

## Research Article

## Spiders newly observed in Czechia in recent years – overlooked or invasive species?

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**OPEN ACCESS****Abstract**

To learn whether the recent increase in the number of Central European spider species reflects a still-incomplete state of faunistic research or real temporal changes in the Central European fauna, we evaluated the records of 47 new species observed in 2008–2020 in Czechia, one of the faunistically best researched regions in Europe. Because of the intensified transportation of materials, enabling the introduction of alien species, and perhaps also because of climatic changes that allow thermophilic species to expand northward, the spider fauna of this region is dynamic. Our analysis showed that only 15 spider species newly recorded in Czechia likely belong to the indigenous fauna. The remaining two-thirds likely appeared in this region recently. Half of these species are likely thermophilic species that expanded their distribution to the north, possibly due to global warming, and the second half are subtropical or tropical species introduced to heated buildings. Only three species were introduced to natural habitats, and only two of them, *Mermessus trilobatus* and *Erigone autumnalis* (Linyphiidae), can be considered true invasive species.

**Key words:** alien species, expansive, faunal dynamics, global warming, introduced, range expansion, synanthropic habitats

**Introduction**

The European fauna is subjected to accelerating changes due to global warming, changes in habitat structure, pollution and the spread of invasive species. Spiders are among the best-known invertebrate groups in Central Europe (Nentwig et al. 2021). Despite good knowledge, new species are found in this region every year. To document the dynamics and trends of the spider fauna in this region, we evaluated the species that have been found in Czechia over the last thirteen years. We aimed to distinguish the overlooked species from actual new colonizers. Among the new colonizers, we attempted to distinguish those that expanded their distribution due to global changes from those that were introduced by humans.

Czechia is one of the faunistically best researched regions in Europe. As of 2007, 852 species had been identified in this country (Buchar and Růžička 2002; Růžička and Buchar 2008). The Czech spider fauna lacks endemic species due to the glacial periods that have occurred. The oldest components of Czech spider fauna are glacial relics that survived in alpine and peat bog habitats and boreal relics that survived in steppe habitats. The Czech spider fauna is thus mainly composed of species with a Palearctic distribution. Only a very small proportion of the species are endemic to Central Europe; in particular, few Carpathian endemics occur in the mountains in eastern Moravia, and few Pannonian endemics occur in the lowlands in southern Moravia. Many species of natural habitats are disappearing, and 58% of the Czech spider fauna are red listed (Řezáč et al. 2015).

To date, approximately twenty species found in Czechia are considered allochthonous. The majority of them are restricted to synanthropic habitats, such as *Triaeris stenaspis* Simon, 1892, *Tapinesthis inermis* (Simon, 1882), *Pholcus phalangoides* (Fuesslin, 1775), *Uloborus plumipes* Lucas, 1846, *Nesticodes rufipes* (Lucas, 1846), *Parasteatoda tepidariorum* (C. L. Koch, 1841), *Steatoda castanea* (Clerck, 1757), *Steatoda grossa* (C. L. Koch, 1838), *Tegenaria domestica* (Clerck, 1757) and *Hasarius adansoni* (Audouin, 1826). Some of them are of cosmopolitan distribution. Moreover, some species have colonized the surroundings of buildings, in particular *Dysdera crocata* C. L. Koch, 1838, *Cheiracanthium mildei* L. Koch, 1864, *Scytodes thoracica* (Latreille, 1802), *Zygiella x-notata* (Clerck, 1757) and *Steatoda triangulosa* (Walckenaer, 1802) (e.g., Nedvěd et al. 2011). Only a small fraction of spider species introduced to Czechia have invaded natural habitats. These are *Zodarion rubidum* Simon, 1914 and *Zodarion italicum* (Canestrini, 1868) and especially the New Zealander linyphiid *Ostearius melanopygius* (O. Pickard-Cambridge, 1879) (Růžička 1995).

In addition to these species introduced by humans, there are also several cases of species that recently expanded their distribution from the south to Czechia, perhaps due to climate warming. The best documented cases are *Argiope bruennichi* (Scopoli, 1772) (Kůrka 1994), *Cheiracanthium punctarium* (Villers, 1789) (Dolanský 2011), *Lycosa singoriensis* (Laxmann, 1770) (Řezáč et al. 2008) and *Brigittea civica* (Lucas, 1850) (Havlová and Hula 2010).

