ZooKeys 351: 1–30 (2013)
doi: 10.3897/zookeys.351.5413
www.zookeys.org

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

Description of *Eucyclops tziscao* sp. n., *E. angeli* sp. n., and a new record of *E. festivus* Lindberg, 1955 (Cyclopoida, Cyclopidae, Eucyclopinae) in Chiapas, Mexico

Martha Angélica Gutiérrez-Aguirre[1,†], Nancy Fabiola Mercado-Salas[2,‡], Adrián Cervantes-Martínez[1,§]

1 *Universidad de Quintana Roo (UQROO), Unidad Cozumel, Av. Andrés Quintana Roo s/n, 77600, Cozumel, Quintana Roo México* **2** *El Colegio de la Frontera Sur (ECOSUR). Unidad Chetumal. Av. Centenario Km. 5.5. Chetumal, Quintana Roo 77014. México*

† *http://zoobank.org/D483F129-B176-4144-A568-5A1A0B26F41F*
‡ *http://zoobank.org/313DE1B6-7560-48F3-ADCC-83AE389C3FBD*
§ *http://zoobank.org/270DEC5B-73CE-460E-80EC-D59DB1995054*

Corresponding author: *Martha A. Gutiérrez-Aguirre* (margutierrez@uqroo.mx; marguta71@gmail.com)

Academic editor: *Danielle Defaye* | Received 26 April 2013 | Accepted 31 October 2013 | Published 15 November 2013

http://zoobank.org/D7E7117C-368A-423F-B6ED-1E4E35B6528C

Citation: Gutiérrez-Aguirre MA, Mercado-Salas NF, Cervantes-Martínez A (2013) Description of *Eucyclops tziscao* sp. n., *E. angeli* sp. n., and a new record of *E. festivus* Lindberg, 1955 (Cyclopoida, Cyclopidae, Eucyclopinae) in Chiapas, Mexico. ZooKeys 351: 1–30. doi: 10.3897/zookeys.351.5413

Abstract

Two new species of the freshwater cyclopoid genera *Eucyclops* are described, *Eucyclops tziscao* sp. n. and *E. angeli* sp. n. Both species belong to the *serrulatus*-group defined by morphological features such as: the presence of distal spinules or hair-like setae (groups N1 and N2) on frontal surface of antennal basis; the fourth leg coxa with a strong inner spine that bears dense setules on inner side, yet proximally naked (large gap) on outer side; and a 12-segmented antennule with smooth hyaline membrane on the three distalmost segments. *Eucyclops tziscao* **sp. n.** is morphologically similar to *E. bondi* and *E. conrowae* but differs from these species in having a unique combination of characters, including a caudal ramus 4.05±0.25 times as long as wide, lateral seta of Enp3P4 modified as a strong, sclerotized blunt seta, coxal spine of fourth leg with inner spinule-like setules distally, and sixth leg of males bearing a strong and long inner spine 2.3 times longer than median seta. *Eucyclops angeli* **sp. n.** can be distinguished by an unique combination of morphological features: the short caudal ramus; the long spine on the sixth antennular segment of A1; the presence of one additional group of spinules (N12') on the caudal surface of A2; the presence of long setae in females, or short spinules in males on the lateral margin of fourth prosomite; the strong ornamentation of the intercoxal sclerite of P4, specially group I modified as long denticles; the distal modified setae of Exp3P3 and Exp3P4 in females and males; and the short lateral seta of P5. Finally, we report on a new record of *E. festivus* in México, and add data on morphology of the species.

Keywords
Copepoda, description, freshwater, free-living, Neotropical

Introduction

Eucyclops Claus, 1893 is the largest genera of the subfamily Eucyclopinae, currently comprising up to 108 species and subspecies distributed mainly in the tropics (Dussart and Defaye 2006, Alekseev and Defaye 2011). Because of its high diversity, this group is one of the taxonomically most challenging genera within the freshwater Copepoda, with several problematic taxa and with high intraspecific variation in some species groups. Also, many *Eucyclops* species are poorly described, therefore the taxonomic position of them remain uncertain (Collado et al. 1984, Reid 1985, Ishida 1997, Suárez-Morales 2004, Mercado-Salas et al. 2012). Nonetheless significant attempts have been made to revise the most problematic species groups in the genus: Ishida (1997, 2001, 2002, 2003) revised the "*serrulatus*-like" and "*speratus*-like species" from Japan; while Alekseev et al. (2006) and Alekseev and Defaye (2011) provided a world-scale overview of the taxonomy and zoogeography of the *Eucyclops serrulatus*-group. These studies revealed the diagnostic significance of many previously neglected characters [e.g. ornamentation of the antennal basis and swimming legs (the fourth leg in particular), or pore signature] which might be also useful in the delineation of other taxa.

In the Americas there are more than 800 records of the genus, corresponding to 28 nominal species, most of which are distributed in the eastern of United States, México, Argentina, and Brazil. Approximately 38% of these records have been assigned to the problematic taxa *Eucyclops serrulatus* (Fischer, 1851) and *Eucyclops agilis* (Koch, 1838) (Lindberg 1955, Collado et al. 1984, Reid 1985, Suárez-Morales 2004, Bruno et al. 2005, Frisch and Threlkeld 2005, Gaviria and Aranguren 2007, Elías-Gutiérrez et al. 2008, Suárez-Morales and Walsh 2009, De los Ríos et al. 2010).

In México 13 species have been recorded so far: *E. agilis* (synonym of *E. serrulatus*), *E. bondi* Kiefer, 1934; *E. chihuahuensis* Suárez-Morales & Walsh, 2009; *E. conrowae* Reid, 1992; *E. cuatrocienegas* Suárez-Morales & Walsh, 2009; *E. elegans* (Herrick, 1884), *E. festivus* Lindberg, 1955; *E. leptacanthus* Kiefer, 1956; *E. pectinifer* (Cragin, 1883), *E. prionophorus* Kiefer, 1931; *E. pseudoensifer* Dussart, 1984; *E. serrulatus* (probably *E. pectinifer*) and *E. torresphilipi* Suárez-Morales, 2004 (Lindberg 1955, Zamudio-Valdéz 1991, Suárez-Morales and Reid 1998, Suárez-Morales 2004, Mercado-Salas 2009).

Grimaldo-Ortega et al. (1998), Elías-Gutiérrez (2000), Rodríguez-Almaraz (2000), Suárez-Morales (2004), and Mercado-Salas (2009) have documented morphological differences between the Mexican populations and the original descriptions of those *Eucyclops* taxa, which indicated that a few undescribed species might have been hidden under the name of the "cosmopolitan" species. Also Suárez-Morales (2004) and Suárez-Morales and Walsh (2009) mentioned that the species richness of *Eucyclops* in Mexico could be underestimated.

In agreement with this assumption, we describe two new *Eucyclops* species and report the new record of a third one in Chiapas, México. Chiapas is one of the hydrologically richest regions in Mexico, with numerous and diverse aquatic environments such as rivers, lakes, lagoons, reservoirs and a large coastline (Velázquez-Velázquez 2011). Although in recent years substantial progress has been made in the knowledge about the freshwater fauna in this region (mainly fishes), hardly anything is known about other animal groups, such as the crustaceans for instance (Velázquez-Velázquez 2011).

The knowledge of the copepod fauna in Chiapas and the cyclopoids in particular, is almost null; only eighteen species have been recorded (Suárez-Morales 2004, Gutiérrez-Aguirre et al. 2006, Elías-Gutiérrez et al. 2008, Gutiérrez-Aguirre and Cervantes-Martínez 2013). Thus the goal of this study is to contribute to the basic knowledge of the freshwater Copepoda of this region.

Methods

The samples were collected from the limnetic zone of Laguna Tziscao, as well as from the littoral of some ephemeral or permanent reservoirs in Chiapas (México) in 2000-2001. The collecting sites (1500 masl) are shown in Fig. 1. The samples were collected by standard plankton net of 0.05 mm mesh-size, performing near-shore and limnetic plankton trawls. The biological specimens were fixed and preserved in 70% ethanol, and then processed for identification following the techniques described by Reid (2003). All adult *Eucyclops* in the samples were identified to species level.

The specimens were dissected with tungsten needles and the appendages were mounted in glycerin for taxonomic analysis. The mouth parts, swimming legs, and other taxonomically important structures were illustrated with the aid of a camera lucida. Specimens were deposited in the Collection of Zooplankton of ECOSUR at Chetumal, Mexico (ECO-CH-Z), in the Collection of Copepoda of the Muséum National d'Histoire Naturelle (MNHN-IU) Paris, and in the Colección Nacional de Crustáceos (CNCR) del Instituto de Biología, Universidad Nacional Autónoma de México. Examination of the specimens has been performed following the current methods used in the morphological investigations of Eucyclopinae (Alekseev 2000, Alekseev et al. 2006).

Abbreviations used in the descriptions are as follows: A1, antennule; A2, antenna; P1-P4, first to fourth swimming legs; P5, fifth leg; Exp, exopod; Enp, endopod; s, seta(e); ae, aesthetasc; sp, spine; Bsp, basis; Fu, caudal ramus. The terminology used for the armament of the antenna and swimming limbs is what was proposed by Alekseev et al. (2006) and Alekseev and Defaye (2011).

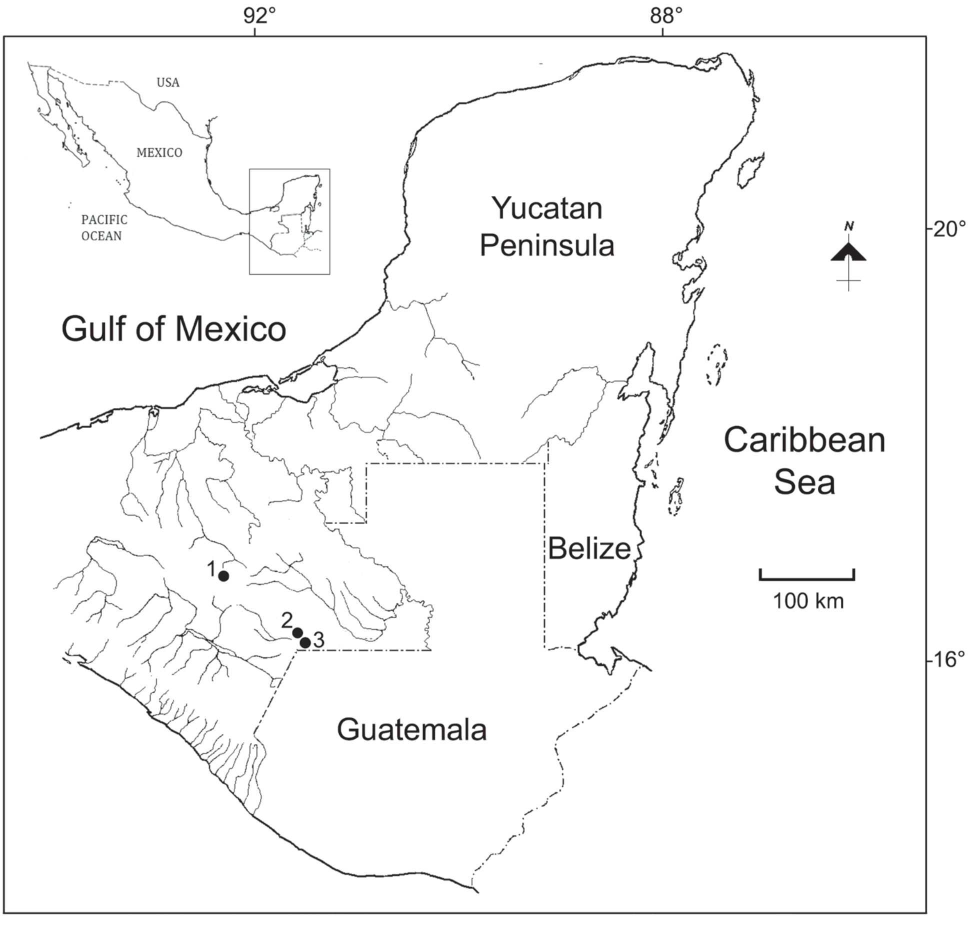


Figure 1. Collecting sites at Chiapas, México. **1** San Cristóbal de las Casas **2** Pond 3 to Laguna Montebello **3** Laguna Tziscao.

Results

Order Cyclopoida Burmeister, 1834
Family Cyclopidae Dana, 1846
Subfamily Eucyclopinae Kiefer, 1927
Genus *Eucyclops* Claus, 1893

***Eucyclops tziscao* Mercado-Salas, sp. n.**
http://zoobank.org/967E9152-65BF-4F59-9D91-ACFF91C7834B
http://species-id.net/wiki/Eucyclops_tziscao
Figs 2–4

Synonym. *Eucyclops bondi*: Gutiérrez-Aguirre and Cervantes-Martínez (2013), Table 1.

Table 1. Comparative material: locality and data on slide labels.

Species	Slide reference number
Eucyclops bondi	SMNK 02079, female sp. n., Trou Caiman, Haiti. 16.02.1933
	SMNK 02080, male, Typus, Trou Caiman, Haiti, 16.02.1933
	SMNK 02393, female, Laguna Rincon, Haiti
	SMNK 02394, female, Laguna Rincon, Haiti
Eucyclops conrowae	USNM-251325, holotype, Id: Janet W. Reid; Collector: R. Conrow; Shark River
	Slough, Everglades National Park, Florida, United States. 1986.
	USNM-251327, paratype; Id: Janet W. Reid; Collector: R. Conrow; Shark River
	Slough, Everglades National Park, Florida, United States. 1986.

Material examined. Holotype: Adult ♀ specimen dissected, mounted in glycerin sealed with Entellan (ECO-CH-Z-08970). Allotype: Adult ♂, dissected, mounted in glycerin sealed with Entellan (ECO-CH-Z-08971). Paratypes: Eight adult ♀♀, one adult ♂ and two copepodites undissected ethanol-preserved (90%) (ECO-CH-Z-08972); three adult ♀♀, undissected, ethanol-preserved (90%) (CNCR-27840). The types were collected at 15.April.2000 by A. Cervantes-Martínez, M. A. Gutiérrez-Aguirre and M. Elías-Gutiérrez.

Comparative material. To complement the morphological analysis, we also examined the type specimens of *E. bondi* deposited in the Staatliches Museum für Naturkunde Karlsruhe (SMNK) from Kiefer's collection, and the type specimens of *E. conrowae* deposited in the National Museum of Natural History Smithsonian Institution, in Washington D. C. (USNM) (Table 1).

Type locality. Laguna Tziscao, Chiapas, México (16°05'19"N; 91°40'10"W). At sampling the maximum depth was 74.5 m, the water temperature 22°C, and the dissolved oxygen 6.6 mg L^{-1}. The system is considered as one of the deepest, oligotrophic lagoons in the southern Mexico, with karstic origin, located in Lagunas de Montebello National Park which belongs to the Usumacinta biogeographic province.

Etymology. The species name is a noun in apposition that makes reference to the Lagoon where the species was collected from. Tziscao (*Tz´isk´a´aw*) is a term composed by two words in the chuj local language (one of the Mayan languages), and it refers to the stone bridge made by hand by the first settlers of the community.

Description. *Female*: Habitus as in Fig. 2A. 620 µm of total body length excluding caudal setae. Prosome expanded at first and second somite, representing 61% of total body length symmetrical in dorsal view. Five-segmented urosome relatively elongated, urosomal fringes strongly serrated (Fig. 2B); posterior margin of anal somite with one row of long spinules. Genital double-somite (Fig. 2C) symmetrical, carrying paired egg sacs. Lateral arms of seminal receptacle rounded on posterior margin. Genital double-somite 1.3 times as long as wide. Anal somite with hair-setae in anal opening, anal operculum serrated (Fig. 2D). Caudal ramus 4.0 times as long as width; inner margin naked, strong spines on the lateral margin (serra) extending 40% of ramus length (Fig. 2D). Dorsal seta (VII) short: 0.65 times the length of caudal ramus, and 1.1 times as long as outermost caudal seta (III). Ratio of innermost caudal seta

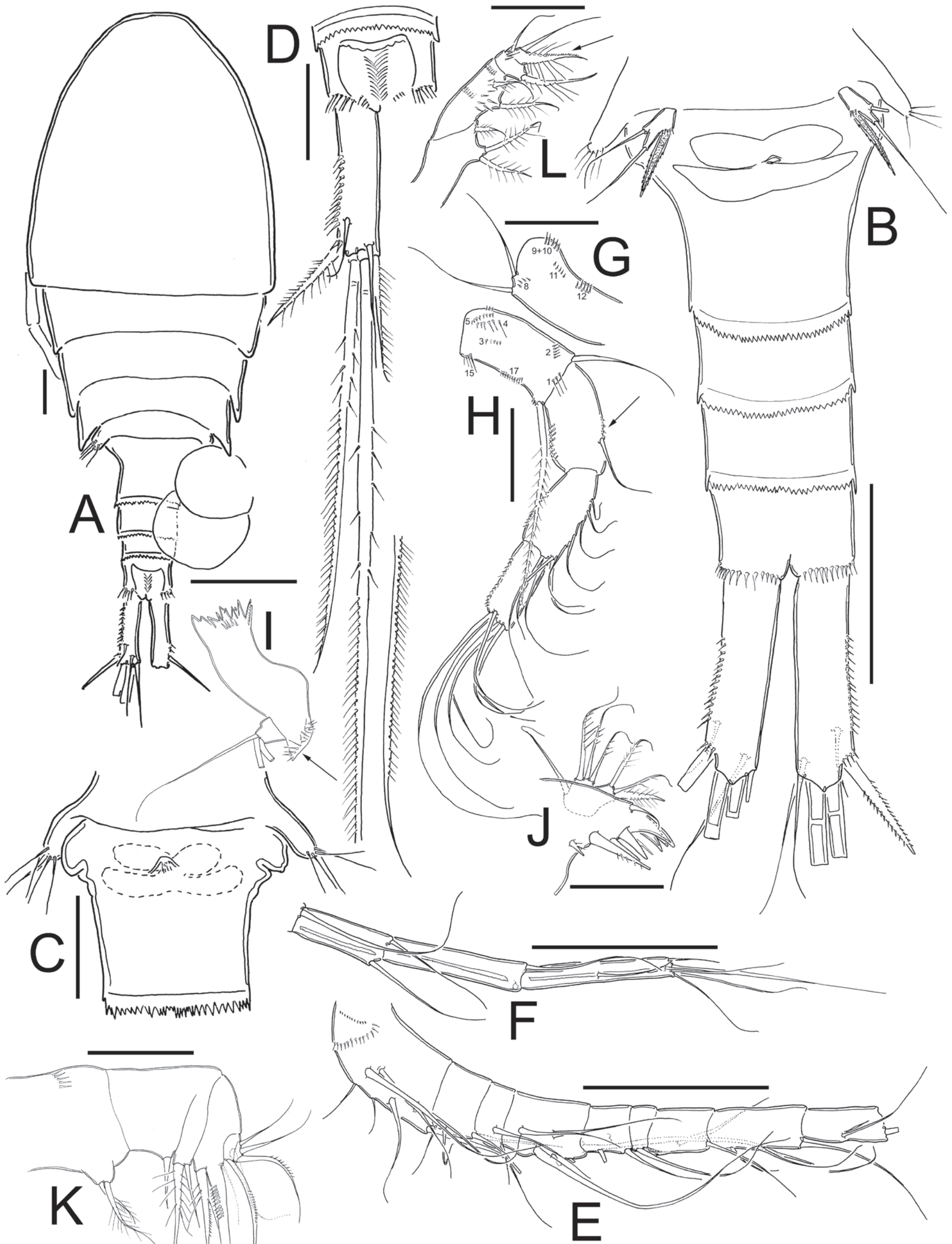


Figure 2. *Eucyclops tziscao* sp. n. **A, C, D** paratype **B, E–L** holotype from Laguna Tziscao, Chiapas. **A** Habitus, dorsal **B** Urosome **C** Genital double-somite, ventral **D** Anal somite and caudal ramus, dorsal **E** Antennule, segments 1–9 **F** Antennule, segments 10–12 **G** Antenna, caudal **H** Antenna, frontal **I** Mandible **J** Maxillule, caudal **K** Maxilla, frontal **L** Maxilliped, frontal. Scales bars: **K** = 20 µm; **A, C, D, G, H, I, J, L** = 50 µm; **B, E, F** = 100 µm.

(VI)/outermost caudal seta (III) is 1.2. Lateral caudal seta (II) inserted at 71% of caudal ramus. All the terminal caudal setae plumose.

Antennule (Figs 2E, F): 12-segmented, reaching from middle to distal margin of third prosomite; last three segments with finely denticulate hyaline membrane at distal margin. Armament per segment as follows (s= seta, ae= aesthetasc, sp= spine):1(8s), 2(4s), 3(2s), 4(6s), 5(4s), 6 (1s+1sp), 7(2s), 8(3s), 9(2s+1ae), 10(2s), 11(3s), 12(8s). Two rows of spines on first segment, first row with small spinules and second row with stronger and longer spinules. Spine on sixth segment reaching middle of seventh antennular segment.

Antenna (Figs 2G, H): Coxa (no seta), basis (2s + 1 seta representing Exp), plus 3-segmented Enp (first to third Enp with 1, 9 and 7 setae, respectively). Basis ornamented with: N1 (3-4 hair-setae), N2 (5 small spinules), N3, N4, N5, N15, and N17 on frontal surface (Fig. 2H); and N8, N9+10, N11, and N12 on caudal surface (Fig. 2G). First to third endopodites with dense rows of spinules along lateral margins; Enp1 with an additional row of 5 spinules along medial margin below seta (arrowed in Fig. 2H).

Labrum: Distal margin toothed.

Mandible (Fig. 2I): With seven teeth on gnathobase. Innermost margin with one spinulose seta. Row of 6 spinules in middle, below gnatobase. Palp with two long and one short seta, group of spinules near to palp (arrowed in Fig. 2I).

Maxillule (Fig. 2J): Precoxal arthrite with naked surface, with three strong chitinized distal claws and one spiniform seta on caudal side. Palp unarmed, Enp with three setae (two smooth setae subequal in size, and one plumose shorter seta), Exp with three setae and Bsp with one plumose seta.

Maxilla (Fig. 2K): Praecoxa and coxa partially fused. Praecoxa with endite bearing two setae and a transverse row of small spinules on frontal surface. Coxa naked, bearing one biserially plumose seta. Distal coxal endite well developed, with two apical setae, one strong and furnished with spinules and other one noticeably thicker and longer. Claw-like basal endite with one row of spinules on inner margin, one chitinized armed seta inserted in front of basal "claw" and one seta inserted at base of claw-like endite on caudal surface. Endopod with a single segment bearing five setae.

Maxilliped (Fig. 2L): Syncoxa with three setae. Basis with two sub equal setae, plus 8 long spinules on frontal surface. Two transverse rows of small spinules, each with 6-8 elements arranged in semi-circular pattern on caudal surface. Endopod two-segmented: Enp1 with one long seta and one transverse row of 5 spinules on frontal surface. Enp2 with three setae, the longest fused to Enp2 and biserially plumose on the proximal half, the distal half ornamented with small spinules in caudal surface (arrowed in Fig. 2L).

Legs 1–4: Endopods and exopods of all swimming legs three-segmented. Armature formula of swimming legs as in Table 2.

Leg 1 (Figs 3A, B): Intercoxal sclerite with one row of spinules arranged in a semicircle on each side of frontal surface (Fig. 3A); caudal surface with two transversal rows of tiny spinules, distal margin with two rounded chitinized projections (Fig. 3B).

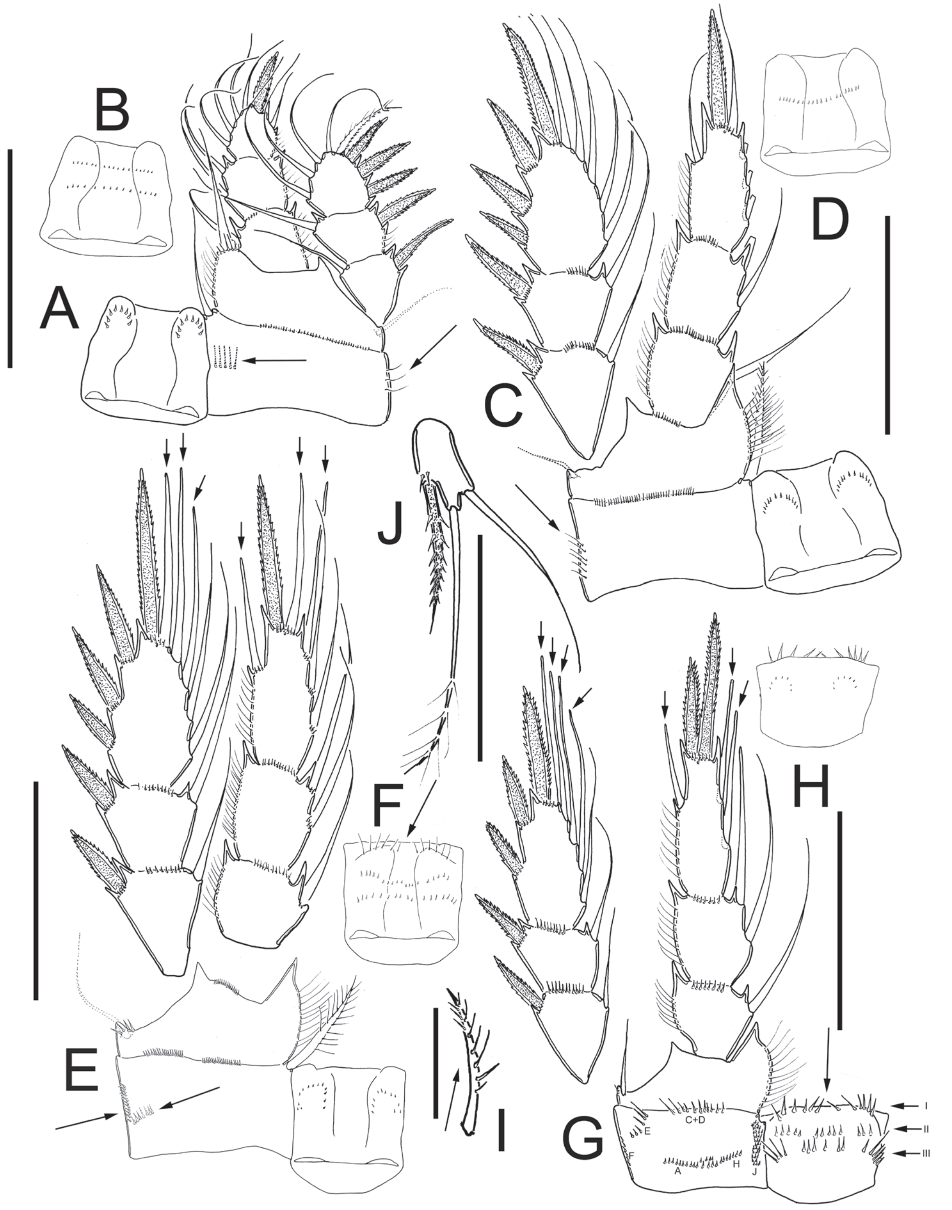


Figure 3. *Eucyclops tziscao* sp. n. Holotype from Laguna Tziscao, Chiapas. **A** P1, frontal **B** Intercoxal sclerite of P1, caudal **C** P2, frontal **D** Intercoxal sclerite of P2, caudal **E** P3, frontal, Exp and Enp separated **F** Intercoxal sclerite of P3, caudal **G** P4, caudal **H** Intercoxal sclerite of P4, frontal **I** Coxal spine P4 **J** P5. Scales bars: **I**= 25µm, **J**= 50 µm; **A–H** = 100 µm.

Coxa with strong biserially plumose inner coxal seta. Coxa with one row of hair-setae on outer margin and one transverse row of hair-setae next medial margin (arrowed in Fig. 3A). Inner basal seta reaching middle of Enp3, 0.76 times as long as Enp.

Leg 2 (Fig. 3C, D): Intercoxal sclerite with two groups of small spinules arranged in semi-circle on each side of frontal surface (Fig. 3C), and one transverse row of spinules in middle on caudal surface (Fig. 3D). Distal margin of intercoxal sclerite with two rounded chitinized projections. Coxa with strong biserially plumose inner coxal seta. Coxa with one row of hair-setae along outer margin on frontal surface (arrowed in Fig. 3C) small spines next insertion of Enp.

Leg 3 (Fig. 3E, F): Intercoxal sclerite with two groups of small spinules on frontal surface (Fig. 3E) caudal surface of intercoxal sclerite with three rows of spinules: distal row bearing long hair-like spinules at each side (arrowed in Fig. 3F), middle and proximal rows with tiny spinules. Distal margin with two slightly rounded projections. Coxa bearing strong biserially plumose inner coxal seta, frontal surface with one row of tiny spinules along outer (lateral) margin, and one transverse row of spinules on caudal surface (arrowed in Fig. 3E). Modified setae on Enp3 and Exp3 (arrowed in Fig. 3E). Tiny spinules at insertion of all setae of Enp and all spines of Exp.

Leg 4 (Figs 3G–I): Intercoxal sclerite with rows I, II, and III on caudal surface. Row I with strong spinules on each side and a small gap. Row II with small spinules divided into three sections with small gaps between them. Row III divided into three sections, the first section with 5 long spinules, the middle section with 6 small strong spinules, and the third section with 5 long spinules (Fig. 3G). Frontal surface of intercoxal sclerite with two groups of tiny spinules arranged in semi-circle on each side (Fig. 3H). Caudal surface of coxa with spinules groups A-C, and E-F-H-J. Inner coxal spine (seta) with heteronomous setulation: proximally with long hair-like setules, distally with spinule-like setules; outer edge of coxal spine with three spinule-like setules distally, naked proximally (arrowed in Fig. 3I). Enp3P4 3.0 times as long as wide; inner spine 1.4 times as long as outer spine and 1.1 times as long as segment; outer spine 0.70 times as long as segment. Lateral seta of Enp3P4 inserted at 66% of the total length of segment. Modified setae on Enp3 and Exp3 (arrowed in Fig. 3G). All setae of exopod with tiny spinules at insertion.

Leg 5 (Fig. 3J): One free segment subrectangular, 2.1 times longer than wide; bearing one inner spine and two setae; median seta about 1.3 times longer than outer seta and 1.8 times longer than inner spine. Inner spine 1.7 times as long as segment.

Male: Habitus as in Fig. 4A; 509 μm of total body length excluding caudal setae. Body more slender than in female. Prosome symmetrical in dorsal view, representing 65% of total body length. Urosome short, representing 35% of total body length. Anal operculum slightly rounded and smooth. Caudal ramus 3.5 times longer than width; medial margin naked, strong spinules at insertion of lateral caudal seta (II) and outermost terminal caudal seta (III). Dorsal seta (VII) short 0.35 times the length of caudal ramus, and 0.75 times as long as outermost caudal seta (III). Ratio of innermost caudal seta (VI)/outermost caudal seta (III) is 1.6. Lateral caudal seta (II) inserted at 70% of caudal ramus. All the terminal caudal setae plumose.

Antennule: 16-segmented (Figs 4C, D), armament per segment as follows (s= seta, ms= modified seta, ae= aesthetasc, sp= spine): 1(7s+2ms); 2(3s+1ms); 3(1s+2ms);

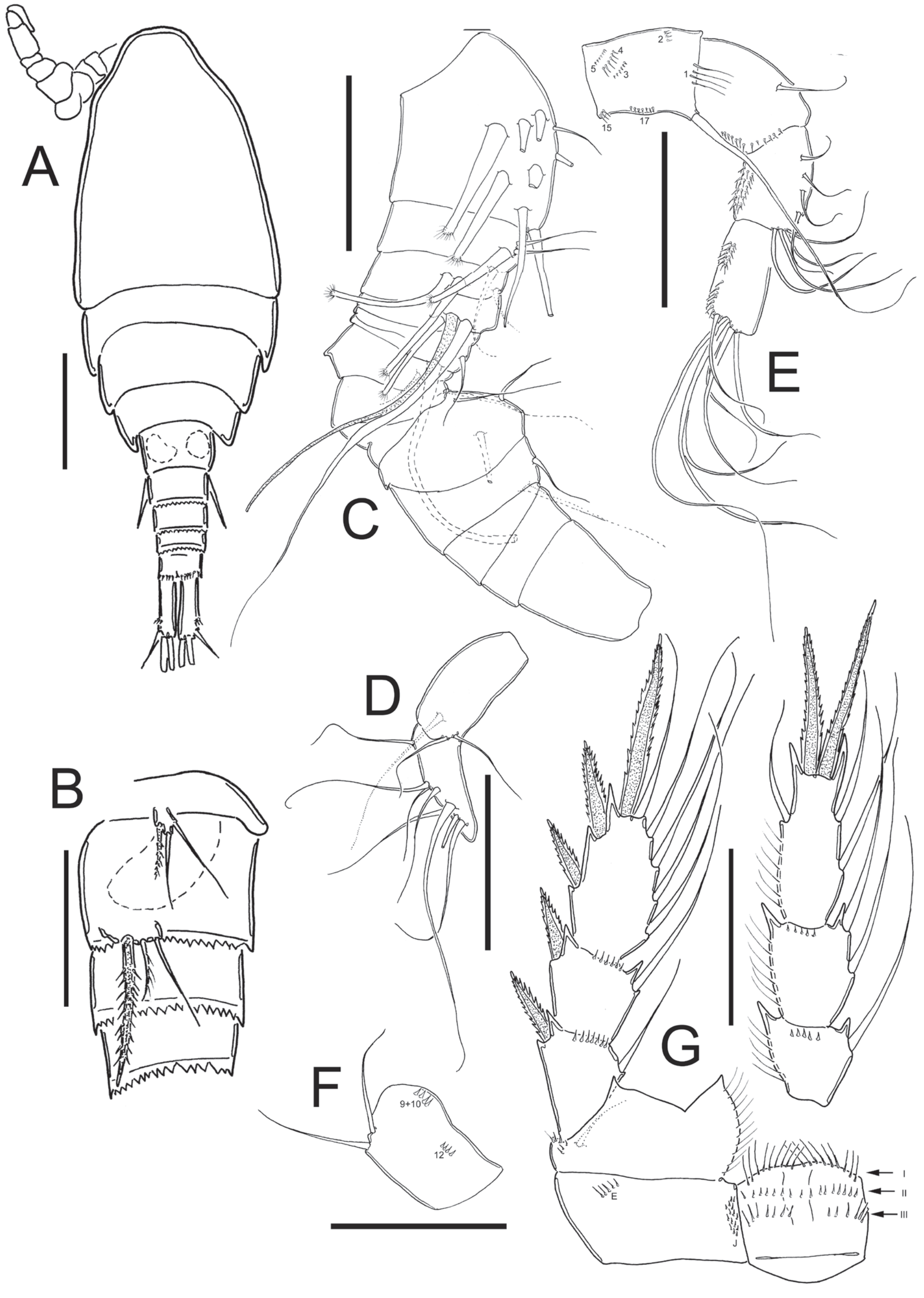


Figure 4. *Eucyclops tziscao* sp. n. **A–B** paratype **C–G** allotype from Laguna Tziscao, Chiapas. **A** Habitus, dorsal **B** P5, and P6 **C** Antennule, segments 1–14 **D** Antennule, segments 15–16 **E** Antenna, frontal **F** Antenna, caudal **G** P4, caudal. Scales bars: **B–G** = 50 µm; **A** = 100 µm.

