Biodiversity & Environment

Volume 18 Number 1 Prešov 2026

BIODIVERSITY & ENVIRONMENT

Vol. 18, No. 1

VYDAVATEĽSTVO PREŠOVSKEJ UNIVERZITY

Prešov 2026

Adresa redakcie: Biodiversity & Environment
Katedra ekológie FHPV PU
ul. 17. novembra 1
081 16 Prešov
Tel: 051 / 75 70 358
e-mail: michal.rendos@unipo.sk

Vydavateľ: Vydavateľstvo Prešovskej univerzity v Prešove
Sídlo vydavateľa: 17. novembra č. 15, 080 01 Prešov
IČO vydavateľa: 17 070 775
Periodicita: 2 čísla ročne
Jazyk: slovenský/anglický/český
Poradie vydania: 1/2026
Dátum vydania: júl 2026
Foto na obálke: *Viscum album* (autor Dušan Solár)

Za jazykovú úpravu príspevkov zodpovedajú autori.

Časopis vychádza od roku 2022 len elektronicky.

Časopis vychádza s podporou Slovenskej zoologickej spoločnosti pri SAV.

ISSN 2585-9242 (online)
EV 181/23/EPP

OBSAH / CONTENTS

Biodiversity & Environment, 2026
Vol. 18, No. 1, 4–8

Original paper

The hidden urban parasite: occurrence of mistletoe (*Viscum album*) in selected areas of Prešov

VERONIKA OBOŇOVÁ[1] & JOZEF OBOŇA [2*]

[1] Grammar School of Ján Adam Rayman, Mudroňova 20, 080 01 Prešov, Slovakia, [2] Department of Ecology, Faculty of Humanities and Natural Sciences, University of Prešov, 17. novembra 1, 081 16 Prešov, Slovakia

Abstract
European mistletoe (*Viscum album*) is an evergreen hemiparasitic shrub that represents an increasing challenge for urban greenery in Central Europe. This study aimed to map the occurrence of mistletoe on urban trees in selected parts of the city of Prešov (eastern Slovakia) and to evaluate its relationship with selected characteristics of host trees. Field surveys were conducted in publicly accessible areas, where tree species, basic dendrometric parameters, health status, and mistletoe infestation characteristics were recorded. Out of 241 surveyed trees, 45 individuals (18.7%) were infested with mistletoe. A total of 607 mistletoe clumps were recorded, with a high average number per infested tree (13.5). Infestation was most frequent on *Acer pseudoplatanus*, *Acer platanoides*, and *Tilia cordata*. Mistletoe occurred predominantly in the middle and upper parts of tree crowns, and trees with reduced health condition often exhibited higher infestation intensity. Spatial analysis revealed a clustered distribution pattern, indicating local spread within the urban environment. The results confirm that European mistletoe represents a significant long-term stress factor for urban trees in Prešov and highlight the need for systematic monitoring and targeted management to reduce its negative impacts on tree vitality and urban safety.

Key words: *Viscum album,* urban greenery, hemiparasitic plant, tree health, mistletoe infestation, Prešov

Introduction

European mistletoe (*Viscum album* L.) is an evergreen hemiparasitic shrub that grows on the branches of both deciduous and coniferous trees. Through specialized organs called haustoria, it extracts water and mineral nutrients from its host, while maintaining its own photosynthetic activity (Zuber 2004). Although mistletoe is culturally perceived as a symbol of tradition and has been historically associated with medicinal use, its ecological role in urban environments is more complex and often problematic. In cities, *Viscum album* represents a significant stress factor for urban trees (Figure 1). By reducing water availability and nutrient balance, mistletoe weakens host vitality, contributes to crown degradation, and increases the risk of branch breakage, which may pose safety hazards in parks, streets, and residential areas (Černý 1976; Rigling et al. 2010; Baltazár 2016). At the same time, mistletoe plays an important ecological role by providing food and shelter for birds, which are also the exclusive vectors responsible for its dispersal (Zuber 2004).

The distribution of mistletoe in Slovakia is spatially uneven and shows a pronounced tendency to concentrate in urban areas, where favorable microclimatic conditions, particularly the urban heat island effect, support its survival and spread (Hajdúk 1977; Eliáš 1981, 1985, 2002, 2010, 2011, 2014; Dobbertin et al. 2005; Baltazár et al. 2018). Several Slovak cities, including Prešov, have been identified as hotspots of mistletoe occurrence with a high diversity of host tree species (Rejmánek et al. 1978; Dostál 1985).

Figure 1. Norway maple (*Acer platanoides*) infested by mistletoe in Prešov.

* Corresponding author: J. Oboňa. Email: jozef.obona@unipo.sk

Despite its visible presence, mistletoe infestation in urban greenery is often underestimated and insufficiently monitored. Given the high occurrence of suitable host trees and favorable environmental conditions, systematic research on *V. album* in the city of Prešov is essential for understanding its impact on tree health and for supporting effective management of urban green infrastructure. The aim of this study was to map the occurrence of European mistletoe on urban trees in selected parts of the city of Prešov and to evaluate its relationship with selected characteristics of host trees, particularly species composition, health status, and crown characteristics.

Materials and methods

Field research was conducted during the winter season 2025 – 2026 in selected parts of the city of Prešov (eastern Slovakia), specifically in accessible sections of Sídlisko 2 (Marka Čulena Street and Levočská Street) and Sídlisko 3 (Alexander Dubček Park), see Figure 2. Only publicly accessible trees were surveyed due to limited access to private areas.

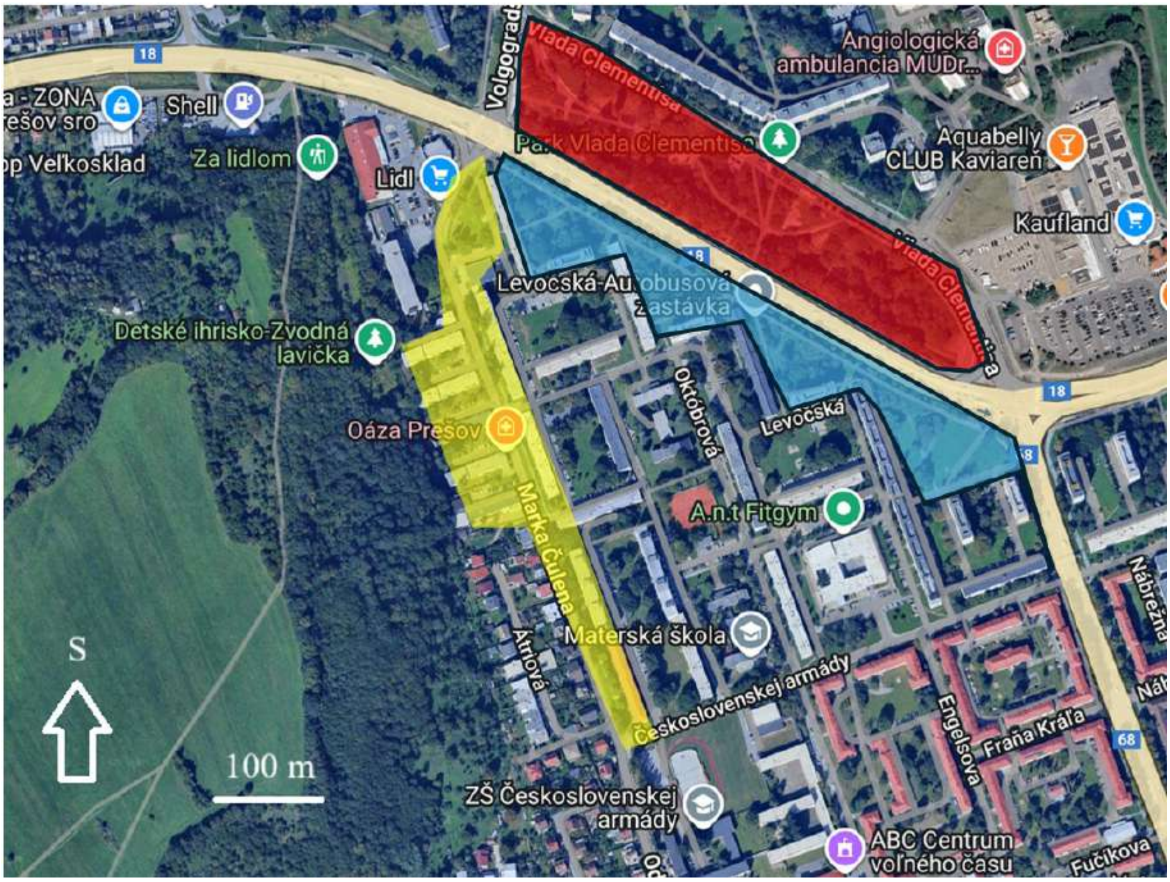

Figure 2. Map of the study area, created using www.google.com/maps. The yellow polygon represents Marka Čulena Street, the blue polygon represents Levočská Street, and the red polygon represents Alexander Dubček Park.

The study focused on urban trees infested with European mistletoe (*V. album*). Each infested tree was recorded and assigned a unique identification number. Tree location was determined using GPS coordinates to enable spatial analysis of mistletoe distribution. For each tree, species identity was determined in the field, and basic dendrometric and biological parameters were recorded. Trunk circumference was measured at 1.3 m above ground level, while tree height was estimated and classified into three height categories (1 – low tree (up to 10 m), 2 – medium-tall tree (10–20 m), 3 – tall tree (over 20 m)). Tree health status was visually assessed and classified into four categories ranging from healthy to declining (1 – healthy tree without visible damage, 2 – slightly damaged tree, 3 – weakened tree with obvious signs of reduced vitality, 4 – dying tree).

Mistletoe infestation was evaluated by recording the number of mistletoe clumps per tree, their size (classified into three categories based on clump diameter (1 – small mistletoe (up to 20 cm in diameter), 2 – medium-sized mistletoe (20–50 cm), 3 – large mistletoe (over 50 cm)), and their position within the tree crown (lower, middle, or upper part). Supplementary field notes, including mechanical damage or proximity to infrastructure, were recorded to support data interpretation. Spatial analysis of infested trees based on GPS data was visualized using artificial intelligence tools (ChatGPT).

Results

A total of 241 urban trees were surveyed in the selected areas of the city of Prešov, of which 45 trees (18.7%) were infested with European mistletoe (*V. album*). In addition, one tree (*Acer platanoides*) was simultaneously infested with Yellow mistletoe (*Loranthus europaeus* Jacq. (Figure 3)). Altogether, 607 mistletoe clumps were recorded, with an average of 13.5 clumps per infested tree and 2.5 clumps per tree when considering the entire surveyed dataset (maximum of 42 clumps; see Figure 4). Although the proportion of infested trees was relatively low, infestation intensity on affected trees was high.

Figure 3. *Acer platanoides* simultaneously infested by *Viscum album* and *Loranthus europaeus*.

Most infested trees were medium-height individuals (10–20 m), representing 76% of the sample, followed by tall trees (>20 m; 22%), while low trees (<10 m) were rarely infested (2%). Mistletoe was recorded on eight identified tree species and one genus (*Salix* sp.) (see Tab. 1). The most frequent host species were *Acer pseudoplatanus* (32%), *Acer platanoides* (30%), and *Tilia cordata* (20%), which together accounted for the majority of infested trees. Other host species (see Tab. 2) occurred only sporadically.

Table 1. Detailed overview of recorded infested trees.

Tree	Number of individuals	Relative abundance (%) of infested trees
Acer pseudoplatanus	14	32%
Acer platanoides	13	30%
Tilia cordata	9	20%
Salix sp.	3	6%
Fraxinus excelsior	2	4%
Quercus rubra	1	2%
Carpinus betulus	1	2%
Acer campestre	1	2%
Sorbus aria	1	2%

Figure 4. *Acer platanoides* infested with up to 42 mistletoe clumps.

The health condition of infested trees was predominantly classified as healthy (44%) or slightly damaged (42%). Trees assessed as weakened or declining were less frequent but often hosted a higher number of mistletoe clumps. The number of mistletoe clumps per tree ranged from 1 to 42 (see Figure 4), with the highest infestation levels observed mainly on maples and lime trees.

Regarding clump size, medium (20–50 cm; 45%) and large clumps (>50 cm; 45%) predominated, while small clumps (<20 cm) accounted for only 10%. Mistletoe occurred most frequently in the middle (45%) and upper (40%) parts of tree crowns, whereas occurrence in the lower crown was less common (15%).

Figure 5. Map of mistletoe hotspots, generated from collected GPS data using artificial intelligence (ChatGPT).

Spatial analysis based on GPS data revealed a predominantly clustered distribution pattern of infested trees (Figure 5). Strongly infested trees were often located in close proximity, indicating local, focal spread of mistletoe within the urban environment.

Discussion

Results from Prešov revealed a higher prevalence of mistletoe infestation (18.7%) compared to values reported from other urban environments, such as Southwest China (5.87%) (Niu et al. 2024) and Vienna (3.06%) (Bilonozhko et al. 2025), indicating that infestation levels may be more pronounced under certain Central European urban conditions. Despite this, a similar pattern was observed in terms of spatial distribution, as infestation in Prešov was clearly clustered, which is consistent with findings from Vienna and Kaliningrad (Skrypnik et al. 2020; Bilonozhko et al. 2025), where mistletoe occurrence tends to form aggregated hotspots rather than being evenly distributed across the landscape.

The host spectrum identified in this study, dominated by species of the genera *Acer* and *Tilia*, corresponds well with previous research, where these taxa are among the most frequently infested in urban environments (Skrypnik et al. 2020; Bilonozhko et al. 2025). Furthermore, although the proportion of infested trees in Prešov remained relatively moderate, the intensity of infection was high, with an average of 13.5 mistletoe clumps per infested tree. This finding aligns with other studies reporting that mistletoe often exhibits relatively low prevalence but high infection intensity on individual host trees (Skrypnik et al. 2020).

The observed preference for medium and tall trees supports the generally accepted relationship between tree size (or age) and mistletoe occurrence, as larger trees provide more suitable conditions for establishment and persistence of the parasite (Skrypnik et al. 2020; Niu et al. 2024). In addition, the clustered spatial pattern detected in this study suggests localized dispersal processes, most likely mediated by birds and facilitated by the proximity of suitable host trees, as also documented in other urban ecosystems (Skrypnik et al. 2020).

Overall, the results confirm that mistletoe distribution in urban environments is driven by a combination of host species composition, tree size, and spatial arrangement of vegetation, rather than by a single dominant factor, which is in agreement with conclusions drawn from other European urban studies (e.g. Bilonozhko et al. 2025).

Conclusion

The results of this study demonstrate that European mistletoe is a common and locally concentrated component of urban greenery in the city of Prešov. Although only a minority of surveyed trees were infested, affected individuals often hosted a high number of mistletoe clumps, indicating long-term and unmanaged infestation. Mistletoe occurrence was strongly associated with specific host species, particularly maples (*Acer* spp.) and small-leaved lime (*Tilia cordata*), and was more frequent in the middle and upper parts of tree crowns. Trees with reduced health condition tended to exhibit higher infestation intensity, suggesting that mistletoe may contribute to the weakening of host trees in urban environments.

Recommendations for the City of Prešov

Based on the findings of this study, it is recommended that the city of Prešov implements regular monitoring of mistletoe occurrence, with particular attention to highly susceptible tree species. Early-stage and targeted removal of mistletoe clumps should be applied to limit further spread. In addition, host species susceptibility should be considered in future urban tree planting and management strategies to reduce long-term risks to tree vitality and public safety.

Acknowledgement

We would especially like to thank the anonymous reviewers for their constructive comments, which greatly improved the manuscript. The publication was created with the support of the Ministry of Education, Research, Development and Youth of the Slovak Republic from the KEGA project No. 014PU-4/2025 Innovative methods in teaching subjects with an ecological focus in university studies.

References

Baltazár T. 2016. *Problematika imela (Viscum L.) z pohľadu záhradnej a krajinnej architektúry*. Dissertation, Mendelova univerzita v Brně. Available from: https://theses.cz/id/ocirc1/?lang=en

Baltazár T, Pejchal M, Varga I. 2018. Predpovedanie ďalšieho šírenia imela bieleho (Viscum album) na základe globálnej zmeny klímy a niektorých lokálnych faktorov. In: Středa T, Rožnovský J, eds. *Monitorování přírodních procesů. Lednice, 12–13 September 2018*. Brno: Mendelova univerzita v Brně.

Bilonozhko Y, Tokarieva O, Heinze B, Feichter J, Kodym A. 2025. Mistletoe on urban trees in the city of Vienna, Austria. *Urban Forestry & Urban Greening* 107: 128740.

Černý A. 1976. *Lesnická fytopatologie*. Praha: Státní zemědělské nakladatelství.

