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A new species of *Rhacophorus* (Anura: Rhacophoridae) from Gunung Kinabalu, Borneo

J. Maximilian Dehling

Institut für Integrierte Naturwissenschaften, Abteilung Biologie, AG Zoologie, Universität Koblenz-Landau, Universitätsstr. 1, 56070 Koblenz, Germany

e-mail: megophrys@gmail.com

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Abstract. A new species of *Rhacophorus* from the eastern slope of Gunung Kinabalu (Sabah, North Borneo) is described. It is similar to, and has previously been confused with, *R. gauni*, but differs from it by length and shape of head, less extensive webbing between fingers and toes, presence of vomerine ridges and teeth, absence of a pointed tubercle on the upper eyelid, relatively larger interorbital width, and a smaller thenar tubercle. Characteristics of the advertisement call and ecological data are provided.

Key words. Amphibia, *Rhacophorus malkmusi* sp. n., *R. gauni*, Sabah, Malaysia, taxonomy.

Introduction

Tree frogs of the genus *Rhacophorus* are a species-rich group in Borneo. Within the last decade, three new species have been discovered and described (Das & Haas 2005, Dehling & Grafe 2008, Dehling 2008) and another species has been shown to be distinct from populations from outside Borneo and given a new name (Matsui et al. 2013). On the other hand, three species that have formerly been included in *Rhacophorus* were assigned to other genera based on genetic analyses (Hertwig et al. 2011, 2013, Yu et al. 2013), so that 14 species of *Rhacophorus* are now known to occur on Borneo.

Rhacophorus gauni (Inger, 1966) is a small species, characterized by having the fourth finger webbed beyond the distal subarticular tubercle, a conical dermal tubercle in the middle of the upper eyelid, and a smooth back (Inger 1966). Originally described from Mengiong River at Nanga Tekalit in Sarawak, it has so far been recorded from several localities in Sabah and Sarawak (Inger 1966, 1992, Inger & Stuebing 1992, Dehling 2010) and was listed for eastern Kalimantan (Iskandar 2004). The record from Brunei Darussalam, which is based on tadpoles (Leong & Tan 2002), probably refers to *Rhacophorus belalongensis* Dehling & Grafe, 2008 (Dehling & Grafe 2008). Examining voucher specimens collected from several localities in Sarawak and Sabah, I found a small series of individuals of a tree frog from submontane forests in Sabah, which have been considered identical with *R. gauni.* However, they show a number of character states that unambiguously distinguish them from *R. gauni*. Therefore, they are herein described as a new species.

Materials and methods

The format of description follows Dehling (2008, 2011). The following measurements were taken with digital callipers (to the nearest 0.1 mm): snout–vent length (SVL, from tip of snout to vent); tibiofibula length (TFL, measured with both knee and tibiotarsal articulation flexed); head width (HW, distance between angles of jaw); head length (HL, distance from angle of jaw to tip of snout); 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, distance between nostrils); hand length (HND, distance from proximal edge of thenar tubercle to tip of third finger); foot length (FOT, distance from proximal edge of inner metatarsal tubercle to tip of fourth toe).

In addition to the distinct morphological characters that distinguish the new species from *R. gauni,* I ran a Principal Component Analysis (PCA) on the morphometric data set including 16 variables with 38 (females) and 37 (males) observations (= individuals), respectively; this included all available specimens of the new species and paratypes of *R. gauni*. The webbing formulae are given as proposed by

Myers & Duellman (1982). Males were identified by the presence of a vocal sac. Females were confirmed by examining their gonads by means of dissection. Life colouration of female type specimens is described after field notes and photographic slides by R. Malkmus. Advertisement calls of topotypic males were recorded in the field (Sungai Langanan) using a Sony WM-D6C stereo cassette recorder and a Sony ECM-S959C microphone. Calls were digitised at 16 bits and 44.1 kHz and analysed using Adobe Audition 1.5.

For comparisons, I examined voucher specimens of *Rhacophorus*, including type specimens and topotypic material of taxa that are morphologically similar to the new species (see Appendix). Museum abbreviations are as follows: The Natural History Museum (British Museum [Natural History]), London (BMNH); The Field Museum (Field Museum of Natural History), Chicago (FMNH); Naturhistorisches Museum Wien (NHW); Naturhistorisches Museum der Bürgergemeinde Bern (NMBE); Museum und Forschungsinstitut Senckenberg, Frankfurt am Main (SMF); Sabah Parks Zoological Museum, Kinabalu Park Headquarters, Ranau District, Sabah (SP); Zoological Museum of the Department of Biology, Universiti Brunei Darussalam, Bandar Seri Begawan (UBD); Zoologisches Forschungsinstitut und Museum Alexander Koenig, Bonn (ZFMK); and Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung an der Humboldt-Universität zu Berlin (ZMB). Additional information used for comparisons was taken from Inger (1954, 1966), Brown &Alcala (1994), Harvey et al. (2002), and Das & Haas (2005).

Figure 1. Dorsal view (top) and ventral view (bottom) of the preserved holotype of *Rhacophorus malkmusi* (ZFMK 85131). Scale bar represents 1 cm.

Taxonomy

Rhacophorus malkmusi sp. n.

Rhacophorus gauni (nec *Philautus gauni* Inger, 1966): Malkmus (1996: 287–288), Malkmus et al. (2002: 212–214, partim).

Holotype: ZFMK 85131, adult female, collected at Sungai Langanan (approx. 750 m a.s.l.) in the vicinity of Air Panas Poring (Poring Hot Springs), Ranau District, Sabah, East Malaysia (Borneo) in August of 1994 by Rudolf Malkmus.

Paratypes: ZFMK 85132, adult female (Figs 1, 2), same data as holotype; SP 21113, adult male, Sungai Kipungit Dua, Poring Hot Springs, collected by M. Matsui, "Paul [Imbun] et al.", 8 August 2005.

