

A new treefrog of the genus *Rhacophorus* (Anura: Rhacophoridae) from Brunei Darussalam (Borneo)

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Abstract. A new species of *Rhacophorus* from the Sultanate of Brunei Darussalam (Borneo) is described. *Rhacophorus belalongensis* sp. n. is similar to *Rhacophorus bimaculatus*, *R. catamitus*, *R. gadingensis*, and *R. gauni*, but can be distinguished from these species and all other Southeast Asian members of the genus by the combination of the following characters: small size (SVL of adult females and males 34.7-38.2 mm and 25.8-30.9 mm, respectively), snout obtuse, head wider than long and wider than body, row of small white tubercles but no dermal flap along forearm, pointed calcar present on heel, supratympanic fold weakly expressed or absent, tympanum diameter one-third of that of eye, canthus rostralis sharp, interorbital distance equals upper eyelid width and internarial distance, dorsum grey to light brown in life, more or less regularly speckled with small dark brown irregularly shaped spots, flanks and anterior surface of thighs with irregularly shaped sky blue blotches on flanks, iris ruby-coloured, diffusing to yellow laterally with distinct black ring along margin. Furthermore, characteristics of the advertisement call and natural history notes are provided.

Key words. Amphibia, Anura, Rhacophoridae, *Rhacophorus belalongensis* sp. n., taxonomy, natural history, advertisement call, Brunei Darussalam, Borneo.

Introduction

The genus *Rhacophorus* KUHL & VAN HASSELT, 1822 is distributed from India to Japan and the Indo-Malayan archipelago and currently contains 73 species (CHOU et al. 2007, FROST 2007). During the last decade, new species have been described almost every year (MANTHEY & STEIOF 1998, HE 1999, INGER et al. 1999, OHLER et al. 2000, VASUDEVAN & DUTTA 2000, KOU et al. 2001, ORLOV et al. 2001, ZIEGLER & KÖHLER 2001, HARVEY et al. 2002, ZHAO et al. 2005, WILKINSON et al. 2005, DAS & HAAS 2005, OHLER & DELORME 2006, MATSUI & PANHA 2006, RAO et al. 2006, CHOU et al. 2007). So far, 15 species of the genus have been reported from Borneo, seven of which are endemic to this island (INGER & TAN 1996, INGER & STUEBING 2005, DAS & HAAS 2005).

The Sultanate of Brunei Darussalam is one of the world's smallest countries. It is situated on the northern coast of Borneo and is surrounded by the Malaysian state of Sarawak.

Herpetologically, it is poorly explored. During field work in Brunei's eastern Temburong district we collected several specimens of an unknown *Rhacophorus* species that differs morphologically from all Southeast Asian members of the genus. We therefore describe it as new to science in the following.

Materials and methods

Type material was collected in May and September 2005, July and September 2006, and June 2007. All specimens were found at night, photographed in life using Kodak Elite-chrome (ASA 100) slide film, and preserved in 70% ethanol. The following measurements were taken with a digital caliper (to the nearest 0.1 mm): snout-vent length (SVL, from tip of snout to vent); tibia-fibula-length (TFL, measured with both knee and tibio-tarsal articulation flexed); head width (HW, distance between angles of jaw); head length (HL, distance from angle of jaw to tip of snout); hor-

horizontal eye diameter (ED); horizontal tympanum diameter (TD); upper eyelid width (EW); interorbital distance (IO, shortest distance between upper eyelids); eye to nostril distance (EN, distance between anterior margin of eye and nostril); nostril to snout distance (NS, distance between nostril and tip of snout); internarial distance (NN); hand length (HND, distance from base of thenar tubercle to tip of third finger); foot length (FOT, distance from base of inner metatarsal tubercle to tip of fourth toe). The webbing formulae are given as proposed by MYERS & DUELLMAN (1982). Sex was determined by presence/absence of vocal sac, size, calling behaviour, and position in amplexus.

