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Spiders (Araneae) from Swiss hothouses, with records of four species new for Switzerland

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Abstract. Investigations of invertebrates in nine hothouses (tropical gardens) in Switzerland provided some spiders as by-catch. In total, we collected 136 spiders, of which 65 specimens represent 14 species from six families (the rest of the collection consisted of unidentifiable juveniles). Nine species are alien for Europe, one originates from the Mediterranean and four species are native to Central Europe. Four species represent first records for the Swiss fauna: Nesticidae: *Nesticella mogera* (Yaginuma, 1972), Oonopidae: *Diblemma donisthorpei* O. Pickard-Cambridge, 1909, *Ischnothyreus peltifer* (Simon, 1892) and *Prida sechellensis* (Benoit, 1979). These four species are discussed briefly and documented with photos.

Keywords: alien species, Nesticidae, Oonopidae, tropical greenhouses

Zusammenfassung. Spinnen (Araneae) aus beheizten Gewächshäusern der Schweiz, mit Erstnachweisen von vier Arten für die Schweiz. Bei Aufsammlungen von Invertebraten in neun Warm-Gewächshäusern (Tropenhäusern) in der Schweiz wurden Spinnen als Beifänge ausgewertet. Von den 136 Individuen konnten 65 bis zur Art bestimmt werden. Die 14 ermittelten Arten verteilten sich auf sechs Familien. Neun der Arten stammen von anderen Kontinenten (alien species), eine stammt aus dem Mittelmeerraum und vier sind zentraleuropäischen Ursprungs Arten. Vier Arten stellen Erstnachweise für die Schweiz dar: Nesticidae: *Nesticella mogera* (Yaginuma, 1972), Oonopidae: *Diblemma donisthorpei* O. Pickard-Cambridge, 1909, *Ischnothyreus peltifer* (Simon, 1892) und *Prida sechellensis* (Benoit, 1979). Diese vier Arten werden kurz besprochen und mit Bildmaterial belegt.

In temperate regions, tropical greenhouses provide a set of conditions that are quite different from the ones outdoors. This, among others, includes higher and more constant temperature, high humidity and the presence of non-native plants. Although these plants are often obtained from other greenhouses in temperate regions, at some point in the past these species were imported from their countries of origin. The anthropogenic transport of exotic plants and potting soil has promoted the introduction and sometimes dispersal of several non-native invertebrate species into greenhouses of different European countries, including Switzerland (Wittenberg 2006). In some cases, species that were supposed to be confined to greenhouses are nowadays also established outdoors (Kozar et al. 1994, Wittenberg 2006). Although an old tradition of searching for exotic invertebrate animals in greenhouses exists (Simon 1896, Boettger 1929, Holzapfel 1932, Knoflach 1999), the knowledge and status of these species today in most countries is still incomplete and strongly discussed. For instance, Wilson (2012) provided a list of non-native spider species for the United Kingdom with 52 species originating from other continents (alien species) or mainland Europe while in 2021 he only listed 33 alien species (Wilson 2021).

Regarding spiders, there was a revival concerning the search for alien species in greenhouses, nurseries and storage buildings because these could be part of the pathways for the introduction of alien species (Segers 1986, Kielhorn 2008, 2009, Kobelt & Nentwig 2008, Kielhorn & Rödel 2011, Reiser 2013, Nentwig 2015, Hänggi & Straub 2016). An overview was given by Reiser (2013). A large part of these alien species in greenhouses seem to be imported with plants from overseas, from nurseries, or from other greenhouses. In most cases they remain restricted to heated greenhouses (hothouses) due to their ecological demands, especially concerning temperature. However, very little is known whether some species are able to escape the greenhouses and spread outside. In Switzerland, the knowledge about spiders in greenhouses is scarce and poorly documented (Holzapfel 1932, Knoflach 1999, Blick et al. 2006, Hänggi & Straub 2016, Rembold et al. 2020). Therefore, the aim of our project was to update the current knowledge about these communities, including the detection of potentially invasive species.

Material and methods

We searched for as many different greenhouses as possible across Switzerland and obtained permission to sample invertebrates in nine of them (Fig. 1, Tab. 1). We sampled invertebrates only in the heated greenhouses. These hothouses differed in some characteristics (such as size, density of plants or amount of fallen leaves on the ground) (Fig. 2), but they all had a relatively stable (higher than outdoors) temperature, with only a couple of cases having noticeable seasonal variations.

