Problems of Conservation of Biodiversity of Relict Oak Groves of the Boreal Zone of the South Urals

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Abstract. An assessment of the phytodiversity of oak groves in the forest zone and forest-steppe of the Urals is presented. Ecological-coenotic analysis of the vegetation cover was carried out, as well as the structure of tree coenopopulations using the express method was evaluated. The categories of the status of individuals of the edificator Quercus robur L. are determined, its allelopathic properties are studied. Assessment of the ecological state of the communities revealed the prospects for their development and the need to preserve relict oak groves.

1. Introduction
Oak groves, fragmentarily found in the zonal type of vegetation in the Southern Urals, are relict and serve as reserves to preserve the diversity of species of the nemoral ecological-coenotic group, which is an integral component of the vegetation cover of forest territories. Relic deciduous-deciduous broad-leaved forests in the Early Tertiary time were widespread in the Urals, and at present, they are noted only on the western slopes of the mountains, which are characterized by increased humidity and the absence of temperature inversions. Such communities are of great scientific value as a reliable source of information about the vegetation cover of past geological eras.

In consequence of vigorous economic activity in the forest zone and forest-steppe of the Urals, the structure of the vegetation cover undergoes significant transformation, the areas of broad-leaved communities are reduced, and therefore the study of cenopopulations (CP) of plants of the nemoral complex is of particular importance. The biodiversity of their CP’s is not well understood in the Urals, there is little information about the characteristics of the phytocenotic association and population structure, which determines the relevance of the study. Data on the peculiarities of the structure of cenopopulations of edificators are necessary for predicting their development, developing measures for effective protection and environmentally sound nature management.

Traditional approaches to assessing the diversity of vegetation, as a rule, are quantitative in nature and statistically reflect the total number of species in the study area and species richness. According to Academician A.S. Isaev, when organizing biodiversity monitoring at the species, ecosystem and landscape levels, it is necessary to use the criteria and indicators developed by domestic and foreign experts, in combination with new approaches and technologies. Among these approaches is the analysis of the functional groups of species in the community — the ecological-coenotic elements of the flora [1] or groups of conjugated species [2], this is especially true for communities with an edificator characterized by high allelopathic activity, to which the oak is referred. Species living with the edificator experience its effect to a lesser extent than alien species, since their biotic relationships were formed in the course of a long co-evolutionary development.

The purpose is to study the structure, dynamics and environmental features of coenopopulations of species of a nemoral ecological-coenotic group in the boreal zone of the Urals, to assess biodiversity, predict the further functioning of oak communities.

2. Materials and methods
The studies were carried out in specially protected natural areas in the forest zone (Nyazepetrovsky and Ashinsky districts), in the forest-steppe zone of the Southern Urals in various types of communities with...
the edificator of the tree layer - *Quercus robur*. According to the scheme of botanical and geographical zoning [3], these territories belong to the Minyar subarea of broad-leaved-coniferous forests of the subzone of coniferous deciduous and southern taiga coniferous forests of the western slopes of the Urals and the northern forest-steppe plain of the West Siberian plain of the northern forest-steppe subzone.

According to the physical-geographical zoning, the territory of the Ashinsky reserve is located in the forest zone of the Chelyabinsk region, in the province of the western foothills of the mountain-forest zone of the Ural mountain country, in the subzone of broad-leaved and spruce-fir forests with high grass stand [4].

The area is characterized by a ridge-bumpy topography with average elevations of 300-400 m above sea level and individual elevations of up to 500-600 m above sea level. The highest point is 608.6 m on the Karatau ridge near the northern border of the reserve. According to the agrometeorological zoning of the Chelyabinsk region, the territory of the reserve is located in the first (I) agro-climatic region - cool and humid, with sharp climatic contrasts, short rainy summers, long and snowy winters [5]. Precipitation during the year falls 580 - 680 mm. The moisture supply of the vegetation period is high, the amount of precipitation exceeds the amount of evaporation. The area is characterized by a short period with temperatures above 10°C (the period of active vegetation), which is 100 to 115 days.

According to physiographic zoning, the territory of the nature monument, «Dubovja roscha» (Nyazpetrovsky district) is located in the Western foothills of the mountain-forest zone of the Ural mountain country, in the subzone of pine-larch forests with admixture of spruce-fir.

Oak groves, confined to the territory of the Kashtak and Chelyabinsk forests, located in the forest-steppe zone of the pre-Urals, are relict ecosystems formed at the turn of the upper Pleistocene and Holocene during the period of xerophytization and aridization of the climate. The climate of the region is continental with cold and long winters and warm summers. The terrain is hilly and rocky.

