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SIZE STRUCTURE OF PHYTOPOPULATIONS AND ITS QUANTITATIVE EVALUATION

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Abstract

There was elucidated the original approach to the evaluation of phytopopulation size structure. For its characteristics it was offered to use the special index – index diversity of size structure (IDSS). There are presented methods and algorithm of its determination. There was demonstrated that index diversity of size structure can be used at populational studies of species that belong to the different living forms. Especially phanerophytes (*Pinus sylvestris*) and hamephytes (*Ledum palustre*). As to *Pinus sylvestris* and *Ledum palustre* with help of index diversity of size structure was objectively proved that its cohorts and ontogenetic groups that growth in composition of forest phytocenoses typical for Ukrainian Polissya are not characterized with high level diversity of size structure. The value of index diversity of size structure is mainly less than 20 %. In phytopopulation the specific and phytocenotic peculiarity is demonstrated by diversity of size structure and also by representation of plants of certain size classes.

Keywords: phytopopulations, morphometric analysis, size classes of plants, size structure of phytopopulation, *Pinus sylvestris* L., *Ledum palustre* L.

1. Introduction

Individual is the structural unit of any vegetable population. It is not identical to each other by many signs and properties. It is resulted in formation of distinctly expressed intrapopulational biodiversity. The study of phytopopulation structures as integral biological systems is a topical problem of population botany [1].

An important characteristic of vegetable populations is its size structure. It characterizes the ratio of individuals of different sizes in population [2]. The size hierarchy appears in the process of individuals growth and development and it is usually well expressed [3–8]. The chain of scientific researches proved that individual size determines its ontogenesis duration, competitive firmness, flowers pollination, the size of reproductive output [9, 10]. Analysis of the size structure is particularly informative at study of the state and functioning of forest phytocenoses and it was used by many researches in this aspect [11–15].

Despite the special attention paid to the study of phytopopulation size structure for a long time this problem remains topical for today. Especially the approaches to the quantitative evaluation of size structure are not properly elaborated. In its turn it can be the base for objective comparison of several phytopopulations on this sign. For today at evaluation of phytopopulation size parameters scientists use Gini index rather often [5, 16, 17].

The aim of this publication is to give information about original approach to evaluation of phytopopulation size structure.

2. Materials and Methods

The base of publication is the results of the studies of the natural renewal state of *Pinus sylvestris* L., *Quercus robur* L., *Acer platanoides* L. that were carried out on the territory of Livo-

beregne Polissya of Ukraine during 2002–2013 years [18]. In its turn these data are based on the system of division of wood vegetable populations on intrapopulational structural groups – cohorts that was offered by Sklyar V. G. and Zlobin Y. A. [19]. On its base in composition of populations of the main forest forming species were separated the following cohorts:

1) *seedling;*
2) *plantlet;*
3) *small undergrowth;*
4) *middle undergrowth;*
5) *large undergrowth;*
6) *young trees of the upper forest tier;*
7) *mature trees of the upper forest tier.*

This publication is also based on the results of populationalal study of autochtonal dendrosozophyts of Ukrainian Polissya carried out in this region since 2013 year. The aforesaid group of plants includes the local flora species that have official status of certain protection grades (international, national or regional) [20].

In this work the approaches to evaluation of phytopopulations size structure were detailed on example of two species that are presented in many forest phytocenoses of Ukrainian Polissya: *Pinus sylvestris* та *Ledum palustre* L. The last one belongs to autochtonal dendrosozophyts of studied region. For substantial elucidation of the problem in *Pinus sylvestris* was selected the small undergrowth cohort and in *Ledum palustre* – plants of generative ontogenetic state. Both individuals of the *Pinus sylvestris* small undergrowth and *Ledum palustre* generative plants are presented in composition of the forest lower tiers. At the same time formation and growth of individuals from these two groups corresponds to the one of node stages of plants development.

