Online ISSN: 2588-3526
Journal of Wildlife and Biodiversity
Volume 8(1):171-191(2024) (http://www.wildlife-biodiversity.com/)
Research Article

On the distribution of Coleoptera in forests and open areas (center of the European part of Russia): A study using beer traps

Alexander B. Ruchin[1*], **Leonid V. Egorov**[1,2]

[1]Joint Directorate of the Mordovia State Nature Reserve and National Park «Smolny», Russia
[2]Prisursky State Nature Reserve, Russia
*Email: ruchin.alexander@gmail.com

Received: 09 June 2022 / Revised: 26 July 2022 / Accepted: 27 July 2022/ Published online: 09 September 2022. Ministry of Sciences, Research, and Technology, Arak University, Iran.

How to cite: Ruchin, A., Egorov, L. (2024). On the distribution of Coleoptera in forests and open areas (center of the European part of Russia): A study using beer traps. Journal of Wildlife and Biodiversity, 8(1), 171-191. **DOI**: https://doi.org/10.5281/zenodo.7064115

Abstract

Natural forests (closed habitats) and meadows (open habitats) are essential for the conservation of terrestrial biodiversity. Pubescent biotopes are of considerable importance as well. It is crucial to obtain data on the spatial distribution of Coleoptera in such biotopes because it helps protect natural biotopes. The research was conducted in 2020 on the territory of the Republic of Mordovia (the center of the European part of Russia). Beer traps (with beer bait) were used to collect Coleoptera. The collections were carried out from April to October in various forests and open biotopes. To clarify the spatial distribution of Coleoptera, various forest interiors (meadow, edges, in the depths of the forest) were studied at two experimental sites. A total of 7771 Coleoptera specimens were recorded. In the open biotopes, the smallest numerical abundance of Coleoptera was obtained with relatively high species richness. The lowest species richness was obtained in the depths of the forest at a height of 7.5 m. The edges of forests at a height of 1.5 m differed in the maximum species richness and number. At a height of 7.5 m, the number of Coleoptera was the greatest, but the species diversity was very low. The number of saproxious species was higher in forest biotopes. The number of anthophilic species was higher in the traps installed at the bottom. Differences in the number of species and individuals on different edges (northern, eastern, and western) were also determined. Thus, on the eastern and northern edges, in contrast to the western edge, the numerical abundance at the top was higher than at the bottom.

Keywords: abundance, Mordovia State Nature Reserve, natural forests, open habitats, spatial structure

Introduction

The spatial structure of the landscape, which has a very different impact on the settlement, behavior, and life cycles of insects, is defined as the composition and spatial configuration of habitats. The mosaic structure of landscapes influences population dynamics and species conservation on a broader scale (Fischer and Lindenmayer 2007; Hanski 2015; Kabak, Liang 2021). That is why the mosaic of landscapes is especially interesting for the conservation of the biodiversity of forest ecosystems (Bondarenko et al., 2020; Polevoi, 2021). Forests are three-dimensional ecosystems where organisms are distributed not only along various horizontal ecological gradients but also along the vertical gradient between the forest floor and tree crowns (Weiss et al., 2019; Puker et al., 2020; Romano et al., 2020; Kunakh et al., 2020; Sergeev, 2020; Avtaeva et al., 2021; Popkova et al., 2021; Ruchin and Egorov 2021b). Many studies indicate certain patterns in the distribution of Coleoptera in forests. The vertical stratification of Chrysomelidae was more seen in wet habitats than in dry ones (Charles and Basset 2005). The distribution of cerambycid beetles also depended to a certain extent on height (Graham et al., 2012). The presence of clearings, meadows and other open forest interiors usually increases the species diversity of insects in such ecosystems (Janssen et al., 2009; Verdú et al., 2011; Komonen et al., 2015; Yekwayo et al., 2017; Palyi et al., 2020; Cárdenas et al., 2020). The spatial distribution of insect species and orders by biotopes was studied on different continents. For example, the diversity of Lepidoptera in the naturally occurring lake edge is very different from the pasture-forest edge. The comparison showed that the distribution of the number of species has significant differences in untouched and disturbed forest areas (Devries et al., 1999). The conditions of forest sites, including biotic and abiotic heterogeneity, as well as the age of the sites, increased the α-diversity of forest species of Carabidae. The beta diversity of non-wood species of Carabidae increased with the heterogeneity of the sites (Marrec et al., 2021).

Border habitats, for example, edges, and edges of the forest play a certain role in mosaic landscapes. The location of the edges relative to the sun, their size, length, and contrast of the edge of the forest have a certain effect on species diversity, and diurnal and seasonal rhythms of insect life (Peyras et al., 2013; Barnes et al., 2014; Martínez-Falcón et al., 2018; Latha and Thomas 2020; Ruchin and Egorov 2021a). The number, total and average biomass of dung beetles varied significantly in different habitats in the forest, on the edge, and in the savanna (Spector and Ayzama 2003). The species richness of Carabidae at the forest edge was intermediate between the inner part of the forest and adjacent agroecosystems (Jung and Lee 2016). At the edge of the forests, there was a significantly higher density, abundance, and species richness of Carabidae than in the depths of the forest (Kriegel et al., 2021). The number of Lepidoptera on the forest edges significantly exceeded open stations (river sand banks, thickets of willows, forest glade, and floodplain meadow) and completely closed stations (inside the forests) (Ruchin 2021). The species richness of Lepidoptera was highest in semi-natural grasslands and forest edges (Kuussaari et al., 2007). In the eucalyptus forest and at its edge, the diversity of butterflies was higher than in the adjacent biotopes (Bragança et al., 1998). Similar patterns have been revealed in Brazil's natural parks, expressed in an increase in the species richness of butterflies on the edges (Melo et al., 2019). In this regard, the unique qualities of the edges make it possible to talk about the edge effect (Ewers and Didham 2006; Magura and Lövei 2020).

As it has already been described, the main part of the publications focuses on soil insects and their distribution in a mosaic landscape. This is clear because it is the easiest way to study such insects using soil traps. However, there is very little research on flying beetles, which are also of great importance in forest and open biotopes. One of the interesting ways to study flying Coleoptera is baits made of fermenting liquids and attractants (Ruchin et al. 2021b). Such traps with lures made of fermenting liquids (wine, beer, molasses, sugar cane juice) and with the addition of bananas, apples, sugar, and other natural fillers have shown their effectiveness for detecting many species of Coleoptera, including new ones (MacRae 2000; MacRae and Rice 2007; Guarnieri, 2009; Bardiani et al., 2017; Redolfi De Zan et al., 2017; Egorov et al., 2020; Barros et al., 2020; Evangelista et al., 2021). However, the use of these traps may be relevant in other studies. For example, Touroult and Dalens (2012) studied longhorn and scarab beetles using baited air traps suspended at three different heights. When using traps with baits located at different heights, Miller et al. (2020) found certain preferences for Coleoptera. Beer traps were also used to study the post-pyrogenic fauna of insects (Ruchin et al. 2021c), to determine the seasonal activity of beetles (Ruchin et al. 2021a). In this study, we focused on studying the distribution of Coleoptera in forests and adjacent open biotopes using beer traps.

Materials and methods

Study area and research design

All studies were conducted in the Republic of Mordovia (Russia) in 2020. (Temnikov district, the territory of Mordovia State Nature Reserve and the immediate surroundings) (Fig. 1). The Mordovia State Nature Reserve is located on the right bank of the Moksha River and occupies an area of 321.62 km^2. The Mordovia State Nature Reserve forests are located in the zone of coniferous-deciduous forests on the border with the forest steppe. They occupy 89.3% of the entire protected area. Pine (*Pinus sylvestris* L.) is the main forest-forming species in the Mordovia State Nature Reserve. It forms pure or mixed plant communities in the southern, central, and western parts. Birch forests occupy second place in the area of forests in the Mordovia State Nature Reserve. These are mainly secondary communities on the sites of cuttings and burnt pine forests. Oak forests are common in the floodplain of the Moksha River in the western part. Spruce forests (*Picea* abies L.) and alders (*Alnus glutinosa* (L.) Gaertn) are located mainly in floodplains of rivers and streams and occupy small areas. The main areas of floodplain meadows are located along the Moksha River in the southwest of the Mordovia State Nature Reserve. The Mordovia State Nature Reserve borders the Nizhny Novgorod Region in the north (Ruchin and Egorov 2017; Ruchin and Khapugin 2019; Ruchin et al., 2019).

