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Authors: Šestáková, Anna, Černecká, Ľudmila, Naumova, Maria, Purgat, Pavol, Szita, Éva, et al.

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# A review of two very rare ground spiders from sandy habitats, new for Slovakia (Araneae: Gnaphosidae)

**Anna Šestáková, Ľudmila Černecká, Maria Naumova, Pavol Purgat, Éva Szita & Peter Gajdoš**

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**Abstract.** Two rare and interesting spider species (*Gnaphosa mongolica* Simon, 1895 and *Haplodrassus bohemicus* Miller & Buchar, 1977) were found during intensive research into the Pannonic sand steppes in Slovakia and represent new records for the country. Numerous specimens of both species were collected between the villages Radvaň nad Dunajom and Marcelová in the years 2017–2020 (145 ind. *G. mongolica* and 82 ind. *H. bohemicus*), indicating stable populations. The Slovak records of *G. mongolica* represent the northernmost and westernmost location of the species in Europe. The characteristic features, photos of the habitus and genitalia, the currently known distribution in Europe and the phenology of both species are provided. A more detailed discussion concerns the morphology of copulatory organs of *H. bohemicus*, including the first report of a lateral gynandromorphy in this species.

**Keywords:** Bulgaria, faunistic, *Gnaphosa mongolica*, gynandry, *Haplodrassus bohemicus*, Pannonic sand steppes, species conservation, sand dunes

**Zusammenfassung. Eine Übersicht zu zwei sehr seltenen Plattbauchspinnen aus Sandhabitaten, neu für die Slowakei (Araneae: Gnaphosidae).** Zwei seltene und interessante Spinnenarten (*Gnaphosa mongolica* Simon, 1895 und *Haplodrassus bohemicus* Miller & Buchar, 1977) wurden während intensiven Untersuchungen der pannonischen Sandsteppenhabitate in der Slowakei gefunden und sind neue Nachweise für das Land. Eine große Anzahl Exemplare beider Arten wurden zwischen den Dörfern Radvaň nad Dunajom und Marcelová in den Jahren 2017-2020 (145 Individuen von *G. mongolica* und 82 Individuen von *H. bohemicus*), was auf stabile Populationen hindeutet. Die slowakischen Nachweise von *G. mongolica* stellen die nördlichsten und westlichsten Lokalitäten der Art dar. Die charakteristischen Merkmale, Habitus, Genitalien und die aktuell bekannte Verbreitung der Art in Europa sowie die Phänologie beider Arten werden präsentiert. Eine etwas detailliertere Diskussion befasst sich mit der Morphologie der Kopulationsorgane von *H. bohemicus*, einschließlich einer erstmals beobachteten lateralen Gynandromorphie.

Sandy habitats in Slovakia belong to interesting and unique ecosystems and are inhabited by several rare and endangered taxa. However, so far only a few studies on spiders were conducted there (Kalivodová et al. 2002, 2008, Prídavka 2002, Gajdoš & Majzlan 2001, 2008, 2010, Gajdoš et al. 2019). The Pannonic sand steppes (EUNIS code 6260), one of the most endangered habitats of the Pannonian region, are characterised by semi-natural dry grasslands and scrubland on mobile or fixed sands (EUNIS 2021). In Slovakia, only small fragments of this habitat are found on the Danubian plain and in the east Slovak lowlands. The major threats are abandonment of traditional land use and sand extraction, which lead to afforestation and spread of invasive species (Šefferová Stanová et al. 2008). Spiders of the Pannonic steppes localities in Slovakia were partly studied by Gajdoš & Majzlan (2001). In recent years, several species new to the Slovak fauna have been discovered in sandy habitats: *Parasyrisca arrabonica* Szinetár & Eichardt, 2009 (Gajdoš & Majzlan 2010), *Erigonoplus foveatus* (Dahl, 1912) (Hollá et al. 2016; although it was recorded on a tree by accident), *Spiracme mongolica* (Schenkel, 1963) and *Walckenaeria stylifrons* (O. Pickard-Cambridge, 1875) (Purgat et al. 2021).

The initial goal of our study was to improve the knowledge of spider species living in Pannonian sand habitats, which led to the discovery of two spider species new for the Slovak fauna. The ground-dwelling gnaphosids *Gnaphosa mongolica* Simon, 1895 and *Haplodrassus bohemicus* Miller & Buchar, 1977 are widespread in the Palearctic (except in Western Europe) (World Spider Catalog 2022). The first species, *G. mongolica*, can be easily identified using the online key of Nentwig et al. (2022). However, *H. bohemicus* can be easily confused with related species, which causes some uncertainty about its previous identifications and localities. Its diagnosis using known descriptions in the literature is ambiguous due to an inconsistent terminology (e.g. embolic/terminal apophysis) and poorly defined diagnostic characters that can be misunderstood, which is due to slightly different angles from which the male palp has been illustrated. Therefore, we focused in depth on copulatory organs of the latter species and discuss misidentified species. For both species, we also summarize all available data on the distribution, habitat preferences, phenology and red list status in Europe. In addition, we present a new case of a bilateral gynander found in a specimen of *H. bohemicus*.

## Material and methods

Spiders were collected by pitfall trapping using five traps in one transect at each study site. They were emptied monthly from March 2017 to April 2019 in Domáňovský majer and from March 2019 to April 2020 at other study sites. The traps consisted of a plastic flowerpot inserted in the ground, into which a removable plastic cup (diameter 10 cm) with a formalin solution was inserted. The here presented phenology summarizes the new data from Slovakia including published records and unpublished data, always dated to the last day the traps were emptied. Habitat summaries were made by simplifying habitat data into four categories: 1. sand dunes (habitat with sparse or almost no vegetation on sandy soil), 2. steppes (grassy habitat with sparse vegetation on sandy soils or other xerotherm habitats), 3. meadows (dense grassy vegetation growing on other type of soil, including records where

Anna ŠESTÁKOVÁ, The Western Slovakian Museum, Múzejné nám. 3, SK-91809 Trnava, Slovakia; E-mail: asestakova@gmail.com
Ľudmila ČERNECKÁ, Institute of Forest Ecology, Slovak Academy of Sciences, Ľudovíta Štúra 2, SK-96053 Zvolen, Slovakia; E-mail: cernecka@ife.sk
Maria NAUMOVA, Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Tsar Osvoboditel blvd., 1000 Sofia, Bulgaria; E-mail: munny@abv.bg
Pavol PURGAT, Institute of Landcape Ecology, Nitra Branch, Slovak Academy of Sciences, Akademická 2, SK-94901 Nitra, Slovakia; E-mail: pavol.purgat@savba.sk
Éva SZITA, Plant Protection Institute, Centre for Agricultural Research, Herman Ottó u. 15, H-1022, Budapest, Hungary; E-mail: szita.eva@atk.hu
Peter GAJDOŠ, Institute of Landcape Ecology, Nitra Branch, Slovak Academy of Sciences, Akademická 2, SK-94901 Nitra, Slovakia; E-mail: p.gajdos@savba.sk