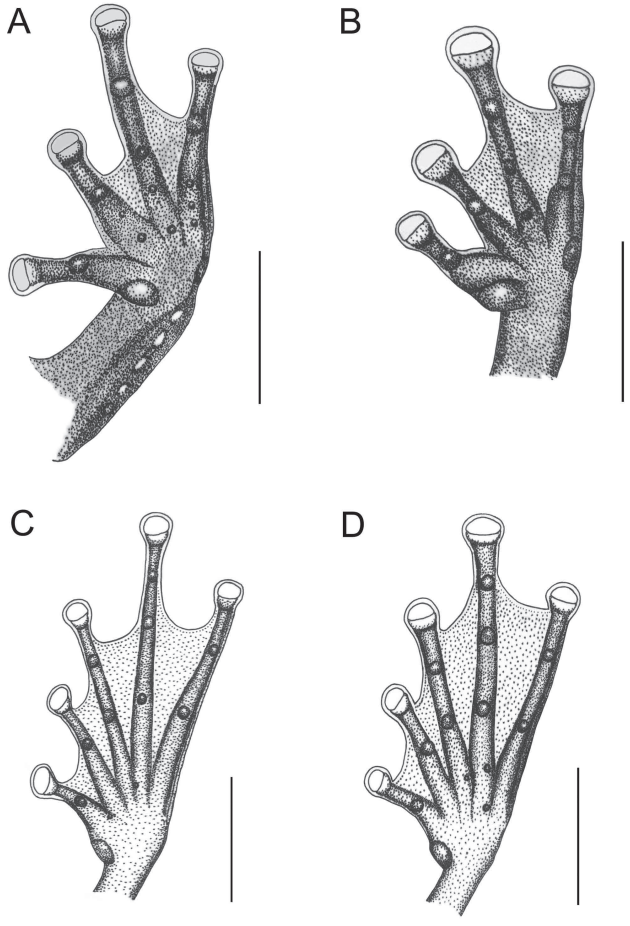

Figure 2. Volar and plantar views of hand (A) and foot (C), respectively, of *Rhacophorus malkmusi* (holotype, ZFMK 85131, adult female), and hand (B) and foot (D), respectively, of *R. gauni* (paratype, FMNH 137981, adult female). Scale bars represent 5 mm.

Referred specimens: SP 2387, adult male, Sungai Malina, Crocker Range Park, collected by "Paul [Imbun], Freddy, Patrick", 16 October 1999; SP 2634, adult male, Sungai Ulu Tomani, Sabah Forest Industry [near Kemabong/Sipitang], collected by "Paul [Imbun], David, Johnny", 10 May 2000.

Diagnosis: Currently, there are no morphological synapomorphic characters considered diagnostic for the genus *Rhacophorus*. I assign the new species to this genus for its morphological resemblance of several Bornean species included in *Rhacophorus*. The new species is distinguishable from all other Southeast Asian members of the genus by the combination of the following characters: Small size, SVL 32.2–35.4 mm in females and 26.4–29.3 mm in males; head wider than long and wider than body; snout obtuse, rounded in dorsal view, sub-truncate in profile, slightly projecting beyond mandible; low, short vomerine ridges between choanae; row of small white tubercles but no dermal flap along forearm; Finger III webbed to proximal subarticular tubercle on the preaxial side and to the distal subarticular tubercle on the postaxial side; Finger IV webbed to distal subarticular tubercle; Toe IV webbed to penultimate subarticular tubercle on the preaxial side and to distal subarticular tubercle on the postaxial side; pointed dermal projection on heel; skin of dorsum, including upper eyelids, smooth; supratympanic and supracloacal folds weakly developed; large number of small white tubercles in the infraanal region and on ventral surface of thighs; dorsum grey to brown in life; lateral faces of legs and groin region bright yellow in life; iris ruby, lightened to yellow marginally.

Description of holotype: Measurements are given in Table 1. Body moderately slender, widest across temporal region, tapering to groin (Fig. 1); head short (HL/SVL 0.27), wider than trunk and wider than long (HW/HL 1.35); snout obtuse, rounded in dorsal view, sub-truncate in lateral view, slightly projecting beyond mandible; canthus rostralis distinct, slightly curved in profile, concave in dorsal view; loreal region oblique; nostrils directed dorsolaterally, situated in low protuberances, a little closer to tip of snout than to eye (EN/NS 1.13), separated from each other by a distance larger than that between eye and nostril (NN/EN 1.43); eyes directed anterolaterally, large (ED/HL 0.53), protruding; pupil horizontal; eye diameter greater than eye–nostril distance (ED/EN 1.75); interorbital distance greater than upper eyelid width (IO/EW 1.58) and greater than internarial distance (IO/NN 1.09); frontoparietals domed, forming two low humps between eyes; skin not co-ossified to forehead; tympanum distinct, its vertical diameter equal to its horizontal diameter, slightly more than one third of eye diameter (TD/ED 0.37); upper jaw with dentition; choanae located on the margins of roof of mouth, largely covered by maxilla in ventral view; low, short vomerine ridges (dentigerous processes of the vomers) between choanae, beginning close to anteriomedial edge of choanae and extending posteromedially, much closer to choanae than to

Table 1. Morphometrics of *Rhacophorus malkmusi* and *R. gauni*. For abbreviations, see Material and methods.

	R. malkmusi	*R. malkmusi*	*R. malkmusi*	*R. malkmusi*	*R. malkmusi*	*R. gauni*	*R. gauni*
voucher	ZFMK 85131	ZFMK 85132	SP 21113	SP 2387	SP 2634	see Appendix	see Appendix
sex	female (holotype)	female (paratype)	male (paratype)	male	male	females (n = 36)	males (n = 34)
origin	Sungai Langanan, Poring Hot Springs, Sabah, Malaysia	Sungai Langanan, Poring Hot Springs, Sabah, Malaysia	Sungai Kipungit II, Poring Hot Springs, Sabah, Malaysia	Sungai Malina, Crocker Range Park, Sabah, Malaysia	Sungai Ulu Tomani, near Kemabong/ Sipitang, Sabah, Malaysia	Sabah & Sarawak (see Appendix)	Sabah & Sarawak (see Appendix)
SVL	32.2	35.4	27.6	29.3	26.4	34.3±2.8 (29.3–40.3)	26.5±1.6 (22.3–29.2)
TFL	17.5	18.1	16.1	15.2	15.3	18.6±1.4 (16.2–21.7)	14.9±1.1 (13.2–17.2)
HW	11.7	12.1	9.9	10.8	9.1	11.6±1.0 (10.3–13.7)	9.1±0.6 (7.7–10.2)
HL	8.7	9.0	6.8	7.9	6.8	9.7±0.9 (8.4–12.0)	7.7±0.5 (6.5–8.9)
ED	4.6	4.7	3.8	3.8	3.5	4.3±0.4 (3.7–5.1)	3.7±0.3 (2.9–4.5)
TD	1.7	1.8	1.5	1.5	1.5	1.8±0.2 (1.4–2.3)	1.4±0.1 (1.2–1.7)
EW	2.6	3.0	2.6	2.6	2.6	3.5±0.3 (3.0–4.4)	2.9±0.3 (2.3–3.4)
IO	4.1	4.4	3.6	3.7	3.4	3.7±0.2 (3.3–4.3)	3.1±0.2 (2.7–3.5)
EN	2.6	2.8	2.3	2.5	2.2	2.8±0.3 (2.3–3.5)	2.1±0.2 (1.9–2.4)
NS	2.3	2.4	2.2	2.4	2.0	2.6±0.2 (2.1–3.0)	2.0±0.2 (1.7–2.3)
NN	3.8	3.5	3.3	3.0	3.0	3.6±0.3 (2.9–4.4)	2.9±0.2 (2.5–3.3)
HND	9.4	10.1	8.0	8.8	8.7	10.2±0.8 (8.8–12.3)	8.2±0.5 (7.2–9.4)
FOT	13.7	14.3	12.6	12.8	11.3	15.1±1.1 (12.9–17.3)	11.9±0.8 (10.6–13.2)