Dobbertin M, Hilker N, Rebetez M, Zimmermann NE, Wohlgemuth T, Rilgling A. 2005. The upward shift in altitude of pine mistletoe (*Viscum album* ssp. *austriacum*) in Switzerland – the result of climate warming? *International Journal of Biometeorology* 50: 40–47.

Dostál Ľ. 1985. Poznámky k rozšíreniu imela bieleho na východnom Slovensku. *Zborník Východoslovenského múzea v Košiciach, Prírodné vedy* 25: 51–67.

Eliáš P. 1981. Hostiteľské dreviny imelovcovitých v ČSSR. *Les, Bratislava* 37: 163–165.

Eliáš P. 1985. K výskytu imelovcovitých na Slovensku. *Zprávy* České *botanické společnosti, Praha* 20: 128–132.

Eliáš P. 2002. Hostiteľské dreviny imelovcovitých (Loranthaceae) na Slovensku. *Bulletin Slovenskej botanickej spoločnosti, Bratislava* 24: 175–180.

Eliáš P. 2010. Imelo v urbánnej vegetácii Slovenska a možnosti ochrany drevín v mestách. In: Juhásová G, ed. *Dreviny vo verejnej zeleni*. Nitra: Ústav ekológie lesa, Slovenskej akadémie vied, 35–39.

Eliáš P. 2011. Stromové poloparazity v historických parkoch a cintorínoch hlavného mesta SR Bratislavy. In: Juhásová G, ed. *Dreviny vo verejnej zeleni*. Nitra: Ústav ekológie lesa, Slovenskej akadémie vied, 41–47.

Eliáš P. 2014. Zmeny v rozšírení imelovcovitých (Loranthaceae s.l.) na Slovensku. In: Barta M, Ferus P, eds. *Dendrologické dni v Arboréte Mlyňany SAV 2014. Prostredie a vitalita drevín*. Vieska nad Žitavou: Arborétum Mlyňany SAV, 32–41.

Hajdúk J. 1977. Poznámky k výskytu a ekológii *Viscum album* L. s. l. na Slovensku. *Zprávy Československé botanické společnosti, Praha* 12: 201–205.

Niu Y, Laffitte B, Zuoqiu S, Seyler BC, Ha Z, Chen J, Chen L, Tang Y. 2024. Understanding predictors of mistletoe infection across an urban university campus in Southwest China. *Urban Ecosystems* 27(4): 1085–1099.

Rejmánek M, Šmídt I, Krlička M. 1978. Hostiteľské dreviny *Viscum album* L. v Košiciach a Prešove. *Zprávy* České *botanické společnosti, Praha* 13: 125–126.

Rigling A, Eilmann B, Koechli R, Dobbertin M. 2010. Mistletoe-induced crown degradation in Scots pine in xeric environment. *Tree Physiology* 30(7): 845–852.

Skrypnik L, Maslennikov P, Feduraev P, Pungin A, Belov N. 2020. Ecological and Landscape Factors Affecting the Spread of European Mistletoe (*Viscum album* L.) in Urban Areas (A Case Study of the Kaliningrad City, Russia). *Plants* **9**: 394.

Zuber D. 2004. Biological flora of Central Europe: *Viscum album* L. *Flora*, 199(3): 81–203.

Biodiversity & Environment, 2026
Vol. 18, No. 1, 9–14 Original paper

Seasonal variability in yellow abdominal colour of *Episyrphus balteatus* (Syrphidae, Diptera)

JOZEF OBOŇA * & PETER MANKO

Department of Ecology, Faculty of Humanities and Natural Sciences, University of Prešov, 17. novembra 1, 081 16 Prešov, Slovakia

Abstract
This study analyses seasonal variation in yellow abdominal colouration in *Episyrphus balteatus* (de Geer, 1776) (Syrphidae, Diptera). A total of 643 field-collected specimens were examined. The proportion of yellow on abdominal tergites (T2–T5) was quantified from dorsal photographs using image analysis. Yellow colouration was highly variable in both sexes. Females were generally darker and showed greater variability than males. In both sexes, the highest proportion of yellow was consistently recorded on tergite 5, while yellow decreased anteriorly, with tergite 2 dominated by black pigmentation. Linear mixed-effects modelling revealed a significant sex × tergite interaction: the male advantage in yellow pigmentation amplified posteriorly, from 4.0 pp on T2 to 14.7 pp on T5. Day-of-year showed a marginally negative trend on yellow proportion ($\beta = -0.027$, $p = 0.053$), consistent with seasonal darkening.

Keywords: marmalade hoverfly, abdominal tergites, yellow colour

Introduction

Seasonal phenotypic plasticity in Diptera frequently affects body colour, body size, pilosity, and wing morphology. In Syrphidae, darker adults typically emerge during cooler periods, while lighter individuals occur during warmer seasons. These changes are largely influenced by temperature during pupal development (e.g. Dušek & Láska 1974; Heal 1981, 1989; Holloway 1993; Ottenheim et al. 1996).

Episyrphus balteatus (de Geer, 1776), commonly known as the marmalade hoverfly, is a widespread and abundant species in Europe (Speight 2011; Mazánek et al. 2025). It plays an important role in biological control of aphids (Hondelmann et al. 2005). In Central Europe, up to four generations per year have been reported (Nawrocka 1988). Both migration and overwintering contribute to population dynamics, but their relative importance remains unclear (Hondelmann & Poehling 2007). Previous studies suggested that seasonal variation in abdominal colour pattern may be linked to thermoregulation (Holloway et al. 1997). The duration of pupal development appears to be a key factor determining adult colour pattern (Ottenheim et al. 1995; Marriott & Holloway 1998). However, the proximate and ultimate causes of abdominal colour plasticity remain incompletely understood.

Unlike previous work that described seasonal trends qualitatively or at the species level, the present study provides quantitative, sex-resolved estimates of yellow pigmentation across four tergites simultaneously, accounting for the non-independence of within-individual measurements using linear mixed-effects modelling. The aim of this study was to quantify seasonal changes in yellow pigmentation on abdominal tergites (T2–T5) in males and females of *E. balteatus* and to describe sex-related differences.

Material and methods

Specimens were obtained from Malaise traps operated in 2008 in Šúr (Slovakia) at five habitats. Sampling was conducted at two-week intervals from April to early November. Specimens were preserved in ethanol, dried, and photographed dorsally under standardized laboratory conditions using a trinocular microscope (10× magnification).

The proportion of yellow pigmentation on tergites T2–T5 was measured from photographs using ImageJ software. Total tergite area and yellow area were measured manually using the Polygon Selection tool, and the percentage of yellow was calculated. Because sample sizes varied throughout the season, analyses were restricted to June, July, and August and evaluated by decades (10-day periods). Measurement error was assessed by repeated measurements of [N] selected specimens. Proportional error was highest on T2 and lowest on T3, consistent with the greater structural complexity and colour variability of the anterior tergite.

Yellow pigmentation (%) on tergites T2–T5 was analysed using linear mixed-effects models (LMM) fitted by maximum likelihood. Analyses were performed in R 4.3.3 (R Core Team 2024) using the packages lme4 (Bates et al. 2015), lmerTest (Kuznetsova et al. 2017), and nlme (Pinheiro et al. 2024). Because each specimen contributed four repeated measurements (one per tergite), individual identity was included as a grouping factor with a random intercept to account for within-individual correlation. Tergite position (coded 1–4) was included as a continuous random slope per specimen to model spatial autocorrelation between adjacent tergites. Temporal autocorrelation was addressed by including day-of-year (DOY), centred at its grand mean, as a continuous fixed-effect covariate. Six candidate models were compared using the Akaike Information Criterion

* Corresponding author: J. Oboňa. Email: jozef.obona@unipo.sk

(AIC; Table 1). Model M5 (nlme, with AR1 residual correlation structure) had the lowest AIC (1685.83); the next best model, M4 (lme4, without AR1 structure), had ΔAIC = 1.24. Although a ΔAIC below 2 represents weak support for one model over another, M5 was selected for inference because it directly and explicitly addresses the spatial autocorrelation between adjacent tergites, whereas M4 only approximates this through a random slope. The estimated AR1 autocorrelation parameter was $\varphi = 0.305$, confirming that residuals for adjacent tergites were moderately correlated within individuals. Fixed-effect coefficients with standard errors, p-values, and 95% Wald confidence intervals of the best model (M5, refitted with REML) are reported in Table 2. The complete dataset and R analysis script are available from the corresponding author upon reasonable request.

Results

A total of 643 specimens (328 females, 315 males) were examined. Most individuals (84%) were collected in July. Per-decade sample sizes were unequal: the largest subgroups were June decade 2 (females $n = 9$, males $n = 14$) and June decade 3 (females $n = 7$, males $n = 3$), while several periods – particularly late July and August – were represented by only one or two individuals per sex (Figures 3 and 4). Boxplot elements for decades with $n = 1$ represent single observations and should be interpreted with caution; model-based estimates (Table 2, Figure 1) are more reliable for inference as they pool information across the full seasonal range. Yellow pigmentation was highly variable in both sexes. Females were generally darker and showed greater variability than males. Across all decades and both sexes: the highest proportion of yellow was consistently recorded on T5; yellow pigmentation decreased anteriorly (T5 → T2); T2 showed the lowest proportion of yellow and was predominantly black.

Model selection based on AIC strongly supported model M5 (LME with AR1 residual correlation structure; ΔAIC ≥ 27 relative to all simpler models; Table 1). At the grand-mean day-of-year (DOY = 206, approximately 25 July), predicted yellow was 37.5% (females) vs. 41.5% (males) on T2, increasing to 80.7% vs. 95.4% on T5 (Table 2, Figure 1). The sex × tergite interaction was significant (Table 2), confirming that the male advantage grew progressively from T2 (difference: 4.0 pp, 95% CI: 1.0–7.1) to T5 (difference: 14.7 pp, 95% CI: 11.6–17.8). Day-of-year showed a marginally negative association with yellow pigmentation ($\beta = -0.027 \pm 0.014$ SE; 95% CI: −0.055 to 0.001; $p = 0.053$). Although this effect did not reach conventional significance, the direction is consistent with the known seasonal darkening trend.

The stepwise increase in yellow colouration from T2 to T5 was not uniform: the transitions between T2 and T3 (females: +21.6 pp; males: +24.4 pp) and between T4 and T5 (females: +16.8 pp; males: +22.5 pp) were substantially larger than the transition between T3 and T4 (females: +4.9 pp; males: +6.9 pp), indicating that T3 and T4 form a plateau of intermediate colouration (Table 2, Figure 1).

Greater individual variability in yellow proportion was observed in females than in males across all tergites, as visible in the seasonal variation plots (Figures 3 and 4).

Table 1. AIC comparison of candidate linear mixed-effects models for yellow abdominal colouration in *Episyrphus balteatus*. df = number of estimated parameters; logLik = log-likelihood; AIC = Akaike Information Criterion; ΔAIC = difference from best model. M0 included as reference only (violates independence assumption).

Model	Description	df	logLik	AIC	dAIC
M5	LME (nlme) – as M4 + AR1 residual correlation within individuals	14	-828.92	1685.83	0
M4	LMM (lme4) – random intercept + random tergite slope + sex × tergite	13	-830.54	1687.07	1.24
M2	LMM (lme4) – random intercept + random tergite slope per specimen	10	-846.75	1713.5	27.67
M1	LMM (lme4) – random intercept per specimen	8	-855.85	1727.7	41.87
M3	LMM (lme4) – random intercept + random DOY slope per specimen	10	-854.56	1729.11	43.28
M0	OLS – no random effects (violates independence; reference only)	7	-882.13	1778.26	92.43

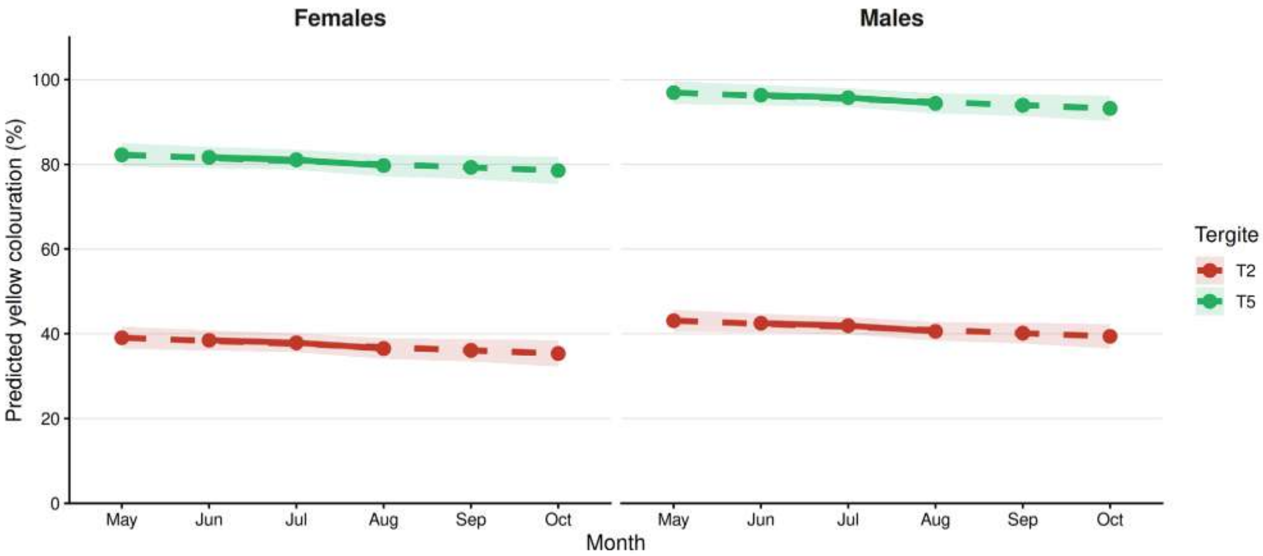

Figure 1. Seasonal trend in model-predicted yellow abdominal colouration (%) for tergites T2 and T5 in females and males of *Episyrphus balteatus* (de Geer, 1776). Lines = fixed-effect predictions of the best-fit model (M5) at the mean day-of-year of each calendar month (June – October); shaded ribbons = 95% Wald confidence intervals. The slight decline from summer to autumn is consistent with the marginally negative DOY effect (β = −0.027, p = 0.053; Table 2).

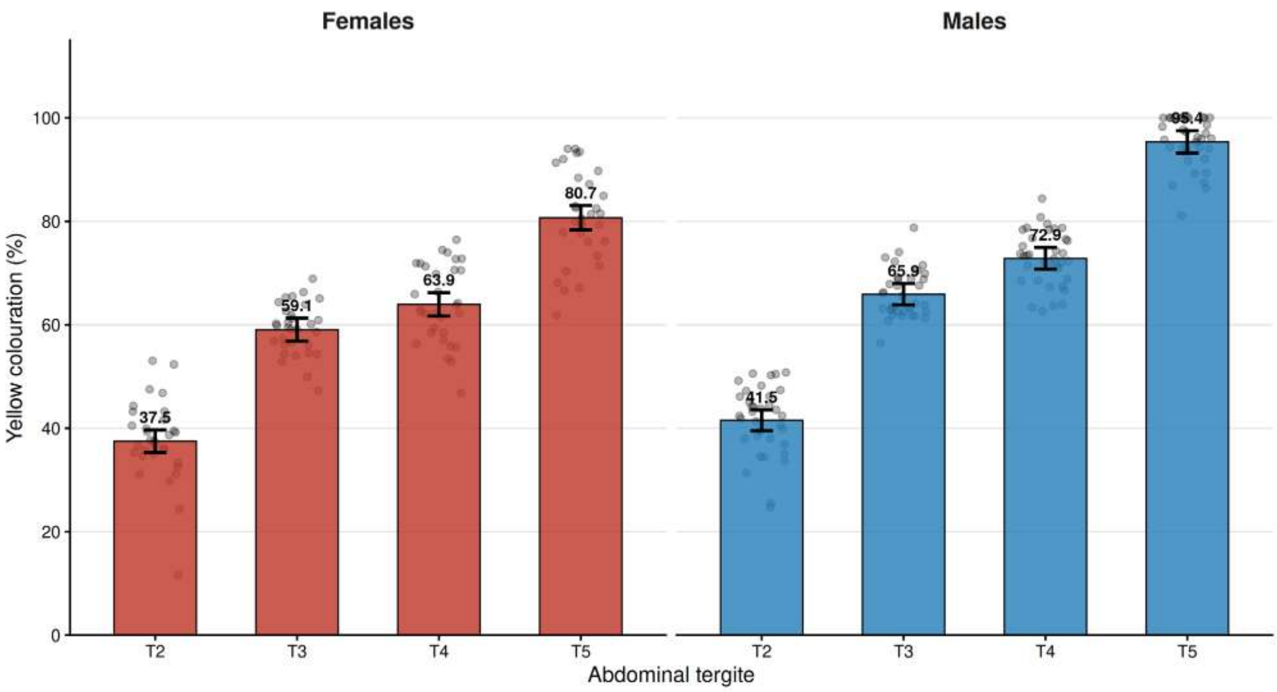

Figure 2. Model-predicted yellow abdominal colouration (%) by tergite and sex in *Episyrphus balteatus* (de Geer, 1776). Bars = population-level fixed-effect predictions of the best-fit model (M5, LME with AR1 residual correlation structure) evaluated at the grand-mean day-of-year (DOY = 206, approximately 25 July); error bars = 95% Wald confidence intervals; dots = individual observed values (jittered for clarity). Dashed lines indicate months outside the analytical range (June – August) and represent model extrapolation. Parameter estimates are given in Table 2.

