* Mat. (1962) 1973. Szczegółowy jej opis oraz zakres i metody badań podano w pierwszej pracy prezentowanego cyklu, w której za miarę jednorodności użyto typ rozkładu wskaźników ogólnej różnorodności gatunkowej i równomierności (Kwiatkowska i Symonides 1985). W mniejszej pracy analizę homogeniczności badanej fitocenozy przeprowadzono na podstawie rozkładu frekwencji gatunków oraz rozkładu wartości stanu biomasy runa i biomasy poszczególnych gatunków — jako funkcji wielkości

powierzchni. Za kryterium jednorodności przyjęto rozkład symetryczny: typu U dla cech jakościowych i normalny dla cech ilościowych (Guinochet 1954, 1957, Kwiatkowska i Symonides 1980). Przy wzrastającym w postępie geometrycznym rozmiarze powierzchni podstawowej (rys. 1) stwierdzono: 1) zmiany typu rozkładu frekwencji gatunków i zmiany typu rozkładu wartości biomasy; 2) zgodność rozkładu frekwencji z rozkładem typu U przy dużej powierzchni podstawowej: 32 lub 64 m^2, zależnie od szerokości przedziałów klasowych frekwencji (rys. 2 i 3); 3) wpływ wielkości powierzchni podstawowej na wartość średniej frekwencji gatunków, odchylenia standardowego i współczynnika zmienności; dwie pierwsze statystyki są wprost proporcjonalne, zaś trzecia — odwrotnie proporcjonalna do logarytmu wielkości powierzchni (rys. 4 i 5); 4) zgodność rozkładu biomasy runa z rozkładem normalnym dla powierzchni 8 i 16m^2 (rys. 7); 5) zbliżony do symetrycznego rozkład wartości biomasy *Vaccinium myrtillus* (dla 8 m^2) i *Pinus sylvestris* (dla 64 m^2) oraz niezgodność rozkładów empirycznych z rozkładem normalnym pozostałych gatunków, niezależnie od wielkości powierzchni podstawowej (rys. 7 i 8). Badania dowiodły, że homogeniczność fitocenozy może się realizować jedynie w określonej skali jej zróżnicowania przestrzennego.