each other, bearing small teeth; tongue moderately broad, bifurcated at distal end and free for about one-third of its length; median lingual process absent.

Dorsal surfaces of head and body smooth; abdomen and ventral side of thighs coarsely granular; chin, throat and chest smooth; supratympanic fold weakly expressed; weak supracloacal fold above vent, not free distally; large number of small tubercles in infraanal region and on ventral side of thigh; row of small white tubercles along postaxial edge of forearm; large conical tubercle on tibiotarsal articulation; several very small white tubercles along postaxial edge of tarsus.

Arms moderately slender; tips of fingers enlarged into broad oval discs, each with circummarginal groove; disc of Finger III as wide as 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; distal subarticular tubercles on Fingers III and IV as large as subarticular tubercles of Fingers I and II and much larger than proximal ones; webbing formula of hand: **I**2-2**II**1.75-3**III**2-2**IV** (Fig. 2); thenar tubercle large (length 1.7 mm), oval; palmar tubercle very small (length 0.6 mm); metacarpals with several supernumerary small tubercles; narrow dermal fringe along postaxial edge of Finger IV between proximal end of disc and palmar tubercle (Fig. 2).

Legs slender, moderately long (TFL/SVL 0.54); heels overlap each other by 4.3 mm when knees are flexed and thighs held perpendicularly to median body plane; tibiotarsal articulation reaching level of tip of snout when legs are adpressed forward along trunk; tips of toes enlarged into broad oval discs, each with circummarginal groove; discs of toes smaller than those of fingers; relative length of toes: I < II < III < V < IV; 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^{+}-2**II**1-2.25**III**1.5-3**IV**2^{+}-1^{+}**V;** inner metatarsal tubercle oval, small (length 1.3 mm); outer metatarsal tubercle absent; few supernumerary small tubercles on metatarsals; narrow dermal fringe along postaxial edge of Toe V from proximal end of disc to base of metatarsus.

Colouration in life: Dorsum ochre during the day, light brown during the night, more or less regularly spotted with minute dark dots; several large, irregularly shaped, dark brown spots on dorsum; narrow, dark brown interorbital band extending to margins of upper eyelids; a large irregularly shaped white infraorbital spot on each side of head, surrounded by a thin dark brown line; two additional small white spots below tympanum on each side of head; dorsal faces of arms and legs with darker, greyish (during the day) to dark brown (during the night) crossbars; groin region, anterior and posterior faces of thighs, ventral face of tibia, anterior face of tarsus, and dorsal face of proximal halves of Toes I to III bright yellow; dorsal faces of Fingers I and II whitish; throat and venter white; ventral face of arms and legs largely unpigmented; ventral faces of feet and hands brown; webbing between fingers and toes greyish; iris ruby, lightened to yellow marginally, and with a black rim along its outer edge.

Character alteration in preservative: Dorsal colouration faded to light grey (Fig. 1). Yellow colouration of legs paled but still discernible. Dark dorsal markings faintly visible except interorbital band, which has remained distinct. Iris colouration faded to bluish grey. Dermal calcars on the heels have shrivelled considerably but are still distinctly discernible.

Variation: The paratypes and referred specimens are very similar to the holotype in measurements, proportions, and extents of hand and toe webbing (Tab. 1). Fingers III and IV of the right hand of the female paratype (ZFMK 85132) are fused, probably as a result of an injury suffered during metamorphosis. In preservative, the yellow colouration of legs has faded and is only faintly discernible in the paratypes and referred specimens. The female paratype is tan brown dorsally, whereas all male specimens are light grey like the holotype.

Advertisement call: In total, 18 advertisement calls from four males were recorded at the type locality (Sungai Langanan) and recorded males were subsequently photographed. They were referred to the new species for showing reduced hand and toe webbings, absence of a pointed tubercle on the upper eyelid, a comparatively small thenar tubercle, and a short, sub-truncate snout. Ambient air temperature was 21°C. The frogs called at irregular intervals between 28 seconds and several minutes. The call consisted of 1–3 very short click notes (Fig. 3). Duration of an individual note was 10–36 ms. In two- and three-note calls, the interval between notes varied between 55 and 168 ms. Energy maximum was at 4650–5400 Hz (Fig. 3). In two- and three-note calls, frequency of the individual notes differed by 50–400 Hz. Prominent harmonics were at 15,000 Hz (Fig. 3).

Ecology: The type specimens were collected in August. The females were encountered at some distance from the nearest stream (Malkmus 1996, Malkmus et al. 2002). They do not contain enlarged eggs, indicating that the species does not reproduce at that time of the year, i.e., the end of the dry season. Calling males and recently deposited foam nest were observed at the type locality in November during the rainy season. Males called from leaves overhanging the water at heights between 1.5 and 4 m. The foam nests were found at similar heights between 1.5 and 2.5 m above the water surface.