Table 2. Fixed-effect coefficients of the best model (M5: LME with random intercept + random tergite slope per individual + AR1 residual correlation; refitted with REML). Reference category: tergite T2, sex Female, grand-mean DOY. SE = standard error; df = Satterthwaite degrees of freedom; CI = 95% Wald confidence interval.

Parameter	Estimate	SE	t value	df	p value	CI 95 lower	CI 95 upper
Intercept (T2, Female, mean DOY)	37.49	1.113	33.695	195	< 0.001	35.295	39.684
Tergite T3 vs T2	21.568	1.047	20.594	195	< 0.001	19.502	23.633
Tergite T4 vs T2	26.448	1.211	21.837	195	< 0.001	24.06	28.837
Tergite T5 vs T2	43.203	1.278	33.804	195	< 0.001	40.682	45.723
Sex: Male vs Female (at T2)	4.044	1.519	2.663	64	0.010	1.01	7.078
Day-of-year (centred)	-0.027	0.014	-1.974	64	0.053	-0.055	0.001
Tergite T3 x Male (interaction)	2.804	1.429	1.963	195	0.051	-0.013	5.622
Tergite T4 x Male (interaction)	4.868	1.652	2.946	195	0.004	1.61	8.127
Tergite T5 x Male (interaction)	10.614	1.744	6.088	195	< 0.001	7.175	14.053

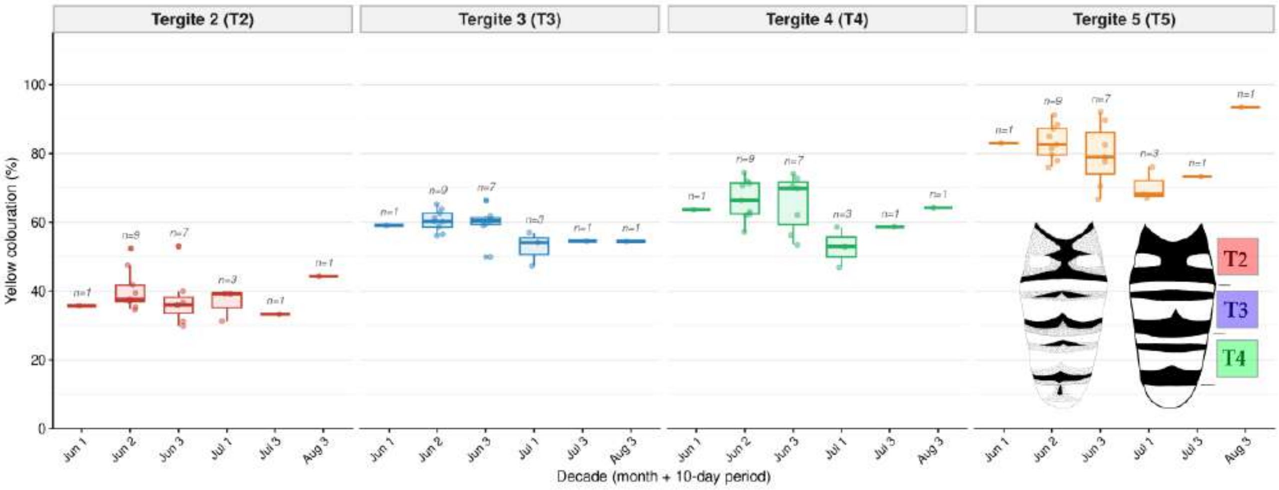

Figure 3. Seasonal variation in yellow abdominal colouration in females of *Episyrphus balteatus* (de Geer, 1776). (A) Schematic representation of the range of phenotypic variation: pale (summer) form (left) and dark (autumn/spring) form (right); labels indicate abdominal tergites T2–T4. (B) Observed values shown as boxplots by 10-day sampling decade (June – August) for each abdominal tergite (T2–T5). Box = interquartile range (IQR); centre line = median; whiskers = 1.5 × IQR beyond box edges; dots = individual specimens. Numbers above each box (n) indicate the count of individuals in that decade. Decades with zero observations are omitted. For model-predicted values see Figure 1. In the bottom right corner, extremely colored individuals are visualized, with the tergites displayed.

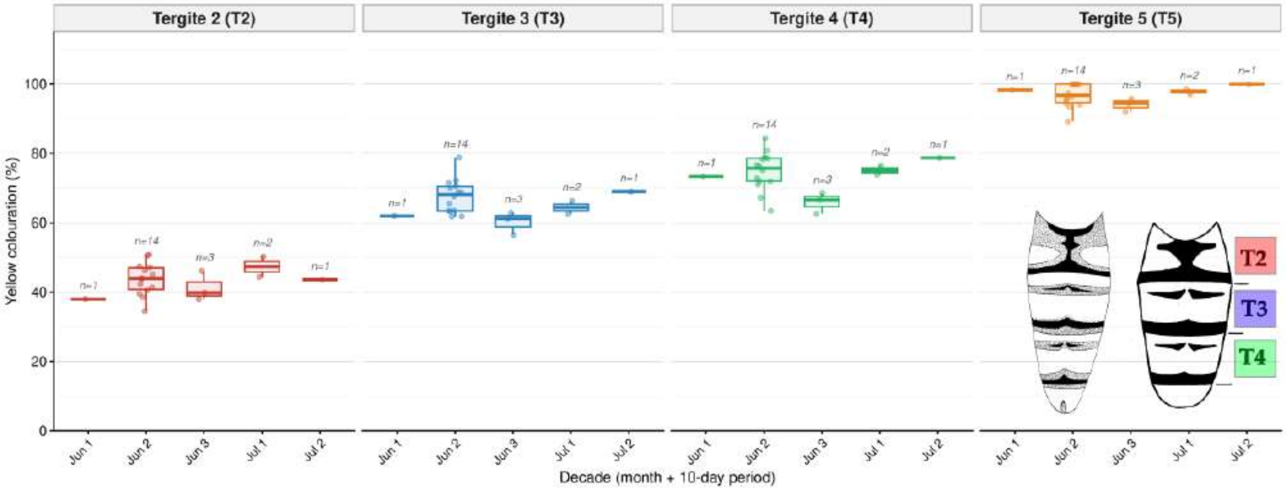

Figure 4. Seasonal variation in yellow abdominal colouration in males of *Episyrphus balteatus* (de Geer, 1776). (A) Schematic representation of the range of phenotypic variation: pale (summer) form (left) and dark (autumn/spring) form (right); labels indicate abdominal tergites T2–T4. (B) Observed values shown as boxplots by 10-day sampling decade (June – August) for each abdominal tergite (T2–T5). Box = interquartile range (IQR); centre line = median; whiskers = $1.5 \times$ IQR beyond box edges; dots = individual specimens. Numbers above each box (n) indicate the count of individuals in that decade. Decades with zero observations are omitted. For model-predicted values see Figure 1. In the bottom right corner, extremely colored individuals are visualized, with the tergites displayed.

Discussion

The use of linear mixed-effects models, which accounted for within-individual non-independence of tergite measurements and spatial autocorrelation between adjacent tergites, extended the previous qualitative and univariate findings with statistically robust, tergite-resolved estimates. The significant sex × tergite interaction indicates that sex differences in pigmentation are not uniform across the abdomen but amplify posteriorly, a pattern that warrants further investigation in the context of thermoregulatory or signalling hypotheses. The present study therefore confirms that abdominal yellow pigmentation in *E. balteatus* is highly variable across the season. Females were generally darker and exhibited greater variability than males. This pattern is consistent with findings of Marriott & Holloway (1998), who reported sex-specific differences in colour plasticity in this species. In both sexes, the highest proportion of yellow pigmentation was consistently recorded on T5, with a gradual decrease towards T2. T2 showed the lowest proportion of yellow and the greatest variability. A similar pattern of differential plasticity among tergites was reported by Marriott & Holloway (1998), who identified T2 as the most plastic segment and T3 as the least plastic. In our dataset, measurement error was highest on T2 and lowest on T3, which corresponds with the observed biological variability. Although measurement error does not explain the pattern, it reflects the higher structural variability of T2.

Seasonal variation in colour pattern in Syrphidae has repeatedly been linked to temperature-dependent phenotypic plasticity during the pupal stage (Dušek & Láska 1974; Heal 1981, 1989; Holloway 1993; Ottenheim et al. 1995, 1996). Holloway et al. (1997) demonstrated that darker individuals of *E. balteatus* are more frequent during cooler parts of the season, supporting a thermoregulatory hypothesis. Our results show clear seasonal variation in yellow proportion; however, because temperature data were not directly analysed in this study, we cannot test the thermoregulation hypothesis explicitly. The observed pattern is nevertheless consistent with previously described seasonal plasticity.

Periods of relatively lower yellow pigmentation visible in the third decade of June and the second decade of August in the seasonal plots (Figures 3 and 4) may reflect overlapping generations. In Central Europe, *E. balteatus* can produce up to four generations per year (Nawrocka 1988), and both migration and local overwintering contribute to seasonal population structure (Hondelmann & Poehling 2007; Speight 2011). Overlapping generations may therefore obscure clear temporal differentiation in colour pattern. Given that generations overlap substantially, precise assignment of individuals to particular generations is not possible based on sampling date alone. The proximate and ultimate bases of abdominal colour plasticity in hoverflies remain unresolved. Although thermoregulation has been proposed as a primary mechanism (Holloway et al. 1997), the developmental duration of the pupal stage appears to be a key proximate factor influencing adult colour pattern (Ottenheim et al. 1995; Marriott & Holloway 1998). Our results support the existence of strong phenotypic plasticity but do not allow discrimination between adaptive thermoregulatory function and developmental constraint. The finding that T3 and T4 form a plateau of intermediate colouration – with much smaller intertergite differences than the T2→T3 and T4→T5 transitions – is consistent with Marriott & Holloway (1998), who identified T2 as the most plastic and T3 as the least plastic segment. Whether this plateau reflects a developmental compartmentalisation of pigment deposition, or is partly an artefact of the increasing proportion of yellow area relative to tergite size in more posterior segments, warrants targeted experimental study.

Long-term sampling covering winter months, combined with direct environmental data (e.g. temperature during development), would allow stronger inference about the mechanisms underlying seasonal colour variation. Integration of multiple sampling methods may also improve temporal coverage. Image-based quantitative analysis, as applied here, provides a reliable and non-destructive approach for future studies of colour plasticity. The study is based on material from a single locality and season, and environmental variables were not directly measured. Overlapping generations and migration may also have influenced the observed seasonal patterns.

Acknowledgement

We are grateful to Oto Majzlan and Matej Žiak for providing the material used in this study. The authors also would like to thank Katarína Fogašová for her valuable assistance with the measurements. This work was supported by the Cultural and Educational Grant Agency of the Ministry of Education, Research, Development and Youth of the Slovak Republic, contract No. KEGA 014PU-4/2025. We are deeply grateful to reviewers for the exceptionally constructive comments and valuable suggestions regarding analytical approaches. These insights significantly contributed to improving the quality, rigor, and clarity of the manuscript.

References

Bates D, Müchler M, Bolker B, Walker S. 2015. Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software* 67(1): 1–48.

Dušek J, Láska P. 1974. Influence of temperature during pupal development on the colour of syrphid adults (Diptera: Syrphidae). *Folia Facultatis Scientiarum Naturalium Universitatis Purkynianae Brunensis (Biologia)* 15: 77–81.

Heal JR. 1981. Colour patterns of Syrphidae. III. Sexual dimorphism in *Eristalis arbustorum*. *Ecological Entomology* 6: 119–127.

Heal JR. 1989. Variation and seasonal changes in hoverfly species: interactions between temperature, age and genotype. *Biological Journal of the Linnean Society* 36: 251–269.

Holloway GJ. 1993. Phenotypic variation in colour pattern and seasonal plasticity in *Eristalis* hoverflies (Diptera: Syrphidae). *Ecological Entomology* 18: 209–217.

Holloway GJ, Marriott CG, Crocker HJ. 1997. Phenotypic plasticity in hoverflies: the relationship between colour pattern and season in *Episyrphus balteatus* and other Syrphidae. *Ecological Entomology* 22: 425–432.

Hondelmann P, Poehling H-M. 2007. Diapause and overwintering of the hoverfly *Episyrphus balteatus*. *Entomologia Experimentalis et Applicata* 124: 189–200.

Hondelmann P, Wyss U, Moelck G, Wagner M, Wittke M. 2005. The hoverfly Episyrphus balteatus: biology and mode of life. In: Reemer M, Smit JT, eds. *3rd International Symposium on Syrphidae, 2–5 September 2005, Leiden, The Netherlands*. Leiden, 40

Kuznetsova A, Brockhoff PB, Christensen RHB. 2017. lmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software* 82(13): 1–26.

Marriott CG, Holloway GJ. 1998. Colour pattern plasticity in the hoverfly *Episyrphus balteatus*: the critical immature stage and reaction norm on developmental temperature. *Journal of Insect Physiology* 44: 113–119.

Mazánek L, Hadrava J, Semelbauer M, Král M. 2025. Updated Checklist of the Syrphidae Latreille, 1802 of Czechia and Slovakia. In: Dvořák L, ed. *Checklist of Some Diptera Families of Czechia and Slovakia*. Biodiversity & Environment 17 (Special issue): 127–141.

Nawrocka B. 1988. Effectiveness of aphidophagous syrphids in controlling the cabbage aphid Brevicoryne brassicae L. In: Niemczyk E, Dixon AFG, eds. *Ecology and Effectiveness of Aphidophaga*. Haag: SPB Academia Publishing, 289–294.

Ottenheim MM, Waller GE, Holloway GJ. 1995. The influence of developmental rates of immature stages of *Eristalis arbustorum* (Diptera: Syrphidae) on adult abdominal colour pattern. *Physiological Entomology* 20: 343–348.

Pinheiro J, Bates D, R Core Team. 2024. *nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-164*. [Accessed 20 June 2026]. Available from: https://CRAN.R-project.org/package=nlme

R Core Team. 2024. *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. [Accessed 20 June 2026]. Available from: https://www.R-project.org/

Speight MCD. 2011. *Species Accounts of European Syrphidae (Diptera). Syrph the Net, the Database of European Syrphidae. Vol. 65.* Dublin: Syrph the Net Publications.

Biodiversity & Environment, 2026
Vol. 18, No. 1, 15–21 Original paper

Beekeeper practices associated with Varroa mite (*Varroa destructor*) infestation and colony losses in Eastern Slovakia

EMMA JUHÁZY[1] & ALEXANDER CSANÁDY [2*]

[1] *Department of Biology, Faculty of Humanities and Natural Sciences, University of Prešov, 17. novembra 1, 081 16 Prešov, Slovakia,*
[2] *Department of Ecology, Faculty of Humanities and Natural Sciences, University of Prešov, 17. novembra 1, 081 16 Prešov, Slovakia*

Abstract
Varroa destructor – external parasitic mite is among the most serious biotic threats affecting honey bee colonies worldwide. This study evaluated associations between beekeeper practices, reported infestation, colony losses and perceived effects on honey production in Eastern Slovakia. Data were obtained from a questionnaire survey of 154 beekeepers and analysed using descriptive statistics and the chi-square test of independence. Regular monitoring was significantly associated with lower reported infestation levels (χ^2 = 26.24, df = 9, P = 0.0019, Cramér's V = 0.24). Regular treatment frequency was significantly associated with lower colony losses (χ^2 = 27.58, df = 9, P = 0.0011, Cramér's V = 0.24). A significant relationship was also found between infestation level and perceived reduction in honey production (χ^2 = 33.05, df = 9, P = 0.0001, Cramér's V = 0.27), and between beekeeper sex and monitoring frequency (χ^2 = 11.03, df = 3, P = 0.0116, Cramér's V = 0.27). No significant associations were detected for beekeeper type and knowledge level, locality and infestation level, or perceived resistance and treatment type. The findings emphasise the practical importance of regular monitoring and treatment practices, together with beekeeper education, for effective varroosis management.

