Трансформация экосистем
Ecosystem Transformation

ISSN 2619-0931 Online
www.ecosysttrans.com

DOI 10.23859/estr-230416
EDN SKYVFH
UDC 595.7: 574.22

Article

Edge effects on insect abundance in the forests of Central European Russia

A.B. Ruchin

Joint Directorate of the Mordovia State Nature Reserve and National Park "Smolny", Krasnaya St. 30, Saransk, 430005 Russia

ruchin.alexander@gmail.com

Abstract. Forest edges are ecotones on the boundary of closed (forest) and open (meadow, field) ecosystems. These are peculiar habitats for a variety of insects which can traverse these boundaries and influence the functioning of adjacent ecosystems. They have become more prevalent in recent years due to anthropogenic fragmentation. Using beer traps, we investigated the number of insects in three locations. Each location represented an open natural ecosystem (a large glade in a forest, a meadow) or an artificially created ecosystem (agroecosystem) and a nearby deciduous forest. The traps were placed on trees at two levels (1.5 and 7.5 m above the soil) at the edges and in the forest interior (300–350 m from the edge). A total of 46116 specimens were collected from ten orders. At the edges in all locations, the total abundance of all orders of insects is higher than inside the forest areas. Dermaptera, Mecoptera and Trichoptera dominated at the edge. The number of Hemiptera in the traps was small, with predominance in the lower traps. Blattodea in all locations dominated at the bottom (the total abundance in the lower traps was 12.5 times higher than in the upper traps). At the edges, the abundance of Blattodea was 3.3 times higher than in the forest interior. The total abundance of Coleoptera at the edges was lower (with the exception of one location). The number of Hymenoptera at the edges and in the forest interior, as well as in the lower and upper traps, did not differ. The number of Diptera in all locations was higher at the edges and always in the lower layer. At the level of 7.5 m, the number of Neuroptera was higher both at the edges and in the forest interior.

Keywords: beer traps, fermental crown traps, number, biodiversity

Funding. This research was supported by the Russian Scientific Foundation, grant No. 22-14-00026.

ORCID:
A.B. Ruchin, https://orcid.org/0000-0003-2653-3879

To cite this article: Ruchin, A.B., 2024. Edge effects on insect abundance in the forests of Central European Russia. *Ecosystem Transformation* **7** (4), 187–204. https://doi.org/10.23859/estr-230416

Received: 16.04.2023
Accepted: 13.07.2023
Published online: 06.12.2024

DOI 10.23859/estr-230416
EDN SKYVFH
УДК 595.7: 574.22

Научная статья

Влияние опушек на численность насекомых в лесах центра европейской части России

А.Б. Ручин

Объединенная дирекция Мордовского государственного природного заповедника им. П.Г. Смидовича и национального парка «Смольный», 430005, Россия, г. Саранск, ул. Красная, д. 30

ruchin.alexander@gmail.com

Аннотация. Опушки лесов являются экотонами на границе закрытых (лес) и открытых (луг, поле) экосистем. Это своеобразные места обитания самых различных насекомых, которые способны проникать через эти границы и влиять на функционирование пограничных экосистем. За последние годы количество опушек увеличилось вследствие антропогенной фрагментации лесов. С помощью пивных ловушек мы исследовали численность насекомых на 3 экспериментальных участках, представлявших собой открытую экосистему с расположенным рядом лиственным лесом. Ловушки располагались на опушках и внутри леса на высоте 1.5 и 7.5 м над уровнем почвы. В общей сложности было собрано 46116 экземпляров из 10 отрядов насекомых. На опушках всех участков суммарная численность отрядов была выше, чем внутри лесных участков. Dermaptera, Mecoptera и Trichoptera преобладали на опушке. На опушках численность Blattodea была выше в 3.3 раза, чем внутри леса. Численность Hemiptera в ловушках была небольшой с преобладанием на нижнем уровне. Blattodea во всех местоположениях многократно преобладали внизу. Общая численность Coleoptera на опушках была ниже (за исключением участка с березняком). Численность Hymenoptera на опушках и внутри леса, а также в нижних и верхних ловушках не отличались. Численность Diptera на всех участках была выше на опушках и всегда в нижнем ярусе. Neuroptera преобладали на верхнем уровне ловушек как на опушках, так и внутри леса.

Ключевые слова: пивные ловушки, ферментные кроновые ловушки, обилие, биоразнообразие

Финансирование. Исследования выполнены при финансировании Российского научного фонда (грант № 22-14-00026).

ORCID:
А.Б. Ручин, https://orcid.org/0000-0003-2653-3879

Для цитирования: Ручин, А.Б., 2024. Влияние опушек на численность насекомых в лесах центра европейской части России. *Трансформация экосистем* **7** (4), 187–204. https://doi.org/10.23859/estr-230416

Поступила в редакцию: 16.04.2023
Принята к печати: 13.07.2023
Опубликована онлайн: 06.12.2024

Introduction

Habitat structure is a key factor in community composition as species exploit available niches in that biotope. The reduction of forest landscapes is a worldwide concern. Deforestation is mainly due to anthropogenic activities, including logging, agricultural expansion and urbanization, which in general has led to global forest loss (Haddad et al., 2015; Hansen et al., 2013; Sayadi et al., 2022; Shashkov et al., 2022; Singh and Singh, 2023; Tiberio et al., 2022).

Forest fragmentation has greatly increased the number of edge habitats. Forest edges are often characterized by increased species richness and abundance (edge effect) and influence the spatial behavior of species and the dynamics of species interactions (Caminha-Paiva et al., 2022; Helsen et al., 2007; Masoudi et al., 2022; Wagle et al., 2022). Structurally complex edges provide shelter for insects, and due to the additional resources available at the edges they are suitable for insects from boundary ecosystems (forest and meadow) (Castro et al., 2010; Schlegel, 2022; Tóthmérész et al., 2014;=).

Through numerous studies, the positive impact of well-structured edges on the biodiversity of a wide variety of invertebrate groups, such as Araneae (Downie et al., 1996), Coleoptera (Magura, 2002) and Lepidoptera (Ries and Sisk, 2008), has been widely recognized. The diversity of butterfly species was higher at the edges than in the interior habitats, especially in pine stands. Of the 23 most common Lepidoptera species, seven species were significantly more common in one or all of the boundary habitat types (van Halder et al., 2011). The depth of edge impact on Coleoptera ranged from 10 m to 25 m deep into the mature forest. The species composition of Coleoptera gradually changed with distance from the edge (Baker et al., 2007). The species composition of host plants and gall-forming insect pests differed between the edge and the interior of forest areas, but the richness of insect pests did not differ (Julião et al., 2004). The type of adjacent open area (clear cutting or treeless bog) did not affect the number of arthropods in the plots. The distance from the forest edge affected the overall abundance of arthropods, flying arthropods and Coleoptera, as their abundance decreased from the forest edge to the interior of the stand (Jokimäki et al., 1998). On the other hand, less complex edges or less diverse insect communities in adjacent ecosystems determine the decline in the abundance and diversity of insects in these places. For example, the forest edge affected the distribution of insect species only at the edges between mature, unmanaged spruce stands and clear cuttings or young seedlings, but not in pine stands (Peltonen et al., 1997).

The aim of this study was to determine the effect of the edges and the height of traps on insect abundance.

Materials and methods

The research was conducted from April to September 2021–2022 in the Republic of Mordovia, located at the junction of the Volga Upland and the Oka-Don Lowland (East European Plain). The study areas were situated within the boundaries of the Oka-Don Lowland. The boundary between the Oka-Don Plain and the Volga Upland is indistinct and is not expressed in the modern relief. The vegetation cover of the plain is primarily represented by forest communities and open spaces (meadows, agroecosystems, etc.). They are characterized by a fairly clear association with different elements of the relief and soil cover. The modern vegetation cover of the studied area has been significantly altered by economic activities (Artemova and Leonova, 2011).

Three sites were investigated. Each site represented an open natural ecosystem (a large glade in a forest – location no. 3, a meadow – location no. 1) or an artificial agroecosystem (location no. 2) adjacent to a nearby deciduous forest (Table 1).

At all sites, the forest was adjacent to the open ecosystem. At the boundary of the open space and the forest area, a forest edge was formed (on the western side of the forest area). Two traps (i.e., two replicates) were installed simultaneously at 1.5 m below and two traps at 7.5 m above the ground at each edge. The distance between the installed pairs of traps was 40–50 m. Simultaneously, in the forest interior, 300–350 m from the edge of the forest, a control inner forest area with a closed canopy was selected. Therefore, eight traps were installed at each site (edge-bottom, edge-top, forest interior-bottom, forest interior-top, two traps in each case).

