



## Descriptions of larvae of three Philopotamidae species from China (Insecta, Trichoptera)

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### Abstract

Adults and larvae of the family Philopotamidae from Zhejiang Province, China, were examined and mtCOI gene sequences were extracted and analyzed, males and larvae of 3 species were successfully associated. The larvae of *Chimarra sadayu* Malicky 1993, *Dolophilodes bellatula* Sun & Malicky 2002, *Wormaldia unispina* Sun 1998 are described in detail and their diagnostic photographs and illustrations are presented. Diagnostic characters for genera and species are discussed.

**Key words:** taxonomy, Trichoptera, larva, DNA barcoding, morphology, philopotamids

### Introduction

The family Philopotamidae Stephens 1829 includes 3 subfamilies, with at least 1508 extant species in 26 extant genera all over the world so far (Morse 2018; Morse *et al.* 2019). *Chimarra* Stephens 1829 is the largest genus in the family, with more than 880 extant species (Morse 2018), distributed in all biogeographic regions except Antarctica (Johanson & Oláh 2012). The second largest genus of the family is *Wormaldia* McLachlan 1865, comprised of 186 extant species, distributed in all faunistic regions except the Australian and the Antarctic (Morse 2018). *Dolophilodes* Stephens 1829, with about 100 species, is widespread in the Nearctic, Palearctic and Oriental regions; *Gunungiella* Ulmer 1913, with 85 species, and *Kisaura* Ross 1956, with 70 species, are distributed in the Oriental and East Palearctic Regions (Morse 2018). Other genera, each with less than 40 species, are often endemic to distinct biogeographic regions or subregions (Morse 2018).

In China, the family is represented by two subfamilies and the abovementioned five genera, with a total of 83 known species (Yang *et al.*, 2016; Hu *et al.*, 2018), of which, 23 species are included in *Chimarra*, 23 in *Wormaldia*, 18 in *Dolophilodes*, 4 in *Gunungiella*, and 15 in *Kisaura*. Among them, 79 species are endemic to China, about 95.2% of the known Chinese species within the family, and 4.8% of the known species in the world. They are mainly distributed in Oriental China.

Compared to the numerous known adults mainly based on males, larvae within the family have been poorly studied, with larval stages of only about 89 species having been described or illustrated worldwide. To date, larvae of a total of 16 species of *Chimarra* have been described, including 8 from the Nearctic Region: *C. obscura* Walker 1852 and *C. feria* Ross 1941 were described by Ross (1944); *C. aterrima* Hagen 1861 and *C. socia* Hagen 1861 by Lloyd (1921) and Ross (1944); *C. texana* Banks 1920 (as *C. betteni* Denning 1941) by Edwards & Arnold (1961); *C. florida* Ross 1944, *C. holzenthali* Lago & Harris 1987, and possibly *C. augusta* Morse 1971 by Morse *et al.* (2017). Three are from the Australasian Region and were described and illustrated by Cartwright (1990, 1997): *C. australica* Ulmer 1916, *C. monticola* Kimmins 1953 (in Mosely & Kimmins 1953), and *C. uranka* Mosely 1953 (in Mosely & Kimmins 1953). Two are from the Palearctic Region: *C. marginata* (Linnaeus 1767), its larva described by Lepneva (1964) and *C. tsudai* Ross 1956 by Kuhara (2017, 2018). One is from the Afrotropical Region: *C. ambulans* Barnard 1934, described by Barnard (1934). One is from the Oriental Region, *C. paramonorum* Hu *et al.* 2018, from China, described by Hu *et al.* (2018). In addition, 28 unspecific larvae of the genus have been described: 14 from Australia by Cartwright (1997), 12 from Vietnam by Hoang & Bae (2008), 1 from USA by Wiggins (1977), and 1 from Japan by Tanida (2005) and Kuhara (2017).

Of 14 described larvae of *Wormaldia* species, 2 are from the Nearctic Region: *W. moesta* Banks 1914 (as *Dolophilus moestus*) and *W. shawnee* Ross 1938 (as *Dolophilus shawnee*), both described by Ross (1944). Five are from the Western Palearctic Region: *W. asterusia* Malicky 1972, described by Karaouzas (2016), *W. occipitalis* Pictet 1834 by Lepneva (1964), *W. subnigra* McLachlan 1865 by Lepneva (1964) and Philipson (1953), *W. triangulifera* McLachlan 1878 by Botosaneanu (1956), and *W. copiosa* McLachlan 1868 by Waringer & Graf (2011). Larvae of *W. uonumana* Kobayashi 1980 and *W. yakusensis* Kobayashi 1980 from the East Palearctic Region were described by Kuhara (2017). Moreover, 5 unspecific larvae, 4 from the East Palearctic Region and one from the Nearctic Region, were described by Kuhara (2017, 2018) and Wiggins (1977), respectively.

Larvae of 9 *Dolophilodes* species have been recognized. The larva of *Dolophilodes distincta* (Walker 1852) from the USA was described by Ross (1944); larvae of the other 8 species from the eastern Palearctic Region were described by Kuhara (2017): *D. angustata* Kuhara 2005 (Japan), *D. auriculata* Martynov 1933 (Japan), *D. commata* (Kobayashi 1980) (Japan), *D. dilatata* Kuhara 2005 (Japan), *D. iroensis* (Kobayashi 1980) (Japan and Russia), *D. japonica* (Banks 1906) (Japan and Russia), *D. nomugiensis* (Kobayashi 1980) (Japan and Russia), and *D. shinboensis* (Kobayashi 1980) (Japan). Besides, an unspecific larva from the former USSR was reported by Lepneva (1964). Blahnik (2005) elevated some subgenera from within *Dolophilodes* to the generic level; as a result, the larva of *Fumonta major* (Banks), described by Weaver *et al.* (1981), and the larvae of *Hydrobiosella mixta* (Cowley 1976) and *Hydrobiosella stenocerus* Tillyard 1924 described by Cowley (1978) were treated by them as *Dolophilodes* species, but are not considered in this paper.

To our knowledge, no larvae of genera *Kisaura* or *Gunungiella* have been described so far.

In this study, larvae of three Chinese species within the family, *C. sadayu* Malicky 1993, *D. bellatula* Sun & Malicky 2002, and *W. unispina* Sun 1998 (in Wang *et al.* 1998), were successfully associated with their adult males by mtCOI gene sequences, and are described and illustrated in detail for the first time.

## Material and methods

**Sampling of specimens.** All specimens were collected from Zhejiang Province, China. Adults were captured in 95% ethanol using pan traps with 15-W ultraviolet light bulbs. Larvae were collected using a D-frame aquatic net. All specimens were then stored in 95% alcohol.

**Morphological study.** Photos for larvae were taken using a Nikon Eclipse 80i microscope and Nis-Element D® software (Version 3.22.14). For each photograph, a series of images at different focal depths were captured, then stacked using Helicon Focus (Version 6.3.5) into an image with a greater depth of field. Other structures were traced in pencil using an Olympus SZX10 stereomicroscope equipped with a drawing tube. The original pencil drawings were inked digitally with Photoshop CS6 and a Wacom Intuos tablet-and-pen (CTL-671/KO-F) to produce illustrations. Plates were arranged using Adobe Photoshop®.

