Vespidae (Hymenoptera: insecta) on forest edges in the European part of Russia

Alexander Ruchin[1,1]

[1]Joint Directorate of the Mordovia State Nature Reserve and National Park «Smolny», 430005 Saransk, Russia

Abstract. The vertical distribution, species richness, and abundance of Vespidae on forest edges in the temperate zone of central European Russia were studied. Forest edges are hotspots of insect diversity and abundance. Research was conducted using beer traps in two plots at two heights (1.5 and 7.5 m). The overall abundance of seven Vespidae species was higher on the forest edges compared to within the forests. *Vespa crabro* was the dominant species in this family, with the highest abundance recorded at the edges. However, there was no difference in its abundance between the two heights at the edges. Inside the forest, *Vespa crabro* showed the highest abundance in the upper traps. The abundance of *Dolichovespula media* and *Polistes nimpha* was higher at lower heights on the edges, and their abundance on edges exceeded that within the forest. In contrast, the abundance of *Vespula vulgaris* did not differ significantly between the forest edges and the forest interior.

1 Introduction

Forests are a crucial resource worldwide; however, they are threatened by climate change and associated problems. Forest ecosystems have long been used by humans for various purposes. One of the major human activities involves timber harvesting and deforestation. Clear-cutting and large-scale mega-fires, which essentially leave no trees standing, contribute to the formation of anthropogenic edges. Such actions lead to forest degradation and loss of biodiversity in forest ecosystems [1–6]. The adaptation of species and ecosystems to natural forest edges may influence the size and extent of the impact of artificially created edges. In heterogeneous natural landscapes, where the mosaic pattern of alternating open and closed habitats has been preserved for centuries, the effect of artificial edges may be less pronounced. In such habitats, animals are better adapted to the landscape's mosaic. In boreal forests and forest-steppe zones, where large natural disturbances (such as fires, insect infestations, floods, and windthrows) have always occurred, it can be expected that the formation of artificial edges will have less environmental impact compared to other forest ecosystems [7–9].

Hymenoptera, along with Coleoptera, Diptera, and Lepidoptera, is considered one of the largest insect orders. The order contains over 160,000 species. Species from this order are

[1] Corresponding author: ruchin.alexander@gmail.com

predators, parasitoids, and plant pollinators. Due to their high numbers, they are found in many forest and non-forest ecosystems. However, the study of the impact of forest edges on members of this order is relatively limited. Particularly well-studied is the distribution and abundance of ants in edge habitats. For example, estimates of abundance and biodiversity have shown a decrease in the species richness of ants from the edge to the interior of the forest. The higher number of ants on the forest edges was due to the presence of species typical of neighboring open habitats. At the same time, most of the typical species of forest ants were equally represented on the edges and in the depths of the forest. However, some ant species reacted to the presence of forest edges by changing their relative abundance and frequency of occurrence [10]. In other studies, in Brazil, ant species diversity was higher in the forest interior than at the edges, though it did not increase with increasing distance from the edge. The observed differences in biodiversity between the forest interior and the edges could be linked to the harsher conditions at the edges, caused by environmental changes. Thus, edges affected the species diversity of ground-dwelling ants at distances of less than 50 meters [11].

On the other hand, more active flying species of Vespidae also exhibit edge-dependent distribution. For example, the influence of distance from the forest edge on solitary wasps and bees was studied in the Atlantic Forest biome in Brazil. Proximity to the forest edge had a positive effect on these species, while forest species experienced a more negative impact. Pest species were more dependent on the distribution of their hosts than on the edge effect [12]. The aim of our study was to investigate the influence of forest edges on Hymenoptera in forests of the temperate zone of European Russia.

2 Materials and methods

The studies were conducted from April to September in 2022 and in 2023 on the territory of the Republic of Mordovia. The region is located at the junction of two large plains: the Volga Upland and the Oka-Don Lowland. At the same time, all the study areas were within the Oka-Don lowland. The vegetation cover of the plain is mainly represented by forest communities and open spaces (thus, there is an alternation of forest and steppe ecosystems) [13].

