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Description of two new species of the genus *Chlorogomphus* Selys, 1854 (Odonata: Chlorogomphidae) and a new record of *Chlorogomphus gracilis* Wilson & Reels, 2001 from the Central Highlands of Vietnam

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Abstract. Two new species of the genus *Chlorogomphus* are described based on both sexes collected from the Central Highlands of Vietnam. These species are *C. hoaian* sp. nov. (holotype male from Kon Ka Kinh National Park, 14.3672° N, 108.5368° E, alt. 1000 m) and *C. vani* sp. nov. (holotype male from Chu Yang Sin National Park, 12.4780° N, 108.4617° E, alt. 749 m). Furthermore, *C. gracilis* Wilson & Reels, 2001 is recorded from Vietnam for the first time, with notes on its morphology and detailed illustrations of male and female structures.

Keywords. Odonata, *Chlorogomphus,* new species, Vietnam.

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Introduction

The genus *Chlorogomphus* Selys, 1854 comprises 45 species (Paulson *et al.* 2021), with several unidentified species recorded from China by Zhang (2019). In Vietnam, Martin (1910) described *C. auratus*, and Martin & Asahina (1969) described *C. vietnamensis* Asahina from northern regions, all based on female specimens. Males were subsequently described by Karube (1995, 2013). Karube (1995) described four new species, namely *C. albomarginatus*, *C. nakamurai*, *C. sachiyoae* and *C. takakuwai*, and recorded *C. nasutus* Needham, 1930 from Vietnam. Asahina (1995, 1998) also reported *C. auratus*, *C. nasutus*, *C. takakuwai*, *C. nakamurai* and *C. miyashitai* Karube, 1995, all from northern Vietnam. Recently, several new species have been discovered, and new records have been documented from different Vietnamese locations: *C. hiten* (Sasamoto, Yokoi & Teramoto, 2011), *C. papilio* Ris, 1927 and *C. piaoacensis* Karube, 2013 were discovered in the North; *C. canhvang* Kompier & Karube, 2018 and

C. danhkyi Phan, Karube, Hung & Anh, 2021 were found in the Central-North; and *C. aritai* Karube, 2013 and *C. caloptera* Karube, 2013 were collected from the Central Highlands (Karube 2013, 2015; Kompier 2014; Kompier & Karube 2018; Phan *et al.* 2021).

Here, we describe two additional species, *Chlorogomphus hoaian* sp. nov. from Kon Ka Kinh National Park, Gia Lai Province, and *C. vani* sp. nov. from Chu Yang Sin National Park, Dak Lak Province, and provide a new record of *C. gracilis* Wilson & Reels, 2001 from Ngoc Linh Nature Reserve, Kon Tum Province. All these locations are located in the Central Highlands of Vietnam. With these two new species and one new record, the total number of species of *Chlorogomphus* in Vietnam reaches 18. We also provide detailed color photographs and illustrations of the male and female structures of *C. gracilis* and discuss its morphological variations.

The systematics of the genus *Chlorogomphus* in Vietnam has been a controversial issue. Karube (2013) allocated 10 Vietnamese species within six subgenera as follows: *Neorogomphus* Carle, 1995 (type species: *C. fraseri* St. Quentin, 1936; including *C. auratus* and *C. caloptera*), *Nubatamachlorus* Karube, 2013 (type species: *C. nakamurai*; including *C. aritai*), *Vietnamchlorus* Karube, 2013 (including only the type species, *C. albomarginatus*), *Orogomphus* Selys, 1878 (type species: *C. splendidus* (Selys, 1878); including *C. piaoacensis*), *Sinorogomphus* Carle, 1995 (type species: *C. nasutus*; including *C. tunti* Needham, 1930, *C. sachiyoae* and *C. vietnamensis*) and *Petaliorogomphus* Karube, 2013 (type species: *C. takakuwai*). Phan *et al.* (2021) followed this systematic arrangement and placed a new species, *C. danhkyi*, in the subgenus *Orogomphus* without explanation. Karube & Phan (2016) recorded *C. papilio* and Kompier & Karube (2018) described *C. canhvang* from Vietnam, without assigning these species to any subgenus. According to Karube (2013), the subfamilial taxonomy within Chlorogomphidae has long been debated, including the allocation of many doubtful species described based only on female specimens. These issues require a complete revision study based on morphology and molecular phylogeny (Karube 2013). Based on our knowledge, the current systematics within this family is a complicated problem, and the supporting DNA evidence is still lacking. Therefore, it would be imprudent to assign the two new species to any subgenus, as Karube (2013) suggested.

Material and methods

Specimens were collected and kept alive for 24 hours to remove their intestinal contents. They were subsequently steeped in acetone for 12–18 hours and dried for 2–4 hours. Each specimen is preserved in a square paper envelope accompanied by locality data. Specimens were examined and photographed using a Zeiss Stemi 508 microscope with an Axiocam Erc 5s camera. Habitus photos of type specimens were taken with a Nikon D850 digital camera and a Nikon AFS DX Micro Nikkor with an 85 mm f/3.5G ED VR lens. Illustrations were rendered using Photoshop ver. 7.0 software.

We generally followed the terminology in Kompier & Karube (2018). The only exception is the term "valvula valvae", referring to the structure on the ventral 8th abdominal segment; this term was described by Karube (2013).

The material described here has been deposited at the Zoological Collection of Duy Tan University, Da Nang, Vietnam (ZCDTU) and at Kanagawa Prefectural Museum of Natural History, Odawara, Japan (KPMNH).

We also provide photographs of specimens of other species of *Chlorogomphus*, namely:

Chlorogomphus fraseri St. Quentin, 1936: 1 ♂, India, Meghalaya, Shilling, Khasi Hills, unknown date and collector (KPMNH Khasi01-ODO).

Chlorogomphus aritai Karube, 2013: 1 ♂, Vietnam, Da Nang City, Ba Na Nui Chua Nature Reserve, 15.9966° N, 108.0067° E, alt. 1200 m, 19 Jun. 2017, Q.T. Phan leg. (ZCDTU 2017061901-ODO); 1 ♀, Vietnam, Da Nang City, Hoa Vang District, Hoa Trung Commune, 16.0947° N, 108.0349° E, alt. 234 m, 19 Jun. 2021, Q.T. Phan leg. (ZCDTU 2021061901).

Chlorogomphus auratus Martin, 1910: 1 ♀, Vietnam, Lang Son Province, Loc Binh District, Mau Son Mount, 21.8454° N, 106.9220° E, alt. 876 m, 9 Jun. 2020, Q.T. Phan leg. (ZCDTU 2020060905-ODO).

Chlorogomphus caloptera Karube, 2013: 1 ♀, Vietnam, Lam Dong Province, Bao Loc City, Doi Cao, 11.6430° N, 107.6889° E, alt. 746 m, 22 Apr. 2016, Q.T. Phan leg. (ZCDTU 2016042201-ODO).

Abbreviations

Ax = antenodal crossveins
Fw = fore wing
Hw = hind wing
Pt = pterostigma
Px = postnodal crossveins
S1–10 = abdominal segments 1 to 10

Results

Class Insecta Linnaeus, 1758
Order Odonata Fabricius, 1793
Suborder Anisoptera Selys, 1854
Family Chlorogomphidae Needham, 1903
Genus *Chlorogomphus* Selys, 1854

Chlorogomphus hoaian sp. nov.
urn:lsid:zoobank.org:act:52E0216D-18F2-4C0A-A7E0-523778EBDFA2
Figs 1–14, 21, 24–25, 61

Diagnosis

In lateral view, *Chlorogomphus hoaian* sp. nov. shows short, robust cerci and an epiproct which are generally similar to those of seven other species: *C. aritai, C. arooni* Asahina, 1981, *C. caloptera*, *C. daviesi* Karube, 2001, *C. fraseri*, *C. nakamurai* and *C. yokoii* Karube, 1995. However, *C. hoaian* sp. nov. is different from these seven species in major characteristics (alternative characters for the seven other species in parentheses): the cerci (Figs 12–13) are subequal in length to the epiproct (half as long except in *C. caloptera*); the dorsoposterior margin of S10 is broadly convex (narrowly convex); the length of the cerci is half that of the epiproct and S10 extends apically (except in *C. caloptera*, *C. arooni* (Asahina 1981: figs 7–8), *C. caloptera* (Karube 2013: fig. 6g), *C. daviesi* (Karube 2001: figs 5–6) and *C. yokoii* (Karube 1995: figs 15–16); the cerci are acute apically (Fig. 12) (blunt apically in *C. nakamurai*; see Karube 1995: figs 36–37).

Chlorogomphus hoaian sp. nov. is most similar to *C. fraseri* and *C. aritai* by the length of the cerci relative to that of the epiproct. Compared to *Chlorogomphus fraseri*, the cerci of *C. hoaian* sp. nov. are triangular in lateral view (Fig. 12), widely separated basally in dorsal view and lack a laterobasal spine (Fig. 13); the epiproct in lateral view is triangular, expanded posteroventrally and armed with a pair of erect inner dorsal projections, separated from each other by a distance greater than the basal width of each projection (Fig. 13) and directed laterally near the apex (Figs 12–14). In *C. fraseri*, the cerci are broad basally in dorsal view (Fig. 16), abruptly narrowed thereafter, with the apex strongly

bent ventrally in lateral view (Fig. 15), abruptly swollen basally medially and laterally in dorsal view (Fig. 16); the bifurcate epiproct in lateral view extends slightly beyond the level of the tip of the cerci; in dorsal view the apex of the epiproct is armed with small teeth dorsally, laterally and apically, with a pair of subbasal, bidentate inner dorsal projections (Figs 15–17). Although structurally similar, the known ranges of the two species are separated by about 2200 km (Fig. 63).