For comparisons we examined museum specimens of several species of *Rhacophorus*, including type specimens of similar species (see Appendix). Comparison with *R. gadingensis* is based on the description by DAS & HAAS (2005) and on detailed photographs of the type specimens. Museum abbreviations are as follows: Field Museum of Natural History, Chicago, USA (FMNH), Museum und Forschungsinstitut Senckenberg, Frankfurt am Main, Germany (SMF), Sabah Parks Zoological Museum, Kinabalu Park Headquarters, Sabah, Malaysia (SP), Zoological Museum of the Department of Biology, Universiti

Brunei Darussalam, Bandar Seri Begawan, Brunei Darussalam (UBD), Zoologisches Museum der Humboldt-Universität, Berlin, Germany (ZMB), Zoological Museum of Biodiversity Research, National University of Singapore, Singapore (ZRC). Additional information about characters used to compare Southeast Asian species of *Rhacophorus* was taken from: SMITH (1930), WOLF (1936), INGER (1954), TAYLOR (1962), INGER (1966), BROWN & ALCALA (1994), MANTHEY & GROSSMANN (1997), MANTHEY & STEIOF (1998), INGER et al. (1999), OHLER et al. (2000), ZIEGLER & KÖHLER (2001), ORLOV et al. (2001), HARVEY et al. (2002), MALKMUS et al. (2002), WILKINSON & RAO (2004), MATSUI (2005), INGER & STUEBING (2005), WILKINSON et al. (2005), MATSUI & PANHA (2006), and OHLER & DELORME (2006).

Advertisement calls of nine males were recorded in the field (Sungai Mata Ikan and Sungai Anak Esu) using a linear PCM Hi-MD recorder (Sony MZ-RH10) and a directional microphone (Sennheiser ME66) at 16 bits and 44 kHz on three nights in 2005 and 2007. Call recordings were analysed using Raven Pro 1.3 beta version (Bioacoustics Research Program, Macaulay Laboratory of Ornithology, Ithaca, NY).



Fig 1. Female paratype of *Rhacophorus belalongensis* sp. n. (UBD GK06-26) in life.



Fig. 2. Lateral view of a male paratype of *Rhacophorus belongensis* sp. n. (UBD GK06-22) in life, showing the blue colouration on flanks and thighs.

Systematics

Rhacophorus belongensis sp. n.

(Figs. 1-7)

Holotype: ZMB 70377, adult female, from Sungai Anak Esu, a tributary of Sungai Belalong (4°32'34"N, 115° 09'33"E, ca. 60-200 m elevation), near Kuala Belalong Field Studies Centre, Temburong District, Brunei Darussalam (Borneo), collected by T.U. GRAFE and A. KELLER, 10 July 2006.

Paratypes: ZMB 70378, adult male, collected by T.U. GRAFE and A. KELLER, 10 July 2006, ZMB 70379, adult male, collected by T.U. GRAFE and A. KELLER, 2 September 2006, same locality data as holotype; UBD GK06-57, adult male from Sungai Mata Ikan, a tributary of Sungai Belalong (4°32'N 115°09'E, ca. 120 m elev.), collected by T.U. GRAFE and T.C. WANGER, 18 May 2005; UBD GK06-22, -23, -24, three adult males, UBD GK06-25, -26, two adult females, from Sungai Mata Ikan, collected by J.M. DEHLING, 14-15 September 2005; UBD G07-1, -2, -3, three adult females, UBD G07-4, -5, -6, -7, -8, five adult males, from Sungai Esu, a tributary of Sungai Belalong, collected by T.U. GRAFE, 23 July 2007.

Diagnosis: The new species is distinguishable from its congeners by the combination of the



Fig. 3. Female paratype of *Rhacophorus belongensis* sp. n. (UBD GK06-25) perching on a newly built foam nest.

following characters: (1) small size (SVL 34.7-38.2 mm and 25.8-30.9 mm of adult females and males, respectively); (2) snout obtuse, sub-acuminate in dorsal view, sub-truncate, sloping anteriorly in profile, slightly projecting beyond mandible; (3) head wider than long and wider than body; (4) row of small white tubercles but no dermal flap along forearm; (5) pointed calcar present on heel; (6) supratympanic fold weakly expressed or absent; (7) supraclacal fold weakly expressed; (8) tympanum diameter one-third of that of eye; (9) canthus rostralis sharp; (10) interorbital distance equals upper eyelid width and internarial distance; (11) dorsum grey to light brown in life, more or less regularly speckled with small dark brown irregularly shaped spots; (12) in life, irregularly shaped sky blue

blotches on flanks and anterior surface of thighs; (13) in life, iris ruby-coloured, diffusing to yellow laterally with distinct black ring along margin.