Keywords: *Apis mellifera*; apiculture; colony loss; honey production; monitoring; varroosis

Introduction

The western honey bee, *Apis mellifera* Linnaeus, 1758 (Hymenoptera: Apidae), is a key pollinator in both, natural and agricultural ecosystems. However, honey bee colonies are currently affected by multiple stressors, including habitat degradation, pesticide exposure, climate-related factors and pathogens. Among these, the ectoparasitic mite *Varroa destructor* Anderson et Trueman, 2000 (Mesostigmata: Varroidae) is regarded as one of the most harmful agents affecting colony survival and productivity (Genersch 2010; Rosenkranz et al. 2010; Toporčák 2012).

In addition to direct parasitism, *V. destructor* acts as an important vector of viral pathogens, particularly deformed wing virus and acute bee paralysis virus, thereby substantially worsening colony health (Martin et al. 2012; Ryabov et al. 2014). Because mite population growth may remain unnoticed until colony condition is already compromised, regular monitoring is considered essential for effective varroosis management (Dietemann et al. 2013; Nazzi & Le Conte 2016). Standard monitoring approaches include natural mite fall counts, alcohol wash, powdered sugar roll, CO_2 testing and other validated methods that differ in their sensitivity and practical application (Dietemann et al. 2013).

Control of varroosis generally relies on combinations of monitoring, chemical or organic treatments, and zootechnical or biotechnical practices, including drone brood removal, brood interruption and other integrated management measures. The success of these measures depends not only on the biology of the parasite, but also on beekeeper knowledge, experience and management consistency (Calderone 2005; Rosenkranz et al. 2010; Toporčák 2012; Nazzi & Le Conte 2016; Ritter 2018; Rangel & Ward 2018; Toporčák & Chlebo 2018; Urban 2018; Bava et al. 2022; Porporato et al. 2022; Toporčák & Fiľo 2023; Cook et al. 2024; Horr & Krupan 2025a, b). The present study therefore aimed to evaluate whether selected beekeeper-reported management practices, particularly monitoring and treatment frequency, are associated with reported *V. destructor* infestation, colony losses and perceived effects on honey production in Eastern Slovakia.

Materials and methods

Study design

The study was based on a questionnaire survey conducted among 154 beekeepers in Eastern Slovakia. The questionnaire collected self-reported information on beekeeping experience, number of managed colonies, apiary locality, frequency of *V. destructor* monitoring, the monitoring method most commonly used (sticky boards, alcohol wash, powdered sugar test or other methods), perceived infestation level, colony losses, treatment method, treatment frequency, perceived treatment resistance, self-assessed knowledge of varroosis and the perceived impact of infestation on honey production.

Monitoring frequency was classified into four categories (regularly, occasionally, rarely and no monitoring). Respondents also indicated the monitoring method they most used. The level of *V. destructor* infestation was recorded as the respondent's own assessment using the categories low, medium, high and unknown; no standardized quantitative thresholds were defined in the questionnaire.

* Corresponding author: A.Csanády. Email: alexander.csanady@unipo.sk

Treatment practices were recorded according to the respondents declared management strategy (chemical treatment, organic acids, biotechnical methods, combined treatment or no treatment) together with the reported frequency of treatment. The questionnaire did not record the seasonal timing of treatment applications or the specific biotechnical procedures used.

Variables analysed
The following relationships were tested:
1. reported monitoring frequency × reported infestation level
2. reported treatment frequency × reported colony loss
3. reported beekeeper type × reported knowledge level
4. reported locality × reported infestation level
5. reported infestation level × reported perceived impact on honey production
6. reported perceived resistance × reported treatment type
7. reported beekeeper sex × reported monitoring frequency

It should be noted that, since the study was based on questionnaires, no independent verification was conducted of the reported levels of infestation or the procedures used to manage them.

Statistical analysis
Data were processed using descriptive statistics, graphical presentation and the chi-square test of independence. Associations were considered significant at $\alpha = 0.05$. Effect size was expressed as Cramér's *V*.
Statistical analyses were performed using GraphPad Prism version 5.01 (GraphPad Software Inc., San Diego, CA, USA).

Results
Beekeeping profile of respondents
A total of 154 respondents participated in the questionnaire survey. Their responses were analysed using descriptive statistics and the chi-square test of independence to evaluate relationships among beekeeper practices, infestation level, colony losses and perceived production effects.
Most respondents had long-term beekeeping experience. As shown in Figure 1, 40% of respondents had more than 10 years of beekeeping experience, 30% had 6–10 years, 22% had 2–5 years, and 8% had less than 2 years of practice.
With respect to the number of managed colonies, 40% of respondents kept 11–30 colonies, 35% kept 1–10 colonies, 15% managed 31–50 colonies, and 10% kept more than 50 colonies (Figure 2). The surveyed sample therefore predominantly represented small-scale beekeeping operations.

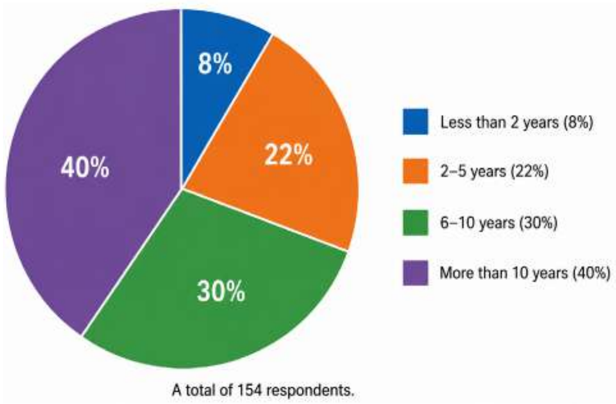

Figure 1. Length of beekeeping experience among respondents.

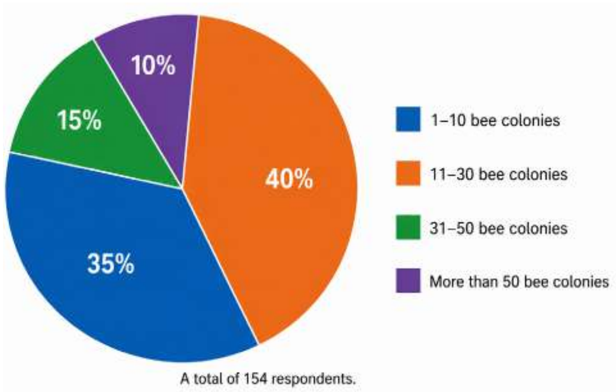

Figure 2. Number of honeybee colonies managed by respondents.

Monitoring and infestation level
The frequency of *V. destructor* among respondents is shown in Figure 3. Regular monitoring was reported by 40% of respondents, occasional monitoring by 35%, rare monitoring by 15%, while 10% stated that they did not monitor mite occurrence at all.
The relationship between reported monitoring frequency and the reported infestation level is presented in Table 1. Respondents who monitored their colonies regularly more frequently reported low infestation levels, whereas respondents monitoring rarely or not at all more frequently reported medium or high infestation levels. The chi-square test revealed a statistically significant association between monitoring frequency and infestation level ($\chi^2 = 26.24$, df = 9, P = 0.0019, Cramér's V = 0.24).

Table 1. Relationship between monitoring frequency and infestation level.

Monitoring frequency	Low	Medium	High	Unknown	Total
Regularly	13	34	9	6	62
Occasionally	5	34	13	2	54
Rarely	1	8	9	5	23
Do not monitor	1	4	5	5	15
Total	20	80	36	18	154

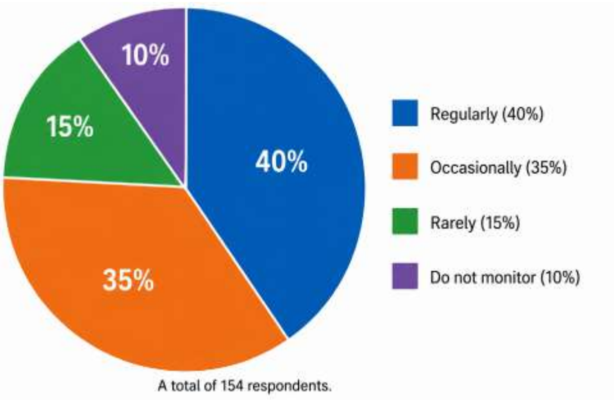

Figure 3. Frequency of *Varroa destructor* monitoring among respondents.

Treatment and colony losses

Annual colony losses associated with *V. destructor* infestation are summarised in Figure 4. The largest proportion of respondents (45%) reported colony losses of 11–25%, whereas 26% reported losses of 0–10%. Higher losses of 26–50% were reported by 19% of respondents, while losses exceeding 50% were reported by 10%.

The relationship between treatment frequency and colony loss is presented in Table 2. Respondents reporting regular treatment more frequently reported lower colony losses, whereas respondents treating only as needed, rarely or not at all more frequently reported higher colony losses. The chi-square test revealed a statistically significant association between treatment frequency and colony loss ($\chi^2 = 27.58$, df = 9, P = 0.0011, Cramér's V = 0.24).

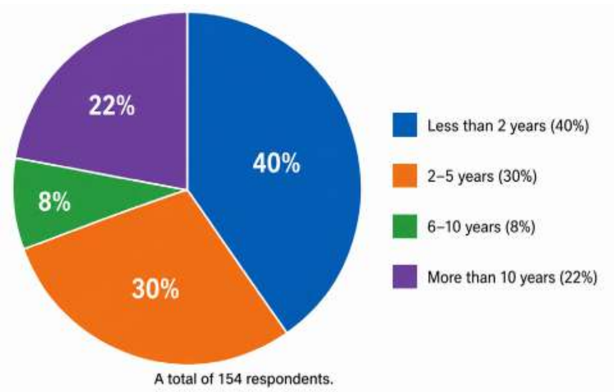

Figure 4. Annual colony losses attributed to *Varroa destructor* infestation.

Table 2. Relationship between treatment frequency and colony loss.

Treatment frequency	0–10%	11–25%	26–50%	>50%	Total
Regularly	29	35	9	4	77
As needed	9	23	8	6	46
Rarely	2	6	6	1	15
No treatment	0	5	7	4	16
Total	40	69	30	15	154

Beekeeper type and knowledge

The structure of respondents according to reported beekeeper type is shown in Figure 5. Hobby beekeepers represented the largest group (55%), followed by semi-professional beekeepers (30%) and professional beekeepers (15%).

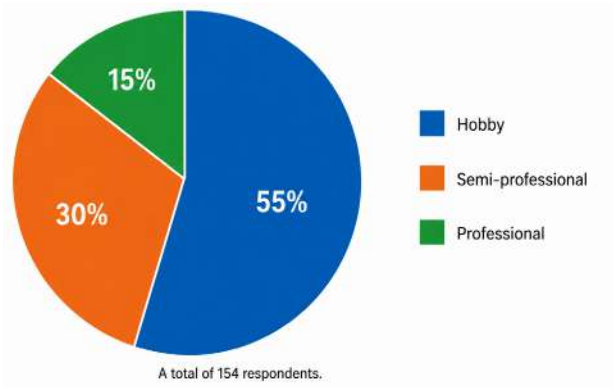

Figure 5. Type of beekeeping activity among respondents.

Self-reported knowledge of varroosis is summarised in Figure 6. More than half of respondents (51%) considered their knowledge sufficient, whereas 26% reported insufficient knowledge. High knowledge was reported by 16% of respondents, while 7% stated that they had no knowledge of the issue.

The relationship between reported beekeeper type and reported knowledge level is presented in Table 3. Although professional beekeepers more frequently reported high or sufficient knowledge than hobby beekeepers, the association was not statistically significant ($\chi^2 = 8.30$, df = 6, P = 0.217, Cramér's V = 0.16)

Table 3. Relationship between beekeeper type and knowledge level.

Beekeeper type	High	Sufficient	Insufficient	None	Total
Hobby	9	42	28	6	85
Semi-professional	9	24	10	3	46
Professional	6	13	2	2	23
Total	24	79	40	11	154

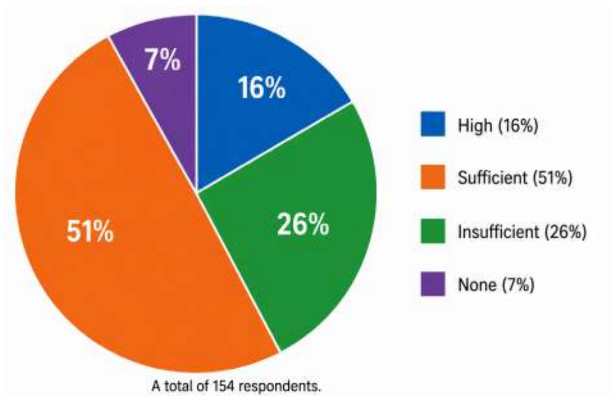

Figure 6. Self-reported knowledge of beekeepers about varroosis.

Locality and infestation level

The reported infestation level of *V. destructor* is shown in Figure 7. Medium infestation was the most frequently reported category (57% of respondents), followed by high infestation (22%) and low infestation (12%). The remaining 9% of respondents were unable to assess the infestation level in their apiaries.

The relationship between reported locality and reported infestation level is presented in Table 4. Although respondents from rural and mountainous areas more frequently reported medium or high infestation levels, the association between locality and infestation level was not statistically significant ($\chi^2 = 13.02$, df = 9, P = 0.1619, Cramér's V = 0.17).

The seasonal period of the highest occurrence of *V. destructor* is shown in Figure 8. Most respondents reported the highest occurrence at the end of summer (45%), followed by autumn (30%) and summer (15%). Lower frequencies were reported for spring and winter (5% each).

Table 4. Relationship between locality and infestation level.

Locality	Low	Medium	High	Unknown	Total
Urban	1	6	4	1	12
Rural	12	55	15	10	92
Mountain	2	14	12	3	31
Lowland	4	13	2	0	19
Total	19	88	33	14	154

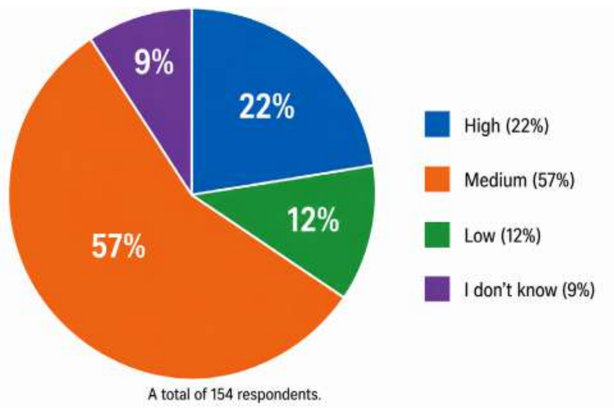

Figure 7. Reported level of *Varroa destructor* infestation in apiaries.

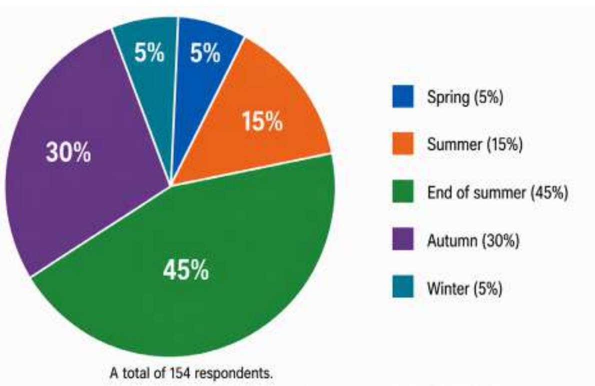

Figure 8. Seasonal period of the highest occurrence of *Varroa destructor*.

Infestation level and honey production

The relationship between reported infestation level and the reported perceived effect on honey production is presented in Table 5. Respondents reporting medium or high infestation levels more frequently perceived a moderate or strong reduction in honey production, whereas respondents reporting low infestation more often reported little or no effect. The chi-square test revealed a statistically significant association between infestation level and perceived reduction in honey production ($\chi^2 = 33.05$, df = 9, P = 0.0001, Cramér's V = 0.27).

Table 5. Relationship between infestation level and honey production.

Infestation level	Strong decrease	Moderate decrease	No effect	Unknown	Total
Low	5	10	2	2	19
Medium	28	40	7	13	88
High	18	13	2	0	33
Unknown	1	5	7	1	14
Total	52	68	18	16	154

Treatment methods and perceived resistance

Preferred treatment strategies are summarised in Figure 9. Combined treatment approaches were the most frequently reported method (43%), followed by organic acid treatments (30%). Chemical treatment was reported by 14% of respondents, biotechnical methods by 10%, whereas 3% stated that they did not treat *V. destructor*.