The research included phytocenoses of 14 associations groups that are typical for Ukrainian Polissya namely:

1. *Pineta (sylvestris) hylocomiosa.*
2. *Pineta (sylvestris) calamagrostidosa (epigeioris).*
3. *Pineta (sylvestris) nardosa (strictae).*
4. *Pineta (sylvestris) franguloso (alni)-vacciniosa (myrtilli).*
5. *Pineta (sylvestris) vacciniosa (myrtilli).*
6. *Pineta (sylvestris) moliniosa (caeruleae).*
7. *Pineta (sylvestris) ledoso (palustris)-vacciniosa (myrtilli).*
8. *Pineta (sylvestris) sphagnosa.*
9. *Querceto (roboris)-Pineta (sylvestris) vacciniosa (myrtilli).*
10. *Querceta (roboris) convallariosa (majalis).*
11. *Betuleta (pendulae) vacciniosa (myrtilli).*
12. *Betuleta (pendulae) stellariosa (holosteae).*
13. *Pineto (sylvestris)-Betuleta (pendulae) eriophoroso (vaginati)-sphagnosa.*
14. *Pineto (sylvestris)-Betuleta (pendulae) vaccinioso (myrtilli)-ledosa (palustris).*

To detect the state and structure of aforesaid forest vegetable groups there were used the generally accepted geobotany methods [21–23]. Populational studies were also based on the use of generally accepted approaches and attended with morphometric analysis [2, 24]. In plants of *Pinus sylvestris* small undergrowth were evaluated 16 indices and in *Ledum palustre* – 20 ones. At the same time the measurement of stem diameter and general height was carried out in individuals of both species.

3. Results and its discussion

For evaluation of cohort size structure on the level of every separately taken group (cohort) of plants we offer the following algorithm of analysis:

1. For all totality of individuals of the certain group (cohort) were determined the minimal and maximal values of two morphometric parameters. For phanerophytes and several hamephytes the most informative in aforesaid aspect are indices of individuals height and stem diameter of the main axial sprout.

2. Taking into account the minimal and maximal values the size classes are determined for every morphoparameter.

3. The matrix of size classes is constructed for totality of the two morphoparameters.

4. Taking into account absolute values of stem height and diameter is determined the place of every plant in matrix sphere.

5. There is calculated the percentage of individuals that represents the different size classes.

6. There is constructed the total generalizing table and index diversity of size structure (IDSS) is calculated on its base.

The last characteristic is the presented in percentage part of the number of associations of combinations variants of the different size classes of stem height and diameter (*Nf*) revealed in certain group compared to the general theoretically calculated number of such combinations (*Nt*):

$$IDSS=(Nf/Nt)\times 100\ \%.$$

At our studies it was find out that in individuals of *Pinus sylvestris* small undergrowth the variation diapason of height absolute values is mainly 10,0–50,0 cm. The plants less than 10,0 cm. and bigger than 50,0 cm. are not often. For stem diameter the variation diapason of values was mainly within 0,1–1,2 cm. On this ground in studied vegetable groups were separated five main classes (from I to V) of height and diameter.

At the same time there were separated three additional classes: the one (Ia) for height and two (Ia and Va) for diameter. Ia class of height corresponds to the plants higher than 50,0 cm. Ia class of diameter corresponds to the individuals which values of this morphoparameter are more than 1,2 cm. and Va клас – to the plants with diameter less than 0,2 cm. In general the theoretically separated number of combinations of different size classes for the small undergrowth is 42 variants.

In *Pinus sylvestris* small undergrowth in conditions of *Pineta hylocomiosa* associations groups the size structure was the most diverse (**Table 1**). In its composition is present the undergrowth of all size classes of height (from Ia to V) and almost all size classes of diameter (except Ia and I) that in totality form 18 variants of size classes associations. The values of index diversity of size structure of the small undergrowth reaches 42,9 %. In this associations group the most specific weight is formed by plants of the following variants of combinations of height and diameter size classes: I–IV – 18,1 %; II–IV – 14,6 %, III–V – 14,0 %, that is individuals with height 20–50 cm. and diameter 0,4–0,6 cm. The least specific weight (0,6 %) is the one of plants with the following combination of height and diameter size classes: IV–IV and V–Va that in absolute expression corresponds to the height 9,0–20,0 cm. and diameter 0,1–0,4 cm.