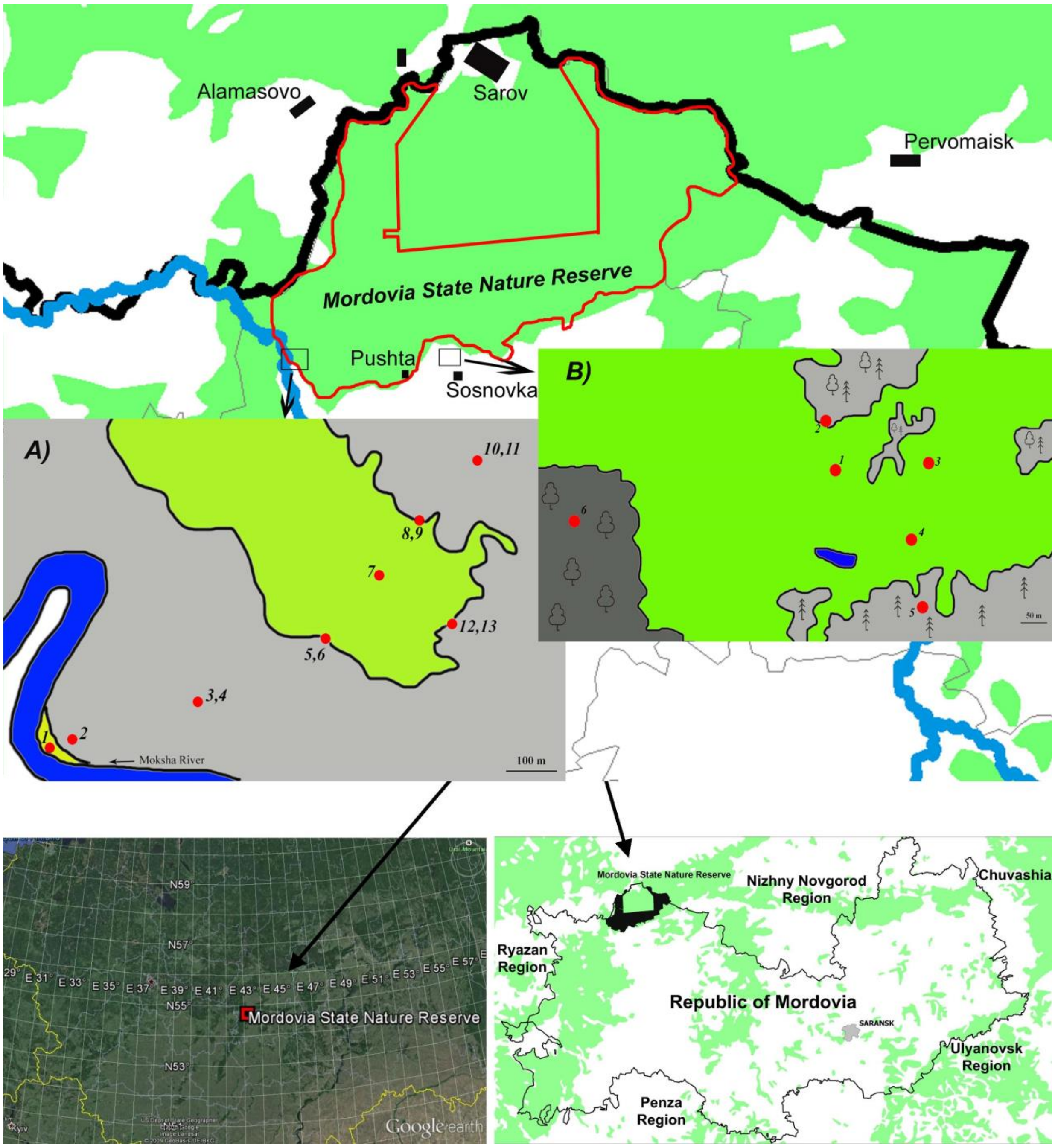

Figure 1. Research locations in the Mordovia State Nature Reserve, Russian Federation and its surroundings. Note: A) Surroundings of the cordon Taratinsky; B) Surroundings of the Sosnovka village.

All collections were carried out using traps of our own design. 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 (Ruchin et al., 2020). Beer was used as bait. Sugar and honey were added to them for fermentation.

1) Experiment No. 1.

In this study, we studied both the horizontal distribution of Coleoptera across individual stations and the vertical distribution within one station were studied (Appendix A, Fig. 1). 1 - open station, river sand banks, 5 m from the edge of the Moksha River, herbaceous vegetation is poorly expressed (trap installation height h=1.5 m); 2 - thickets of willows *Salix* sp. near floodplain deciduous forest, transitional station (h=1.5 m); 3 and 4 – a glade in the floodplain deciduous forest, overgrown with nettles, one trap h=1.5 m (below), the second trap h=7.5 m (above); 5 and 6 – the edge of the floodplain deciduous forest (edge of the floodplain deciduous forest), west side (west side), maximum sun illumination, one trap h=1.5 m (below), the second trap h=7.5 m (above); 7 – the center of the floodplain meadow, the grassy cover is good, the height of grasses is up to 1.2 m, the species diversity of grassy vegetation is significant (h=1.5 m); 8 and 9 – the edge of the floodplain deciduous forest, east side, sun illumination is observed after 12-00 h, one trap h=1.5 m (below), the second trap h=7.5 m (above); 10 and 11 – in the depth of the floodplain deciduous forest interiors, one trap h=1.5 m (below), the second trap h=7.5 m (above), high closeness of the crowns, the undergrowth is well expressed, there are almost no herbaceous plants, there are single fallen trunks of deciduous trees (mainly oak and linden); 12 and 13 - the edge of the floodplain deciduous forest, north side, there is no direct hit of solar rays, one trap h = 1.5 m (below), the second trap h=7.5 m (above).

Pairs of traps at two heights (below-above) were located within the same station (4-5 m from each other). The studies were conducted from April to August. In total, 10 collections (expositions) were completed. During the experiment, 6211 Coleoptera individuals were studied.

2) Experiment No. 2.

In this experiment, the horizontal distribution of Coleoptera was studied at low heights over closed and open stations (Appendix A, Fig. 2). The traps were located at a height of 1.5 m from the ground level. 1 - open station, dry meadow, the grassy cover is represented by various cereals; 2 - the edge of the mixed forest, the young forest appeared as a result of natural seed settlement in the meadow; 3 - open station, dry meadow, grassy cover is represented by various cereals and perennial grasses; 4 – an open station, a moist meadow, in a hollow where there is water in the spring, the herbaceous cover is represented by various perennial grasses; 5 - the edge of a young pine forest formed as a result of natural seed reproduction in the meadow; 6 – in the depth of medium-aged birch, the herbaceous cover is poorly expressed, high shading due to significant closeness of the crowns, there is a significant number of fallen hardwood trees (mainly birch and aspen), stumps and decomposing brushwood. The studies were carried out from May to August. In total, 12 collections (expositions) were carried out. During the experiment, 1,560 Coleoptera individuals were studied.

Identification and taxonomic position of samples

The classification of the family-group taxa used in this checklist follows predominantly Bouchard et al. (2011) with subsequent additions (Bouchard and Bousquet 2020). Changes for Coleoptera have been taken into account from the Catalogue of Palearctic Coleoptera (2011, 2013, 2015, 2016, 2017, 2020a, 2020b), as well as for Cucujoidea from the publication of Robertson et al. (2015) and for Curculionoidea from the publication of Alonso-Zarazaga et al. (2017). To clarify the nomenclature, the cited works were used, as well as the Catalogue of Palaearctic Coleoptera (2007, 2010). The years of the description of some species are specified according to Bousquet (2016). The species identification was carried out by L.V. Egorov.

Data analyses

When analyzing the results, we used only data on the quantitative parameter (number) of all Coleoptera individuals in traps for exposure time. Saproxylic species were determined by taking into account the approaches adopted by a number of authors (Lachat et al. 2012; Carpaneto et al. 2015; Gutowski et al. 2020). The anthophilic species were classified according to our own long-term observations.

Based on the collected data, we calculated widely used biodiversity indices, namely Shannon's diversity index and the Simpson diversity index (Shannon 1948; Magurran 1996). We did not take into account insects, which were not identified to species level.