Table 2. *Eucyclops tziscao* sp. n. Setation formula of the swimming legs in female, and male (spine in Roman numerals, seta in Arabic numerals).

	Coxa	Basis	Exp	Enp
P1	0-1	1-I	I-1; I-1; III-5	0-1; 0-2; 1-I-4
P2	0-1	1-0	I-1: I-1; IV-5	0-1; 0-2; 1-I-4
P3	0-1	1-0	I-1; I-1; IV-5	0-1; 0-2; 1-I-4
P4	0-1	1-0	I-1; I-1; III-5	0-1; 0-2; 1-II-2

4(1s+1ms+1ae); 5(0); 6(2s); 7(1s); 8(1s); 9(0); 10(3s); 11(2s); 12(0); 13(0); 14(0); 15(3s); 16(8s).

Antenna (Fig. 4E, F): Coxa (no seta), basis (2s + 1 seta representing Exp) plus 3-segmented Enp (first to third Enp with 1, 8, and 7 setae respectively). Basis ornamented with: N1 (4 hair-setae), N2 (4 small spinules), N3, N4, N5, N15, and N17 on frontal surface (Fig. 4E); and N9+10, and N12 on caudal surface (Fig. 4F).

Legs 1–4: Endopods and exopods of all swimming legs three-segmented (Table 2); P1-P3 as described in females.

Leg 4 (Fig. 4G): Coxa, Bsp, and intercoxal sclerite as described in female, except for the distal row of spinules of intercoxal sclerite, which consists of 9 spinules longer and slender than in female (arrow of row I, in Fig. 4G). Enp3P4: 2.6 times as long as width; inner spine 1.2 times as long as outer spine, and 1.2 times as long as segment. No modified setae on fourth leg. Lateral seta of Enp3P4 inserted at 64.7% of segment length, lateral seta reaching the middle of outer spine.

Leg 5 (Fig. 4B): One free segment subrectangular, 1.5 times longer than wide;

bearing one inner spine and two setae: outer seta subequal to median seta and 1.3 times longer than inner spine. Inner spine 1.8 times as long as segment.

Leg 6 (Fig. 4B): Represented by small, low plate near lateral margin of genital somite with one strong and long inner spine and two unequal setae. Inner spine reaching the distal margin of fourth urosomite. Inner spine about 2.3 times longer than median seta and about 1.6 longer than outer seta.

Eucyclops angeli Gutiérrez-Aguirre & Cervantes-Martínez, sp. n.

http://zoobank.org/A2A11871-BE4A-48AC-9777-3735A0FF3EEA
http://species-id.net/wiki/Eucyclops_angeli
Figs 5–9

Material examined. Holotype: Adult ♀ specimen dissected, mounted in glycerin sealed with Entellan (ECO-CH-Z- 8967). Allotype: Adult ♂, dissected, mounted in glycerin sealed with Entellan (ECO-CH-Z-8968). Paratypes: Eight adult ♀♀ undissected ethanol-preserved (90%) (ECO-CH-Z-8969); five adult ♀♀ and one adult ♂ undissected, ethanol preserved (90%) (MNHN-IU-2013-5970); four adult ♀♀, un-

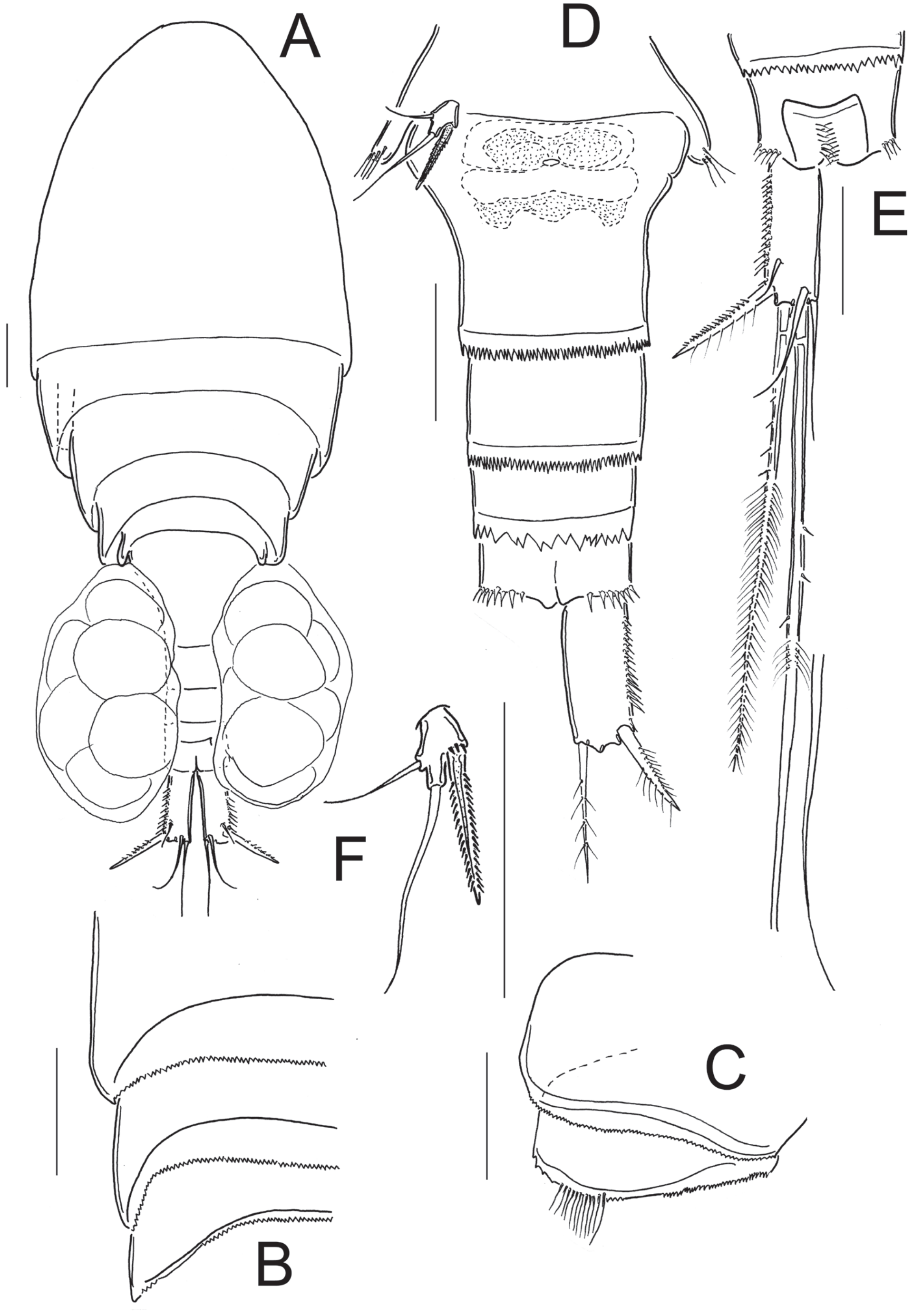


Figure 5. *Eucyclops angeli* sp. n. **A–C** paratype **D–F** holotype from grassland in San Cristóbal de las Casas, Chiapas. **A** Habitus, dorsal **B** Second to fourth prosomites, dorsal **C** Third and fourth prosomites, lateral **D** Urosome, ventral **E** Anal somite and one caudal ramus, dorsal **F** P5. Scale bars 50 µm.

dissected, ethanol preserved (90%) (CNCR 27841). Samples from type locality collected at 13. January. 2001 by A. Cervantes-Martínez, M. A. Gutiérrez-Aguirre and M. Elías-Gutiérrez.

Type locality. Grassland near ECOSUR in San Cristóbal de las Casas City (Chiapas, México) (16°43'43"N; 92°38'14"W). At sampling the maximum depth was 1.48 m, the water temperature 21.5°C, and the dissolved oxygen 8.1 mg l^{-1}.

Etymology. This species is dedicated to Angel Cervantes Rivas, the first son of A C-M.

Description. *Female*: Habitus as in Fig 5A; 600 µm of total body length excluding caudal setae. Prosome expanded at first and second somite, representing 58% of total body length, symmetrical in dorsal view (Figure 5A). Prosomal fringes serrated dorsally (Figure 5B); fourth prosomite with long, lateral, hair-setae (Fig 5C). Five-segmented urosome, relatively elongated; first urosomite with long spinules on lateral margin; urosomal fringes strongly serrated (Fig. 5D). Posterior margin of anal somite with large spinules on ventral and dorsal surfaces, except for the medialmost section. Genital double-somite symmetrical, lateral arms of anterior part of seminal receptacle rounded; posterior part forming sinuous sac (Fig. 5D). Anal somite subequal in length to preanal somite and around 60% of caudal ramus length; with hair-setae in anal opening (Fig. 5D, E). Length/width ratio of caudal ramus 2.1; inner margin of caudal ramus naked, strong spines on lateral margin (serra) extending 62% of ramus length (Figure 5D). Dorsal seta (VII) relatively short, 0.83 times the length of caudal ramus, and 1.1 times as long as outermost terminal caudal seta (III). Innermost caudal seta (VI) 1.5 as long as outermost caudal seta (III). Lateral caudal seta (II) inserted at 71.6% of caudal ramus. Lateral seta (II) is 0.4–0.5 the length of outermost caudal seta (III). All terminal caudal setae plumose. Relative lengths of terminal caudal setae from outermost caudal seta to innermost caudal seta: 1.0: 3.9: 7.5: 1.2 (Fig. 5E).

Antennule (Fig. 6A): 12-segmented, tip reaching from middle to distal margin of second prosomite; smooth hyaline membrane on segments 10–12. The length ratio of segments 12/11 is 1.1. Armament per segment as follows (s= seta, ae= aesthetasc, sp= spine): 1(8s); 2(4s); 3(2s); 4(6s); 5(4s); 6(1s+1sp); 7(2s); 8(3s); 9(2s+1ae); 10(2s); 11(2s+1ae); 12(7s+1ae). Row of spinules on first segment: inner spinules shorter than outer spinules. Long spine on sixth segment, reaching the distal third of seventh antennular segment.

Antenna (Fig. 6B, C): Coxa (no seta), basis (2 s + 1 s representing Exp), plus 3-segmented Enp (first to third endopodite with 1, 9 and 7 setae respectively). Basis ornamented with: N1 (5 hair-setae), N2 (3 hair-setae), and N3, N4, N5, N17 (Fig. 6C) on frontal surface; and N7, N8, N10, N11, N12, N12', N13, N15, and N16 on caudal surface (Fig. 6B). First to third endopodal segments with dense rows of spinules along lateral margin; Enp1 with additional row of 2 spinules on caudal surface (arrowed in Fig. 6B).

Labrum (Fig. 6D): Distal margin toothed. Ventral surface with long hair-setae. Two rounded lateral protuberances bearing spinules.

Mandible (Fig. 6E): With nine teeth on gnathobase, the innermost bi-toothed. Innermost margin with one spinulose seta. Palp with two long and one short setae. Three rows of tiny spinules next to palp.

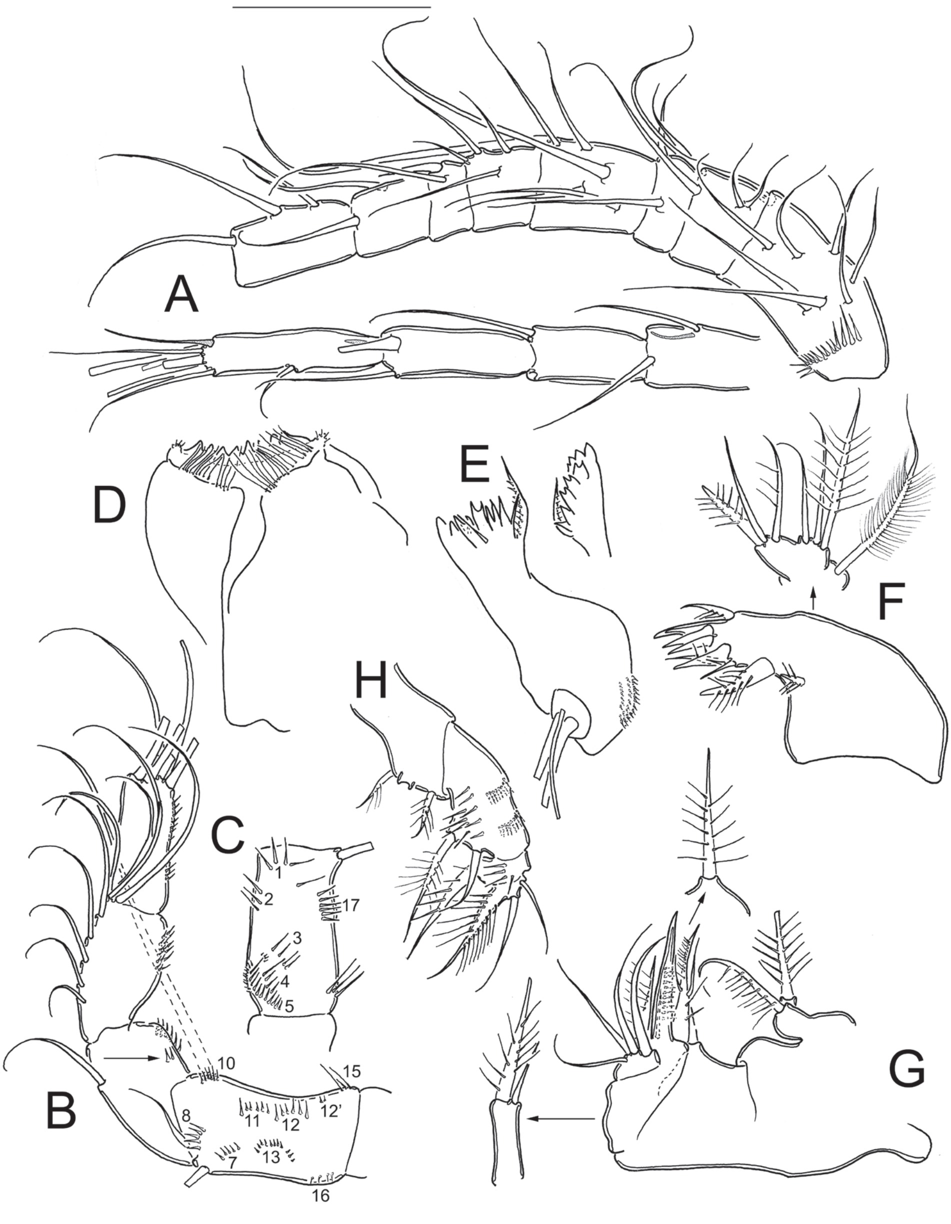


Figure 6. *Eucyclops angeli* sp. n. Holotype from grassland in San Cristóbal de las Casas, Chiapas. **A** Antennule **B** Antenna, caudal **C** Antenna, frontal **D** Labrum **E** Mandible **F** Maxillule, palp separated **G** Maxilla, proximal and distal endites of the coxa, separated **H** Maxilliped, frontal. Scale bar 50 µm.

Maxillule (Fig. 6F): Praecoxal arthrite with 3 chitinized claws and one spinulose seta on caudal side. Inner margin with two biserially plumose setae and four spiniform setae. Praecoxal surface naked. Palp naked, with Enp (3 long setae: one smooth, plus two plumose), Exp (3 long setae), and Bsp (with one plumose seta) (Fig. 6F).

Table 3. *Eucyclops angeli* sp. n. Setation formula of the swimming legs in female, and male (spine in Roman numerals, seta in Arabic numerals).

	Coxa	Basis	Exp	Enp
P1	0-1	1-I	I-1; I-1; III-5	0-1; 0-2; 1-I-4
P2	0-I	1-0	I-1: I-1; IV-5	0-1; 0-2; 1-I-4
P3	0-I	1-0	I-1; I-1; IV-5	0-1; 0-2; 1-I-4
P4	0-I	1-0	I-1; I-1; III-5	0-1; 0-2; 1-II-2

Maxilla (Fig. 6G): Praecoxa and coxa partially fused. Praecoxal endite with two armed setae. Coxa naked and with two endites: proximal endite bearing one biserially plumose seta, distal endite with one long, plumose seta plus one short smooth seta. Claw-like basal endite with row of spinules on inner margin; one small seta inserted on caudal surface, and one chitinized armed seta inserted in front of claw-like endite. Endopod one-segmented bearing four smooth, long setae plus one plumose seta.

Maxilliped (Fig. 6H): Syncoxa with three setae bearing spiniform setules. Basis with two subequal setae and 9 spinules frontally. Two rows of acute spinules, each with 8 elements, arranged in semi-circular pattern on caudal surface. Endopod two-segmented: Enp1 with 4 basal spinules and one long seta fused to segment; Enp2 with three setae, longest seta biserially plumose and fused to Enp2.

Legs 1–4: With three-segmented Exps and Enps; intercoxal sclerites ornamented on frontal and caudal surfaces (Fig. 7). Armature formula of P1-P4 as in Table 3.

Leg 1 (Fig. 7A): Intercoxal sclerite armed with two arched rows of long spinules frontally and one row of tiny spinules caudally (Fig. 7A). Frontal surface of coxa with row of long spinules along lateral margin; long, feathered seta at mediodistal angle. Basis with one delicate outer seta, and one inner armed spine as long as Enp. Inner margin of Bsp hairy. Inner spine of Bsp with small basal spines, long setules proximally, and spine-like setules distally (Fig. 7A). Setae of Enp and Exp of P1 are unmodified, and regularly plumose in both edges (Fig 7A). Caudal surface of coxa with four groups of spinules and one row of hair-like spinules near medial margin (Fig 7B).

Leg 2 (Figs 7C–E): Intercoxal sclerite with two rows of hair-setae on each of the two rounded projections on frontal surface (Fig. 7C), and three groups of spinules on caudal surface (Fig. 7E). Coxa with one row of long spinules along outer margin and two groups of spinules on distal margin on frontal surface (Fig. 7C). Lateral margin of coxa with two groups of long spinules, one group of short spinules, and one row of hair-setae in medial position on caudal surface (Fig. 7D). Armed coxopodal spine at mediodistal angle. Basis with one outer seta, inner margin hairy. All setae of Enp and Exp of P2 not constricted, plumose in both edges (Fig 7C).

Leg 3 (Fig. 7F–I): All setae on Exp and Enp as described in P2, except for the two distalmost setae of Exp3P3, which have very short setules along outer (constricted) edge (Fig. 7F). Caudal surface of P3 coxa with one row of tiny spinules along outer margin, one group of long spinules, one group of short spines, and one row of medial hair-setae (Fig 7G). Caudal surface of intercoxal sclerite with three rows of hair- setae

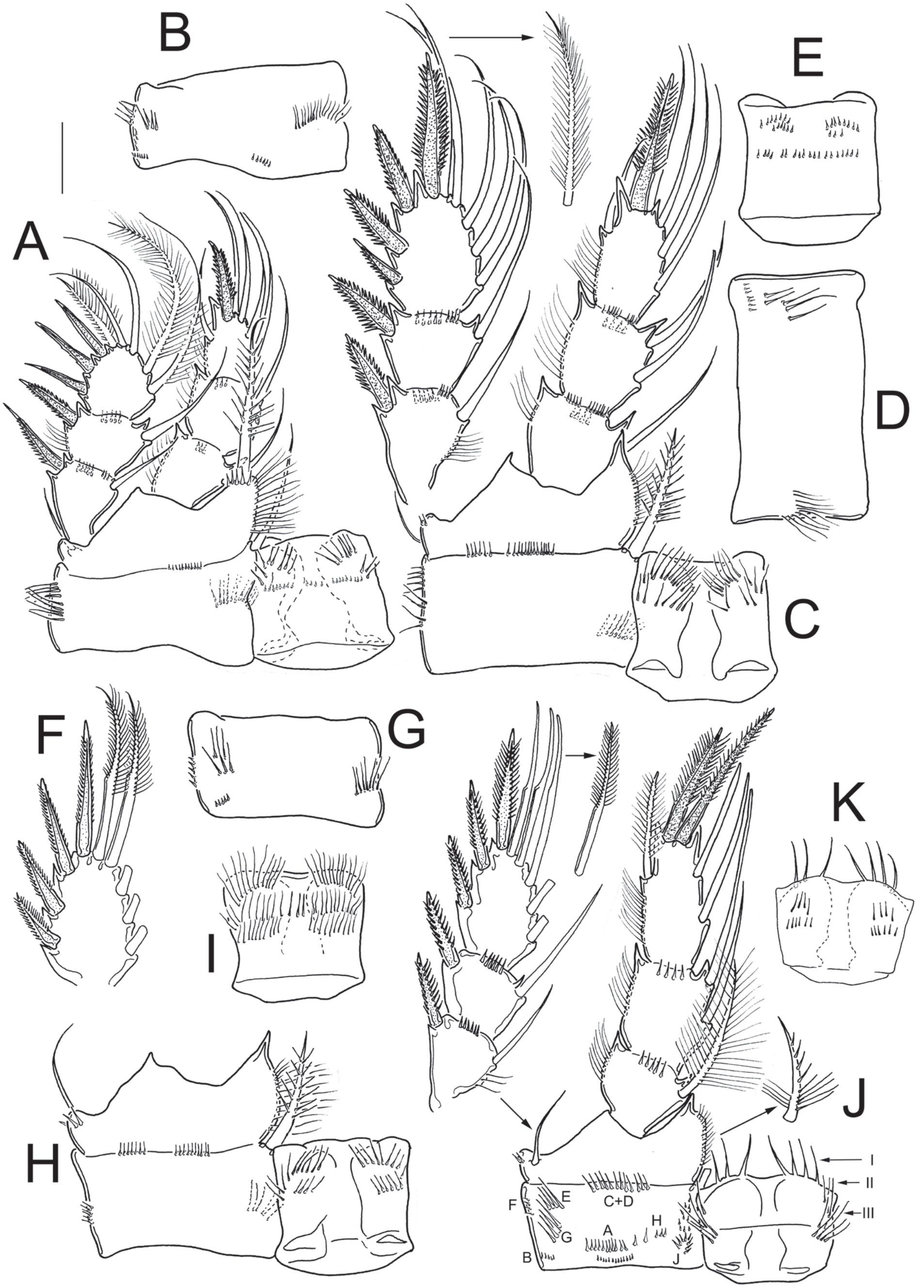


Figure 7. *Eucyclops angeli* sp. n. Holotype from grassland in San Cristóbal de las Casas, Chiapas. **A** P1, frontal **B** Coxa of P1, caudal **C** P2, frontal, Exp separated **D** Coxa of P2, caudal **E** Intercoxal sclerite of P2, caudal **F** Exp3P3 **G** Coxa of P3, caudal **H** Coxa, basis, and intercoxal sclerite of P3, frontal **I** Intercoxal sclerite P3, caudal **J** P4, caudal; exopod and coxal spine separated **K** Intercoxal sclerite of P4, frontal. Scale bar 50 µm.

(Fig. 7I). On frontal surface, the ornamentation of coxa, Bsp, and intercoxal sclerite of P3, is similar to those in P2 (Fig 7H).

Leg 4 (Fig. 7J, K): Caudal surface of coxa with spinule ornamentation consisting of groups A–J. Coxal spine (inner seta) with heteronomous setulation: proximally with long setules, distally with spine-like setules; outer edge of coxal spine with a gap (Fig. 7J). Basis with delicate outer seta, and short hairs on inner margin. Three setae of Exp3P4 with constricted outer edge, and with short setules. Enp3P4 1.8 times as long as wide; inner spine 1.3 as long as outer spine and 1.3 as long as segment; outer spine 0.93 as long as segment. Caudal surface of intercoxal sclerite of P4 armed with 7 long denticles in position I, and long hair-setae in position II and III (Fig. 7J). Frontal surface of intercoxal sclerite of P4 with four rows of short spinules (Fig 7K).

Leg 5 (Fig. 5F): One free segment 1.4 times longer than wide; bearing one inner spine and two setae. Outer seta shorter than inner spine, relative lengths from outer seta to inner spine: 0.5: 1.6: 1 (Fig. 5F). Inner spine 2.0 times longer than segment.

Male: Habitus as in Fig. 8A; body length excluding caudal setae= 540–580 µm (n= 4) average body length= 552.9±15.56. Prosome symmetrical in dorsal view, representing 60–63% of total body length (Fig. 8A). Fourth prosomite with two spines, one spine on ventral margin, and one spine on posterior margin (Fig 8B). Six-segmented urosome, relatively elongated; first urosomite naked on lateral margin (Fig. 8C); posterior margin of anal somite with a continuous (dorsally and ventrally) row of spinules (Fig. 8A, D). Anal region armed with two parallel rows of hair-setae; anal operculum slightly rounded and smooth (Fig 8D). Caudal ramus 2.1±0.07 times longer than width (n= 4); medial margin of caudal ramus naked, strong spines at insertion of lateral caudal seta (Fig. 8D). Innermost caudal seta (VI) 1.0–1.14 times longer than caudal ramus (n= 3). Relative lengths of terminal caudal setae from outermost (III) to innermost (VI): 1.0: 5.7–6.4: 10.8–12.0: 1.45–1.6. Lateral caudal seta (II) 0.64–0.83 the length of outermost caudal seta (III) (Fig. 8D).

Antennule (Fig. 8E): 16-segmented, between segments 14–15 is the geniculation; armament per segment as follows (s= seta, modified seta= ms, ae= aesthetasc, sp= spine): 1(6s+2ms+1ae); 2(3s+1ms); 3(1s+1ms); 4(1s+1ms+1ae); 5(2s+1ms); 6(1s+1ae); 7(1s); 8(2s); 9(2s); 10(2s); 11(1s); 12(1s); 13(3s); 14(0); 15(1s); 16(9s). Row of spinules on first segment: inner spinules shorter than outer spines.

Antenna: As in female except for that the spinule groups N7, N13, and N16 are absent on caudal surface of antennal Bsp (Fig. 8F). Basis ornamented with: N1 (4 hair setae), N2 (2 hair setae) and spinules in groups N3, N4, N5, and N17 on frontal surface (Fig. 8G).

Labrum, mandible, maxillule, maxilla, and maxilliped as in female.

Legs 1–4: Exps and Enps three-segmented. Intercoxal sclerites armed as in Fig. 9A–C, F. Setation formula of swimming legs as in female (Table 3).

Leg 1 (Fig. 9A): Intercoxal sclerite armed with two rows of tiny spinules on caudal surface. Ornamentation of Bsp, Enp, and Exp, as in female. Caudal surface of coxa with three groups of spinules and one row of hair-setae.

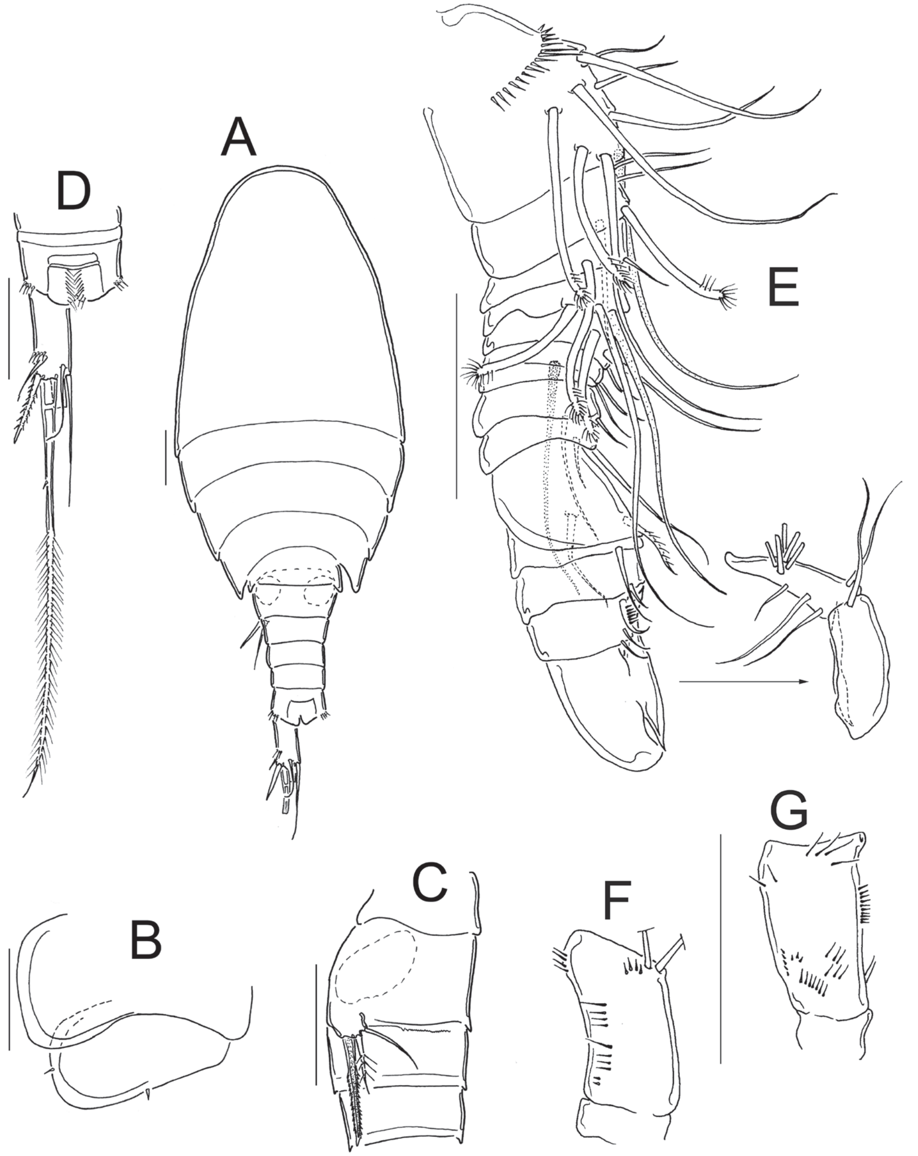


Figure 8. *Eucyclops angeli* sp. n. **A–B** paratype **C–F** allotype from grassland in San Cristóbal de las Casas, Chiapas. **A** Habitus, dorsal **B** Third, and fourth prosomites, lateral **C** First to fourth urosomites, lateral **D** Anal somite and caudal ramus, dorsal **E** Antennule, last two segments separated **F** Antenna, caudal **G** Antenna, frontal. Scale bars 50 µm.

Leg 2 (Fig. 9B): As in female, except for that intercoxal sclerite is naked on caudal surface, yet with two arched rows of long spinules on frontal surface.

Leg 3 (Fig. 9C–E): Modified, intercoxal sclerite with rows of spinules caudally, and rows of hair-setae frontally (Fig. 9C). Two distalmost setae of Exp3P3 and Enp3P3

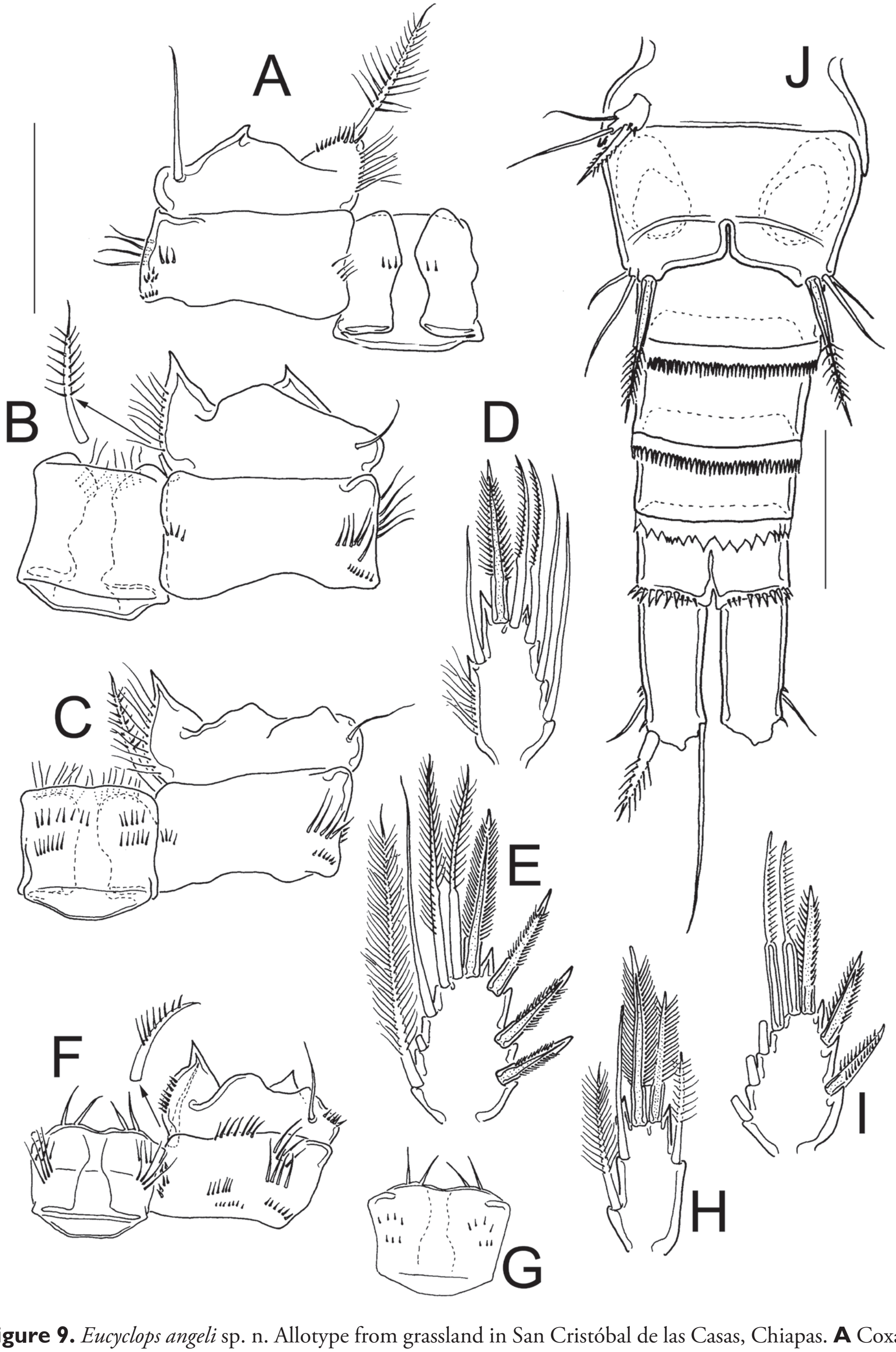


Figure 9. *Eucyclops angeli* sp. n. Allotype from grassland in San Cristóbal de las Casas, Chiapas. **A** Coxa, basis, and intercoxal sclerite of P1, caudal **B** Coxa, basis, and intercoxal sclerite of P2, caudal **C** Coxa, basis, and intercoxal sclerite of P3, caudal **D** Enp3P3 **E** Exp3P3 **F** Coxa, basis, and intercoxal sclerite of P4, caudal **G** Intercoxal sclerite of P4, frontal **H** Enp3P4 **I** Exp3P4 **J** Urosome, ventral. Scale bars 50 µm.

with constricted outer edges, and very short setules (Fig. 9D, E). Coxa and Bsp as described in female (Fig. 9C).

