



Four new species of *Rhyacophila* Pictet, 1834 (Trichoptera: Rhyacophilidae) from Southeast Asia

NANNAPHAT SUWANNARAT¹, HANS MALICKY², JOHN C. MORSE³ & PONGSAK LAUDEE^{1,4}

¹Department of Fishery and Coastal Resources, Faculty of Science and Industrial Technology, Prince of Songkla University, Surat Thani Campus, Muang District, Surat Thani Province, Thailand 84100.

²Sonnengasse 13, A-3293 Lunz am See, Austria

³Department of Plant & Environmental Sciences, Clemson University, Clemson, South Carolina 29634-0310 USA

⁴Corresponding author. E-mail address: pongsak.l@psu.ac.th

Abstract

Four new species of genus *Rhyacophila* are described and illustrated from Thailand and Myanmar, Southeast Asia. *Rhyacophila longicaudata* sp. n. is in the *R. nigrocephala* Group; the very long basal segment of each inferior appendage distinguishes it from other related species. *Rhyacophila aksornkoei* sp. n. and *R. limsakuli* sp. n. are in the *R. anatina* Group: they can be differentiated from other species of the group by the brush-like parameres and presence of a ventral process of the aedeagus in *R. aksornkoei* sp. n., and by the rectangular apical segment of each inferior appendage and the hooked parameres in *R. limsakuli* sp. n. *Rhyacophila kengtungensis* is in the *R. yishepa* Group and is characterized by the subtriangular shape of the preanal appendages in dorsal view and by the very large dorsal appendages of the phallic apparatus.

Key words: caddisfly, Thailand, Myanmar

Introduction

Rhyacophila (Trichoptera: Rhyacophilidae) is one of the most diverse genera of Trichoptera, with 780 extant species recorded worldwide (Morse 2018). Malicky (2010) reported 88 species of *Rhyacophila* from Southeast Asia (Andaman Islands to Vietnam to Borneo and Indonesia-Java). Among these, 37 species were recorded from Thailand alone by Chantaramongkol *et al.* (2010). In Myanmar, 20 species of *Rhyacophila* have been reported, mostly described by Kimmins in 1953 (Wityi *et al.* 2015). In Southeast Asia, in the Oriental Region, where Trichoptera biodiversity is high (Morse 2016), there are undoubtedly still many species unknown to science (Malicky 2010).

Schmid (1970) established diagnostic Branches, Twigs, and Groups of *Rhyacophila* by characters of male genitalia, including the *R. anatina*, *R. nigrocephala*, and *R. yishepa* Groups. Sun (2016) described 2 new species of the *R. anatina* Group from China and listed the species of the *R. anatina* Species Group worldwide, including 36 species from the Oriental Region (33 species) and the East Palearctic Region (3 species). Laudee & Malicky 2014 subsequently described a new species in the *R. anatina* Group from southern Thailand and Kiss (2017) described one new species of the *R. yishepa* Group from Nepal.

This study describes 4 new species of *Rhyacophila* from the lower hill evergreen forest and lowland evergreen forest of Thailand and Myanmar.

Materials and Methods

The caddisfly specimens were collected by an UV pan light trap (12 V, 10 W) placed near a stream overnight at locations and times indicated below. The Trichoptera specimens were preserved in 70% ethanol and manually sorted afterwards. Adult male genitalia of the new species were removed and muscle tissue was macerated by heating in

10% KOH at 60°C for 30–60 minutes or in lactic acid (Blahnik *et al.* 2007). The male genitalia of the new species were drawn using compound microscopy and a drawing tube, first as a pencil template and then with vector-graphic Adobe Illustrator© software. Holotypes and paratypes are stored in 70% ethanol and are deposited in the Princess Maha Chakri Sirindhorn Natural History Museum, Prince of Songkla University, Hat Yai Campus, Hat Yai District, Songkhla Province, Thailand (PSUNHM). Additional paratypes are deposited in the Clemson University Arthropod Collection, Clemson University, Clemson, South Carolina, USA (CUAC), as indicated in the species descriptions. Terminology for genitalic structures is that of Schmid (1970).