## Materials and methods

We collected faunistic records for the spider species that were newly found in Czechia over the last thirteen years (see Supplementary material Appendix 1), since Růžička and Buchar (2008) last evaluated the Czech spider fauna. Then, we evaluated the history, distribution and habitat of these species according to records from both Czechia and the literature. We classified the newly recorded species into eight categories representing different reasons for their new entry into the record in the region.

Species identity was based on Nentwig et al. (2021). The nomenclature follows the World Spider Catalog (2021).

## Results

Since 2008, 47 new spider species have been observed in Czechia (Table 1). We classified these 47 species into eight categories:

### 1. Native species

#### 1.2. Native, not yet observed species

*History:* Present but not observed.

*Habitat:* A habitat or region that is unique or difficult to access, arachnologically unexplored at present. Result of application of new collection methods or focus on previously omitted regions.

*Distribution:* Rare, only in some regions, often at the edge of the distributional area.

*Species:* *Caviphantes saxetorum* (Hull, 1916), *Centromerus piccolo* Weiss, 1996, *Enoplognatha bryjai* Řezáč, 2016, *Eresus fulvus* Rossi, 1846 (senior synonym of *E. hermani* Kovács, Prazsák, Eichardt, Vári & Gyurkovics, 2015), *Erigone cristatopalpus* Simon, 1884, *Iberina candida* (Simon, 1875), *Iberina microphthalma* (Snazell & Duffey, 1980), *Oreonetides quadridentatus* (Wunderlich, 1972), *Palliduphantes ericaeus* (Blackwall, 1853), *Pardosa tenuipes* L. Koch, 1882, *Piniphantes pinicola* (Simon, 1884), *Tapinocyba pallens* (O. Pickard-Cambridge, 1873), *Yllenus arenarius* Simon, 1868, *Zelotes mundus* (Kulczyński, 1897).

#### 1.2. Newly distinguished species

*History:* Present but not distinguished from other species.

*Habitat:* Any.

*Distribution:* Any.

*Species:* *Micaria micans* (Blackwall, 1858), *Porrhoclubiona leucaspis* (Simon, 1932).

### 2. New colonizers

#### 2.1. Thermophilic species that have expanded their ranges

*History:* Absent from the region in the past – new records even from arachnologically well researched sites in the past.

*Habitat:* Often newly created habitats such as mining areas.

*Distribution:* Known to occur south of Central Europe, usually absent north of Central Europe.

*Species:* *Collinsia inerrans* (O. Pickard-Cambridge, 1885), *Emblyna brevidens* (Kulczyński, 1897), *Gnaphosa modestior* Kulczyński, 1897, *Heliophanus simplex* Simon, 1868, *Larinia elegans* Spassky, 1939, *Leviellus thorelli* (Ausserer,

**Table 1.** Spider species newly observed in Czechia in 2008–2020. Information on distributions is from Nentwig et al. 2021 if no other source is cited.

