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A NEW SPECIES OF *RANA* (AMPHIBIA: ANURA: RANIDAE) FROM THE HIGHLANDS OF THE MALAY PENINSULA, WITH DIAGNOSTIC LARVAL DESCRIPTIONS

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***ABSTRACT.* –** The adults and larvae of a new species of *Rana* are described from representative mountain ranges of the Malay Peninsula, namely Hala Bala Wildlife Sanctuary (south Thailand), Maxwell's Hill, Cameron Highlands, Fraser's Hill and Genting Highlands, with Cameron Highlands designated as the type locality. Both adults and larvae of this montane form have been previously misidentified as either of two *Rana* species (*R. signata* or *R. glandulosa*). Adults of this new highland species may be diagnosed by a combination of the following characters: (a) presence of dorsolateral skin folds in varying degrees, (b) longitudinal dermal ridges on tibia, (c) reduced webbing on hindfeet, (d) raised granules on dorsum and flanks, each granule tipped with whitish asperities and surrounded by smaller ones [in both sexes], (e) similar asperities on dorsal surfaces of fore- and hindlimbs [in both sexes], (f) presence of nuptial pad on first finger, subgular vocal sacs, but absence of humeral gland [in males]. The diagnostic characters of its tadpoles include: (a) a large size [maximum attainable total length ca. 65 mm], (b) presence of sub-dermal whitish glandules on body and tail fins, (c) black spots on body and tail, (d) oral disc not emarginate, (e) labial tooth row formula of 3(2-3)/3(1) with short third row on posterior labium.

***KEY WORDS.* –** *Rana*, Ranidae, Malay Peninsula, Cameron Highlands, montane.

INTRODUCTION

The present day topography of the Malay Peninsula is characterised by a series of hills and mountains originating from the north (southern most Thailand), advancing southward in an almost longitudinal arrangement. The five recognised mountain ranges are Banjaran Bintang, Banjaran Titi Wangsa, Banjaran Benom, Banjaran Gunong Tahan and Banjaran Timur [Fig. 1; *Banjaran* = mountain range (Malay)]. The longest mountain range, Banjaran Titi Wangsa, is also known as the Main Range. It stretches from the Thai mountains at the Thailand-Malaysia border and reaches the mountains in the southern state of Negri Sembilan, spanning a distance of almost 400 km.

Previous herpetofaunal research in each respective mountain range has focused on specific localities (prominent hill stations/summit areas) and serves as an indispensable foundation for our understanding of the montane amphibians and reptiles of the peninsula. One of the earliest efforts was by Boulenger (1900), who described new species of frogs, lizards, and a snake from specimens collected by A. L. Butler in Maxwell's Hill (Bukit Larut), Perak. In the Main Range, Smith (1922) reported on the collections from Fraser's Hill (Bukit Fraser), Selangor-Pahang border, while Smedley (1931) reported on the Cameron Highlands, Pahang. Berry (1972) described a tadpole from Gunong Bunga Buah, Selangor. Grandison (1972) published results from the Gunong Benom (Pahang) expedition. The vicinity of Gunong Tahan, Pahang (highest summit in Peninsular Malaysia at 2,187 m asl) was explored by Boulenger (1908) and Smith (1922) as well. Around a northern summit (Gunong Lawit, Terengganu) of the Eastern Range (Banjaran Timur), Dring (1979) completed a two-month long survey with significant findings.

Of the anuran species listed in the afore-mentioned highland herpetofaunal expeditions, two ranid identities have reasonable cause for doubt. Smith (1922) reported two specimens of *Rana glandulosa* Boulenger from Fraser's Hill (ca. 1,000 m asl) [subsequently reported by Berry (1975)]; while Berry (1972) assigned a developmental series from Gunong Bunga Buah (1,280 m asl) as belonging to *R. glandulosa* based merely on webbing of emergents. This

larval identity was subsequently cited in Manthey and Grossmann, 1997; and a larval series from Cameron Highlands was identified as belonging to this species (Leong & Tan, 2001), based on agreements with Berry's (1972) larval description. True *R. glandulosa* is a large species, with males and females attaining snout-vent lengths of 93 mm and 84 mm, respectively (Inger & Stuebing, 1997). Males of *R. glandulosa* produce distinctly loud and resonant calls. Apart from *R. hosii*, no other large species of *Rana* has been recorded from the Malay Peninsula highlands. Neither have the characteristic calls of *R. glandulosa* been heard at the hill stations (pers. observ.). *R. glandulosa* is known to occur in the lowlands within swampy forests, along the coast, but has not been recorded above 700 m asl (Inger & Stuebing, 1997). Hence, its occurrence in the highlands remains questionable.

Similarly, the altitudinal distribution of *Rana signata* (Günther) is comparable with that of *R. glandulosa* [*R. signata* is used here as the collective term that encompasses *R. picturata* Boulenger and other species/sub-species within this complex; see Brown & Guttman (2002) for a recent clarification between the Bornean and Philippine members of this group]. Although *R. signata* has not been found beyond 750 m asl (Inger & Stuebing, 1997; pers. observ.), highland records of this species had been reported by Smedley (1931) from Cameron Highlands and Berry (1975) from Fraser's Hill. A recent colour plate of this form (referred to as *Rana* cf. *signata*) appeared in Chan-ard et al. (1999)