Description of the holotype: Body slender with narrow waist; head short (HL/SVL 0.28), wider than body and wider than long (HW/HL 1.25); snout obtuse, sub-acuminate in dorsal view, sub-truncate, sloping anteriorly in profile, slightly projecting beyond mandible; nostril closer to tip of snout than to eye (EN/NS 1.26); internarial distance larger than eye to nostril distance (NN/EN 1.26); canthus rostralis distinct, sharp, slightly rounded in lateral view, strongly rounded in dorsal view; loreal region sloping, oblique; eyes directed anterolaterally, protruding and large (ED/HL 0.43); pupil horizontal; eye diameter wider than eye-to-nostril distance (ED/EN 1.41); interorbital distance equals upper eyeid width (IO/EW 1.07) and internarial distance (IO/NN 0.99); tympanum visible, but indistinct; its vertical diameter equal to horizontal diameter, about one-third of eye diameter (TD/ED 0.34); skin not co-ossified to forehead; maxillary teeth present; choanae located at margins of roof of mouth; vomerine teeth or bony ridges (dentigerous processes of the vomers) absent; tongue bifurcated at base and free for about two-fifths of its length; median lingual process absent; dorsum shagreened with tiny, low, rounded tubercles; abdomen and ventral side of thighs coarsely granular; chin, throat and chest region smooth; supratympanic fold only weakly expressed; weak supraclacal fold above the vent, not free distally; numerous small tubercles in infraanal region and on ventral side of thighs; row of small white tubercles, but no dermal flap along postaxial edge of forearm; arms moderately slender; tips of fingers enlarged into broad oval disks, each with circummarginal groove; disk of third finger wider than tympanum diameter; relative length of fingers $I < II < IV < III$; subarticular tubercles rounded, well developed, numbering one on fingers I and II, two on fingers III and IV; webbing formula

of hand $I_2-2II_{1.5-3}III_{2-1.5}IV$ (Fig. 6); thenar tubercle large (length 1.8 mm), oval; palmar tubercle V-shaped (length 0.6 mm); narrow fringe of skin on postaxial edge of fourth finger between base of disk and palmar tubercle; metacarpals with several supernumerary small tubercles; legs slender, moderately long (TFL/SVL 0.54); heels overlap each other for 3.5 mm when legs are folded right angle to body; tibio-tarsal articulation reaching tip of snout; heel bears large dermal calcar; tarsus with several very small white tubercles; relative length of toes $I < II < III < V < IV$; disks of toes smaller than those of fingers; subarticular tubercles numbering one on toes I and II, two on toes III and V, and three on toe IV; pedal webbing formula $I_{1-1.5}II_{1-2}III_{1+}2^{+}IV_{2-1}V$ (Fig. 7); inner metatarsal tubercle oval, small (length 1.3 mm), no outer one; few supernumerary small tubercles on metatarsals; dermal fringe on postaxial edge of fifth toe from disk to base of metatarsus.

Measurements (in mm): SVL 36.3, TFL 19.5, HW 12.6, HL 10.1, ED 4.4, TD 1.5, EW 3.6, IO 3.9, EN 3.1, NS 2.5, NN 3.9, HND 10.7, FOT 14.9.

Colouration in life: Dorsum varied from light brown at night to grey during the day, sparsely speckled with small dark brown spots; narrow dark olive green interorbital band reaching lateral margin of upper eyelid; large irregularly shaped white infraorbital spot on both sides of head, surrounded by a thin brown line; large, irregularly shaped sky blue blotches on flanks and anterior surface of thighs; chin white, speckled with dark brown spots on the margins of the lower jaw; throat and chest white; venter white, speckled with light brown spots; groin region, anterior and posterior surfaces of thighs, ventral surfaces of arms and tibia, anterior surface of tarsus, and dorsal surface of proximal half of toes I to III largely unpigmented; dorsal surfaces of arms and legs with darker, greyish to dark brown crossbars; dorsal surface of fingers I and II whitish; ventral surfaces of feet and hands light brown; webbing between fingers

and toes greyish; iris ruby-coloured, diffusing to yellow laterally with distinct black ring along margin.

Colouration in preservative: Dorsum light grey; small spots on the dorsum dark brown; colour of the iris faded to bluish-grey. Blue markings on flanks and legs have faded to grey.

