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All stages of the Palaearctic predaceous midge *Palpomyia schmidti* Goetghebuer, 1934 (Diptera: Ceratopogonidae)

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Abstract

All stages and the ecology of the Southern Palaearctic *Palpomyia schmidti* collected from the vicinity of the saline Lake Elton in Russia are described and illustrated. The morphology of larvae and pupae as well as the detailed ecology of the larvae are described for the first time. *P. schmidti* is a halobiontic biting midge, widely distributed in the steppes and deserts of the Palaearctic region. It is proposed that the *Palpomyia schmidti* group should include five Holarctic species. *P. downesi* Grogan & Wirth, 1979 from north-western North America is recognized as a new junior synonym of the Eastern Palaearctic *P. tuvae* Remm, 1972. **New synonymy.**

Key words: Ceratopogonidae, *Palpomyia schmidti*, larva, pupa, female, male, ecology, Russia

Introduction

Biting midges comprise a relatively well studied, large family of the nematocerous Diptera. The recent World fauna comprises over 6224 extant species grouped in over 110 genera and 4 subfamilies (Borkent 2015). However, although they are present on every continent except Antarctica, our knowledge of their taxonomy and geographical distribution remains unsatisfactory.

The genus *Palpomyia* Meigen of the tribe Palpomyiini Enderlein, which includes exclusively predatory biting midges, has a worldwide distribution and is represented by 271 extant species (Borkent 2015), 69 of which are known from Europe (Szadziewski *et al.* 2013). The immature stages are poorly known. So far, 23 species of larvae (9% of all known species of the genus) and 41 species of pupae (15%) have been described (Borkent 2014). *Palpomyia schmidti* has so far been described twice, and only on the basis of females: from Iraq as *P. schmidti* (Goetghebuer 1934a, b) and from Hungary as *P. miki* (Szadziewski *et al*. 2009). The purpose of this paper is to provide amended diagnoses of adults, descriptions of hitherto unknown pupae and larvae, and detailed data on the larval ecology of *P. schmidti*.

Material and methods

The males (5), females (11), pupae (13) and larvae (19) described in the paper are from the River Chernavka (49º 12′ N 46º 40′ E), which flows into the hypersaline Lake Elton in the Volgograd region of Russia (Fig. 1). Adults and pupae of *Palpomyia schmidti* were reared under laboratory conditions from larval stage IV. Larvae were collected on 28 May 2015 at the mouth of the Chernavka (salinity—28.2 g l^{-1}, water temperature—25.5°C) and then transported in 0.500 ml containers filled with river water to the laboratory in a cooler bag. In the laboratory the larvae were removed from the substrate and placed in an aquarium with river water and subsequently reared as described by Glukhova (1989). Each larva was placed in a double Petri dish (diameter 40 mm) with a small amount

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of saline river water. As soon as a larva pupated, it was placed on a piece of moist cotton wool, which in turn was inserted into a tube. Larval and pupal exuviae as well as emerged adults were preserved in 70% ethanol.

The description of the species' ecology is based on sampling in the middle reaches and mouths of seven rivers—the Chernavka (Fig. 1B, C), Solyanka, Lantsug, Khara and Bolshaya Samoroda—all of which flow into the hypersaline Lake Elton. A description of the study area can be found in Zinchenko *et al.* (2014). Samples were taken in summer (August 2006–2014; July 2011), spring (April 2007; May 2011–2013, 2015) and autumn (September 2008).

The photographs were taken using the LAS Montage multifocus with a Leica DM6000. For scanning electron microscopy larvae were dehydrated in a graded ethanol series, dried in 1.1.1.3.3.3-hexamethyldisilazane (HMDS) and stored at 37°C for 24 h. The material was coated with gold using a SC7640 Sputter Coater and examined with a Zeiss EVO40 (Adam Mickiewicz University, Laboratory of Electron and Confocal Microscopy).

The specialist morphological terms and abbreviations used in the paper follow those explained by Wirth & Grogan (1988), Glukhova (1979), Murphee & Mullen (1991), Szadziewski *et al.* (2007) and Borkent (2014). The specimens examined are deposited in the Collection of Extant Invertebrates at the Department of Invertebrate Zoology and Parasitology, University of Gdańsk [CEI UG].