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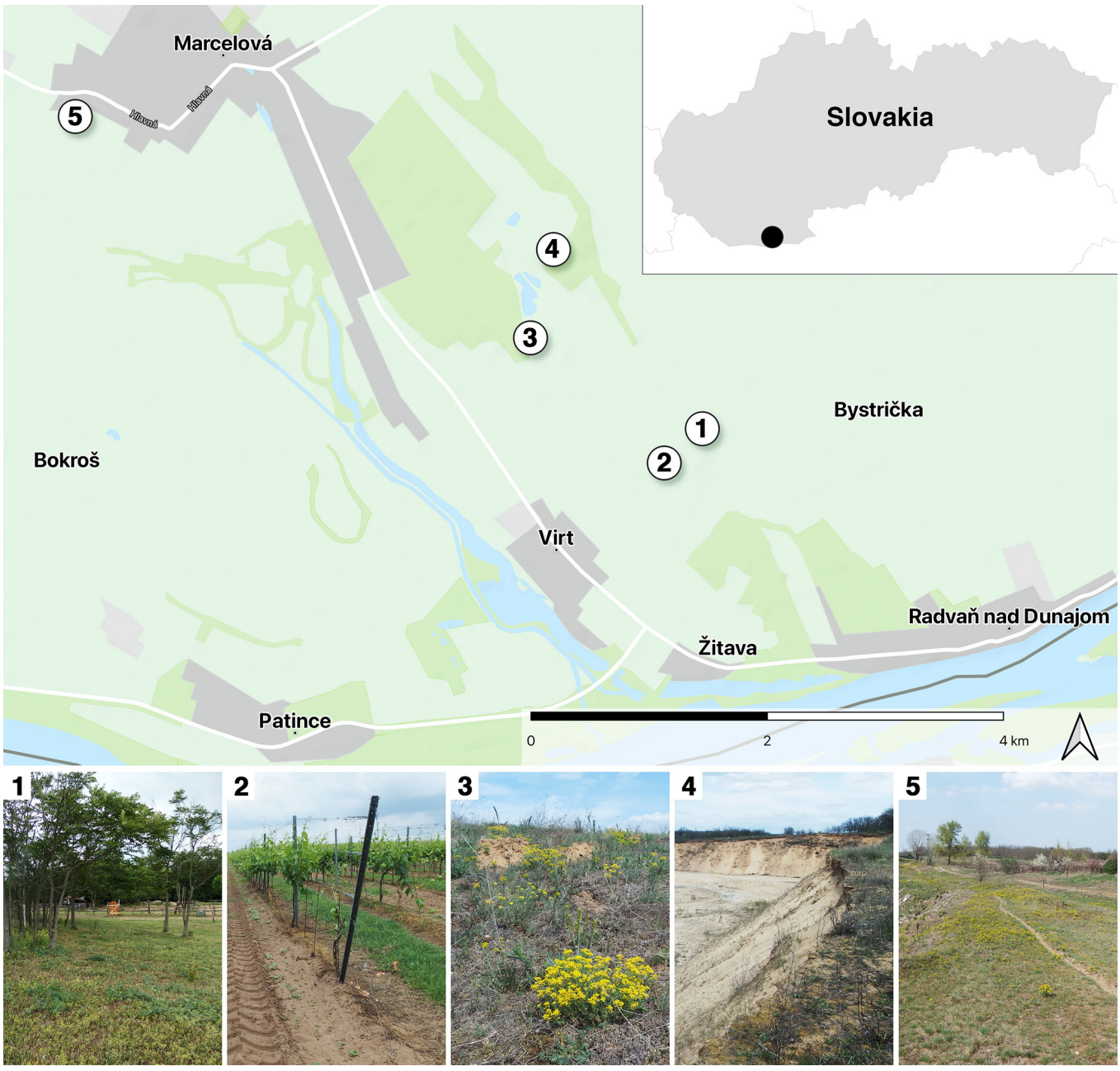


**Fig. 1:** Map and photos of studied sites in Slovakia: **1.** Domáňovský majer; **2.** Virt; **3.** Mašan Nature Reserve; **4.** Bašovský Kopec; **5.** Marcelovské piesky Nature Reserve (photo by O. Majzlan)

no soil or exposure was specified), and 4. other habitats (forest, potentially including ecotones, and vineyards). All these records are summarized in the Appendix Tab. S1. Both maps were created in QGIS 3.20 software using MapTiler plugin for basemaps.

Faunistic data are listed in the following order: abbreviation of the locality name, date of collecting, number and sex of specimens (♀ – female, ♂ – male, sad.♂/♀ – subadult male/female, j – juvenile), collector. The notes on comparative material contain additional information about the locality, name of the collector and the reference where the record was published. Spiders were identified to species level whenever possible following Nentwig et al. (2022), using the nomenclature in the World Spider Catalog (2022). The terminology of copulatory organs for the genus *Haplodrassus* follows Bosmans et al. (2018). Digital images were taken using a stereomicroscope OLYMPUS SZX16, Leica DVM6, and Canon EOS1300D digital camera attached to Stemi 2000-c stereomicroscope and were combined in Zerene Stacker v. 1.04. Measurements were made using AxioVision v. 4.6, the values were compiled from published and original data (see also appendix S1). The specimens are stored in 70% ethanol and were deposited in the collection of P. Gajdoš at the Institute of Landscape Ecology of Slovak Academy of Sciences in Nitra, Slovakia, the only exception being the gynandromorph specimen, which is deposited at the Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences.

The countries included in the manuscript are divided into three groups: Central Europe (C-EU): Austria, Czechia, Hungary, Poland, Slovakia; Eastern Europe (E-EU): Russia, Ukraine; Southeastern Europe (S-EU): Bulgaria, Greece, North Macedonia, Romania, Serbia.

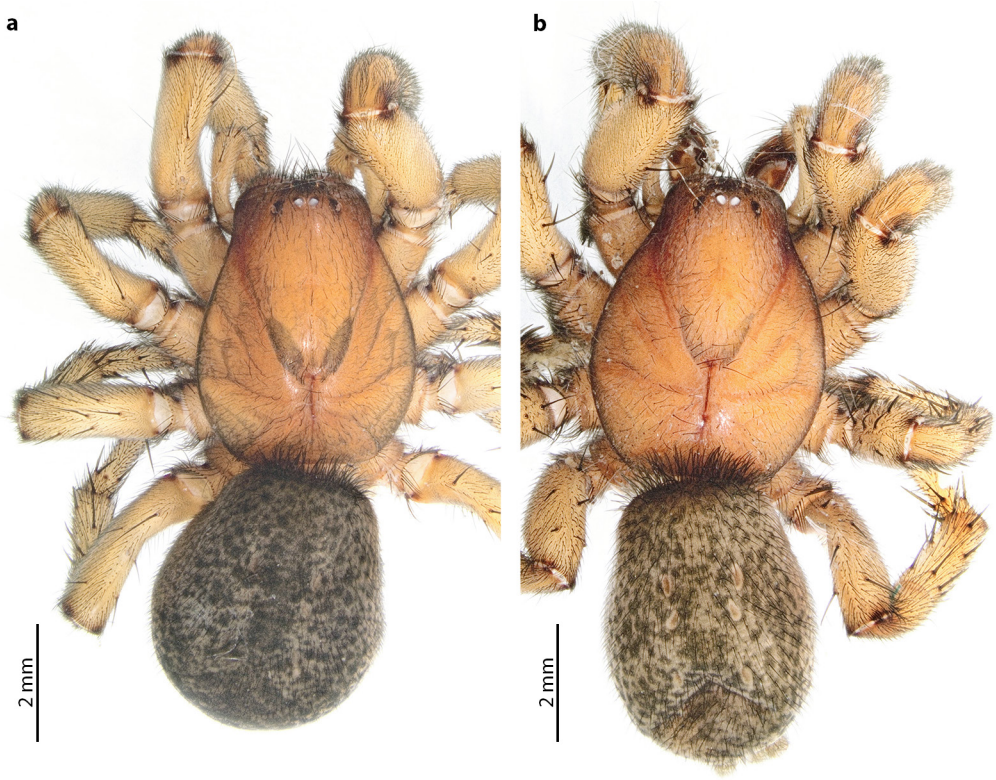


**Fig. 2:** Dorsal view of *Gnaphosa mongolica* from Slovakia. **a.** female; **b.** male

## Study sites

The study sites (Fig. 1) were situated between the villages Radvaň nad Dunajom and Marcelová near the Hungarian border in the Danubian lowland, belonging to the North-East side of the Pannonian basin (south-western Slovakia).

**1. Domáňovský majer – DM** (Domány puszta) (47.76290°N, 18.33813°E, 125 m a.s.l.). A farm with a mosaic of different sandy habitats, like the sand steppe overgrown with a small group of alien *Ailanthus altissima* (Mill.) trees (location of study site), and open sandy pastures and abandoned vineyards used for horse and cattle breeding.


**Fig. 3:** Epigyne of *Gnaphosa mongolica* from Slovakia

**2. Virt – VI** (47.76030°N, 18.33380°E, 119 m a.s.l.). A large, intensively used vineyard on sandy soil alternately with ploughed and grassy rows, treated with herbicides and cultivated by a tractor.

