THE EFFECT OF VERTICAL ZONATION ON THE COMPOSITION OF ENTOMOCOENOSES IN THE SELECTED MEADOW BIOTOPES OF THE BESKYDY PROTECTED LANDSCAPE AREA (NW SLOVAKIA)

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Abstract
During the vegetation period (June – October) of 2020, we monitored the quantitative and qualitative composition of insect communities (*Insecta*) in a meadow biotop within the Beskydy Protected Landscape Area (NW Slovakia). The objective of the study was to determine the effect of vertical zoning on insect communities at two tourist-attractive sites with different altitudes: Trojmedzie Meadow (560 m a.s.l.) and Girová Meadow (840 m a.s.l.). Using the intact sticky trap method, we collected a total of 1212 individuals (indiv.) belonging to 73 species (spp.) from 9 orders and 35 families. The most represented orders of the class Insecta were Coleoptera (24 spp., 297 indiv.) and Lepidoptera (17 spp., 288 indiv.). At the higher altitude site (Girová, 840 m), 580 individuals were recorded, compared to 632 individuals at the lower-altitude Trojmedzie site (560 m). The research also provides data on the spectral sensitivity of individual insect orders to different color versions of sticky traps (transparent, yellow, and blue). Furthermore, the study includes results regarding the impact of tourism and human mobility restrictions during the Covid-19 period on the quantitative representation of entomocoenoses, which did not show statistically significant differences between the compared periods.

Key words: insect, vertical zonation, color spectrum, Girová, Trojmedzie, tourism

Introduction

The present study investigates the effect of vertical zonation of the studied area as a limiting abiotic factor on the composition of entomocenoses inhabiting two different meadow sites (Trojmedzie: 560 m a.s.l.) and (Gírová: 840 m a.s.l.), located in a touristically important Carpathian region of the Beskydy Protected Landscape Area (PLA) in NW Slovakia. Previous studies from the nearby Kysuce region (Kvasničák - Bestwinová, 2018) compared the abundance and diversity of entomocenoses on a deforested slope of Mt. Liesková (849 m a.s.l., Kysuce PLA). From the Orava region (Horná Orava PLA), the impact of tourism on the composition of entomofauna in recreationally attractive areas of the Babia hora and Pilsko Nature Reserves has been investigated (Kvasničák et al., 2021).From the Oravská Magura region (Magurka, 1107 m a.s.l.), results are also available concerning vertical zonation (Kvasničák – Dzureková, 2018), as well as the trophic and developmental fidelity of meadow beetle species that actively seek flowers for olfactory cues, food resources, mating sites, sun-exposed locations, and shelter. International studies have documented the influence of altitude on insect communities in the foothills of the Italian Alps (Chamberlain et al., 2015 and 2020) and in the Mexican region of Central America (Rivas-Arancibia, 2015). The effects of vertical zonation on beetle bioindicators have also been studied in the tropical forests of Ecuador (Dominguez, 2015), as well as biodiversity patterns in high-altitude regions (3400 m a.s.l.) of the Peruvian Andes (Maveety, 2013). Based on the aforementioned studies, we assume that communities of pterygote insects inhabiting meadow biotopes at higher altitudes occur in lower abundance compared to those in areas with lower elevations.The study also aimed to determine the spectral sensitivity and colour preferences of selected insect orders as potential pollinators with colour vision (Long, - Flint - Lepper, 2011), as well as to compare the effect of human mobility on the abundance of praticolous beetle species at tourist-frequented sites during the pandemic period (2020) and the non-pandemic period (Kvasničák - Bestwinová, 2018).

Materials and methods

The collection of entomological material was carried out in 2020 during the vegetation period (June–October) in the Beskydy PLA at two different recreational sites of meadow biotopes with an altitudinal difference of 280 m a.s.l. (Fig. 1). The first, lower-altitude site was a meadow at Trojmedzie (560 m a.s.l.), while the second site was a meadow on Mt. Gírová (840 m a.s.l.). Entomological material was collected using the method of impact sticky traps (Hagstrum, Dowdy, Lippert, 1994) without pheromone attraction. The traps were mounted on a wooden support at a height of approximately 60 cm above ground level. At each sampling site, a total of 30 sticky traps were arranged vertically, consisting of three colours of the visible spectrum (transparent: 10 units, yellow: 10 units, and blue: 10 units), coated with a non-degraded adhesive. The traps were positioned at each site at one-metre intervals along a 30-metre straight line (Fig. 2). Sampling was conducted monthly, always during the first half of the month, with traps left in place for 7 days at each selected site. The collected insect samples were taxonomically identified to the level of orders and families in a biological laboratory using standard entomological literature (Jelínek, 1993) and electronic identification keys (www.kerbtier.de; www.coleoptera.org; www.hmyzslovenska.info).