Leg 4 (Fig. 9F–I): Coxa, basis, and intercoxal sclerite as in female; except for that entire outer margin of coxal seta is naked (Fig. 9F, G). Enp3P4: 2.07–2.25 (n= 2) times as long as wide; inner apical spine 1.24–1.31 (n= 2) as long as outer spine and 1.08–1.26 (n= 2) times as long as segment (Fig. 9H). Two distal setae of Exp3P4 modified: chitinized, both edges constricted, and bearing short setules on outer edge (Fig. 9I).

Leg 5 (Fig. 9J): One free segment, 1.6 times longer than wide; and bearing three elements of which outer seta is slightly longer than that in female (subequal in length to inner spine) (Fig. 9J). Inner spine 1.8 times as long as segment.

Leg 6 (Fig. 9J): Represented by a small, low plate near lateral margin of genital somite, armed with one inner spine, which is 1.7–1.87 times longer than outer seta, and 1.2–1.6 times longer than median seta. Inner spine of sixth leg reaching the distal margin of fourth urosomite.

Eucyclops festivus **Lindberg, 1955**

http://species-id.net/wiki/Eucyclops_festivus
Figs 10–11

Eucyclops festivus: Lindberg (1955), fig. 2a–d.
E. festivus: Suárez-Morales (2004), 617 p.
E. festivus: Mercado-Salas (2009), table 3, figs 138-139
Synonym: *E. pectinifer*, Gutiérrez-Aguirre and Cervantes-Martínez (2013), table 1.

Material examined. One adult ♀ specimen dissected, mounted in glycerin sealed with Entellan. One adult ♂, dissected, mounted in glycerin sealed with Entellan, and seven adult males undissected, ethanol preserved (90%) with a drop of glycerin, deposited in the senior author's collection, at Universidad de Quintana Roo, Cozumel. Samples collected at 14. April. 2000 by A. Cervantes-Martínez, M. A. Gutiérrez-Aguirre and M. Elías-Gutiérrez in pond 3 to Laguna Montebello, Chiapas, México (16°06'42"N; 91°41'32"W). At sampling the maximum depth was 0.2 m; the water temperature 24°C and the dissolved oxygen 6.8 mg L^{-1}.

Remarks. *Eucyclops festivus* has been recorded in North and Central Mexico (Suárez-Morales and Reid 1998, Mercado-Salas 2009). This is the southernmost record of the species in the country. Specimens from Chiapas were assigned to *E. festivus* because all the morphological characters, even the meristic features observed in the specimens from Chiapas are similar to those in the original description: in females and males the inner spine of fifth leg is 1.7–1.8 times longer than outermost seta, and the median seta is 1.5 times longer than the inner spine (Fig. 10A, B, D). The Fu length/width ratio is between 5–6 in the females, with spinules along the entire outer margin, and naked along inner margin (Fig. 10B, C). Caudal rami parallel in the male (Fig.

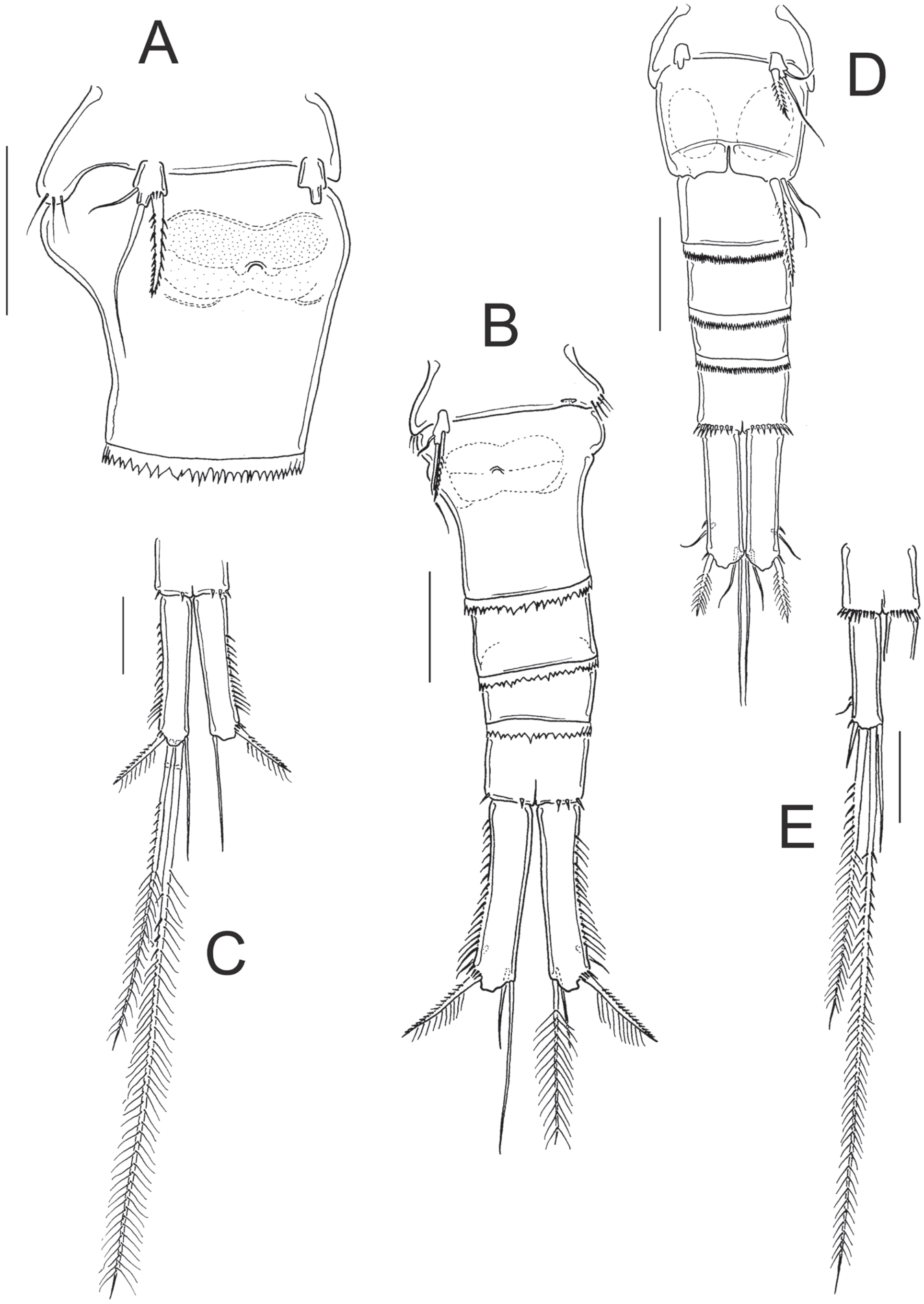


Figure 10. *Eucyclops festivus* Lindberg, 1955; from pond 3 to Laguna Montebello, Chiapas. **A** First urosomite, and genital double-somite, ventral **B** Urosome, ventral **C** Anal somite and caudal ramus, ventral **D** Urosome, ventral **E** Anal somite and caudal ramus, ventral. Scale bars 50 µm. **A–C** female; **D–E** male.

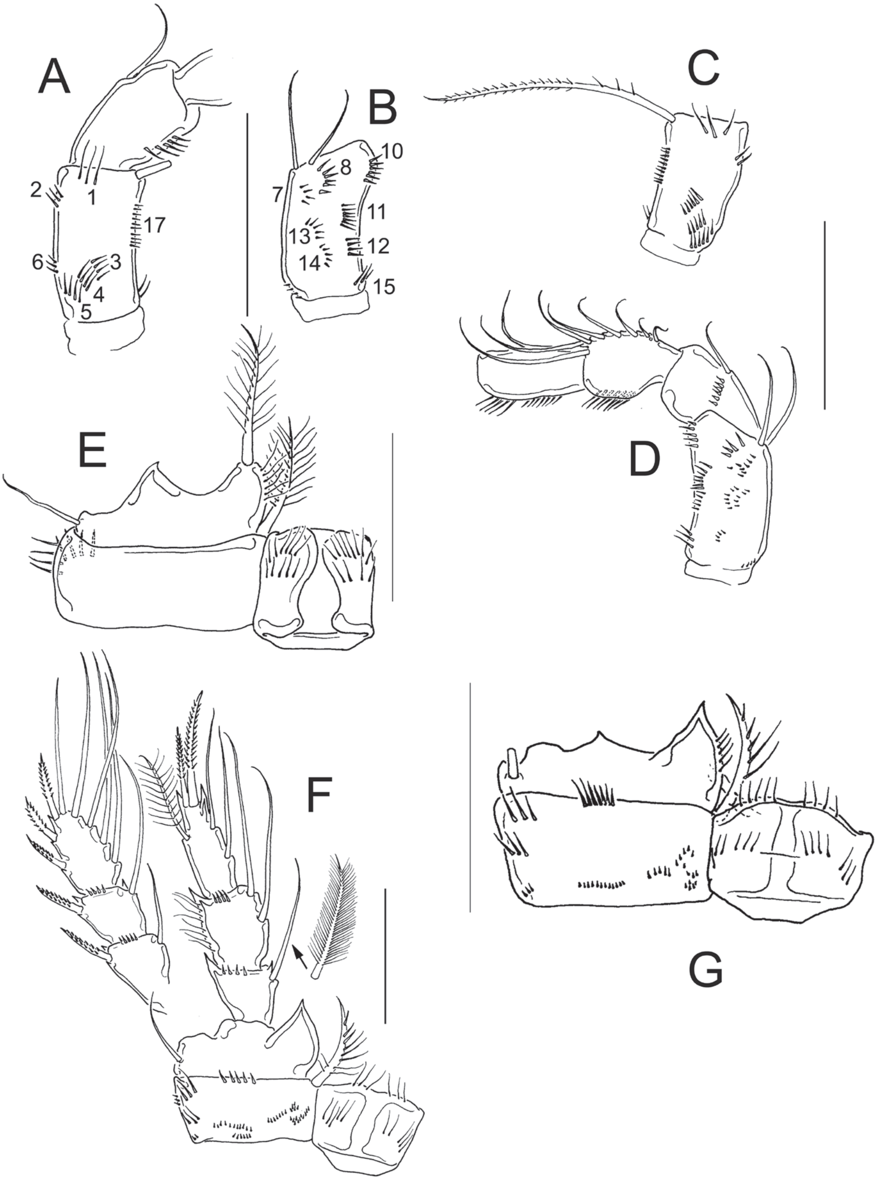


Figure 11. *Eucyclops festivus* Lindberg, 1955; from pond 3 to Laguna Montebello, Chiapas. **A** Antenna, frontal **B** Antenna, caudal **C** Antenna, frontal **D** Antenna, caudal **E** Coxa, basis, and intercoxal sclerite of P1, frontal **F** P4, caudal, Exp, and one inner seta separated **G** Coxa, basis, and intercoxal sclerite of P4, caudal. Scale bars 50 µm. **A, B, E, F** female; **C, D, G** male.

10D, E). The length ratio of innermost caudal seta (VI)/outermost terminal caudal seta (III) is 1.24±1.6 (Fig. 10C, E).

The antennal basis is adorned with the spinule groups N1, N2, N3, N4, N5, N6, and N17 on the frontal surface; whereas the groups N7, N8, N10, N11, N12, N13, N14, N15, and N16 are present on the caudal surface in female and male (Fig. 11A–D). Distal margin of the intercoxal sclerites in P1-P4 bear fine hair-setae (Fig. 11E–G). The length/width ratio of Enp3P4 is 2.2, the inner spine is 1.21 times longer than the segment, and the inner margin of BspP4 is naked in female (Fig. 11F).

Based on the presence of the group N6 on the frontal surface of antennal basis, the naked inner margin of BspP4, the long caudal rami, and the serrated hyaline membrane on the three distalmost segments of A1 in females, *E. festivus* is not included in the *serrulatus*-group.

Discussion

The characters that allow us to include *E. tziscao* sp. n. and *E. angeli* sp. n. in the *serrulatus*-group sensu Alekseev and Defaye (2011) are as follows: 1) seminal receptacle bilobed, and the lobes subequal in size; 2) caudal ramus 2.0–7.0 times as long as wide, and with longitudinal row of spinules along most of the outer edge; 3) twelve-segmented antennule, with smooth hyaline membrane along distalmost segments; 4) frontal surface of antennal basis with 2–6 long spinules in N1, and variable number of spinules or strong denticles in the subdistal N2; 5) strong coxal spine of P4 with dense setules on inner side, and a large gap in setulation on outer side; and 6) one-segmented fifth leg with wide and strong, spine-like inner seta.

Following the identification key to the species of the *serrulatus*-group (Alekseev and Defaye 2011), *E. tziscao* was identified as *E.* cf. *bondi*, but after having performed a deeper analysis and compared our material to the types of *E. bondi* we concluded that our specimens belong to an another, though closely related species. The main characteristics that both species share are: a) on frontal surface of antennal basis, group N2 is represented by small spinules, b) the distal segment of P4 endopod with short inner distal seta, not reaching the end of outer apical spine and, c) caudal ramus with dorsal seta (seta VII) longer than outermost terminal caudal seta (III).

The differences between *E. tziscao* sp. n. and *E. bondi* are slight also in other characters, such as the proportion of the caudal ramus (3.8–4.3 in *E. tziscao* sp. n., and 3.18–4.1 in *E. bondi*), the proportion of dorsal seta and caudal ramus length (0.63 in *E. tziscao* sp. n., and 0.73–0.80 in *E. bondi*) and the proportion of dorsal seta and innermost caudal seta length (0.8 in *E. tziscao* sp. n., and 1.0 in *E. bondi*).

Comparison of the type specimens of *E. bondi* to *E. tziscao* sp. n. revealed clear morphological separation of these taxa. One of the main distinguishing features between the two species is the length of the lateral seta on Enp3P4, which has already been reported as an important character in another species of the *serrulatus* group as in *E. delachauxi* (Kiefer, 1926). In *E. bondi* this seta exceeds the half length of the outer apical spine and it is not modified, while in *E. tziscao* sp. n. this seta is shorter, not reaching the half length of the outer apical spine, and it is modified as a strong, sclerotized blunt seta (arrowed in Fig. 3G). All setae on Enp3P4 are modified (strong, sclerotized and blunt) in *E. tziscao* sp. n., while in *E. bondi* they are not. In addition, the most apical seta of Exp3P4 is modified in *E. tziscao* while all setae are normal in *E. bondi*. All the setae on the swimming legs of *E. tziscao* sp. n. are shorter than in *E. bondi*. Finally, the length/width ratio of Enp3P4 is 2.6–3.0 in *E. tziscao* sp. n. while it is 2.4–2.6 in *E. bondi*.

The proportion of the inner apical spine and Enp3P4 segment length is slightly different in the species; it is 1.06 in the new species while it is 1.25 in *E. bondi*. Another useful character to differentiate taxa (as it has already been pointed out by Alekseev and Defaye 2011) is the setulation gap on the coxal spine of P4. Both the original drawings of Kiefer and the examination of the type material showed that in *E. bondi* the entire outer margin of the coxal seta is naked, while in *E. tziscao* sp. n. the apical region of the seta bears hair-like setules.

The use of male morphology in delineation of the species has been demonstrated in some genera of Eucyclopinae (e.g. *Paracyclops*, see Karaytug 1999; Karaytug and Boxshall 1999). One important feature that easily distinguishes *E. tziscao* sp. n. from *E. bondi* is the P6 armature, which is completely different in these two species. Our examinations showed that *E. bondi* has a unique sixth leg, in which the inner spine is relatively short in comparison to the median and outer setae: the proportion of the inner spine and outer seta length is 0.71 in *E. bondi,* while it is 1.5 in *E. tziscao* sp. n. also the proportion of inner spine and median seta length is about 1.07 in *E. bondi,* yet 2.5 in *E. tziscao* sp. n. In *E. bondi* the inner spine of sixth leg barely reaches the posterior margin of genital somite, while in *E. tziscao* sp. n. the spine extends up to the posterior margin of the fourth urosomite. All the records of *E. bondi* in the Americas should be re-evaluated considering this unique character (the very short inner spine of the male sixth leg) and also other morphological features, in order to clarify if they in fact belong to the species. For instance on the drawings of a material identified as *E. bondi* from Costa Rica (Collado et al. 1984) the sixth leg structure clearly does not correspond to the state present in the type of the species (cf. fig. 14 in Collado et al. 1984).

The species *Eucyclops pectinifer* seems to be closely related to *E. tziscao* sp. n., general body shape and some proportion of swimming legs are shared between both species. However the caudal ramus is shorter in *Eucyclops tziscao* sp. n. than in *E. pectinifer*, in the new species is 3.8-4.3 times longer than wide while in *E. pectinifer* is 4.5–5.0. Proportion of dorsal seta/length of caudal ramus is slightly longer in *E. tziscao* (0.6) than in *E. pectinifer* (0.4). Another difference between these two species is the shape of the anal operculum, in *E. pectinifer* is smooth and rounded, as in most *Eucyclops* species, while in *E. tziscao* sp. n. is rounded but strongly serrated (Fig. 2D). The ornamentation on frontal surface of antennal basis is similar in both species, they share groups N1 armed with long hairs, N2 bearing small and strong spinules, N3, N4, N5, N15 and N17; but the caudal surface of antennal basis is different: in *E. pectinifer* the groups of spinules N7, N13, N14 and an additional group of spinules below group N12 (see fig. 17-7 in Alekseev et al. 2006) are absent in *E. tziscao* sp. n.

Proportion of segments and elements in Enp3P4 are similar between species, length/width ratio of Enp3P4 is 3.2 in *E. pectinifer* while in *E. tziscao* sp. n. is 3.0; proportion of inner/outer apical spines of Enp3P4 is similar, 1.3 in *E. pectinifer* and

1.4 in *E. tziscao* sp. n.; in both species the lateral seta of Enp3P4 does not reach the half length of the outer apical spine, and it is modified as a strong, sclerotized blunt seta. But clear differences can be observed among the species in the fourth leg: in the intercoxal sclerite the row I in *E. pectinifer* bears fine, long hair-setae while in *E. tziscao* sp. n. it is armed with strong, short spinules. On the other hand, modified setae on swimming legs are present in both species but in *E. pectinifer* are present only in P4 while in *E. tziscao* sp. n. are present in P3 and P4.

In males, the antennular segments in *E. pectinifer* are 14 (Alekseev et al. 2006) while in *E. tziscao* 16. Proportional length of elements in P5 is clearly different among the species, in *E. tziscao* sp. n. outer and median setae are almost equal in size and clearly longer than inner spine; while in *E. pectinifer* median seta is more than two times longer than outer seta and inner spine, and the inner spine and outer seta are subequal in length. Sixth leg of males of both species differs slightly, in *E. tziscao* sp. n. the outer seta is two thirds the length of inner spine while in *E. pectinifer* this seta is shorter, being the half of size of the inner spine.

Another species that resembles *E. tziscao* sp. n. by sharing the modified setae on the third and fourth swimming legs and showing similar length and width proportion of the caudal ramus is *E. conrowae*. However when we compared the type material of *E. conrowae* deposited in Dr. Reid´s Collection (Smithsonian Institution) we found many differences. First of all *E. conrowae* is not a member of the *serrulatus*-group: the holotype and one paratype of *E. conrowae* do not have the groups N1 and N2 on the antennal basis (Table 4) whereas in *E. tizcao* sp. n. both groups are present in all the specimens here examined. Also, a group of spinules (J) is absent on the caudal surface of P4 coxa in *E. conrowae* (Table 5). Last, the seminal receptacle is completely different in these species; the posterior lobe is about twice the width of the anterior lobe in *E. conrowae*, whereas both lobes are approximately equal in size in the member taxa of the *serrulatus*-group.

Eucyclops angeli sp. n. can be distinguished from all the other *Eucyclops* species by: the short caudal rami; long spine on the sixth antennular segment; presence of an additional group of spinules (N12') on the caudal surface of antennal basis; presence of long hair-setae in females, and short spinules in males on the lateral margin of fourth prosomite; rich surface ornamentation of P1-P4 intercoxal sclerites both on the frontal and caudal surfaces, long denticles in group I on the intercoxal sclerite of P4; modified distal setae of Exp3P3 and Exp3P4 in females and males; as well as the short outer seta of P5.

In the Americas there are some other species which have similarly short caudal rami. *Eucyclops breviramatus* Loeffler, 1963 in Ecuador, l/w: 2.3–2.6 (Loeffler 1963); and *E. siolii* Herbst, 1962 in Brazil and Venezuela, l/w: 2.18 (Herbst 1962). The morphological characters of A1, A2, P4, P5, and the caudal ramus indicate that *E. angeli* sp. n. belongs to the *serrulatus*-group as defined by Alekseev et al. (2006) and Alekseev and Defaye (2011). Relying upon the information given in Loeffler's description (1963) on the morphology of A1 (12-segmented), P5 (medial spine longer than free segment), and caudal rami (with longitudinal row of spinules along most of outer edge), *E. breviramatus* can be considered as member of the *serrulatus*-group too.

Table 4. Comparison of the surface-ornamentation pattern of the antennal basis in some species of *Eucyclops*. Coding of the particular element follows Alekseev and Defaye (2011); Roman numerals, hairs; Arabic numerals, denticles; ?, structure not verified; NP, structure absent.

Species	1	2	3	4	5	6	7	8	9	10	11	12	12’	13	14	15	16	17
E. tziscao sp. n.	III-IV	5	5	6	8	NP	NP	4	5		5	5	NP	NP	NP	4	NP	10
E. angeli sp. n.	V	III	4	4	11	NP	5	5	NP	6	6	6	2	11	NP	3	4	6
E. bondi (type specimens)	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
E. conrowae (type specimens)	NP	NP	6	5	9	6	?	3	8		5	3	NP	NP	NP	3	NP	10
E. serrulatus (Alekseev and Defaye 2011)	IV-IX	I-IV	6–10	7–9	12–18	NP	3–5	5–8	NP	NP	5–6	6–8	NP	0–4	3–8	4–7	0	10–13
E. albuferensis (Alekseev 2008)	VII	III	8	3	3	NP	8	5	NP	7	9	9	NP	7	10	6	7	18
E. dumonti (Alekseev 2000)	NP	NP	NP	7	15	NP	NP	5	NP	4	8	8–9	NP	NP	NP	3	4	10–12

Even though the microcharacters of the antennule, antenna, intercoxal sclerites, and P1-P4 coxa are unknown in *E. breviramatus* (see Loeffler 1963), there are other characteristics that can differentiate *E. breviramatus* from *E. angeli* sp. n. for instance, the length/width ratio of Enp3P4 (1.81–1.97 in *E. angeli* vs. 1.4–1.5 in *E. breviramatus*); the short outer seta of P5 in *E. angeli* (outer seta subequal or slightly longer than inner spine in *E. breviramatus*); and the different length proportion of the caudal setae: whereas the relative length of the terminal caudal setae from outermost to innermost is 1.0: 2.98–3.55: 5.4–6.5: 1.06–1.16 in *E. breviramatus*, clearly the inner median and inner outer setae are longer in *E. angeli* sp. n. because the relative length is: 1.0: 3.9–4.5: 7.5–9.6: 1.2–1.4.

Another American species with very short caudal rami is *E. siolii*, yet likely this species does not belong to the *serrulatus*-group. *Eucyclops siolii* has a very short inner spine on the leg 5 (proportion of the spine and free segment length, 0.75), the coxal spine of P4 bears hair-setules on the inner and outer margin, and the intercoxal sclerite of P4 is only adorned with the spinule groups I and II on the caudal surface (see Herbst 1962).

Eucyclops conrowae shares the modified distal setae on the exo- and endopod of P3 and P4 with *E. angeli*, yet analysis of the holotype and paratype of the former species revealed several differences on the antennal basis, the coxa, and intercoxal sclerite of P4, which separate these two taxa. In *E. conrowae* the groups N1, N2, N13, N14, and N16 are absent on the antennal basis (Table 4), the spiny group J is absent on the P4 coxa, and the P4 intercoxal sclerite bears only denticles (Table 5).

Recently Alekseev (2008) described *E. albuferensis*, from Valencia Spain, which is similar to *E. angeli* sp. n. in the ornamentation of the caudal surface of P4 coxa, setulation of the P4 coxal spine, and ornamentation of the antennal basis. However unlike *E. angeli*, *E. albuferensis* only has short hairs in the groups I, and II on P4 intercoxal sclerite, whereas *E. angeli* has long denticles in group I, and long hairs in groups II, and

Table 5. Comparison of the surface-ornamentation pattern of the P4 coxa in some species of *Eucyclops*. Coding of the particular elements follows Alekseev and Defaye (2011) (see fig. 2C in Alekseev and Defaye 2011). Y, present; N, absent; H, hairs; LH, long hairs; SH, short hairs; D, denticles.

Species	A	B	C+D	E	F	G	H	J	I	II	III	Gap on coxal spine	Hair-like setae on basipodite
E. tziscao sp. n.	Y	N	11	5–6	Y	N	Y	Y	D	D	D	Y	Y
E. angeli sp. n.	Y	6	10–12	4	Y	Y	Y	Y	LD	LH	LH	Y	Y
E. bondi (type specimens)	Y	5	12	4	Y	Y	Y	Y	D	SH	LH	Y	Y
E. conrowae (type specimens)	Y	N	10	6	N	Y	Y	N	D	D	D	Y	Y
E. serrulatus (Alekseev and Defaye 2011)	Y	4–5	12–14	2–4	N	N	Y	Y	LH, SH	SH	LH	Y	Y
E. albuferensis (Alekseev 2008)	Y	N	13	5	Y	Y	Y	Y	SH	SH	SH	Y	Y
E. dumonti (Alekseev 2000)	Y	2–3	10–12	2	Y	Y	Y	Y	SH	SH	SH	N	N

III. Also, *E. albuferensis* has longer caudal rami in the female (about 5 times as long as wide), and it does not have modified setae-spines on Enp3P3 and Enp3P4. Last, in the male of *E. albuferensis* the inner spine of the sixth leg, does not reach the distal margin of the fourth urosomite, as it does in *E. angeli* sp. n.

Eucyclops dumonti Alekseev, 2000 is another species with short caudal rami (about 2.9 times as long as wide) (Alekseev 2000) which lives in a spring lake in Central Mongolia. *Eucyclops dumonti* differs from *E. angeli* sp. n. in the intercoxal sclerites of P1-P4, which have much less surface structures in *E. dumonti*: P1-P4 intercoxal sclerites bears more groups of long hairs in *E. angeli*. Moreover, the inner margin of P4 basis is naked in the female of *E. dumonti*, yet it has short hair-like spinules in *E. angeli*. The spinule groups N7 and N13 (caudal surface), and N1 and N2 (frontal surface) that are present on the antennal basis in *E. angeli* sp. n., are absent in *E. dumonti*. Finally, in the male of *E. dumonti* the tip of the medial spine of P6 reaches the distal margin of the third urosomite, yet in *E. angeli* this spine is longer, reaching the fourth urosomite.

Eucyclops echinatus (Kiefer 1926) distributed in Africa (Angola, Democratic Republic of Congo, Ivory Coast, Kenya, and Madagascar) is another species with short caudal rami (length/width, 2.22–2.26), but it differs from *E. angeli* sp. n. in the ornamentation of the dorsal and medial surface of the caudal rami (with short denticles in *E. echinatus*) (Kiefer 1926), and the relative length of the outer seta of P5: in *E. echinatus* the outer seta is 1.3 times longer than the inner spine, whereas in *E. angeli* sp. n., this seta is 0.6–0.9 times the length of the inner spine.

Eucyclops festivus has so far been known from North and Central regions of Mexico, mainly from the littoral region of dams, and permanent or ephemeral ponds (Lindberg 1955, Mercado-Salas 2009). The southernmost confirmed record in Mexico is that from Hidalgo State (Lindberg 1955, Suárez-Morales and Reid 1998), thus the known distribution of this species in Mexico, including our present finding in Chiapas, extends from 21°N to 16°N.

Conclusion

The two new species here described belong to the *Eucyclops serrulatus*-group. Due to the complex taxonomy and uncertain status of most species in *Eucyclops*, a morphological revision should be performed in the Americas. The genus has been revised in some regions of the world, but many American records still need verification. The use of new morphological characters facilitated better delineation of *Eucyclops* species which in turn resulted in better knowledge of the zoogeography of the genus – contrarily to what was believed, most species have well defined restricted geographic distribution, and they are not cosmopolitan.

With the description of the two new species, the number of *Eucyclops* taxa in Mexico now reaches 15 species, however several records referring to the problematic taxa should be revised. We strongly recommend to use males in the identification of *Eucyclops* species, because they present highly informative characters. Male morphology could help to clarify the identity of some problematic species, as shown for *E. bondi*.

Acknowledgements

We gratefully acknowledge the support of Dr. Hans-Walter Mittmann, Staatliches Museum Für Naturkunde, Karlsruhe, by loaning us the type specimens of *E. bondi* from Kiefer´s collection. Also, we acknowledge the help and advice of Dr. Frank Ferrari and Dr. Chad Walter (National Museum of Natural History-Smithsonian Institution) in the analysis of the type specimens of *E. conrowae.* This work is part of the second author's (NFM-S) Doctoral Thesis developed at El Colegio de la Frontera Sur (ECOSUR). This contribution was supported by CONACyT proyect133404-Investigación Científica Básica 2009. Danielle Defaye (Editor) and two anonymous reviewers made valuable comments and suggestions.

References

Alekseev V (2000) *E. dumonti* sp. nov. from Central Mongolia. Hydrobiologia 441: 63–71. doi: 10.1023/A:1017592005551

Alekseev V (2008) *Eucyclops albuferensis* sp. nov. (Cylopoida: Copepoda: Crustacea) from Albufera lake, Valencia, Spain. Proceedings of the Zoological Institute RAS 312(1/2): 127–134.

Alekseev V, Defaye D (2011) Taxonomic differentiation and world geographical distribution of the *Eucyclops serrulatus* group (Copepoda, Cyclopidae, Eucyclopinae). In: Defaye D, Suárez-Morales E, von Vaupel Klein JC (Eds) Studies on freshwater Copepoda: a volume in honour of Bernard Dussart. Koninklijke Brill NV, Leiden, 41–72. doi: 10.1163/ej.9789004181380.i-566.8

Alekseev V, Dumont HJ, Pensaert J, Baribwegure D, Vanfleteren JR (2006) A redescription of *Eucyclops* (Fischer, 1851) (Crustacea: Copepoda: Cyclopoida) and some related taxa, with a phylogeny of the *E. serrulatus*-group. Zoologica Scripta 35: 123–147. doi: 10.1111/j.1463-6409.2006.00223.x

Bruno MC, Reid JW, Perry SA (2005) A list and identification key for the freshwater, free-living copepods of Florida (U.S.A.). Journal of Crustacean Biology 25: 384–400. doi: 10.1651/C-2538

Collado C, Defaye D, Dussart BH, Fernando CH (1984) The freshwater copepod (Crustacea) of Costa Rica with notes on some species. Hydrobiologia 119: 89–99. doi: 10.1007/BF00011948

De los Ríos P, Rivera R, Morrone JJ (2010) Cyclopoids (Crustacea:Copepoda) reported from Chilean inland waters. Boletín de Biodiversidad de Chile 2: 10–20.

Dussart BH, Defaye D (2006) World Directory of Crustacea Copepoda of Inland Waters II-Cyclopiformes. Backhuys Publishers, Leiden-The Netherlands, 334 pp.

Elías-Gutiérrez M (2000) Informe final del Proyecto S050: Microcrustáceos zooplanctónicos y litorales del Sureste de México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Chetumal-México, 53 pp.

Elías-Gutiérrez M, Suárez-Morales E, Gutiérrez-Aguirre MA, Silva-Briano M, Granados-Ramírez JG, Garfias-Espejo T (2008) Cladocera y Copepoda de las aguas continentales de México guía ilustrada. Universidad Nacional Autónoma de México, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, El Colegio de la Frontera Sur, Consejo Nacional de Ciencia y Tecnología, Secretaría de Medio Ambiente y Recursos Naturales, México DF-México, 322 pp.

Frisch D, Threlkeld ST (2005) Flood-mediated dispersal versus hatching: Early recolonization strategies of copepods in floodplain ponds. Freshwater Biology 50: 323–330. doi: 10.1111/j.1365-2427.2004.01321.x

Gaviria S, Aranguren N (2007) Especies de vida libre de la subclase Copepoda (Arthropoda, Crustacea) en aguas continentales de Colombia. Biota Colombiana 8: 53–68.

Grimaldo-Ortega D, Elías-Gutiérrez M, Camacho-Lemus M, Ciros-Pérez J (1998) Additions to Mexican freshwater copepods with the description of the female *Leptodiaptomus mexicanus* (Marsh). Journal of Marine Systems 15: 381–390. doi: 10.1016/S0924-7963(97)00069-9

Gutiérrez-Aguirre MA, Suárez-Morales E, Cervantes-Martínez A (2006) Distribución de las especies de *Mesocyclops* (Copepoda: Cyclopoida) en el sureste mexicano y región norte de Guatemala. Hidrobiológica 16: 259–265.

Gutiérrez-Aguirre MA, Cervantes-Martínez A (2013) Diversity of freshwater copepods (Maxillopoda: Copepoda: Calanoida, Cyclopoida) from Chiapas, Mexico with a description of *Mastigodiaptomus suarezmoralesi* sp. nov. Journal of Natural History 47: 479–498. doi: 10.1080/00222933.2012.742587

Herbst HV (1962) Crustacea aus dem Amazonasgebiet, gesammelt von Prof. Dr. H. Sioli und Dr. R. Braun. I. Litorale und substratgebundene Cyclopoida Gnathostoma (Copepoda). Crustaceana 3: 259–278. doi: 10.1163/156854062X00508

Ishida T (1997) *Eucyclops roseus*, a new Eurasian copepod, and the *E. serrulatus-speratus* problem in Japan. Japanese Journal of Limnology 58: 349–358. doi: 10.3739/rikusui.58.349

Ishida T (2001) *Eucyclops borealis* sp. nov. from Alaska, and *E. tseshimensis* sp. nov. from Tsushima Island, Japan (Crustacea, Copepoda, Cyclopoida). Biogeography 3: 51–57.

Ishida T (2002) Illustrated fauna of the freshwater cyclopoid copepods of Japan. Bulletin of the Biogeography Society of Japan 57: 37–106.

Ishida T (2003) Description of *Eucyclops serrulatus* (Fisher, 1851) (Copepoda, Cyclopoida) from Japan, with reference to the degree of difference from specimens from the type locality. Biogeography 5: 1–7.

Karaytug S (1999) Genera *Paracyclops*, *Ochridacyclops* and key to the Eucyclopinae. Guide to the Identification of the Microinvertebrates of the Continental Waters of the World, No. 14. Backhuys Publishers, Leiden-The Netherlands, 217 pp. doi: 10.2307/1549244

Karaytug S, Boxshall GA (1999) Antennules of the male of *Paracyclops* (Copepoda): functional significance and their importance in systematic. Journal of Crustacean Biology 19: 371–379.

