Structure peculiarities of *Pinus sylvestris* L. consortium

N V Turmukhametova*, P V Bedova and I G Vorobeva
Mari State University, 1 Lenin Square, Yoshkar-Ola, 424000, Russia

*E-mail: bonid@mail.ru

**Abstract.** The structure of *Pinus sylvestris* L. consortium of various ontogenetic conditions in the regions of the Republic of Mari El and the city of Yoshkar-Ola in the territory of Russia is described. Based on modern methods of collecting arthropod animals in tree crowns and studying the structure of consortium, data analysis has been performed. With *P. sylvestris* coenopopulations, 73 species of Insecta and Arachnida are associated. The dominant species diversity is Coleoptera. The trophic groups of Insecta and Aranei, the groups in the breadth of the range of nutrition and harmfulness are characterized. It is shown that the diversity of Insecta and Aranei complexes in *P. sylvestris* coenopopulations is determined by the age features of the tree and the ecological conditions of the study areas. Consideration of the ontogenetic state of the determinant of the consortium and analysis of the formation of different types of integumentary tissue contributes to the prediction of the stages of colonization and damage to trees by harmful Insecta. It was suggested that for the detailed characterization of the consortium, it is necessary to organize a long-term monitoring of the state of tree stands and the composition of their consorts using the population-ontogenetic approach.

1. **Introduction**

The study of ecosystem biodiversity involves the identification of consortium that include individuals of the species of the determinant plant and the associated organisms-consorts connected with it by biocenotic relationships – different species of lichens, bryophytes, fungi, algae and animals cumulatively confined to the conditions of a particular environment. This approach to the study of biodiversity was called the consortiumal [1-3]. The term «consortium» underwent a number of changes. It was first used by A. Grisebach [4] to denote the symbiosis of organisms forming Lichenes. K. Friederichs [5] under the «consortium» the totality of interrelated members of the same community is understood.

W. Tischler [6] proposed the term «biozontische Konnex» as a set of relationships between organisms. Studies on consortium [7, 8] formed the basis of a new scientific direction – consortiology, which is developed primarily in Russia. The study of plant populations [9, 10] promoted the development of population-consortial analysis, where the coenopopulations of plants are considered a determinant of the consortium [11]. Until now, there is no single theoretical basis for solving the problem of studying consortium. In our study, we follow the population direction of the study of woody plants consortia.

One of the tree species being the most widespread in the forest zone of Russia, including the Republic of Mari El (the RME), is *Pinus sylvestris* L. The wide range of *P. sylvestris* increases the importance of studying the dynamics of the formation of consortium in tree ontogeny. Previously, the changes in the structure of the Lichenes and Bryophyta consortium during the ontogenesis of *P. sylvestris* [2] were analized. A lot of attention was paid to dangerous pests of trees in the forestry, their lists were compiled,
including *P. sylvestris* [12-14]. However, the analysis of the total consortium of arthropods was not specially conducted. Individual groups of Insecta and Aranei were studied in plantations of pine forests of RME [15-17]. For the first time in the territory of the Republic of Mari El the study of the structure of a consortium of coenopopulations of *P. sylvestris* of different biological ages was conducted.

The aim of the work is to analyze the variability of insects and arachnids inhabiting the crowns of the trees of the coenopopulations of *P. sylvestris* in different ecotopes.

2. Materials and methods

The studies were carried out in the period 2011-2014 in the subzone of coniferous-broad-leaved forests of the Republic of Mari El (RME) of Russia. The material was collected on the territory of the Morki district (sites 1-4), where the effect of the anthropogenic factor is not noted. Material was also collected in the city of Yoshkar-Ola (sites 5-7). The sites that differ in the degree of pollution of the environment by industrial and transport emissions were selected: No. 5, 6 – Specially protected Natural Territory «Sosnovaya Rosha» («Pine Grove», zone of least pollution), No. 7 – Alley along the street in one of the microdistricts (zone of low pollution) [18].