Family	Species	History	Habitat in Czechia	Distribution
Agelenidae	<i>Tegenaria parietina</i>	Introduction of a single individual	Heated greenhouse in a zoo	Warm parts of Europe, North Africa and Central Asia
Araneidae	<i>Larinia elegans</i>	Expansion, found in south Moravia, an area that has been arachnologically well researched in the past	Webs on reeds on banks of an artificial lake	Steppe zone of the Palaearctic region, only in Pannonia (E Austria, SE Czechia, Hungary) in Europe
	<i>Leviellus thorelli</i>	Native/expansion, found in south Moravia, an area that has been arachnologically well researched in the past	Webs on old solitary oaks, poplars and willows. Rarely on walls in towns	Central Europe, the Balkans and Italy
	<i>Neoscona adianta</i>	Expansion, found in south Moravia, an area that has been arachnologically well researched in the past	Various open grassland habitats	Palaearctic region
Clubionidae	<i>Porrhoclubiona leucaspis</i>	Native, recently distinguished from <i>C. genevensis</i> – progress in taxonomy	On trunks and branches of sun-exposed trees	North Africa and Western Europe
Dictynidae	<i>Emblyna brevidens</i>	Expansion, found in south Moravia, an area that has been arachnologically well researched in the past	Abandoned clay pit with a lake, new habitat in the landscape	Central Europe, the Balkans, Italy, and Finland
Eresidae	<i>Eresus fulvus</i>	Native	Rocky steppes	South-eastern and Central Europe
Gnaphosidae	<i>Gnaphosa modestior</i>	Possible recent range expansion, found in south Moravia, an area that has been arachnologically well researched in the past (Řezáč et al. 2018)	Open xerothermic habitats, partly newly created (Henneberg & Řezáč 2014) and open forests	Southern Europe and Pannonia
	<i>Micaria micans</i>	Native, recently distinguished from <i>M. pulicaria</i> – progress in taxonomy	Open xerothermic habitats	Relatively warm parts of the Palaearctic region
	<i>Zelotes mundus</i>	Native	Sandy xerothermic habitat, rare unexplored habitat	Palaearctic species with a distribution across the basins of the Eurasian steppe belt (Milasowszky et al. 2007; Schmidt and Hänggi 2007)
Hahniidae	<i>Iberina candida</i>	Native	Shrubs on rocky steppe on limestone	Mediterranean and Central Europe
	<i>Iberina microphthalma</i>	Small, native	Shallow subterranean habitats on limestone and marlite, unexplored habitat	From England to Hungary (Růžička and Dolanský 2016)
Linyphiidae	<i>Caviphantes saxetorum</i>	Native	Stony riverbank in a lowland forest, rare habitat	Central and Northern Europe, possibly recent expansion to the east; introduced to Oregon, USA (Aakra 2000)
	<i>Centromerus piccolo</i>	Native	Shallow subterranean habitats in loess accumulation, unexplored habitat	Germany (Weiss 1996), Czechia
	<i>Collinsia inerrans</i>	Expansion, it appeared in artificial habitats close to Prague, arachnologically the best researched region of Czechia	Dry grassland, winter wheat field, expanding	Palaearctic species, expanding in Europe
	<i>Erigone autumnalis</i>	Invasive	Dry grassland with shrubs	Native to North America, introduced to Europe
	<i>Erigone cristatopalpus</i>	Native	Glacial corrie in mountains, unique, so far unstudied habitat	Holarctic; European mountain ranges: the Alps (Muster and Hänggi 2009), The High Tatra Mountains (Miller 1971), Giant Mountains (Wiśniewski and Wesolowska 2016) and Hrubý Jeseník Mountains
	<i>Mermessus trilobatus</i>	Invasion (Nentwig 2015)	Various open habitats, including relict habitats or cultivated fields, expanded	North American, invasive in Europe (Nentwig 2015)
	<i>Oreonetides quadridentatus</i>	Native	Shallow subterranean habitats on marlite bedrock, inaccessible habitat	Central Europe (Baert and Kekenbosch 2011; Bosmans et al. 1986; Blick 2011)
	<i>Palliduphantes ericaeus</i>	Native	In moss in a peat bog	Western Palaearctic, Atlantic parts of Europe, southern border of distribution in Czechia