**3. Mašan Nature Reserve – MA** (47.76976°N, 18.31874°E, 131 m a.s.l.). A small hill, formed by a degraded sand dune that was used as a military training area in the past. It is currently covered with psammophytic vegetation. The reserve is the grassiest of the studied sites. Traps were located near the top of the hill.

Traps were damaged regularly in July, August and October.

**4. Bašovský Kopec – BK** (47.77646°N 18.32127°E, 126 m a.s.l.). An old sand quarry surrounded by natural sandy habitats. Traps were located at the edge of the quarry with very sparse vegetation.

**5. Marcelovské piesky Nature Reserve – MP** (47.78660°N, 18.26730°E, 111 m a.s.l.).

Sand dunes near the village cemetery. The reserve is affected by several human activities, e.g. occasional digging creates small hills with no or sparse vegetation, illegal dumping of waste and grazing of sheep.

During July and August, several traps dried up, damaging the material.

## Survey of species

Two new spider species for the Slovak fauna were documented from studied sandy habitats of SW Slovakia. During our study a total of 145 individuals of *G. mongolica* (61 ♂♂, 13 ♀♀, 71 juv.) and 59 individuals of *H. bohemicus* (33 ♂♂, 26 ♀♀, 23 juv.) were collected and identified.

***Gnaphosa mongolica* Simon, 1895** (Figs 2-4)

**Material.** SLOVAKIA: MA: 17. Apr. – 16. May 2019, 1 ♂, 1 juv.; 16. May – 5. Jun. 2019, 18 ♂♂, 2 ♀♀, 1 sub. ♀; 05. – 25. Jun. 2019, 3 ♂♂, 1 ♀, 2 sub. ♂♂, 1 sub. ♀; 19. Aug. – 4. Sept.

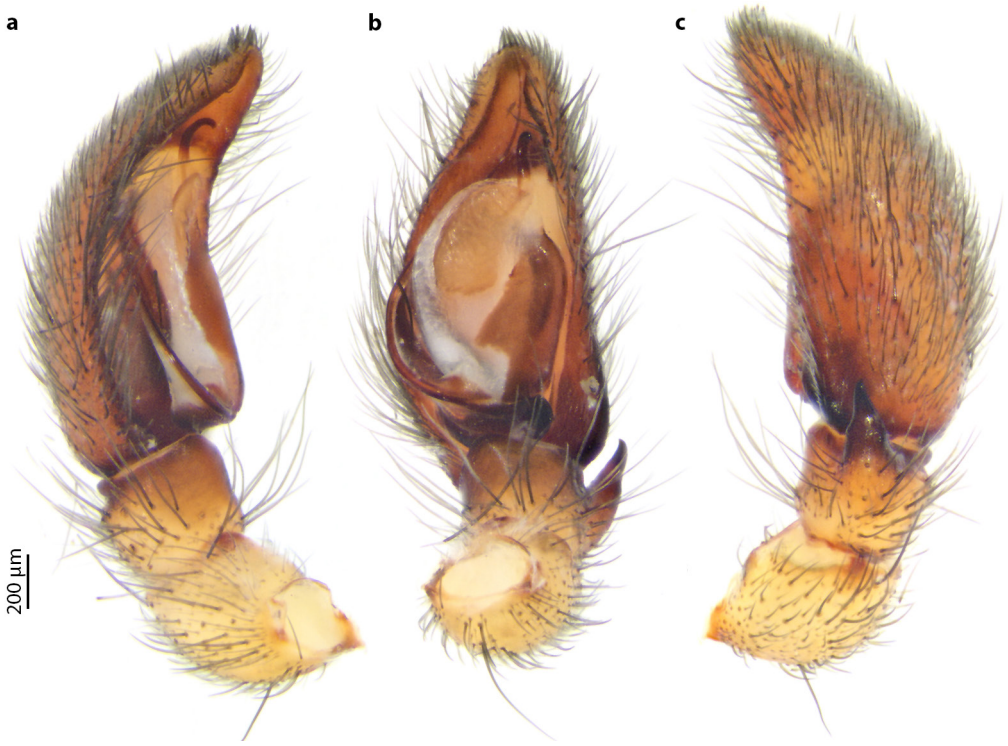


**Fig. 4:** Male palp of *Gnaphosa mongolica* from Slovakia. **a.** prolateral view; **b.** ventral view; **c.** retrolateral view

2019, 5 sub. ♀♀. BK: 28. Mar. – 17. Apr. 2019, 1 sub. ♂, 5 sub. ♀♀, 6 juv.; 17. Apr. – 16. May 2019, 4 ♂♂, 2 sub. ♀♀, 1 sub. ♂, 5 juv.; 16. May – 5. Jun. 2019, 19 ♂♂, 1 ♀, 1 juv.; 5. – 25. Jun. 2019, 9 ♂♂, 2 ♀♀, 1 sub. ♂, 4 juv.; 24. Jul. – 19. Aug. 2019, 3 ♀♀, 2 sub. ♀♀, 3 juv.; 19. Aug. – 4. Sept. 2019, 8 sub. ♀♀, 10 juv.; 4. Sept. – 1. Oct. 2019, 1 sub. ♀; 27. Nov. 2019 – 9. Jan. 2020, 2 juv. (leg. P. Gajdoš, P. Purgat).

**Diagnosis.** *Gnaphosa mongolica* can be confused with *G. muscorum* (L. Koch, 1866), but differs by:

1) absence of the basal spur on the embolus (can be broken off in *G. muscorum*);
2) wider and larger epigynal scapus;
3) epigynal ducts extended anteriorly in comparison to closely spaced ducts in *G. muscorum*.

**Taxonomic notes.** Some old records from Europe were published as *G. spinosa* Kulczyński, 1897 and *G. chaffanjoni* Schenkel, 1963. Both names were later synonymised with *G. mongolica* by Ovtsharenko et al. (1992).

**Measurements.** Males. Total length 8.08–10.73 mm. Carapace 3.81–5.14 mm long, 3.14–4.00 mm wide. Opisthosoma 4.27–5.80 mm long, 3.32–3.95 mm wide. Females. Total length 9.03–13.6 mm. Carapace 4.74–5.18 mm long, 3.63–3.76 mm wide. Opisthosoma 4.48–8.42 mm long, 3.90–4.68 mm wide.

**Distribution** (Fig. 5)**.** In Europe it is known from Hungary (Samu & Szinetár 1999), Serbia (Grbić et al. 2021), Romania (Weiss & Marcu 1988), Russia (Ponomarev 1981), Ukraine (Ovtsharenko et al. 1992) and Slovakia (this paper), and also from Turkey to China (WSC 2022).

***Haplodrassus bohemicus* Miller & Buchar, 1977** (Figs 6-8, 9a-c, 10)

**Material.** SLOVAKIA: DM: 17. May – 31. May 2017, 1 ♂; 4. – 17. May 2018, 7 ♂♂, 3 ♀♀ (leg. P. Gajdoš). VI: 12. Apr. – 4. May 2018, 1 ♀; 18. May – 7. Jun. 2018, 1 ♂. MA: 17. Apr. – 16. May 2019, 1 ♂, 1 ♀, 1 sub. ♂, 3 sub. ♀♀, 1 juv.; 16. May – 5. Jun. 2019, 1 ♂, 3 ♀♀, 1 sub. ♀; 5. – 25. Jun. 2019, 2 ♀♀. MP: 17. Apr. – 16. May 2019, 7 ♂♂, 2 ♀♀, 5 sub. ♂♂, 4 sub. ♀♀; 16. May – 5. Jun. 2019, 10 ♂♂, 10 ♀♀, 1 sub. ♀, 1 juv.; 5. – 25. Jun. 2019, 4 ♂♂, 3 ♀♀; 1. Oct. – 27. Nov. 2019, 1 ♀, 1 juv. BK: 28. Mar. – 17. Apr. 2019, 2 sub. ♀♀, 17. Apr. – 16. May 2019, 1 ♂, 1 sub. ♂, 1 sub. ♀; 19. Aug. – 4. Sept. 2019, 1 juv. (leg. P. Gajdoš & P. Purgat).