The determinants of the consortium were young and adult trees *Pinus sylvestris*: of virginal and young generative ontogenetic states. In different areas the material was collected either from undergrowth or from adult trees. A total of 220 trees were examined. Virginal plants (*v*) *P. sylvestris* represent single-stemmed trees with an actively forming crown. Virginal individuals of the first subgroup have a widely spindle-shaped crown up to the very base of the earth. The lower part of the trunk is almost not cleared from the lower branches and covered with periderm. The average age of trees is 8 years, the minimum age is 6, the maximum age is 10 years. Seedling of *P. sylvestris* in the young generative ontogenetic state (*g1*) is uninfluential and irregular. The trees are distinguished by a regular pointed conical crown. From its base to the top, the main axis is clearly traced. A crust appears at the base of the trunk. In individuals grown on dry land, this period can last about 50 years [19]. *P. sylvestris* belongs to euribiotic species and has broad environmental ranges for climatic and soil factors according to D. N. Tsyganov's scales [20, 21].

Arthropods (Insecta and Aranei) were collected in the lower and middle parts of the tree crown and on the trunks using standard methods: mowing by entomological nets, shaking, mechanical seizure of individuals and colonies, use of stem and soil traps [22]. The work was carried out from the end of May to August inclusive. Insects and araneis were harvested once in 10 days, on sunny days. Some insects were diagnosed by the specific damage to the vegetative and generative structures of trees [23]. The relative abundance of dendrobionts was calculated [24]. The species got 1 point (single) if the number of individuals of the species from the volume of the collection (N) estimated 0-2%, 2 points (rare) – 2-6%, 3 points (usual) – 6-16%, 4 points (numerous) – 16-40%, 5 points (mass) – 40-100%.

Characteristics of the species diversity are calculated with the Chekanovsky-Sorensen index [25]. For the statistical processing of the results we used the criterion $\chi^2$, cluster analysis: Euclidean distance, Ward's method [26].

3. Results and discussion

Consors of the studied plantations of *P. sylvestris* number 73 species of Insecta and Aranei, including 56 species in the Morky region of the RME, 49 species in the town of Yoshkar-Ola. The structure of consortiums of virgin and young generative trees of *P. sylvestris* includes three concentrates. The first one is herbivorous insects, the second one is entomophages, the third one is zoophagy of the second order. Mixed 1, 2 concentrates include pantophagy, in 2, 3 – spiders, which are actually zoophages of the first and second orders.

In the crowns of the studied plantations of *P. sylvestris*, 40 species of phytophagous insects have been identified. Among the herbivorous insects, beetles were more common (59%) (table 1). They represent the families Curculionidae, Scolytidae, Scarabaeidae, Cerambycidae, Chrysomelidae, Elateridae, Buprestidae, Tenebrionidae. The number of Coleoptera taxa found in the crowns of *P. sylvestris* is dominated by Curculionidae: *Hylobius abietis* (Linnaeus, 1758), *Otiorthynchus ovatus*.
(Linnaeus, 1758), Brachyderus incanus (Linnaeus, 1758), Magdalis frontalis (Gyllenhal, 1827), Otiorhynchus scaber (Linnaeus, 1758), Srophosoma capitatum (De Geer, 1775), Otiorhynchus tristis (Scopoli, 1763), Tanamecnum palliatum (Fabricius, 1787), Pissodes piniphilus (Herbst, 1797), Cleonus piper (Scopoli, 1763), Pissodes notatus (Linnaeus, 1758). It is known that after leaving the wintering grounds Curculionidae gnaw the cortex of shoots and spring shoots of young trees, damage kidneys and needles. The places of cuttings can be covered with resin and formed characteristic resin influx. Among the Hemiptera species Coreidae, Lygaeidae, Aradidae, Pentatomidae were found, among Lepidoptera species Geometridae, Noctuidae, Sphingidae, Pilaridae, Tortricidae, Orgyidae. In the crowns of P. sylvestris, there are 10 species of omnivorous Insecta, Aranei. Among them there are Pyrrhocoris apterus (Linnaeus, 1758), Palomena prasina (Linnaeus, 1758), Harpalus latu (Linnaeus, 1758), Amara fulva (De Geer, 1776), Lacocon murinus (Linnaeus, 1758) and others. The second concentrator consists of 19 representatives of carnivorous Insecta: Nabidae, Carabidae, Coccinelidae, Silphidae, Ichneumonidae. We also identified consorts of 2 and 3 concentrates being able to eat «themselves» as well as other insects. They refer to Aranei: Gnaphosidae, Lycosidae, Dictynidae. The relationship between the determinant and the consorts in better degree is more trophic and topical, the fensive ones are also manifested: the protective ones and vice versa, sometimes – the factory ones: giving the consorts a support or material for the arrangements of shelters, for example, with Dictynidae building dense trap networks.