**Terminology.** Terminology for larvae follows that of Lepneva (1964) and Wiggins (1977).

**DNA analysis.** Right hind legs (male) or the whole body (larvae) of 14 individuals were taken for DNA extractions (Table 1). DNA extraction, fragment sequencing, and analysis followed the procedures of Xu *et al.* (2015). The PCR primers are listed in Table 1. Neighbor-joining (NJ) trees (Fig. 1) were constructed using Mega® 6.0 (Tamura *et al.* 2013).

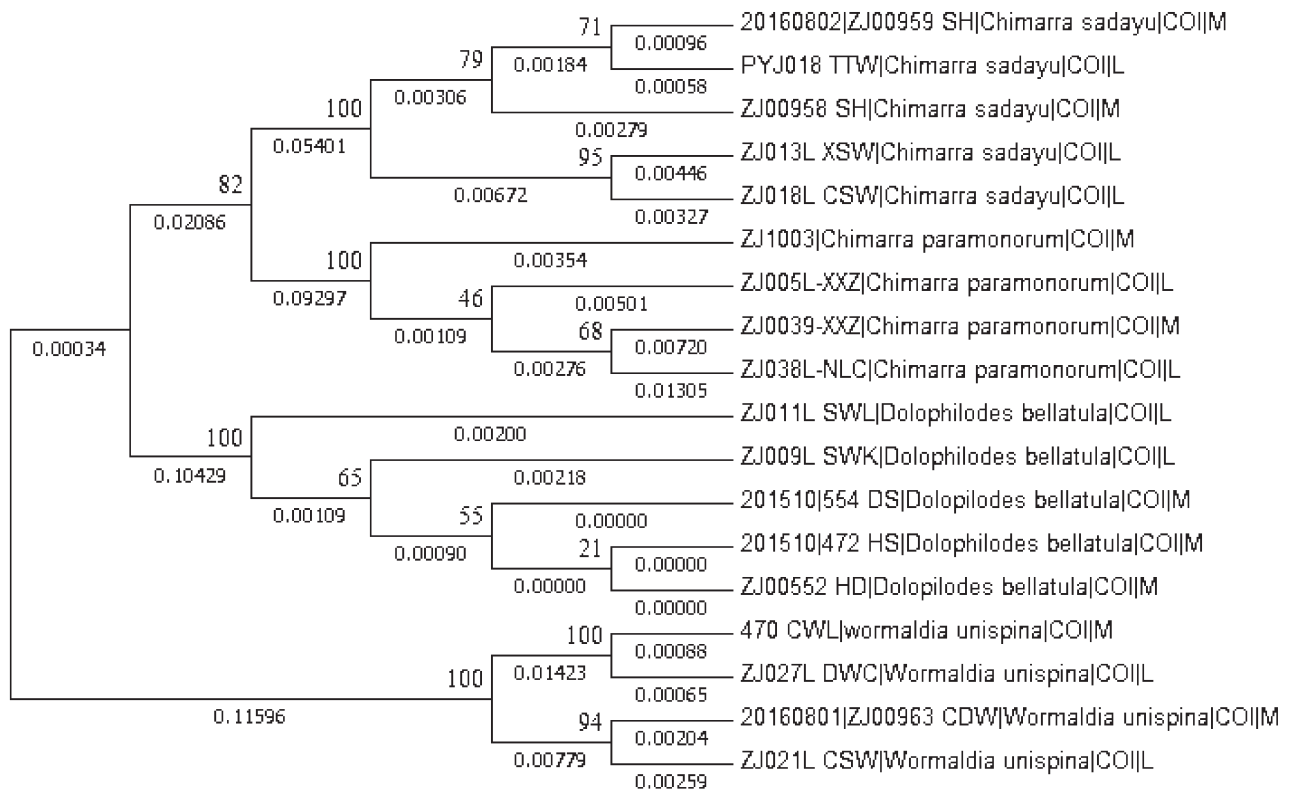
**TABLE 1.** Polymerase chain reaction primers used to sequence mtCOI genes of Philopotamidae specimens.

Primer	Sequence (5' to 3')	Reference
LCO1490	GGTCAACAAATCATAAAGATATTGG	Folmer <i>et al.</i> 1994
HCO2198	TAAACTTCAGGGTGACCAAAAAATCA	Folmer <i>et al.</i> 1994

### *Chimarra sadayu* Malicky 1993

(Figs 2A–3E)

**Description. Larvae (5th instar).** Body length 8–10 mm (n = 5), membranous body in alcohol white with head and pronotum yellowish brown (Fig. 2A).



**FIGURE 1.** COI neighbor-joining diagram used to determine larva-male associations of Chinese Philopotamidae species. M. = male; L. = larva.