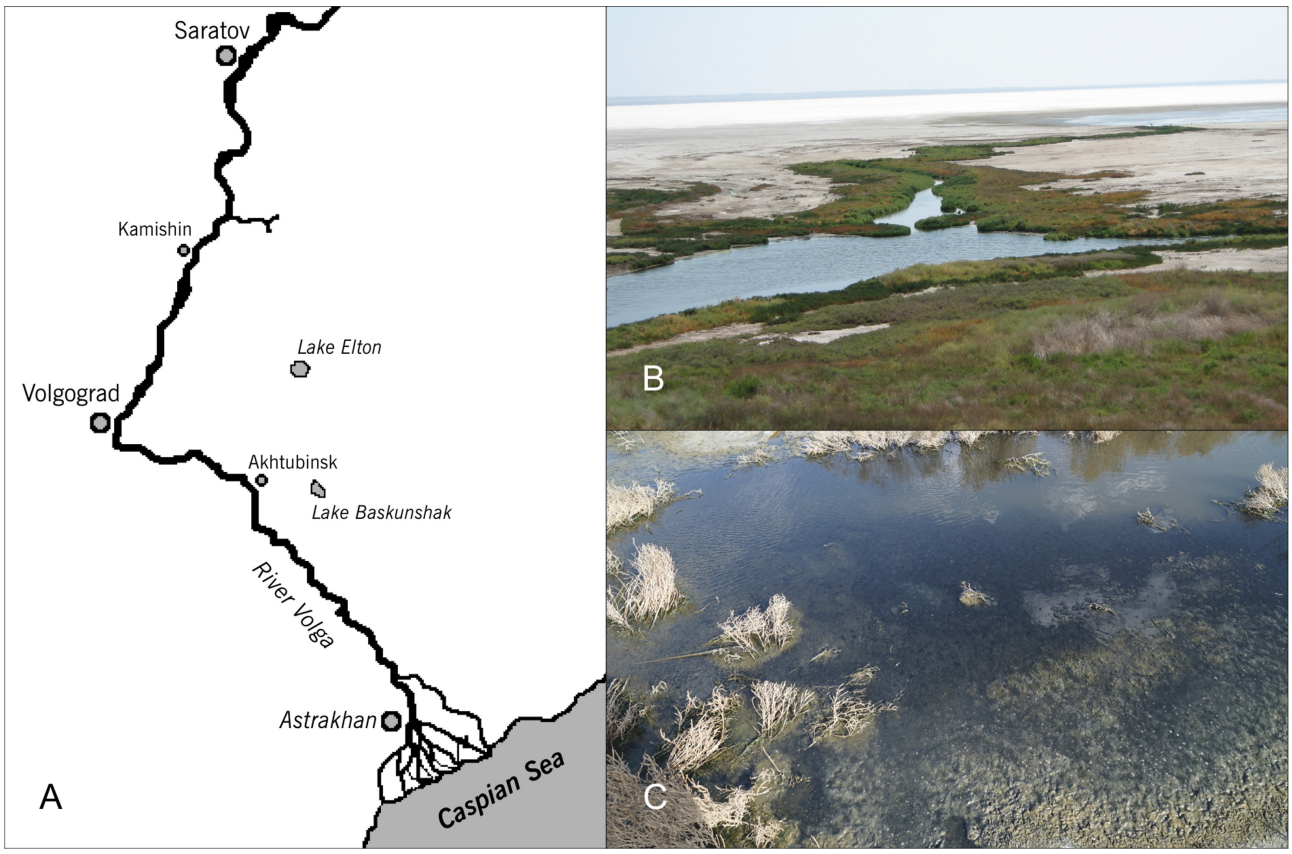

FIGURE 1. Breeding sites of *Palpomyia schmidti*. A—Map showing the geographical position of Lake Elton; B—The River Chernavka, which flows into Lake Elton; C—The bottom of the Chernavka covered with algae. On the map: Caspian Sea; River Volga.

Results

Palpomyia schmidti (Goetghebuer, 1934)

Palpomyia schmidti Goetghebuer, 1934a: 36 (Iraq, female) (5 March 1934); Szadziewski *et al.* 2009: 195 (Iraq, female redescribed, male diagnosed, figs, syn. *P. miki*).

Palpomyia miki Goetghebuer, 1934b: 91 (Hungary, female, fig. total habitus) (20 April 1934); Remm 1976: 175 (Russia, female, male, figs); Delécolle *et al.* 1997: 342 (Spain, female, figs).

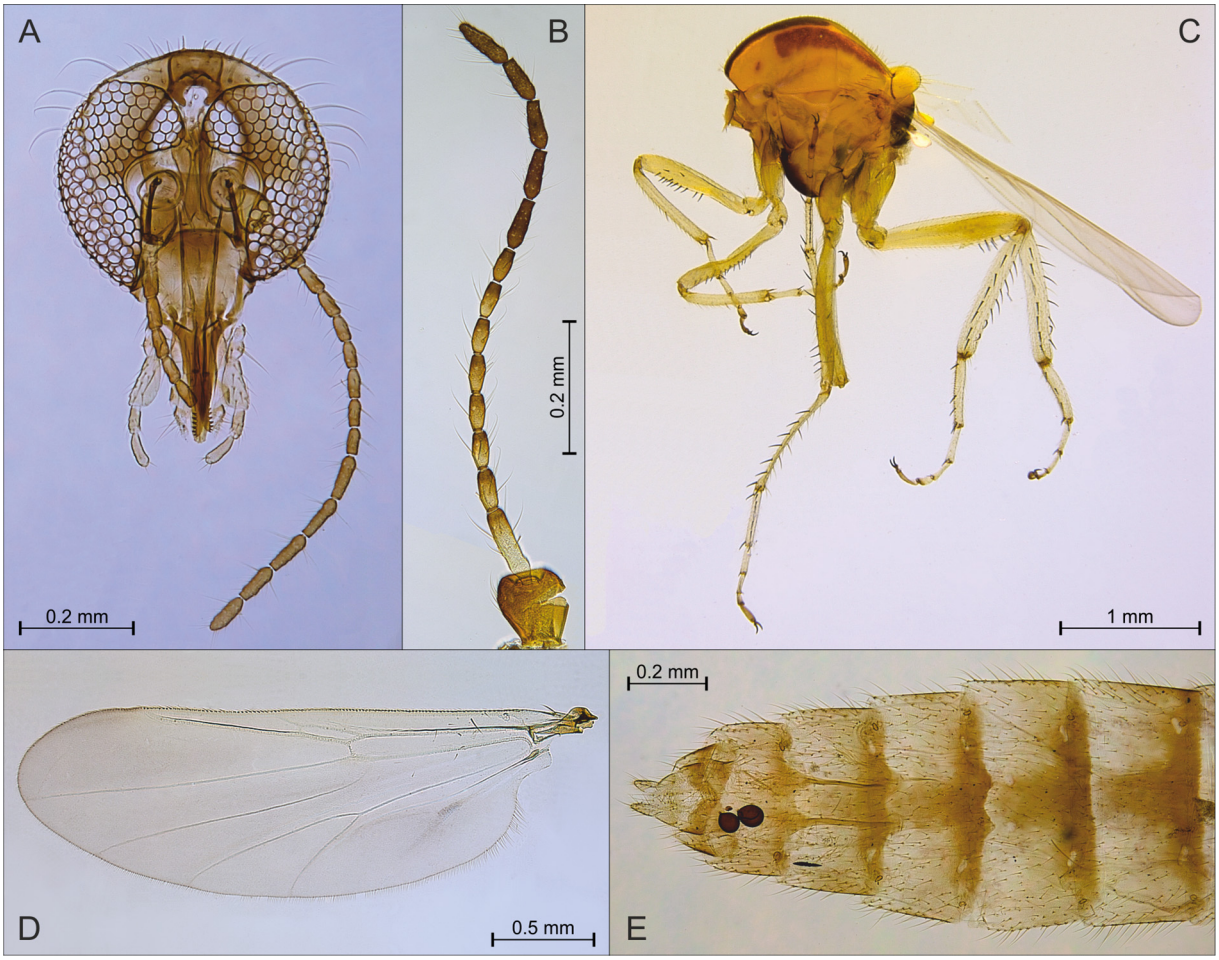

FIGURE 2. Female of *Palpomyia schmidti.* A—frontal view of head; B—flagellum; C—lateral view of thorax; D—wing; E—ventral view of abdomen.

