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Two new species of the genus *Rhyacophila* Pictet (Trichoptera, Rhyacophilidae) from Korea and Japan

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Abstract

Two new species of the genus *Rhyacophila* Pictet, *R. kangae* Park & Nozaki **sp. nov.** and *R. yamamotoi* Nozaki **sp. nov.**, are described from Korea and Japan, respectively. Both species belong to the *Rhyacophila nigrocephala* Species Group, and their genitalic morphology is very similar to those of *R. confissa* Botosaneanu 1970 and *R. vicina* Botosaneanu 1970 described from the Korean Peninsula. These four species can be distinguished from each other by the shape of the complex of preanal appendages and apicodorsal lobe of segment IX in males, and by the shape of the vaginal apparatus in females. Males of the two new species bear larger compound eyes in proportion to the head widths than those of *R. confissa* and *R. vicina*.

Key words: descriptions, male, female, *Rhyacophila nigrocephala* Species Group, eye size

Introduction

The genus *Rhyacophila* Pictet 1834 is one of the largest genera in Trichoptera, composed of more than 800 species in the Nearctic, Holarctic, and Oriental Biogeographic Regions (Morse 2021). In Japan and Korea, 64 species and 27 species of this genus are known, respectively (Park & Kong 2020; Nozaki 2021). The *Rhyacophila nigrocephala* Species Group Ross 1956 is distributed in the Oriental and Palearctic Biogeographic Regions (Schmid 1970; Sun 2017), and a total of 10 species of this Group are known from Japan and Korea (Hattori 2005; Park & Kong 2020): *Rhyacophila confissa* Botosaneanu 1970 (Korea), *Rhyacophila formosana* Ulmer 1927 (Japan), *Rhyacohila kawamurae* Tsuda 1940 (Japan & Korea), *Rhyacophila kuwayamai* Schmid 1970 (Japan), *Rhyacophila lata* Martynov 1918 (Korea), *Rhyacophila manuleata* Martynov 1934 (Korea), *Rhyacophila nigrocephala* Iwata 1927 (Japan), *Rhyacophila nipponica* Navás 1933 (Japan), *Rhyacohila shikotsuensis* Iwata 1927 (Japan), and *Rhyacophila vicina* Botosaneanu 1970 (Korea). However, the taxonomic study of the genus *Rhyacophila* in both countries remains insufficient (Hattori 2005; Park & Kong 2020), and there are some records of unidentified species belonging to the *R. nigrocephala* Species Group (e.g., Hattori 2005; Kang 2020).

Recently, Kang (2020) recorded an unidentified species similar to *R. confissa* and *R. vicina*. *Rhyacophila confissa* and *R. vicina*, originally described from North Korea, are very similar to each other in male and female genitalia (Botosaneanu 1970) and have been commonly found in South Korea (Park & Kong 2020). Yamamoto *et al.* (in press) recorded an unidentified species similar to *R. confissa* and *R. vicina* from Shikoku, western Japan. We examined those specimens and other materials collected from Korea and Japan and recognized two new species. In this paper, we describe these two new species from Korea and Japan and also provide illustrations and photographs of *R. confissa* and *R. vicina* for comparison.

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Materials and methods

Associations of males and females were based on similar general body characters when they were collected together multiple times. Male and female genitalia were figured after being cleared in a 10% solution of KOH. Morphological terminology used in this study mainly follows Schmid (1970), Sun (2017), and Arefina (2001). The width of each compound eye and the distance between eyes (a and b in Fig. 1F) were measured by binocular microscopy using an ocular micrometer. Depositories of specimens used in this study are abbreviated as follows: Kanagawa Prefectural Museum of Natural History, Odawara, Japan (KPM-NK); Minakuchi Kodomo-no-mori Nature Center, Shiga (MITR); Natural History Museum and Institute, Chiba, Japan (CBM-ZI); National Institute of Biological Resources, Incheon, Korea (NIBR); and personal collections of N. Kawase (NK), S.-J. Park (SJP), and T. Nozaki (TN).

Species descriptions

Rhyacophila kangae Park & Nozaki sp. nov.

(Figs 1, 4, 9)

Rhyacophila sp. 3: Kang 2020, 232–233, male (photographs), Korea.