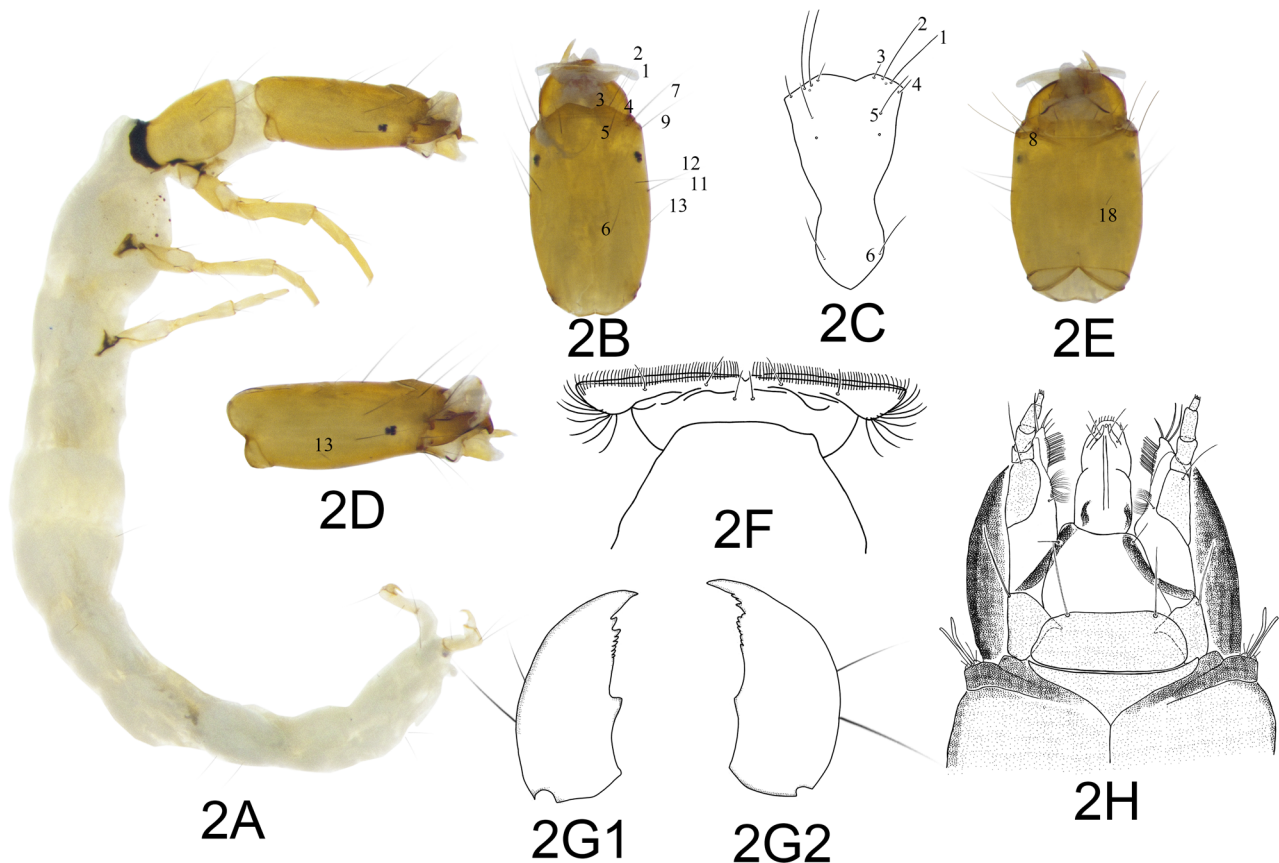
*Head.* Head capsule yellowish brown, smooth; in dorsal view somewhat elongate-elliptical, length about 2 times width, with posterior margin rounded (Fig. 2B); frontoclypeal apotome (Fig. 2C) with anterior margin dark brown in colour, apex asymmetrically bilobed, left lobe with anterolateral margin equaling inner margin in length, while right lobe with anterolateral margin longer than inner margin (Fig. 2C); setae no. 1 and setae no. 2 equal in length, setae no. 3 shortest; setae no. 4 located at anterolateral angle, each with length equal to distance between setae no. 1 and no. 4; setae no. 5 long, located anterior to tentorial pits. In lateral view (Fig. 2D), head capsule subrectangular, smooth, with posterior margin notched and darkly spotted at notch; setae no. 13 situated on anterior half of head capsule. In ventral view head capsule subrectangular (Fig. 2E), with posterior margin concave, paired setae no. 18 centrally located on each side; anterior ventral apotome triangular, with anterior margin slightly concave. Eyes (Fig. 2A, 2B, 2D) oval, black, surrounded by faint yellow halo. Antennae (Fig. 2H) unusual, located on small light areas just behind bases of mandibles, each supporting two long and thin clavate spines of equal length and three short setae. Labrum (Fig. 2F) T-shaped, white, membranous; transverse distal portion rod-like, transparent, edged with dense setae, notched mesally, its anterolateral margins each having tuft of bristles curved anterad; stalk of labrum strong, lateral margins constricted at base. Mandibles (Figs. 2G1, 2G2) of same colour as head or slightly darker; each with outer margin arched, bearing two basolateral bristles; in dorsal view with broad projection 1/3 distance from base (more prominent on left mandible), with serration 3/4 distance from base, small tooth in subapical recess, apex acute. Maxillae each with cardo cup-like in ventral view (Fig. 2H), outer apical angle with one long seta, inner apical angles acute and produced mesad; stipes membranous, with dark oblique elongate sclerite; palpifer large, subrectangular in ventral view, with anterior margin having one subapical seta; maxillary palp four-segmented, first and fourth segments subequal in length, shorter than second and third segments subequal in length. Galea (Fig. 2H) triangular in ventral view, each with inner margin bearing 2 tufts of fine bristles sub-basally and subapically and with apex bearing three strong bristles.

Labium in ventral view (Figs. 2E, 2H) with submentum trapezoidal, having one seta near each anterolateral angle; mentum not sclerotized, trapezoidal; labial part proper in lateral view (Figs. 2A, 2D) tongue-like, with apex depressed, in ventral view (Figs. 2E, 2H) elliptical, ventral rods each elongate-elliptical, palpifer arched, labial palpi each 2-segmented, first segment cylindrical, second one triangular.

*Thorax.* Pronotum (Figs. 3A, 3B) yellow in colour, strongly sclerotized, in dorsal view subrectangular, longer than wide, with posterior margin black and notched mesally; anterior 1/3 with shallow transverse depression, posterior 1/5 with deep and broad transverse depression; posterior parts of lateral margins each with narrow black stripe just above its forecoxa, not connecting with aforementioned broad black posterior border (Fig. 3B); each anterior angle with scattered setae of varied length, each lateral margin with 1 small seta just above its forecoxa, middle portion having three setae on each side with two pairs of anterior setae much longer than posterior pair.

Proepisternum elongate-triangular in lateral view, with lower and anterior margins black, anterior margin slightly concave; proepimeron triangular, yellow, with lower margin deeply concave. Foretrochantin (Fig. 3B) slender, progressively enlarged from base to subapex, with distal 1/3 suddenly narrowed. Meso- and metanota (Fig. 2A) unsclerotized, white in colour; meso- and metaepisternum somewhat triangular, mes- and metepimera semicircular.

*Legs.* Legs (Fig. 3C1–3C3, 3D) yellowish brown and sclerotized, with few scattered bristles on coxae, femora, and tibiae. Forelegs strongest, hind legs smallest. Forecoxae cylindrical (Fig. 3C1), each with apex obliquely truncate, sclerotized seta-bearing process tubular, tapering from base to apex, slightly curved laterad, with subapex having one small hair dorsally; trochanter 2-segmented, first segment trapezoidal, second one triangular; femur with base obliquely truncate in lateral view, progressively enlarged from base to apex; tibia cylindrical, about half as long as femur; tarsus slender, slightly longer than tibia, tapering from base to apex, with row of short spine-like setae ventrally (Fig. 3D); claw small but well developed, slightly curved downwards and with conspicuous basal seta-bearing process. Mid- and hind legs similar to forelegs in overall morphology, but their coxae slightly longer than in forelegs, and lacking seta-bearing processes; femora, tibiae and tarsi slightly shorter than in forelegs, tarsi each without ventral row of spine-like setae.