Kiefer F (1926) 4. Beiträge zur Copepodenkunde. (IV). Sonderabdruck aus dem Zoologischer Anzeiger 49: 21–26.

Lindberg K (1955) Cyclopoïdes (Crustacés copepods) du Mexique. Arkiv för Zoologi 7: 459–489.

Loeffler H (1963) Zur Ostrakoden- und Copepodenfauna Ekuadors mit Beschreibung 6 neuer Arten und 3 neuer Unterarten. Archiv für Hydrobiologie 59: 196–234.

Mercado-Salas NF (2009) Diversidad y Distribución de los Cyclopoida (Copepoda) de las zonas Áridas del Centro-Norte de México. MSc thesis, Chetumal. El Colegio de la Frontera Sur, Quintana Roo.

Mercado-Salas NF, Pozo C, Morrone JJ, Suárez-Morales E (2012) Distribition patterns of the American species of the freshwater genus *Eucyclops* (Copepoda: Cyclopoida). Journal of Crustacean Biology 32: 457–464. doi: 10.1163/193724012X626502

Reid JW (1985) Chave de identificação e lista de referências bibliográficas para as espécies continentais Sulamericanas de vida livre da Ordem Cyclopoida (Crustacea, Copepoda). Boletim de Zoología, Universidade de São Paulo 9: 17–143.

Reid JW (2003) A technique for observing copepods. In: Ueda H, Reid JW (Eds) Copepoda: Cyclopoida, genera *Mesocyclops* and *Thermocyclops*. Backhuys Publishers, Leiden, 8.

Rodríguez-Almaraz GA (2000) Informe final del Proyecto S104: Biodiversidad de los crustáceos dulceacuícolas del centro de Nuevo León y noreste de Tamaulipas. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México DF-México, 33 pp.

Suárez-Morales E (2004) A new species of *Eucyclops* Claus (Copepoda: Cyclopoida) from southeast Mexico with a key for the identification of the species recorded in Mexico. Zootaxa 617: 1–18.

Suárez-Morales E, Reid JW (1998) An updated list of the free-living freshwater copepods (Crustacea) of Mexico. Southwestern Naturalist 43: 256–265.

Suárez-Morales E, Walsh E (2009) Two new species of *Eucyclops* Claus (Copepoda: Cyclopoida) from the Chihuahuan Desert with a redescription of *E. pseudoensifer* Dussart. Zootaxa 2206: 1–22.

Velázquez Velázquez E (2011) Informe final SNIB-CONABIO proyecto FM005: Inventario de peces y crustáceos decápodos de la Reserva de la Biosfera Selva El Ocote y Presa Nezahualcóyotl (Malpaso), Chiapas México. Universidad de Ciencias y Artes de Chiapas, Tuxtla Gutiérrez-México, 23 pp.

Zamudio-Valdéz JA (1991) Los copépodos de vida libre (Crustacea: Maxillopoda) del Valle de Cuatro Ciénegas, Coahuila, México. BSc thesis, San Nicolás de los Garza. Universidad Autónoma de Nuevo León, Nuevo León.

ZooKeys 351: 31–36 (2013)
doi: 10.3897/zookeys.351.6255
www.zookeys.org

SHORT COMMUNICATION

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

First description of the male of *Cryptothele verrucosa* L. Koch, 1872 (Araneae), the type species of the genus

Yuri M. Marusik[1,2], Mikhail M. Omelko[3,4]

1 *Institute for Biological Problems of the North, RAS, Portovaya Str. 18, Magadan 685000, Russia* **2** *Zoological Museum, University of Turku, FI-20014 Turku, Finland* **3** *Gornotaezhnaya Station FEB RAS, Gornotaezhnoe Vil., Ussuriyski Dist., Primorski krai 692533 Russia* **4** *Far Eastern Federal University, Sukhanova, 8, Vladivostok 690950 Russia*

Corresponding author: *Yuri M. Marusik* (yurmar@mail.ru)

Academic editor: *Shuqiang Li* | Received 16 September 2013 | Accepted 10 November 2013 | Published 15 November 2013

Citation: Marusik YM, Omelko MM (2013) First description of the male of *Cryptothele verrucosa* L. Koch, 1872 (Araneae), the type species of the genus. ZooKeys 351: 31–36. doi: 10.3897/zookeys.351.6255

Abstract

The male of *Cryptothele verrucosa* L. Koch, 1872, the type species of *Cryptothele* L. Koch, 1872, known from Fiji and Samoa, is described for the first time. It is compared with the male of *C. alluaudi* Simon, 1893, the single properly described species of the genus.

Keywords

Spider, Zodariidae, Cryptothelidae, Fiji

Introduction

Cryptothele L. Koch, 1872 is a small genus of litter dwelling spiders, the bodies of which are covered with dirt. Up to now eight species and two subspecies are known in the genus. The genus occurs from Seychelles to Fiji and Samoa. Family placement of *Cryptothele* remains uncertain. Originally the genus was placed in a separate family Cryptothelidae L. Koch, 1872. Soon after, Simon (1890) downgraded this group to a subfamily level and placed it in Zodariidae Thorell, 1881, although Cryptothelidae had formal priority. This group was returned to family status by Davies (1985), but then Wunderlich (2004) reduced its status back to a subfamily of Zodariidae. Currently (Platnick 2013) the younger name, Zodariidae, is amply protected by usage.

Of ten species and subspecies described to date, only one species, *C. alluaudi* Simon, 1893, is relatively well described and its somatic morphology and the conformation of copulatory organs studied (Saaristo 2010; Marusik and Omelko 2012). Five of ten species and subspecies are known from females only; one species, *C. cristata* Simon, 1884, with an unknown type locality, is described from a juvenile, and the description of *C. collina* Pocock, 1901 is based on specimens for which there are no indication of sex or stage (Platnick 2013).

Working with collections of the Zoological Museum, University of Turku we found a single male from Fiji identified by Pekka Lehtinen as *C. verrucosa* L. Koch, 1872. *Cryptothele verrucosa* is the type species of the genus and known on the basis of female sex and only from Fiji and Samoa. Since its description it has never been considered in taxonomic papers (*cf.* Platnick 2013). Although the species is known from females only, and original description is rather poor it is reasonable to conclude that the identification made by Lehtinen is correct, because all species of the genus have allopatric distribution (*cf.* Fig. 10, Marusik and Omelko 2012). Therefore, the purpose of this paper is to provide the first description of male of *C. verrucosa*.

Material and methods

Specimens were photographed using an Olympus Camedia E-520 camera attached to an Olympus SZX16 stereomicroscope. The images were montaged using "CombineZP" image stacking software. Photographs were taken in dishes of different sizes with paraffin in the bottom. Different sized holes were made in the paraffin to keep the specimens in the correct position. The studied material is kept in the Zoological Museum, University of Turku (ZMUT). All measurements are in mm.

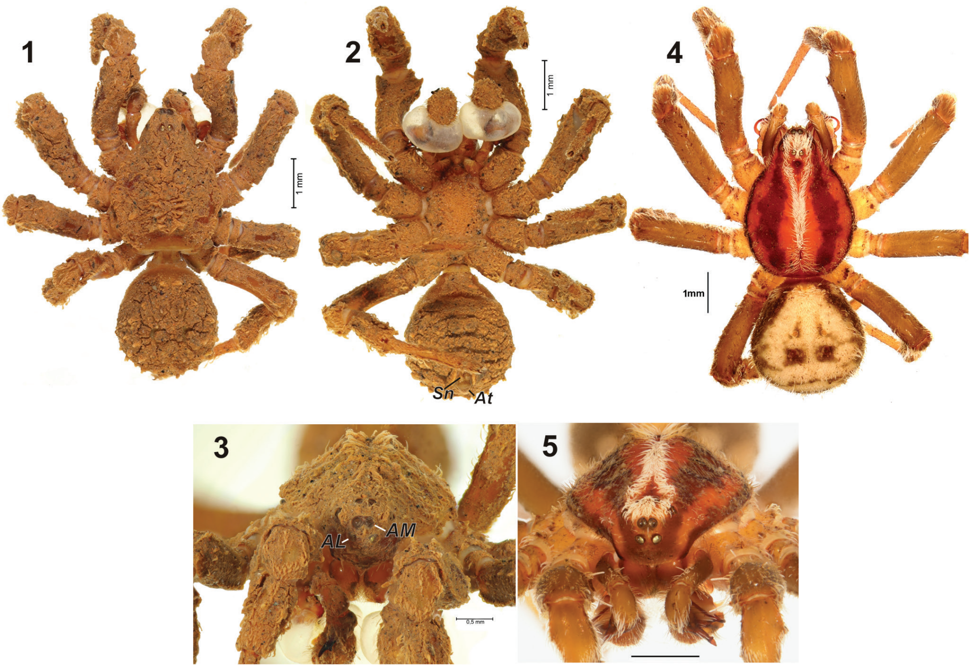
Taxonomy

***Cryptothele verrucosa* L. Koch, 1872**
http://species-id.net/wiki/Cryptothele_verrucosa
Figs 1–3, 6–11

C. v. L. Koch, 1872: 240, pl. 20, f. 2 (D♀).

Material examined. FIJI: 1♂ (ZMUT AA 5.828), Viti Levu, Suva rain forest, 26.05.1973 (J.M. Ackerman).

Diagnosis. *Cryptothele verrucosa* differs from *C. alluaudi*, the only properly described species in the genus, by lack of carapace pattern, much more heavy camouflage of dirt that covers whole body, straight row of posterior eyes, anterior lateral eyes spaced by one diameter (1/2 of diameter in *C. alluaudi*), shape of tibial apophysis (*cf.* Figs 11, 12), short and broad embolus with two processes (long and filamentous in *C. alluaudi*, Fig. 12).



Figures 1–5. General appearance of males of *Cryptothele verrucosa* (**1–3**) and *C. alluaudi* (**4–5**). **1, 4** dorsal **2** ventral **3, 5** frontal **4–5** after Marusik and Omelko (2012). Abbreviations: ***AL*** anterior lateral eye; ***AM*** anterior median eye; ***At*** anal tubercle, ***Sn*** spinneret.

Description. Measurements. Total length 5.5, carapace 3.0 long, 2.28 wide. AME 0.14, AME-AME 0.15. Position of metatarsal trichobothria IV 0.9.

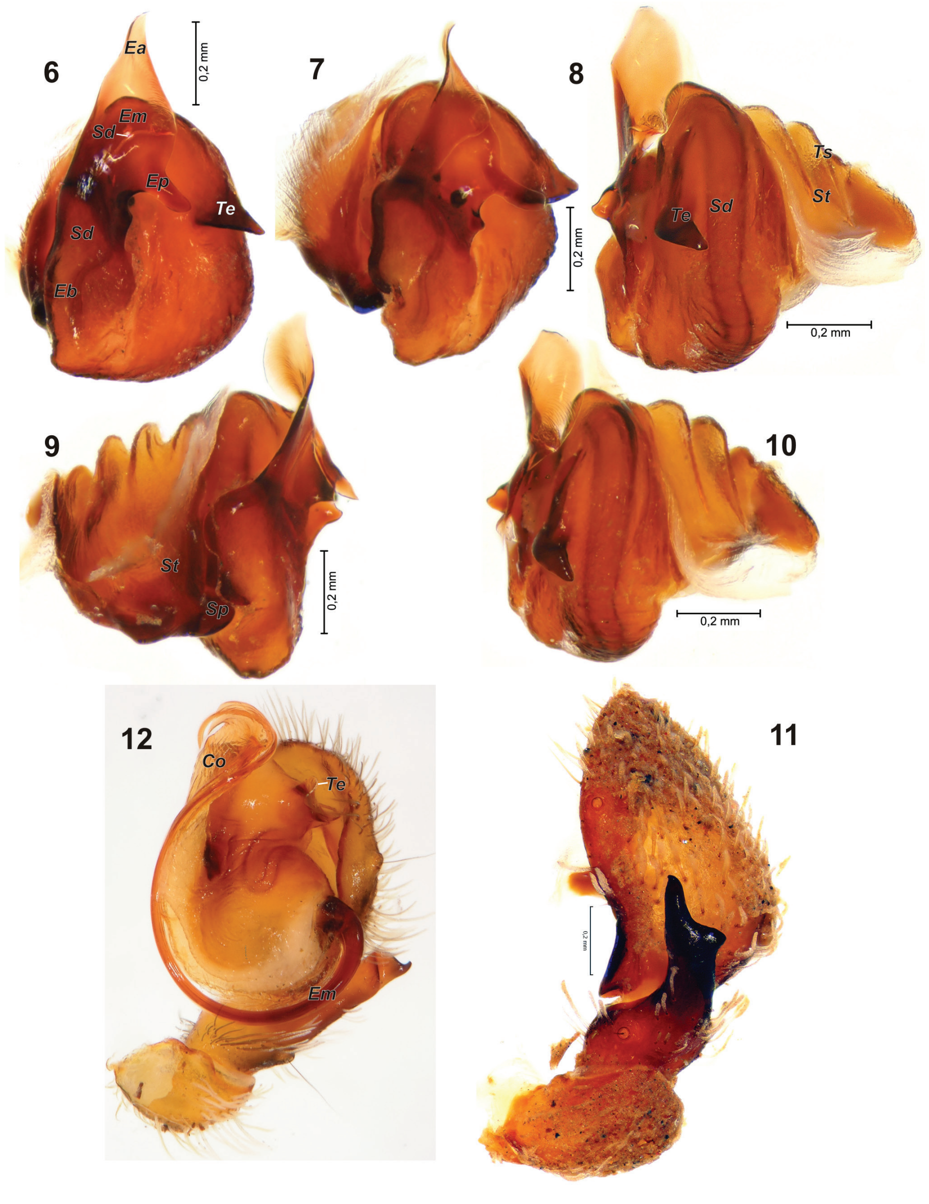
Whole body, including sternum and venter of abdomen covered by comouflaging dirt (Figs 1–2). Carapace brown, without pattern, with two rows of hairs aside of median line, these rows are visible after removing the comouflaging dirt. AME spaced by one diameter (Fig. 3), anterior eyes form inverted trapezium (ALE row wider than AME row), posterior eye row almost straight, cephalic area with pit behind posterior median eyes. Leg subeaqual in length, formula 1423. Legs heavily built, with thick femur–tibia and twice as thin metatasrus–tarsus, border between tarsus and metatarsus poorly visible, metatarsi with terminal trichobothria.

Length of legs and leg joints.

	Fe	Pa	Ti	Mt	Ta	Total
I	1.8	0.88	1.08	1.12	0.88	5.76
II	1.63	0.88	1.0	1.0	0.88	5.39
III	1.5	0.88	1.0	0.9	0.88	5.16
IV	1.63	0.88	1.12	0.9	0.95	5.48

Abdomen oval, with two spinnerets (*Sn*) about the size of anal tubercle (*At*).

Palp as shown in Figs 6–11. The single specimen examined has both palps expanded. Tibia (Fig. 11) with long retrolateral apophysis tapering in terminal 1/3, dorsal



Figures 6–12. Male palp of *Cryptothele verrucosa* (**6–11**) and *C. alluaudi* (**12**). **6** bulbus, ventral **7** bulbus, ventro-prolateral **8, 10** bulbus, retrolateral **9** bulbus, prolateral **11** palp with removed bulbus, retrolateral **12** palp, ventral (after Marusik and Omelko (2012)). Abbreviations: ***Co*** conductor; ***Ea*** terminal process of embolus; ***Eb*** embolus base; ***Em*** embolus; ***Ep*** posterior process of embolus; ***Sd*** seminal duct; ***Sp*** subtegular process; ***St*** subtegulum; ***Te*** triangle extesion of tegulum; ***Ts*** threads of subtegulum.

side of apophysis with shallow blunt outgrowth, retrolateral side of tibia with trichobothrium in proximal part; cymbium oval, with trichobothrium on retrolateral side. Subtegulum (*St*) (Figs 8–10) large (as long as tegulum in lateral view), cone-shaped with three threads (*Ts*); prolaterally with process (*Sp*) directed to notch of embolic base. Tegulum nearly oval with triangle extesion (*Te*) in terminal part (Figs 6, 8, 10). Embolus (*Em*) broad, longer than tegulum, heavily built in the base (*Eb*), terminal part lamellated with two processes: digitiform posterior process (*Ep*) and triangle shape terminal process (*Ea*), seminal duct (Sd) broad and heavily sclerotised in the base of embolus, and very fine in lamellar part of embolus.

Comments. Thanks to the discovery of the male of *C. verrucosa* (the easternmost species of the genus) it has became possible to compare it with the westernmost species, *C. alluaudi*. General appearance of the two species is rather similar (Figs 1–5). They differ in amount of camouflage cover which is almost absent in *C. alluaudi*, but *C. verrucosa* is covered heavily on dorsal and ventral sides. Both male and female of *C. alluaudi* have a distinct pattern on the carapace. Such a pattern is absent in the studied male of *C. verrucosa* (we have removed the camouflage cover); it is also absent in the conspecific female, judging from L. Koch's description. Male of *C. alluaudi* has relatively longer and thinner legs (cf. Figs 1 and 4) and less spaced anterior lateral eyes (Figs 3 and 5). The posterior eye row is straight in *C. verrucosa* (Fig. 1) and recurved in *C. alluaudi* (Fig. 4). Male palps in two species are strikingly different. *Cryptothele alluaudi* has a long filamentous spiraled embolus and conductor (*Co*) (Fig. 12). In *C. verrucosa* the embolus is flat and broad. Extension of tegulum in *C. alluaudi* is weakly sclerotized and has subparallel margins, while in *C. verrucosa* it is triangle–shaped and strongly sclerotized.

In the collection of the Zoological Museum, University of Turku we had the opportunity to examine males of two unidentified species of *Cryptothele*, one from Thailand (which seems new to science) and another from Indonesia (probably *C. sundaica* Thorell, 1890). Males of both species have conformation of the palp similar to that in *C. alluaudi* (a thin and long embolus, a well developed conductor, etc.). This may indicate that *C. alluaudi, C. sundaica* and the mentioned undescribed species most likely are not congeneric with *C. verrucosa* and the genus could be split in the future into two separate genera.

Comparative material examined. *Cryptothele* sp. (presumably new) 1♂ (ZMUT: AA 5.812), Thailand, Chanthaburi Pr., Kho Yai N.P., Wang Chum Pee, rain forest, 27.10–22.11.1976 (P.Lehtinen) covered with dirt, even cymbium, but RTA like in *C. alluaudi*, embolus and conductor long.

Cryptothele sundaica?: 2♂ 1♀ (ZMUT: AA 5.806), Indonesia, Sumatera Barat, Paykumbuh d., Lubu Bangku, low jungle, 7.12.1980 (P.T.Lehtinen).

Acknowledgements

We wish to thank Seppo Koponen who arranged our stay in Turku and allowed the use of local facilities (digital camera attached to microscope). We also thank anonymous reviewers and Shuqiang Li for helpful comments on a draft of the manuscript. English of the final draft was kindly checked and corrected by Donald Buckle (Saskatoon, Canada). This work was supported in part by the Russian Foundation for Basic Research (grants № 11–04–01716 and 12–04–01548) and Far Eastern Federal University (Vladivostok).

References

Davies VT (1985) Araneomorphae (in part). Zoological Catalogue of Australia 3: 49–125.

Koch L (1872) Die Arachniden Australiens. Nürnberg 1: 105–368.

Marusik YM, Omelko MM (2012) Redescription of *Cryptothele alluaudi* Simon, 1893 (Araneae). Arthropoda Selecta 21, 2: 183–186.

Platnick NI (2013) The World Spider Catalog, Version 14.0 American Museum of Natural History. http://research.amnh.org/entomology/spiders/catalog/index.html [accessed 8 September 2013]

Saaristo MI (2010) Araneae. In: Gerlach J, Marusik YM (Eds) Arachnida and Myriapoda of the Seychelles islands. Siri Scientific Press, Manchester, 8–306.

Simon E (1890) Etudes arachnologiques. 22e Mémoire. XXXVI. Arachnides recueillis aux îles Mariannes par M. A. Marche. Annales de la Société entomologique de France 10: 131–136.

ZooKeys 351: 37–48 (2013)
doi: 10.3897/zookeys.351.6259
www.zookeys.org

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

New species and records of the stonefly genus *Neoperla* (Plecoptera, Perlidae) from Jinhuacha Nature Reserve, Guangxi of China

Guo–Quan Wang[1,†], Wei–Hai Li[2,‡], Juan Yang[1,§]

1 *Department of Plant Protection, Guangxi University, Nanning, Guangxi 530004, China* **2** *Department of Plant Protection, Henan Institute of Science and Technology, Xinxiang, Henan 453003, China*

† *http://zoobank.org/351B5BB1-A386-43D3-AE8D-4A273CA7BA4D*
‡ *http://zoobank.org/81D57DE5-E00B-4F6B-A0B3-E81D3C865208*
§ *http://zoobank.org/F35841D2-961F-4B21-ABCA-F91E9E29DA17*

Corresponding author: *Wei–Hai Li* (lwh7969@163.com)

Academic editor: *M. Gottardo* | Received 17 September 2013 | Accepted 11 November 2013 | Published 15 November 2013

http://zoobank.org/B6EA1840-CFFC-4717-BBB7-B48B32B6320D

Citation: Wang G-Q, Li W-H, Yang J (2013) New species and records of the stonefly genus *Neoperla* (Plecoptera, Perlidae) from Jinhuacha Nature Reserve, Guangxi of China. ZooKeys 351: 37–48. doi: 10.3897/zookeys.351.6259

Abstract

Two new *Neoperla* species (*Neoperla mesospina*, *Neoperla latispina*) are described from the adult male stage from the Jinhuacha Nature Reserve, Guangxi of China. The new species are compared with similar taxa. Taxonomic remarks are also provided for *N. transversprojecta* Du & Sivec and *N. yao* Stark. The latter species is newly recorded for Guangxi.

Keywords

Plecoptera, Perlidae, *Neoperla mesospina*, *Neoperla latispina*, new species, China

Introduction

The stonefly genus *Neoperla* is a species-rich perlid stonefly genus in China (Sivec et al. 1988, DeWalt et al. 2013). The works of this genus in China was mainly contributed by Chu (1929), Du (1999, 2000a, 2000b), Du and Sivec (2004, 2005), Du and Wang

(2005, 2007), Du et al. (1999, 2001), Li et al. (2011a), Li et al. (2011b), Li and Wang (2011), Li et al. (2012a), Li et al. (2012b), Li and Li (2013), Li et al. (2013a), Li et al. (2013b), Qin et al. (2013), Sivec and Zwick (1987), Wang et al. (2013),Wu (1935, 1938, 1948, 1962, 1973), Wu and Claassen (1934), Yang and Yang (1990, 1991), and Yang and Yang (1992, 1993, 1995a, 1995b, 1996, 1998).

In the present paper, four species of the genus *Neoperla* are threated from the specimens collected in Jinhuacha Nature Reserve, Guangxi of China in the recent two years, including two new one: *N. latispina* sp. nov and *Neoperla mesospina* sp. n. The Reserve is located in Fangchenggang city of Guangxi Zhuang Autonomous Region and was established to protect rare or endangered species of *Camellia nitidissima* Chi (Chinese name Jinhuacha).

Material and methods

The specimens used in this study were collected by light trap. Types and other examined material are deposited in the Insect Collection of Henan Institute of Science and Technology (HIST), Xinxiang, and the Entomological Museum of China Agricultural University (CAU), Beijing. They were examined with the aid of a Motic SMZ 168 microscope and the color illustrations were captured using digitalized software Motic Images Advanced 3.2. All specimens were kept in 75% ethanol. Aedeagi were everted using the cold maceration technique of Zwick (1983). Terminology follows that of Sivec et al. (1988). All the scale lines in the figures stand for 0.5 mm.

Results

***Neoperla latispina* Wang & Li, sp. n.**
http://zoobank.org/96D00CD1-528F-40F4-891A-0B5B9CF19762
http://species-id.net/wiki/Neoperla_latispina
Figs 1–2

Type material. 1 male (CAU), China: Guangxi, Fangcheng, Jinhuacha Nature Reserve, 21°76,09'N, 108°43,49'E, light trap, 15 May 2013, G.Q. Wang.

Male. Forewing length 12.6 mm. Distance between ocelli about 1.5× as wide as diameter of the ocellus. Head pale yellow, slightly wider than pronotum, with a black area covering ocelli which extends forward to contacting a quadrate black stigma on frons (Fig. 1a); compound eyes black and antennae dark except scape pale; maxillary palpi brownish. Pronotum with obscure rugosities and pale lateral margins, meso- and metathorax mostly brown (Fig. 1a); wing membrane subhyaline, veins brown; legs dark brown with femora pale brown, but distal fourth of foreleg femora dark brown (Fig. 1e).

Terminalia. The posterior margin of tergum 7 with a trapezoidal sclerotized area extended into a rounded quadrate process covered with distal sensilla basiconica (Fig. 1b).

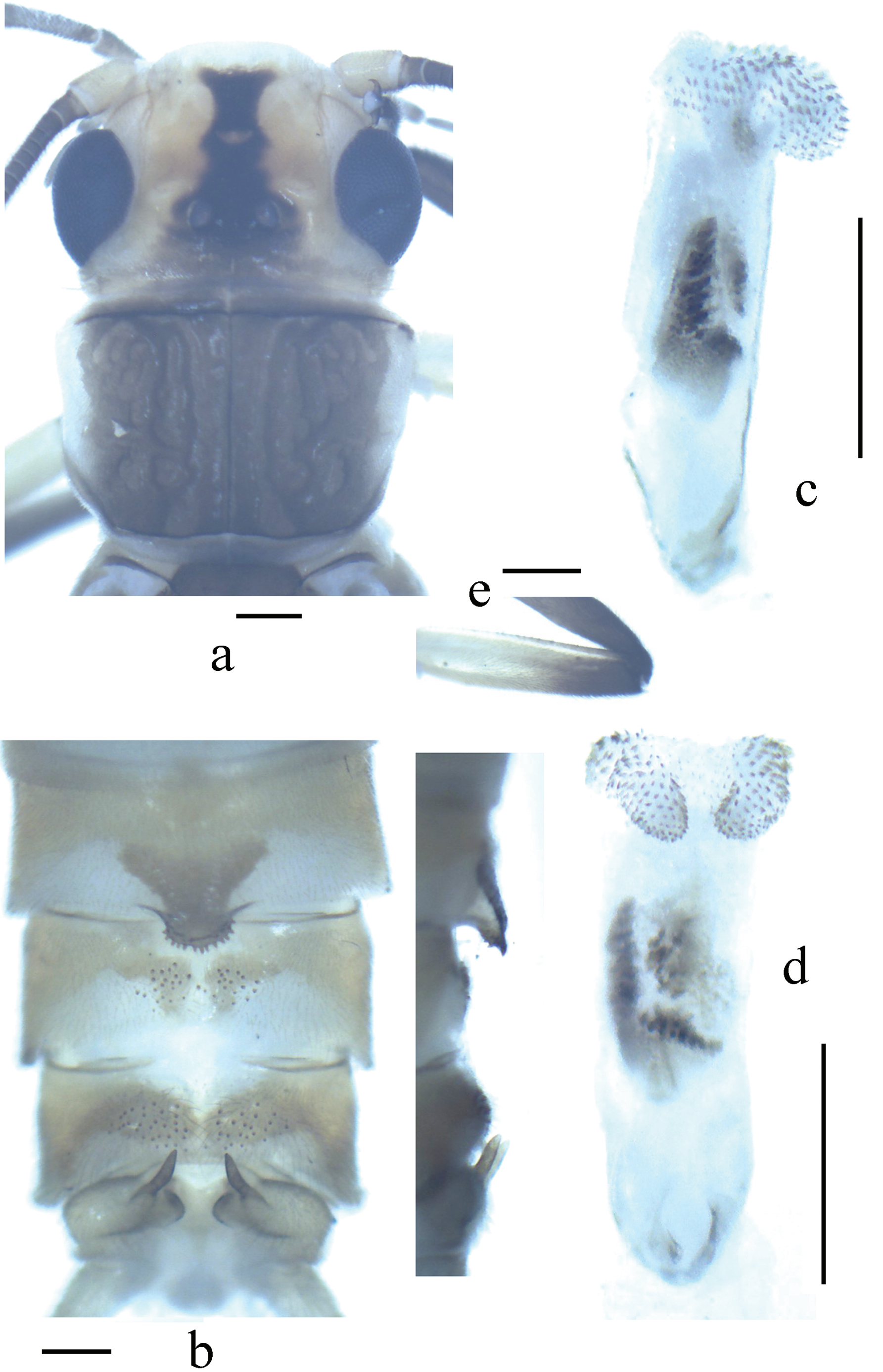


Figure 1. *Neoperla latispina* Wang & Li, sp. n. Male. **a** Head and pronotum, dorsal view **b** Terminalia, dorsal and lateral views **c** Aedeagus before eversion, lateral view **d** Aedeagus before eversion, dorsal view **e** foreleg femur.

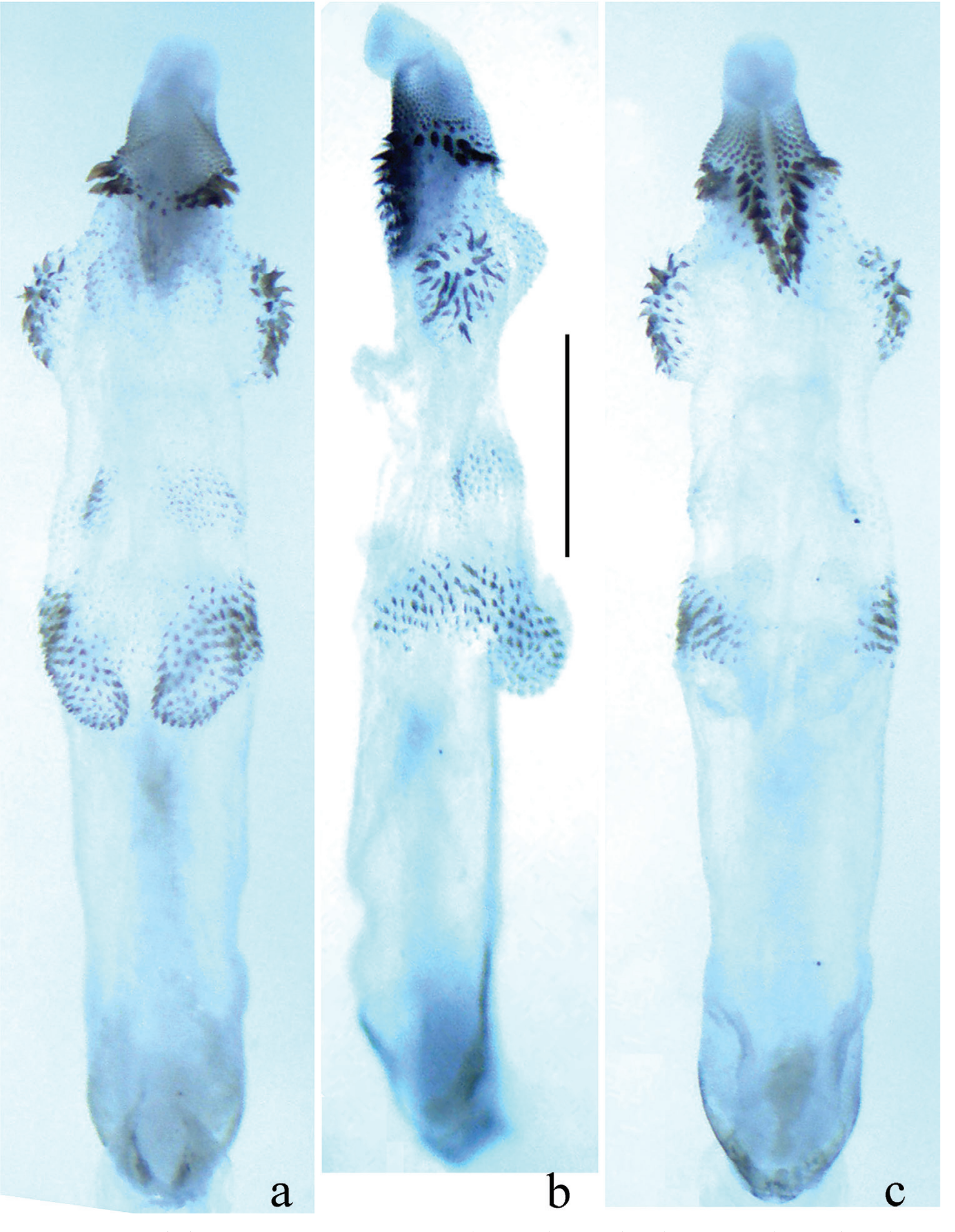


Figure 2. *Neoperla latispina* Wang & Li, sp. n. Male. **a** Aedeagus, dorsal view **b** Aedeagus, lateral view **c** Aedeagus, ventral view.

Tergum 8 with two median weak humps covered by sensilla basiconica (Figs 1b). Tergum 9 with two patches of sensilla basiconica. Hemitergal processes of tergum 10 sclerotized, with rod-like base and sharp apex (Fig. 1b). Aedeagal tube membranous with a weak basodorsal sclerite, apically with a pair of separate dorsal spinous lobes covered by small spines connected with two lateral spinous bands, in lateral view the lobes plump and nipple like (Figs 1c–d, 2). Aedeagal sac slightly longer than tube, essentially straight along with tube in outline; two spinulose dorsal patches present at slightly swollen base, single ventral lobe without spines, located near midlength of sac, a pair of mesolateral protrusions rounded, covered by large spines and two nearby elevated dorsal lobes triangular in lateral view covered with tiny spines; distal portion of sac with two rows of large spines which extend laterally below the apical fine spinules (Fig. 2).

Female. Unknown.

Etymology. The specific epithet refers to the lateral spinous patch of aedeagal sac.

Distribution. China (Guangxi).

Diagnosis and remarks. *Neoperla latispina* belongs to *oculata* species complex defined by Zwick (1986) in the *montivaga* species group (Zwick 1983) which includes species bearing a similar T7 lobe and several lobes, protrusions or finger shaped extensions of the aedeagal sac (see figs 1–2 and figs 51–63 in Zwick 1986 for comparison). This species shares dorsal lobe characteristics of the aedeagal tube with *N. securifera* Zwick 1986 and *N. multilobata* Zwick 1986 (figs 57 & 59 in Zwick 1986). *Neoperla latispina* also shares a straight outline of the extruded aedeagus with *N. multilobata* whereas the sac of *N. securifera* stands at right angle to tube. However, the dorsal lobes of aedeagal tube in *N. latispina* are paired but that of *N. multilobata* is single. Additionally, *N. latispina* bears only single ventral lobe near midlength while *N. multilobata* has spinous ventrobasal and ventrodistal lobes (fig. 59 in Zwick 1986).