Results

1) *Experiment No. 1.*

As a result of processing the material, 135 species from 36 families of Coleoptera were identified (Appendix B, Table B1). Some specimens from the families Staphylinidae, Nitidulidae, Phalacridae, Latridiidae, Mordellidae, Chrysomelidae, and Buprestidae could not be identified as species. The greatest species diversity was found in Nitidulidae (15 species), Elateridae and Curculionidae (13 species each), Cerambycidae and Coccinellidae (11 species each), Carabidae and Scarabaeidae (7 species each). Only five species were similar for all biotopes: *Cryptarcha strigata* (Fabricius, 1787), *Glischrochilus grandis* (Tournier, 1872), *Glischrochilus hortensis* (Geoffroy, 1785), *Soronia grisea* (Linnaeus, 1758), and *Anisandrus dispar* (Fabricius, 1792).

The open biotopes had the lowest numerical abundance of Coleoptera. However, the species richness and the number of families were very high (Fig. 2). The lowest species richness with an average number was observed in closed biotopes (deep in the forest) at a height of 7.5 m. At the edges below, with an average number of beetles, a maximum of species diversity and the number of families was obtained, while at the edge at an height of 7.5 m, the number of captured individuals was the greatest, but the species diversity was very low (Fig. 2).

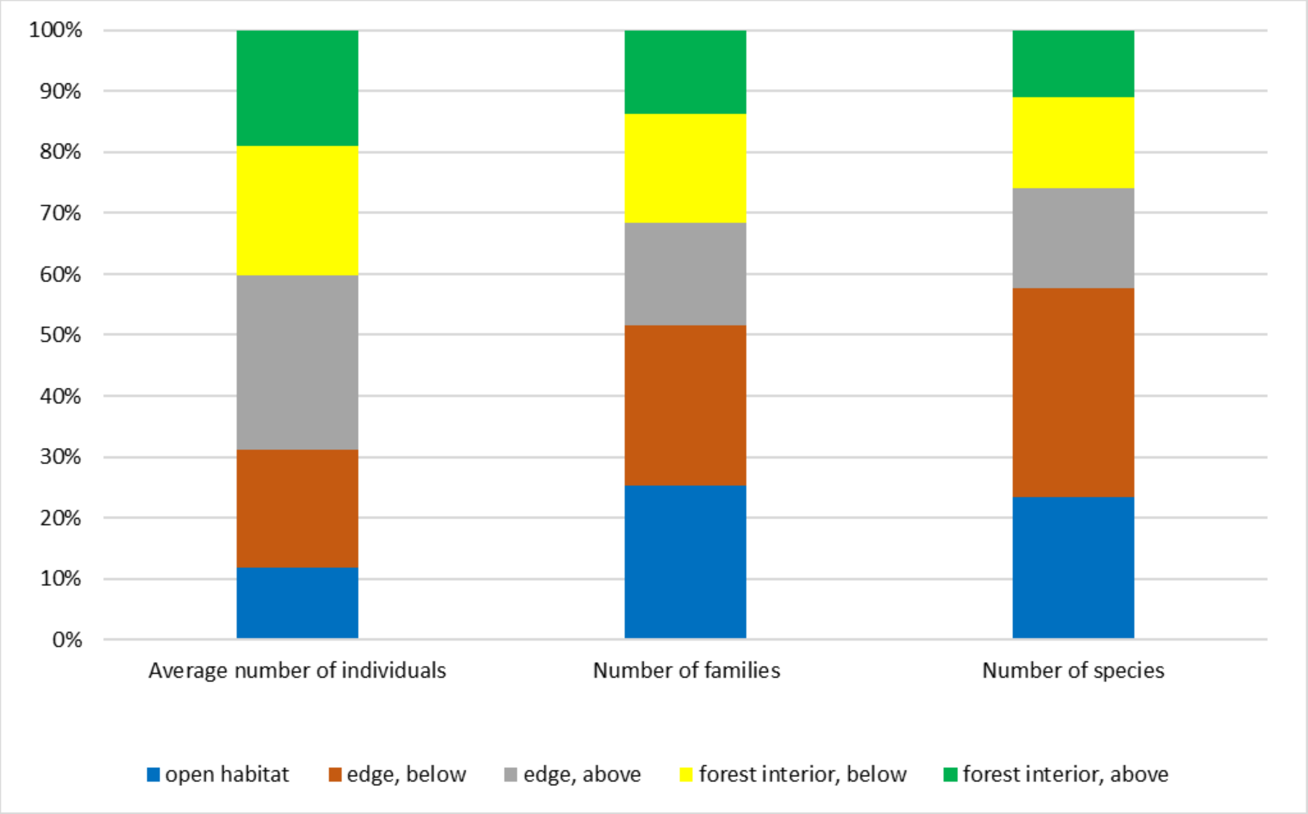

Figure 2. Numerical abundance, number of families and number of Coleoptera species in individual biotopes.

It should be noted that there were differences in the abundance and species diversity of Coleoptera on the edges, which are differently illuminated by the sun (Fig. 3 and 4). On the western edge, which receives maximum solar insolation during the day, the greatest numerical abundance was obtained (844 individuals at the bottom, 541 individuals at the top), but the least species diversity (36 and 15, respectively). However, on the eastern edge of the species diversity was greatest (41 species at the bottom, 25 species at the top). It should be noted that on the northern edge of the forest, which is not illuminated by the sun at all during the day, the species diversity of Coleoptera was high, but the total numerical abundance differed little from the eastern edge.

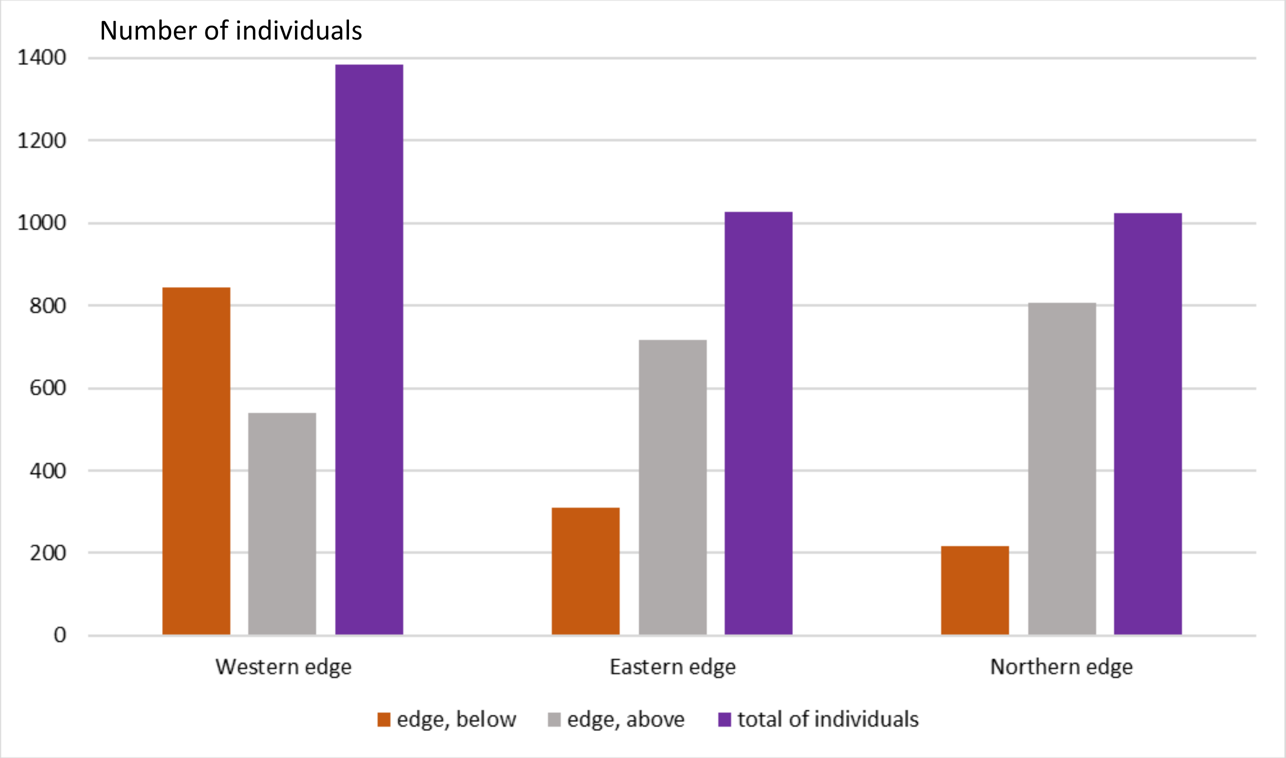

Figure 3. Numerical abundance of Coleoptera on the edges of different levels illuminated by the sun.