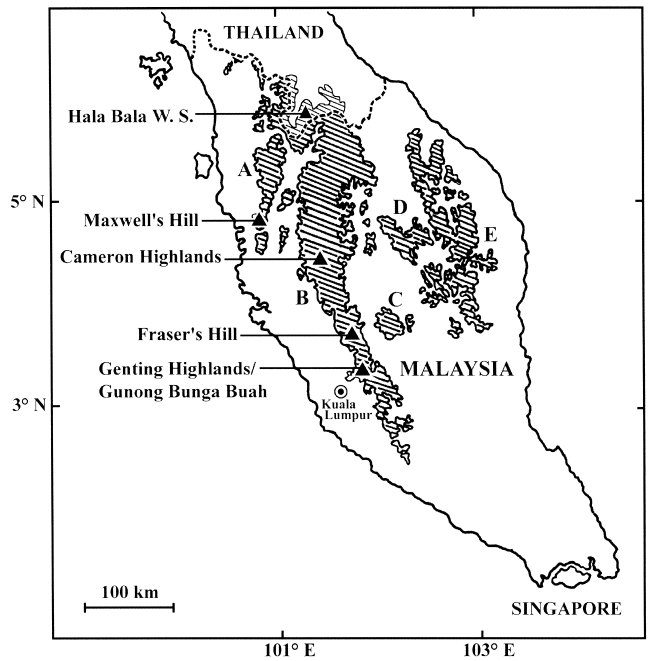

Fig. 1. Schematic map of the Malay Peninsula, illustrating the five mountain ranges (from west to east): A, Banjaran Bintang; B, Banjaran Titi Wangsa; C, Banjaran Benom; D, Banjaran Gunong Tahan; E, Banjaran Timur, and the currently known distribution of *Rana banjarana*, new species, in the highlands (from north to south): Hala Bala Wildlife Sanctuary (Yala Province, South Thailand), Maxwell's Hill, Cameron Highlands, Fraser's Hill, Genting Highlands, Gunong Bunga Buah. Banjaran = mountain range (Malay). Hatched areas represent elevation of 300m asl and above.

and was photographed at Tanah Rata, which is the same locality where Smedley obtained his specimens. Smedley's specimens had been deposited and were examined at the Raffles Museum of Biodiversity Research (RMBR), Singapore. Fresh specimens of adults, belonging to this form, were subsequently obtained by the present authors from recent field trips to the Cameron Highlands, along with diagnostic larval series. The previously proposed larval identity of *R. glandulosa* by Berry (1972) is thus re-assigned as belonging to this montane form, reverting the true tadpole type of *R. glandulosa* to its original unknown status.

In addition to specimens from Cameron Highlands, adult specimens initially identified as *R. signata* from four other high altitude localities [Hala Bala Wildlife Sanctuary (south Thailand), Maxwell's Hill, Fraser's Hill and Genting Highlands] were examined in the amphibian collections at the National Science Museum, Thailand (NSM), Department of Wildlife and National Parks (DWNP – Peninsular Malaysia) and RMBR. These populations were found to be in agreement with those from Cameron Highlands. Previously unidentified larvae (among RMBR larvae collection) from both Maxwell's Hill and Fraser's Hill were also found to be the same as those from Cameron Highlands.

After examination of adult characters and comparisons with relevant literature, this highland form was not clearly identifiable to any described species of *Rana* in Peninsular Malaysia (Berry, 1975), Indo-China (Bourret, 1942; Inger et al., 1999; Taylor, 1962), Sumatra (Kampen, 1923), Java (Iskandar, 1998), Borneo (Inger, 1966; Inger & Stuebing, 1997), or the Philippines (Inger, 1954; Alcala & Brown, 1998). Comparisons with Boulenger's (1920) *Rana* monograph also failed to positively identify this form. Diagnoses and descriptions for both adults and larvae of this new *Rana* species are herewith provided.

MATERIALS AND METHODS

Adults were fixed in 10% formalin, and stored in 70% ethanol thereafter. Representaive tissue samples were collected from liver (ZRC.1.8326) and stored in 95% ethanol. Slide verniers were used to obtain morphometric measurements (to 0.1mm), including SVL (snout vent length: from snout tip to vent), HL (head length: from jaw angle to snout tip), HW (head width: distance between angle of jaws), ED (eye diameter: greatest diameter of orbit), TD (tympanum diameter: greatest diameter of tympanum), IOD (inter-orbital distance: least distance between upper eyelids), IND (inter-narial distance: distance between nostrils), ESD (eye-snout distance: distance between anterior margin of eye to snout tip), END (eye-nostril distance: distance between anterior margin of eye to nostril), BW (body width: highest width of abdominal region), AGD (axilla-groin distance: distance from posterior base of forelimb at its emergence from body to base of hindlimb at its emergence from body), TBL (tibia length: distance between knee and heel), HND (hand length: from proximal edge of outer metacarpal tubercle to tip of third finger), FT (foot length: from proximal edge of inner

metatarsal tubercle to tip of fourth toe). The holotype, first and second paratypes are deposited at the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research, Department of Biological Sciences, National University of Singapore. The third paratype will be deposited at the Department of Wildlife and National Parks (DWNP, Perhilitan), Selangor, Peninsular Malaysia. The fourth paratype will be deposited at Field Museum of Natural History (FMNH), Chicago, USA. In addition, non-types will be distributed between ZRC, DWNP and FMNH. Non-types from south Thailand were also examined at the herpetology collection of the National Science Museum, Thailand (NSM). Comparative material (see Appendix) of *Rana glandulosa* and *Rana signata* were examined from ZRC, DWNP, NSM and Balitbang Zoologi, Puslitbang Biologi – LIPI [formerly Museum Zoologicum Bogoriense (MZB)], Cibinong, West Java, Indonesia.

A diagnostic larval developmental series (ZRC.1.8328-8373; n = 46, Stages 25-46) was collected from the type locality, Cameron Highlands (July, 2001) and preserved in 10% formaldehyde. Staging is in accordance with Gosner (1960). Morphometric measurements were taken using slide verniers (to 0.1 mm). These include BL (Body Length: measured from snout tip to body-tail junction), TAL (Tail Length: from body-tail junction to tail tip), TL (Total Length: from snout tip to tail tip), MTH (Maximum Tail Height: greatest distance between dorsal and ventral fin margins), IOD (Inter-Orbital Distance: between centres of the pupils), IND (Inter-Narial Distance: between centers of narial apertures); abbreviations and definitions follow Altig & McDiarmid, 1999. In addition, BW (Body Width: widest part of body) and BH (Body Height: measured at mid-body) were also taken. Description of oral apparatus and labial tooth row formula (LTRF) is in accordance with Altig, 1970. Subsequently, additional larvae were obtained from the same microhabitat (ZRC.1.9676-9711, n = 36, collected May 2002), and representative larval vouchers from this series will be deposited at both DWNP and FMNH. Larval vouchers from Maxwell's Hill (ZRC.1.6042) and Fraser's Hill (ZRC.1.1108-1110, 1834-1835) were also examined.