The methodology followed in each greenhouse included active search and pitfall trapping. When we obtained permission to sample in more than one hothouse at a certain location (Porrentruy, Geneva, Zurich and Fribourg), we selected the one with the highest temperature and humidity ("more tropical"), but an additional sampling (only visual search, without pitfall trapping) was conducted in the remaining hothouses. The active search targeted mainly invertebrates on and in the soil, in leaf litter, and under stones and deadwood, but we also searched among plants. The search was conducted by two people during a 30 min attendance in each greenhouse. Invertebrates were captured with forceps and directly transferred to vials with 70% ethanol. Eight pitfall traps were distributed throughout

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Tab. 1: Date of sampling and setting of the pitfall taps, geographical positions of the investigated hothouses in Switzerland. In brackets abbreviations as used in Tab. 2

Locality	Date	Lat°	Long°	m a.s.l.
Basel, Botanical Garden, Tropenhaus (Basel BOGA)	26. Jun. 2019	47.55862°N	7.58176°E	270
Basel, Zoo, Vogelhaus (Basel ZOO)	3. Oct. 2019	47.54821°N	7.57864°E	270
Zürich, Botanical Garden of the University of Zurich (Zürich BOGA)	4. Dec. 2019	47.35790°N	8.56183°E	440
St. Gallen, Botanical Garden (St.Gall. BOGA)	2. Oct. 2019	47.44024°N	9.40712°E	660
Porrentruy, Jurassica (Porr. BOGA)	7. Nov. 2019	47.41371°N	7.07690°E	440
Kerzers, Papiliorama Tropical Garden (Kerz. TROGA)	12. Sep. 2019	46.99001°N	7.20115°E	440
Bern, Botanical Garden of the University of Bern (Bern BOGA)	4. Dec. 2019	46.95249°N	7.44562°E	530
Fribourg, Botanical Garden of the University of Fribourg (Frib. BOGA)	23. Oct. 2019	46.79315°N	7.15550°E	630
Geneva, Conservatory and Botanical Garden (Geneva BOGA)	15. Oct. 2019	46.22835°N	6.14854°E	380

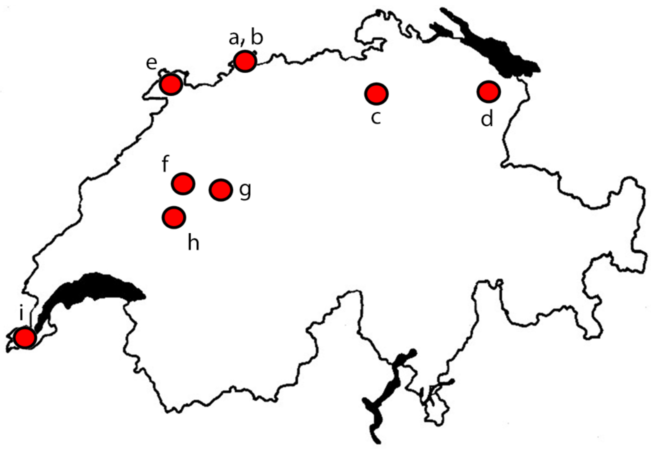

Fig. 1: Location of the sampled greenhouses in Switzerland. **a.** "Tropenhaus", Botanical Garden of the University of Basel; **b.** "Vogelhaus", Basel Zoo; **c.** Botanical Garden of the University of Zurich; **d.** Botanical Garden of St. Gallen; **e.** Jurassica Botanical Garden (Porrentruy); **f.** Papiliorama Tropical Garden (Kerzers); **g.** Botanical Garden of the University of Bern; **h.** Botanical Garden of the University of Fribourg; **i.** Conservatory and Botanical Garden, Geneva

the area of each greenhouse, following the recommendations of the gardeners to avoid damage to some plants, and as hidden as possible from the visitor's sight. They were emptied after seven days. The traps consisted of plastic cups (5.8 cm in diameter) filled with propylene glycol, buried at ground level and covered by a plastic roof at approximately 2 cm above the ground to prevent water or leaves falling in. The samples were sorted in the lab and the specimens from the traps were transferred to 70% ethanol. Species identification is based on Nentwig et al. (2021), followed by using the original literature (cited only if used in the text below). Male palps were detached and female epigynes were dissected and examined in clove oil if necessary. Photos were taken using a KEYENCE VHX-6000 with autostacking. Nomenclature follows the World Spider Catalog (2021). A reference collection is deposited at the Natural History Museum Basel (NMB).