Compared to those of *Chlorogomphus aritai*, the male cerci of *C. hoaian* sp. nov. are armed with a pair of large inner dorsal projections, easily visible in lateral view (Fig. 12), dorsally smoothly concave basally and then slightly convex distally, the apex not pointed in dorsal view and directed posterolaterally (Fig. 13), whereas in *C. aritai*, the inner dorsal projections are short, not visible in lateral view (Fig. 18) and the cercus is armed laterobasally with a strong acute spine, its apex acute and directed posteriorly (Fig. 19). The epiproct of *C. hoaian* sp. nov. is widely divaricate, broadly U-shaped (Fig. 14), but in *C. aritai*, the branches of the epiproct are strongly curved with tips almost touching, forming an incomplete circle (Fig. 20).

The wing pattern in females of *Chlorogomphus hoaian* sp. nov. is similar to that of *C. caloptera* (Figs 21, 23), but the brownish markings on both wings are less extensive than those in *C. aritai* (Fig. 22). Moreover, the vertex in the female of *C. hoaian* sp. nov. is armed posteriorly with a well-developed club-like process (Fig. 25), somewhat similar to *C. aritai* (Karube 2013: fig. $8b_2$), while the posterior margin of the vertex is deeply incised in *C. caloptera* (Karube 2013: fig. 6b). No specimens of *C. fraseri* females have been reported.

Etymology

'*Hoaian*', named after Mrs Van Cong Hoai An (born 1992) of Da Nang City, Vietnam, the wife of the first author, a noun in apposition.

Material examined

Holotype

VIETNAM – **Gia Lai Province** • ♂; Mang Yang District, Ayun Commune, streams about 2 km from Kon Ka Kinh National Park Headquarters; 14.3672° N, 108.5368° E; alt. 1000 m; 20 Apr. 2019; Q.T. Phan leg.; ZCDTU 2019042001-ODO.

Paratypes (13 ♂♂, 5 ♀♀)

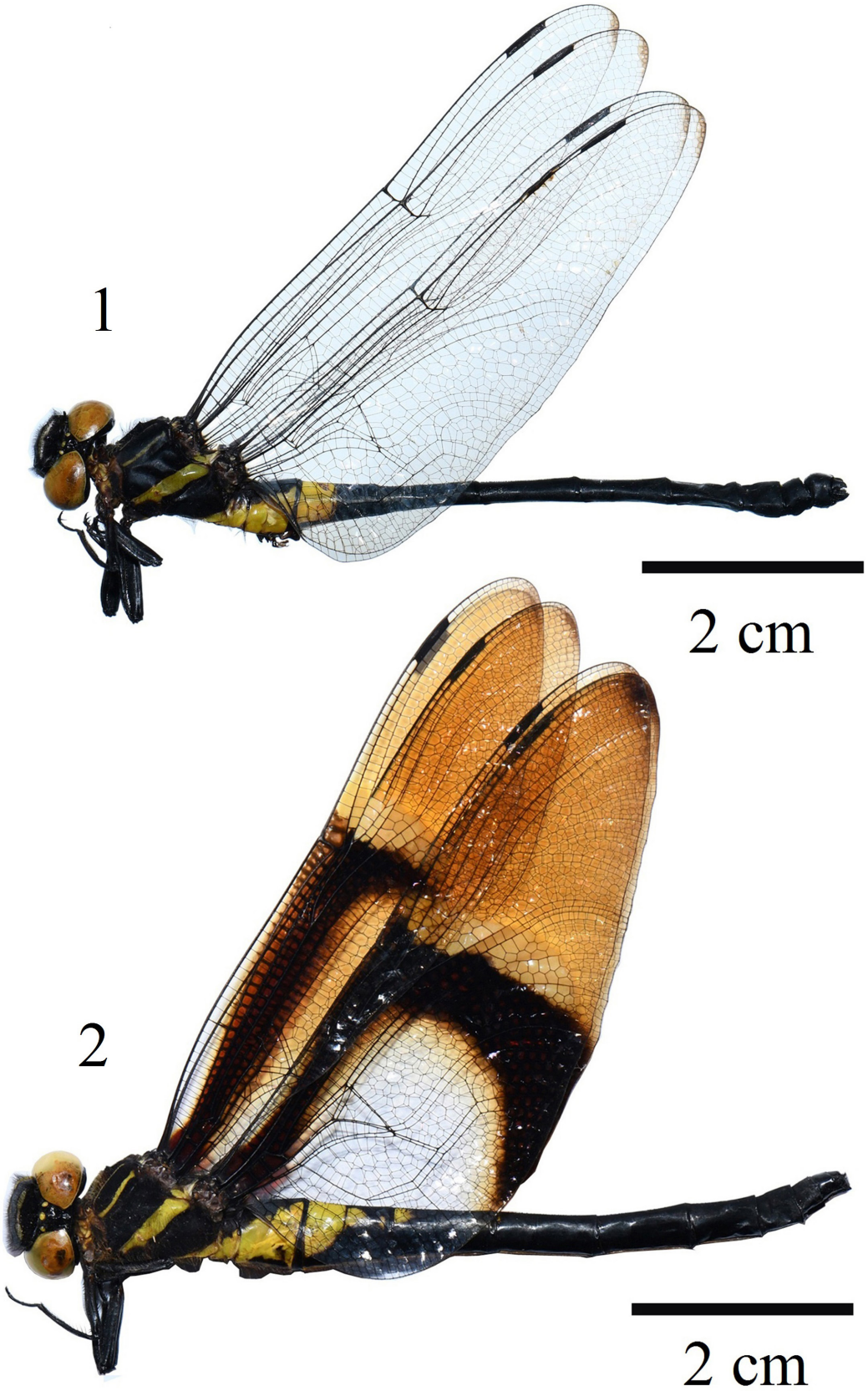
VIETNAM – **Gia Lai Province** • 1 ♂, 2 ♀♀; same collection data as for holotype; ZCDTU 2019042002-ODO to 2004-ODO • 7 ♂♂; same locality and collector as for holotype; 20 May 2018; ZCDTU 2018052001-ODO to 2006-ODO • 4 ♂♂, 1 ♀; same collection data as for preceding; KPMNH 2018052007 to 2011 • 1 ♀; Ka Bang District, Dak Roong Commune, Dak Trum village; 14.6845° N, 108.7667° E; alt. 923 m; 24 May 2018; Q.T. Phan leg.; ZCDTU 2018052401-ODO. – **Kon Tum Province** • 1 ♂, 1 ♀; Dak Glei District, Dak Man Commune, 2 km from Headquarters of Ngoc Linh Nature Reserve; 15.1471° N, 107.7526° E, alt. 1008 m; 7 Jun. 2019; Q.T. Phan leg.; ZCDTU 2019060701-ODO to 0702-ODO.

Description

Male (Figs 1, 3–4, 7–9, 12–14, 24)

Measurements. Hw 51 mm long, abdomen (including anal appendages) 55 mm long.

Head. Labrum shines black with a small U-shaped yellow marking medially. Anteclypeus black, with lower and upper margins yellow. Postclypeus yellow with lower margin black. Antefrons entirely black. Postfrons black with a large transverse yellow stripe. Distance between eyes 0.7 mm. Antennae



Figs 1–2. Habitus of *Chlorogomphus hoaian* sp. nov. **1**. Holotype, ♂ (ZCDTU 2019042001-ODO). **2**. Paratype, ♀ (ZCDTU 2019042003-ODO).

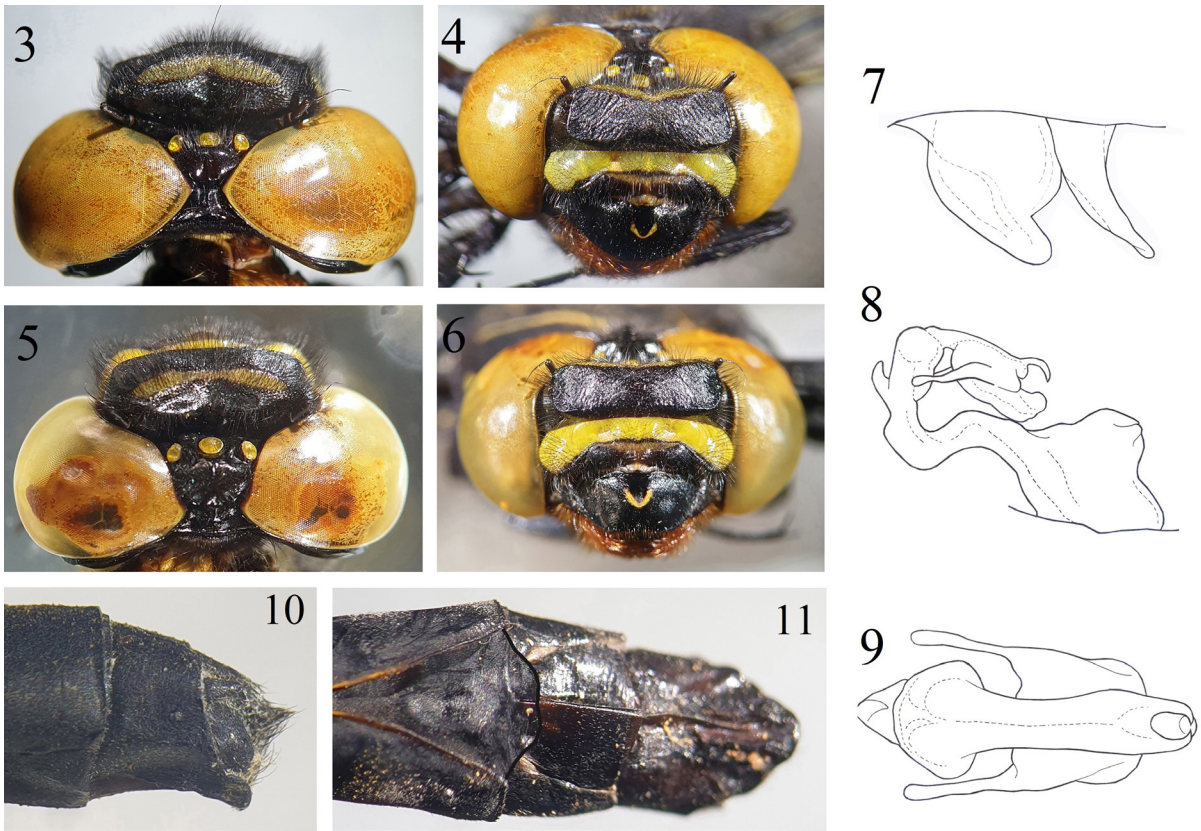
black with pale second segment of anterior part (Figs 3–4). Vertex subtriangular with a longitudinal prominence dorsally (Fig. 24). Occiput black, triangular, armed with long setae posteriorly.