Taxonomy

Rhyacophilidae

Rhyacophila longicaudata n. sp. Suwannarat & Malicky

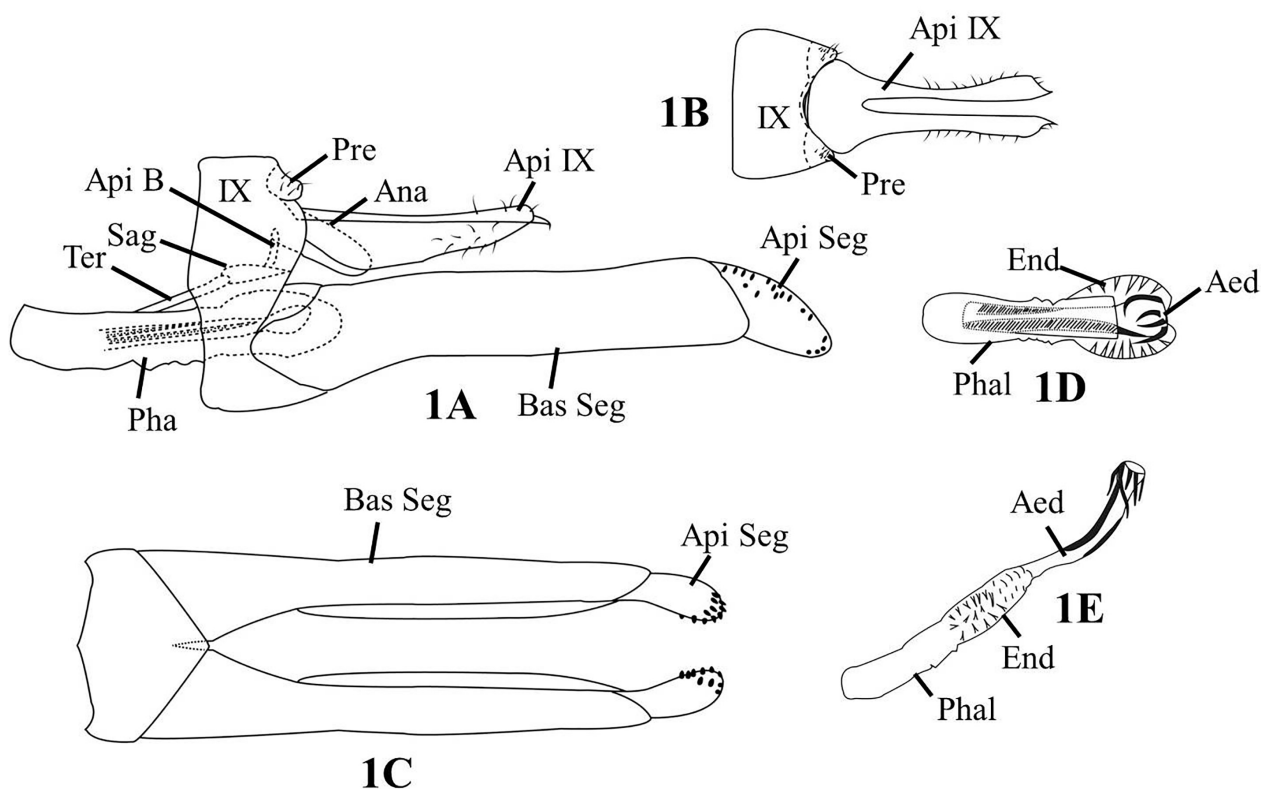
Figs. 1A–1E

Type material. Holotype male (PSUNHM). THAILAND: Surat Thani Province, Tai Rom Yen National Park, Pha San Yen stream, 8°42'43"N, 99°30'36"E, ca. 1100 m a.s.l., 12 February 2017, leg. Pongsak Laudee.

Paratypes: Same data as holotype, 1 male (PSUNHM).

Eymology. The species epithet comes from Latin adjectives longus, -a, -um and caudatus, -a, -um, meaning “long tailed,” in reference to the long inferior appendages.

Description. Length of each male forewing 7.0 mm (n = 2); specimens in alcohol with head, thorax, and forewings dark brown.



FIGURES 1A–1E. Male genitalia of *Rhyacophila longicaudata* n. sp. 1A, left lateral, with left inferior appendage omitted. 1B, dorsal. 1C, ventral. 1D, phallus, ventral. 1E, phallus, left lateral. IX = segment IX, Pre = preanal appendages, Api IX = apico-dorsal lobe of segment IX, Ana = anal sclerites, Api B = apical band, Sag = sagittal appendage, Ter = tergal band, Pha = phallus, Bas Seg = basal segment of an inferior appendage (paired), Api Seg = apical segment of an inferior appendage (paired), Aed = aedeagus, Phal = phallosome, End = endothenca.