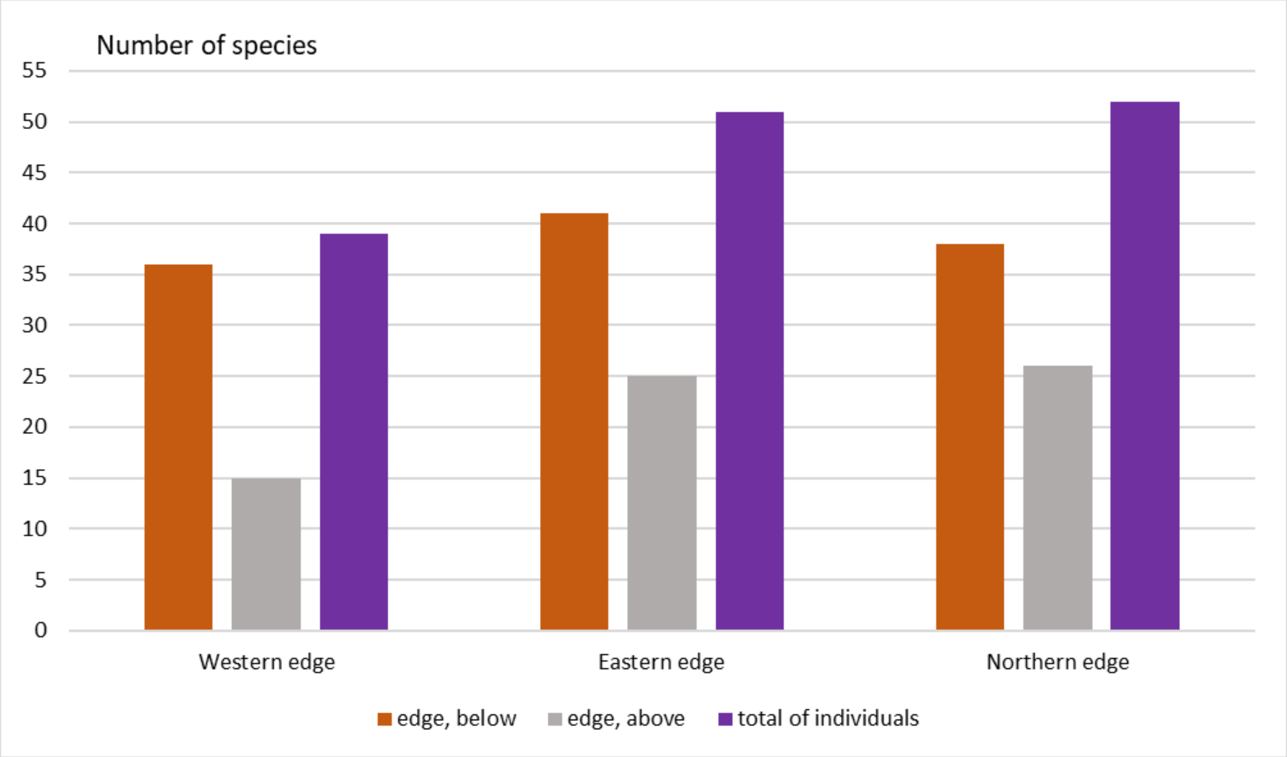

Figure 4. Species richness of Coleoptera on the edges of different levels of illumination by the sun.

It is interesting that on the eastern and northern edges, in contrast to the western edge, the numerical abundance at the top was higher than at the bottom.

The maximum values of the Shannon index and the minimum values of the Simpson index were found in plots 8 and 12 (Table 1). In both cases, this is due to the equal distribution of Coleoptera species in terms of their abundance in catches with a simultaneous significant species richness of species in these places. On the other hand, the minimum values of the Shannon and Simpson indices are obtained in plots 2 and 6.

The number of saproxylic species was higher in forest biotopes, and a decrease in saproxylic species was observed in open biotopes. At the same time, the largest proportion of such species is found in traps installed at a height of 7.5 m – both on the edges and inside the forest. The number of anthophilic species was higher in the traps set at the bottom.

Table 1. The main indicators of Coleoptera individuals collected using beer traps in experiment No. 1

Indicators	Plots												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Total of individuals	178	573	592	446	844	541	105	311	717	421	458	218	807
Number of species (excluding unidentified ones)	30	23	21	20	36	15	24	41	25	24	18	38	26
Number of species saproxylic beetles (% of the total number of species)	46.7	82.6	80.9	85.0	80.6	80.0	58.3	56.1	88.0	79.2	77.8	55.3	80.8
Number of species anthophilic beetles (% of the total number of species)	50.0	30.4	38.1	35.0	27.8	20.0	45.8	43.9	52.0	29.2	27.8	44.7	53.8
Shannon index	2.40	1.51	1.89	1.93	2.20	1.57	2.41	2.52	1.91	2.22	1.79	2.67	1.69
Simpson index	0.15	0.31	0.19	0.20	0.16	0.29	0.17	0.13	0.19	0.16	0.23	0.12	0.28

The number of individuals of Staphylinidae was greater at the bottom in closed stations and on the edges. The number of Scarabaeidae was greater at the edges in the crowns. The number of Elateridae was greater in open stations. The number of Cantharidae and Cerambycidae was greater in open stations and on the edges below. The number of Nitidulidae was greater at the edges above and below.

2) Experiment No. 2.

As a result of processing the material, 77 species from 23 Coleoptera families were identified (Appendix B, Table B2). Some specimens from the families Staphylinidae, Nitidulidae, Throscidae, and Scraptiidae could not be identified to species. The greatest species diversity was found in Curculionidae (11 species), Nitidulidae and Cerambycidae (nine species each), Elateridae (seven species) and (13 species each), Coccinellidae and Scarabaeidae (six species each). Only six species were similar for all biotopes: *Cetonia aurata* (Linnaeus, 1758), *Cryptarcha strigata*, *Glischrochilus grandis*, *Glischrochilus hortensis*, *Soronia grisea*, and *Anisandrus dispar*.

As in experiment No. 1, the pubescent biotopes were distinguished by a greater species diversity than the open biotopes. However, unlike the previous experiment, the species abundance and number of Coleoptera individuals were higher in the forest (41 species) than at the edges (26 species) (Table 2).

Table 2. The main indicators of Coleoptera individuals collected using beer traps in experiment No. 2

Indicators	Plots					
	1	2	3	4	5	6
Total of individuals	169	192	129	180	141	749
Number of species (excluding unidentified ones)	22	26	21	23	26	41
Number of species saproxylic beetles (% of the total number of species)	59.1	73.1	57.1	69.6	73.1	70.7
Number of species anthophilic beetles (% of the total number of species)	45.5	57.7	42.9	56.5	46.1	36.6
Shannon index	2.30	2.43	2.68	2.44	2.35	2.34
Simpson index	0.15	0.13	0.18	0.13	0.16	0.15

The highest value of the Shannon index is obtained in plot No. 3 (Table 2). However, there was a maximum dominance and, accordingly, an increase in the Simpson index. The minimum value of the Shannon index was obtained in plot No. 1. Communities in plots No. 2 and No. 4 had maximum alignment and minimal dominance. The number of saproxylic species was highest at the edge of young forests and in birch forests. At the same time, the number of anthophilic species increased at the edge of the pine forest and in the moist meadow and significantly decreased in the birch forest.

Discussion

Naturally fragmented landscapes are extremely important for assessing the patterns and mechanisms that determine the distribution of species in the environment. In such conditions, the effects of landscape fragmentation caused by human activity do not mix, and habitat loss does not affect (Fahrig 2017; Kuchenbecker et al., 2021). Lacasella et al. (2015) found that meadow (open) and fringe habitats had high species richness compared to forest habitats. At the same time, the indicator species associated with the forest were not affected by proximity to the edge of the biotope. Individuals of such species, which are typical of forest habitats, tended to move to grassland habitats (Lacasella et al. 2015). In South Africa, natural forests surrounded by meadows had a higher species richness than forests surrounded by young pine forests. There were more arthropods on the margins of meadows than in other biotopes (Yekwayo et al. 2016).

From the results obtained at both experimental sites, it follows that in open habitats (meadows) the species and numerical abundance is lower than at the edges. However, at the same time, the number of species in these biotopes was usually higher than the number of species in forest interiors. Thus, the edges of temperate forests are ecotones where the species diversity and numerical abundance of actively flying Coleoptera species are higher than in adjacent biotopes. In addition, other scientists (Cadenasso et al., 1997; Ewers and Didham 2006) confirm that it can be seen that the edge effects were asymmetric along the edges of the habitat. The number of anthophilic Coleoptera species was greater in open biotopes than in forest ecosystems, which is quite logical. There are much more flowering plants in the meadows, which attract flying beetles (Janssen et al., 2009).