For trapping, we used simple traps of our own design with baits. A five-liter plastic container with a window cut out on one side at a distance of 10 cm from the bottom was used as a trap. Beer (beer traps) was used as bait. Sugar and honey were added for digestion (Ruchin et al., 2020). Exposure time

Table 1. A brief description of the studied locations.

No.	Location	Layer		
		Forest	Shrub	Herbaceous
1	Temnikovsky district (N 54.7278 E 43.3247)	This site features a birch forest dominated by *Betula pendula,* with a projective cover of 50%. The crown density is low, allowing ample sunlight to penetrate deep into the forest. A meadow is located nearby.	The shrub layer at the edge is sparse, composed of *Salix caprea*, *S. cinerea*, *Malus domestica*, *Frangula alnus*, and *Sorbus aucuparia.* Within the forest, the shrub layer is well-developed, featuring *Sorbus aucuparia*, *Frangula alnus*, and growing aspens.	In the herbaceous-shrub layer, the predominant species are *Pimpinella saxifraga*, *Fragaria vesca*, *Rubus saxatilis*, *Viola canina*, *Melampyrum nemorosum*, *Phleum pratense*, *Plantago lanceolata*, *Hypericum perforatum*, *Dryopteris carthusiana*, and others
2	Krasnoslobodsky district (N 54.4813 E 43.5221)	This site features an oak forest of *Quercus robur* with an admixture of coniferous species, alongside an agroecosystem (in the studied year, the field was planted with *Triticum* sp.*).* In the inner part of the forest, *Quercus robur* and *Betula pendula* dominate the first layer, while the second layer consists of *Larix sibirica* and *Betula pendula.*	The shrub layer (with a projective cover of 30%) is represented by Sorbus aucuparia along with undergrowth of *Quercus robur* and *Malus domestica.*	In the inner part of the forest, the shrub and herbaceous layers are poorly developed due to the high canopy density of the first layer. The herbaceous cover is sparse and consists of *Stellaria holostea* (40%), *Aegopodium podagraria* (20%), *Glechoma hederacea* (8–10%), *Geum urbanum,* and others. The herbaceous-shrub layer (with a projective cover of 70%) includes *Galium mollugo*, *Viola hirta*, *Fragaria vesca*, *Pimpinella saxifraga*, *Hypericum perforatum*, *Filipendula vulgaris*, *Campanula trachelium*, *C. rapunculoides*, *Glechoma hederacea*, *Poa nemorosa*, and others.
3	Temnikovsky district (N 54.7280 E 43.1519)	A large glade with an area of 0.93 hectares is located in the center of the forest. On the southern side, it is bordered by a lake. The northern, western, and eastern sides are bounded by deciduous and mixed forests consisting of *Quercus robur*, *Betula pendula*, *Betula alba*, *Populus tremula*, *Pinus sylvestris*, *Tilia cordata*, and *Alnus glutinosa*.	The undergrowth is well-developed and consists of shrubs such as *Euonymus verrucosa*, *Lonicera xylosteum*, and *Frangula alnus.*	In the glade, there is a significant number of *Carex praecox*, *Calamagrostis epigeios*, *Bromopsis inermis*, *Elytrigia repens*, and *Dactylis glomerata.* A certain quantity *of Acinos arvensis*, *Galium verum*, *Galium mollugo*, *Veronica prostrata*, *Achillea millefolium, Fragaria viridis*, *Erigeron annuus*, and *Conyza canadensis* is also present. *Verbascum thapsus*, *Rumex confertus*, *Poa bulbosa*, *Alchemilla* sp. and other herbaceous plants grow sporadically in the glade.

(from 7 to 15 days) – the period between hanging a trap and taking samples for analysis (expressed in days). A total of 32 experiments were conducted (from May to August or September). Determination to the species in most cases was not carried out. We followed taxonomic categories by publication Z.-Q. Zhang (2013). In total, more than 46000 individuals were caught in the experiments.

Results

In total, representatives of ten orders of insects were identified in traps (Table 2). The main groups that prevailed in traps in terms of numbers were Lepidoptera, Coleoptera, and Hymenoptera. Blattodea and Neuroptera were represented by an insignificant number of specimens, while the remaining orders in traps did not exceed 100 specimens in number.

In our studies, it turned out that the total abundance of insects at the edges was higher. For example, the abundance of insects was 18.3% higher at the edge of location no. 1 than in the forest interior, in location no. 2 and in location no. 3, respectively, 41.3% and 36.0% higher than in the forest interior. During the experiments, the greatest number of specimens of all insects was caught in location no. 3, and the smallest – in location no. 2.

Dermaptera were noted only in location no. 3 with predominance at the edge. Mecoptera and Trichoptera were also noted mainly at the edges in location no. 3 and in location no. 2. Mecoptera were predominant in numbers at the below and at the edges of the forest (location no. 3). The abundance of Hemiptera in the traps was low, with most individuals found in the lower traps, while only a few were detected in the upper traps.

Along with Hemiptera, representatives of the order Blattodea dominated below in all locations (the total abundance in the lower traps was 12.5 times higher than in the upper traps). And this dependence was maintained at the edges and in the forest interior. The abundance of Blattodea was 3.3 times higher at the edges than in the forest interior. The opposite dependence was obtained when analyzing the abundance of Neuroptera. It turned out that at the level of 7.5 m, the abundance of this group was

Table 2. List of order and abundance of insect catches in different locations.

Order	Location no. 1		Location no. 2		Location no. 3		Total
	Edge	Interior	Edge	Interior	Edge	Interior	
Dermaptera	0	0	0	0	4	1	5
Blattodea	3	6	85	27	36	5	162
Hemiptera	1	0	7	2	4	5	19
Hymenoptera	148	171	78	54	792	597	1840
Coleoptera	2811	2478	932	1568	1276	2069	11134
Neuroptera	4	3	10	3	47	49	116
Trichoptera	0	0	1	0	4	3	8
Lepidoptera	2468	1787	2781	1808	3599	2478	14921
Diptera	1383	1319	2892	1341	6858	4078	17871
Mecoptera	0	0	0	1	26	13	40
Всего	**6818**	**5764**	**6786**	**4804**	**12646**	**9298**	**46116**

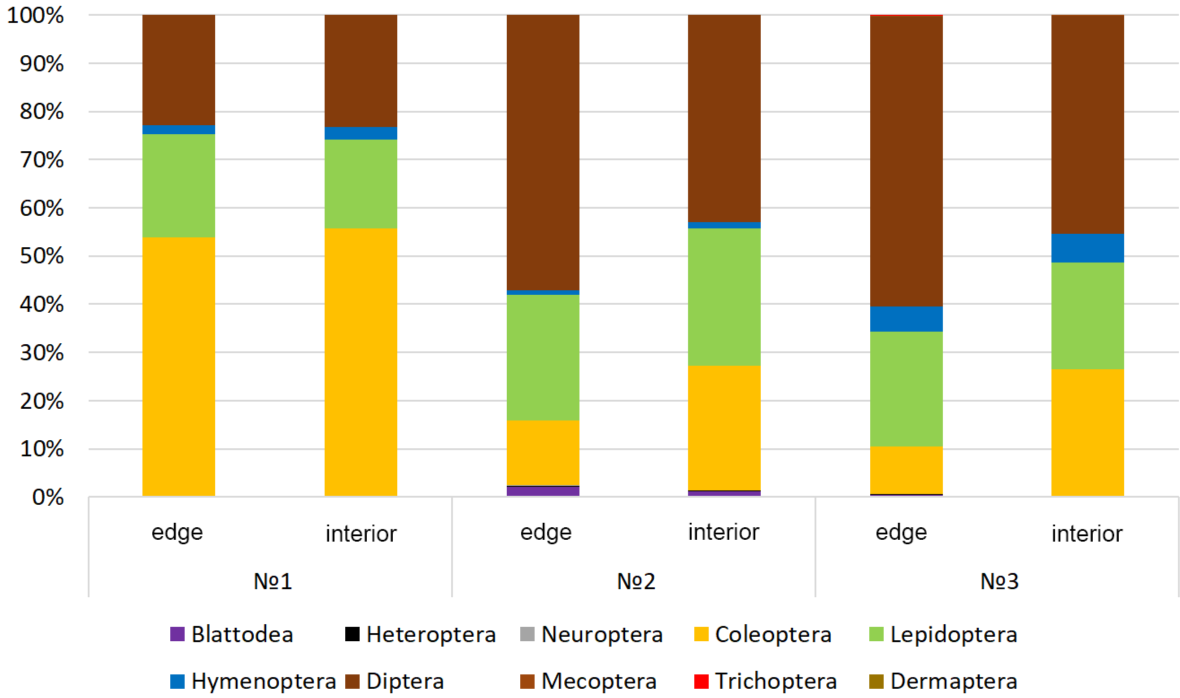

Fig. 1. Ratio (%) of insects at the edges and in the forest interior at a height of 1.5 m in the forests of central European Russia.