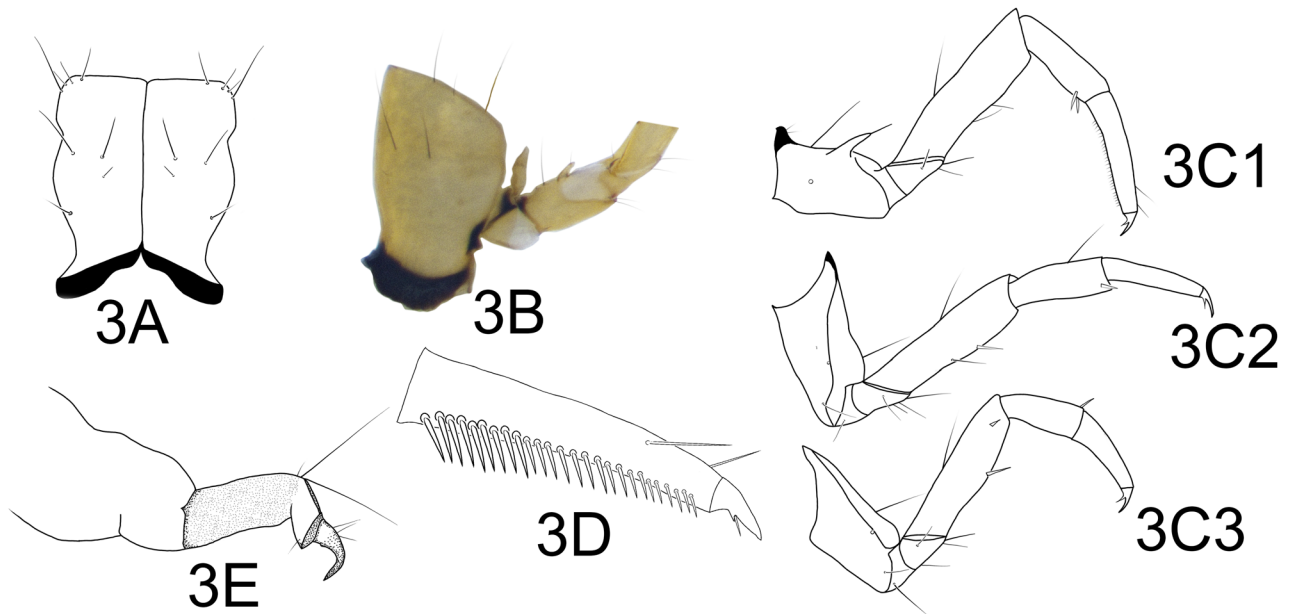
**FIGURE 2.** *Chimarra sadayu* Malicky 1993, larva. 2A, habitus, right lateral; 2B, head, dorsal; 2C, frontoclypeal apotome, dorsal; 2D, head, right lateral; 2E, head, ventral; 2F, labrum, dorsal; 2G1, left mandible, dorsal; 2G2, right mandible, dorsal; 2H, maxilla and labium, ventral. 1–18 = setae 1–18.

*Abdomen.* Abdominal segments I–IX white, with sparse short setae on each surface. No lateral fringe present; segment IX in dorsal view with posterior margin concave, with 5 single apicodorsal anal papillae (Fig. 2A). Anal prolegs (Fig. 3E) unsclerotized basally, sclerotized distally; anal claws in lateral view each with base strong and sharp, apices curved downwards at 90 degrees, each with dorsal margin having 3 small basodorsal setae.



**Materials examined.** CHINA, Zhe-jiang Province, Lin-an, Tianmu Mountains: 1 larva, Xi-shan-wu, 30.2797°N, 119.4922°E, Alt. 219.3 m, 10 Oct 2017; 3 larvae, Che-shui-wu, 30.3558°N, 119.4522°E, Alt. 503.9 m; Hu-zhou, An-ji County: 5 larvae, Dong-wu-cun, 30.4656°N, 119.5781°E, Alt. 348.7 m, 13 Oct 2017.10 Oct 2017; 1 larva, Shui-wu-li, 30.3550°N, 119.5958°E, Alt. 230 m, 12 Oct 2017; collected by Yan-li Hu, Yu Wang & Lang Peng. Jin-hua, Pujiang County: 2 larvae, Tai-tou-wan, 29.4561°N, 119.7517°E, Alt. 137 m, 30 Aug 2017, collected by Lei Zhang and Cong Wu. Long-quan: 17 larvae, 28.1596°N, 118.8527°E, Alt. 484.96 m, collected by Yan-li Hu, Cong Wu and Jin Gao. Ning-bo, Yu-yao county, Siming Mountain National Forest Park: 2 males, Shen-hu, 29.7271°N, 121.0776°E, Alt. 851.94 m, 2 Aug 2016, collected by Ji-hua Xu.

**Distribution.** China (Zhejiang, Fujian).



**FIGURE 3.** *Chimarra sadayu* Malicky 1993, larva. 3A, pronotum, dorsal; 3B, right side of pronotum, right foretrochantin, and right forecoxa, right dorsolateral; 3C1, right foreleg, posterolateral; 3C2, right midleg, posterolateral; 3C3, right hind leg, posterolateral; 3D, terminal portion of tarsus and claw of right prothoracic leg, posterolateral; 3E, left proleg, left lateral.

### *Dolophilodes bellatula* Sun & Malicky 2002

(Figs 4A–5F)

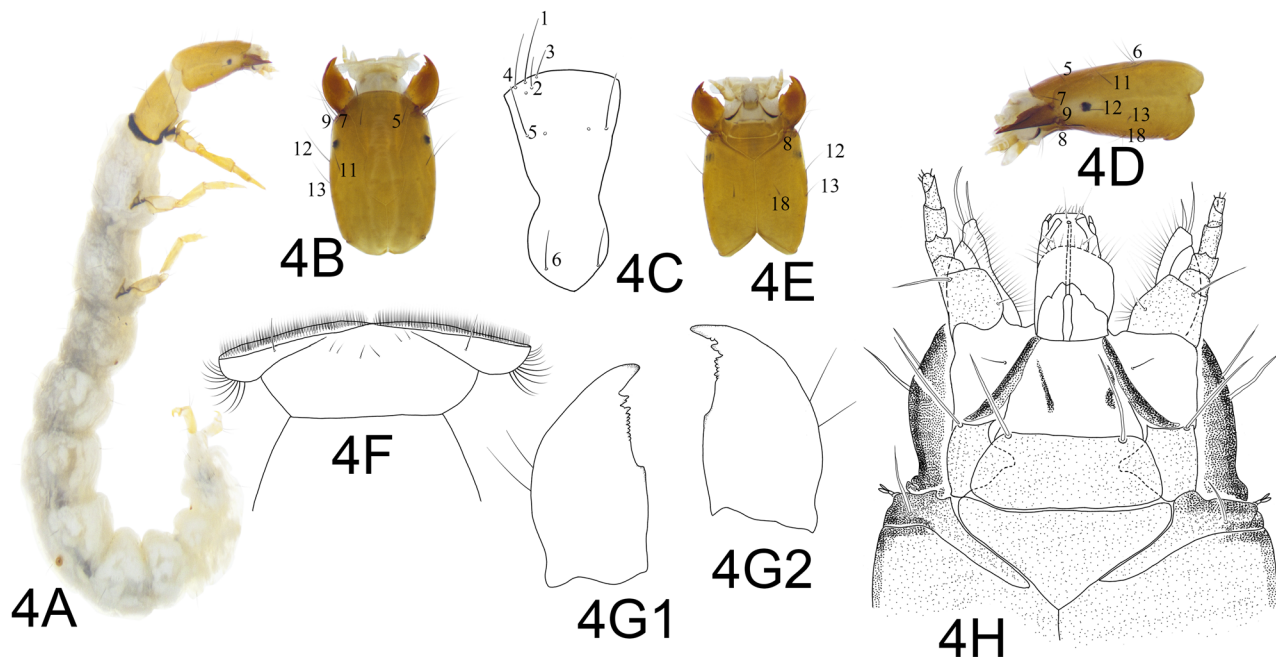
**Description. Larvae (5th instar).** Body length 11–13 mm (n = 5), membranous body in alcohol white with head and pronotum yellowish brown (Fig. 4A).