Diagnosis. The only species in the genus with a triangular gonocoxite and totally separated parameres in the male genitalia, femora and tibiae armed with dark spine-like bristles. Females can be separated from other Palaearctic congeners in that they have simple claws, all femora armed with ventral spines, mid and hind tibiae with dorsal spine-like bristles, basitarsus of midleg with some median spines. Larvae: head relatively broad; collar of the head capsule with a triangular ventral expansion; a long epicranial suture (ES), reaching the level of seta q; a dorsal paired comb of the epipharynx with long, slender teeth. Pupae: dorsal apotome with 1 pair of setae and 1 pair of sensory pits (sensilla campaniformia); numerous spiracles arranged in a horseshoe shape, occupying the distal half of the respiratory horn.

Description. **Female**. Head yellowish. Eyes broadly separate, vertex with strong setae (Fig. 2A). Antennal flagellum 0.90 mm long, AR 0.84–0.86. Proximal flagellomeres subcylindrical, distal cylindrical (Fig. 2B). Palpus 5-segmented, third palpal segment stout, 0.11 mm long. Mandible with 7 stout teeth (Fig. 2A). Scutum yellowish with brown longitudinal stripes, scutellum yellow, postscutellum dark brown (Fig. 2C). Scutum without anterior tubercle, with numerous simple setae. Scutellum bearing 9–10 bristles and numerous small setae. Paratergite broad, bare. Anterior anepisternum with a group of 7–8 setae. Katepisternum dark and bare. Wing without pattern (Fig. 2D), length 2.10–2.90 mm, CR 0.71–0.78. Second radial cell about twice as long as first one. Base of vein M_2 proximal to vein M_1. Legs yellow with darker coxae and distal tarsomeres. Lateral surface of coxae with some setae. All femora armed with ventral spines (Fig. 2C). Fore femur enlarged with 6–18 ventral spines, mid femur slender with 1–4 spines and hind femur with 1–3 ventral spines. All tibiae armed with strong dark dorsal bristle-like spines. Fore tibia with 1 anterior spine, mid tibia with 4–10 spines and hind tibia with 12–16 dark spines. Tibial comb with 6–7 pale spines. First tarsal segment of foreleg armed with 2 apical spines, that of midleg with 2 basal, 5–6 median and 2 apical spines, hindleg with 5 dark spines, palisade setae in one row. Fourth tarsomere

subcylindrical. Tarsal ratio of foreleg TR(I) 1.6–1.8, midleg TR(II) 1.9–2.2, hindleg TR(III) 1.8–2.0. Claws almost equal, simple, without internal basal tooth. Abdomen yellow with brownish triangles on tergites. Two pairs of apodemes of eversible sacs present. Seminal capsules ovoid, unequal, with distinct necks, length 0.08–0.11 mm, and 0.06–0.08 mm (Fig. 2E).

Male. Similar to female with the usual sexual differences. Eyes broadly separate. Flagellum 0.765 mm long, with greatly reduced plume, all flagellomeres cylindrical, terminal three slightly elongate (Fig. 3A). Proportions of flagellomeres as follows: 40-15-15-15-16-15-15-14-16-16-20-25-35. Third palpal segment stout, 0.037-0.045 mm long, with some sensilla capitata on surface.

Wing length 1.60–1.75 mm, CR 0.73–0.75. Tibial comb with 7–8 spines, hind tibial spur short. Tarsal ratio TR(I) 1.9, TR(II) 2.5–2.6, TR(III) 1.8–2.0.

Genitalia as in Fig. 3. Sternite 9 with broad caudomedian excavation. Tergite 9 elongate, with broad cerci. Gonocoxite stout, as long as broad, with long triangular internal extension Fig. 3C). Gonostylus stout, evenly bent, with pointed dark apical portion Fig. 3D). Aedeagus stout, scutiform and covered with short spiculae; basal arch high; apex with evenly rounded cap (Fig. 3E). Parameres separate, apex distinctly expanded, bulbous (Fig. 3F).