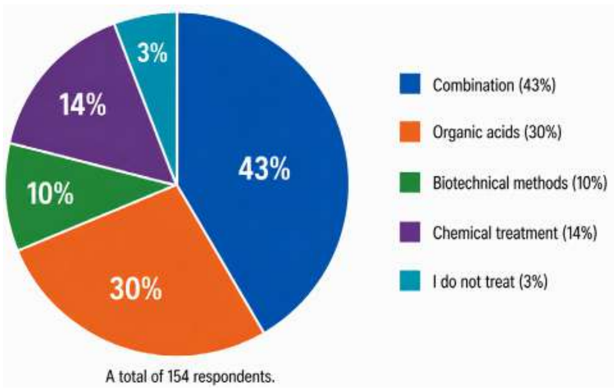

Figure 9. Treatment methods used against *Varroa destructor* by respondents.

Interest in new treatment methods is shown in Figure 10. Occasional interest in new treatment approaches was reported by 45% of respondents, whereas 30% regularly searched for and tested new methods. The remaining 25% of respondents reported no interest in new treatment strategies.

The relationship between reported perceived mite resistance and reported treatment type is presented in Table 6. Although some variation among treatment categories was observed, the association was not statistically significant ($\chi^2 = 11.52$, df = 8, P = 0.1741, Cramér's V = 0.19).

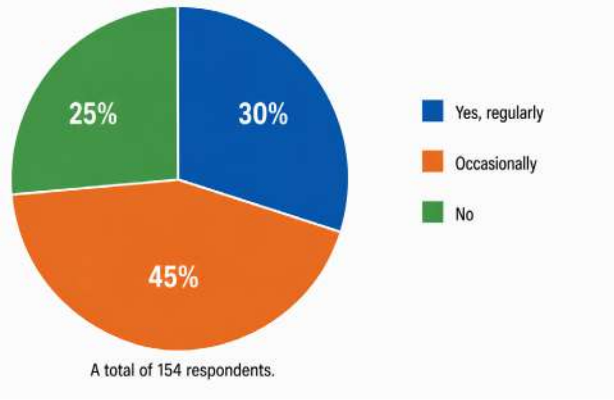

Figure 10. Interest of respondents in searching for and testing new treatment methods against *Varroa destructor*.

Sex and monitoring frequency

The relationship between reported beekeeper sex and reported monitoring frequency is presented in Table 7. Male respondents more frequently reported regular monitoring, whereas female respondents were proportionally more represented in less frequent monitoring categories. The chi-square test revealed a statistically significant association between sex and monitoring frequency ($\chi^2 = 11.03$, df = 3, P = 0.0116, Cramér's V = 0.27). However, this finding should be interpreted cautiously because the analysed sample was strongly male-biased, which may have influenced the observed association.

Table 6. Relationship between perceived resistance and treatment type.

Resistance	Chemical	Organic acids	Biotechnical	Combination	No treatment	Total
Yes	9	21	5	19	0	54
No	4	14	2	18	1	39
Unknown	9	11	9	29	3	61
Total	22	46	16	66	4	154

Table 7. Relationship between beekeeper sex and monitoring frequency.

Sex	Regularly	Occasionally	Rarely	No monitoring	Total
Male	56	47	15	10	128
Female	6	7	8	5	26
Total	62	54	23	15	154

Discussion

The present study provides further evidence that *V. destructor* remains one of the principal threats affecting honey bee colony health and productivity. The overall pattern of responses is consistent with previous studies identifying this ectoparasitic mite as a major factor contributing to colony weakening, viral transmission and increased colony mortality (Rosenkranz et al. 2010; Genersch 2010; Ryabov et al. 2014).

One of the most important findings of the present study was the significant relationship between monitoring frequency and infestation level. Respondents who monitored their colonies regularly more frequently reported lower infestation levels than beekeepers performing only occasional or no monitoring. These findings support previous conclusions that regular monitoring represents a fundamental component of effective varroosis management (Dietemann et al. 2013; Nazzi & Le Conte 2016). However, the present questionnaire evaluated primarily the reported frequency of monitoring and did not distinguish between the effectiveness of different diagnostic approaches. Consequently, the present study cannot assess whether monitoring methods differ in their ability to detect increasing mite populations or reduce colony losses. Early detection of increasing mite populations allows timely intervention and may reduce the probability of severe infestation and colony decline.

A similarly important result was the significant association between reported treatment frequency and colony losses. Respondents reporting regular treatment more frequently reported lower annual colony losses, whereas irregular treatment or absence of treatment was associated with higher mortality. Although these findings are consistent with current knowledge of varroosis management, the questionnaire did not record the seasonal timing of treatment. Consequently, no conclusions can be drawn regarding the influence of treatment timing, which is considered an important determinant of successful Varroa control (Rosenkranz et al. 2010; Jack et al. 2023).

Although professional beekeepers more frequently reported high or sufficient knowledge levels than hobby beekeepers, the relationship between beekeeper type and knowledge level was not statistically significant. This suggests that practical experience and individual interest in bee health management may influence knowledge acquisition independently of beekeeper category. Nevertheless, the descriptive pattern observed in the present study generally supports previous findings emphasising the importance of beekeeper education and management experience for successful disease control (Jacques et al. 2017).

The relationship between locality and infestation level was also not statistically significant. Although respondents from rural and mountainous areas more frequently reported medium or high infestation levels, the observed variation among localities was insufficient to support a clear geographic effect. These results suggest that colony management practices may exert stronger effects on infestation dynamics than locality alone within the studied region. Another factor that may contribute to infestation dynamics is the density of neighbouring apiaries and the associated risk of mite reinvasion. This variable was not included in the questionnaire and therefore could not be evaluated, although it may represent a more direct determinant of infestation pressure than the general classification of apiary locality. Similar conclusions were reported by Smoliński et al. (2021), who emphasised that environmental and climatic factors interact with management practices, colony condition and local environmental characteristics.

The significant association between infestation level and perceived reduction in honey production further supports the importance of *V. destructor* as a major economic and biological threat in apiculture. Respondents reporting higher infestation levels more frequently indicated moderate or severe decreases in honey production. Previous studies similarly demonstrated that mite infestation negatively affects colony vitality, worker longevity and foraging efficiency, which may ultimately reduce colony productivity (Medina-Flores et al. 2011).

No statistically significant relationship was detected between perceived mite resistance and treatment type. This may reflect the multifactorial nature of treatment efficacy, which depends not only on resistance development, but also on treatment timing, dosage, rotation of active substances and overall colony condition. In addition, the questionnaire did not distinguish between individual biotechnical practices, such as drone brood removal, brood interruption or queen replacement, which may also influence treatment effectiveness. Nevertheless, resistance to acaricides remains an important concern in modern apiculture, particularly under repeated use of identical active compounds (Elzen et al. 1999). The present findings therefore support recommendations favouring integrated and rotational treatment strategies.

The significant relationship detected between beekeeper sex and monitoring frequency should be interpreted cautiously because the analysed sample was strongly male-biased. Consequently, the observed pattern may partly reflect unequal sample structure rather than biologically meaningful behavioural differences. Additional studies using more balanced respondent samples would be necessary to evaluate this relationship more reliably.

Several limitations of the present study should also be acknowledged. The analyses were based on self-reported questionnaire data rather than direct field measurements, and several evaluated variables reflected respondent perception rather than objectively quantified infestation or production parameters. Infestation level was based on respondents' own assessment, and no standardized quantitative thresholds were applied. Furthermore, although the questionnaire included information on monitoring methods, the present study focused primarily on monitoring frequency and therefore did not evaluate differences among individual monitoring methods. In addition, the questionnaire did not record the seasonal timing of treatment or specific biotechnical management practices. Finally, the study was geographically restricted to Eastern Slovakia, and variables such as apiary density or the risk of mite reinvasion from neighbouring colonies were not assessed. Despite these limitations, the study provides useful information on beekeeper behaviour, management practices and perceived impacts of *V. destructor* under regional apicultural conditions.

Conclusion

The present study showed that beekeeper practices were significantly associated with several important aspects of *Varroa destructor* management and colony health in Eastern Slovakia. Regular monitoring was associated with lower reported infestation levels, whereas regular treatment was associated with lower annual colony losses. In addition, higher reported infestation levels were significantly associated with a perceived reduction in honey production.

In contrast, no statistically significant relationships were detected between beekeeper type and knowledge level, locality and infestation level, or perceived resistance and treatment type. These findings suggest that colony management practices, particularly regular monitoring and treatment, may represent more important determinants of infestation dynamics than beekeeper category or locality alone.

The results emphasise the importance of regular monitoring, regular treatment and continued beekeeper education for effective varroosis management. Despite the limitations associated with questionnaire-based and self-reported data, the study provides useful insight into beekeeper behaviour and management strategies under regional apicultural conditions in Eastern Slovakia.

References

Bava R, Castagna F, Piras C, Musolino V, Lupia C, Palma E, Britti D, Musella V. 2022. Entomopathogenic fungi for pests and predators control in beekeeping. *Veterinary Sciences* 9(2): 95.

Calderone NW. 2005. Evaluation of drone brood removal for management of *Varroa destructor* (Acari: Varroidae) in colonies of *Apis mellifera* (Hymenoptera: Apidae) in the northeastern United States. *Journal of Economic Entomology* 98(3): 645–650.

Cook S, Posada-Florez F, Sonenshine D, Evans J, Boncristiani D, Pava-Ripoll M. 2024. Natural enemies of *Varroa destructor* identified from eastern North American honey bee colonies: A biological survey of candidates for mite control from Maryland, USA. *Biocontrol Science and Technology* 35(1): 52–70.

Dietemann V, Nazzi F, Martin SJ, Anderson D, Locke B, Delaplane KS, Wauquiez Q, Tannahill C, Frey E, Ziegelmann B, Rosenkranz P, Ellis JD. 2013. Standard methods for *Varroa* research. *Journal of Apicultural Research* 52(1): 1–54.

Elzen PJ, Baxter JR, Spivak M, Wilson WT. 1999. Amitraz resistance in *Varroa*: New discovery in North America. *American Bee Journal* 139: 362.

Genersch E. 2010. Honey bee pathology: Current threats to honey bees and beekeeping. *Applied Microbiology and Biotechnology* 87: 87–97.

Horr B, Krupan F. 2025a. *Almanach moderného včelára. 1. časť.* Nitra: PTH.

Horr B, Krupan F. 2025b. *Almanach moderného včelára. 2. časť.* Nitra: PTH.

Jack CJ, de Bem Oliveira I, Kimmel CB, Ellis JD. 2023. Seasonal differences in *Varroa destructor* population growth in western honey bee (*Apis mellifera*) colonies. *Frontiers in Ecology and Evolution* 11: 1102457.

Jacques A, Laurent M, Ribière-Chabert M, Saussac M, Bougeard S, Budge GE, Hendrikx P, Chauzat MP. 2017. A pan-European epidemiological study reveals honey bee colony survival depends on beekeeper education and disease control. *PLoS ONE* 12(3): e0172591.

Martin SJ, Highfield AC, Brettell L, Villalobos EM, Budge GE, Powell M, Nikaido S, Schroeder DC. 2012. Global honey bee viral landscape altered by a parasitic mite. *Science* 336: 1304–1306.

Medina-Flores CA, Guzmán-Novoa E, Hamiduzzaman MM, Aréchiga-Flores CF, López-Carlos MA. 2011. Africanized honey bees (*Apis mellifera*) have low infestation levels of the mite *Varroa destructor* in different ecological regions in Mexico. *Genetics and Molecular Research* 10(4): 2432–2440.

Nazzi F, Le Conte Y. 2016. Ecology of *Varroa destructor*, the major ectoparasite of the western honey bee, *Apis mellifera*. *Annual Review of Entomology* 61: 417–432.

Porporato M, Manino A, Cuttini D, Lorenzon S, Ciaudano S, Parodi V. 2022. *Varroa* control by means of a hyperthermic device. *Applied Sciences* 12(16): 8138.

Rangel J, Ward L. 2018. Evaluation of the predatory mite *Stratiolaelaps scimitus* for the biological control of the honey bee ectoparasitic mite *Varroa destructor*. *Journal of Apicultural Research* 57(3): 425–432.

Ritter W. 2018. *Zdravé včely: Prevencia, diagnostika a liečba chorôb.* Bratislava: Citadella.

Rosenkranz P, Aumeier P, Ziegelmann B. 2010. Biology and control of *Varroa destructor*. *Journal of Invertebrate Pathology* 103: S96–S119.

Ryabov EV, Wood GR, Fannon JM, Moore JD, Bull JC, Chandler D, Mead A, Burroughs N, Evans DJ. 2014. A virulent strain of deformed wing virus is associated with colony losses and vectored by *Varroa destructor*. *PLoS Pathogens* 10: e1004230.

Smoliński S, Langowska A, Głazaczow A. 2021. Raised seasonal temperatures reinforce autumn *Varroa destructor* infestation in honey bee colonies. *Scientific Reports* 11: 22256.

Toporčák J, Chlebo R. 2018. *Veterinárna a produkčná prax vo včelárstve.* Bratislava: Slovenský zväz včelárov.

Toporčák J, Fiľo P. 2023. *Metodika na celoročné ošetrovanie včelstiev proti kliešťikovosti.* Bratislava: Slovenský zväz včelárov.

Toporčák J. 2012. *Hodnotenie rizika pre SR – Varroóza (Varroa destructor).* Košice: Univerzita veterinárskeho lekárstva a farmácie v Košiciach.

Urban M. 2018. *Včelaření od jara do zimy.* Praha: Grada Publishing.

Biodiversity & Environment, 2026
Vol. 18, No. 1, 22–29

Original paper

Faunistic notes on butterflies (Lepidoptera: Hesperioidea, Papilionoidea) from selected localities in Montenegro

ALEXANDER CSANÁDY [1*], JOZEF OBOŇA [1], PETER MANKO [1], JAKUB FEDORČÁK [1], BRANISLAV TEJ [1], LAURA MLYNÁROVÁ [1], MILICA JOVANOVIĆ [2] & VLADIMIR PEŠIĆ [2]

[1] *Department of Ecology, Faculty of Humanities and Natural Sciences, University of Prešov, 17. novembra 1, 081 16 Prešov, Slovakia,*
[2] *Department of Biology, University of Montenegro, Cetinjski put 2, 81000 Podgorica, Montenegro*

Abstract
A short-term faunistic survey of butterflies was conducted at six localities in Montenegro during May 2026. The surveyed localities represented a mosaic of habitat types, including wetland habitats, riverine vegetation, montane meadows, ecotonal habitats, and semi-natural rural landscapes distributed across continental and mountainous regions of the country. A total of 75 individuals belonging to 20 taxa and 6 families were recorded. Nymphalidae was the most abundant family (26 individuals), followed by Lycaenidae (22 individuals) and Pieridae (18 individuals). The highest species richness was recorded at Etno Selo Vrelo (Berane) in northeastern Montenegro, where 10 taxa and 24 individuals were observed, whereas Pošćensko jezero (Durmitor NP) and Plav yielded the lowest diversity, each with a single species. The most abundant species was *Coenonympha pamphilus* (12 individuals), followed by *Leptidea sinapis* and *Polyommatus icarus* (9 individuals each). Several taxa were restricted to a single locality, including *Papilio machaon*, *Carterocephalus palaemon*, and *Glaucopsyche alexis*, each recorded from a single locality. The assemblage was dominated by Palaearctic and West Palaearctic faunistic elements; the Pontomediterranean *Cupido decolorata* was noteworthy as an indicator of the xerothermic character of certain investigated habitats and the presence of south-eastern European biogeographical affinities in the studied area. Despite the limited sampling period, the study contributes additional distributional and ecological data on the butterfly fauna of Montenegro and expands current knowledge of butterfly diversity in the investigated region.

Key words: butterflies, Lepidoptera, Hesperioidea, Papilionoidea, faunistics, biodiversity, Montenegro, short-term survey, species diversity

Introduction

Butterflies are among the best-studied insect groups in Europe and serve as important bioindicators due to their sensitivity to habitat alteration and their dependence on specific host plants and habitat conditions (Erhardt & Thomas 1991; Fox 2013). Consequently, butterfly assemblages are widely used to assess the conservation status and ecological integrity of terrestrial ecosystems.

In recent decades, butterfly populations throughout Europe have declined mainly because of habitat loss, agricultural intensification, abandonment of traditional land use, urbanisation, fragmentation of semi-natural habitats, and climate change (Maes & Van Dyck 2001; Sánchez-Bayo & Wyckhuys 2019). These negative trends affect both habitat specialists and widespread generalist species, leading to substantial reductions in regional biodiversity and ecosystem functioning. Similar patterns have also been reported from the Balkan Peninsula, where many ecologically valuable grassland and mountain habitats are increasingly threatened by land-use changes and succession processes.