Forest edges formed by natural ecosystems have a stratified horizontal structure, with a zone of shrubs towards the interior of the forest and a layer of perennial grasses towards the open habitat. Because of this structure, supported by natural processes, the edges have a special microclimate, high heterogeneity of the habitat, and environmental conditions that change with a small amplitude (Cadenasso et al., 2003; Harper et al., 2005; Swart et al., 2018). Forest edges supported by natural processes usually contain species both from neighboring habitats and species characteristic of the edge and are often limited to it (Lacasella et al., 2015; Magura, 2002; Stone et al. 2018; Habel et al., 2021; Franklin et al. 2021). In addition, a rich food supply for Coleoptera is maintained at the edges due to natural processes, which attract many species to visit the edges for feeding, as well as for breeding, resting and wintering during their life cycle (Cadenasso et al., 2003; Máthé 2006). In addition, the diversity and abundance of insects change during the season (Gerónimo-Torres et al. 2021).

Normann et al. (2016) studied the Coleoptera fauna for 7 months using 92 flight interception traps in tree crowns and near the ground in the Heinich National Park (Germany). They showed that the abundance of saproxylic beetles peaked in the canopy, while representatives of a wide range of habitats and not only saproxylic beetles prevailed in the understory. The edge effects in the canopy were weaker than in the understory due to the higher, edge-like variability of the microclimate and the harshness of the canopy. Habitat generalists caused the marginal reaction to the richness of beetle species, while forest and saproxylic species reacted less strongly. In studies by Cauwer et al. (2006), the total number of beetle species in traps at ground level decreased significantly with the distance from the edge deep into the forest, and the species richness at the canopy level did not depend on the distance to the edge. Within the canopy, the distance from the forest edge had no effect, and the analysis of indicators did not reveal an increase in species diversity (Stone et al. 2018). Major et al. (2003) similarly revealed the absence of distinct “internal” species between arboreal Coleoptera and Heteroptera in the remnants of forests surrounded by anthropogenic pastures in southeastern Australia. In our studies, the minimum species diversity was obtained in closed biotopes (in the depths of the forest), while the maximum species abundance was detected at the edges, which is similar to the results of these authors.

In addition, we have identified differences not only in horizontal spatial distribution, but also in vertical stratification. There were differences in species abundance and number of individuals in the canopy of the forest and in the canopy at the edge of the forest. However, these differences were not so significant compared to the differences between the edge and the depth of the forest at low height (undergrowth level). The difference in the reaction of Coleoptera to the edges between the undergrowth and the canopy is quite understandable. Firstly, insects living in the forest canopy may react differently to the edge of the forest than insects living in the undergrowth, due to differences in insect communities in each of these layers. Some previous studies in different types of forests have revealed strong differences in the number and species abundance of beetles (Stork and Grimbacher 2006; Stork et al., 2016; Ruchin and Egorov 2021b). Therefore, different ecological features of the soil and canopy can mediate different types of reactions to forest edges, for example, there is a large proportion of bad flyers at ground level (Basset et al., 2003). Secondly, the microclimate varies significantly between the vertical layers of the forest. The patterns of differences between the internal boundaries of abiotic factors are also likely to differ vertically, and this may lead to contrasting reactions of the community to the edges. For example, abiotic conditions may be similar vertically on an open forest edge, while conditions may differ on the ground in closed forest biotopes (Didham and Ewers 2014).

The station placement of individual representatives of different Coleoptera families may differ, but at the same time, the number of individuals of the entire family shows quite definite patterns. Thus, the number of individual Coleoptera families differed significantly in the forests and on the edges of southeastern Kenya (Habel et al., 2021). We also noted a different number of families on the edges, in woodlands, and in open biotopes.

The geographical orientation of the edges also affects the magnitude of edge effects (Ries et al., 2004; Cauwer et al., 2006; De Smedt et al., 2019; Bernaschini et al. 2020). Didham and Ewers (2014) observed the relationship between height and distance from the edge on the edges. At the same time, the differences in microclimate increased in magnitude from the edge to the interior at ground level but decreased in magnitude from the edge to the interior at the canopy level. The attenuation of edge effects was lower above ground level (Didham and Ewers 2014). The number of insect families preferring the shaded side was five times greater than the number of families preferring the non-shaded side. In particular, insect families associated with wet conditions preferred or exclusively occurred on the shaded side, had a higher moisture content in the soil (Cauwer et al., 2006). Microclimatic marginal gradients are extreme at the southern edges compared to the northern edges (Chen et al., 1995; Matlack, 1993). It is believed that the shaded, north-oriented edges more resemble the interior of the forest, which leads to a smaller discrepancy in the composition of the community between the forest edge and the interior (De Smedt et al., 2019).

In our studies, the western edge, which is maximally illuminated by the sun during the warm season, differed from other edges by the largest number of beetles. However, at the same time, its species richness was lower than on other edges. At the same time, the eastern and northern edges had similar total numbers of Coleoptera, but their species diversity was noticeably higher. The increase in insect diversity was due to an increase in anthophilic species. We assume that in this case, these were microclimatic conditions, such as insolation, humidity, wind, etc., which influenced this ratio. Especially the first two factors could have an impact on this ratio. In the floodplain meadows in summer, there is a frequent loss of dew. It usually disappears after sunrise and the warming of the surface layer of air. However, at the northern edge, unlike the western and eastern edges, the warming of the surface layer of air is slower. In such conditions, the temperature in this station near the grassy cover is lower than in similar conditions on other edges. At the same time, temperature differences are less seen in the crown of trees. It is possible that such microclimatic conditions attract different species of Coleoptera, which prefer high humidity and a certain shade. This creates prerequisites for increasing the species diversity of beetles at low height on the western and northern edges.

Another observation was made during two experiments. The proportion of anthophilic species in experiment No. 2 was significantly higher than in experiment No. 1. On the contrary, the proportion of saproxylic species was lower. The site in experiment No. 1 included old-age forest biotopes that possessed all the attributes of mature forests (fallen trees, stumps, dead trees, wood debris). The presence of all this is an excellent food base for saproxylic species, most of which fly well over long distances. We used beer traps for the first time at low height in open biotopes. In temperate forests, such traps are used to detect species that feed on the fermenting sap flowing from trees. Therefore, they are most often used in forest biotopes (Allemand and Aberlenc 1991; Barros et al. 2020; Wong and Hanks 2016; Ruchin et al. 2021b, Ruchin et al. 2021d). It turned out that traps with this type of bait attract species that are looking for food on flowers. They actively feed on nectar, sweet secretions of plants.

Conclusion

In the open biotopes, the smallest numerical abundance of Coleoptera was obtained with relatively high species richness. The lowest species richness with an average abundance was obtained in the depths of the forest at a height of 7.5 m. The maximum species richness and abundance differed from the edges of forests at a height of 1.5 m. At the same time, at a height of 7.5 m, the number of Coleoptera was the greatest, but the species diversity was very low. The number of saproxylic species was higher in forest biotopes and decreased in open biotopes. The number of anthophilic species was higher in the traps set at the bottom. In addition, differences were determined in the number of individuals of different families by biotopes. We also determined the differences in the number of species and individuals on different edges (northern, eastern, and western). Thus, on the eastern and northern edges, in contrast to the western edge, the numerical abundance at the top was higher than at the bottom. Our results highlight the value of the natural forest and meadow edges (ecotones) for the conservation of Coleoptera diversity, as they replenish the local species stock.

Acknowledgments

The manuscript was prepared partly at the expense of a grant from the Russian Science Foundation (project No. 22-14-00026).

References

Allemand, R., & Aberlenc, H.-P. (1991). Une méthode efficace d’echantillonage de l’entomofaune des frondaisons: le piège attractif aérien. Bulletin de la Société Entomologique Suisse 64: 293–305.

Alonso-Zarazaga, M. A., Barrios, H., Borovec, R., Bouchard, P., Caldara, R., Colonnelli, E., Gültekin, L., Hlaváč, P., Korotyaev, B., & Lyal, C.H.C., et al. (2017). Cooperative Catalogue of Palaearctic Coleoptera Curculionoidea. Monogr. Electrón. SEA 8, 1–729.

Avtaeva, T. A., Sukhodolskaya, R. A., & Brygadyrenko, V. V. (2021). Modeling the bioclimatic range of Pterostichus melanarius (Coleoptera, Carabidae) in conditions of global climate change. Biosystems Diversity 29(2), 140–150. doi:10.15421/012119

Barnes, A. D., Emberson, R. M., Chapman, H. M., Krell, F. T., & Didham, R. K. (2014). Matrix habitat restoration alters dung beetle species responses across tropical forest edges. Biological Conservation 170: 28-37.

