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Notes on *Pachypasa otus* and the description of a new Iranian *Pachypasa* species (Lepidoptera, Lasiocampidae, Lasiocampinae, Lasiocampini)

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Abstract

The synonymy between *Pachypasa otus* (Drury, 1777) and *P. otus fulvescens* Kotsch, 1932 is supported by the lack of any stable morphologic characters and average distance of 0.3% in the cytochrome C oxidase (COI) gene between the Balkan (n = 4) and the Levantine (n = 2) populations. The Iranian population is described as a new species, *Pachypasa hausmanni* sp. n., based on morphologic difference, geographic isolation, and an average genetic distance of 6.1%.

Key words: barcoding, biodiversity, lappet moth, Levant, Western Asia.

Introduction

The genus *Pachypasa* Walker, 1855 was revised by Zolotuhin and Gurkovich (2009) and left monotypic with *Pachypasa otus* (Drury, 1773) – “the largest Palearctic Lasiocampid” (Grünberg, 1910). The authors suggested that *P. otus* may contain the “darker [...] cream-grey” nominate subspecies and the “brighter sandy-yellow” *P. otus fulvescens* Kotsch, 1932 from “Syria and Southern Iran” (Zolotuhin & Gurkovich 2009: 7), but at the time they did not use genetic analysis to verify the suggestion. The present study follows their original thoughts and specifies morphologic characters, the distribution area of *P. otus*, and adds genetic comparison of distant populations.

Material and methods

Adults were photographed with a Nikon D3300 and a Nikon 40 mm f/2.8G. Morphologic preparations were photographed using Fujifilm X-T10 with Motic SMZ-161-TLED. All images were processed in Photoshop CS6 (Adobe, 2012).

Specimens from the following collections were examined:

- CAF** collection of Alessandro Floriani (Milan, Italy);
- CAS** collection of Aidas Saldaitis (Vilnius, Lithuania);
- CCS** collection of Cristian Sitar (Cluj Napoca, Romania);
- CGM** collection of Günter Müller (Freising, Germany);
- CJM** collection of Jörg Meineke (Karlsruhe, Germany);
- CMS** collection of Manfred Ströhle (Weiden, Germany);
- CSL** collection of Szekely Levente (Brașov, Romania);
- GNMT** Georgian national Simon Janashia Museum (Tbilisi, Georgia);
- KLM** Landesmuseum Kärnten (Klagenfurt am Wörthersee, Austria);
- MWM** Museum Witt Munich (Munich, Germany);
- SMNK** State Museum of Natural History (Karlsruhe, Germany);
- SMNS** State Museum of Natural History (Stuttgart, Germany);
- SNHM** Swedish Natural History Museum (Stockholm, Sweden);
- ZSM** Bavarian State Collection of Zoology (Munich, Germany).

Molecular analysis

Sampling and collection of data

Six sequences of *Pachypasa* were obtained for this study. The samples originate from Greece, Croatia, Lebanon, and Iran and are stored as vouchers in various institutions (Table 1). One leg from each individual was preserved in tubes with 96% ethanol and used consecutively for DNA analysis. The sequences were obtained at the Biodiversity Institute of Ontario, Canada. DNA isolation, PCR amplification, and DNA sequencing followed standard protocols (Hebert *et al.*, 2003; DeWaard *et al.*, 2008).

Sequence analysis

Sequence alignment and calculation of genetic distances were done with MEGA11 software. Bootstrap analysis (1000 replicates) and the neighbor-joining tree of the COI sequences (the Kimura-two-parameter was used) were built in MEGA11. The sequence of *Macrothylacia rubi* (Lepidoptera: Lasiocampidae) was used as an out-group.

Taxonomy

Pachypasa otus (Drury, 1773)

(Figs 1–22, 28–32, 35–36, 38–40)

Sphinx otus Drury, 1773, *Illustrations of natural history* 2, index to 1; 1770, *ibidem* 1: 30. Type locality: [Turkey, İzmir] Smyrna. Type specimens unknown.