Pinus sylvestris small undergrowth that takes place in the forest of associations group *Pineta franguloso-vacciniosa* has the lower values of index diversity of size structure comparing with *Pineta hylocomiosa* (33,3 %). There are revealed 14 combination variants of height and diameter size classes. In composition of this associations group is presented the undergrowth of almost all size classes of height (except V) and size classes of diameter (except Ia and I). Among the small undergrowth in aforesaid group prevail plants with following combination of height and diameter size classes: I–IV – 22,8 %; II–IV – 17,3 %; III–V – 17,2 %, in absolute expression it corresponds to the height 20–50 cm and diameter 0,2–0,6 cm. In this association group the least part is plants with the following combination of size classes: Ia–II (0,2 %), Ia–IV (0,3 %), Ia–III (0,4 %), II–III (0,4 %), I–V (0,5 %), IV–V (0,7 %).

In *Pineta sphagnosa* and *Querceto-Pineta vacciniosa* associations groups were revealed 12 variants of combination of height and diameter size classes and the value of diversity index of size structure of *Pinus sylvestris* small undergrowth in it is 28,6 %. The common sign of undergrowth from these associations groups is the fact that there are individuals of all height size classes in it (except V) that in absolute expression corresponds to the height from 10,0 cm to 53,5 cm. But on diameter values in *Pineta sphagnosa* association group are present the plants of III–Va classes (0,1–0,8 cm.) and in *Querceto-Pineta vacciniosa* associations group – II–Va classes (0,1–1,0 cm). The special feature of the size structure of small undergrowth from *Pineta sphagnosa* association group is the fact that the most part of its composition (30,2 %) is individuals with the following combination of size classes: I height (40–50 cm) and IV diameter (0,4–0,6 cm). Whereas among the

undergrowth of *Querceto-Pineta vacciniosa* associations group the most specific weight (23,0 %) is formed by the plants of II height class (0,3–0,4 cm) and of IV diameter class.

Table 1

Representation of individuals of small undergrowth Pinus sylvestris different size classes in associations groups

Morphometric parameters				The proportion of individuals of different size in associations groups, % (numbered associations groups are as in the text)									
height		diameter											
class	ampl. absolute values, cm	class	ampl. absolute values, cm	1	2	3	4	5	8	9	10	11	12
Ia	more than 0,5	II	0,8–1,0	2,3	–	–	0,2	–	–	4,8	–	–	–
Ia	more than 0,5	III	0,6–0,8	4,1	8,3	–	0,4	10,0	–	14,5	13,9	14,4	14,3
Ia	more than 0,5	IV	0,4–0,6	6,4	11,1	–	0,3	–	10,1	–	9,8	6,8	18,6
I	0,4–0,5	II	0,8–1,0	1,8	10,5	–	8,6	–	–	5,1	–	–	–
I	0,4–0,5	III	0,6–0,8	12,3	11,8	–	10,2	9,6	5,6	13,6	16,3	21,3	–
I	0,4–0,5	IV	0,4–0,6	18,1	22,2	49,6	22,8	31,2	30,2	–	–	29,1	38,5
I	0,4–0,5	V	0,2–0,4	1,2	–	–	0,5	–	2,8	–	–	–	14,3
II	0,3–0,4	II	0,8–1,0	2,3	–	–	–	–	–	–	–	–	–
II	0,3–0,4	III	0,6–0,8	4,7	–	–	0,4	–	–	–	–	–	–
II	0,3–0,4	IV	0,4–0,6	14,6	–	17,2	17,3	10,4	11,3	23,0	33,2	28,4	14,3
II	0,3–0,4	V	0,2–0,4	5,8	21,9	–	11,6	19,1	16,7	9,7	17,3	–	–
II	0,3–0,4	Va	0–0,2	–	–	–	–	–	2,8	–	–	–	–
III	0,2–0,3	II	0,8–1,0	–	–	–	–	–	–	4,2	–	–	–
III	0,2–0,3	III	0,6–0,8	1,8	–	33,2	–	11,2	–	3,9	–	–	–
III	0,2–0,3	IV	0,4–0,6	3,5	–	–	8,6	–	4,7	5,0	–	–	–
III	0,2–0,3	V	0,2–0,4	14,0	14,2	–	17,2	8,5	2,6	9,4	9,5	–	–
III	0,2–0,3	Va	0–0,2	–	–	–	–	–	5,8	–	–	–	–
IV	0,1–0,2	IV	0,4–0,6	0,6	–	–	–	–	5,9	–	–	–	–
IV	0,1–0,2	V	0,2–0,4	3,0	–	–	0,7	–	–	3,3	–	–	–
IV	0,1–0,2	Va	0–0,2	2,9	–	–	1,2	–	1,5	3,5	–	–	–
V	less than 0,1	Va	0–0,2	0,6	–	–	–	–	–	–	–	–	–
Index diversity of size structure (IDSS), %				42,9	16,7	7,1	33,3	16,7	28,6	28,6	14,3	11,9	11,9

