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FAUNISTIC AND ECOLOGICAL STUDY OF DRAGONFLIES (INSECTA: ODONATA) OF THE MALÉ KARPATY MOUNTAINS

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Abstract: This study presents a comprehensive faunistic and ecological assessment of dragonflies (Odonata) in the Malé Karpaty Mountains, southwestern Slovakia. Based on 539 occurrence records from 166 sites collected between 1956 and 2024, we documented 43 taxa comprising 3,375 individuals. Among the eudominant species were *Aeshna affinis* (D = 29.78 %), *Cordulegaster heros* (D = 16.86 %), *Coenagrion puella* (D = 12.53 %), and *Platycnemis pennipes* (D = 12.36 %). Autochthonous reproduction of *A. affinis* was not confirmed. Seventeen species of conservation concern were recorded, including ten legally protected taxa such as *Coenagrion ornatum*, *Epitheca bimaculata*, *Cordulegaster heros*, *Brachytron pratense*, and *Leucorrhinia pectoralis*. Reproduction was not confirmed by larvae or exuviae in 25 species. Ordination analyses revealed strong ecological structuring. Detrended Correspondence Analysis indicated a pronounced gradient in community composition (gradient length = 5.77). Canonical Correspondence Analysis confirmed significant relationships between species composition and 13 habitat types (pseudo- F = 5.7; p = 0.002), explaining 30.8 % of total variability. A simple effects analysis identified the metarhithral zone (submontane streams) as the most influential factor (10.1 % variability; pseudo- F = 18.3; p = 0.002), strongly correlated with the primary ordination axis (CorE. 1 = 0.94). Small water reservoirs explained 6.8 % of variability and were negatively associated with the main gradient (CorE. 1 = -0.67). Our findings highlight the conservation priority of maintaining natural forest streams to support stable populations of *Cordulegaster heros*, which occurred at 121 sites and was the sole species at 33 sites. Small water reservoirs serve as important habitats for local biodiversity hotspots, with the highest richness (17 species) recorded at SWR Druhý rybník (Železná studnička), despite low diversity indices (N_2 = 4.82, H´ = 1.97, e = 0.69) due to dominance by a few taxa. Rare habitats such as peat bogs and marshes host specialized species, including *Leucorrhinia pectoralis* and *Brachytron pratense*.

Key words: dragonflies, faunistic, ecology, Malé Karpaty Mts., Slovakia

INTRODUCTION

The geomorphological unit of the Malé Karpaty mountains is located in western Slovakia, between the Podunajská Lowland and the Záhorská Lowland. The mid-mountain belt extends northwest from Bratislava to Nové Mesto nad Váhom, approximately 100 km long, with a variable width ranging from 16 km (Lozorno – Svätý Jur) to 3 km (Čachtice – Prašník). The Malé Karpaty Mts., which belong to the Fatra-Tatra region (Mazúr & Lukniš 1978), are formed by four geomorphological subunits (Devínske, Pezinské, Brezovské, and Čachtické Karpaty). In the Pezinské Karpaty subunit, the mountain range reaches its highest point at Mt. Záruby (768 m a.s.l.). The geological structure of the Malé Karpaty Mts. includes Paleozoic crystalline rocks (primordial granites, gneisses, paragneisses) and Mesozoic (Cretaceous) carbonate sediments, arranged in a complex nappe structure during the Cretaceous and Paleogene Alpine orogeny. The nappes have a Mesozoic sedimentary cover (limestones, dolomites, sandstones), which outcrops in the central and northern parts of the mountain range (Brezovské and Čachtické Karpaty), with karst landforms (Plašienka et al. 1997). The Malé Karpaty Mts. represent an important segment at the junction of the Western Carpathians and the Eastern Alps. The current form of the Malé Karpaty Mts. was shaped in the late Neogene (Minár et al. 2011), when the mountain range became independent from Neogene basins, and during the Quaternary, when river networks deepened, valleys widened, and karst relief developed.

The Malé Karpaty Mts. belong to the moderate climate zone with a transition between warm lowland and slightly cool mountain climates. The average annual temperature is 9–10 °C above 600 m a.s.l., and 6–7 °C at lower elevations. The average July temperatures range from 19 °C to 15 °C at higher elevations. Annual precipitation totals range from 550–650 mm (foothills) to 700–900 mm (middle and higher elevations). The Malé Karpaty Mts. are a divide between the basins of the Morava River (Záhorská Lowland) and the Danube (Podunajská Lowland). Watercourses mainly have a rain-snow runoff regime, with a maximum in spring and a minimum in summer (Lapin et al. 2002).

The current landscape cover mainly consists of beech, oak-hornbeam forests, thermophilous oak groves, and forest-steppe (70.8 % of the area). From the perspective of biodiversity and nature conservation, xerothermophilous grassland and herbaceous communities are significant. A substantial part of the area is covered by the Malé Karpaty Protected Landscape Area (PLA), small-scale protected areas, and Natura 2000 sites: the Malé Karpaty Special Protection Area (SPA) and the six Special Areas of Conservation (SACs), such as Devínska Kobyla, Buková, and Čachtické Karpaty. The area has significant forestry, recreational, and viticultural potential (Izakovičová 2006).

From the perspective of zoogeographical regionalization of the terrestrial biocycle of Slovakia according to JEDLIČKA & KALIVODOVÁ (2002), the Malé Karpaty Mts. are located at the contact between the steppe and deciduous forest provinces (the Pannonian and Subcarpathian sections). HENSEL & KRNO (2002) classified the area as part of the Pontic-Caspian province of the Limnic biocycle.

The beginnings of research on dragonflies in Bratislava, or rather the Bratislava metropolitan area, are linked to faunistic data by V. Balthasar (BALTHASAR 1936, 1938), a Czech naturalist (*1897–†1978) who served as curator of collections at the then Bratislava Museum of Local History until 1939. The localization of V. Balthasar's findings is influenced by the conventions of the time, with only the names of villages mentioned, e.g., Čilistov, Vojka nad Dunajom (Vajka), Rača (Račištorf), Šúr near Svätý Jur, Zlatná na Ostrove, or 'in the immediate vicinity of Bratislava.' Only for the species *Anax imperator* and *Sympetrum depressiusculum* is it stated 'from the Malé Karpaty Mts. near Bratislava.' Faunistic data from the Malé Karpaty Mts. have been systematically collected within the research project of the Slovak National Museum – Natural History Museum, Bratislava (SNMB), by V. Janský since 1990. Interest in the forest streams of the Malé Karpaty Mts. increased after the confirmation of a new dragonfly species of scientific significance here – the Balkan Goldenring *Cordulegaster heros* subsp. heros Theischinger, 1979 (THEISCHINGER 1979). The first occurrence of the species from three sites of the Malé Karpaty forest streams was published by BLAŠKOVIČ et al. (2003). By 2008, 23 sites were already known (JANSKÝ & DAVID 2008). One of the oldest records of the species is a 1980 photograph of a female *C. heros*, taken by the well-known nature photographer J. Ponec (*1918–†2006). It should be noted that *C. heros* was confused with a similar species, Two-toothed Goldenring (*Cordulegaster bidentata*). The first overview of dragonflies in the Bratislava metropolitan area was prepared by LOJKOVÁ (2012). She supplemented published field research data from 2008 (LOJKOVÁ 2010) with a literature review and data from the museum collection of dragonflies at SNMB in Bratislava, covering 1903 to 2008. In total, she reports 51 dragonfly species from 61 sites in the Bratislava metropolitan area, including contact geomorphological units of the Záhorská and Podunajská lowlands. In the Malé Karpaty Mts., LOJKOVÁ (2012) reports 18 sites with 24 species. In the publication by ŠÍBLOVÁ & LEHOTSKÁ (2024) titled 'Dragonflies of Bratislava', the authors present occurrence data (own research and data excerpted since 1938). The localization is given in 5 x 5 km squares, without additional information (date, location, collector, number of individuals, developmental stage). For the Malé Karpaty Mts., 29 species are definitely recorded, and 16 common species are listed by LOJKOVÁ (2012) and ŠÍBLOVÁ & LEHOTSKÁ (2024), such as *Aeshna affinis*, *A. cyanea*, *Anax imperator*, *Brachytron pratense*, *Calopteryx splendens*, *Cordulegaster heros*, *Lestes sponsa*, *Orthetrum cancellatum*, *Pyrrhosoma* *nymphula*, and *Sympetrum sanguineum*. In both cases, the highest number of species sightings and the most sites are concentrated in the lowland part of the Bratislava metropolitan area (the floodplain of the Danube River, where there is/was high habitat diversity for dragonflies, e.g., directly in the city—material pits, park and garden ponds, and regulated streams). Little data comes from the Malé Karpaty Mts., even though seven city districts extend into the Malé Karpaty Mts. (Rača, Nové Mesto, Lamač, Záhorská Bystrica, Karlova Ves, Dúbravka, and Devínska Nová Ves). Aside from historical data from V. Balthasar, information on dragonflies from the Malé Karpaty Mts. is known only from the early 1990s.

The aim of our study is to summarize the currently available data on the dragonflies of the Malé Karpaty orographic unit and compile their faunistic and ecological characteristics, including their sites, as a basis for further research and conservation management.

MATERIAL AND METHODS

Most of the data were obtained through field research conducted by the study's authors between 1987 and 2024. The methods used included semi-quantitative faunistic survey of dragonflies with entomological and hydrobiological nets. Water habitats with potential dragonfly occurrences and their contact terrestrial environments were sampled. In addition to field research, dragonfly material was obtained through various methods: by excerpting published and unpublished data, e.g., from collections of SNMB in Bratislava, and by identifying photographic material from websites (nahuby.sk, fotonet.sk, inaturalist.org). The excerpted data used to compile the dragonfly database of the Malé Karpaty Mts. were provided by authors. For the dragonfly dataset of the Malé Karpaty Mts., we included complete data (location, date, collector), but only 14 occurrence records obtained before 1990 met the criteria. Imagoes, larval, and exuvial stages were recorded, and the necessary material for identification was fixed in 70 % ethanol. The dragonflies were identified or revised by the authors of the article; part of the material is stored in the SNMB collection in Bratislava and at the Institute of Landscape Ecology of the Slovak Academy of Sciences (ILE SAS, p.r.i.), Nitra branch. For identifying dragonflies, we used several identification keys, e.g., Dijkstra & Lewington (2006), Smallshire & Swash (2020), Dolný et al. (2016), Heidemann & Seidenbusch (1993), and Brochard et al. (2012). The nomenclature of species and their systematic order were adjusted according to An Annotated Checklist of the Dragonflies (Odonata) of Slovakia (David & Šácha 2019). The classification and nomenclature of habitats are based on Ružičková et al. (1996). Species conservation status was determined according to the European (De Knijf et al. 2024) and Carpathian (Šácha et al. 2014) Red Lists of Dragonflies, as well as the Slovak national legislation (MoE SR 2021). The authors' findings were localized using geographic coordinates, with the most accurate localization being a common challenge in the extracted data. The selection of sites (and species) for the orographic unit of the Malé Karpaty Mts. was performed in ArcMap 10.2 (ESRI 2011), using spatial attribute selection. Because it was not always possible to achieve the desired localization accuracy, this also applies to the GIS layer's boundary for the Malé Karpaty Mts. orographic unit; we also used a 300 m outer buffer for site selection. The locations of occurrences are supplemented by codes from the Central European mapping system (JASIČOVÁ & ZAHRADNÍKOVÁ 1976) and WGS coordinates. We used the code of the basic field (size 12 x 11.2 km), divided into quadrants (e.g., A/a, size 6 x 5.6 km) and sub-quadrants (size 3 x 2.5 km), Fig. 1. Locations of dragonfly finds in the Malé Karpaty Mts. The data are in the following format: site number, site description, site coordinates in WGS84 (degrees, minutes, seconds), grid code from the Slovak Fauna Database, and altitude. An example of coding is provided for a site outside the orographic unit of the Malé Karpaty Mts. (bottom left): DFS code = 7867 (polygon size 10 x 11 km), quarter-square A (size 5 x 5.5 km), and sixteenth-square 2 (size 2.5 x 2.75 km). For example, site 1 has the code 7470C1, marked with an asterisk (Fig. 1).

