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# *REGULARITIES OF THE DISTRIBUTION OF BIOTIC TAXA ON THE TERRITORY OF THE WEST SIBERIAN PLAIN*

*ABSTRACT. This article studies quantitative regularities of biotic taxa distribution on the territory of the West Siberian Plain within Tyumen and Omsk regions. Their climatic dependence is investigated. The nature of the distribution of species, genuses, families and orders of the biota within the geographical subzones of the considered area is established. Formulas of geographical and hierarchical dependence of taxa are found; their self-similarity is shown. It is claimed that existence of a biotic system and its state can be interpreted as a result of dichotomous interaction of two opposites – the dominant and subdominant, expressed in a relative form so that their sum is equal to one. The ratio of the maximum of the taxon to the sum of the other taxa of the same category is accepted as a dominant. For example, in the animal group it is the relation of the birds taxa to the sum of the taxa of birds and mammals. The authors introduce and evaluate indicators of interaction between floristic and faunistic components of biota. Formulas for determination of stability and harmony of biotic systems are suggested.*

*KEY WORDS. West Siberian Plain, biota, interaction, stability.*

**Introduction (approaches and methods).** A detailed qualitative description of the grass cover and animal world of the West Siberian Plain (WSP) is offered in the works [1-3]. The present article is devoted to the quantitative regularities of biotic taxa distribution and interaction of their systematic groups on the territory of WSP within Tyumen and Omsk regions.

The biotic system can be interpreted as the result of the interaction of two opposites — dominant and sub-dominant whose relation to each other is expressed in the following: their sum equals to one. A similar (dichotomous) approach was used in [4] where the landscape was seen as a whole entity in the field of action of the opposite forces. In our research we employed this approach for the purpose of the analysis of the pattern of change of the hierarchical groups of taxa within WSP and evaluation of their stability. Numerical coefficients and parameters of the received empirical equations have been matched with the generalized golden ratios (GGR) [5-6].

Formulas of the geographical and hierarchical dependence of the number of taxa, their graphic representation and $R^2$ validity have been defined with the help of the standard Excel software.

**Research findings and their discussion.** ***Indicators of heat and moisture supply.***

Spatial (geographical) distribution of biota is mainly conditioned by climate. All climate elements (CE) are interconnected. Certain quantifications of these connections for the conditions of Tyumen and Omsk regions had been discovered [7] which allowed defining any index by the one known CE, for example by an aridity index. Aridity index J = B/kU (B – radiation balance, U – annual precipitation amount, k – latent heat of vaporization) is the most important, complex CE responsible for heat and moisture distribution at the Earth surface. It ranges from 0 in the zone of the arctic deserts to 3-5 and higher in the deserts of the subtropical and tropical belts [8].

Depending on the value of J the phytosphere can be divided into the northern $J_n$ (cool and humid) and southern $J_s$ (warm and dry). The border between them approximately coincides with the isoline J=1. Conditions of the heat and moisture exchange in the northern and southern phytospheres characterized by value J are anti (logarithmically) symmetric. For instance, the region of stable vegetation existence is limited in the north by isolines Jn ~~0.2…0.33 (northern tundra), in the south by Js ~~ 5…3 (southern semi-desert) [8]; thus, $J_n$ ~~ 1/Js or ln $J_n$~~ln/(1/Js)~~ - ln(Js).

Other values are also anti symmetric. They are expressed as dependencies of J, in particular amounts of annual precipitation, group palynological spectrums and phytoproductivity [7]. Curves of these dependencies are of cycloid types whose maximum (peak) falls on J=0.95÷1.2 (close to J~~1). As an example fig. 1 presents the dependence of the annual precipitation amount U (cm) and phytoproductivity (annual production) of the grass cover Pr (g/ha year) on J.

**Distribution of biotic taxa**. Table 1 presents the distribution of biotic taxa and mean values J in the natural zones and subzones of WSP (according to [1-3]).

