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A new burrow-utilising fanged frog from Sarawak, East Malaysia (Anura: Dicroglossidae)

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Abstract. We found a unique, burrow-utilising dicroglossid frog of the genus *Limnonectes* from western Sarawak, East Malaysia. This frog is always found near burrows on the ground, into which it escapes when disturbed. It is much divergent from other congeners in morphology and mtDNA sequences. This species is nested using molecular phylogeny in a clade with Bornean populations of *L. kuhlii* complex and *L. hikidai*, but differs completely from the others by having relatively smooth skin, distinct tympanum, and chocolate brown dorsum with tiny blue spots laterally. We thus describe it as a new species and discuss its unique habit of burrow utilisation.

Key words. New *Limnonectes*, MtDNA phylogeny, burrow utilisation, Sarawak, taxonomy

INTRODUCTION

The island of Borneo is famous for its diverse endemic amphibian species (Inger, 1966; Inger & Tan, 1996; Matsui et al., 2014), but the species diversity will be surely much more increased by the finding of many cryptic taxa, including the *Limnonectes kuhlii* complex (Matsui et al., 2010a; McLeod, 2010). Frogs of this complex have enlarged head with fang-like processes on lower jaw in males, thus they are called fanged frogs. They normally have brown dorsum covered by tubercles in various degrees, and inhabit near mountain streams of various altitudes (Inger, 1966). *Limnonectes kuhlii* was once considered a wide-ranging species, but is now regarded as a complex of many distinct species that are phylogenetically remote from Javanese *L. kuhlii* (Tschudi, 1838). Although several continental populations have been described as distinct species, studies on Bornean populations have been lacking (Matsui et al., 2013).

In our recent amphibian survey in Serian, southwestern Sarawak (Fig. 1), we encountered a frog with unique coloration, but could not collect it because it was unusually cautious and quickly escaped. In a follow up survey, we succeeded in taking photographs of the frog, but again it escaped into a nearby burrow on the ground. However, at the third visit, we successfully collected the frog and observed a part of its ecology.

The frog from Serian is surely a member of *Limnonectes*, but is different from all species currently known from Borneo. Rather, it is superficially similar to *L. tweediei* (Smith, 1935) from the Malay Peninsula in possessing relatively smooth skin. In the molecular phylogenetic tree among several species of *Limnonectes*, *L. tweediei* forms a clade with *L. macrognathus* (Boulenger, 1917) and *L. khasianus* (Anderson, 1871) (including *L. laticeps* [Boulenger, 1882]; Ohler & Deuti, 2013), both never recorded from Borneo (Matsui & Nishikawa, 2014). Thus, it was interesting to elucidate the phylogenetic position of the frog from Serian from a biogeographical viewpoint.

Our subsequent analyses on molecular phylogeny of the species revealed it to be actually nested in a clade within Bornean populations of *L. kuhlii* complex and *L. hikidai* (formerly called *L. laticeps*: Matsui & Nishikawa, 2014), and not with continental species including *L. tweediei*. Genetic divergence of the species from the other congeners was substantially large. The Serian species is also morphologically unique from the others, and what is more interesting is its ecology of using burrows as retreats, which has never been reported in *Limnonectes*. Based on these results, we describe this unique frog as a new species in this paper.

MATERIAL AND METHODS

The DNA sequence data were obtained from tissues frozen or preserved in 99% ethanol (Table 1). Methods for DNA extraction, and amplification and sequencing of the mtDNA fragments are same as those reported by Matsui et al. (2010a, b). The resultant sequences were deposited in GenBank (Accession numbers AB981409–981421: Table 1). We reconstructed phylogenetic (maximum likelihood [ML] and Bayesian inference [BI]) trees from 2430 base pairs (bp) of partial sequences of mitochondrial 12S and 16S rRNA genes.

From specimens stored in 70% ethanol, we took body measurements mainly following Matsui (1984, 1994): (1) snout-vent length (SVL); (2) head length (HL); (3) nostril-

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Table 1. Sample of *Limnonectes* species from Serian, Sarawak and other species used for DNA analysis in this study together with the information on voucher, collection locality, and GenBank accession numbers. Voucher abbreviations: BORN = BORNEENSIS Collection, University Malaysia Sabah, CIB = Chengdu Institute of Biology; KUHE = Graduate School of Human and Environmental Studies, Kyoto University; UI = University of Indonesia.

