Biodiversity & Environment, 2023
Vol. 15, No. 2, 11–16 Original paper

The moth flies (Diptera: Psychodidae) of different ecosystems of the karst Barrois plateau, France

JOZEF OBOŇA[1], FRANÇOIS LE PONT[2], JEAN-MARIE GOUTORBE[3] & JAN JEŽEK[4]

[1] Department of Ecology, Faculty of Humanities and Natural Sciences, University of Prešov, 17. novembra 1, 081 16 Prešov, Slovakia, [2] Boulevard Aristide Briand 95, Montreuil-Sous-Bois, F-93100, France, [3] 13, route des Fusillés, Bar-le-Duc, F-55000, France, [4] Department of Entomology, National Museum, Cirkusová 1740, 193 00 Prague 9 – Horní Počernice, Czech Republic

Abstract
The psychodid fauna of the karst Barrois plateau in France is documented for the first time. Eight moth flies species were recorded in five different ecosystems. *Trichomyia urbica* Haliday in Curtis, 1839, and *Mormia revisenda* (Eaton 1893) are rare European species. On the other hand, *Psychodocha cinerea* (Banks 1894) and *Psychodocha gemina* (Eaton 1904) are very common and occur in all the ecosystems studied. Karst landscapes represent a very interesting and at present highly endangered ecosystem that deserves our attention.

Keywords: Biodiversity, faunistics, Karst, Trichomyiinae, Psychodinae, Mormiina, Trichopsychodina, Psychodini, Europe, Palaearctic Region

Introduction

According to Hamilton-Smith (2001), it is important to think of karst areas not just as caves or a landscape, but rather as "a karst system, incorporating component landforms as well as life, energy, water, gases, soils and bedrock", simply the karst ecosystem (see also in Eberhad 1994).

Much of the study of karst biota has focused on macrocaverns, simply because these are the only caverns directly accessible to biologists (Hamilton-Smith 2001). However, Howarth (1983) demonstrated the immense importance of smaller cavities as habitats for invertebrates. Most biological work has focused on subterranean fauna, particularly bats and troglobitic invertebrates. There are, however, a number of other extremely important and often neglected karst-dependent species, such as microbiota, plants, vertebrates and invertebrates, which are dependent on the karst vegetation or are otherwise restricted to karst areas (Hamilton-Smith 2001). Many of the threats to karst biota are large-scale events that threaten the very integrity or even survival of the karst itself (Watson et al. 1997). These include: i.) total destruction of the karst as a result of mining, quarrying, submersion of water reservoirs; ii.) major land or hydrological disturbance, e.g., monoculture forestry, quarrying, land clearing, construction, waste disposal or other landfills; iii.) pollution from sewage and domestic drainage, farm or industrial waste, hydrocarbons from fuel spills or microbial contamination; and iv.) human entry to caves or other uses, e.g., military, religious observance and monuments, sanatoria, research, tourism, etc. (e.g. Watson et al. 1997; Hamilton-Smith 2001).

From the point of view of the biodiversity of the family Psychodidae, there are only a few notes devoted to this group of organisms in karst ecosystems in Europe (e.g., Ježek 1982; Ježek et al. 2014), especially from caves, e.g., Ježek (1983, 1990), Košel & Horváth (1996), Ježek & Omelková (2012), Omelková & Ježek (2012), etc.

The main goal of this work is to describe the biodiversity and seasonal changes of the family Psychodidae in different ecosystems of the karst Barrois plateau in France.

Material and methods

Sampling was carried out in 2022 at three different sites: Mussey station (48°48'23.4"N 5°04'40.2"E, 204 m a.s.l.), Ville-sur-Saulx station (48°42'45.6"N 5°03'14.7"E, 207 m a.s.l.), and Robert-Espagne station (48°44'52.0"N 5°01'49.0"E, 160 m a.s.l.), all in the forest, on a karst plateau in north-eastern France, west of Bar-le-Duc, prefecture of the Meuse department (Figure 1).

The climate is oceanic with continental tendencies, an average annual temperature of 11°C and regular monthly rainfall (annual average of 845 mm). This region suffers from the effects of climate change, with inter-seasonal heatwaves damaging the forest ecosystem, and unusual tornadoes causing flooding at the resurgences in the valley of the Saulx River, which crosses the karst Barrois plateau. A miniature CDC light trap (a miniature light trap with an attractant to lure flies into the collection chamber) was used for sampling, powered by new Simply LR20/D alkaline batteries. A detailed overview of the investigated ecosystems is in Table 1.