Despite its relatively small territory, Montenegro represents one of the biologically most diverse countries in the Balkan Peninsula due to its pronounced geomorphological heterogeneity, climatic variability, and the presence of diverse habitat types ranging from Mediterranean coastal ecosystems to mountainous continental environments (Franeta 2018). These environmental conditions create suitable habitats for a remarkably rich butterfly fauna. According to the most recent checklist, 192 butterfly species have been recorded in Montenegro, representing a substantial proportion of the European butterfly fauna (Franeta 2018).

Research on the butterfly fauna of Montenegro dates to the late nineteenth century, with the pioneering faunistic observations of Nicholl (1899). More systematic investigations were subsequently conducted by Rebel (1913), Rebel & Zerny (1931), Carnelutti & Michieli (1958), Sijarić (1984), and Jakšić (1988), while additional faunistic and distributional data were later supplemented by numerous regional studies (Franeta 2018). Although the butterfly fauna of Montenegro has been relatively well documented (Franeta 2018), additional local faunistic surveys continue to provide valuable distributional and ecological records that complement existing knowledge of the country's butterfly fauna. Recent conservation assessments indicate increasing threats to butterfly diversity in Montenegro. The Red List of Butterflies of Montenegro evaluated all 192 recorded species in the country, of which 35 species were classified within threatened categories or considered regionally vulnerable (Roganović & Malidžan 2023). The importance of butterflies as ecological indicators and conservation targets has therefore gained increasing attention within biodiversity monitoring and nature protection programmes.

The present study provides faunistic notes on butterflies recorded during a short-term survey conducted in selected localities of Montenegro in May 2026. The study aimed to document species composition, relative abundance, habitat affiliation, and faunistic characteristics of the recorded

* Corresponding author: A. Csanády. Email: alexander.csanady@unipo.sk

butterfly assemblages and to contribute additional data to the knowledge of Montenegrin butterfly fauna.

Materials and methods

Study area

The field survey was conducted on 19 and 20 May 2026 at six investigated localities in Montenegro (Figures 1 and 2). The investigated sites represented a mosaic of habitat types, including montane meadows, river valleys, wetland habitats, forest edges, canyon habitats, and anthropogenically influenced rural areas. The surveyed localities covered both continental and mountainous regions of Montenegro and ranged from lowland habitats to montane lake surroundings.

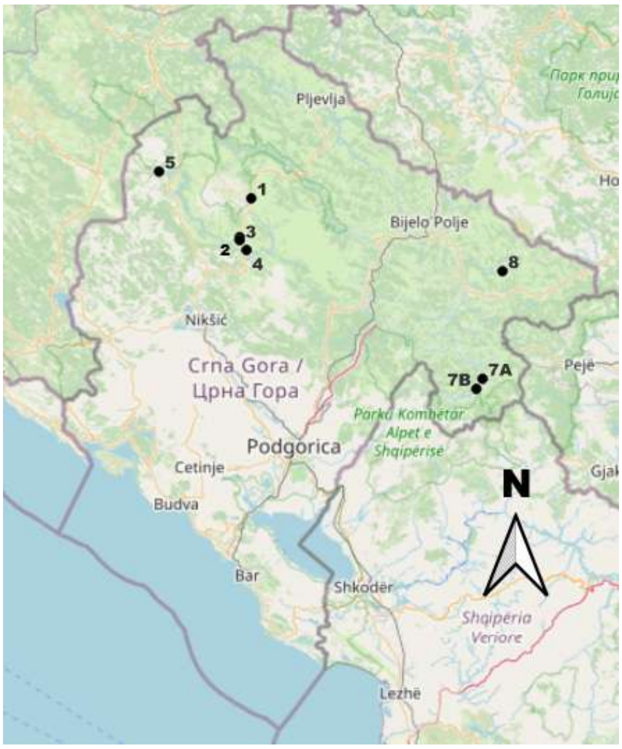

Figure 1. Investigated localities of butterfly sampling in Montenegro. Localities: L1 – Pošćensko jezero; L2-L3 transect – Komarnica; L4 – Šavnik; L5 – Camp Vrbnica; L7A – Brezojevica; L7B – Plav; L8 – Etno Selo Vrelo.

Locality L1 – Durmitor National Park (Pošćensko jezero; 43.0916 N, 19.1099 E; ca 1,487 m a.s.l.): was situated in the vicinity of Pošćensko Lake and represented a wetland habitat with surrounding mesophilous vegetation. Butterfly sampling at this locality was conducted between 08:00 and 09:00 h.

L2 to L3 transect (Komarnica; 42.9900 N, 19.0689 E; ca 950–1,000 m a.s.l. and 42.9821 N, 19.0683 E; ca 930–980 m a.s.l.): the transect were located near fishpond habitats and riverine vegetation in the Komarnica region. Butterfly sampling at these localities was carried out between 10:00 and 12:00 h and included observations and sampling both directly at the investigated sites and along the route connecting the two localities sampled as a continuous unit.

Locality L4 (Šavnik**; 42.9562 N, 19.0929 E; ca 830–875 m a.s.l.):** was situated near a river corridor with adjacent meadow vegetation. Sampling was conducted between 12:30 and 13:30 h.

Locality L5 (Camp Vrbnica; 43.161680 N, 18.779737 E; ca 520–560 m a.s.l.): represented a riverine habitat with anthropogenically influenced surroundings near a campsite area. Sampling was conducted between 16:15 and 17:15 h.

Locality L6 (Tara Canyon; 43.127990 N, 19.310080 E; ca 700–750 m a.s.l.): was visited during the field campaign; however, no butterfly sampling was conducted at this site because the locality was excluded from the butterfly survey. The numbering was retained to ensure consistency with parallel studies on other invertebrate groups conducted within the same expedition.

Locality L7A (Brezojevica; 42.6177 N, 19.9378 E; ca 930–970 m a.s.l.): represented ecotonal habitats near cemeteries and a mountain pass. Sampling was carried out between 11:40 and 12:00 h.

Locality L7B (Plav; 42.5914 N, 19.9154 E; ca 900–930 m a.s.l.): was situated near riverine habitats in the surroundings of a local farm. Sampling was conducted between 12:30 and 13:30 h.

Locality L8 (Etno Selo Vrelo (Trpezi, Berane Municipality) 42.9006 N, 20.0092 E; ca 700–750 m a.s.l.): represented semi-natural meadow and rural habitats associated with traditional land use. Sampling was conducted between 15:10 and 16:20 h.

Sampling and species identification

Sampling was carried out using standard entomological methods, including direct observation and capture using an entomological net. All observed and captured individuals were identified directly in the field using standard identification guides and publications (e.g., Slamka 2004; Laštůvka 2008; Franeta 2018). Voucher material was not collected, except for specimens of the genus *Leptidea*, which were taken for subsequent dissection and examination of genital structures for species determination. Individuals that could not be reliably identified to species level under field conditions were recorded only to genus level. The observed *Colias* individual could not be identified to species level, as it was recorded only in flight.

Figure 2. Habitats surveyed for butterflies: wetlands, rocky xerothermic sites, fishpond surroundings, riverine habitats, forest edges, ecotonal meadows, and traditionally managed semi-natural meadows at localities L1–L8.

Taxonomic arrangement and nomenclature of the recorded taxa followed the checklist of butterflies of Montenegro published by Franeta (2018), which currently represents one of the most comprehensive overviews of the Montenegrin butterfly fauna.

Ecological and faunistic classification

Based on habitat affiliation, butterfly species were assigned to ecological categories following Macek et al. (2015). The habitat categories used were ubiquitous species (U), mesophilous meadow species (M1), woodland-edge and forest-margin species (M2), forest species (M3), xerothermophilous grassland species (X1), forest-steppe and shrubland species (X2), and hygrophilous wetland species (H1). In cases where species exhibited two habitat optima, only the primary habitat affiliation was considered in subsequent analyses.

According to faunistic distribution type, species were classified into the following categories modified after Macek et al. (2015): Cosmopolitan (KOS), Holarctic (HOL), Palaearctic (PAL), Euro-Siberian (ESI), West Palaearctic (WPA), and European (EUR).

Butterfly mobility categories followed the classification proposed by Bartoňová et al. (2014), ranging from extremely sedentary species to extremely mobile species: extremely sedentary (1), very sedentary (2), sedentary (3), rather sedentary (4), less sedentary (5), willing to disperse (6), mobile (7), very mobile (8), extremely mobile (9).

Threat categories were assigned according to the *Red List of Butterflies of Montenegro* (Roganović & Malidžan 2023). Conservation status followed the IUCN classification system. Among the recorded taxa, only the categories Least Concern (LC) and Near Threatened (NT) were represented, whereas no species belonging to the categories Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Data Deficient (DD), or Not Evaluated (NE) were confirmed during the present survey.

Results and Discussion

During the short-term survey conducted on 19 and 20 May 2026, a total of 20 butterfly taxa belonging to six families were recorded from six investigated localities in Montenegro, including two localities surveyed as paired sampling sites (L2/L3 and L7A/L7B), with an overall abundance of 75 individuals (Tables 1–3). The recorded assemblage represents approximately 10.4% of the 192 butterfly species currently known from Montenegro (Franeta 2018; Roganović & Malidžan 2023). Despite the limited temporal extent of the survey, the recorded assemblage comprised a relatively diverse spectrum of butterflies associated mainly with open and semi-natural habitats, including grasslands, ecotones, riverine vegetation, and traditionally managed rural landscapes typical of the western Balkan Peninsula.

The highest species richness was recorded within the families Pieridae and Lycaenidae, each represented by six taxa, corresponding to 30.0% and 11.5% of the species currently known from Montenegro, respectively. Nymphalidae, represented by four taxa (4.4% of the national fauna), was the most abundant family with 26 recorded individuals (Tables 1 and 3). Hesperiidae comprised two taxa (8.7% of the national fauna), whereas Papilionidae and Riodinidae were each represented by a single species, corresponding to 16.7% and 100% of the species currently known from Montenegro, respectively. Comparable dominance of Nymphalidae, Pieridae and Lycaenidae has previously been reported from meadow and forest-edge habitats in Montenegro (Franeta 2018). The predominance of these families in the present study most likely reflects the prevalence of open and semi-natural habitats among the investigated localities rather than the overall composition of the Montenegrin butterfly fauna. Despite the limited sampling effort, the survey captured a relatively broad taxonomic spectrum of the country's butterfly fauna.

The recorded assemblage was dominated by widespread and ecologically tolerant species, including *Vanessa cardui*, *Pieris rapae*, *Polyommatus icarus* and *Coenonympha pamphilus*, reflecting the predominance of common spring species associated with open and semi-natural habitats (Table 2). These species are capable of occupying a broad spectrum of environmental conditions (Macek et al. 2015). Habitat specialists and stenotopic mountain species were represented only marginally, which is likely attributable to the short sampling period and the habitat types investigated.

Table 1. Overview of butterfly species recorded at individual localities in Montenegro.

Species	L1	L2–L3 transect	L4	L5	L7A area	L7B area	L8	Total
Hesperiidae								
Pyrgus malvae L.	–	1	1	–	2	–	1	5
Carterocephalus palaemon Pall.	–	–	–	–	–	–	1	1
Papilionidae								
Papilio machaon L.	–	–	1	–	–	–	–	1
Pieridae								
Pieris rapae L.	–	1	–	1	–	–	–	2
Pieris napi L.	–	–	–	1	–	–	–	1
Colias sp.	–	1	–	–	–	–	–	1
Gonepteryx rhamni L.	–	–	1	1	–	–	–	2
Leptidea sinapis L.	–	–	–	2	–	–	7	9
Anthocharis cardamines L.	–	–	–	–	–	–	3	3
Riodinidae								
Hamearis lucina L.	–	–	–	1	–	–	1	2
Lycaenidae								
Polyommatus icarus Rott.	–	4	4	–	1	–	–	9
Aricia agestis Den. et Schiff.	–	1	–	–	–	–	–	1
Cupido decolorata Staud.	–	1	–	–	1	–	2	4
Lysandra bellargus Rott.	–	–	–	1	–	–	–	1
Celastrina argiolus L.	–	–	–	–	–	–	1	1
Glaucopsyche alexis Poda	–	–	–	–	–	–	6	6
Nymphalidae								
Vanessa cardui L.	3	3	1	–	–	–	–	7
Coenonympha pamphilus L.	–	6	–	–	3	2	1	12
Erebia medusa Den. et Schiff.	–	5	–	–	1	–	–	6
Pararge aegeria L.	–	–	–	–	–	–	1	1
Total	3	23	8	7	8	2	24	75

Numbers indicate the abundance of recorded individuals at individual localities. Locality codes correspond to the study sites listed in the Materials and Methods section.

Analysis of habitat affiliation demonstrated that ubiquist species (U), together with species associated with mesophilous meadows (M1) and woodland margins (M2), represented the dominant ecological groups within the recorded assemblage (Table 2). Ubiquist species included *P. machaon*, *P. rapae*, *P. napi*, *P. icarus*, and *V. cardui*. Mesophilous and ecotonal habitats were represented mainly by *C. pamphilus*, *Anthocharis cardamines*, and *Erebia medusa*. Xerothermophilous species (X1), particularly among Lycaenidae and Hesperiidae, also formed an important component of the assemblage and included *Pyrgus malvae*, *Aricia agestis*, *Glaucopsyche alexis*, and *Cupido decoloratus*. Strictly forest-associated species (M3) were represented only by *Pararge aegeria*. Overall, the ecological structure of the assemblage reflects the predominance of open-habitat and ecotonal species within the investigated landscape mosaic.

The most abundant species recorded during the survey was *C. pamphilus* with 12 individuals, followed by *Leptidea sinapis* and *P. icarus* with nine individuals each (Table 1). *L. sinapis* was recorded predominantly at locality L8, where semi-natural meadow habitats and traditionally managed rural vegetation probably provided suitable habitat conditions. The relatively high abundances of *C. pamphilus* and *E. medusa* further indicate the presence of structurally diverse grassland habitats with relatively preserved vegetation continuity and suitable nectar resources.

Table 2. Ecological and faunistic characteristics of recorded butterfly species in Montenegro.

Species	Habitat affinity	Faunistic element	Mobility	Red List MNE
Hesperiidae				
Pyrgus malvae L.	X1	PAL	3	LC
Carterocephalus palaemon Pall.	M2	HOL	3	LC
Papilionoidea				
Papilio machaon L.	U	HOL	5	NT
Pieridae				
Pieris rapae L.	U	KOS	7	LC
Pieris napi L.	U	PAL	7	LC
Colias sp.	–	–	–	LC
Gonepteryx rhamni L.	M2	PAL	7	LC
Leptidea sinapis L.	X2, M2	PAL	6	LC
Anthocharis cardamines L.	M1	PAL	4	LC
Riodinidae				
Hamearis lucina L.	M2	EUR	3	LC
Lycaenidae				
Polyommatus icarus Rott.	U	PAL	3	LC
Aricia agestis Den. et Schiff.	X1	PAL	4	LC
Cupido decolorata Staud.	X1	PME	2	LC
Lysandra bellargus Rott.	X1	WPA	2	LC
Celastrina argiolus L.	M2	PAL	5	LC
Glaucopsyche alexis Poda	X1	PAL	3	LC
Nymphalidae				
Vanessa cardui L.	U	KOS	9	LC
Coenonympha pamphilus L.	M1	WPA	3	LC
Erebia medusa Den. et Schiff.	M2	ESI	3	LC
Pararge aegeria L.	M3	WPA	4	LC

Habitat affinity categories – U: ubiquist species, M1: mesophilous meadow species, M2: woodland edge and forest-margin species, M3: forest species, X1: xerothermophilous grassland species, X2: forest-steppe and shrubland species. Faunistic elements – KOS: Cosmopolitan, HOL: Holarctic, PAL: Palaearctic, ESI: Euro-Siberian, WPA: West Palaearctic, EUR: European. Mobility categories – 1: extremely sedentary, 2: very sedentary, 3: sedentary, 4: rather sedentary, 5: less sedentary, 6: willing to disperse, 7: mobile, 8: very mobile, 9: extremely mobile. Threat categories – LC: Least Concern, NT: Near Threatened.

Locality L8 exhibited the highest diversity, with 10 recorded taxa and 24 individuals (Table 3). The locality represented a mosaic of semi-natural meadows, rural habitats and ecotonal vegetation associated with traditional land use. Such habitat heterogeneity probably contributed to the occurrence of several ecologically distinct taxa, including *G. alexis*, *C. decoloratus*, *L. sinapis* and *A. cardamines*. Semi-natural extensively managed grasslands are generally considered important habitats for butterfly assemblages because they provide diverse nectar resources, larval host plants and favourable microclimatic conditions. However, it should be emphasised that the investigated localities were selected primarily for ichthyological research rather than butterfly surveys; therefore, the observed diversity should not be regarded as representative of the regional butterfly fauna. By contrast, localities L1 and L7B exhibited very low diversity, each yielding only a single recorded species. These low values may reflect the short sampling duration, local weather conditions, lower habitat heterogeneity, or temporary phenological mismatches between butterfly emergence and the survey period.

