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The relationship of spore (mosses) and seed plants with mesorelief types of oak forests

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Abstract. A transect from the watershed to Voronezh reservoir storage has been made to study the influence of geomorphological factors on the biodiversity level of mosses and vascular plants in Voronezh upland oak forest (East of Russia). Taxonomic, ecological, biological, and geographical analyses of flora have been done. Geobotanical research methods have been used to assess phytocoenosis. Certain laws in ecotopic plants distribution and projective covering have been scored; the parameters to assess ecosystem biodiversity have been proposed and used in the studies. The three chosen zones are very different in a number of natural indicators, especially in mesorelief type and moisture degree. Mosses and vascular plants, while developing the habitats, are differently manifested in these areas. Very often they do not reflect landscape and environment peculiarities. But, according to the results, most plant species (over 55.9%), belong to mesophytes no matter which zone they grow. So, the near-valley slope zone of the Voronezh River is poor in species richness and density, genus and family diversity. These parameters increase towards the plateau.

1. Introduction

Vegetation cover of the Voronezh region (central zone of the East European Plain between 49034 'and 52006' northern latitude and 38009 'and 42055' eastern longitude; it occupies an area of 52.4 thousand km²) is a part of the Euro-Asian steppe region. Forest type vegetation covers about 10% of the studied area. In the past, the steppe was much more forested (not less than 50%). Broad-leaved forests are zonal ones, and oak forests are the most frequent. Tellerman grove (40 thousand hectares) and Shipov forest (over 34.1 thousand hectares) are the oldest and well-preserved, isolated isles of broad-leaved forests in Eastern Europe.

Natural zones transformations as well as complex movement of plant formations from different florogenetic centers took place all over the Central Russian steppe during the Quaternary period. Intensive human activity was a powerful factor to transform the broad-leaved forests of forest-steppe and steppe zones from the zonal vegetation type into the azonal type. Anthropogenic aridization of forests in the southern part has resulted into great weakening of forest tree species, shrubs and herbs. Today broad-leaved forests are represented by separate forest isles. Repeated forest burning has resulted in dominance of ecologically tolerant plant species.

Rational use of all the forest resources is one of the most important tasks for ecologists. The most important ones are the works to study the biological stability of ecosystems with the help of lower spore plants, because they are the most sensitive indicators of the environment state as well as the indicators to assess the grass covering state.

Forests are greatly pressed by a number of factors in Voronezh region; these factors do influence their condition. Besides the anthropogenic factors (fires, recreational pressing), natural abiotic factors (typical for the forest-steppe dry air, types of mesorelief) influence the forests too.

Zones of strong, medium and low anthropogenic impact, as well as stages of vegetation degradation are determined on the basis of the spatial structure of the transformed vegetation (including depending on the elements of the relief) [1].

Mosses and lichens are traditionally used as biomonitors in the studies of the effects of pollutants on ecosystems. Spore plants show just the same: a decrease in the level of biodiversity of plant communities, according to the degree of deposition of heavy metals reveal the ranking of areas [2-7]. Thus, researchers point out that the influence of pollutants is an additional environmental factor that significantly changes the environment and creates new artificial ecosystems in which species diversity has significantly decreased among all systematic groups of higher and lower plants.

A number of researchers are considering (in detail) the issues relating to the assessment of the status of oak biogeocenoses under the influence of various combinations of environmental factors, both natural and anthropogenic ones [8-12].

We have been interested in the work on conceptualization of the factors affecting biodiversity at different spatial scales by adding relationships at different scales (between microenvironment and richness of habitats) [4]. Our attention has been attracted to the works devoted to the study of specific reactions of mosses and herbaceous plants to the heterogeneity of the mesorelief. Researchers identify the relationship between plant biodiversity and small-scale heterogeneity of mesorelief, which leads to niche opportunities on a small scale [4, 8]. A transect in the Voronezh upland oak forest has been used as a visual model to identify the natural factors that determine the level of biodiversity.

The purpose of the study is to study the relationship of spore (mosses) and seed plants with certain types of mesorelief suburban oak forest (Voronezh upland oak forest) based on the use of a set of estimated parameters.

2. Experimental part

Voronezh upland oak forest has a number of features different from the forest-steppe oak forests in the Voronezh region. The oak forest stretches from the Northern district of Voronezh to Ramon settlement strictly to the north along Voronezh reservoir. It is located on the steep right bank of the Voronezh river, it reaches almost to the watershed between the Voronezh and the Don rivers in the west; so, its western part takes the fourth terrace above the Don floodplain. This fact has caused soil specificity (podzolic ones) and vegetation specificity. In the past, it was subor. Today it is justifies by very old pines, pine plantations, a number of taiga elements in the grass covering. The relief is greatly crossed with narrows and watercourses, opposite to the two above-mentioned upland oak forests in Voronezh region. Voronezh upland oak forest is pressed greatly with recreation load according to numerous paths which can be seen everywhere.