**Table 1.** (continued).

Family	Species	History	Habitat in Czechia	Distribution
Linyphiidae	<i>Piniphantes pinicola</i>	Native	Scree forest, unexplored habitat	Western Palaearctic, Europe except for the northern parts
	<i>Sintula spiniger</i>	Expansion, found in south Moravia, an area that has been arachnologically well researched in the past	Ruderal vegetation adjacent to crop fields	Western Palaearctic, south-eastern parts of Central Europe and the Balkans
	<i>Tapinocyba pallens</i>	Native	Natural or artificial scree slopes, an unexplored region	Western Palaearctic, only western Czechia
Lycosidae	<i>Pardosa nebulosa</i>	Expansion, appeared in more sites in recent years, found in south Moravia, an area that has been arachnologically well researched in the past	Abandoned clay and gravel pits with lakes, new habitats in the landscape	Palaearctic, south-eastern Europe
	<i>Pardosa tenuipes</i>	Native (or expansion)	Wet meadow adjacent to wetlands	Western Europe
Nesticidae	<i>Nesticella mogera</i>	Introduction	Heated greenhouse, absent in nature	Southeast Asian species, introduced to several European countries (Rozwałka et al. 2016)
Ochyroceratidae	<i>Theotima minutissima</i>	Introduction	Heated greenhouse in a ZOO	Tropical Asia, introduced to two European countries: Germany (Kielhorn 2008) and Czechia
Oonopidae	<i>Cortestina thaleri</i>	Introduction	Tree trunk on a city street	Introduced to Europe (Italy, Austria, Czechia), area of origin unknown
	<i>Heteroonops spinimanus</i>	Introduction	Heated greenhouse in a zoo	Central American species, introduced to two European countries: Germany (Kielhorn 2008) and Czechia
Philodromidae	<i>Philodromus buxi</i>	Expansion, it appeared in artificial habitats in the cities of Prague and Brno, arachnologically the best researched sites in Czechia	On trees in city parks	Palaearctic
	<i>Thanatus vulgaris</i>	Introduction	Heated cricket cultures, absent in nature	Native to southern Europe, introduced to more northern countries (Jäger 2002)
Pholcidae	<i>Holocnemus pluchei</i>	Introduction	Heated buildings (storage building and a shopping centre), absent in nature	Mediterranean species introduced to northern parts of Europe (Rozwałka and Stachowicz 2010)
	<i>Modisimus culicinus</i>	Introduction	Two heated greenhouses in a zoo, absent in nature	South American species, introduced to two European countries (Czechia, Germany) (Huber et al. 2017)
	<i>Pholcus alticeps</i>	Introduction/progress in taxonomy	Heated houses, absent in nature	Central Asian, introduced to Central Europe (Astrin et al. 2016)
	<i>Physocyclus globosus</i>	Introduction, possibly overlooked for some time	Heated biological laboratory, absent in nature	North American species introduced to several continents, including Europe (Czechia) (World Spider Catalog 2021)
	<i>Psilochorus simoni</i>	Introduction	Close to the floor of rooms with relatively high humidity in heated houses, absent in nature	Native to the western USA, introduced to many European countries
Salticidae	<i>Heliophanus simplex</i>	Expansion, found in south Moravia, an area that has been arachnologically well researched in the past	Grassland	South-eastern and Central Europe
	<i>Yllenus arenarius</i>	Native	A sand dune, unique rare habitat	Central and Eastern Europe (Logunov and Marusik 2003)
Sicariidae	<i>Loxosceles rufescens</i>	Introduction of a single individual	Heated greenhouse in a zoo	Mediterranean to Iran
Theridiidae	<i>Coleosoma floridanum</i>	Introduction	Heated greenhouses at botanical gardens, absent in nature	Tropical American species, introduced to several European countries (Šestáková et al. 2013)
	<i>Enoplognatha bryjai</i>	Native	Habitat difficult to access - littoral zone of ponds and lakes	Pannonian region (Řezáč et al. 2016)
	<i>Steatoda nobilis</i>	Introduction	Heated houses, absent in nature	Originally Macaronesia, introduced to western Europe
	<i>Steatoda paykulliana</i>	Introduction	Heated houses, absent in nature	Mediterranean and central Asia, introduced to central Europe
	<i>Theridion cinereum</i>	Expansion, found in south Moravia, an area that has been arachnologically well researched in the past	In xerothermic grassland in an abandoned quarry, newly created habitat in the landscape	Western Palaearctic species, South-eastern and Central Europe

**Table 1.** (continued).

Family	Species	History	Habitat in Czechia	Distribution
Theridiidae	<i>Theridion hannoniae</i>	Expansion, found in areas that had been arachnologically well researched in the past (Český kras and České středohoří protected landscape areas)	On rocks in quarries	Mediterranean and Western Europe
Trachelidae	<i>Paratrachelas maculatus</i>	Introduction	Heated houses, absent in nature	Northern Mediterranean, introduced to Central Europe
Zodariidae	<i>Zodarion ohridense</i>	Introduction	Dry abandoned quarry (Krejčí et al. 2017)	Balkan Peninsula, isolated site in Czechia

1871), *Neoscona adianta* (Walckenaer, 1802), *Pardosa nebulosa* (Thorell, 1872), *Philodromus buxi* Simon, 1884, *Sintula spiniger* (Balogh, 1935), *Theridion cinereum* Thorell, 1875, *Theridion hannoniae* Denis, 1945.