Barros, R. C., Fonseca, M. G., Jardim, M. T., Vendramini, V. E., Damiani, B. C. B., Julio, C. E. A. (2020). Species of Cerambycinae (Insecta, Coleoptera, Cerambycidae) from east Paraná State (Brazil), with new geographic records. Zootaxa 4845(1), 001–025. https://doi.org/10.11646/zootaxa.4845.1.1

Basset, Y., Hammond, P. M., Barrios H., Holloway, J. D., & Miller, S. E. (2003). Vertical stratification of arthropod assemblages. In: Basset Y., Novotny V., Miller S.E., Kitching R.L. eds. Arthropods of tropical forests: spatiotemporal dynamics and resource use in the canopy. Cambridge, Cambridge University Press; pp. 17–27.

Bernaschini, M. L., Valladares, G., & Salvo, A. (2020). Edge effects on insect–plant food webs: assessing the influence of geographical orientation and microclimatic conditions. Ecol. Entomol. 45(4), 806-820. https://doi.org/10.1111/een.12854

Bondarenko, A.S., Zamotajlov, A.S., Belyi, A.I., & Khomitskiy, E.E. (2020). Fauna and ecological characteristics of ground beetles (Coleoptera, Carabidae) of the Nature Sanctuaries «Prichernomorskiy» and «Tuapsinskiy» (Russia). Nature Conservation Research 5(3): 66-85. https://dx.doi.org/10.24189/ncr.2020.032

Bouchard, P., Bousquet, Y., Davies, A.E., Alonso-Zarazaga, M. A., Lawrence, J. F., Lyal, C. H. C., Newton, A. F., Ried, C. A. M., Schmitt, M., & Ślipiński, S. A., et al. (2011). Family-group names in Coleoptera (Insecta). ZooKeys 88, 1–972. doi:10.3897/zookeys.88.807.

Bouchard, P., Bousquet, Y. (2020). Additions and corrections to "Family-group names in Coleoptera (Insecta)". ZooKeys 922: 65–139, doi:10.3897/zookeys.922.46367.

Bousquet, Y. (2016). Litteratura Coleopterologica (1758–1900): A guide to selected books related to the taxonomy of Coleoptera with publication dates and notes. ZooKeys 583: 1–776. doi:10.3897/zookeys.583.7084.

Bragança, M. A. L., Zanuncio, J. C., Picanço, M., & Laranjeiro, A. J. (1998). Effects of environmental heterogeneity on Lepidoptera and Hymenoptera populations in Eucalyptus plantations in Brazil. Forest Ecology and Management. 103: 287-292.

Cadenasso, M.L., Traynor, M.M., & Pickett, S.T.A. (1997) Functional location of forest edges: gradients of multiple physical factors. Canadian Journal of Forest Research, 27: 774-782.

Cadenasso, M.L., Pickett, S.T.A., Weathers, K.C., & Jones, C.G. (2003). A framework for a theory of ecological boundaries. BioScience, 53, 750-758.

Cárdenas, A.M., Gallardo, P., Salido, Á., & Márquez, J. (2020). Effects of environmental traits and landscape management on the biodiversity of saproxylic beetles in Mediterranean oak forests. Diversity 12: 451. https://doi.org/10.3390/d12120451

Carpaneto, G.M., Baviera, C., Biscaccianti, A.B., Brandmayr, P., Mazzei, A., Mason, F., Battistoni, A., Teofili, C., Rondinini, C., & Fattorini, S., et al. (2015). A red list of Italian saproxylic beetles: Taxonomic overview, ecological features and conservation issues (Coleoptera). Fragm. Entomol. 47: 53–126.

Cauwer, B., Reheul, D., Laethauwer, S., Nijs, I., & Milbau, A. (2006). Effect of light and botanical species richness on insect diversity. Agronomy for Sustainable Development, 26 (1): 35-43. DOI: 10.1051/agro:2005058

Charles, E., & Basset, Y. (2005). Vertical stratification of leaf-beetle assemblages (Coleoptera: Chrysomelidae) in two forest types in Panama. Journal of Tropical Ecology 21: 329–336.

Chen, J., Franklin, J. F., & Spies, T. A. (1995). Growing-season microclimatic gradients from clearcut edges into old-growth Douglas-fir forests. Ecological Applications 5(1): 74–86.

Danilevsky, M. (Ed.) (2020). Catalogue of Palaearctic Coleoptera. Vol. 6/1. Updated and Revised Second Edition. Chrysomeloidea I (Vesperidae, Disteniidae, Cerambycidae); Brill: Leiden, The Netherlands; Boston, MA, USA, 712 p.

DeVries, P.J., Walla, T.R., & Greeney, H.F. (1999). Species diversity in spatial and temporal dimensions of fruit-feeding butterflies from two Ecuadorian rainforests. Biological Journal Linnean Society. 68: 333–353.

De Smedt, P, Baeten, L, Proesmans, W., Poel, S.V., Van Keer, J., Giffard, B., Martin, L., Vanhulle, R., Brunet, J., Cousins, S.A.O., Decocq, G., Deconchat, M., Diekmann, M., Gallet-Moron, E., Le Roux, V., Liira, J., Valdés, A., Wulf, M., Andrieu, E., Hermy, M., Bonte, D., & Verheyen, K. (2019). Strength of forest edge effects on litter-dwelling macroarthropods across Europe is influenced by forest age and edge properties. Diversity and Distributions 25(6): 963–974.

Didham, R.K., & Ewers, R.M. (2014). Edge effects disrupt vertical stratification of microclimate in a temperate forest canopy. Pacific Science 68(4): 493-508. https://doi.org/10.2984/68.4.4

Egorov, L.V., Ruchin, A.B., Semenov, V.B., Semionenkov, O.I., & Semishin, G.B. (2020). Checklist of the Coleoptera of Mordovia State Nature Reserve, Russia. ZooKeys 962: 13–122. https://doi.org/10.3897/zookeys.962.54477.

Evangelista, J., Rocha, M.V.C., Monné, M.L., Monné, M.A., & Frizzas, M.R. (2021). Diversity of Cerambycidae (Insecta: Coleoptera) in the Cerrado of Central Brazil using a new type of bait. Biota Neotrop. 21(1): e20201103. https://doi.org/10.1590/1676-0611-BN-2020-1103

Ewers, R.M., & Didham, R.K. (2006). Continuous response functions for quantifying the strength of edge effects. Journal Applied Ecology. 43(3): 527-536. https://doi.org/10.1111/j.1365-2664.2006.01151.x

Gerónimo-Torres, J.C., Oporto-Peregrino, S., Magaña-Alejandro, M.A., Ríos-Rodas, L., Sánchez-Díaz, B., Monroy-Hernández, R., & Pozo-Santiago, C.O. (2021). Vertical distribution of bark beetles and borers in a tropical forest. Tropical and Subtropical Agroecosystems 24: 74.

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). J. Econ. Entomol. 105: 837–846.

Guarnieri, F.G. 2009. A survey of longhorned beetles (Coleoptera: Cerambycidae) from Paw Paw, Morgan County, West Virginia. Maryland Entomologist. 5: 11–22.

Gutowski, J.M., Sućko, K., Borowski, J., Kubisz, D., Mazur, M.A., Melke, A., Mokrzycki, T., Plewa, R., & Żmihorski, M. (2020). Post-fire beetle succession in a biodiversity hotspot: Białowieża Primeval Forest. For. Ecol. Manag. 461: 117893, https://doi.org/10.1016/j.foreco.2020.117893.

Fahrig, L. (2017). Ecological responses to habitat fragmentation per se. Annu. Rev. Ecol. Evol. Syst. 48: 1–23. doi: 10.1146/annurev-ecolsys-110316-022612

Fischer, J., & Lindenmayer, D.B. (2007). Landscape modification and habitat fragmentation: a synthesis. Global Ecology and Biogeography 16(3): 265-280. https://doi.org/10.1111/j.1466-8238.2007.00287.x

Franklin, C.M.A., Harper, K.A., & Clarke, M.J. (2021). Trends in studies of edge influence on vegetation at human-created and natural forest edges across time and space. Canadian Journal of Forest Research. 51(2): 274-282. https://doi.org/10.1139/cjfr-2020-0308

Habel, J.C., Koc, E., Gerstmeier, R., Gruppe A., Seibold S., & Ulrich W. (2021). Insect diversity across an afro-tropical forest biodiversity hotspot. J. Insect. Conserv. 25: 221–228. https://doi.org/10.1007/s10841-021-00293-z

Hanski, I. (2015). Habitat fragmentation and species richness. Journal Biogeography 42(5): 989-993. https://doi.org/10.1111/jbi.12478

Harper, K.A., Macdonald, S.E., Burton, P.J., Chen, J., Brosofske, K.D., Saunders, S.C., Euskirchen E.S., Roberts D., Jaiteh M.S., & Esseen, P.A. (2005). Edge influence on forest structure and composition in fragmented landscapes. Conservation Biology 19: 768-782.

