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Vertical stratification and dynamics of insect communities in deciduous forests (Center of European Russia)

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Abstract. The vertical distribution of insects was studied in deciduous forests of the temperate zone (the center of European Russia). During the research, 81342 individuals from 10 insect orders (Dermaptera, Blattodea, Hemiptera, Hymenoptera, Coleoptera, Neuroptera, Trichoptera, Lepidoptera, Diptera, Mecoptera) were collected. Diptera, Lepidoptera and Coleoptera were the most numerous. The total number of Coleoptera and Diptera was higher at an altitude of 1.5 m, and Lepidoptera prevailed at an altitude of 12 m. Species from the orders Hymenoptera, Dermaptera, Neuroptera and Trichoptera dominated the tree crowns. The number of Blattodea was higher in the lower tiers of the forest. The seasonal dynamics of the number of insects in traps tended to increase significantly by September. But each order had its own dynamics of numbers during the season.

1 Introduction

In the center of the European part of Russia, forest ecosystems have undergone significant changes due to anthropogenic load. Climate change, river degradation, landscape fragmentation, long-term logging, and agricultural development have made significant adjustments to the functioning of forest ecosystems. However, insect communities in these ecosystems, even when they change, can rebuild and continue to maintain their existence [1-4].

In tropical climate forests, when studying insect communities, it turned out that many species are distributed not only along horizontal ecological gradients, but also have quite vertical stratification. Such stratification is caused by the tiered composition of forest ecosystems [5, 6]. Similar dependencies were found for temperate forests and insect communities living in them [7-9]. For example, in deciduous forests of Japan, the number of Coleoptera was greater in the upper tiers of the forest than at the undergrowth level [10]. On the other hand, in the deciduous forests of France, a higher abundance and species richness of beetles was observed in the undergrowth [11]. In Canadian temperate forests, the composition and dynamics of Coleoptera and Diptera communities varied significantly

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depending on the height of the traps placed. More samples and species of coleoptera have been collected in window traps [12].

2 Materials and methods

Insects were collected from May to September in the spring and autumn. Field studies were conducted at 4 plots in the deciduous forests of the Republic of Mordovia (the center of European Russia). At each site within 20 m in a horizontal plane, 4 traps were installed on tree branches. To study vertical stratification, the traps were located at heights specific to deciduous forest tiers: 1.5, 3.5, 7 and 12 m above the ground. All experimental plots were located in the forest interior. The distance between the plots was at least 1.5 km from each other. The vegetation on each plot was to some extent different from other plots. However, the tiers of the forest were expressed the same everywhere and the similarity between them accounted for 85%. At the plots, the first tier of the forest consisted of linden and oak with a projective coverage of 60%. The undergrowth layer was represented by maple, elm, buckthorn, rowan, small linden and oak trees. The herbaceous tier was represented by various types of sedges (*Carex*), violets, lily of the valley, compound and rosaceae plants [13].

The material was collected using beer traps of our own design. Each trap was a plastic five-liter bottle with a window cut out on one side to catch insects. Beer was used as a bait, sugar and honey were added [14]. The collected samples were washed, placed in alcohol and delivered to the laboratory. Then the samples were counted, sorted and identified in the laboratory. The invertebrate system was used for classification [15].

3 Results

In total, 81,342 individuals from 10 insect orders were studied (Table 1). The most numerous in beer traps were representatives of the orders Diptera (72.2% relative to the total number of individuals), Lepidoptera (18.3%) and Coleoptera (8.3%). These data once again confirm that beer traps usually lure these orders [14]. The other order did not have such a significant value in the total number. The total number of all insects was the largest at a height of 1.5 m, at the level of tree crowns, the number of insects was slightly lower.

Table 1. Cumulative data on the number of insect order captured at different heights in deciduous forests.

Order	1.5 m	3.5 m	7 m	12 m	Total
Dermaptera	2	5	15	4	**26**
Blattodea	10	1	5	4	**20**
Hemiptera	3	3	0	1	**7**
Hymenoptera	116	116	156	182	**570**
Coleoptera	1876	1891	1596	1390	**6753**
Neuroptera	16	70	68	116	**270**
Trichoptera	0	6	4	8	**18**
Lepidoptera	2570	3691	4004	4603	**14868**
Diptera	19416	11362	13538	14436	**58752**
Mecoptera	14	18	14	12	**58**
Total	**24023**	**17163**	**19400**	**20756**	**81342**
Number of orders	**9**	**10**	**9**	**10**	**10**

However, some peculiarities were observed in the vertical distribution of individual insect groups. As Table 1 shows, for the entire season, the largest number of Diptera individuals were caught at a height of 1.5 m, and the minimum number was caught in the undergrowth at a height of 3.5 m. In the tree crowns (7 and 12 m), the number of Diptera was intermediate. The total number of Coleoptera was higher at a height of 1.5 m and gradually decreased as the height increased, i.e. the higher the traps were located, the smaller the number of beetles. The largest total number of Lepidoptera for the season was obtained at an altitude of 12 m, the smallest number was obtained at an altitude of 1.5 m. At other altitudes, the abundance values had intermediate indicators.