The study used standard geobotanical approaches describing temporary trial areas on the territory of the natural monument «Dubovja roscha», in the Ashinsky state biological nature reserve, in the vicinities of the Asha-city, on the territory of natural monuments – «Kashtaksky Bor» and «Chelyabinsk gorodskoy bor». The size of the sample areas was determined by the size of the phytocenotic field of edifiers, as customary in population studies, and amounted to 400 m².

For ecological and phytocenotic analysis of forest vegetation, a set of ECGs was used, including boreal Br, nemorale Nm, nitrophilic Nt, pine-forest Pn, xerophilic-oak's Qx, meadow-steppe Md, wetland W, and adventive group Ad. The structure of tree cenopopulations is described taking into account the rapid assessment of their state in the phytocenosis based on typical geobotanic descriptions, which took into account the abundance of species in each of the tiers of the forest community [6].

The analysis of the diversity of the studied associations for the degree of similarity-differences in their species compositions according to the coefficients of Jacquard (Kj) and Sierensen (Ks). For its evaluation, a cluster analysis was used, the results of which are displayed on the dendrogram.

For adult individuals of the cenopopulations of oak, the categories of tree condition were determined [7]: 1-without signs of weakening, 2-weakened, 3-severely weakened, 4-shrinking, 5-fresh dead wood, 6-old dead wood.

The study of allelopathic properties of *Quercus robur* L. was carried out according to the generally accepted method of biological samples of A. M. Grodzinsky (1991) [8] using *Lepidium sativum* L. as a test object.

3. Results and Discussion

The assessment of phytodistribution allows obtaining on the one hand comparable quantitative parameters of species diversity (alpha-diversity), on the other – characterizes combinations of species between different communities and reveals the degree of similarity and differences of communities. Thus, beta diversity characterizes the variability of indicators of alpha diversity in space by gradients of environmental factors or during the transition from one type of community to another. 24 species of higher vascular plants belonging to 22 genera, 16 families, and 2 divisions (*Magnoliophyta* and *Polypodiophyta*) were identified in associations identified in plant communities on the territory of the natural monument «Dubovja roscha», Quercetum fragarum and Quercetum-Aegopodium podogrum. The families *Rosaceae* (4 species) and *Fabaceae* (3 species) have the greatest species diversity.
As for the surveyed oak forests of the Ashinsky reserve, the taxonomic analysis of the selected associations (acid-mixed oak forests, with an admixture of ash-tree maple *Acer nigundo* L.) includes 34 species of higher vascular plants belonging to 33 genera, 23 families, and 3 divisions (*Magnoliophyta*, *Equisetophyta*, and *Polypodiophyta*). The *Ranunculaceae* and Poaceae families have the highest degree of species diversity, with the remaining families represented by 1-2 species. Of particular note is the discovery of the sweet violet (*Viola odorata* L.), listed in the red Book of the Chelyabinsk region (category III, rare species).

In the Acero-Quercetum oxlidosum association in the vicinity of the city of Asha, 16 species of higher plants are described, belonging to 16 genera, 14 families, 2 divisions (*Magnoliophyta* and *Polypodiophyta*). Two species are represented by the families *Rosaceae* and *Lamiaceae*, the remaining families are represented by 1 species. Concerning the examined afforestation, confined to the vicinity of the city of Asha, one can note the occurrence of dominants of the tree layer and the transition of *Acer nigundo* L. to the status of edificator, which ultimately leads to a change in vegetation cover due to the introduction of coenopopulation of the invasive species.

An analysis of the plantations in the forest-steppe zone of the Southern Urals showed that poorer species composition was noted in nemoral oak communities compared with forest zone communities.

Sixteen species of higher vascular plants belonging to 16 genera, 13 families, 2 divisions (*Magnoliophyta* and *Polypodiophyta*) were noted in the Kashtaks pine forest for a Betuleto-Quercetum Gramineum association. The greatest species diversity is the *Rosaceae* family - 3 species.

In the Chelyabinsk city forest, 15 species of angiosperms belonging to 15 genera and 12 families are described for a Betuleto-Quercetum Gramineum association. The greatest species diversity is the *Rosaceae* family - 4 species.

We give an analysis of the similarity of species composition of phytocenoses in Table 1.

An analysis of the similarities / differences in the species composition of the studied communities shows that the maximum degree of similarity is noted only between the associations of oak groves associated with the natural-territorial complexes of protected areas.

Between the oak forests of different natural zones, a high degree of specificity of the partial flora was noted, reflecting a low degree of similarity of species compositions. At the same time, one can note a high degree of similarity of the species composition of two oak groves located in specially protected natural areas with a high degree of recreational load Kashtak and Chelyabinsk urban forests, $K_s = 0.83$ and $K_j = 0.63$, sites 8 and 9, respectively.