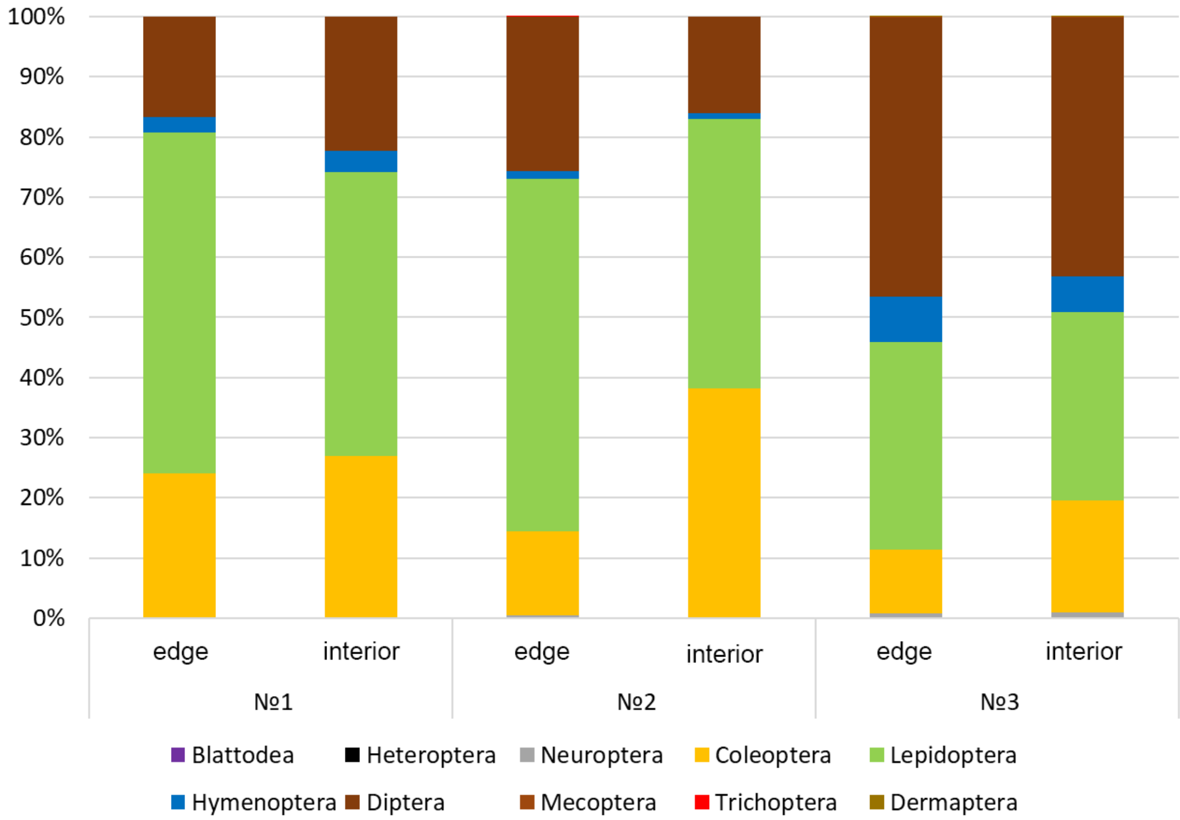

Fig. 2. Ratio (%) of insects at the edges and in the forest interior at a height of 7.5 m in the forests of central European Russia.

higher both at the edges and in the forest interior. The abundance of Hymenoptera at the edges and in the forest interior, as well as in the lower and upper traps, did not differ (Figs. 1, 2).

The total abundance of Coleoptera was lower at the edges (except for location no. 1, where there was a slight increase in the number of beetles at the edge). At the same time, both at the edges and in the forest interior, in the lower traps, in most cases, the ratio was higher than in the upper traps (Figs. 1, 2). The highest total values of Lepidoptera abundance were obtained in forest edge biotopes. At the same time, in traps located below and above of forest edges, the abundance of butterflies was higher than in traps of similar height located in the forest interior. The abundance of Diptera in all locations was higher at the edges and always in the lower layer. The abundance of Diptera was always lower in the upper traps.

Discussion

Boundary habitats (ecotones) typically exhibit abiotic and biotic similarities to adjacent open and closed ecosystems. Alhough they can also have specific features. That is, forest edges represent a more or less abrupt transition zone that may support communities of species well adapted to this type of environment, serve as a secondary shelter for species from neighboring habitats after source-sink dynamics, or even represent a habitat that limits the occurrence of some sensitive forest-adapted species (Magura and Lövei, 2020; Murcia, 1995; Schlegel, 2022; Tóthmérész et al., 2014). In addition, a study of the vertical distribution of arthropods in temperate deciduous forests has shown that different insect communities exist in different forest layers (Ulyshen, 2011).

From Dermaptera, *Forficula auricularia* Linneus, 1758 was represented in the samples. This species on trees may be incidental, as their primary habitat is the soil surface and grass layer (Helsen et al., 2007). However, it often falls into beer traps with bait, even at a height of up to 10 m (Dvořák and Tětál, 2013; Ruchin, 2021). From Hemiptera, representatives of the families Miridae, Pentatomidae, and Cicadidae were recorded in traps. All of them are inhabitants mainly of the herbaceous and shrub layer of the forest. Therefore, it is not surprising that they are present mainly in the lower traps.

Two species of Blattodea (*Ectobius lapponicus* (Linnaeus, 1758) and *Ectobius sylvestris* (Poda, 1761)) are common representatives of the temperate forest fauna. Adult males and nymphs are usually found in low vegetation (grasses, shrubs), while females are more often found in fallen leaves and decaying wood (Holuša and Kočárek, 2000). Both species feed on plant debris, liquid food, and decaying plants (Schal et al., 1984). According to many data (Clements et al., 2013; Holuša and Kočárek, 2000) and our observations, these species prefer edges of forests, glades, cuttings, i.e., sufficiently illuminated biotopes, although not rare in the depths of forests.

The abundance of representatives of the order Hymenoptera (mainly wasps of the family Vespidae) at the edges and in the forest interior at different heights did not differ. The results of other studies differ, which may be due to differences in the methods of enumeration. For example, J.P. Torretta and H.J. Marrero (2019) found no reliable difference in the vertical distribution of some Hymenoptera groups in the forests of Argentina. A study by F. Giovanni et al. (2017) shows that the bulk of the Sphecidae community in the undergrowth consists of species that prey on Diptera and spiders. At that time, the species most commonly found in the forest canopy are mainly predators of phytophages such as aphids, thrips, and barkflies. M.D. Ulyshen et al. (2011) collected 522 vespids representing eight species in two traps located in the canopy and close to the ground. Only 1% of individuals were caught close to the ground. Coleoptera, Diptera, and Hymenoptera were more diverse and abundant at the forest edge (González et al., 2017).

Based on the publications, there is a certain dependence of the number of Coleoptera species and families on the place of sampling at the edges and in the forest interior, and there is also a vertical stratification. For example, according to some data, the higher abundance of Buprestidae is characteristic of forest glades than of forest edges (Wermelinger et al., 2007). It was reported that the abundance of Curculionidae in the depths of the forest is higher (Peltonen and Heliövaara, 1998). Forest Carabidae species are capable of penetrating deep into grasslands up to 30 m from the forest edge. Beyond this distance, grasslands become a barrier to them (Rocca et al., 2021). Allison et al. (2019) reported three different models for the horizontal gradient effects of interior edges for Cerambycidae species. Two species were more common in the open fields than in the depths of the forest, one species was more common in the forest edge than in the interior, and five species were more common in the depths of the forest than in the adjacent open field. The abundance and species richness of Scolytidae and Cerambycidae were higher in the forest canopy and forest edges compared to traps in open areas (Dodds, 2011).

In two locations (no. 2 and no. 3), Coleoptera abundance was higher inside the forest plots. And only in location no. 1, the opposite trend was observed. Location no. 1 is a birch forest, which differs from other locations in the transparency of tree crowns of the first layer (birch). This transparency of crowns allows good penetration of sunlight and, accordingly, the development of shrubs and grasses. The edge of this forest is transparent and allows Coleoptera to penetrate deep into the forest area. Opportunities for active Coleoptera to penetrate deep into forests have been described for many families (Huber and Baumgarten, 2005; Maguire et al., 2016).