Male genitalia (Figures 1A–1E5). In lateral view (Fig. 1A), segment IX subrectangular with broad posterolateral excision below midline, its apicodorsal lobe very long, lancet-like with short setae subapicodorsally, acute apically; in dorsal view (Fig. 1B), annular portion of segment IX transversely straight anteriorly, appearing separated by concave suture from its apicodorsal lobe (Schmid 1970), apicodorsal lobe of segment IX very long, hour-glass-like with very deep incision in apical 3/4 of posterior margin, apices acute. Preanal appendages located at posterodorsal margin of annular portion of segment IX, very short, black, wart-like. Segment X reduced, obscure, except anal sclerites, the latter oval in lateral view, rounded posteriorly, positioned underneath anterior portion of apicodorsal lobe of segment IX. Inferior appendages very long, more than twice as long as apicodorsal lobe of segment IX, cylindrical; each with basal segment about six times as long as apical segment, dorsal and ventral margins parallel in lateral view (Fig. 1A), broader basally in ventral view (Fig. 1C), with longitudinal ridge dorsomesally; apical segment short and ovoid in lateral and ventral views, with numerous stout subapicomeral setae. Tergal band from dorsal base of phallosome terminating in sagittal appendage articulating with apical band connected with root of anal sclerite. In dorsal and ventral views (Figs. 1A, 1D), retracted phallus clavate, with phallosome rectangular, endotheca thicker and oval with numerous spines, and aedeagus long and spoon-like with two long internal spines and five curved hooks apically (only four visible ventrally); in lateral view (Fig. 1E) protracted phallus long, phallosome cylindrical, endotheca with numerous spines basally and membranous apically; aedeagus slender and cylindrical with two long internal spines of which dorsal spine about twice as long as ventral spine and with five long hooks apically.

Diagnosis. *Rhyacophila longicaudata* n. sp. is a member of *R. nigrocephala* Group (Schmid 1970) in which there is a long apicodorsal lobe of segment IX extending caudad from the annular portion of that segment, the fused anal sclerites are reduced, apical and tergal bands are present and sclerotized, and in most species (including this new species) the phallic parameres are absent and the basal segments of the inferior appendages are fused with each other at their extreme bases. This species is similar to *R. drosampa* Schmid 1970, *R. laocai* Armitage & Arefina 2003, *R. lhabu* Schmid 1970, *R. paratecta* Mey 1996, and *R. mayestril* Malicky 1991. However, *R. longicaudata* n. sp. differs from those by the unusually long inferior appendages and by the presence of long hooks at the apex of the aedeagus.

Rhyacophila aksornkoaei sp. n. Laudee & Malicky

Figs. 2A–2C

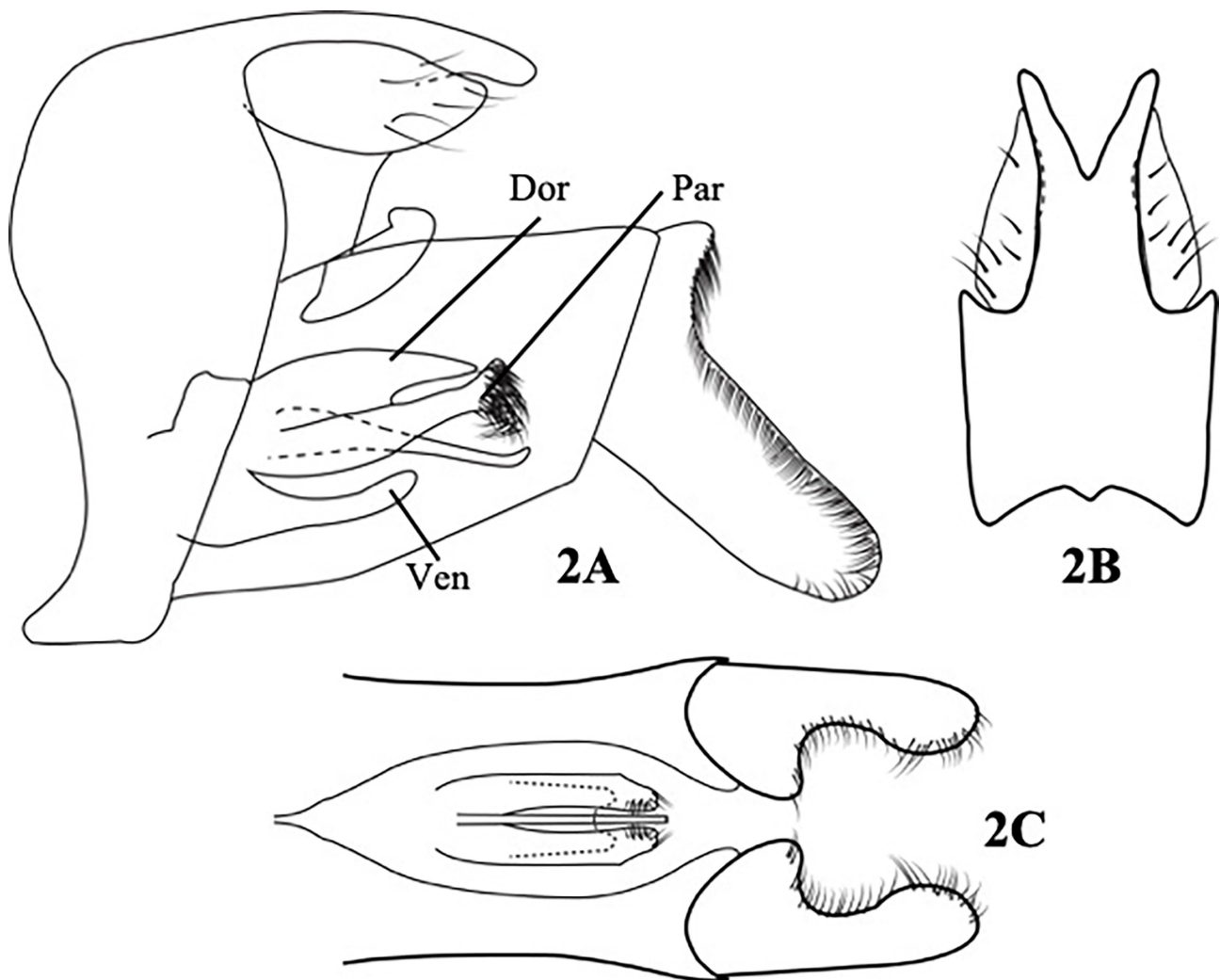
Type material. Holotype male (PSUNHM). THAILAND: Surat Thani Province, Khao Luang National Park, Tha Di stream, 8°28'46"N, 99°45'07"E, ca. 802 m a.s.l., 31 March 2018, leg. Nannaphat Suwannarat.