Table 1. The ratio of systematic groups of Insecta and Arachnida on different-aged Pinus sylvestris trees in various habitats.

| Orders        | Total number of species | Quantity of species in P. sylvestris in habitats |
|---------------|-------------------------|-------------------------------------------------|
| Homoptera     | 3                       | 1                                                              |
| Hemiptera     | 7                       | 1                                                              |
| Coleoptera    | 43                      | 1                                                              |
| Lepidoptera   | 7                       | 1                                                              |
| Hymenoptera   | 4                       | 1                                                              |
| Diptera       | 3                       | 1                                                              |
| Orthoptera    | 2                       | 1                                                              |
| Aranei        | 4                       | 1                                                              |
| Total         | 73                      | 27                                                             |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|----------------------------|---|---|---|---|---|---|---|
| Homoptera                 | v | g1 | v | g1 | v | g1 | g1 |
| Hemiptera                 | 1 | 1 | 0 | 1 | 1 | 2 | 2 |
| Coleoptera                | 14 | 7 | 7 | 16 | 22 | 21 | 14 |
| Lepidoptera               | 1 | 3 | 3 | 2 | 0 | 5 | 4 |
| Hymenoptera               | 1 | 2 | 2 | 2 | 1 | 4 | 2 |
| Diptera                   | 1 | 2 | 2 | 2 | 1 | 1 | 1 |
| Orthoptera                | 2 | 1 | 1 | 2 | 1 | 1 | 0 |
| Aranei                    | 1 | 1 | 1 | 2 | 1 | 1 | 0 |
| Total                     | 27 | 18 | 26 | 26 | 36 | 25 |

There were few kinds of the same species in discovered different habitats (Cs = 0.32-0.40). They include 7 species of Insecta: Nabis sp., Coccinella septempunctata (Linnaeus, 1758), Harpalus latus, Lagrida hirta (Linnaeus, 1758), Amphilallon solstitialis (Linnaeus, 1758), Bupalus piniaria (Linnaeus, 1758), Formica aquilonia (Yarrow, 1955). Consequently, the lists of P. sylvestris consorts in the studied habitats differ, which is determined by their ecological specificity.

Young generative plantations of P. sylvestris revealed 51 species of consorts, in Virginal types – 42 species. With the help of cluster analysis, it was established that the lists of consorts of virginyl trees from three ecotopes, as well as lists of consorts of adult trees from four other ecotopes, were the most similar. When assessing the species diversity by the Chekanovsky-Sorensen index, we obtained the results similar to cluster analysis. Lists of consorts on P. sylvestris trees of the same biological age are more similar (Cs = 0.55-0.56).

In the study of P. sylvestris, the lesions of needles, cones, crusts and wood were visually detected in the sites studied by various phytotribes. The ratio of trophic groups of insects on trees of different biological ages and in various biotopes is different (P<0.01). In the first concentration of consortium undergrowth P. sylvestris pest wilt dominates, however, pest cones and gall-producers are not found. In the consortium of adult trees, there are predominantly conophagous, bark beetles and xylphagous. Many phytophages use several morphological structures of P. sylvestris as a food source.
In most phytophages and zoophagous of consortium P. sylvestris the relative abundance is not significant – 1-2 points [24]. Among zoophagi, a high abundance is noted in Coccinella septempunctata, which feeds on Aphididae. In P. sylvestris virgin trees, a significant abundance of Amphimallon solstitialis (Linnaeus, 1758) was recorded at 5 points, on generative – average (3 points). A. solstitialis larvae damage the roots of P. sylvestris young specimens. From imago harm is negligible if they do not start to gnaw leaves and needles massively. In general, virginal trees that have experienced the impact of horseradish can be assessed as «weakened», and young generative trees as «healthy» ones.