Diagnosis. This species belongs to the *Rhyacophila nigrocephala* Species Group (Ross 1956). The male genitalia are similar to those of *R. confissa* and *R. vicina*, but the male of *R. kangae* **sp. nov.** is distinguishable from those of the latter two species by the shape of the complex of preanal appendages and apicodorsal lobe of segment IX: In dorsal aspect, the two lobes are widely separated from each other, forming a large U-shape in *R. kangae* **sp. nov.** (Fig. 1B), but they form a narrow slit in *R. confissa* and *R. vicina* (Figs. 2B, 3B). Furthermore, the male of *R. kangae* **sp. nov.** bears large compound eyes in proportion to its head width when compared with those of *R. confissa* and *R. vicina*: 0.37–0.45 in *R. kangae*, but 0.23–0.31 in *R. confissa* and *R. vicina* (Figs. 1F a b, 2C, 3C). The female genitalia are similar to those of *R. confissa* and *R. vicina* but can be distinguished by the shape of the vaginal apparatus: In ventral aspect, the posterior process of the vaginal apparatus is long and rectangular in *R. kangae* **sp. nov.** (Fig. 4F), but that of *R. confissa* bears an 8-shaped unpigmented part apicoventrally (Fig. 6B), and that of *R. vicina* is constricted at 2/5 from the posterior apex (Fig. 7B). The male and female of *R. kangae* **sp. nov.** are also similar to those of a Japanese species, *R. yamamotoi* **sp. nov.**, but they are distinguished by the characters given in the diagnosis for that species, below.

Adult. Specimens in alcohol mostly dark brown, but tibiae and tarsi of all legs light brown. Forewings each 12.2–13.5 mm in male (n = 6), 13–14.8 mm in female (n = 2). Ratio of width of eye to distance between eyes (a/b in Fig. 1F) 0.37–0.45 in male (n = 6), 0.25–0.33 in female (n = 6).

Male genitalia. Segment IX (IX) longitudinally short in lateral aspect (Fig. 1A), ventral half longer than dorsum; membranous along midline in dorsal aspect (Fig. 1B). Complex of pair of preanal appendages and apicodorsal lobe of segment IX (com.) bilobed from about basal 2/5, widely separated, large, U-shaped in dorsal aspect (Fig. 1B); each lobe finger-like in lateral aspect (Fig. 1A), with 3 tiny teeth apicomesally (2 dorsal, 1 ventral, inset for Fig. 1A). Anal sclerites (a.s.) fused basally, bilobed apically, each round apex with minute black denticles dorsally. Apical band (a.b.) long, curved posterad, dorsal margin connected to base of anal sclerite; ventral margin connected to base of sagittal appendage (s.a.) of tergal band (Fig. 1A); sagittal appendage trapezoidal in dorsal and ventral aspects (Fig. 1C). Basal segment of each inferior appendage (i.a.) thick in lateral aspect (Fig. 1A); posteromesal angle triangular, directed mesad in dorsal aspect (Fig. 1B); mesal face with ridged tendon (t.i.a.) along midline, extending to phallotheca (pha.) (Figs 1A, 1D). Distal segment of each inferior appendage bilobed, dorsal lobe club-like in lateral aspect (Figs 1A, 1D), ventral lobe semicircular in lateral aspect, both lobes with minute spines apicomesally. In phallic apparatus (Fig. 1E), aedeagus (ae.) bottle-shaped in dorsal and ventral aspects; parameres (para.) slender, club-like, apices curve laterad, and with tiny spines.

Female genitalia. Segment VIII (VIII) annular, but semi-membranous along dorsal and ventral midlines, with pair of dorsal weakly sclerotized extensions (Fig. 4C); pair of apodemal rods reaching posterior end of segment VI. Segment IX (IX) membranous, with pair of strongly sclerotized bands dorsolaterally extending into segment VI as

apodemal rods (Fig. 4B, ap. IX); fused with segment X (X) ventrally, pair of ventrolateral sclerotized bands extending to segment X (Fig. 4B). Segment X slender, with pair of strongly sclerotized bands dorsolaterally; fused with segment XI (XI) (Fig. 4B). In vaginal apparatus, processus spermathecae (p.s.) claw-like in lateral aspect (Fig. 4E), semicircular in ventral aspect (Fig. 4F); posterior process (p.p.) long rectangular in ventral aspect, more than 3 times longer than anterior width, face-down and saucer-shaped in lateral aspect (Fig. 4E).

Immature stages. Unknown.

Holotype. Male (in alcohol), Bangtaecheon Stream, Jindong-ri, Girin-myeon, Inje-gun, Gangwon-do, Korea, 38.024°N, 128.472°E, alt. 690 m, 23.v.2018, MS. Kang (net sweeping) (NIBR0000935610).

Paratypes. 1 male, 1 female, same data as the holotype (NIBR0000935608–0000935609); 4 males, 1 female, Samil River, Sanae-myeon, Hwacheon-gun, Gangwon-do, Korea, 10.vi.2014, T. Ito (net sweeping) (CBM-ZI 0180236–0180240).

Other specimens examined. KOREA: 2 males, 4 females, Gyebangsan, Gangwon-do, 11.vi.2014, T. Ito (net sweeping) (1 male, 2 females: SJP; 1 male, 2 females: TN).

Etymology. This species is dedicated to Ms. Mi-Sook Kang, who gifted us valuable specimens and information concerning Korean caddisflies, including this species.

Distribution. The Korean Peninsula (Gangwon-do, South Korea).