## 2.2. Species introduced by humans

### 2.2.1. Alien species introduced to natural habitats

#### 2.2.1.1. Species that lack invasive tendencies and that were introduced by humans to natural habitats

*History:* Newly introduced by humans.

*Habitat:* Disturbed habitats in nature.

*Distribution:* Sites of introduction isolated from the continuous distribution area of the species.

*Species:* *Zodarion ohridense* Wunderlich, 1973.

#### 2.2.1.2. True invasive species

*History:* Introduced by humans and expanding their range.

*Habitat:* Variety of natural habitats, often disturbed.

*Distribution:* Native on other continents, often North America.

*Species:* *Erigone autumnnalis* Emerton, 1882, *Mermessus trilobatus* (Emerton, 1882).

### 2.2.2. Alien species introduced to heated buildings

#### 2.2.2.1. Alien species introduced to heated buildings and spreading further

*History:* Newly introduced by humans and expanding their range.

*Habitat:* All kinds of heated buildings, absent in nature.

*Distribution:* Mainly subtropical regions.

*Species:* *Cortestina thaleri* Knoflach, 2009, *Holocnemus plucheii* (Scopoli, 1763), *Paratrachelas maculatus* (Thorell, 1875), *Pholcus alticeps* Spassky, 1932, *Psilochorus simoni* (Berland, 1911), *Steatoda nobilis* (Thorell, 1875), *Steatoda paykulliana* (Walckenaer, 1806).

#### 2.2.2.2. Alien species introduced to heated buildings and not expanding their range

*History:* Newly introduced by humans.

*Habitat:* Large heated buildings with complex synanthropic habitats, such as large greenhouses with high air humidity and rich prey resources, absent in nature.

**Table 2.** Composition of spider species newly observed in Czechia in recent years. Sums are in bold.

Native species	<b>16</b>
Not yet observed	14
Newly distinguished	2
New colonizers	<b>31</b>
Thermophilic, expanding	12
Species introduced by humans	
Introduced to natural habitats	
Species that lack invasive tendencies	1
True invasive species	2
Introduced to heated buildings	
Spreading further	7
Not expanding	7
Introduced individuals, no populations	<b>2</b>

*Distribution:* Mainly tropical regions.

*Species:* *Coleosoma floridanum* Banks, 1900, *Heteroonops spinimanus* (Simon, 1892), *Modisimus culicinus* (Simon, 1893), *Nesticella mogera* (Yaginuma, 1972), *Physocyclus globosus* (Taczanowski, 1874), *Thanatus vulgaris* Simon, 1870, *Theotima minutissima* (Petrunkevitch, 1929).

### 3. Single individuals introduced by humans, no populations established

*History:* Introduced with material, for example, fruit.

*Habitat:* Any, occurrence is limited by the life span of the introduced individual.

*Distribution:* Any.

*Species:* *Loxosceles rufescens* (Dufour, 1820), *Tegenaria parietina* (Fourcroy, 1785) (common in synanthropic habitats in Western Europe).

## Discussion

The evaluation of spider species newly observed in Czechia showed that only one-third of newly recorded species likely belong to the indigenous fauna (Table 2). Thus, the current knowledge of the indigenous Central European spider fauna is close to complete. The remaining two-thirds likely came to this region recently. Half of those species are likely thermophilic species that expanded their distribution to the north, possibly due to global warming, and the second half are subtropical or tropical species introduced to heated buildings. Only three species were introduced into natural habitats, and only two of them can be considered true invasive species.