In adult trees we detected a greater variety of trophic groups, which is due to the appearance of phytoprotobes attracted by generative structures. On sites No. 2, 4, the active center of Aradus cinnamomeus (Panzer, 1806) was recorded on young generative trees of P. sylvestris. The population of A. cinnamomeus in P. sylvestris was average. At 1 dm2 of the most populated interstitial of the auxiblast occurs up to 16-30 individuals of the bug. At the initial stage of damage to P. sylvestris, by the bug silvery-white spots on the surface of the wood under the bark appear. Over time the P. sylvestris can slow down growth processes. It is known that individuals of A. cinnamomeus choose young trees for colonization, where crust flakes have already been formed on the trunks, which serve as shelter for them. The maximum population of A. cinnamomeus reaches the age of 12-18 years of P. sylvestris, and by 30 years the lesions in cultures are completely damped [12]. Consequently, the change in the course of ontogeny of the determinant of the consortium of types of integumentary tissue and the appearance of the crust causes the attraction of insect-ecrisiotrovs, bark beetles and xylophages.

Among phytophages P. sylvestris species with a wide range of food – polyphages dominate (58%): Curculionidae, Elateridae. Monophages (33%) are some dangerous pests of P. sylvestris: Pineus strobi Htg., A. cinnamomeus, Blastophagus piniperda (Linnaeus, 1758), Thecodiplosis brachyntera (Schwagrichen, 1835). Oligophages (9%) include Insecta, which find food on other coniferous trees: Hyllobius abietis, Cleonus piger, Pissodes notatus. In all studied plantations of P. sylvestris, most phytophages are polyphages, although the ratio of the number of species in a certain group and place of collection is statistically insignificant (P>0.05).

When considering insects as pests of trees from forestry positions, we distributed first-order consorts P. sylvestris on the harmfulness of the primary, secondary and optional pests. The largest or most significant pests include the largest number of consorts – 55%, many of which are monoprotobes or oligoprotobes. Secondary pests (30%), which occur but frequently and not in significant amounts, include Otiorhynchus scaber, O. tristis, Tanumecus palliatius. Facultative pests occupy 15%, which include Lygus sp., Harpalus latus, H. rufipes (Degeer, 1774). From an ecological point of view, outbreaks of mass reproduction of insects should be considered as a natural phenomenon. Accelerating the circulation of elements, insects contribute to an increase in the productivity of plants [27].

The different ratio of ecological-trophic groups to the different ages of the determinant of the consortium is due to different reasons. Among them there are the anatomical and morphological features of a plant of a certain age, the specificity of the passage of the various stages of ontogenesis by the phytoprotobate, the cyclic development of the insect population. In P. sylvestris generative trees, the thickness of the cuticle and the membranes of cells of mechanical tissue increases. These differences can help attract more insects to the young trees with a gnawing oral apparatus. Going through various stages of the ontogenesis of some Insecta feeding on needles (Curculionidae, Scarabaeidae) is associated with the growth of P. sylvestris. Their larvae live in the soil and feed on the roots of young trees.

4. Conclusions
In the studied plantations of Pinus sylvestris, 73 species of Insecta and Aranei, belonging to the three concentrations of the consortium, were identified. The dominant species diversity is Coleoptera. The taxonomic diversity of arthropods and their relative abundance in P. sylvestris trees of the same biological age in different habitats is more similar. The preference for food resource by phytophages and distribution of predatory arthropods depend on the age features of the determinant of the consortium. In the first concentration of consortium undergrowth P. sylvestris pest wilderness dominate, in the consortium of adult trees – pests of cones, crusts and wood. In the consortium of P. sylvestris,
polypHages predominate. The phytPhagous of *P. sylvestris* is dominated by insects that are dangerous from forestry positions. In young plants *P. sylvestris*, a considerable abundance of *Amphimallon solstitialis* was noted, in adult trees – the active focus of *Aradus cinnamomeus*. This study has the value for forest pathological research. Consideration of the ontogenetic state of the determinant of the consortium and analysis of the formation of different types of integumentary tissue contributes to the prediction of the stages of colonization and damage to trees by harmful *Insecta*. For a detailed characterization of the consortium, it is necessary to organize a long-term monitoring of the state of tree stands and the composition of their consorts using the population-ontogenetic approach.

