Diversity of Dendrobionts, Hortobionts, and Herpetobionts of Some Biotopes of Specially Protected Natural Territory «Sosnovaya Rosha»

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Abstract. The paper describes the diversity of invertebrates belonging to dendro-, horto-, and herpetobionts in conditions of Specially Protected Natural Territory «Sosnovaya Rosha» in the city of Yoshkar-Ola, Republic of Mari El Russia. The diversity of invertebrates in different biotopes of the studied protected territory was 323 species: 3 species of Chilopoda; 63, Arachnida with prevalence of Aranei; and 257, Insecta with prevalence of Coleoptera. The variety of consortive relations may indicate resistance of the cenopopulation of the consortium determinant to adverse conditions. The diversity and abundance of hortobionts is determined by the type of the herbaceous community. The abundance of animals and the number of dominant groups of the soil herpetobionts depend on the location of the protected territory in the vicinity of Yoshkar-Ola, on soil composition and phytocenosis composition, on ontogeny stages, and on climatic factors. Heterogeneity of conditions of different biotopes in the forest park «Sosnovaya Rosha» contributes to an increase in the diversity of groups of invertebrates along the vertical gradient of a community (herpetobionts, hortobionts, and dendrobionts), which may preserve the stability of the community under the impact of anthropogenic factors.

1. Introduction
The preservation of the biodiversity of animal and plant species, landscapes, and ecosystems is one of the most relevant problems of our times. It is known that heterogeneity of habitat conditions tends to increase the diversity of various components of the community. Studying the spatial diversity of community elements is important for understanding the mechanisms of how ecosystems function, particularly in conditions of anthropogenic impact. Understanding these processes would make it possible to use an integrated approach to organizing nature conservation measures, because without the preservation of separate components of the system it is impossible to ensure the stability of its functioning as a whole [1-5].

Studying biodiversity of ecosystems involves identifying consortia comprised of the determinant plant species and consort organisms having biocoenotic relations with it and adapted to specific environmental conditions [3, 6, 7]. There are few works devoted to studying the whole complex of dendrobiont arthropods of various tree plantings [8-13]. As environmental conditions grow worse, especially near highways, industrial enterprises, and large cities, soil invertebrates are used increasingly more often in assessment of toxic pollution of ecosystems, since they are sensitive to changes in environmental parameters [14, 15].
The goal of this work was to examine the diversity of invertebrates belonging to dendro-, horto-, and herpetobionts in conditions of Specially Protected Natural Territory «Sosnovaya Rosha» («Pine Grove»).

2. Materials and methods
SPNT (Specially Protected Natural Territory) «Sosnovaya Rosha» is located in the forest park zone of the eastern part of Yoshkar-Ola, Mari El Republic and is adjacent to south-eastern blocks of the transriverine part of the city. The zone of coniferous and broad-leaved forests, which the forest park belongs to, is characterized mainly by birch, linden, aspen, and pine trees [16]. The forest park is within the city limits and according to the data of environmental monitoring it can be placed into the zone of the lowest pollution [17-19].

The research was carried out in 2009–2020. Dendrobiont arthropods were studied in the crowns of reproducing specimens of Betula pendula и Tilia cordata, determinant species of their consortia.

Arthropods (Insecta and Arachnida) were collected in the lower and middle parts of the tree crown and on the trunks using standard methods: sweep netting, tree-beating, manual collection of individuals and colonies, use of stem and pitfall traps [20]. The work was carried out from the end of May to August inclusive. Insects and arachnids were collected once in 10 days, on sunny days. Some insects or phytophagous mites were identified by the specific damage to the vegetative and reproductive structures of trees [21]. The relative abundance of dendrobionts was calculated and given a score [22]. The species got 1 point (sporadic) if the amount of individuals of the species from the total of the collection (N) was estimated at 0-2%; 2 points (rare), 2-6%; 3 points (common), 6-16%; 4 points (numerous), 16-40%; 5 points (mass), 40-100%.