S/N	Species	Locality	Voucher No.	Accession No.
1	*Limnonectes* sp.	Serian, Sarawak, Borneo, Malaysia	KUHE 47859	AB981409
2	*Limnonectes* sp.	Serian, Sarawak, Borneo, Malaysia	KUHE 47824	AB981410
3	*Limnonectes* sp.	Serian, Sarawak, Borneo, Malaysia	KUHE 47858	AB981411
4	*Limnonectes* sp.	Serian, Sarawak, Borneo, Malaysia	KUHE 47815	AB981412
5	*L.* "*kuhlii*"	Matang, Sarawak, Borneo, Malaysia	KUHE 12025	AB526322
6	*L.* "*kuhlii*"	Kinabalu, Sabah, Borneo, Malaysia	BORN 22645	AB526323
7	*L. hikidai*	Matang, Sarawak, Borneo, Malaysia	KUHE 10654	AB971130
8	*L. jarujini*	Kaeng Krachan, Phetchaburi, Thailand	KUHE 20101	AB558942
9	*L. bannaensis*	Jinghong, Yunnan, China	CIB 200901116	AB526312
10	*L. khasianus*	Bala, Narathiwat, Thailand	KUHE 23158	AB981414
11	*L. tweediei*	Johor, Malaysia	KUHE 52184	AB981415
12	*L. macrognathus*	Ranong, Thailand	KUHE 23923	AB981416
13	*L. limborgii*	Janda Baik, Malaysia	KUHE 15614	AB981417
14	*L. paramacrodon*	Tawau, Sabah, Borneo, Malaysia	BORN 09154	AB981418
15	*L. palavanensis*	Penrissen, Sarawak, Borneo, Malaysia	KUHE 54429	AB981419
16	*L. leporinus*	Matang, Sarawak, Borneo, Malaysia	KUHE 53486	AB981420
17	*L. kuhlii*	Java, Indonesia	KUHE 26127	AB981421
18	*Fejervarya iskandari*	East Java, indonesia	UI unnumbered	AB526324

eyelid length (N-EL); (4) snout length (SL); (5) eye length (EL); (6) tympanum-eye length (T-EL); (7) tympanum diameter (TD); (8) head width (HW); (9) internarial distance (IND); (10) interorbital distance (IOD); (11) upper eyelid width (UEW); (12) forelimb length (FLL); (13) lower arm and hand length (LAL); (14) first finger length (1FL); (15) inner palmar tubercle length (IPTL); (16) hindlimb length (HLL); (17) tibia length (TL); (18) foot length (FL); (19) inner metatarsal tubercle length (IMTL); (20) first toe length (1TOEL); and (20) fourth toe disk diameter (4TDW). In describing morphometric characteristics, percentage ratios (R) of the characters to SVL were used. Due to the paucity of specimens available, no statistical analyses were conducted. The system of description of toe-webbing states followed that used by Savage (1997).

Specimens of *Limnonectes* examined for morphological comparisons are stored at the Sarawak Research Collections (SRC) and Graduate School of Human and Environmental Studies, Kyoto University (KUHE).

Fig. 1. Map of Sarawak, Malaysian Borneo, showing the locality where new *Limnonectes* species was collected (filled star).

RESULTS

In the phylogenetic trees obtained (Fig. 2), the specimens of *Limnonectes* sp. from Serian examined here proved to form a fully supported clade (ML-BS = 100, BI = 1.0) within the well-supported clade of the Bornean *L. kuhlii* complex (ML-BS = 99, BI = 1.0), together with *L.* "*kuhlii*" from Sabah and a clade of *L.* "*kuhlii*" from Sarawak and *L. hikidai*. However, the relationships among these three groups were not resolved. The sister clade of the Bornean *L. kuhlii* complex included continental *L. kuhlii* complex (*L. jarujini* Matsui, Panha, Khonsue, & Kuraishi, 2010b and *L. bannaensis* Ye, Fei, & Jiang, 2007), and *L. tweediei* showed no close relationships with *Limnonectes* sp. from Serian in spite of their morphological similarity. *Limnonectes* sp. from Serian substantially differed genetically from three lineages of the Bornean *L. kuhlii* complex in the sister clade by large genetic distances (uncorrected p-distance in 16S rRNA of 11.8–13.5%, Table 2), which values are higher than those observed between *L. limborgi* (Sclater, 1892) and *L. macrognathus* (9.4%) or between *L. jarujini* and *L. bannaensis* (10.9%).