Results

The total catch included 136 spiders, 6 ♂♂, 44 ♀♀ and 86 juveniles. Only 65 individuals could be identified to species level, resulting in 14 species from six families (Tab. 2). Juveniles were only identified to species level when adults were present and when there was no doubt about their identity. Only nine specimens out of the 65 identified spiders (13.8%) belong to native species (four of the 14 identified species, 28.6%: *Amaurobius ferox*, *Erigone dentipalpis*, *Parasteatoda simulans* and *Tenuiphantes tenuis*). The remaining 56 individuals (86.2% of the identified spiders) belong to ten non-native species (71.4% of the species) (Tab. 2).

Three species are typical outdoor species, five are widely distributed in European indoor localities or in caves. Two species are recorded here only for the second time in Switzerland and four species, one from Nesticidae and three from Oonopidae, represent first records for the Swiss fauna and are discussed below.

First records for the Swiss fauna

NESTICIDAE

***Nesticella mogera* (Yaginuma, 1972)** (Fig. 3a-c)

Material. SWITZERLAND, Zürich, Botanischer Garten, 47.35790°N, 8.56183°E, active search, 1 ♀, 4. Dec. 2019, NMB-ARAN-29483.

Identification. Liu & Li (2013), Bielak-Bielecki & Rozwałka (2011), Marusik & Guseinov (2003).

Remarks. The first European record of this species of Asian origin (Caucasus to East Asia) was made by Snazell & Smithers (2007) from a humid tropical greenhouse of the Eden Project in Cornwall, England, in which numerous other species were also recorded (Smithers et al. 2004). The first record for the European Mainland was published by Kielhorn (2009), collected in the Zoo-Aquarium, Berlin, Germany. Meanwhile some further records for Europe were published (Bielak-Bielecki & Rozwałka 2011, Pfliegler 2014). For a summary see Bloem & Noordijk (2021). While all these records are connected to synanthropic indoor conditions, the record from Calabria, Italy, comes from an outdoor locality (Pantini et al. 2020).

Another record from Switzerland comes from Papiliorama in Kerzers and does not originate from our survey. The specimen with uncertain identification was collected earlier (15. Jun. 2013, 1 ♀; leg. G. Ackermann), revised by us, and turned out to be *N. mogera* as well. In summary, this species is currently known in Switzerland from two localities.

OONOPIDAE

***Diblemma donisthorpei* O. Pickard-Cambridge, 1909** (Fig. 4a-d)

Material. SWITZERLAND, Kerzers, Papiliorama, 46.99001°N, 7.20115°E, active search, 1 ♀, 12. Sep. 2019, NMB-ARAN-29494.

Identification. Locket & Millidge (1951), Saaristo (2001, 2010).

Fig. 2: Four of the sampled greenhouses. **a.** Conservatory and Botanical Garden, Geneva; **b.** Botanical Garden of the University of Zurich; **c.** Jurassica Botanical Garden (Porrentruy); **d.** Papiliorama (Kerzers).

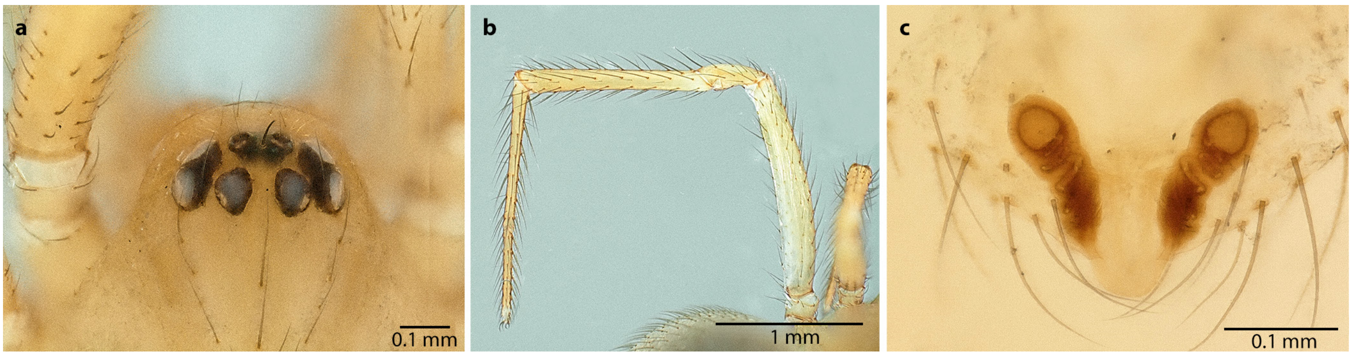

Fig. 3: *Nesticella mogera*, Botanical Garden Zürich, female. **a.** eye region, dorsal view; **b.** leg 4, retrolateral view; **c.** vulva, ventral view, cleared in clove oil

