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Mosquito fauna of Cat Ba Island with a focus on breeding site characteristics in residential areas

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Abstract
Mosquitoes are key vectors of numerous human diseases, yet their diversity and breeding ecology remain poorly understood in many tropical island ecosystems. This study provides the first comprehensive assessment of mosquito species composition and larval breeding site characteristics on Cat Ba Island, a UNESCO Biosphere Reserve in northeastern Vietnam. A total of 26 mosquito species belonging to six genera were recorded across four major habitat types: evergreen forest, mangrove, residential areas, and rice fields. *Culex* was the most diverse with 11 species, followed by *Aedes* (nine species) and *Anopheles* (three species). Species richness was highest in the evergreen forest with 18 species. The mangrove and residential areas were recorded ten and seven species, respectively, while rice fields had the lowest richness with five species recorded. Species overlap between habitats was limited, except for *Culex quinquefasciatus* Say, 1823, which occurred widely in all habitat types. Larval habitat analysis in residential areas revealed a strong association of vector species with artificial containers. *Aedes albopictus* (Skuse, 1894) was the dominant species, mainly found in plastic containers. Further, the invasion of *Aedes aegypti* (Linnaeus, 1762) in the island was clearly revealed. These findings underline the influence of human-modified habitats on mosquito distribution and emphasize the need for targeted source reduction strategies to manage vector populations in urban settings in tropical islands.

Key words: vector ecology, urbanization, tropical islands, *Aedes aegypti*, *Aedes albopictus*

Introduction

Mosquitoes represent a critical component of ecological systems, fulfilling dual functions as key contributors to the food web and as vectors for a range of pathogenic diseases with significant public health challenges, including malaria, dengue fever, Zika virus, and chikungunya (Dhiman & Singh 2024; WHO 2020; Wilson et al. 2020). Most mosquito-borne diseases are reported in tropical regions (Hashimoto et al. 2017; Jupp 2005; Meyer Steiger et al. 2016). However, numerous cases have also been detected in temperate areas due to travel to endemic regions (Brown et al. 2011; Osman & Preet 2020). Therefore, reducing the risk of exposure to travelers has become an important aspect of mosquito vector management in such areas. Understanding vector species composition, distribution patterns, and breeding site characteristics is essential for developing effective and targeted mosquito control strategies (Wilson et al. 2020). Cat Ba Island, located in northern Vietnam, is call as the pearl of the Gulf of Tonkin, so it has become a must-visit destination for tourists when visiting Vietnam. The island is renowned for its high biodiversity and unique combination of terrestrial and marine ecosystems (Cao & Nguyen 2018). The island attracts millions of visitors from worldwide annually and has experienced increasing levels of urbanization in recent decades. This combination of rapid anthropogenic development and habitat heterogeneity may create a diverse of potential mosquito habitats, from densely populated residential zones and agricultural fields to pristine mangrove forests and evergreen forests, these diverse environments may harbor distinct mosquito communities (Čabanová et al. 2018; Li et al. 2014; Ortiz Diana et al. 2022). Despite the ecological importance of the island and the potential public health implications, there has been no prior comprehensive study documenting the mosquito fauna or their larval breeding site characteristics on Cat Ba Island. Furthermore, residential areas on Cat Ba Island are rapidly expanding to accommodate tourism-driven development, often without adequate environmental planning or vector control infrastructure. Dengue has been reported to Cat Ba Island since 2013 (Le et al. 2015); however, the distribution of mosquito vector species and their larval breeding sites are underexplored. Therefore, characterizing mosquito larval breeding sites in residential areas is crucial due to the high risk of vector-human contact in these environments.

In this study, we aim to (1) investigate the mosquito species composition across four major habitat types of land uses, including residential areas, rice fields, mangroves, and evergreen forests to understand how diverse land-use types influenced mosquito diversity in a tropical island. Further, we also focus on (2) identifying the types of containers used by mosquito larvae, quantifying larval densities, and documenting the associated species. This information is essential for informing targeted control strategies, such as eliminating or modifying the most productive breeding sites, and raising public awareness about household-level mosquito management. Our findings contribute essential baseline data for vector surveillance and public health planning in ecologically sensitive and rapidly developing islands in tropical regions.

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Materials and methods

Study area

Cat Ba Island located in northeastern Vietnam, characterized by numerous limestone islands and islets that are relicts of karstic limestone mountains submerged by the sea during the Holocene transgression 7000-8000 years ago (Cao & Nguyen 2018; Pham et al. 2014). In recent years, the archipelago has played a significant role in the socio-economic development of local provinces and is undergoing significant changes due to land planning initiatives (Nguyen et al. 2025). This not only leads to the disruption of the native habitat but also can enhance the risk of emerging transmission epidemics (Čabanová et al. 2018; Lee et al. 2020).

Larval and adult collection

Both immature and adult mosquitoes were collected from 30 sites from 2023 to 2025 on Cat Ba Island, grouped into four different types of habitats including residential areas, rice fields, mangroves, and evergreen forests (Figure 1). In Cat Ba Island, the evergreen forest is a natural, undisturbed habitat characterized by dense canopy cover and year-round foliage. Mangroves are coastal wetland habitats characterized by brackish water, tidal influence, muddy substrate, and complex root systems provided by salt-tolerant mangrove vegetation. Residential areas are represented by a human-modified habitat providing numerous artificial containers. And rice fields habitat is agricultural habitat dominated by seasonal rice cultivation and under periodic flooding and management practices, with shallow standing water during the cropping period and low vegetation diversity (Figure 1).

Mosquito larvae were collected from breeding sites such as artificial containers, ground pools, rock holes, and rice fields (Medlock et al. 2018). All water-holding containers were inspected for mosquito breeding, and a site was recorded as positive if any mosquito larvae or pupae were detected. Besides, adults were also collected using sweeping nets and aspirators. Further, we also aim to characterize the breeding sites in urban areas by documenting habitat types, species occurrence and abundance. Collected larvae were filtered through fine mesh to exclude excess water, and the sorted samples were preserved in 80% ethanol for later taxonomic identification. Adult mosquitoes were pinned immediately in the field to preserve their morphological characteristics for accurate subsequent identification. Mosquito samples were preserved either in dry (adults) or wet (larvae) in the laboratory of the Department of Applied Zoology, VNU University of Science, Hanoi. Mosquito collections were conducted without the need for special permits at most locations. However, access to private residences and island sites was granted only after obtaining consent from property owners and local authorities.