Thorax. Prothorax black with anterior margin of anterior pronotal lobe yellow. Synthorax black with a dorsal thin whitish stripe and a narrow antehumeral stripe along lower margin of mesepisternum. Mesepimeron entirely black with a broad, almost parallel-sided yellow stripe covering spiracle; metepimeron black, lined with a narrow yellow stripe on ventral margin. Legs black (Fig. 1).

Wings. Wings hyaline, brownish at tip. Ax/Px ratio 28/16 in Fw and 19/17 in Hw. All wings with a median space with 2 crossveins. Anal triangle in Hw with 3 cells. Triangles of all wings with 3 cells, with basal side longer than costal side. In all wings, cubital space with 8–9 crossveins. Anal loop with 16 cells. Pt black, 4.5–5 mm long in all wings, covering 3–3.5 underlying cells (Fig. 1).

Abdomen. S1 with a broad oblique stripe, terminating dorsally at end of S2; basal half of S3 yellow and S4–10 black (Fig. 1).

Secondary genitalia. Anterior lamina in lateral view robust, broad basally, tapering towards apex, strongly petiolate posteriorly. Posterior hamule slender, slightly longer than anterior lamina, curved anteriad (Fig. 7).



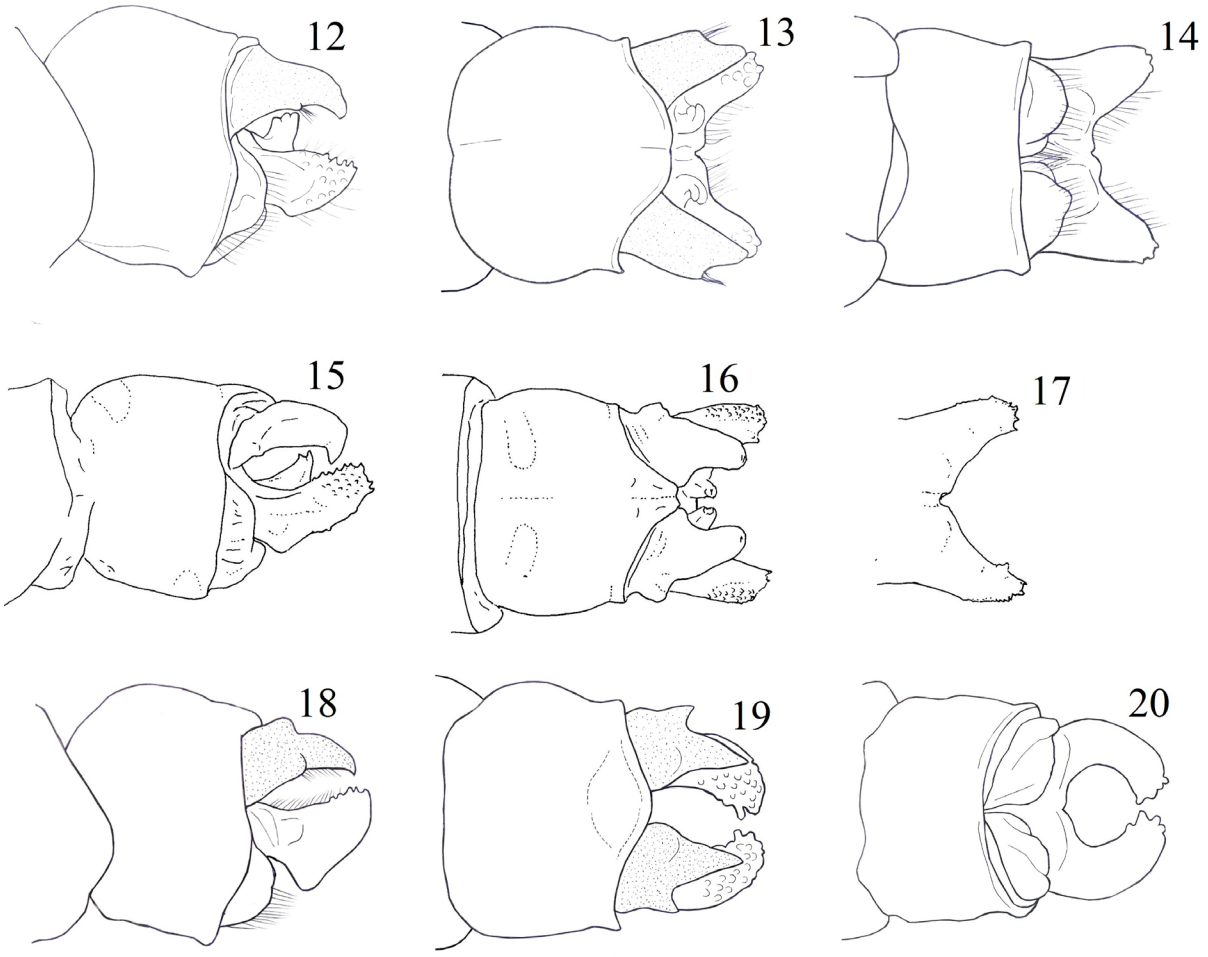
Figs 3–11. Features of *Chlorogomphus hoaian* sp. nov., holotype, ♂ (3–4, 7–9) (ZCDTU 2019042001-ODO) and paratype, ♀ (5–6, 10–11) (ZCDTU 2019042003-ODO). **3–4**. Head in dorsal and frontal views. **5–6**. Head in dorsal and frontal views. **7**. Accessory genitalia. **8**. Vesica spermalis in lateral view. **9**. Terminal segment of vesica spermalis in ventral view. **10–11**. Abdominal tip in lateral and ventral views. Images not to scale.

Vesica spermalis. With typical shape in genus. Terminal segment with a well-developed lateral keel with a pair of long, curvilinear directed projections at posterior corners. Apical lobes of ventral plate short, hook-like in lateral view. Dorsal part of terminal segment subequal to ventral part. Second segment broad, with a stout spine (Figs 8–9).

Anal appendages. Black. Cercus in lateral view shorter than S10, broad basally, tapering toward apex, with tip curved posteroventrally (Fig. 12) and a small lateral projection with long setae apically on distal third. In dorsal view, cerci widely separated at tip, concave subapically (Fig. 13). Epiproct slightly longer than cerci, bearing a pair of large inner dorsal projections, broadly based and tridentate. In lateral view, epiproct expanded apically, dorsal margin serrated apically, inner dorsal projections clearly visible (Fig. 12). In dorsal view, epiproct deeply incised, U-shaped, branches widely separated (Fig. 14). In ventral view, epiproct broad at base, rounded apically (Fig. 14).

Female (Figs 2, 5–6, 10–11, 21, 25)

Measurements. Hw 60 mm long, abdomen (including appendages) 56 mm long.