Paratypes: Same data as holotype, 5 male (PSUNHM).

Etymology. The species is dedicated to Prof. Dr. Sanit Aksornkoae, who is a prominent Thai ecologist.

Description. Length of each male forewing 11.0 mm (n = 2); specimens in alcohol with head, thorax, and forewings dark brown.

Male genitalia (Figures 2A–2C). Segment IX anterior margins convex dorsally and concave ventrally, posterior margins convex below its apicodorsal lobe, longitudinally longest at 2/3 height, anterodorsal margin concave except for small triangular mesal projection, its apicodorsal lobe about as long as annular portion of segment, divided by deep V-shaped apical incision nearly half its length mesally, slightly concave laterally, dark brown apically and subapically. Preanal appendages drop-like, shorter than apicodorsal lobe of segment IX. Segment X trapezoid, hidden below apicodorsal lobe of segment IX and between preanal appendages. Anal sclerite flat oval, oblique in lateral view. Inferior appendages each with basal segment shaped as parallelogram in lateral view, in ventral view slender in middle; apical segment mitten-shaped in mesal and ventral views, with short triangular “thumb” and with stout marginal and submarginal setae along subapicomeral and apicomeral margins. Phallus complex; phallosome short, tubular, its dorsal process somewhat triangular, convex dorsally, acute apically; ventral process tubular with expanded base and blunt apex; parameres long, tubular, expanded and bent slightly upward, each with tuft of bristles subapicomeral and apically, slightly expanded and truncate in lateral view and slightly convergent and blunt in ventral view; aedeagus as long as parameres, needle-like, expanded basally and upturned apically in lateral view (Fig. 2A), uniformly slender and straight in ventral view (Fig. 2C).



FIGURES 2A–2C. Male genitalia of *Rhyacophila aksornkoaei* n. sp. 2A, left lateral, with left inferior appendage omitted. 2B, dorsal. 2C, ventral. Par = parameres, Dor = dorsal process of the phallic apparatus, Ven = ventral plate of the aedeagus.

Diagnosis. This new species is a member of *Rhyacophila anatina* Group (Schmid 1970) and is similar to other species of this Group found in Asia. According to Sun (2016), the males of this Group can be diagnosed as follows: “segment IX is short ventrally; the apicodorsal lobe of segment IX is strong and bilobed; the preanal appendages are large and closely joined to the apicodorsal lobe, segment X is vertical; the anal sclerites are usually paired, without roots; the apical band is strongly sclerotized and with its two lateral arms not joined to each other at the base; the tergal band is short and membranous; the basal segment of the inferior appendages are usually long, and the apical segments are short, the phallosome is cylindrical and the endotheca well developed; the aedeagus is slender, tubular; parameres are slender, with the distal ends heavily bristled.” *Rhyacophila aksornkoaei* sp. n. is very similar to *R. surathaniensis* Laudee & Malicky 2014 and *R. petersorum* Schmid & Denning 1971 (in Denning & Schmid 1971), but can be distinguished in that (1) the phallus of the new species is armed with a ventral plate that is absent in *R. surathaniensis* Laudee & Malicky 2014 and *R. petersorum* Schmid & Denning 1971 (in Denning & Schmid 1971), (2) the distal ends of the parameres of *Rhyacophila aksornkoaei* sp. n. are bent upward and bristled apically, but bristles are arranged like a toothbrush in *R. surathaniensis* and the paramere apices bear several thin and long spines directed distad in *R. petersorum*.