The diversity of hortobionts (organisms found on herbaceous plants) was studied in habitats characterized by ruderal, sedge and meadowsweet, and grass and forb communities. The standard entomological methods were used [20]. To estimate the number of hortobionts per unit area we used L. G. Dinesman’s method [23].

To study the diversity of herpetobionts we selected 2 sample areas in a forb pine forest and a floodplain oak forest. Soil invertebrates were collected with standard pitfall traps (Barber traps) [24]. The traps in SPNT (Specially Protected Natural Territory) «Sosnovaya Rosha» were used starting from June 16 and until the end of July of 2020. The traps were set in two lines, with five traps per line. This census provided the data on the dynamic density of herpetobionts in the studied biotopes, expressed in the commonly accepted metric of specimens per 100 trap-days [24]. As the result of the field work during the research period a total of 1621 specimens of soil invertebrates were collected.

Characteristics of the species diversity were calculated with the Chekanovsky-Sorensen index [1]. For the statistical processing of the results we used the $\chi^2$ criterion [25].

3. Results and discussion
In the studied stands of B. pendula, specimens of 71 species of Insecta and Arachnida were found; in those of T. cordata, 65 species. The structure of the consortium of the studied trees includes three concentric circles (in addition to the centre, i.e. the determinant): the first circle is represented by phytophages, i.e. herbivorous insects and mites; the second, by entomozoophages. Mixed 1–2 circles include pantophages, mixed 2–3 circles include spiders, i.e. zoophages preying on the first and second circles. Looking at the separate taxa, to which the consorts of B. pendula and T. cordata belong, it can be seen that Coleoptera dominate in the number of species (30% and 26%, respectively; table 1). In the crowns of B. pendula we found herbivorous beetles of the families Curculionidae, Apionidae, Attelabidae, Chrysomelidae, Elateridae, and Thysanidae; for T. cordata this list also includes the Dascillidae, Nitidulidae, Byturidae, Mordellidae, and Staphylinidae.

The leaf-sucking inhabitants of B. pendula and T. cordata are represented by the order Homoptera: Aphididae, Aphrophoridae, Cicadellidae, Psyllidae, Membracidae, Fulgoridae; and Hemiptera: Acanthosomatidae, Lygaeidae, Pentatomidae, Miridae. Dominant groups among the entomophages are the Aranei and Coccinellidae (Coleoptera) with 17% and 19% respectively (table 1). The pantophages are
represented by *Carpocoris fuscispinus* (Boheman, 1851), *Palomena prasina* (Linnaeus, 1761), *Pentatoma rufipes* (Linnaeus, 1758), *Pyrrhocoris apterus* (Linnaeus, 1758), *Panorpa communis* (Linnaeus, 1758), *Formica rufa* L., *Formica truncorum* Fabr., *Vespula vulgaris* (Linnaeus, 1758) and others.

Table 1. The structure of taxonomic groups of Arthropoda in different biotopes of SPNT «Sosnovaya Rosha».

| Orders (Class) | Total number of species | Dendrobionts | Hortobionts | Herpetobionts |
|---------------|-------------------------|--------------|-------------|---------------|
| Lithobiomorpha (Chilopoda) | 3 | 0 | 0 | 0 | 0 | 2 | 1 |
| Opiliones (Arachnida) | 11 | 0 | 0 | 2 | 4 | 3 | 1 | 1 |
| Aranei (Insecta) | 52 | 3 | 11 | 3 | 2 | 3 | 18 | 12 |
| Odonata (Insecta) | 4 | 0 | 0 | 1 | 2 | 1 | 0 | 0 |
| Orthoptera | 3 | 0 | 0 | 1 | 0 | 2 | 0 | 0 |
| Homoptera | 19 | 11 | 4 | 1 | 0 | 2 | 1 | 0 |
| Hemiptera | 37 | 15 | 9 | 5 | 2 | 3 | 2 | 1 |
| Coleoptera | 118 | 21 | 17 | 4 | 5 | 2 | 36 | 33 |
| Neuroptera | 5 | 2 | 2 | 0 | 1 | 0 | 0 | 0 |
| Mecoptera | 3 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| Lepidoptera | 16 | 6 | 3 | 2 | 2 | 3 | 0 | 0 |
| Hymenoptera | 34 | 9 | 10 | 1 | 2 | 5 | 4 | 3 |
| Diptera | 18 | 3 | 8 | 2 | 3 | 2 | 0 | 0 |
| Total | 323 | 71 | 65 | 22 | 23 | 27 | 64 | 51 |