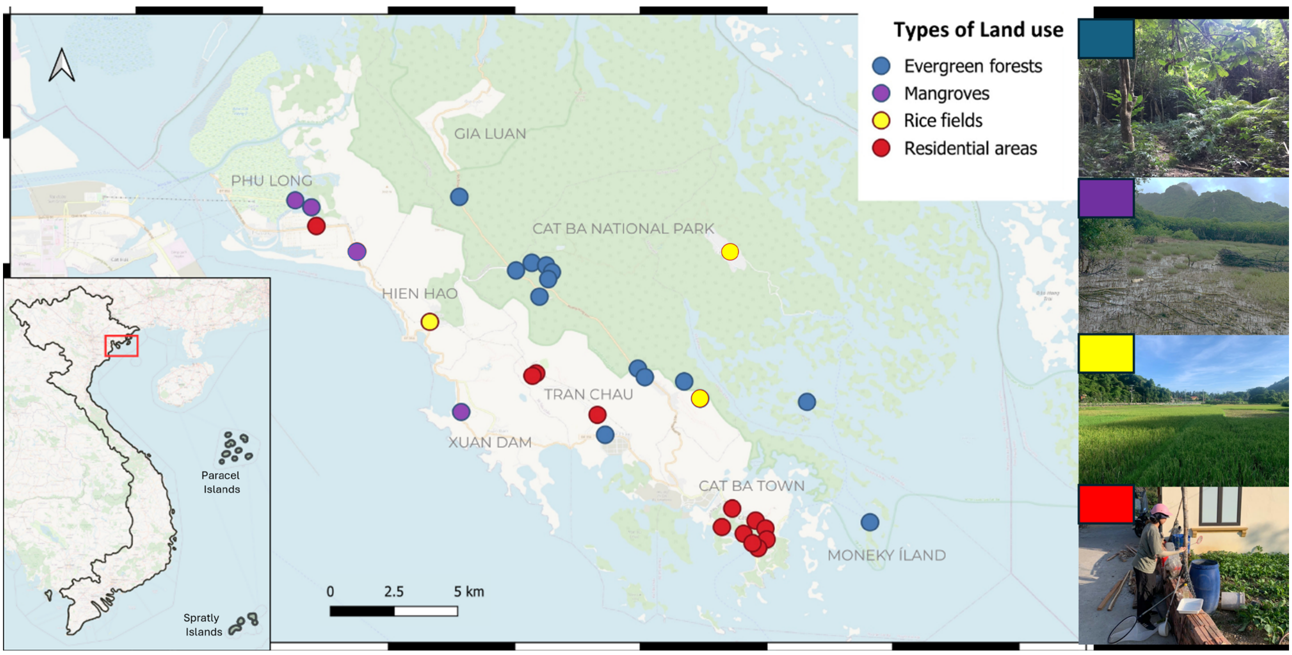

Figure 1. Map showing the distribution of mosquito sampling sites across four habitat types on Cat Ba Island, northern Vietnam. Colored dots represent different habitat types: evergreen forests (blue), mangroves (purple), rice fields (yellow), and residential areas (red). The inset map indicates the location of Cat Ba Island within Vietnam. Photographs on the right illustrate representative landscapes of each habitat type.

Results

We recorded 26 species belonging to six genera of mosquitoes in Cat Ba Islands. Among them, *Culex* was the most diverse with 11 species, followed by *Aedes* with nine species, *Anopheles* with three species. The other genera (*Armigeres, Coquillettidia, Toxorhynchites*) have only one species each (Figure 2).

Species richness was highest in the evergreen forest, with 18 out of 26 recorded species, including nine unique species for this habitat. The mangrove habitat contained ten species, of which four were exclusive. Residential areas harbored seven species, while the rice field had the lowest richness, with five species recorded (Figure 2). *Culex quinquefasciatus* Say, 1823 was the most common species occurred in all kinds of habitats. Four species were shared between the evergreen forest and residential area including *Armigeres subalbatus* (Coquillett, 1898), *Aedes albopictus* (Skuse, 1894), *Culex murrelli* Lien, 1968, and *Culex fuscocephala* Theobald, 1907. Three species were shared between the residential area and mangrove including *Anopheles barbumbrosus* Strickland & Chowdhury, 1927, *Aedes vexans* (Meigen, 1830), and *Culex mimulus* Edwards, 1915. Two species were shared between the rice field and mangrove including *Culex tritaeniorhynchus* Giles, 1901 and *Culex vishnui* Theobald, 1901. *Culex vishnui* was shared among the evergreen forest, rice field, and mangrove. *Culex sitiens* was found in both the rice field and the residential area.

We surveyed 194 water containers but 186 were recorded as positive breeding sites of mosquitoes, in which artificial-material containers accounted for largest proportion (91.9%) (Table 1). Among them, plastic containers were the most abundant with 75.8% were positive for mosquito larvae. A total of 1828 larvae were collected resulting in seven mosquito species for residential areas in Cat Ba Island (Figure 2). Among them, *Ae. albopictus* was the most dominant species, accounting for over half of all specimens (68.9%) and occurred in most of positive containers (66.1%), thriving nearly all types of available containers with highest productive in man-made containers (86.3%). *Aedes aegypti* (Linnaeus, 1762), the invasive species of Vietnam, occurred in residential areas and was strongly associated with artificial containers such as plastic and ceramic containers. *Culex* was only found in artificial containers, with *Cx. quinquefasciatus* being the most common species in the genus (Table 1).