Remarks. This species was originally described from the Royal Gardens at Kew, England (Pickard-Cambridge 1909) and, already at that point, it was questioned whether it was of British origin. Today the species is thought to come from the Seychelles, the only place where it is known from outdoor habitats (Saaristo 2010). The record in the Papiliorama is the first for Mainland Europe. It would be of interest to know if this species was transported to Switzerland from other European greenhouses, or from its native range.

***Ischnothyreus peltifer* (Simon, 1892)** (Fig. 5a-e)
Material. SWITZERLAND, Kerzers, Papiliorama, 46.99001°N, 7.20115°E, active search, 1 ♀, 12. Sep. 2019, NMB-ARAN-29495.
Identification. Saaristo (2001), Platnick et al. (2012).
Remarks. According to Nentwig et al. (2021) this species is of Asian origin and is known in Europe only from Great Britain but is not listed in the current checklist of the spiders of Great Britain (Lavery 2019). The record in Nentwig

Tab. 2: Species list of spiders collected in nine hothouses in Switzerland. Indicated are the numbers of males (♂), females (♀) and juveniles (j), the origin of the species according to the World Spider Catalog (2021) and the actual occurrence of the species outdoors in Europe. First records for Switzerland are marked with * after the name. Abbreviations of the localities according to Tab. 1.

Taxon	Origin	Outdoors in Europe yes/no	Basel BOGA ♂/♀/j	Basel ZOO ♂/♀/j	Bern BOGA ♂/♀/j	Frib. BOGA ♂/♀/j	Geneva BOGA ♂/♀/j	Kerz. TROGA ♂/♀/j	Porr. BOGA ♂/♀/j	Zürich BOGA ♂/♀/j	St.Gall. BOGA ♂/♀/j	Total ♂/♀/j
Amaurobiidae												
Amaurobius ferox (Walckenaer, 1830)	Native	yes	.	.	1/-/1	-/1/-	.	.	.	.	.	1/1/1
Linyphiidae												
Erigone dentipalpis (Wider, 1834)	Native	yes	.	.	.	2/2/-	.	.	.	.	.	2/2/-
Mermessus trilobatus (Emerton, 1882)	Nearctic	yes	.	.	.	1/1/-	.	.	.	.	.	1/1/-
Tenuiphantes tenuis (Blackwall, 1852)	Native	yes	.	.	.	.	.	.	.	-/1/-	.	-/1/-
Nesticidae												
Nesticella mogera (Yaginuma, 1972)*	Asian	no	.	.	.	.	.	.	.	-/1/-	.	-/1/-
Oonopidae												
Diblemma donisthorpei O. Pickard-Cambridge, 1909*	Seychelles	no	.	.	.	.	.	-/1/-	.	.	.	-/1/-
Ischnothyreus peltifer (Simon, 1892)*	Asian	no	.	.	.	.	.	-/1/-	.	.	.	-/1/-
Prida sechellensis (Benoit, 1979)*	Seychelles	no	.	.	.	.	-/12/-	.	.	.	.	-/12/-
Triaeris stenaspis Simon, 1892	African	no	.	.	-/2/9	-/2/-	-/8/3	-/1/-	-/2/-	.	-/1/-	-/16/12
Pholcidae												
Pholcus phalangioides (Fuesslin, 1775)	Asian	yes	.	.	.	-/1/-	.	.	.	.	.	-/1/-
Psilochorus simoni (Berland, 1911)	Nearctic	yes	.	.	.	.	.	.	-/2/1	.	.	-/2/1
Theridiidae												
Coleosoma floridanum Banks, 1900	Americas	no	.	.	.	1/2/1	.	.	.	1/-/-	.	2/2/1
Parasteatoda simulans (Thorell, 1875)	Native	yes	.	.	.	-/1/-	.	.	.	.	.	-/1/-
Steatoda triangulosa (Walckenaer, 1802)	Medi-terranean	yes	.	.	.	.	-/1/-	.	-/1/-	.	.	-/2/-
Fam. gen. spec. (juveniles)			-/-/2	-/-/3	-/-/3	-/-/9	-/-/22	-/-/2	-/-/6	-/-/23	-/-/1	-/-/71
Sum			-/-/2	-/-/3	1/2/13	4/10/10	-/21/25	-/3/2	-/5/7	1/2/23	-/-/1	6/44/86

et al. (2021) goes back to Locket & Millidge (1951, sub *Ischnothyreus velox* Jackson, 1908, only fig. 38E) and Saaristo (2010: 120) who mentioned its presence in hothouses in Kew Gardens in London. All later checklists for Great Britain did not include this species, although other species established only in "artificial biomes" are listed in Lavery (2019).