**Comparative material.**

***H. bohemicus.*** Czech Republic: Louny, Raná: 50.40655°N, 13.77120°E; 400 m a. s. l., rocky steppe, 4. Oct. – 1. Nov. 1963, 1 ♀ (paratype, coll. National Museum Prague, Czech Republic: P6A 5351), leg. J. Buchar (Miller & Buchar 1977); Bzenec: 48.92657°N, 17.26802°E, 190 m a. s. l., sand dunes, 30. May 1998, 1 ♂, leg. Bezděčka (Růžička & Bezděčka 2000); Bulgaria: Tsarev Vrah (near peak, above Paril vill.): 41.418°N, 23.664°E, 1100 m a. s. l., 29. Jun. 1937, 1 ♀, leg. P. Drensky (Naumova 2009); old border post 1 (above Paril vill.): 41.413°N, 23.659°E, 1300 m a. s. l., 2. Jul. 1937, 1 ♀, leg. Drensky (unpublished); Plovdiv: 42.14883°N, 24.6845°E, 160 m a. s. l., spring 2020, rural habitat on the bank river, 1 gynandromorph, leg. I. Delev (this paper).

***H. pseudosignifer.*** Russia: Altai Republic (Katun' River valley): 50.133°N, 86.083°E, 895 m a. s. l., 22. Jun. – 26. Jul. 1983, 1 ♂ (paratype, ISEA (Institute of Systematics and Ecology of Animals, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia) 000.122, ex-BI-1405), leg. H. Hippa (Marusik et al. 1996); Novosibirsk Area (Karasuk District): 53.72272°N, 77.72887°E, 101 m a. s. l., under birch, 01. Jul. 2007, 9 ♂♂, 1 ♀ (ISEA 001.1872), leg. I.I. Lubechankii; 53.73167°N, 77.86467°E, 102 m a. s. l., 13. May 2001, 1 ♂ (ISEA 001.8928), leg. G.N. Azarkina.

**Diagnosis.** In Slovakia and neighbouring countries, *H. bohemicus* is most similar to *H. signifer* (C. L. Koch, 1839), but males of *H. bohemicus* differ by:

1) a shorter embolic apophysis and embolus (Fig. 9);
2) the base of the embolic division reaching 1/2 of bulbus length in comparison to 2/3 in *H. signifer*;

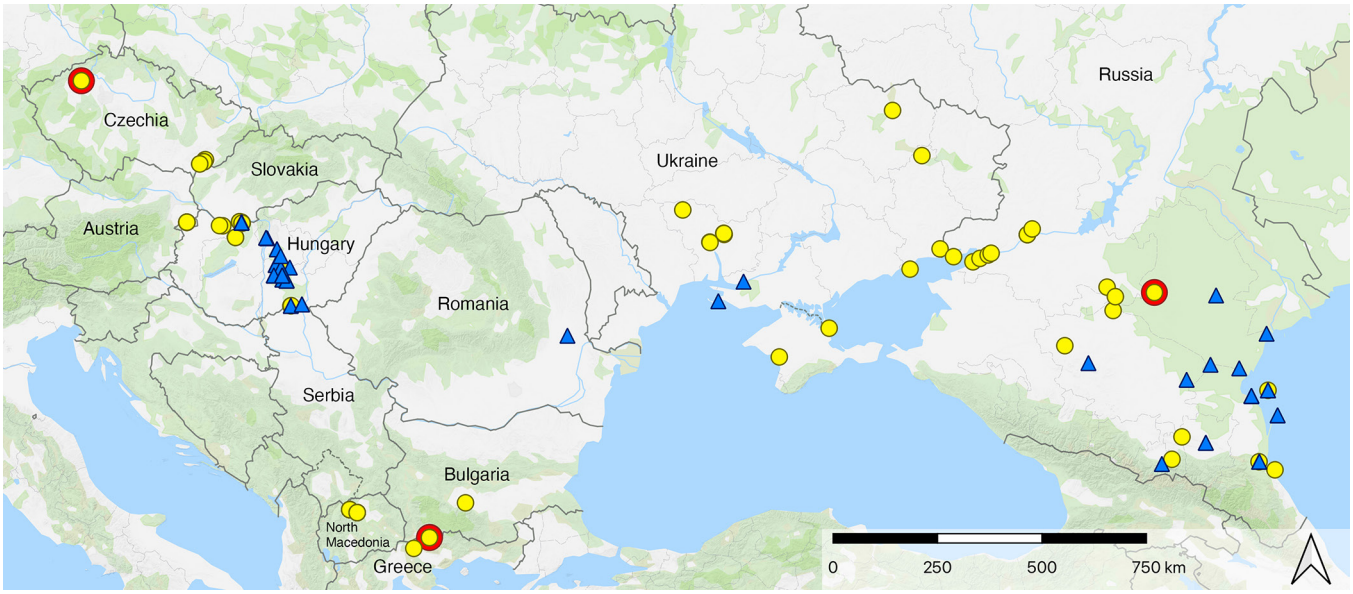


**Fig. 5:** Distribution of *Gnaphosa mongolica* (blue triangle) and *Haplodrassus bohemicus* (yellow circle, red stroke = oldest records; CZ: Miller & Buchar (1977), BG: Naumova (2009), RU: Ponomarev & Tsvetkov (2006)) in Europe (not all published records from European Russia included)

3) the retrolateral tibial apophysis has a step-like dorsal margin and is apically oblique, not rounded as in *H. signifer*;
4) the female epigyne of *H. bohemicus* has narrower sub-parallel lateral pockets in comparison to a wide and reniform one;
5) hood is narrower than areola, not wider as in the latter species.

**Gynandromorphy.** One recently collected specimen from Bulgaria was found to have a lateral gynandromorphy, type 1 sensu Roberts & Parker (1973). Male characters are on the left (bulbus, darker coxa 1, darker and slimer half of the opisthosoma) and female on the right (half of the epigyne with lateral developed pocket, larger opisthosoma). The left and right eyes are different as well (by shape and size) especially the posterior median ones (Fig. 6d, 7d, 8b, d-e). It represents the first record of gynandry for the species and first gynandromorph spider found in Bulgaria as well.

**Taxonomic notes.** While studying the two fundamental works on the genus *Haplodrassus* (Kovblyuk et al. 2012, Bosmans et al. 2018), we noted the absence of some important diagnostic features. For example, it is necessary for determination to extract the cymbium because from the commonly used ventral view a certain sclerite behind the embolus is usually not visible (Fig. 10, sclerite "X"). This sclerite is only rarely mentioned in the genus *Haplodrassus* (e.g. Grimm 1985: Dorsalbereich des Embolus ["a dorsal side of embolus"]; Chatzaki 2021: dorsal apophysis). According to its position, it could be a terminal apophysis and appears to be important for the delimitation of related species (e.g. Grimm 1985, Marusik et al. 1996, Kamura 2007). Unfortunately, in *H. bohemicus*, this sclerite was drawn only from an apical view by Kovblyuk et al. (2012). In addition, slightly different angles of the bulbus may cause a significantly different appearance of sclerites, e.g. the presence, width or shape of the apical embolic lamella; the shape and edges of the embolic apophysis; the presence of a step-like dorsal margin in the retrolateral tibial apophysis. Thaler (1984) also observed a further diagnostic feature on the tip of the embolus in the genus *Haplodrassus*, but its detailed structure is only apparent by SEM or probably on microscopic slides.

The Slovak specimens match the original description by Miller & Buchar (1977), and to the paratype female. Unfortunately, the female holotype and male allotype were not found, probably because they were accidentally moved to another storage box (Petr Dolejš pers. comm.). Compared to other published drawings or photographs of this species, with the exception of those by Bosmans et al. (2018), all visible structures match the drawings by Miller. In our opinion, specimens from Ukraine and Russia described by Kovblyuk et al. (2012) could represent a variability, or the differences may be due to slightly different angles shown. The apical view shows the beak-shaped tip of sclerite X (Kovblyuk et al. 2012: figs 3, 6), as in our Slovak specimens. A comparison of our material with photographs of this species from North Ossetia (Ponomarev et al. 2021) and Rostov (unpublished, photographed by Ponomarev) confirm the presence of such a sclerite at least in other specimens of *H. bohemicus* collected from the eastern part of the distribution. However, it must be said that modern genetic methods would certainly help to solve the problems of species identity within this group.