Species representation was measured using the species dominance index (D = ni/N * 100, ni = number of individuals of each species, N = total number of individuals). According to LOSOS et al. (1984), we used the following categories of species dominance: eudominant (Eu ≥ 10 %), dominant (Do = 5–9.9 %), subdominant (Su = 2–4.9 %), recedent (Re 1–1.9 %), and subrecedent (Su ≤ 0.9 %). To evaluate the significance of the sites, we used the Statistics of compositional table tool in the Canoco5 program (TER BRAAK & ŠMILAUER 2018). We selected

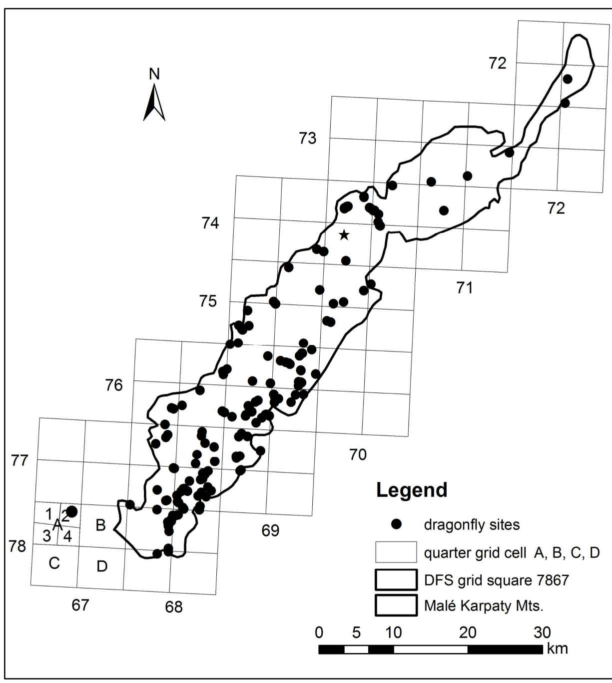

Fig. 1. Coding of sites according to the Databank of Slovak Fauna: basic square, e.g. 7867 (site outside the Malé Karpaty Mts.), quadrant A/a, subquadrant 2 (7867A2). Site 1, Buková water reservoir (DFS code 7470C1), is marked with an asterisk.

variables: Count (number of species at the site), Total (number of individuals), and for ecological indices of the sites: the inverse value of the Simpson index (N2 = 1/D, D = (ni/N)^2), species diversity of the sites according to the Shannon-Wiener index (H´ = −∑ ni/N × ln(ni/N)), the maximum diversity value (Hmax= ln(s), where s = number of species), and community evenness (e = H´/Hmax). The calculated values were summarized in an overview table by site and species. The structure of species data and the significance of selected environmental features (predictors) were analyzed in the Canoco5 program. When testing for statistical significance (p), we also report the adjusted p-value (p(adj)) with the Bonferroni correction (p-value multiplied by the number of tested predictors to control for Type I errors). The map output was created in ArcMap 10.1 (ESRI 2011), and the map background is from Zbgis (OpenStreetMap).

RESULTS

Site overview

Within the geomorphological unit of the Malé Karpaty Mts., we obtained dragonfly data from 166 sites, documenting 539 records from 1956 to 2024 (Fig. 2), with a confirmed total of 3,375 individuals. The list of sites with localization data is in Appendix 1, and Fig. 2, shows the network used for localization in the Slovak Fauna Database, along with the method used to encode locations.

The elevation of sites in the Malé Karpaty Mts. ranges from 140 to 540 meters above sea level. The highest number of dragonfly finds comes from the elevation ranges of 190 to 239 meters above sea level (33 sites), 240 to 289 meters above sea level (39 sites), and 290 to 339 meters above sea level (36 sites) (see Fig. 3), etc.

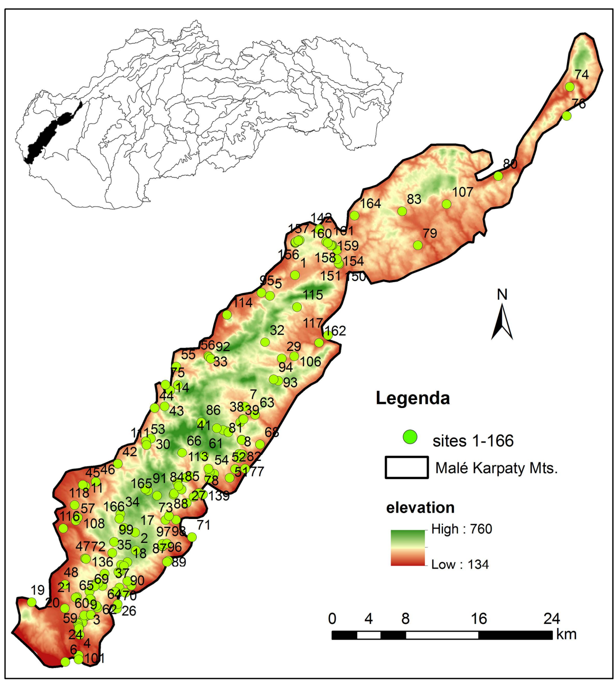

Fig. 2. Distribution of dragonfly occurrence sites in the Malé Karpaty Mts. (source data: DMR, ÚGKK SR).

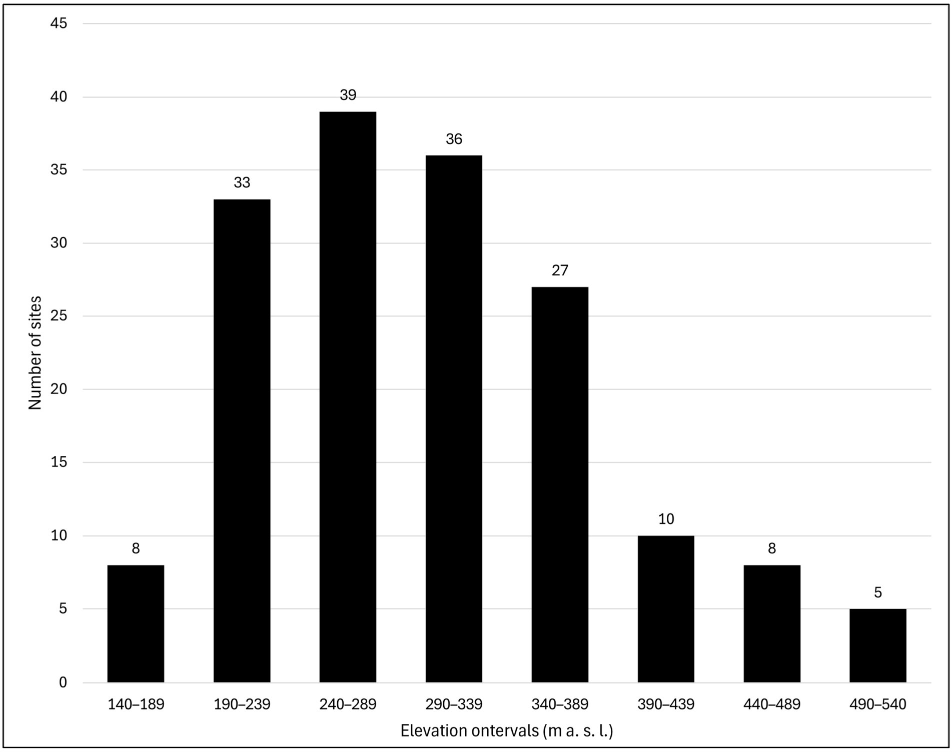

Fig. 3. Hypsometric distribution and number of dragonfly occurrence sites in the Malé Karpaty Mts.

Sites with dragonfly occurrences (166 sites) were assigned to 13 habitat types (Table 1), with the dominant type being submontane streams – metarhithral, with 125 sites. The second most common are small water reservoirs (multi-purpose – 12 and single-purpose – 6). Other habitats for flowing waters include spring areas – epicrenal (3 sites), flooded old quarries (3 sites), excavation pits (2 sites), concrete fire protection reservoirs (2 sites), and lowland rivers – eupotamal (1 site). Dragonflies were also recorded in semi-ruderal and terrestrial habitats.

Systematic overview of dragonflies of the Malé Karpaty Mts.

In the area of the Malé Karpaty Mts., we recorded the occurrence of 43 dragonfly taxa, with their sexes and developmental stages represented as follows: 1,323 males (♂), 353 females (♀), 545 larvae (L), 52 exuviae (Ex), and 1,102 imagos (I), for which the sex was not determined. A total of 3,375 individuals were recorded. In the systematic overview, we present the numbers, occurrence locations in the Malé Karpaty Mts., conservation status, and legislative protection. Complete occurrence data are in Appendix 2. The chorological and ecological characteristics are according to BOUDOT & KALKMAN (eds.) (2015), and the photographs are available to interested parties, for example, at: https: //www.dragonflypix.com. We present the abbreviations for endangerment and protection: ERL (European Red List – DE KNIJF et al. 2024), CRL (Carpathian Red List – ŠÁCHA et al. 2014), and § (Decree of the Ministry of the Environment of the Slovak Republic No. 170/2021 Coll.). Dragonflies of the Malé Karpaty Mts. are classified into threat categories according to the European and Carpathian Red List of endangered species, used in the 'red lists': LC (Least Concern) a less affected species with no current threat, NT (Near Threatened) a near-threatened species, DD (Data Deficient) a poorly known species, VU (Vulnerable) a vulnerable species (this is a 'own' threat category). In the Carpathian Red List (CRL), a non-standard category *NT is also used. This means the marked taxon tends to be classified into a higher threat category, VU. We also used the new edition of the Red Book – Invertebrates (DAVID et al. 2025).

Table 1. Habitat types and number of sites with dragonfly occurrences in the Malé Karpaty Mts.

BIOTOP	NUMBER	SITES
Water biotopes/habitats		
Spring areas (epicrenal)	3	61, 78, 120
Submontane stream (metarhithral)	125	3, 4, 7–9, 11–14, 17, 21–60, 62–67, 74–7, 79–86, 88, 90–8, 100–113, 115–117, 122–125, 130, 131, 139–161, 163
Small single-purpose reservoirs	6	10, 69, 70, 71, 73, 138
Small multi-purpose reservoirs	12	1, 15, 18, 68, 119, 128, 132–135, 162, 164
Excavation pits, breeding ponds, and flooded borrow pits	2	126, 127
Flooded old quarry	3	19, 20, 72
Concrete fire protection reservoirs	2	16, 166
Lowland river (eupotamal)	1	6
Semi-terrestrial biotopes/habitats		
Marshes	2	118, 129
Periodically drying terrain depressions	1	99
Peatlands	3	2, 5, 165
Terrestrial biotopes/habitats		
Forest edges	5	87, 114, 121, 136, 137
Field road	1	89

When describing the chorological characteristics of species, we mention a broader glacial refuge of the last (Würmian) glaciation. Its glacial maximum was about 21,000 years ago, when large parts of the Palearctic were uninhabitable for dragonflies (see KALKMAN et al. 2022). After the retreat of the ice sheet (which ended about 11,700 years ago), species spread from these refuges (centers of dispersal) into Central and Northern Europe. Therefore, Mediterranean-origin species are common, originating in the Mediterranean region (Mediterranean subregion) and distributed across one or more subregions of the Palearctic area (Palearctica). If the distribution of a species is described as Palearctic, it occurs in at least two Palearctic subregions, e.g., the Eurosiberian and Mediterranean regions.