### Table 1

| $K_s$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|------|---|---|---|---|---|---|---|---|---|
| 1  |   | 0.80 | 0.15 | 0.11 | 0.11 | 0.08 | 0.16 | 0.25 | 0.21 |
| 2  | 0.89 |    | 0.24 | 0.16 | 0.12 | 0.13 | 0.22 | 0.27 | 0.23 |
| 3  | 0.26 | 0.39 | 0.58 | 0.39 | 0.36 | 0.52 | 0.30 | 0.31 |   |
| 4  | 0.20 | 0.28 | 0.74 |    | 0.44 | 0.36 | 0.40 | 0.12 | 0.14 |
| 5  | 0.20 | 0.22 | 0.56 | 0.62 | 0.44 | 0.29 | 0.06 | 0.09 |   |
| 6  | 0.16 | 0.11 | 0.53 | 0.53 | 0.62 |    | 0.30 | 0.06 | 0.10 |
| 7  | 0.29 | 0.36 | 0.69 | 0.57 | 0.44 | 0.46 |    | 0.23 | 0.35 |
| 8  | 0.40 | 0.42 | 0.46 | 0.22 | 0.11 | 0.11 | 0.38 |    | 0.63 |
| 9  | 0.35 | 0.38 | 0.47 | 0.18 | 0.17 | 0.18 | 0.52 | 0.83 |   |

1, 2 – «Dubovja roscha», 3-6 – Ashinsky state biological nature reserve, 7 – the vicinity of the Ashacity, 8 – «Kashtaksky bor», 9 – «Chelyabinsk gorodskoy bor».

As a result of the analysis of floristic lists, the similarity / difference coefficients of the studied communities were obtained, a cluster analysis was carried out, the reflection of which is the dendrogram (figure 1).
Figure 1. Similarity of species composition of model associations

From the dendrogram obtained, it can be seen that sites No. 1 and 2 and No. 8 and 9 have the smallest association distance, therefore, the species composition of the sites is most similar, despite the fact that the communities are located in different botanical and geographical zones (forest and forest-steppe zones). The revealed similarity, in our opinion, is explained by the same types of wood sinusia (*Quercus robur* and *Betula pendula* Roth.) that determine the environmental conditions for growth in the crown space. The next strongest connection is observed between the sites of the Ashinsky reserve, however, the association distance at these objects is much greater. The similarity is explained by the high vitality of the oak in these biotopes, which determines its allelopathic effect on the grass-shrub layer adapted to this effect. The most significant differences from all clusters are at site No. 7, confined to the vicinity of Asha and experiencing various kinds of impacts. The results of cluster analysis confirm the values of the coefficients of floristic similarity, which shows the feasibility of their use for assessing biodiversity.

In the process of development and functioning of the vegetation cover, plant individuals adapt to the ecotope and biotope conditions, which determines the combination of species in phytocenoses and, ultimately, the types of vegetation. The term «ecological-coenotic groups» (ECG) is used to designate «units of species combinations», which means groups of plant species that are similar to the set of environmental factors inherent in biotopes of one type or another, characterized by a high degree of mutual contiguity and confined to habitats of a certain type.

The analysis of the ECG spectrum is a convenient tool for studying phytocenotic shifts, since it contains integral information about the presence of a large number of species. It, along with an analysis of the presence of key species and their coenopopulations, shows succession changes in plant communities and helps to predict their further development in a spontaneous mode. The results of the analysis of the ecological-coenotic structure of the vegetation cover of forest territories on the example of model, confined to two natural zones of the Urals, are presented in figure 2-5.

The results of the ecological-coenotic analysis of the vegetation cover of relict oak groves, confined to the boreal zone of the Southern Urals, showed that in all model communities, a significant representation of the non-moral ECG is logical and proves the stability of the relationship between species that form the ecological retinue that has historically developed in certain ecological phytocenotic conditions. At the same time, in the communities of the forest-steppe zone, along with the immoral zone, the edge-meadow ECG is widely represented, which can be explained by a change in the light regime due to the low vitality of the oak, which leads to the loss of the edifier from the stand and the formation of ecotones.
It should be noted that European nemoral forest species are widely represented in the grass-shrub layer of oak grove communities, many of which have an eastern distribution border in the Southern Urals (species of the European nemoral floristic complex associated with broad-leaved and coniferous-deciduous forests): Galium odoratum, Pulmonaria obscura, Stachys sylvatica, Polygonatum multiflorum) Festuca gigantea, including relict species such as Viola odorata, Lathyrus Gmelinii, Asarum europaeum. Preservation and maintenance of the above non-nemoral complex of species in the boreal zone will contribute to an increase in biodiversity and, as a result, an increase in the stability of the vegetation cover of forest territories.

The vertical structure of the organization of the vegetation cover of forest territories is determined by the type of cenopopulations of edificators. Individuals of persistently existing normal coenopopulations of trees are present in all tiers. Regressive or invasive coenopopulations are presented only in the forest stand or in the grass-shrub layers, respectively.