Table 1. Information on the barcoded specimens used in phylogenetic analysis.

| Taxon | Sample ID / GenBank ## | Sex | Collection data | Collection |
|---------------------|-------------------------|-----|---------------------------------------------------------------------------------------------------|------------|
| <i>M. rubi</i> | RONOC001-16 / OP013270 | ♂ | Romania, Cluj County, Floresti, 46.75 N, 23.52 E, 358 m, 21.V.1988 | CCS |
| <i>P. hausmanni</i> | LBEOW1514-11 / OP013269 | ♂ | Iran, Kohgiluyeh and Boyer-Ahmad Province, Yasuj, 30.70 N, 51.60 E, 2400 m, 29.VI.2005 | CMS |
| | RONOC163-18 / OP013272 | ♂ | Iran, Kohgiluyeh and Boyer-Ahmad Province, Zagros Mountains, 31.10 N, 50.72 E, 2431m, 15.VII.2006 | CSL |
| <i>P. otus</i> | LBEOW1513-11 / OP013268 | ♂ | Croatia, Lika-Senj County, Sveti Juraj (Lopci), 44.91 N, 14.93 E, 350 m, 12.VII.2002 | CMS |
| | LBEOW1857-11 / OP013267 | ♂ | Lebanon, North Governorate, Chira, 34.27 N, 35.86 E, 700 m, 2.X.2008 | MWM/ZSM |
| | PHLAJ071-13 / OP013263 | ♂ | Greece, Epirus, Agia Paraskevi, 40.14 N, 20.86 E, 700 m, 1.VIII.2012 | KLM |
| | RONOC087-16 / OP013271 | ♂ | Greece, Rhodos, 10.IX.2007 (ex. ovo) | CCS |

= *Phalæna Bombyx fulminea* Goeze, 1781, *Entomologische Beyträge zu des Ritter Linné zwölften Ausgabe des Natursystems* 3, 65. Type locality not stated. Type specimens unknown.

= *Bombix agrius* Olivier, 1790, *Encyclopédie méthodique. Insectes* 5, 39. Type locality: the Levant, in Smyrna, on the side of Syria. Type specimens unknown.

= *Bombyx dryophaga* Geyer, 1828, In: Hübner, J. (ed.) *Sammlung europäischer Schmetterlinge*, Lepidoptera 3, Figs 306, 307. Type locality not stated. Type specimens unknown.

= *Pachypasa otus fulvescens* Kotsch, 1932, *Internationale Entomologische Zeitschrift*, 25(43), 440. Type locality: [probably Syria, Meidan Ekbiz] Syria, Akbés. Type specimens unknown.

Diagnosis. Light to dark brown-colored moth with dark crenated medial lines, average wingspan 85 mm in males and 100 mm in females. The second lasiocampid species in size after *P. hausmanni* sp. nov. within the Palaearctic realm, externally more contrasty and does not fly in Iran. Male genitalia accordingly smaller, phallobase medially less swollen and bent. Antevaginal plate in female genitalia about 3 times smaller.

External variability (Figs 1–22). Dark brown speckles on male forewing vary from sparse to very dense, hindwing color from creamy to brown. Female forewing from creamy with dense brown speckles to brown, hindwing more or less dark with more or pronounced dark external field.