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

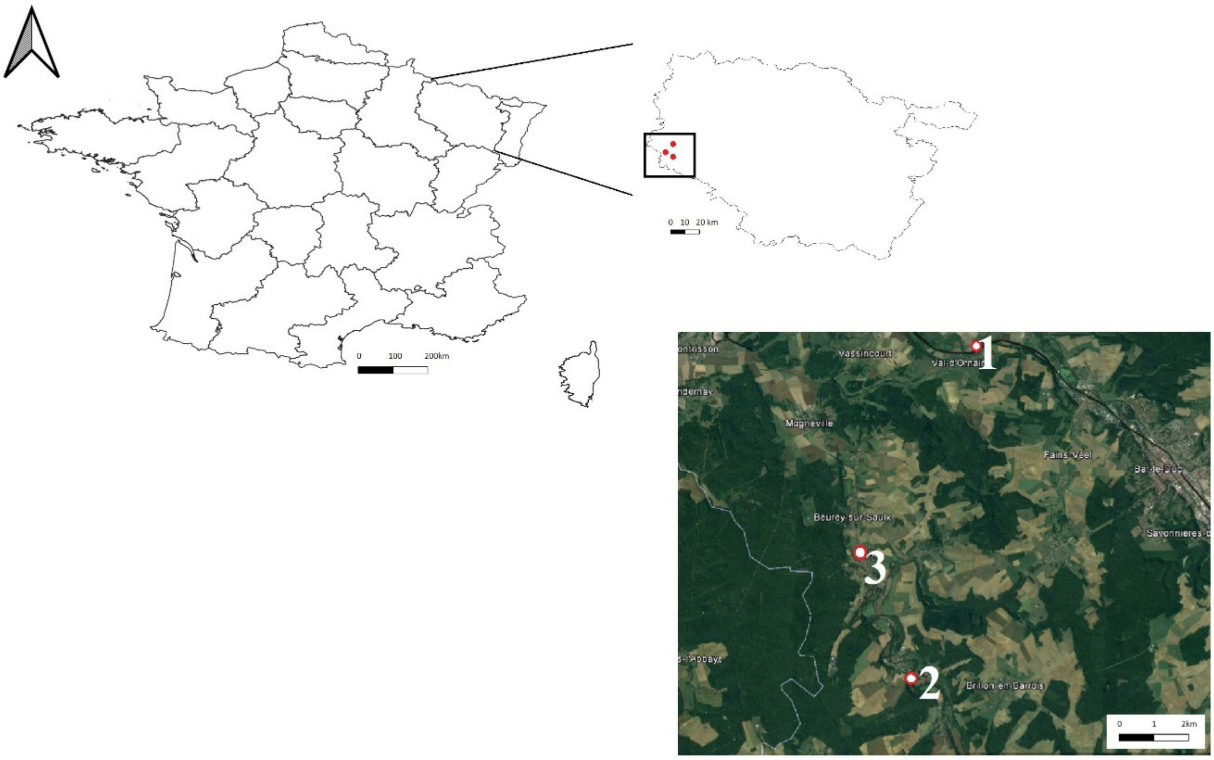

Figure 1. Map showing the sampling sites on the karst Barrois plateau, France. Prepared by Lenka Demková. 1: Mussey station, 2: Ville-sur-Saulx station, 3: Robert-Espagne station.

Table 1. Detailed overview of the investigated ecosystems.

Station	Ecosystem	Short description and collecting methods
Mussey station	undergrowth	CDC at 1.20 m from the ground at the bottom of a unique sinkhole (a funnel-shaped collapse 10 to 15 m deep, found in karst regions, the bottom is blind, with a tangle of vegetation and trees)
	sinkholes	varying depth and appearance Perini (Figure 2), Blaireau, Huss, and Petit bois communal
Ville-sur-Saulx station	undergrowth	same location of the CDC
	trench	Figure 4; path 400 m long, 15 m wide, and 5 m deep, dug by quarrymen to reach the limestone layer, along which the various entrances to the underground quarry can be seen; CDC always placed in the same location
	underground quarries	entrances to Agouti 1 (Figure 3), 2, and 3 on the right side, and two others on the left side; CDC placed at each entrance
Robert-Espagne station	chasms	La Laie (Figure 5), Paul, Ohzi, and Renaisson

Each ecosystem was sampled during four periods: May, July, September, and November. The captured moth flies (approximately 340 specimens in total) were preserved in 70% ethanol in the field by the second author and subsequently identified by the first author. The studied material is deposited in the alcohol collection of insects (Diptera) at the University of Prešov.