SYSTEMATICS

Rana banjarana, new species

(Figs. 2-4, Table 1)

Material examined. - Holotype - ZRC.1.8325 (adult male), from bank of gentle, slow-flowing stream (1 m wide, 20 cm deep) in montane forest, feeding into main river of Parit Falls, Tanah Rata, Cameron Highlands, Pahang, Peninsular Malaysia (4º 28'N, 101º 23'E, ca. 1,300 m asl), coll. T. M. Leong, 30 Jul.2001 (Fig. 2).

Paratypes – (four designated, all adult males) ZRC.1.8326, 8327: same collector and date of collection as holotype; ZRC.1.9670, 9672: coll. T. M. Leong, K. K. P. Lim & B. L. Lim, 10 May.2002.

Non-types – [West Malaysia] Cameron Highlands: ZRC.1.855-858 (three females, one male), from Tanah Rata, coll. N. Smedley (19 May.1931: 855-857, 28 May.1931: 858); ZRC.1.854 (female), from Sungai Brinchang, coll. N. Smedley, 29 May.1931; ZRC.1.9668, 9669, 9671, 9673 (all adult males), from same microhabitat/type locality as type series, coll. T. M. Leong, K. K. P. Lim & B. L. Lim, 10 May.2002. Maxwell's Hill: DWNP.A.1203-1204 (sub-adult, adult male), from forests in vicinity of upper guest houses below the peak area (ca. 1,000 m asl), coll. Jim McGuire, (17 Oct.1997: 1203, 21 Nov.1997: 1204); ZRC.1.6048-6049 (adult males), from creeks beside road near upper guest houses (ca. 1,000 m asl), coll. T. M. Leong, 17 Dec.2000. Fraser's Hill: ZRC.1.3455a & b (adult males), from small stream at Bishop's Trail (ca. 1,000 m asl), coll. T. M. Leong, 11 Dec.1996. Genting Highlands: ZRC.1.10050-10051 (two males), from small stream along primary hill forest, ca. 700 m asl, coll. Jeet Sukumaran & Peter Paul van Dijk (Apr.2002). [South Thailand] Yala Province; Hala Bala Wildlife Sanctuary, Ban Chula Porn 7: NSM 4095-4096, 4112-4116 (one female, six males) along small waterfalls and rocky streams between 700-1,200 m asl., coll. Tanya Chan-ard & Yodchaiy Chuaykern, 10-11 Mar.2002.

Diagnosis. – Dorsolateral skin folds present in varying degrees, a continuous ridge from post-orbital to inguinal area; longitudinal dermal ridges on dorsal surface of tibia, from knee to tibiotarsal joint; raised, rounded granules on dorsum and flanks, each granule tipped with whitish asperities and surrounded by smaller ones [present in both sexes] (Fig. 3); similar asperities on dorsal surfaces of fore- and hindlimbs [present in both sexes]; finger and toe tips dilated, similar in size, not twice as broad as penultimate joint, circum-marginal grooves present (Fig. 4); reduced webbing on

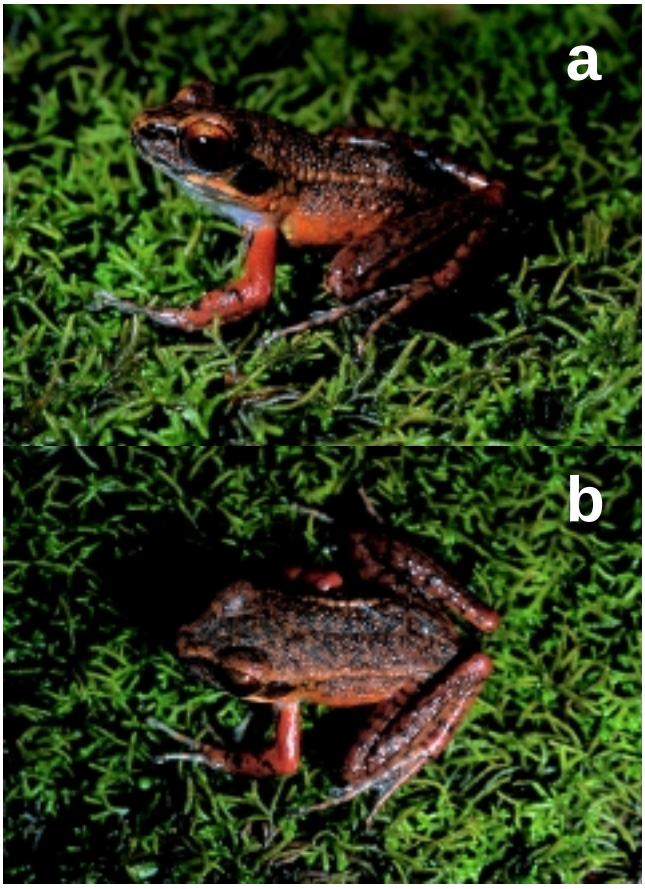

Fig. 2. Lateral (a) and dorsal (b) aspects of adult male *Rana banjarana*, new species (Holotype: ZRC.1.8325, SVL 34.6mm). Note dorsolateral dermal folds, longitudinal ridges on tibia, raised granules on dorsum and flanks, and absence of humeral gland.

hindfeet (Fig. 4b): web between 1st and 2nd toes just reaching respective subarticular tubercles, slightly surpassing proximal subarticular tubercles between 2nd and 3rd, reaching distal subarticular tubercle on outer edge of 3rd toe and middle subarticular tubercle of 4th toe on both sides, reaching just beyond distal subarticular tubercle of 5th toe; nuptial pad on first finger (Fig. 4a) and subgular vocal sacs present, but humeral gland absent [in males].