Remarks. This species was found in Gangwon-do, South Korea, where both *R. confissa* and *R. vicina* are distributed (Fig. 9). One of the sites where *R. confissa* was collected in this study is only 1.4 km from the type locality of *R. kangae* **sp. nov.** in the same stream (Bangtaecheon Stream). Although the genitalic morphology of the new species is similar to those of *R. confissa* and *R. vicina*, the differences in diagnostic characters described above are stable.

The male of *R. kangae* **sp. nov.** bears large compound eyes in proportion to its head width when compared with those of males of *R. confissa* and *R. vicina*, and also with those of females of these three species. The sexual dimorphism in the size of compound eyes observed in this new species suggests that the mating behavior of this species may differ from that of *R. confissa* and *R. vicina*.

Rhyacophila yamamotoi Nozaki sp. nov.

(Figs 5, 8, 9)

Rhyacophila sp. B: Morita 2009, 6–7, list.
Rhyacophila sp. 4: Kawase & Morita 2010, 36, list
Rhyacophila sp. 3: Yamamoto & Ito 2014, 7, list.

Diagnosis. Male and female of this species are most similar to those of *R. kangae* **sp. nov.** but can be distinguished by characters of the genitalic morphology. In males, the apex of each preanal appendage of this species is weakly bilobed apically in lateral aspect (Fig. 8B) but is rounded in *R. kangae* (Fig. 1A). Each paramere is expanded subapically in this species (Fig. 8E) but is club-like in *R. kangae* (Fig. 1E). In the female, the posterior process of the vaginal apparatus of this species is broader and thicker than that of *R. kangae* (Figs 4E, 4F, 5E, 5F). In Japan, the male genitalia of this species are somewhat similar to that of *Rhyacophila kawamurae* in lateral aspect, especially in the shape of the inferior appendages, but can be easily distinguished by the shape of the complex of a pair of preanal appendages and the apicodorsal lobe of segment IX in dorsal aspect: These are bilobed from the basal 1/3–1/2 in this species but bearing only a minute apical notch in *R. kawamurae* (Tsuda 1940, fig. 17).

Adult. Specimens in alcohol mostly dark brown to black, but legs light brown. Forewings each 8.0–11.5 mm in male (n = 10), 10.2–11.0 mm in female (n = 7). Ratio of width of eye to distance between eyes (a/b in Fig. 1F) 0.33–0.40 in male (n = 10) (Fig. 8A), 0.24–0.30 in female (n = 8).

Male genitalia. Segment IX longitudinally short in lateral aspect (Fig. 8B), ventral half longer than dorsum; membranous along midline in dorsal aspect (Fig. 8C). Complex of pair of preanal appendages and apicodorsal lobe of segment IX bilobed from basal 1/3–1/2, widely separated, large, U-shaped in dorsal aspect (Fig. 8C); in lateral aspect each lobe rectangular, apex slightly concave (Fig. 8B); with 2 teeth apicomesally, dorsal one small, ventral one tiny (inset of Fig. 8B). Anal sclerites fused basally, bilobed, each round apex with minute black denticles dorsally (Fig. 8C). Apical band long, curved posterad, ventral margin connected to sagittal appendage of tergal band (Fig. 8B); sagittal appendage round trapezoidal in dorsal and ventral aspects. Basal segment of each inferior appendage

thick in lateral aspect (Figs 8B, 8D); mesal face with ridged tendon longitudinally, extending to phallotheca (Figs 8B, 8D); posteromesal angle acute, directed mesad in dorsal aspect (Fig. 8C). Distal segment of each inferior appendage bilobed (Figs. 8B, 8D); both lobes club-like in lateral aspect, with minute spines apicomesally (Fig. 8D). In phallic apparatus, aedeagus bottle-shaped in dorsal and ventral aspects (Fig. 8E); with pair of parameres, each broadened subapically, with tiny spines apically in dorsal aspect (Fig. 8E).

Female genitalia. Segment VIII annular, but semi-membranous along dorsal midline, with pair of dorsal weakly sclerotized extensions (Fig. 5C); pair of apodemal rods reaching posterior end of segment VI. Segment IX membranous, with pair of dorsolateral apodemal rods extending into segment VI; fused with segment X ventrally, with pair of ventrolateral sclerotized band extending to segment X. Segment X slender, with pair of strongly sclerotized bands dorsolaterally; fused with segment XI. In vaginal apparatus, processus spermathecae claw-like in lateral aspect (Fig. 5E), semicircular in ventral aspect (Fig. 5F); posterior process tongue-like in ventral aspect (Fig. 5F), not more than 3 times longer than anterior width, elliptical in lateral aspect.

Immature stages. Unknown.

Holotype. Male (in alcohol). Namakusa-dani, Odamiyama, Uchiko-cho, Ehime, Shikoku, Japan, 33.560°N, 132.918°E, alt. 1225 m, 11–20.v.2020, E. Yamamoto (Malaise trap) (CBM-ZI 0180217).