*a* in the crowns of *B. pendula*.

*b* in the crowns of *T. cordata*.

*c* ruderal community.

*d* sedge and meadowsweet community.

*e* grass and forb community.

*f* forb pine forest.

*g* floodplain oak forest.

Similar species were observed in the crowns of *B. pendula* and *T. cordata*; Chekanovsky-Sorensen index is 0.37. For example, typical pests of *B. pendula*: *Betulapion simile*, *Kleidocerys resedae*, and *Bytiscus betulae* (Linnaeus, 1758), are also found on *T. cordata*. Most of the insects detected are not included in the lists of the main pests of *B. pendula* and *T. cordata* [10, 21], may be due to the insufficient knowledge of the consortia of these determinants in our region.

In the studied plantings of *B. pendula* predominating trophic groups are phyllophages (leaf-sucking and leaf-eating insects), carphophages, and (in the *T. cordata* plantings) also anthophiles. Among the dendrobionts, polypophages were observed more often. Despite the variety of the found phytophages in the studied tree species, relative abundance of the insects is at low figures (score 1–3). The abundance of predatory insects, controlling the abundance of phyllo- and carphophages, is within the same limits. In the urban environment, for example, a different tendency was revealed: a decrease in the diversity of dendrobiont insects associated with *B. pendula* against an increase of their abundance (p< 0.05) [13].
The analysis of the hortobiont diversity allowed us to find 22 species of Insecta and Arachnida in the ruderal community (table 1) with the total abundance of Arthropoda being at 24.4 specimens/m². Representatives of Hemiptera dominated in this group in species diversity and abundance, comprising 29.60 % of the total abundance. In the sedge and meadowsweet community Arthropoda were represented by 23 species of Insecta and Arachnida (table 1) with the total abundance of 19.41 specimens/m². Representatives of Coleoptera dominated in species diversity (21.74 %); Diptera, in abundance (34.2 %). The highest diversity of hortobionts was observed in the grass and forb community: 27 species of Insecta and Arachnida (table 1), with abundance of 32.97 specimens/m². The group that dominated in species diversity was Hymenoptera (18.52 %) with abundance share of 29.4 %, and in abundance it were Homoptera (38.7 %) with diversity share of 7.41 %. Dominants in occurrence (100 %) in herbaceous communities were Adelphocoris sp. and Cantharis livida (Linnaeus, 1758). Rather high occurrence (66.6 %) was observed in Grophosoma lineatum (Linnaeus, 1758), Lygaeus sp., Coenagrion hastulatum (Vander Linden, 1825), Coccinella septempunctata (Linnaeus, 1758), and Apis mellifera (Linnaeus, 1758).

The hortobionts in the pine forest were represented by 64 species of Insecta, Arachnida and Chilopoda, with dominance of Coleoptera (56.25 %) and Aranei (28.12 %) (table 1). In the oak forest the diversity of hortobionts was somewhat lower: 51 species with the same dominant groups as in the pine forest. The dynamic density of herpetobionts in the sampling areas varied within season from 122 to 380 specimens per 100 trap-days (figure 1). Higher abundance levels of invertebrates were observed in the forb pine forest; especially noticeable this trend was between June 16 and June 26 (exposure period no. 1), and also between July 6 and July 16 (exposure period no. 3). This is because the oak forest is in the lower part of the floodplain of the Malaya Kokshaga River and during the research period had excessive soil moisture.