*Table 1*

**The number of taxa of animals (birds + mammals) and vascular plants as well as mean values J in the subzones of WSP**

| No. | Subzone | J | Animals | | | | Plants | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Orders | Families | Genera | Species | Orders | Families | Genera | Species |
| 1 | Northern tundra | 0,35 | 7+5 | 20+9 | 46+15 | 73+18 | 17 | 17 | 35 | 57 |
| 2 | Southern tundra | 0,6 | 11+5 | 30+11 | 79+22 | 148+32 | 31 | 31 | 67 | 126 |
| 3 | Wooded tundra | 0,75 | 15+5 | 39+12 | 107+27 | 194+42 | 28 | 28 | 58 | 99 |
| 4 | Northern taiga | 0,87 | 16+6 | 41+15 | 115+33 | 207+51 | 38 | 43 | 86 | 174 |
| 5 | Middle taiga | 0,96 | 18+6 | 48+17 | 136+38 | 257+59 | 46 | 50 | 147 | 247 |
| 6 | Southern taiga | 1,0 | 16+6 | 47+17 | 130+38 | 246+60 | 57 | 73 | 203 | 380 |
| 7 | Subtaiga | 1,1 | 18+6 | 54+18 | 141+41 | 271+67 | *57* | *74* | 260 | 493 |

*Continued table 1*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 8 | Northern wooded steppe | 1,3 | 19+6 | 50+19 | 139+43 | 259+63 | 55 | 64 | ***267*** | ***540*** |
| 9 | Southern wooded steppe | 1,5 | 18+6 | 48+18 | 135+44 | 252+67 | 46 | 54 | 226 | 449 |
| 10 | Steppe | 1,9 | 19+6 | 45+16 | 115+40 | 208+58 | 33 | 36 | 131 | 215 |
| | Total | | 19+6 | 55+20 | 145+47 | 369+95 | 67 | 88 | 364 | 996 |

Notes: 1. Taxa orders (zoolog.) and orders (botan.) are identical in the content; 2. Maximum taxa values are in bold.

From Table 1 it is evident that the quantities of the biotic taxa, both of the flora and fauna, change in the same way and in general from the north to the south they first increase and then decrease.

The vector change occurs in the subtaiga – northern wooded steppe. Consequently it can be claimed that the most favorable living conditions for the biota are in the area of transformation of the taiga into the wooded steppe where the aridity index J ranges within 0.95÷1.2.

The specificity of the geographical zones and subzones in table 1 is reflected in their ordinal numbers i. In fig. 2 you can see graphs of dependence of the number of the taxa of animals $T_a$ and plants $T_p$ of I, according to table 1 (thin lines) and their approximations (thick lines).

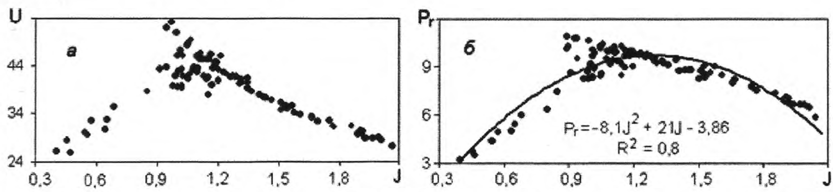


Fig. 1. Dependence of U (a) and Pr (b) of J

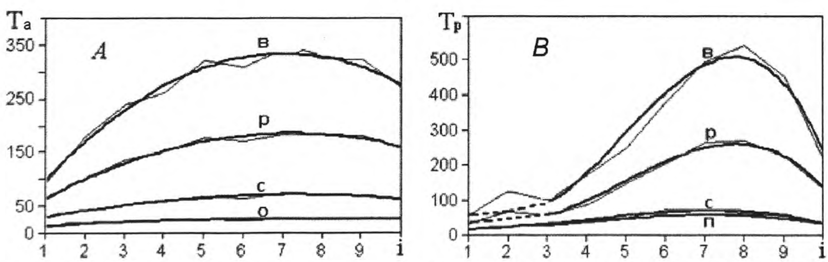


Fig. 2. Dependence of $T_a$ (A) and $T_p$ (B) of I (the curves are marked with the first letters of the taxa names; dashed lines – smoothed variant of the movement of the genera and species of plants in the tundra)

We have defined a general equation of the zonal distribution of biotic taxa

$T_{p,a} = Ai^3+Bi^2+Ci+D,$ (1)

where A, B, C, and D are empirical constants defined by table 2.