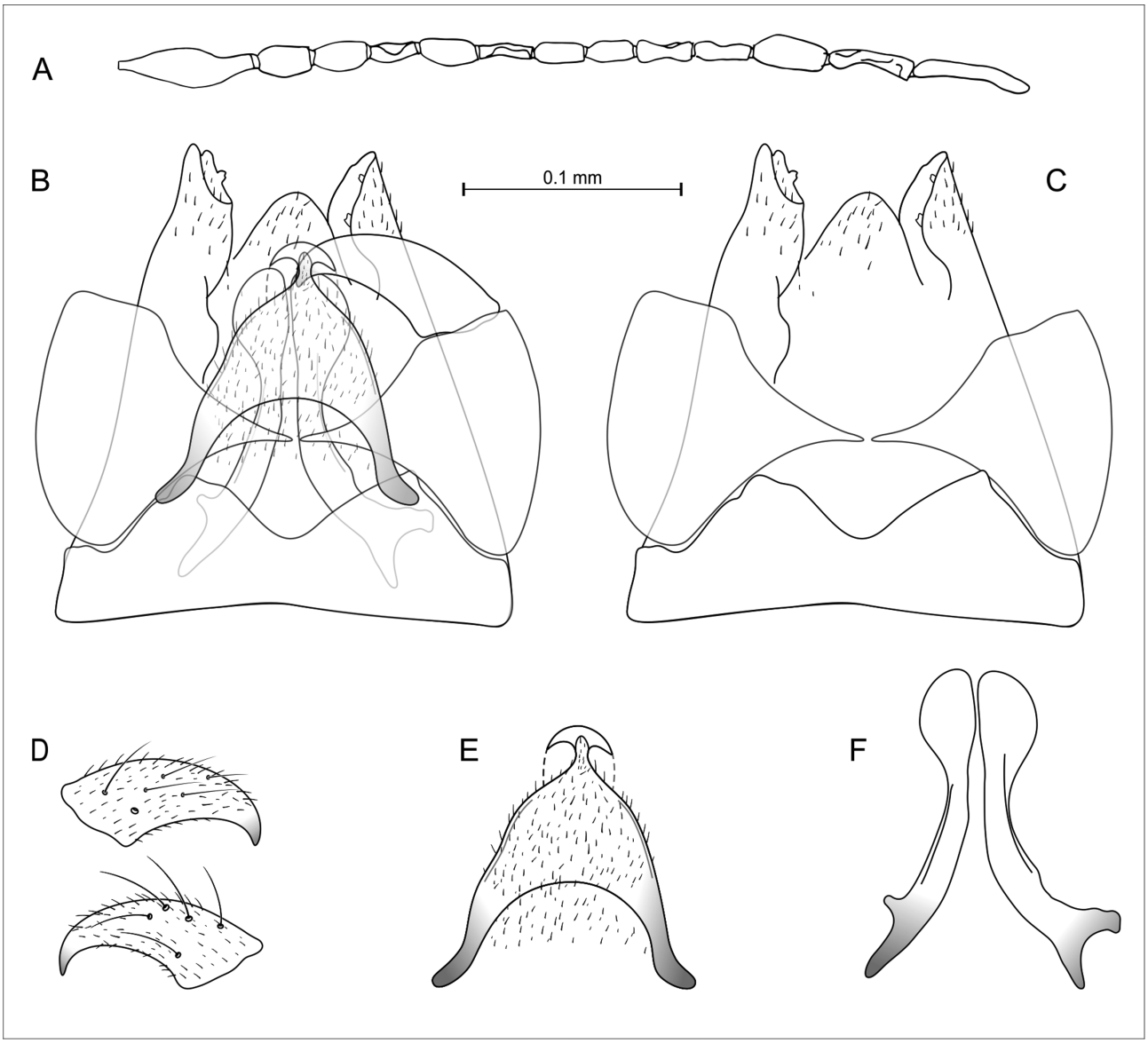

FIGURE 3. Male of *Palpomyia schmidti*. A—flagellum; B–F—genitalia, ventral aspect: B—complete, only one gonostylus removed; C—gonocoxites, sternite and tergite 9; D—gonostyli; E—aedeagus; F—parameres.