The male specimens in Bosmans et al. (2018), tentatively designated as *H. bohemicus*, correspond to the description of *H. pseudosignifer* Marusik, Hippa & Koponen, 1996 according to:

1) apically rounded retrolateral tibial apophysis without a step-like dorsal margin;
2) shorter and more massive median apophysis;
3) tip of embolus directed upwards;
4) embolic apophysis with distinct ridge.

Other important characters of the male palp are not easily comparable with published descriptions and figures. Also, a comparison with *H. pseudosignifer* from Russia (including a paratype from Altai) does not solve the problem, because we cannot see further details that are only visible after the extraction of the endaparatus or cymbium. The female epigyne depicted in Bosmans et al. (2018) has a broad sclerotised areola compared to a very narrow one in *H. bohemicus*. It resembles *H. concertor* (Simon, 1878), but it differs by a wider hood. In addition, it is very similar to the drawings of the epigyne

of *H. pseudosignifer* from Crimea in Kovblyuk et al. (2012). However, in both cases (Bosmans et al. 2018: fig 204; Kovblyuk et al. 2012: fig. 75) there are also differences (possible variability) that distinguish them from the original description (Marusik et al. 1996: fig. 69):
1) epigyne has a narrower hood than areola;
2) fovea is narrower with constricted lateral sclerotised edges;
3) areola is rounded at its outer edge.
Unfortunately, without re-examination of the specimens by Bosmans et al. (2018) we cannot make a final decision on species status of the specimens collected by us. However, it should be noted that the occurrence of *H. bohemicus* in Greece has not been questioned by this assessment. The identification of the first country record (Van Keer et al. 2010) was recently discussed with Johan Van Keer (pers. comm.), and he confirmed that two females are identical to the original species description.

**Measurements.** Males. Body length 5.21–6.65 mm. Carapace 2.17–2.80 mm long, 1.75–2.17 mm wide. Opisthosoma 3.04–3.72 mm long, 1.71–2.01 mm wide. Females. Body length 5.63–7.32 mm. Carapace 2.26–2.65 mm long, 1.66–2.12 mm wide. Opisthosoma 3.37–4.67 mm long, 2.10–2.81 mm wide. Gynandromorph. Body length 7.50 mm. Carapace 3.36 mm long, 2.71 mm wide. Opisthosoma 4.28 mm long, 3.07 mm wide, strongly asymmetric.

**Distribution** (Fig. 5)**.** Austria (Milasowszky et al. 2008), Bulgaria (Naumova 2009), Czech Republic (Miller & Buchar 1977), Greece (Van Keer et al. 2010), North Macedonia (Stefanovska et al. 2008), Russia (Esyunin & Tuneva 2020), Serbia (Grbić et al. 2021), Ukraine (Polchaninova & Prokopenko 2019), Hungary (Keresztes et al. 2012, Szinetár pers. comm.) and now known from Slovakia (this paper).

**Comments.** The species was described from the Raná National Nature Reserve (Czech Republic) in the 1960s, but during a repeated survey in 1988, Buchar did not find it there (Růžička & Bezděčka 2000). The latest findings in the Czech Republic come from South Moravian sandy sites (Hula et al. 2004, Hula 2014). The species were recorded in 1937 in Bulgaria (Naumova 2009; revision of Drensky's collection in 2021 by M. Naumova & C. Deltshev) and in 1975 in Russia (Kalmykia) (Ponomarev & Tsvetkov 2006). It is interesting that two of the earliest findings in Europe were collected far away from the type locality, which could indicate a relict-like character of the species' localities and a scattered distribution in the Western Palearctic.

## Notes on ecology and conservation

### Phenology

Both species have adult stages that are active from May to June (Fig. 11), which means that damaged traps in later periods (see "Material and methods") did not affect the data on the phenology of adult specimens. Adults of *G. mongolica* were recorded in Slovakia from April to August with the highest abundance in June. In comparison with other records from Europe, our results correspond to the central European findings (Fig. 11a). Although only a few records from southern Europe have been published, we assume a shift in the occurrence of adults to August. In Hungary, *G. mongolica* overwinters as juveniles or subadults (Szita et al. 2006). The same was confirmed in Slovakia by our findings of immature stages from September to April.

Adults of *H. bohemicus* were recorded in Slovakia mainly from May to June, with the highest abundance in June. Only one female was sampled late in November, suggesting that some adults may be overwintering. In comparison with other records from Europe, our results correspond to findings from Central Europe, where *H. bohemicus* was mostly collected in May and June (Fig. 11b). On the other hand, in southern Europe more than 80% of all adults were recorded in June. In eastern Europe, the highest activity was found in June and July.

A comparison of the phenology of *H. bohemicus* and *H. signifer* collected on our study sites in Slovakia suggests that *H. bohemicus* is mostly active in May and June, while *H. signifer* is significantly active only in May (Fig. 12).

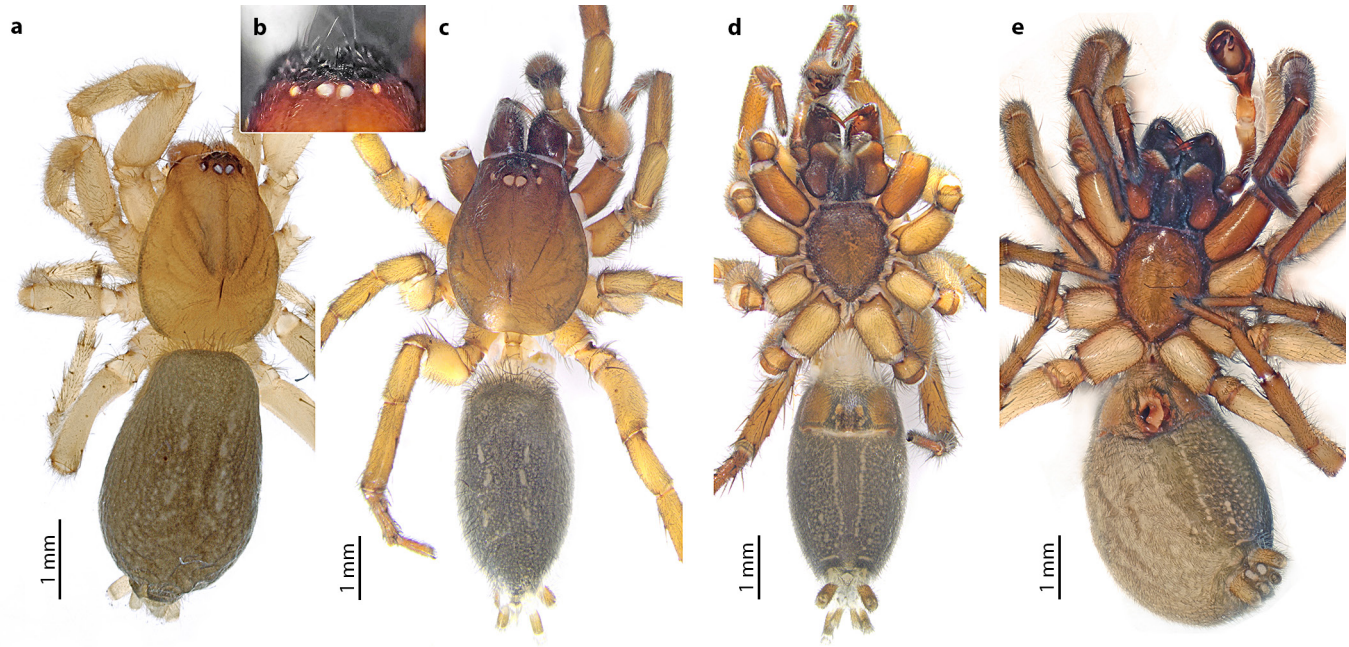


**Fig. 6:** Habitus of female and male of *Haplodrassus bohemicus* from Slovakia and gynandromorph from Bulgaria. **a.** female, dorsal view; **b.** eyes asymmetry of gynandromorph; **c.** male, dorsal view; **d.** idem., ventral view; **e.** gynandromorph, ventral view