Suborder: Zygoptera Selys, 1854

Family: Lestidae Calvert, 1901

1. ***Chalcolestes viridis*** (Vander Linden, 1825) šidlovka zelená – Western Willow Spreadwing

Findings from 1990 to 2021; 8 ♂, 4 ♀, 8 juveniles, 1 I, Σ = 21. Threats and conservation: CRL-LC. A Mediterranean species with distribution in southern Europe and the Eurosiberian subregion of the Palearctic. Breeding habitat: *Ch. viridis* breeds in various standing and slow-flowing waters, from ponds and rainwater catchment reservoirs to canals, streams, rivers, and their dead arms. The species also occurs in heavily anthropogenically altered habitats. Suitable habitats include trees or shrubs with soft bark and wood (e.g., willows and poplars) along the shoreline, which females use for laying eggs. Unlike species of the genus *Lestes*, *Ch. viridis* is not found in ephemeral (temporary) waters; its presence has been recorded up to mountainous areas.

2*.* ***Lestes barbarus*** (Fabricius, 1798) šidlovka – Migrant Spreadwing

Findings from 2020; 1 ♂, 3 ♀, Σ = 4. Threats and conservation: CRL-LC. A holomediteranean species of Eurosiberian distribution from Western Europe to Eastern Asia. Reproductive habitat: the species prefers sunny, shallow waters that often dry temporarily, such as inland lakes, ponds, gravel pits, and periodic pools in terrain depressions. The species rapidly colonizes new habitats and is often found in ponds that are flooded in spring and dry out in summer. During drying, they survive in diapause until re-flooding occurs.

3**. *Lestes dryas*** Kirby, 1890 šidlovka tmavá – Robust Spreadwing

Findings from 1998 and 2010; 2 ♂, 1 ♀, Σ = 3. Threats and protection: CRL-LC. The Siberian species of dragonfly with a Palearctic distribution. Reproductive habitat: *L. dryas* occurs near still waters such as ponds, peat bogs, channels, sandpits, and gravel pits. It prefers drying still waters and marshes with dense stands of sedges (*Juncus*) and sedges (*Carex*), creating suitable microhabitats for larval development.

4. ***Lestes sponsa*** (Hansemann, 1823) šidlovka pásikavá – Common Spreadwing
Findings from 1987 to 2021; 12 ♂, 8 ♀, Σ = 20. Threats and conservation: CRL-LC. Originally an Euro-Siberian species with a Palearctic distribution from England, Scandinavia through Siberia to Japan. Breeding habitat: *L. sponsa* inhabits a wide range of still waters, mostly unshaded, with emergent vegetation (rushes, reeds, sedges), e.g., ditches, ponds, small lakes, and overgrown gravel pits. The species can also be abundant in newly created shallow aquatic habitats with well-developed vegetation.

5. ***Sympecma fusca*** (Vander Linden, 1820) šidlovka hnedá – Common Winter Damselfly
Findings from the years 1993–2021; 7 ♂, 2 ♀, 3 I, Σ = 12. Threats and protection: CRL-LC, § – species monetary value: €200 per specimen. The holomediteran species of dragonfly with Palearctic distribution from Western Europe to Kazakhstan and Tajikistan. Reproductive habitat: *S. fusca* occurs near shallow standing or slow-flowing waters with abundant shoreline vegetation. In spring, the presence of floating plant debris is essential, as overwintering females use it to lay eggs. The species inhabits a wide range of habitats, such as peatlands, marshes, ponds, and gravel pits. In autumn, adults disperse and seek overwintering sites, which are often located several kilometers from the breeding site. Suitable overwintering sites include reed vegetation and tall dead herbs or grasses (0.5 to 1 m) near or at the edges of forests.

Family: Calopterygidae Selys, 1850

6. ***Calopteryx splendens*** (Harris, 1780) hadovka lesklá – Banded Demoiselle
Findings from the years 2010–2021; 13 ♂, 5 ♀, Σ = 18. Threat and protection: CRL-LC. A Pontomediterranean species with a Palearctic distribution from Western Europe to Eastern Asia. Reproductive habitat: *C. splendens* prefers unshaded streams and rivers, but is usually absent from rapids and shaded waters. The highest population densities are achieved where the watercourse has a relatively natural morphology, occurs in channels and regulated streams, provided that sufficient shoreline vegetation is maintained. It is a lowland-to-submontane species. It avoids torrents.

7. ***Calopteryx virgo*** (Linnaeus, 1758) hadovka obyčajná – Beutiful Demoiselle
Findings from the years 2013–2015; 12 ♂, 2 L, Σ = 14. Threats and Conservation: CRL-LC. A West Mediterranean species with distribution from England to the Far East. Reproductive habitat: *C. virgo* reproduces in flowing waters, mainly in hilly and mountainous areas, where it prefers small to medium-sized, partially shaded streams and rivers. It is less common in lowlands because currents are weaker and there are fewer shaded streams with high oxygen content. Therefore, the

species is rare in agricultural landscapes. The ideal summer water temperature is 13 to 18°C; within this temperature range, *C. virgo* larvae have higher respiratory activity and are also more sensitive to organic pollution than *C. splendens*.

Family: Platycnemididae Jacobson and Bianchi, 1905

8. ***Platycnemis pennipes*** (Pallas, 1771) šidielko ploskonohé – Blue Featherleg
Findings from the years 1987–2023; 326 ♂, 70 ♀, 1 L, 20 I, Σ = 417.Threats and Conservation: CRL-LC. A Pontic-Caspian species with a distribution from England through Turkey to Central Asia. Reproductive habitat: *P. pennipes* is common in all types of flowing and standing waters, except mountain streams. These include rivers, streams, dead arms, larger ponds, fish farms, and even abandoned gravel pits. The standing waters where this species occurs are often large and relatively deep, with surface ripples mimicking conditions of flowing water. The presence of shores with emergent vegetation and aquatic plants supports the development of large populations.

Family: Coenagrionidae Kirby, 1890

9. ***Coenagrion ornatum*** (Selys, 1850) šidielko ozdobné – Ornate Bluet
Finding from 1998; 1 ♂, Σ = 1. Threat and protection: CRL-*NT, § – species monetary value: €300 per specimen, a species of Community interest. A Pontomediterranean species with a Palearctic distribution. Reproductive habitat: *C. ornatum* occurs in lowlands and hilly areas near sunny streams and canals with slow flow and shallow water. The bottom usually contains organic mud and detritus, accompanied by moderately dense herbaceous vegetation. The water is typically eutrophic and relatively warm. Many of these habitats depend on cyclic stream cleaning and shoreline vegetation mowing to prevent overgrowth; shading by shoreline vegetation is a risk factor.

10. ***Coenagrion puella*** (Linnaeus, 1758) šidielko obyčajné – Azure Bluet
Findings from the years 1987–2021; 328 ♂, 55 ♀, 3 L, 37 I, Σ = 423. Threat and protection: CRL-LC. A Pontomediterranean faunal element with a Palearctic distribution. Reproductive habitat: *C. puella* occurs in a wide range of mesotrophic to eutrophic waters, with well-developed shoreline vegetation. The species clearly prefers waters with floating vegetation, which serves as a substrate for egg-laying. Suitable environments include drainage ditches and other channels, garden ponds, natural lakes and ponds, peat bogs, and marshes with open water surfaces.

11. ***Coenagrion pulchellum*** (Vander Linden, 1825) šidielko veľkoškvrnné – Variable Bluet
Findings from the years 1997–2020; 10 ♂, 3 ♀, 2 L, Σ = 15. Threat and protection: CRL-DD. A Pontomediterranean faunal element of Palearctic distribution.

Reproductive habitat: the species occurs near still waters and slow-flowing sections of rivers. Habitats are mostly unshaded, oligotrophic, mesotrophic, or eutrophic, and almost always have a well-developed shoreline and aquatic vegetation. *C. pulchellum* prefers lakes, ponds, marshes, peatlands, dead river bends, ditches, and channels in lowlands.

12. ***Enallagma cyathigerum*** (Charpentier, 1840) šidielko krúžkované – Common Bluet
Findings from the years 1990 and 1998; 1 ♂, 3 ♀, Σ = 4. Threat and Protection: CRL-LC. Originally a Euro-Siberian species with a circumboreal distribution, the nominal subspecies *E. c. cyathigerum* is found from southern Europe and Scandinavia across Siberia to the Far East. Reproductive habitat: *E. cyathigerum* reproduces in still and slow-flowing waters, preferring habitats without fish populations or types of water bodies overgrown with vegetation that provides shelter from predators (especially fish). It is also found in mountainous areas.

13. ***Erythromma najas*** (Hansemann, 1823) šidielko červenooké – Large Redeye
Finding from 2012; 2 I, Σ = 2. Threat and protection: CRL-LC. Originally a West Siberian species with a Palearctic distribution from England across Siberia, Mongolia to the Far East. Reproductive habitat: *E. najas* occurs in unshaded standing or slow-flowing eutrophic to mesotrophic waters, less frequently in oligotrophic waters in lowlands. An important habitat characteristic is the presence of floating leaves of aquatic plants, e.g., water lilies (*Nuphar*), water lilies (*Nymphaea*), and pondweeds (*Potamogeton*).

14**. *Erythromma viridulum*** (Charpentier, 1840) šidielko ixové – Small Redeye
Finding from 2020; 1 ♂, Σ = 1. Threats and protection: CRL-LC. Originally a Pont-Mediterranean species of the Eurosiberian distribution from eastern England, the Pyrenean Peninsula to the Caspian Sea. Breeding habitat: the species is mainly found near unshaded still or slow-flowing waters with floating aquatic vegetation on the water surface, often occurring with *E. najas*. *E. viridulum* is a common species in waters with abundant floating vegetation, such as water plants like waterweed (*Elodea*), hornwort (*Ceratophyllum*), water milfoil (*Myriophyllum*), or pondweed (*Potamogeton*).

15. ***Ischnura elegans*** (Vander Linden, 1820) šidielko väčšie – Common Bluetail
Findings from the years 1987– 2020; 65 ♂, 34 ♀, 2 L, 1 I, Σ = 102. Threat and protection: CRL-LC. Originally a Pontic-Caspian (Eurasian) species with a Palearctic distribution from England, southern Scandinavia through Siberia, Mongolia to Sakhalin. Reproductive habitat: *I. elegans* is the most common damselfly species, and is found in all types of standing and slow-flowing waters. It is very abundant in mesotrophic to eutrophic sites and tolerates relatively high salinity and slight water acidity. The species occurs from lowlands to mountain regions.

16. ***Ischnura pumilio*** (Charpentier, 1825) šidielko menšie – Small Bluetail
Findings from the years 1987–2011; 4 ♂, 2 L, Σ = 6. Threat and protection: CRL-LC. A Pontomediterranean species with Palearctic distribution from England, the Pyrenean Peninsula through Kazakhstan to Mongolia. Breeding habitat: as a pioneer species, *I. pumilio* most often occurs in habitats with shallow water and sparse vegetation, which are either newly created or where vegetation has been removed (material pits, periodic ditches in fields, and ditches). The number of adult individuals increases in the first years after colonization, then decreases as vegetation becomes denser.