Experimental plots of 1 hectare in Voronezh upland oak forests have been chosen to study the grass covering. The description has been done as follows. Each typical section of the phytocenosis of the oak forest was divided into 5 experimental plots of 100 m². The relative projective covering (RPC) was defined. The relative projective covering is the relative percentage of the area covered with plants. It is shown in percentage from possible 100%. The relative projective covering is thought to be one of the important indicators of ecosystem preservation. It characterizes vegetation shading. Besides, a qualified list of species was prepared for each experimental plot containing species richness and density (species number per 1 hectare). Each species is characterized by: vegetation phase; age group; score activity, which allows estimating the species role in the community. The species activity index was proposed by Dr. B. Yurtsev in 1968 to find the role of vascular plants in the process of vegetation formation. Species activity is a combination of occurrence, abundance and latitude of the ecological amplitude of the species within the experimental area in the species ecotopes.

Basing upon the similar studies [13, 14] the first two indicators have been used (occurrence and abundance): highly active species (5 points) – frequent and abundant; active (4 points) – sporadic,

abundant; semi-active (3 points) – frequent, non-abundant; inactive (2 points) – sporadic, uninhabited; inactive (1) - rare, non-abundant.

A polyethylene decimeter square has been chosen to describe the epiphytic mosses. The relative projective covering (not absolute one when entire moss turf is cut off) has been determined separately for the butt part of a tree (beginning from the trunk base up to 50 cm height) and on the trunk itself (up to 120 cm) in four expositions – North, South, East and West ones. The relative projective covering has been calculated in 2 levels (from 0 up to 50 cm and up to 120 cm) in four expositions for every tree. The development degree of ground mosses has been made for an experimental plot as a whole, finding its projective covering.

To assess the state of oak forest ecosystems on the moss component example the following parameters are considered to be effective: species richness, species density; score activity; species number per 1 trunk of epiphytic mosses.

3. Results and discussion

There is information about weak development of ground moss covering in the published articles on the mosses in broadleaved forests. Indeed, the mode of the main environmental factors in sustainable oak forests of steppe-forest zone is good. So, it causes rapid development of the grass covering, and mosses are strongly oppressed then and are not dominative ones. Our studies show the opposite picture: great representation and percentage of the relative projective covering of the epigeal group of mosses in general and especially in one zone.

A transect from the watershed to the reservoir (from West to East) which is 4 km is made long to study the influence of geomorphological factors onto plant biodiversity level in Voronezh oak forest. The following geomorphological zones, different in relief, soils and phytocenotic features, are chosen: plateau, ravines, the valley slope to the Voronezh River.

While doing the research works the facts have been noted: species composition of mosses depends on the mesorelief types, opposite to higher plants, they change their relative projective covering, species spectrum and age groups ratio. So, table 1 shows the species distribution of mosses only, indicating their score activity. Quantitative descriptions of both plant groups are given in the text.

Plateau-type area has oak plantations on a relatively flat relief, with shallow groundwater, gray forest soil and occupies more than half of the oak forest. It is 1 km long. Typical associations are goutweed (*Aegopodium*) oak forest and goutweed and sedge (*Aegopodium-Carex*) oak forest. Tree vegetation is shown by *Quercus robur* L. mixed with *Fraxinus excelsior* L. and *Acer platanoides* L. The age of *Quercus robur* L. is 70-100 years, trunk diameter is 30-40 cm, II site class.

22 species of mossy plants are founded on the experimental plots (62.9% of the species composition), species density is 15 species. The identified species belong to 13 families and to 17 genera. Environmental groups are represented by mesophytae, humidity index is 72.7%, by helioscopia, light index is 36.4% as well as by sciatica (40.9 %). More than half of the species composition grows on wood substrates (21 species). The maximum number of bonded epiphytes (10) is practically the same as in the ravine zone. The number of ground-based species is significant –11, (the same number in valley slope zone). RPC in the trunk part of an oak is 0.36 %, in the trunk base - 19.93 %.

Totally, there are 2187 species of vascular plants from 131 families in the flora of the Voronezh region, but only 14 are dominative ones [15]. 31 species have been identified on the experimental plots.