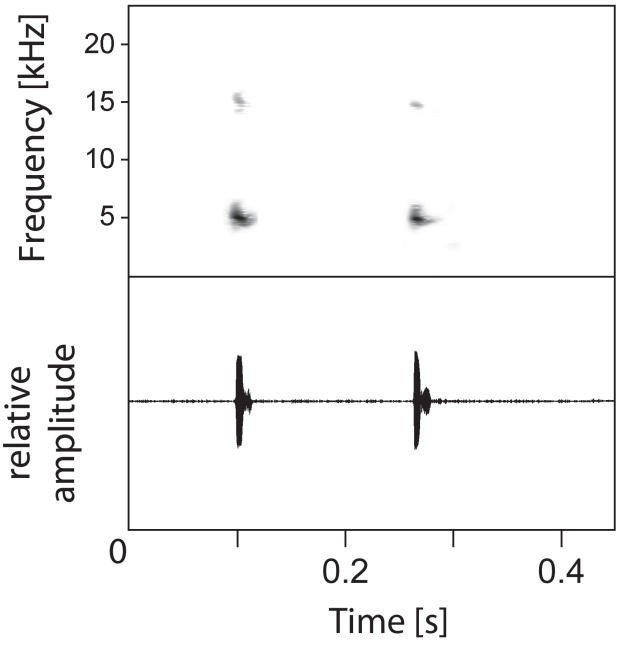

Figure 3. Audiospectrogram (top) and corresponding oscillogram (bottom) of a two-note advertisement call of a topotypic male *Rhacophorus malkmusi*. Ambient air temperature 21°C.

Etymology: The specific epithet is dedicated to Rudolf Malkmus, honouring his contributions to our knowledge of the amphibians of Gunung Kinabalu.

Comparisons: Because of their close morphological resemblance, the specimens of the new species were previously referred to *R. gauni*. They were compared with voucher specimens of *R. gauni* from throughout the range of the species, including several of the type specimens (Fig. 4, Tab. 1, Appendix). *Rhacophorus malkmusi* differs from *R. gauni* (characters in parentheses) by the absence of a large, pointed tubercle on the edge of the upper eyelid (tubercle usually present); the presence of vomerine ridges bearing small teeth (ridges and teeth absent); a relatively larger interorbital distance, IO/EW 1.47–1.57 (0.81–1.21) in females, 1.33–1.42 (0.86–1.22) in males; a relatively shorter head, HW/HL 1.34–1.35 (1.11–1.28) in females and 1.33–1.44 (1.11–1.27) in males (Fig. 5A); an obtuse snout, sub-truncate in lateral view (less obtuse, rather sloping from nostril to tip of snout in lateral view; Fig. 5B); an oblique loreal region (loreal region concave); a smaller thenar tubercle, its size being less than half the length and volume of the metacarpal of Finger I (larger, two-thirds to four-fifth the size of the metacarpal; Fig. 2); and less developed toe webbing, **I**$1^{(+)}$-2**II**1-2.25**III**1.5-3**IV**$2^{(+)}$-$1^{(+)}$**V**(**I**[1–1.5]-[1–2]**II**1-[1.5–2]**III**1-[2–$2^{(+)}$]**IV**[$2^{(-)}$–2]-1**V**) in females (Fig. 2), **I**($1^{(+)}$–1.5)-2**II**(1–$1^{(+)}$)-(2–$2^{(+)}$)**III**($1^{(+)}$–1.5)-(2.5–3)**IV**($2^{(-)}$–2)-1**V** (**I**[1–2]-[1.25–2]**II**1-[$2^{(-)}$–2]**III**1-[2–$2^{(+)}$]**IV**[$2^{(-)}$–2]-1**V**) in males. Finger webbing is quite variable in *R. gauni*, with **I**2-2**II**(1–1.75)-(2–3)**III**(1–2)-(1–1.75)**IV** in females and **I**2-2**II**(1–$2^{(-)}$)-(2–3)**III**(1–2)-(1–2)**IV** in males, but generally more extensive than in *R. malkmusi* (**I**2-2**II**1.75-3**III**2-2**IV** in females, **I**2-2**II**1.5-3**III**2-2**IV** in males) (Fig. 2). In a few specimens, however, webbing occasionally attains lower values compared to those of *R. malkmusi* on one finger or another, which in combination accounts for the high level of variation observed in *R gauni*.

PCA corroborated that the two species were morphometrically distinct. PC 1 and PC 2 clearly separated *R. malkmusi* from *R. gauni* (Fig. 6). Interorbital distance, eyelid width, head width, and webbings on Finger IV and Toe IV most heavily loaded PC 1, and head length, and hand and foot lengths PC 2 in males, whereas interorbital distance and webbings on Finger IV and Toe IV heavily loaded PC 1, and head length, eyelid width, and hand and foot lengths PC 2 in females (Tab. 2).

Apart from *R. gauni*, the new species could be confused with a few other species from Southeast Asia, i.e., *R. bimaculatus* (Peters, 1867) (Philippines), *R. belalongensis* Dehling & Grafe, 2008 (Borneo, Fig. 7A), and

R. gadingensis Das & Haas, 2005 (Borneo, Fig. 7B). All three species have a relatively longer head, with HW/HL 1.01–1.11 in *R. belalongensis*, 1.02–1.20 in *R. bimaculatus*, and 1.08–1.19 in *R. gadingensis* (vs. 1.33–1.44 in *R. malkmusi*; see also Fig. 7), and have blue spots on the flank, groin and thigh (yellow without blue spots in *R. malkmusi*). *Rhacophorus belalongensis* (**I**1-1.5**II**1-2**III**1^{+}-2^{+}**IV**2-1**V**) and *R. gadingensis* (**I**1-2**II**1-2**III**1-2^{+}**IV**2-1**V**) have more extensively webbed toes, and the interorbital distance is relatively smaller with IO/EW 0.92–1.07 in *R. belalongensis* and 1.05–1.22 *R. gadingensis* (vs. 1.33–1.57 in *R. malkmusi*). *Rhacophorus bimaculatus* and *R. gadingensis* lack vomer ridges and teeth (present in *R. malkmusi*).

The advertisement call of *R. malkmusi* differs from the advertisement calls of most of the other *Rhacophorus* species from Borneo (Malkmus et al. 2002, Dehling 2008, Dehling et al. 2010). It is similar to the calls of *R. belalongensis*, *R. gadingensis*, and *R. gauni*, which all emit series of 1–3 short clicks (Inger & Stuebing 2005, M. Dehling unpubl. data). Only the advertisement call of *R. belalongensis* has been analysed in detail (Dehling & Grafe 2008). The click notes of *R. belalongensis* have a longer duration (70 ms) and a higher frequency (5.8 kHz) than those of *R. malkmusi* (10–36 ms, 4.6–5.4 Hz).