Hymenoptera were collected using beer traps of our own design. These traps were made from 5-liter plastic bottles with a single hole to attract insects. The bait consisted of beer mixed with sugar. The collected specimens were placed in plastic bags with 70% alcohol. Identification of the specimens was carried out in the laboratory. In total, two study sites were used. In all plots, the forest under study was adjacent to an open ecosystem. As a result, the forest edge was characterized by a high density of stands. The forest edge in all the studied plots was located on the western side of the forest. In each location, two traps were set at the edge of the forest at the same time (that is, we did two repetitions): from below at a height of 1.5 m, as well as two traps at a height of 7.5 m above the ground. The distance between such pairs of traps was 40-50 m. Thus, the following plots were studied: edge-bottom, edge-top, forest interior-bottom, forest interior-top, with two traps in each case. All data were then summed. A total of 366 specimens were studied from all sampling locations.

3 Results

During the course of the study, a total of only 7 Vespidae species were recorded in the studied areas (Table 1). Among the Vespidae, *Vespa crabro* was the most abundant species. During the experiments, its abundance reached 68.0% of the total number of individuals

across both plots. The highest abundance of this species was recorded at the forest edges, with no difference in abundance between the two investigated heights. However, inside the forest, the highest abundance of *Vespa crabro* was found in the upper traps. When considering the total number of individuals at both heights, it was found that the abundance of *Vespa crabro* was 13% higher at the edges than inside the forest.

Table 1. The distribution of Vespidae abundance at forest edges and within forest plots at different heights (total data).

Species	Edge		Interior		**Total**
	bottom	top	bottom	top	
Vespa crabro Linnaeus, 1758	68	65	49	67	**249**
Dolichovespula media (Retzius, 1783)	19	8	7	7	**41**
Polistes nimpha (Christ, 1791)	15	12	6	6	**39**
Vespula vulgaris (Linnaeus, 1758)	3	8	2	8	**21**
Vespula germanica (Fabricius, 1793)	2	1	1	4	**8**
Dolichovespula saxonica (Fabricius, 1793)		4	2	1	**7**
Vespula rufa (Linnaeus, 1758)			1		**1**
Number of species	**5**	**6**	**7**	**6**	**7**
Total	**103**	**97**	**72**	**94**	**366**

The other species were represented in much lower numbers. For instance, the abundance of *Dolichovespula media* and *Polistes nimpha* was higher at the lower height at the forest edge. Additionally, the abundance of these species at the edges exceeded that within the forest. Interestingly, the abundance of *Vespula vulgaris* was similar both at the edges and within the forest. However, this species clearly preferred the upper traps, both at the edges and inside the forest.

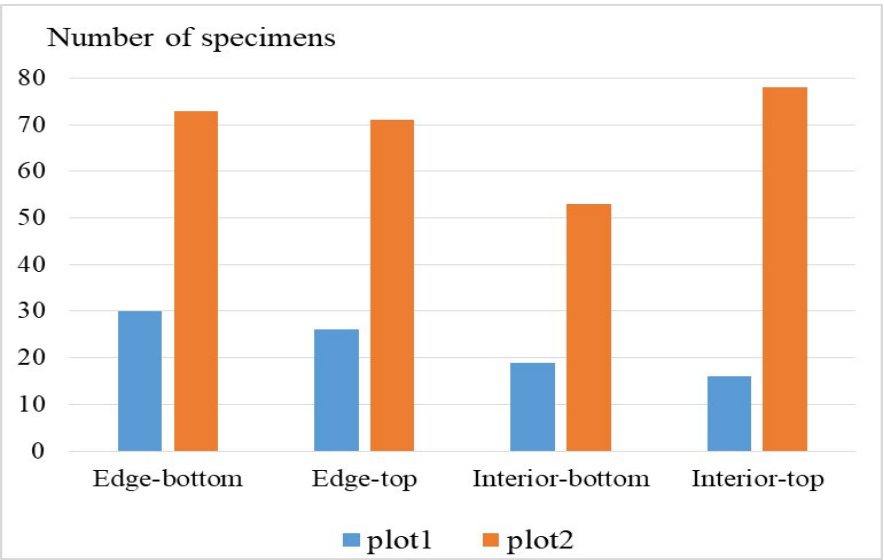

Fig. 1. The total number of Vespidae specimens across different plots during the study period.