References

[1] Negrobov V V and Hmelev K F 2000 The modern concepts of a consortiology Bulletin of Voronezh State University Chemistry series Biology 118-21

[2] Notov A A and Zhukova L A 2015 Epiphytic lichens and bryophytes at different ontogenetic stages of Pinus sylvestris *Wulfenia* 22 245-60

[3] Ozerski P V 2016 Some approaches to building of schemes of consortium *Functional morphology, ecology and life cycles of animals* 16(1) 48-56

[4] Grisebach A H R 1872 *Die Vegetation der Erde nach ihrer klimatischen Anordnung. Ein Abriß der Vergleichenden Geographie der Pflanzen* (Leipzig: Wilhelm Engelmann)

[5] Friederichs K 1930 *Die Grundfragen und Gesetzmassigkeiten der land-und forstwirtschaftlichen Zoologie* (Berlin) s 417

[6] Tischler W 1951 *Der biozonotische Konnex* *Biol. Zbl.* 70 110-4

[7] Beklemishev V N 1951 About classification of the biocenotic connections *The Bulletin of the Moscow society of verifiers of the nature Office of biology* 61(5) 3-30

[8] Ramensky L G 1952 About some key provisions of the modern geobotany *The Botanical magazine* 37(2) 181-201

[9] Harper J L 1977 *Population biology of plants* (London, New York) 892

[10] Zhukova L A and Ermakova I M 1985 Structure and dynamics of coenopopulation of some temperate grasses *The population structure of vegetation. Handbook of vegetation* (Dodrecht, Boston, Lancaster) 170-205

[11] Rabotnov T A 1994 Development of some theoretical representations of L. G. Ramensky and V. N. Sukachev in the field of a phytocenology *Russian Journal of Ecology* 4 3-85

[12] Mozolevskaia E G, Kataev O A and Sokolova E S 1984 *Methods of pathological examination of foci of stem pests and forest diseases* (Moscow: Timber industry) 152

[13] Hanks L and Denno R 1993 Natural enemies and plant water relations influence the distribution of an armored scale insect *Ecology* 74 1081-91

[14] Macfadyen S et al. 2009 Parasitoid control of aphids in organic and conventional farming systems *Agriculture, Ecosystems & Environment* 133 14-8

[15] Kamaev I O 2008 Vertical structure of the population Aranei pine forests *Scientific works of the state nature reserve «Bolshaya Kokshaga»* 198-213

[16] Matveev V A 2009 Species composition *Insecta*, Heteroptera of the Republic of Mari El *Scientific works of the state nature reserve «Bolshaya Kokshaga»* 4 247-63

[17] Demakov Yu P, Safin M G and Shvetsov S M 2012 *Sphagnum pine forests of Mari Polesie: structure, growth and productivity* (Yoshkar-Ola: MarSTU) 275

[18] Yoshkar-Ola. Information portal. Ecological situation Retrieved from: https://i-ola.ru/city/ecologia/

[19] Zhukova L A, Notov A A, Turmuhametova N V and Teterin I S 2013 Ontogenesis Pinus sylvestris L. *Ontogenetic atlas of plants* (Yoshkar-Ola: MarSU) 26-65

[20] Zhukova L A, Dorogova Y A Turmuhametova N V, Gavrilova M N and Polyanskaya T A 2010 *Ecological indicator values and methods of analysis of ecological diversity of plants* (Yoshkar-Ola Mari State Univ) 368

[21] Dorogova Y A, Zhukova L A, Turmuhametova N V, Polyanskaya T A, Notov A A and
Dementyeva S M 2016 Methods of Analysis of Environmental Diversity of Plants Biology and Medicine 8(6) 7
[22] Tsurikov M N 2003 Humane methods of investigations of invertebrates. Nature reserves in Ukraine 9(2) 52-7
[23] Gusev V I 1984 Continuants of damages forest, decorative and fruit-trees and bushes (Moscow: Forest industry) 472
[24] Pesenko Yu A 1982 The Principles and methods of the quantitative analysis in faunistic researches (Moscow: Science) 287
[25] Magurran A E 1983 Ecological diversity and its measurement (London, Sydney) 181
[26] Sokal R R and Rohlf F J 1995 Biometry (New York: Freeman) 887
[27] Eastern European forests: history in the Holocene and modernity 2004 (Moscow: Science) 479