Remarks: *Rhacophorus malkmusi* was confused with *R. gauni* in the past because of its close morphological resemblance. The two species occur sympatrically at Poring Hot Springs on the eastern slope of Gunung Kinabalu. Apart from Malkmus (1996) and Malkmus et al. (2002),

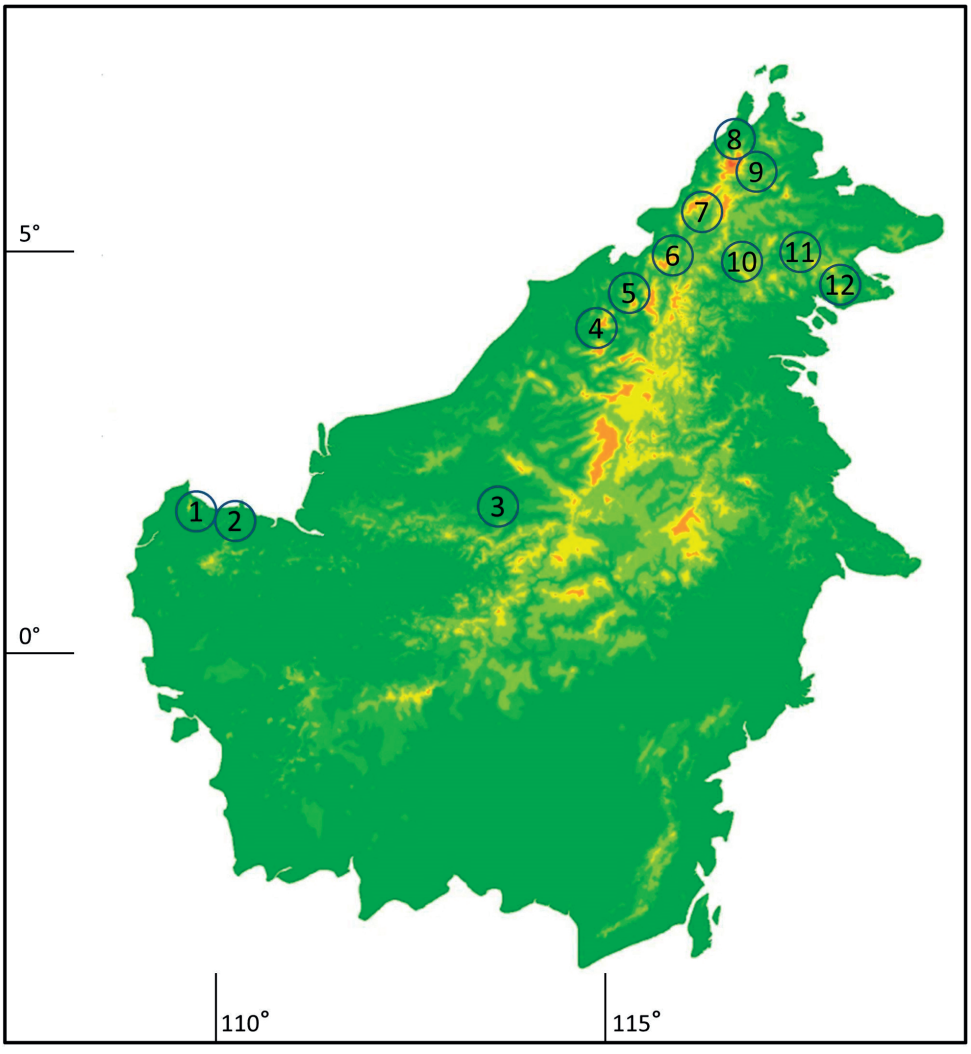

Figure 4. Collecting localities of examined voucher specimens of *Rhacophorus gauni*, *R. malkmusi*, *R. belalongensis*, and *R. gadingensis* in Borneo (see Appendix). 1 – Gunung Gading, Sarawak (type locality of *R. gadingensis*); 2 – Kubah National Park, Matang Range, Sarawak; 3 – Nanga Tekalit, Sarawak (type locality of *R. gauni*); 4 – Gunung Mulu National Park, Sarawak; 5 – Ulu Temburong National Park; Brunei Darussalam (type locality of *R. belalongensis*); 6 – Mendolong Camp, Sipitang District, Sabah; 7 – Crocker Range, Sabah; 8 – Marak Parak, Sabah; 9 – Poring Hot Springs, Sabah (type locality of *R. malkmusi*); 10 – Maliau Basin, Sabah; 11 – Danum Valley Field Centre, Sabah; and 12 – Tawau Hills National Park, Sabah.

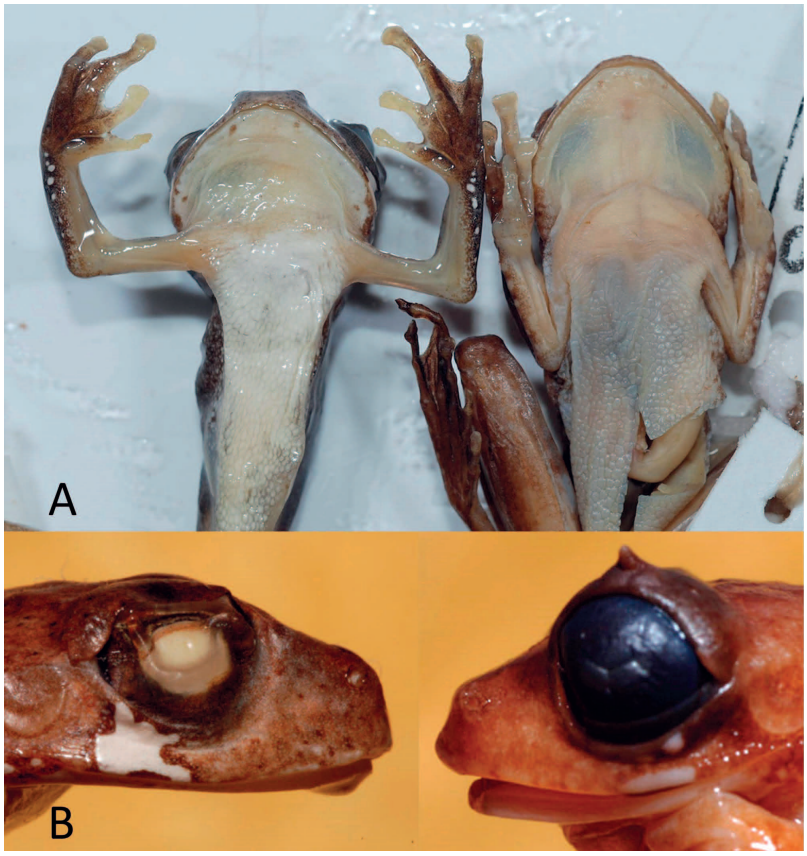

Figure 5. A) Male paratype of *Rhacophorus malkmusi* (left, SP 21113, SVL 27.6 mm) and male *R. gauni* (right, SP 1257, SVL 28.4 mm) from Poring Hot Springs. Note the comparatively short head and small thenar tubercle in *R. malkmusi*. B) Lateral view of the heads of *R. malkmusi* (left, female paratype, ZFMK 85132) and *R. gauni* (right, female paratype, FMNH 139346).