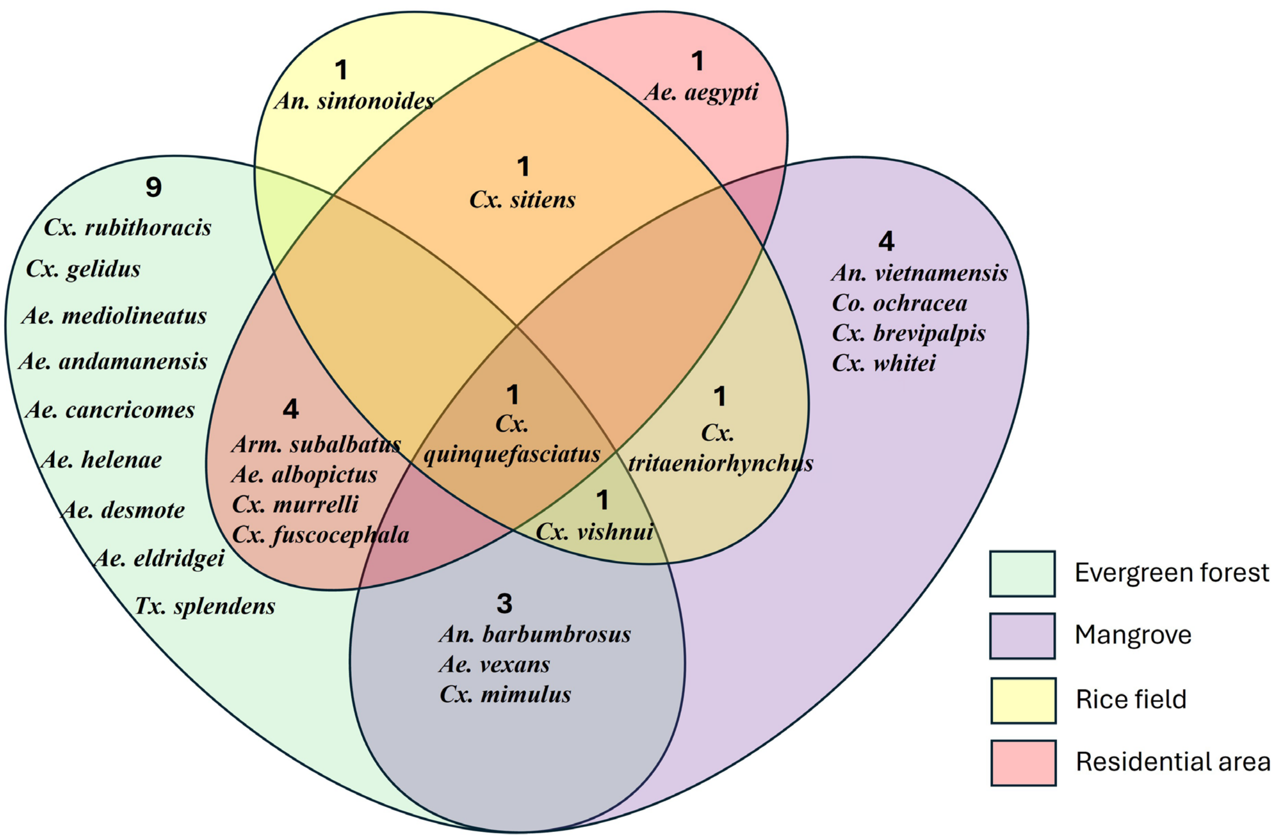

Figure 2. Venn diagram showing the distribution of mosquito species across four habitat types: evergreen forest (blue), rice field (yellow), residential area (red), and mangrove (purple). Numbers indicate the count of species in each intersection, and species names are listed within each section according to their presence in one or more habitats.

Table 1. Mosquito species and larval abundance in different types of artificial and natural breeding containers surveyed in residential areas of Cat Ba Island. Values represent the number of individuals, with the number of positive breeding sites shown in parentheses. - not computed.

	Species	Type of containers										Total (N)
		Artificial material breeding sites				Natural material breeding sites						
		Plastic containers	Ceramic jar	Used tires	Cement tanks	Discarded glass containers	Discarded Styrofoam box	Tree holes	Leaf axils	Bamboo joints	Coconut shells	
No. number of individuals (No. of breeding sites)	*Armigeres subalbatus*	12 (2)	-	14 (2)	-	-	-	-	-	-	-	26 (4)
	Aedes albopictus	1260 (123)	11 (4)	155 (5)	36 (4)	8 (2)	38 (7)	21 (4)	4 (2)	5 (3)	16 (6)	1554 (160)
	Aedes aegypti	39 (7)	21 (2)	-	-	-	12 (1)	-	-	-	-	72 (10)
	Culex quinquefasciatus	55 (3)	-	-	14 (1)	-	41 (1)	-	-	-	-	110 (5)
	Culex murrelli	-	18 (1)	-	-	-	-	-	-	-	-	18 (1)
	Culex sitiens	41 (5)	-	-	-	-	-	-	-	-	-	41 (5)
	Culex fuscocephala	7 (1)	-	-	-	-	-	-	-	-	-	7 (1)
Total (N)		1414 (141)	50 (7)	169 (7)	50 (5)	8 (2)	91 (9)	21 (4)	4 (2)	5 (3)	16 (6)	1828 (186)

Discussion

This study provides the first comprehensive assessment of mosquito species composition and breeding site characteristics on Cat Ba Island, a key conservation and tourism area in northern Vietnam. Habitat comparisons revealed low overlap in species composition, suggesting strong habitat-specificity of mosquitoes on the island. In residential areas, artificial containers were found more common than natural habitats, resulting in a higher species richness and abundance in these kinds of containers. Below, we discuss the variation in habitat distribution of mosquitoes in Cat Ba Island, along with the characteristics of breeding sites in residential areas, and the implication for mosquito control.

The evergreen forest harbored the highest mosquito diversity, with 18 species, including nine that were exclusive to this habitat. This highlights the importance of intact forest ecosystems for supporting native and potentially specialized mosquito fauna. The forest habitat likely provides a variety of natural breeding microhabitats such as tree holes, rock pools, and shaded puddles, along with stable humidity and minimal disturbance, creating favorable conditions for less urban-tolerant species (Wilke et al. 2021). However, several forest-associated mosquito species, such as *Ae. aegypti*, have successfully adapted to urban environments in response to land use changes (Wilke et al. 2021). Therefore, ongoing surveillance of mosquito adaptation in tropical forests may offer critical insights into emerging invasion patterns and the potential expansion of vector species into human-dominated areas. In contrast, rice fields showed the lowest species richness, likely due to their high exposure to agricultural disturbance, temporary water regimes, and limited vegetation diversity (Kaboré et al. 2023). The mangrove forest, while ecologically unique, supported moderate diversity, likely influenced by tidal fluctuations, salinity gradients, and limited breeding niche availability (Kaboré et al. 2023).

Species overlap across habitats was limited, suggesting niche specialization or habitat filtering. Only a few species, such as *Cx. quinquefasciatus* and *Ae. albopictus*, were broadly distributed across multiple environments. Their wide ecological tolerance and ability to exploit both natural and artificial habitats may explain their presence across residential, forested, and agricultural areas (Anwar et al. 2015; Bradshaw et al. 2004). In contrast, the presence of unique species in evergreen and mangrove forests such as *Toxorhynchites splendens* (Wiedemann, 1819), reflects habitat-specific mosquito assemblages and emphasizes the need for multi-habitat sampling to understand mosquito diversity in island ecosystems.

In residential areas, artificial containers were the dominant larval habitats, with a high number of positive breeding sites and overall larval abundance. Among these, plastic containers such as water storage jars and discarded items were especially productive. *Aedes albopictus* was the most abundant species, accounting for over half of all larvae and found in nearly all container types. This species' dominance and container flexibility reinforces its role as a major urban vector, well-suited to human environments (Paupy et al. 2009). *Aedes aegypti*, although less common, showed a preference for specific artificial materials like plastic and ceramic, aligning with previous studies that document its breeding preferences in densely populated areas (Getachew et al. 2015). The presence of *Cx. quinquefasciatus* in a range of container types, including cement basins and plastic tanks, also reflects its adaptation to urban conditions and poor water management systems (Samson et al. 2015).