***Description.* –** Habitus moderately stocky, head longer than wide; snout obtuse, slightly projecting, rounded in profile; nostril closer to snout tip than eye; canthus rostralis distinct, lores concave; eye diameter about equal to eye-snout distance; tympanum distinct, diameter 0.57-0.67 of eye diameter, supratympanic fold present, but not extending to axilla; vomerine teeth in short oblique rows, in line with and bordered by choanae.

Finger tips expanded into distinct, small discs less than twice width of penultimate phalanges; all discs bearing circum-marginal grooves; first finger longer than second; subarticular and metacarpal tubercles prominent; discs of toes equal to finger discs, all with circum-marginal grooves; webbing of 1st and 2nd toes just reaching respective subarticular tubercles, on 2nd and 3rd just beyond proximal subarticular tubercles, reaching distal subarticular tubercle on outer edge of 3rd toe and middle subarticular tubercle of 4th toe on both sides, reaching just beyond distal subarticular tubercle of 5th toe; 4th toe with three phalanges free; inner and outer metatarsal tubercles distinct, inner metatarsal tubercle elongate, half length of 1st toe, outer metatarsal tubercle conical, smaller than inner; no free skin flaps on margins of 1st or 5th toes; tibia 0.58-0.64 of snout-vent.

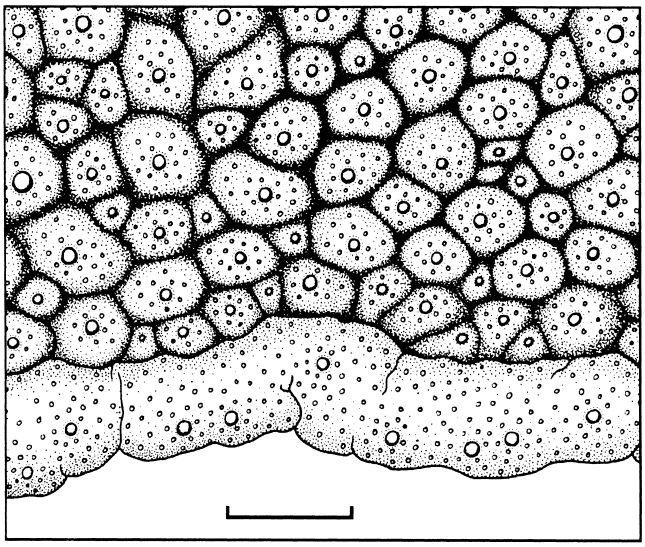

Fig. 3. Dermal segment of *Rana banjarana* dorsum, depicting dorsolateral skin fold and raised granules bearing apical asperities/ glandules, each surrounded by smaller ones (head towards left; illustrated from holotype: ZRC.1.8325). Scale bar = 1mm.

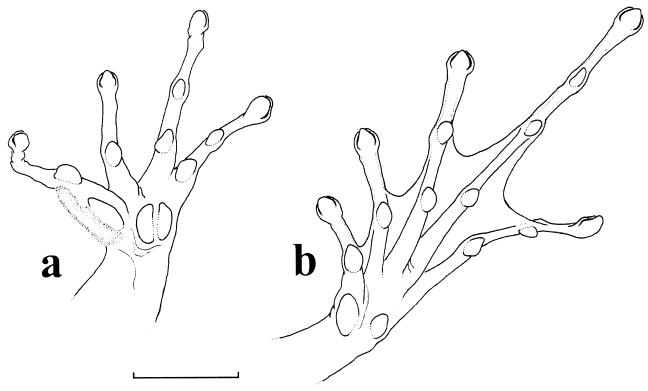

Fig. 4. Ventral aspects of left forelimb (a) and left hindlimb (b) of adult male *Rana banjarana* (illustrated from holotype: ZRC.1.8325). Note nuptial pad (unpigmented, non-constricted) on inner face of first finger. Scale bar = 5mm.

Continuous dorsolateral fold present in the form of distinctly raised or low-lying chain of enlarged/fused granules; dorsum (from post-orbital to vent) with polygonal mosaic of raised granules, each granule rounded at its apex and tipped with whitish glandule, each glandule surrounded by other smaller glandules; same granular ornamentation on upper flanks, continuous with dorsolateral fold; whitish glandules also present on dorsolateral fold itself and on dorsal surfaces of all limbs, but not extended onto fingers and toes; tibia with parallel streaks of longitudinal dermal ridges; ventral surfaces smooth. In Smedley's specimens (ZRC.1.854-858, collected May 1931, presumably fixed in ethanol instead of formalin), the dorsolateral folds and longitudinal tibial ridges have become less pronounced, but still discernible under magnification; dermal glandules and sub-glandules are still clearly visible.

***Colour.* –** In life, basal colour of dorsum and flanks olive brown to orange brown, with black reticulations; snout tip, canthus rostralis, margin of upper eyelid, dorsolateral folds usually devoid of black pigmentation; lores black, iris orange, tympanum deep brown, upper jaw with streaks of basal colour from below eye to jaw angle; forelimbs with same basal colour as body, black barring/reticulation on forearms only, never on upper arms; hindlimbs (from femur to toe tips) barred/reticulated with black; venters light grey to dark brown with randomly distributed white spots (under throat, belly and/or hind limbs); webbing of hindfeet finely pigmented with dark brown. In preservative, basal colours of body fade to beige, the orange of iris disappears, but all black pigmentation remains.

***Sexual dimorphism.* –** There is a noticeable size difference between males and females of this species, with males having an SVL of 32.9-42.2 mm, while females range between 40.9-55.0 mm. A mature female (ZRC.1.855, SVL 52.4 mm, from Cameron Highlands) was found to have pigmented ova (diameter 1.8-2.0 mm). Males exhibit non-constricted, unpigmented, finely granular nuptial pads spanning the inner surface of the first finger, beginning from the proximal margin of the inner metacarpal tubercle and not exceeding distal margin of the subarticular tubercle (Fig. 4a). Males also possess paired subgular vocal sacs, exhibiting wrinkling of the skin on the ventral portions of the jaw angles.