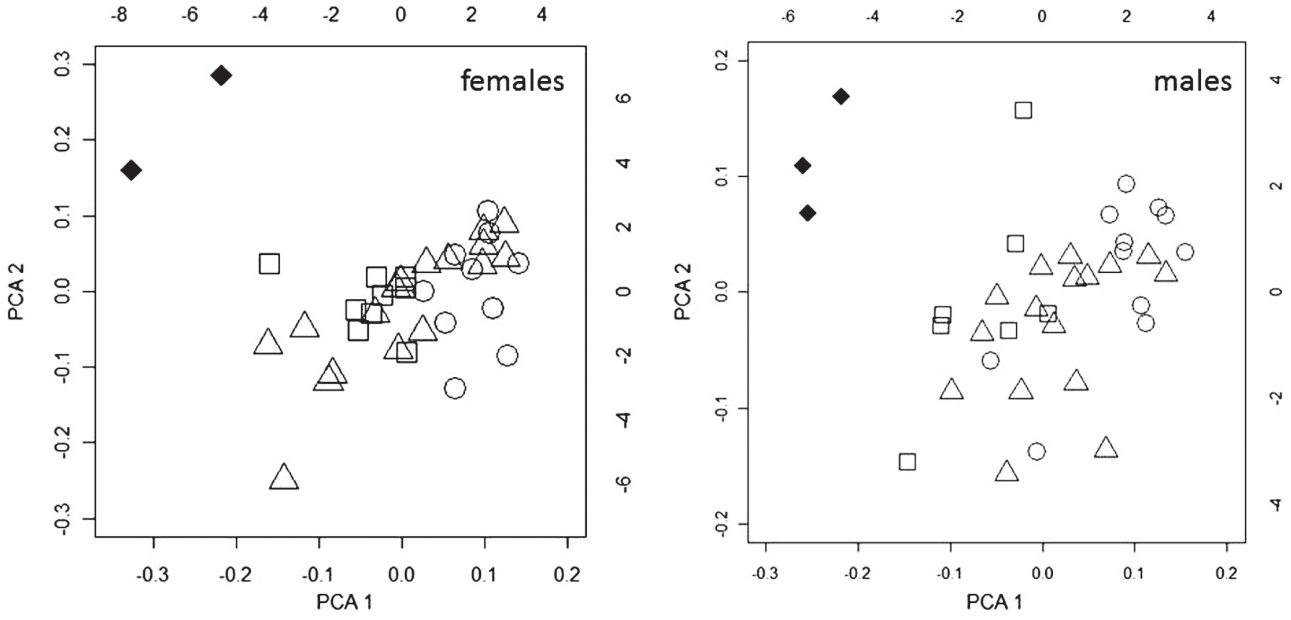

Figure 6. Morphometric differentiation as assessed by principal component analysis (Tab. 2) among 38 female specimens (left) and 37 male specimens (right) representing *Rhacophorus malkmusi* (filled rhomb) and *Rhacophorus gauni* from three geographic regions: Sarawak (circle); submontane sites in western Sabah (square); lowlands of eastern Sabah (triangle).

who in fact referred to *Rhacophorus malkmusi*, "*R. gauni*" has been reported from Gunung Kinabalu by Inger & Tan (1990), Inger & Stuebing (1992), Wong (1994), Inger et al. (1996), Lakim et al. (1999), and Inger et al. (2000). It is currently unclear to which species these reports actually refer because no references were made to postmetamorphic voucher specimens or photographs of those. Both species are represented in scientific collections by very few specimens from Gunung Kinabalu, even though *Rhacophorus malkmusi* is common at its type locality. Besides Gunung Kinabalu, *R. malkmusi* has been collected at two submontane sites in southwestern Sabah (at the foothills of the Crocker Range and near Kemabong/Sipitang). These isolated records do probably not reflect properly the geographic distribution of *R. malkmusi* in Sabah. The herpetological inventory of the montane regions of western