![Figure 1](image.png)

**Figure 1.** Dynamic density of soil invertebrates in the studied communities.

The analysis of the soil biodiversity has shown that the herpetobionts are represented by all the typical groups of soil invertebrates. The forb pine forest during the whole season was dominated by the Opiliones, whose density reached 249 specimens per 100 trap-days. High values of dynamic density (up to 106 specimens per 100 trap-days) were noted in spiders (Aranei). Among the Carabidae in the pine forest mainly representatives of small species were encountered. Carabus and Cychrus were found sporadically.

The floodplain oak forest was dominated by the same herpetobiont groups. Abundance of Opiliones increases by the mid July, this causes an increase in the amount of the Carabidae, since Opiliones are a food source for the Carabidae. The high abundance of the Carabidae was determined essentially by one species, *Epaphius secalis* (Payk., 1790) (up to 62 specimens per 100 trap-days).

Studies into the composition and distribution of the soil mesofauna in the soil biocenoses were also conducted on the territory of the State Nature Reserve Bolshaya Kokshaga. It is worth noting that in the
woodland areas of the floodplain that get inundated during the spring floods the values of abundance and biomass are higher than in the floodplain terrace areas. The ecological spectrum of the mesofauna species groups to a considerable degree depended on the hydrothermal conditions of a specific biocenosis [26].

Interesting results were obtained when studying linear dimensions of 3 species of Carabus, 2 species of Pterostichus, and 1 species of Poecilus on urban territories. The measurement results have shown that different traits can respond to urbanization with opposite changes: a decrease in length with an increase in width and vice versa. Males and females often respond to urbanization oppositely, which intensifies sexual dimorphism in the body size along the urbanization gradient [27].

4. Conclusions
The diversity of invertebrates in different biotopes of the studied protected territory was 323 species: 3 species of Chilopoda; 63, Arachnida with prevalence of Aranei; and 257, Insecta with prevalence of Coleoptera.

The variety of consortive relations may indicate resistance of the cenopopulation of the consortium determinant to adverse conditions.

The diversity and abundance of hortobionts is determined by the type of the herbaceous community.

The abundance of animals and the number of dominant groups of the soil herpetobionts depend on the location of the protected territory in the vicinity of Yoshkar-Ola, on soil composition and phytocenosis composition, on ontogeny stages, and on climatic factors.

From the ecological position, various insect phytophages by accelerating the cycles of elements contribute to an increase in plant productivity [28]. The described groups of invertebrates are included in various grazing and detritus food chains, and variety of these chains is a factor in optimizing the cycles of matter and energy in the ecosystem.

Heterogeneity of conditions of different biotopes in the forest park "Sosnovaya Rosha" contributes to an increase in the diversity of groups of invertebrates along the vertical gradient of a community (herpetobionts, hortobionts, and dendrobionts), which may preserve the stability of the community under the impact of anthropogenic factors.