Figure 2. The Perini sinkhole in old-growth forest, with large oak trees and a low density of growing trees in the understory.

Figure 3. Entrance to the Agouti 1 underground quarry. The entrance is blocked by the soil from the erosion of the hill since the quarry was closed.

Figure 5. The "La laie" chasm in Robert-Espagne, a classically shaped chasm.

Figure 4. The trench is still covered with vegetation despite the winter. On the left, in the background in the middle of the path, is a CDC trap. On the right and halfway up, another CDC at the entrance to a quarry, nommée "the first on the left".

Identification keys used: Vaillant (1971–1983), Szabó (1983), Withers (1989) and original papers with species descriptions (Ježek 1977, 1983, 1985, 1990; Ježek & Goutner 1993; Omelková & Ježek 2012). The nomenclature and classifications are modified using Ježek & Omelková (2012), Oboňa & Ježek (2014), Kroča & Ježek (2015, 2019, 2022) and Ježek et al. (2021b).

Results and Discussion

During 2022, five different types of ecosystems were sampled in three different locations: chasm, undergrowth, underground quarry, sinkhole and trench. A total of eight species of family Psychodidae were recorded. Faunal data from the same ecosystems are summarised in Table 2.

Table 2. Alphabetic overview of species of the family Psychodidae recorded in the studied ecosystems.

	Chasm	Undergrowth	Underground quarry	Sinkhole	Trench
Logima zetterstedti Ježek, 1983	*		*		
Mormia revisenda (Eaton, 1893)	*	*	*		
Philosepedon humerale (Meigen, 1818)	*				
Psychodocha cinerea (Banks, 1894)	*	*	*	*	*
Psychodocha gemina (Eaton, 1904)	*	*	*	*	*
Psychodula minuta (Banks, 1894)	*	*	*		*
Tinearia alternata (Say, 1824)		*			
Trichomyia urbica Haliday in Curtis, 1839			*		

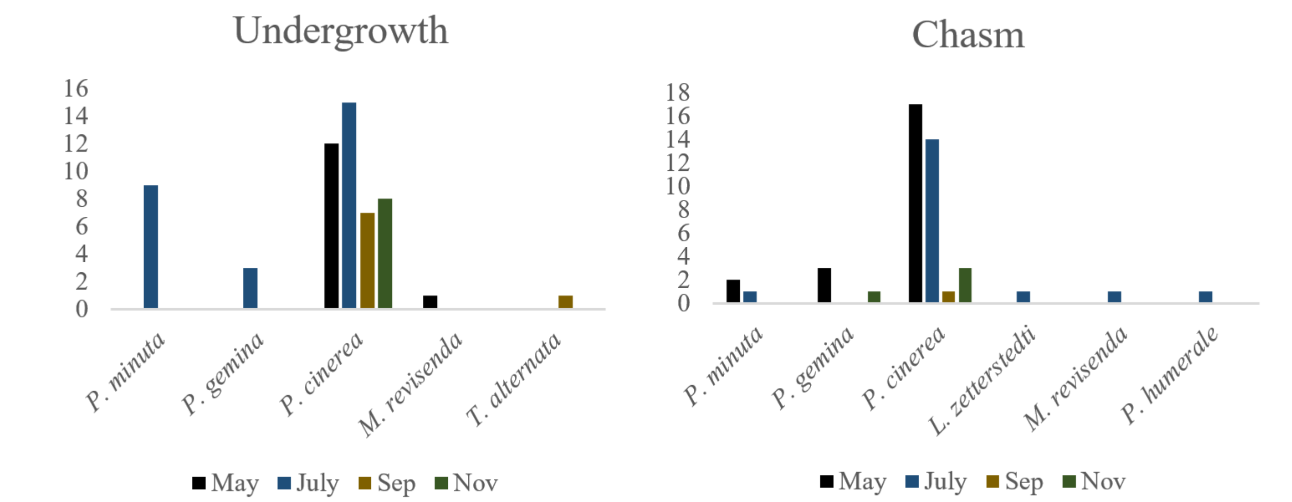

Figure 6. An overview of the occurrence of the moth flies in chasms and in undergrowth. The x-axis shows the presence of species in the months of May, July, September and November; the y-axis shows the abundance of species.