Rhyacophila limsakuli sp. n. Laudee & Malicky

Figs. 3A–3D

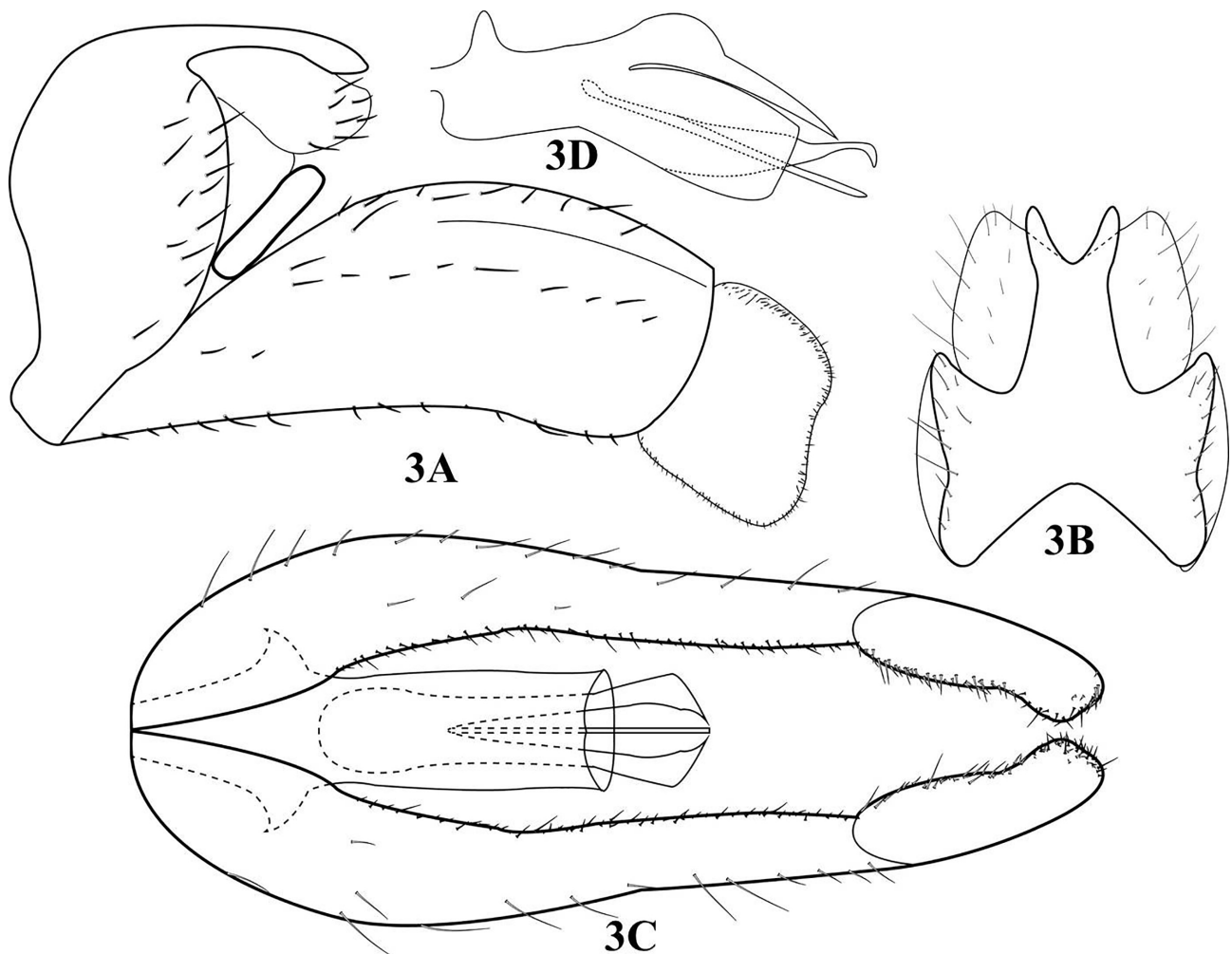
Type material. Holotype male (PSUNHM). THAILAND: Phetchaburi Province, Kaeng Krachan National Park, Ban Klang stream, 12°47'54"N, 99°27'09"E, ca. 352 m a.s.l., 1 June 2017, leg. Pongsak Laudee.

Paratypes: Same data as holotype, 1 male (PSUNHM).

Etymology. The species is dedicated to Assoc. Prof. Dr. Chusak Limsakul, who was the President of Prince of Songkla University during 2013–2018.