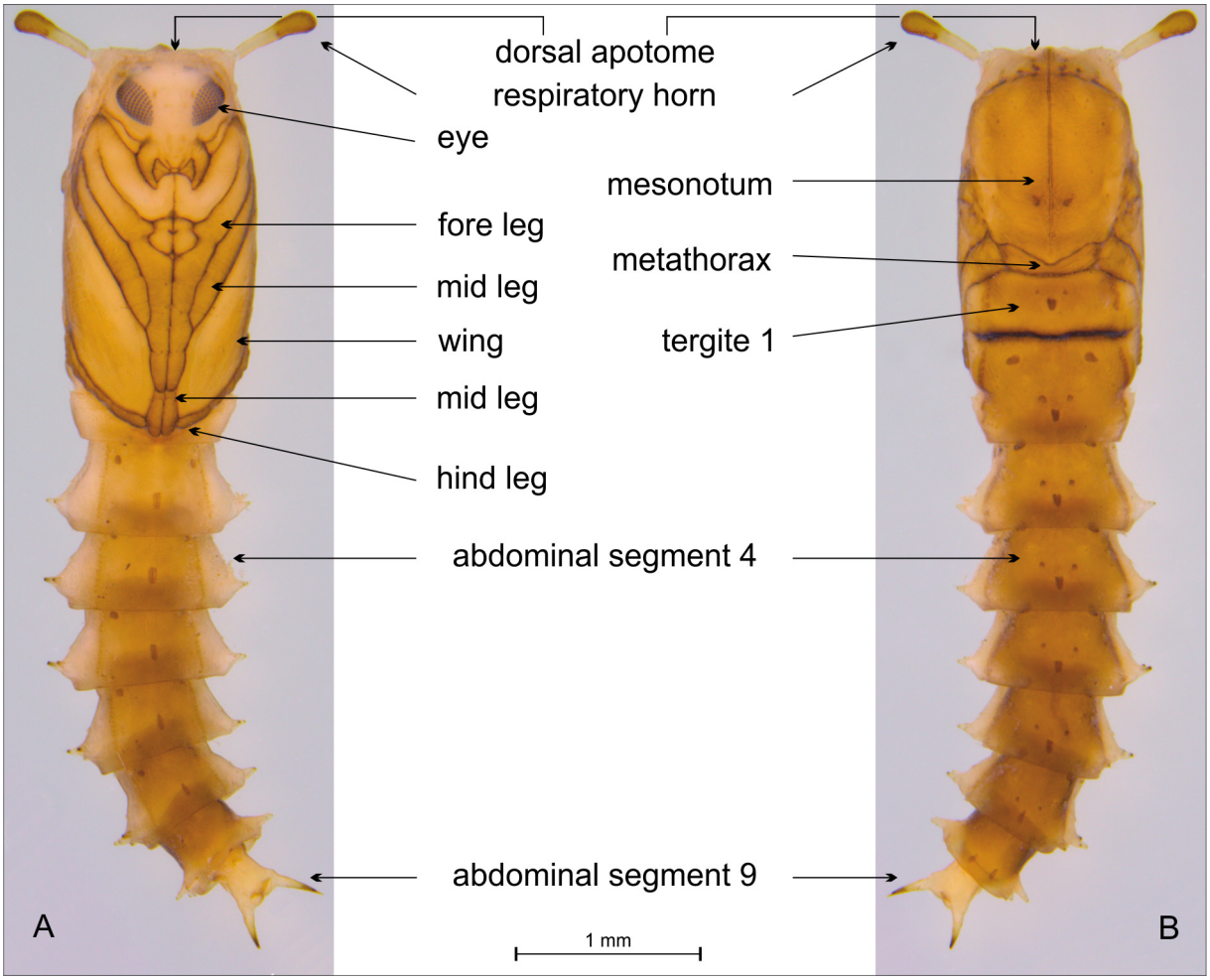

FIGURE 4. Habitus of female pupa of *Palpomyia schmidti*. A—ventral aspect; B—dorsal aspect.

Pupa. Body pale brown (Fig. 4). Length: female 4.3–6.6 mm; male 4.9–5.5 mm. Respiratory horn (Fig. 5C) slender, about 3.8–4.1 times longer than broad, surface bare, distal half with about 40 spiracles in one horseshoe-like row, length 0.40–0.46 mm in male, 0.460– 0.510 mm in female. Dorsal apotome (operculum) (Fig. 5B) 1.0–1.3 times as long as greatest width, covered with small tubercles, posterior margin pointed; anterolateral tubercle bearing single long seta and single sensory pit (campaniform sensillum). Antennae short, ventrally wings separated by legs (Fig. 5A). Caudomedian expansion of mesothorax indistinct, evenly rounded (Fig. 4B). Metathorax slender, distinctly emarginated, with single pair of sensilla campaniformia (M-3-T) (Fig. 5D). Abdominal segments with scattered small spinules. Tergites 1–7 with medial area displaying 1 longitudinal stripe and 2 darker spots (Fig. 4B). First abdominal tergite with 3 groups of setae on lateral surface (Fig. 5D); anterodorsal group including 2 setae and 1 sensory pit (campaniform sensillum), posterodorsal group with 2 setae and 1 sensory pit; lateral group composed of 3 setae. Dorsal surface of fourth abdominal segment with setae and sensory pits as in Fig. 5E. Dorsal seta D-2 on rounded pale spot. Ventral surface only with two groups of 3 small setae (V-5,6,7). Abdominal segment 9 without setae, but with 2 dorsal sensilla campaniformia (D-5, 6) on apicolateral processus. Apicolateral processes of terminal abdominal segment 9 highly variable, long or short, covered with spinules or bare, slightly to greatly divergent (Figs. 5F,G). In females apicolateral processes (Fig. 5F) more divergent than in males (Fig. 5G).

Larva. IV instar (Figs. 6, 7). Body slender (Fig. 6A), total length to 11–12 mm. Head capsule pale brown, slightly conical, 1.925 as long as broad (HR), subgenal ratio (SGR) 1.951. Collar narrow, brownish; on ventral surface with distinct triangular extension (Fig. 7). Epicranial suture moderately long, reaching level of seta q (Fig. 7A, C). Sensory pits (sensilla campaniformia) r, k, z, j indistinct. Setae s, u, o, x forked. Labrum slightly elongate, almost square with sensory organs typical of the subfamily; messors slightly sclerotized, hook-shaped. Mandible slender, hook-like, with double hook at midlength; fossa mandibularis distinct (Fig. 6G, H). Labium triangular with distinctly pointed apex (Fig. 6E). Hypostoma broad, slightly arched, smooth (Fig. 6E). Hypopharynx elongate,

slightly sclerotized, hypopharyngeal fringe indistinct (Fig. 6E, F). Epipharynx with single, dorsal comb armed with 24–26 teeth on its posterior margin (Fig. 6H), 0.068–0.075 mm wide.

Neck or cervix distinct, about 7 times shorter than prothorax (Fig. 6B). Body segments moderately elongate, second thoracic segments 1.0–1.4 times longer than broad, abdominal segments about 1.5 times longer than broad. Anal segment slender, 3.3 times longer than broad; apex with group of 2 short outer and 2 long inner setae on dorsal and ventral surfaces (Fig. 6C, D); 2 dorsal and 2 ventral short caudal setae, in addition 2 lateral setae at level of shorter dorsal/ventral setae and 2 before mid-length of segment present (Fig. 6C).