Neoperla mesospina Li & Wang, sp. n.

http://zoobank.org/1D766031-1F27-48B8-B91A-C1D12FD2D661
http://species-id.net/wiki/Neoperla_mesospina
Figs 3–4

Type material. Holotype: 1 male (HIST), Guangxi, Fangcheng, Jinhuacha Nature Reserve, 21°76,09'N, 108°43,49'E, light trap, 16 April 2012, G.Q. Wang. Paratypes: 2 males (HIST), same as holotype; 1 male (CAU), same locality, 2013. May 15, G.Q. Wang.

Male. Forewing length 11.1–11.3 mm. Distance between ocelli about as wide as diameter of the ocellus. Head mostly yellow brown, lateral margins and frons pale, a subquadrate dark area covering ocelli, slightly wider than pronotum; antennae brown; compound eyes dark; mouthparts brown (Fig. 3a). Thorax brownish with darker median stripe and scattered rugosities, legs brown; wings pale. Abdomen brownish yellow.

Terminalia. Tergum 7 with an elevated trapezoidal median process at posterior margin, which is covered by many tiny sensilla basiconica. Process of tergum 8 moderately sclerotized, recurved backward and tougue–shaped, lateral marings with tiny spines. Tergum 9 without sensilla patches. Hemitergal processes of tergum 10 strongly sclerotized and with slightly curved apex (Figs 3a, b). Aedeagal tube long and slender, relatively straight and moderately sclerotized, medially with a nipple-like process in ventral surface; everted sac strongly curved ventrad as a loop, about half as long as tube,

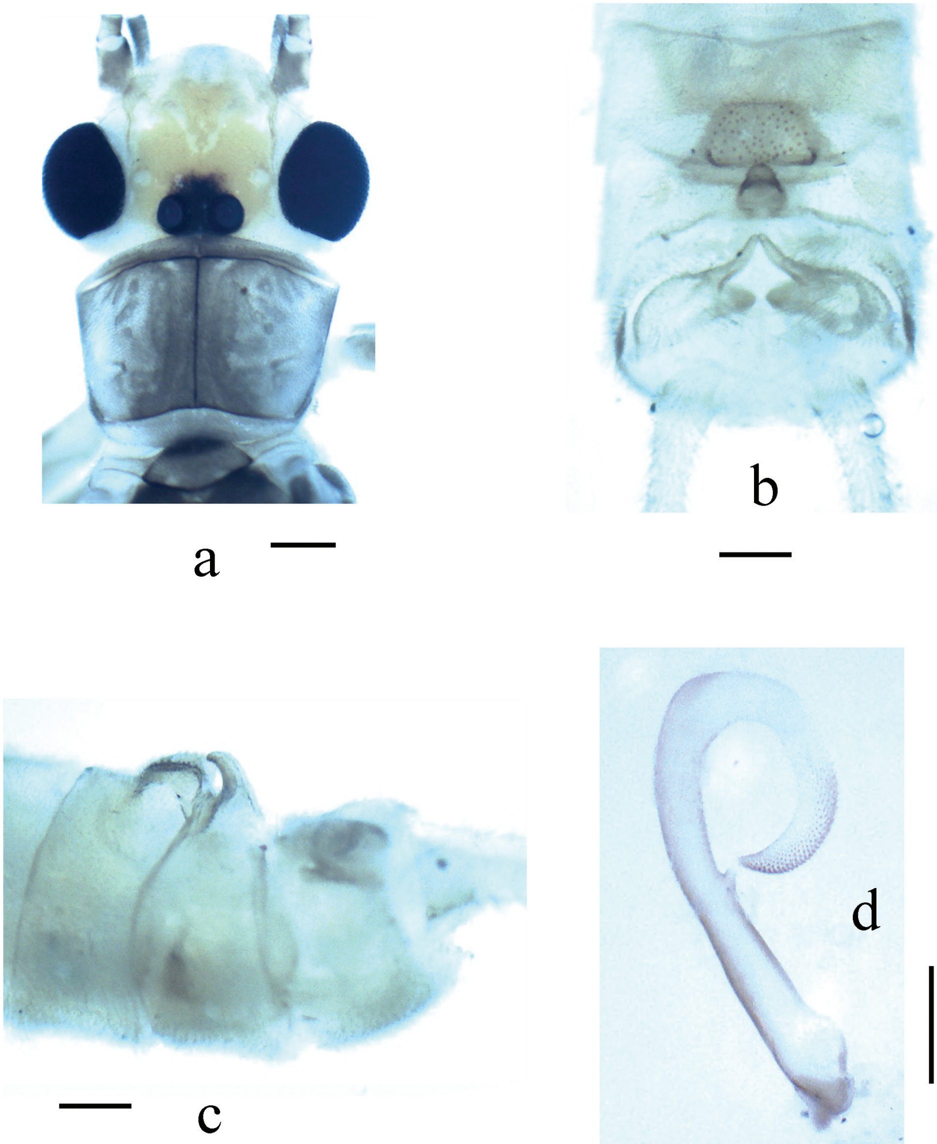


Figure 3. *Neoperla mesospina* Li and Wang, sp. n. Male. **a** Head and pronotum, dorsal view **b** Terminalia, dorsal view **c** Terminalia, lateral view **d** Aedeagus, lateral view.

irregular rows of small to median sized spines present along dorsal and lateral surfaces from medial portion to apex of the sac (Figs 3d & 4).

Female. Unknown.

Etymology. The specific epithet refers to the location of the nipple-like process on the aedeagal tube.

Distribution. China (Guangxi).

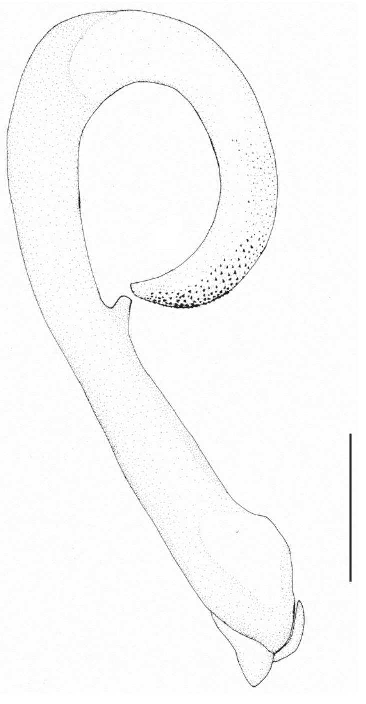


Figure 4. *Neoperla mesospina* Li and Wang, sp. n. Male aedeagus, lateral view.

Diagnosis and remarks. The new species seems closely related to *N. dao* Stark & Sivec, 2008, a recently described species from Vinh Phu Province of Vietnam. They are very similar in head pattern, general features of male terminalia and the aedeagal tube. However, the new species can be easily separated from *N. dao* Stark & Sivec by the relatively long (about half as long as tube) and strongly curved aedeagal sac in lateral view. In *N. dao* Stark & Sivec, the sac is very short, somewhat straight and triangular in outline (fig. 22 in Stark and Sivec 2008). There are no other Chinese species of *Neoperla* that appear related to *N. mesospina*.

Neoperla transversprojecta **Du & Sivec, 2004**
http://species-id.net/wiki/Neoperla_transversprojecta
Fig. 5

Neoperla transversprojecta Du & Sivec, 2004. In Yang X-K (Ed) Insects from Mt. Shiwandashan Area of Guangxi. China Forestry Publishing House: 42. Type locality: China, Guangxi, Fangcheng County, Banba town; Li et al. 2011. Zootaxa 2735: 57.

Material examined. 2 males (HIST), China: Guangxi, Fangcheng, Jinhuacha Nature Reserve, 21°76,09'N, 108°43,49'E, light trap, 2013. May 15, G.Q. Wang.

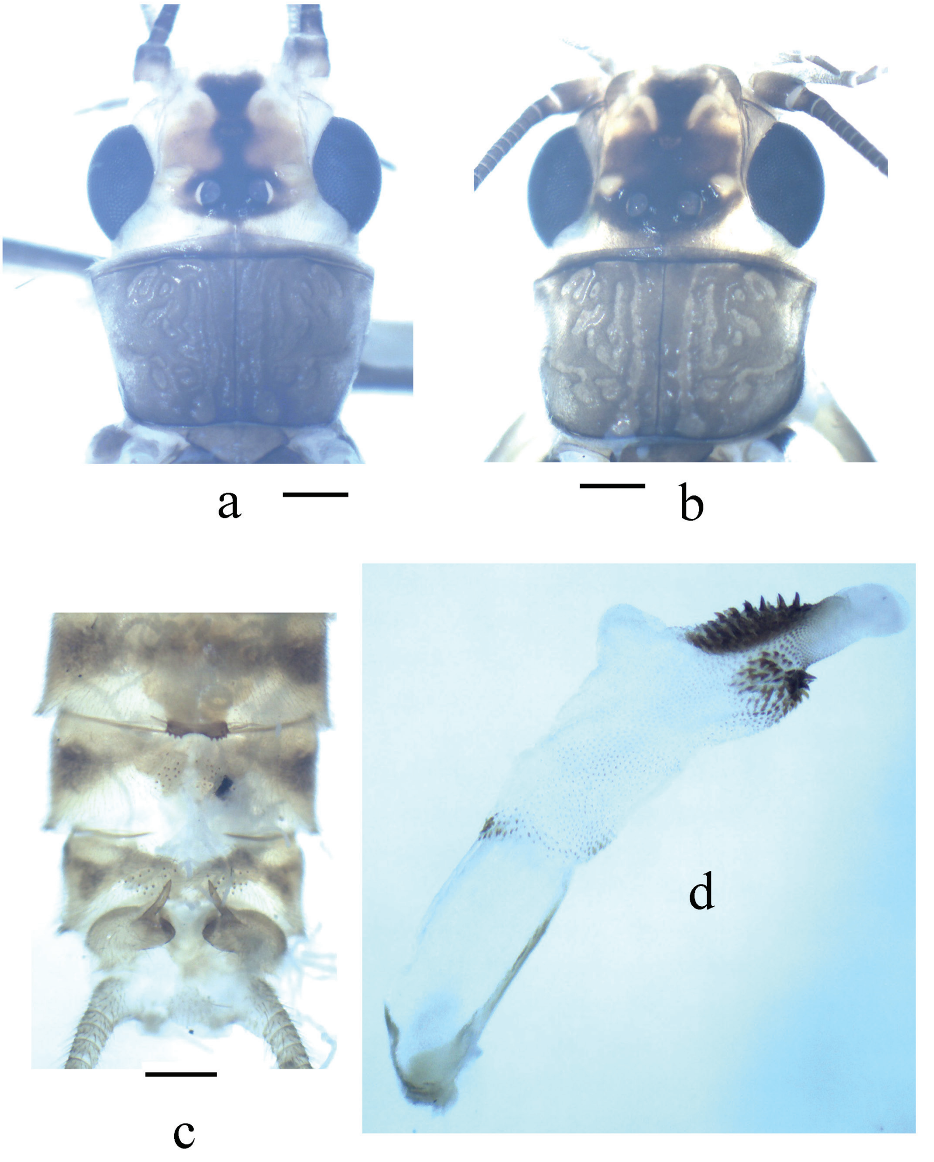


Figure 5. *Neoperla transversprojecta* Du & Sivec, 2004. Male. **a** Head and pronotum (teneral specimen), dorsal view **b** Head and pronotum (older specimen), dorsal view **c** Terminalia, dorsal view **d** Aedeagus, lateral view.

Distribution. China (Guangxi).

Remarks. This species was originally described by Du and Sivec (2004). 2 males were available to the present study and only the tip of sac shows a slight difference with original drawing (fig. 4 in Du and Sivec 2004). The dorsal patch of subapical spines in the present material seems prominent than as in original drawing.

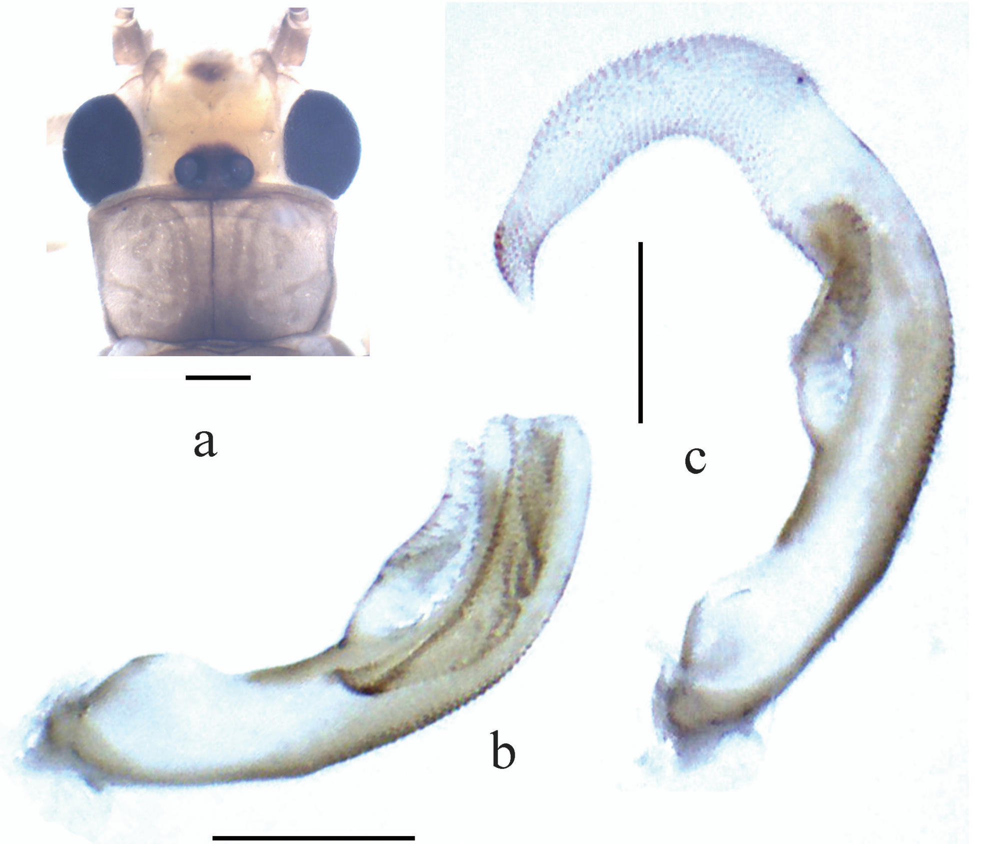


Figure 6. *Neoperla yao* Stark, 1987. Male. **a** Head and pronotum (teneral specimen), dorsal view **b** Aedeagus before eversion, lateral view **c** Aedeagus, lateral view.

Neoperla yao **Stark, 1987**
http://species-id.net/wiki/Neoperla_yao
Fig. 6

Neoperla yao Stark, 1987. Aquatic Insects 9: 47. Type locality: Vietnam, 6 km S Dalat; Stark & Sivec, 2008. Illiesia 4: 41; Wang et al. 2013. Zookeys 313: 87.

Material examined. 1 male (HIST), China: Guangxi, Fangcheng, Jinhuacha Nature Reserve, 21°76,09'N, 108°43,49'E, light trap, 2012. April 16, G.Q. Wang.

Distribution. Vietnam, China (Guangxi, Guangdong).

Remarks. This species was originally described by Stark (1987) from Vietnam and China based on three males (two from Vietnam, one from China), its female was recently associated (Stark and Sivec 2008). One male was available to the present study and the tip of sac seems slightly hooked with sharper apex that appears somewhat blunt in original drawing (fig. 6 in Stark 1987).

Concluding remarks

Previous studies on the genus *Neoperla* from Guangxi include Wu (1948), who described *Neoperla curvispina* and *N. rotunda* from Mountain Yaoshan. Subsequently Yang and Yang (1990) described *Neoperla wui* from Jinxiu, and Du (1998) reported the presence of *Neoperla mnong* Stark, 1987 from Guangxi. Du and Sivec (2004) summarized the stonefly fauna from Mountain Shiwandashan in Guangxi, describing three new *Neoperla* species and adding two other records. Recently, two new species were added from Guangxi by Li et al. (2013b) and Wang et al. (2013). However, there was still no record of the genus *Neoperla* or other stoneflies in previous studies on the insect fauna of the Jinhuacha Nature Reserve. In this study, two additional new species are described and a new record for Guangxi is recorded. Therefore, there are up to 14 known *Neoperla* species from Guangxi presently.

Acknowledgments

We acknowledge the partial support of our research by the Guangxi Scientific and Technology Project (GUIKEGONG 08126001) and the National Natural Science Foundation of China (No. 31000977).

References

Chu Y-T (1929) Descriptions of four new species and one new genus of stone-flies in the family Perlidae from Hangchow. The China Journal 10: 88–92.

De Walt RE, Neu-Becker U, Stueber G (2013) Plecoptera Species File Online. Version 5.0/5.0. 8/30/2013. http://Plecoptera.SpeciesFile.org

Du Y-Z (1998) Two new record species of genus *Neoperla* Needham (Plecoptera: Perlidae: Perlinae) from China. Journal of Zhejiang Agricultural University 24: 392–394.

Du Y-Z (1999) Plecoptera. In: Huang BK (Ed) Fauna of Insects in Fujian Province of China. Vol. 3. Fujian Science and Technology Publishing house, Fuzhou, Fujian, China, 301–335.

Du Y-Z (2000a) *Neoperla magisterchoui*, a new species of the genus *Neoperla* Needham (Plecoptera: Perlidae) from China. In: Zhang YL (Ed) Systematic and faunistic research on Chinese insects. Proceedings of the 5th National Congress of Insect Taxonomy. China Agriculture Press, Beijing, 1–3.

Du Y-Z (2000b) Two new species of the genus *Neoperla* Needham (Plecoptera: Perlidae: Perlinae) from Guizhou, China. Entomotaxonomia 22: 1–5.

Du Y-Z, Sivec I (2004) Plecoptera: Perlidae, Nemouridae, Leuctridae. In: Yang XK (Ed) Insects from Mt. Shiwandashan area of Guangxi. China forestry Publishing House, Beijing, 39–45.

Du Y-Z, Sivec I (2005) Plecoptera. In: Yang XK (Ed) Insect Fauna of Middle-west Qinling Range and South Mountains of Gansu Province. Science Press, Beijing, 38–54.

Du YZ, Sivec I, He J-H (1999) A checklist of the Chinese species of the family Perlidae (Plecoptera: Perloidea). Acta Entomologica Slovenica 7: 59–67.

Du Y-Z, Sivec I, Zhao M-S (2001) Plecoptera. In: Wu H, Pan CW (Eds) Insects of Tianmushan National Nature Reserve. Science Press, Beijing, 69–80.

Du Y-Z, Wang Z-J (2005) Plecoptera: Leuctridae, Nemouridae, Perlidae and Peltoperlidae. In: Yang MF, Jin DC (Eds) Insects from Dashahe Nature Reserve of Guizhou. Guizhou People Press, Guiyang, Guizhou, 51–57.

Du Y-Z, Wang Z-J (2007) Nemouridae and Perlidae. In: Li ZZ, Yang MF, Jin DC (Eds) Insects from Mountain Leigongshan Landscape of Guizhou. Guizhou Science and Technology Publishing house, Guiyang, Guizhou, 84–90.

Li W-H, Li X-P (2013) A new species of the genus *Neoperla* (Plecoptera: Perlidae) from China. Acta Zootaxonomica Sinica 38: 75–77.

Li W-H, Liang H-Y, Li W-L (2013a) Review of *Neoperla* (Plecoptera: Perlidae) from Zhejiang Province, China. Zootaxa 3652(3): 353–369. doi: 10.11646/zootaxa.3652.3.4

Li W-H, Wang R-F (2011) A new species of *Neoperla* (Plecoptera: Perlidae) from China. Entomological News 122: 261–264. doi: 10.3157/021.122.0308

Li W-H, Wang H-L, Lu W-Y (2011a) Species of the genus *Neoperla* (Plecoptera: Perlidae) from Henan, China. Zootaxa 2735: 57–63.

Li W-H, Wang G-Q, Lu W-Y (2012a) Species of *Neoperla* (Plecoptera: Perlidae) from Hubei, China. Zootaxa 3478: 32–37.

Li W-H, Wang G-Q, Li W-L, Murányi D (2012b) Review of *Neoperla* (Plecoptera: Perlidae) from Guangdong Province of China. Zootaxa 3597: 15–24.

Li W-H, Wang G-Q, Qin X-F (2013b) Two new species of *Neoperla* (Plecoptera: Perlidae) from China. ZooKeys 290: 21–30. doi: 10.3897/zookeys.290.4568

Li W-H, Wu L-M, Zhang H-R (2011b) A new species of the genus *Neoperla* (Plecoptera: Perlidae) from Henan, China. Acta Zootaxonomica Sinica 36: 33–35.

Qin X-F, Murányi D, Wang G-Q, Li Q-H (2013) Stoneflies of the genus *Neoperla* (Plecoptera, Perlidae) from Wuyi Mountain National Nature Reserve, Fujian of China. ZooKeys 326: 1–16. doi: 10.3897/zookeys.326.5911

Sivec I, Zwick P (1987) Some *Neoperla* (Plecoptera) from Taiwan. Beiträge zur Entomologie 37: 391–405.

Sivec I, Stark BP, Uchida S (1988) Synopsis of the world genera of Perlinae (Plecoptera: Perlidae). Scopolia 16: 1–66.

Stark BP (1987) Records and descriptions of Oriental Neoperlini (Plecoptera: Perlidae). Aquatic Insects 9: 45–50. doi: 10.1080/01650428709361270

Stark BP, Sivec I (2008) New species and records of *Neoperla* (Plecoptera: Perlidae) from Vietnam. Illiesia 4: 19–54.

Wang H-L, Wang G-Q, Li W-H (2013) Two new species in the subfamily Perlinae (Plecoptera, Perlidae) from China. ZooKeys 313: 81–90. doi: 10.3897/zookeys.313.5460

Wu C-F (1935) Aquatic insects of China. Article XXI. New species of stoneflies from East and South China. (Order Plecoptera). Peking Natural History Bulletin 9: 227–243.

Wu C-F (1938) Plecopterorum sinensium: A monograph of stoneflies of China (Order Plecoptera). Yenching University, 225 pp.

Wu C-F (1948) Fourth supplement to the stoneflies of China (Order Plecoptera). Peking Natural History Bulletin 17: 75–82.

Wu C-F (1962) Results of the Zoologico-Botanical expedition to Southwest China, 1955–1957 (Plecoptera). Acta Entomologica Sinica 11 (Supplement): 139–153.

Wu C-F (1973) New species of Chinese stoneflies (Order Plecoptera). Acta Entomologica Sinica 16: 97–118.

Wu C-F, Claassen PW (1934) Aquatic insects of China. Article XXI. New species of Chinese stoneflies. (Order Plecoptera). Peking Natural History Bulletin 9: 111–129.

Yang C-K, Yang D (1990) New and little-known species of Plecoptera from Guizhou Province (I). Guizhou Science 8: 1–4.

Yang C-K, Yang D (1991) New and little-known species of Plecoptera from Guizhou Province (II). Guizhou Science 9: 48–50.

Yang D, Yang C-K (1992) Plecoptera: Perlidae. In: Huang FS (Ed) Insects of Wuling Mountains area, Southwestern China. Science Press, Beijing, 62–64.

Yang D, Yang C-K (1993) New and little-known species of Plecoptera from Guizhou Province (III). Entomotaxonomia 15: 235–238.

Yang D, Yang C-K (1995a) Three new species of Plecoptera from Hainan Province. Acta Agriculture Universitatis Pekinensis 21: 223–225.

Yang D, Yang C-K (1995b) Plecoptera: Perlidae. In: Wu H (Ed) Insects of Baishanzu Mountain, Eastern China. China Forestry Publishing House, Beijing, 59–60.

Yang D, Yang C-K (1996) Four new species of Plecoptera from Nei Mongol. Journal of China Agricultural University 1: 115–118.

Yang D, Yang C-K (1998) Plecoptera: Styloperlidae, Perlidae and Leuctridae. In: Wu H (Ed) Insects of Longwangshan. China Forestry Publishing House, Beijing, 40–46.

Zwick P (1983) The *Neoperla* of Sumatra and Java (Indonesia) (Plecoptera: Perlidae). Spixiana 6: 167–204.

Zwick P (1986) The Bornean species of the stonefly genus *Neoperla* (Plecoptera: Perlidae). Aquatic Insects 8: 1–53. doi: 10.1080/01650428609361227

ZooKeys 351: 49–81 (2013)
doi: 10.3897/zookeys.351.5999
www.zookeys.org

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

Taxonomic and morphological survey of the *Lygephila lusoria* (Linnaeus, 1758) species-group with description of a new species (Lepidoptera, Erebidae, Toxocampinae)

Oleg Pekarsky[1,†]

1 *H-1068, Budapest, Felsőerdősor u. 16-18, Hungary*

† *http://zoobank.org/40DC027F-FCF3-4953-AC60-C071E814A768*

Corresponding author: *Oleg Pekarsky* (opbp@t-online.hu)

Academic editor: *D. Lafontaine* | Received 21 July 2013 | Accepted 1 November 2013 | Published 15 November 2013

http://zoobank.org/51D02BF6-3203-4105-A73F-498F39A01106

Citation: Pekarsky O (2013) Taxonomic and morphological survey of the *Lygephila lusoria* (Linnaeus, 1758) species-group with description of a new species (Lepidoptera, Erebidae, Toxocampinae). ZooKeys 351: 49–81. doi: 10.3897/zookeys.351.5999

Abstract

The taxa of the *Lygephila lusoria* (Linnaeus, 1758) species-group are revised. The genital features of all known taxa are described and illustrated with special reference to the structure of vesica. The male genitalia of *L. pallida pallida* (Bang-Haas, 1907) are described and illustrated for the first time. *L. pallida subpicata* (Wiltshire, 1971) is treated here as a species, *L. pallida subpicata* (Wiltshire, 1971), **stat. n.**, distinct from *L. pallida*. A new species, *L. minima* **sp. n.**, from South Russia is described. Illustrations of the holotype and its genitalia are provided; a diagnostic comparison with *L. pallida* is given. *L. alaica* Remm, 1983 is included in the *L. lusoria* species-group for the first time.

Keywords

Lepidoptera, Erebidae, Toxocampinae, *Lygephila lusoria* species-group, new species, vesica structure, Russia, Europe

Introduction

The genus *Lygephila* Billberg, 1820 is a popular group; several authors have published new results concerning the taxonomy, faunistics and bionomics of the group during the last century, increasing our knowledge of this diverse and taxonomically difficult group. The recent wave of investigations, after the works of Bryk (1948), Draudt (1950), Sheljuzhko (1955), Wiltshire (1961, 1971), Sugi (1982), Remm (1983), Behounek and Hacker (1986), Kinoshita and Sasaki (1986), Kinoshita (1989), Calle (1983), Sviridov (1990), Yela and Calle (1990), Yela (1989), produced remarkable results published by Kononenko and Fibiger (2008), Fibiger et al. (2008), Bertaccini et al. (2008), Babics and Ronkay (2009) and Babics and Stüning (2011). The sketch of the species content of the genus and the characterisation of certain species-groups are published by Goater et al. (2003) and Babics and Ronkay (op. cit.). Following this wave of publications, I intend to revise the species-groups of *Lygephila*, concentrating the study on the formerly neglected types and structure of the vesica. The present paper is addressed to the taxonomy of the *Lygephila lusoria* species-group.

Abbreviations of material depositories BMNH = The Natural History Museum (British Museum, Natural History) London (United Kingdom), HNHM = Hungarian Natural History Museum Budapest (Hungary); MA = Matov Alexey, St. Petersburg (Russia); MNHN = Museum National d'Histoire Naturelle Paris (France); MNHU = Museum für Naturkunde der Humboldt-Universität zu Berlin (Germany); NHMW = Naturhistorisches Museum Wien (Vienna, Austria); ZISP = Zoological Institute, Russian Academy of Sciences St. Petersburg (Russia); OP = Oleg Pekarsky, Budapest (Hungary).

Materials and methods

Male and female genitalia were dissected and mounted in euparal on glass sides. Photos of genitalia where made by Svitlana Pekarska using microscope Nikon SMZ745T and camera Moticam 2500. Photos of imago where taken by the author using camera Nikon D3000/Sigma 105, f/2.8.

Systematic accounts

Description of the *Lygephila lusoria* species-group

Head and body greyish brown with frons and collar chocolate brown. Forewing in general broad, elongated with pointed apex, greyish brown with indistinct transverse lines, orbicular stigma dot-like, reniform stigma more or less triangular, black, sometimes with sharp extension at inner corner and satellite streak-like spots on outer margin; hindwing with wide outer band and visible discal spot. The first characterisation of the genitalia structure of the *L. lusoria* species-group was given by Babics and Ronkay in

2009 and this characterisation is to be revised and amended. Some of the previously mentioned characters, such as the strong, sabre-shaped uncus being broadened in third quarter, and having an acute tip, the elongated valva with more or less parallel margins, the wide, funnel-shaped ostium bursae, and the membranous, elliptical corpus bursae are shared features with the *Lygephila lubrica* species-group. Therefore, these characters cannot be considered as distinctive features for the *L. lusoria* group. The autapomorphies of this group can be found in the shape of the ampulla, the aedeagus, the vesica structure and some of the specific parameters of the ostium bursae. The ampulla is tapered with a long, skewed base, which is comparable in length in practically all members of the group. The aedeagus is short and wide; the vesica has six or seven diverticula, the subbasal diverticulum is well developed with a ridge-like cornutus complex. The female genitalia are characterised by the markedly asymmetrical ostium bursae, in comparison with the other species groups of the genus.

The *L. lusoria* species-group comprises the following species: *L. lusoria lusoria* (Linnaeus, 1758); *L. lusoria glycyrrhizae* (Rambur, 1866); *L. amasina* (Staudinger, 1878); *L. colorata* Babics & Ronkay, 2009; *L. moellendorffi* (Herz, 1904); *L. pallida* (Bang-Haas, 1907); *L. subpicata* Wiltshire, 1971, stat. n.; *L. minima* sp. n.; *L. fereidun* Wiltshire, 1961; *L. alaica* Remm, 1983.

Lygephila lusoria lusoria **(Linnaeus, 1758)**

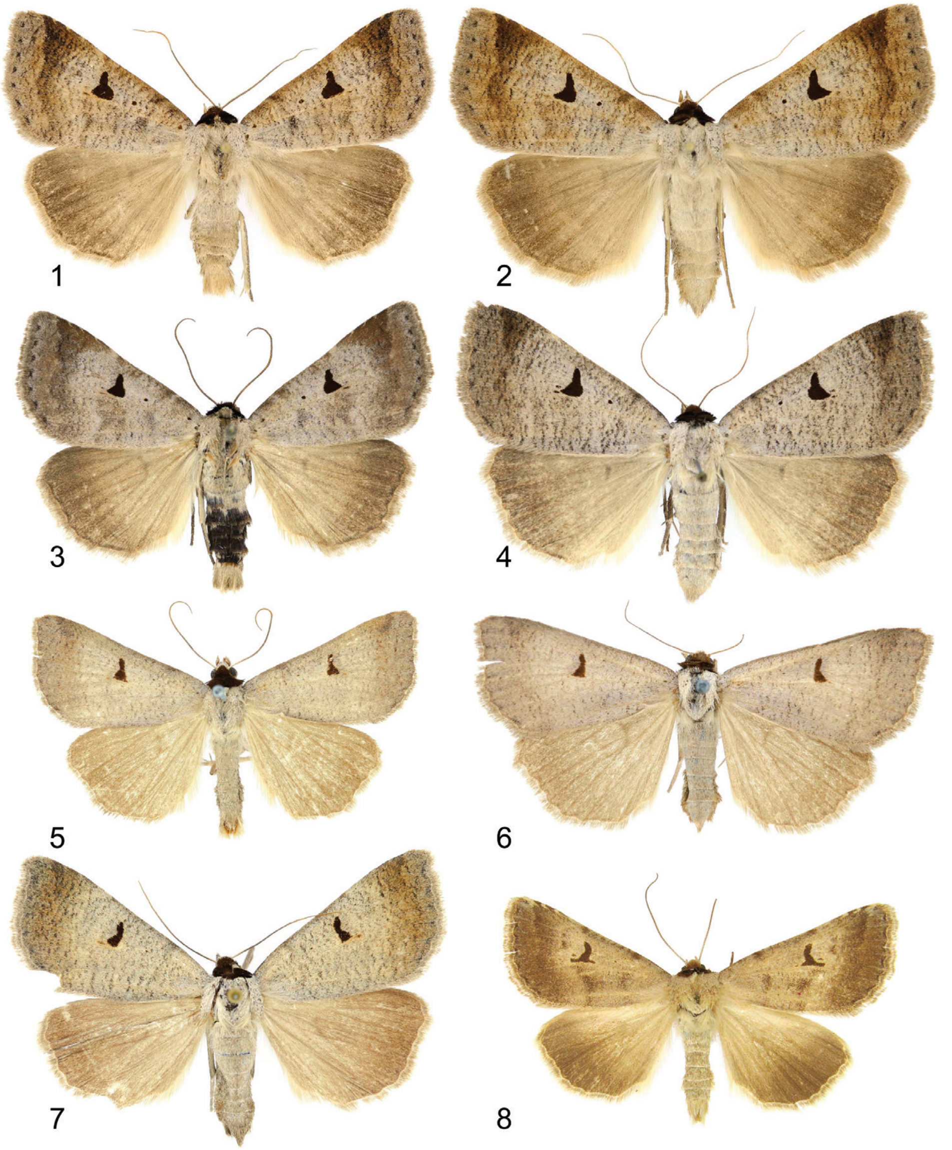
http://species-id.net/wiki/Lygephila_lusoria_lusoria

Figs 1–4

Material examined. 1 ♂, Hungary, Pilisszántó, Üdülőtelep, Plachkó u., 18.VI.2007, leg. & coll. O. Pekarsky slide No: OP1953m, 1 ♀, Hungary, Naszály, Sejce, N47°50'304, E019°06'762, 11.VI.2007 leg. & coll. O. Pekarsky, slide No: OP1954f; 1 ♂, 1 ♀, Süd-Frankreich, Provence Serres, 4 km südlich Orpierre, 1000 m, 18.07.1999, leg. P. Kuhna, coll. ZFMK, slide Nos: OP2263m, OP2264f; 1 ♂, 1 ♀, Crimea, Alushta, Luchistoe, South Demergi Mt., 16.06.2012, leg. V. Savchuk, coll. N. Kaygorodova, slide Nos: OP2052m, OP2053f; 1 ♂, Russia, S Ural, Orenburg Obl., Kuvandyk, 23–24.6.2009, leg. & coll. L. Srnka, slide No: OP2122m.

Diagnosis. *Lygephila lusoria lusoria* is the largest representative of the species group. Differ from *L. amasina* by less contrast wing pattern and not sharp inner corner of the reniform stigmata. Nominotypical subspecies in most cases lager, with more contrast wing pattern comparing with *L. lusoria glycyrrhizae* from Spain.