The analysis of coenopopulations of the main forest-forming species by the express method revealed the following features of their vertical structure (figure 6-8).
As the analysis of the diagrams of cenopopulation of oak shows, it can be attributed to normal, since its individuals are present in all tiers of model sites. This indicates that the community is in a stable, sub-climax status. Since, the quantitative participation of trees in the first tier (A) determines the modern structure of the community and reflects the previously existing opportunities for self-support of populations. The composition of the second tier (B) characterizes the orientation of the restructuring of the modern first tier in the near future due to the replacement of dying old trees with younger ones. The participation of species in the third tier (C) reflects the influence of the modern structure of the community on the survival of the young generation of the edifier. A similar trend was revealed when studying the influence of oak litter in the European Mediterranean on the nature of the soil-absorbing complex and as a result on the germination of all diaphores of the edaphotope community [10].

Assessing the state of individuals of the oak according to the “Scale of Categories of the Condition of Trees” in the study areas, it can be noted that they differ in epimorphological characters, the nature of the damage, and belong to three categories. The first category includes individuals with a dense green crown, a normal growth rate of annual shoots, and the absence of external signs of weakening, confined exclusively to the territory of the Ashinsky district. Second category trees are weakened, characterized by openwork crown, defoliation, a decrease in annual growth to half the shoot length, drying out of individual branches, local trunk damage, and the presence of regenerative shoots. Strongly weakened trees belonging to the 3rd category have small, light leaves that fall early, an annual growth of up to 1/3 of the shoot length, drying out of the crown, numerous fungal lesions of the trunk and leaves. Trees belonging to 2nd and 3rd categories form coenopopulations of oak in the Nyazepetrovsky district and in the vicinity of Asha. As for the cenopopulations of oak in the forest-steppe zone, their individuals are strongly weakened and correspond to 3rd category.

The stable state of normal coenopopulations of relict oak groves is explained, in our opinion, by the physiological characteristics of the edificator, namely, allelopathic activity, which determines high competitiveness. A similar property can be detected only in laboratory experiments by the influence of allelochemicals on test objects. Studies of water extracts from *Quercus pubescens* Willd leaves showed different degrees of inhibition of selected test objects [11].

We also studied the allelopathic properties of extracts from leaf litter and the root layer of soil of the surface roots of *Quercus robur* L. of two concentrations on the root system of the test object (1% and 10%, respectively), using the generally accepted method of biological samples A.M. Grodzinsky.

According to the approaches of the author of the technique, the root growth of control test objects is taken as 100%. The root length of the experimental seedlings is expressed as a percentage of the growth.
of control seedlings (Grodzinsky, 1991). The results of the experiment are presented in graphs (Figure 9, 10).

![Seed germination percentage Lepidium sativum L.](image)

**Figure 9.** Germination of lettuce under the influence of secretions of leaf litter *Quercus robur* L.

![Germination of lettuce under the action of secretions of the root layer of the soil *Quercus robur* L.](image)

**Figure 10.** Germination of lettuce under the action of secretions of the root layer of the soil *Quercus robur* L.

Analysis of the diagrams shows that the effect of solutions on the growth of the roots of the test object is inhibitory. It should be noted that with an increase in the concentration of the aqueous extract, its allelopathic effect increases. The smallest effect on the test object was recorded in samples taken in «Kashtaksky bor», and extracts from samples taken in the Ashinsky reserve had the greatest inhibitory effect. In our opinion, the results can be explained by the state of the stand, which determines the physiological activity of the edificator. As noted, on the territory of the Ashinsky reserve, species of oak is predominant, belonging to the 1st category of state and, probably, exhibiting high allelopathic activity, which can be explained by more optimal climatic conditions that correspond to the ecological preferences of the species.

### 4. Conclusion

Our studies have shown the high specificity of the partial flora, reflecting the low degree of similarity of the species composition of oak groves of different botanical and geographical zones of the Urals.
The studied oak groves can be characterized as a diaspora subclimax, capable of long-term spontaneous existence, containing a few forest species, due to the limited drift of their diaspors, but characteristic of a non-moral complex that ensures community stability.

In all model communities, coen populations of pedunculate oak are normal, independent of drifts of primordia from the outside, capable of self-maintenance by seed and are represented by individuals in all tiers.

Allelopathic activity of oak is directly related to the vitality of its individuals and is determined by optimal climatic and edaphotopic conditions, the presence of competitors, and also explains its phytocenotic position in the community.

Ecological and coenotic analysis of the vegetation cover of oak groves showed the introduction of Acer negundo L. in some communities (the vicinity of the Asha-city), which is an invasive species with high growth energy, ruderal strategy, which can subsequently lead to dynamic changes and, ultimately, to change of the edifier. It is necessary to control the number of populations of ash maple by removing seedlings, undergrowth and cutting down adult trees.

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