Thus, in total, some differences in the abundance of Vespidae were observed between the forest edges and the forest interior. However, when examining the distribution of

Vespidae abundance across different plots, the results were not consistent (Fig. 1). In plot 1, the highest abundance of Vespidae was recorded at the lower height at the forest edge. At the same time, the overall abundance at the edge was higher than inside the forest. In plot 2, the abundance of Vespidae at the lower and upper edges did not differ. However, inside the forest, the abundance of the family was higher than at the lower edge (unlike in plot 1), but the total abundance at the edge was still higher than inside the forest (similar to plot 1).

4 Discussion

Habitats at the boundaries of two entirely different ecosystems are commonly referred to as ecotones. Forest edges are considered such habitats, as they lie at the boundaries between forested and open ecosystems. Biotopes such as ecotones show abiotic and biotic similarities with adjacent open and closed ecosystems. However, they may also have specific features related to the ecosystems that form them. Forest edges often represent a sharp transition zone that can support different communities of species. It is these species that are well adapted to such a dramatically changing type of environment. Flying Hymenoptera, due to their activity, are expected to occur in various environments without showing strong preferences for vertical (height) or horizontal distribution between ecosystems. However, in reality, many studies have shown that certain Hymenoptera families prefer specific habitats. For example, *Euglossina* bees were found at five distances from the forest edge: 0 m (directly at the edge), 100 m, 500 m, 1000 m, and 1500 m. The data suggest the existence of a gradient from the edge into the forest in terms of species diversity and abundance [14]. In the Czech Republic, five microhabitats were studied for nesting Hymenoptera: at the forest edge, in a shady forest with a closed canopy, in open areas in the forest with a closed canopy, on open trees in a forested pasture, and in shady groves on a forested pasture. It was found that species diversity was not significantly higher in any of the studied microhabitats compared to the others. However, it was shown that communities in forests with a closed canopy differed significantly from those in other, more open areas. Gutiérrez-Chacón et al. [15] found that the overall species diversity and abundance of bees increased with a higher proportion of trees and depended on the number of flowers. However, underground nests did not respond to the effect of forest area at any spatial scale. The highest number of species was found in clearings and meadows, i.e., in open habitats, as well as at forest edges. Few species were found in closed forests. More species were found at ground level than in the tree canopies at three stations. Even in specific experiments, it was shown that the highest diversity of bees was found at forest edges and nearby areas, but not in open habitats. These findings convincingly demonstrate that in the edges of different forests, both tropical and temperate, the diversity and abundance of Hymenoptera differ significantly from adjacent biotopes.

The main abundance in our experiments in the traps was represented by the hornet *Vespa crabro*. Its abundance was higher at the forest edges than inside the forest. Interestingly, at the edges, the abundance was the same at both experimental heights, which replicates earlier studies of this species' abundance at different heights in clearings. However, inside the forest, its abundance at higher elevations was noticeably higher. Typically, *Vespa crabro* builds large paper nests in sheltered locations, primarily in tree cavities, on building roofs, but also in abandoned hives, rodent burrows, hollow walls, and other construction voids [14,15]. It hunts a wide variety of arthropods, including beetles, large flies, grasshoppers, dragonflies, large cicadas, and honeybees. In Japan and North America, *Vespa crabro* is considered a semi-specialized species, as it preys on various types of prey, with a preference for

cicadas. Thus, this active predator prefers large prey, which in forest ecosystems is often concentrated in the tree canopies. Additionally, in the shaded lower layers of temperate forests, prey is less noticeable than in the bright sunlight at the upper levels. Adult hornets feed on honey, fruit, and plant juices that flow onto tree bark [28]. Under these conditions, *Vespa crabro* is most likely to hunt and feed in the upper canopy layers of the forest.