Because the specimens from Serian are separated not only genetically, but also morphologically (see comparisons below) from the known species, we conclude the specimens as a distinct species and describe it as follows:

TAXONOMY

Limnonectes cintalubang, new species
(Figs. 3–5)

Etymology. The species name is from the Malay words "cintai", meaning to love, and "lubang", meaning a hole, alluding burrow-utilising habits of the new species.

Material examined. Holotype: KUHE 47859, an adult male from Ranchan, Serian, Samarahan Division, Sarawak, East Malaysia (01°08'30"N, 110°34'57"E, 64 m asl); K. Nishikawa, 4 July 2014. Paratypes: A total of nine specimens all from the type locality. KUHE 47824, 47858 (two females), SRC 00088 (former KUHE 47832), KUHE 47815, 47823, 47825, 47833, 47834, 47857 (seven juveniles); K. Nishikawa and K. Eto 3 and 4 July 2014.

Diagnosis. A small species of *Limnonectes* (SVL 45 mm in a male and 32–43 mm in females); cephalic hump absent in mature male; pointed tusk in mature male; tympanum distinct; hindlimb relatively short, tibiotarsal articulation of adpressed limb reaching center of eye; tips of digits dilated, forming small pads; toe webs poorly developed, at least $2^1/_2$ phalanges free of web on fourth toe; flaps on outer edge of fifth toe and along both edges of second and third fingers not movable; dorsum relatively smooth, with only weak transverse wrinkles, without dorsolateral fold; chocolate brown dorsally without markings except for small blue spots extending to flank and limbs.

Description of holotype (measurements in mm). Snout-vent length (SVL) 45.0; habitus moderately stocky (Figs. 3, 4); head slightly enlarged, as long (HL 17.7, 39.3%SVL) as broad (HW 17.7, 39.3%SVL); cephalic hump absent; snout obtusely rounded, obtuse in profile, well-projecting beyond lower jaw; eye length (EL 6.3, 14.0%SVL) slightly shorter

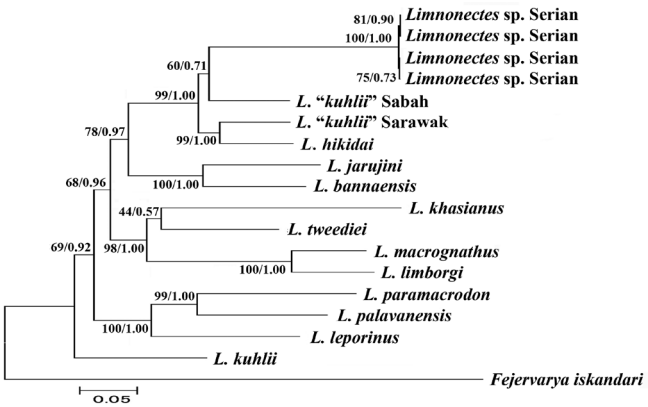

Fig. 2. ML tree from a 2430 bp sequence of mitochondrial 12S rRNA and 16S rRNA genes for samples of *Limnonectes* species from Serian and related frogs from Southeast Asia. Numbers above or below branches represent bootstrap supports for ML inference and Bayesian posterior probability (ML-BS/BPP).

than snout length (SL 6.7, 14.9%SVL); canthus rounded; lore sloping, concave; nostril dorsolateral, below canthus, slightly nearer to snout than to eye (N-EL 3.0, 6.6%SVL); internarial distance (IND 4.0, 8.9%SVL) narrower than interorbital distance (IOD 4.4, 9.8%SVL), latter wider than upper eyelid (UEW 3.3, 7.3%SVL); pineal spot absent; tympanum distinct, subcircular, length (TD 4.6,10.2%SVL) more than half eye diameter and separated from eye by two-fifths of tympanum diameter (T-EL 1.9, 4.2%SVL); vomerine teeth in oblique groups, behind line connecting rear rims of choanae, groups separated from one another and from choana by half length of one group, lower jaw with a pair of tooth like pointed projections near symphysis, about similar depth of mandible at base of projections; tongue oval, deeply notched posteriorly, without papillae; vocal sac and vocal slits absent.