Fig. 1: Intact sticky traps in different color spectra (M. Bestwinová, 2020)

Fig. 2: Map showing the location of the study sites (A: Trojmedzie, 560 m a.s.l.; B: Gírová, 840 m a.s.l.) in the border area of the Beskydy PLA (Scale 1:40 000)

Results

During the entomological survey conducted from June to October 2020, a total of 1,212 individuals of the class *Insecta* were collected at the selected sites, belonging to 9 orders, 35 families, and 73 species. From both qualitative and quantitative perspectives, the most represented orders of *Insecta* were *Coleoptera* and *Lepidoptera*. The order *Coleoptera* was represented by 10 families, 24 species, and 297 individuals (24.50%), while *Lepidoptera* comprised 7 families, 17 species, and 288 individuals (23.76%). Among the eudominant families (ED), *Pentatomidae* accounted for 10.89%. Dominant families (D) included *Coccinellidae* (8.32%), *Tortricidae* (5.36%), *Noctuidae* (6.02%), and *Hesperiidae* (6.19%). At the Gírová site (840 m a.s.l.), a total of 580 individuals were recorded, representing 47.85% of the total 1,212 individuals collected. At the lower-altitude site Trojmedzie (560 m a.s.l.), 632 individuals of the class *Insecta* were obtained, representing 52.15% of the total sample (Appendix 1). The observed differences between the sites with different altitudes were statistically significant ($p < 0.05$), confirming the effect of vertical zonation at the compared localities. This difference in abundance between the sites during the vegetation period (June–October) is also illustrated by the seasonal dynamics curve (Fig. 3). At the higher-altitude site Gírová (840 m a.s.l.), a summer peak in abundance was recorded in August (141 individuals), compared to the lower-altitude site Trojmedzie (560 m a.s.l.), where 157 individuals were recorded. Subsequently, an autumn minimum was observed at both sites in October, with a total of 183 individuals. In terms of coenotic characteristics, praticolous insect species dominated at both meadow sites (75%), with a predominance of mesophilic indicator values (84%).

A total of 64 species (spp.) were shared between the two studied localities. The Jaccard index of faunistic similarity reached a value of 87.67% for both sites. The Shannon-Weaver diversity index was 3.43 at the Gírová site (840 m a.s.l.) and showed a very similar value of 3.42 at the Trojmedzie site (560 m a.s.l.). According to Trnka (2020), both studied localities can be classified as ecologically stable environments without significant anthropogenic disturbance. Within the study, we also examined the colour preference of insects for sticky traps (Graph 4). In terms of the number of individuals recorded at both sites, a similar increasing preference for colour spectrum was observed in the following order: yellow (446 individuals), transparent (391 individuals), and blue (275 individuals). The orders *Orthoptera* (41 individuals), *Neuroptera* (10 individuals), *Coleoptera* (108 individuals), and *Diptera* (45%) showed a preference for yellow sticky traps (560–590 nm). The order *Hymenoptera* (55 individuals) preferred transparent sticky traps (300–400 nm). The orders *Lepidoptera* (114 individuals) and *Mecoptera* (10 individuals) preferred blue sticky traps (400–500 nm).