Male genitalia (Figs 25, 39, 40). Uncus stem narrow and relatively long, dilated distally with fine tip, scaphium membranous with sclerotized plate on subscaphium; valva elongated, narrowed at base, apex rather acute; ampulla spine-like, almost straight, not reaching apex of valva, its base asymmetrical. Aedeagus straight, tubular, slightly dilated at carina with heavily sclerotized field on it. Vesica globular, everted forward and recurved laterally; medial part membranous; subbasal diverticulum oblate with heavily sclerotized crest contacting carina; 1st medial diverticulum small; 2nd and 3rd



Figures 1–8. Adults. **1–4** *Lygephila lusoria lusoria* **1** male, Hungary, slide No. OP1953m **2** female, Hungary, slide No. OP1954f **3** male, S Ural, slide No. OP2122m **4** female, France, slide No. OP2264f **5–7** *Lygephila lusoria glycyrrhizae* **5** male, Spain, Andalusia, slide No. OP1977m **6** female, Spain, Andalusia, slide No. OP1978f **7** female, Spain, Granada, slide No. OP2265f **8** *Lygephila moellendorffi* paratype, male, N Korea (photo A. Matov).

medial diverticula elongated, tube-like, rising from extension of main vesica chamber located opposite to each other; 4th medial diverticulum on opposite side topped with large, rounded, plate-like cornutus with two teeth; 1st terminal diverticulum tapered with large basal swelling; 2nd terminal diverticulum tapered, bordering 2nd medial diverticula, bearing three small pockets; terminal tube membranous with weak scobination at end near gonopore (starting point of ductus ejaculatorius), opening point of terminal tube located at base of medial part of vesica near carina. **Female genitalia** (Figs 76, 77). Ovipositor relatively short, broad; papillae anales hairy with long setae on apical edges. Apophyses anteriores slender, apophyses posteriores thin with acute tips, longer than apophyses anteriores. Antrum tapering, ostium bursae broad with acute lateral edges, posterior margin incised producing shallow triangular cleft with almost straight margins; ductus bursae large, wide with coarse well-sclerotized wrinkles laterally. Appendix bursae small with ductus seminalis located near ductus bursae. Corpus bursae membranous, large, ellipsoidal.

Distribution. West Palearctic. In Europe it ranges from Spain to Bulgaria, from Ukraine to south Russia and western Kazakhstan (Uralsk). All earlier records for Asia Minor refer to *L. amasina*, whereas the records from north Caucasus and Transcaucasia belong to *L. minima* sp. n.

Lygephila lusoria glycyrrhizae (Rambur, 1866)

http://species-id.net/wiki/Lygephila_lusoria_glycyrrhizae
Figs 5–7

Material examined. 1 ♂, Andalusien, Sierra de Alfacar, 1905, C. Ribbe, coll. MNHU Berlin, slide No: OP1977m; 1 ♀, Andalusien, Sierra de Alfacar, 1905, C. Ribbe, coll. MNHU Berlin, slide No.: OP1978f; 1 ♀, Espania, S. Albarracin, 1500m, (Teruel), 8.7.1987, leg. Fidel Fernandez-Rubio, coll. P. Gyulai, slide No.: OP2128f; 1 ♀, Spain, Sierra de Bata, Sta Barbara, Granada, 1800 m, 30.vi.1994, leg. B. Goater, coll. G. Ronkay, slide No.: OP2137f; 1 ♀, Spanien, Granada, Sierra Nevada, Pico Valeta, 2500 m, 4.7.1987, leg. P. Kuhna, coll. ZFMK, slide No.: OP2137f.

Note. The name of this taxon is unavailable from Rambur, 1866, and there is some debate as to the correct authorship and date of this subspecies. This issue will be dealt with in a separate publication.

Diagnosis. This taxon was downgraded to a subspecies of *L. lusoria* by Bertaccini et al. (2008). It is interesting that, despite the remarkable external differences between *L. l. lusoria* and *L. l. glycyrrhizae*, no valuable differences can be recognised in the male and female genitalia of the two taxa. The most significant distinctive feature of *L. l. glycyrrhizae* is, in comparison with *L. l. lusoria*, the small size of the genitalia of both sexes. The genitalia of the Spanish moths are approximately 1.3 times smaller than those of *L. l. lusoria* from Central and Eastern Europe, Crimea and Urals. In addition, there are a few hardly recognisable differences in the shape of uncus, valva and aedeagus: *L. l. glycyrrhizae* has somewhat shorter uncus stem and valvae with costal dilatation medially and less curved aedeagus, whereas the plan of the female genitalia of the two taxa is practically the same.

Male genitalia (Figs 26, 41, 42). Uncus stem narrow and relatively short, dilated distally with fine tip; scaphium membranous with sclerotized plate on subscaphium; valva elongated, narrowed at base, margins not parallel due to large costal dilatation medially, valval apex rather acute; ampulla almost straight, spine-like with symmetrical base. Aedeagus a straight tube with heavily sclerotized field on carina. Vesica globular, everted forward and recurved laterally; medial part membranous; subbasal diverticulum oblate with heavily sclerotized crest contacting carina; 1st medial diverticulum small; 2nd and 3rd medial diverticula elongated, tube-like, rising from extension of main vesica chamber, located opposite to each other; 4th medial diverticulum on opposite side topped with large, rounded, plate-like cornutus with two teeth; 1st terminal diverticulum tapered, with large basal swelling; 2nd terminal diverticulum bears three small pockets; terminal tube membranous with weak scobination at distal end near gonopore (starting point of ductus ejaculatorius); opening point of terminal tube located at base of medial part of vesica near to carina. **Female genitalia** (Figs 78–80). Ovipositor relatively short, broad, papillae anales hairy with long setae on apical edges. Apophyses anteriores slender, apophyses posteriores longer than apophyses anteriores, thin with acute tips. Antrum tapering, ostium bursae broad with acute lateral edges, posterior margin incised showing shallow triangular cleft with almost straight margins; ductus bursae large, wide with coarse well-sclerotized wrinkles laterally. Appendix bursae small with ductus seminalis located near ductus bursae. Corpus bursae membranous, large, elongated, ellipsoidal.

Distribution. Spain.

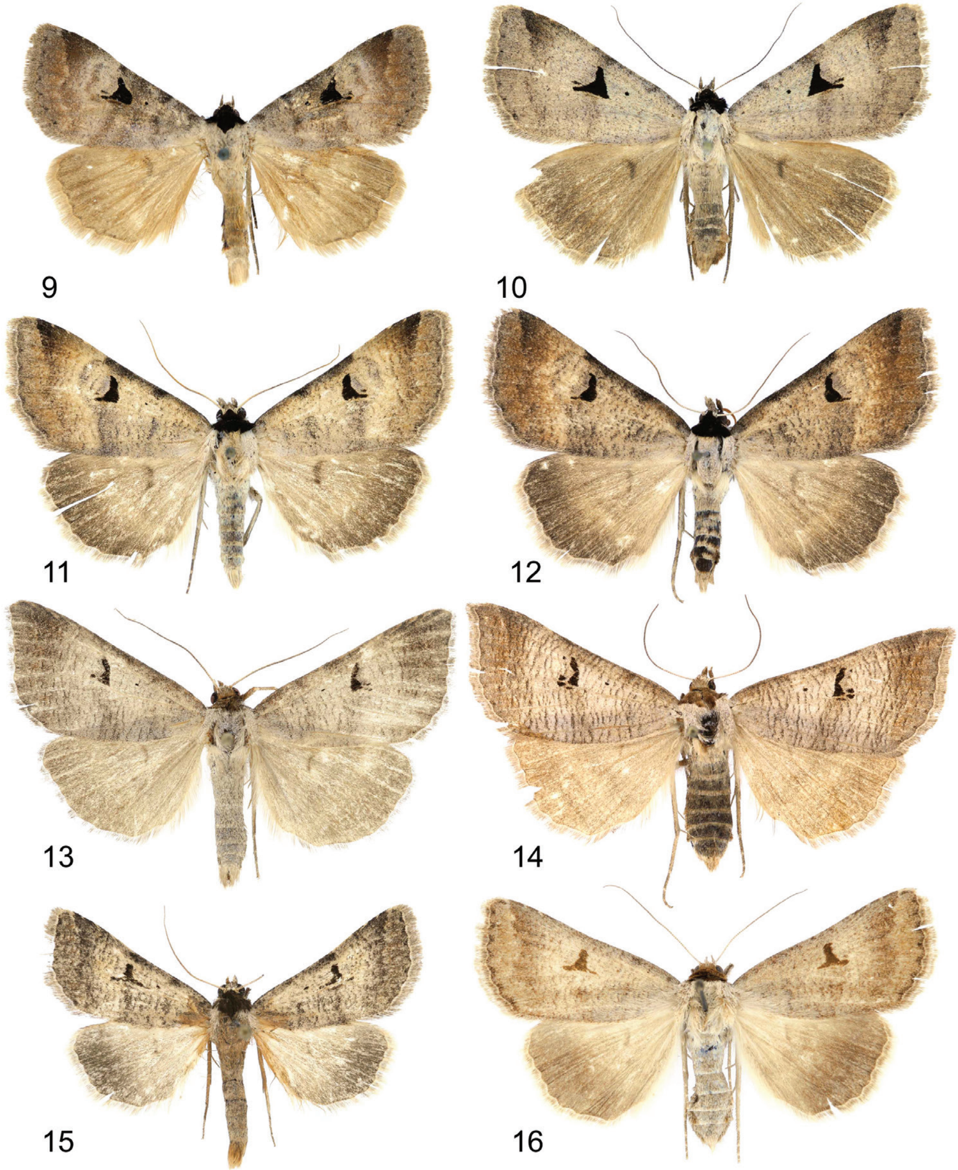
Lygephila amasina **(Staudinger, 1878)**

http://species-id.net/wiki/Lygephila_amasina
Figs 9, 10

Material examined. 1 ♂, Turkey, Prov. Agri, Karasu-Aras Mts, 2100m, 7km E from Aydintepe, 42°28'27"E; 39°47'4"N, 04.VII.2000, leg. Gy. Fábián, I. Szécsényi & K. Székely, coll. O. Pekarsky, slide No.: OP1959m; 1 ♂, Türkei, 12 km west Ürgüp, 1400 m, 21.6.1979, leg. P. Kuhna, coll. ZFMK, slide No. OP2260m; 1 ♀, Türkei, 12 km west Ürgüp, 1400 m, 11.9.1981, leg. P. Kuhna, coll. ZFMK, slide No. OP2261f; 1 ♀, Libanon, Jabal el Laqlouq, Street Mkhada–Laqloq, 1300–1500 m NN, 13.06.1999, leg. J. Krüger, coll. ZFMK, slide No. OP2262f; 1 ♀, Lebanon, Laqlouq, h-1600m, 25.07.2011, leg. Floriani & Saldaitis, coll. O. Pekarsky, slide No.: OP1960f.

Diagnosis. *L. amasina* distinguishing from similar *L. lusoria lusoria* by more contrast wing pattern and somewhat longer, sometimes with acute apex of inner corner of the reniform stigmata. In genital structures it differs from *L. lusoria* by broader uncus, longer, thinner ampulla reaching apex of valva, not sharp lateral edges of antrum and ovoid corpus bursa.

Male genitalia (Figs 27, 43–46). Slightly asymmetrical (right valva narrower). Uncus short, dilated distally, with fine tip; scaphium membranous with sclerotized



Figures 9–16. Adults. **9, 10** *Lygephila amasina* **9** male, Turkey, slide No. OP1959m **10** female, Lebanon, slide No. OP1960f **11, 12** *L. colorata* **11** paratype, male, Pakistan, slide No. OP1969m **12** paratype, female, Pakistan, slide No. OP1970f **13, 14** *L. alaica* **13** male, Tajikistan, slide No. OP1819m **14** female, Uzbekistan, slide No. OP1792f **15, 16** *L. subpicata* **15** male, Iran, Zagros Mts, slide No. OP2002m **16** paratype, female, Iran, Semnan slide No. OP2060f.

plate on subscaphium; valva elongated, narrowed at base with apex rather acute; ampulla long, stick-like, slightly curved towards costa, reaching apex of valva. Aedeagus short with heavily sclerotized convex field on carina and spinulose area on lamina.

Vesica small, globular, everted laterally; medial part membranous; heavily sclerotized crest with ridge-like cornutus complex based on elongated oblate diverticulum-like subbasal hump; 1st medial diverticulum medium-sized, 2nd medial diverticulum much larger, located on the opposite side of vesica with sclerotized area on the top; 1st terminal diverticulum two-chambered, one of them elongated tapering, another globular; 2nd terminal diverticulum tapering with acute top; 3rd terminal diverticulum situated in the same line with 2nd medial diverticulum; opening point of terminal tube located at base of medial part of vesica near to carina; terminal tube membranous with narrow sclerotized crest at base and weak scobination at distal end near gonopore (starting point of ductus ejaculatorius). **Female genitalia** (Fig. 81). Ovipositor short, papillae anales hairy with long setae on apical edges. Apophyses anteriores slender, apophyses posteriores thin, 1.6 times longer than apophyses anteriores. Antrum infundibuliform, asymmetrical, with heavily sclerotized elongated plate dorsally; ostium bursae broad, posterior margin gently concave; ductus bursae practically absent. Appendix bursae indistinct. Corpus bursae membranous, ovoid.

Distribution. Turkey, Lebanon and Israel.

Lygephila colorata Babics & Ronkay, 2009

http://species-id.net/wiki/Lygephila_colorata
Figs 11, 12

Material examined. 1 ♂, Paratype, Pakistan, Karakoram Mts, Naltar valley, 2800m, 74°12'E, 36°09.6'N, 30.06.2000, leg. Z. Varga & G. Ronkay, coll. O. Pekarsky, slide No.: OP1969m; 1 ♀, same data as male, slide No.: OP1970f.

Diagnosis. *L. colorata* differ from somewhat externally similar *L. amasina* by more elongated forewing with pointed apex. In male genitalia it differ from congeners by very wide, massive valva, strong, thick ampulla. Female genitalia characterised by deeply concave posterior margin of antrum.

Male genitalia (Figs 30, 47–51). Clasping apparatus slightly asymmetrical (right valva narrower). Uncus short, dilated medially, apex with fine tip; scaphium membranous with sclerotized plate on subscaphium; valva elongated, narrowed at base with rather rounded apex (right valva more acute); ampulla large, massive, slightly curved towards costa, with obtuse tip. Aedeagus short, bent medially, with heavily sclerotized convex field on carina and spinulose area on lamina. Vesica large rather globular, multidiverticulate, everted laterally; medial part membranous; 1st subbasal diverticulum bearing heavily sclerotized crest with ridge-like cornutus complex; 2nd subbasal diverticulum bifurcated, composed from two narrow, elongated tube-like diverticula; medial diverticulum large, elongated, S-shaped with bilobate base and tapering upper part with acute tip; large, elongated terminal complex consists of five diverticula, one of them with densely scobinated top; opening point of terminal tube located at base of vesica near the carina; terminal tube membranous with slightly sclerotized area at base and weak scobination near gonopore (starting point of ductus ejaculatorius). **Female**

genitalia (Fig. 82). Ovipositor short, papillae anales small, hairy with long setae on apical edges. Apophyses anteriores slender with fine tip, apophyses posteriores thin, somewhat longer than apophyses anteriores. Antrum U-shaped, asymmetrical, ostium bursae broad, posterior margin deeply concave; ductus bursae small. Appendix bursae small. Corpus bursae membranous, ovoid.

Distribution. North-western Pakistan.

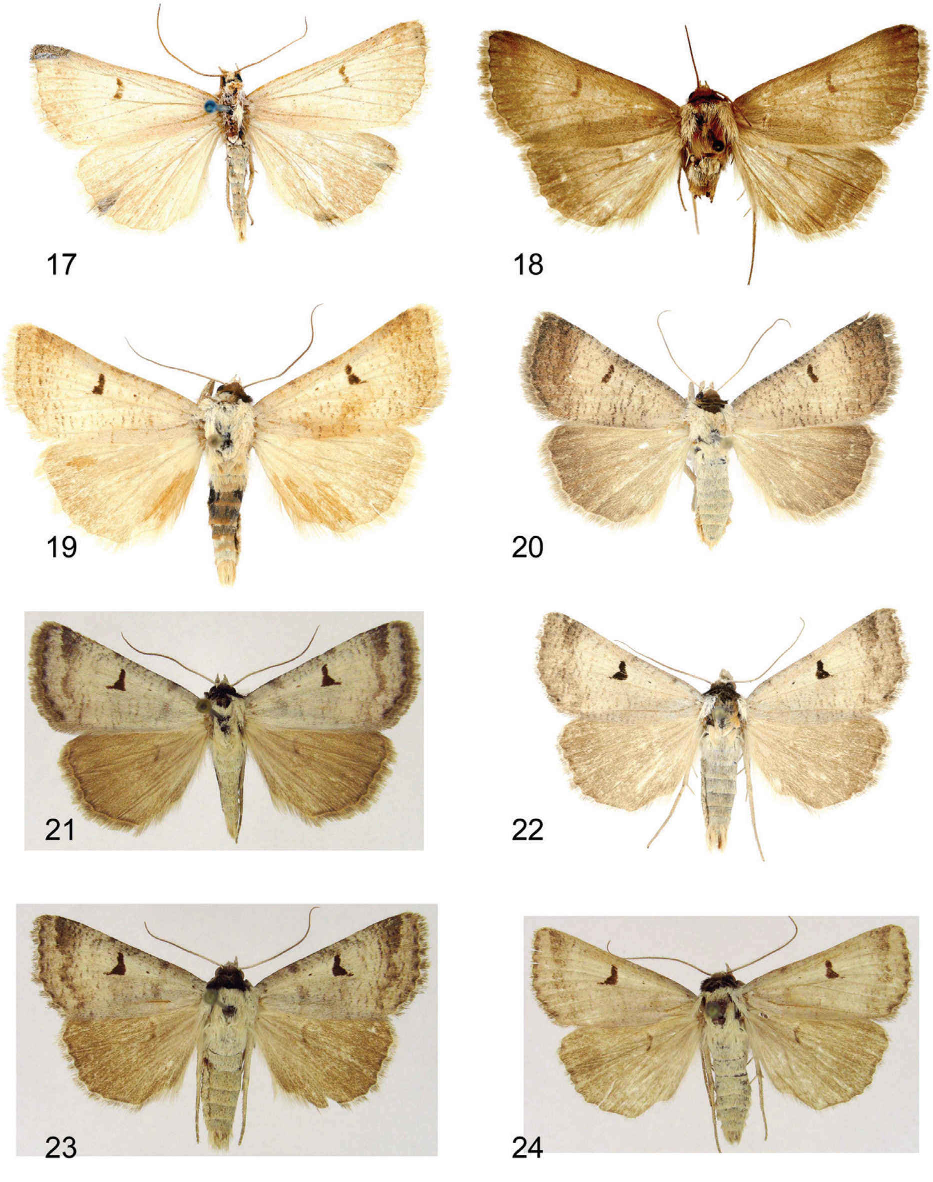
Lygephila pallida (Bang-Haas, 1907)

http://species-id.net/wiki/Lygephila_pallida
Figs 17, 19, 20

Material examined. 1 ♂, Cotype label1: Cotype, pallida B.-H. ♂; label2: As. min. m. (Zeitun), revers - pallida B.-H. ♂, 5/08 vom Autor; label3: Zeitun; label4: 962; ex. coll. Püngeler, coll. MNHU Berlin, slide No: OP1933m; 1 ♂, Turkey, Prov. Kayseri, 5 km NW Ercios Dagh, 2000 m, 22.7.1986, leg. M. Fibiger, coll. G. Ronkay, slide No: OP1967m; 1 ♂, Turkey, Prov. Sivas, Ziyaret gecidi, 2100 m, 36°45'E, 38°42'N, 27–28.07.1993, leg. Gy. László, coll. O. Pekarsky, slide No: OP1961m; 1 ♀, Turkey, Prov. Sivas, Ziyaret gecidi, 1950–2050 m, 36°45'E, 38°42'N, 27.07.1988, leg. Gyulai, Hreblay, Ronkay & Ronkay, coll. G. Ronkay, slide No: OP1966f; 1 ♀, Türkey, Prov. Sivas, 5 km E of Imranli, 38°06'E, 39°53'N, 11.VII.1989, leg. & coll. P. Gyulai, slide No: OP2014f; 1 ♂, [Turkey] O Anatolien, Gürün, 4.VII.76, leg. Pinker, coll. NHMW, Vienna, slide No: OP2065m; 1 ♀, [Turkey] O Anatolien, Gürün, 4.VII.76, leg. Pinker, coll. NHMW, Vienna, slide No: OP2066f; 1 ♂, Turkey, Prov. Erzurum-Erzincan, 10 km W of Askale, 1700m, 40°34'E, 39°50'N, 08.08.1988, leg. Gyulai, Hreblay, Ronkay & Ronkay, coll. G. Ronkay, slide No: OP2029m; 1 ♂, Turkey, Prov. Erzurum, 4 km W of Tahir, 2500 m, 42°27'E, 39°51'5"N, 22.07.1993, leg. Gy. László, coll. G. Ronkay, slide No: OP2030m; 1 ♂, Türkei, Palandoeken, 2500 m, 28 Juli 1980, leg. Dittrich Austria, coll. NHMW, Vienna, slide No: OP2069m; 1 ♀, Türkei, Palandoeken, 2500 m, 28 Juli 1980, leg. Dittrich Austria, coll. NHMW, slide No.: OP2070f; 1 ♀, Turkey, Prov. Agri, 7 km W of Aydintepe, 2200 m, 42°30'E, 39°49'N, 20–22.VII.1990, leg. Gy. László & G. Ronkay, coll. G. Ronkay, slide No: OP1968f.

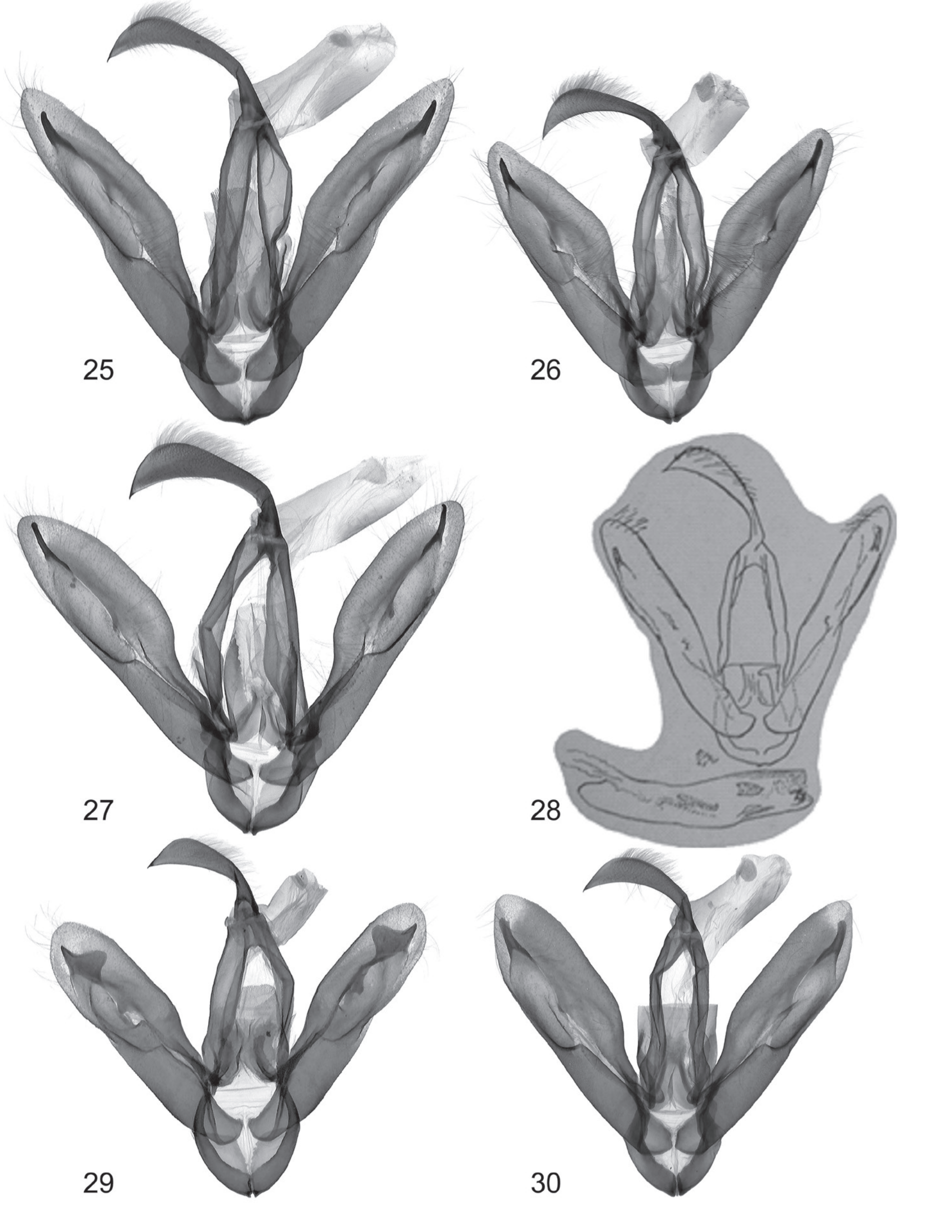
Diagnosis. Distinguishable from similar species only by genitalia characters. It differ from *L. subpicata* by shorter spine-like ampulla not reaching the valval edges and from *L. minima* sp. n. by narrower valva, longer ampulla and absents of sclerotization on top of the 2nd medial diverticulum.

Male genitalia (Figs 31, 52–59). Clasping apparatus somewhat asymmetrical (right valva narrower). Uncus stem narrow, short, dilated distally, with fine tip; scaphium membranous with weakly sclerotized plate on subscaphium; valva elongated, narrowed at base with rather acute apex; ampulla spine-like, slightly curved towards costa, finely pointed, does not reaching apex of valva. Aedeagus short, slightly curved medially, with heavily sclerotized convex field on carina and spinulose area on lamina. Vesica globular, everted forward and recurved laterally; medial part membranous; heavily



Figures 17–24. Adults. **17, 19, 20** *Lygephila pallida* **17** Cotype, male, Turkey, Zeitun, slide No. OP1933m **18** *L. fereidun* holotype, male, Iran, Elburz (photo G. Ronkay) **19** male, Turkey, Prov. Sivas, slide No. OP1961m **20** female, Turkey, Prov. Sivas, slide No. OP2014f **21–24** *L. minima* sp. n. **21** holotype, South Russia, Stavropol krai, slide No. 0329Matov (photo A. Matov) **22** paratype, male, South Russia, Stavropol krai, slide No. OP1607m **23, 24** paratypes, males, South Russia, Stavropol krai (photo A. Matov).

sclerotized ridge on subbasal diverticulum with cornutus complex contacting carina at base; 1st medial diverticulum medium-sized, wide at base; 2nd medial diverticulum very large, conical, with sclerotized area on the top; 1st terminal diverticulum two cham-



Figures 25–30. Clasping apparatus **25** *Lygephila lusoria lusoria* Hungary, slide No. OP1953m **26** *L. lusoria glycyrrhizae* Spain, slide No. OP1977m **27** *L. amasina* Turkey, slide No. OP1959m **28** *L. fereudun* Type, Iran, Elburz, after Wiltshire (1961) **29** *L. alaica* Tajikistan, Gissar Mts, slide No. OP1819m **30** *L. colorata* paratype, Pakistan, slide No. OP1969m.

bered, one of them elongated tapering, another globular; 2nd terminal diverticulum tapered; 3rd terminal diverticulum elongated with very wide base and curved tapered part; opening point of terminal tube located at base of medial part of vesica near carina, terminal tube membranous with narrow sclerotized crest at base and weak scobination near gonopore (starting point of ductus ejaculatorius). **Female genitalia** (Fig. 83). There were no females with type labels or from the same collecting place as the cotype in the MNHU collection. Taking into consideration that the exemplar from Palandöken, Turkey is the most similar in male genitalia structure to the cotype specimen (the two slides are almost fully agree with each other) one can conclude that the female specimen from the same site would represent the female sex of *L. pallida*. Ovipositor short, papillae anales small, hairy with long setae on apical edges. Apophyses anteriores slender with fine tip, apophyses posteriores thin, somewhat longer than apophyses anteriores. Antrum U-shaped, asymmetrical, ostium bursae broad, posterior margin deeply concave with large prolongation of posterior end on one side; ductus bursae small, practically absent. Appendix bursae small. Corpus bursae membranous, ovoid.

Distribution. Central and eastern Turkey.

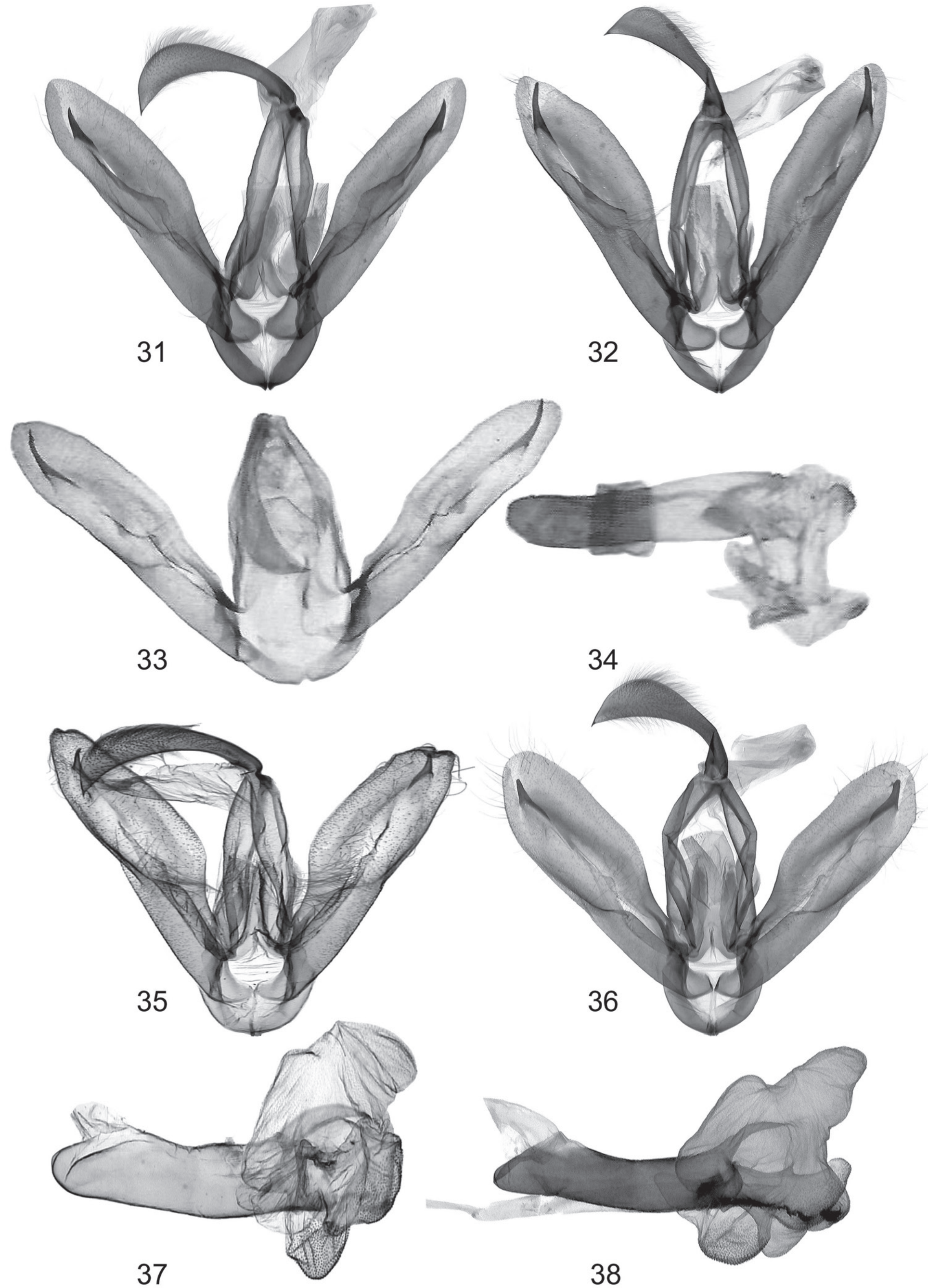
Lygephila fereidun Wiltshire, 1961

http://species-id.net/wiki/Lygephila_fereidun
Fig. 18

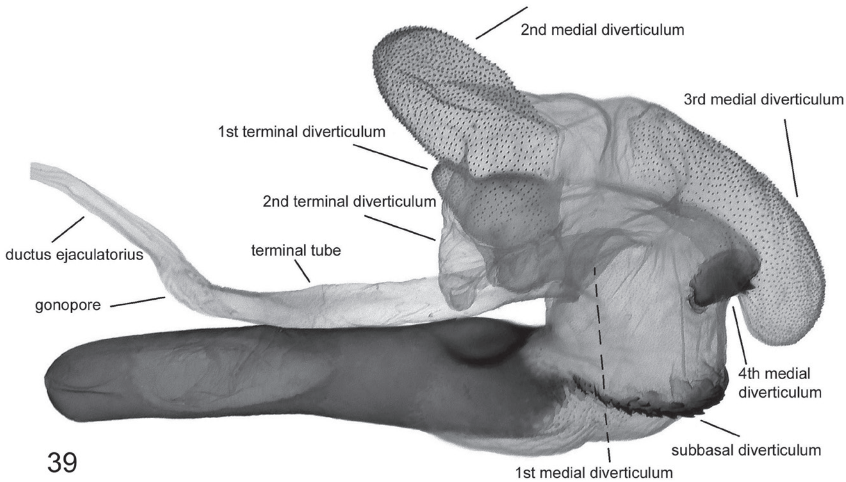
Taxonomy. This taxon, described from the Elburz Mountains, Northern Iran, is known only from the holotype (coll. BMNH). In the original description the color was characterized as pale straw and the wing pattern close to the Spanish species *glycyrrhizae*. The diagnostic comparison was made with *L. craccae* ([Denis & Schiffermüller], 1775) and *L. lusoria* only, whereas a comparison with another similar species, *L. pallida*, was neglected. The original description contains the following text about the clasping apparatus structure (Fig. 28): "The harpe [ampulla], longer than that of *craccae,* is nevertheless shorter than that of *lusoria.*" Comparative analysis of the ampullar length (shorter than that of *lusoria*) given by Wiltshire, makes it possible to conclude that the *L. fereidun* is different from the *L. amasina* and *L. subpicata*, because they have longer ampullae that reach the costal margin of the valva. So, by this feature *L. fereidun* could be compared only with *L. pallida*, the ampulla of which is rather shorter than that of *L. lusoria* and other members of its species group. Vesica structure in the original description is characterized as follows: "The vesica contains similar elements to those of *lusoria* but the proximal scobinated field is shorter and the five or six teeth on the distal chitinous lump are larger and more like cornuti than in *lusoria*." However, the only sclerotized cornutus formation illustrated in the original drawing looks similar to that of *L. subpicata*, but *L. subpicata* has two heavily-sclerotized crown-like cornuti on the top of subbasal and 2nd medial diverticula.

The above-mentioned contradictions in the original description thereby make it impossible to clarify the taxonomical situation of this taxon without a study of the genitalia of the holotype, the preparation of which is opaque and requires specific recovery treatment. Based on the currently known characters *L. fereidun* is most likely an aberrant specimen of *L. pallida*.