Forelimb moderately thick, relatively short (FLL 27.1, 60.2%SVL); fingers slender; finger length formula: II = I < IV < III (Fig. 3A), first finger subequal to second; length of first, measured from distal edge of inner palmar tubercle (1FL 6.7, 14.9%SVL) slightly larger than length of eye; tips of fingers slightly swollen, forming small pads without circummarginal grooves; no webs between fingers; inner palmar tubercle moderate (IPTL 2.4, 5.3%SVL), oval, not elevated; middle palmar tubercle circular, indistinct, not contacting inner palmar tubercle; outer palmar tubercle slightly smaller than inner tubercle; proximal subarticular tubercles oval and elevated; distal subarticular tubercles low, flat and indistinct; no supernumerary metacarpal tubercles; edges of fingers with narrow ridges of skin at least distally, not freely movable.

Hindlimb thick, moderately short (HLL 65.6, 145.8%SVL) about 2.4 times length of forelimb; tibia short (TL 20.5, 45.6%SVL), heels not overlapping when limbs are held at right angles to body; tibiotarsal articulation of adpressed limb reaching to center of eye; foot (FL 20.8, 46.2%SVL) slightly longer than tibia; toe length formula I < II < V < III < IV; tips of toes swollen into distinct, small disks (disk diameter of fourth toe, 4TDW 1.0, 2.2%SVL); webbing formula: I 1 – 2 II 1 – $1^2/_3$ III 1 – 3 IV 3 – 1 V (Fig. 5B); no flap of skin along outer edge of fifth toe; subarticular tubercles oval and distinct; an elongate inner metatarsal tubercle, length (IMTL 3.4, 7.4%SVL), more than half length of first toe (1TOEL 5.6, 12.4%SVL); no outer metatarsal tubercle.

Skin very fragile in life, easily damaged when handled; dorsum relatively smooth, with faint transverse wrinkles; no warts or wrinkles on eyelid and top of snout; no transverse fold between posterior margins of eyes; moderate temporal fold from eye to above axilla; no dorsolateral ridge from posterior corner of eye to sacral region; no warts anterior to anus; side of trunk rugose, without tubercles; dorsal surface of hindlimb without warts; distal one-third of tarsus with a blunt dermal ridge extending proximally from metatarsal tubercle; throat, chest, and abdomen smooth; skin of gular region not modified; distinct brownish tinge, but without asperities, forming a nuptial pad covering medial surface of first finger from its base to level of subarticular tubercle.

Table 2. Uncorrected p-distances (in %) for fragment of 16S rRNA among sample of *Limnonectes* species from Serian and other species compared. See Table 1 for voucher details.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	*Limnonectes* sp.																	
2	*Limnonectes* sp.	0.1																
3	*Limnonectes* sp.	0.3	0.2															
4	*Limnonectes* sp.	0.2	0.3	0.1														
5	*L.* "*kuhlii*" Sabah	13.5	13.4	13.4	13.4													
6	*L.* "*kuhlii*" Sarawak	11.9	11.8	11.9	12.0	9.6												
7	*L. hikidai*	13.1	13.0	13.1	13.2	8.8	9.8											
8	*L. jarujini*	16.3	16.2	16.2	16.3	14.4	13.4	14.2										
9	*L. bannaensis*	16.1	16.1	16.1	16.2	14.6	13.7	14.2	10.9									
10	*L. khasianus*	18.7	18.6	18.8	18.9	17.7	17.4	17.0	16.6	15.8								
11	*L. tweediei*	17.2	17.1	17.3	17.4	15.6	14.4	14.4	13.8	14.4	15.1							
12	*L. macrognathus*	17.8	17.8	17.6	17.6	17.1	16.0	17.0	16.2	15.4	16.6	15.0						
13	*L. limborgii*	18.4	18.4	18.4	18.4	17.1	16.3	16.6	16.4	16.0	16.8	14.8	9.4					
14	*L. paramacrodon*	18.4	18.3	18.5	18.5	18.1	16.6	17.4	16.9	16.9	17.8	16.8	18.1	19.7				
15	*L. palavanensis*	18.4	18.3	18.4	18.5	16.4	16.1	15.4	16.8	15.2	18.6	16.8	16.5	17.4	13.9			
16	*L. leporinus*	17.3	17.2	17.3	17.3	15.6	14.8	15.3	16.1	14.4	18.0	15.6	16.6	18.3	15.5	14.6		
17	*L. kuhlii*	16.1	16.1	16.1	16.2	15.5	14.6	14.3	14.9	13.7	16.3	14.1	14.5	15.7	16.1	15.6	14.2	
18	*Fejervarya iskandari*	20.9	20.9	20.9	20.9	21.2	20.6	20.7	21.0	21.1	22.6	19.7	21.7	22.6	21.8	22.6	19.5	20.7

Table 3. Measurements of *Limnonectes cintalubang*, new species. SVL (mean ± 1SD, in mm) and medians of ratios (R) of other characters to SVL, followed by ranges in parenthesis. See text for character abbreviations.

