Hemeroby and homotoneity of plant communities: can we detect evident codependencies?

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Abstract. The results of codependency analysis of 9 qualitative and 4 quantitative measures of plant communities homotoneity with statuses of their naturalness based on the application of the indicator value scale of hemeroby tolerance of South Siberian plants are presented. The highest correlation with level of naturalness was performed by qualitative multiplace measure of similarity by Jaccard.

1 Introduction

Environmental quality assessment and monitoring of the biota in the areas subjected to significant anthropogenic impact require reliable and objective indicators of the state of plant communities, as one of the basic ecosystem components. The degree of vegetation hemeroby can't be directly measured by instrumental control. An effective means of quantitatively assessing anthropogenic transformation is the method of indicator values analysis (IVA), or phytoindication, which is based on an indirect probabilistic assessment of this complex factor according to the reference synecological statuses of indicator taxa registered in the plant communities in the study area. To assess an ecosystem disruption several scales of hemeroby have been developed and successfully used [1, 2]. In collaboration with Dr. A. Ebel we developed such scale of hemeroby tolerance for Southern Siberia [3].

Since disturbances in ecotopes lead to significant shifts in the qualitative and structural composition of phytocoenoses as a result of changes in the set and occupancy of available ecological niches, it can be assumed that this should increase the floristic and ecological heterogeneity of vegetation units. The aim of this study is to try to find confirmation of the interdependence of changes in phytoindication status of disturbance of plant communities with qualitative and quantitative indicators of the homogeneity of flora of associations belonging to different types of vegetation.

According to the views the Braun-Blanquet phytosociological school [4] "… homogeneity is an analytic concept, based on comparing different plots of the same size

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taken from an individual stand, whereas homotoneity is a synthetic concept, based on comparing similar plots from different stands of the same community-type or phytocoenon." Several more specific or general terms are used as synonymous with theses concepts: homotopy, evenness of assemblage, uniformity of composition, average similarity, and affinity of communities. And since even with a change in methodological bases, mathematically, all quantitative indicators of homogeneity are calculated in the same way, the competence of using them to assess specific sets of relevés remains at the discretion of a researcher.

2 Materials and methods

2.1 Study area and Materials

The study area "The Tom river slope", designated as a specially protected natural area (SPNA) of local importance in 2011, is located in the southern part of Tomsk on the riverbed terrace of the Tom river and occupies 527.70 hectares. The territory lies in the extreme southeast of the West Siberian Plain, at its contact with the northern spurs of the Kuznetsk Alatau, and is distinguished by a complex and highly dissected valley-gully relief [5]. The region belongs to the continental climate zone, with characteristic warm summers and cold winters (average temperature is 19.8 °C in July and −21.3 °C in January) and moderate precipitation level - 553 mm per year. The soil cover is very diverse, but in general it is dominated by gray forest and soddy-podzolic soils. The vegetation is characterized by indigenous and derivatives of small-leaved forests, often of a park type, with a well-developed graminous-forb layer. However, diverse landforms often determine the complex composition of plant communities [5]. The area of SPNA is subjected to significant recreational stress.

The set of relevés (n=231, with a total list 361 of vascular taxa) on the territory of SPNA was recorded by E.P. Prokopiev [1, 6] with further identification of 38 vegetation associations. To check the influence of the volume of associations on the calculation of homotoneity indices we formed 3 set of associations as following: 23 associations with at least 5 relevés in each, 12 associations with at least 7 relevés, and 7 associations with at least 10 relevés.

2.2 Evaluation of hemeroby

The model territory once used to develop the hemeroby tolerance scale of plants in southern Siberia [3] also covers our study area. The high relevance of the scale is confirmed by the average representation of indicator taxa determined across this scale, which is 99.593 ± 0.105% (hereinafter, the arithmetic mean values are given with their standard errors) of the total number of taxa registered in the relevés. Brief characteristic of the scale: type - amplitude-optimum; number of gradations - 9; number of indicator taxa - 2748, the average amplitude of tolerance (in gradations) - 3.904 ± 0.041. The mean hemeroby status for the association was obtained by averaging the statuses of all relevés of phytocoenoses within the association. When performing IVA, relevés' statuses were calculated by the double weighted averaging (by the amplitudes of tolerance and the covers in a 9-point geometric scale [7]) the individual statuses of indicator taxa [2]. The statuses were normalized to the number of scale gradations, so the values were in the range 0.0÷1.0.