17. ***Pyrrhosoma nymphula*** (Sulzer, 1776) šidielko červené – Large Red Damsel
Findings from the years 1995– 021; 70 ♂, 17 ♀, 28 L, 4 Ex, 2 I, Σ = 121. Threats and Protection: CRL-LC. A Palearctic species with a Mediterranean distribution from the British Isles to the Ural and Turkey. Breeding habitat: in most of Europe, this species occurs in both still and flowing waters, often in partially shaded areas, with abundant aquatic and shoreline vegetation. Still-water habitats include marshy and peat-bog wetlands, dead arms of rivers, ponds, and channels. In flowing waters, the species is found in gently flowing lowland streams and channels with rich vegetation.

Suborder: Anisoptera Selys, 1854 (= Epiprocta Lohmann, 1996)

Family: Aeshnidae Leach, 1815
Note: the expected form of the genus name is *Aeschna*, as is often cited in the literature, and it corresponds to the etymology of the genus name. The form *Aeshna* is likely the result of a transcription error or a printing error. According to the rules of zoological nomenclature (ICZN), the genus name must be used as published by Fabricius (1775), i.e., *Aeshna* (see also David and Šácha (2019), p. 58).

18. ***Aeshna affinis*** Vander Linden, 1820 šidlo trstinové – Blue-eyed Hawker
Findings from the year 1995–2023; 113 ♂, 59 ♀, 28 L, 4 Ex, 922 I, Σ = 1 126. Threat and protection: CRL-LC

Fig. 3. Blue-Eyed Hawker (*Aeshna affinis* ♂), Photo: S. David.

(Fig. 4, 16). Dragonfly of Pontopanonic origin with distribution in the Mediterranean and southern parts of the Eurosiberian subregion Palearctic (Turkey, Kazakhstan). Breeding habitat: *A. affinis* breeds exclusively in standing waters, preferring shallow, vegetated waters that are protected from the wind and exposed to sunlight. Many habitats (marshes, old dead arms, flooded depressions in agricultural landscapes) dry out partially or completely in summer, have a muddy littoral zone bordered by sparse to dense vegetation (sedges, rushes) or low reeds. The species most often occurs in lowlands; in Central Europe, it is rare above 700 m a.s.l.

19. ***Aeshna cyanea*** (Müller, 1764) šidlo modré – Blue Hawker
Findings from the year 1995–2022; 11 ♂, 3 ♀, 31 L, 3 Ex, 11 I, Σ = 59. Threats and protection: CRL-LC. Originally a holomediteranean species with a Palearctic distribution from the British Isles to the Ural and the Caspian Sea. Breeding habitat: *A. cyanea* is mainly found near standing, less often slow-flowing waters. It has a strong preference for small and at least partially shaded habitats. In small, heavily shaded forest ponds, puddles, and pools with a leaf layer, it is often the only dragonfly species present, with larvae potentially occurring at very high densities. In Central Europe, it is among the most common dragonflies in garden ponds. It has a wide altitudinal range—from lowlands to mountainous areas.

20. ***Aeshna grandis*** (Linnaeus, 1758) šidlo veľké – Brown Hawker
Finding from the year 1995; 1 L, Σ = 1. Threats and Conservation: ERL-VU, CRL-NT. Originally a holomediteranean species with a Palearctic distribution from England, France, and Scandinavia to the Ob Bay and Lake Baikal. Breeding habitat: *A. grandis* occurs in a wide range of stagnant and slow-flowing waters, such as large ponds (including peat), lakes, canals, dead arms, peat bogs, marshes, and artificially created peat excavations. These habitats have dense floating or submerged vegetation. In Central and Northern Europe, most populations are found in lowlands up to 500 m a.s.l., but they also breed at elevations over 1,000 meters.

21. ***Aeshna isoceles*** (Müller, 1767) šidlo – Norfolk Hawker
Findings from the years 2010 and 2020; 1 ♂, 3 I, Σ = 4. Threat and protection: CRL-LC, § - species monetary value: €200 per specimen. Originally an Atlantic-Mediterranean species with a distribution center in the Mediterranean region, its range extends into Western Europe, the Baltic States, across the Balkans to Iran. Reproductive habitat: *A. isoceles* prefers habitats with extensive stands of reeds (*Phragmites*), cattails (*Typha*), sedges (*Carex*), or the yellow water-lily (*Stratiotes aloides*). It reproduces in reed beds near still waters or along slow-moving waters, including canals, marshes, ponds, and lakes. It favors sunny habitats; well-developed aquatic vegetation provides larvae with shelter from predators.

22. ***Aeshna mixta*** Latreille, 1805 šidlo pestré – Migrant Hawker

Findings from the years 2010 and 2015; 7 ♂, Σ = 7. Threat and protection: CRL-LC. Eurosiberian (?) faunal element with a distribution from Spain to China and Japan, south from northern Africa to southern Scandinavia. Breeding habitat: the species breeds in unshaded, larger, still water bodies with open water surfaces and abundant shoreline vegetation, such as reed beds (*Phragmites*) and cattails (*Typha*), with large populations occurring in both natural and artificially created habitats.

23. ***Anax imperator*** Leach, 1815 šidlo obrovské – Blue Emperor

Findings from the year 2011–2020; 3 ♂, Σ = 3. Threat and protection: CRL-LC. An Ethiopian (Afrotropical) faunal element with Palearctic and Afrotropical distribution from North Africa to Uzbekistan and Pakistan. It is spreading (expanding) into northern parts of Europe, and so far it is absent in Scandinavia. Breeding habitat: *A. imperator* is common near still waters in lowlands, such as unshaded gravel pits and sandy areas, water reservoirs, larger garden and park ponds, but it also occurs near very slow-flowing waters.

24. ***Anax parthenope*** (Selys, 1839) šidlo tmavé – Lesser Emperor

Findings from the year 2020 and 2021; 2 ♂, 1 I, Σ = 3. Threat and protection: CRL-LC, § – species monetary value: €200 per specimen. A species of Pontomediterranean origin with Palearctic distribution from Western Europe and Northern Africa to western Mongolia and China. Breeding habitat: *A. parthenope* occurs near stagnant, often extensive water bodies, such as sandpits, gravel pits, and water reservoirs. Suitable habitats are those with well-developed shoreline vegetation and areas of floating aquatic plants (hydrophytes). The species also appears in newly created, smaller habitats such as material pits and ponds.

25. ***Brachytron pratense*** (Müller, 1764) šidlo lúčne – Hairy Hawker

Findings from the years 1998 and 2021; 1 ♂, 1 Ex, Σ = 2. Threat and protection: CRL-DD, § - species monetary value: €200 per specimen. A Pontomediteranean faunal element with Palearctic distribution from the British Isles and southern Scandinavia to the Ural. Breeding habitat: the species occurs near still or slow-flowing waters, around stands of reeds (*Phragmites*), cattails (*Typha*), bur-reeds (*Sparganium*), bulrushes (*Schoenoplectus*), and tall sedges. Suitable habitats include lakes, ponds, old dead arms, gravel pits, sandpits, clay pits, (breeding) ponds, channels, marshes, and, less frequently, water bodies in peatlands and abandoned quarries.

Family: Gomphidae Rambur, 1842

26. ***Gomphus vulgatissimus*** (Linnaeus, 1758) klinovka obyčajná – Common Clubtail
Findings from the years 1960 and 2013; 2 L, Σ = 2. Threat and Protection: CRL-LC. A clubtail of Pontomediterranean origin of Palearctic distribution, extending into southern Scandinavia in the north. Reproductive habitat: the species occurs in lowland rivers, where it can be abundant, as well as in submontane streams. Occasionally, populations are found in smaller streams and ditches with flowing water. It is most commonly found in areas with sandy, silty, or loamy sediment; it is absent from fast-flowing, rocky streams.

Family: Cordulegastridae Hagen, 1875

27. ***Cordulegaster bidentata*** Selys, 1843 pásikavec dvojzubý – Sombre Goldenring
Findings from the year 1960–2023; 5 ♂, 1 ♀, 101 L, 5 Ex, Σ = 112. Threat and protection: CRL-LC, § – species monetary value: €200 per specimen. Pontopanonic faunal element, distributed only within Europe (European endemic). It occurs from eastern France to Romania and Bulgaria, from Sicily to southern Poland. Reproductive habitat: *C. bidentata* has a strong connection to mixed and deciduous beech forests in hilly and mountainous areas. Adults mainly reproduce in short sections of headwater areas, with the most suitable habitats being sandy or small limestone springs. Populations are also found in places where water seeps gently from the rocky substrate, without a visible open water surface.

28. ***Cordulegaster heros*** subsp. ***heros*** Theischinger, 1979 pásikavec velký – Balkan Goldenring
Findings from the year 1956–2024; 126 ♂, 43 ♀, 325 L, 35 Ex, 43 I, Σ = 571. Threats and protection: CRL-NT, § – species monetary value: €200 per specimen, a species of Community interest (Fig. 5, 14). *C. heros* is endemic to Central and Southeastern Europe. The nominative subspecies *C. heros* subsp. *heros* (hereinafter in the text and in the graphics referred to as *C. heros*) occurs in Central Europe and the Balkans. In Slovakia and southern Moravia, it reaches the northern limit of its distribution; its occurrence is rare in Hungary, Moldova, Romania, and Bulgaria. The oldest record from Slovakia is a larva of *Cordulegaster heros* from 1956 (initially identified as *C. annulatus*, Slološnický Stream,

Fig. 5. Balkan Goldenring (*Cordulegaster heros* ♂), Photo: Z. Šíblová.

collected by Jedlička, identified by M. Trpiš, collection SNMB), and the previously mentioned photograph of the same species by J. Ponec from 1980 (photo archive collection SNMB). Reproductive habitat: *C. heros* occurs in shaded forest streams and small rivers in valleys with sandy substrates, mainly in foothill and mountain regions. Unlike *C. bidentata*, *C. heros* usually occurs in the lower parts of streams, and their co-occurrence is relatively common.

Family: Corduliidae Selys, 1850

29. ***Cordulia aenea*** (Linnaeus, 1758) ligotavka medená – Downy Emerald
Findings from the years 1960, 2013, and 2020; 40 I, Σ = 40. Threats and Conservation: CRL-LC. The Eurosiberian species with a distribution from the British Isles to the Far East, south from Greece to northern Scandinavia. Reproductive habitat: *C. aenea* occurs near permanent, medium to large standing water bodies (forest lakes, dead arms, ponds, peatlands, older gravel pits). It is also rarely found in slow-flowing waters, in sections with well-developed vegetation and a thick layer of organic detritus on the bottom.

30. ***Epitheca bimaculata*** (Charpentier, 1825) ligotavka – Eurasian Baskettail
Findings from the year 1993; 1 ♀, Σ = 1. Threat and Protection: CRL-DD, § – species monetary value: €200 per specimen. The Siberian species with distribution from Western Europe to the Far East (southern Kamchatka and Japan). Reproductive habitat: *E. bimaculata* is most commonly found in lowlands, near medium- to large-forest lakes, on dead branches, and in abandoned oligotrophic to eutrophic gravel pits. It is less frequently found near ponds. Suitable habitats have a mosaic of open water surfaces and areas with abundant submerged and floating vegetation, such as water lilies (*Nuphar*), water lilies (*Nymphaea*), pondweed (*Potamogeton*), and water milfoil (*Myriophyllum*).

31. ***Somatochlora metallica*** (Vander Linden, 1825) ligotavka zelená – Brilliant Emerald
Finding from the year 2020; 3 I, Σ = 3. Threat and protection: ERL-VU, § – species monetary value: €200 per specimen. The Eurasian species with distribution from Western Europe and Scandinavia to southwestern Siberia and western Mongolia. Reproductive habitat: *S. metallica* occurs near still and slow-flowing waters that are partially or almost completely shaded. In lowlands and mid-altitude areas, suitable habitats are often found in forested landscapes. These are mainly still waters, e.g., lakes, ponds with open water in wetlands and peat bogs with Sphagnum moss, with bottoms containing organic detritus and often muddy. Less common habitats include slow-flowing streams and channels with reeds or floating Sphagnum moss, as well as shoreline vegetation. The species has a wide altitudinal range from lowlands to mountainous areas.