***Prida sechellensis* (Benoit, 1979)** (Fig. 6a-d)
Material: SWITZERLAND, Geneva, Botanical Garden, 46.22835°N, 6.14854°E, 15.–22. Oct. 2019, pitfall traps, 12 ♀♀, NMB-ARAN-29486-29490, one sample NMB-ARAN-29489 with five specimens is deposited at the Natural History Museum Bern.
Identification: Benoit (1979), Saaristo (2001, 2010).
Remarks. Twelve specimens were captured in four different traps. Some further juveniles were also recorded, but their identity remains questionable. This is the first record for Europe of this endemic species from the Seychelles (Saaristo 2010, World Spider Catalog 2021). To date, only females of this species were recorded and it is supposed that the species is parthenogenetic (Saaristo 2010). A further monitoring of this species in the botanical garden of Geneva could be of special interest.

Discussion
The number of spiders captured in the greenhouses (136 individuals) is low, which is a consequence of a fairly low sampling effort (1 hour of active search and eight pitfall traps working during a week per greenhouse). The aim of the survey was to capture all kind of ground-dwelling invertebrates, especially soil-dwelling arthropods, so most likely, a survey specifically designed for spiders would increase these numbers significantly. Seasonal effects could also be of importance, even if one would assume that seasonality is less important in heated greenhouses. For instance, *Nesticella mogera* is found more often in April and May (Nentwig et al. 2021), while we caught it in December.