The dominance of vector species in artificial containers within residential areas has important implications for public health. Given that both *Ae. albopictus* and *Ae. aegypti* are competent vectors of dengue and other arboviruses (Gómez et al. 2022), their presence in common household containers raises concerns about potential disease outbreaks, especially in a tourism-intensive setting like Cat Ba. Control efforts should prioritize public education and source reduction strategies targeting the most productive container types. Simple interventions, such as covering water containers, removing unused items, and improving waste management, could significantly reduce breeding opportunities. In addition, the high container productivity highlights the need for integrating community engagement with routine surveillance to maintain sustainable vector control.

Conclusion

This research highlights substantial changes in the mosquito species composition and abundance between distinct land-use categories on Cat Ba Island and highlights the implications of land-use change driven by urbanization and tourism development in terms of ecological importance. The evergreen forests possessed the greatest range of mosquito species, which underscore their value as biodiversity reservoirs, while in residential areas there existed a lower diversity yet higher abundance of disease vectors. These findings underscore the imperative of including vector surveillance within land-use planning and conservation management. Future research would be well-suited to explore seasonal patterns and vector competence to inform more efficaciously public health intervention and biodiversity conservation on rapidly changing tropical island ecosystems.

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Original paper

Zaujímavé nálezy chrobákov (Insecta: Coleoptera) z jaskynnej bioty na Slovensku

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Abstract: Interesting findings of beetles (Insecta: Coleoptera) from cave biota in Slovakia
Between 2021 and 2023, research on the cave fauna of the Slovakia yielded several remarkable beetle species. This study provides detailed accounts of their records and associated ecological observations. The circumstances of their discovery are briefly summarized, offering new insights into the occurrence and ecology of the adult stages, and in some cases their bionomics. The general distribution of the species is supplemented by published distribution data in Slovakia.

Key words: Coleoptera, faunistics, cave biota, Slovakia

Úvod

Jaskynné prostredie predstavuje špecifický ekosystém s mimoriadnymi podmienkami, ktoré ovplyvňujú druhové zloženie a ekologické nároky organizmov. Fauna chrobákov (Coleoptera) v slovenských jaskyniach je pritom stále relatívne málo preskúmaná, hoci systematické štúdie z posledných desaťročí postupne odhaľujú jej diverzitu a biogeografický význam. Historické údaje sú rozptýlené v staršej literatúre (napr. Roubal 1930, 1936), ktorá často uvádzala lokality bez presnejšej dokumentácie, čo sťažuje ich porovnanie so súčasnými poznatkami.
Výskum zameraný na jaskynnú faunu v Slovenskej republike v posledných rokoch priniesol nové údaje o viacerých skupinách bezstavovcov, avšak nálezy chrobákov zostávali skôr ojedinelé. Zaznamenávanie ich výskytu je dôležité nielen z hľadiska faunistického, ale aj pre lepšie pochopenie ekologických väzieb a potenciálneho výskytu subtroglofilných alebo trogloxénnych druhov.
Cieľom tejto práce je predstaviť nové údaje o štyroch druhoch chrobákov zaznamenaných v jaskynnej biote Slovenska počas rokov 2021 – 2023. Tieto nálezy rozširujú poznatky o ich výskyte, ekológii a rozšírení a zároveň poskytujú prvé potvrdené doklady o výskyte niektorých druhov v podzemnom prostredí.

Materiál a metódy

Metódy zberu

Chrobáky boli odoberané spolu s inými suchozemskými bezstavovcami pomocou štandardných metód používaných pre zachytenie diverzity v jaskynnom prostredí, so zameraním na terestrickú zložku fauny. Zoologický materiál chrobákov sme získali metódou zemných pascí a individuálnym zberom. Zemné pasce boli exponované v jaskynnom sedimente po dobu od 3 do 6 kalendárnych mesiacov. Na študijnej ploche bolo exponovaných 5 zemných pascí s návnadou. Pasce sa líšili dizajnom – jogurtové poháre (250 ml, Ø = 7 cm) a polyetylénové fľaše (100 ml, Ø = 3 cm) – a návnadou. Metódu individuálneho ručného odchytu sme použili na rozličných mikrohabitatoch v jaskyniach. Miloš Melega a Andrej Mock zbierali materiál v lokalite jaskyne Puklina v Skale a na ostatných lokalitách zbieral M. Melega. Chrobáky boli konzervované v 75 % liehu a sú deponované v zbierkach SMB.

Použité skratky

coll. – zbierka; SMB – Šarišské múzeum Bardejov; [= ...] – pôvodné názvy lokalít, ktoré sú uvedené v citovanej staršej literatúre; lgt. – zbieral.

Študované lokality

Skúmané podzemné habitaty sú umiestené v troch rozličných geomorfologických celkoch.
Hornonitrianska kotlina: Bojnická hradná jaskyňa je 65 m dlhá a 26 m hlboká syngenetická kráterová jaskyňa vytvorená v travertínoch v nadmorskej výške 325 m. Je sprístupnená v rámci prehliadky Bojnického zámku (Bella et al. 2018). V čase výskumu bol v jaskyni veľmi bohatý výskyt lampenflóry. GPS: 48°46'47.3"N 18°34'40.1"E, pasce exponované v dobe od 22.6.–6.12.2022.
Veľká Fatra: jaskyňa Hrboltová 3 je relatívne nedávno (jún 2023) objavenou jaskyňou. Vytvorená je v slienitých vápencoch osnického súvrstvia. Leží v nadmorskej výške 523 m s dĺžkou 43 m a vertikálnym rozpätím 9 m (Littva et al. 2023). V súvislosti s výstavbou diaľnice D1 sa predpokladá, že jej väčšia časť bude odťažená. Pasce exponované krátko po objavení jaskyne v dobe od 6.7.-31.10.2023, GPS: 49°06'36.9"N 19°14'26.4"E.
Volovské vrchy: Jaskyňa Puklina v Skale je relatívne krátka 7 m dlhá korózno-kryogénna jaskyňa (Bella et al. 2018). Situovaná je tesne pod krasovou planinou Slovinská skala v nadmorskej výške 900 m. GPS: 48°52'10.8"N 20°48'23.4"E, pasce exponované v dobe od 25.7. –17.12.2021.

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Výsledky a Diskusia

Staphylinidae

***Aloconota planifrons* (Waterhouse, 1863)**

Materiál: 1♀ + 1ex. (juvenil): Veľká Fatra: jaskyňa Hrboltová 3: 6.7. –31.10.2023, pasca – 50 % etylénglykol, biostacionárna plocha za meračským bodom 9 (mapa jaskyne podľa P. Hericha v Littva et al. 2023), lgt. Miloš Melega; 1♂: jaskyňa Hrboltová 3: pasca – 4% formalín, biostacionárna plocha za meračským bodom 9 (mapa jaskyne z práce Littva et al. (2023), autor mapy P. Herich), lgt. Miloš Melega, coll. SMB.