Species from the order Hymenoptera mostly prevailed at a higher altitude. In the case of Neuroptera, a similar dependence was noticed, which was expressed much more clearly. The number of representatives of Dermaptera and Trichoptera was higher at the level of the crown of trees, while Blattodea prevailed in the lower traps. The number of Mecoptera did not depend on height.

The seasonal dynamics of the insect population was quite natural. The total number gradually increased during the season from May to August (Figure 1). In September, the number decreased. However, we will point out that our experiments were completed in mid-September and the September numbers are incomplete. It is important to mention that at all altitudes the dynamics of the number was the same.

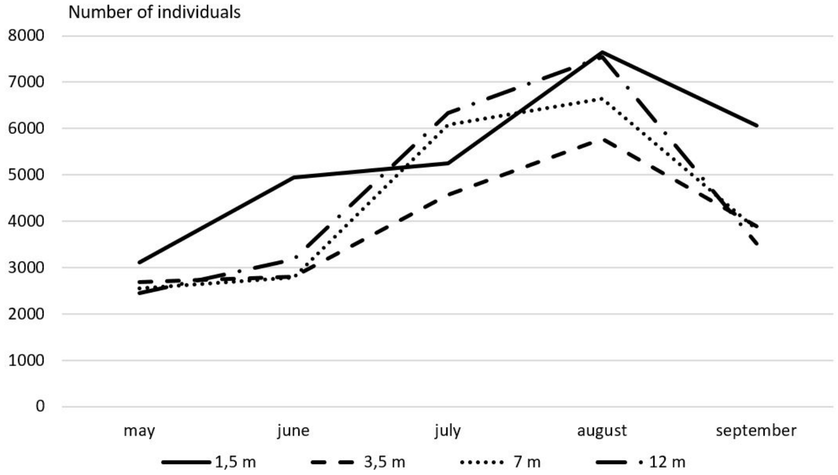

Fig. 1. Seasonal dynamics of insect numbers at different heights in deciduous forests (Center of European Russia).

It should be noted that such dynamics was not typical for all insect orders. Thus, the dynamics of the number of Lepidoptera was a two-peak at all altitudes. The first small peak in numbers was recorded in mid-June. The second maximum number was obtained in the second half of July. At the same time, in September, the number of butterflies was significantly higher than in May. As in the case of the dynamics of the number of butterflies, Diptera and Neuroptera showed a gradual increase in this indicator by the end of the growing season. The number of Coleoptera was higher in May and June and gradually decreased by mid-July. In later periods, the number of Coleoptera in traps was low. Seasonal dynamics of Hymenoptera abundance differed from all other groups: the maximum values were obtained in August and September; the minimum values were in June.

4 Discussion

Various methods are used to study the spatial distribution of insects. In most cases, various designs of traps for passive insect fishing are used for these purposes. At the same time, traps with baits are also used, which attract insects with the help of various substances and substrates [13, 14, 16, 17]. In our study, traps with baits made of beer and sugar were used. Such baits attract a well-defined entomofauna, which actively flies to the fermented substrate [14, 18].

Many studies of the vertical distribution of insects in forests of different climatic zones have shown that there are communities unevenly distributed vertically. These patterns are determined by a variety of factors that affect individual taxonomic groups of insects in different ways [10, 12, 19]. We have also obtained results that indicate a certain stratification of insects from the grassy tier to the crowns of trees.

For each group of insects, we obtained the specific information on vertical stratification. In our opinion, in many cases, the explanation of preferences for a certain tier of the forest can be found in the biological characteristics of certain representatives who are attracted to beer traps. For example, Diptera, which dominated at a height of 1.5 m, were represented by groups of saprophages, mycophages, phytophages and xylophages. It is possible to assume that Diptera communities in deciduous forests react most to bait, microclimate, and availability of imago and larval food resources [19, 20].

Some similar patterns in the preferences of the forest tier and the detected ecological groups were also obtained for Coleoptera. This confirms our assumptions about the driving forces of vertical stratification, such as microclimate and availability of imago and larval food resources. It is in the lower tier of the forest that the amount of food for all these forms is quite abundant (plant juices, flowering plants, decomposing organic substrates in the form of mushrooms, stumps, branches, carrion, leaves, etc.) [21, 22]. At the level of tree crowns and under the canopy of the forest, the number of those orders increases, whose imagos mainly consume the leaking juice, and the larvae are xylophages, mycophages or phytophages. For example, adult moths, Hymenoptera and Neuroptera are actively attracted to beer traps, they consume the leaking juice [8, 23].