**Head.** Head capsule (Fig. 4B) oblong in dorsal view, length about 1.5 times width, with smooth surface; yellowish brown, with black spot mesally on each posterolateral margin. Anterior margin of frontoclypeal apotome (Fig. 4C) extending forward in symmetrical arc, each anterolateral margin with 3 setae, seta no.1 strongest; seta no. 4 located near anterolateral angle, setae no. 5 located at level of tentorial pits. In lateral view (Fig. 4D), subrectangular, smooth, with posterior margin having V-shaped notch; setae no.13 short and small, situated about midlength on genae; lower margin of genal region with distinct stridulating ridges, indiscernible in ventral view. In ventral view (Fig. 4E) posterior margin incised, V-shaped, paired setae no.18 each located at midlength of genae; anterior ventral apotome triangular, its anterior margin straight with anterolateral angles rounded and slightly produced anterad; without posterior transverse sulcus. Eyes (Fig. 4D) oval, black, surrounded by yellow halo. Antennae small, each bearing of two rod-like spines subequal in length, located near base of its mandible. Labrum (Fig. 4F) white, membranous, T-shaped; transverse distal portion rod-like, transparent, with 4 discernable pairs of setae behind anterior margin; anterior margin densely setose and notched mesally; anterolateral margins each having tuft of bristles curved antirad; labral stalk constricted basally.

Mandibles (Figs. 4G1, 4G2) brown, slightly darker than head, each with two bristles situated about midlength of arched outer margin; inner margins each with broad mesal tooth near midlength, serrate margin about 3/4 length, small tooth in subapical recess; distal tooth of left mandible slightly larger than right one. Maxillae and labium fused

(Figs. 4E, 4H). Maxillae each with cardo somewhat pentagonal, its inner mesal angle covered by submentum; stipes membranous, with oblique blade-shaped sclerite issuing from anterior margin of cardo and extending to mentum of labium; fused galea and lacinia in ventral view triangular, their mesal margin heavily setose, lacinia with apex having two spine-like bristles; palpifer large, subrectangular in ventral view, with basal margin sinuate; maxillary palp 4-segmented, with first segment shortest, second slightly longer, third and fourth segments of same length, each equalling length of first and second segments combined, fourth segment with sensillae.

Submentum of labium trapezoidal, with each anterolateral angle having strong bristle; mentum elliptical, with anterior margin irregularly convex anteriorly; labial part proper with apical margin rounded, setose; palpiger bar-shaped and slightly sinuate, labial palpi each 2-segmented.



**FIGURE 4.** *Dolophilodes bellatula* Sun & Malicky 2002, larva. 4A, habitus, right lateral; 4B, head, dorsal; 4C, frontoclypeal apotome, dorsal; 4D, head, right lateral; 4E, head, ventral; 4F, labrum, dorsal; 4G1, left mandible, dorsal; 4G2, right mandible, dorsal; 4H, maxilla and labium, ventral. 1–18 = setae 1–18.

**Thorax.** Pronotum (Fig. 5A) rectangular in dorsal view, length equal to width, constricted posteriorly, sclerotized, of same colour as head, with broad black posterior border extending anterad on lateral margins to anterior edges of proepisterna (Fig. 5B). Anterolateral angles each with several setae, mid-posterior area with transverse row of 10 relatively small setae. Foretrochantins (Fig. 5B) fingerlike, each with tip blunt and rounded, slightly bent downwards. Meso- and metanota (Fig. 4A) completely membranous, white.

Proepisterna black, triangular in lateral view, each with anterodorsal and anteroventral angles pointed; proepimeron semi-circular, with upper margin black, other portions brown. Meso- and metaepisterna dark brown, triangular, each with anterodorsal angle slightly curved upwards, meso- and metepimera dark brown, somewhat elliptical vertically.

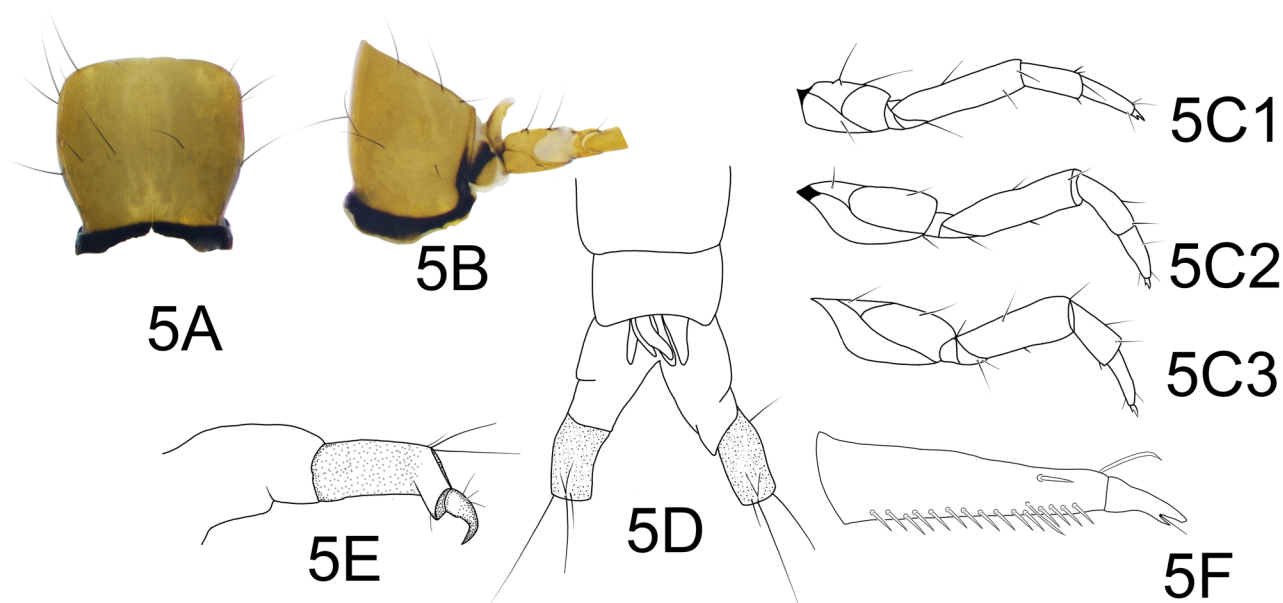
**Legs.** Legs (Figs. 5C1–5C3) yellowish brown, sclerotized and subequal. Forelegs slightly stouter and darker than mid- and hind legs; each with coxa having long black bristles and small sclerotized basodorsal process bearing long black bristle; tarsus with row of short spine-like setae ventrally (Fig. 5F). Trochanter of each leg 2-segmented; femora, tibiae, and tarsi of all legs almost equally broad, with sparse spine-like setae on their surfaces; claws small but well developed, slightly curved downwards and each with conspicuous basal process and basal seta.