***Natural history.* –** At night, along the stream of the type

Table 1. Morphometric measurements of *Rana banjarana* type series, comprising holotype and four paratypes (Paratypes #3 and #4 to be deposited at DWNP and FMNH respectively). See text for abbreviations.

Measurements (to 0.1mm)	Holotype ZRC.1.8325 Adult male	Paratype #1 ZRC.1.8326 Adult male	Paratype #2 ZRC.1.8327 Adult male	Paratype #3 ZRC.1.9670 Adult male	Paratype #4 ZRC.1.9672 Adult male
SVL	34.6	35.3	35.6	35.9	37.3
HL	13.0	12.2	13.5	13.7	14.5
HW	11.9	12.1	12.8	12.4	12.7
ED	5.0	5.1	5.2	5.1	5.4
TD	3.1	2.9	3.5	2.9	3.1
IOD	3.2	3.7	3.5	3.4	3.4
IND	3.7	3.9	3.7	4.1	4.0
ESD	5.1	5.1	5.1	5.0	5.3
END	3.0	3.0	2.9	2.9	3.2
BW	8.1	8.5	8.9	11.8	10.1
AGD	13.1	14.4	15.1	14.5	14.3
TBL	20.9	22.2	22.9	21.5	21.6
HND	8.9	8.6	9.5	9.3	10.2
FT	17.9	19.5	18.3	18.9	19.4

locality, adult males were observed to be calling individually from the sides while perched low on fallen branches, live vegetation, from sandy bank, or leaf litter. No females were encountered at this site. Other frogs encountered along the same stream as *Rana banjarana* include *Limnonectes laticeps* (Boulenger) and *Megophrys longipes* Boulenger. Along the main river, we observed *Rana hosii* Boulenger and *Bufo asper* Gravenhorst. While exploring this stream, a venomous snake (*Trimeresurus popeiorum* Smith) was found to be hunting and it is most likely that *Rana banjarana* (along with *L. laticeps* and *M. longipes*) would be preyed upon by this viper (Family Crotalidae). The calls of male *Rana banjarana* are superficially similar to that of *R. signata*, comprising a single burst of a series of pulses (T. M. Leong & J. Sukumaran, pers. observ.).

***Etymology.* –** This new species is named after the local Malay term for 'mountain range' – '*banjaran*', indicative of its altitudinal distribution, which is restricted to the highlands of the peninsula.

***Larval microhabitat.* –** Found in well shaded forest stream of type locality; waters clear, slow-flowing, substrate mostly sandy. Larvae observed to be most active at night, feeding on detritus along stream bed.

***Larval diagnosis.* –** A large tadpole (the longest larva [Stage 40] attained a total length of 64.6mm); body and tail lightly scattered with small, whitish glandules (glandules on tail predominantly confined to a single sub-marginal row each in both dorsal and ventral fins); pigmentation pattern of black spots/blotches on body and tail (in advanced stages, black spots of dorsum begin to aggregate, resembling reticulation of the adults); oral disc not emarginate; LTRF 3(2-3)/3(1), width of third labial tooth row of posterior labium _ of second row.

***Larval morphology.* –** (Figs. 5, 6) Body elliptical, BL 1.43-1.71 of BW, mildly depressed dorsoventrally, BH 0.67-0.75 of BW; snout rounded, nostril equidistant between eye and snout tip; eyes dorsolateral, IOD 1.85-2.37 of IND; spiracle sinistral, slightly projecting as a short, free tube, tapered towards the opening, oval opening directed upwards and backwards, spiracle visible from above and below, snout-spiracle 0.43-0.55 of BL; vent dextral, tubular, fused with ventral fin, opening directed towards posterior. Tail gently tapering towards a round tip, fins sub-parallel for anterior half of tail, deepest point at middle of tail, dorsal fin slightly deeper than ventral fin, TAL 1.73-2.40 of BL, MTH 0.24-0.28 of TAL. Lateral line pores on body and along tail muscle distinct. Small, whitish glandules scattered on dorsum, sides and venter of body; arranged sub-marginally along dorsal and ventral fins.

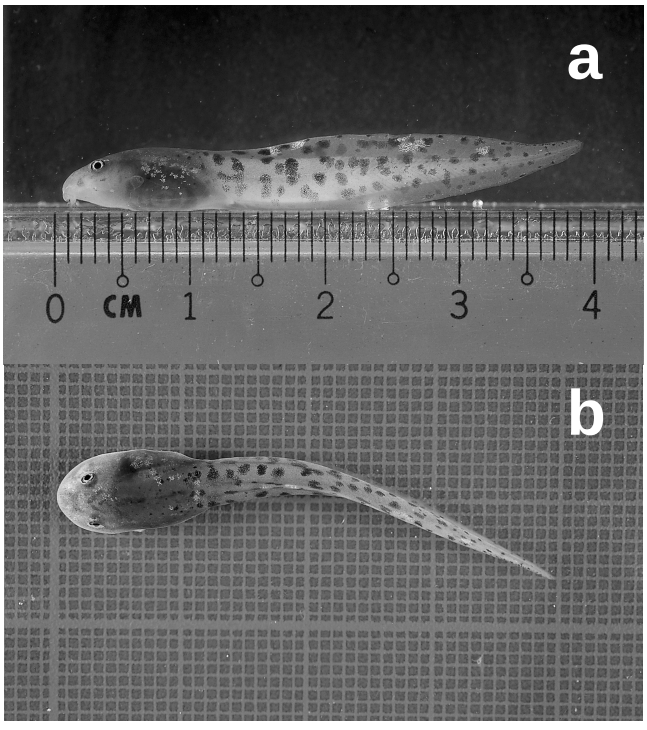

Fig. 5. Lateral (a) and dorsal (b) aspects of early (Stage 27) larval *Rana banjarana*.

***Colour/Markings.* –** In life, dorsum and flanks of body light honey brown, tail muscle beige, tail fins translucent; numerous black specks/spots/ blotches on body and tail; venter unpigmented, translucent, internal organs (e.g., coiled gut) visible, ventral tube unpigmented. In preservative, body becomes a lighter shade of brown, but all black patterns are retained.