As it is evident from fig. 2 and table 2, validity of formula (1) is high especially for the animals for the taxa of which the cubic formula of the polynom (1) turns into a more simple one – quadratic (A=0). The curves on the graphs of fig. 2 and fig. 1 are almost symmetrical in relation to J~-1.

*Table 2*

**Constants in formula (2) and its validity ($R^2$) for: I – plants, II – animals**

| № | Taxa | A | B | C | D | $R^2$ |
|---|---|---|---|---|---|---|
| I | Species | -4,82 | 70,5 | -225,8 | 261,7 | 0,95 |
| | Genera | -2,25 | 32,6 | -100,1 | 122,5 | 0,97 |
| | Families | -0,39 | 4,78 | -7,44 | 22,5 | 0,94 |
| | Orders | -0,23 | 2.62 | -1,48 | 18,6 | 0,95 |
| II | Species | 0 | -6,42 | 90 | 15,1 | 0,98 |
| | Genera | 0 | -3,1 | 44,6 | 22,6 | 0,98 |
| | Families | 0 | -1,01 | 14,7 | 15,2 | 0,98 |
| | Orders | 0 | -0,25 | 3,9 | 9,3 | 0,94 |

The mean values of the number of the taxa of plants and animals in the families, genera and species in the zones in question are $T_p$: 47, 148, 278 and $T_a$: 57.4, 148.4, and 263 correspondingly. In each class (rank – r=1,2,3) they are close in their value. Our analysis has shown that dependence of the mean values in all the zones and subzones $T_{p,a}$ of r with validation $R^2$=0.99 is approximated with a line formula:

$Tp,a = 109.2\ r - 61.4.$ (2)

The next, after the species, rank of biotic hierarchy, the fourth (r = 4) is its structural unit – population which is the "form of the species existence" [9]. By putting into (2) r = 4 we get an approximate average number of the biota populations in the zone in question: $T_{p,p} \approx T_{ap} \approx 375.4$.

***Dichotomous nature of interaction of biotic groups***. The biotic system can be presented as a dichotomy – sum of two opposites, dominant Y and subdominant Y̆, expressed in the unit fractions so that Y̆ +Y = 1. However the subdominant usually consists of a number (n) of small particles. Let us represent it as the geometric mean from the number of these particles X= Y̆1/n; in that case the expression for the sum will transform into Xn +Y =1. When X increases, Y decreases. In the points where they are equal: Y=X=Φ=const., the system finds itself in a stable equilibrium with its components and the formula looks like [10]:

$\Phi^n + \Phi = 1.$ (3)

The values Φ = Φn calculated with the help of (3) with different wholes n≥1 establish a sequence 1) 0.5; 2) 0.618; 3) 0.682;…; 31) 0.923…, the members of which are called Generalized Golden ratios (GGR). According to (6) "the generalized golden ratios are invariants on the basis of which and via which in the process of self-organization natural systems acquire a harmonic structure, stable mode of existence, structural and functional stability". GGR are characterized by two constants: the main (bigger) $\Phi > 0.5$ and auxiliary $1-\Phi=\Phi n$ which co-exist as a dichotomy in the mode of unity and opposition. The golden ratio can be found when we introduce n=2 into (3):

$$(\Phi 2/1) = (1-\Phi 2)/\Phi 2 = 0.618 \approx 0.62 \quad (4)$$

This is one of the most common proportion of balanced oppositions in different systems, which is the most favorable energetically. It is an optimum correlation of the structural elements of the system which ensures its maximum orderliness [5-6].