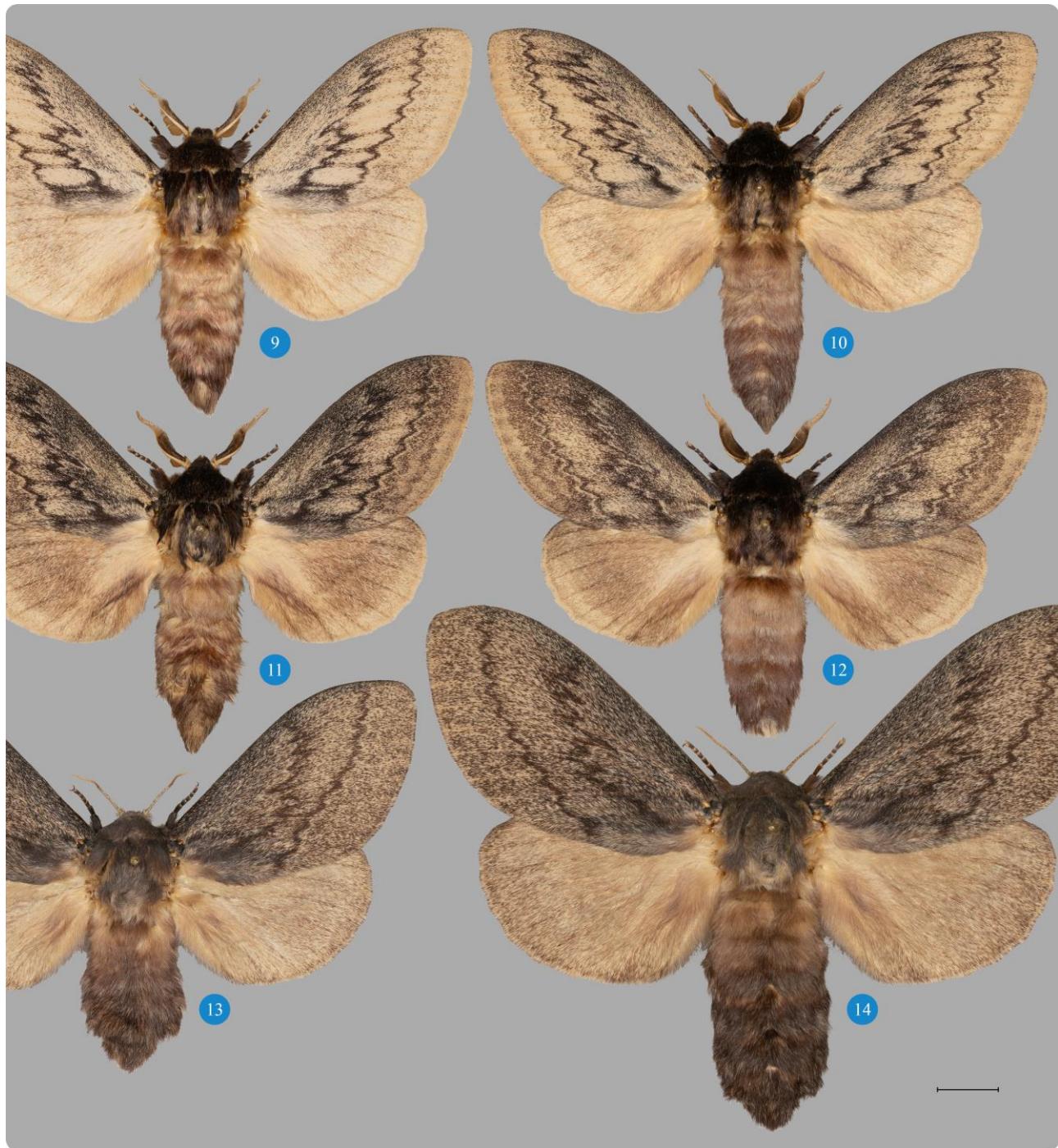
Distribution (Fig. 37). *Europe*: Sicily and the Italian Peninsula, the Balkans along the Adriatic, Ionian, Aegean, and Mediterranean seas; *Asia*: from Western Turkey eastwards to Georgia and southwards through the Levant; *Africa*: South Egypt. In Egypt and Western Saudi Arabia all records are from urban environments, the species was most likely introduced with ornamental pine trees. It is not clear if they will survive over the long run.

Taxonomic note. 1. Drury figured and described *P. otus* in the first volume of *Illustrations of natural history* (1770: 30–31, plate XVI, fig. III), but he did not provide the name of the species. The name appeared in the index of the first volume which “was not published until 1773” (Hemming, 1958). Therefore, 1773 is considered the year of the original description instead of 1770.



Figures 1–8. Adults of *P. otus* (all MWM/ZSM). 1. Female, S Italy, Foggia. 2. Male, Sicily. 3. Female, Croatia, Lovran. 4. Male, Croatia, Zadar. 5–6. Female and male, Greece, Rhodes. 7. Male, Greece, Crete. 8. Male, North Macedonia, Nikolić. Scale bar – 1 cm.

2. Zolotuhin and Gurkovich (2009: 7) mentioned the “brighter sandy-yellow” coloration of *P. otus fulvescens* which is a mistake. Kotzsch (1932) wrote that adults of *P. otus fulvescens* are “[...] not only much larger than the Dalmatian form in both sexes, but also have much darker forewings and with a reddish sheen



Figures 9–14. Adults of *P. otus* bred from the type locality – W Turkey, İzmir (SMNS). Scale bar – 1 cm.