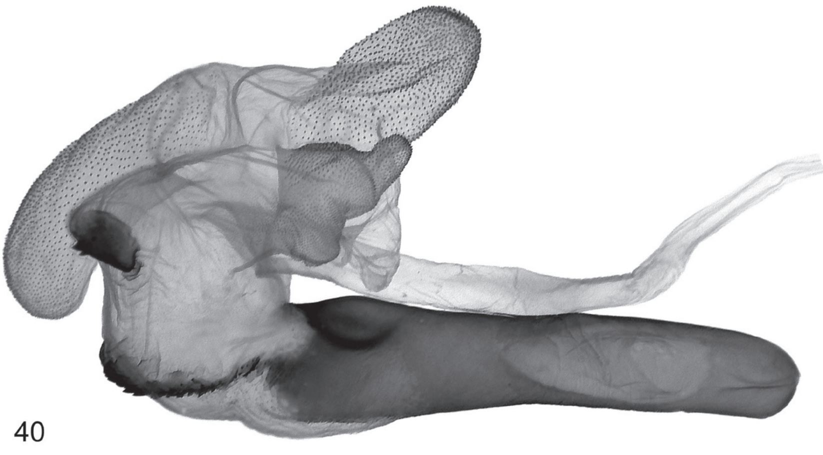
Distribution. Northern Iran.



Figures 31–38. Clasping apparatus **31** *Lygephila pallida* Cotype, Turkey, Zeitun, slide No. OP1933m **32** *L. subpicata* Iran, Prov. Fars, slide No. OP2002m **33, 34** *Lygephila moellendorffi* paralectrotype, N Korea, slide No. VK210394-10 ZIN (photo V. Kononenko) **35, 37** *L. minima* sp. n. holotype, South Russia, Stavropol krai, slide No. 0329Matov (photo A. Matov) **36, 38** paratype, male, South Russia, Stavropol krai, slide No. OP1607m.



39



40

Figures 39, 40. Vesica structure of *Lygephila lusoria lusoria* Hungary, slide No. OP1953m **39** dorsal view **40** ventral view.

Lygephila minima sp. n.

http://zoobank.org/ED5224B3-3A40-4A84-8EFA-F4F498213211
http://species-id.net/wiki/Lygephila_minima
Figs 21–24

Type material. Holotype: Male (Fig. 21), [Russia], Stavropolskiy krai, NW suburbs of station Podkumok, 26.06.2008, leg. E. Tsvetkov, slide No.: 0329Matov (coll. ZISP)

Paratypes. Males. 1 ♂, [Russia], Stavropolskiy krai, suburbs of Pyatigorsk, station Podkumok, 20.07.2007, leg. E. Tsvetkov; slide No.: OP1607m (coll. O. Pekarsky). 2 ♂♂, [Russia], Stavropolskiy krai, suburbs of station Podkumok, N43°57'43'', E42°46'18'', leg. E. Tsvetkov, 20.07.2007; 1 ♂, [Russia], Stavropolskiy krai, suburbs of Piatigorsk, station Podkumok, 18.07.2007, leg. E. Tsvetkov; 1 ♂, Armenia, Daralagez, 12.VIII.[19]63, slide No.: 0341Matov (coll. ZISP).

Etymology. The name "*minima*" refers to the small size of the moth in contrast to the largest representative of the genus, *Lygephila maxima* (Bremer, 1861).

Diagnosis. The new species resembles *L. pallida* by its small size and pale brown ground color of the forewing. *L. minima* differs from the related species by its better developed noctuid pattern, more rounded wings and pale grey-brown ground color of the forewings. Apical dilatation of uncus wide, valva wide with rounded apex, ampullar tip not sharp, 1st medial diverticulum reniform; 2nd medial diverticulum hemispherical, membranous, without sclerotized areas, whereas *L. pallida* has narrower dilatation at the top of the uncus, longer, narrower valva with acute apex, fine tipped ampulla, 1st medial diverticulum very wide at base, swelling-like; 2nd medial diverticulum large, tubular, with sclerotized area on the top.

Description. Male (Figs 21–24). Wingspan 33 mm, length of forewing 17 mm. Head and collar coffee brown. Palpi short, relatively narrow, beige; antenna filiform. Thorax and abdomen beige. Forewing beige with silver shining, irrorated with a few blackish-brown scales; forewing short, wide; costa straight; outer margin rounded; wing pattern indistinct: basal, subbasal and antemedial lines hardly recognisable; medial line represented by large costal patch and some darker spots medially; postmedial line indistinct; subterminal line curved, composed by blackish-brown scales; terminal line marked by large triangular patches; cilia long, uniformly light brown; orbicular stigma dot-like, as coffee-brown colored as V-shaped reniform; claviform stigma indistinct. Hindwing beige brown, discal spot narrow. Female unknown.

Male genitalia (Figs 35–38, 60–67). Uncus stem short, broadly dilated distally with fine tip; valva short, wide, rounded apically with rather parallel margins in distal two-thirds, slightly narrower at base; ampulla spine-like with long base and pointed tip which does not reaching margin of valva. Aedeagus short, curved medially, with heavily sclerotized field on carina and spinulose area on lamina. Vesica globular, everted forward and recurved laterally; medial part membranous; basal cornutus ridge interrupted without sclerotized base, subbasal diverticulum medium sized; 1st medial diverticulum large, reniform; 2nd medial diverticulum hemispherical; 3rd medial diverticulum tapered, 1st distal diverticulum large, subconical, 2nd distal diverticulum with wide base and crooked tip; opening point of terminal tube located at base of medial part of vesica, terminal tube membranous with sclerotized ribbon at base and weak scobination at end near gonopore.

Distribution. The species is known from south Russia, Stavropol region and Armenia.

Lygephila subpicata (Wiltshire, 1971), stat. n.

Figs 15, 16

Material examined. 1 ♂, 1 ♀ Paratypes, N-Iran, Berge östl. Semnan, 18.VI.1963, leg. Kasy & Vartian, coll. NHMW, slide Nos: OP2059m, OP2060f; 1 ♂, 1 ♀ S-Iran, 100 km südl. Abadeh, nördl Didegan, 2000 m, 9.6.1969, leg. Vartian, coll. NHMW, slide Nos: OP2061m, OP2062f; 2 ♂♂ Iran, Prov. Fars, Zagros Mts, Ardakan, 2500–3000 m, 18.VI.2010, leg. B. Benedek & T. Hácz, coll. P. Gyulai, slide Nos: OP2002m, OP2003m.

Diagnosis. *Lygephila subpicata* differs from its sister species, *L. pallida* in the length and shape of the ampulla, and in vesica and aedeagus structure. *L. subpicata* has a much longer, curved ampulla, which reaches apex of valva and costal margin; subbasal diverticulum large with crown-like cornutus on top, tapering part of 1st terminal diverticulum small, short and narrow, 2nd medial diverticulum with crown-like cornutus on top, carinal extension practically absent. In comparison, *L. pallida* has shorter, less curved, finely pointed ampulla that does not reach apex of valva, a small, oblate subbasal diverticulum with a long, heavily-sclerotized, ridge-like cornutus complex that is a continuation of the carina.

Male genitalia (Figs 32, 68–73). Clasping apparatus somewhat asymmetrical. Uncus stem narrow, short, dilated distally, with fine tip; scaphium membranous with weakly-sclerotized plate on subscaphium; valva elongated, narrowed at base, with acute apex; ampulla long, spine-like, curved towards costa, finely pointed, reaching apex of valva and costal margin. Aedeagus short, straight, with heavily sclerotized convex field on carina. Vesica globular, everted forward and recurved laterally; medial part membranous; subbasal diverticulum with small, heavily-sclerotized crown-like cornutus on top; 1st medial diverticulum elliptical; 2nd medial diverticulum large with crown-like cornutus on the top; 1st terminal diverticulum two-chambered, scobinated, one of them elongated-tapering, another globular; 2nd terminal diverticulum tapered; opening point of terminal tube located at base of medial part of vesica near carina, terminal tube membranous with narrow sclerotized crest at base and weak scobination near gonopore (starting point of ductus ejaculatorius). **Female genitalia** (Fig. 84). Ovipositor short, papillae anales small, hairy with long setae on apical edges. Apophyses anteriores slender with fine tip, apophyses posteriores thin, somewhat longer than apophyses anteriores. Antrum triangular, very narrow anteriorly, wide posteriorly, with straight lateral margins, ductus bursae absent. Corpus bursae membranous, ovoid.

Distribution. North and western Iran.

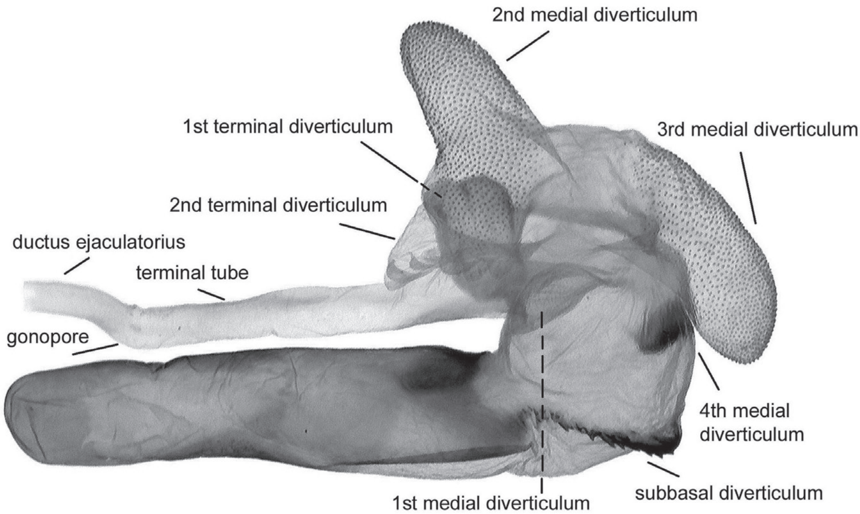
Lygephila moellendorffi (Herz, 1904)

http://species-id.net/wiki/Lygephila_moellendorffi
Fig. 8

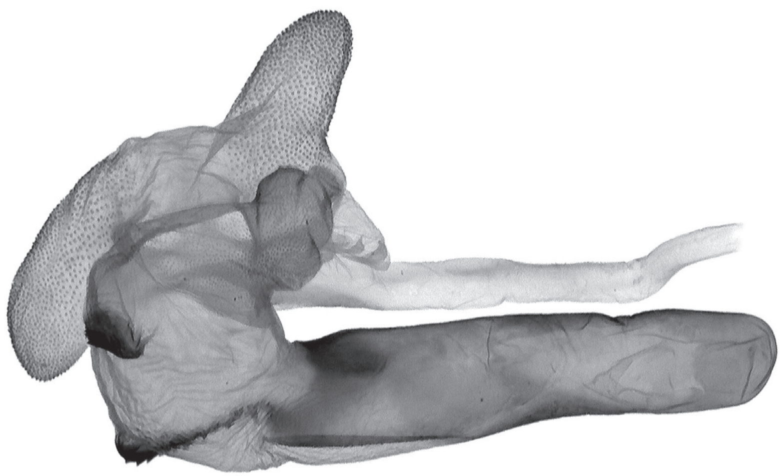
Material examined. Paralectotype, ♂ [North] Korea (ZISP).

Note. The name of this taxon was erroneously written as *moellendorfii* in Poole (1989) and as *moellendorfi* in Kononenko et al. (1998) and Kononenko and Han (2007). The correct spelling of the species described by Herz in honour of Paul von Moellendorff as per original description was *moellendorffi*.

Diagnosis. *Lygephila moellendorffi* is known only from two males representing the type series. The photo of the paralectotype was illustrated in Kononenko et al. (1998);



41



42

Figures 41, 42. Vesica structure of *Lygephila lusoria glycyrrhizae* Spain, slide No. OP1977m **41** dorsal view **42** ventral view.

the genitalia of the paralectotype was first illustrated by Kononenko and Han (2007). Surprisingly, this species is confusingly similar to *L. subpicata*, displaying no differential features comparing the habitus and the genitalia structures of the two species. The similarly elongated forewings with pointed tips have the same pattern, especially the triangular reniform stigma with sharp extension on the inner corner and satellite streak-like spots are practically identical in the two taxa. The common features of the male genitalia are the similar shape of uncus and valvae with the similarly sized and shaped ampulla being also located subapically and reaching the apical valval margins. Both species have short and relatively wide aedeagus and vesica with characteristic subbasal and 2nd medial diverticula topped by crown-like cornuti; the terminal diverticula are also similar. This striking resemblance suggests that they represent the same species, but the great distance between their ranges does not support this conclusion.

Male genitalia (Figs 33, 34). Clasping apparatus somewhat asymmetrical (left valva slightly wider). Uncus stem narrow, dilated distally, with fine tip; valva elongated, narrowed at base, with acute apex; ampulla long, spine-like, curved towards costa, finely pointed, reaching apex of valva and costal margin. Aedeagus short, straight, with heavily sclerotized convex field on carina. Vesica globular, everted forward and recurved laterally; medial part membranous; subbasal diverticulum with small, crown-like cornutus on top; 1st medial diverticulum elliptical; 2nd medial diverticulum large with crown-like cornutus on the top; 1st terminal diverticulum located near base of 2nd medial diverticulum. Female unknown.

Distribution. North Korea.

Lygephila alaica Remm, 1983

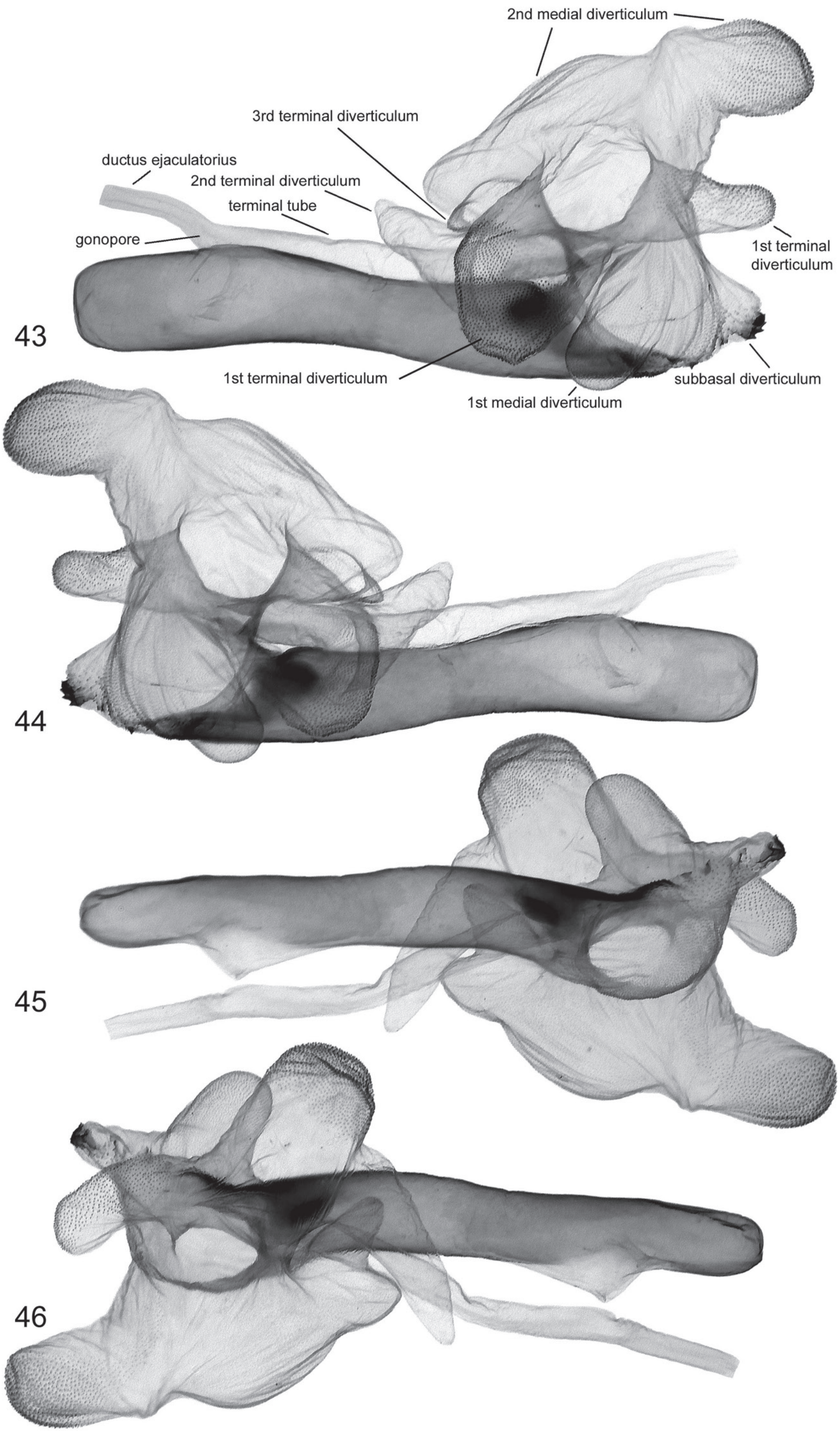
http://species-id.net/wiki/Lygephila_alaica

Figs 13, 14

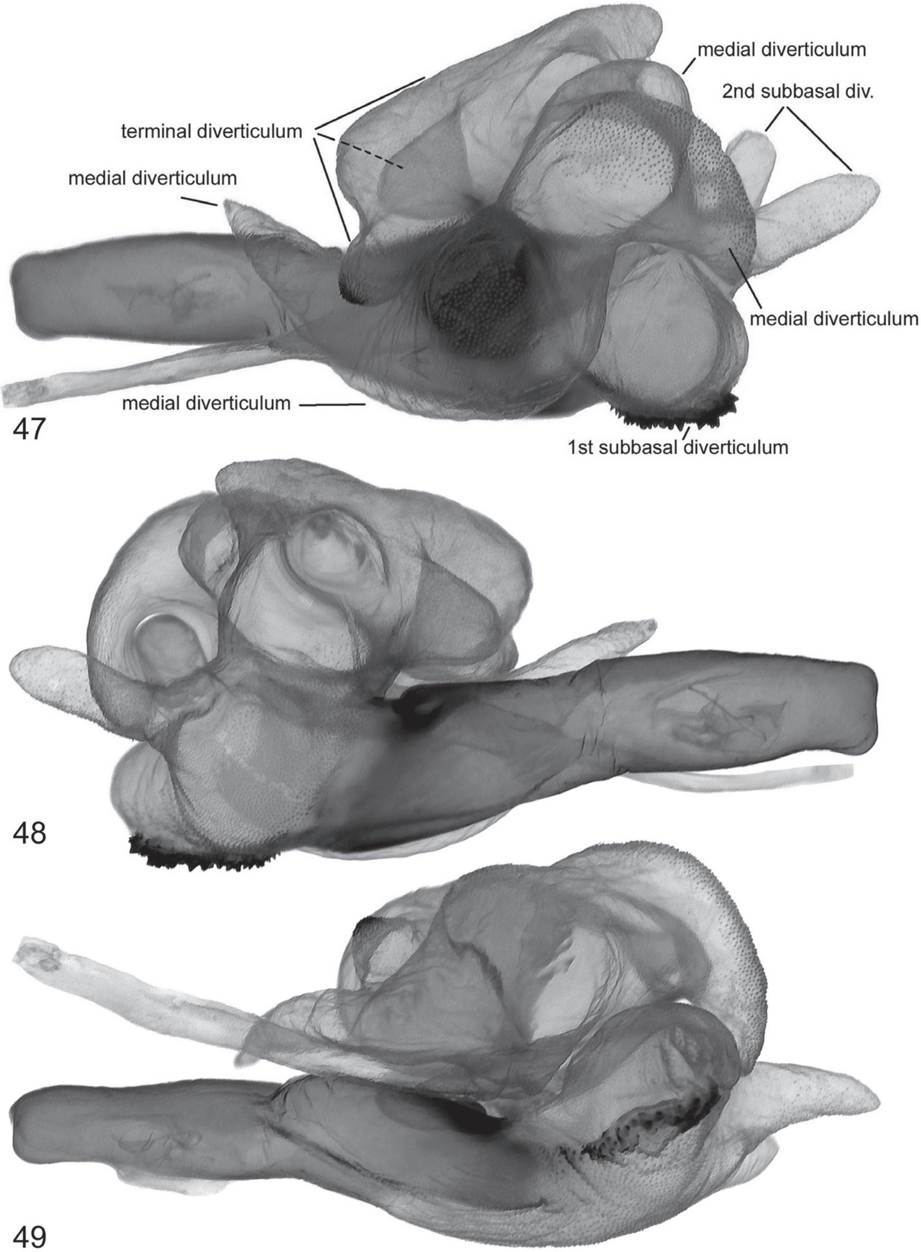
Material examined. 1 ♂ Tajikistan, Gissar Mts, distr. Varzob, vill. Kondara, 1150–1200 m, 17–18.VI.2012, leg. E. Rutjan, coll. O. Pekarsky, slide No: OP1819m; 1 ♀, Tajikistan, Khatlonskaya reg., Muminabadsky distr., Lidzhak, 2000 m, 27.V.2006, leg. O. Pak, coll. O. Pekarsky, slide No: OP1568f; 1 ♀, Uzbekistan, Hissarskiy range, Metchetli Mts, Shargunsay, 38°36'N, 67°57'E, 1550m, 30.May, 2004, leg. Z. Weidenhoffer, coll. M. Dvořák, slide No: OP1792f.

Diagnosis. *Lygephila alaica* should be attributed to the *L. lusoria* species-group on the basis of both the external and genital diagnostic characters. The elongated forewing with pointed apex is similar to those of all species of this species-group, particularly to eastern representatives, *L. colorata* and *L. subpicata.* The spine-like ampulla with long skewed base, the short and wide aedeagus, the characteristic vesica structure, especially the presence of the well-developed subbasal diverticulum with large cornutus in the male genitalia and the heavily sclerotized, funnel-shaped antrum with strongly asymmetrical ostium bursae in the female genitalia indicate the close relationship with the *L. lusoria* species-group.

Male genitalia (Figs 29, 74, 75). Slightly asymmetrical (right valva somewhat narrower). Uncus stem narrow, moderately dilated distally, with fine tip; scaphium membranous with sclerotized plate on subscaphium; valva wide, elongated with almost

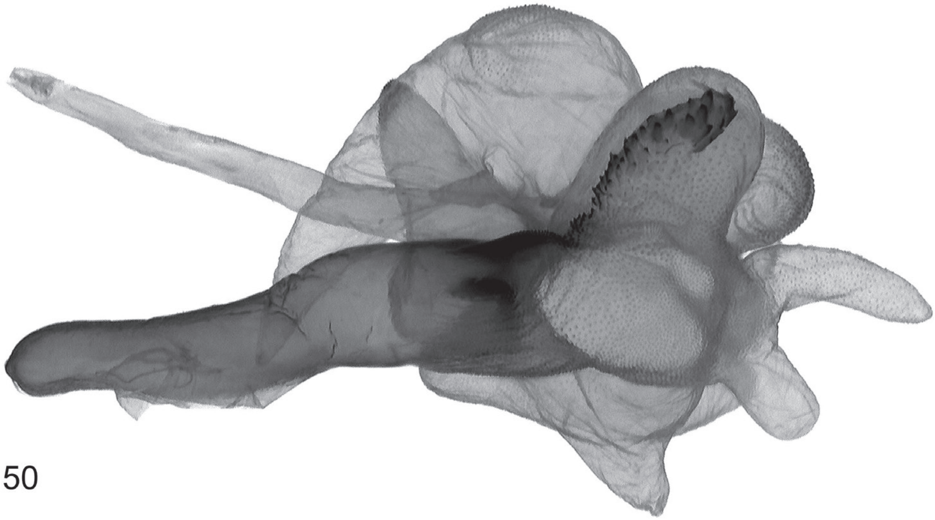


Figures 43–46. Vesica structure of *Lygephila amasina* Turkey, slide No. OP2260m **43** dorsal view **44** ventral view **45** lateral view **46** lateral view opposite side.

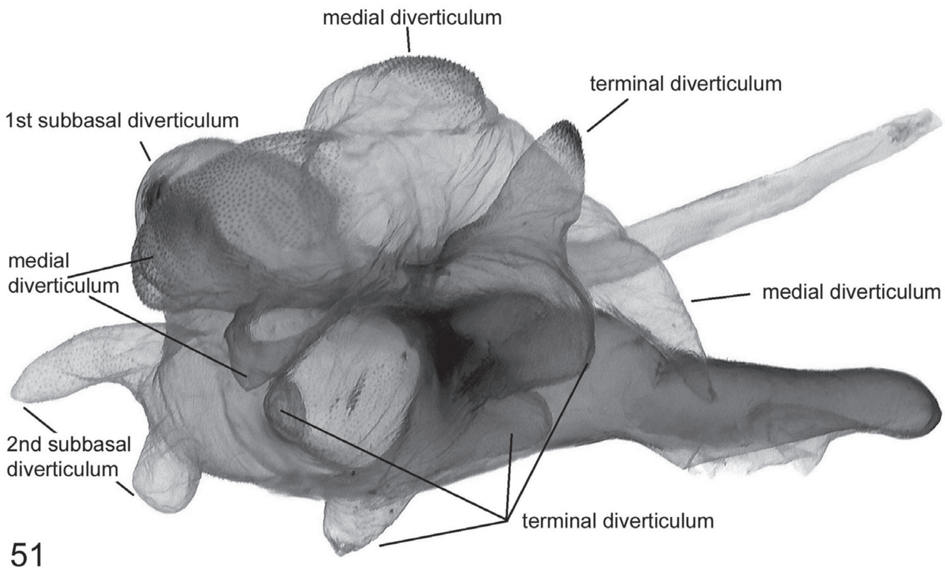


Figures 47–49. Vesica structure of *Lygephila colorata* paratype, Pakistan, slide No. OP1969m **47** dorsal view **48** ventral view **49** sublateral view.

parallel margins, apex rounded; ampulla dentiform with large plate-like lateral extension. Aedeagus straight, carina slightly dilated with transverse wrinkles. Vesica globular, everted laterally; medial part membranous; small subbasal diverticulum topped by



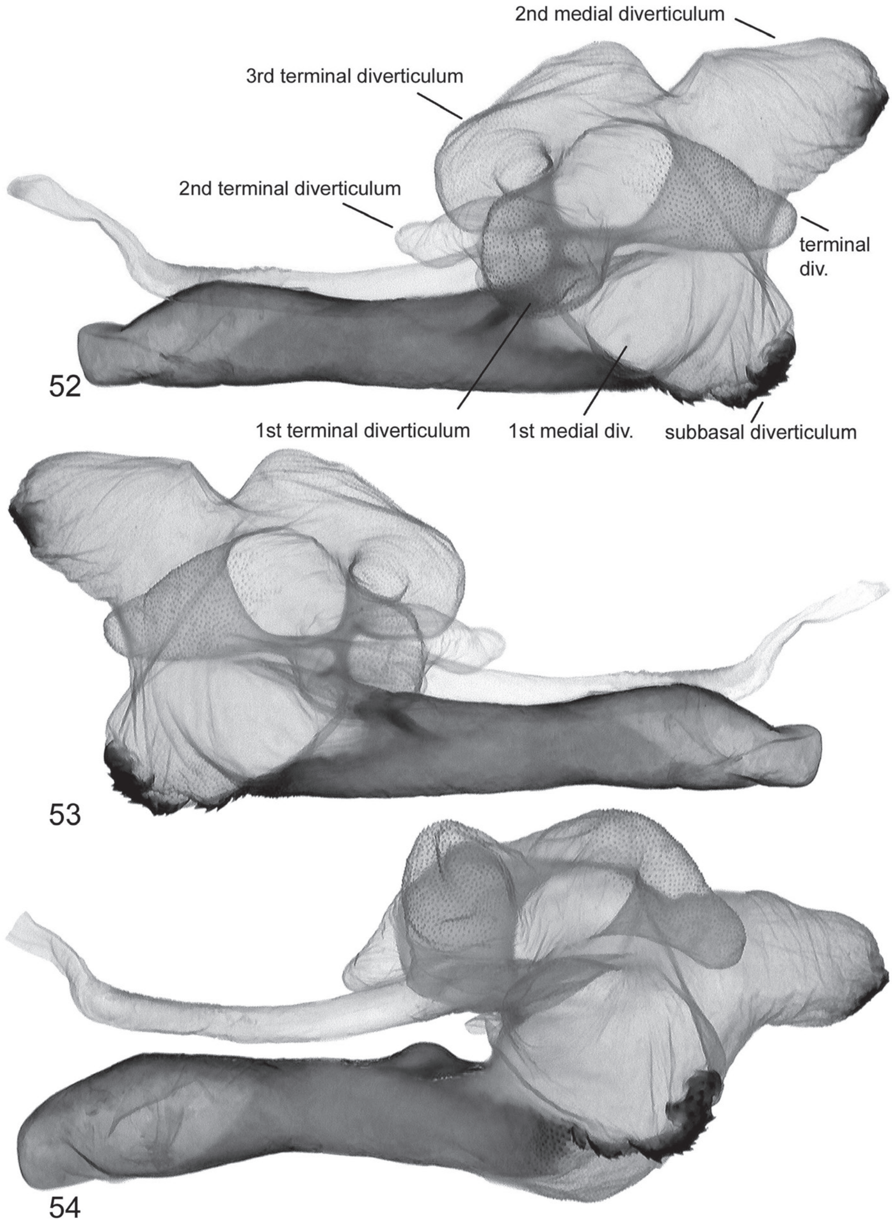
50



51

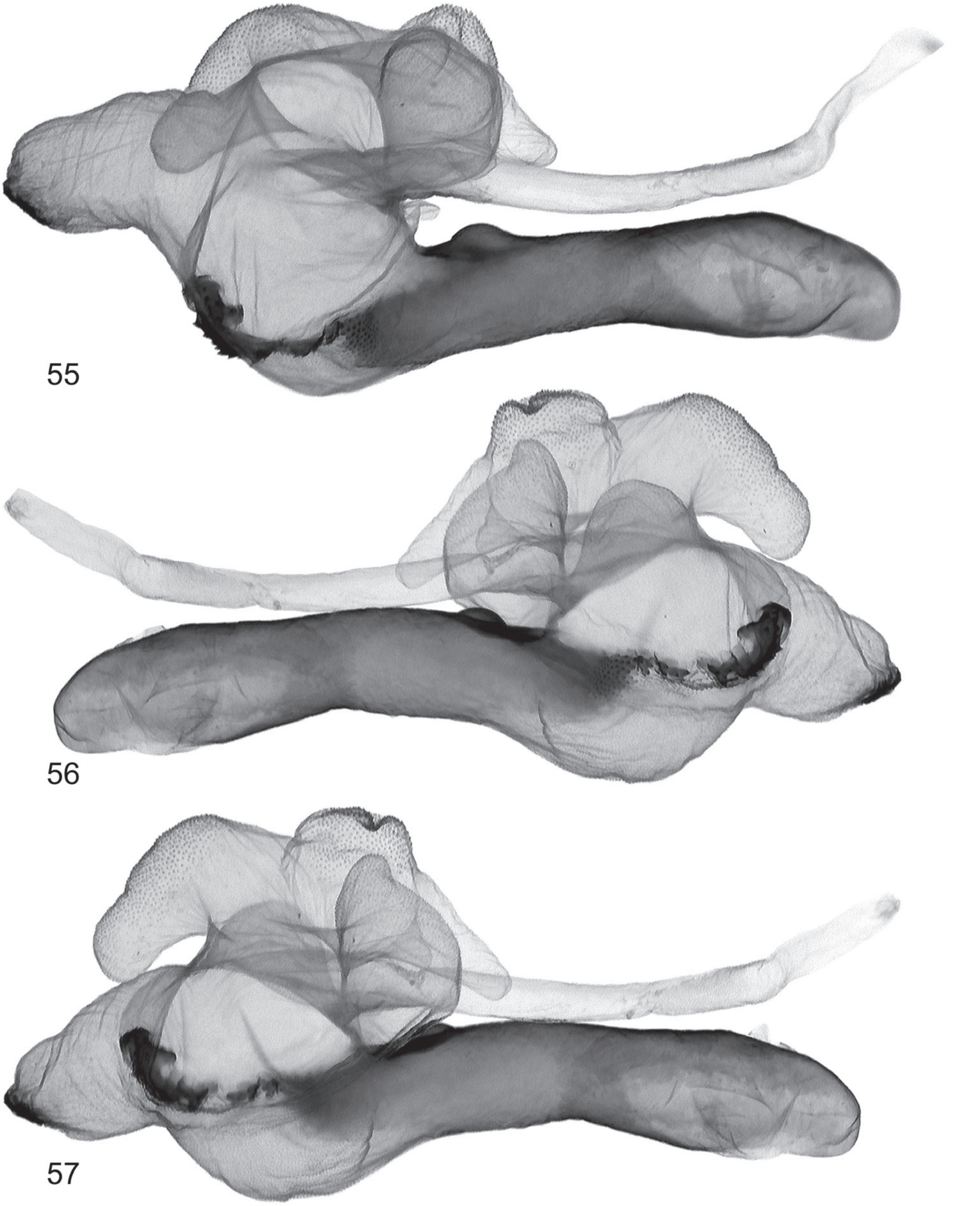
Figures 50, 51. Vesica structure of *Lygephila colorata* paratype, Pakistan, slide No. OP1969m **50** lateral view **51** lateral view opposite side.

heavily sclerotized plate-like cornutus with two teeth; 1st and 2nd medial diverticula small; 1st distal diverticulum resembles high-heeled shoe, 2nd, 3rd and 4th distal diverticula roughly equal in size and similar in shape; opening point of terminal tube located at base of medial part of vesica near carina, membranous with weak scobination from middle towards gonopore. **Female genitalia** (Fig. 85). Ovipositor relatively short,



Figures 52–54. Vesica structure of *Lygephila pallida* Cotype, Turkey, Zeitun, slide No. OP1933m **52** dorsal view **53** ventral view **54** subdorsal view.