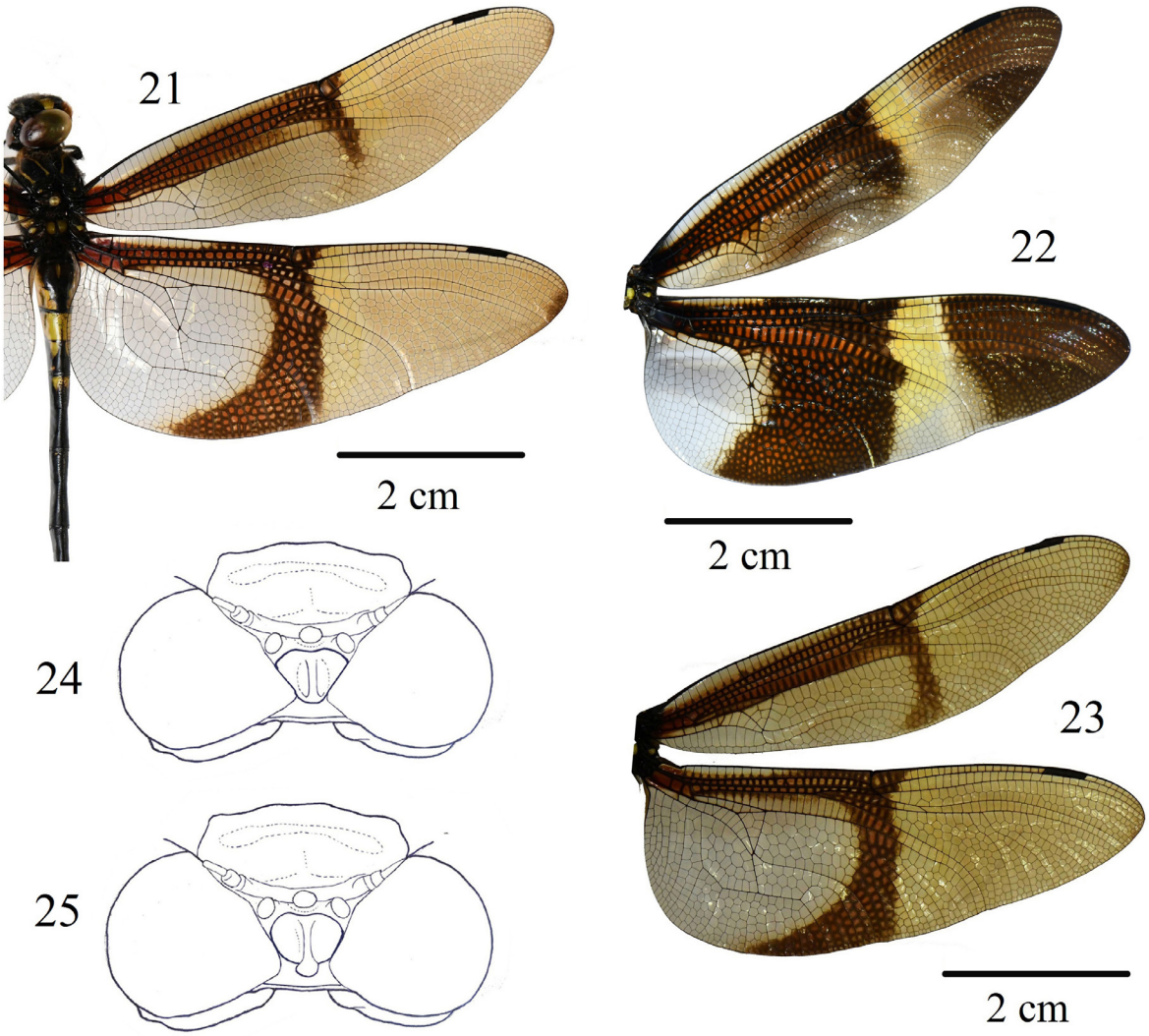


Figs 12–20. Anal appendages of species of *Chlorogomphus* Selys, 1854, ♂♂. **12–14**. *C. hoaian* sp. nov., holotype (ZCDTU 2019042003-ODO). **15–17**. *C. fraseri* St. Quentin, 1936 (KPMNH Khasi01-ODO). **18–21**. *C. aritai* Karube, 2013 (ZCDTU 2017061901-ODO). **12, 15, 18**. Anal appendages in lateral view. **13, 16, 19**. Anal appendages in dorsal view. **14, 17, 20**. Epiproct in ventral view. Images not to scale.

Head. As in holotype male, but yellow stripe on postfrons slightly narrower (Figs 5–6) and vertex broadly spherical, with a longitudinal raised area terminating posteriorly as an expanded, club-like prominence (Fig. 25). Distance between eyes 1.5 mm.

Thorax and legs. As in holotype male (Fig. 2).

Wings. Hyaline with black venation. Wing colour pattern tinged with dark golden yellow and patterned as follows: on Fw, brownish band covers space between subcosta to MA vein, runs from base to just beyond nodus, extends from this point, reaching to cubital vein. Wing tip slightly brownish. Hw with a broad, arcuate brown band encompassing most of antenodals (but anterior half of antenodals hyaline), extending posteriorly to wing margin and expanding posteromedially beyond level of triangle, surrounding a large, oval hyaline patch basally. Area between brown band and small darkened mark at wing tip tinged with yellow (Figs 2, 21). Ax/Px ratio 33/17 in Fw and 24/21 in Hw. Median space with



Figs 21–25. 21–23. Right wings of species of *Chlorogomphus* Selys, 1854, ♀♀. **21**. *C. hoaian* sp. nov. (ZCDTU 2019042003-ODO). **22**. *C. aritai* Karube, 2013 (ZCDTU 2021061901). **23**. *C. caloptera* Karube, 2013 (ZCDTU 2016042201-ODO). **24**. Head of *C. hoaian* sp. nov., holotype, ♂ (ZCDTU 2019042001-ODO). **25**. Head of *C. hoaian* sp. nov., paratype, ♀ (ZCDTU 2019042003-ODO). 24–25 not to scale.

2 crossveins on all wings. Triangles 4-celled in Fw and 5-celled in Hw. Basal side of triangles of Hw longer than costal side. Cubital space with 10–11 cells in all wings. Anal loop with 26 cells. Pterostigma black, 4.2–4.5 mm long on all wings, covering 3.5–4 underlying cells.

Abdomen. Abdominal pattern as in holotype male, but yellow pattern slightly more extensive. S4–5 mostly black with a yellow spot at anterior margin. Yellow spot on S5 small. S6–10 entirely black (Fig. 2).

Cerci. Entirely black, narrow. Length ⅓ that of S10 (Fig. 10). Valvula valvae trapezoidal-shaped, as shown in Fig. 11. Ventral projection of S10 reaches slightly beyond equal cerci (Fig. 10).

Morphological variation in paratypes

Measurement variation. Males: Hw 52–53 mm long, abdomen (including anal appendages) 52–56 mm long. Females: Hw 57–58 mm long, abdomen (including appendages) 55–58 mm long.

Wing venation. Males: Ax/Px ratio 26–29/14–16 in Fw and 19–23/16–17 in Hw. Cubital space with 8–9 crossveins in all wings. Anal loop 15–17-celled. Females: Ax/Px ratio 31–33/17–18 in Fw and 22–25/21 in Hw. Triangles of all wings 4–5-celled. Cubital space with 10–11 cells in all wings. Anal loop with 25–26 cells.

Other characters. The S4 in a male from Ngoc Linh Nature Reserve has a tiny yellow spot at the anterior end (entirely black in the holotype and other male specimens). The width of the brown band on Hw of the female specimens from Ngoc Linh (ZCDTU 2019060701-ODO and 0702-ODO) and Dak Trum (ZCDTU 2018052401-ODO) are much narrower than in specimens from the type locality.

Distribution

Vietnam (Fig. 61: yellow circle): Kon Tum Province (Dak Glei District) and Gia Lai Province (Mang Yang District and Ka Bang District).

Habitat and ecology

The new species was discovered coursing up and down over small streams (2–4 m width) interspersed with large stones within dense vegetation in a pristine forest. No other specimens of *Chlorogomphus* were found at the type locality.

Chlorogomphus vani sp. nov.
urn:lsid:zoobank.org:act:9C02830B-F58F-4024-A1E3-C7BE8DCCC11B
Figs 26–38, 43, 45–46, 62

Diagnosis

Within this genus, the new species seems to be closest to *Chlorogomphus auratus* and *C. canhvang* based on the similar male appendage morphology and the amber pattern on the female wings. *Chlorogomphus vani* sp. nov. differs from two above mentioned species by the following characters: In the male anal appendage morphology, (1) in lateral view, the cercus is shorter than the epiproct (Fig. 37), while it is subequal in *C. auratus* (Fig. 39) and *C. canhvang* (Fig. 41); (2) in dorsal view, the cercus is simple and bluntly acute apically (Fig. 38), while it is expanded apically in *C. auratus* (Fig. 40) and *C. canhvang* (Fig. 42); (3) in lateral view, S10 has no protrusion between the cerci in *C. vani* sp. nov. (Fig. 37), but this structure is clearly visible and stout in *C. auratus* (Fig. 39); and (4) the secondary genitalia of *C. vani* sp. nov. are similar to those in *C. auratus* (Karube 1995: fig. 8) but its anterior lamina is subequal in length to the posterior hamule (Fig. 32), while in *C. canhvang*, the anterior lamina is half the length of

the posterior hamule (Kompier & Karube 2018: fig. 3c). In the female, (1) the tinted golden area is less extensive and lacks the black wing tips (Fig. 43), while these features are obvious in *C. canhvang* and *C. auratus* (Fig. 44); (2) the shape of the female vertex is posterodorsally concave in *C. vani* sp. nov. and *C. canhvang* (Fig. 46), but the posterodorsal margin of the vertex of *C. auratus* is rounded (Kompier & Karube 2018: fig. 3a); (3) in the synthoracic pattern, *C. vani* sp. nov. has five narrow yellowish stripes (Fig. 27), but *C. auratus* and *C. canhvang* only have three stripes (Kompier & Karube 2018: fig. 1b, e); and (4) the yellow marking on the abdomen of *C. vani* sp. nov. (Fig. 43) is less extensive than in *C. auratus* or *C. canhvang* (Kompier & Karube 2018: fig. 1c, f).

Female specimens of *Chlorogomphus auripennis* Zhang & Cai, 2014 from southern China also have golden wings, but with a different pattern (Zhang & Cai 2014: figs 2–3). The male of this species is easily distinguished from that of *C. auratus*, *C. canhvang* or *C. vani* sp. nov. by its cercus having a stout ventral spine at the basal ⅔, thus being forked in dorsal view (Zhang & Cai 2014: figs 6–7).

The anal appendages of *Chlorogomphus shanicus* Wilson, 2002 are somewhat similar to those of *C. vani* sp. nov., but the epiproct is relatively longer than the cerci and deeply incised in dorsal view (Wilson 2002: figs 12–13).

Etymology

'*Vani*', a noun in the genitive case, is named after Mr Dang Ngoc Van (born 1987), resident of Bao Loc District of Lam Dong Province, who kindly supplied the authors with the specimens of this new species, as well as other material from southern Vietnam.

Material examined

Holotype

VIETNAM – **Dak Lak Province** • ♂; K'Rong Bong District, Hoa Phong Commune, Chu Yang Sin National Park; 12.4780° N, 108.4617° E; alt. 749 m; 20 Apr. 2021; Dang Ngoc Van leg.; ZCDTU 2021042001-ODO.

Paratypes

VIETNAM – **Dak Lak Province** • 1 ♂, 4 ♀♀; same collection data as for holotype; ZCDTU 2021042002-ODO to 2006-ODO.