Description. Length of each male forewing 7.0 mm (n = 2); specimens in alcohol with head, thorax, and forewings dark brown.

Male genitalia (Figures 3A–3D). Anterolateral margins of segment IX convex subdorsally and concave subventrally, posterolateral margins convex; apicodorsal lobe of segment IX about as long as preanal appendages, convex dorsally and apically blunt in lateral view; in dorsal view slightly concave laterally and with V-shaped incision in apicomeresal 1/3. Preanal appendages as long as apicodorsal lobe of segment IX, oval in lateral view, blunt in dorsal view. Anal sclerite flat, oval in lateral view, oriented obliquely dorsad from root. Basal segment of each inferior appendage tubular, tapered anteriorly, rounded posteriorly, and with longitudinal ridge subdorsally in apical half, apical segment nearly rectangular with broad and shallow invagination apically; in ventral view basal segment of each inferior appendage cylindrical and apical segment peanut-like with subapicomeresal setae. Phallus complex; phallosome tubular with lateral tenons; in lateral view dorsal process somewhat bird-head-like with round “crown” dorsally and long “beak” apically; aedeagus as long as parameres, needle-like; parameres fused basally, thick especially basally, their apices horizontally flattened and hooked ventromesad and caudad.



FIGURES 3A–3D. Male genitalia of *Rhyacophila limsakuli* n. sp. 3A, left lateral, with left inferior appendage and phallus omitted. 3B, dorsal. 3C, ventral. 3D, phallus, left lateral. Ana = anal sclerites.

Diagnosis. This new species is a member of *R. anatina* Group (Schmid 1970). It is similar to other species from Asia and can be diagnosed by the characters mentioned by Sun (2016). *Rhyacophila limsakuli* sp. n. closely resembles *R. noeibia* Malicky & Chantaramongkol 1993, but the two species can be distinguished in that (1) the basal segment of each inferior appendage of *R. limsakuli* sp. n. is 4.5 times as long as the apical segment, but only 2.5 times as long in *R. noeibia*, (2) the apical segment of each inferior appendage of *R. noeibia* is boot-shaped and projected dorsad, but that of *R. limsakuli* sp. n. is rectangular and lacks a dorsal projection, and (3) the apices of the parameres of *R. noeibia* are bent upward, but in *R. limsakuli* sp. n. they are bent downward.