***Dolichovespula media* showed high abundance at the forest edges at the lower heights. It is known that the nests of *Dolichovespula media* are located in the air on natural or anthropogenic objects. The species demonstrates flexibility in choosing nesting sites and the ability to use anthropogenic habitats. Typically, this species is considered a forest species preferring moist habitats [11]. However, in recent years, it has increasingly been found in anthropogenic habitats, and it has become more widespread in Europe [14]. The prey of this species are often various small flies, horseflies, and mosquitoes. The family development cycle of this species is short and lasts from the end of May to August. At the edges, small Diptera are more commonly found in the lower layers. Therefore, the result observed in our study is quite predictable, despite the fact that no significant difference in height preference for this species was found previously in clearings.**

On the forest edges, *Polistes nimpha* was dominant, in contrast to the interior of the forest. Interestingly, its abundance was almost identical both at the lower and upper heights. *Polistes nimpha* constructs its nests on plant stems and small shrubs. The species prefers to hunt small caterpillars. The family development cycle lasts from May to October [15]. This species tends to fly close to the ground level, at the height of herbaceous vegetation or slightly above, rarely flying higher. However, on clearings, it can reach heights of up to 10 m, whereas inside the forest, it is rarely seen above a height of 7 meters [14]. Thus, *Polistes nimpha* does not venture deeply into forest interiors, preferring open spaces where it hunts and builds its nests.

Interestingly, the abundance of *Vespula vulgaris* did not differ between the forest edges and the interior. It is the most numerous and widespread species of eusocial wasps in the central regions of European Russia. It constantly dominates open habitats and is found in large numbers in parks, meadows, clearings, but is not uncommon in various forest ecosystems. We have repeatedly observed nests of this species in soil cavities, rodent burrows, under stumps and driftwood, fallen trees inside forest ecosystems at a sufficient distance from the forest edges. It is worth noting that its abundance was higher in the upper traps compared to the lower ones.

The highest abundance values were observed at the forest edges, especially in the lower traps, where the abundance on the edges was higher than at the same height inside the forest. In the upper layers, the abundance at the edges and within the forest did not differ from each other. At the same time, some differences in these patterns were registered across the different plots. This suggests that the observed trends may not be consistent across all habitats.

5 Conclusion

Usually, forest edges are hotspots of biodiversity and insect abundance, as they are located on the borders of forest and open ecosystems. In total, in our experiments in two plots, the abundance of seven Vespidae species at the edges was higher than inside the forests. The Vespa crabro prevailed among this family. The largest number of this species was obtained on the edges. At the same time, at both studied heights (bottom and top) she was no different. At the same time, inside the forest, the largest number of Vespa crabro was obtained in the upper traps (at an height of 7.5 m). The abundance of *Dolichovespula media*

and *Polistes nimpha* was higher in the lower traps at the forest edges, and overall, these species were more abundant at the edges than in the forest interior. In contrast, the abundance of *Vespula vulgaris* did not differ between the forest edges and the interior.

Acknowledgements

This research was funded by Russian Science Foundation, grant number 22-14-00026-П.