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References
[1] Magurran A E 1983 Ecological diversity and its measurement (London, Sydney) p 181
[2] Zhukova L A, Dorogova Y A, Turmuhamekova N V, Gavriloa M N and Polyanskaia T A 2010 Ecological indicator values and methods of analysis of ecological diversity of plants (Yoshkar-Ola: Mari State Univ) p 368
[3] Notov A A and Zhukova L A 2015 Epiphytic lichens and bryophytes at different ontogenetic stages of Pinus sylvestris Wulfenia 22 245-60
[4] Dorogova Y A, Zhukova L A, Turmuhametova N V, Polyanskaia T A, Notov A A and Dement’yeva S M 2016 Methods of Analysis of Environmental Diversity of Plants Biology and Medicine 8(6) 7
[5] Bedova P, Bogdanov G, Anichkin A, Vorobeva I and Turmuhametova N 2018 Experience in establishing specially protected natural areas in case of small scale landscapes – objective criteria and arguments to justify 18th Int. Multidisciplinary Scientific GeoConference SGEM 2018, Conf. Proc. 18 429-35
[6] Negrobov V V and Hmelev K F 2000 The modern concepts of a consortiology Bulletin of Voronezh State University Chemistry series Biology 118-21
[7] Ozerski P V 2016 Some approaches to building of schemes of consortium Functional morphology, ecology and life cycles of animals 16(1) 48-56
[8] Rafes P M 1980 Biocenological studies of herbivorous forest insects (Moscow: Science) p 168
[9] Kutenkova N N 1991 Invertebrate complexes in birch crowns and their use of food resources
Entomological research in the Kivach reserve (Petrozavodsk: KSC of the USSR Academy of
Sciences) 75-98
[10] Tarasova O V, Kovalyov A V, Sukhovolsky V G and Hlebopros R G 2004 Insects of a fillofaga
of green plantings of the cities: Specific structure and features of dynamics of number
(Novosibirsk: Science) p 180
[11] Belov D A 2011 Ecological and trophic complexes of herbivorous arthropods in Moscow
plantations Lesnoy Vestnik 4 5-12
[12] Turmukhametova N V, Bedova P V and Vorobeva I G 2020 Structure peculiarities of Pinus
sylvestris L. consortium IOP Conf. Series: Earth and Environmental Science 548(4) 042035
[13] Turmukhametova N V, Zelev R M and Zabotin Y I 2021 A new approach to description of the
structure of the consortium of Betula pendula Roth and Tilia cordata Mill. and its capabilities
for bioindication IOP Conf. Series: Earth and Environmental Science 677(4) 042008
[14] Konovalova O N, Popova L F and Filippov B Yu 2013 Soil invertebrates as bioindicators of
anthropogenic impact on the ecosystem of Arkhangelsk Living and bioinert systems 3 11
[15] Elantseva A A 2015 Insects-herpetobionts in urban plantings Bulletin of the Samara Scientific
Center of the Russian Academy of Sciences 17(4) 134-141
[16] Report on the implementation of work on the inventory of green spaces and the design of activities
within the boundaries of the protected area «Pine Grove» 2013 (Yoshkar-Ola) p 155
[17] Yoshkar-Ola. Information portal. Ecological situation Retrieved from: https://iola.ru/city/ecologia/
[18] Turmukhametova N V 2020 Evaluation of the State of the Environment in Yoshkar-Ola Using
Morphometric Indicators of Betula pendula Roth Biology Bulletin 47(2) 191–197
[19] Turmukhametova N and Shadrina E 2020 Changes in the Fluctuating Asymmetry of the Leaf and
Reproductive Capacity of Betula pendula Roth Reflect Pessimization of Anthropogenically
Transformed Environment Symmetry 12(12) 1-18
[20] Tsurikov M N 2003 Humane methods of investigations of invertebrates. Nature reserves in
Ukraine 9(2) 52-57
[21] Gusev V I 1984 Continuant of damages forest, decorative and fruit-trees and bushes (Moscow:
Forest industry) p 472
[22] Pesenko Yu A 1982 The Principles and methods of the quantitative analysis in faunistic
researches (Moscow: Science) p 287
[23] Dunaev E A 1997 Methods of ecological and entomological research (Moscow) p 44
[24] Gilyarov M S 1965 Zoological method for soil diagnostics (Moscow: Science) p 281
[25] Sokol R R and Rohlf F J 1995 Biometry (New York: Freeman) p 887
[26] Bastrakov A I, Rybalov L B and Vorobieva I G 2014 Soil mesofauna in the valley of the Bolshaya
Kokshaga River (by the example of the middle course) Povolzhsky ecological journal 4 452–
462.
[27] Mukhametnabiev T, Sukhodolskaya R A, Savilev A A, Eremeeva N I and Vorobyova I 2019
Urbanization effect on ground beetle (coleopteran, Carabidae) MOJ Ecology & Environmental
Sciences. 4(6) 252–256
[28] Eastern European forests: history in the Holocene and modernity 2004 (Moscow: Science) p 479