of the hindwings [...]” (“In einer großen Ausbeute aus Syrien (Akbés) erhielt ich unter anderem eine Anzahl *Pachypasa otus* Dru., welche nicht nur in beiden Geschlechtern viel größer als die Dalmatiner Form sind, sondern auch viel dunklere Vorderflügel haben und mit rötlichem Schein der Hinterflügel; dem Thorax fehlt die übliche Aufhellung. Ich schlage für diese Form den Namen *fulvescens* vor.”) Indeed, most European and Balkan male adults in collections are light creamy-colored (Figs 2, 4, 6 and 9 from the type locality of *P. otus*) – this is the “Dalmatian form” sensu Kotzsch – and some males from Syria and surrounding countries are bigger and darker – that is the form *fulvescens* (Fig. 20). Although, pale, dark and intermediately colored adults occur sympatrically in various locations (Figs 9–14). Mediocaudal outgrowth of cubile (sensu Lajonquière, 1968; Fig. 28, shown with arrow) also vary in size from very short to slightly elongated c-shaped and does not correlate with wing coloration or collecting locality (Figs 28–32). Average pairwise

distance in COI between three European (one Croatian, LBEOW1513-11 and two Greek, PHLAJ071-13 and RONOC087-16) and one Lebanese specimen (LBEOW1857-11) is only 0.3%. Thus, due to lack of any stable morphological characters or significant genetic distance whithin *P. otus*, we do not divide it into subspecies.



Figures 15–22. Adults of *P. otus*. 15–16. Female and male, Georgia, Vashlovani Reserve (GNMT). 17–18. Males, E Turkey, Province Tunceli (MWM/ZSM). 19. Male, E Turkey, Nur Mts (MWM/ZSM). 20. Male, SW Jordan, Ar Rajif (MWM/ZSM). 21. Male, SE Egypt, Ras Gharib (MWM/ZSM). 22. Male, Israel, 21 km SW Jerusalem (MWM/ZSM). Scale bar – 1 cm.

Material examined: **Italy:** ♀, Foggia, 27.VII.1987 (MWM/ZSM); ♂, ♀, Sicily (ZSM); ♂, Sicily, Biancavilla, 1500 m, 10.VII.1983, leg. Tardelli (CGM). **Croatia:** ♀, Lovran, 31.VII.1962, leg. Friedel (MWM/ZSM); ♂, Zara, 1.IX.1936 (MWM/ZSM); ♀, Zara (MWM/ZSM); ♀, Zara, 8.VII.1965, leg. Eidkum (MWM/ZSM); ♀, “Dalmatien” (MWM/ZSM). **Greece:** ♂, Peloponnes, Zachlorou, 600 m, VIII.1961, leg. H.