Variation: In life, colouration of the paratypes was similar to that of the holotype (Figs. 1-5). In preservative, most of the paratypes are light brown, some light grey dorsally. In most of the paratypes, moderately to very large spots are present on the dorsum. These were dark olive green or dark brown in life, surrounded by a thin light brown line, and are dark brown in preservative. In life, blue colouration was also present on the tarsus and the dorsal surface of the feet in some specimens. Presence, shape, and size of the infraocular spots varies, and in some of the paratypes, the spots are absent on one or both sides of the head, as reported in many other species of *Rhacophorus* with infraocular spots (INGER 1966, 1992, MALKMUS 1993, 1995, ZIEGLER & KÖHLER 2001). The supratympanic fold is absent in half of the specimens. Presence of vomerine teeth is variable. Two male paratypes have vomerine teeth on both sides (numbering 2/1 and 2/2), a female and a male paratype have vomerine teeth on only one side (numbering 0/4 and 0/2, respectively), and another female paratype has a vomerine ridge without teeth only on the left side. All other specimens lack vomerine ridges and teeth. Webbing on hands and feet is conservative. Also, there is no difference in the extension of the webbing between males and females. The chin region of the male paratypes is unpigmented without small brown blotches, whereas in all females small blotches are present on the margin of the lower jaw and on the venter. In life, the colouration of the ventral side of the fingers is yellow in males, but light brown in females. The head is only slightly wider than long in males (HW/HL

1.01-1.11), but conspicuously wider than long in females (HW/HL 1.21-1.28). Males have median subgular vocal sacs but lack nuptial pads or asperities. Measurements (in mm) of the male paratypes (n = 11): SVL 25.8 - 30.9, TFL 15.0-16.9, HW 8.8-10.7, HL 8.0-10.0, ED 3.4-4.4, TD 1.3-1.6, HND 7.8-8.5, FOT 11.5-13.0; variation of ratios is given as range, followed by mean \pm standard deviation (in parentheses): TFL/SVL 0.54-0.62 (0.57 \pm 0.02), HW/HL 1.01-1.11 (1.06 \pm 0.03), EN/NS 1.17-1.32 (1.25 \pm 0.05), IO/EW 0.92-1.12 (1.03 \pm 0.06). Measurements of female paratypes (n = 5): SVL 34.7-38.2, TFL 19.5-20.7, HW 11.7-12.7, HL 9.6-12.5, ED 4.1-4.7, TD 1.3-1.8, HND 9.7-11.9, FOT 14.6-16.4; ratios vary as follows: TFL/SVL 0.51-0.57 (0.55 \pm 0.02), HW/HL 1.21-1.28 (1.24 \pm 0.03), EN/NS 1.17-1.36 (1.30 \pm 0.07), IO/EW 1.04-1.17 (1.09 \pm 0.05).

Vocalisations: Multiple advertisement calls of nine males were recorded. They consisted of 1-3 short clicks given at irregular intervals, often with long pauses between bouts of clicking. Most advertisement calls consisted of two clicks (Fig. 8). Temperatures varied between 24.4 and 25.6 °C. Measurements are given as mean \pm standard deviation. For calls consisting of two clicks, the first click had an average duration of 70.7 \pm 7.4 ms (n = 9) and a dominant frequency of 5.87 \pm 0.42 kHz (n = 9). The second click had an average duration of 69.8 \pm 7.0 ms (n = 9) and a dominant frequency of 5.82 \pm 0.41 kHz (n = 9). Within males, there were no significant differences in duration or frequency between the two notes (Paired t-test: t = 0.774, df = 8, p = 0.461 and t = 1.047, df = 8, p = 0.326, respectively). Interclick intervals were 90.0 \pm 17.4 ms (n=9). Clicks had prominent harmonics at 12-13 kHz and 18-19.5 kHz. Dominant frequencies of advertisement clicks are much lower in *R. angulirostris* (3.4-4.8 kHz) and *R. cyanopunctatus* (2.3-4.8 kHz) (see MALKMUS et al. 2002). Bioacoustic analyses are sparse for rhacophorids with no information on calls in *R. gadingensis* and *R. gauni* (SUKUMARAN et al. 2006).

A female and three male paratypes were



Fig. 4. Ventral view of a male paratype of *Rhaconophorus belalongensis* sp. n. (UBD GK06-22) in life.



Fig. 5. Ventral view of a female paratype of *Rhaconophorus belalongensis* sp. n. (UBD GK06-25) in life.

kept in a terrarium after collection for the rest of the night (14-15 September 2005). During that time, males emitted advertisement calls, but three times we also heard another call type. It was a deep, soft, drawn-out “wuuuoo-ab”, repeated for up to six times. Unfortunately, we could not determine whether it was a female reciprocation call or a call emitted by males. The next morning, the female was sitting on a new-built foam nest (Fig. 3).