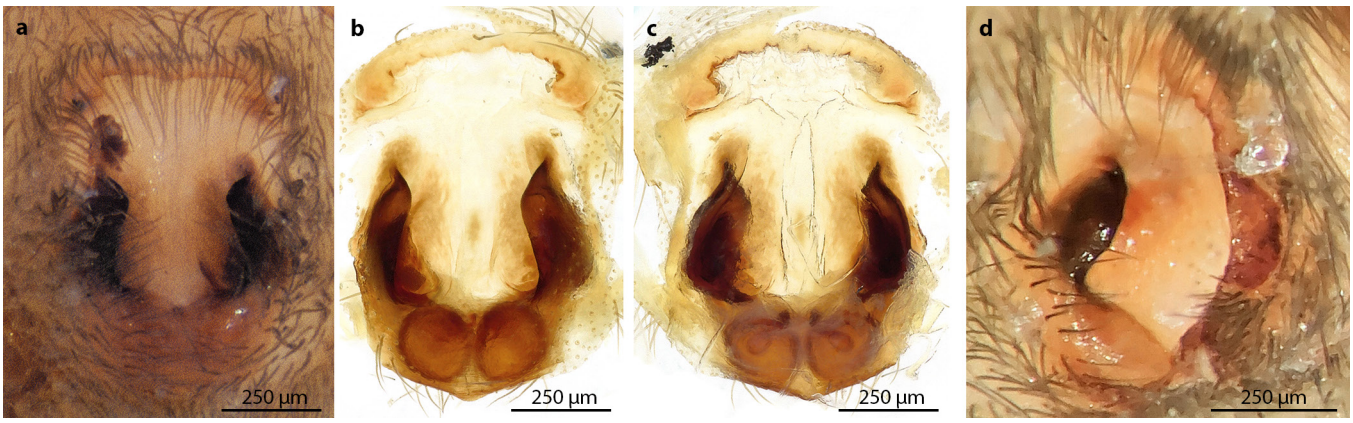


**Fig. 7:** Epigyne of two females of *Haplodrassus bohemicus* from Slovakia and one gynandromorph from Bulgaria. **a.** ventral view; **b.** extracted and cleared (hood slightly deformed), ventral view; **c.** Idem., dorsal view; **d.** gynadromorph, ventral view

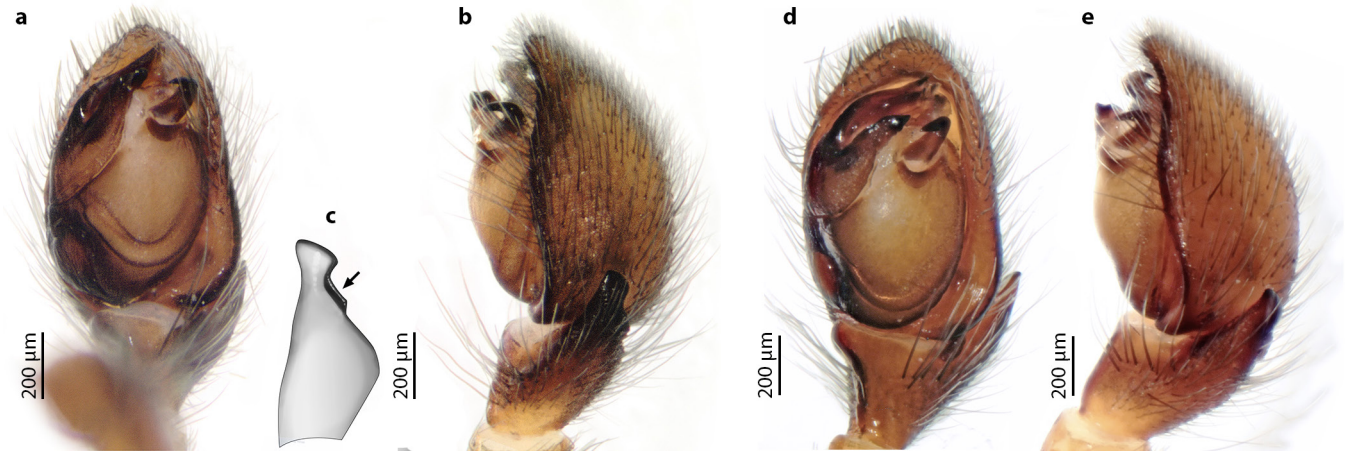


**Fig. 8:** Left male palp, *Haplodrassus bohemicus*. **a–e.** male (Slovakia); **d–e.** gynandromorph (Bulgaria); **a, d.** ventral view; **b, e.** retrolateral view; **c.** retrolateral tibial apophysis (without scale). Arrow pointed step-like process

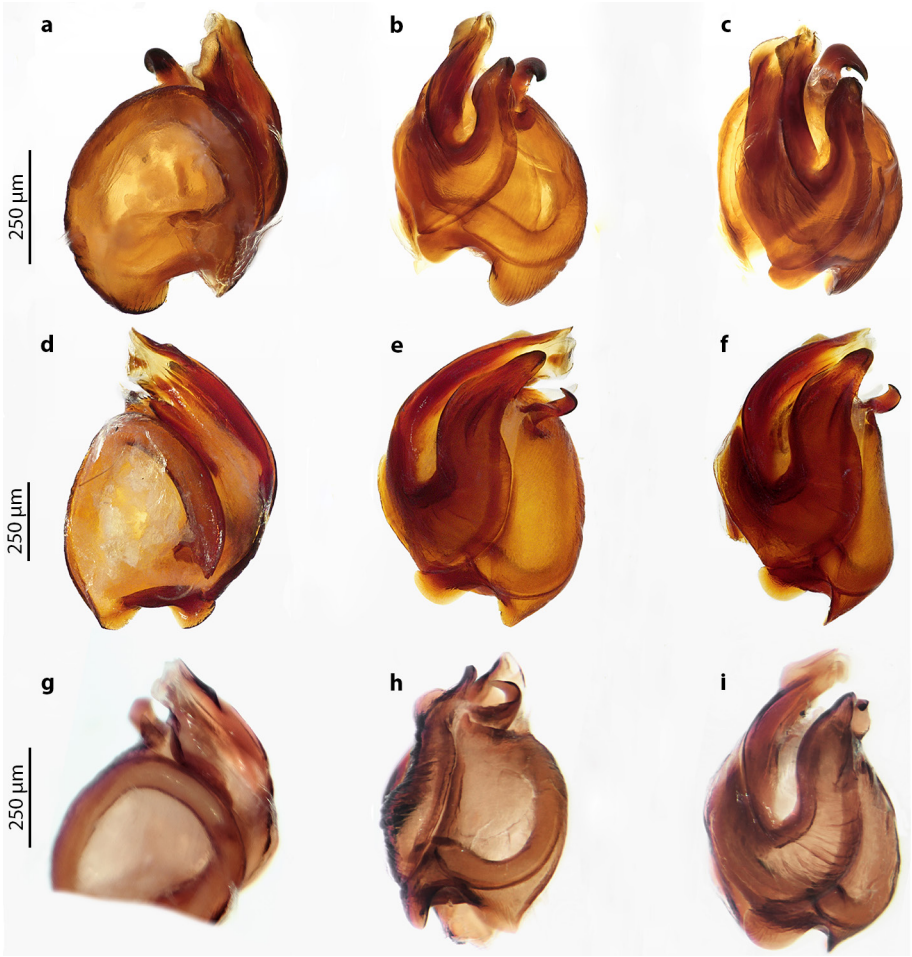


**Fig. 9:** Bulbus with extracted cymbium. **a-c.** *H. bohemicus* (Slovakia); **d-f.** *H. signifier* (Slovakia); **g-i.** *H. pseudosignifer* (Russia, Novosibirsk); **a, d, g.** dorsal view; **b, e.** ventral view; **c, f, i.** ventro-prolateral view; **h.** retrolateral view