Description

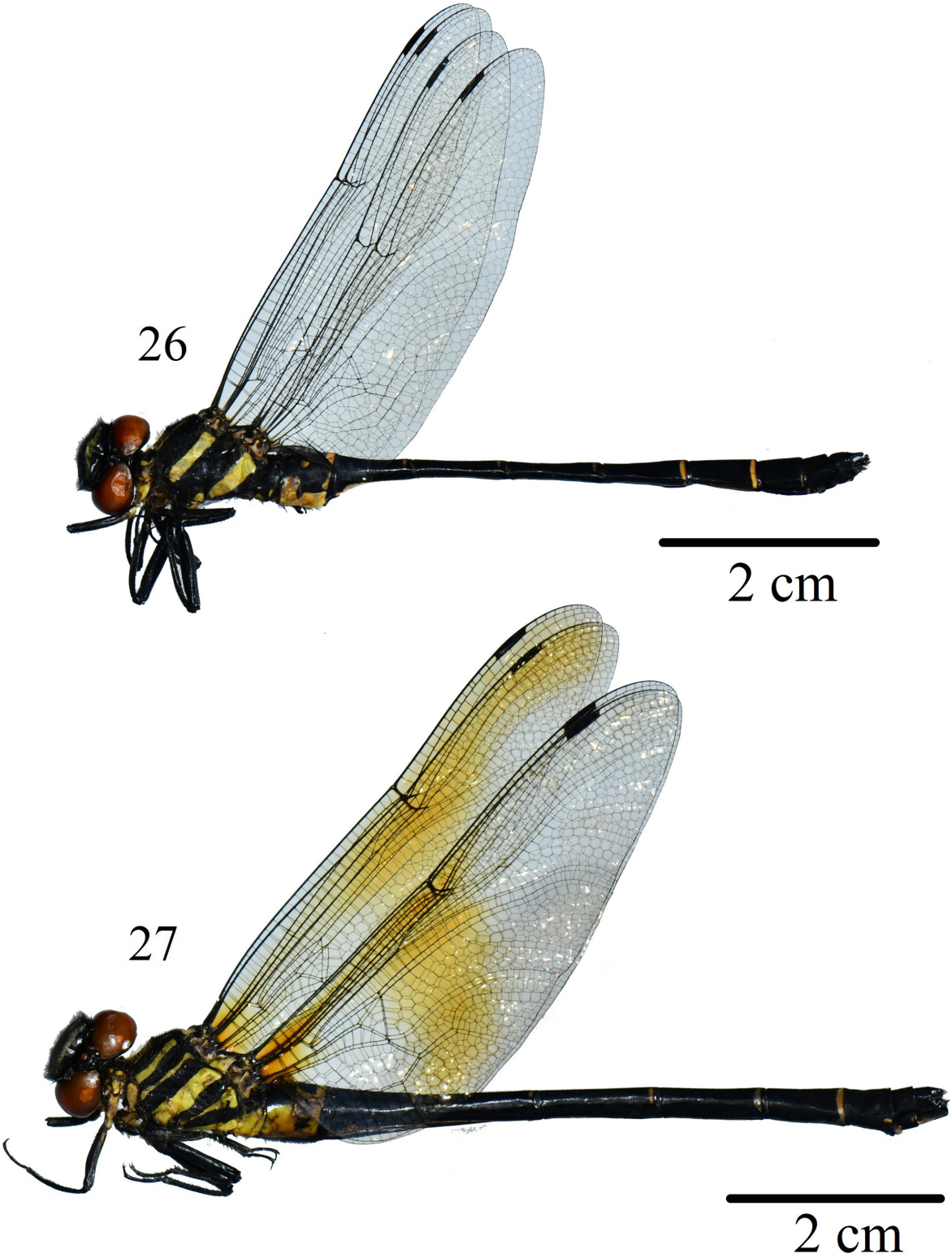
Male (Figs 26, 28–29, 32–34, 37–38, 45)

Measurements. Hw 44 mm long, abdomen (including appendages) 56 mm long.

Head. Labrum black with a semicircular yellowish marking at central dorsal margin. Anteclypeus black with a narrow, transverse, dark yellow stripe bordering upper margin. Postclypeus yellow with two tiny black spots mediolaterally. Antefrons prominent medially and entirely black. Postfrons black, with a narrow, transverse, yellowish cross stripe. Antennae black, but anterior part of first and second segments dark yellowish (Figs 28–29). Vertex black, hemispherical, posterior margin narrowly concave (Fig. 45). Occiput triangular, black, with long setae on posterior margin. Distance between eyes 0.3 mm.

Thorax. Anterior and middle lobes of prothorax black, posterior lobe black with yellow marks medially. Synthorax black with three yellowish stripe markings as follows: dorsal stripe on mesepisternum narrow; lateral stripes on mesepisternum and metepisternum well developed and broader than dorsal ones; mesepimeron entirely black; metinfraepisternum black with large yellow marking. Coxae and trochanter of fore legs largely yellowish, remainder black; middle and hind legs entirely black (Fig. 26).

Wings. Hyaline with black venation (Fig. 26). Ax/Px ratio 21/14 in Fw and 19/14 in Hw. In all wings, median space with 1 crossvein. In Hw, basal triangle with 3 cells. Triangle 4-celled and 3-celled in Fw and Hw, respectively, with costal side equal to basal side. Cubital space with 7 crossveins in Fw and



Figs 26–27. Habitus of *Chlorogomphus vani* sp. nov. **26**. Holotype, ♂ (ZCDTU 2021042001-ODO). **27**. Paratype, ♀ (ZCDTU 2021042003-ODO).

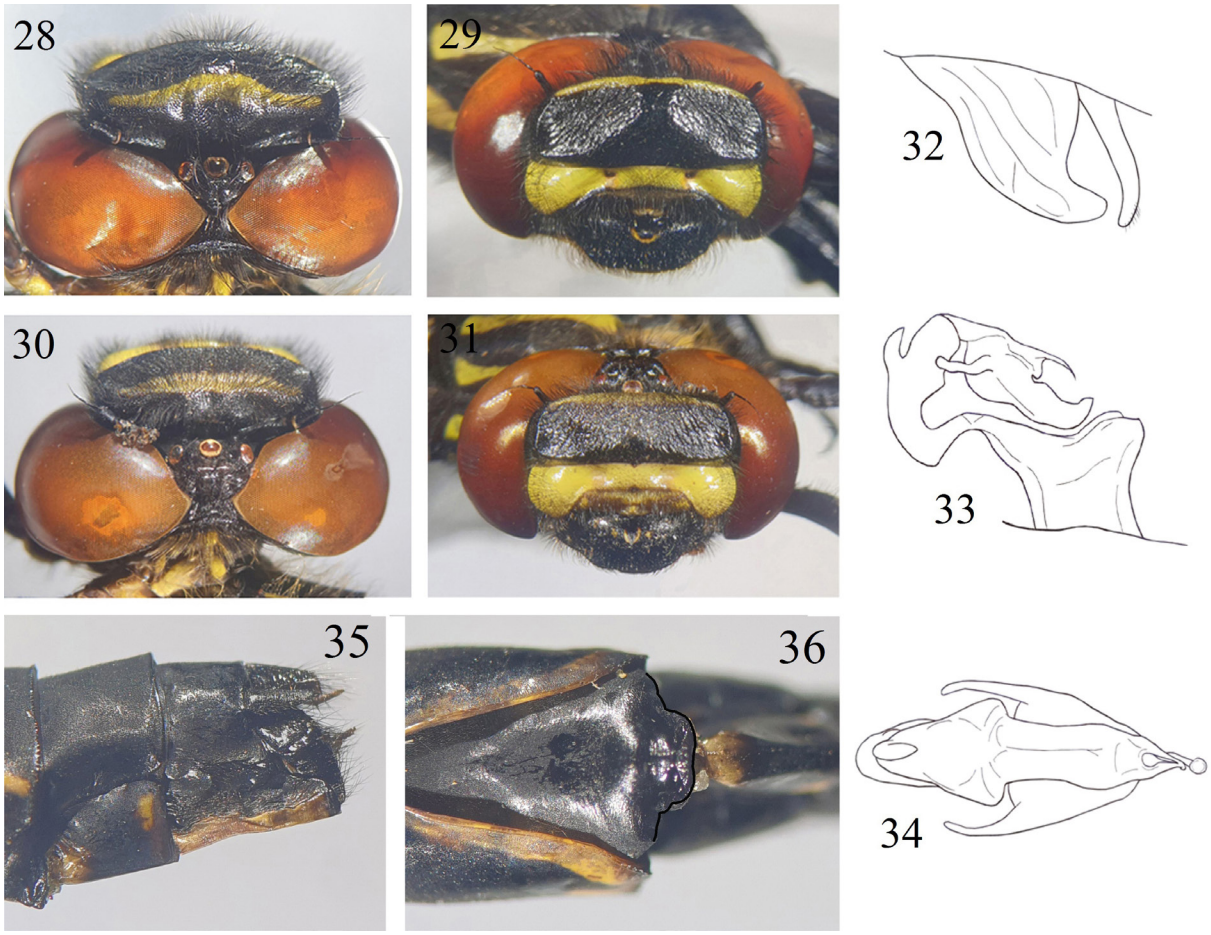
8 crossveins in Hw. Anal loop 14-celled. Pt black, 3–3.2 mm long on both wings, covering 3.5 underlying cells.

Abdomen. S1 black with two small yellow spots latero-ventrally. S2 black, dorsally with a yellow spot, distal margin yellowish with another larger yellow marking covering half latero-ventrally. S1–2 broad, subsequently narrower toward tip from S3; S3 with a small yellow anteroventral spot; S3–5 with a small yellow ventral spot; S6–7 black, each with a subapical dorsal spot; S8 black with a short yellow lateroventral strip; S9 entirely black; S10 black with a yellowish marking on ventral side (Fig. 26).

Secondary genitalia. Anterior lamina broad basally, gradually narrowing apically and strongly curved posteriorly. Posterior hamule thin, as long as anterior lamina, slightly curved anteriorly at tip (Fig. 32).

Vesica spermalis. With typical shape in the genus, as in Figs 33–34. Terminal segment with two long projections and dorsal part of terminal segment subequal to ventral plate; second segment broader and with a stout spine.