The value n is the number of the particles in the subdominant. It indicates dimensionality of the object. The line is one-dimensional — n=1; the sub-space is two-dimensional — n = 2; the geometrically represented space is three-dimensional — n=3. Formula (6) is valid not only for the whole n but also for all their range from 0 to $\infty$. Basically GGR is any pair of numbers less than 1 the sum of which equals 1.

The space between ($1-\Phi n$) and $n\Phi$ on the bell-shaped graph of the "life" cycle of the system including "youth" (rise), "maturity" and "ageing" (fall) is the stage of maturity characterized by constant and minimal speed of deformation during the whole cycle [10]. Living systems at this stage are reproductive [10].

Increase in the number of particles in the system brings about increase in the number of the separating lines – borders which act as stress concentrators. These points (ecotones, sea and river coasts, snow lines, and transitional seasons: spring and fall, borders between states and ethnic groups etc.) are characterized by the biggest variability of parameters and deformations and, correspondingly, the least stability. The fewer particles there are in the system, the fewer different borders and, as a result, a bigger stability. The notion of *stability* is closely connected with *balance*. The more stable the system is, the more balanced it is. Therefore, the reciprocal value of the number of particles in the system 1/n=Z, changing from 1 to 0, can be a relative measure of stability (and balance) of the system. It is evident that maximum stability and balance is achieved when n=1 but in this case the subdominant turns into a monolith without any subjects of self-organization – particles. As a result of which some "quasi-living" force, which ensures the system's capability of self-organization (which can be interpreted as consistent (harmonic) integration of particles including self-restoration of the system's parameters after non-destructive deformation), is lost [10]. In mechanics its analog is elasticity characterized by Young modulus and equal to tension at which the linear dimension of the body is twice increased [11].

Expression for Z (or n) can be received from (4):

$$Z = \ln(\Phi)/\ln(1-\Phi). \quad (5)$$

Capability of self-organization likening any system with a "living" one appears when n>1 and reaches its maximum when n=2 (compare with Young modulus) or Z=0.5 or $\Phi$=0.62 and then, with the further growth of n, decreases together with stability. i.e. maximum harmony between the system components is observed when Z=0.5; with harmony decreasing in both directions until 0.

To measure harmony we introduce coefficient Γ. In accordance with the above mentioned dependence of the values of interaction of the system components $\Phi$, Z and Г of n can be shown on a graph (fig. 3), where Г must be calculated with formula (8) if n>2, or Г≈0.5 (n-1) if n<2.

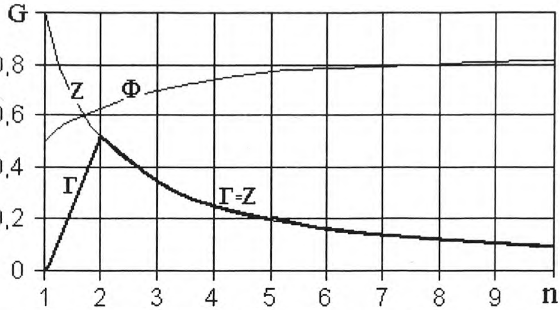


Fig. 3. Dependence G (Ф, Z and Г) of n (in bold dependence Г of n)

***Character of interaction of biotic components***. We take birds and mammals comprising the faunal component of biota as an example. Birds dominate in this pair (table 1). Therefore, value Ф is defined as relation of the birds' taxa to the sum of the taxa of birds and mammals. Picture 4 presents dependence Ф as well as mean values Фс, Zc and Гс of I (subzone numbers).As n>2 Zc = Гс according to picture 5.