***Oral Disc.* –** (Fig. 7) Mouth ventral, sub-terminal, oral disc width 0.26-0.37 of BW, oral disc not emarginate (i.e. no distinct indentations at lateral corners to demarcate anterior and posterior labia), single row of marginal papillae at lateral corners of anterior labium and continuous with entire margin of posterior labium, infra-marginal papillae on posterior labium; upper and lower jaw sheaths serrated, edged with black; upper jaw sheath with slight median convexity.

***LTRF.* –** 3(2-3)/3(1); first labial tooth row of anterior labium continuous, second and third rows broadly interrupted by jaw sheaths, width of each half about 1/5 of first row; first labial tooth row of posterior labium narrowly interrupted at the centre, second row uninterrupted, slightly shorter than first, third row shortest, about 1/4 width of first row.

***Developmental changes.* –** In the advanced stages (Stage 40 onwards), the black pigmentation of the dorsum begins to resemble the reticulated pattern of the adults, and crossbars are already visible on the limbs. About two days after eruption of forelimbs, the tail is completely resorbed, and the emergent exhibits an orange iris, as in the living adults. The venter of emergents are grey to brown, with scattered white spots. The dorsolateral dermal folds and tibial ridges are not pronounced as yet, but the individual granules on the dorsum are already demarcated and tipped with a whitish granule each. However, the smaller sub-glandules are not developed at this point. Measurements of BL and TL of the developmental series are reflected in Table 2. A stage 40 larva was dissected to reveal a set of poorly developed lungs, indicative of its high reliance on gill respiration even at this advanced stage (T. M. Leong & R. J. Wassersug pers. observ.). This may point towards high levels of dissolved oxygen in its mountain stream habitat, which would allow for a delayed development of the lungs.

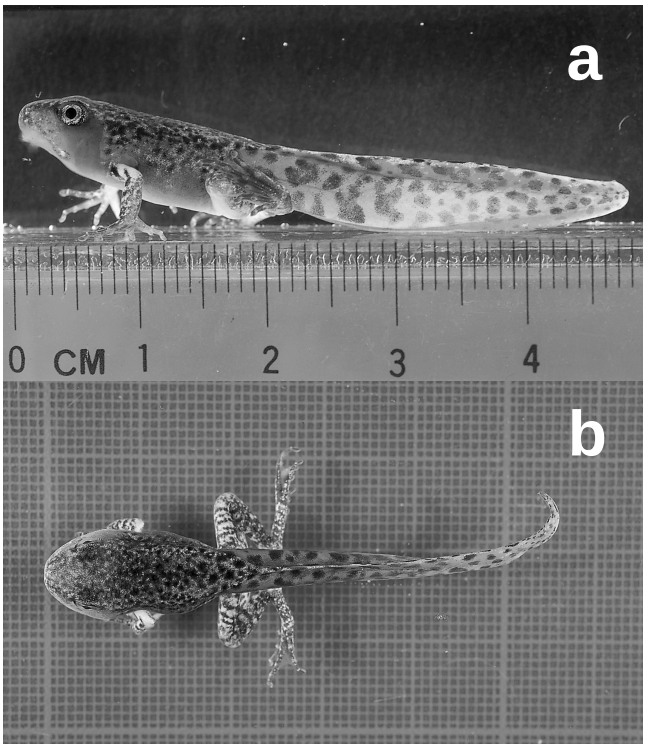

Fig. 6. Lateral (a) and dorsal (b) aspects of advanced (Stage 43) larval *Rana banjarana*.

***Remarks.* –** The presence of whitish glandules on the body and tail is not unique to the larvae of *R. banjarana* alone. Subdermal glandules are also found in larval *R. signata* as well (Inger, 1966, 1985), although these glandules occur at a much higher density than in *R. banjarana*. Besides this shared character, *R. banjarana* tadpoles differ significantly from those of *R. signata* in terms of their larger size and spotted pattern. Its oral disc is also significantly different, not only from *R. signata*, but also from the other known *Rana* (*Hylarana*) larvae of Sundaland, in terms of the unique non-emarginate condition. Although this condition was not specifically emphasised in Berry's (1972) description, it was clearly illustrated as such (Berry, 1972: 345, Fig. 3(7)).

Based on adult characters, *R. banjarana* may be placed within the subgenus *Hylarana* Tschudi. These characters include: finger and toe tips dilated into distinct discs, with circum-marginal grooves separating upper and lower surfaces; outer metatarsals separated nearly to the base, omosternal style not forked at base; terminal phalanges with feeble transverse expansion. According to Boulenger's (1920) organisation of this subgenus into ten sections, *R. banjarana* would come under the Ranae Erythreae section, which exhibit the following characters: finger discs similar to and not larger than toe discs, which are not twice width of penultimate joint; transverse distal expansion of terminal phalanx feeble; dorsolateral fold present. The south-east Asian species belonging to this section include *R. erythraea*, *R. miopus*, *R. macrodactyla*, *R. nicobariensis* and *R. alticola* (see Boulenger, 1920). *R. banjarana* may be readily distinguished from these five species by its unique granular texture of the dorsum and flanks, bearing apical glandules and peripheral sub-glandules.

Another section (Ranae Luctuosae) proposed by Boulenger (1920) shared all the above-mentioned characters with the Ranae Erythreae section, except for the dorsolateral fold, which is absent in this section. This included the south-east Asian species of *R. luctuosa*, *R. baramica*, *R. glandulosa*, *R. signata*, and *R. picturata* (see Boulenger, 1920). A recently described species, *R. siberu* Dring, McCarthy & Whitten 1990, which also lacks dorsolateral folds, may also be included within this section. For *R. signata*, however, the presence/absence of dorsolateral folds has suffered from repeated inconsistencies in various references. Inger (1966) and Berry (1975) reported that there was no distinct dorsolateral fold, but the dichotomous key in Berry (1975) implied that *R. signata* may be either with, or without such folds. In Taylor's (1962) identification key to the Thai ranids,

Table 2. Developmental changes in BL (body length) and TL (total length) of larval *Rana banjarana* (ZRC.1.8328-8373; n = 46, Stages 25-46).