Anal appendages. Black. Cercus as long as S10, with a simple structure. In lateral and dorsal view, cercus broad basally, gradually narrowing apically; tip rounded, slightly curved ventrally in lateral view



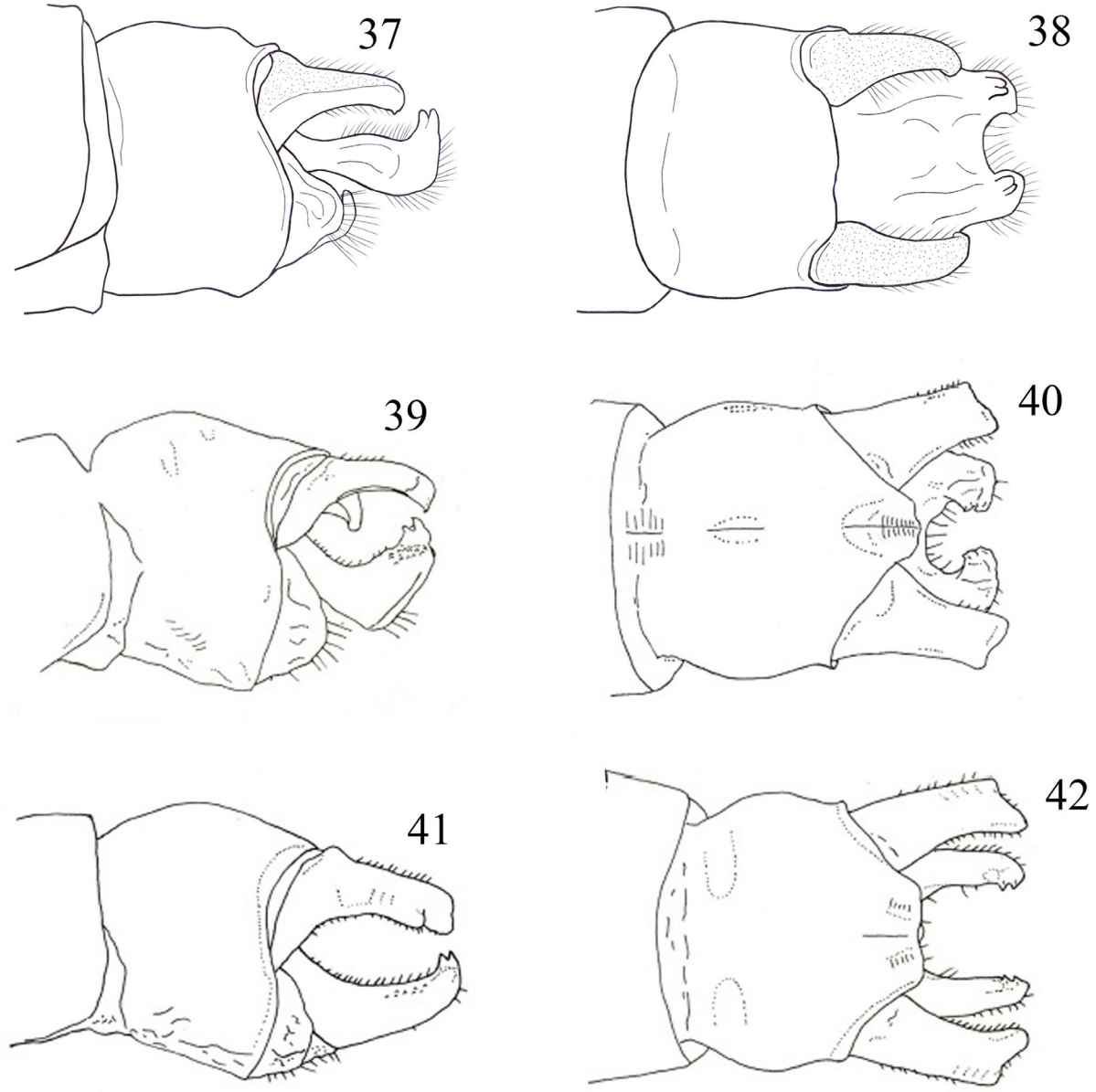
Figs 28–36. Features of *Chlorogomphus vani* sp. nov., holotype, ♂ (28–29, 32–34) (ZCDTU 2021042001-ODO) and paratype, ♀ (30–31, 35–36) (ZCDTU 2021042003-ODO). **28–29**. Head in dorsal and frontal views. **30–31**. Head in dorsal and frontal views. **32**. Accessory genitalia. **33**. Vesica spermalis in lateral view. **34**. Terminal segment of vesica spermalis in ventral view. **35–36**. Abdominal tip in lateral and ventral views. Images not to scale.

(Figs 37–38). Epiproct in lateral view longer than cercus, abruptly curved dorsally at apical fourth and armed apically with two short teeth (Fig. 37) in dorsal view, epiproct broadly concave apically (Fig. 38).

Female (Figs 27, 30–31, 35–36, 43, 46)

Measurements. Hw 53 mm long, abdomen (including appendages) 63 mm long.

Head. As in holotype male, but anteclypeus of head dark yellowish with brownish marking ventrally; postfrons with a dorsal transverse yellow stripe, curved medially as in holotype male (Figs 30–31); circular vertex larger than in male, its posterior margin concave, V-shaped (Fig. 46). Distance between eyes 1.4 mm.



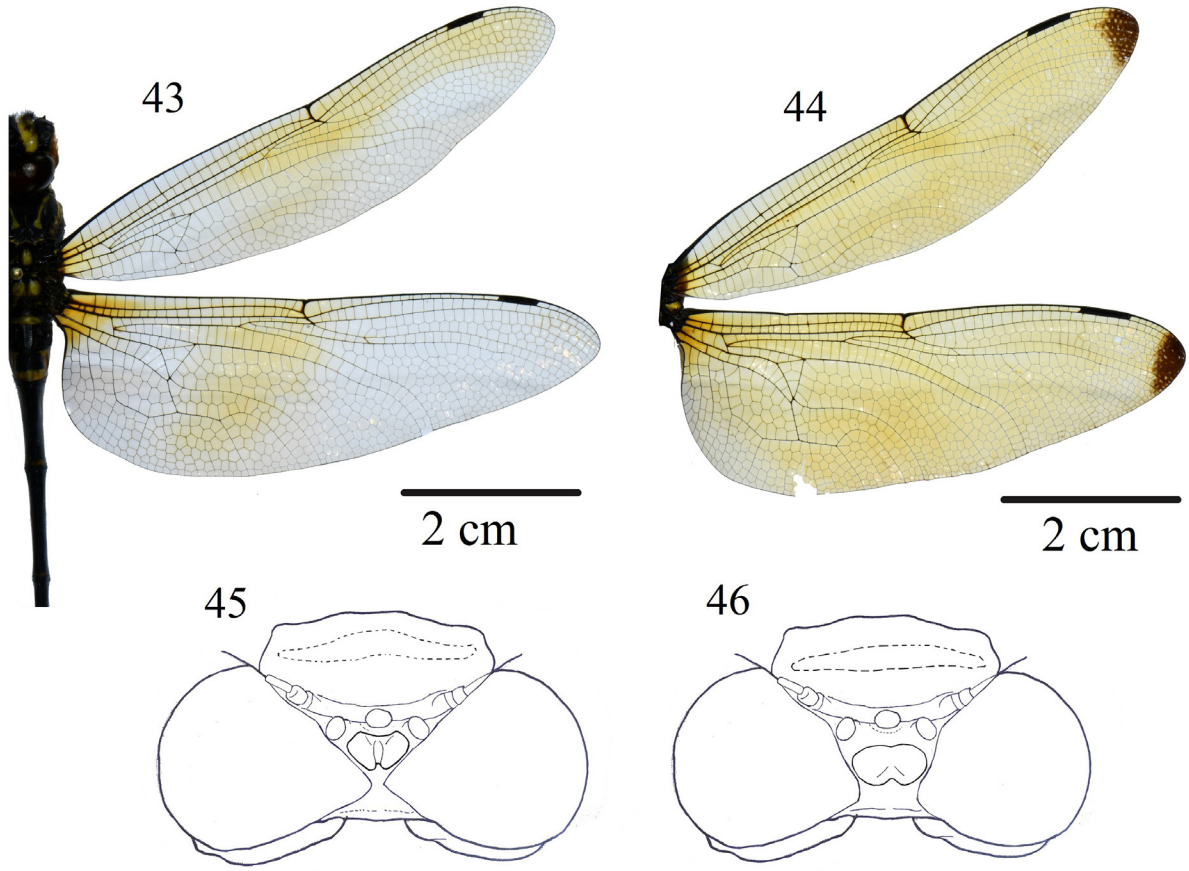
Figs 37–42. Anal appendages of species of *Chlorogomphus* Selys, 1854, ♂♂. **37–38**. *C. vani* sp. nov., holotype (ZCDTU 2021042001-ODO). **39–40**. *C. auratus* Martin, 1910 (rearranged from Kompier & Karube 2018: fig. 2a–b). **41–42**. *C. canhvang* Kompier & Karube, 2018 (rearranged from Kompier & Karube 2018: fig. 2e–f). **37, 39, 41**. Anal appendages in lateral view. **38, 40, 42**. Anal appendages in dorsal view. Images not to scale.

Thorax and legs. Prothorax and legs as in holotype male. Synthorax black with several yellowish areas as follows: dorsal stripe on mesepisternum narrow; lateral stripe on mesepisternum broader, slightly sinuous; stripes on mesepimeron slender, longer than those on mesepisternum; lateral stripe on metepisternum largest, covering most of segment and overlapping spiracle and part of metinfraepisternum; mesepimeron black with dorsal and ventral margin yellowish, upper stripe narrow anteriorly, broader near wing base, inner alar sclerite yellow (Fig. 27).

Wings. Hyaline with amber pattern as follows: on Fw, amber pattern interrupted, beginning to extend from about 15th Ax to wingtip, darker around nodus; on Hw amber pattern runs from base, covering Ax and beginning to extend from about 14th Ax to just beyond nodus and to distal margin of anal loop (Figs 27, 43). Ax/Px ratio 25/13 and 20/18 in Fw and Hw, respectively. In all wings, median space with 2 crossveins. Triangles with 4 cells in all wings. Triangle in Hw with costal side equal to basal side. Cubital space with 9–10 crossveins in all wings. Anal loop 19-celled. Pt black, 4 mm long on all wings, surmounting 3.5 underlying cells.