From a faunistic perspective, the recorded assemblage was dominated mainly by Palaearctic (PAL) and West Palaearctic (WPA) elements (Table 2). Palaearctic taxa included *P. malvae*, *L. sinapis*, *P. icarus* and *G. alexis*, whereas West Palaearctic elements were represented mainly by *C. pamphilus* and *P. aegeria*. Holarctic (HOL) species were represented by *P. machaon* and *Carterocephalus palaemon*, while Mediterranean (MED) elements occurred only sporadically, represented by *Lysandra bellargus*. Cosmopolitan species (KOS), including *P. rapae* and *V. cardui*, reflected the presence of ecologically tolerant taxa with broad geographical distributions. The assemblage also included a Pontomediterranean (PME) element represented by *C. decoloratus*, a species associated mainly with xerothermic habitats of south-eastern Europe. Its occurrence further supports the xerothermic character of some investigated habitats and reflects the south-eastern European biogeographical affinities of the Montenegrin butterfly fauna. The predominance of broadly distributed faunistic elements corresponds well with previous studies conducted in Montenegro and neighbouring Balkan regions (Jakšić 1998; Franeta 2018).

Table 3. Summary of butterfly records by family from Montenegro.

Family	Number of taxa	Number of individuals
Hesperiidae	2	6
Papilionidae	1	1
Pieridae	6	18
Riodinidae	1	2
Lycaenidae	6	22
Nymphalidae	4	26
Total	20	75

Mobility analysis indicated a predominance of species with low to intermediate dispersal ability, particularly those belonging to mobility categories 3–5 (Table 2). Sedentary and rather sedentary taxa included *P. malvae*, *C. decoloratus*, *G. alexis* and *E. medusa*, whereas highly mobile species were represented mainly by *V. cardui* (mobility category 9), *P. rapae* and *P. napi* (mobility category 7). This pattern suggests that many recorded species are closely associated with local habitat conditions and highlights the importance of maintaining habitat continuity within semi-natural landscapes.

Several taxa exhibited localised occurrence patterns. *P. machaon* was recorded exclusively at locality L4, whereas *C. palaemon* and *G. alexis* were observed only at locality L8 (Table 1). Although these records originate from a short-term survey, they provide valuable distributional data and contribute to current knowledge of butterfly distribution in Montenegro.

From a conservation perspective, most recorded species belonged to the Least Concern (LC) category according to the Red List of Butterflies of Montenegro (Roganović & Malidžan 2023). Only *P. machaon* belonged to the Near Threatened (NT) category. Nevertheless, the occurrence of species associated with traditionally managed grasslands and ecotonal habitats underlines the conservation value of semi-natural landscape mosaics in Montenegro. Although no nationally threatened butterfly species were recorded, the survey provides additional faunistic records from six investigated localities, several of which have received relatively little lepidopterological attention.

Although Montenegro is recognised as one of the biodiversity hotspots of the Balkan Peninsula, the butterfly assemblages recorded during the present survey were dominated by widespread and ecologically tolerant species. This pattern most likely reflects the short duration of the survey, its restriction to a single sampling period, and the fact that the investigated localities were selected primarily for ichthyological rather than lepidopterological research. Consequently, the recorded assemblage should not be considered fully representative of the butterfly diversity of the investigated region.

Nevertheless, habitat loss, abandonment of traditional land use, vegetation succession, agricultural intensification and landscape fragmentation have been identified as major drivers of butterfly declines throughout Europe, including the Balkan Peninsula (Van Swaay et al. 2006; Kuussaari et al. 2007; Van Dyck et al. 2009; Ekroos et al. 2010; Warren et al. 2021). Similar threats have also been recognised in Montenegro, where the conservation of semi-natural grasslands and traditionally managed landscapes is considered essential for maintaining butterfly diversity (Franeta 2018; Roganović & Malidžan 2023).

The surveyed localities retained many characteristics of well-preserved semi-natural grasslands, ecotonal habitats and riverine landscape mosaics, indicating that suitable conditions for diverse butterfly assemblages are still present in parts of Montenegro. Although no nationally threatened species were recorded during the present survey, the study provides additional faunistic and ecological information from six investigated localities and complements the current knowledge of butterfly distribution in the country. Future surveys covering the entire flight season and targeting a broader spectrum of habitats will be necessary to obtain a more comprehensive assessment of butterfly diversity and to improve our understanding of species distribution and habitat associations in Montenegro.

Acknowledgement

This work was supported by the Slovak Research and Development Agency under the Contract no. SK-MNE-25-0001.

References

Bartoňová A, Beneš J, Konvička M. 2014. Generalist-specialist continuum and life history traits of Central European butterflies (Lepidoptera) – are we missing a part of the picture? *European Journal of Entomology* 111(4): 543–553.

Carnelutti J, Michieli V. 1958. Contribution to the knowledge of Lepidoptera fauna of Montenegro. *Biološki Vestnik* 6: 45–58.

Ekroos J, Heliölä J, Kuussaari M. 2010. Homogenization of lepidopteran communities in intensively cultivated agricultural landscapes. *Journal of Applied Ecology* 47(2): 459–467.

Erhardt A, Thomas JA. 1991. Lepidoptera as indicators of change in the semi-natural grasslands of lowland and upland Europe. In: Collins NM, Thomas JA, eds. *The Conservation of Insects and Their Habitats*. London: Academic Press, 213–236.

Fox R. 2013. The decline of moths and butterflies in Great Britain. *Journal of Insect Conservation* 17: 429–436.

Franeta F. 2018. Checklist of the butterflies (Lepidoptera: Papilionoidea) of Montenegro. *Zootaxa* 4392(1): 128–148.

Jakšić NP. 1988. *Provisional distribution maps of the butterflies of Yugoslavia*. Belgrade: Yugoslav Association for Lepidopterology.

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(3): 366–376.

Laštůvka Z. 2008. *Denní motýli (Rhopalocera) zemědělské krajiny. Metodika hodnocení biodiverzity a zdravého prostředí*. Brno: Biocont Laboratory.

Macek J, Laštůvka Z, Beneš J, Traxler L. 2015. *Motýli a housenky střední Evropy. Vol. 4. Denní motýli*. Praha: Academia.

Maes D, van Dyck H. 2001. Butterfly diversity loss in Flanders (north Belgium): Europe's worst case scenario? *Biological Conservation* 99: 263–276.

Nicholl M de la Beche. 1899. Notes on butterflies collected in Montenegro. *Entomologist's Record and Journal of Variation* 11: 97–101.

Rebel H. 1913. Studien über die Lepidopterenfauna der Balkanländer. *Annalen des Naturhistorischen Museums in Wien* 27: 281–334.

Rebel H, Zerny H. 1931. Die Lepidopterenfauna Albaniens. *Denkschriften der Akademie der Wissenschaften in Wien* 103: 37–161.

Roganović D, Malidžan S. 2023. *Red List of Butterflies of Montenegro*. Podgorica: Environmental Protection Agency of Montenegro.

Sánchez-Bayo F, Wyckhuys KAG. 2019. Worldwide decline of the entomofauna: A review of its drivers. *Biological Conservation* 232: 8–27.

Sijarić R. 1984. Butterflies of Montenegro. *Glasnik Republičkog Zavoda za Zaštitu Prirode i Prirodnjačkog Muzeja Titograd* 17: 65–92.

Slamka F. 2004. *Die Tagfalter Mitteleuropas – östliche Teil. Bestimmung, Biotope und Bionomie, Verbreitung, Gefährdung*. Bratislava: Slamka.

van Dyck H, van Strien AJ, Maes D, van Swaay CAM. 2009. Declines in common, widespread butterflies in a landscape under intense human use. *Conservation Biology* 23(4): 957–965.

van Swaay CAM, Warren MS, Loïs G. 2006. Biotope use and trends of European butterflies. *Journal of Insect Conservation* 10(2): 189–209.

Warren MS, Maes D, van Swaay CAM, Goffart P, van Dyck H, Bourn NAD, Wynhoff I, Hoare D, Ellis S. 2021. The decline of butterflies in Europe: problems, significance, and possible solutions. *Proceedings of the National Academy of Sciences of the United States of America* 118(2): e2002551117.

Biodiversity & Environment, 2026
Vol. 18, No. 1, 30–32

Short note

An unexpected host: *Wohlfahrtia magnifica* (Schiner, 1862) recorded from a nestling of *Cinclus cinclus* (Linnaeus, 1758)

JOZEF OBOŇA [1*], MIROSLAV FULÍN [2] & PETER MANKO [1]

[1] *Department of Ecology, Faculty of Humanities and Natural Sciences, University of Prešov, 17. novembra 1, 081 16 Prešov, Slovakia,*
[2] *Puškinova 15, 083 01, Sabinov, Slovakia*

Abstract
We report a rare case of myiasis caused by *Wohlfahrtia magnifica* (Diptera: Sarcophagidae) in a nestling of *Cinclus cinclus* in eastern Slovakia. The larva was recorded on one of five nestlings during routine ringing in a nest located under a bridge (Tichý Potok village) on 16. May 2025. Identification was based on larval morphology, including posterior spiracles with two distinctly curved slits, consistent with a second instar, and conspicuous bands of cuticular spines. Although *W. magnifica* is a well-known obligate agent of traumatic myiasis in mammals, records from wild passerine birds are scarce. This observation represents an unusual host association and highlights the potential for infestation in nestling birds.

Key words: myiasis, Sarcophagidae, white-throated dipper, Slovakia, host record

Introduction

Wohlfahrtia magnifica (Schiner, 1862) (Diptera: Sarcophagidae) is a well-known species of flesh fly and an obligate agent of traumatic myiasis of considerable medical and veterinary importance (Farkas et al. 2001). The species is widely distributed throughout the Palaearctic region, including Central and Eastern Europe, the Mediterranean basin, North Africa, the Middle East, and parts of Asia (Farkas et al. 2009). Its larvae develop exclusively in living vertebrate hosts (Table 1), where they feed on living tissues and may cause severe tissue damage.

Infestation by *W. magnifica* (wohlfahrtiosis) affects a wide range of domestic and wild animals, particularly livestock such as sheep, cattle, horses, and pigs, as well as dogs (Farkas et al. 2001, 2009). Birds are considered relatively rare hosts, although cases have been reported in domestic geese and other avian species (Farkas et al. 2001, 2009). In avian hosts, infestations are often associated with injuries or other predisposing conditions and may lead to severe tissue destruction.

Table. 1. Reported hosts of *Wohlfahrtia magnifica* with documented geographic occurrence and literature sources.

Host species	Country of occurrence	Reference
Ovis aries (sheep)	Greece; Italy; Europe (general)	Sotiraki & Hall 2012; Hall & Farkas 2000
Capra hircus (goat)	Europe (multiple countries)	Sotiraki & Hall 2012
Bos taurus (cattle)	Italy	Ambrosi & Principato 1994
Canis lupus familiaris (dog)	Italy	Bonacci et al. 2017
Canis lupus familiaris (dog)	Greece	Orfanou et al. 2011
Canis lupus familiaris (dog)	Hungary	Farkas et al. 2009
Canis lupus familiaris (dog)	Turkey	Şaki 2004; Ütük 2006; Dik et al. 2012
Canis lupus familiaris (dog)	Iran	Rafinejad et al. 2014
Canis lupus familiaris (dog)	Morocco	Farkas et al. 2009
Canis lupus familiaris (dog)	Israel	Schnur et al. 2009
Canis lupus familiaris (dog)	Russia	Portchinsky 1916
Homo sapiens (human)	Italy	Perroncito 1900
Homo sapiens (human)	Turkey	Kokcam & Şaki 2005
Felis catus (cat)	Italy	Bonacci et al. 2020
Equus caballus (horse)	Italy	Bonacci et al. 2020
Sus scrofa domesticus (pig)	Italy	Bonacci et al. 2020
Sus scrofa (wild boar)	Italy	Bonacci et al. 2020
Oryctolagus cuniculus (rabbit)	Italy	Bonacci et al. 2020
Vicugna pacos (alpaca)	Italy	Bonacci et al. 2020
Anser (domestic goose)	Hungary	Farkas et al. 2001
Various mammalian hosts	Europe; North Africa; Asia	Hall et al. 2016; Spradbery 1991

* Corresponding author: J. Oboňa. Email: jozef.obona@unipo.sk

Observation

Locality and date: Tichý Potok village, tributary Filipovec (stream) of Torysa river (Slovakia), 16. May 2025.

Host and context: The record originates from a nest of the white-throated dipper *Cinclus cinclus* (Aves: Passeriformes: Cinclidae) located in a half-open nest box ("polobúdka") under a bridge. The nest contained five nestlings at the time of inspection during bird ringing activities.

Findings: One dipteran larva (Figures 1–2) was detected on one of the five nestlings. No additional larvae were observed on the remaining nestlings during the same visit. No further individuals of *C. cinclus* were examined on that day. The exact localization of the larva on the host body was not recorded. The specimen was collected during ringing and subsequently examined under magnification.

Identification: The larva was identified based on morphological characters following Niederegger et al. (2019). Diagnostic features included posterior spiracles with two distinctly curved slits, consistent with a second instar larva; a robust and apparently incomplete peritreme; and conspicuous bands of cuticular spines on the body segments (Figures 1–2).

The combination of spiracular morphology and body armature allows reliable separation from other myiasis-causing Diptera. These characters are consistent with larvae of *W. magnifica* (Diptera: Sarcophagidae) and differ from those of *Protocalliphora* (Calliphoridae), which typically exhibit smoother cuticle and different spiracular morphology (Niederegger et al. 2019).

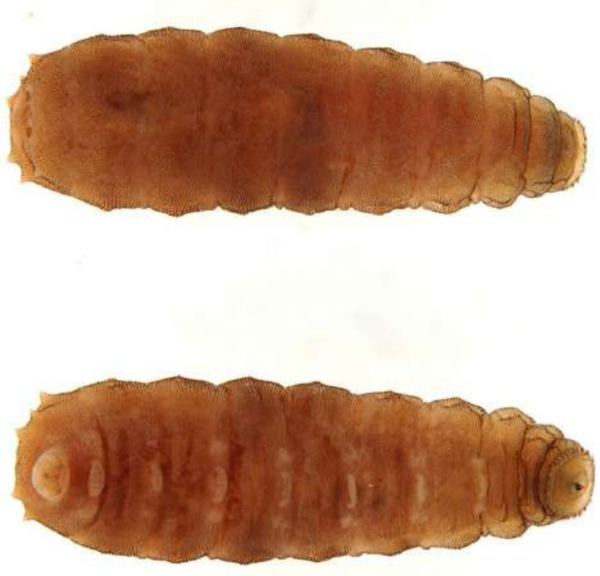

Figure 1. Second instar larva of *Wohlfahrtia magnifica* (Diptera: Sarcophagidae) collected from a nestling of *Cinclus cinclus* (Tichý potok, Slovakia, 16 May 2025): dorsal view showing segmentation and cuticular spines, ventral view.

Figure 2. Posterior spiracular disc of a second instar larva of *Wohlfahrtia magnifica* (Diptera: Sarcophagidae): detail of the posterior end showing two curved spiracular slits and a weakly developed peritreme.

Discussion

Wohlfahrtia magnifica is primarily associated with mammalian hosts, and its occurrence in wild passerine birds appears to be rare. The present finding represents an unusual host association in the white-throated dipper *C. cinclus*. Although the exact site of infestation was not recorded, the presence of a larva on a nestling suggests that even aquatic passerines may be susceptible to infestation, possibly in connection with minor injuries or other predisposing factors.

Further observations are needed to assess the frequency of such host associations and their ecological significance.

Acknowledgement

We would like to thank Anonymous reviewers who helped by providing constructive comments and improving the manuscript. Work of JO was supported by the Scientific Grant Agency of the Ministry of Education, Research, Development and Youth of the Slovak Republic project no. VEGA 1/0783/26, the Slovak Research and Development Agency under contract no. APVV-22-0440 and Recovery and Resilience Plan of the Slovak Republic no. 09I03-03-V06-00052.

References

Ambrosi M, Principato M. 1994. Outbreak of vaginomyiasis by *Wohlfartia magnifica* in grazing cattle in Central Italy. *Parassitologia* 36: 5.

Bonacci T, Curia G, Leoncini R, Whitmore D. 2017. Traumatic myiasis in farmed animals caused by *Wohlfahrtia magnifica* in southern Italy (Diptera: Sarcophagidae). *Fragmenta Entomologica* 49(1): 57.