Rozšírenie: Známy z nálezov z Európy – Českej republiky, Dánska, Estónska, Fínska, Francúzska, Grécka, Írska, Nemecka, Nórska, Poľska, Rakúska, Slovenska, Švajčiarska, Švédska, Talianska, Ukrajiny, Veľkej Británie, zo severnej Afriky – Madeirských ostrovov a z Ázie – Turecka a z Afrotropického regiónu (Schülke & Smetana 2015). V Európe je známy najmä z horských oblastí. Vyskytuje sa všade zriedkavo, niekedy je len lokálne hojnejší. Druh je charakterizovaný ako hygrofilný, stenotopný, boreomontánny druh (Koch 1989), žije v horských riečnych údoliach v štrku na brehoch horských potokov, vlhkých lesoch, a v pôdnej hrabanke, len príležitostne vo väčšom počte zistený v Alpách počas povodní (Benick & Lohse 1974; Burakowski et al. 1981; Koch 1989). Zo Slovenska poznáme len nekonkrétny údaj „Slovakei“ (Horion 1951) a neskoršie aj jediný konkrétny údaj z lokality Kováčov, „na kamenitém břehu stinného potůčku“, ktorý uvádza Smetana (1957). Ďalšie respektíve novšie údaje zo Slovenska sme v literatúre nenašli. S istou rezervou je potrebné hľadieť na tri staršie literárne údaje veľmi podobných druhov *Aloconota debilicornis* Er., z lokality Michalovce [=N. Mihály] (Legit Dr. C. Chyzer.) od autora Kuthy (1897), *Atheta debilicornis* Er. z lokality Trenčín [=Trencsén] (Br) od autora Brancsik (1908), a *A. debilicornis* Er. z Nízkych Tatier „U horských bystrín nižších polôh na vápne je hojná“ od autora Roubal (1924), ktoré neskôr cituje Roubal (1930) vo svojom „Katalógu coleopter...“ uvádza pod menom *Atheta debilicornis* Woll. (v tejto práci je nesprávne uvedený autor opisu druhu Wollaston). Je teda otázne, o ktorý druh v skutočnosti z trojice známych z územia Slovenska *Aloconota debilicornis* (Erichson, 1839), *A. eichhoffi* (Scriba, 1868) alebo *A. planifrons* (Waterhouse, 1863) (Jászay & Hlaváč 2016) sa vlastne jedná. Ide totiž o navzájom ľahko zameniteľné druhy. *Atheta* (*Aloconota*) *debilicornis* Er. je u niektorých autorov považovaný za synonymum k *Aloconota planifrons* (Waterhouse, 1863) napr. Burakowski et al. (1981).

V blízkosti Slovenska bol *Aloconota planifrons* zistený v Poľsku na viacerých lokalitách: na brehu potoka Wołowiec na lokalite Sololiky v katastri obce Tarnawa Nižna na severovýchodnom úpätí Bieszczad (Szujecki 1996), údaj opakujú Pawłowski et al. (2000); ďalej sú známe údaje viacerých autorov z územia Poľska z lokalít: Śląsk Dolny; Vyžina Krakowsko-Wieluńska: okolie Krakova; Sudety Zachodnie: Brachów; Beskid Zachodni: nad Olzą v okolí Czieszyna; Beskid Wschodni: okolie Przemyśla; a niekoľko nekonkrétnych starých údajov: Polska; Prusy; Śląsk; Galicja, ktoré sú uvedené v Katalógu fauny Polski autorov Burakowski et al. (1981). Najbližšie známy nález z Ukrajiny je z lokality Lwów, ktorý uvádza Smoleński (1996). Napriek tomu, že vyššie uvedený nález už bol v literatúre publikovaný (Littva et al. 2023), považovali sme za potrebné uviesť niekoľko ďalších poznámok k samotnému nálezu a k výskytu druhu na území Slovenska. Je to prvý zaznamenaný výskyt v jaskynnom habitate, ale je možné, že otvorením jaskynných priestorov s vonkajším prostredím pri výstavbe diaľnice, je jeho výskyt v jaskynnom prostredí sekundárny.

***Dropephylla vilis* (Erichson, 1840)**

Materiál: 1♀: Hornonitrianska kotlina: Bojnická hradná jaskyňa: 22.6.–6.12.2022, pasca – etylénglykol-pivo 1:1, biostacionárna plocha pri meračskom bode 12 (pozri plán jaskyne Holúbek & Marušin 2000), návnada štiepka z krovia, organický substrát pre kvety a ovsené vločky, lgt. Miloš Melega; 1♂: Bojnická hradná jaskyňa: 22.6.2022, ručný zber, stena-sediment v hlavnej sieni s porastom lampenflóry, lgt. Miloš Melega; 1♀: Bojnická hradná jaskyňa: 15.5.2023, ručný zber, stena-sediment v hlavnej sieni s porastom lampenflóry, lgt. Miloš Melega, coll. SMB.

Rozšírenie: Je známy z nálezov v Západnej Európe – Francúzsko, Gibraltár, Monako, Nemecko, Portugalsko, Španielsko, Švajčiarsko, Taliansko a Sicília a Veľká Británia a Severnej Afrike – Alžírsko, Tunis (Jászay & Hlaváč 2006; Schülke & Smetana 2015). Najnovšie zistený aj v Turecku a v Rusku (Shavrin 2024). Neďaleko Slovenska z Ukrajiny (Podkarpatská Rus) z vrchu Pop Ivan uvádzajú Fleischer et al. (1924) a z Užhorodu Roubal (1930). Vo viacerých literárnych zdrojoch sa uvádza, že druh žije na okrajoch lesov, pod kôrou, na starých konároch, v práchne stromov, v humuse, na kvetoch, pod machom a podobne. Je nachádzaný v ihličnatých a listnatých lesoch, v chodbách podkôrnikovitých chrobákov (Scolytidae), pod kôrou, na konárikoch (*Picea*, *Pinus*, *Quercus*, *Populus*, *Acer*, *Betula* a druhov ovocných stromov) alebo v hrabanke v okolí drevín a na jar na kvitnúcich rastlinách (napr. Burakowski et al. 1979; Roubal 1930), saproxylický druh (Fowles et al. 1999), pod kôrou (Legner & Moore 1977), rozšírený, ale lokálny druh pod kôrou mŕtvych alebo chorých listnatých alebo ihličnatých stromov (Anderson 1997). Z hľadiska ekologického Horion (1963) a Koch (1989) hodnotia druh: eurytop, silvikol, kortikol, humikol v lesoch a záhradách, pod práchnivejúcou kôrou a v práchne odumretých stromov a pňov, v chodbách myšovitých a pod hnijúcou vegetáciou, v kompostoch, živia sa podkôrnikmi najmä *Ips sexdentatus* (Börner, 1776). Z literatúry z územia Slovenska poznáme len jeden starý údaj Malý Kriváň, 1 667 m n. m. v pohorí Malá Fatra [=Kis-Kriván] (Brancsik 1910), tento údaj cituje vo svojej práci aj Csiki (1913), ktorý neskoršie cituje aj vo svojom katalógu Roubal (1930). Pretože Brancsikov dokladový materiál sa nenašiel v zbierkach a nebol ani k dispozícii na preštudovanie počas revízie rodu *Dropephylla* Mulsant & Rey, 1880 (Jászay & Hlaváč 2006), bol jeho výskyt na Slovensku považovaný za pochybný a nebol uvedený v zozname drobčíkovitých (Coleoptera: Staphylinidae) zo Slovenska (Jászay & Hlaváč 2016). Je to vlastne potvrdený nález po vyše 116 rokoch a prvý doložený výskyt pre faunu Slovenska. Jeho výskyt v jaskynnom prostredí považujeme za sekundárny. Pri revízii druhu *Dropephylla vilis* (Jászay & Hlaváč 2006) bol opísaný jemu veľmi podobný druh *Dropephylla koltzei* Jászay & Hlaváč 2006, ktorý je v súčasnosti známy z nálezov zo strednej a západnej Európy. Preto ekologické údaje publikované v staršej literatúre sa vzťahujú na oba spomínané druhy *D. vilis* a *D. koltzei*.