Sex	7 young	1 M	2 F
SVL	22.3 ± 6.4 (13.4–34.7)	45.0 –	37.6 (32.0–43.1)
RHL	42.2 (41.1–46.5)	39.3 –	42.2 (40.6–43.8)
RN-EL	7.5 (6.5–9.4)	6.6 –	8.0 (7.5–8.4)
RSL	16.0 (14.7–17.5)	14.9 –	16.7 (16.5–16.9)
REL	17.3 (15.3–18.0)	14.0 –	13.0 (12.9–13.1)
RT-EL	1.6 (0.6–2.5)	4.2 –	3.4 (3.1–3.7)
RTD	7.8 (6.5–10.2)	10.2 –	8.7 (8.4–9.0)
RHW	43.2 (39.5–44.5)	39.3 –	43.1 (42.5–43.8)
RIND	11.5 (9.1–12.2)	8.9 –	9.0 (8.4–9.7)
RIOD	9.7 (8.9–12.2)	9.8 –	8.8 (8.2–9.4)
RUEW	8.6 (7.7–9.1)	7.3 –	8.2 (7.4–9.1)
RFLL	62.9 (59.1–69.4)	60.2 –	61.2 (58.9–63.4)
RLAL	48.6 (46.6–51.4)	45.8 –	50.1 (47.3–52.8)
R1FL	14.1 (12.2–15.4)	14.9 –	14.8 (13.9–15.6)
RIPTL	5.7 (4.5–6.2)	5.3 –	4.9 (4.9–5.0)
RHLL	157.8 (156.4–161.9)	145.8 –	158.9 (156.8–160.9)
RTL	49.3 (47.5–49.8)	45.6 –	48.5 (48.4–48.5)
RFL	50.7 (46.3–53.7)	46.2 –	49.5 (48.0–50.9)
RIMTL	6.7 (6.4–8.6)	7.4 –	8.5 (8.2–8.8)
R1TOEL	13.8 (11.8–15.2)	12.4 –	12.4 (11.6–13.1)
R4TDW	2.9 (2.2–3.2)	2.2 –	2.4 (2.3–2.6)

Color. In life, dorsum chocolate-brown without marking except for small bluish white spots scattered laterally from above tympanum to the level of sacrum (Fig. 3); head with a faint orange interorbital bar posterior to eye; no dark supratympanic stripe; side of body similar to flank with light spots; upper lip without dark bars; lower lip dark brown with white spots; limbs dorsally tinged reddish brown, without dark crossbars; throat irregularly mottled with light brown (Fig. 4B); chest to abdomen cream without dark spots; lateral side of limbs slightly mottled with brown, especially heavily on posterior thigh, tibia, and tarsus; ventral surfaces of hand and foot light brown. In preservative, dorsal color has become darker and bluish-white spots faded to white.

Variation. Individuals of the type series are very similar to each other in coloration. However, as shown in Table 3, individual variation in body proportions is not small surely because of ontogenetic change. In adults, a single male and only two females available can not be statistically compared, but they did not overlap in many characters: the male has larger values in SVL, REL, RT-EL, RTD, RIOD, and RIPTL, and smaller values in RHL, RN-EL, RSL, RHW, RUEW, RLAL, RHLL, RTL, RFL, RIMTL, and R4TDW than females. The point at which tibiotarsal articulation of adpressed limb reached is uniform, to center of eye, and tympanum is always distinct. In three larger paratypes, phalanges free of broad web vary from $2^1/_2$ to $3^3/_4$ on inner side, and $2^1/_2$ to $3^1/_3$ on outer side of fourth toe. Some smaller specimens have trace of dark brown bars on tibia and tarsus.

Comparisons. *Limnonectes cintalubang*, new species, is superficially similar to the continental *L. tweediei* in body size (females 32–43 mm vs. 33–41 mm in *L. tweediei*), nearly smooth body lacking warts, presence of visible tympanum, and poorly developed toe webs, but is differentiated from it by lacking dorsolateral fold and yellow tinge on ventral

Fig. 3. Dorsolateral view of a male holotype of *Limnonectes cintalubang*, new species (KUHE 47859).