Iwan, D., & Löbl, I. (Eds.) (2020). Catalogue of Palaearctic Coleoptera. Vol. 5. Revised and Updated Second Edition. Tenebrionoidea; Brill: Leiden, The Netherlands; Boston, MA, USA, 945 p.

Janssen, P., Fortin, D., & Hébert, C. (2009). Beetle diversity in a matrix of old-growth boreal forest: influence of habitat heterogeneity at multiple scales. Ecography 32(3): 423-432. https://doi.org/10.1111/j.1600-0587.2008.05671.x

Jung, J.K., & Lee, J.H. (2016). Forest–farm edge effects on communities of ground beetles (Coleoptera: Carabidae) under different landscape structures. Ecological Research 31: 799–810. https://doi.org/10.1007/s11284-016-1388-1

Kabak, I.I., & Liang, H.-B. (2021). An annotated list of the genus Chlaenius Bonelli, 1810 (Coleoptera: Carabidae) of Xinjiang Uygur Autonomous Region of China. Far Eastern Entomologist 429: 12-28. https://doi.org/10.25221/fee.429.3

Komonen, A., Övermark, E., Hytönen, J., & Halme, P. (2015). Tree species influences diversity of ground-dwelling insects in afforested fields. Forest Ecology and Management 349: 12-19. https://doi.org/10.1016/j.foreco.2015.04.014

Kriegel, P., Fritze, M.-A., & Thorn, S. (2021). Surface temperature and shrub cover drive ground beetle (Coleoptera: Carabidae) assemblages in short-rotation coppices. Agric. For. Entomol. 23(4): 400-410.

Kuchenbecker, J., Macedo-Reis, L.E., Fagundes, M., & Neves, F.S. (2021) Spatiotemporal distribution of herbivorous insects along always-green mountaintop forest islands. Frontiers in Forests and Global Change 4: 709403. doi: 10.3389/ffgc.2021.709403

Kunakh, O. M., Yorkina, N. V., Zhukov, O. V., Turovtseva, N. M., Bredikhina, Y. L., & Logvina-Byk, T. A. (2020). Recreation and terrain effect on the spatial variation of the apparent soil lectrical conductivity in an urban park. Biosystems Diversity 28(1): 3–8. doi:10.15421/012001

Kuussaari, M., Heliölä, J., Luoto, M., & Pöyry, J. (2007). Determinants of local species richness of diurnal Lepidoptera in boreal agricultural landscapes. Agriculture, Ecosystems & Environment. 122: 366-376.

Lachat, T., Wermelinger, B., Gossner, M.M., Bussler, H., Isacsson, G., & Müller, J. (2012). Saproxylic beetles as indicator species for dead-wood amount and temperature in European beech forests. Ecol. Indic. 23: 323–331, https://doi.org/10.1016/j.ecolind.2012.04.013.

Lacasella, F., Gratton, C., De Felici, S., Isaia, M., Zapparoli, M., Marta, S., & Sbordoni, V. (2015). Asymmetrical responses of forest and “beyond edge” arthropod communities across a forest-grassland ecotone. Biodiversity and Conservation 24: 447–465.

Löbl, I., & Löbl, D. (Eds.) (2015). Catalogue of Palaearctic Coleoptera. Vol. 2/1. Revised and Updated Version. Hydrophiloidea–Staphylinoidea; Brill: Leiden, The Netherlands; Boston, MA, USA, 1702 p.

Löbl, I., & Löbl, D. (Eds.) (2016). Catalogue of Palaearctic Coleoptera. Vol. 3. Revised and Updated Version. Scarabaeoidea–Scirtoidea–Dascilloidea–Buprestoidea–Byrrhoidea; Brill: Leiden, The Netherlands; Boston, MA, USA, 983 p.

Löbl, I., & Löbl, D. (Eds.) (2017). Catalogue of Palaearctic Coleoptera. Vol. 1. Revised and Updated Version. Archostemata–Adephaga–Myxophaga; Brill: Leiden, The Netherlands; Boston, MA, USA, 1443 p.

Löbl, I., & Smetana, A. (Eds.) (2011). Catalogue of Palaearctic Coleoptera. Vol. 7: Curculionoidea I; Apollo Books: Stenstrup, Denmark, 373 p.

Löbl, I., & Smetana, A. (Eds.) (2013). Catalogue of Palaearctic Coleoptera. Vol. 8: Curculionoidea II; Apollo Books: Stenstrup, Denmark, 707 p.

Löbl, I., & Smetana, A. (Eds.) (2007). Catalogue of Palaearctic Coleoptera. Vol. 4. Elateroi-dea–Derodontoidea–Bostrichoidea–Lymexyloidea–Cleroidea–Cucujoidea; Apollo Books: Stenstrup, Denmark, 935 p.

Löbl, I., & Smetana, A. (Eds.) (2010). Catalogue of Palaearctic Coleoptera. Vol. 6: Chrysomeloidae; Apollo Books: Stenstrup, Denmark, 924 p.

Latha, T., & Thomas, S.K. (2020). Edge effect on roller dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) in the moist South Western Ghats. J. Entomol. 8: 1044–1047.

MacRae, T.C. (2000). Review of the genus Purpuricenus Dejean (Coleoptera: Cerambycidae) in North America. Pan-Pacific Entomologist. 76: 137–169.

MacRae, T.C., & Rice M.E. (2007). Distributional and biological observations on North American Cerambycidae (Coleoptera). Coleopterists Bulletin 61(2): 227–263.

Magurran, A.E. (1996). Ecological Diversity and Its Measurement; Chapman & Hall: London, UK, 179 p.

Magura, T. (2002). Carabids and forest edge: Spatial pattern and edge effect. Forest Ecology and Management 157: 23–37.

Magura, T., & Lövei, G.L. (2020). The permeability of natural versus anthropogenic forest edges modulates the abundance of ground beetles of different dispersal power and habitat affinity. Diversity 12: 320. https://doi.org/10.3390/d12090320

Major, R.E., Christie, F.J., Gowing, G., Cassis, G., & Reid, C.A. (2003). The effect of habitat configuration on arboreal insects in fragmented woodlands of south-eastern Australia. Biological Conservation. 113: 35–48.

Marrec, R., Le Roux V., Martin L., Lenoir J., Brunet J., Cousins S. A. O., De Smedt P., Deconchat M., Diekmann M., Ehrmann S., Gallet-Moron E., Giffard B., Liira J., Lindgren J., Valdes A., Verheyen K., Wulf M., & Decocq G. (2021). Multiscale drivers of carabid beetle (Coleoptera: Carabidae) assemblages in small European woodlands. Global Ecology and Biogeography 30: 165–182.

Martínez-Falcón, A.P., Zurita, G.A., Ortega-Martínez, I.J., & Moreno, C.E. (2018). Populations and assemblages living on the edge: dung beetles responses to forests-pasture ecotones. PeerJ 6: e6148 https://doi.org/10.7717/peerj.6148

Máthé, I. (2006). Forest edge and carabid diversity in a Carpathian beech forest. Community Ecology 7: 91–97. https://doi.org/10.1556/ComEc.7.2006.1.9

Matlack, G. R. (1993). Microenvironment variation within and among forest edge sites in the eastern United States. Biological Conservation, 66(3), 185–194.

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.

Miller, D.R., Crowe, C.M., & Sweeney, J.D. (2020). Trap height affects catches of bark and woodbor-ing beetles (Coleoptera: Curculionidae, Cerambycidae) in baited multiple-funnel traps in Southeast-ern United States. Journal of Economic Entomology, 113(1): 273–280. https://doi.org/10.1093/jee/toz271

Normann, C., Tscharntke, T., & Scherber, C. (2016). Interacting effects of forest stratum, edge and tree diversity on beetles. Forest Ecology and Management 361: 421-431. https://doi.org/10.1016/j.foreco.2015.11.002

Palyi, A. P., Makshei, A. N., Kasianenko, O. I., Petrov, R. V., Faly, L. I., & Palyi, A. P. (2020). Distribution, bioecological peculiarities of staphylinids (Coleoptera, Staphylinidae) in livestock biocenoses of forest-steppe and steppe Ukraine. Biosystems Diversity 28(1): 24–28. doi:10.15421/012004

Peyras, M., Vespa, N.I., Bellocq, M.I., & Zurita, G.A. (2013). Quantifying edge effects: The role of habitat contrast and species specialization. J. Insect Conserv. 17: 807–820.