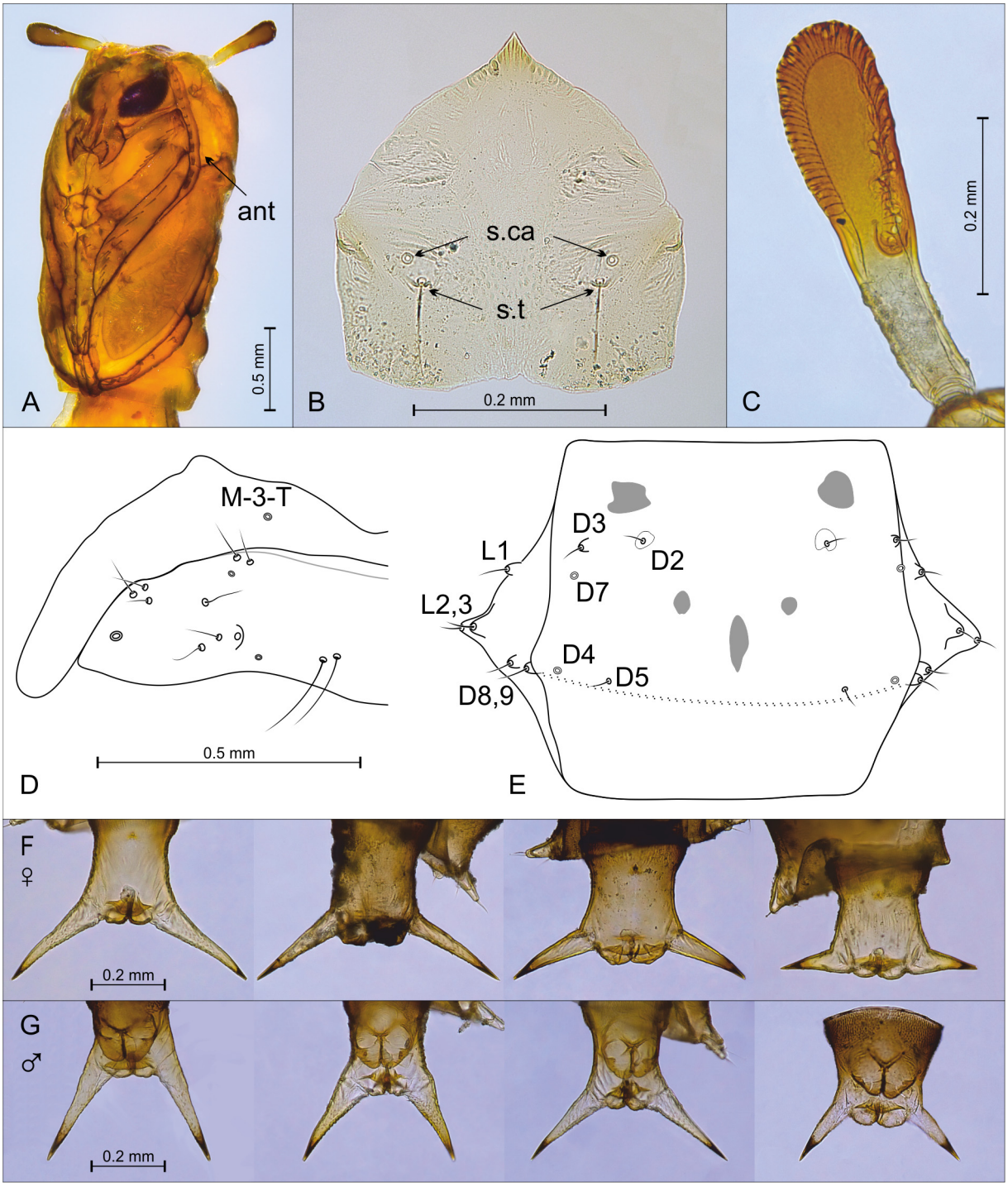

FIGURE 5. Pupa of *Palpomyia schmidti.* A—lateroventral aspect of female thorax; B—dorsal apotome; C—respiratory horn; D—chaetotaxy of metathorax and abdominal tergite 1; E—chaetotaxy of abdominal segment 4, dorsal view; F—female abdominal segment 9; G—male abdominal segment 9. Abbreviations: s.ca—campaniform sensillum, s.t—sensillum trichoideum. Names of other sensilla as proposed by Borkent (2014).