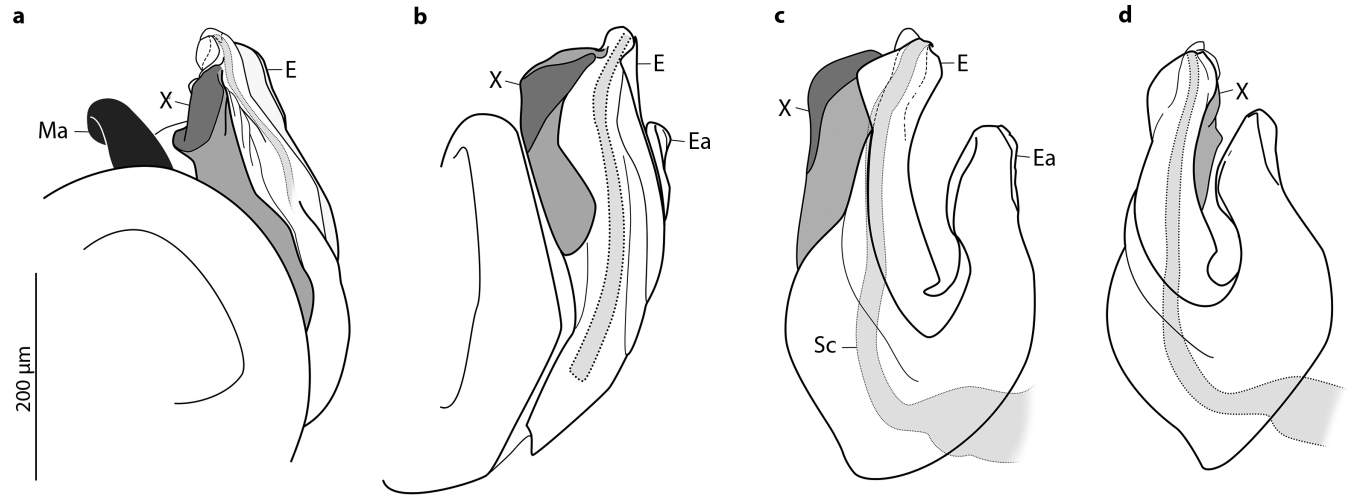


**Fig. 10:** Bulbus of *H. bohemicus*. **a.** dorsal view; **b.** prolateral view; **c.** ventro-prolateral view; **d.** ventral view. E = embolus, Ea = embolic apophysis, Ma = median apophysis, Sc = spermatic canal, X = sclerite "X"

## Habitat

Both species inhabit xerothermic steppe habitats. *Gnaphosa mongolica* was recorded in Europe mainly from sandy meadows, which also fits to our recent findings from Slovakia (Fig. 13). In Hungary (Szinetár et al. 2005, Szita et al. 2006) it seems to be the dominant species on sandy grasslands and on clearings of *Juniperus* downs on sand. Several specimens were found on sand dunes with sparse vegetation in Romania (Weiss & Marcu 1988) and Russia (Ponomarev et al. 2011, 2017, Ponomarev & Abdurakhmanov 2014). One study site in Slovakia (Bašovský kopec) was located very close to the sand pit where this species was most abundantly collected (Fig. 14). Its retreat was found built under stones, which is characteristic for ground spiders (Seyyar et al. 2008, Grbić et al. 2021).

*Haplodrassus bohemicus* occurs in meadows, steppes and sand dunes (Kovblyuk et al. 2012). In central Europe, the majority of findings derive from sandy grasslands. In Serbia (Southern Europe), the species has been recorded from a sandy meadow that was dominated by xerophilic steppe vegetation on brown sand (Grbić et al. 2021). The findings from Slovakia presented herein are also mostly from a sandy grass steppe, with only two specimens that were recorded from an intensively used vineyard (see above). However, specimens from south-eastern and eastern Europe were frequently collected on mesophilic meadows and meadows with a xerothermic character (low precipitation, typical plant composition), which can be explained by the different climate compared to central Europe (Fig. 13). O. Machač observed this species under stones and fallen trunks (ČAS 2021).

## Discussion on the red list status

The abundance (in each site and in total) of *H. bohemicus* (82 ind.) and *G. mongolica* (145 ind.) appears to be, at least

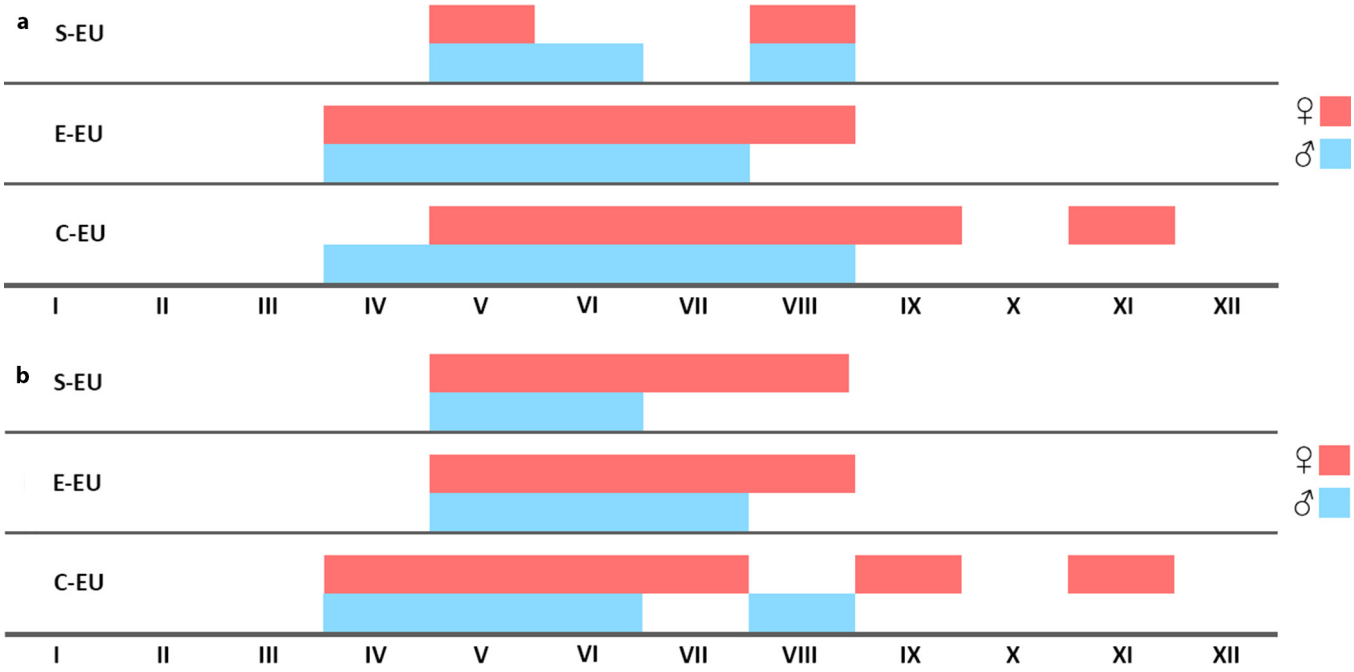


**Fig. 5:** Comparison of phenology of adults *G. mongolica* (**a**) and *H. bohemicus* (**b**) for subregions of Europe based on published and unpublished data. C-EU = Central Europe, E-EU = East Europe, S-EU = Southeast Europe

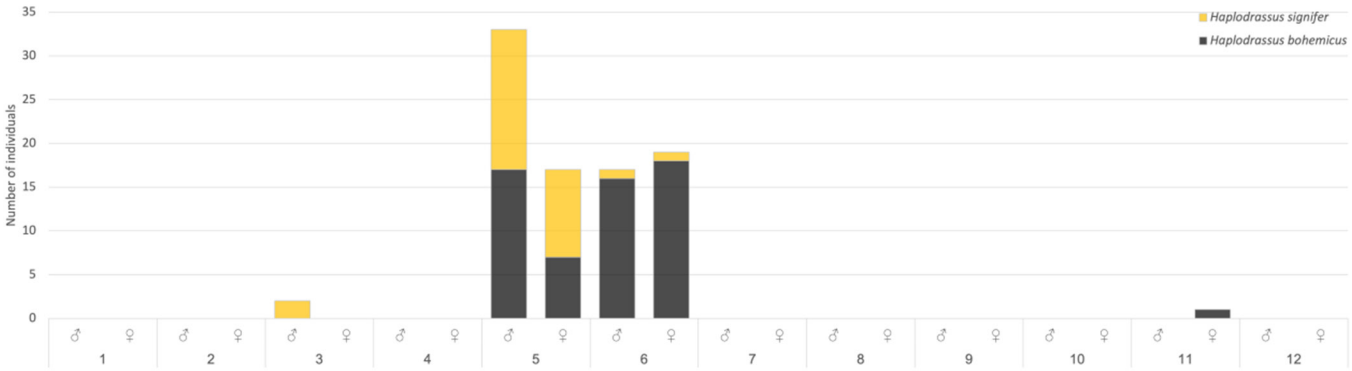


**Fig. 12:** Occurrence over the year of adults of *H. bohemicus* (black) and *H. signifer* (orange) in Slovakia, collected with pitfall traps