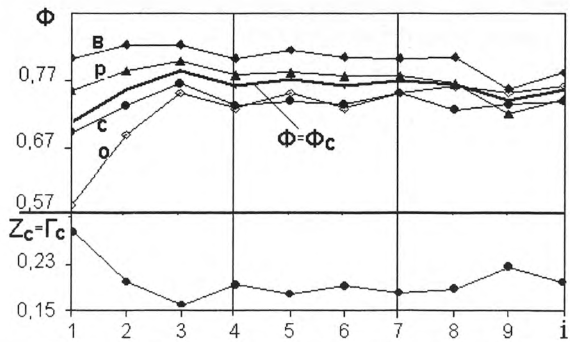


Fig. 4. Dependence Ф and Zc= Гс) of i (in bold run of the mean value $Ф=Ф_c$)

It can be seen in the picture that zonal distribution of dominant Ф in this system is approximately similar (fractal) for all the taxa gradations [12]. Subzonal mean values Ф for the four-member hierarchy *order (o), family (f), genus (g) and species (s)* are correspondingly equal to: *0.72; 0.73; 0.77; 0.8.*

Such distribution is close to fractal one: each consequent value $Ф_c$ is bigger than the previous value by about 1.035. Insignificant fluctuations Ф around the mean values can be possibly connected with observational errors. The mean values $Z_c = Г_c = 0.2$ are far from their maximums which indicates a relatively little interdependence of birds and mammals.

A different picture is observed when we analyze dichotomies including faunal and floral biotic components opposing each other and stably balanced according to the classical scheme "hunter (eater) – victim (food)". Table 1 shows that animals dominate in the northern (cold and humid) phytosphere where $J<1$; plants dominate in the southern (warm and dry) phytosphere where $J>1$; and only in the steppe animals dominate again. In both parts of the phytosphere the dominant value decreases in the direction of the deserts: arctic in the north and tropical in the south. During the analysis we defined values $\Phi$ as relations of the factual dominant – animals, for example birds or plants, to the sum of the dominant and subdominant (birds plus plants).

Picture 5 presents dependence $\Phi$ for different taxa gradations (in the listing from top to bottom): *species, genus, family* as well as the mean values of the interaction indicators $\Phi_c$ (in bold), $Z_c$ and $\Gamma_c$ of the subzone number i (according to table 1) for the system birds-plants. Values Zc were defined with the help of formula (8) and $\Gamma_c \approx 0.5(n-1)$.

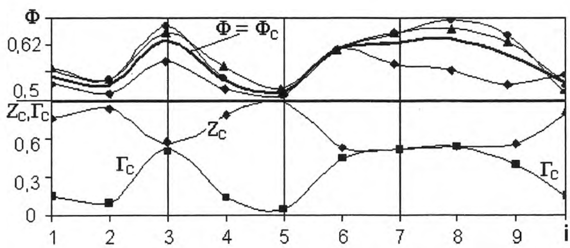


Fig. 5. Dependence $\Phi$, $\Phi_c$, $Z_c$ and $\Gamma_c$ of i

The dependences in question vary wavelike; $\Phi c$ (i) and $\Gamma c$ (i) are similar and Zc (i) is reciprocally similar (symmetrical) to them. Value i=5, corresponding to the middle taiga, where the aridity index is close to optimal $J\approx1$, when warmth and moisture are maximum (stably) balanced, is the center of the symmetry, which is characterized by a close to maximum value $Zc\approx1$ and close to minimum values $\Phi$ and $\Gamma$. In both directions from i=5 $\Phi$ and $\Gamma$ increase and Z decreases.

The zonal mean values $\Phi_c$ for the three-member hierarchy *family, genus and species* are correspondingly equal to 0.*72; 0.83* and *0.95*. Such distribution is also close to a fractal one: each consequent value $\Phi_c$ is bigger than the previous one by 1.14 on average.

**Conclusion**. The number of biotic taxa depends on the hierarchical ranking and geographical position. The maximum values of the taxa corresponding to the optimum conditions of existence are observed in the region sub-taiga — northern wooded steppe where the aridity index varies within $0.95\div1.2$ (close to 1). To the north and south from this region the taxa values decrease due to lack of warmth in the north and excess of it in the south. We have established a formula of zonal dependence of the number of taxa of plants and animals of any rank. Distribution of the biotic taxa in the line species-genus-family is fractal.

On the whole the results obtained demonstrate unity and interdependence of existence of plants and animals and their general dependence on climate.

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