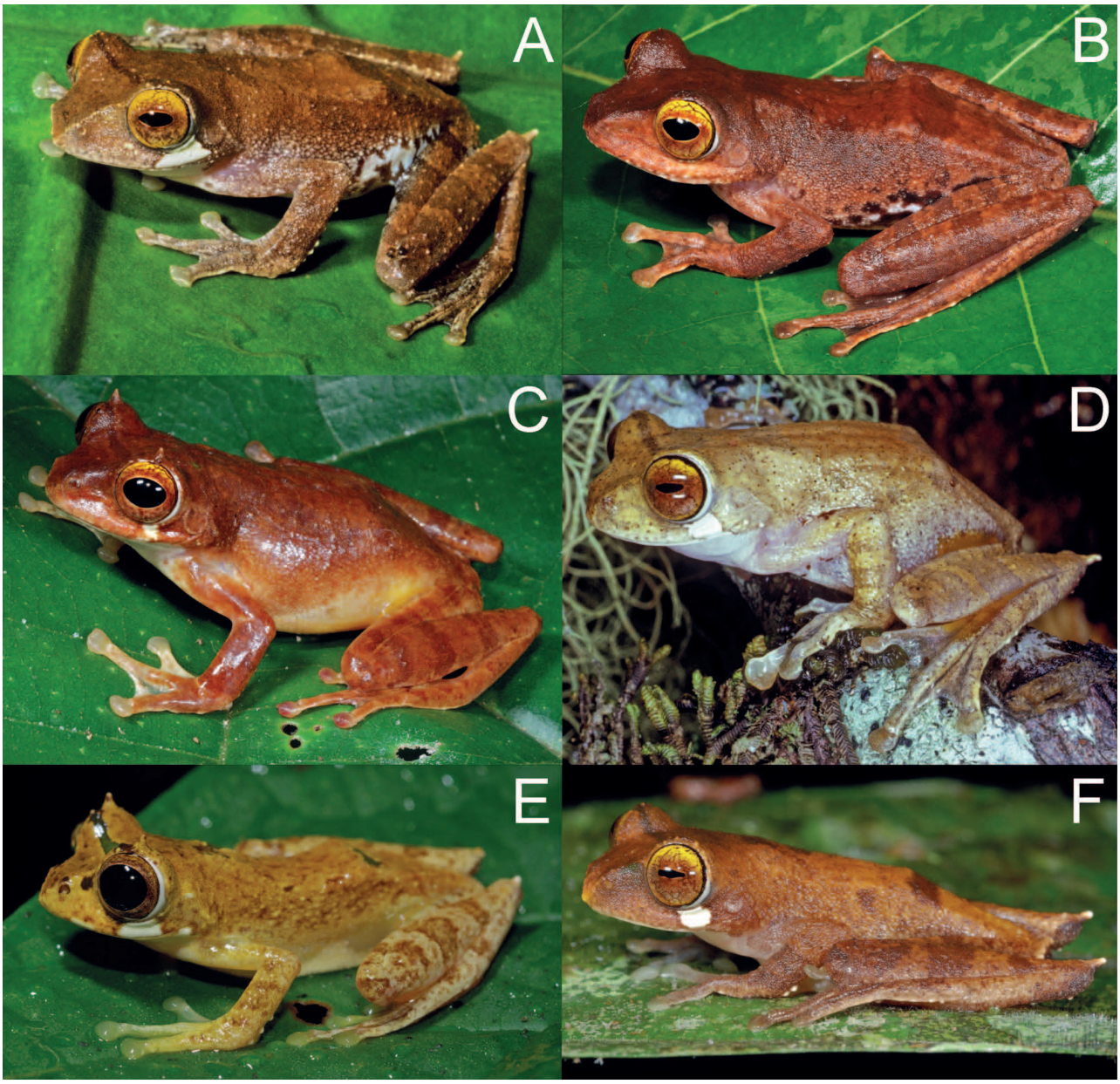

Figure 7. Photographs of live specimens of *Rhacophorus malkmusi* and morphologically similar Bornean *Rhacophorus* species. A) *Rhacophorus belalongensis*, adult female (holotype) from Kuala Belalong Field Studies Centre, Brunei Darussalam; B) *R. gadingensis*, adult female from Kubah National Park, Sarawak, Malaysia; C) *Rhacophorus gauni*, adult female from Sungai Melinau Paku, Gunung Mulu National Park, Sarawak, Malaysia; D) *Rhacophorus malkmusi*, adult female (paratype) from Sungai Langanan, Poring Hot Springs, Sabah, Malaysia (Photo: R. Malkmus); E) *Rhacophorus gauni*, adult male from Sungai Melinau Paku, Gunung Mulu National Park, Sarawak, Malaysia; F) *Rhacophorus malkmusi*, adult male (topotype) from Sungai Langanan, Poring Hot Springs, Sabah, Malaysia.

Table 2. Principal component analysis based on 16 standardized morphometric features of 34 males and 36 females of *Rhacophorus malkmusi* and *R. gauni*. Morphometric parameters accounting strongly for discrimination among species are highlighted in bold.

	males		females	
	PC 1	PC 2	PC 1	PC 2
tibia-fibula	-0.18	-0.21	-0.19	-0.28
head width	**-0.27**	-0.12	-0.25	-0.23
head length	0.18	**-0.33**	-0.01	**-0.35**
eye diameter, horiz.	0.12	-0.13	-0.26	-0.04
tympanum diameter	-0.05	-0.25	-0.14	-0.14
eyelid width	**0.30**	-0.20	0.18	**-0.30**
interorbital distance	**-0.36**	-0.08	**-0.36**	-0.03
eye to nostril	-0.24	-0.11	-0.16	-0.23
nostril to snout	-0.17	-0.03	-0.10	-0.35
internarial distance	-0.11	-0.31	-0.16	-0.21
hand length	-0.06	**-0.37**	-0.11	**-0.31**
webfing III	-0.21	-0.14	-0.23	0.03
webfing_IV	**-0.28**	0.02	**-0.29**	0.06
foot length	-0.01	**-0.38**	-0.09	**-0.31**
webtoe IV pre	**-0.31**	0.21	**-0.30**	0.24
webtoe IV post	**-0.26**	-0.13	**-0.29**	0.18
Eigenvalue	5.04	2.52	5.40	3.96
Cumulative proportion of explained variance	0.28	0.42	0.30	0.52

Sabah is still largely incomplete (Das 2006, Matsui 2006) and additional field work will likely reveal the presence of *R. malkmusi* at numerous sites along these mountain ranges.

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Appendix
Comparative material examined

Rhacophorus angulirostris – Malaysia: Sabah: Gunung Trusmadi (SP 2859, 2869, 2884, 2896, 2904, 2913); Sungai Silau-Silau, Headquarters, Kinabalu National Park (ZMB 49022, 70073).

Rhacophorus baluensis – Malaysia: Sabah: Headquarters, Taman Kinabalu, Ranau District (SP 24, 1291); Restaurant Bayu, near Kinabalu Park, Ranau District (SP 2802).

Rhacophorus belalongensis – Brunei Darussalam: Kuala Belalong Field Studies Centre, Temburong District (ZMB 70377 [holotype], 70378, 70379 [paratypes]; UBD GK 06-22, 06-23, 06-24, 06-25, 06-26, 06-57, G07-1, 07-2, 07-3, 07-4, 07-5, 07-6, 07-7, 07-8, 07-9 [paratypes]).

Rhacophorus cf. *bipunctatus* – India: "Travancore", Kerala state (ZMB 10131). MYANMAR: "Birma" (ZMB 11575, 70072).

Rhacophorus bimaculatus – Phillipines: Agusan River, Mindanao (ZMB 5681 [syntype]); Dapitan, Mindanao (SMF 7053).

Rhacophorus borneensis – Malaysia: Sarawak: Batang Ai National Park, Sri Aman Division (NMBE 1056516–1056518). "Borneo" (SMF 76372 [two specimens]).