In *Pineta calamagrostidosa* and *Pineta vacciniosa* associations groups among the *Pinus sylvestris* small undergrowth are presented plants which parameters corresponds to the seven variants of size classes combination and index diversity of size structure is 16,7 %. In general the size structure of small undergrowth in these two groups turned out rather similar: there are plants of the Ia–III height classes and of III–V diameter classes only though in *Pineta calamagrostidosa* associations group take place also individuals of II diameter class. The most distinctly expressed difference in size structure of the small undergrowth from *Pineta calamagrostidosa* and *Pineta vacciniosa* associations groups is that in the first one the more (in 1,9 times) part of the small undergrowth is formed by plants of Ia height class.

In *Querceta convallariosa* associations group are presented six variants of combination of height and diameter size classes and index diversity of size structure of *Pinus sylvestris* small undergrowth is 14,3 %. There are present the plants of Ia–III height size classes and of III–V diameter classes. In composition of this associations group the more part (33,2 %) is formed by the individuals which size corresponds to the II height class (30,0–40,0 cm) and IV diameter class (0,4–0,6 cm). The specific weight of the plants of Ia height class is significant (23,7 %).

In *Betuleta vacciniosa* and *Betuleta stellariosa* associations groups is present the *Pinus sylvestris* small undergrowth which size parameters represent only five variants of combination

of height and diameter size classes, index diversity of size structure is 11,9 %. The undergrowth size parameters mainly correspond to Ia–II height classes and to III–IV diameter classes though in *Betuleta stellariosa* associations group there are also individuals of V diameter class. In *Betuleta vacciniosa* associations group the most part is formed by the plants with the following variants of combination of height and diameter size classes: I–IV (29,1 %) and II–IV (28,4 %) that is individuals which absolute values of height are within 30,0–50,0 cm and of diameter 0,4–0,6 cm. In *Betuleta stellariosa* associations group the most part (38,5 %) is plants which height corresponds to the I class and diameter to the IV one.

The simplest size structure is inherent to the small undergrowth from *Pineta nardosa* associations group: it includes the vegetable size parameters that represents only three variants of combination of size classes of height and stem diameter, index diversity of size structure is 7,1 %. This associations group include undergrowth of I–III height classes and III–IV diameter classes and the most part (49,6 %) is formed by plants of the I height class (40,0–50,0 cm) and of IV diameter class (0,4–0,6 cm).

At studying *Ledum palustre* it was find out that in its generative plants the diapason of variation of height absolute values is mainly 30,0–110,0 cm. Plants less than 30,0 cm and bigger than 110,0 cm are rather seldom. For stem diameter the diapason of values variation was within 0,1–1,2 cm. Based on this for *Ledum palustre* were separated five main classes (from I to V) of height and diameter that included the main diapason of height and diameter values.

Besides it there were separated three additional classes: one for height and two for diameter. Ia height class corresponds to the plants higher than 110,0 cm. Ia diameter class corresponds to individuals which values of this morphoparameter are more than 1,2 cm and Va class – to plants with diameter less than 0,2 cm. In general the theoretically separated number of combinations of different size classes for *Ledum palustre* generative plants as for *Pinus sylvestris* small undergrowth is 42 variants.

There was detected that the *Ledum palustre* from phytocenoses of *Pineto-Betuleta vaccinioso-ledosa* associations group is characterized with the highest diversity of size structure (**Table 2**). In this associations group the most specific weight is formed by the plants of following variants of combinations of height and diameter size classes: I–IV – 19,8 %; II–IV – 13,3 %, II–V – 12,6 %, that is individuals with height 70–110 cm and diameter 0,2–0,6 cm. The least one (5,6 %) is the specific weight of plants which first height class (90–110 cm) is combined with the III diameter class (0,6–0,8 cm).