***Bryaxis frivaldszkyi slovenicus* (Machulka, 1926)**

Materiál: 1♂: Volovské vrchy: jaskyňa Puklina v Skale: 25.7. –17.12.2021, pasca – 4 % formalín, biostacionárna plocha na konci jaskyne, návnada organický substrát pre kvety, lgt. Miloš Melega a Andrej Mock, coll. SMB.

Rozšírenie: Druh známy zo Slovenska (Löbl & Besuchet 2015), nedávno nájdený aj v Českej republike v Zbrašovskej aragonitovej jaskyni (Mlejnek et al. 2015). Zo Slovenska je známy iba z niekoľkých lokalít: v hnijúcej listovej opadanke v okolí jaskýň v Ružínskej doline [=Oružínske údolí] (Machulka 1926), ktorú cituje vo svojom katalógu ako lokalitu Košice Roubal (1930), Poľana – Hrochotská jaskyňa, Banská Bystrica – Jaskyňa pri Jakube, Jelšavský kras – Veľká Mutonská jaskyňa (Franc & Mlejnek 2000), Čierna hora Mts.: Humenecká jaskyňa, Klenbová jaskyňa, Predná veľká jaskyňa, Veľká ružínska jaskyňa (Mock et al. 2009), subteránne prostredie zalesnenej sutiny v Národnej prírodnej rezervácii Sivec (Rendoš et al. 2012), Volovské vrchy: Svätojánska jaskyňa (Melega et al. 2022), jaskyňa Kolónia 2, Hornádska kotlina: Puklinová jaskyňa na Dreveníku, Levočské vrchy: Jaskyňa pod Spišskou (Kováč et al. 2012), Slovenský raj: jaskyňa Duča (Kováč et al. 2012), Veľká Fatra: jaskyňa Horná Túfna (Melega et al. 2023). Druh bol najpočetnejšie zaznamenaný v jaskynných biotopoch, prekvapujúci je nález druhu na suťovitej alpínskej lúke vo Vysokých Tatrách vo Velickej doline (Jászayová et al. 2023). Druh je známy ako edafický, poznáme viac literárnych údajov z jaskynného prostredia, v skalných sutinách v chladných horských biotopoch, bol zaznamenaný aj jeho povrchový výskyt v hnijúcej listovej opadanke v okolí jaskýň, pod kameňmi a dokonca aj na suťovitej alpínskej lúke, pravdepodobne je to subtroglofilný druh. V tomto prípade ide o prvé faunistické údaje z tejto jaskyne ale zároveň i o prvé publikované údaje o subteránnej faune planiny Slovinská skala.

Bothrideridae

***Anommatus reitteri* Ganglbauer, 1899**

Materiál: 1ex.: Hornonitrianska kotlina: Bojnická hradná jaskyňa: 22.6.–6.12.2022, pasca – etylénglykol-pivo 1:1, biostacionárna plocha pri meračskom bode 12 (mapa jaskyne podľa Holúbek 1999), návnada štiepka z krovia, organický substrát pre kvety a ovsené vločky, lgt. Miloš Melega, coll. SMB.

Rozšírenie: Je známy z nálezov z Albánska, Bosny a Hercegoviny, Českej republiky, Chorvátska, bývalej Juhoslávie (Srbska a Čiernej Hory), Maďarska, Rakúska, Rumunska, Slovenska, Slovinska, Švajčiarska a Talianska. Druhy rodu *Anommatus* Wesmaël, 1835 žijú subteránne a v prostredí v ktorom žijú sú ťažko zistiteľné, sú to malé chrobáky žijúce subteránne, nepigmentované, slepé a bezkrídle. Sú to väčšinou lokálne rozšírené glaciálne relikty z Balkánu, severného Talianska a južného Francúzska (Vogt 1967). *A. reitteri* sa od ostatných našich druhov rodu *Anommatus* odlišuje výrazným lemom na zadnej (posteriórnej) strane štítu a rýhou lemu, ktorá je výrazne a nepravidelne bodkovaná (Kaszab 1947). Uprednostňuje južné a teplé polohy v strednej Európe (Roubal 1936). Z územia Rakúska [=Öesterreich], Karpát [=Karpathen], Maďarska [=Ungarn], Západného Balkánu: Albánska [=Illyrien], Chorvátska [=Croatien] a varietu *A. reitteri* var. *reitteri* zo Slovinska z okolia Ľubľany [=Krain], Južného Maďarska [=Südungarn], Bosny [=Bosnien] a Hercegoviny [=Hercegovina] uvádza Reitter (1900). Zo Slovenska sú známe staršie údaje: Bratislava, Banská Bystrica pri päte starého javora (*Acer* sp.) v meste, v záhrade, v kolónii mravcov *Lasius brunneus* Latr., viac exemplárov mimo hniezda v pôde, a z Košíc (Roubal 1936). Novšie údaje: Rusovce-park, v parku hojne pod pokosenou trávou, pilinami so zárastom húb na povrchu pôdy (Majzlan 2021). V Čechách bol zbieraný v pôdnych presevoch v starom mestskom parku, v preseve dutiny živej lipy (*Tilia* spp.) (Růžička & Vávra 1997), v zachovalom zvyšku zmiešaného lesa parkového typu na aluviálnej terase rieky Odry, v preseve bielo tlejúceho dreva pri päte starých pňov listnatých stromov (Vávra & Stanovský 2013), v mŕtvom dreve na spodnej strane pňa, v mŕtvom dreve duba na spodnej strane pňa a pod kôrou, ďalej uvádza, že druh žije skryto v mŕtvom dreve, predovšetkým listnatých stromov, často v podzemných častiach starých pňov (Krásenský 2020). V Rakúsku bol druh nachádzaný pomerne často v rôznych typoch lesov, najmä v presevoch koreňov starých stromov alebo pňoch napadnutých bielou alebo červenou hnilobou (Neuhäuser-Happe 1997). Vo Viedni (park Rathauspark) bol nájdený v nezarastenej vegetáciou v povrchovej vrstve, mierne zhutnenej minerálnou pôdou pod porastom agátov (*Robinia pseudoacacia*) a javorov mliečnych (*Acer platanoides*) (Christian 2000). Je to prvý nález tohto druhu z jaskynných priestorov.