In location no. 2, the agroecosystem is closely adjacent to the forest. The abundance of Coleoptera at the edge and in the forest interior in the lower traps is almost the same, but in the upper traps in the forest interior, the abundance of Coleoptera is actually twice higher than in similar traps located at the edge. Closure of tree crowns in the first layer at this location is quite high and little light penetrates into the lower layers. Accordingly, the abundance of Coleoptera in the forest interior increases in places that are illuminated by the sun, i.e., in crowns. This confirms the fact that the vertical stratification of insects in forests depends on the availability of the sun/openness of the habitat (Ruchin and Egorov, 2021; Ruchin et al., 2022; Vodka and Cizek, 2013).

The number of Lepidoptera was higher at the edges than in the forest interior. Open sunny edges are known to be the most preferred for many butterfly species (Mathew, 1994; Melo et al., 2019), which was the result of our research. Forest edges functioned as strong filters on the landscape, creating unique aggregations of Lepidoptera species that are distinct from neighboring forest habitats. These ecotones had a higher abundance than cuttings, but not forests (Pinksen et al., 2021).

Edge effects have also been identified for many Diptera. For example, in winter, the total abundance of Drosophilidae is much higher in the forest interior than at the edge. However, such effects were not recorded in summer. Some species of Drosophilidae are generally found either only at the edge, or only in the forest interior (Mendes et al., 2021). Similar effects were obtained when studying the distribution and abundance of Culicidae, the number of which significantly increased at the edges, but in certain seasons of the year (Costa et al., 2023). The highest abundance and the lowest species diversity of Calliphoridae were characteristic of forest edge habitats, while the opposite trend was observed in the forest interior (Gadelha et al., 2015).

The results of our studies on Neuroptera (representatives of the Chrysopidae family) are consistent with some other results. Thus, 22–28 species have been identified in the canopy of pine and mixed forests in Poland (Czechowska, 1994). The largest number of Neuroptera species in five different forest areas was caught in tree crowns (Gruppe and Schubert, 2001). C. Saure and K.H. Klelhorn (1993) caught 22 and 24 species in pine and oak crowns, respectively. According to P. Duelli et al. (2002) Neuroptera showed their highest species abundance in the shrub belt and crowns. In the depths of the forest, the number of species also reached its maximum values precisely in the forest canopy. The obtained clear preference for tree crowns indicates the thermophilicity of many Chrysopidae in temperate climates (Aspöck et al., 2001).

The habitat of Mecoptera in temperate forests is undergrowth, plant communities on the banks of forest streams, swampy meadows, sometimes gardens and parks; moderately humid deciduous mixed forests. Habitats are often well-lit forest edges and glades (Dvořák et al., 2023; Lange, 2008; Ruchin et al., 2021). Our information confirms these data from the publications of other authors.

Consistent with our expectations, the number of flying insects was higher at the forest edge than in the forest interior, and these results suggest that arthropod aggregations were sensitive to the edges. Similar results are described in other publications. The highest diversity and abundance of some insect groups were found at the forest edge, and the lowest – at a distance of 100–150 m from the forest edge (Darsono et al., 2020). An increase in the abundance of terrestrial arthropods at the edges was repeatedly recorded in studies (Downie et al., 1996; Lacasella et al., 2015; Magura, 2002). On the other hand, there are also opposite results. For example, a decrease in the abundance of dung beetles was observed just near the edges (Villada-Bedoya et al., 2017). The abundance of native arthropod species was higher in the forest interior than at the edges or intermediate habitats (Tsafack et al., 2023).

M.J. Stone et al. (2018) conducted a detailed analysis of edge effects on flying insects using flight intercept traps. They noted that within the forest canopy, the distance from the edge to the interior of the forest has no effect. The analysis revealed no species-specific increase in abundance associated with either the edge or the interior of the forest. The authors put forward two reasons for the results. First, insects living in the forest canopy may respond differently to forest edges due to differences in insect communities in each of these layers. A number of studies in many forest ecosystems have revealed significant vertical differences in biodiversity and insect abundance (Birtele and Hardersen, 2012; Dvořák et al., 2020; Graham et al., 2012; Kirstová et al., 2017; Procházka et al., 2018; Ruchin and Egorov, 2021; Ruchin et al., 2022). Secondly, the abiotic properties of habitats differ among vertical forest layers, such as humidity, solar radiation, temperature, etc. (Kirstová et al., 2017; Procházka et al., 2018; Ruchin, 2021; Stone et al., 2018). These factors in the forest canopy between the edges and the interior of the forest are more similar than in the surface layer, where there are much more factors and they act interrelatedly. In other words, the abiotic factors in the canopies are more similar to each other than in the surface layer. The crowns create such microclimatic conditions, which contribute to the diversity of entomofauna. High solar radiation leads to high temperatures at certain altitudes. Due to the roughness of the crown, the wind slows down, resulting in higher humidity and weaker moisture gradients in shaded areas.

Conclusions

This study demonstrates strong edge effects for many invertebrate groups. The total abundance of insects was higher at the edges in all locations than inside the forest plots. The influence of the forest edge is mediated by the history and structure of the edge, the forest area itself, and the adjacent open habitat. The different types of responses to the edges may also be mediated by different ecological features of the soil and canopy. Boundaries created by natural ecological processes (ecotones) are permeable to active insect species, provided the first forest layer is transparent. Vertical stratification plays a certain role in the distribution of insects. Each group of insects dominated in one or another horizontal-vertical plane in the forest plots. Some of the orders were predominant at the edges, while others were predominant in the forest interior. The results of this study clearly indicate that efforts to survey and detect species must consider trap placement along horizontal and vertical gradients.

References

Artemova, S.N., Leonova, N.A., 2011. Morfologicheskaia struktura landshaftov Oksko-Donskoi ravniny v predelakh Penzenskoi oblasti [The morphological structure of landscapes the Oka-Don Plain within the Penza region]. *Izvestia Penzenskogo gosudarstvennogo pedagogicheskogo universiteta im. V.G. Belinskogo [News of Penza State Pedagogical University named after V.G. Belinsky]* **25**, 652–660. (In Russian).

Allison, J.D., Strom, B., Sweeney, J., Mayo, P., 2019. Trap deployment along linear transects perpendicular to forest edges: Impact of capture of longhorned beetles (Coleoptera: Cerambycidae). *Journal of Pest Science* **92**, 299–308.

Aspöck, H., Hölzel, H., Aspöck, U., 2001. Kommentierter Katalog der Neuropterida (Insecta: Raphidioptera, Megaloptera, Neuroptera) der Westpaläarktis. *Denisia* **2**, 1–606.

Baker, S.C., Barmuta, L.A., McQuillan, P.B., Richardson, A.M.M., 2007. Estimating edge effects on ground-dwelling beetles at clearfelled non-riparian stand edges in Tasmanian wet eucalypt forest. *Forest Ecology and Management* **239**, 92–101. https://doi.org/10.1016/j.foreco.2006.11.012

Birtele, D., Hardersen, S., 2012. Analysis of vertical stratification of Syrphidae (Diptera) in an oak-hornbeam forest in northern Italy. *Ecological Research* **27**, 755–763.

Caminha-Paiva, D., Gomes, V.M., Cunha-Blum, J., Alves, M.J.P., Rosa, D.C.P. et al., 2022. Floristic mosaics of the threatened Brazilian campo rupestre. *Nature Conservation Research* **7** (1), 10–18. https://dx.doi.org/10.24189/ncr.2022.004

Castro, S.A., Daehler, C.C., Silva, L., Torres-Santana, C.W., Reyes-Betancort, J.A. et al., 2010. Floristic homogenization as a teleconnected trend in oceanic islands. *Diversity and Distributions* **16**, 902–910. https://doi.org/10.1111/j.1472-4642.2010.00695.x

Clements, J.C., Doucet, D.A., McCorquodale, D.B., 2013. Establishment of a European cockroach, *Ectobius lapponicus* (L.) (Dictyoptera: Blattodea), in the Maritime Provinces of eastern Canada. *Journal of the Acadian Entomological Society* **9**, 4–7.

Costa, L.N.P., Novais, S., Oki, Y., Fernandes, G.W., Borges, M.A.Z., 2023. Mosquito (Diptera: Culicidae) diversity along a rainy season and edge effects in a riparian forest in Southeastern Brazil. *Austral Ecology* **48**, 41–55. https://doi.org/10.1111/aec.13250

Czechowska, W., 1994. Neuropterans (Neuropteroidea: Rhaphidioptera, Planipennia) of the canopy layer in pine forests. *Fragmenta Faunistica* **36**, 459–467.