Paratypes. 10 males, 2 females, same data as the holotype (CBM-ZI 0180218–0180229), 6 males, same data as the holotype excepting the collection period 11–20.vi.2020 (CBM-ZI 0180230–0180235); 1 male, 1 female, Izugatani-yama, Nishidani, Kumakogen-cho, Ehime, Japan, 1–10.v.2018, E. Yamamoto (Malaise trap) (NIBR0000935602–0000935603); 5 males, 2 females, same locality, 11–20.v.2018, E. Yamamoto (Malaise trap) (KPM-NK); 4 males, same locality, 21–31.v.2018, E. Yamamoto (Malaise trap) (NIBR0000935604–0000935607).

Other specimens examined. JAPAN: Honshu: Shizuoka: 1 male, tributary of Nishigochi-gawa, Yokosawa, Aoi-ku, Shizuoka-shi, alt. 550 m, 5.v.2006, T. Nozaki (net sweeping) (TN). Mie: 4 males, Sakashita, Kameyama-shi, 14.v.2006, N. Kawase (net sweeping) (MITR-20090042); 10 males, Ojigahata, Taga-cho, alt. 600 m, 19.v–8.vi.2009, H. Morita (Malaise trap) (NK). Shiga: 2 males, Yuzurio, Eigenji, Higashi-omi, 12–31.v.2009, N. Kawase (Malaise trap) (MITR-20090419). **Shikoku:** Ehime: 2 males, same data as holotype (TN); 1 male, Izugatani-yama, Nishidani, Kumakogen-cho, 21.vi.2018, E. Yamamoto (light trap) (TN); 14 males, 1 female, same locality, 1–30.vi.2018, E. Yamamoto (Malaise trap) (TN); 7 males, 1 female, same locality, 1.vii–10.viii.2018, E. Yamamoto (Malaise trap) (SJP). Kochi: 1 male, 1 female, Nishikuma-rindo, Monobe-cho, Kami-shi, M. Takai (TN); 1 male, Befu-kyo, Monobe-cho, Kami-shi, 24.iv.2004, M. Takai (TN).

Etymology. This species is dedicated to Mr. Eiji Yamamoto, who gifted us valuable specimens, including specimens of this species.

Distribution. Japan (Honshu, Shikoku).

Remarks. This species was found from two major islands, Honshu and Shikoku, in Japan (Fig. 9). The genitalic characteristics are consistent in both populations, and there are stable differences between this species and a Korean species, *R. kangae* **sp. nov.**

Rhyacophila confissa Botosaneanu 1970

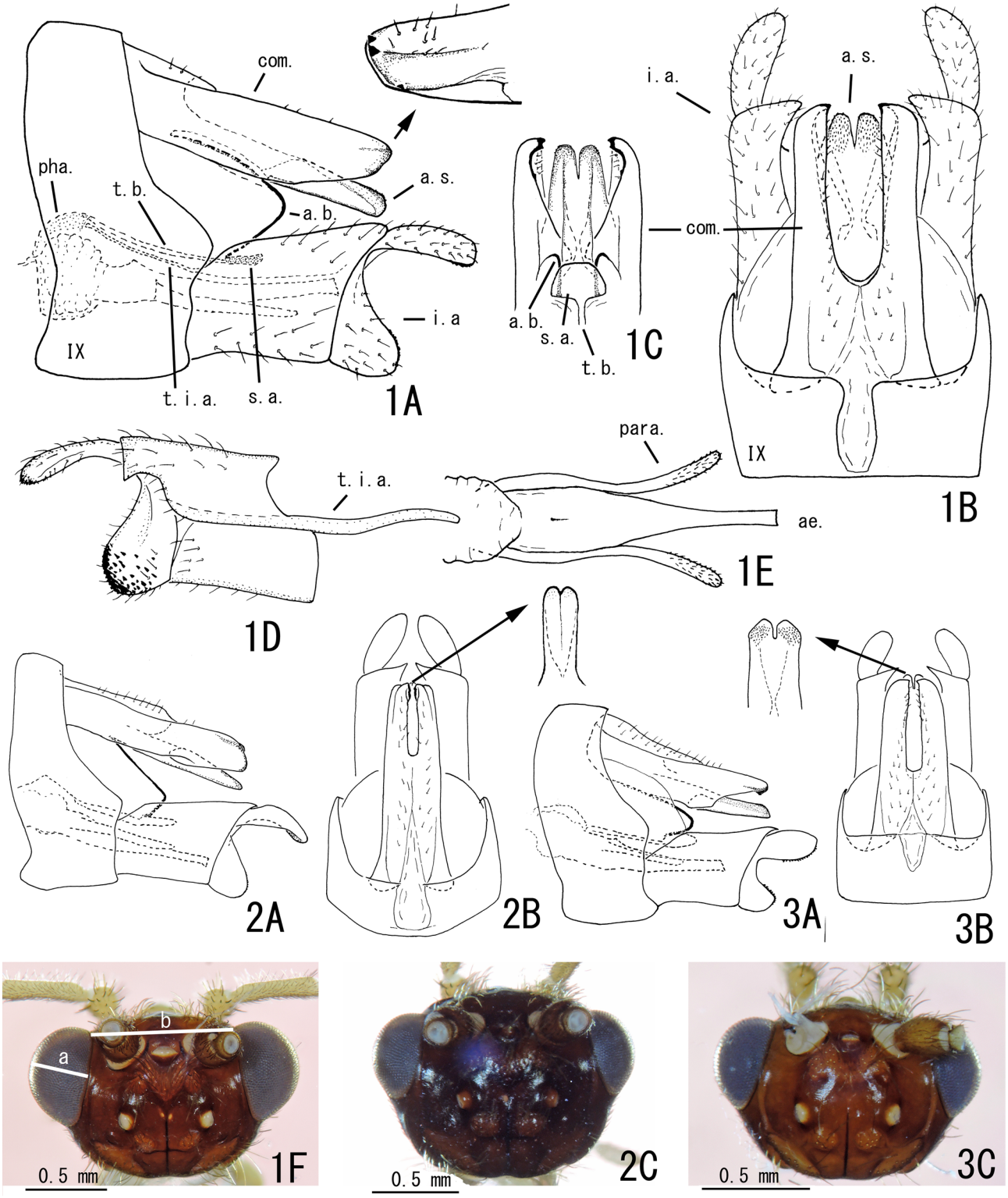
(Figs 2, 6, 9)