Noack (MWM/ZSM); ♂, Crete, ex larva 20–24.VI.1987, leg. Wenzel, genitalia slide 13.504 (MWM/ZSM); ♂, Crete, Anogia, 15.VII.1988, leg. M. Hreblay (MWM/ZSM); ♂, Rhodes, ex ovo 22.I.1988, leg. R. Gleichauf (MWM/ZSM); ♂, Rhodes, ex larva 9.II.1988, leg. R. Gleichauf (MWM/ZSM); ♀, Rhodes, ex larva 22.I.1988, leg. R. Gleichauf (MWM/ZSM). **North Macedonia:** ♂, Nikolić, 29.[?].1918, leg. H. Burgeff (ZSM). **Turkey:** ♂, ♀, İzmir (ZSM); 4♂, 2♀, İzmir env., ex larva 17.IX.1974, 21.IX.1974, 7.X.1974, 20.X.1974, 23.X.1974, leg. H. Horwath (SMNS); ♂, Alanya, 10–25.VI.1983, leg. J. Mooser, genitalia slide otus-1 (CGM); ♂, Turgutlu, 5.IX.1986, leg. A. Schneider (CGM); 3♀, Adana, 11.IX.1987, leg. Kuchler (CGM); 3♂, Province Tunceli, Munzur Dağları, 28 km E Tunceli, Munzur Vadisi Milli Park, 1080 m, 30.VII.2005, 31.VII.2005, 7.VIII.2005, leg. T. Csőváry (MWM/ZSM); ♂, Province Tunceli, 15 km NW Tunceli, 1050 m, 7–9.VIII.1992, leg. P. Kautt & V. Weiss (MWM/ZSM); ♂, ♀, Province Van, 10 km N of Catak, 43°05'E, 38°05'N, 20–21.VII.1989, leg. P. Gyulai & M. Hreblay, genitalia slide 8017 (MWM/ZSM); ♀, E Anatolia, Hakkari, 2500 m, 20–30.VII.1983, leg. J. Mooser, genitalia slide otus-2 (MWM/ZSM). **Georgia:** ♂, ♀, Vashlovani Reserve, 15.VIII.1976, leg. E. Didmanidze (GNMT). **Syria:** 2♂, 2♀, Amanus-Geb., 1200 m, leg. Gurndach (MWM/ZSM). **Lebanon:** ♂, Berhalion, Shira env., ca. 700 m, 2.X.2008, leg. I. & A. Floriani, A. Saldaitis, LBEOW1857-11 (MWM/ZSM); ♂, Bscharre, 1300 m, VIII–IX.1931 (MWM/ZSM). **Armenia:** ♂, 2♀, Tatev Valley, 900 m, 29.VII.2022, leg. A. Saldaitis (CAS). **Jordan:** 4♂, ♀, Ar Rajif, ca. 1200 m, XI–XII.2002, leg. G. Müller (MWM/ZSM); ♀, Amman, IX.1964 (MWM/ZSM). **Israel:** ♂, Northern Golan Heights, Majdal Shams, 1200 m, mid VIII.2000, leg. G. Müller, genitalia slide 10.632 (MWM/ZSM); ♂, Mt Hermon, Upper Cable, 2100 m, VIII.2000, leg. G. Müller (MWM/ZSM); ♂, 21 km SW Jerusalem, Hadassa, 800 m, 4.IX.1994, leg. G. Müller (MWM/ZSM); ♀, 9 km W Jerusalem, Moza Izlit, 900 m, 15.IX.1994, leg. G. Müller (MWM/ZSM); ♂, Dead Sea, En-Gedi, 27.XI.2005, leg. G. Müller, genitalia slide otus-3 (CGM); ♀, Mt Hermon, early VII.2009, leg. V. Kravchenko & G. Müller (CGM). **Saudi Arabia:** ♀, Jabal Ra's Madhar, 800 m, 15.XI.2001, leg. A. Saldaitis (CGM). **Egypt:** ♂, Eastern Desert, Marsa Alam City, 50 m, IX.2003, leg. G. Müller (MWM/ZSM); ♀, Eastern Desert, Upper Nile, Aswan, IX.2003, leg. G. Müller (MWM/ZSM); ♂, Eastern Desert, Ra's Gharib City, 50 m, X.2002, leg. G. Müller (MWM/ZSM); ♂, Eastern Desert, Hurghada City, 50 m, leg. G. Müller (MWM/ZSM).

***Pachypasa hausmanni* sp. n.**

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(Figs 23–27, 33–34, 37, 38–40)

Type material: HOLOTYPE ♂, **Iran**, Fars Province, 17.7 km SE Komehr, 30.50221 N, 51.70643 E, 2417 m, 30.VI.2005, leg. T. Hácz, G. Juhász, L. Ábrahám, G. Petrányi (ZSM). **PARATYPES** (29♂, 3♀): **Iran, Fars Province:** ♂, Zagros Mts, Sepidan, 2400–3000 m, 15.VII.2000 (CAF); 18♂, 17.7 km SE Komehr, 30.50221 N, 51.70643 E, 2417 m, 30.VI.2005, leg. T. Hácz, G. Juhász, L. Ábrahám, G. Petrányi (CGM); ♂, Zagros Mts., Barm Firuz Mt., 15 km S Komehr, 30.3417 N, 51.9555 E, 3000 m, 26.VI.2000, leg. Gy. Fábián & K. Székely (CMS); 3♂, Ardekan – Talochosroe road, Comé, 2600 m, VII.1937, leg. Brandt, 7138 E95, 7139 E95 (SNHM); ♀, Chiraz – Kazeroun road, Fort Mian – Kotal, ca. 2000 m, 26.VIII.1937, leg. Brandt, 7136 E95 (SNHM). **Kohgiluyeh and Boyer-Ahmad Province:** ♂, Zagros Mts, Yasuj, 2400 m, 28–30.VI.2005, leg. T. Hácz (CGM); ♂, Zagros Mts, Yasuj, 2400 m, 28–30.VI.2005, leg. T. Hácz, LBEOW1514-11 (CMS); ♀, Zagros Mts, Yasuj, 2500 m, 7–9.VII.2006, leg. T. Hácz (CMS); 3♂, ♀, Zagros Mts, near Meymand, 2500 m, 11–12.VII.1999, leg. A. Hofmann, J. Meineke (CJM); ♂, Zagros Mountains, 31.10 N, 50.72 E, 2431m, 15.VII.2006, leg. Sz. Levente (CSL); ♂, Yasuj, Sisakht, Dena, 30.9565 N, 51.3914 E, 2799 m, 30.VII.2016, leg. Sh. Feizpour (SMNS). **Kermanshan Province:** ♂, 40 km S Schahabad, Ghalladje Pass, 1880 m, 13.VII.1975, leg. Ebert & Falkner (SMNK).