Rhyacophila kengtungensis sp. n. Morse & Malicky

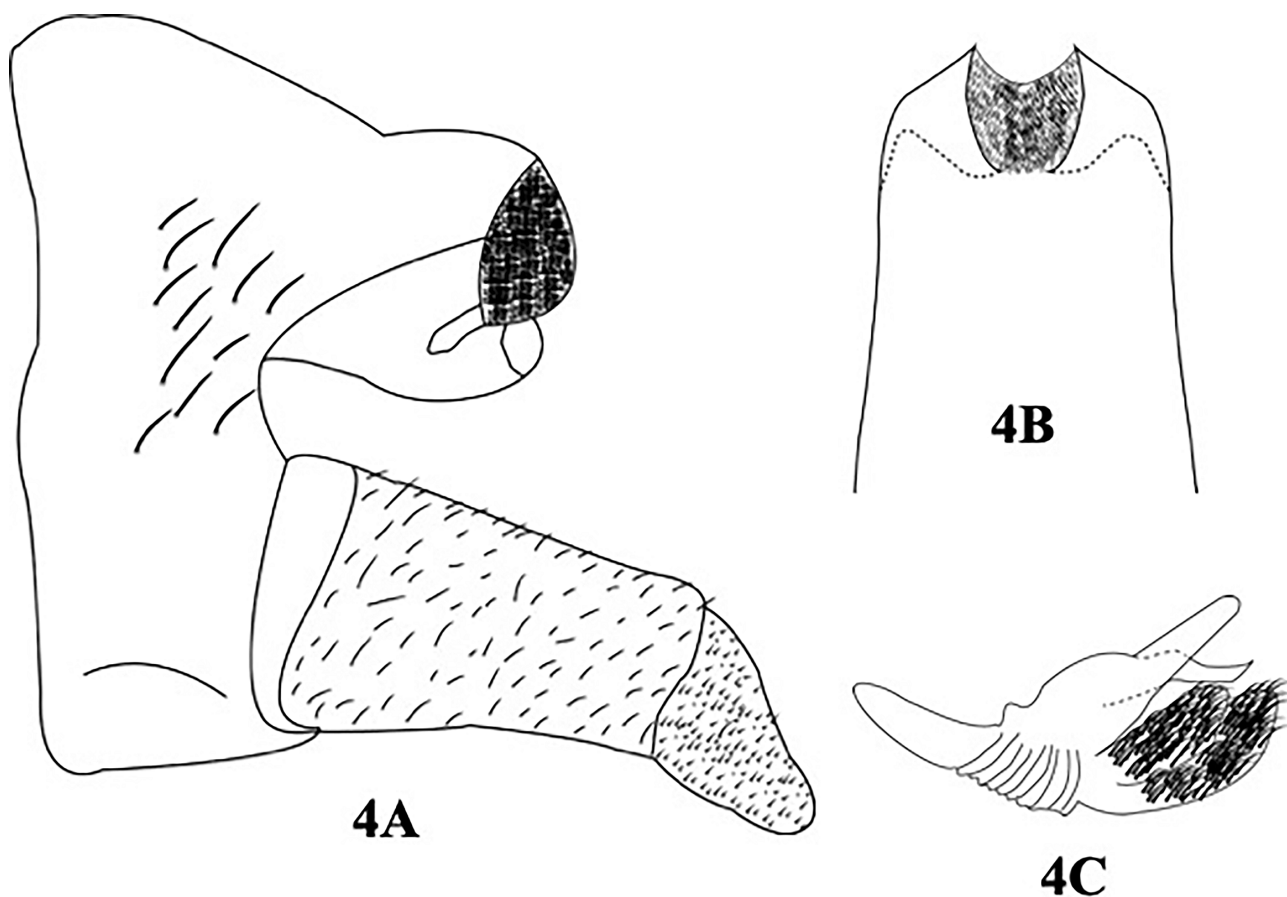
Figs. 4A–4C

Type material. Holotype male (PSUNHM). MYANMAR: Shan State, Keng Tung Province, Pin Tao Waterfall, 21°26'37"N, 99°34'42"E, ca. 977 m a.s.l., 13 January 2015, leg. Pongsak Laudee.

Paratypes: Same data as holotype, 1 male (CUAC).

Etymology. The species epithet refers to the province where the new species was found.

Description. Length of each male forewing 5.0 mm (n = 2); specimens in alcohol with head, thorax, and forewings light yellow.



FIGURES 4A–4C. Male genitalia of *Rhyacophila kengtungensis* n. sp. 4A, left lateral, with left inferior appendage and phallus omitted. 4B, dorsal. 4C, phallus, left lateral. Pre = preanal appendages, Api IX = apicodorsal lobe of segment IX, Ana = anal sclerites.

Male genitalia (Figures 4A–4C). Segment IX anterolateral margins nearly straight, posterolateral margins sinuous below apicodorsal lobe, apicodorsal lobe short, half as long as inferior appendages, and nearly as wide as annular portion of segment, tubular. Preanal appendages strongly sclerotized, extending beyond apicodorsal lobe of segment IX, their mesal surfaces covered with short dark brown setae, oval in lateral view, subtriangular in dorsal view. Anal sclerites small, beneath preanal appendages. Inferior appendages long, cylindrical, each with basal seg-

ment twice as long as apical segment; apical segment subtriangular, its dorsal margin forming 50° angle with dorsal margin of basal segment, blunt apically, mesal surface covered with numerous setae. Phallus (Fig. 4C) small, dorsal appendage of phallic apparatus cylindrical, aedeagus short, apically acute; pair of ventral appendages of phallic apparatus very large, curved upward, covered with strong setae.

Diagnosis. *Rhyacophila kengtungensis* sp. n. is a member of the *R. yishepa* Group, in which males each have a short and broad apicodorsal lobe of segment IX, a reduced anal sclerite, and no parameres (Schmid 1970). This species is close to *R. ligulata* Malicky & Sun 2002 and *R. suah* Malicky & Chantaramongkol 2009 (in Malicky 2009). However, *R. kengtungensis* sp. n. differs from those species by (1) the subtriangular shape of the preanal appendages in dorsal view in *R. kengtungensis* sp. n., but hooked in *R. ligulata* and bilobed in *R. suah*; (2) the right-angled triangular shape of the apical segment of each inferior appendage in *R. kengtungensis* sp. n., contrasting with the oval apical segment of each inferior appendage in *R. ligulata* and *R. suah*; and (3) the ventral plate of the aedeagus of *R. kengtungensis* is obscured by the setose dorsal appendages of the phallic apparatus, but is conspicuous, slender, tubular, and acute in *R. ligulata* and *R. suah*.

Acknowledgements

We thank the Department of National Parks, Wildlife, and Plant Conservation for their permission to carry out this research. This research was financially supported by Prince of Songkla University, Surat Thani Campus Collaborative Research Fund.