**Abdomen.** Abdominal segments I–IX white, with sparse short setae on their surfaces. Lateral fringe and tracheal gills absent; with 5 single apicodorsal anal papillae at end of segment IX in dorsal view (Fig. 5D). Anal prolegs (Fig. 5E) each with basal half unsclerotized, distal half sclerotized and of same colour as mid- and hind legs, each with one sub-basodorsal seta and three much longer subapicodorsal setae. Anal claws (Fig. 5E) in lateral view each with base strong and sharp apex curved downwards at 90 degrees, with 4 small sub-basodorsal setae.

**Materials examined.** CHINA, Zhe-jiang Province, Lin-an, Tianmu Mountains: 1 larva, Shui-wu-li, 30.3550°N, 119.5958°E, Alt. 230 m, 12 Oct 2017; 57 larvae, Shui-wu-kou, 30.4008°N, 119.5944°E, Alt. 616.8 m,

12 Oct 2017; collected by Yan-li Hu, Yu Wang & Lang Peng. **Lin-an:** 1 male, Heng-du, 30.2951°N, 119.5687°E, Alt. 169 m, 21 Oct 2015; 1 male, Gao-hong Town, Da-shan, 30.3944°N, 119.6190°E, Alt. 507 m, 12 May 2015; collected by Ji-hua Xu. **Anhui Province, Mount Huangshan,** 2 males, Hou-shan, 29.7201°N, 118.3321°E, Alt. 120 m, collected by Ji-hua.

**Distribution.** China (Zhejiang, Anhui).



**FIGURE 5.** *Dolophilodes bellatula* Sun & Malicky 2002, larva. 5A, pronotum, dorsal; 5B, right side of pronotum, right foret-rochantin, and right forecoxa, right dorsolateral; 5C1, right foreleg, posterolateral; 5C2, right midleg, posterolateral; 5C3, right hind leg, posterolateral; 5D, segment IX and prolegs, dorsal; 5E, left proleg, left lateral; 5F, terminal portion of tarsus and claw of right prothoracic leg, posterolateral.

### *Wormaldia unispina* Sun 1998

(Figs 6A–7E)

**Description. Larvae (5th instar)** Body length 8–10 mm (n = 3), body in alcohol white with head and pronotum yellow.

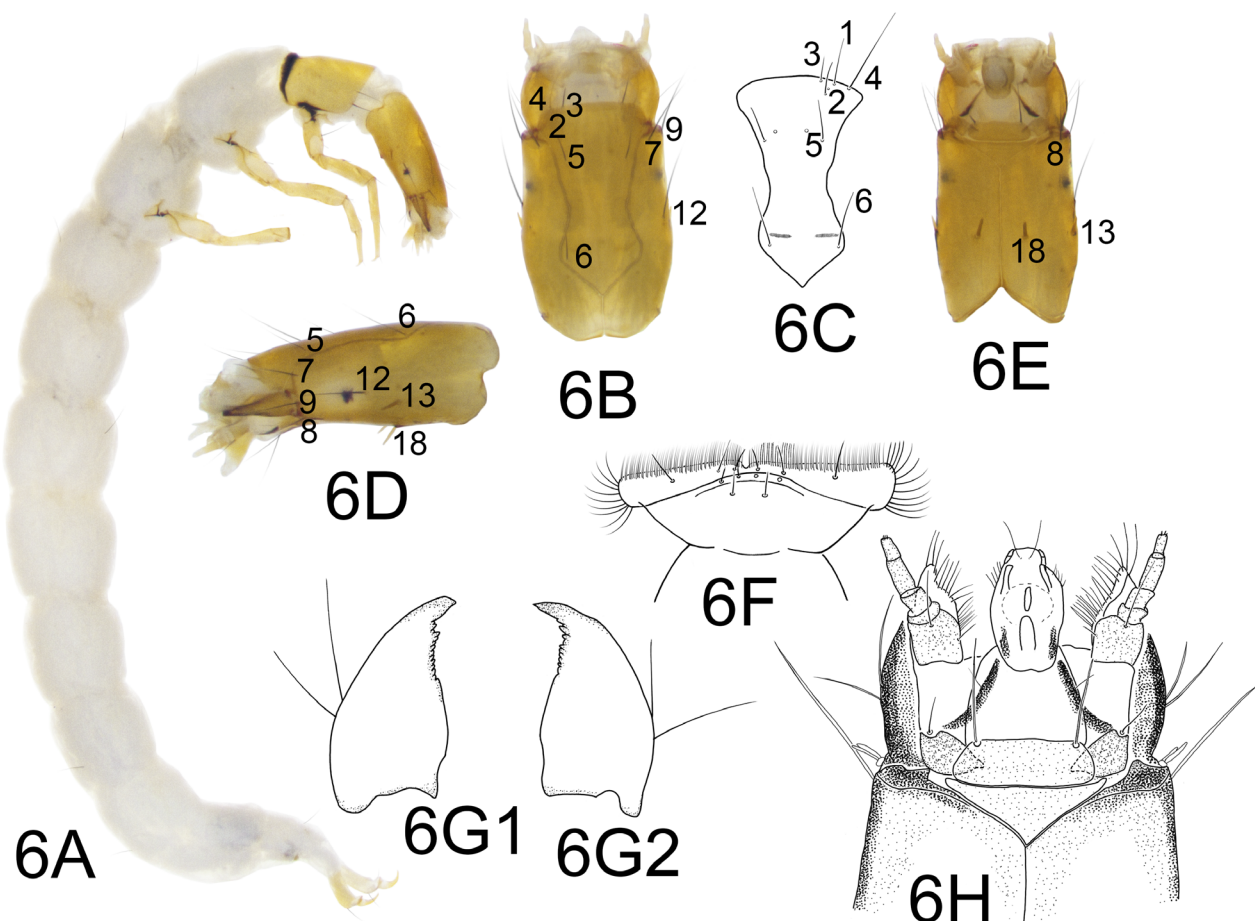
**Head.** Head capsule (Fig. 6B) yellowish brown; subrectangular in dorsal view, length about 1.5 times width, with surface smooth; frontoclypeal apotome (Fig. 6C) with anterior margin symmetrically convex, with 3 fine setae on each side; pair of dark brown transverse stripes located anterior of setae no. 6 between posterior angles of frontoclypeal sutures in posterior expansion; frontoclypeal sutures each about 5 times as long as coronal suture. Setae no. 4 located near anterolateral angle of frontoclypeal apotome; setae no. 5 posterior to tentorial pits; setae no. 6 posterior to aforementioned transverse stripes (Figs. 6B, 6C). In lateral view (Fig. 6D), subrectangular, smooth, with occipital margin notched; seta no. 13 spike-like, situated at midlength of gena. In ventral view (Fig. 6E) subrectangular, posterior margin with V-shaped excision, paired setae no. 18 stout and of same length as setae no. 13, located on center of each side; anterior ventral apotome triangular, with anterior margin straight and with each anterolateral angle slightly produced anterad; without transverse sulcus posteriorly. Eyes (Fig. 6A, 6D) oval, black, surrounded by faint yellow halo. Antennae (Fig. 6H) unusual, each supporting two separate rod-like spines and two tiny bristles, located at base of mandibles.