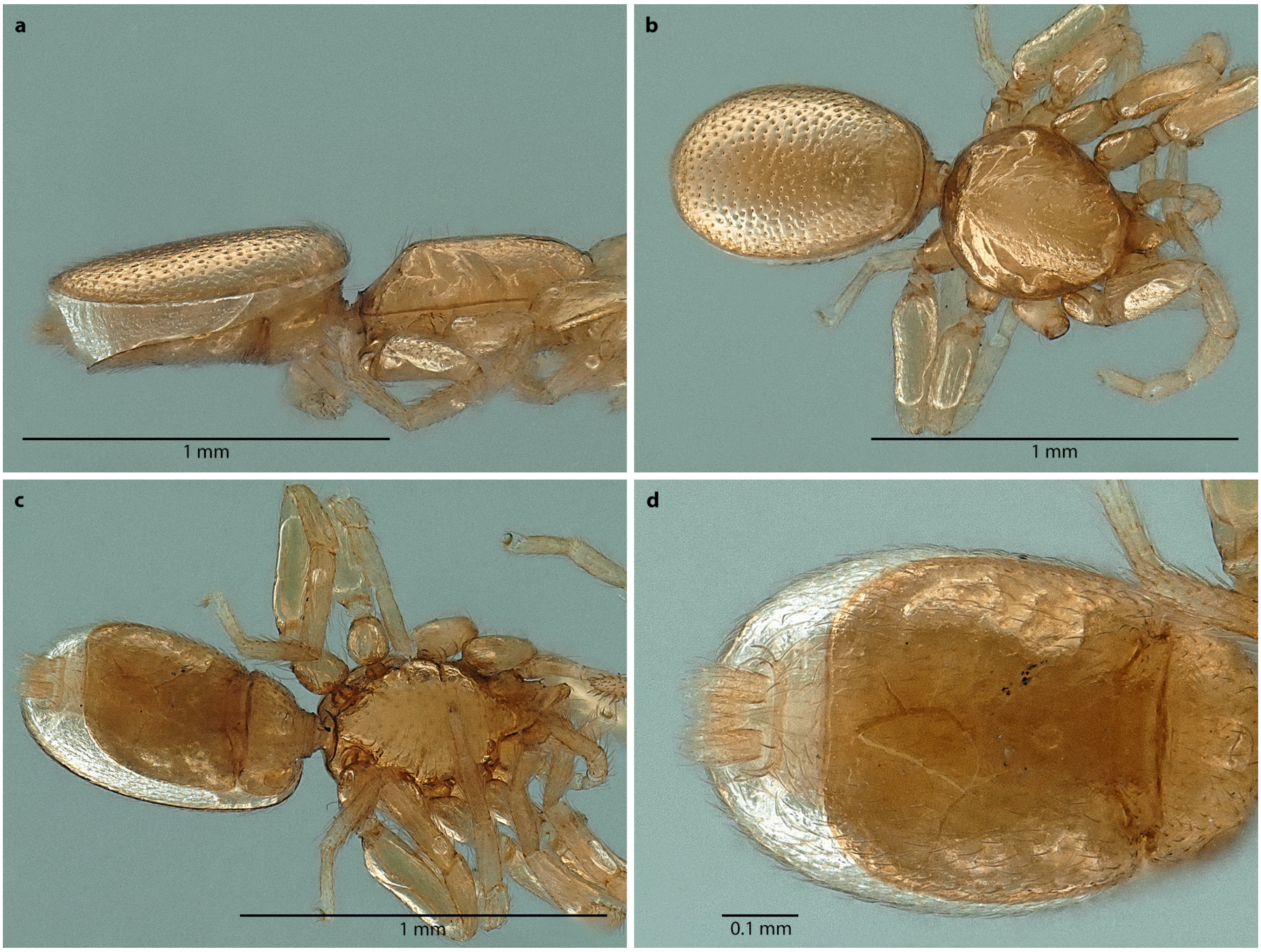

Fig. 4: *Diblemma donisthorpei*, female, Kerzers, Papiliorama. **a.** habitus, lateral view; **b.** habitus, dorsal view; **c.** habitus, ventral view; **d.** opisthosoma, ventral view