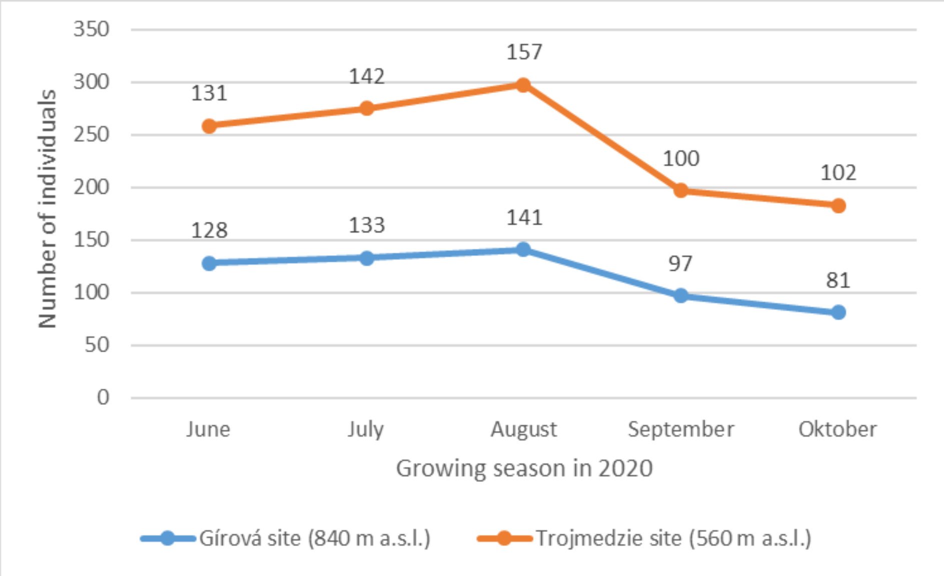

Fig. 3: Seasonal dynamics of insect occurrence at the compared sites with different altitudes.

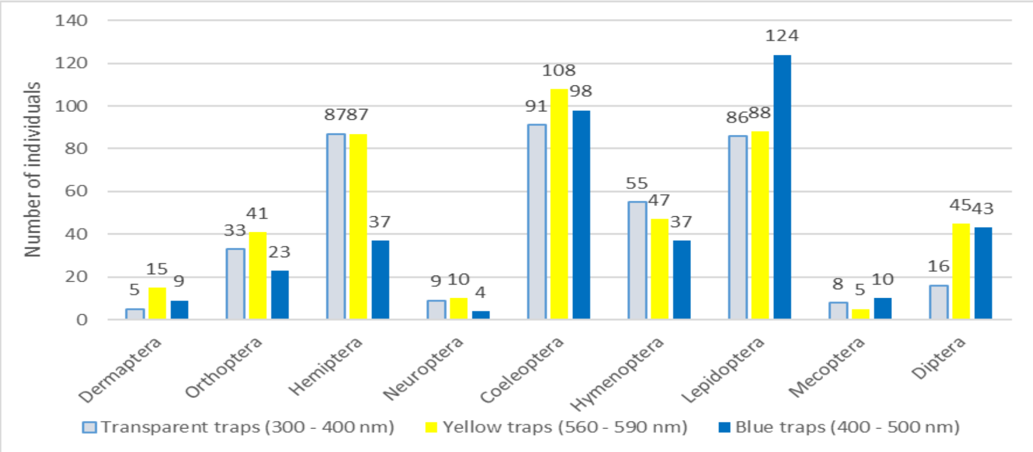

Fig. 4: Abundance (N) and spectral sensitivity of individual insect orders to different colors of the sticky traps.

The study also included a comparison of the abundance of individuals of the order Coleoptera obtained using transparent sticky traps at the study sites during the COVID-19 period with restricted tourism (2020) and a period without limitations on human mobility (2017) (Kvasničák - Bestwinová, 2018). The abundance of beetle individuals at the Gírová site (40 individuals) and Trojmedzie (51 individuals) during the pandemic period showed, on average, lower representation of coleopteran assemblages compared to two sampling sites (A, B) at Mt. Liesková (A = 59 individuals, B = 63 individuals) in the nearby Kysuce PLA, with comparable altitudes (849 m a.s.l. and 550 m a.s.l.). The observed differences in beetle abundance between the compared sites, despite the temporal gap, were not statistically significant ($p > 0.05$), indicating no significant effect of restricted human mobility on the quantitative representation of individuals of the order Coleoptera in the studied tourist-frequented area.