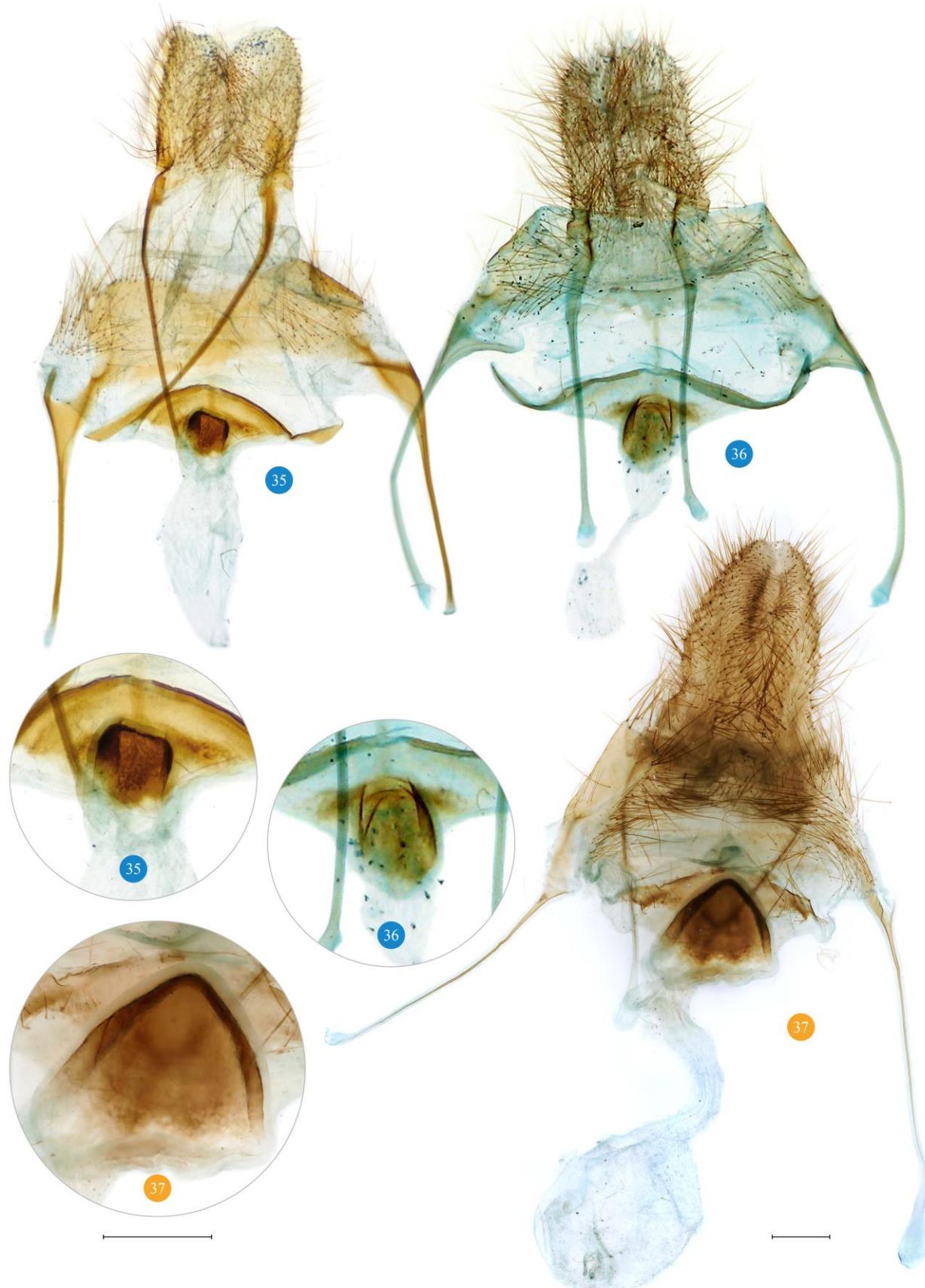
Diagnosis. Brown-colored moth with dark crenulated medial lines on the forewing and a dark hindwing. The average wingspan is 95 mm in males and 140 mm in females. The largest lasiocampid species within the Palaearctic region, externally less contrast than *P. otus*. Male genitalia accordingly bigger, phallobase medially more swollen and bent, microcornuti on vesica better developed. Antevaginal plate in female genitalia about 3 times bigger. Endemic in Iran.