### *Native species*

The newly recorded native species have not been recorded before because of their rarity or because they were not distinguished from similar taxa. The rare species are usually restricted to small regions of Czechia. Examples include *Palliduphantes ericaeus*, *Piniphantes pinicola* and *Tapinocyba pallens* in westernmost Bohemia, *Pardosa tenuipes* in northern Moravia, and *Zelotes*

*mundus* in southern Moravia. They may live in rare habitats, such as *Caviphantes saxetorum* on gravel banks, *Erigone cristatopalpus* in glacial corries, or *Yllenus arenarius* on sandy dunes. They may live in inaccessible habitats, such as *Enoplognatha bryjai* in the flooded littoral zone or *Oreonetides quadridentatus*, *Iberina micropthalma* and *Centromerus piccolo* in shallow subterranean habitats. *Iberina candida* was found on dry rocky steppe on limestone. It is possible that this species could be hidden in limestone crevices. Recent progress in research on shallow subterranean habitats was enabled by the application of pipe traps (Růžička and Dolanský 2016).

Two species, *Micaria micans* and *Porrhoclubiona leucaspis*, were recently distinguished from *M. pulicaria* and *P. genevensis*, respectively, because of taxonomic progress (a similar case is *Pholcus alticeps*, which was recently distinguished from *P. phalangioides*, but both of these *Pholcus* species were introduced; they are not native to Czechia).

#### *Species expanding their distribution*

Several species are known to occur in regions south of Czechia and recently appeared in Czechia, mostly in south Moravia, the warmest region of Czechia. Their expansion to the north was possibly enabled by recent warming of the climate. We reject the possibility that these species are native to Czechia because they were found in some araneologically very well researched areas/sites, and the probability that they had previously been overlooked there is very low. Several of these species were found only (*Emblyna brevidens*, *Theridion cinereum*, *Theridion hannoniae*) or predominantly (*Pardosa nebulosa*, *Gnaphosa modestior*) in xerothermic habitats that developed in abandoned mining areas, such as quarries and sand and clay pits. Not only is the macroclimate of these habitats suitable for such thermophilic species, but these habitats are also colonized *de novo*; thus, the expanding species do not compete with established populations of native species. *Philodromus buxi* was found on trees in parks within large cities. Two thermophilic araneid spiders, *Larinia elegans* and *Neoscona adianta*, have long been expected to appear in south Moravia—the warmest area of Czechia—as they are known to occur close to the border. *Sintula spiniger* was found on the edges of fields and forests in southern Moravia. *Collinsia inerrans* was observed in crop fields; it was the only species from this category that also colonized the western part of Czechia, Central Bohemia in particular.

#### *Species introduced by humans to natural habitats*

Only three spider species have been recently introduced to natural habitats in Czechia. *Zodarion ohridense* was introduced from the Balkan Peninsula to one abandoned quarry in Central Bohemia (Krejčí et al. 2017), but it

does not tend to expand in Czechia. Species of the genus *Zodarion* are well preadapted for passive human transport due to their tolerance of dry environments and especially their ability to attach silken shelters masked by soil particles to solid objects on the ground. Spiders are thus transported inside these objects, and if there are suitable conditions at their final destination, the spiders can establish new populations far from their continuous distributional area (Pekár 2002). However, because these spiders are not able to balloon (passive transport by means of wind and silk fibres), they do not tend to spontaneously expand further.

In contrast, *Erigone autumnalis* and *Mermessus trilobatus*, both native to North America, are good ballooners. In North America, they inhabit both natural and human-modified habitats (Millidge 1987). The ability to tolerate a wide range of environmental conditions, together with a strategy of aerial dispersal, allows the species to spread quickly and easily on the new continent (Hirna 2017). *Mermessus trilobatus* was able to colonize a wide range of habitats, mainly open habitats, across the whole Czech territory. It is currently the most invasive spider in Europe (Narimanov et al. 2020). It was first detected in 1981 near Karlsruhe in southwest Germany (Dumpert and Platen 1985). The concentric expansion through Europe, mainly eastwards (the prevailing wind direction), is briefly described by Hirna (2017).