Family: Libellulidae Leach, 1815

32. ***Crocothemis erythraea*** (Brullé, 1832) vážka – Broad Scarlet

Finding from the year 2012; 10 ♂, Σ = 10. Threat and protection: CRL-LC. An expanding species of Ethiopian origin, ranging from the eastern coast of the British Isles to southwestern Asia and from southern Africa (Afrotropis) to southern Sweden. Breeding habitat: *C. erythraea* occurs near a wide range of standing, unshaded, and open water bodies with littoral vegetation (small water reservoirs, material pits, dead river branches).

33. ***Leucorrhinia pectoralis*** (Charpentier, 1825) vážka jasnoškvrnná – Yellow-spotted Whiteface

Findings from 1960 and 1998; 2 ♂, 2 L, Σ = 4. Threat and protection: CRL- *NT, § – species monetary value: €200 per specimen, a species of Community interest. Eurosiberian faunal element of Palearctic distribution from Western Europe to Western Siberia, south to the Caucasus. In Europe, the southern boundary of its range passes through northern Italy, and the northern boundary extends to southern Scandinavia. Breeding habitat: compared to other species of the genus *Leucorrhinia*, this species occurs in a relatively wide range of habitats (edges of peat bogs (Fig. 13) with Sphagnum moss, gravel pits, forest lakes, ponds with extensive reed beds, marshes, swampy ditches, dead river branches). The water surface of the breeding habitat is usually unshaded, dominated by submerged vegetation, such as bladderworts (*Utricularia*) and hornworts (*Ceratophyllum*). The species is considered a specialist of shallow marshy and peat bog habitats. Larvae are sensitive to predation by fish; development in fish-containing water bodies is successful if reed and sedge stands are developed, providing shelter and protection.

34. ***Libellula depressa*** Linnaeus, 1758 vážka ploská – Broad-bodied Chaser

Findings from the year 1995–2022; 18 ♂, 3 ♀, 15 L, 1 Ex, Σ = 37. Threat and protection: CRL-LC. A Pontomediteranean species with a western Palearctic distribution from Spain to Central Asia. Absent in northern Africa and in the Siberian part of Eurasia. Reproductive habitat: *L. depresa* occurs in almost any type of standing water with fluctuating water levels (sometimes drying up), muddy sediment, and submerged vegetation (material pits, drinking troughs, garden ponds, water reservoirs). It also reproduces in slow-flowing waters (such as canals and spring streams in marshes). It is often found in habitats in early stages of ecological succession and is among the species that quickly colonize water bodies created by humans, including small garden ponds. It occurs from the lowlands up to an altitude of 700-800 meters.

35. ***Libellula quadrimaculata*** Linnaeus, 1758 vážka štvorškvrnná – Four-spotted Chaser
Findings from the year 1998–2020; 5 ♂, 1 I, Σ = 6. Threats and Conservation: CRL-LC. An Arctic (Siberian) species of dragonfly with a distribution in the Palearctic (from the British Isles to Kamchatka) and Nearctic (from the southern parts of Alaska and Canada to the southern parts of the USA) regions. Reproductive habitat: *L. quadrimaculata* occurs in a wide range of predominantly still water bodies, but is most commonly found in unshaded lakes and ponds, dead river bends, peat bogs, marshes, and areas after peat extraction. However, the species is also commonly found in human-made water bodies such as ditches, garden ponds, and fish ponds.

36. ***Orthetrum albistylum*** (Selys, 1848) vážka – White-tailed Skimmer
Findings from the year 2010–2021; 18 ♂, 2 ♀, Σ = 20. Threats and Protection: CRL-LC. A Ponto-Mediterranean faunal element with Eurosiberian distribution from Western Europe in a narrow band toward the Black and Caspian Seas, Lake Baikal, and the Far East. Reproductive habitat: *O. albistylum* occurs in a wide range of sunny standing waters, less frequently in slow-flowing streams. The species shows a preference for human-created habitats such as flooded quarries, sand pits, ponds, and water reservoirs. In natural habitats, it can be found, for example, in dead river branches, flooded terrain depressions with extensive reed (*Phragmites*), sedge (*Carex*), rush (*Juncus*), and milfoil (*Myriophyllum*) zones. The species is not dependent on shoreline vegetation and can tolerate the presence of fish, mainly occurring in areas below 500 meters above sea level.

37. ***Orthetrum brunneum*** (Fonscolombe, 1837) vážka – Southern Skimmer
Findings from the years 2021 and 2022; 15 ♂, 3 ♀, 1 L, 1 Ex, Σ = 20. Threat and protection: CRL-LC, § – species monetary value: €200 per specimen. Originally a holomediteranean dragonfly, it has a Eurasian distribution from the Pyrenees Peninsula to southeastern China. Reproductive habitat: the lowland species *O. brunneum* occurs in a wide range of habitats, including: sunlit streams and canals, slow-flowing rivers, man-made ponds, flooded quarries, sandpits, and gravel pits. It is most commonly found in sites in early stages of succession, where there is relatively little shoreline or aquatic vegetation. It inhabits new, often human-created habitats, but as the vegetation develops, its presence decreases or disappears entirely.

38. ***Orthetrum cancellatum*** (Linnaeus, 1758) vážka rybničná – Black-tailed Skimmer
Findings from the year 2009–2021; 69 ♂, 3 ♀, 7 I, Σ = 79. Threat and protection: CRL-LC. Originally a holomediteran species of Palearctic distribution from the British Isles, North Africa to Lake Baikal. Reproductive habitat: *O. cancellatum* is generally widespread, found in almost all types of standing and slow-flowing waters (ponds, natural and artificial lakes, marshes, larger garden ponds,

concrete tanks, channels). The species is rare to absent in heavily shaded and fast-flowing waters, but it is regularly found in newly created habitats.

39. ***Orthetrum coerulescens*** (Fabricius, 1798) vážka – Keeled Skimmer

Findings from the year 2021; 1 ♂, 1 I, Σ = 2. Threat and protection: CRL-LC, § – species monetary value: €200 per specimen (Fig. 6). A species of holomediterranean origin found from the Pyrenean Peninsula, England, and North Africa through Turkey to Afghanistan and India. Reproductive habitat: *O. coerulescens* most commonly occurs near small, unshaded flowing waters (streams, channels, ditches) that are not overgrown with macrophyte and tree vegetation. Reproduction has also been confirmed in drainage channels, spring trenches, and spring basins on peatlands.

Fig. 6. Keeled Skimmer (*Orthetrum coerulescens* ♂), Photo: V. Janský.

40. ***Sympetrum meridionale*** (Selys, 1841) vážka – Southern Darter

Findings from the years 1996, 2006, and 2021; 2 ♂, 1 ♀, Σ = 3. Threats and protection: CRL-LC, § - species monetary value: €200 per specimen. Originally a holomediteranean species with a distribution from the Pyrenees Peninsula to western Mongolia, China, and Pakistan. Reproductive habitat: *S. meridionale* typically occurs in lowland and sunlit, shallow standing waters (marshes overgrown with vegetation, terrain depressions, temporary pools, material pits), which often dry up in summer. Suitable habitats obtain most of their water from winter rains, melting snow, or spring floods.

41 ***Sympetrum sanguineum*** (Müller, 1764) vážka červená – Ruddy Darter

Findings from the year 1987–2023; 99 ♂, 36 ♀, 13 L, 1 Ex, 1 I, Σ = 150. Threat and protection: CRL-LC. Originally a holomediteranean species with a Palearctic distribution from the British Isles through the Mediterranean to Kazakhstan. The northern boundary of the area runs from southern Scandinavia through Russia to Lake Baikal. Breeding habitat: the species occurs in a wide range of (including deeper) standing or slow-flowing waters. It prefers unshaded habitats with abundant aquatic and shoreline vegetation. Typical habitats occupied include: lakes, dead arms, mining pits, garden ponds, marshes, ditches, channels, and sedimentation sections of flowing rivers. The species is rare in acidic water bodies with Sphagnum moss and in newly formed ponds without vegetation.

42. ***Sympetrum striolatum*** (Charpentier, 1840) vážka pestrá – Common Darter

Findings from the year 1987–2021; 21 ♂, 36 ♀, 8 L, 7 I, Σ = 72. Threat and protection: CRL-LC. A holo-mediterranean species, it has a Palearctic distribution from the British Isles — a narrow band through Turkey, Kazakhstan, Mongolia to Japan, and from North Africa to southern Scandinavia. Breeding habitat: in temperate zones, *S. striolatum* occurs in open and sunlit standing waters, less often in slow-flowing waters. As a pioneer species, it colonizes new habitats created by humans.

43. ***Sympetrum vulgatum*** (Linnaeus, 1758) vážka obyčajná – Moustached Darter

Findings from the year 1990–2021; 3 ♂, 4 ♀, 2 L, Σ = 9. Threats and protection: ERL-VU (Fig. 7, 13, 15). A Eurosiberian faunal element with Palearctic distribution from Western Europe, southern Scandinavia through Siberia, Mongolia, to Sakhalin. Breeding habitat: *S. vulgatum* occurs in a wide range of sunlit standing waters, garden and park ponds, gravel and sand pits, terrain depressions, and the littoral zones of water bodies overgrown with vegetation. A species of lowlands and foothills.

Fig. 7. Moustached Darner (*Sympetrum vulgatum* ♂), Photo: Z. Šíblová.

Conservation assessment of dragonflies

According to sources: § – Decree of the Ministry of Environment of the Slovak Republic No. 170/2021 Coll., CRL – Carpathians Red List, ERL – European Red List, we confirmed the occurrence of 17 conservation-important species in the area: *Sympecma fusca* §; *Coenagrion ornatum* § CRL – *NT; *C. pulchellum* CRL – DD; *Aeshna grandis* ERL VU, CRL – NT; *A. isoceles* §; *Anax parthenope* §; *Brachytron pratense* § CRL – DD; *Cordulegaster heros* §; *Cordulia aenea* CRL – LC; *Epitheca bimaculata* § CRL – DD; *Somatochlora metallica* § ERL VU; *Crocothemis erythraea* CRL – LC; *Leucorrhinia pectoralis* § CRL – *NT; *Orthetrum brunneum* §; *O. coerulescens* §; *Sympetrum meridionale* §; *S. vulgatum* ERL – VU. The species *Cordulegaster heros*, *Epitheca bimaculata*, and *Leucorrhinia pectoralis* are listed in the Red Book – Invertebrates: Dragonflies (David et al. 2025).

Ecological assessment of dragonflies, their habitats, and sites

Despite the simple calculation, dominance (D) has significant interpretive value because it reflects not only the autecological characteristics of the species but also the suitability of habitat conditions for the species and their changes over time (Fig. 8). The eudominant species of dragonflies in the Malé Karpaty Mts. are *Aeshna affinis* (Eu = 29.78 %, 1,005 individuals), *Cordulegaster heros* (Eu = 16.86 %, 569 individuals), *Coenagrion puella* (Eu = 12.53 %, 423 individuals), and *Platycnemis pennipes* (Eu = 12.36 %, 417 individuals). Dominant species (Do = 5–9.9 %) were not recorded. There were five Subdominant species: *Sympetrum sanguineum* (Su = 4.44 %, 150 individuals), *Pyrrhosoma nymphula* (Su = 3.59 %, 121 individuals), *Cordulegaster bidentata* (Su = 3.26 %, 110 individuals), *Ischnura elegans* (Su = 3.02 %, 102 individuals), and *Orthetrum cancellatum* (Su = 2.34 %, 79 individuals). Four species were Recedent: *Aeshna cyanea* (Re = 1.75 %, 59 individuals), *Sympetrum striolatum* (Re = 1.24 %, 42 individuals), *Cordulia aenea* (Re = 1.19 %, 40 individuals), and *Libellula depressa* (Re = 1.10 %, 37 individuals). The remaining species fall into the subrecedent dominance category (Su 0.9 %), totaling 30 species. A total of 43 species and 3,375 individuals were evaluated.