Gosner Stage	No.	BL (mm)	TL (mm)
25	8	7.6-10.3	20.6-32.5
26	4	11.1-12.9	34.4-35.7
27	7	13.0-14.4	35.6-45.0
28	4	14.0-15.9	41.8-52.8
31	1	16.0	50.3
37	5	17.2-17.9	55.3-57.8
39	2	15.7-18.5	51.9-56.5
40	8	18.4-19.0	56.4-64.6
41	3	16.3-18.8	56.9-58.1
42	1	19.2	60.8
43	1	18.6	56.1
44	1	19.0	41.8
46	1	SVL = 19.5mm	

R. signata stems from the dichotomous branch which states the absence of a dorsolateral glandular fold, but contradicts himself when he mentions a dorsolateral fold as part of the diagnostic character in this species.

Furthermore, in Kampen's (1923) account of *R. signata*, he mentions 'a flat dorsolateral glandular fold, which may be little distinct or absent, or represented by a chain of large warts'. In his identification key, both paths originating from the absence/presence of these glands also lead to *R. signata*. In addition to previously available references, Kampen examined specimens from the west Sumatran coast of Airbangis, as indicated by an (!) just after the said locality. Another Sumatran locality mentioned was Mt. Simbolon, but without any (!) indicated after this locality. However, upon examination of *R. signata* specimens from Sumatra, Thailand, Peninsular Malaysia and Borneo (see Appendix), it was determined that such a fold/ridge was not present at all, although it is understandable how the characteristic colour pattern of the contrasting light dorsolateral stripes against a dark background may create the initial impression/ illusion that a raised skin fold exists.

While no highland specimens resembling *R. signata* from Sumatra were available, there is a possibility that a montane species comparable with *R. banjarana* may occur there, due to its proximity and earlier connections with the Malay Peninsula (Voris, 2000; Inger & Voris, 2001). Until research efforts in Sumatra are heightened, *R. banjarana* is currently regarded as endemic to the Malay Peninsula. Within Peninsular Malaysia, the occurrence of *R. banjarana* in the other mountain ranges (Banjaran Benom, Banjaran Gunong Tahan and Banjaran Timur) remains to be investigated. As further herpetological expeditions are carried out in the peninsula, it will not be surprising to discover range extensions for this species in these highlands.

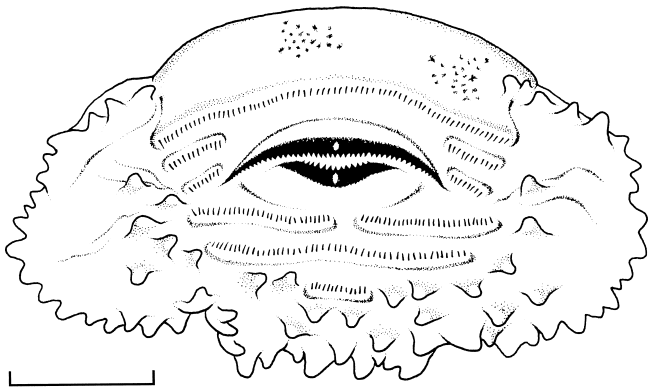

Fig. 7. Oral disc of larval *Rana banjarana* (Stage 39). Note non-emarginate condition; LTRF 3(2-3)/3(1). Scale bar = 1mm.

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LITERATURE CITED

Alcala, A. C. & W. C. Brown, 1998. *Philippine Amphibians – an illustrated field guide*. Bookmark, Makati City, Philippines. xi + 116pp.

Altig, R., 1970. A key to the tadpoles of the continental United States and Canada. *Herpetologica*, **26**: 180-207, 3 figs.

Altig, R. & R. W. McDiarmid, 1999. Body plan: development and morphology. In: McDiarmid, R. W. & R. Altig (eds.), *Tadpoles: The Biology of Anuran Larvae*. The University of Chicago Press, Chicago & London, xiv + 444 pp.

Berry, P. Y., 1972. Undescribed and little known tadpoles from West Malaysia. *Herpetologica*, **28**(4): 338-346.

Berry, P. Y., 1975. *The Amphibian Fauna of Peninsular Malaysia*. Tropical Press, Kuala Lumpur, x + 130 pp., 91 figs.

Boulenger, G. A., 1900. Description of new batrachians and reptiles from Larut Hills, Perak. *Annals & Magazine of Natural History*, **7** Ser. 6: 186-193.

Boulenger, G. A., 1908. Report on the Gunong Tahan expedition, May-Sept 1905, III: Fishes, batrachians and reptiles. *Journal of the Federated Malay States Museum*, **3**: 61-69.

Boulenger, G. A., 1920. A monograph of the South Asian, Papuan, Melanesian and Australian frogs of the genus *Rana*. *Records of the Indian Museum*, **20**: 1-226.

Bourret, R. 1942. *Les Batraciens de l'Indochine*. Institut Océanographique. Hanoi. 547 pp.

Brown, R. M. & S. I. Guttman, 2002. Phylogenetic systematics of the *Rana signata* complex of Philippine and Bornean stream frogs: reconsideration of Huxleys's modification of Wallace's Line at the Oriental-Australian faunal zone interface. *Biological Journal of the Linnean Society, London*, **76**: 393-461.

Chan-ard, T., W. Grossmann, A. Gumprecht & K.-D. Schulz, 1999. *Amphibians and Reptiles of Peninsular Malaysia and Thailand*. Bushmaster Publications, Wuerselen, Germany, 240 pp.

Dring, J. C. M., 1979. Amphibians and reptiles from northern Trengganu, Malaysia, with description of two new geckoes: *Cnemaspis* and *Cyrtodactylus*. *Bulletin of the British Museum of Natural History* (*Zoology*), **34**(5): 181-241.