All the species belong to 19 families and the number of species in each of these families ranges from 1-2 to 3-4 (Rosaceae, Lamiaceae, Ranunculaceae, Asteraceae).

20 species of vascular plants (64.5% of the species composition of the whole area) have been recorded on the plateau; species density has been 9 species per 1 hectare. Environmental groups are represented by mesophytae, humidity index is 60% and light index is 45.3 %.

In spring *Scilla Sibirica* Andrews., *Corydalis Halleri* Willd., *Anemone ranunculoides* L. were blooming abundantly on the test sites. Cenotic populations of those ephemeroids are characterized by

intense seed regeneration, so specimens of virginal period are dominated. In summer, grass cover is dominated by *Aegopodium podagraria* L. and *Carex pilosa* Scop., also significant groups are made of *Asarum europeum* L., *Asperula odorata* L., *Polygonatum multiflorum* L., *Pulmonaria obscura* Dumort., *Orobus vernus* L., *Lamium maculatum* L., *Viola mirabilis* L.

Table 1. Mosses distribution in geomorphological transect and biodiversity parameters.

Species	Experimental plots		
	Plateau	Ravine zone	Valley-slope zone
<i>Lophocolea heterophylla</i>	0	1	0
<i>L.minor</i>	0	3	0
<i>Marchantia polymorpha</i>	0	1	0
<i>Radula complanata</i>	0	2	0
<i>Atrichum undulatum</i>	4	5	1
<i>Funaria hygrometrica</i>	1	1	1
<i>Barbula unguiculata</i>	0	2	2
<i>Fissidens bryoides</i>	1	1	0
<i>Orthotrichum pumilum</i>	0	3	0
<i>O.speciosum</i>	3	3	3
<i>Ceratodon purpureus</i>	1	3	3
<i>Dicranum polysetum</i>	0	1	0
<i>D.scoparium</i>	0	1	0
<i>Dicranella heteromalla</i>	1	2	1
<i>Orthodicranum montanum</i>	1	1	0
<i>Bryum argenteum</i>	0	0	1
<i>B.caespiticium</i>	0	2	1
<i>B.capillare</i>	3	4	3
<i>Pohlia nutans</i>	1	2	0
<i>Mnium stellare</i>	0	1	0
<i>Plagiomnium cuspidatum</i>	4	5	4
<i>Anomodon longifolius</i>	1	3	0
<i>Homalia trichomanoides</i>	1	1	0
<i>Leskea polycarpa</i>	2	4	3
<i>Leskeella nervosa</i>	4	5	4
<i>Amblystegium serpens</i>	3	4	2
<i>Sanionia uncinata</i>	0	1	0
<i>Brachythecium albicans</i>	1	2	1
<i>B.campestre</i>	2	5	2
<i>B.oedipodoim</i>	1	2	0
<i>B.reflexum</i>	3	4	1
<i>B.rutabulum</i>	0	2	0
<i>B.salebrosum</i>	5	5	5
<i>B.velutinum</i>	5	5	3
<i>Eurhynchium hians</i>	3	5	3

Aegopodium podagraria L. and *Carex pilosa* Scop. have the highest relative projective covering – 45-55%. These species have the highest activity – 5. Then *Orobus vernus* L. (4 points), *Asarum europeum* L. (4 points), *Stellaria lanceolata* L. (3 points) have 10-20% of relative projective covering. Other species have less than 5%. The types of generative period are dominative in all the populations, senile specimens are practically not presented. No doubt, lack of virginising specimens and the abundance of flowering specimens do not show cenotic population degradation. Many plants may

have development "waves" (the so-called "population waves" or "waves of life") when a cenotic population entirely transforms into generative and senile state, regenerating later with the help of previously reproduced rudiments.

There have been weed species such as *Agropyron repens* L., *Celidonium majus* L. Their relative projective covering is less than 3% -5% at the forest edge zone.

The ravine zone is 1.5 km long and has a lot of deeply embedded ravines with slopes of different expositions, sometimes having fontanels or streams. Soils are loamy and sandy, more or less watered. Ravine bottoms are covered with *Populus tremula* L. and *Alnus glutinosa* (L.) Gaerth, mixed with *Betula pendula* Roth., but *Quercus robur* L. are dominating species. *Quercus robur* L. is 60-90 years old, class II and class III site class, trunk diameters are 30-33 cm. Fontanels, ravines with water streams (especially in the part next to the reservoir), remains of a numerous trenches and blindages, a lot of paths, bare or grassy soil. Rotten wood is typical for the ravine zone.