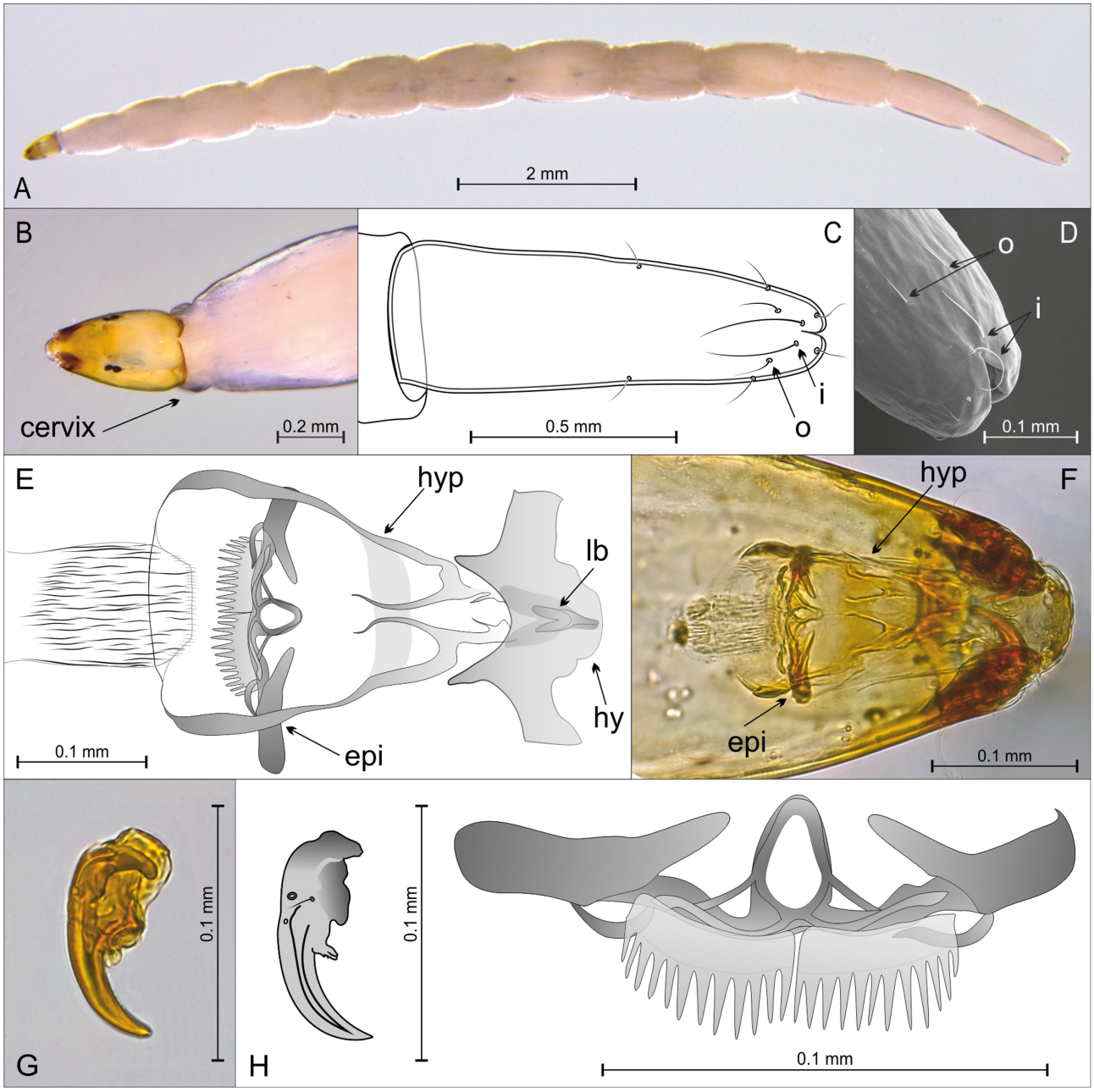

FIGURE 6. Larvae of *Palpomyia schmidti*. A—total habitus; B—head and prothoracic segment; C—anal segment, dorsal view; D—apex of anal segment, dorsal view; E—pharyngeal apparatus, ventral view; F—pharyngeal apparatus, ventral view; G—mandible; H—drawing of mandible; dorsal comb of epipharynx. Abbreviations: epi—epipharynx. hy—hypostoma, hyp—hypopharynx, lb—labium, i—inner seta, o—outer seta.

Distribution and ecology. The species is halobiontic and represents the meridional faunal element in the Palaearctic Region (Szadziewski 1985) or the Saharo-Arabian element (Alwin-Kownacka *et al.* 2016). It was usually collected on rivers in steppes and deserts (Remm 1976). It has been reported from Iraq (Goetghebuer 1934a), Hungary (Goetghebuer, 1934b), Spain (Delécolle *et al.* 1997), Slovakia (Tothova & Knoz 2006), Ukraine (Crimea), Russia (Rostov, southern Siberia), Azerbaijan, Tadjikistan, Kazakhstan, Iran, southern Siberia and Mongolia (Remm 1976, 1988). We are unable to confirm Remm's (1976, 1988) reports of the species from northern China.

Larvae of *P. schmidti* were observed in black and grey sandy mud, often with plant debris in the Rivers Chernavka, Solyanka, Lantsug, Khara and Bolshaya Samoroda, which flow into Lake Elton (Figs 1B, C). They were also observed among dense filamentous algae and *Enteromorpha intestinalis*. Larvae were collected at depths

of 0.03–0.8 m, where the water was flowing at 0.01–0.4 m s^{-1}. They live in riverine waters with salinities of 5.8–31.7 g l^{-1}, dissolved oxygen concentrations of 2.3–35.0 mg l^{-1} and pH levels of 6.5–9.4. These larvae were also found at the bottom of Lake Elton, where the salinity was 112.5 g l^{-1}. In the Chernavka, larvae of *P. schmidti* occurred together with *Cricotopus* (*Cricotopus*) *salinophilus* Zinchenko, Makarchenko & Makarchenko, 2009 and *Chironomus salinarius* Kieffer, 1915.

Under laboratory conditions, mature larvae pupated within 1–2 days. The pupal stage lasted 3 days. In the aquarium pupae floated on the water surface. Among the emerging adults, females were distinctly predominant over males, with a percentage ratio of 85:15 in favour of the former. Larval and pupal mortality in the laboratory was less than 5%, a very low figure.

The abundance of 48 000 ind./m^{-2} recorded in the Chernavka (28 May 2015) is probably a maximum value for populations of larvae of this species in saline rivers. The average abundance and biomass were much higher in the highly saline Chernavka and Solyanka (17.17–31.7 g l^{-1}) than in the less saline Khara, Lantsug and B. Samoroda (3.97–21.6 g l^{-1}). The theoretical ecological salinity optimum for the halobiontic larvae of *P. schmidti* is 31.7 g l^{-1}, with the tolerance interval varying from 20.76 to 33.14 g l^{-1} (unpublished data).

Discussion

Adults of the distinctly Holarctic *Palpomyia schmidti* species group are characteristic in having the first tarsomere of the mid leg armed with median ventral spines, unique male genitalia with a triangular gonocoxite armed with a long internal extension and parameres separated, with a bulbous apex, and simple claws without inner teeth in females. Earlier, Remm (1976) had proposed the subgenus *Gluhhovia* Remm, 1976 for the group of species living in Palaearctic steppes and deserts, including *P. schmidti* Goetghebuer, 1934, *P. tuvae* Remm, 1972, *P. bipicta* Remm, 1976, *P. arenosa* (Remm & Nazarmuchamedov, 1969), *P. turanicola* Remm, 1976, and *P. tamaricis* Remm, 1976; this was subsequently accepted by Glukhova (1979). Grogan & Wirth (1979) considered *Gluhhovia* to be a synonym of *Palpomyia* and included *P. schmidti* (as *miki*) together with *P. downesi* Grogan & Wirth, 1979 in their broad *flavipes* group. Here, we treat the group *schmidti* as a distinct natural group within *Palpomyia*. We transfer to the *schmidti* group *P. downesi* Grogan & Wirth, 1979 from north-western North America and propose to treat it as a new synonym of the Eastern Palaearctic *P. tuvae* Remm, 1972. **New synonymy.** Adults of the species are small, black and have only the fore femora armed with 2–5 ventral spines. Their male genitalia, illustrated by Remm (1976) and Grogan & Wirth (1979), have gonostyli with abruptly curved and pointed apices. In the similar genitalia of *P. schmidti* the gonostyli are evenly curved and taper to a sharply pointed apex (Fig. 3D). We do not include *P. bipicta* Remm, 1976 in the *schmidti* group, as it has fused parameres like the members of the *flavipes* group as defined by Grogan & Wirth (1979).