Darsono, Riwidiharso, E., Santoso, S., Sudiana, E., Yani, E. et al., T., 2020. Insect diversity in various distances to forest edge in small nature reserve: A case study of Bantarbolang Nature Reserve, Central Java, Indonesia. *Biodiversitas* **21**, 4821–4828. https://dx.doi.org/10.13057/biodiv/d211048

Dodds, K.J., 2011. Effects of habitat type and trap placement on captures of bark (Coleoptera: Scolytidae) and longhorned (Coleoptera: Cerambycidae) beetles in semiochemical-baited traps. *Journal of Economic Entomology* **104** (3), 879–888. https://doi.org/10.1603/EC10358

Downie, I.S., Coulson, J.C., Butterfield, J.E.L., 1996. Distribution and dynamics of surface-dwelling spiders across a pasture-plantation ecotone. *Ecography* **19** (1), 29–40. https://doi.org/10.1111/j.1600-0587.1996.tb00152.x

Duelli, P., Obrist, M.K., Flückiger, P.F., 2002. Forest edges are biodiversity. *Acta Zoologica Academiae Scientiarum Hungaricae* **48** (Supplement 2), 75–87.

Dvořák, L., Dvořáková, K., Oboňa, J., Ruchin, A.B., 2020. Selected Diptera families caught with beer traps in the Republic of Mordovia (Russia). *Nature Conservation Research* **5** (4), 65–77. https://dx.doi.org/10.24189/ncr.2020.057

Dvořák, L., Ruchin, A.B., Egorov, L.V., Aleksanov, V.V., Alekseev, S.K., Shulaev, N.V., Zakharova, E.Yu., 2023. Distribution of species from the genus *Panorpa* (Mecoptera, Panorpidae) in European Russia except the Caucasus. *Nature Conservation Research* **8** (1), 24–33. https://dx.doi.org/10.24189/ncr.2023.001

Dvořák, L., Tětál, I., 2013. Earwigs (Dermaptera) on heathlands and their surroundings in Western Bohemia (Czech Republic): results of monitoring using pitfall traps. *Erica, Plzeň* **20**, 141–150.

Gadelha, B.Q., Ribeiro, A.C., Aguiar, V.M., Mello-Patiu, C.A., 2015. Edge effects on the blowfly fauna (Diptera, Calliphoridae) of the Tijuca National Park, Rio de Janeiro, Brazil. Brazilian *Journal of Biology* **75** (4), 999–1007. https://doi.org/10.1590/1519-6984.05614

Giovanni, F., Mei, M., Cerretti, P., 2017. Vertical stratification of selected Hymenoptera in a remnant forest of the Po Plain (Italy, Lombardy) (Hymenoptera: Ampulicidae, Crabronidae, Sphecidae). *Fragmenta Entomologica* **49** (1), 71–77.

González, E., Salvo, A., Valladares, G., 2017. Natural vegetation cover in the landscape and edge effects: differential responses of insect orders in a fragmented forest. *Insect Science* **24**, 891–901.

Graham, E.E., Poland, T.M., McCullough, D.G., Millar, J.G., 2012. A comparison of trap type and height for capturing cerambycid beetles (Coleoptera). *Journal of Economic Entomology* **105**, 837–846.

Gruppe, A., Schubert, H., 2001. The spatial distribution and plant specificity of Neuropterida in different forest sites in Southern Germany (Raphidioptera and Neuroptera). *Beiträge zur Entomologie* **51**, 517–527.

Haddad, N.M., Brudvig, L.A., Clobert, J., Davies, K.F., Gonzalez, A. et al., 2015. Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances* **1** (2), e1500052. https://doi.org/10.1126/sciadv.1500052

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A. et al., 2013. High-resolution global maps of 21st-century forest cover change. *Science* **342**, 850–853. https://doi.org/10.1126/science.1244693

Helsen, H., Trapman, M., Polfliet, M., Simonse, J., 2007. Presence of the common earwig *Forficula auricularia* L. in apple orchards and its impact on the woolly apple aphid *Eriosoma lanigerum* (Haussmann). *IOBC/WPRS Bulletin* **30**, 31–35.

Holuša, J., Kočárek, P., 2000. Seasonal dynamics of the dusky cockroach *Ectobius lapponicus* (Blattodea, Blattellidae) in the eastern part of the Czech Republic. *Biologia, Bratislava* **55**, 483–486.

Huber, C., Baumgarten, M., 2005. Early effects of forest regeneration with selective and small scale clear-cutting on ground beetles (Coleoptera, Carabidae) in a Norway spruce stand in Southern Bavaria (Höglwald). *Biodiversity and Conservation* **14**, 1989–2007. https://doi.org/10.1007/s10531-004-2528-4

Jokimäki, J., Huhta, E., Itämies, J., Rahko, P., 1998. Distribution of arthropods in relation to forest patch size, edge, and stand characteristics. *Canadian Journal of Forest Research* **28** (7), 1068–1072. https://doi.org/10.1139/x98-074

Julião, G., Amaral, M., Fernandes, G., Oliveira, E.G., 2004. Edge effect and species-area relationships in the gall-forming insect fauna of natural forest patches in the Brazilian Pantanal. *Biodiversity and Conservation* **13**, 2055–2066. https://doi.org/10.1023/B:BIOC.0000040006.81958.f2

Irmler, U., Hingst, R., 1993. Ecology of the earwig *Chelidurella acanthopygia* (Dermaptera) in Schleswig-Holstein (Northern Germany). *Faunistisch-Oekologische Mitteilungen* **6** (9), 377–390.

Kirstová, M., Pyszko, P., Šipoš, J., Drozd, P., Kočárek, P., 2017. Vertical distribution of earwigs (Dermaptera: Forficulidae) in a temperate lowland forest, based on sampling with a mobile aerial lift platform. *Entomological Science* **20** (1), 57–64.

Lacasella, F., Gratton, C., De Felici, S., Isaia, M., Zapparoli, M., Sbordoni, V., 2015. Asymmetrical responses of forest and "beyond edge" arthropod communities across a forest-grassland ecotone. *Biodiversity and Conservation* **24**, 447–465. https://doi.org/10.1007/s10531-014-0825-0

Lange, L., 2008. Faunistische Notizen: Beitrag zur Verbreitung der Skorpionsfliegen (Panorpa) im Kreis Steinburg (Schleswig-Holstein). *Faunistisch-ökologische Mitteilungen* **9**, 61–70.

Maguire, D.Y., Buddle, C.M., Bennett, E.M., 2016. Within and among patch variability in pat-terns of insect herbivory across a fragmented forest landscape. *PLoS ONE* **11** (3), e0150843. https://doi.org/10.1371/journal.pone.0150843

Magura, T., 2002. Carabids and forest edge: spatial pattern and edge effect. *Forest Ecology and Management* **157** (1–3), 23–37. https://doi.org/10.1016/S0378-1127(00)00654-X

Magura, T., Lövei, G.L., 2020. The type of forest edge governs the spatial distribution of different-sized ground beetles. *Acta Zoologica Academiae Scientiarum Hungaricae* **66** (Supplement), 69–96. https://doi.org/10.17109/AZH.66.Suppl.69.2020

Masoudi, M., Maivan, H.Z., Mehrabian, A., 2022. Abundance and occurrence of Danae racemosa growing in Hyrcanian forest understory in relation to static and dynamic environmental variables. *Journal of Wildlife and Biodiversity* **6** (2), 1–21. https://doi.org/10.5281/zenodo.6501685

Mathew, G., 1994. Insect biodiversity in tropical forests: A study with reference to butterflies and moths (Insecta: Lepidoptera) in the Silent Valley National Park (Kerala). *Advances in Forestry Research in India* **11**, 134–171.

Melo, D.H.A., Duarte, M., Mielke, O.H.H., Robbins, R.K., Freitas, A.V.L., 2019. Butterflies (Lepidoptera: Papilionoidea) of an urban park in northeastern Brazil. *Biota Neotropica* **19** (1), e20180614.

Mendes, M.F., Blauth, M.L., Santos, L.A.D., Gaiesky, V.L.S.V., Gottschalk, M.S., 2021. Temporal edge effects structure the assemblages of Drosophilidae (Diptera) in a Restinga forest fragment in Southern Brazil. *Neotropical Biology and Conservation* **16** (2), 299–315. https://doi.org/10.3897/neotropical.16.e61481

Murcia, C., 1995. Edge effects in fragmented forests: implications for conservation. *Trends in Ecology and Evolution* **10**, 58–62. 10.1016/S0169-5347(00)88977-6

Peltonen, M., Heliövaara, K., 1998. Incidence of *Xylechinus pilosus* and *Cryphalus saltuarius* (Scolytidae) in forest-clearcut edges. *Forest Ecology and Management* **103**, 141–147.