Rhyacophila confissa Botosaneanu 1970, 285–287, 326, 329, plate VI figs 1–5, plate IX figs 5–8, male, female.

Adult. Forewings each 10.0–11.5 mm in male (n = 14), 11.5–12.1 mm in female (n = 6). Ratio of width of eye to distance between eyes 0.23–0.31 in male (n = 10), 0.21–0.25 in female (n = 6).

Specimens examined. KOREA: 26 males, 3 females, Kangrimchon, Chiaksan National Park, Pugok-ri, Hoengsong-gun, Gangwon-do, 19.v.2000, T. Nozaki (net sweeping) (TN)); 4 males, 3 females, Gombaeryeong, Bangtaecheon Stream, Jindong-ri 218, Girin-myeon, Inje-gun, Gangwon-do, 23.v.2018, MS. Kang (net sweeping) (SJP); 2 males, Jangjeon Valley, Jangjeon-ri 218, Jinbu-myeon, Pyeongchang-gun, Gangwon-do, 16.v.2015, MS. Kang (net sweeping) (SJP); 4 males, Byeongjibang Valley, Byeongjibang-ri, Gapcheon-myeon, Hoengsung-gun, Gangwon-do, 06.v.2016, MS. Kang (net sweeping) (SJP); 1 male, 2 females, Geumcheon Valley, Geumcheon-ri, Daapmyeon, Gwangyang-si, Jeollanamdo, 9.iv.2016, MS. Kang (net sweeping) (SJP).

Distribution. The Korean Peninsula (South Korea and North Korea).



FIGURES 1–3. *Rhyacophila* spp., male. 1A–1F, *Rhyacophila kangae* **sp. nov.** 1A–1E, genitalia: 1A, left lateral, apicomesal part of complex of preanal appendages and apicodorsal lobe of segment IX enlarged; 1B, dorsal; 1C, upper part, ventral; 1D, left inferior appendage, mesal; 1E, phallic apparatus, dorsal. 1F, head, dorsal (a, b: see text). 2A–2C, *Rhyacophila confissa* Botosaneanu 1970: 2A, genitalia, left lateral; 2B, same, dorsal, anal sclerite enlarged; 2C, head, dorsal. 3A–3C, *Rhyacophila vicina* Botosaneanu 1970: 3A, genitalia, left lateral; 3B, same, dorsal, anal sclerite enlarged; 3C, head, dorsal. Abbreviations: a.b. = apical band, ae. = aedeagus, a.s. = anal sclerite, com = complex of preanal appendages and apicodorsal lobe of segment IX, i.a. = inferior appendage (paired), para. = paramere (paired), pha. = phallotheca, s.a. = sagittal appendage, t.b. = tergal band, t.i.a., = tendon of inferior appendage (paired), IX = segment IX.