2.3 Evaluation of homotoneity

We used 13 reported earlier measures to assess the homogeneity of a relevé set separately for each of the 23 vegetation associations. All indices belong to two categories: the first of them take into account only qualitative (binary) indicators - the presence of taxa in a relevé (B_1–B_9 below), while the second are based on the analysis of the quantitative expression of their participation in the phytocoenosis - in our study it was the percentage cover (Q_1–Q_5). Some of these indices are well known and widely used in the analysis of vegetation (for example, the average Jaccard similarity index B_9 or biotic dispersion index B_1 by Koch), while others, especially quantitative ones, are very rare in the analytical arsenal of botanists (possibly due to the bigger complexity of their calculation). Because of the limited volume of this publication, we do not present here the formulas of the indices, but we indicate the main literary sources where these formulas or a description of the calculation algorithm are present.

Homotoneity indicators based on qualitative data: B_1 Koch's biotal dispersity index [8]; B_2 Dahl's index [9]; B_3 Basic homotoneity coefficient by Moravec [10]; B_4 Homogeneity value by Raabe [11]; B_5 Index of homogeneity by Curtis [9]; B_6 Frequency saturation quotient [4]; B_7 Corrected homotoneity coefficient by Moravec [10]; B_8 Normalized dispersity coefficient [12]; B_9 Average similarity by Jaccard [13].

Homotoneity indicators based on quantitative data: Q_1 Quantitative variant of Koch's biotal dispersity index [12]; Q_2 Quantitative frequency saturation quotient [12]; Q_3 Quantitative normalized dispersity coefficient [12]; Q_4 Multiplace measure of similarity by Jaccard K_1 [12]

All indices saving B_2 have their upper limit of 1 (or 100%), which is interpreted as complete homogeneity of a relevé array.

2.4 Data management and Statistical analysis

Statistical methods used in this work are as followers: descriptive sample statistics, tests for normal distribution, nonparametric correlation analysis: Spearman's rank correlation coefficients are further denoted as r_s. The set of model relevés was created in the form of a database of the integrated botanical information system IBIS v.7.2. [2, 7]. The IVA module of this software was used for all calculations of hemeroby status of phytocoenosis; the homogeneity assessment module calculates all homotoneity indicators. StatSoft Statistica v.12 and MS Excel 2010 were used for statistical processing and data transformation.

3 Results and discussion

According to B.I. Semkin and M.V. Gorshkov [12], specific numerical values of homotoneity indices do not play a significant role in determining the similarity of relevés, since the ordering of these indices is of primary importance, i.e. how the objects (relevés) are ordered according to the calculated indices. In the case of our study, we tried to answer the question of how consistent the changes in homotoneity in a series of associations with changes in their ecological homogeneity and hemeroby statuses of habitat disturbance are. For this, a correlation analysis was used, namely Spearman's nonparametric rank correlation, since the samples for most of the calculated indices showed a distribution statistically significantly different from the normal one (Lilliefors and Shapiro-Wilk tests were used to check it).

We do not expose the complete matrices of the correlation coefficients of hemeroby and parameters за homotoneity due to their extensionality, limiting ourselves to discussing the main results.

A strong and significant negative dependence on the number of relevés in the association was demonstrated by both the frequency saturation quotient indices B_6 and Q_2

(r_s = −0.909 and −0.817); average and significant – by quantitative Q_1 (r_s = −0.527). The relationship between the volume of associations and other indices was much weaker. General observation regarding the consistency of the assessment of qualitative and quantitative homotoneity indices: the average correlation with each other in the first group (r_s = 0.510 ± 0.034) is lower than in the second (r_s = 0.611 ± 0.071). Varying in strength of correlation, all indices show a synchronous change in the estimating of homotoneity, with the exception of the normalized dispersity coefficient B_8 and Q_3, which in their groups show weak and statistically insignificant correlations with other indices.