Záver

V príspevku sú uvedené nálezy štyroch zaujímavých druhov chrobákov *Aloconota planifrons* (Waterhouse, 1863), *Dropephylla vilis* (Erichson, 1840) a *Bryaxis frivaldszkyi slovenicus* (Machulka, 1926) z čeľade

Staphylinidae a *Anommatus reitteri* Ganglbauer, 1899 z čeľade Bothrideridae, ktoré boli zistené počas výskumu fauny jaskýň Slovenskej republiky v rokoch 2021-2023. Pre jaskyňu Puklina v Skale vo Volovských vrchoch je to aj vôbec prvý faunistický záznam. Pri druhoch *Aloconota planifrons*, *Dropephylla vilis* a *Anommatus reitteri* bol prvýkrát zaznamenaný ich výskyt v jaskynnej biote. Pre druh *Aloconota planifrons* je vzhľadom k ekológii imág výskyt v jaskynnej biote pravdepodobne sekundárny. Pre druh *Dropephylla vilis* je to vlastne aj potvrdený literárny údaj po vyše 116 rokoch a prvý doložený nález pre faunu Slovenska ale vzhľadom k jeho známym údajom z bionómie je jeho výskyt v jaskynnej biote sekundárny. Pre druh *Bryaxis frivaldszkyi slovenicus* je ďalším nálezom tohto zriedkavo sa vyskytujúceho druhu na Slovensku, pre ktorého je jaskynná biota charakteristický habitat.

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Original paper

Bycatch with benefits: CO_2 traps reveal new Hybotidae for Slovakia

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Abstract
Carbon dioxide–baited traps are widely used in mosquito surveillance, yet their bycatch often remains overlooked. In this study, we analysed nontarget Diptera, specifically empidoid flies, collected using BG-Sentinel 2 traps in Slovakia during 2023–2024. Although the target group was rare, empidoids were found in 11 out of 472 samples (2.3%). Their taxonomic significance was striking. We identified one species of Empididae and ten species of Hybotidae. Five of these represent the first records for the Slovak fauna. Our results demonstrate that even minimal bycatch from nontraditional trapping methods can yield noteworthy faunistic discoveries. The rarity of these records underscores their importance: even a handful of specimens can reshape our understanding of national species diversity. This study highlights the value of integrative approaches that embrace incidental data, offering new insights into the hidden diversity of Diptera.

Key words: Central Europe, dance flies, faunistic, new records, unconventional collection method

Introduction

Carbon dioxide–baited traps are widely recognized for their ability to mimic mammalian exhalation, serving as indispensable tools for vector surveillance targeting Diptera such as mosquitoes and sand flies (e.g. Farajollahi et al. 2009; Cilek et al. 2024; Rodríguez-Rojas et al. 2024). However, these traps often capture a broader spectrum of insects beyond the intended target taxa (e.g. Oboňa et al. 2025). Such bycatch from nonculicid Diptera is typically overlooked, dismissed as negligible collateral noise (e.g. Kurina et al. 2025; Grundmann et al. 2025). Yet, this overlooked assemblage can harbor ecologically valuable or scientifically intriguing species worthy of study.

In this work, we explore a seldom-employed, holistic approach: analysing nontarget Diptera captured in CO_2 traps originally deployed for mosquito surveillance programs. By focusing on an unexpected family drawn to CO_2 allure, we challenge the prevailing assumption that bycatch from these traps lacks scientific value. Drawing attention to this incidental catch, we aim to demonstrate that it can broaden our ecological and taxonomic insight, adding a rich, untapped dataset to entomological research. Although there are numerous studies have quantified mosquito and sand fly captures using CO_2 traps (Cotteaux-Lautard et al. 2013; Arimoto et al. 2015; Carvalho et al. 2021; González et al. 2024; Ruiz-Arrondo et al. 2023), integrative analyses that incorporate incidental Diptera data from these traps are rare. Here, we present one of the first assessments dedicated to nontarget Diptera assemblages obtained via CO_2 trapping. We advocate for a more inclusive surveillance paradigm that capitalizes on every insect drawn to the collecting nets.

Materials and methods

Sampling

The bycatch presented in this study was collected during mosquito sampling using BG-Sentinel 2 traps (Biogents,

Figure 1. Photographs of BG Sentinel 2 traps (Biogents, Germany), photographs by Tomáš Csank.

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Germany) baited with CO_2 cylinders (Figure 1). These traps were deployed at various locations in 2023 and 2024 (see Table 1). The collection nets were replaced once or twice per week and stored at -20 °C until transported to the laboratory, where they were further stored at -80 °C. The date of trap removal is reported in Results.

After the mosquitoes were sorted, the remaining material was preserved in 75% ethanol. The collected specimens were initially sorted to the family level by the last author and identified to species level by the first author. The material studied is deposited in the insect collection of the first author (RBINS).

Table 1. An overview of sampling sites.

Region	District	City/Municipality	Locality / code	GPS
Bratislava	Senec	Hrubý Šúr	Hrubý Šúr ostrov / SC	48°11'27"N 17°23'24"E
Trnava	Trnava	Slovenská Nová Ves	Ronava / TT	48°18'25"N 17°32'32"E
Trnava	Dunajská streda	Potônske Lúky	Potônske Lúky / DS	48°05'43"N 17°35'22"E
Trenčín	Prievidza	Bojnice	Bojnice / PD	48°46'49"N 18°34'34"E
Nitra	Nitra	Nitra	Sokoliareň SPU / NR	48°18'13.5"N 18°05'51.6"E
Nitra	Komárno	Zlatná na Ostrove	Veľký Lél / KN	47°45'23"N 17°56'30"E
Žilina	Žilina	Žilina	Mojšova lúčka / ZA	49°11'33"N 18°49'15"E
Banská Bystrica	Veľký Krtíš	Lesenice	Lesenice / VK	48°06'18"N 19°14'57"E
Banská Bystrica	Rimavská Sobota	Mojín	Mojín / RS	48°20'17"N 19°58'20"E
Banská Bystrica	Banská Bystrica	Rakytovce	Rakytovce / BB	48°40'39"N 19°07'27"E
Prešov	Stará Ľubovňa	Nová Ľubovňa	Farma Stará Ľubovňa / SL	49°15'43"N 20°41'20"E
Prešov	Stropkov	Lomné	Lomné / SP	49°06'17"N 21°38'24"E
Košice	Michalovce	Senné	Senianské rybníky / MI1	48°40'11"N 22°01'54"E
Košice	Košice	Kavečany	ZOO / KE	48°47'01"N 21°12'14"E
Košice	Košice	Kavečany	ZOO, Upper pond / UP	48°47'11.4"N 21°12'11.9"E
Košice	Košice	Kavečany	ZOO, Lower pond / LP	48°47'20.6"N 21°12'22.0"E
Bratislava	Bratislava	Podunajské Biskupice	Podunajské Biskupice / BA	48°07'08.5"N 17°12'40.1"E
Košický	Trebišov	Beša	Beša / MI2	48°32'04.8"N 21°57'20.2"E