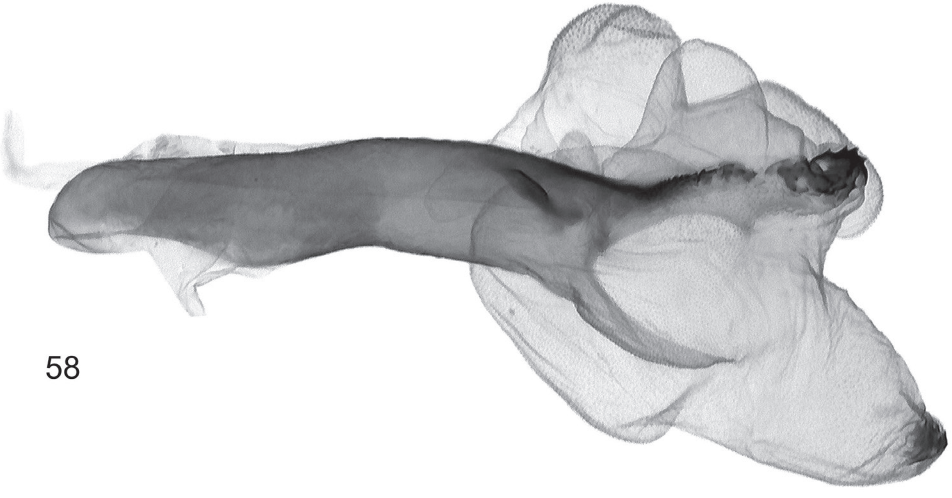
broad, papillae anales hairy with short setae on apical edges. Apophyses anteriores slender, apophyses posteriores thin, more than two times longer than apophyses anteriores. Antrum wide, short, ostium bursae asymmetrical, posterior margin with skewed



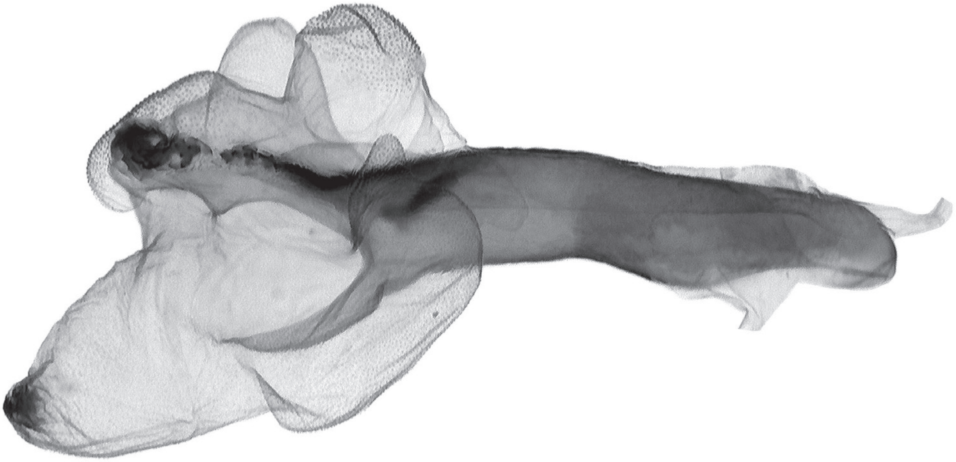
Figures 55–57. Vesica structure of *Lygephila pallida* Cotype, Turkey, Zeitun, slide No. OP1933m **55** subdorsal view opposite side **56** sublateral view **57** sublateral view opposite side.

concavity; ductus bursae as large as antrum, heavily sclerotized. Appendix bursae small, corpus bursae membranous, ovoid.

Distribution. Central Asia – Tajikistan and Uzbekistan.

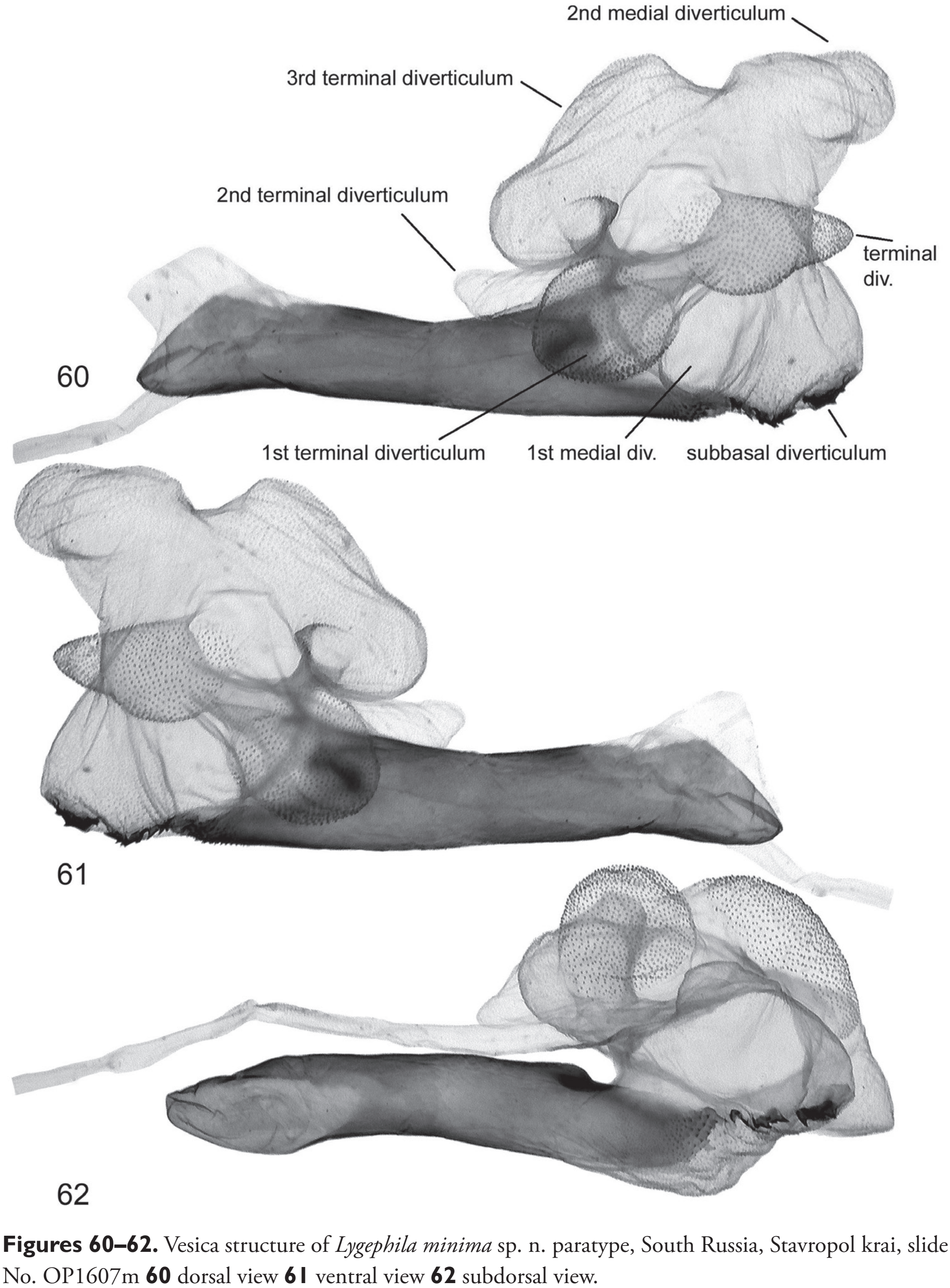


58

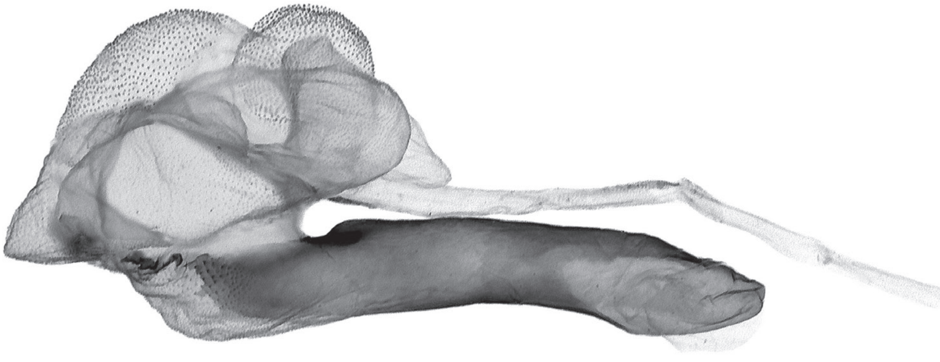


59

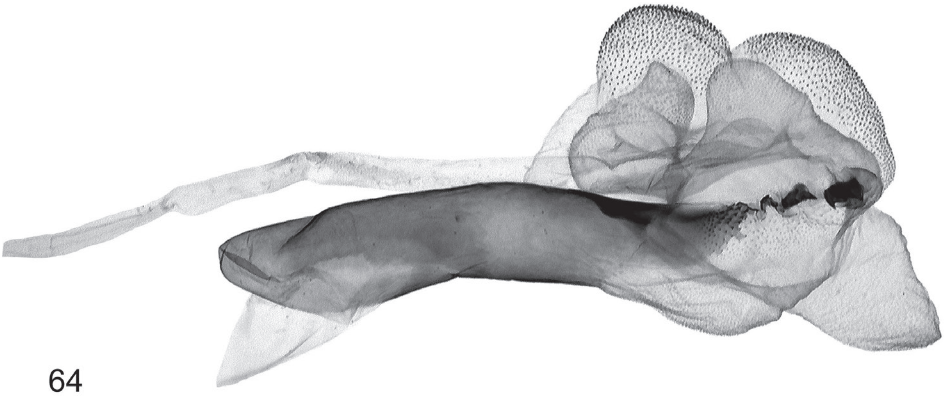
Figures 58, 59. Vesica structure of *Lygephila pallida* Cotype, Turkey, Zeitun, slide No. OP1933m **58** lateral view **59** lateral view opposite side.



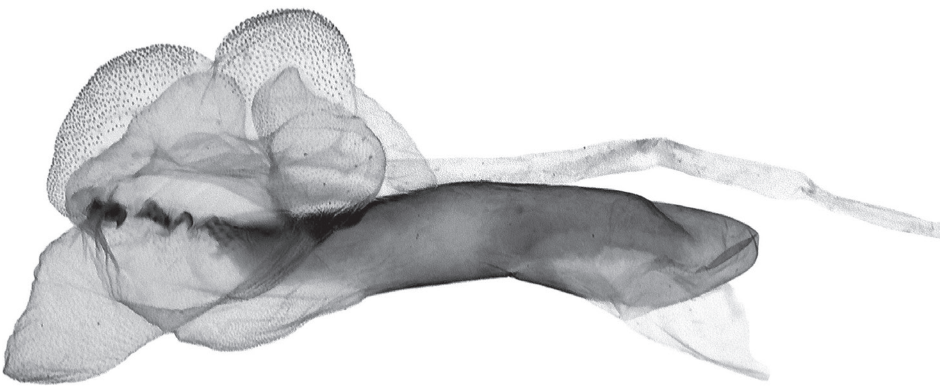
Figures 60–62. Vesica structure of *Lygephila minima* sp. n. paratype, South Russia, Stavropol krai, slide No. OP1607m **60** dorsal view **61** ventral view **62** subdorsal view.



63

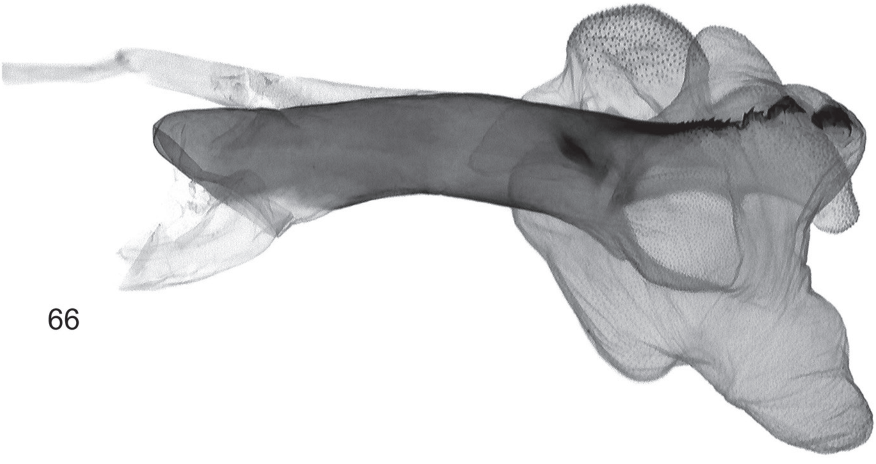


64

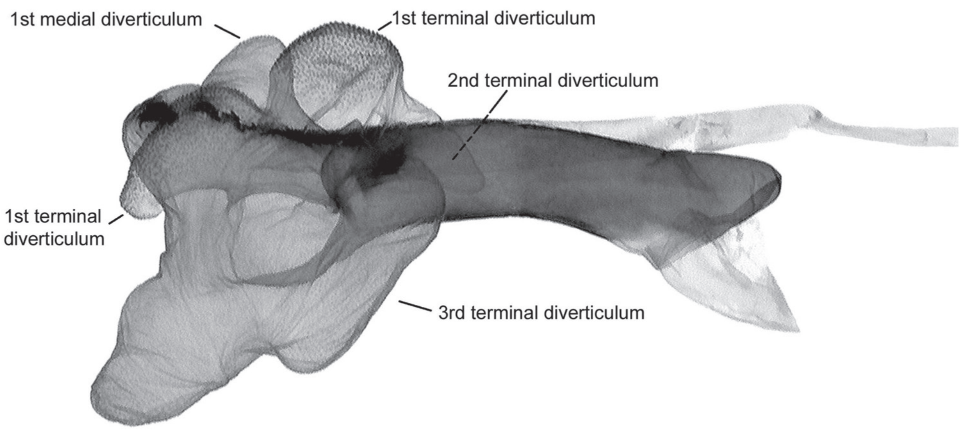


65

Figures 63–65. Vesica structure of *Lygephila minima* sp. n. paratype, South Russia, Stavropol krai, slide No. OP1607m **63** subdorsal view opposite side **64** sublateral view **65** sublateral view opposite side.

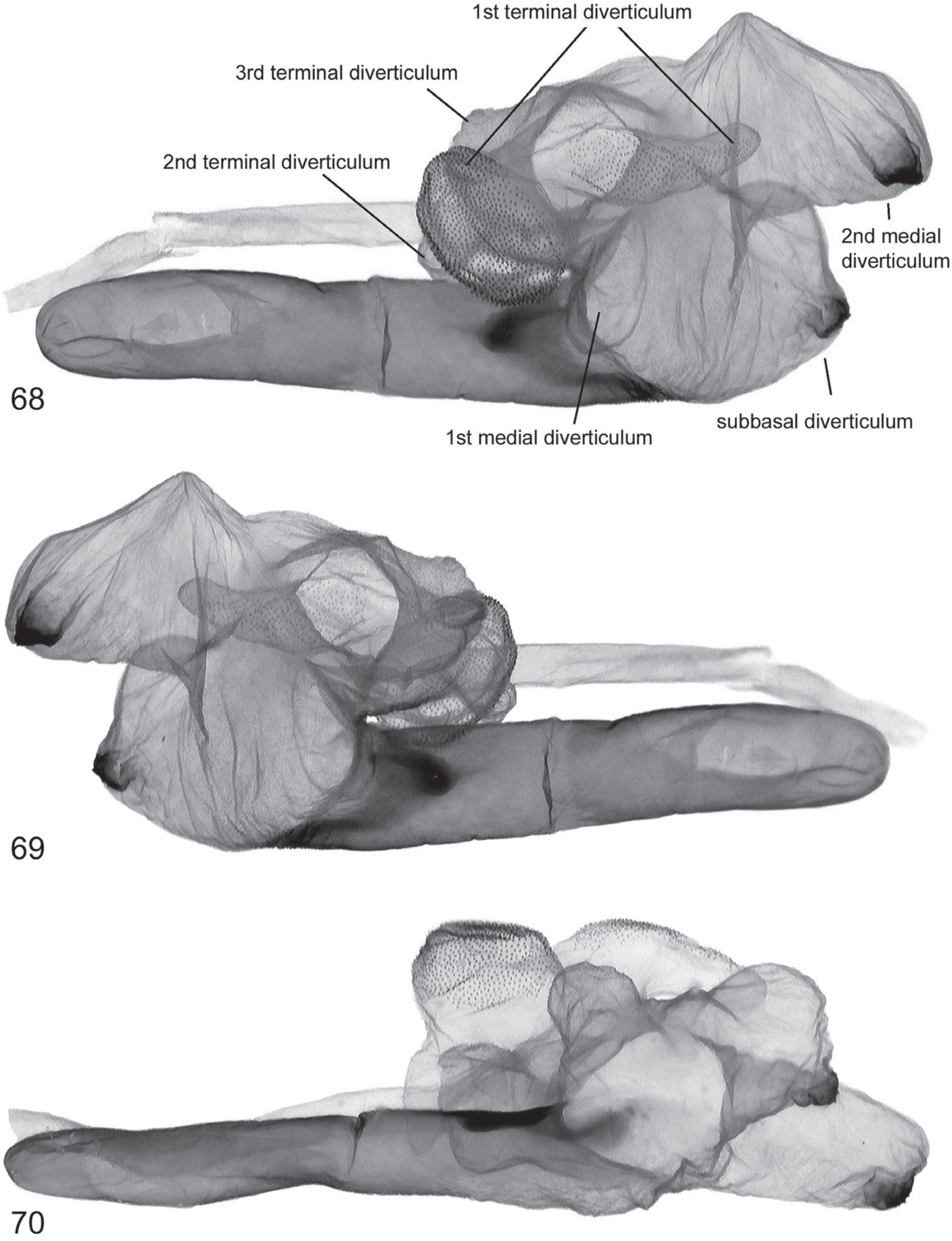


66

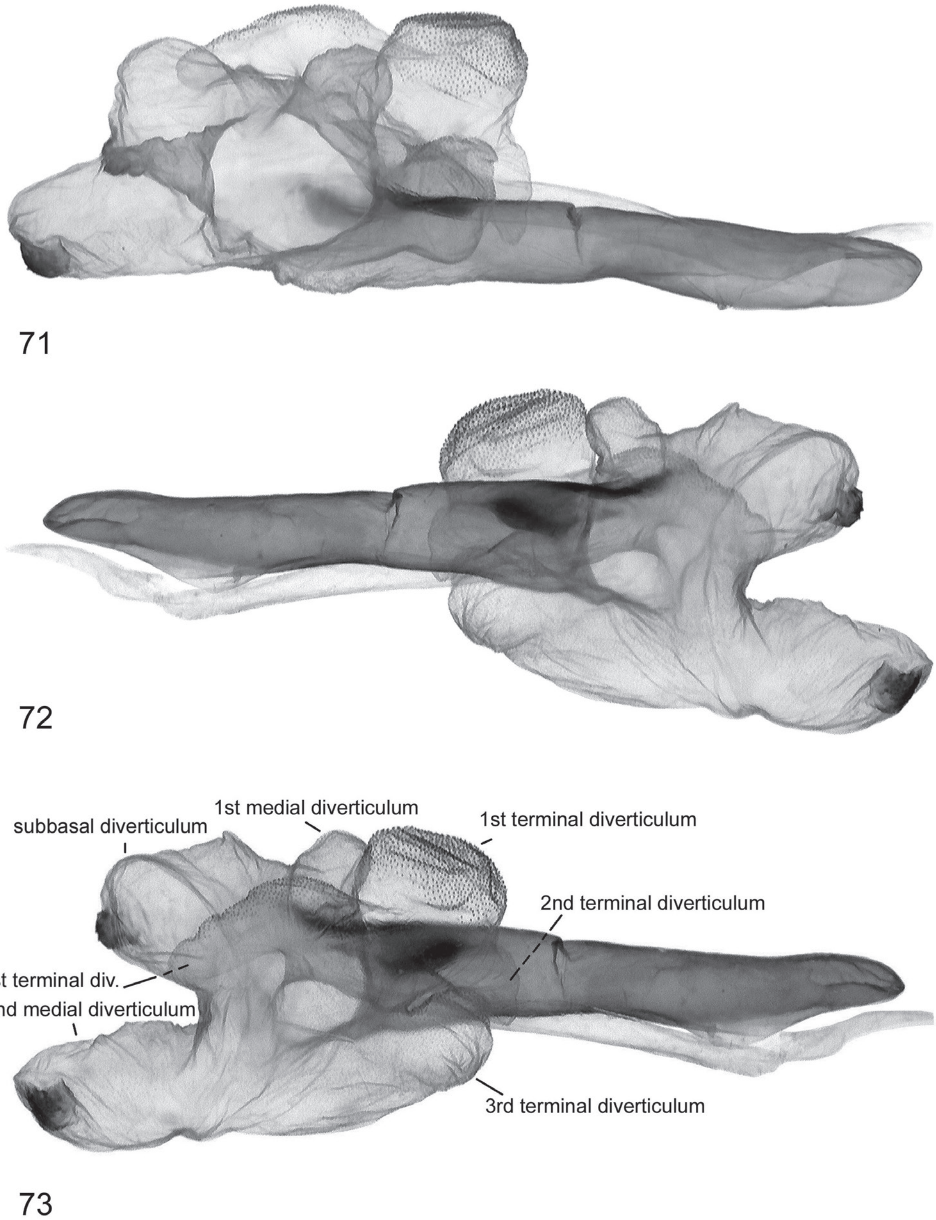


67

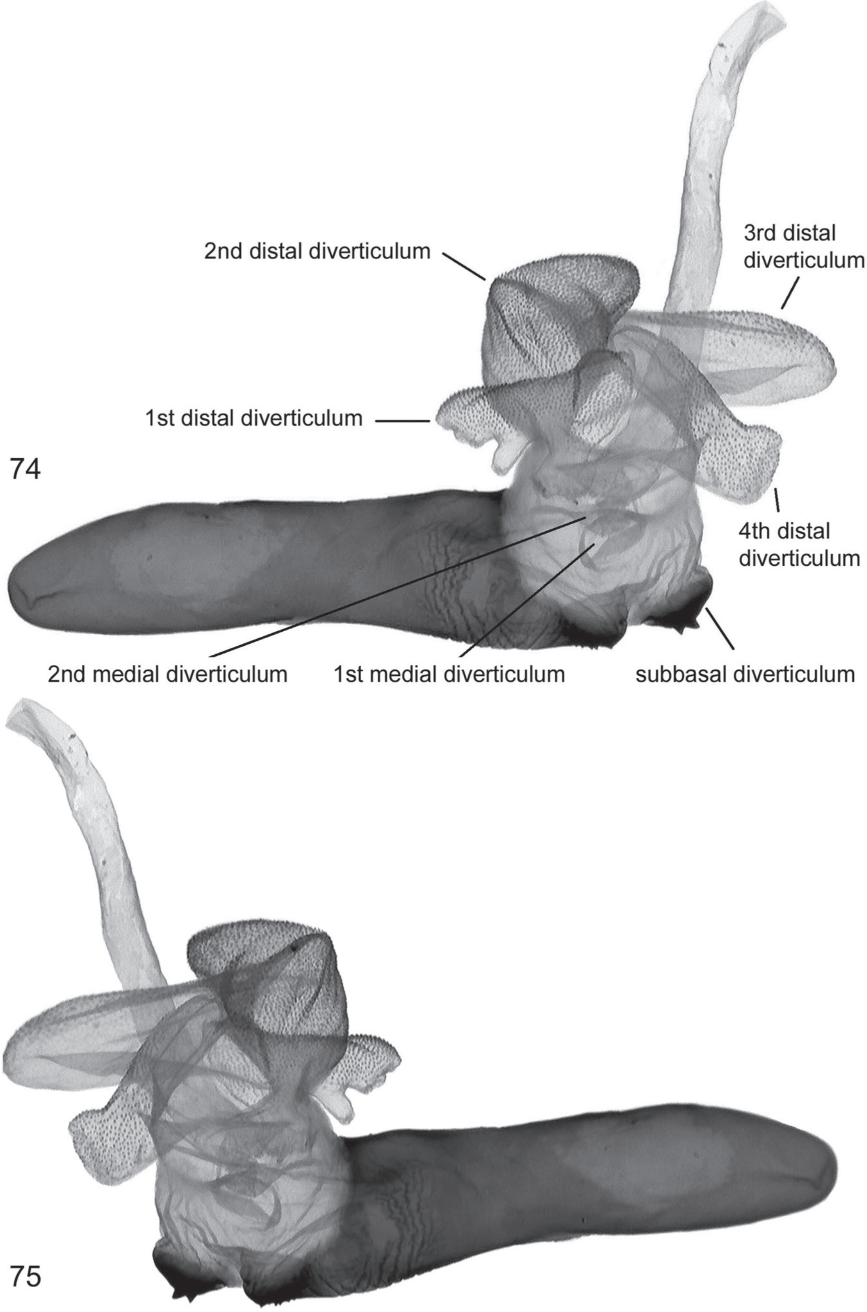
Figures 66, 67. Vesica structure of *Lygephila minima* sp. n. paratype, South Russia, Stavropol krai, slide No. OP1607m **66** lateral view **67** lateral view opposite side.



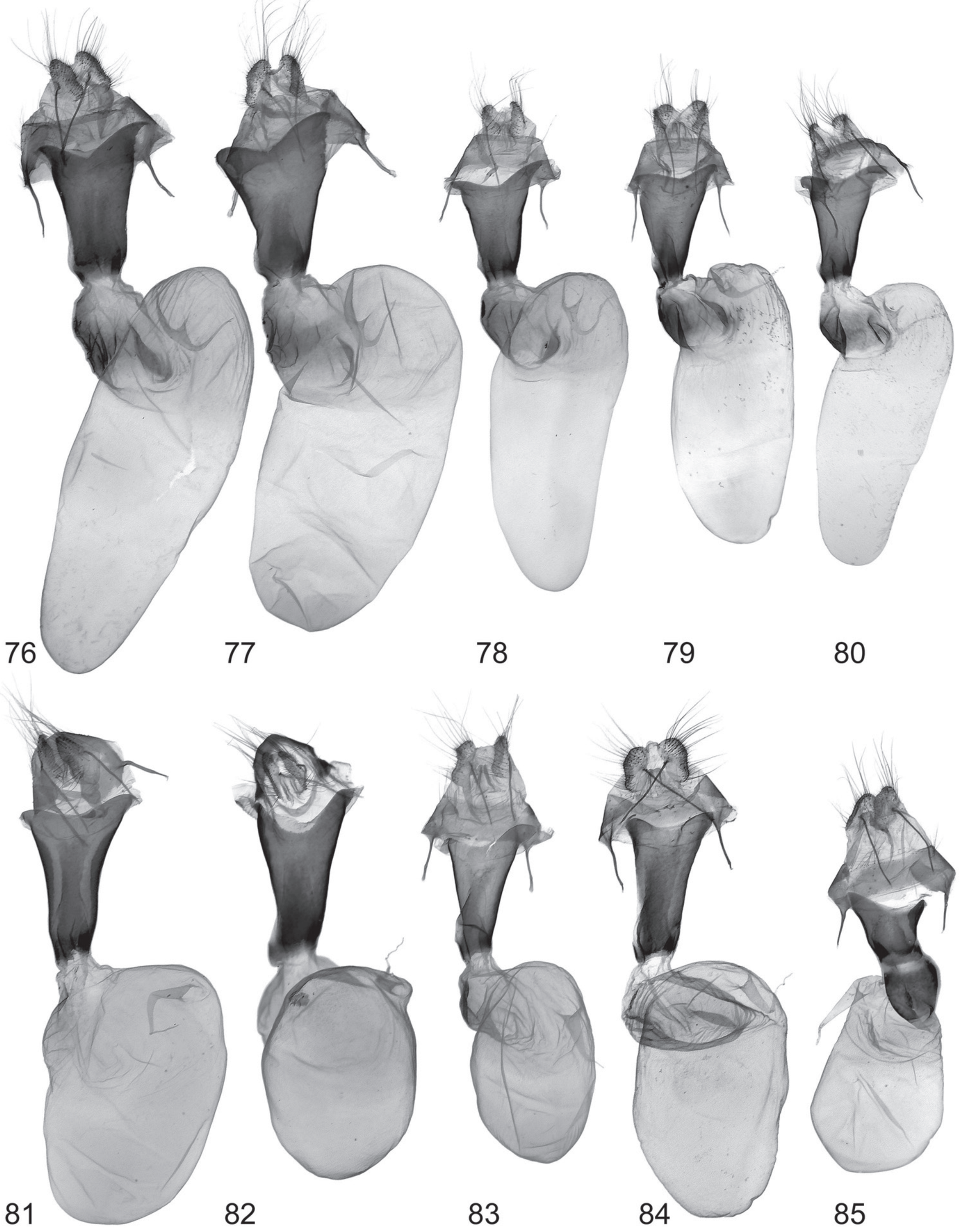
Figures 68–70. Vesica structure of *Lygephila subpicata* Iran, Prov. Fars, slide No. OP2002m **68** dorsal view **69** ventral view **70** sublateral view.



Figures 71–73. Vesica structure of *Lygephila subpicata* Iran, Prov. Fars, slide No. OP2002m **71** sublateral view opposite side **72** lateral view **73** lateral view opposite side.



Figures 74, 75. Vesica structure of *Lygephila alaica* Tajikistan, Gissar Mts, slide No. OP1819m **74** dorsal view **75** ventral view.



Figures 76–85. Female genitalia. 76, **77** *Lygephila lusoria lusoria* **76** Hungary, slide No. OP1954f **77** Ukraine, Crimea, slide No. OP2053f **78–80** *L. lusoria glycyrrhizae* **78** Spain, slide No. OP1978f **79** Spain, slide OP2137f **80** Spain, slide No. OP2265f **81** *L. amasina* Lebanon, slide No. OP1960f **82** *L. colorata* paratype, Pakistan, slide No. OP1970f **83** *L. pallida* Turkey, Palandoeken, slide No. OP2070f **84** *L. subpicata* paratype, Iran, Semnan, slide No. OP2060f **85** *L. alaica* Tajikistan, Gissar Mts, slide No. OP1568f.

Acknowledgements

I would like to express my profound gratitude to László Ronkay for reading the manuscript and for his critical comments, to Gábor Ronkay (Budapest, Hungary) and Péter Gyulai (Miskolc, Hungary) for access to their extensive private collections. I'm grateful to Marek Dvořák (Smrčná, Czech Republic), Luboš Srnka (Lehota pod Vtáčnikom, Slovakia), Matjaž Černila (Kamnik, Slovenia), Aidas Saldaitis (Vilnius, Lithuania), Natalia Kaygorodova and Vladimir Savchuk (Feodosia, Crimea, Ukraine), Evgenij Rutjan (Kiev, Ukraine), and Stanislav Korb (Nizhniy Novgorod, Russia) for providing material from their collections for the examination; to Alexey Matov (ZISP St. Petersburg) for adult and genitalia photos of holotype and two paratypes of *Lygephila minima* sp. n. from South Russia; to Vladimir Kononenko (Vladivostok, Russia) for genitalia photo of Lygephila moellendorffi; to Martin Lödl and Sabine Gaal (NHM Vienna), Dieter Stüning (ZFMK, Bonn) and Wolfram Mey (MNHU Berlin) for access to the museum collections and for their help in finding the literature.

References

Babics J, Ronkay L (2009) Two new *Lygephila* Billberg, 1820 species from the Himalayan-Sino-Tibetan region (Lepidoptera, Noctuidae, Catocalinae). Folia Entomologica Hungarica 70: 169–180.

Babics J, Stüning D (2011) A cryptic species in the *Lygephila vicioides* Hampson, 1826 species-group: description of a sister-species of *L. angustissima* found in the Höne collection. Esperiana 16: 127–134.

Behounek G, Hacker H (1986) *Lygephila schachti* sp. n., eine neue Noctuidenart nebst faunistischen Angaben für 29 weitere Noctuidenarten aus der Ost-Türkei (Lepidoptera, Noctuidae). Entomofauna Zeitschrift für Entomologie 7(3): 41–53.

Bertaccini E, Fiumi G, Parenzan P, Zilli A (2008) Nottuidi d'Italia 1. Calpinae e Catocalinae. Natura – Giuliano Russo Editore, Monterenzio, 287 pp.

Bryk F (1948) Zur Kenntnis der Gross-schmetterlinge von Korea. Pars II. Macrofrenat II (finis). Arkiv för Zoologi 41 A(1): 1–225, pl. 7.

Calle JA (1983) Noctuidos españioles. Boletin del Servicio de Defensa contra Plagas e Inspección Fitopatólogica, (fuera de serie) 1 (1982): 1–430.

Draudt M (1950) Beiträge zur Kenntnis der Agrotiden-Fauna Chinas aus den Ausbeuten Dr. H. Höne's. Mitteilungen der Münchner Entomologischen Gesellschaft 40(1), 1–174.

Fibiger M, Kononenko VS, Nilsson D (2008) Description of a new species of *Lygephila* Billberg, 1820 (Lepidoptera: Noctuidae, Catocalinae) from Russian Far East and North China. Zootaxa 1922: 62–68.

Goater B, Ronkay L, Fibiger M (2003) Catocalinae & Plusiinae. Noctuidae Europaeae, volume 10. Entomological press, Sorø, 452 pp.

Kinoshita S (1989) Two New Species of the Genus *Lygephila* BILLBERG from Taiwan (Lepidoptera, Noctuidae). Tyô to Ga 40(2): 141–148.

Kinoshita S, Sasaki N (1986) A New Species of the Genus *Lygephila* BILLBERG from Japan (Lepidoptera, Noctuidae). Tyô to Ga 37(4): 209–216.

Kononenko VS, Han SB, Ronkay L (1998) Illustrated catalogue of Noctuidae in Korea (Lepidoptera). In: Insects of Korea [3], 509 pp.

Kononenko VS, Han HL (2007) Atlas genitalia of the Noctuidae in Korea (Lepidoptera). In: Park KT (Ed) Insects of Korea [11], 464 pp.

Kononenko VS, Fibiger M (2008) A new subgenus and three new species of catocaline noctuids from China (Lepidoptera, Noctuidae: Catocalinae). Zootaxa 1876: 19–28.

Poole RW (1989) Lepidopterorum Catalogus (New Series), fascicle 118, Noctuidae. E. J. Brill, Leiden, 1314 pp.

Rambur P (1866) Catalogue Systématique des Lépidoptéres de L'Andalousie. Pl. 7, 6.

Remm H, (1983) New species of Noctuidae (Lepidoptera) from the USSR. Revue d'Entomologie de l'URSS 62: 596–599.

Sheljuzhko L (1955) Neue und wenig bekannte Noctuiden und Geometriden der Zoologischen Staatssammlung in München. Mitteilungen der Münchner Entomologischen Gesellschaft 45: 277–283.

Sviridov AV (1990) K tipovym materialam sovok, opisannyh F. Brikom iz Korei. Novosti faunistiki i sistematiki, Kiev, 97–100. [in Russian]

Sugi S (1982) Noctuidae (except Herminiinae). In: Inoue H, Sugi S, Kuroko H, Moriuti S, Kawabe A. Moths of Japan, Vol. 1: 669–913, Vol. 2: 334–405. Kodansha, Tokyo.

Wiltshire EP (1961) A new genus, eight new species, seven new forms, and notes on the Lepidoptera of Saudi Arabia, Bahrain, and Iran (With four plates and three text-figures). Journal of the Bombay Natural History Society 58 (3): 608–631.

Wiltshire EP (1971) Österreichische Expeditionen nach Persien und Afghanistan - Beiträge zur Lepidopterenfauna, Teil 15 - Noctuidae — Quadrifinae) - (Middle East Lepidoptera XXVII). Annalen des Naturhistorischen Museums in Wien 75: 627–649.

Yela JL (1989) Una especie nueva del género *Lygephila* Billberg, 1820 descubierta en la Península Ibérica (Lepidoptera, Noctuidae). Eos 65(2): 293–300.

Yela JL, Calle JA (1990) *Lygephila fonti* sp. n., de la Península Ibérica (Lepidoptera, Noctuidae). Miscellània Zoològica 12(1988): 205–211.