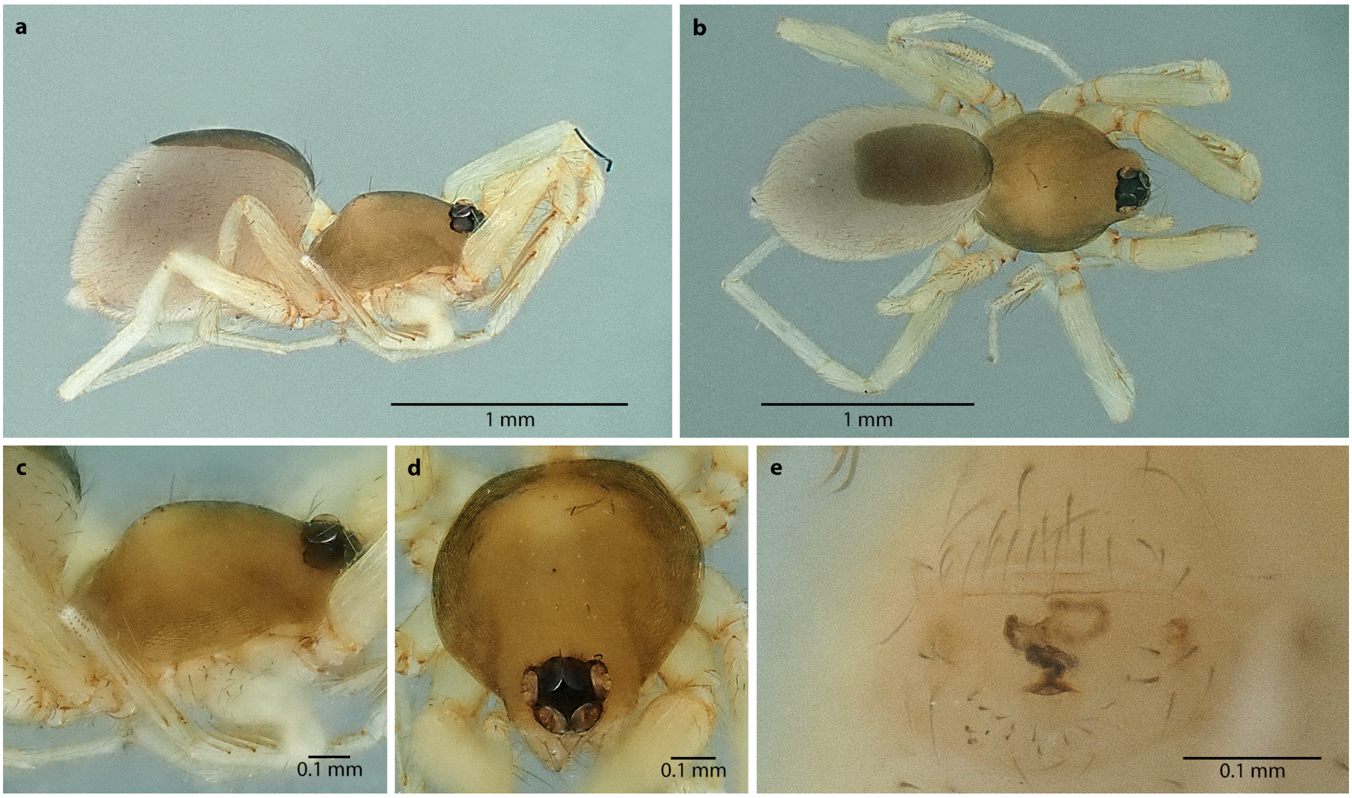

Fig. 5: *Ischnothyreus peltifer*, female, Kerzers, Papiliorama. **a.** habitus, lateral view; **b.** habitus, dorsal view; **c.** prosoma, lateral view; **d.** prosoma, dorso-frontal view; **e.** epigyne, ventral view