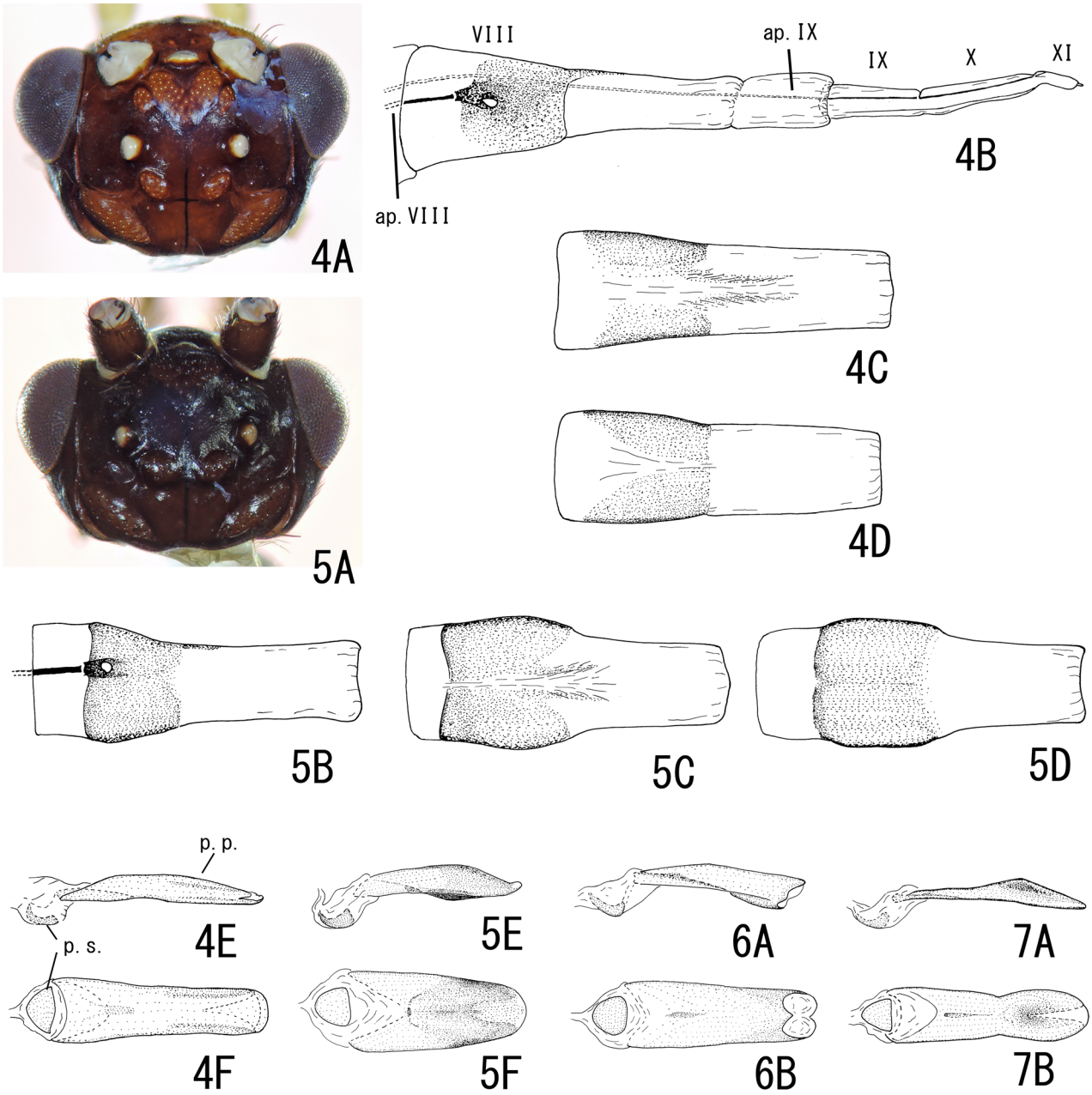


FIGURE 4–7. *Rhyacophila* spp., female. 4A–4F, *Rhyacophila kangae* **sp. nov.**: 4A, head, dorsal; 4B, abdominal segments VIII to XI, left lateral, 4C, abdominal segment VIII, dorsal; 4D, same, ventral; 4E, vaginal apparatus, left lateral; 4F, same, ventral. 5A–5E, *Rhyacophila yamamotoi* **sp. nov.**: 5A, head dorsal; 5B, abdominal segment VIII, left lateral; 5C, same, dorsal; 5D, same, ventral; 5E, vaginal apparatus, left lateral; 5F, same, ventral. 6A, 6B, *Rhyacophila confissa* Botosaneanu 1970: 6A, vaginal apparatus, left lateral; 6B, same, ventral. 7A, 7B, *Rhyacophila vicina* Botosaneanu 1970: 7A, vaginal apparatus, left lateral; 7B, same, ventral. Abbreviations: ap.VIII = apodemal rod of abdominal segment VIII (paired); ap.IX = apodemal rod of abdominal segment IX (paired); p.p. = posterior process; p.s. = processus spermathecae; VIII, IX, X, XI = abdominal segments VIII, IX, X, XI.

Rhyacophila vicina **Botosaneanu 1970**

(Figs 3, 7, 9)

Rhyacophila vicina Botosaneanu 1970, 287–288, 327, plate VII figs 1–6, male, female.
Rhyacophila jirisana Kobayashi, 1989, 4, 6, figs 3A, 3B, male. Synonymized by Nozaki *et al*. (2019).