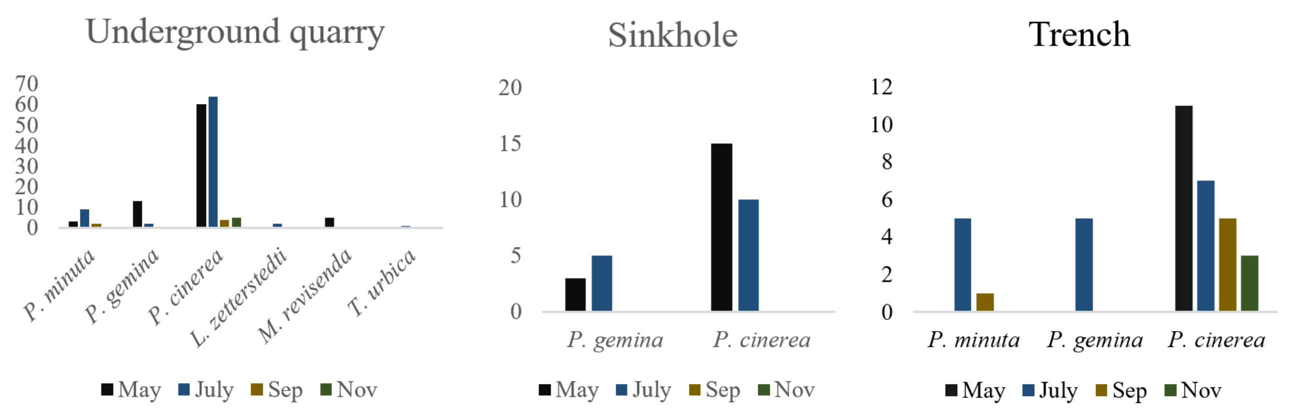

Figure 7. An overview of the occurrence of moth flies in underground quarries, sinkholes and trenches. The x-axis shows the presence of species in the months of May, July, September and November; the y-axis shows species abundance.

In the chasms, 44 moth flies belonging to five species were collected. *P. cinerea* dominated with 35 individuals. This species was present in chasms throughout the year. In the undergrowth, 56 moth flies belonging to five species were collected. Again, *P. cinerea* dominated with 42 individuals. This species was present in undergrowth throughout the year. An overview of the occurrence of other species is given in Figure 6.

The most flies were collected the underground quarries – 170 moth fly individuals in total, belonging to six species. *P. cinerea* dominated with 133 individuals. In sinkholes, only 33 moth flies belonging to two species were collected. None of the captured species occurred in sinkholes throughout the year. In the trenches 37 moth fly samples were caught belonging to three species. *P. cinerea* dominated with 26 samples. This species was present here throughout the entire year. An overview of the occurrence of other species is in Figure 7.

There are five species in the flat undergrowth of the plateau; the psychodid fauna of the chasms and underground quarries is slightly richer compared to the undergrowth which characterises the natural environment of the forest which is particularly evident from Figure 7 (Sinkhole and Trench). In general, it can by noted (see also Table 2) that the fauna is remarkably similar (although there are no harvests during the winter period). The chasms, although more exposed to bad weather, provide shelter for the same number of species as the undergrowth. If we consider common undergrowth dipterans from other families found in this biotope, such as *Limonia nubeculosa* Meigen, 1804 (Diptera: Limoniidae), we observe that its outbreaks in September 2021 and 2022 were as abundant at the entrance of underground quarries as above chasms, confirming the shelter role of the latter.

Recorded species

From eight recorded species, one belongs in subfamily Trichomyiinae, and seven in subfamily Psychodinae (one from Mormiina, one from Trichopsychodina, five from Psychodini).

Subfamily Trichomyiinae

Trichomyia urbica Haliday in Curtis, 1839

A rare European and Transcaucasian species (Ježek et al. 2021a). The larvae are xylophagous and occur in habitats with decaying cellulose (Ježek & Omelková 2012). Only one individual of this species was found, in July in an underground quarry (site Ville sur Saulx).