Labrum (Fig. 6F) white membranous, generally more or less T-shaped; anterior margin densely setose with small median notch; anterolateral angles rounded, setose with long hairs curved anterad; primary setae small, distance between setae no. 3 and no. 2 about 2 times distance between setae no. 2 and no. 1, setae no. 6 separated from setae no. 4 and no. 5 by transverse curved line.

Mandibles (Fig. 6G1, 6G2) of same colour as head and in some individuals slightly darker than head; each with outer surface bearing two bristles; inner margin smooth in basal half, serrate along 3/4 of length, subapical tooth very small, slightly larger and not recessed on right mandible.

Maxillae fused with labium (Fig. 6H). Each with cardo somewhat triangular, its inner angle produced into acute process covered by submentum, anterolateral margin concave, with seta; stipes membranous, bearing oblique blade-shaped sclerite with seta at midlength; fused lacinia-galea in ventral view triangular, lacinia with inner margin having two tufts of hairs; palpifer large, subrectangular in ventral view, with long subapical seta and small seta on inner margin; maxillary palp (Fig. 6H) four-segmented and slightly incurved in ventral view; first segment shortest, second and fourth segments equal in length, third segment as long as first and second segments combined.

Labium consisting of basal submentum and mentum, and distal labial part proper (Fig. 6H). Submentum trapezoidal, with one long black seta at each anterolateral angle; mentum membranous, contiguous with oblique sclerites from stipites. Labial part proper in lateral view (Fig. 6D) with lower angle producing into blunt process, dorsal margin heavily setose; in ventral view (Fig. 6H) somewhat tube-like, apically truncate; palpifer bar-shaped, labial palpi each 2-segmented.



**FIGURE 6.** *Wormaldia unispina* Sun 1998, larva. 6A, habitus, right lateral; 6B, head, dorsal; 6C, frontoclypeal apotome, dorsal; 6D, head, left lateral; 6E, head, ventral; 6F, labrum, dorsal; 6G1, left mandible, dorsal; 6G2, right mandible, dorsal; 6H, maxilla and labium, ventral. 1–18 = setae 1–18.

*Thorax.* Pronotum (Fig. 7A) rectangular in dorsal view, sclerotized, of same colour as head, with posterior margin having V-shaped incision, its black border on each side disconnected from longitudinal curved black strips on lateral margin just above insertion of forecoxa (Fig. 7B); midlength with broad transverse constriction; anterolateral setae longer than those at midlength; six pairs of small midlength setae arranged in transverse row just behind aforementioned transverse constriction; at each side spine-like seta located above curved black strip. Proepisternum black, elongate, with apex furcate in lateral view, anterodorsal branch much longer than anteroventral branch; proepimeron semicircular, yellow, with anterior margin slightly concave; foretrochantin (Fig. 7B) fingerlike, apex pointed, upper margin produced into a triangular process at mid-length. Meso- and metanota (Fig. 6A) completely membranous, white.

*Legs.* Legs yellowish brown, sclerotized and subequal, but forelegs slightly shorter and darker than mid- and hind legs. Forecoxae (Fig. 7C1) with dorsal margin having one long bristle at midlength and one strong curved

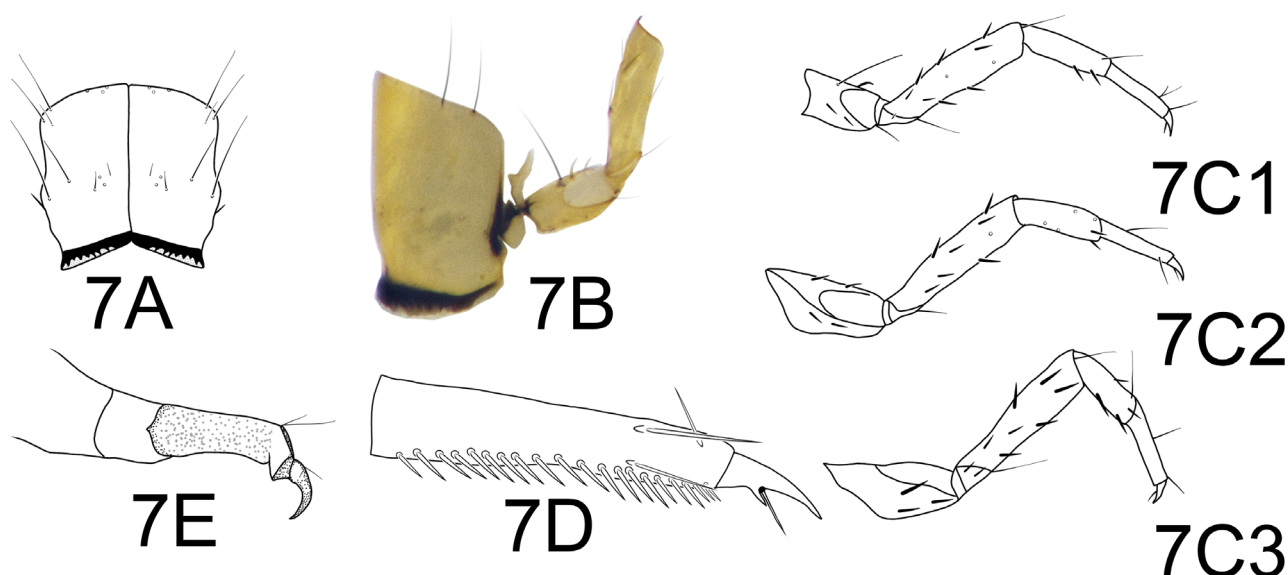


yellow spine beyond it; trochanters each 2-segmented, first segment short, with ventral margin about 1/3 as long as that of second segment; femora tubular, setose with spine-like setae; tibiae tubular, about 2/3 as long as femora, sparsely setose with spine-like setae; tarsi about same length as tibiae, each tapering from base to apex, with row of spine-like setae on ventral margin, otherwise sparsely setose (Fig. 7D); claws small, triangular, slightly curved downwards, each with apex pointed, ventral margin with conspicuous basal process and basal seta. Mid- and hind legs of same structure as forelegs, except for absence of strong bristles and spines on coxae.

**Abdomen.** Abdominal segments I–IX white, with sparse short setae. No lateral fringe present; without tracheal gills; segment IX in dorsal view with posterior margin concave. Anal prolegs (Fig. 7E) each with basal part soft, not sclerotized; medial part sclerotized and cylindrical, with two strong bristle apicodorsally; apical part triangular, articulated with apical sclerite within medial part; claw unciniate, with apex pointed, basodorsal surface setose.