Abdomen. Black, with yellowish markings as follows: half ventral of S1 (Fig. 27); S2 except for antero-dorsally black; S3–7 with a small yellow anteroventral spot, each subsequently becoming larger on successive segments; S8–9 with a small anteroventral yellow spot; S10 entirely black (Fig. 27).

Cerci. Black, as long as S10 (Fig. 35). Valvula valvae trapezoid-shaped, as in Fig. 36. Ventral projection of S10 reaches beyond equal cerci (Fig. 35).



Figs 43–46. 43–44. Right wings of species of *Chlorogomphus* Selys, 1854, ♀♀. **43**. *C. vani* sp. nov., paratype (ZCDTU 2021042003-ODO). **44**. *C. auratus* Martin, 1910 (ZCDTU 2020060905-ODO). **45**. Head of *C. vani* sp. nov., holotype, ♂ (ZCDTU 2021042001-ODO). **46**. Head of *C. vani* sp. nov., paratype, ♀ (ZCDTU 2021042003-ODO). 45–46 not to scale.

Morphological variation in paratypes

Measurement variation. Male: abdomen (including appendages) 58 mm long. Females: Hw 52–53 mm long, abdomen (including appendages) 60–65 mm long.

Wing venation. Male: Ax/Px ratio 22/11 and 17/15 in Fw and Hw, respectively. Triangle 3-celled in all wings. Cubital space with 6 cells in Hw. Females: Ax/Px ratio 24–26/12–14 and 19–21/16–19 in Fw and Hw, respectively. Median space with 2–3 crossveins in all wings. Cubital space with 9–10 crossveins in all wings. Anal loop 16–17-celled.

Other characters. Male paratype differs from holotype by having yellow marking on S8 extending posteriorly to latero-ventral margin. One paratype female darker golden than the others, with the tip of Hw slightly amber.

Distribution

Vietnam (Fig. 62: yellow rectangle): Dak Lak (Chu Yang Sin National Park) Province.

Chlorogomphus gracilis Wilson & Reels, 2001
Figs 47–60, 63

Material examined

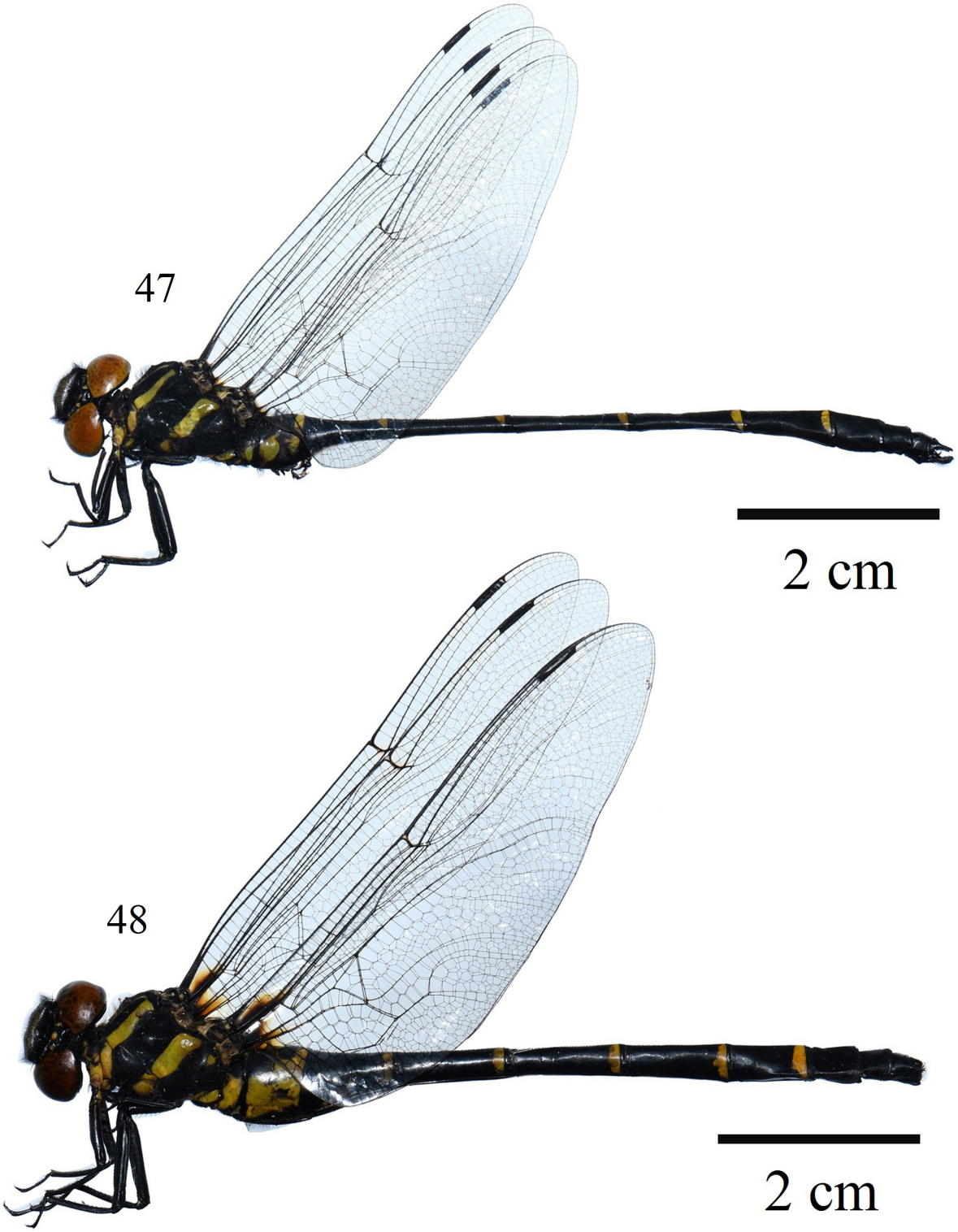
VIETNAM – **Kon Tum Province** • 2 ♂♂; Dak Glei District, Ngoc Linh Commune, Ngoc Linh Nature Reserve; 15.0444° N, 107.9270° E; alt. 1480 m; 5 Jun. 2019; Q.T. Phan leg.; ZCDTU 2019060501-ODO to 0502-ODO • 1 ♀; same collection data as for preceding; ZCDTU 2019060503-ODO • 1 ♂; same locality as for preceding; 12 May 2017; Dang Ngoc Van leg.; KPMNH 2017051201.

Remarks

Chlorogomphus gracilis is a new record for the Vietnamese fauna and for continental Asia. The body coloration and all structural features of the Vietnamese specimens (Figs 47–60) agree well with the original description of *C. gracilis* from Hainan. There is only one exception, i.e., that the epiproct of the Vietnamese specimens is gently expanded apically (Fig. 58), whereas in the Chinese *C. gracilis* it is narrower from its base to the tip (Wilson & Reels 2001: fig. 77; Zhang 2019: 530). Wilson & Reels (2001) considered *C. gracilis* as similar to *C. fraseri* by the similarity of having a peg-like process in the epiproct, but the illustrated epiproct from the holotype has only a single process arising from the center. Wilson & Reels (2001) described the "hooked peg-like process arising from the centre of the base plate formed by the two conjoined inferior appendages". This process on the epiproct of the holotype of *C. gracilis* (Wilson & Reels 2001: fig. 77) differs from conditions in the Vietnamese specimens, which have two long erect spines rising from the base of the epiproct (Figs 58–59) that are not conjoined. Zhang (2019: 530) also provided two photos of the anal appendages of *C. gracilis* from Hainan, but the structure of the process arising from the basal epiproct is not clearly visible in lateral and dorsal views. We consider that the single peg-like process, albeit formed from conjoined pegs, described and figured in Wilson & Reels (2001: fig. 78) is an extraordinary character within the genus (with several other species of *Chlorogomphus* having two separate spines arising from the base of the epiproct; see, e.g., Fig. 13 for *C. hoaian* sp. nov. and Fig. 16 for *C. fraseri*). We cannot verify differences in other characters such as secondary genitalia and the vesica spermalis between specimens of *C. gracilis* from Vietnam and Hainan, since Wilson & Reels (2001) did not provide sufficiently detailed drawings of these structures in their original description. Keith Wilson kindly supplied us with detailed images of the head and the abdominal tip of female *C. gracilis* from Hainan. The shape of the vertex and valvula valvae of the Hainan specimen appear to be identical to conditions in our Vietnamese female (Figs 51, 57).

Habitat and ecology

Chlorogomphus gracilis was observed only at a small rocky stream on a high mountain (altitude nearly 1500 m) near a main road. We conducted surveys at other streams at elevations of 1000–2000 m along the same road but did not find any other individuals of this species or any other Chlorogomphidae.