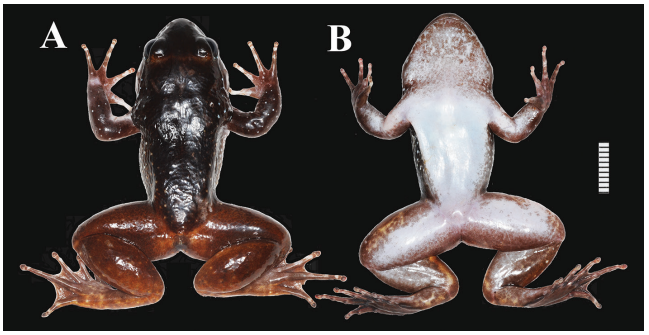

Fig. 4. A, dorsal; and B, ventral views of male holotype of *Limnonectes cintalubang*, new species (KUHE 47859). Scale bar = 10 mm.

side, and having weak transverse wrinkles on dorsum. *Limnonectes rhacodus* (Inger, Boeadi, & Taufik, 1996) has the back with numerous transverse wrinkles, but is much smaller (females 21–24 mm) and tympanum is partially obscured by skin (Inger et al., 1996).

The new species is easily differentiated from species of the *L. kuhlii* complex and *L. hikidai* by the presence of visible tympanum and much smoother skin. Also the new species differs from members of the *L. kuhlii* complex (*L. kuhlii*; *L. bannaensis*; *L. fujianensis* Ye & Fei, 1994; *L. isanensis* McLeod, Kelly, & Barley, 2012; *L. jarujini*; *L. sisikdagu* McLeod, Horner, Husted, Barley, & Iskandar, 2011; *L. megastomias* McLeod, 2008; *L. taylori* Matsui, Panha, Khonsue, & Kuraishi, 2010b, *L. namiyei* [Stejneger, 1901], *L. asperatus* [Inger, Boeadi, & Taufik, 1996], and *L. fragilis* [Liu & Hu, 1973]), by smaller body size and much less developed toe webbing (females 32–43 mm, web of fourth leaving at least $2^1/_2$ phalanges on each side, no movable flaps of skin on edges of fingers and toes in the new species, vs. females 40–86 mm, usually all of the toes broadly webbed to disks, and movable flaps of skin present along both edges of the second and third fingers and on outer edge of the fifth toe in the *L. kuhlii* complex and other related species). Small body size (females 32–43 mm in SVL), poorly developed toe webbing, and lack of movable flaps on edges of fingers and toe of the new species all apply to *L. hikidai* (females 34–40 mm), but they are completely different in dorsal color and skin texture as noted above.

Range. Known only from the type locality, Ranchan, Serian, Samarahan Division, state of Sarawak, East Malaysia.

Natural history. The new species was found in loose slopes of secondary forests with mixed bamboo and broad-leaf trees, always on the ground. The surface of the ground is flat and sparsely covered by dead leaves, but with plant roots and stones densely packing the shallow layers under the soil surface. Frogs were active after 1930 h and each always stayed near a burrow (Fig. 6A), into which they quickly escaped when disturbed. The burrow was up to ca. 5–10 cm in diameter (Fig. 6B) and had a long tunnel at the depth of 50–60 cm, and it was impossible to dig out the frog. Although only one of about 20 burrows observed had underground water, there was no pool at the immediate vicinity of the holes. The nearest water body was a stream ca. 8–12 m apart from the area.

We did not hear males calling in March, July, or December at the type locality. However, because females collected in early July possessed large ovarian eggs, the breeding season is thought to include summer seasons. The diameter of 10 eggs from a female (KUHE 47824) ranged from 1.63–1.88 (mean±1SD = 1.71±0.09) mm. Both the animal and vegetal hemispheres of eggs are creamy white in color, suggesting they are laid in shaded places.

Other species found in association with the present new species in the forest were: *Leptolalax gracilis* (Günther, 1872), *Leptolalax* sp., *Meristogenys jerboa* (Günther, 1872), *Nyctixalus pictus* (Peters, 1871), and *Polypedates leucomystax* (Gravenhorst, 1829).

