

Taxonomic re-evaluation of the enigmatic *Polypedates chlorophthalmus* Das, 2005 (Anura: Rhacophoridae) from Gunung Murud, Sarawak, Malaysia (Borneo), a junior synonym of *Philautus hosii* (Boulenger, 1895)

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Abstract. We re-examined the holotype of *Polypedates chlorophthalmus*, the only specimen of the species that has ever been collected. Detailed comparison to recently collected specimens of *Philautus hosii* revealed that the two taxa are identical in general habitus, shape of snout, hands and feet, extent of toe webbing, presence and shape of hand and foot tubercles, size and shape of vomerine teeth, dorsal and ventral colouration and pattern, iris colouration, as well as body size and proportions. We refer *Polypedates chlorophthalmus* to the synonymy of *Philautus hosii*.

Key words. taxonomy, synonymisation, tree frog, Gunung Murud, Sarawak, Borneo

INTRODUCTION

The genus *Polypedates* Tschudi, 1838, is represented on Borneo by five nominal species (Inger et al., 2017). The most enigmatic among them is *P. chlorophthalmus* Das, 2005. The species was described from a single female, collected at 1,351 m a.s.l. at a mid-elevation forest of Gunung [=Mount] Murud, northern Sarawak, East Malaysia, in 2003 and has never been collected or observed again. The primary diagnostic characters of the species are the large size (for a tree frog), the elongate, rounded snout, a distinct canthus rostralis, the absence of dermal flaps along limbs and above cloaca, and a distinctive green iris. Since the publication of the original description of *P. chlorophthalmus*, we collected numerous series of tree frogs of the genera *Polypedates*, *Rhacophorus* Kuhl & van Hasselt, 1822, and *Philautus* Gistel, 1848, from several locations on Borneo and documented the live colouration in these species. Among the new material were several specimens of *Philautus hosii* (Boulenger, 1895) that exhibited a greenish-coloured iris, instead of the more typical golden iris. *Philautus hosii* is of similar size and shares the aforementioned characters considered diagnostic for *Polypedates chlorophthalmus*. Therefore, we re-examined the holotype of *P. chlorophthalmus* and compared the species in detail to *Philautus hosii*. We herein present the results

of our morphological examination and refer *Polypedates chlorophthalmus* to the synonymy of *Philautus hosii*.

MATERIAL AND METHODS

The holotype of *Polypedates chlorophthalmus* was deposited in the Zoological Reference Collection (ZRC) of the Lee Kong Chian Natural History Museum, Singapore. Comparative material was deposited in the Naturhistorisches Museum der Burgergemeinde Bern, Switzerland (NMBE) and the Staatliches Museum für Naturkunde Stuttgart, Germany (SMNS).

We took the following measurements to the nearest 0.1 mm using digital callipers: Snout-vent length (SVL); tibiofibula length (TFL, measured with both knee and tibiotarsal articulation flexed); thigh length (THL, from vent to knee with thigh being held vertically to median body plane and knee flexed); total hindlimb length (LEG, from vent to tip of fourth toe with leg fully extended and being held perpendicularly to median body plane); tarsus + foot length (TarL, from tibio-tarsal articulation to tip of fourth toe); foot length (FOT, from proximal end of inner metatarsal tubercle to tip of fourth toe); hand length (HND, distance from proximal end of palmar tubercle to tip of third finger); head width (HW, measured at the level of the jaw joint); head length (HL, distance from rear end of jaw to tip of snout); interorbital distance (IO, shortest distance between upper eyelids); upper-eyelid width (EW); horizontal eye diameter (ED); vertical tympanum diameter (TD); eye-to-tympanum distance (ET, shortest distance between orbit and tympanic rim); eye-to-nostril distance (EN, distance between anterior margin of eye and centre of nostril); nostril-to-snout distance (NS, distance between centre of nostril and tip of snout);