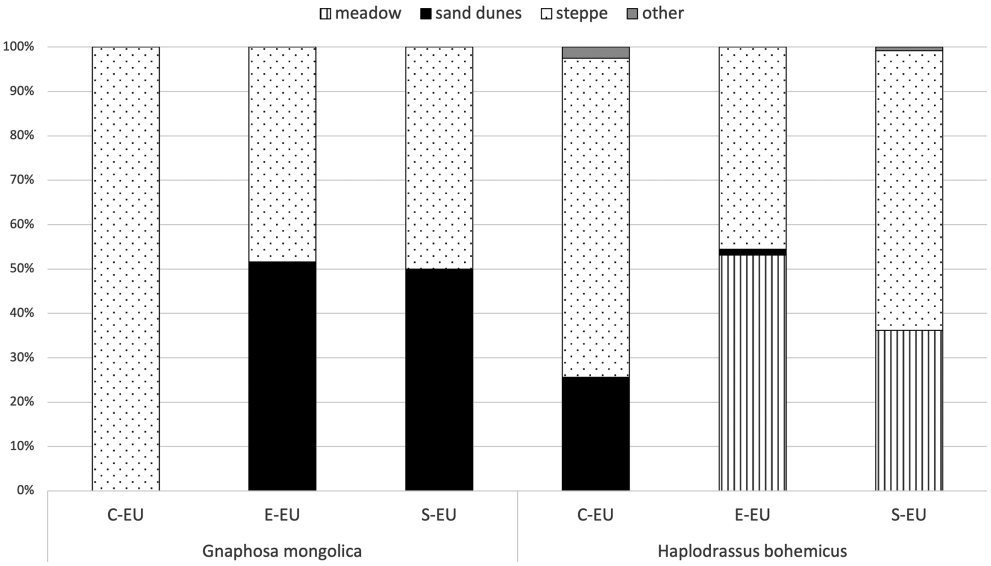


**Fig. 13:** Habitat preferences in each subregion of Europe expressed as relative abundance of *G. mongolica* and *H. bohemicus* adults based on data in this work and other published and unpublished data (see appendix Tab. S1). C-EU = Central Europe, E-EU = East Europe; S-EU = South and Southeast Europe, Dots = steppes (xerothermic grasslands with sparse vegetation; sandy meadows, steppes, sand pits etc.), black = sandy dunes (very sparse or no vegetation), vertical lines = meadows (grasslands with dense vegetation, incl. grassy habitats without closer specifications of soil and exposition), grey = other habitats (vineyards and forests)

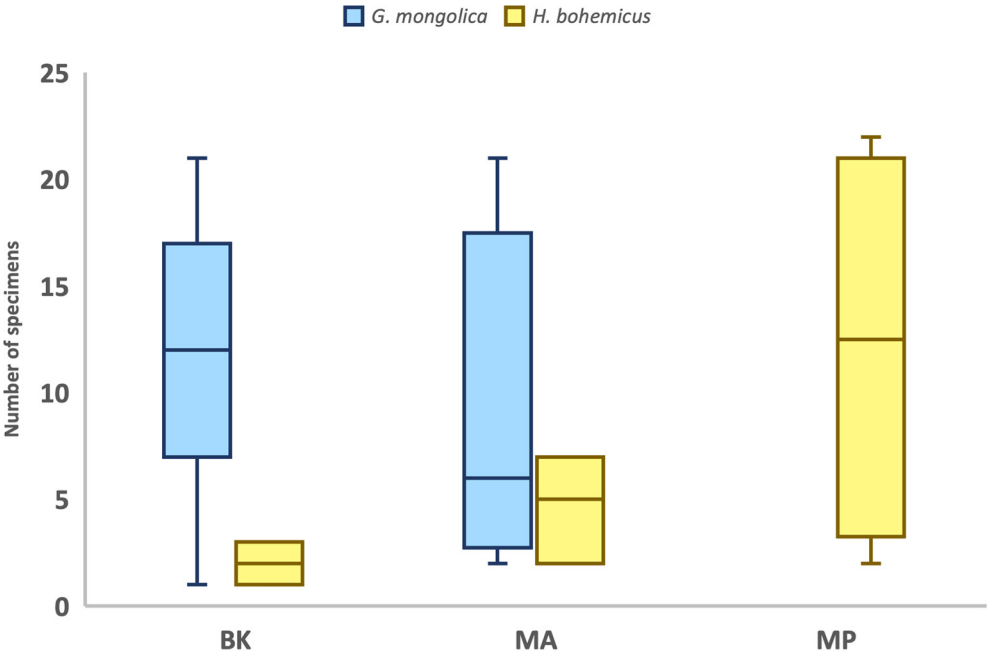


**Fig. 14:** Comparison of specimens numbers of *G. mongolica* (blue) and *H. bohemicus* (yellow) collected on each study site in Slovakia from March to November in 2019 (when traps were active on all localities). Abbreviations: BK = Bašovský kopec, MA = Mašan, MP = Marcelovské piesky

partly, influenced by anthropogenic disturbances of the habitat. Horváth et al. (2015) found that increasing isolation of grassland fragments decreases the abundance of *G. mongolica*, a habitat specialist, which also seems unable to settle down permanently in adjacent lands altered by human activities. Grbić et al. (2021) suggest that *G. mongolica* should be classified as an endangered species due to the limited geographical distribution in Europe and its apparently narrow ecological niche that is under increasing economic pressure. In Slovakia, *G. mongolica* inhabits only natural sandy habitats and seems to avoid sites with anthropogenic influences (pastures and vineyard), judging by the fact that all sites are very close to

each other without significant migration barriers. In contrast, *H. bohemicus*, whose occurrence was most likely overlooked in Slovakia, seems to cope better with anthropogenic influence in its habitat, as shown by the high numbers collected at Marcelovské piesky (Fig. 14) and the presence of the species at each of the five Slovak locations that were investigated. A quick revision of a spider collection from Gönyű (Hungary) showed that *H. bohemicus* has been confused with the similar *H. signifer* in some cases (Szinetár, pers. comm.). The latter situation could also have happened in Slovakia, but it should be noted that these habitats have not been studied intensively in the past.

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We are grateful to Peter Dolejš and the National Museum in Prague (Czech Republic), who provided comparative photographs of the paratype female of *H. bohemicus*. Our thanks also go to Robert Bosmans, Johan Van Keer and Yuri Marusik for the valuable discussion, Christo Deltshev, Csaba Szinetár and Norbert Milasowszky, who provided us important details on their published and unpublished records and Galina Azarkina for comments and photographs of *H. pseudosignifer*. Thanks to Ivelin Mollov and Ivan Delev (Bulgaria, University of Plovdiv "Paisii Hilendarski", Faculty of Biology), who provided the gynandromorph specimen. Finally, we thank the editor Tobias Bauer and the reviewers Milan Řezáč and Mykola Kovblyuk. This research was funded by the Operational Program of Integrated Infrastructure: DNA barcoding of Slovakia (SK-BOL), as a part of the international initiative International Barcode of Life (iBOL) (ITMS2014+313021W683) and by the Slovak Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic, as part of project VEGA No. 2/0135/22 (Research of specific landscape elements of bio-cultural landscape in Slovakia).

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**Electronic supplement**

**Tab. S1:** compilation (.xls) of additional data and records of *Gnaphosa mongolica* and *Haplodrassus bohemicus* in the literature