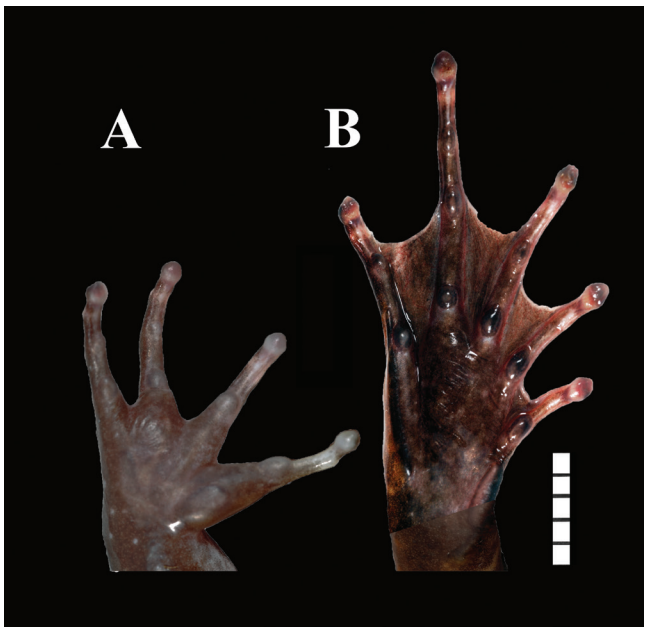

Fig. 5. A, ventral view of right hand; and B, foot of male holotype of *Limnonectes cintalubang*, new species (KUHE 47859). Scale bar = 5 mm.

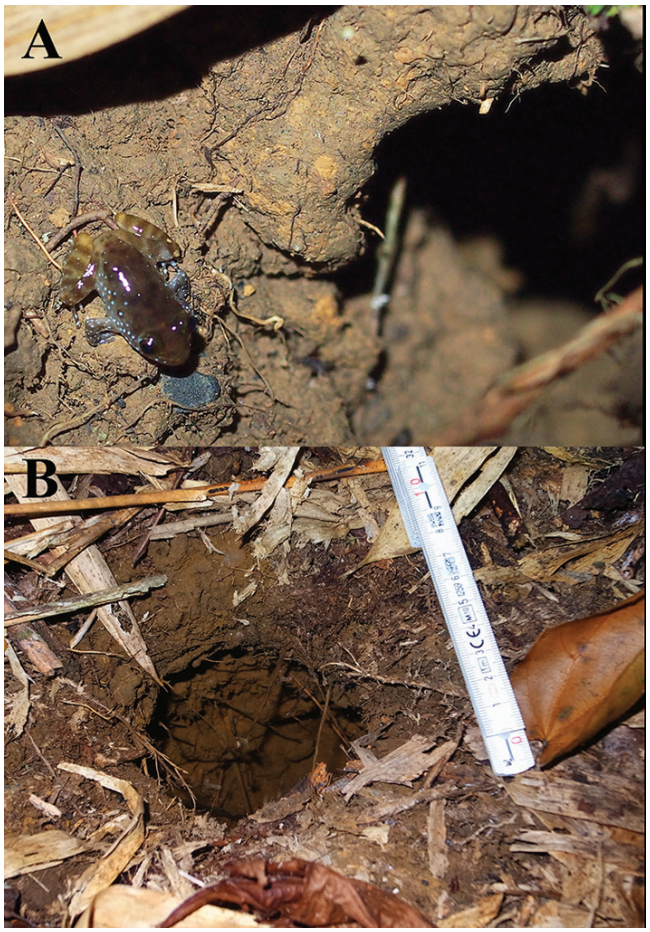

Fig. 6. Habitat of *Limnonectes cintalubang*, new species, showing: A, a juvenile sitting near a burrow and B, the size of a burrow.

DISCUSSION

In spite of its bizarre coloration, *L. cintalubang* has never been reported in the past. This rarely encountered species is probably due to its utilisation of underground habitats. Among Bornean anurans, some rare species like *Gastrophrynoides borneensi*s (Boulenger, 1897) is fossorial (Matsui et al., unpublished data), and probably other rare species like *Calluella brooksii* (Boulenger, 1904) and *C. smithi* (Barbour & Noble, 1916) would have similar habits (Inger, 1966). All individuals of *L. cintalubang* were invariably found at night near burrows on the forest floor. However, they seem not to dig the hole by themselves; but rather utilising burrows constructed by other animals. There are quite a few anuran species utilising underground environments, but purely fossorial frogs mainly use spade-like inner metatarsal tubercle like European *Pelobates* (Nöllert & Nöllert, 1992). However, in the present new species, the shape and size of inner metatarsal tubercle are not much different from those of other congeners, and purely fossorial habits are not likely. Similarly, the snout region is not modified in *L. cintalubang* unlike African *Hemisus*, which uses spade-like snout to dig a hole (Passmore & Carruthers, 1995). Moreover, the forelimb of the new species is neither particularly robust nor large unlike Australian *Myobatrachus* (Barker et al., 1995), and is probably not used for digging. From these characteristics of external morphology, the new species is thought to utilise burrows made not by itself but by other animals.