Ecological notes: Males and females were found on vegetation next to small, fast-flowing creeks at heights between one and three meters above the ground. Males were also heard calling from the crown region of small trees that were up to 10 m high. Amplexant pairs were found in September 2005 and July 2006 on a rattan shrub and leaves overhanging streams at heights between 1.6 and 3

m above ground. Eggs are deposited within foam nests, which are attached to the surface of leaves above fast-flowing creeks. The size of a foam nest collected in 2007 was 38.4 x 26.9 x 9.1 mm and was cream-coloured on the night it was constructed. A nest sampled on 24 July 2006 had 25 eggs with 17 hatching into tadpoles. A nest collected on 2 August 2007 had 16 eggs all of which hatched into tadpoles.

Superficially, the tadpoles of the new species resemble those of *R. angulirostris*. LEONG & TAN (2002) reported tadpoles of *R. gauni* from Sungai Mata Ikan and Sungai Enkabang. Though we did not examine these specimens, it is likely that these tadpoles actually represent tadpoles of *R. belalongensis*.

Distribution: The new species is known only from several small tributaries of both Sungai



Fig. 6. Ventral view of the hand of *Rhacophorus belalongensis* sp. n. (holotype, ZMB 70377).

Belalong and Sungai Temburong in the area of the confluence of the two rivers.

Etymology: The new species is named after the Sungai Belalong valley, where it was discovered.

Comparisons: In the following Southeast Asian congeners, webbing reaches disk on postaxial side of third finger (f), on preaxial and postaxial sides of fourth toe (t), or both (f&t), and these species are thus distinguished from *Rhacophorus belalongensis*: *R. annamensis* SMITH, 1924 (f&t); *R. dennysi* BLANFORD, 1881 (t); *R. dulitensis* BOULENGER, 1892 (t); *R. exechopygus* INGER, ORLOV & DAREVSKY, 1999 (f&t); *R. fasciatus* BOULENGER, 1895 (f&t); *R. feae* BOULENGER, 1893 (f&t); *R. georgii* ROUX, 1904 (f&t); *R. harrissoni* INGER & HAILE, 1959 (f&t); *R. htunwini* WILKINSON, THIN, LWIN & SHEIN, 2005 (t); *R. jarujini* MATSUI & PANHA, 2006 (t); *R. kio* OHLER & DELORME, 2006 (f&t); *R. maximus* GÜNTHER, 1858 (f&t); *R. nigropalmatus* BOU-



Fig. 7. Ventral view of the foot of *Rhacophorus belalongensis* sp. n. (holotype, ZMB 70377).

LENGER, 1895 (f&t); *R. pardalis* GÜNTHER, 1858 (f&t); *R. poecilonotus* BOULENGER, 1920 (t); *R. prominanus* SMITH, 1924 (t); *R. reinwardtii* (SCHLEGEL, 1840) (f&t); *R. robinsonii* BOULENGER, 1903 (f&t); *R. rufipes* INGER, 1966 (f&t). Webbing between fingers is confined to base in *R. everetti* BOULENGER, 1894 and *R. kajau* DRING, 1983.

Distinct dermal flaps or fringes along postaxial edges of forearm (F), tarsus (T), or both (F&T) separate the following species from *R. belalongensis*: *Rhacophorus ach-antharrhena* HARVEY, PEMBERTON & SMITH, 2002 (F&T); *R. appendiculatus* (GÜNTHER,

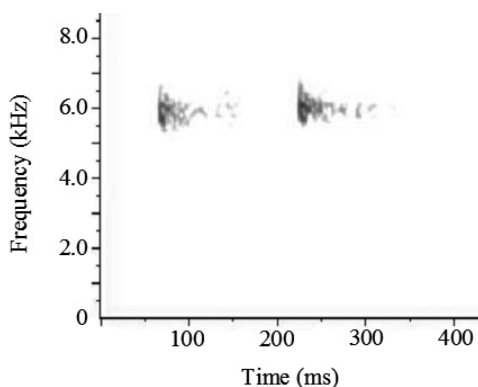


Fig. 8. Sound spectrogram of two-click advertisement call given by a male *Rhacophorus belalongensis* at 25.2 °C.