Subfamily Psychodinae

Subtribe Mormiina

Tribe Mormiini

Mormia revisenda (Eaton, 1893)

A rare European species (Ježek et al. 2018, 2020; Morelli & Biscaccianti 2021). This species was recorded in a chasm (1 specimen), undergrowth (1 ind.) and an underground quarry (4 ind.) in May and in July.

Subtribe Trichopsychodina

Tribe Paramormiini

Philosepedon humerale (Meigen, 1818)

It is known from the Western Palearctic and the Afrotropical region (Afzan & Belqat 2016; Ježek et al. 2020). The larvae were found in dead snails of various species (Beaver 1972; Ježek 1985). This species was only recorded in a chasm (1 individual) in July.

Tribe Psychodini

Logima zetterstedti Ježek, 1983

A common European, Transcaucasian and West Siberian species (e.g. Ježek et al. 2021a,b; Gibernau & Albre 2022). The larvae are saprobionts, inhabiting the soil of paddocks, drains and water pipes, dead fungi (genus *Craterellus* Pers.), excrements of vertebrates, banks of polluted water reservoirs, manure and decaying plant material, etc. (e.g. Jung 1956; Wagner 1977; Ježek 1983). This species was recorded only in a chasm (1 specimen) and the underground quarry (2 ind.), both in July.

Psychodocha cinerea (Banks, 1894)

A very common cosmopolitan species (e.g. Ježek et al. 2017, 2021a,b, 2023). The larvae have been recorded in rotten vegetables, in an algae cover of a trough with water in shady places, in sewage works, in paddocks in sludge, in manure, in sewers, on toilets, water pipes, etc. (Crisp & Lloyd 1954; Jung 1956; Duckhouse 1966; Wagner 1977; Ježek 1990). This species was recorded in large numbers in all the ecosystems studied. Most specimens were caught in May and June. The abundance of the species always decreased in September and November, which can be related, for example, to the availability of resources and environmental conditions, but also interspecies competition.

Psychodocha gemina (Eaton, 1904)

A common European and Transcaucasian species (Ježek et al. 2021a). The larvae live in the damp mud of paddocks, in manure, sewers, on toilets, sewage works, water pipes, among decaying leaves on the banks of ponds and near springs (Jung 1956; Ježek 1990). This species was found in small numbers in all the ecosystems studied. In none of the monitored ecosystems was this species present throughout the season.

Psychodula minuta (Banks, 1894)

A generally common Holarctic species (Ježek et al. 2017). Larvae are saprobionts that develop in decaying vegetation, caves, damp places, mostly in dung or animal faeces, especially of vertebrates. Adults are often found on the banks of ponds, forest streams, swamps, gutters, outflows from water reservoirs and in waste pits (Jung 1956; Quate 1960; Wagner 1977; Ježek 1990). This species was recorded in smaller numbers in all the ecosystems studied except sinkholes. In none of the monitored ecosystems did this species occur throughout the season.

Tinearia alternata (Say, 1824)

A cosmopolitan and euryvalent species (Kroča & Ježek, 2019; Ježek et al. 2021b, 2023). Larvae can be found in sewage treatment plants, on grave beds, in organically polluted water, on faeces, on fresh potato litter and in alder swamps. Adults occur on the banks of streams and ponds, on the walls of buildings and stables or in nests and burrows of small mammals (e.g. Ježek 1977; Semelbauer et al. 2020; Oboňa et al. 2022; Roháček et al. 2022). This species (only 2 individuals) was only found underground (in July and September) at the site Ville-sur-Saulx.

As the karst environment is very sensitive to disturbance, once a strong disturbance occurs in a karst ecosystem, it will undergo reverse succession, and both its recovery and restoration may be difficult. Therefore, biodiversity is an important factor in the maintenance of existing karst landscapes and provides the basis for the recovery of degraded karst ecosystems. Monitoring could provide scientific data to help maintain biodiversity in karst areas (Li et al. 2013).

Acknowledgements

Our thanks go to Lenka Demková for her help with the creation of the map. We are particularly thankful to the editor and anonymous reviewers for their constructive comments and improvement of the manuscript. This work was supported by the Slovak Scientific Grant Agency, contract no. VEGA-1/0012/20, by the Slovak Research and Development Agency under contract no. APVV-20-0140, and by the Ministry of Culture of the Czech Republic (DKRVO 2019–2023/5.I.e, National Museum, 00023272).

References

Afzan H, Belqat B. 2016. Faunistic and bibliographical inventory of the Psychodinae moth-flies of North Africa (Diptera, Psychodidae). *ZooKeys* 558: 119–145.