Dring, J. C. M., C. J. McCarthy & A. J. Whitten, 1990. The terrestrial herpetofauna of the Mentawai Islands, Indonesia. *Indo-Malayan Zoology*, **6**(1989): 119-132.

Gosner, K. L., 1960. A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica*, **16**: 183-190.

Grandison, A. G. C., 1972. The Gunong Benom expedition 1967. 5: Reptiles and amphibians of G. Benom with a description of a new species of *Macrocalamus*. *Bulletin of the British Museum of Natural History* (*Zoology*), **23**: 45-101.

Inger, R. F., 1954. Philippine Zoological Expedition (1946-1947), systematics and zoogeography of Philippine Amphibia. *Fieldiana* (*Zoology*), **33**(4): 183-531.

Inger, R. F., 1966. The systematics and zoogeography of the Amphibia of Borneo. *Fieldiana* (*Zoology*), **52**: 1-402.

Inger, R. F., 1985. Tadpoles of the forested regions of Borneo. *Fieldiana* (*Zoology*), new series, **26**: 1-89.

Inger, R. F. & R. B. Stuebing, 1997. *A field guide to the frogs of Borneo*. Natural History Publications, Kota Kinabalu, Sabah. ix + 205pp.

Inger, R. F., N. Orlov & I. Darevsky, 1999. Frogs of Vietnam: a report on new collections. *Fieldiana* (*Zoology*), **92**: 1-46.

Inger, R. F. & H. K. Voris, 2001. The biogeographical relations of the frogs and snakes of Sundaland. *Journal of Biogeography*, **28**: 863-891.

Iskandar, D. T., 1998. *The amphibians of Java and Bali*. LIPI – The field guide series. Research and Development Centre for Biology – LIPI, Indonesia. xiv + 117pp.

Kampen, P. N. van, 1923. *The Amphibia of the Indo-Australian Archipelago*. Leiden (E. J. Brill), xii + 304pp.

Leong, T. M. & H. H. Tan, 2001. *Rana glandulosa* – Geographic Distribution. *Herpetological Review*, **32**(1): 55-56.

Manthey, U. & W. Grossmann, 1997. *Amphibien & Reptilien Südostasiens*. Natur und Tier, Verlag, Münster. 512 pp.

Smedley, N., 1931. Amphibians and Reptiles from the Cameron Highlands, Malay Peninsula. *Bulletin of the Raffles Museum*, Singapore, **6**: 105-123, pl. 2, 5 text-figs.

Smith, M. A., 1922. On a collection of reptiles and batrachians from the mountains of Pahang, Malay Peninsula. *Journal of the Federated Malay States Museums*, **10**: 263-282.

Taylor, E. H., 1962. The amphibian fauna of Thailand. *The University of Kansas Science Bulletin*, **43**: 265-599.

Voris, H. K., 2001. Maps of Pleistocene sea levels in Southeast Asia: shorelines, river systems and time durations. *Journal of Biogeography*, **27**: 1153-1167.

APPENDIX

COMPARATIVE MATERIAL EXAMINED

Rana glandulosa

[SUMATRA]: MZB 918 (Sungai Siak, Central Sumatra), MZB 3263 (Rantau Prapat, Labuhan Batu, North Sumatra), MZB 6902 (Sungai Pasilog, Bukit Lawang, North Sumatra), MZB 3644 (Padang, West Sumatra), MZB 3755-3759 (Pulau Pini, north of Siberut), MZB 3322 (Tasik Serai, Mandau, Riau), MZB 893-895 (Sungai Tanajan, Pekan Baru, Riau). [THAILAND]: NSM 4354 (Hala, Yala Province). [PENINSULAR MALAYSIA]: DWNP.A.0427 (Tasek Bera, Pahang), DWNP.A.0428 (Paya Indah, Kuala Langat, Selangor), DWNP.A.0429, 0430, 0433, 0434 (Krau Wildlife Reserve, Pahang), DWNP.A.0431-0432 (Sungkai Forest Reserve, Perak), DWNP.A.0566 (Kuala Koh, Kelantan), DWNP.A.1133-1135 (Sungai Ambat, Tenggaroh, Mersing, Johor), DWNP.A.1166-1168, 1171 (Lubuk Rincing, Sungai Keniam, Taman Negara, Pahang), ZRC.1.3881 (Batu Pahat, Johor), ZRC.1.7956-7957 (Bukit Rengit, Pahang), ZRC.1.8614 (Kahang, Johor), ZRC.1.9164 (Sungai Kancing, Selangor), ZRC.1.10149-10150 (Lakun Forest Reserve, Raub, Pahang). [BORNEO]: MZB 3806 (Sungai Bulit, Karimun, West Kalimantan), MZB 2564-2565 (Kapuas, West Kalimantan).

Rana signata

[SUMATRA]: MZB 3481 (Kubu Perahu, Bukit Barisan, Lampung), MZB 4205-4220 (Lembah Anai, West Sumatra). [THAILAND]: NSM 3931-3932 (Narathiwat Province: Bala), NSM 4088, 4131-4132 (Yala Province: Khlong Hala, Ban Chula Porn). [PENINSULAR MALAYSIA]: DWNP.A.0416 (Bukit Rengit, Pahang), DWNP.A.1125-1128 (Hutan Simpan Tenggaroh, Mersing, Johor), DWNP.A.1164 (Lubuk Rincing, Sungai Keniam, Taman Negara, Pahang), ZRC.1.1547-1550 (Kota Tinggi waterfalls, Johor), ZRC.1.8240, 8615-8616 (Jemaluang, Johor), ZRC.1.9752-9753 (Belumut, Johor), ZRC.1.10153 (Lakun Forest Reserve, Raub, Pahang). [BORNEO]: MZB 7733-7749, 7755-7758 (tributary of Sungai Temalong, East Kalimantan), MZB 4828-4835 (Sungai Petang Hulu, Bentuang Karimun, West Kalimantan), ZRC.1.3948 (Sungai Lumbi, Mahakam Basin, East Kalimantan), ZRC.1.7697 (Betong, Sarawak), ZRC.1.2734 (Danum Valley, Sabah).