**Materials examined.** CHINA, Zhe-jiang Province, Lin-an, Tian-mu Mountains: 1 larva, Che-shui-wu, 30.3558°N, 119.4522°E, Alt. 503.9 m, 10 Oct 2017. Hu-zhou, An-ji County: 2 larvae, Dong-wu-cun, 30.4656°N, 119.5781°E, Alt. 348.7 m, 13 Oct 2017; collected by Yan-li Hu, Yu Wang, and Lang Peng. Yong-kang: 10 larvae, Tong-keng-cun, 28.9495°N, 120.2191°E, Alt. 212.51 m, 24 Mar 2018, collected by Yan-li Hu, Jin Gao, and Cong Wu; 1 male, Tian-huang-ping Town, Chi-wu-li, 30.50°N, 119.60°E, Alt. 236 m, 12 May 2015, collected by Ji-hua Xu. Yu-yao County, Simingshan National Forest: 2 males, Chuan-di-wan, 29.7177°N, 121.0657°E, Alt. 729.54, 1 Aug 2016, collected by Ji-hua Xu.

**Distribution.** China (Zhejiang).



**FIGURE 7.** *Wormaldia unispina* Sun 1998, larva. 7A, pronotum, dorsal; 7B, right side of pronotum, right foretrochantin, and right forecoxa, right dorsolateral; 7C1, right foreleg, posterolateral; 7C2, right midleg, posterolateral; 7C3, right hind leg, posterolateral; 7D, terminal portion of tarsus and claw of right prothoracic leg, posterolateral; 7E, left proleg, left lateral.

## Discussion

As noted in the introduction, only a small number of larvae within the family Philopotamidae have been described so far. Even so, characteristics for distinguishing genera and species have been put forward. Generally, larvae of the genus *Chimarra* are characterized by the asymmetrically notched anterior margin of the frontoclypeal apotome, setae no. 18 at the level of the posterior point of the ventral apotome, the head capsule having a transverse sulcus near its posteroventral margin, and the large curved spine on each forecoxa. However, the anterior margin of the frontoclypeal apotome in larvae of other genera vary greatly, it may be notched as for *Chimarra* larvae, or only slightly sinuous, or completely symmetrical, or serrated. In these circumstances, *Dolophilodes* larvae can be diagnosed by the finger-like foretrochantins, continuous black border of posterior and lateral portions on the pronotum, and the small, rounded seta-bearing process on each forecoxa; *Wormaldia* larvae can be diagnosed by the break in the black border of posterior and lateral portions on the pronotum, the relatively small foretrochantins, the small curved spine on each forecoxa, and the stout and spine-like setae no. 13 and 18 of the head.

In this study, we found that the positions of setae no. 5 in relation to the tentorial pits on the frontoclypeal apotome may help diagnose larvae belonging to these genera: setae no.5 are anterior to the tentorial pits in *Chimarra* larvae, slightly posterior to the tentorial pits in *Wormaldia* larvae, and at the level of the tentorial pits in *Dolophilodes* larvae. However, we are not sure if these characters are stable in all genera or species because variations are common in insects. For example, as mentioned above, the larvae of *Chimarra* usually have setae no. 18 at the level of the posterior point of the ventral apotome, but in *Chimarra sadayu*, setae no. 18 are located near the middle of the ventral ecdysial line.

Moreover, the number of teeth and other aspects of the morphology of the mandibles and labrum may be useful characters in diagnosing larval species. By these characters, Kuhara (2017) distinguished larvae of 8 *Dolophilodes* species and 6 *Wormaldia* species. However, when species are closely related, such characters are often not effective. Adults of *D. bellatula* and *D. commata* (Kobayashi 1980) are similar in male genitalia, and their larvae show no observed differences in the labrum and mandibles. Similarly, in *Wormaldia unispina* Sun 1998 (in Wang et al. 1998) and Kuhara's *W. sp.1* (Kuhara 2017) we can hardly distinguish them from each other because of a lack of detailed descriptions.

In conclusion, more philopotamid specimens need to be examined and more effective characters discovered for diagnosing larvae of each genus. Also, detailed descriptions are needed to distinguish larvae of closely related species.

**TABLE 2.** Specimens used in larva-male associations of Philopotamidae.

Sample ID	GenBank ID	Species	Life stage	Collection Site	Collection Date
470	N/A	<i>Wormaldia unispina</i>	Male	Chi-wu-li, An'ji county, Zhejiang	12.May. 2015
ZJ00963	MK789663	<i>Wormaldia unispina</i>	Male	Chuan-di-wan, Simingshan National Forest, Yu-yao county, Zhejiang	1.Aug. 2016
ZJ00552	N/A	<i>Dolophilodes bellatula</i>	Male	Heng-du, Lin'an, Zhejiang	21.Oct. 2015
ZJ00554	N/A	<i>Dolophilodes bellatula</i>	Male	Da-shan, Gao-hong Town, Lin'an, Zhejiang	12.May. 2015
472	MK789660	<i>Dolophilodes bellatula</i>	Male	Hou-shan, Huangshan, Anhui	10.Oct. 2015
ZJ00958	N/A	<i>Chimarra sasayu</i>	Male	Shen-hu, Simingshan National Forest Yuyao county, Zhejiang	2.Aug. 2016
ZJ00959	MK789658	<i>Chimarra sadayu</i>	Male	Shen-hu, Simingshan National Forest Yu-yao county, Zhejiang	2.Aug. 2016
ZJ01003	MG871356	<i>Chimarra paramonorum</i>	Male	Xin-dun-cun, Er-ba Town, Jiang-shan, Zhejiang	12.Aug. 2016
ZJ0039	N/A	<i>Chimarra paramonorum</i>	Male	Xian-xi Town, Le Qing, Zhe-jiang	26.May 2017
ZJ038L	N/A	<i>Chimarra paramonorum</i>	Larva	Yao-chuan Town, Pan'an County, Zhe-jiang	27.Mar. 2018
ZJ005L	MG871355	<i>Chimarra paramonorum</i>	Larva	Xian-xi Town, Le Qing, Zhe-jiang	26.May 2017
ZJ011L	N/A	<i>Dolophilodes bellatula</i>	Larva	Shui-wu-li, Lin'an, Zhejiang	12.Oct. 2017
ZJ009L	MK789661	<i>Dolophilodes bellatula</i>	Larva	Shui-wu-kou, Lin'an, Zhejiang	12.Oct. 2017
ZJ021L	MK789662	<i>Wormaldia unispina</i>	Larva	Che-shui-wu, Tianmu Mountains, Zhejiang	11.Oct. 2017
ZJ027L	N/A	<i>Wormaldia unispina</i>	Larva	Dong-wu-cun, An'ji, Zhejiang	13.Oct. 2017
ZJ013L	N/A	<i>Chimarra sasayu</i>	Larva	Xi-shan-wu, Tianmu Mountains, Zhejiang	10.Oct. 2017
ZJ018L	N/A	<i>Chimarra sasayu</i>	Larva	Che-shui-wu, Tianmu Mountains, Zhejiang,	11.Oct. 2017
PYJ0018	MK789659	<i>Chimarra sasayu</i>	Larva	Tai-tou-wan, Pujiang County, Zheji-ang	30.Aug. 2017

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