Around the habitat of the new species, there are several animal species such as crabs, tarantulas, mole crickets, rodents, and badgers, that can dig burrows on the forest floor, but because the burrow is neither very small nor very large (diameter > ca. 5 cm, Fig. 6B), animals other than rats would be excluded. Burrowing rodents recorded in Borneo include *Rattus argentiventer* (Robinson & Kloss, 1916; Payne et al., 1998), but unfortunately, we did not encounter any rats at the site. Anyway, as far as we have observed, the burrow seems to have been abandoned and was not occupied by other animals. Schalk & Sezano (2014) reported the use of theraphosid tarantula burrows by *Leptodactylus bufonius* Boulenger, 1894 and *Rhinella major* (Müller & Hellmich, 1936) in Bolivia, but the burrows were always abandoned ones. By contrast, some microhylid frogs are known to take refuge within an occupied tarantula burrow and coexist with them (Cocroft & Hambler, 1989; Dundee et al., 2012), by producing toxic skin secretions that makes them unpalatable to spiders (Garton & Mushinsky, 1979). Although the new species seem to use exclusively abandoned burrows, where no possible predators have been identified, its unusually smooth skin unlike its relatives (the Bornean *L. kuhlii* complex), may have some function, possibly including secretions. However, it is more likely that the relatively smooth skin of the species is used for another purpose. The skin of the species is notably fragile and tears easily when captured. Skin fragility is more pronounced than in *L. fragilis* from Hainan, China (Matsui, personal observation), whose name came from this property. It is possible that the species has a strong ability of integument regeneration and escapes from enemies by loosing a part of its skin.

The eggs of *L. cintalubang* are creamy white unlike other congeners from Borneo (e.g., Matsui & Nishikawa, 2014). Among Bornean anurans, creamy white eggs without dark animal hemisphere are known in megophryid genera *Leptolalax* and *Leptobrachella*, and some ranids (e.g., *Hylarana baramica* [Boettger, 1900], *H. glandulosa* [Boulenger, 1882], and *Odorrana hosii* [Boulenger, 1891]), in addition to some rhacophorids that make a foam nest (Inger, 1966). The megophryids and ranids with such eggs breed in completely shaded places like underground small streams at the headwater of streams, in muds of marshes, and under leaf litter on the bottom of deep pools. From these examples, *L. cintalubang* is hypothesised to lay eggs not in open water but shaded places. One of the burrows we observed had underground water, and it is possible that they lay eggs in such hidden water bodies.

The island of Borneo is famous for its diverse anurans (Inger & Tan, 1996; Matsui et al., 2014), but its high endemism should also be paid more attention. In addition to the many endemic species, particularly recently split from former wide-ranging species (e.g., Inger & Stuart, 2010), some groups of Bornean anurans, like a ranid genus *Meristogenys* (e.g., Shimada et al., 2011), are known to be endemic to Borneo. The genus *Leptobrachella* could be also considered endemic although one species occurs on Natuna Island. Moreover, another megophryid, Bornean *Leptolalax* is almost certainly endemic to the island and is already split from continental congeners as a distinct subgenus (Ohler et al., 2011). *Limnonectes cintalubang* was found to be nested in a clade of Bornean fanged frogs of the *L. kuhlii* complex. This complex has recently been revised based on results of molecular phylogenetic analyses, and is now becoming clear that the complex is split into three lineages that geographically correspond to continental, Javanese, and Bornean regions. As is shown in the phylogenetic tree in this paper, the Bornean lineage is monophyletic and is expected to be endemic to the island. Although it is not easy to classify the Bornean lineage of the *L. kuhlii* complex because of highly uniform morphology of contained taxa, future taxonomic revision of this group will surely contribute to increase herpetofaunal diversity on this island.

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