*Mermessus trilobatus* is able to integrate into even the most relict natural communities: peat bogs, heathlands, relic steppe grasslands and alpine grasslands. Thus, it presumably causes changes to the structure of such communities of conservation interest and outcompetes endangered species. For example, we studied the alpine spider community near Vyšné Wahlenbergovo pleso lake (altitude 2157 m) in the High Tatra Mountains in Slovakia one year after the first record of *Mermessus trilobatus* in this mountain range (July 2014–September 2015, collected by K. Tajovský and P. Čuchta, identified by V. Růžička, unpublished). The community was composed of 54 species; 43% of 1021 identified specimens were relict alpine species: *Mughiphantes varians* (Kulczyński, 1882) (endemic to The High Tatra Mountains), *Scotinotylus antennatus* (O. Pickard-Cambridge, 1875), *Agyneta milleri* (Thaler, Buchar & Kúrka, 1997), *Pardosa nigra* (C.L. Koch, 1834), *Coelotes atropos* (Walckenaer, 1830), *Anguliphantes monticola* (Kulczyński, 1881), *Clubiona alpicola* Kulczyński, 1882, *Oreonetides glacialis* (L. Koch, 1872), *Mughiphantes pulcher* (Kulczyński, 1881) and the boreomontane species *Tiso aestivus* (L. Koch, 1872). *Mermessus trilobatus* constituted 2.4% of the community.

In open habitats within agricultural landscapes in Germany, *M. trilobatus* can be among the most abundant spider species (Schmidt et al. 2008). According to our experience from Czechia, it does not tend to be dominant in the community (as well as another European invasive linyphiid spider, *Ostearius melanopygius*). Quick invasion is obviously facilitated by a

remarkable ability and tendency to disperse by ballooning. Ballooning might also explain why we captured this otherwise ground-dwelling species high above the ground in oak canopies.

The speed of *Mermessus trilobatus* invasion eastward through Europe can be calculated from the first record near Karlsruhe, Germany, in 1981 and the easternmost records in the High Tatra Mountains in Poland in 2013 (Rozwałka et al. 2016) (840 km/32 years = 26 km/year) or the Carpathians in Ukraine in 2016 (Hirna 2017) (1170 km/35 years = 33 km/year). Interestingly, a very similar speed (30 km/year) was recorded during the invasion of another linyphiid spider, *Ostearius melanopygius* (O. Pickard-Cambridge, 1879), eastward through Europe (Růžička 1995). Together with *Ostearius melanopygius*, *Mermessus trilobatus* is the best example of an invasive spider species in Central Europe.

### *Species introduced by humans to heated buildings*

Several subtropical and tropical species have been recently recorded in heated buildings in Czechia. Most of them were found only at a few unique sites, such as in greenhouses in zoos and botanical gardens (*Modisimus culicinus*, *Nesticella mogera*, *Coleosoma floridanum*) or insect breeding colonies in laboratories (*Thanatus vulgaris*, *Physocyclus globosus*). These species do not tend to expand to more common types of heated buildings (Hänggi and Straub 2016). The only exceptions are *Pholcus alticeps*, *Psilochorus simoni*, *Holocnemus pluchei*, *Steatoda nobilis*, *Steatoda paykulliana* and *Paratrachelas maculatus*, which were able to colonize private houses. *Pholcus alticeps* was possibly misidentified as *Pholcus phalangioides* and thus overlooked for some time.

*Tegenaria parietina* and *Loxosceles rufescens* were found only once; thus, they were likely once introduced to the heated pavilions in zoos and did not establish populations.

*Cortestina thaleri* is a special case because it was obviously introduced to Europe, but its area of origin is not known (Knoflach et al. 2009). In Czechia, it was found in synanthropic habitats in cities outside buildings. The ability to survive outside heated buildings might be evidence of a subtropical rather than tropical origin.

## **Conclusion**

In the future, we can expect further changes in the species composition of the European spider fauna. Climatic changes will allow more thermophilic species to expand to the north. Additionally, an increased amount of transported material will increase the cases of further introduction of alien species (Nentwig 2015; Kobelt and Nentwig 2008). Because of the limited number of niches, such enrichment will inevitably cause the suppression of some native species.

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### Supplementary material

The following supplementary material is available for this article:

**Appendix 1.** Records of spider species observed in Czechia in 2008–2020.

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