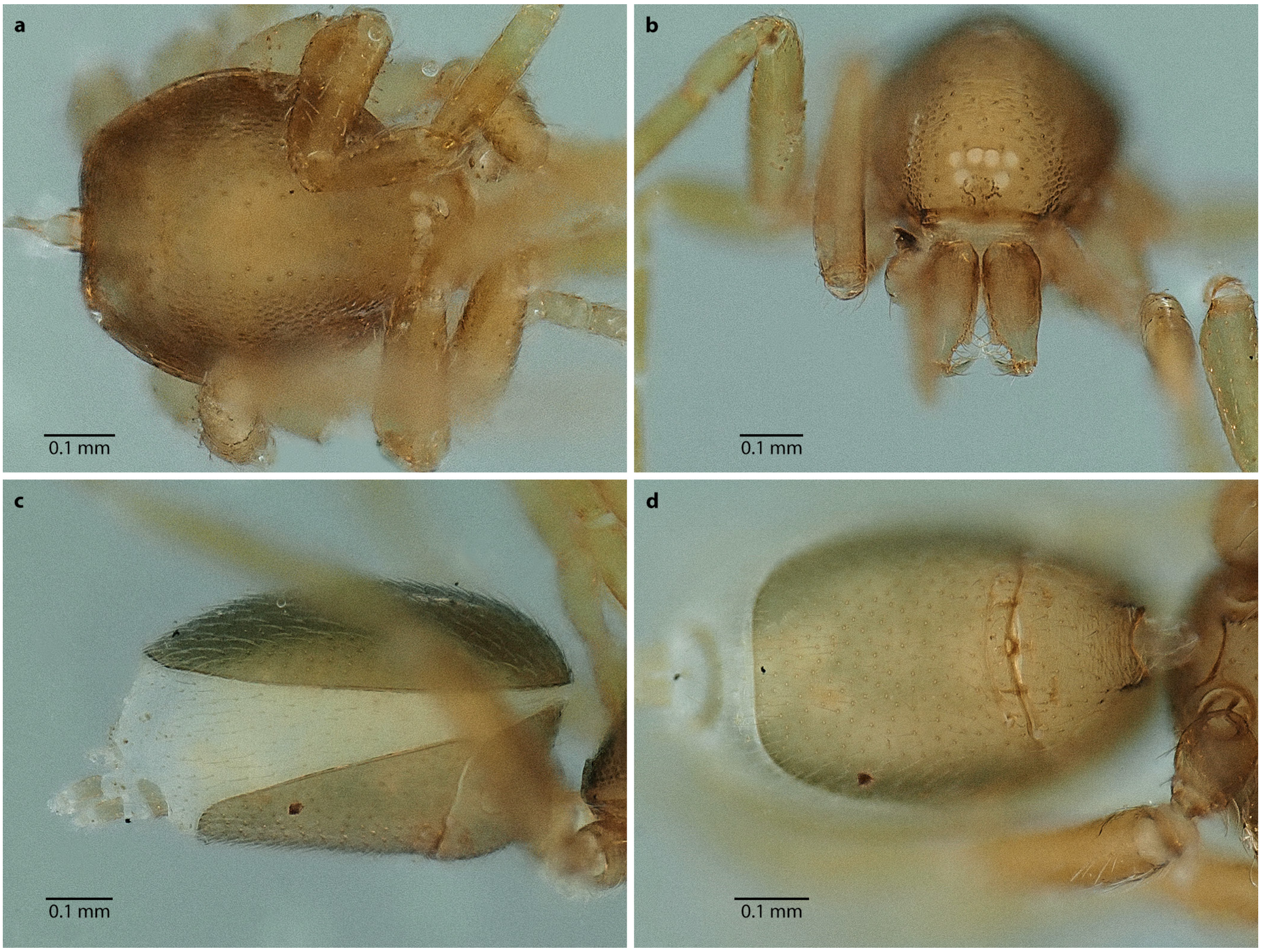

Fig. 6: *Prida sechellensis*, Botanical Garden Geneva. **a.** prosoma, dorsal view; **b.** prosoma, frontal view; **c.** opisthosoma, lateral view; **d.** opisthosoma, ventral view

Three species of the family Linyphiidae (*Erigone dentipalpis*, *Mermessus trilobatus* and *Tenuiphantes tenuis*) are widely distributed outdoors. All three are well known to disperse by ballooning and easily colonise new open habitats. One of them, *Mermessus trilobatus,* is an alien Nearctic species that was captured for the first time in Europe only in 1981 in Germany (Dumpert & Platen 1985) and then quickly spread all over Europe (overview in Hirna 2017). Four species are widely distributed in European indoor localities or caves: Amaurobiidae: *Amaurobius ferox*; Theridiidae: *Steatoda triangulosa*; Pholcidae: *Pholcus phalangioides* and *Psilochorus simoni*. The first two species are of Central European origin. *Steatoda triangulosa* is of Mediterranean origin and has been spreading northwards during the last decades (Nentwig et al. 2021). *Psilochorus simoni*, first recorded for Switzerland by Comellini (1954), is of Nearctic origin but is known in Europe since 1911 and, during the last century, has established itself widely within synanthropic habitats across Europe (Fürst & Blandenier 1993). The same is true for *Pholcus phalangioides,* except for having an Asian origin instead (Nentwig et al. 2021). Two species, *Coleosoma floridanum* (Theridiidae) and *Triaeris stenaspis* (Oonopidae), are recorded for the second time in Switzerland. The first finding of *Coleosoma floridanum* took place in the Tropenhaus of the Botanical Garden Basel in 1999 (Knoflach 1999). Only two years ago, *Triaeris stenaspis* was found in the tropical fern house of the Botanical Garden Bern for the first time in Switzerland (Rembold et al. 2020) and is now known from six of the nine investigated localities. *Triaeris stenaspis* is another species that is long known from tropical hothouses of Botanical gardens (Simon 1896, Kielhorn 2008).

The geographical origin of the non-native species includes different regions of the world, with three American species, three Asian, three African (incl. Seychelles) and one Mediterranean (nine specimens, four species, Tab. 2). Altogether, these numbers indicate that greenhouses in this study harbour many more non-native spider species and individuals than native ones, and that they originate from almost every continent. Most likely, this bias towards non-native species is promoted by the temperature and humidity conditions inside the greenhouses, although other factors such as the filters for colonization (different treatments of plants or soil), or availability of prey could also play a role.

The four new records for Switzerland (*Diblemma donisthorpei*, *Ischnothyreus peltifer*, *Nesticella mogera* and *Prida sechellensis*) and the further records of *Triaeris stenaspis* and *Coleosoma floridanum* underline the fact that the knowledge of the spider fauna of the heated greenhouses of Switzerland is still extremely poor. The other studied invertebrates from this project seem to be showing a similar pattern (in prep.). These non-native species must have arrived at European greenhouses via import of plants and potting soil, and the dispersal among greenhouses within Europe probably happens through the frequent exchange of plant material between institutions.

As expected, we detected several non-native species, nine from other continents, and only one from the Mediterranean region. While most of the tropical non-native species in European greenhouses pose little to no potential to establish populations outdoors, or even to become invasive, there is evidence that some greenhouse insect pest species have naturalized and became invasive (Wittenberg 2006). Moreover, in the context of climate change, some species may eventually be able to become invasive as temperatures rise in Europe (Gilgado 2020). Gardeners and managers of greenhouses should do their best to minimize the settlement and dispersal of non-native species as much as possible. A further important step would be to promote a monitoring of the arthropod fauna in their greenhouses and implement control measures.

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