Discussion

The influence of altitude as an abiotic factor and the effect of vertical zonation on the composition of entomocenoses has been highlighted not only in Slovakia, particularly in studies from the Kysuce region (Kvasničák - Bestwinová, 2018) and the Horná Orava region (Kvasničák et al., 2021), but also in international research from various parts of the world. A study conducted in the foothills of the Italian Alps (Chamberlain et al., 2020) investigated biodiversity stability based on selected epigeic beetle species from the families *Geotrupidae* and *Aphodiidae*. Notable findings from Mexico were reported by Rivas-Arancibia et al. (2015), who examined the developmental fidelity of praticolous beetle and *Hymenoptera* species associated with the native deciduous tree *B. copallifera*, considering selected environmental factors such as temperature, humidity, and altitude. Similarly, recent synecological studies from Central America by Dominguez et al. (2015) have focused on beetle bioindicators, whose occurrence is simultaneously limited by altitude, air temperature, and precipitation in tropical forest ecosystems of Ecuador. In contrast, biodiversity at high elevations (1400–3400 m a.s.l.) in the Peruvian Andes was studied by Maveety et al. (2013), who identified bioindicators of environmental stability within the order *Coleoptera* (family *Carabidae*), depending on both spatial structure (altitude) and temporal factors (wet and dry seasons) of mountainous habitats. Under Slovak conditions, future research could expand the experimental design by incorporating partial monitoring of entomocenoses across multiple meadow–forest ecotone sites with varying altitudes (e.g., a deforested meadow ski slope approximately 1000 m in length or a forest clearing influenced by meadow succession). Such an approach would enable more detailed qualitative assessment of vertical zonation effects across multiple sampling sites simultaneously, for example at 100 m altitudinal intervals, focusing on the composition of more narrowly defined insect communities, particularly praticolous beetle assemblages. Within coleopteran assemblages, an interesting comparison of beetle abundance can be observed on meadow slopes at different altitudes in the Malé Karpaty (Kvasničák - Štiavnická, 2014) and with different slope orientations (north–south). Factors such as heliophily and solar radiation (Kvasničák - Schmidtová, 2014), also influence the abundance of praticolous insect communities in the border region of Veľká Javorina (Biele Karpaty PLA).

Conclusion

The conducted research examined the effect of altitude on the quantitative and qualitative composition of insect communities at two tourist-recreational sites, Gírová (840 m a.s.l.) and Trojmedzie (560 m a.s.l.), located in the Beskydy PLA. The proposed hypothesis that vertical zonation influences the quantitative and qualitative composition of entomocenoses was confirmed. At the higher-altitude site, characterized by cooler climatic conditions, a lower abundance of insects was recorded during the vegetation period compared to the lower-altitude site with a warmer climate. It was demonstrated that an altitudinal difference of 280 m significantly affects both the abundance and species diversity of insect communities, as also reflected by the seasonal dynamics curve. At both sites, an increasing preference for the colour spectrum of sticky traps was observed among insect orders, as follows: yellow (*Orthoptera*, *Neuroptera*, *Coleoptera*, and *Diptera*), transparent (*Hymenoptera*), and blue (*Lepidoptera* and *Mecoptera*). No clear effect of human mobility on communities of pterygote beetles was confirmed during the pandemic period. Both studied sites (Gírová and Trojmedzie), despite their recreational use, currently represent ecologically stable environments without significant anthropogenic disturbance.

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Souhrn
Chráněná krajinná oblast Beskydy v současnosti představuje rekreační a turisticky vyhledávanou oblast situovanou v karpatské pohraniční oblasti Slovenska, Česka a Polska. Realizovaným výzkumem jsme během pětiměsíčního období roku 2020 zjišťovali vliv vertikální zonálnosti území na skladbu pratikolních entomocenóz. Jako výzkumné plochy byly zvoleny dva luční stacionáře s různou nadmořskou výškou a to v lokalitě Trojmezí (560 m n. m.) a Girová (840 m n.m.). Metodou intaktních lepových pastí jsme dohromady získali 1212 jedinců (ex.) hmyzu příslušejících k 73 druhům (spp.) z 9 řad a 35 čeledí. Četnost jedinců v níže položené oblasti (632 ex.) byla statisticky významně vyšší než na lokalitě s vyšší nadmořskou výškou (580 ex.). Uvedenou skutečnost vlivu vertikální zonálnosti srovnávaných stacionářů dokumentuje během vegetačního období i křivka sezónní dynamiky. Nejvíce zastoupenými řadami ze třídy hmyz byly Coleoptera (24 spp., 297 ex.) a Lepidoptera (17 spp., 288 ex.) s dominantou výskytu pratikolních druhů hmyzu s mezofilní indikační hodnotou. Na obou stanovištích evidujeme v počtu získaných jedinců i vzestupnou preferenci barevného spektra lepových pascí v pořadí: žlutá (446 ex.), bezbarvá (391 ex.) a modrá (275 ex.). Následně na srovnávaných stacionářích jsme jednoznačně nepotvrdili vliv lidské mobility na společenství koleopter během pandemického období, přičemž oba výzkumné stacionáře s turistickým využitím v CHKO Beskydy (Girová, Trojmezí) vykazují v současnosti ekologicky vyvážené prostředí bez výrazných antropogenních vlivů.