Table 2

Representation of individuals of Ledum palustre different size classes in associations groups

Morphometric parameters				The proportion of individuals of different size associations groups, % (number of associations groups are as in the text)						
height		diameter								
class	ampl. absolute values, m	class	ampl. absolute values, cm	1	5	6	7	8	13	14
Ia	more than 1,1	I	1,0–1,2	–	–	–	–	7,4	–	6,2
Ia	more than 1,1	III	0,6–0,8	–	13,1	–	–	–	–	-
Ia	more than 1,1	IV	0,4–0,6	–	7,9	–	–	–	–	7,1
I	0,9–1,1	III	0,6–0,8	–	–	–	6,9	16,2	–	5,6
I	0,9–1,1	IV	0,4–0,6	–	30,8	–	14,5	–	–	19,8
I	0,9–1,1	V	0,2–0,4	–	–	–	–	–	–	6,7
II	0,7–0,9	III	0,6–0,8	–	–	10,2	7,4	51,3	7,9	-
II	0,7–0,9	IV	0,4–0,6	–	28,7	31,5	20,9	8,3	41,4	13,3
II	0,7–0,9	V	0,2–0,4	9,4	–	9,1	22,8	6,4	–	12,6
II	0,7–0,9	Va	0–0,2	–	–	–	–	–	–	6,5
III	0,5–0,7	III	0,6–0,8	–	–	–	–	10,4	–	–
III	0,5–0,7	IV	0,4–0,6	20,5	9,3	28,5	21,6	–	40,2	7,1
III	0,5–0,7	V	0,2–0,4	49,3	10,2	11,6	5,9	–	–	6,2
III	0,5–0,7	Va	0–0,2	12,2	–	–	–	–	–	–
IV	0,3–0,5	IV	0,4–0,6	–	–	9,1	–	–	–	–
IV	0,3–0,5	V	0,2–0,4	8,6	–	–	–	–	10,5	–
IV	0,3–0,5	Va	0–0,2	–	–	–	–	-	-	8,9
Index diversity of size structure (IDSS), %				11,9	14,3	14,3	16,7	14,3	9,5	26,2

Ledum palustre generative plants that growth in *Pineta ledoso-vacciniosa* associations group are rather diverse on size structure. It represent seven variants of combination of height and diameter indices and the value of index diversity of size structure is 16,7 %. The most part (20,9–22,8 %) is formed by plants that have the following combinations of height and diameter size values: II–IV, II–V and III–IV.

Ledum palustre generative plants from *Pineta vacciniosa, Pineta moliniosa, Pineta sphagnosa* phytocenoses turned out to be similar on values of index diversity of size structure (IDSS=14,3 %). Although the *Ledum palustre* from aforesaid groups essentially differs on representantion of plants of correspondent height and diameter size classes. Especially in *Pineta vacciniosa* the most part (30,8 %) is formed by individuals that belong to the I height class and to the IV diameter one. In *Pineta moliniosa* the most ponderable part (31,5 %) is formed by plants of II height class and IV diameter class and in *Pineta sphagnosa* prevail plants of II height class and III diameter class (51,3 %).

The simplest size structure is inherent *Ledum palustre* from phytocenoses of *Pineto-Betuleta eriophoroso-sphagnosa* associations group. The plants of this specie represents only three variants of combination of height and diameter size classes and value of index diversity of size structure is 9,5 %.

4. Conclusions

1. The researches testified to the high level of informational content of evaluation of plants phytopopulations size structure (cohorts, separate ontogenetic groups) and expediency of the use of original index – index diversity of size structure (IDSS).

2. Index diversity of size structure can be used at populational studies of species that belong to the different living forms. Especially as was demonstrated in this publication to phanerophytes **(***Pinus sylvestris)* and hamephyts (*Ledum palustre).*

3. Taking into account the values of index diversity of size structure of studied species there was objectively proved the high level of size structure diversity is not inherent to its cohorts or ontogenetic groups presented in composition of region forest phytocenoses. The IDSS value is mainly less than 20 %.

4. Both specific and phytocenotic peculiarity is demonstrated in phytopopulations by the diversity of size structure and also by representation of plants of certain size classes.

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