Beaver RA. 1987. Biological studies of non-muscoid flies (Diptera) bred from mollusc carrion in Southeast Asia. *Medical Entomology and Zoology* 38: 187–195.

Crisp G, Lloyd L. 1954. The community of insects in a patch of woodland mud. *Transactions of the Royal Entomological Society of London* 105: 269–313.

Duckhouse DA. 1966. Psychodidae (Diptera, Nematocera) of Southern Australia: subfamily Psychodinae. *Transactions of the Royal Entomological Society of London* 118: 153–220.

Eberhard R. 1994. Inventory and management of the Junee River Karst System, Tasmania. Hobart, Tasmania, Forestry Tasmania. 125 pp.

Gibernau M, Albre J. 2022. First insights on the diversity of the genus *Psychoda* Latreille (Diptera: Psychodidae) in Corsica using DNA barcoding. *Annales de la Société entomologique de France (NS)* 58: 81–91.

Hamilton-Smith E. 2001. Current initiatives in the protection of karst biodiversity. *Natura Croatica: Periodicum Musei Historiae Naturalis Croatici* 10: 229–242.

Howarth FG. 1983. Ecology of Cave Arthropods. *Annual Review of Entomology* 28: 365–389.

Ježek J. 1977. Reinstatement of the genus *Tinearia* Schellenberg (Diptera, Psychodidae). *Acta Entomologica Bohemoslovaca* 74: 232–241.

Ježek J. 1982. Some new faunistic records of Psychodidae (Diptera) of Bohemian Karst. In: Rozkošný R, Vaňhara J, eds. *Dipterologica Bohemoslovaca 3.* (*Folia Facultatis Scientiarum Naturalium Universitatis Purkynianae Brunensis 23). Biologia* 74: 1–145.

Ježek J. 1983. Contribution to the taxonomy of the genus Logima Eat. (Diptera, Psychodidae). *Acta Entomologica Musei Nationalis Pragae* 41: 213–34.

Ježek J. 1985. Contribution to the knowledge of a new subtribe Trichopsychodina (Diptera, Psychodidae) from Czechoslovakia. *Acta Museu Nationalis Pragae* 40: 65–92.

Ježek J. 1990. Redescriptions of nine common palaearctic and holarctic species of Psychodini End. (Diptera: Psychodidae). *Acta Entomologica Musei Nationalis Pragae* 43: 33–83.

Ježek J, Chvojka P, Manko P, Oboňa J. 2017. Faunistic and bibliographical inventory of moth flies from Ukraine (Diptera, Psychodidae). *ZooKeys* 693: 109–128.

Ježek J, Goutner V. 1993. Two interesting species of moth flies (Diptera: Psychodidae) from Greece. *Aquatic Insects* 15: 185–191.

Ježek J, Grootaert P, Lock K, Manko P, Oboňa J. 2018. Moth flies (Diptera: Psychodidae) from the Belgian transition of the Atlantic to the Central European faunal zones. *Biodiversity & Environment* 10: 5–17.

Ježek J, Manko P, Oboňa J. 2020. Synopsis of the Psychodidae (Diptera) fauna of Bulgaria. *Zootaxa* 4877: 201–240.

Ježek J, Manko P, Fedorčák J, Koco Š, Varga J, Shumka S, Oboňa J. 2023. Psychodidae of Albania. *Redia* 106: 21–26.

Ježek J, Manko P, Oboňa J. 2021a. Psychodidae (Diptera) of Azerbaijan and Georgia – faunistics with biodiversity notes. *ZooKeys* 1049: 15–42.

Ježek J, Oboňa J, Manko P, Trýzna M. 2021b. Moth flies (Diptera: Psychodidae) of the northern Hercynian Mountains and adjacent localities (Czech Republic). *Acta Musei Silesiae. Scientiae Naturales* 70: 135–182.

Ježek J, Omelková M. 2012. Moth flies (Diptera: Psychodidae) of the Bílé Karpaty Protected Landscape Area and Biosphere Reserve (Czech Republic). *Acta Musei Moraviae, Scientiae Biologicae* (Brno) (2011) 96: 763–802.

Ježek J, Omelková M, Heřman P. 2014. Koutulovití (Psychodidae, Diptera) Českého krasu a přilehlých lokalit. (Moth flies (Psychodidae, Diptera) of the Český kras /Bohemian Karst and neighbouring localities (Czech Republic)). *Bohemia Centralis* 32: 321–344.