Peltonen, M., Heliövaara, K., Väisänen, R., 1997. Forest insects and environmental variation in stand edges. *Silva Fennica* **31** (2), 129–141.

Pinksen, J., Moise, E.R.D., Sircom, J., Bowden, J.J., 2021. Living on the edge: Effects of clear-cut created ecotones on nocturnal macromoth assemblages in the eastern boreal forest, Canada. *Forest Ecology and Management* **494**, 119309. https://doi.org/10.1016/j.foreco.2021.119309

Procházka, J., Cizek, L., Schlaghamerský, J., 2018. Vertical stratification of scolytine beetles in temperate forests. *Insect Conservation and Diversity* **11**, 534–544.

Ries, L., Sisk, T.D., 2008. Butterfly edge effects are predicted by a simple model in a complex landscape. *Oecologia* **156** (1), 75–86. https://doi.org/10.1007/s00442-008-0976-3

Rocca, F.D., Venturo, A., Milanesi, P., Bracco, F., 2021. Effects of natural and seminatural elements on the composition and dispersion of carabid beetles inhabiting an agroecosystem in Northern Italy. *Ecology and Evolution* **11** (5), 10526–10537. https://doi.org/10.1002/ece3.7857

Ruchin, A.B., 2021. Contribution to the study of Orthoptera and Dermaptera (Insecta) of the Czech Republic. *Proceedings of the Mordovia State Nature Reserve* **26**, 232–236.

Ruchin, A.B, Egorov, L.V., 2021. Vertical stratification of beetles in deciduous forest communities in the Centre of European Russia. *Diversity* **13** (11), 508. https://doi.org/10.3390/d13110508

Ruchin, A.B., Egorov, L.V., Khapugin, A.A., Vikhrev, N.E., Esin, M.N., 2020. The use of simple crown traps for the insects collection. *Nature Conservation Research* **5** (1), 87–108. https://dx.doi.org/10.24189/ncr.2020.008

Ruchin, A.B., Egorov, L.V., MacGowan, I., Makarkin, V.N., Antropov, A.V. et al., 2021. Post-fire insect fauna explored by crown fermental traps in forests of the European Russia. *Scientific Reports* **11**, 21334. https://doi.org/10.1038/s41598-021-00816-3

Ruchin, A.B., Egorov, L.V., Khapugin, A.A., 2022. Vertical distribution of beetles (Coleoptera) in pine forests in central European Russia. *Diversity* **14**, 622. https://doi.org/10.3390/d14080622

Saure, C., Kielhorn, K.H., 1993. Netzflügler als Bewohner der Kronenregion von Eiche und Kiefer (Neuroptera: Coniopterygidae, Hemerobiidae, Chrysopidae). *Faunistisch-Ökologische Mitteilungen* **6**, 391–402.

Sayadi, S., Mehrabian, A., Mostafavi, H., 2022. Diversity centers and distribution patterns of Eudicot crop wild relatives of Iran: priorities for conservation and important plant areas. *Journal of Wildlife and Biodiversity* **6** (1), 1–19. https://doi.org/10.22120/jwb.2021.526979.1219

Shashkov, M.P., Bobrovsky, M.V., Shanin, V.N., Khanina, L.G., Grabarnik, P.Ya., Stamenov, M.N., Ivanova, N.V., 2022. Data on 30-year stand dynamics in an old-growth broad-leaved forest in the Kaluzhskie Zaseki State Nature Reserve, Russia. *Nature Conservation Research* **7** (Supplement 1), 24–37. https://dx.doi.org/10.24189/ncr.2022.013

Schal, C., Gautier, J.Y., Bell, W.J., 1984. Behavioural ecology of cockroaches. *Biological Reviews* **59**, 209–254.

Schlegel, J., 2022. Butterflies benefit from forest edge improvements in Western European lowland forests, irrespective of adjacent meadows' use intensity. *Forest Ecology and Management* **521**, 120413, https://doi.org/10.1016/j.foreco.2022.120413

Singh, G., Singh, S.K., 2023. Evapotranspiration over the Indian region: Implications of climate change and land use/land cover change. *Nature Environment and Pollution Technology* **22** (1), 211-219. https://doi.org/10.46488/NEPT.2023.v22i01.019

Stone, M.J., Catterall, C.P., Stork, N.E., 2018. Edge effects and beta diversity in ground and canopy beetle communities of fragmented subtropical forest. *PLoS ONE* **13** (3), e0193369. https://doi.org/10.1371/journal.pone.0193369

Tiberio, F.C.S., Xavier, R.O., Dodonov, P., Silva Matos, D.M., 2022. Fire has short-term negative effects on a super-dominant native fern, *Pteridium arachnoideum* (Dennstaedtiaceae), in a Brazilian savanna. *Nature Conservation Research* **7** (3), 15–25. https://dx.doi.org/10.24189/ncr.2022.027

Torretta, J.P., Marrero, H.J., 2019. No vertical stratification found in cavity-nesting bees and wasps in two neotropical forests of Argentina. *Neotropical Entomology* **48**, 779–787. https://doi.org/10.1007/s13744-019-00696-3

Tóthmérész, B., Nagy, D.D., Mizser, S., Bogyó, D., Magura, T., 2014. Edge effects on ground-dwelling beetles (Carabidae and Staphylinidae) in oak forest-forest edge-grassland habitats in Hungary. *European Journal of Entomology* **111** (5), 686–691.

Tsafack, N., Pozsgai, G., Boieiro, M., Ros-Prieto, A., Nunes, R., Ferreira, M.T., Borges, P.A.V., 2023. Edge effects constrain endemic but not introduced arthropod species in a pristine forest on Terceira (Azores, Portugal). *Forest Ecology and Management* **528**, 120646. https://doi.org/10.1016/j.foreco.2022.120646

Ulyshen, M.D., 2011. Arthropod vertical stratification in temperate deciduous forests: Implications for conservation-oriented management. *Forest Ecology and Management* **261**, 1479–1489.

Ulyshen, M.D., Soon, V., Hanula, J.L., 2011. Vertical distribution and seasonality of predatory wasps (Hymenoptera: Vespidae) in a temperate deciduous forest. *Florida Entomologist* **94** (4), 1068–1070. https://doi.org/10.1653/024.094.0450

van Halder, I., Barbaro, L., Jactel, H., 2011. Conserving butterflies in fragmented plantation forests: are edge and interior habitats equally important? *Journal of Insect Conservation* **15**, 591–601. https://doi.org/10.1007/s10841-010-9360-9

Villada-Bedoya, S., Cultid-Medina, C.A., Escobar, F., Guevara, R., Zurita, G., 2017. Edge effects on dung beetle assemblages in an Andean mosaic of forest and coffee plantations. *Biotropica* **49** (2), 195–205.

Список литературы

Артемова, С.Н., Леонова, Н.А. Морфологическая структура ландшафтов Окско-Донской равнины в пределах Пензенской области. *Известия ПГПУ им. В.Г. Белинского* **25**, 652–660.

Allison, J.D., Strom, B., Sweeney, J., Mayo, P., 2019. Trap deployment along linear transects perpendicular to forest edges: Impact of capture of longhorned beetles (Coleoptera: Cerambycidae). *Journal of Pest Science* **92**, 299–308.

Aspöck, H., Hölzel, H., Aspöck, U., 2001. Kommentierter Katalog der Neuropterida (Insecta: Raphidioptera, Megaloptera, Neuroptera) der Westpaläarktis. *Denisia* **2**, 1–606.

Baker, S.C., Barmuta, L.A., McQuillan, P.B., Richardson, A.M.M., 2007. Estimating edge effects on ground-dwelling beetles at clearfelled non-riparian stand edges in Tasmanian wet eucalypt forest. *Forest Ecology and Management* **239**, 92–101. https://doi.org/10.1016/j.foreco.2006.11.012

Birtele, D., Hardersen, S., 2012. Analysis of vertical stratification of Syrphidae (Diptera) in an oak-hornbeam forest in northern Italy. *Ecological Research* **27**, 755–763.

Caminha-Paiva, D., Gomes, V.M., Cunha-Blum, J., Alves, M.J.P., Rosa, D.C.P. et al., 2022. Floristic mosaics of the threatened Brazilian campo rupestre. *Nature Conservation Research* **7** (1), 10–18. https://dx.doi.org/10.24189/ncr.2022.004

Castro, S.A., Daehler, C.C., Silva, L., Torres-Santana, C.W., Reyes-Betancort, J.A. et al., 2010. Floristic homogenization as a teleconnected trend in oceanic islands. *Diversity and Distributions* **16**, 902–910. https://doi.org/10.1111/j.1472-4642.2010.00695.x

Clements, J.C., Doucet, D.A., McCorquodale, D.B., 2013. Establishment of a European cockroach, *Ectobius lapponicus* (L.) (Dictyoptera: Blattodea), in the Maritime Provinces of eastern Canada. *Journal of the Acadian Entomological Society* **9**, 4–7.