The largest number of moss species (34 species) is recorded there. Species density is also the highest one comparing to the other zones – 22 species. Family and genus diversity is 17 and 24 (the highest rate). The species number per tree is 3-5. Terrain features are resulted into a large group of ground moss – about 16 species. Epigeal mosses are taxonomically diverse (table 1) and have a high percentage of relative projective covering – 8-10%, in some parts - up to 15%. There are 13 species on trunk bases, when 10 species are bonded epiphytes, they have low relative projective covering, are rare and found in oak cenoses. Five species of bryophytes are discovered on the rotten wood.

The relative projective covering of mosses is the highest one in this zone, both at 120 cm – 3.06% and 50 cm – 23.3%.

However, the ratio of ecological types as for moisture index in this mesorelief does not show special features of landscape and ecological conditions. This ratio is clear because of dominance of mosses (55.9%) and vascular plants (57.2%) from mesophytes group, not from mesohygrophytes or hygrophorous ones.

There is no strict regularity in changing the species spectrum of vascular plants comparing to the previous zone. Species diversity is 19; species density is 7 species per 1 hectare. So, they show no difference.

The relative projective covering the *Aegopodium podagraria* L. decreases sharply from 45-55% to 25-30% on the previous ecotope, its score activity decreases to 2-3 points, *Carex pilosa* Scop. shows the same percentage in relative projective covering and activity.

The density degree of other species is about 5-8%. The score species activity is low - 2 points (sometimes 3). Highly thinned grassy covering influenced the population composition – the oppressed specimens of virginal period were dominating ones. Young and oppressed vegetative *Aegopodium podagraria* L. specimens are found, they grew from the seeds stock preserved in the soil. It should be noted that species of boggy areas - Ranunculaceae, *Impatiens noli-tangere* L., *Urtica dioica* L – grew there.

Valley slope to the Voronezh River on the East descends smoothly to the reservoir. It has erosional washed-away loamy soils. The stand belongs to IV site class, the diameter of *Quercus robur* L. is 22-25 cm. The moss species diversity is 19 species (54.3 per cent) on experimental plots, species density is the lowest one, i.e. 8. The number of mosses on an oak trunk is usually 2-3. The genus number lowered to 13, families number to 11, i.e. the genus and family diversity is the lowest one. Half of the identified species (57.9%) belongs to mesophytes. The ground moss species (11) with a low activity score (1 point) are *Funaria hygrometrica*, *Dicranella heteromalla*, *Bryum argenteum*, *B. caespiticium*, slightly higher in *Barbula unguiculata* (2) and *Ceratodon purpureus* (3). Obligate epiphytes activities (there are only 7) are low too. The RPC at 120 cm is 0.33%, at 50 cm - is 11.1%, i.e. it is very low. The vascular plants flora demonstrates decrease in species diversity to 14. Species density is the lowest one - 5 plants per 1 hectare. The score activity of individual specimens never exceeds 2 points. The ground covering of typical nemorose species is represented by some specimens with a relative projective covering less than 5%. This is due to the multiple floodplain plowing. Nearby recreational areas also

affect the zone. There is a clear introduction of meadow, meadow-steppe and ruderal flora representatives.

4. Conclusion

Summarizing the main zones' indicators these facts should be noted. The three zones are very different in a number of natural indicators – mesorelief type and soil type, phytocenoses safety, and, especially, moisture degree. But, according to results, most plant species (from 55.9% and above) belong to mesophytes. The valley slope is poor in species and species density for a number of indicators.

Mosses on the plateau do have taxonomic diversity, species density, the number of bonded epiphytes. In this zone vascular plants also increase species diversity (20), species density (9), weight percentage of relative projective covering (from 10-20% to 45-55%) and score activity (3-5) especially in the ground dominants.

A variety of habitats are concentrated in the ravine zone, in mosses it is expressed in the increase of species diversity – 34, species density – 22. Families number of increases to 17 comparing to the plateau zone, but genera number increases greatly - up to 24, the largest number of rare species is 10. Only in the area ground bryophyte species dominate over the other ones, their number is 16. However, the average mosses score activity varies slightly in this ecotope. In the ravine zone, vascular plants have the opposite picture - low species diversity (19), occurrence and abundance of more than 90% species have only 1-2 points. Geographical element analysis has showed that nemorose vascular plants' participation in flora formation is the greatest one in the upland parts. Mosses and higher plants have the highest projective covering percentage on the plateau. Some species (mainly epigeal mosses and hairlike sedge) increases this percentage in ravines.

So, the near-valley slope zone is poor in species diversity, species density, genera and family diversity, these parameters increase towards the plateau.

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