Among the five members of the *Palpomyia schmidti* group, *P. schmidti* is a pale-coloured species, with all femora and tibiae armed with spines or spine-like setae. *P. tuvae* (*syn. P. downesi*) is black with only the fore femur armed with ventral spines. Other species of the group are also pale but have spineless tibiae: *P. tamaricis* (all femora unarmed), *P. arenosa* and *P. turanica*) (fore femur with 3–5 ventral spines).

Larvae of *P. schmidti* are similar to those of *P. tuvae* Remm and *P. tibialis* (Meigen) in having a short conical head with a low HR < 1.92. Larvae of *P. tuvae* are much smaller (5–6 mm), and the ventral surface of their head collar has an indistinct triangular extension. Larvae of *P. schmidti* are large (11–12 mm), with a distinct triangular extension of the collar as in *P. tibialis*. The latter species, while being of similar length (9–11 mm), differs in having a broad head with a lower HR (1.5–1.6) and 2 pairs of large setae on the anal segment (Glukhova 1979). In *P. schmidti* there is only 1 pair of long setae on each of the dorsal and ventral surfaces.

The pupae of *P. schmidti* belong to the group of species in which the dorsal apotome has only 1 campaniform sensillum DA-2 distal to long seta DA-1 (Borkent 2014). In other species groups there are 2 campaniform sensillae (DA-2,3) distal to long seta DA-1 or a single one in a more proximal position (Borkent 2014). They belong to the group of species which have a respiratory horn with numerous spiracles arranged in a horseshoe shape occupying almost the whole distal half of the horn. In other species, there are fewer spiracles on the apex (Borkent 2014). The apicolateral processes of abdominal segment 9 are highly variable and indicate that their morphology within the genus should be treated with great caution in diagnoses.

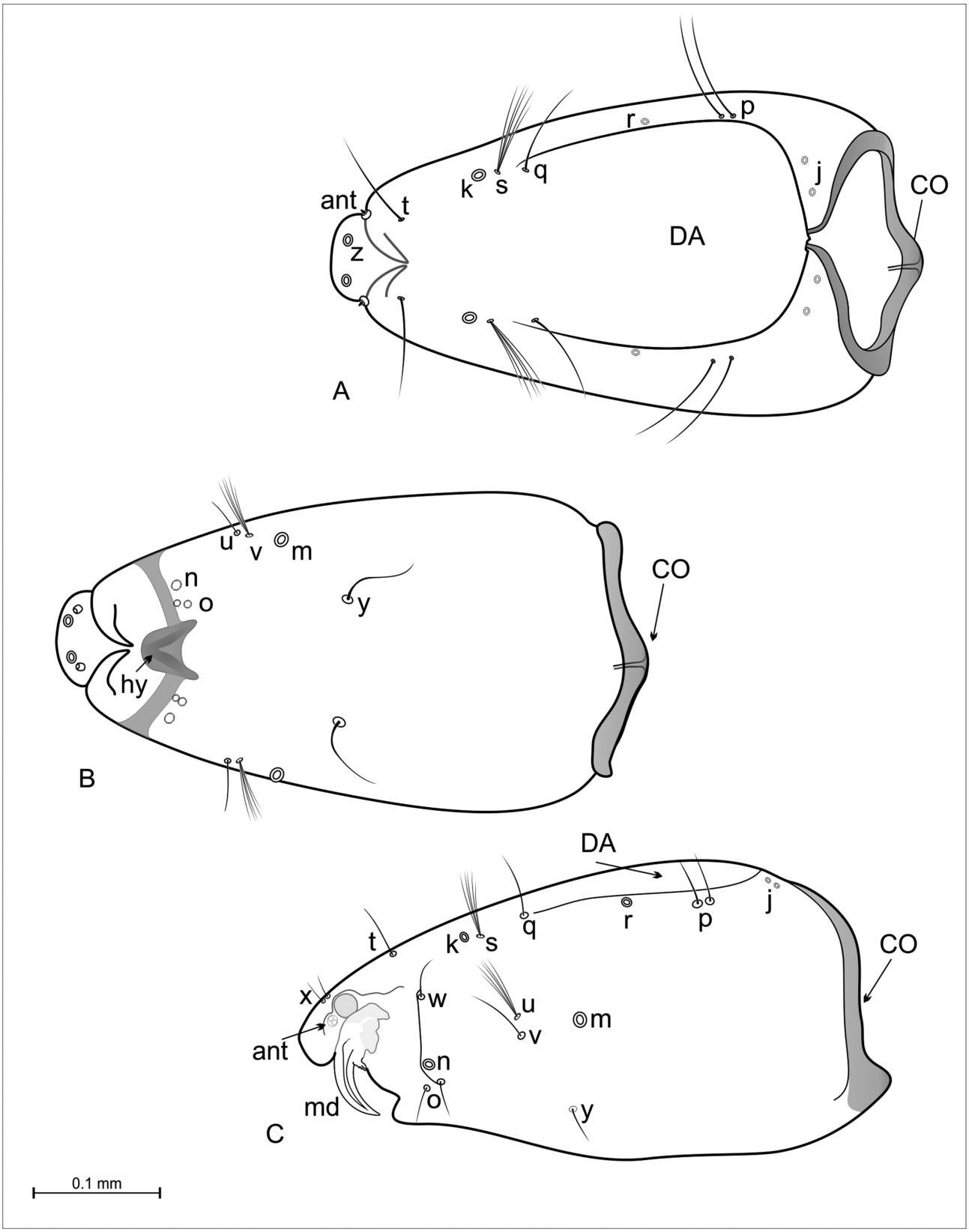

FIGURE 7. Head capsule of larvae of *Palpomyia schmidti*. A—dorsal view; B—ventral view; C—lateral view. Abbreviations: ant—antenna; CO—collar; DA—dorsal apotome; frontoclypeus; hy—hypostoma; md—mandible; j, k, m, n, r, z—sensory pits, sensilla campaniformia; o, p, q, s, t, u, v, w, x—setae, sensilla trichoidea.

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