Adult. Forewings each 8.5–10.0 mm in male (n = 12), 8.5–10.0 mm in female (n = 8). Ratio of width of eye to distance between eyes 0.25–0.31 in male (n = 12), 0.26–0.31 in female (n = 8).

Specimens examined. KOREA: 2 males, 1 female, Kangrimchon, Chiaksan National Park, Pugok-ri, Hoengsong-gun, Gangwon-do, 19.v.2000, T. Nozaki (net sweeping) (TN); 2 males, Jomurak Valley, Gapyeong-gun, Gyeonggi-do, alt. 410 m, 2.vi.2014, T. Nozaki (net sweeping) (TN); 2 males, 1 female, Myeonji Mt. Valley, Gapyeong-gun, Gyeonggi-do, alt. 269 m, 2.vi.2014, T. Nozaki (net sweeping); 1 male, 1 female, Myeonji Mt. Valley, Gapyeong-gun, Gyeonggi-do, alt. 250 m, 3.vi.2014, T. Nozaki (light trap) (TN); 5 males, 5 females, Gwangchi Valley, Gaojak-ri, Yanggu-gun, Gangwon-do, 26.v.2015, MS. Kang (net sweeping) (SJP); 4 males, Sambong National Recreation Forest, Gwangwon-ri, Nae-myeon, Hongcheon-gun, Gangwon-do, 14.v.2018, MS. Kang (net sweeping) (SJP); Choamsa Temple, Jukgyegugok Valley, Baejeom-ri, Sunheung-myeon, Yeongju-si, Gyeongsangbuk-do, 1.vi.2013, MS. Kang (net sweeping) (SJP).

Distribution. The Korean Peninsula (South Korea and North Korea), Russia (South Primorye), China (Liaoning).