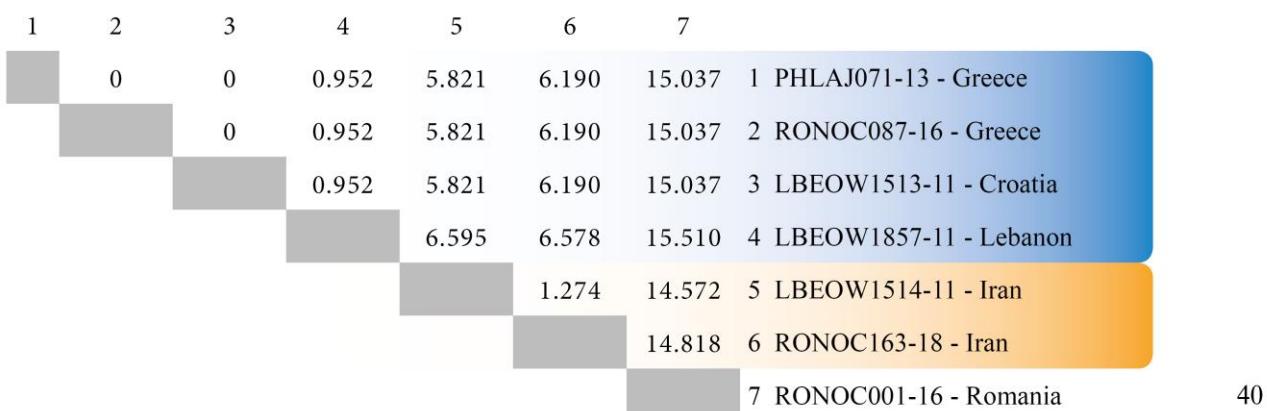
Figures 23–27. Adults of *Pachypasa hausmanni*. 23. Male paratype, Iran, Province Fars (CGM). 24. Male holotype, Iran, Province Fars (ZSM). 25. Male paratype, Iran, Province Kohgiluyeh and Boyer-Ahmad (CGM). 26. Male paratype, Iran, Province Fars (CGM). 27. Female paratype, Iran, Province Fars (RMS). Scale bar – 1 cm.



Figures 28–33. Male genitalia. 28–31. *P. otus*. 28. Greece, Crete, genitalia slide 13.504 (MWM/ZSM). 29. SW Turkey, Alanya, genitalia slide otus-1 (CGM). 30. SE Turkey, Province Van, genitalia slide 8017 (MWM/ZSM). 31. Israel, N Golan Heights, genitalia slide 10.632 (MWM/ZSM). 32. Israel, Dead Sea, genitalia slide otus-3 (CGM). 33–34. *P. hausmanni*. 33. Holotype, Iran, Province Fars, genitalia slide hausm-1 (CGM). 34. Paratype, Iran, Province Kohgiluyeh and Boyer-Ahmad, genitalia slide hausm-2 (CGM). Scale bar – 1 mm.



Figures 35–37. Female genitalia of *Pachypasa* spp. 35–36. *P. otus*. 35. SE Turkey, Hakkari, genitalia slide otus-2 (CGM). 36. Croatia, genitalia slide 13.235 (MWM/ZSM). 37. *P. hausmanni*, Iran, Kohgiluyeh and Boyer-Ahmad Province (CJM). Scale bar – 1 mm.



Figures 38–40. Principal differences between *P. otus* (light blue) and *P. hausmanni* (orange): 38. Distribution map (for details visit bit.ly/3O5PbcG). 39. Phylogenetic tree (NJ, Kimura-2, 1000 replicates). 40. Genetic distances (%).