References

1. A. A. Aleinikov, V. E. Aleksutin, F. K. Vozmitel, A. N. Gunya, Long-term dynamics of forests with Pinus sibirica in the upper reaches of the River Kolva (Northern Pre-Urals, Russia) from 1938 to 2023. Nat. Cons. Res. **9**(3): 72–91. (2024) https://dx.doi.org/10.24189/ncr.2024.022
2. E. N. Broadbent, G. P. Asner, M. Keller, D. E. Knapp, P. J. C. Oliveira, J. N. Silva, Forest fragmentation and edge effects from deforestation and selective logging in the Brazilian Amazon. Biol. Cons. **141**: 1745–1757. (2008). https://doi.org/10.1016/j.biocon.2008.04.024
3. R. A. J. Duco, S. G. F. Bejar, J. G. Bañez, J. S. Fidelino, M. V. Duya, P. S. Ong, M. R. M. Duya, Forest fragments matter: a look into the species richness and diversity patterns of birds in a small, isolated, Protected Landscape in Mindanao Island, Philippines. Nat. Cons. Res. **9**(2): 47–60. (2024) https://dx.doi.org/10.24189/ncr.2024.012
4. J. C. G. Figueiredo, D. Negreiros, L. Ramos, D. C. Paiva, Y. Oki, W. S. Justino, R. M. Santos, R. Aguilar, Y. R. F. Nunes, G. W. Fernandes, Reference sites of threatened riverine Atlantic forest in upper Rio Doce watershed. Nat. Cons. Res. **9**(1): 58–71. (2024) https://dx.doi.org/10.24189/ncr.2024.006
5. Zh. V. Atutova, Post-fire restoration of pine forests in the Badary area, Tunkinskiy National Park, Russia. Nat. Cons. Res. **8**(2): 22–32. (2023) https://dx.doi.org/10.24189/ncr.2023.010
6. V. A. Ananyev, A. N. Pekkoev, S. I. Grabovik, S. A. Moshnikov, M. V. Medvedeva, A. V. Ruokolainen, V. M. Kolesnikova, V. V. Grabeklis, Biodiversity dynamics in primary mid-taiga spruce forests after total windthrow in the Vodlozersky National Park, Russia. Nat. Cons. Res. **8**(3): 75–93. (2023) https://dx.doi.org/10.24189/ncr.2023.024
7. M. Masoudi, H. Z. Maivan, A. Mehrabian, Abundance and occurrence of Danae racemosa growing in Hyrcanian forest understory in relation to static and dynamic environmental variables. J. Wildl. Biod. **6**(2): 1 – 21. (2022) https://doi.org/10.5281/zenodo.6501685
8. A. D. Kataev, A. I. Kuznetsova, V. A. Kuznetsov, A. V. Gornov, D. N. Tebenkova, M. V. Gornova, E. Yu. Kaygordova, A. D. Nikitina, Relationships between the seasonal dynamics of soil fungi biomass and environmental factors in predominating forest types in the Bryansk woodlands (European Russia). Nat. Cons. Res. **8**(4): 112–125. (2023) https://dx.doi.org/10.24189/ncr.2023.035
9. D.A. Kupriyanov, E.M. Volkova, E.Yu. Novenko, The reconstruction of the frequency of fires in the Upper Don River Basin over last 4000 years, based on macrocharcoal data from Podkosmovskoye Mire. Proc. Mordovia State Nat. Res. **34**: 45-58. (2024). https://dx.doi.org/10.24412/cl-31646-2686-7117-2024-34-45-58

10. K. Ivanov, J. Keiper, Ant (Hymenoptera: Formicidae) diversity and community composition along sharp urban forest edges. Biod. Cons. **19**: 3917–3933 (2010) https://doi.org/10.1007/s10531-010-9937-3
11. T. Sobrinho, J. Schoereder, Edge and shape effects on ant (Hymenoptera: Formicidae) species richness and composition in forest fragments. Biod. Cons. **16**: 1459–1470. (2007) https://doi.org/10.1007/s10531-006-9011-3
12. G. A. Alves, J. P. A. de Deus, P. C. Montagnana, et al. Edge effects on the cavity-nesting hymenopteran communities and their natural enemies within fragmented landscapes. Apidologie. **55**: 24. (2024) https://doi.org/10.1007/s13592-024-01061-z
13. M. A. Chursina, A. B. Ruchin, A checklist of Syrphidae (Diptera) from Mordovia, Russia. Halteres. **9**: 57-73 (2018). https://doi.org/10.5281/zenodo.1255874
14. J. A. Coswosk, R. A. Ferreira, E. D. G. Soares, et al. Responses of Euglossine Bees (Hymenoptera, Apidae, Euglossina) to an Edge-Forest Gradient in a Large Tabuleiro Forest Remnant in Eastern Brazil. Neotrop. Entomol. **47**: 447–456 (2018) https://doi.org/10.1007/s13744-017-0533-z
15. C. Gutiérrez-Chacón, C. F. Dormann, A. M. Klein, Forest-edge associated bees benefit from the proportion of tropical forest regardless of its edge length. Biol. Cons. **220**: 149-160. (2018). https://doi.org/10.1016/j.biocon.2018.02.009