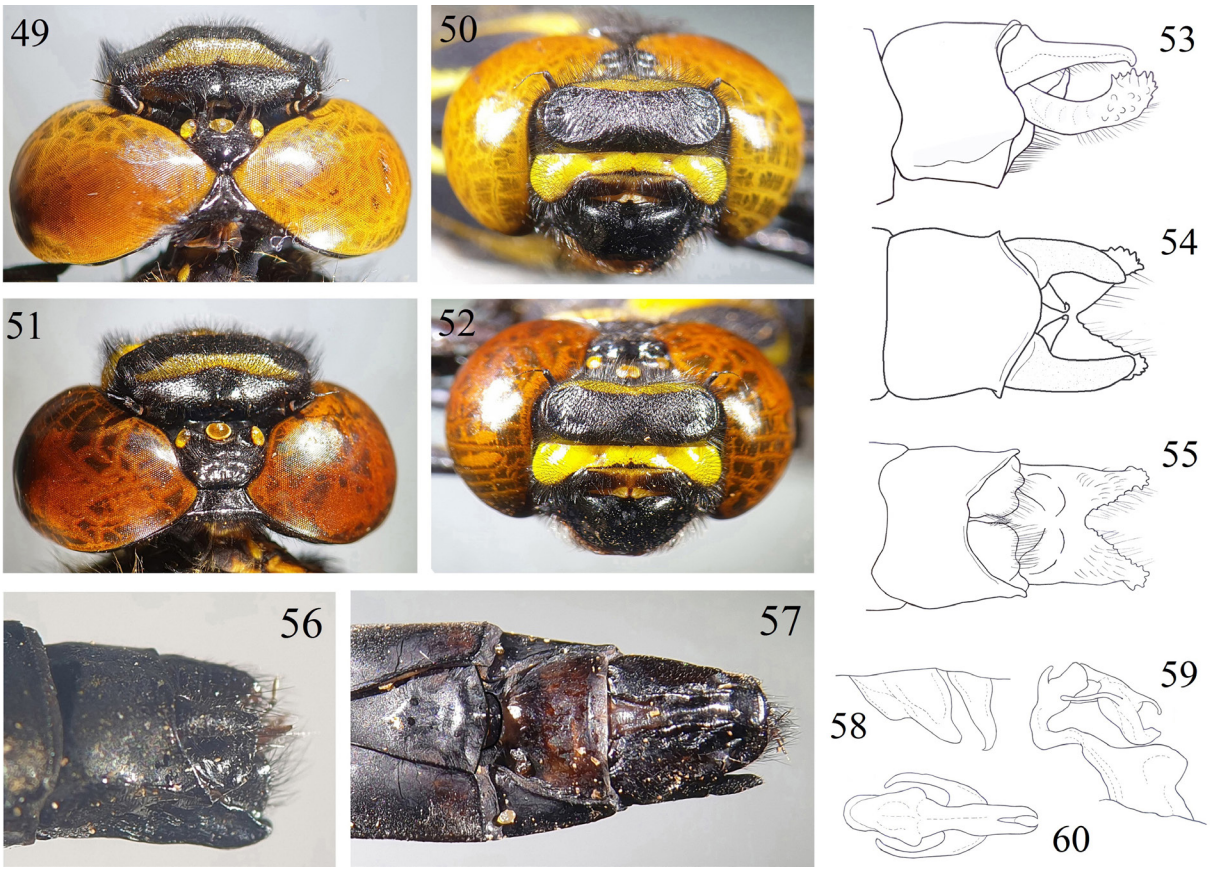
Figs 47–48. Habitus of *Chlorogomphus gracilis* Wilson & Reels, 2001. **47**. ♂ (ZCDTU 2019060501-ODO). **48**. ♀ (ZCDTU 2019060503-ODO).

Distribution

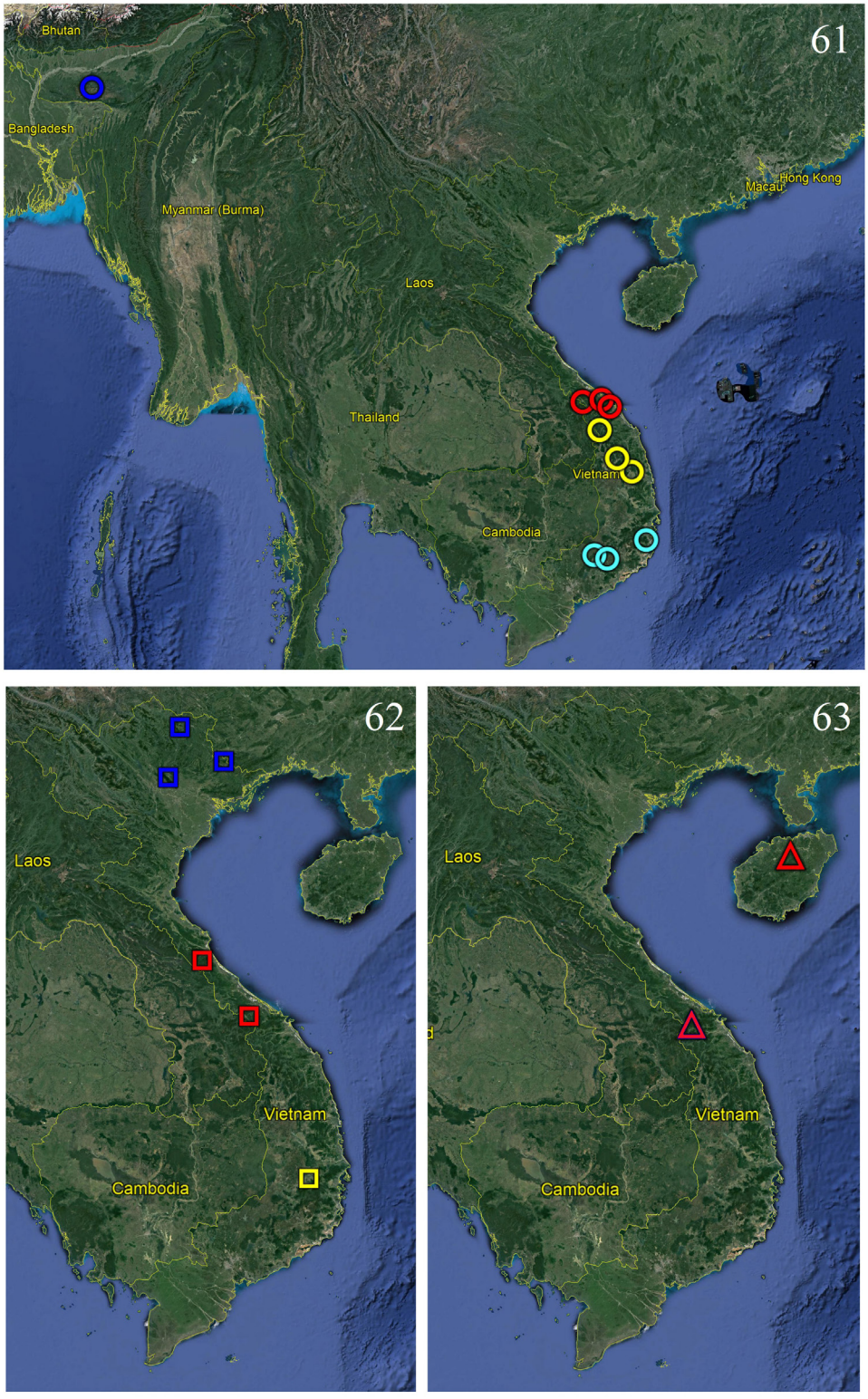
Vietnam: Kon Tum (Ngoc Linh Nature Reserve) Province; China: Hainan Island (Fig. 63: red triangle).

Discussion

Within the family Chlorogomphidae, two species, *Chlorogomphus montanus* Chao, 1999 (from Hubei, Fujian and Guangdong, China) and *C. schmidti* Asahina, 1986 (from Manipur State, India), are known only based on females (Asahina 1986; Chao 1999). As pointed out by Karube (2013), describing new species based only on female specimens should be avoided, because they resemble one another in color pattern and in the structure of anal appendages and valvula, although the females of some species have characteristic wing patterns. *Chlorogomphus hoaian* sp. nov. and *C. vani* sp. nov. have golden-tinted or amber wings, while they are completely hyaline in *C. schmidti*; the wings of *C. montanus* are almost hyaline with basal brown markings in the Hw (Zhang 2019: 541). Females of *C. montanus* have a long abdomen (67–75 mm) and long Hw (60 mm) compared with 60–63 mm and 53–56 mm, respectively, in *C. hoaian* sp. nov. and *C. vani* sp. nov. The valvula valvae of *C. vani* sp. nov. is trapezoid-shaped (Fig. 57), as in *C. schmidti* (Asahina 1986: fig. 47), but pyramid-shaped in *C. montanus* (Chao 1999: fig. 5). In addition, *C. schmidti* from India is also geographically separated from *C. hoaian* sp. nov. and *C. vani* sp. nov. in Vietnam. Based on these observations, we consider it safe to describe the two new species from the Central Highlands of Vietnam here.



Figs 49–60. Features of *Chlorogomphus gracilis* Wilson & Reels, 2001, ♂ (49–50, 53–55, 58–60) (ZCDTU 2019060501-ODO) and ♀ (51–52, 56–57) (ZCDTU 2019060503-ODO). **49–50**. Head in dorsal and frontal views. **51–52**. Head in dorsal and frontal views. **53–55**. Anal appendages in lateral, dorsal and ventral views. **56–57**. Abdominal tip in lateral and ventral views. **58**. Accessory genitalia. **59**. Vesica spermalis in lateral view. **60**. Terminal segment of vesica spermalis in ventral view. Images not to scale.



Figs 61–63. Distribution maps of species of *Chlorogomphus* Selys, 1854. **61**. Distribution map of *C. fraseri* St. Quentin, 1936 (dark blue circle), *C. aritai* Karube, 2013 (red circles), *C. hoaian* sp. nov. (yellow circles) and *C. caloptera* Karube, 2013 (light blue circles). **62**. Distribution map of *C. auratus* Martin, 1910 (blue squares), *C. canhvang* Kompier & Karube, 2018 (red squares) and *C. vani* sp. nov. (yellow square). **63**. Distribution map of *C. gracilis* Wilson & Reels, 2001 (red triangles) in Vietnam and China.

The two new species and their congeners have allopatric distributions in Vietnam and other countries: *C. hoaian* sp. nov. is thus far known only from high altitude evergreen forests in the Central Highlands, but *C. aritai* is found only around Da Nang City and in Thua Thien Hue Province in central Vietnam, *C. caloptera* is from southern Vietnam, and *C. fraseri* is known from India (Fig. 61). *Chlorogomphus auratus* was found in northern Vietnam, *C. canhvang* in north-central Vietnam, and both species also occur in southern China (Zhang 2019). *Chlorogomphus vani* sp. nov. is found in the Central Highlands (Fig. 62). However, the identification of a male of *C. canhvang* from southern China by Zhang (2019: 507) is doubtful, because the presence of a laterally clearly visible projection on the dorsal margin between the cerci is not in agreement with *C. canhvang* at all. This may be another closely related species, and study of further specimens of *C. canhvang* sensu Zhang (2019) from southern China is required.

Acknowledgments

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