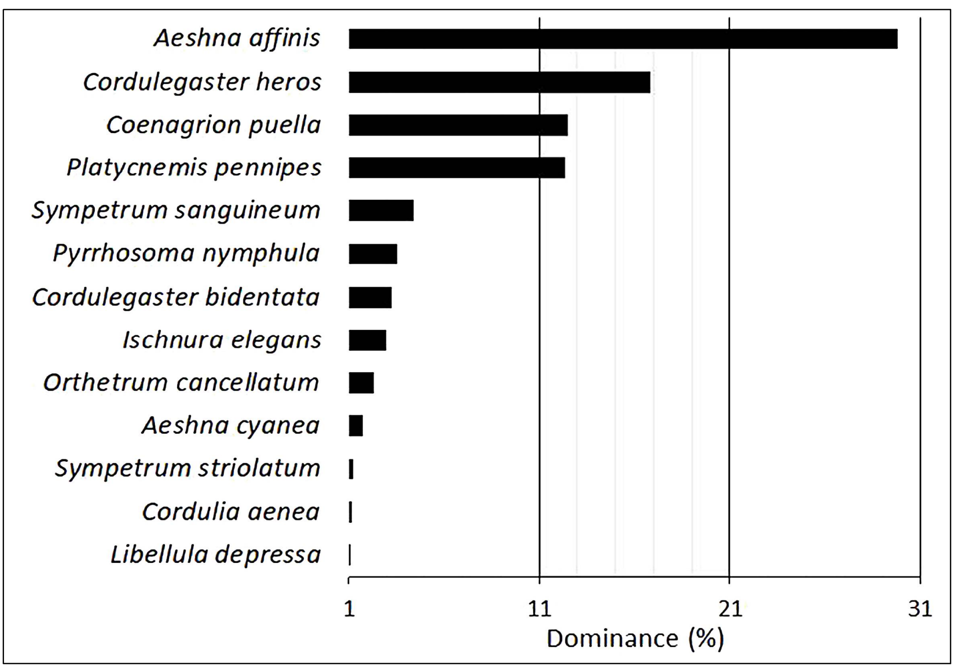

Fig. 8. Dominance of dragonflies in the Malé Karpaty Mts.: eudominant species (Eu > 10 %), subdominant species (Su 2–4.9 %), recedent species (Re 1–1.9 %), and subrecedent species (Su < 0.9 %).

We used a data matrix (transformed using log(z+1)) to analyze the species structure of the dragonfly community in Canoco5. Unconstrained detrended correspondence analysis (DCA) yielded an average value of total variability of species data (7.55419) and indicated a pronounced ecological gradient in species composition along the first ordination axis (gradient length = 5.77); due to its high value, unimodal ordination techniques were used. Species ordination (Fig. 9) grouped them along the 1st ordination axis, which explained 11.91 % of the species data variability. However, another environmental gradient along the 2nd ordination axis also plays a significant role, explaining 6.80 % of the variability; the cumulative variability on the 1st and 2nd axes is 18.71 % (11.91 + 6.80), with the 4th axis explaining 27.48 % of the cumulative variability in species data. According to species centroids, the expected main ecological gradient of the 1st ordination axis – standing versus flowing water environments – was not observed. We conclude this because rheophilic (flowing water) species such as *Orthetrum brunneum*, *Gomphus vulgatissimus*, *Calopteryx virgo*, *C. splendens*, *Cordulegaster bidentata*, and *C. heros* are ordinated along the 1st axis, but there are also stagnicolous (standing water) species such as *Erythromma najas*, *Crocothemis erythraea*, and *Aeshna mixta* (Fig. 9). Other factors influence the area, and their effects make the separation of stagnicolous and rheophilic species more apparent along the 2nd ordination axis (explaining 6.80 % of the variability).

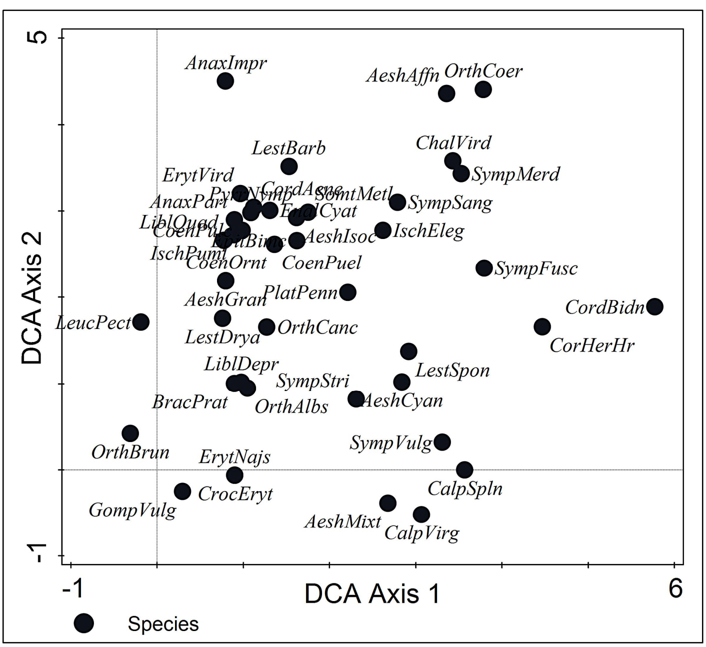

Fig. 9. DCA of dragonfly species of the Malé Karpaty Mts.; taxon names are given in abbreviated form using the genus and species names (4 + 4 characters), e.g., CordBidn = *Cordulegaster bidentata*. See species names in the systematic section of the article.

The basic gradient of the aquatic environment (flowing vs. standing water) was projected onto habitat types, with dragonfly occurrence, which we assigned to sites and used as explanatory (independent) variables, totaling 13 (Table 1). It is evident that some habitat types will be problematic due to their (low) number, as habitats like eupotamal, periodic depressions, and field margins occur only once, or because of their mutual correlation leading to collinearity. The result of the pseudo-F value distribution (comparing the variability explained by the model and the residual variability) tested with a permutated Monte Carlo test under the 'multivariate model' confirmed a fairly strong link (pseudo-F = 5.7; p = 0.002) between the explanatory variables (habitat types) and the response variables (dragonfly species). The explanatory variables explain up to 30.8 % of the variability, with an adjusted value of 25.39 % (i.e., the variance explained by the selected variables). In several steps, we combined or reduced the number of variables to 8 based on collinearity (metarhithral, small water reservoirs (SWR), excavation pits, fire protection reservoirs, eupotamal, marshes, peatlands, and forest edges). These explanatory variables captured 27.13 % of the total variability (total variation = 7.55419). In the constrained canonical correspondence analysis (CCA) of species and environmental variables, there is a significant correlation between the metarhithral (submontane streams) factor with the first ordination axis and eupotamal (lowland streams with a marginal system) with the second axis (Fig. 10). The outlier positions of dragonflies *Gomphus vulgatissimus* and *Leucorrhinia pectoralis* significantly distort the ordination space, and the centroids of species form an unreadable cluster at the intersection of the ordination axes.

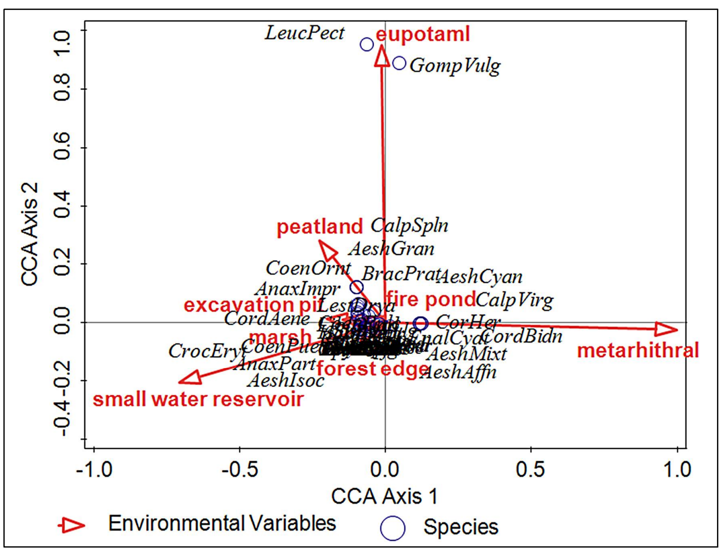

Fig. 10. CCA of dragonfly species and environmental variables confirms the correlation and significance of the metarhithral factor with ordination axis 1 and the eupotamal with ordination axis 2, as well as the distant (outlier) positions of *Gomphus vulgatissimus* and *Leucorrhinia pectoralis*.

The statistical significance of eight explanatory variables (habitats) was tested using a Monte Carlo test (499 permutations). The Summarize effects function allowed assessment not only of significance but also of the contribution of individual factors to the explained variability. The Simple effects analysis identified 5 significant variables (pα = 0.05), while the Conditional effects confirmed the significant contribution of four factors independent of covariates (Table 2).

Table 2. Assessment of the significance of explanatory variables using a permutation test.

Biotop	**Simple effects (test variable independently)**			
Name	Explains %	pseudo-F	P	P(adj)
metarhithral	10,1	18,3	0,002	0,016
SWR	6,8	12	0,002	0,016
eupotamal	6,6	11,6	0,01	0,08
peatlands	3,9	6,7	0,026	0,208
marshes	3	5,1	0,046	0,368
Biotop	**Conditional effects (is additional information added)**			
	Explains %	pseudo-F	P	P(adj)
metarhithral	10,1	18,3	0,002	0,016
eupotamal	6,6	12,9	0,012	0,096
peatlands	3,6	7,4	0,042	0,336
marshes	2,9	6,1	0,038	0,304

Explanation note: SWR – small water reservoir

The Simple Effects analysis shows the contribution of each individually tested factor. The largest proportion of explained variability is attributed to the metarhithral (10.1 %), followed by SWR (6.8 %) and eupotamal (6.6 %). Other factors (peatlands, marshes, forest edges, material pits, fire tanks) have a lower share (1-4 %). Conditional effects indicate the additional contribution of a factor after accounting for the previous ones. The metarhitrál maintains the same value (10.1 %) because it is first in the order; eupotamal explains an additional 6.6 %; and similarly, the other factors lose only a small part of their effect. An exception is the fifth factor in the order, SWR, where the contribution drops from 6.8 % to 1.7 %, suggesting shared variability with the preceding factors.

The ordination graph with 5 variables (without forest edges, fire reservoirs, and material pits) had a similar distribution of species and remaining explanatory variables, including the distant position of the species *Leucorhinia pectoralis* and *Gomphus vulgatissimus* (Fig. 10). After removing these two species and the eupotamal factor, we constructed an ordination graph of canonical correspondence analysis with 4 variables (Fig. 11). For clarity, we classified the dragonfly species into ecological groups: species of standing waters – stagnicolous, flowing waters – rheophilic, and species inhabiting various types of habitats – euryecious. Their distribution in the ordination space is highlighted by envelopes (ellipses) that represent the 95 % confidence intervals around the centroids of each ecological group.