Answering the question that served as an impetus for this study (is there an co-dependence of hemeroby and homotoneity), we can note the following trends and patterns:

1. The relationship of hemeroby statuses is expressed not for all homotoneity indices: there are relatively weak and medium negative (as expected) dependencies with indices B_2, B_8, Q_1, Q_3, Q_4. The classical Koch's biotal dispersity index B_1 is associated with the hemeroby weaker than its quantitative version (Q_1). The compatibility of the variability of some indicators is shown in the figure, where the hemeroby statuses are transformed into homogeneity values (naturalness) for clarity of comparison with the homotoneity values. The associations with the highest degree of disturbance (ass. 18 "Small-grass high degradation meadows" 0.707 ± 0.013 and ass. 21 "Large-grass moist ruderal communities" 0.706 ± 0.014) have low homotoneity values, but not minimal for the sample. In particular, ass. 14 "Sparse plantings of introduced broad-leaved species", with estimated 0.562 ± 0.041, has minimal floristic homogeneity (Q_4).

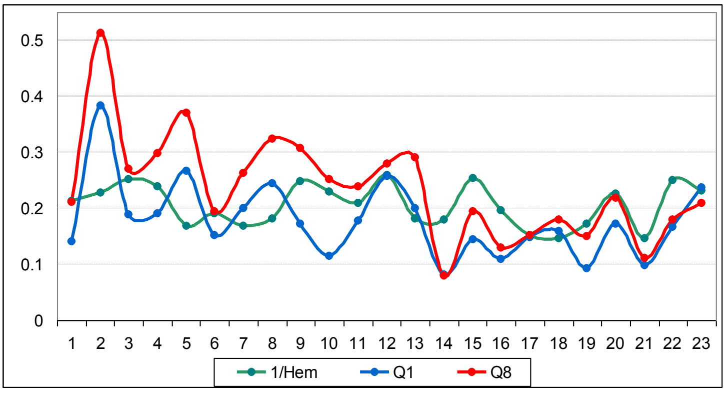

Fig. The consistency of the variability of hemeroby statuses and homotoneity indices (Q_1 and Q_8, designations in the text) for 23 associations: 1/Hem - inverse value of hemeroby (naturalness); horizontally - ordinal numbers of associations

2. A decrease in the sample size of associations with an increase in the average number of relevés in them shows a stable tendency: all homotoneity indices negatively associated with hemeroby (see paragraph above) increase the strength of their connection, reaching even statistically significant and large values, in particular: r_s = −0.734 for Q_4. This confirms the opinion of W. Westhoff and E. van der Maarel [4] that indices based on the average floristic similarity are more suitable for measuring homotoneity. However, Dutch botanists had been talking about qualitative indices (in particular, about B_9), and in our case, it is the quantitative version of this classical index (Q_4) that has a much greater negative correlation interdependence with the average hemeroby statuses of the associations. It can be assumed that with an increase in disturbance, its more informative indicator is not the depletion of the floristic composition of communities itself, but an increase in quantitative floristic heterogeneity, which is manifested in a change in the ratios of weights of species participation in a phytocoenosis, in shifts in the character of dominance, up to a sharp “stratification” of communities.

4 Conclusion

Summarizing the main results of this pilot study, it can be argued that the set of published indicators of homotoneity of plant communities is not a homogeneous tool for analyzing phytodiversity, but shows good potential for diversifying of analytical trajectories for studying the structure of vegetation. Only some indices for assessing homotoneity are suitable in study of the degree of hemeroby during anthropogenic transformations of vegetation. Given the high consistency of the values for assessing disturbance using our scale and other IVA scales of hemerobo- and anthropotolerance [6] (the correlation coefficients with five previously published scales are in the range of 0.826 ÷ 0.972), the preliminary obtained conclusions can be extended to other systems of quantitative assessment of hemeroby. An obvious development of this study for the future seems to be the verification of the revealed regularities in the relationship between the indices of hemeroby and homotoneity of phytocoenoses on vegetation data, which is larger in terms of geographic, ecological and taxonomic coverage.

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