Rhacophorus cyanopunctatus – Brunei Darussalam: Kuala Belalong Field Studies Centre, Temburong District (UBD GK06-13). Malaysia: Sabah: East Coast Residency, Kinabatangan District (FMNH 77158); Sungai Tawau, Tawau Hills Park, Tawau District (FMNH 250942). Sarawak: Gunung Mulu National Park, Miri Division (NMBE 1056480; ZMB 70707–70709); Nanga Tekalit Camp, Kapit Division (FMNH 136316, 137990–137992, 139347, 146199, 221749, 221750); Labang camp on Sungei Seran, Bintulu Division (FMNH 147892, 147898); Tubau camp on Sungei Pesu, Bintulu Division (FMNH 157308, 157309, 157312, 157313, 157319, 157321–157323). Singapore: no locality (FMNH 100964). Thailand: Khao Sok National Park, Surat Thani (ZMB 57895 [holotype]).

Rhacophorus dennysi – China: Northern Guangdong Province (ZMB 27715); "Gao-fung Provinz", Kuangtun [= Guangdong Province] (ZMB 39303); "Pingshiang", Jiangxi Province (ZMB 28683); no locality (ZMB 24117, 54915, 66196–66202).

Rhacophorus dugritei – China: Batang, Sichuan Province (ZMB 27878, 27879, 54916–54928 [syntypes of *Rhacophorus pleurostictus batangensis* Vogt, 1924]).

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 1165–1168, 20377); Taman Bukit-bukit Tawau, Tawau District (SP 637, 1264). Sarawak: Gunung Mulu National Park, Miri Division (NMBE 1056481–1056485).

Rhacophorus edentulus – Indonesia: Northern Sulawesi (ZMB 34323).

Rhacophorus fasciatus – Malaysia: Sarawak: Gunung Mulu National Park, Miri Division (NMBE 1056492, 1056525; ZMB 70710).

Rhacophorus gadingensis – Malaysia: Sarawak: Gunung Gading National Park, Lundu Division (JMD 494); Kubah National Park (JMD 342–348).

Rhacophorus gauni – Malaysia: Sabah: Sungai Kilampun, Purulon Camp, Crocker Range National Park (FMNH 239235; SP 2172, 2176); Mendolong Camp, Sipitang District (FMNH 235045, 239236, 239240, 242922, 242923, 242941, 242926; SP 2178, 2179);

Poring Station, Mt. Kinabalu Park, Ranau District (FMNH 248308; SP 1257, 1805); Tawau Hills Park, Tawau District (FMNH 248924, 248925, 249833–249836; SP 645, 646, 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, 245905, 245909, 245910, 245913, 245915, 245920); Sungai Agathis, Maliau Basin (SP 20244). Sarawak: Mengiong River, Nanga Tekalit, Kapit Division (FMNH 137981, 137983, 137985, 139343, 139344, 139346 [paratypes], FMNH 145542, 145545, 146269, 195359, 195445–195449, 221743, 221744, 221746–221748); Gunung Mulu National Park, Miri Division (ZMB 70711–70717, NMBE 1056493–1056496).

Rhacophorus georgii – Indonesia: Tanke Solokko, Mekongga Mountains, Southeast Sulawesi (ZMB 34322).

Rhacophorus harrissoni – Brunei Darussalam: Batu Apoi, Temburong District (UBD 214). Malaysia: Sabah: Lower Segama, Lahad Datu District (SP 20392–20394); Maliau Basin (SP 20279–20281). Sarawak: Gunung Mulu National Park, Miri Division (NMBE 1056497–1056499).

Rhacophorus maximus – India: "Khassja" [= Khasi Hills, Assam] (ZMB 8498); North India (ZMB 10129).

Rhacophorus monticola – Indonesia: Southern Sulawesi (SMF 6829).

Rhacophorus nigropalmatus – Brunei Darussalam: Batu Apoi, Temburong District (UBD 366). Indonesia: Palembang, Sumatra (NMBE 1018981–1018989). Malaysia: Sabah: Sungai Stuebing, Trusmadi, Tambunan District (SP 223); Tawau Hills Park, Tawau District (SP 1286); "primary forest" (SP 20696).

Rhacophorus orlovi – Vietnam: Ky Anh-Ke Go, Ha Tinh Province (ZMB 63294, 63295 [paratypes]); Kannack Town, Buon Luoi village, Ankhe District, Gia-Lai Province (FMNH 253156).

Rhacophorus pardalis – 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 640–642, 644, 2778–2781); 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 1917–1919, 2084); Maliau Basin (SP 20255–20257); Sungai Rompon, Trusmadi (SP 671); Pulau Jembongan (SP 2190); Lower Segama, Lahad Datu District (SP 20378, 20381, 20382, 20384, 20389); Hutan Simpan, Mendamai, Pitas Kudat (SP 1169–1180); no locality (SP 1688, 1694, 1696); PDC Lembak Inbak, Telupid (SP 2660–2661); Malangkap Tomis, Kinabalu Park, Kota Belud District (SP 20768–20771); Sg. Kimanis, Kg. Kindosodon, Tambunan District (SP 21634). Sarawak: Bako National Park, Kuching Division (NMBE 1056564, 1056570); Batang Ai National Park, Sri Aman Division (NMBE 1056512–1056514); Gunung Mulu National Park, Miri Division (NMBE 1056515); Kubah National Park, Kuching Division (NMBE 1056579). Phillipines: Palawan (SMF 6994); Claveria, Northern Luzon (SMF 6995).

Rhacophorus penanorum – Malaysia: Sarawak: Gunung Mulu National Park, Miri Division (ZMB 70718 [holotype], 70719, 70720 [paratopotypes]).

Rhacophorus prominanus – Malaysia: Pahang: Gunung Brinchang, Cameron Highlands (ZMB 47984); Bukit Fraser (ZMB 52067, 52331).

Rhacophorus pseudacutirostris – Indonesia: Padang, Sumatra (NHW 16301:5 [holotype], NHW 16301:1-4 [paratypes]).

Rhacophorus reinwardtii – Indonesia: Java (NMBE 1018979, 1018980).

Rhacophorus rufipes – Brunei Darussalam: Kuala Belalong Field Studies Centre, Temburong District (UBD GK06-08). Malaysia: Sarawak: Gunung Mulu National Park, Miri Division (NMBE 1056519–1056524).