Costa, L.N.P., Novais, S., Oki, Y., Fernandes, G.W., Borges, M.A.Z., 2023. Mosquito (Diptera: Culicidae) diversity along a rainy season and edge effects in a riparian forest in Southeastern Brazil. *Austral Ecology* **48**, 41–55. https://doi.org/10.1111/aec.13250

Czechowska, W., 1994. Neuropterans (Neuropteroidea: Rhaphidioptera, Planipennia) of the canopy layer in pine forests. *Fragmenta Faunistica* **36**, 459–467.

Darsono, Riwidiharso, E., Santoso, S., Sudiana, E., Yani, E. et al., T., 2020. Insect diversity in various distances to forest edge in small nature reserve: A case study of Bantarbolang Nature Reserve, Central Java, Indonesia. *Biodiversitas* **21**, 4821–4828. https://dx.doi.org/10.13057/biodiv/d211048

Dodds, K.J., 2011. Effects of habitat type and trap placement on captures of bark (Coleoptera: Scolytidae) and longhorned (Coleoptera: Cerambycidae) beetles in semiochemical-baited traps. *Journal of Economic Entomology* **104** (3), 879–888. https://doi.org/10.1603/EC10358

Downie, I.S., Coulson, J.C., Butterfield, J.E.L., 1996. Distribution and dynamics of surface-dwelling spiders across a pasture-plantation ecotone. *Ecography* **19** (1), 29–40. https://doi.org/10.1111/j.1600-0587.1996.tb00152.x

Duelli, P., Obrist, M.K., Flückiger, P.F., 2002. Forest edges are biodiversity. *Acta Zoologica Academiae Scientiarum Hungaricae* **48** (Supplement 2), 75–87.

Dvořák, L., Dvořáková, K., Oboňa, J., Ruchin, A.B., 2020. Selected Diptera families caught with beer traps in the Republic of Mordovia (Russia). *Nature Conservation Research* **5** (4), 65–77. https://dx.doi.org/10.24189/ncr.2020.057

Dvořák, L., Ruchin, A.B., Egorov, L.V., Aleksanov, V.V., Alekseev, S.K., Shulaev, N.V., Zakharova, E.Yu., 2023. Distribution of species from the genus *Panorpa* (Mecoptera, Panorpidae) in European Russia except the Caucasus. *Nature Conservation Research* **8** (1), 24–33. https://dx.doi.org/10.24189/ncr.2023.001

Dvořák, L., Tětál, I., 2013. Earwigs (Dermaptera) on heathlands and their surroundings in Western Bohemia (Czech Republic): results of monitoring using pitfall traps. *Erica, Plzeň* **20**, 141–150.

Gadelha, B.Q., Ribeiro, A.C., Aguiar, V.M., Mello-Patiu, C.A., 2015. Edge effects on the blowfly fauna (Diptera, Calliphoridae) of the Tijuca National Park, Rio de Janeiro, Brazil. Brazilian *Journal of Biology* **75** (4), 999–1007. https://doi.org/10.1590/1519-6984.05614

Giovanni, F., Mei, M., Cerretti, P., 2017. Vertical stratification of selected Hymenoptera in a remnant forest of the Po Plain (Italy, Lombardy) (Hymenoptera: Ampulicidae, Crabronidae, Sphecidae). *Fragmenta Entomologica* **49** (1), 71–77.

González, E., Salvo, A., Valladares, G., 2017. Natural vegetation cover in the landscape and edge effects: differential responses of insect orders in a fragmented forest. *Insect Science* **24**, 891–901.

Graham, E.E., Poland, T.M., McCullough, D.G., Millar, J.G., 2012. A comparison of trap type and height for capturing cerambycid beetles (Coleoptera). *Journal of Economic Entomology* **105**, 837–846.

Gruppe, A., Schubert, H., 2001. The spatial distribution and plant specificity of Neuropterida in different forest sites in Southern Germany (Raphidioptera and Neuroptera). *Beiträge zur Entomologie* **51**, 517–527.

Haddad, N.M., Brudvig, L.A., Clobert, J., Davies, K.F., Gonzalez, A. et al., 2015. Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances* **1** (2), e1500052. https://doi.org/10.1126/sciadv.1500052

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A. et al., 2013. High-resolution global maps of 21st-century forest cover change. *Science* **342**, 850–853. https://doi.org/10.1126/science.1244693

Helsen, H., Trapman, M., Polfliet, M., Simonse, J., 2007. Presence of the common earwig *Forficula auricularia* L. in apple orchards and its impact on the woolly apple aphid *Eriosoma lanigerum* (Haussmann). *IOBC/WPRS Bulletin* **30**, 31–35.

Holuša, J., Kočárek, P., 2000. Seasonal dynamics of the dusky cockroach *Ectobius lapponicus* (Blattodea, Blattellidae) in the eastern part of the Czech Republic. *Biologia, Bratislava* **55**, 483–486.

Huber, C., Baumgarten, M., 2005. Early effects of forest regeneration with selective and small scale clear-cutting on ground beetles (Coleoptera, Carabidae) in a Norway spruce stand in Southern Bavaria (Höglwald). *Biodiversity and Conservation* **14**, 1989–2007. https://doi.org/10.1007/s10531-004-2528-4

Jokimäki, J., Huhta, E., Itämies, J., Rahko, P., 1998. Distribution of arthropods in relation to forest patch size, edge, and stand characteristics. *Canadian Journal of Forest Research* **28** (7), 1068–1072. https://doi.org/10.1139/x98-074

Julião, G., Amaral, M., Fernandes, G., Oliveira, E.G., 2004. Edge effect and species-area relationships in the gall-forming insect fauna of natural forest patches in the Brazilian Pantanal. *Biodiversity and Conservation* **13**, 2055–2066. https://doi.org/10.1023/B:BIOC.0000040006.81958.f2

Irmler, U., Hingst, R., 1993. Ecology of the earwig *Chelidurella acanthopygia* (Dermaptera) in Schleswig-Holstein (Northern Germany). *Faunistisch-Oekologische Mitteilungen* **6** (9), 377–390.

Kirstová, M., Pyszko, P., Šipoš, J., Drozd, P., Kočárek, P., 2017. Vertical distribution of earwigs (Dermaptera: Forficulidae) in a temperate lowland forest, based on sampling with a mobile aerial lift platform. *Entomological Science* **20** (1), 57–64.

Lacasella, F., Gratton, C., De Felici, S., Isaia, M., Zapparoli, M., Sbordoni, V., 2015. Asymmetrical responses of forest and “beyond edge” arthropod communities across a forest-grassland ecotone. *Biodiversity and Conservation* **24**, 447–465. https://doi.org/10.1007/s10531-014-0825-0

Lange, L., 2008. Faunistische Notizen: Beitrag zur Verbreitung der Skorpionsfliegen (Panorpa) im Kreis Steinburg (Schleswig-Holstein). *Faunistisch-ökologische Mitteilungen* **9**, 61–70.

Maguire, D.Y., Buddle, C.M., Bennett, E.M., 2016. Within and among patch variability in pat-terns of insect herbivory across a fragmented forest landscape. *PLoS ONE* **11** (3), e0150843. https://doi.org/10.1371/journal.pone.0150843

Magura, T., 2002. Carabids and forest edge: spatial pattern and edge effect. *Forest Ecology and Management* **157** (1–3), 23–37. https://doi.org/10.1016/S0378-1127(00)00654-X

Magura, T., Lövei, G.L., 2020. The type of forest edge governs the spatial distribution of different-sized ground beetles. *Acta Zoologica Academiae Scientiarum Hungaricae* **66** (Supplement), 69–96. https://doi.org/10.17109/AZH.66.Suppl.69.2020

Masoudi, M., Maivan, H.Z., Mehrabian, A., 2022. Abundance and occurrence of Danae racemosa growing in Hyrcanian forest understory in relation to static and dynamic environmental variables. *Journal of Wildlife and Biodiversity* **6** (2), 1–21. https://doi.org/10.5281/zenodo.6501685

Mathew, G., 1994. Insect biodiversity in tropical forests: A study with reference to butterflies and moths (Insecta: Lepidoptera) in the Silent Valley National Park (Kerala). *Advances in Forestry Research in India* **11**, 134–171.

Melo, D.H.A., Duarte, M., Mielke, O.H.H., Robbins, R.K., Freitas, A.V.L., 2019. Butterflies (Lepidoptera: Papilionoidea) of an urban park in northeastern Brazil. *Biota Neotropica* **19** (1), e20180614.