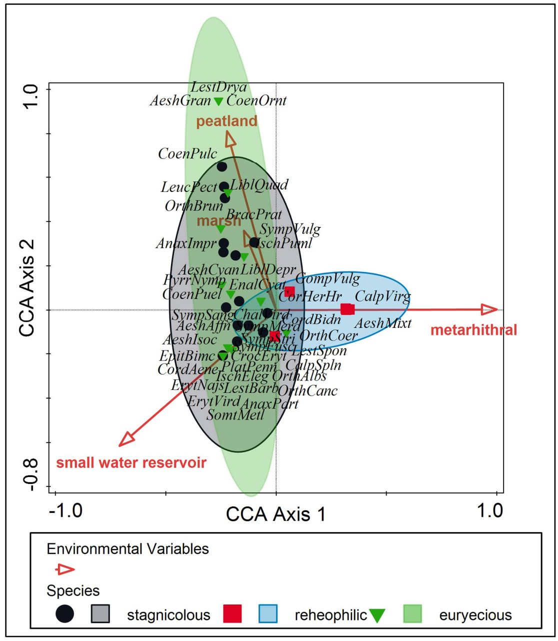

Fig. 11. CCA of dragonfly species and 4 environmental variables, which account for 18.23 % of the explained variability (adjusted value = 16.20 %). Species are classified into ecological groups (stagnicolous, rheophilous, and euryecious), and their distribution in ordination space is highlighted by ellipses representing the 95 % confidence intervals around the group centroids.

Based on the values provided in Canoco on the Score Pages in the Analysis Notebook, we interpret the most important outputs of the ExplVars page. The VIF (Variance Inflation Factor) values range up to 3.31, which is relatively low, indicating that multicollinearity among the four explanatory variables does not need to be addressed. The variable 'metarhithral' was strongly associated with the first ordination axis (CorE.1 = 0.94), and BipE.1 (0.99; 99 % of the variability of this factor) represented it. The metarhithral has a dominant influence on the main ecological gradient. High regression coefficient values on axis 1 (RegrE.1 = 0.95) and the t-value for the significance of the coefficients (TValE.1 = 17.77; $p < 0.0001$) confirm the high statistical significance of this relationship. The variable SWR shows negative correlations with the first (CorE.1 = -0.67) and second (CorE.2 = -0.54) axes. This type of habitat is negatively correlated with the main gradient, and the high t-value on axis 2 (TValE.2 = -8.05; $p < 0.0005$) indicates its significant (negative) influence. Wetlands show the highest correlation with the third ordination axis (CorE.3 = 0.58; BipE.3 = 0.91), suggesting that this habitat type is associated with a specific ecological gradient, as confirmed by t-values on axis 3 (TValE.3 = 8.11). Peatlands are associated with the second ordination axis (CorE.2 = 0.71; BipE.2 = 0.81), indicating their role in separating sites along this gradient. The t-value on axis 2 (TValE.2 = 11.61) confirms a significant relationship between these variables and this gradient.

The ordination of sites and 4 predictors is shown in the CCA analysis graph (Fig. 12). The sites are grouped based on similarity in species composition and the selected (4 predictors) environmental conditions. The ordination axes (Axis 1 and Axis 2) represent the most significant ecological gradients influencing species composition. The first ordination axis (Axis 1) represents a gradient from standing water habitats (SWR) to metarhithral sections of mostly forested streams; this predictor has the longest vector, indicating its dominant influence on the main ecological gradient. The predictor with the longest vector indicates its dominant influence on the main ecological gradient. The second ordination axis (Axis 2) separates sites associated with peatlands from marsh sites. The length and angle of the predictor vector for peatlands with respect to the 2nd ordination axis indicate a strong connection to Axis 2. The sample locations reflect similarities in species composition. Sites closer to the environmental variable arrow are more strongly correlated with that habitat type. For example, sites on the right (around points 108, 122, and 145) are associated with metarhithral zones, while sites at the top (e.g., 165, 5, and 2) are typical of peatlands. Sites on the left (151, 162) are characteristic of dead arms.

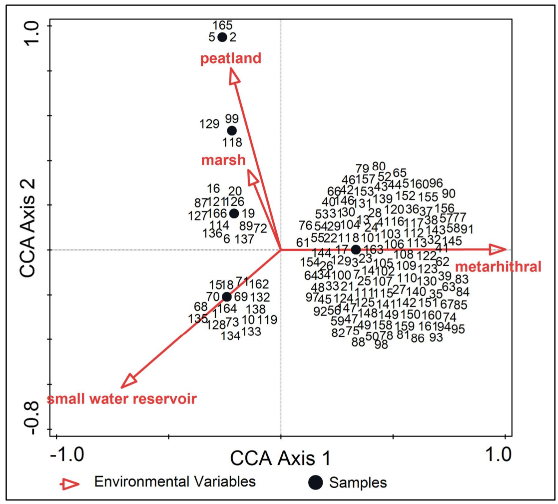

Fig. 12. CCA of dragonfly sites and 4 environmental variables (metarhithral, peat bogs, marshes, and small water reservoirs), the positions of site numbers are shifted around their projection relative to the ordination axes and predictors for better readability.

From the interactive panel (analysis notebook), we selected the Cases page (which contains statistics, scores on the ordination axes, etc.) for individual cases (sites) to identify the 4 characteristics with the highest values for 10 dragonfly sites in the Malé Karpaty Mts. (Table 3). We chose the variables: CaseW (weight, or significance of the site in the analysis), with the most significant being site 15 (30.13); CaseN2 (Simpson's index 1/D), with the highest diversity also in site 15 (12.28); Het4 (overall heterogeneity expressed by four ordination axes), with the highest heterogeneity in site 99 (297.21); and FitC4 (percent of variability explained by 4 axes), with the highest explained variability in site 82 (76.92).

Table 3. Selection of ten sites with the highest values of the selected site variables CaseW, CaseN2, Het4, and FitC4.

CaseW	Lok.	CaseN2	Lok.	Het4	Lok.	FitC4	Lok.
30.13	15	12.28	15	279.21	99	76.92	82
29.33	132	10.29	132	245.76	129	76.92	161
27.32	1	10.17	2	168.62	121	71.76	2
25.34	69	9.75	1	164.66	2	65.49	4
23.22	133	8.23	69	162.30	114	65.49	7
21.36	2	7.61	128	158.15	5	65.49	8
19.25	128	7.32	133	155.56	165	65.49	9
17.49	18	7.06	18	152.90	72	65.49	11
14.90	129	6.99	72	152.34	20	65.49	12
12.01	126	5.96	164	151.13	16	65.49	13

Explanation notes: CaseW (site weight), CaseN2 (Simpson's index), Het4 (overall heterogeneity), FitC4 (explained % of variability).

We have supplemented the assessment of sites with dragonfly occurrences in the Malé Karpaty Mts. with a tabular overview (Table 4) showing the distribution of sites by the number of dragonfly species present. For these groups of sites, we include: the number of sites, the number of individuals (mean value = arithmetic average, minimum and maximum counts), and the median values of diversity indices (Simpson's index – N2, Shannon-Wiener index – H´, its maximum value (H´max), and evenness (E)). The values were exported from the data matrix in the Canoco program (Data | Add new table | Statistics...). Up to 100 sites (Table 4) have only one dragonfly species present (individuals = 797), so the Simpson's index values (N2 = 1/D) for these sites = 1, the species diversity according to the Shannon-Wiener index, the maximum diversity value (Hmax), and community evenness (e) are all zero.

Of the 166 sites, 121 had *C. heros* present (= 569 individuals). At 88 sites, only the species *C. heros* was found, totaling 383 individuals. Thirty-three sites had only a single individual of *C. heros* (= 33 individuals). At sites with only one species and one individual, the following species were also recorded: *C. bidentata* (sites 84, 86, and 143), *C. splendens* (site 163), *A. imperator* (site 165), and *S. sanguineum* (site 166). For sites with only one dragonfly species but with a higher number of individuals (n > 1), the following were noted: *S. sanguineum* (site 87, n = 19), *A. affinis* (site 136, n = 250; site 137, n = 120), and *C. bidentata* (site 141, n = 12; site 155, n = 6). The number of *A. affinis* individuals (n = 250) was also the highest in the entire sampled dragonfly population of the studied area (see dominance, Fig. 8).

Table 4. Overview of sites by species count, including the number of sites, individuals, and the mean value of Simpson's (N2) and Shannon–Wiener (H´) diversity indices and evenness (e).

Count: species/sites/individuals	**Number of individuals**		**N2**	**H´**	**H_{max}**	**e**
Number of species per site: 1	Mean	7.97	1	0	0	0
Number of sites: 100	Minimum	1				
Number of individuals: 797	Maximum	250				
Sites: 4, 7, 8, 9, 11, 12, 13, 17, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 55, 56, 57, 58, 59, 60, 63, 64, 65, 66, 67, 75, 77, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 115, 116, 117, 130, 136, 137, 139, 141, 143, 147, 149, 153, 154, 155, 157, 163, 165, 166.						
Number of species per site: 2	Mean	7.66	1.66	0.56	0.69	0.80
Number of sites: 32	Minimum	2	1.12	0.21	0.69	0.31
Number of individuals: 245	Maximum	29	2	0.69	0.69	1
Sites: 3, 6, 10, 14, 20, 43, 61, 62, 68, 76, 78, 82, 96, 114, 118, 122, 127, 131, 140, 142, 144, 145, 146, 148, 150, 151, 152 ,156, 158, 159, 160, 161						
Number of species per site: 3	Mean	8	2.55	0.97	1.10	0.88
Number of sites: 9	Minimum	3	1.22	0.38	1.10	0.35
Number of individuals: 72	Maximum	31	3	1.10	1.10	1
Sites: 16, 19, 71, 73, 74, 83, 95, 120, 121						
Number of species per site: 4	Mean	51.33	2.39	0.92	1.39	0.66
Number of sites: 3	Minimum	5	1.22	0.39	1.39	0.28
Number of individuals: 154	Maximum	133	3.57	1.33	1.39	0.96
Sites: 54, 138, 162						
Number of species per site: 5	Mean	25.8	3.04	1.28	1.61	0.79
Number of sites: 5	Minimum	8	2.11	0.92	1.61	0.57
Number of individuals: 129	Maximum	82	3.60	1.41	1.61	0.88
Sites: 79, 113, 123, 124, 135						
Number of species per site: 6	Mean	26	3.62	1.51	1.79	0.84
Number of sites: 3	Minimum	12	3.41	1.46	1.79	0.81
Number of individuals: 78	Maximum	53	4	1.58	1.79	0.88
Sites: 80, 119, 129						
Number of species per site: 7	Mean	92	2.38	1.06	1.95	0.54
Number of sites: 4	Minimum	40	1.35	0.60	1.95	0.31
Number of individuals: 368	Maximum	170	4.26	1.63	1.95	0.84
Sites: 5, 70, 129, 134						
Number of species per site: 8	Mean	20	4.10	1.69	2.08	0.81
Number of sites: 2	Minimum	18	2.95	1.53	2.08	0.74
Number of individuals: 40	Maximum	22	5.26	1.85	2.08	0.89
Sites: 72, 164						
Number of species per site: 9	Mean	8	3.71	1.60	2.20	0.73
Number of sites: 1	Minimum	1				
Number of individuals: 99	Maximum	40				
Sites: 18						
Number of species per site: 10	Mean	208.5	3.24	1.45	2.30	0.63
Number of sites: 2	Minimum	110	2.10	1.18	2.30	0.51

Count: species/sites/individuals	**Number of individuals**		**N2**	**H´**	**H_{max}**	**e**
Number of individuals: 417	Maximum	307	4.38	1.72	2.30	0.75
Sites: 128, 133						
Number of species per site: 11	Mean	10				
Number of sites: 1	Minimum	1	3.25	1.55	2.40	0.64
Number of individuals: 260	Maximum	129				
Sites: 69						
Number of species per site: 12	Mean	133	6.75	2.09	2.48	0.84
Number of sites: 2	Minimum	82	6.31	2.02	2.48	0.81
Number of individuals: 266	Maximum	184	7.20	2.15	2.48	0.86
Sites: 1, 2						
Number of species per site: 15	Mean	14				
Number of sites: 1	Minimum	1	4.21	1.77	2.71	0.65
Number of individuals: 260	Maximum	102				
Sites: 132						
Number of species per site: 17	Mean	6				
Number of sites: 1	Minimum	1	4.81	1.96	2.83	0.69
Number of individuals: 190	Maximum	62				
Sites: 15						

Explanation notes: Mean – arithmetic mean; N2 – Simpson's index; H' – Shannon–Wiener index; H_{max} – maximum value of H'; e – evenness (equitability).