Description. Male habitus (Figs 23–27). Head ash brown to brown, flagellum speckled brown. Antenna pectination gradually shortens apically. Thorax dorsolaterally ash brown, medially paler. Abdomen speckled brown. Forewing length: 47–52 mm; wingspan: 90–99 mm. Wing elongated, apex obtuse. The background color is pale brown with dark speckles. The forewing pattern consists of two dark brown crenulated medial lines, speckles may lay along veins, and hindwing may have a darker medial field with a more or less pronounced speckled external band. Cilia is pale brown, distally darkened. **Male genitalia** (Figs 33–34).

Tegumen is a triangular band loosely covered with chaetae; it bears a pair of tubercle-shaped socii covered with chaetae. Vinculum distally elongated with fused distal processes (cubile sensu Lajonquière, 1968), each of two processes triangular, mediocaudally harder sclerotized with short apically rounded distal outgrowth. Sacculus elongated, finger-shaped, apically rounded and bent, and loosely covered with chaetae. Cucullus is almost twice shorter than the sacculus, triangular, apically pointed, and covered with chaetae. Juxta is medially fused with aedeagus. Aedeagus c-shaped, hardly sclerotized; caulis short (Fig. 33) to elongated (Fig. 34, shown with arrow); phallobase medially widened, apically pointed. Vesica compact, apically narrowing, its surface rough, covered with something resembling microcornuti. **Female habitus** similar to male (Fig. 27), but larger and fore wings darker with dense speckles, antenna pectination shorter. Forewing length: 65–74 mm; wingspan: 130–155 mm. **Female genitalia** (Fig 37). Papillae anales elongated, densely covered with chaetae. Posterior apophyses are slightly shorter than anterior. Lamella antevaginalis triangular with a wide base, and lamella postvaginalis is a narrow somewhat rhomboid-shaped band. Ductus bursae about the length of corpus bursae, membranous, wrinkled. Corpus bursae spherical, medium-sized.

Etymology. We name the largest Palaearctic Lasiocampidae species after our dear friend Dr. Axel Hausmann (ZSM).

Distribution. Endemic in Iran: Fars, Kohgiluyeh and Boyer-Ahmad, and Kermanshan provinces (Fig. 37; Zolotuhin & Zahiri, 2008).

Biology. Adults were collected in June, July, and August, the new species is local within the Zagros Mountains forest steppe ecoregion (Dinerstein et al., 2017). Specimens were collected from 1880 to 3000 m a.s.l. Modares Awal (1997) recorded early stages feeding on *Pistacia*, *Quercus*, *Juniperus*, and *Cypressus sempervirens* var. *cereiformes*.



Figures 41–42. Habitat (41) and adult female of *P. hausmanni* (42) near Meymand in Zagros Mts, 2500m, Kohgiluyeh and Boyer-Ahmad province, Iran (photos: A. Hofmann)

Molecular Analysis

In the molecular analysis, we examined 6 sequences of *Pachypasa*: 4 sequences of *Pachypasa otus* (2 from Greece, 1 from Croatia, and 1 from Lebanon) and 2 sequences of *Pachypasa hausmanni* sp. n., registered in BOLD, and they were submitted to GenBank (OP013263, OP013267–OP013272, see Table 1 for details). The neighbor-joining (NJ) tree was made based on all 6 sequences (Figure 38). The lowest values of the recorded genetic distances are 0 between specimens of *Pachypasa otus* from Greece and Croatia. The average distance between the four *P. otus* sequences is 0.3%. The distance between the two *P. hausmanni* sp. n. sequences is 1.2%. The average genetic distance between *P. hausmanni* and *P. otus* is 6.1%. The genetic distance from the out-group for *P. otus* is 15.1%, and for *P. hausmanni* is 14.6%. The values of genetic distance between the sequences of *Pachypasa* and the out-group are shown in Figure 40.

Our results show that DNA barcoding worked well in discriminating *Pachypasa* sequences. According to Hebert *et al.* (2003), divergence values between species are ordinarily greater than 3%. In our case, the genetic distance of 6% between the sequences of *P. otus* and *P. hausmanni* sp. n. indicates the existence of two distinct species.

Conclusion

Because of the lack of morphologically or genetically defined intraspecific groups within *P. otus*, additional genetic analysis of Italian and Caucasian specimens may show further genetic diversity. The recently discovered Italian *Lemonia italiana* Prozorov *et al.*, 2022 the Caucasian *Tethea or monazoni* Zolotuhin, 2021 and the Iranian *P. hausmanni* sp. n. show that there is still room for new findings in presumably well-known taxa in the West Palearctic.

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