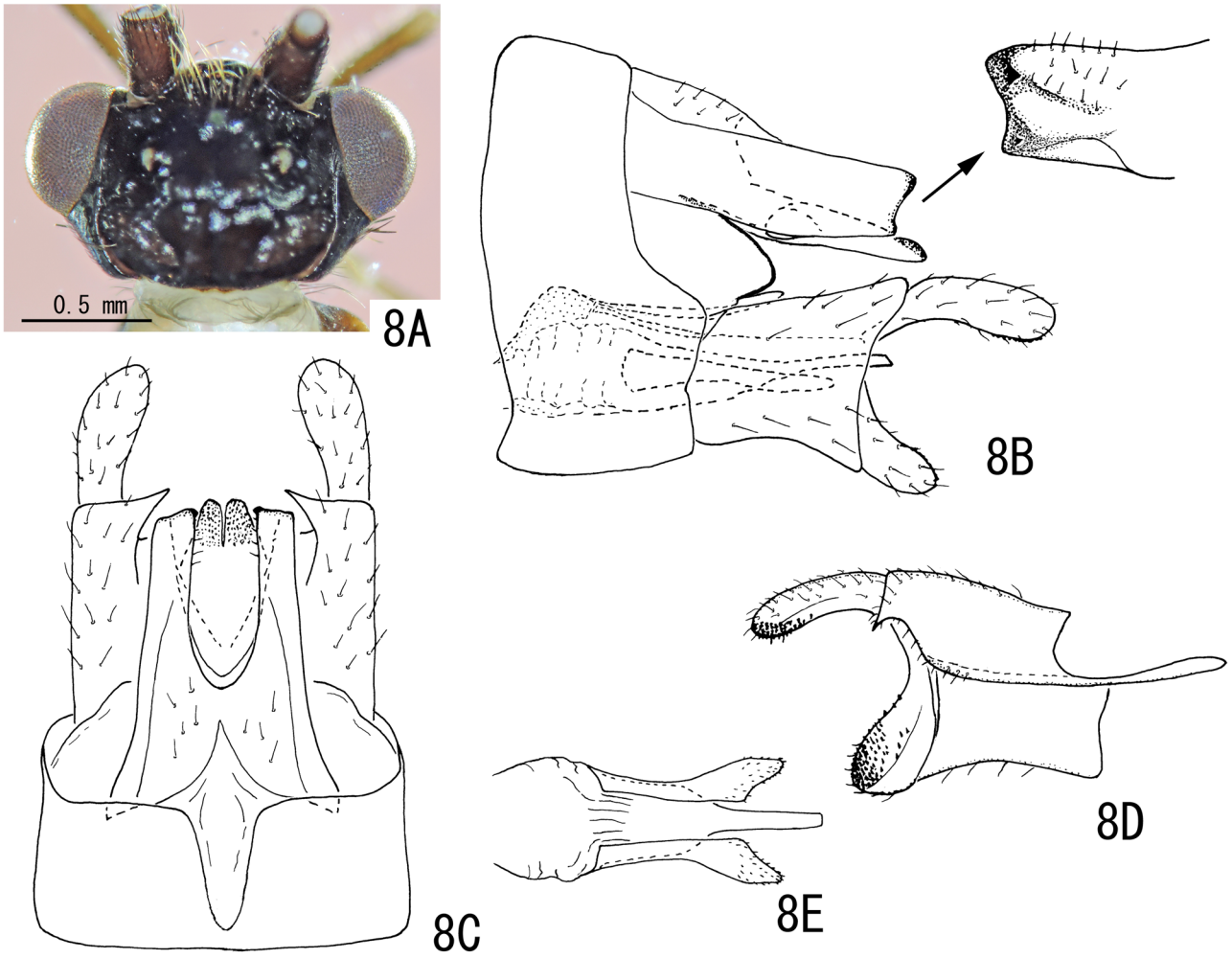


FIGURE 8. *Rhyacophila yamamotoi* **sp. nov.**, male. 8A, head, dorsal. 8B–8E, genitalia: 8B, left lateral, apicomesal part of complex of preanal appendages and apicodorsal lobe of segment IX enlarged; 8C, dorsal; 8D, left inferior appendage, mesal; 8E, phallic apparatus, dorsal.

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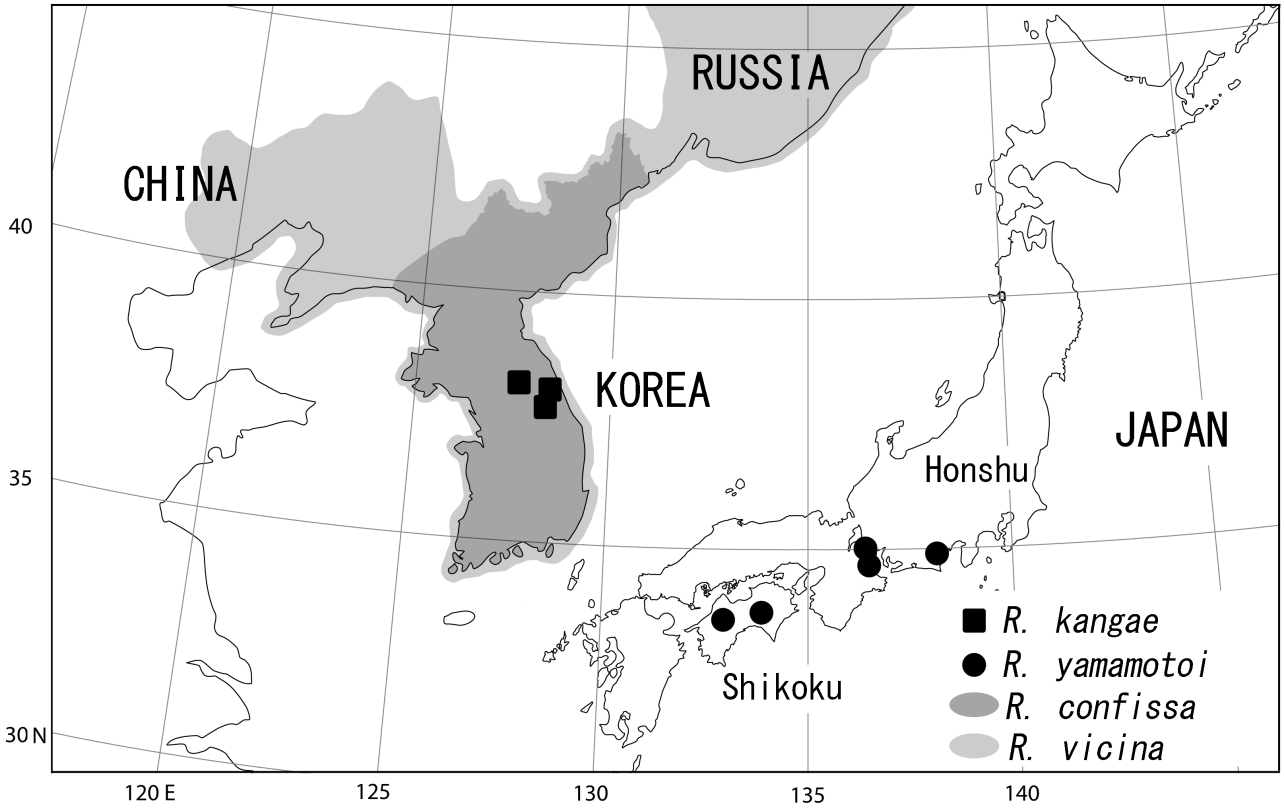

FIGURE 9. Distributions of 4 *Rhyacophila* species in East Asia. Distribution areas of *R. confissa* and *R. vicina* are cited from Ivanov (2011), Park & Kong (2020), and Yang *et al*. (2016).

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