1858) (F&T); *R. baluensis* INGER, 1954 (F&T); *R. barisani* HARVEY, PEMBERTON & SMITH, 2002 (F&T); *R. bipunctatus* AHL, 1927 (F&T); *R. calcaneus* SMITH, 1924 (T); *R. edentulus* MÜLLER, 1894 (F&T); *R. hoanglienensis* ORLOV, LATHROP, MURPHY & HO, 2001 (F); *R. margaritifera* (SCHLEGEL, 1837) (F&T); *R. monticola* BOULENGER, 1896 (F&T); *R. taronensis* SMITH, 1940 (F&T); *R. turpes* SMITH, 1940 (F&T).

The remaining Southeast Asian *Rhacophorus* species may be distinguished from *R. belalongensis* (characters given in parentheses) by the following characters: *Rhacophorus duboisi* OHLER, MARQUIS, SWAN & GROSJEAN, 2000 differs in having a SVL up to 65.7 mm (up to 38.2 mm), head longer than wide (head wider than long), pointed snout (snout sub-acuminate), tympanum two-thirds of eye diameter (one-third of eye diameter), dermal fringe on fifth toe reaching to proximal sub-articular tubercle only (reaching to base of disk), and absence of dermal fringe on fourth finger (present on postaxial side of fourth finger). *Rhacophorus modestus* BOULENGER, 1920 lacks dermal projections at heel (calcar present at heel) and has a tympanum wider than half eye diameter (one-third of eye diameter). *Rhacophorus cyanopunctatus* MAN-

THEY & STEIOF, 1998 and *R. orlovi* ZIEGLER & KÖHLER, 2001 resemble *R. belalongensis* in the blue colouration of flanks and thighs. However, both have a distinct supratympanic fold (weakly expressed or absent), more extensively webbed outer fingers, formula being II₁-2.5III_{1.5}-1IV and II₁'-2III_{1.5}-1.5IV, respectively (versus II_{1.5}-3III₂-1.5IV), and a tympanum diameter wider than half the eye diameter (one-third of eye diameter). In addition, *R. cyanopunctatus* has a pointed snout, considerably protruding in profile (sub-truncate in profile, not protruding) and lacks dermal projections at heel (calcar present at heel), and *R. orlovi* has the head longer than wide (wider than long).

Superficially, the new species is similar to *R. catamitus* HARVEY, PEMBERTON & SMITH, 2002 and male *R. angulirostris* AHL, 1927. These species differ in the following characters:

Rhacophorus angulirostris: snout pointed in profile (sub-truncate), distinct supratympanic fold from eye to axilla (supratympanic fold indistinct or absent), iris blue and red in life (red, lightened to yellow at margins), absence of dermal projections at heel (calcar present at heel), females dorsally green in life (brown to grey).

Rhacophorus catamitus: SVL of males 31.0-35.2 mm (25.8-30.9 mm), of female 50.6 mm (34.7-38.2 mm), webbing less extensive in males with hand webbing II(2⁺-2.5)-3.5III_{2.75}-(2⁺-2.75)IV (versus II_{1.5}-3III₂-1.5IV) and foot webbing I_{1.75}-(2⁺-2.5)II(1.25-1.75)-(2.75-3)III(1.5-1.75)-(2.5-3.25)IV(2.25-2.75)-(1.25-1.75)V (versus I_{1.5}II₁-2III₁⁺-2⁺IV₂-1V); in the only known female referred to this species webbing is more extensive and reaches disks of all toes (does not reach disks of all toes), hand webbing I_{2.5}-2.5II₁-2III₁⁺-1IV (versus I₂-2II_{1.5}-3III₂-1.5IV); supratympanic fold thick and conspicuous, overlapping upper edge of tympanum and its annulus (supratympanic fold absent or only weakly expressed, not overlapping tympanum), supra-cloacal ridge white and low (fold but no ridge present), groin and ventral surfaces of thighs,

hands, and feet orange in life (unpigmented with blue and brown blotches).

Most similar to the new species are *R. bimaculatus* (PETERS, 1867), *R. gadingensis* DAS & HAAS, 2005, and *R. gauni* (INGER, 1966). In *R. bimaculatus*, heels meet each other but do not overlap when folded right angle to body (heels overlap), interorbital distance is larger than upper eyelid width with IO/EW 1.37-1.47 (equals upper eyelid width, IO/EW 0.92-1.07), canthus rostralis less sharp, palmar tubercles indistinct (distinct), snout broadly rounded in dorsal view (sub-acuminate), webbing does not reach disk on first toe (reaches disk), nor distal subarticular tubercle on preaxial side of fourth toe (reaches distal subarticular tubercle), and does not reach beyond distal subarticular tubercle on fourth finger (reaches half way between subarticular tubercle and disk).