Mendes, M.F., Blauth, M.L., Santos, L.A.D., Gaiesky, V.L.S.V., Gottschalk, M.S., 2021. Temporal edge effects structure the assemblages of Drosophilidae (Diptera) in a Restinga forest fragment in Southern Brazil. *Neotropical Biology and Conservation* **16** (2), 299–315. https://doi.org/10.3897/neotropical.16.e61481

Murcia, C., 1995. Edge effects in fragmented forests: implications for conservation. *Trends in Ecology and Evolution* **10**, 58–62. 10.1016/S0169-5347(00)88977-6

Peltonen, M., Heliövaara, K., 1998. Incidence of *Xylechinus pilosus* and *Cryphalus saltuarius* (Scolytidae) in forest-clearcut edges. *Forest Ecology and Management* **103**, 141–147.

Peltonen, M., Heliövaara, K., Väisänen, R., 1997. Forest insects and environmental variation in stand edges. *Silva Fennica* **31** (2), 129–141.

Pinksen, J., Moise, E.R.D., Sircom, J., Bowden, J.J., 2021. Living on the edge: Effects of clear-cut created ecotones on nocturnal macromoth assemblages in the eastern boreal forest, Canada. *Forest Ecology and Management* **494**, 119309. https://doi.org/10.1016/j.foreco.2021.119309

Procházka, J., Cizek, L., Schlaghamerský, J., 2018. Vertical stratification of scolytine beetles in temperate forests. *Insect Conservation and Diversity* **11**, 534–544.

Ries, L., Sisk, T.D., 2008. Butterfly edge effects are predicted by a simple model in a complex landscape. *Oecologia* **156** (1), 75–86. https://doi.org/10.1007/s00442-008-0976-3

Rocca, F.D., Venturo, A., Milanesi, P., Bracco, F., 2021. Effects of natural and seminatural elements on the composition and dispersion of carabid beetles inhabiting an agroecosystem in Northern Italy. *Ecology and Evolution* **11** (5), 10526–10537. https://doi.org/10.1002/ece3.7857

Ruchin, A.B., 2021. Contribution to the study of Orthoptera and Dermaptera (Insecta) of the Czech Republic. *Proceedings of the Mordovia State Nature Reserve* **26**, 232–236.

Ruchin, A.B, Egorov, L.V., 2021. Vertical stratification of beetles in deciduous forest communities in the Centre of European Russia. *Diversity* **13** (11), 508. https://doi.org/10.3390/d13110508

Ruchin, A.B., Egorov, L.V., Khapugin, A.A., Vikhrev, N.E., Esin, M.N., 2020. The use of simple crown traps for the insects collection. *Nature Conservation Research* **5** (1), 87–108. https://dx.doi.org/10.24189/ncr.2020.008

Ruchin, A.B., Egorov, L.V., MacGowan, I., Makarkin, V.N., Antropov, A.V. et al., 2021. Post-fire insect fauna explored by crown fermental traps in forests of the European Russia. *Scientific Reports* **11**, 21334. https://doi.org/10.1038/s41598-021-00816-3

Ruchin, A.B., Egorov, L.V., Khapugin, A.A., 2022. Vertical distribution of beetles (Coleoptera) in pine forests in central European Russia. *Diversity* **14**, 622. https://doi.org/10.3390/d14080622

Saure, C., Kielhorn, K.H., 1993. Netzflügler als Bewohner der Kronenregion von Eiche und Kiefer (Neuroptera: Coniopterygidae, Hemerobiidae, Chrysopidae). *Faunistisch-Ökologische Mitteilungen* **6**, 391–402.

Sayadi, S., Mehrabian, A., Mostafavi, H., 2022. Diversity centers and distribution patterns of Eudicot crop wild relatives of Iran: priorities for conservation and important plant areas. *Journal of Wildlife and Biodiversity* **6** (1), 1–19. https://doi.org/10.22120/jwb.2021.526979.1219

Shashkov, M.P., Bobrovsky, M.V., Shanin, V.N., Khanina, L.G., Grabarnik, P.Ya., Stamenov, M.N., Ivanova, N.V., 2022. Data on 30-year stand dynamics in an old-growth broad-leaved forest in the Kaluzhskie Zaseki State Nature Reserve, Russia. *Nature Conservation Research* **7** (Supplement 1), 24–37. https://dx.doi.org/10.24189/ncr.2022.013

Schal, C., Gautier, J.Y., Bell, W.J., 1984. Behavioural ecology of cockroaches. *Biological Reviews* **59**, 209–254.

Schlegel, J., 2022. Butterflies benefit from forest edge improvements in Western European lowland forests, irrespective of adjacent meadows' use intensity. *Forest Ecology and Management* **521**, 120413, https://doi.org/10.1016/j.foreco.2022.120413

Singh, G., Singh, S.K., 2023. Evapotranspiration over the Indian region: Implications of climate change and land use/land cover change. *Nature Environment and Pollution Technology* **22** (1), 211-219. https://doi.org/10.46488/NEPT.2023.v22i01.019

Stone, M.J., Catterall, C.P., Stork, N.E., 2018. Edge effects and beta diversity in ground and canopy beetle communities of fragmented subtropical forest. *PLoS ONE* **13** (3), e0193369. https://doi.org/10.1371/journal.pone.0193369

Tiberio, F.C.S., Xavier, R.O., Dodonov, P., Silva Matos, D.M., 2022. Fire has short-term negative effects on a super-dominant native fern, *Pteridium arachnoideum* (Dennstaedtiaceae), in a Brazilian savanna. *Nature Conservation Research* **7** (3), 15–25. https://dx.doi.org/10.24189/ncr.2022.027

Torretta, J.P., Marrero, H.J., 2019. No vertical stratification found in cavity-nesting bees and wasps in two neotropical forests of Argentina. *Neotropical Entomology* **48**, 779–787. https://doi.org/10.1007/s13744-019-00696-3

Tóthmérész, B., Nagy, D.D., Mizser, S., Bogyó, D., Magura, T., 2014. Edge effects on ground-dwelling beetles (Carabidae and Staphylinidae) in oak forest-forest edge-grassland habitats in Hungary. *European Journal of Entomology* **111** (5), 686–691.

Tsafack, N., Pozsgai, G., Boieiro, M., Ros-Prieto, A., Nunes, R., Ferreira, M.T., Borges, P.A.V., 2023. Edge effects constrain endemic but not introduced arthropod species in a pristine forest on Terceira (Azores, Portugal). *Forest Ecology and Management* **528**, 120646. https://doi.org/10.1016/j.foreco.2022.120646

Ulyshen, M.D., 2011. Arthropod vertical stratification in temperate deciduous forests: Implications for conservation-oriented management. *Forest Ecology and Management* **261**, 1479–1489.

Ulyshen, M.D., Soon, V., Hanula, J.L., 2011. Vertical distribution and seasonality of predatory wasps (Hymenoptera: Vespidae) in a temperate deciduous forest. *Florida Entomologist* **94** (4), 1068–1070. https://doi.org/10.1653/024.094.0450

van Halder, I., Barbaro, L., Jactel, H., 2011. Conserving butterflies in fragmented plantation forests: are edge and interior habitats equally important? *Journal of Insect Conservation* **15**, 591–601. https://doi.org/10.1007/s10841-010-9360-9

Villada-Bedoya, S., Cultid-Medina, C.A., Escobar, F., Guevara, R., Zurita, G., 2017. Edge effects on dung beetle assemblages in an Andean mosaic of forest and coffee plantations. *Biotropica* **49** (2), 195–205.

Vodka, Š., Cizek, L., 2013. The effects of edge-interior and understorey-canopy gradients on the distribution of saproxylic beetles in a temperate lowland forest. *Forest Ecology and Management* **304**, 33–41.

Wagle, Y., Bhattarai, B.P., Adhikari, J.N., 2022. Factors influencing distribution and habitat utilisation of *Leptoptilos javanicus* in and around Barandabhar Corridor Forest, Chitwan, Nepal. *Nature Conservation Research* **7** (1), 19–26. https://dx.doi.org/10.24189/ncr.2022.005

Wermelinger, B., Flückiger, P.F., Obrist, M.K., Duelli, P., 2007. Horizontal and vertical distribution of saproxylic beetles (Col., Buprestidae, Cerambycidae, Scolytinae) across sections of forest edges. *Journal of Applied Entomology* **131**, 104–114.

Zhang, Z.-Q. (ed.), 2013. Animal Biodiversity: An Outline of Higher-level Classification and Survey of Taxonomic Richness (Addenda 2013). *Zootaxa* **3703**, 1–82. http://dx.doi.org/10.11646/zootaxa.3703.1.6