Jung HF. 1956. Beiträge zur Biologie, Morphologie und Systematik der Europäischen Psychodiden (Diptera). *Deutsche Entomologische Zeitschrift (Berlin), N.F.* 3: 97–257.

Košel V, Horváth M. 1996. Temporal and spatial dynamics of Nematocera (Insecta, Diptera) in a cave of the Western Carpathians (Slovakia). *Acta Zoologica Universitatis Comenianae* 40: 75–114.

Kroča J, Ježek J. 2015. Moth flies (Psychodidae: Diptera) of the Moravskoslezské Beskydy Mts and Podbeskydská pahorkatina Upland (Czech Republic). *Acta Musei Silesiae. Scientiae Naturales* 64: 27–50.

Kroča J, Ježek J. 2019. Moth flies (Psychodidae: Diptera) of the Moravskoslezské Beskydy Mts and Podbeskydská pahorkatina Upland (Czech Republic), II. *Acta Musei Silesiae. Scientiae Naturales* 68: 201–232.

Kroča J, Ježek J. 2022. Moth flies (Diptera: Psychodidae) of the Moravskoslezské Beskydy Mts and Podbeskydská pahorkatina Upland (Czech Republic), III. *Acta Musei Silesiae. Scientiae Naturales* 71: 1–29.

Li C, Xiong K, Wu G. 2013. Process of biodiversity research of karst areas in China. *Acta Ecologica Sinica* 33: 192–200.

Morelli A, Biscaccianti AB. 2021. New records of moth flies (Diptera Psychodidae) mainly from protected areas of peninsular Italy. *Redia* 104: 111–123.

Oboňa J, Fogašová K, Hrabuša E, Ježek J, Manko P, Kozánek M. 2022. The seasonal wing-length variation and bionomy of *Tinearia alternata* (Diptera: Psychodidae). *Biodiversity & Environment* 14: 10–15.

Oboňa J, Ježek J. 2014. Prodromus of moth flies (Diptera: Psychodidae) from Slovakia. *Acta Musei Silesiae. Scientiae Naturales* 63: 193–251.

Omelková M, Ježek J. 2012. A new species of the genus Trichomyia (Diptera: Psychodidae) and new faunistic data on non-phlebotomine moth flies from the Podyjí NP and its surroundings (Czech Republic). *Acta Entomologica Musei Nationalis Pragae* 52: 505–33.

Roháček J, Oboňa J, Csanády A. 2022. New records of Diptera from nests of *Micromys minutus* and *Muscardinus avellanarius* in Slovakia. *Acta Musei Silesiae. Scientiae Naturales* 71: 285–290.

Quate LW. 1960. *Guide to the Insects of Connecticut, Part VI: The Diptera or True Flies of Connecticut, Seventh Fascicle: Psychodidae (No. 92).* Hartford: State Geological and Natural History Survey of Connecticut.

Semelbauer M, Oboňa J, Barta M, Mangová B, Kozánek M. 2020. Spatial distribution and seasonal dynamics of non-biting moth flies (Diptera, Psychodidae) in confound conditions of a stable. *Polish Journal of Entomology* 89: 190–199

Szabó J. 1983. 10. család: Psychodidae – Lepkeszúnyogok. *Fauna Hungariae* 156: 1–78.

Vaillant F. 1971–1983. 9d. Psychodidae – Psychodinae (not finished). In: Lindner E., ed. Die *Fliegen der palaearktischen Region*. Stuttgart. Vols. 287(1971): 1–48; 291(1972): 49–78; 292(1972): 79–108; 305(1974): 109–142; 310(1975): 143–182; 313(1977): 183–206; 317(1978): 207–238; 320(1979): 239–270; 326(1981): 271–310; 328(1983): 311–358.

Wagner R. 1977. Zur Kenntnis der Psychodidenfauna des Allgäus (Diptera: Nematocera). *Nachrichtenblatt der Bayerischen Entomologen* 26: 23–28.

Watson J, Hamilton-Smith E, Gillienson D, Kiernan K. 1997. *Guidelines for Cave and Karst Protection*. Postojna: International Union of Speleology and Gland: IUCN, 53

Withers P. 1989. Moth Flies. Diptera: Psychodidae. *Dipterists Digest* 4: 1–83.