References

- Armitage, B. J. & Arefina, T. (2003) The genus *Rhyacophila* Pictet (Trichoptera: Rhyacophilidae) in Vietnam. *Aquatic Insects*, 25, 95–124.
<https://doi.org/10.1076/aqin.25.2.95.14037>
- Blahnik, R.J., Holzenthal, R.W. & Prather, A. (2007) The lactic acid method for clearing Trichoptera genitalia. In: Bueno-Soria, J., Barba-Álvarez, R. & Armitage, B. (Eds.), *Proceedings of the 12th International Symposium on Trichoptera*. The Caddis Press, Mexico City, pp. 9–14.
- Chantaramongkol, P., Thapanya, D. & Bunlue, P. (2010) The aquatic insect research unit (AIRU) of Chiang Mai University, with an updated list of the Trichoptera species of Thailand. *Denisia*, 29, 55–79.
- Denning, D.G. & Schmid, F. (1971) Descriptions of four new *Rhyacophila* (Trichoptera: Rhyacophilidae). *Canadian Entomologist*, 103, 1553–1556.
<https://doi.org/10.4039/Ent1031553-11>
- Kimmins, D.E. (1953) Entomological results from the Swedish expedition 1934 to Burma and British India—Trichoptera: The genus *Rhyacophila* Pictet (Fam. Rhyacophilidae). *Arkiv för Zoologi, Serie 2*, 4 (29), 505–555.
- Kiss, O. (2017) A new species of *Rhyacophila* from Nepal (Trichoptera: Rhyacophilidae). *eActa Naturalia Pannonica*, 14, 29–32.
- Laudee, P. & Malicky, H. (2014) Trichoptera fauna from Nakhon Si Thammarat Range (southern Thailand), with the description of a new species of *Rhyacophila* Pictet, 1834 (Trichoptera: Rhyacophilidae). *Aquatic Insects*, 36 (3–4), 161–169.
<https://doi.org/10.1080/01650424.2015.1064965>
- Malicky, H. (1991) Some unusual caddisflies (Trichoptera) from southeastern Asia (Studies on caddisflies of Thailand, No. 5). In: Tomaszewski, C. (Ed.), *Proceedings of the 6th International Symposium on Trichoptera*. Adam Mickiewicz University Press, Poznan, Poland, pp. 381–384.
- Malicky, H. (2009) Beiträge zur Kenntnis asiatischer Trichopteren. *Braueria*, 36, 11–58.
- Malicky, H. (2010) *Atlas of Southeast Asian Trichoptera*. Faculty of Science Printing Unit, Chiang Mai University, Chiang Mai Province, 346 pp.
- Malicky, H. & Chantaramongkol, P. (1993) Neue Trichopteren aus Thailand. Rhyacophilidae, Hydrobiosidae, Philopotamidae, Polycentropodidae, Ecnomidae, Psychomyiidae, Arctopsychidae, Hydropsychidae (Arbeiten über thailändische Köcherfliegen Nr. 12) (Fortsetzung). *Linzer Biologische Beiträge*, 25 (1), 433–487.
- Malicky, H. & Sun, C. (2002) 25 new species of Rhyacophilidae (Trichoptera) from China. *Linzer Biologische Beiträge*, 34 (1), 541–561.
- Mey, W. (1996) Die Köcherfliegenfauna des Fan Si Pan-Massivs in NordVietnam. *Beiträge zur Entomologie*, 46 (1), 39–65.
- Morse, J.C. (2016) Keynote: The Trichoptera fauna of Asia. In: Vshivkova, T.S. & Morse, J.C. (Eds.), *Proceedings of the 14th International Symposium on Trichoptera*, Vladivostok, Russia. *Zoosymposia*, 10, 20–28.
<https://doi.org/10.11646/zoosymposia.10.1.4>

- Morse, J.C. (2018) Trichoptera World Checklist. Available from: <http://www.clemson.edu/cafls/departments/esps/database/trichopt/> (accessed 29 November 2018)
- Pictet, F.J. (1834) *Recherches pour Servir à l'Histoire et à l'Anatomie des Phryganides*. A. Cherbuliez, rue de la Cit, Geneva, 235 pp.
<https://doi.org/10.5962/bhl.title.8547>
- Schmid, F. (1970) *Le genre Rhyacophila et la Famille des Rhyacophilidae (Trichoptera)*. Mémoires de la Société Entomologique du Canada, 66, 230 pp.
<https://doi.org/10.4039/entm10266fv>
- Sun, C. (2016) Two new species of the *Rhyacophila anatina* Species Group from China (Trichoptera: Rhyacophilidae). *Zootaxa*, 4085 (2), 273–278.
<https://doi.org/10.11646/zootaxa.4085.2.7>
- Wityi, H., Nozaki, T. & Fujino, T. (2015) A list of Myanmar caddisflies (Trichoptera including recently collected data). *Entomological Research Bulletin*, 31 (1), 41–55.