Bonacci T, Curia G, Scapoli C, Pezzi M. 2020. Wohlfahrtiosis in Italy: a case in a puppy and overview of geographical distribution. *Acta Veterinaria Brno* 89(2): 171–177.

Dik B, Uslu U, Işik N. 2012. Myiasis in animals and human beings in Turkey. *Kafkas Universitesi Veteriner Fakultesi Dergisi* 18: 37–42.

Farkas R, Hall MJR, Bouzagou AK, Lhor Y, Khallaayoune K. 2009. Traumatic myiasis in dogs caused by *Wohlfahrtia magnifica* and its importance in the epidemiology of wohlfahrtiosis of livestock. *Medical and Veterinary Entomology* 23: 80–85.

Farkas R, Szántó Z, Hall M. 2001. Traumatic myiasis of geese in Hungary. *Veterinary Parasitology* 95(1): 45–52.

Hall MJ, Wall RL, Stevens JR. 2016. Traumatic myiasis: a neglected disease in a changing world. *Annual Review of Entomology* 61(1): 159–176.

Hall MJR, Farkas R. 2000. Traumatic myiasis of humans and animals. In: Papp L, Darvas B, eds. *Contributions to a Manual of Palaearctic Diptera. Volume 1. General and Applied Dipterology*. Budapest: Science Herald, 751–768.

Kokcam I, Saki CE. 2005. A case of cutaneous myiasis caused by *Wohlfahrtia magnifica*. *The Journal of dermatology* 32(6): 459–463.

Niederegger S, Akbarzadeh K, Szpila K. 2019. Muscle attachment site patterns for species determination in West Palaearctic *Wohlfahrtia* (Diptera: Sarcophagidae) of medical and veterinary importance. *Scientific Reports* 9(1): 19151.

Orfanou DC, Papadopoulos E, Cripps PJ, Athanasiou LV, Fthenakis GC. 2011. Myiasis in a dog shelter in Greece: Epidemiological and clinical features and therapeutic considerations. *Veterinary parasitology* 181(2-4): 374–378.

Perroncito E. 1900. Le larve della "*Sarcophila magnifica*" (Schiner) nell'intestino dell'uomo. (The larvae of "*Sarcophila magnifica*" (Schiner) in human intestine) *Giornale della Reale Accademia di medicina di Torino* 6: 522–525.

Portchinsky IA. 1916. *Wohlfahrtia magnifica*, Schin., and allied Russian species. The biology of this fly and its importance to man and domestic animals. *Memoirs of the Bureau of Entomology of the Scientific Committee of the Ministry of Agriculture, Saint Petersburg* 11: 1–108.

Rafinejad J, Akbarzadeh K, Rassi Y, Nozari J, Sedaghat MM, Hosseini M, Alipour H, Ranjbar A, Zeinali D. 2014. Traumatic myiasis agents in Iran with introducing of new dominant species, *Wohlfahrtia magnifica* (Diptera: Sarcophagidae). *Asian Pacific Journal of Tropical Biomedicine* 4: 451–455.

Şaki CE. 2004. Elazığ'da köpeklerde tespit edilen travmatik myiasisler. (Traumatic myiasis of dogs in Elazığ, Turkey) *Fırat Üniversitesi Sağlık Bilimleri Veteriner Dergisi* 18: 29–33.

Schnur HJ, Zivotofsk D, Wilamowski A. 2009. Myiasis in domestic animals in Israel. *Veterinary Parasitology* 12: 352–355.

Sotiraki S, Hall MJ. 2012. A review of comparative aspects of myiasis in goats and sheep in Europe. *Small Ruminant Research* 103: 75–83.

Spradbery JP. 1991. *A Manual for the Diagnosis of Screw-worm Fly*. Canberra: CSIRO Division of Entomology.

Ütük AE. 2006. Bir köpekte travmatik miyazis olgusu. (Traumatic myiasis in a dog). *Fırat Üniversitesi Sağlık Bilimleri Veteriner Dergisi* 20: 97–99.

Yildirim I, Ceyhan M, Cengiz AB, Saki CE, Ozer E, Beken S, Cilsal E. 2008. What's eating you? Cutaneous myiasis (Wohlfahrtia magnifica). *Cutis* 82(6): 396–39

Abstrakty 6. ročníka Študentskej vedeckej a odbornej činnosť (ŠVOČ) Katedry ekológie

Katedra ekológie, Fakulta humanitných a prírodných vied, Prešovská univerzita v Prešove

15. apríla 2026

Zoznam príspevkov

Patrícia Hagyariová
Dĺžková štruktúra a kondícia lososovitých druhov rýb vo vzťahu k biotopu a sezóne

Nina Peráčková
Vplyv bioplynovej stanice na emisie skleníkových plynov a životné prostredie

Vladyslav Zelenchuk
Staré banské diela na území Ukrajiny

Prezentované príspevky hodnotila Rada KE FHPV ŠVOČ v zložení: A. Eliašová, B. Baranová, L. Bobuľská, A. Csanády, L. Demková, J. Fedorčák, J. Oboňa, M. Sabalová. Abstrakty prezentovaných prác boli následne recenzované dvoma nezávislými recenzentami.

Dĺžková štruktúra a kondícia lososovitých druhov rýb vo vzťahu k biotopu a sezóne

HAGYARIOVÁ PATRÍCIA & JAKUB FEDORČÁK

Katedra ekológie, Fakulta humanitných a prírodných vied, Prešovská univerzita v Prešove, 17 novembra 1, 080 01 Prešov, Slovakia, Emails: patricia.hagyariova@smail.unipo.sk, jakub.fedorcak@unipo.sk

Lososovité ryby sú celosvetovým predmetom záujmu vzhľadom na ich sociálno-ekonomický význam v oblasti športového rybolovu, akvakultúry a gastronómie. Na strane druhej sa v Európe vyskytujú aj nepôvodné lososovité druhy rýb, ktoré sú kontroverznou témou najmä pre ich potenciálne negatívny vplyv na ekosystémy. Invazívny potenciál pstruha dúhového (*Oncorhynchus mykiss* Walbaum, 1792, Actinopterygii: Salmonidae) je často prehliadaný. To potvrdzuje aj recentný výskyt 130 tzv. „*self-sustaining*" populácií v 16-tich štátoch Európy. Výskyt takýchto populácií na území Slovenska doposiaľ nebol mapovaný. Jednou z kandidátskych lokalít na našom území je povodie rieky Okna (Tisa), kde bol tento druh introdukovaný v 20. storočí a vyskytuje sa tu dodnes. V auguste a októbri 2024, a v marci a máji 2025 sme v rieke Okna odobrali vzorky z 3 lokalít (biotopov) – Barlahov, Remetské Hámre a Nižná Rybnica. Celkovo sme v rieke Okna počas rokov 2024 až 2025 zaznamenali 389 jedincov rýb a mihúľ. Ako eudominantné druhy boli identifikované pstruh dúhový (71,47 %) a pstruh potočný (*Salmo trutta morpha fario* Linnaeus, 1758, Actinopterygii: Salmonidae) (17,74 %). Cieľom práce bolo analyzovať dĺžkovú štruktúru a kondíciu populácií nepôvodného pstruha dúhového a pôvodného pstruha potočného v lokalitách so spoločným výskytom. Celkovo sme pre štatistickú analýzu použili 278 jedincov pstruha dúhového a 69 jedincov pstruha potočného. Štandardná dĺžka tela (SL) sa u pstruha dúhového pohybovala v rozpätí 35 – 250 mm (mean 98,5 mm, s. d. 40,3, počet dĺžkových skupín 21), pre pstruha potočného sme zaznamenali dĺžkové rozpätie 48 – 250 mm (mean 118,7, s. d. 45,1, počet dĺžkových skupín 17). Zaznamenané priemerné dĺžky tiel sa líšili medzi oboma druhmi (t-test: $t = -3{,}64$; $df = 276$; $p < 0{,}001$). Priemerné dĺžky tiel sa medzi lokalitami významne líšili (Kruskal–Wallis test, $p < 0{,}001$), pričom najväčšie jedince boli zaznamenané v lokalite Rybnica a najmenšie v Barlahove. Zastúpenie pstruha dúhového v dĺžkových skupinách prevyšuje zastúpenie pstruha potočného a to v 14 z 21 skupín. Početnostná prevaha druhu pstruha dúhového je viditeľná najmä v prvých dvoch dĺžkových skupinách (30 – 50 mm), čo môže zároveň naznačovať zvýšenú mortalitu kratších (juvenilných) jedincov. V skupinách dlhších jedincov (170 – 250 mm) sa zastúpenie oboch druhov početnostne vyrovnáva. Analýza kondície bola realizovaná na súbore 328 jedincov pstruhov (pstruh dúhový 263 ks, pstruh potočný 65 ks). Hodnoty Clarkovho koeficientu kondície všetkých skúmaných jedincov boli nasledovné mean 1,4, min. 0,79, max. 2,87, pričom hodnoty boli medzi jednotlivými biotopmi veľmi podobné. To poukazuje na to, že nami zvolené biotopy kondíciu jedincov neovplyvňovali. Naopak, rozdiely v kondícii oboch druhov sa líšili v rámci sezóny s najvyššími hodnotami v mesiaci máj (pstruh dúhový 1,7, pstruh potočný 1,5), čo pravdepodobne súviselo s dostupnosťou potravy.

Kľúčové slova: pstruh dúhový, pstruh potočný, kondícia, dĺžková štruktúra, povodie Tisy.

Poďakovanie: Práca bola vypracovaná s podporou projektu APVV SK-AT-23-0007.

Vplyv vybranej bioplynovej stanice na emisie skleníkových plynov a životné prostredie

NINA PERÁČKOVÁ[1], ADRIÁN MERIČKO[2] & LENKA BOBUĽSKÁ[1]

[1] Katedra ekológie, Fakulta humanitných a prírodných vied, Prešovská univerzita, 17. novembra 1, 081 16 Prešov, Emails: nina.perackova@smail.unipo.sk, lenka.bobulska@unipo.sk, [2] Bioplynová stanica Kamenica s.r.o., Železničná 855, 067 83 Kamenica nad Cirochou

Získavanie energie z biomasy patrí medzi obnoviteľné zdroje energie. V bioplynových staniciach prebiehajú procesy, pri ktorých sa z rôznych organických materiálov, ako sú zvyšky rastlín, zvieracie exkrementy či biologicky rozložiteľné odpady, vyrába bioplyn. V práci bolo popísané ako bioplynové stanice fungujú, čo je bioplyn a ako sa tvorí. Bolo poukázané na to, že najekologickejšie je na výrobu bioplynu používať odpadové produkty, a nie cielene pestované rastliny. V prípade kukuričnej siláže bolo jej uhlíkové skóre 29,83 gCO_2eq/MJ. Naopak, pri odpadových substrátoch, ako sú maštaľný hnoj alebo kurací trus, boli tieto hodnoty mierne nad nulou alebo dokonca záporné. Z tohto dôvodu predstavujú odpadové substráty environmentálne výhodnejšiu alternatívu oproti cielene pestovaným energetickým plodinám. Pozornosť bola venovaná výrobe elektrickej energie a produkcii tepla v kogeneračnej jednotke. V rozkladných procesoch okrem bioplynu vzniká aj digestát pozostávajúci z tuhej a kvapalnej zložky. Keďže obsahuje množstvo živín, v poľnohospodárskej praxi je využívaný ako organické hnojivo. Uvedené teoretické poznatky boli aplikované v praktickej časti práce. Objektom spolupráce bola vybraná bioplynová stanica v Kamenici nad Cirochou. V rámci výskumu boli sledované používané vstupné suroviny a technologické procesy. V novembri 2025 sa realizovalo emisné meranie. Boli sledované koncentrácie tuhých znečisťujúcich látok, oxidov dusíka, oxidu uhoľnatého, formaldehydu a celkového organického uhlíka. Analyzované boli aj konkrétne údaje bioplynovej stanice za rok 2025, ktoré zahŕňali množstvo vstupných

surovín, produkciu bioplynu a celkové množstvo emisií oxidu uhličitého a metánu. Do celkovej bilancie bioplynovej stanice boli zahrnuté nielen emisie, ktoré vznikli počas samotnej tvorby bioplynu, ale aj tie, ktoré vznikli pri pestovaní plodín, ich transporte na stanicu a emisie (alebo ich úspory) prameniace zo zmien zásob organického uhlíka v pôde. Tieto dáta boli porovnané s vyprodukovanými emisiami z iných zdrojov energie uvedenými v správe Life Cycle Assessment of Electricity Generation Options vydanej organizáciou UNECE. Priemerné hodnoty emisií predstavujú približne 923 gCO_2eq/kWh pri uhlí, 458 gCO_2eq/kWh pri zemnom plyne. Pri fotovoltických elektrárňach činia 45,5 gCO_2eq/kWh a pri koncentrovanej solárnej energii 74,5 gCO_2eq/kWh. Priemerne 76,5 gCO_2eq/kWh emisií vzniká pri energii z vody, 11,9 gCO_2eq/kWh pri veterných elektrárňach na pevnine, 17,5 gCO_2eq/kWh u veterných elektrární na mori a 5,75 gCO_2eq/kWh pri jadrovej energii. Stredné hodnoty emisií z biomasy dosahujú 83 gCO_2eq/kWh, pričom v analyzovanej bioplynovej stanici v Kamenici nad Cirochou bola vypočítaná hodnota 75,6 gCO_2eq/kWh. Zhodnotené bolo, že emisie spojené s výrobou bioplynu boli v porovnaní s tradičnými spôsobmi získavania energie nižšie, a to najmä pri využívaní odpadových substrátov.

Kľúčové slová: bioplynová stanica, bioplyn, emisie skleníkových plynov, oxid uhličitý, metán, anaeróbna fermentácia, životné prostredie

Poďakovanie: Práca bola podporená projektom VEGA 1/0356/26.

Staré banské diela na území Ukrajiny

VLADYSLAV ZELENCHUK & LENKA DEMKOVÁ

Katedra ekológie, Fakulta humanitných a prírodných vied, Prešovská univerzita, 17. novembra 1, 081 16 Prešov, Emails: vladyslav.zelenchuk@smail.unipo.sk, lenka.demkova@unipo.sk

Ukrajina je bohatá na nerastné suroviny. Podľa Mykhailova & Hrinchenka (2018) základňu nerastných zdrojov Ukrajiny predstavuje približne 8000 ložísk, ktoré sú zdrojom viac ako 120 druhov nerastných surovín, vrátane ložísk horľavých nerastov, rúd, priemyselných nerastov a hornín. Nerastné bohatstvo Ukrajiny je podmienené predovšetkým rozmanitosťou geologickej stavby krajiny. Najstaršia známa baňa na území Ukrajiny pochádza už z obdobia eneolitu (4. tisícročie pred n. l.), čo poukazuje na dlhú tradíciu baníctva v tejto oblasti. Významné archeologické nálezy pochádzajú napríklad z Luhanskej oblasti, kde boli objavené pozostatky kremíkových baní patriace k najstarším vo východnej Európe. V oblasti Donbasu, v ktorej došlo k zatopeniu veľkého množstva podzemných banských priestorov, je charakteristická prítomnosť kyslých banských vôd, ktorých pH klesá na hodnoty 2 – 3. Tieto príklady ilustrujú nielen historický význam, ale aj environmentálne dôsledky baníckej činnosti a zároveň naznačujú, že na Ukrajine sa nachádza veľké množstvo baní s rôznorodými ťaženými nerastmi. Cieľom tejto práce bola komplexná analýza vývoja a súčasného stavu baníctva na Ukrajine s dôrazom na jeho historický vývoj, štruktúru ťažených nerastných surovín a charakteristiku banských diel a tiež identifikácia a zhodnotenie kvality pôdneho prostredia v okolí vybraných starých banských diel. Vo vzorkách pôdy (n=10) odobratých z banských lokalít Chyvčinsko-Hryňavských hôr bol stanovený celkový obsah ortuti (Hg). Na hodnotenie úrovne kontaminácie bol použitý faktor kontaminácie (Cf) a index geoakumulácie (Igeo). Zo získaných výsledkov možno konštatovať, že skúmané územia nevykazujú extrémne znečistenie ortuťou, avšak v niektorých lokalitách je evidentný vplyv antropogénnej činnosti – predovšetkým historickej banskej ťažby. Najvyššie hodnoty kontaminácie sú lokálne a poukazujú na potrebu ďalšieho monitoringu týchto oblastí.

Kľúčové slova: staré banské diela, ťažké kovy, štôlne, Ukrajina, Karpaty, Chivchyno-Hryniavske hory, banská činnosť

Poďakovanie: Práca bola podporená projektom VEGA 1/0356/26.