The microclimate is very important for insects, it is very different near the soil, under the canopy and in the canopy of the forest. In temperate forests, the microclimate has specific temperature, humidity, and light [24]. In deciduous forests, the canopy was quite closed, the grassy tier was poorly expressed due to the transmission of a small amount of sunlight through the foliage of the upper tiers of the forest. But at the same time, the climate in the lower tiers is more stable in contrast to the upper tiers, where quite significant differences in the daily rhythm of temperature and illumination are expressed [25-27].

Seasonal rhythms of activity and abundance were revealed in almost all insect groups in temperate and tropical latitudes. They are usually associated with photoperiodic regulation, seasonal changes in temperature, humidity, and other rhythmic processes [28-30]. In temperate latitudes, the seasonal rhythm of life cycles is associated with the change of seasons. In the spring, the wintering stages of insects appear – adult individuals or larval stages, which after a certain time turn into an imago. Therefore, in temperate latitudes, there is usually a gradual increase in the number of insects by August and September. However, not all groups have such dynamics. We have already indicated that the maximum number of beetles was observed in May and June. On the other hand, in the insect communities of deciduous forests, there was clearly a tendency to the maximum number in August. But at the same time, the main part of individuals and species at this time accounted for the orders Lepidoptera, Diptera, Hymenoptera (in May, the basis of the community was Diptera and Coleoptera). The autumn increase in the number of Diptera and Lepidoptera exceeded the summer peak by several times [31, 32].

5 Conclusion

In our research, for the first time, information was obtained on vertical communities and their seasonal dynamics in deciduous forests of the temperate zone of Russia. Representatives of 10 insect orders were identified in beer traps. The main ones were Diptera, Lepidoptera and Coleoptera. During the whole season, the largest number of individuals was detected at an altitude of 1.5 m. In the second position in terms of numbers, there was a height of 12 m (tree crowns). The vertical stratification for each order was specific. The total number of Coleoptera and Diptera was higher at an altitude of 1.5 m, and Lepidoptera prevailed at an altitude of 12 m. Hymenoptera, Dermaptera, Neuroptera and Trichoptera dominated the tree crowns. The number of Blattodea was higher in the lower tiers of the forest. However, the number of Mecoptera did not depend on height. Our results indicate a significant role of different insect orders in seasonal changes in arthropod communities in deciduous forests. If in the spring some insect orders predominate in communities, then by the end of summer there is a dominance of other orders. But at the same time, the general trend in the number of insect communities is expressed in an increase in individuals by August and September. The results of these studies stimulate new questions about the driving forces regarding the differences obtained.

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References

1. T. A. Avtaeva, R. A. Sukhodolskaya, V. V. Brygadyrenko, Bios. Div. **29(2)**, 140-150 (2021). https://dx.doi.org/10.15421/012119
2. N. V. Ivanova, M. P. Shashkov, Nat. Cons. Res. **7(Suppl.1)**, 52-63 (2022). https://dx.doi.org/10.24189/ncr.2022.018
3. A. O. Kharitonova, T. I. Kharitonova, Nat. Cons. Res. **6(2)**, 29-41 (2021). https://dx.doi.org/10.24189/ncr.2021.022
4. S. V. Dedyukhin, Nat. Cons. Res. **7**(4), 55-69 (2022). https://dx.doi.org/10.24189/ncr.2022.036
5. M. Weiss, R.K. Didham, J. Procházka, J. Schlaghamerský, Y. Basset, F. Odegaard, A. Tichechkin, J. Schmidl, A. Floren, G. Curletti, H.-P. Aberlenc, J. Bail, H. Barrios, M. Leponce, E. Medianero, L. L. Fagan, B. Corbara, L. Cizek, Forest Ecol. Manag. **444**, 50-58 (2019). https://doi.org/10.1016/j.foreco.2019.04.021
6. Y. Wagle, B. P. Bhattarai, J. N. Adhikari, Nat. Cons. Res. **7(1)**, 19-26 (2022). https://dx.doi.org/10.24189/ncr.2022.005
7. M. Kirstová, P. Pyszko, J. Šipoš, P. Drozd, P. Kočárek, Entomol. Sci. **20(1)**, 57-64. 2017.
8. M. D. Ulyshen, V. Soon, J. L. Hanula, Florida Entomol. **94(4)**, 1068-1070 (2011). https://doi.org/10.1653/024.094.0450
9. O. Parhomenko, V. Langraf, K. Petrovičová, V. Komlyk, V. Brygadyrenko, Nat. Cons. Res. **7(1)**, 42-69 (2022). https://dx.doi.org/10.24189/ncr.2022.008
10. T. Hirao, M. Murakami, A. Kashizaki, Ecol. Res. **24**, 263-272 (2009). https://doi.org/10.1007/s11284-008-0502-4
11. C. Bouget, A. Brin, H. Brustel, Forest Ecol. Manag. **261(2)**, 211-220 (2011). https://doi.org/10.1016/j.foreco.2010.10.007
12. D. Y. Maguire, K. Robert, K. Brochu, M. Larrivée, C. M. Buddle, T.A. Wheeler, Environ. Entomol. **43**, 9-17 (2014). https://doi.org/10.1603/EN13056