Locality

Sampling was performed at 2 sites in 2023 (site codes UP and LP), and other 16 sites in 2024 (See Table 1).

The "Annotated list of recorded species" includes the number and sex of specimens, the date of trap collecting, and the locality name (for more detail see Table 1). For newly recorded species in Slovakia, brief notes on their distribution are provided.

Results

A total of 15 empidoid specimens representing one species of Empididae and ten species of Hybotidae were collected using "BG-Sentinel 2" CO_2 traps during 2023 (58 samples) and 2024 (414 samples), (see Annotated List of Recorded Species). The studied group was detected in 11 out of a total of 472 samples, corresponding to a detection rate of 2.3%.

Annotated list of recorded species

Diptera
Empididae

Rhamphomyia (*Amydroneura*) *gibba* (Fallén, 1816)
Material examined: ♂, 11.9.2023, Lower pond.

Hybotidae
TACHYDROMIINAE
TACHYDROMIINI
Platypalpus albiseta (Panzer, 1806)
Material examined: ♀, 21.7.2023, Upper pond; ♀, 22.9.2024, Veľký Lél.

Platypalpus longiseta (Zetterstedt, 1842)
Material examined: ♀, 22.8.2023, Upper pond.

Platypalpus pallidiventris (Meigen, 1822)
Material examined: ♀, 16.6.2024, Ronava.

DRAPETINI

Crossopalpus aeneus (Walker, 1871)
Material examined: ♂, 4.8.2024, Podunajské Biskupice.
Distribution. Austria, Azores Islands, Belgium, Bosnia and Herzegovina, Bulgaria, Canary Islands, Cyprus, mainland France, Germany, mainland Greece (including Crete and Dodecanese), Hungary, mainland Italy (including Sardinia), Madeira, Malta, North Africa, Switzerland, Russia (European part), Ukraine, and West Asia (Grootaert et al. 1991; Shamshev 2016; Grootaert & Beuk 2024). Recorded for the first time in Slovakia.

Crossopalpus chvalai Kovalev, 1976
Material examined: ♂, 6.10.2024, Ronava.
Distribution. Central and South European Russia, Hungary, mainland Greece (Shamshev 2016; Grootaert & Beuk 2024). Recorded for the first time in Slovakia.

Drapetis assimilis (Fallén, 1815)
Material examined: ♀, 9.6.2024, Rakytovce.

Drapetis convergens Collin, 1926
Material examined: 3 ♀♀, 8.9.2024, Veľký Lél.
Distribution. Czech Republic, England, Germany, and Ukraine (Yang et al. 2007). Recorded for the first time in Slovakia.

Drapetis infitialis Collin, 1961
Material examined: ♂, ♀, 25.8.2024, ZOO Kavečany.
Distribution. Belgium, England, mainland France and Corsica, Czech Republic, Finland, Germany, Great Britain, Italy, Norway, and Russia (Shamshev 2016; Grootaert 2023; Grootaert et al. 2023). Recorded for the first time in Slovakia.

Drapetis monsmargila Grootaert, Beuk & Shamshev, 2020
Material examined: ♂, 14.7.2024, Veľký Lél.
Distribution. Bulgaria, Czech Republic, and the Netherlands (Roháček et al. 2021; Grootaert et al. 2024). Recorded for the first time in Slovakia.

Elaphropeza ephippiata (Fallén, 1815)
Material examined: ♂, 7.7.2024, Farma Stará Ľubovňa.

Discussion

This study is part of a series examining Diptera bycatch from CO_2 traps (e.g., Oboňa et al. 2025; Grundman et al. 2025; Kurina et al. 2025). Before this study, the Hybotidae family in Slovakia included 170 species (Chvála 2009), a number that was later increased by Weele et al. (2015, 2018), Oboňa et al. (2021), and Beuk et al. (2025) to 178 species. Records of *Crossopalpus aeneus*, *C. chvalai*, *Drapetis convergens*, *D. infitialis*, and *D. monsmargila* in this study increased the total number to 183 species.

The present study moreover highlights the potential of using carbon dioxide-baited BG-Sentinel 2 traps, which were originally designed for mosquito surveillance, to collect valuable faunistic data on nontarget dipteran taxa, particularly within the Empidoidea family. While these traps are not typically used to survey predatory flies, such as those from Empididae and Hybotidae, our findings demonstrate that even low-yield bycatch can significantly contribute to national biodiversity records. This is particularly relevant for regions where targeted surveys are scarce because even limited incidental material can help fill critical faunistic gaps.

The number of empidoid specimens collected was relatively small (only 15 individuals from 472 trap samples) yet their taxonomic diversity was notable. The recorded material included ten species of Hybotidae and one species of Empididae. Five species reported here as first records for Slovakia. This underlines the importance of not dismissing trap bycatch, even when it represents a minor fraction of total captures (see also Rozkošný & Vaňhara 1995; Sladonja et al. 2023).

The observed diversity, particularly among species of the genera *Drapetis* and *Crossopalpus*, suggests that the microhabitats associated with the trapping sites (such as leaf litter, soil surface, and decaying wood) may harbor previously overlooked dipteran assemblages incidentally attracted to CO_2 plumes. Since many hybotids are ground-dwelling or develop in microhabitats influenced by soil respiration (Drapetini are also known to visit hollows and other partially enclosed spaces), the CO_2 cue could mimic natural conditions and thus act as an attractant. Emphasizing the need for targeted supplementary research to better understand the mechanisms underlying fly attraction would provide a more balanced reflection of the current state of knowledge, while also acknowledging the value of these bycatch data.

Our results support the idea that unconventional or opportunistic sampling methods can play a complementary role in biodiversity assessments and highlight the scientific value of bycatch. We advocate for a more integrative approach to entomological monitoring, where nontarget taxa from surveillance programs are routinely examined. Such incidental collections can provide meaningful insights into species distributions, reveal undocumented taxa, and expand our knowledge of Diptera diversity.

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