Rhacophorus gadingensis differs in the following characters: SVL of the only known female 29.5 mm (34.7-38.2 mm), of the only known male 23.7 mm (25.8 - 30.9); interorbital distance 1.8 and 1.6 times the width of upper eyelid, and 2.1 and 1.7 times the internarial distance in female and male, respectively (interorbital distance equals upper eyelid width, IO/EW 0.92-1.17, and internarial distance, IO/NN 0.98-1.06), internarial distance slightly less than distance from anterior margin of eye to nostril, with NN/EN 0.97 (1.24-1.36), loreal region strongly concave (sloping, slightly concave only), thenar tubercle smaller and low, palmar tubercles indistinct (palmar tubercles conspicuous), inner metatarsal tubercle absent or at least indistinct (distinctly present), dorsal surfaces of trunk and limbs smooth (finely shagreened with tiny, low tubercles), postaxial edge of forearm and lower leg smooth (postaxial edge of forearm and lower leg with row of conspicuous, white tubercles), only few tubercles present below vent (many tubercles below vent and on ventral surface of thighs), heels meet each other but do not overlap when legs are folded right angle to body (heels overlap), according to DAS & HAAS (2005), the only known male

lacks external vocal pouches (males have median subgular vocal sacs), chin and throat of the only known female white (DAS & HAAS 2005: "unpigmented yellow-cream") (versus white with small, irregularly shaped, brown blotches).

Rhacophorus gauni can be separated from the new species by the following characters: large, pointed, conical tubercle usually present on the margin of the upper eyelid (absent), groin and ventral surfaces of thighs, hands and feet reddish orange in life (unpigmented with light blue and brown blotches), canthus rostralis distinct, but not as sharp as in *R. belalongensis*, loreal region concave (oblique), hand webbing of outer fingers a little more extensive with (2.25-3)III(1-1.75)-(1-1.5)IV (versus 3 III2-1.5IV), thenar tubercle large, two-thirds to three-fourths the length and volume of base of first finger (one-third the volume), in males, head relatively wide with HW/HL 1.13-1.26 (mean 1.18, n = 30) (versus HW/HL 1.01-1.11, mean 1.06, n = 11), distance between nostril and eye less or only slightly larger than between nostril and tip of snout in both males and females with EN/NS 0.92-1.16, mean 1.05, n = 30, and EN/NS 0.93-1.19, mean 1.07, n = 31, respectively (versus in both males and females, nostrils situated closer to tip of snout than to eye, EN/NS 1.17-1.32, mean 1.25, n = 11, and 1.17-1.36, mean 1.29, n = 6, respectively).

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Appendix

Comparative material examined

Rhacophorus angulirostris: Malaysia: SABAH: Gunung Trusmadi (SP 2859, 2869, 2884, 2896, 2904, 2913). *Rhacophorus appendiculatus*: Philippines: Culion, Calamian Group (SMF 6984); Northeast Mindanao (SMF 6985-86); no locality (ZMB 5464, 70071). Malaysia: SABAH: Taman Bukit Tawau, Tawau District (SP 1098-1101, 2355, 26064); Limunsumut Lake, Maliau, (SP 2817); Lower Segama, Lahad Datu District (SP 20370-72, 20374-75). *Rhacophorus baluensis*: Malaysia: SABAH: Headquarters, Taman Kinabalu, Ranau District (SP 24, 1291); Restaurant Bayu, near Kinabalu Park, Ranau District (SP 2802). *Rhacophorus bipunctatus*: Myanmar: "Birma" (ZMB 11575; 70072). "Travancore" (ZMB 10131). *Rhacophorus bimaculatus*: Philippines: Agusan River, Mindanao (ZMB 5681 [syntype]); Dapitan, Mindanao (SMF 7053). *Rhacophorus cyanopunctatus*: Thailand: Khao Sok National Park, Surat Thani (ZMB 57895 [holotype]). Brunei Darussalam: Kuala Belalong Field Studies Centre, Temburong District (UBD GK06-13). *Rhacophorus dulitensis*: Brunei Darussalam: Batu Apoi, Temburong District (UBD 550). Malaysia: SABAH: Marak Parak, Kota Merudu District (SP 634-636, 842-844); Hutan Simpan, Mandamui, Pitas Kudat (SP 1165-68, 20377); Taman Bukit-bukit Tawau, Tawau District (SP 637, 1264). *Rhacophorus edentulus*: Indonesia: Northern Sulawesi (ZMB 34323). *Rhacophorus everetti*: Malaysia: SABAH: Marai Parai (SP 362, 1123); Sayap, Kota Belud District (SP 1202-03, 1773, 1865, 2185); Headquarters, Kinabalu Park, Ranau District (SP 2700-01, 20020, 20322, 20325, 20327, 20362, 21412, 21451-52); Trusmadi (SP 2891, 2901). *Rhacophorus gadingensis*: Malaysia: SARAWAK: Gunung Gading National Park, Lundu Division (ID[Indraneil Das, field number]-7831; ID-7832 [holotype and paratype, respectively]). *Rhacophorus gauni*: Malaysia: SARAWAK: Mengiong River, Nanga Tekalit, Third Division (FMNH 137981, 137983, 137985, 139343-44, 139346 [paratypes], FMNH 145542, 145545, 146269, 195359, 195445-49); Nanga Tekalit, Seventh Division (FMNH 221743, 221744, 221746-48); Pa' Ramapah, Bario (ZRC 1.11794). SABAH: Sungai Kilampun, Purulon Camp, Crocker Range National Park (FMNH 239235; SP 2172, 2176); Mendolong Camp, Sipitang District (FMNH 235045, 239236, 239240, 242922-23, 242941, 242926; SP 2178-79);