DISCUSSION

By summarizing data on dragonflies in the Malé Karpaty Mts., we defined a period of usable data on dragonfly occurrence in the territory from 1956 to 2024. We did not use historical records (BALTHASAR 1936, 1938) because of their imprecise localizations. The identified number of 166 sites is considered high for the forested mid-mountain landscape of the Malé Karpaty Mts. This is the result of long-term targeted research aimed at locating the Balkan Goldenring (*Cordulegaster heros*), a species of Community interest. The problem was the GIS layer's boundary being inaccurate when selecting sites within the orographic unit, so we used an external buffer of 300 meters to account for this. Several sites are on the border of the orographic unit, e.g., site 6 (Karlova Ves, side arm of the Danube river), site 19 (Devínska Nová Ves, Štokeravská vápenka), site 89 (Svätý Jur, Fofovský stream southwest of the lookout tower), site 162 (Horné Orešany, SWR). The highest number of sites (from 33 to 27) is from altitudes of 191 to 390 m a.s.l. The sites were classified into 13 types of aquatic, semi-aquatic, and terrestrial habitats, with the most numerous being metarhithral (125 sites) and small water reservoirs, e.g., pools in the upper Mlynská valley.

The identified number of dragonflies for the Malé Karpaty mts. is 43 taxa (1,323 males, 353 females, 545 larvae, 52 exuviae, and 1,102 imagos, for which the sex was not determined (= 3,375 individuals), representing approximately 60 % of the total number of species known from Slovakia (cf. DAVID and ŠÁCHA 2019).

Considering that the Malé Karpaty Mts. are a relatively low mountain range with predominantly small watercourses (metarhithral) in beech forests and a lack of natural lake systems (partially replaced by small water reservoirs), this number is relatively high. In the Malé Karpaty Mts., LOJKOVÁ (2012) and ŠÍBLOVÁ and LEHOTSKÁ (2024) list 29 species, including, for example, *Aeshna affinis*, *A. cyanea*, *Anax imperator*, *Brachytron pratense*, *Calopteryx splendens*, and *Cordulegaster heros*. Among the species observed, we expected the highest dominance for the long-term monitored species *Cordulegaster heros* (D = 16.86 %, 569 individuals). Its presence at 121 sites (73 % of all surveyed sites) confirms that the Malé Karpaty Mts. region is one of the key areas for the occurrence of this 'nature' species in Slovakia. This assumption aligns with previous findings (e.g., BLAŠKOVIČ et al. 2003; JANSKÝ, DAVID 2008) and emphasizes the importance of this mountain range for the conservation of this species, which is associated with forest streams (metarhithral). Surprisingly, the highest abundance and dominance are observed in the dragonfly *Aeshna affinis*, recorded at 13 sites. In 2020 (July 21, July 23) and 2021 (July 9, July 22, and August 11), mass flights of 100 to 150 individuals, totaling approximately 1,000 individuals, were recorded at sites such as Sv. Jur-Biely kríž, Krasňany SWR, Pezinok-Kučišdorfská dolina, Rača-Pariská, and others. In the late summer evenings, groups of dozens to hundreds of individuals can be observed hunting over heated playgrounds, park areas, and parking lots. The years mentioned were favorable for mass hatching, and *A. affinis* is a species subject to significant fluctuations in population size and migrations (BOUDOT, KALKMAN 2015).

Analysis of species composition using ordinations (DCA and CCA) revealed that the main environmental gradient in the area is not a simple division of aquatic ecosystems into standing and flowing waters, but rather a more complex relationship between dragonflies and habitat types. Our CCA analysis demonstrated that there is a strong association (pseudo-F = 5.7; p = 0.002) between 13 habitat types (RUŽIČKOVÁ et al. 1996), into which we classified sites with dragonfly occurrences, and the explanatory variables (habitats, explaining 30.8 % of variability) and the response variables (dragonflies). Due to collinearity, removal of outliers, and testing for statistical significance (using the Summarize effects and Simple effects functions), we reduced the explanatory variables to four: metarhithral, peatlands, marshes, and small water reservoirs (Fig. 13). The interpretation of the variable effects in the model using Conditional effects confirmed the significant contribution of these four factors, independent of covariates. The most significant variable (explaining 10.1 % of the variability) is the habitat metarhitrhal (submontane streams), which corresponds to the area's geomorphological character. The metarhitrhal variable is strongly associated with the first ordination axis (CorE.1 = 0.94), accounting for 99 % of the variability of this factor, and the t-value for the significance of the coefficients (TValE.1 =

17.77; $p < 0.0001$) confirms the high statistical significance of this association. The SWR variable shows negative correlations with the first (CorE.1 = -0.67) and second (CorE.2 = -0.54) axes; the t-value on axis 2 (TValE.2 = -8.05; $p < 0.0005$) indicates a significant (negative) influence.

The strong association of species such as *Cordulegaster heros*, *C. bidentata* and *Calopteryx virgo* with the first ordination axis confirms that these streams are the most stable habitats in the area. The presence of small water reservoirs (SWR) in the area along watercourses creates a habitat mosaic that is the second-most significant habitat for species richness (explaining 6.8 % of the variability). From site 15 (Mlynská Dolina, SWR Druhý rybník), 17 species were recorded, making it the second in order, followed by site 132 (Mlynská Dolina, SWR U Slivu) with 15 species (Appendix 2). Peatlands and marshes have a specific position. Although they explain a smaller portion of the variability (about 3–4 %), they host specialized species (as indicated by the separate positions of *Leucorrhinia pectoralis* and *Gomphus vulgatissimus* in the graphs). These biotopes are fragmented and rare in the Malé Karpaty Mts., but they are important for the occurrence of rare species. Multiple species have been recorded outside their primary reproductive habitats, which is a common phenomenon among dragonflies (CORBET 1999). Of the dragonflies in the Malé Karpaty Mts., up to 25 species (58 %) have not been confirmed by larval development stages or exuviae. Confirming the autochthonous presence of these species in the area is a task for ongoing dragonfly research in the region.

In the area, we confirmed the occurrence of 17 ecologically significant species, of which 11 are legally protected. The species *Cordulegaster heros*, *Epitheca bimaculata*, and *Leucorrhinia pectoralis* are listed in the Red Book – Invertebrates (DAVID et al. 2025). Surprisingly, the dragonfly *Sympetrum vulgatum* is classified as vulnerable (VU) in the European Red List (DE KNIJF et al. 2024).

CONCLUSION

The presented study offers a comprehensive faunistic and ecological synthesis of available data on dragonflies (Odonata) from the Malé Karpaty mountain range. Based on an extensive dataset of 539 faunistic records from 166 sites spanning the years 1956 to 2024, we have reached several conclusions with implications for the conservation of dragonfly biodiversity in this area.

An important factor in data quality is time, as the dataset spans 1956 to 2024. During this nearly 70-year period, there have been changes in the status of water bodies in the area, in the management of watercourses, and in successional changes in standing waters. Before 2000, only 84 records of dragonfly sightings were obtained. There is also an uneven representation of habitats (for example, eupotamal is represented by only one site, which creates statistical artifacts—outliers—in multivariate analyses). The most common habitat types are submontane streams (metarhitrhal = 125 times) and small water reservoirs (18 times).

When interpreting the results, we must consider the high heterogeneity in the number of individuals in the findings. The average number of individuals in the sample is 6.26 ± 0.772 (at a 95 % confidence interval), with a minimum of 1 and a maximum of 206 (on July 22, 2021, Z. Šíblová observed aggregation of *Aeshna affinis* at the reservoir in upper Mlynská valley near Františkov Spring, documented with 1 male, 5 females, and an estimate of 200 individuals). The median number of individuals in the dataset is 2, the most common value (mode) is 1, and the forest streams of the Malé Karpaty Mts. are poor in both the number of individuals and species. The standard deviation (SD = 17.92) is three times the average number of individuals, and the sample variance (321.07) is also high. The coefficient of variability (CV %) = SD / mean * 100 = 17.92 / 6.26 ≈ 286 %) indicates extreme variability in the number of individuals in the dataset. The dataset of dragonfly samples from the Malé Karpaty Mts. contains 305 samples (observation/site/date), with an average of 1.77 ± 0.081 species per sample (at a 95 % confidence interval). The median, mode, and minimum number of species per sample are 1, while the maximum is 9. The standard deviation (SD = 1.42), variance (2.00), and coefficient of variability (CV %) = 1.42 / 1.77 ≈ 80 %) show that the number of species varies considerably between samples, although most samples have a low number of species.

In the Malé Karpaty Mts., 43 dragonfly taxa were confirmed, representing 60.6 % of Slovakia's species richness. However, 25 species (58 % of the recorded species richness) among those identified were not verified through larval developmental stages or exuviae. Confirmation of autochthonous occurrence in the area needs to be verified through further research. Seventeen species are of conservation significance, of which 10 are legally protected, highlighting the area's high biological value. Despite the dominance of common species (*Aeshna affinis*, *Coenagrion puella*, *Platycnemis pennipes*, *Sympetrum sanguineum*, etc.), the presence of the eudominant species of the community interest, *Cordulegaster heros*, confirms the existence of stable forest stream habitats of the metarhithral type. From a conservation perspective, the priority is to preserve the natural character of these forest streams for the population of *Cordulegaster heros*. Small water reservoirs function in the area as local biodiversity "hot spots" for stagnicolous species. Peatlands and marshes, although small in area, require protection and management because they support specialists (e.g., *L. pectoralis*).

Canonical correspondence analysis (CCA) confirmed that the overall species structure of the dragonfly community is strongly influenced by the characteristics of the aquatic habitat, accounting for 30.8 % of the total variability in species data. The factor with the greatest explanatory power (10.1 % of variability) identified in the area was the metarhithral zone (submontane streams). At the other end of the ordination gradient are small water reservoirs (SWR), which are important for stagnicolous species, confirming their role as local biodiversity "hot spots", especially in areas without extensive natural standing waters. The presence of specialists such as Leucorrhinia pectoralis in peatlands and marshes underscores the importance of protecting these rare and vulnerable habitats. Based on the obtained results, we recommend focusing conservation management primarily on:

- preservation of the natural state of the metarithral sections of forest streams and the reduction of trees along the streams (riparian vegetation), which serve as reproductive habitats for the larval stages of *Cordulegaster heros* and other rheophilic species,
- protection and management of SWR, to protect them from extinction, and to protect selected SWR from the intensification of fishing and recreational use,
- continue monitoring the species *Leucorrhinia pectoralis* and *Cordulegaster heros*.

This study provides a faunistic and ecological overview of dragonflies in the Malé Karpaty Mts. and can serve as a basis for implementing effective conservation measures and further research on dragonflies in the Malé Karpaty Mts.

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