Appendix: 1: Orders and families of insect with the number of individuals (N), species (S), and their dominance (D) at individual sites

Orders and families	Girová (840 m a.s.l.)				Trojmedzie (560 m a.s.l.)			
	N	D [%]	S	D [%]	N	D [%]	S	D [%]
Dermaptera								
Forficulidae	15	2,59	2	3,08	14	2,22	2	2,78
Orthoptera								
Phaneropteridae	8	1,38	2	3,08	2	0,32	2	2,78
Tettigoniidae	10	1,72	1	1,54	11	1,74	1	1,39
Gryllidae	16	2,76	1	1,54	22	3,48	1	1,39
Acrididae	13	2,24	2	3,08	15	2,37	2	2,78
Hemiptera								
Miridae	25	4,31	2	3,08	32	5,06	3	4,16
Pentatomidae	54	9,31	3	4,61	78	12,34	4	5,56
Aphididae	10	1,72	2	3,08	12	1,90	2	2,78
Neuroptera								
Chrysopidae	12	2,07	1	1,54	11	1,74	1	1,39

Coleoptera								
Carabidae	4	0,69	2	3,08	5	0,79	3	4,16
Staphylinidae	7	1,21	1	1,54	4	0,63	1	1,39
Cantharidae	18	3,10	2	3,08	26	4,11	2	2,78
Elateridae	7	1,21	2	3,08	3	0,47	2	2,78
Coccinellidae	50	8,62	4	6,14	51	8,07	4	5,56
Lucanidae	1	0,17	1	1,54	0	0	0	0
Cerambycidae	16	2,76	2	3,08	14	2,22	2	2,78
Chrysomelidae	20	3,45	3	4,61	23	3,64	4	5,56
Curculionidae	23	3,97	3	4,61	13	2,06	3	4,16
Scolytidae	7	1,21	2	3,08	5	0,79	2	2,78
Hymenoptera								
Ichneumonidae	22	3,79	1	1,54	24	3,80	1	1,39
Formicidae	25	4,31	2	3,08	32	5,06	2	2,78
Sphecidae	7	1,21	1	1,54	11	1,74	1	1,39
Apidae	8	1,38	3	4,61	11	1,74	3	4,16
Lepidoptera								
Tortricidae	36	6,21	1	1,54	29	4,59	1	1,39
Zygaenidae	4	0,69	1	1,54	13	2,06	2	2,78
Noctuidae	37	6,38	3	4,61	36	5,70	3	4,16
Nymphalidae	10	1,72	3	4,61	18	2,85	4	5,56
Hesperiidae	37	6,38	3	4,61	38	6,01	3	4,16
Lycaenidae	6	1,03	1	1,54	7	1,11	1	1,39
Pieridae	6	1,03	3	4,61	11	1,74	3	4,16
Mecoptera								
Panorpidae	16	2,76	1	1,54	7	1,11	1	1,39
Diptera								
Bibionidae	13	2,24	1	1,54	13	2,06	1	1,39
Syrphidae	20	3,45	2	3,08	23	3,64	2	2,78
Muscidae	0	0	0	0	3	0,47	2	2,78
Calliphoridae	17	2,93	1	1,54	15	2,37	1	1,39
SPOLU	580	100	65	100	632	100	72	100

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