Poring Station, Mt Kinabalu Park, Ranau District (FMNH 248308; SP 1257, 1805); Tawau Hills Park, Tawau District (FMNH 248924-25, 249833-36; SP 645-46, 1072); Marak Parak, Kota Marudu District (FMNH 235747); Rangkam Kimanis, Pantod Besar, Tambunan District (FMNH 239233); Danum Valley Field Centre, Lahad Datu District (FMNH 231062, 231069, 231071, 231073, 231075, 234990, 234994, 241081, 241083, 241085, 241086, 241090, 245890, 245892, 245894, 245904-05, 245909-10, 245913, 245915, 245920); Sungai Agathis, Maliau Basin (SP 20244). *Rhacophorus georgii*: Indonesia: Tanke Solokko, Mekongga Mountains, Southeast Sulawesi (ZMB 34322). *Rhacophorus harrisoni*: Brunei Darussalam: Batu Apoi, Temburong District (UBD 214). Malaysia: SABAH: Lower Segama, Lahad Datu District (SP 20392-94); Maliau Basin (SP 20279-81). *Rhacophorus monticola*: Indonesia: Southern Sulawesi (SMF 6829). *Rhacophorus nigropalmatus*: Brunei Darussalam: Batu Apoi, Temburong District (UBD 366). Malaysia: SABAH: Sungai Stuebing, Trusmadi, Tambunan District (SP 223); Tawau Hills Park, Tawau District (SP 1286); "primary forest" (SP 20696). *Rhacophorus pardalis*: Philippines: Palawan (SMF 6994); Claveria, Northern Luzon (SMF 6995). Brunei Darussalam: Kuala Belalong Field Studies Centre, Temburong District (UBD GK06-07); without locality (UBD 17). Malaysia: SABAH: Taman Bukit Tawau, Tawau District (SP 2723, 26060); Danum Valley Field Centre, Lahad Datu District (SP 2082); Pulau Tiga National Park (SP 640-42, 644, 2778-81); Kg. Tipasu, Napong 1, Ranau District (SP 2033); Mongkopo, Ranau District (SP 21986); Sungai Kokoguan, Marak Parak, Kota Marudu District (SP 353, 2083); Mendulong, Sipitang District (SP 1917-19, 2084); Maliau Basin (SP 20255-57); Sungai Rompon, Trusmadi (SP 671); Pulau Jembongan (SP 2190); Lower Segama, Lahad Datu District (SP 20378, 20381-82, 20384, 20389); Hutan Simpan, Mendamai, Pitas Kudat (SP 1169-1180); no locality (SP 1688, 1694, 1696); PDC Lembak Inbak, Telupid (SP 2660-61); Malangkap Tomis, Kinabalu Park, Kota Belud District (SP 20768-71); Sg. Kimanis, Kg. Kindosodon, Tambunan District (SP 21634). *Rhacophorus reinwardtii*: Borneo (SMF 76372 [two specimens]). *Rhacophorus rufipes*: Brunei Darussalam: Kuala Belalong Field Studies Centre, Temburong District (UBD GK06-08).

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