13. A. B. Ruchin, L. V. Egorov, Diversity **13**, 508 (2021). https://doi.org/10.3390/d13110508
14. A. B. Ruchin, L. V. Egorov, A. A. Khapugin, N. E. Vikhrev, M. N. Esin, Nat. Cons. Res. **5(1)**, 87-108 (2020). https://dx.doi.org/10.24189/ncr.2020.008
15. Z.-Q. Zhang, (Ed.), Zootaxa **3703**, 1-82.
16. L. Dvořák, A. B. Ruchin, L. V. Egorov, V. V. Aleksanov, S. K. Alekseev, N. V. Shulaev, E. Yu. Zakharova, Nat. Cons. Res. **8(1)**, 24-33 (2023). https://dx.doi.org/10.24189/ncr.2023.001
17. A. V. L. Freitas, C. A. Iserhard, J. P. Santos, J. Y. O. Carreira, D. B. Ribeiro, D. H. A. Melo, A. H. B. Rosa, O. J. Marini-Filho, G. M. Accacio, M. Uehara-Prado, Rev. Colomb. Entomol. **40(2)**, 203-212 (2014)
18. J. Touroult, P. H. Dalens, ACOREP-France: Coléoptères de Guyane. **VI**, 16-24 (2012)
19. M. D. Ulyshen, Forest Ecol. Manag. **261**, 1479-1489 (2011)
20. S. I. Tanabe, Ecolog. Entomol. **27(6)**, 720-731 (2002). https://doi.org/10.1046/j.1365-2311.2002.00469.x
21. D. de Souza Amorim, B.V. Brown, D. Boscolo, et al, Sci Rep **12**, 1734 (2022). https://doi.org/10.1038/s41598-022-05677-y
22. T. V. Popkova, V. A. Zryanin, A. B. Ruchin, Nat. Cons. Res. **6(3)**, 45-57 (2021). https://dx.doi.org/10.24189/ncr.2021.037
23. P. Duelli, M. K. Obrist, P. F. Acta Zool. Acad. Sci. Hung. **48**, 75-87 (2002)
24. D. Thom, A. Sommerfeld, J. Sebald, J. Hagge, J. Müller, R. Seidl, Agr. Forest Meteor. **291**, 108066 (2020). https://doi.org/10.1016/j.agrformet.2020.108066
25. C. S. B. Grimmond, S. M. Robeson, J. T. Schoof, Climate Res. **15**, 137-149 (2000). https://doi.org/10.3354/cr015137
26. T. Ghassemi-Khademi, R. Khosravi, A. Sajjad, J. Wild. Biod. **6(1)**, 87-101 (2022). https://doi.org/10.22120/jwb.2021.538276.1254
27. A. V. Polevoi, Nat. Cons. Res. **6(1)**, 5-16 (2021). https://dx.doi.org/10.24189/ncr.2021.001
28. A. Zouaimia, Y. Adjami, R. Zebsa, A. Youcefi, Z. Bensakhri, S. Bensouilah, H. Amari, M.-L. Ouakid, M. Houhamdi, H. Mahdjoub, R. Khelifa, Nat. Cons. Res. **7(1)**, 1-9 (2022). https://dx.doi.org/10.24189/ncr.2022.003
29. S. J. Brooks, A. Self, G. D. Powney, W. D. Pearse, M. Penn, G. L. J. Paterson, Ecography **40**, 1152-1165 (2017). https://doi.org/10.1111/ecog.02658
30. S. S. Shinkarenko, Nat. Cons. Res. **7(3)**, 26-45 (2022). https://dx.doi.org/10.24189/ncr.2022.028
31. A. B. Ruchin, M. N. Esin, Bios. Div. **29(4)**, 374-379 (2021). https://dx.doi.org/10.15421/012147
32. K. J. Kirby, G. P. Buckley, J. Mills, Folia Geobot. **52**, 5-13 (2017). https://doi.org/10.1007/s12224-016-9252-1