Polevoi, A.V. (2021). Fungus gnats (Diptera: Bolitophilidae, Diadocidiidae, Keroplatidae, Mycetophilidae) in the Kostomuksha State Nature Reserve, Russia. Nature Conservation Research 6(Suppl.1): 5–16. https://dx.doi.org/10.24189/ncr.2021.001

Popkova, T.V., Zryanin, V.A., & Ruchin, A.B. (2021). The ant fauna (Hymenoptera: Formicidae) of the Mordovia State Nature Reserve, Russia. Nature Conservation Research 6(3): 45–57. https://dx.doi.org/10.24189/ncr.2021.037

Puker, A., Correa, C.M.A., Silva, A.S., Silva, J.V.O., Korasaki, V., & Grossi, P.C. (2020). Effects of fruit-baited trap height on flower and leaf chafer scarab beetles sampling in Amazon rainforest. Entomological Science 23(3): 245-255.

Redolfi De Zan, L., Bardiani, M., Antonini, G., Campanaro, A., Chiari, S., Mancini, E., Maura, M., Sabatelli, S., Solano, E., Zauli, A., Sabbatini, P.G., & Roversi, P.F. (2017). Guidelines for the monitoring of *Cerambyx cerdo*. Nature Conservation. 20: 129–164. https://doi.org/10.3897/natureconservation.20.12703.

Ries, L., Fletcher, R. J., Battin, J., & Sisk, T. D. (2004). Ecological responses to habitat edges: Mechanisms, models, and variability explained. Annual Review of Ecology, Evolution and Systematics 35: 491–522.

Robertson, J., Ślipiński, A., Moulton, M., Shockley, F.W., Giorgi, A., Lord, N.P., McKenna, D.D., Tomaszewska, W., Forrester, J., & Miller, K.B., et al. (2015). Phylogeny and classification of Cucujoidea and the recognition of a new superfamily Coccinelloidea (Coleoptera: Cucujiformia). Syst. Entomol. 40: 745–778, doi:10.1111/syen.12138.

Romano, V.A., Rosati, L., & Fascetti, S. (2020). Trends in population size of *Ophrys argolica* subsp. *biscutella* in the Appennino Lucano-Val d'Agri-Lagonegrese National Park (Italy). Nature Conservation Research 5(Suppl.1): 155–164. https://dx.doi.org/10.24189/ncr.2020.058

Ruchin, A.B. (2021). Seasonal dynamics and spatial distribution of lepidopterans in selected locations in Mordovia, Russia. Biodiversitas. 22(5): 2569-2575. DOI: 10.13057/biodiv/d220515

Ruchin, A.B., Alekseev, S.K., & Khapugin, A.A. (2019). Post-fire fauna of carabid beetles (Coleoptera, Carabidae) in forests of the Mordovia State Nature Reserve (Russia). Nature Conservation Research 4(Suppl.1): 11–20. https://dx.doi.org/10.24189/ncr.2019.009

Ruchin, A.B., & Egorov, L.V. (2017). Overview of insect species included in the Red Data Book of Russian Federation in the Mordovia State Nature Reserve. Nature Conservation Research 2(Suppl. 1): 2–9. doi: 10.24189/ncr.2017.016

Ruchin, A.B., & Egorov, L.V. (2021a). On the use of wine vinegar as an attractant in crown traps. Proceedings of the Mordovia State Nature Reserve. 29: 3-12.

Ruchin, AB, Egorov, LV. (2021b). Vertical stratification of beetles in deciduous forest communities in the Centre of European Russia. Diversity. 13: 508. https://doi.org/10.3390/d13110508

Ruchin, A.B., Egorov, L.V., & Khapugin, A.A. (2021a). Seasonal activity of Coleoptera attracted by fermental crown traps in forest ecosystems of Central Russia. Ecological Questions. 32(1): 37-53. http://dx.doi.org/10.12775/EQ.2021.004

Ruchin, A.B., Egorov, L.V., & Khapugin, A.A. (2021b). Usage of fermental traps for studying the species diversity of Coleoptera. Insects 12: 407. https://doi.org/10.3390/insects12050407

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., Gornostaev, N.G., Khapugin, A.A., Dvořák, L., & Esin, M.N. (2021c). 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., & Polumordvinov, O.A. (2021d). Coleoptera of the Penza region, Russia based on fermental crown trap). Biodiversitas 22(4): 1946-1960. https://doi.org/10.13057/biodiv/d220443

Ruchin, A.B., Egorov, L.V., Sazhnev, A.S., Polumordvinov, O.A., & Ishin, R.N. (2019). Present distribution of Protaetia fieberi (Kraatz, 1880) (Insecta, Coleoptera, Scarabaeidae) in the European part of Russia. Biharean Biologist 13 (1): 12-16.

Ruchin, A.B., & Khapugin, A.A. (2019). Red Data Book Invertebrates in a Protected Area of European Russia. Acta Zoologica Academiae Scientiarum Hungaricae 65(4): 349–370. DOI: 10.17109/AZH.65.4.349.2019

Sergeev, M.E. (2020). Species composition and biotopic distribution of leaf beetles (Coleoptera: Megalopodidae, Chrysomelidae) in the Sikhote-Alin State Nature Reserve (Russia). Nature Conservation Research 5(2): 80–88. https://dx.doi.org/10.24189/ncr.2020.020

Shannon, C.E. (1948). A mathematical theory of communication. Bell Syst. Tech. J. 27: 379–423.

Spector, N., & Ayzama, S. (2003). Rapid turnover and edge effects in dung beetle assemblages (Scarabaeidae) at a Bolivian neotropical forest-savanna ecotone. Biotropica 35(3): 394-404.

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

Stork, N.E., & Grimbacher, P.S. (2006). Beetle assemblages from an Australian tropical rainforest show that the canopy and the ground strata contribute equally to biodiversity. Proceedings of the Royal Society B: Biological Sciences. 273: 1969–1975.

Stork, N.E., Stone, M., & Sam, L. (2016). Vertical stratification of beetles in tropical rainforests as sampled by light traps in North Queensland, Australia. Austral Ecology. 41: 168–78.

Swart, R.C., Pryke, J.S. & Roets, F. (2018). Arthropod assemblages deep in natural forests show different responses to surrounding land use. Biodivers Conserv 27: 583–606. https://doi.org/10.1007/s10531-017-1451-4

Touroult, J., & Dalens, P.H. (2012). Beetles vertical stratification in French Guiana’ forests: study using aerial fruit traps. ACOREP-France: Coléoptères de Guyane. VI: 16-24.

Verdú, J.R., Numa, C., & Hernández-Cuba, O. (2011). The influence of landscape structure on ants and dung beetles diversity in a Mediterranean savanna – Forest ecosystem. Ecological Indicators, 11(3): 831-839. https://doi.org/10.1016/j.ecolind.2010.10.011.

Weiss, M., Didham, R.K., Procházka, J., Schlaghamerský, J., Basset, Y., Odegaard, F., Tichechkin A., Schmidl, J., Floren, A., Curletti, G., Aberlenc, H.-P., Bail, J., Barrios, H., Leponce, M., Medianero, E., Fagan, L.L., Corbara, B., & Cizek, L. (2019). Saproxylic beetles in tropical and temperate forests – a standardized comparison of vertical stratification patterns. Forest Ecology and Management 444: 50-58. https://doi.org/10.1016/j.foreco.2019.04.021.

Wong, J.C.H., & Hanks, L.M. (2016). Influence of fermenting bait and vertical position of traps on attraction of cerambycid beetles to pheromone lures. Journal of Economic Entomology 109(5): 2145–2150. https://doi.org/10.1093/jee/tow197

Yekwayo, I., Pryke, J.S., Roets, F., & Samways, M.J. (2016). Surrounding vegetation matters for arthropods of small, natural patches of indigenous forest. Insect Conservation and Diversity 9(3): 224-235. https://doi.org/10.1111/icad.12160

Yekwayo, I., Pryke, J.S., Roets, F., & Samways M.J. (2017). Responses of ground living arthropods to landscape contrast and context in a forest-grassland mosaic. Biodiversity and Conservation 26: 631–651. https://doi.org/10.1007/s10531-016-1262-z