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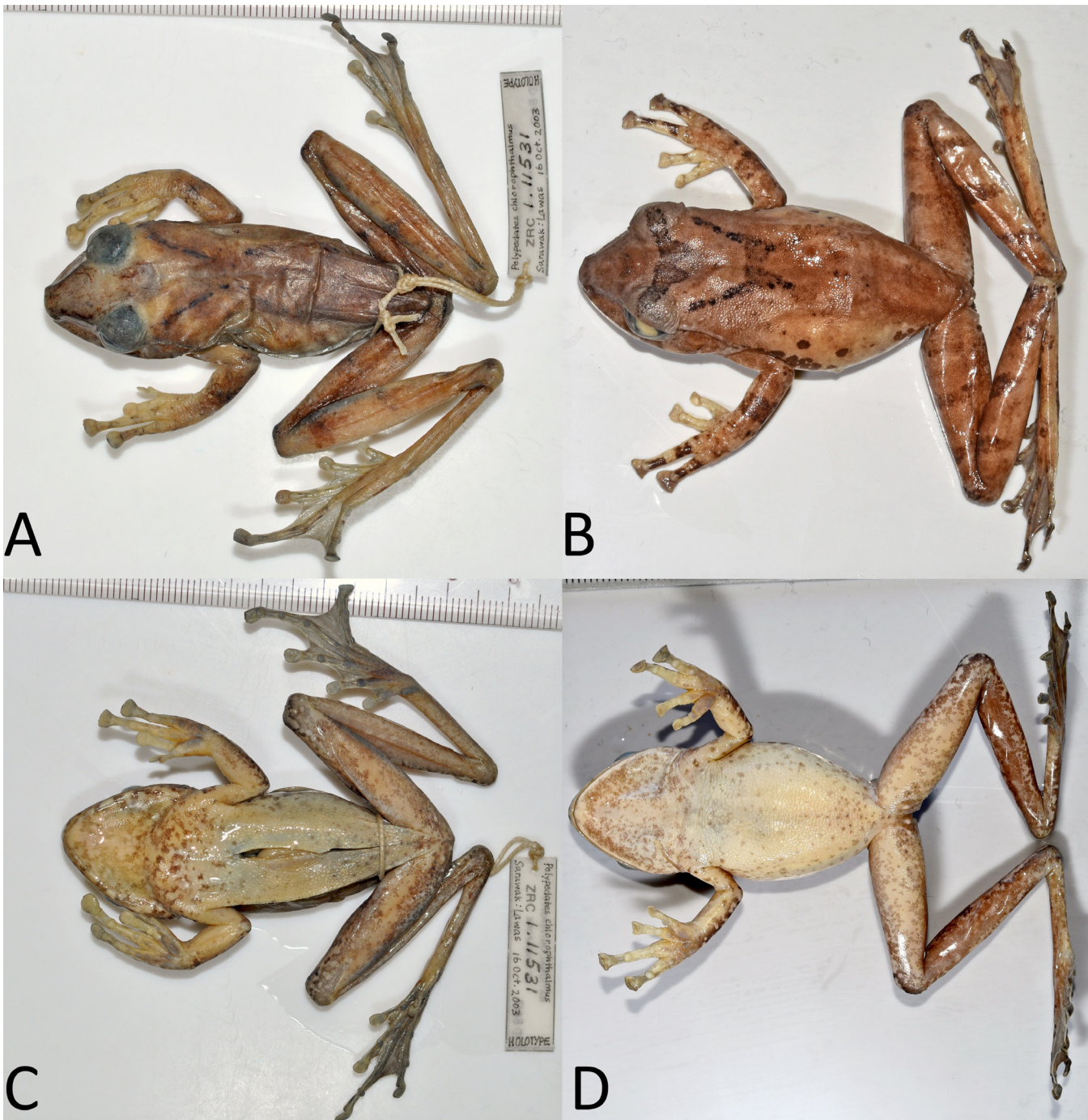


Fig. 1. A, dorsal view and C, ventral view of the holotype of *Polypedates chlorophthalmus* Das, 2005 from Gunung Murud, Sarawak, Malaysia (adult female ZRC 1.11531). B, dorsal view and D, ventral view of an adult female *Philautus hosii* from Gunung Mulu National Park, Sarawak, Malaysia (SMNS 13628).

snout length (SL, distance between anterior margin of eye to tip of snout); intereye distance (EE, distance between anterior margins of eyes); internarial distance (NN, distance between centres of nostrils). Extent of toe webbing is described using the formula proposed by Dehling (2015).

RESULTS

The re-examination of the holotype of *Polypedates chlorophthalmus* showed no distinguishing differences to *Philautus hosii*. Therefore, we conclude that the two taxa

are conspecific and refer *Polypedates chlorophthalmus* to the synonymy of *Philautus hosii*.

Philautus hosii (Boulenger, 1895)

- Rhacophorus hosii* Boulenger, 1895: 169.
- Rhacophorus buergeri hosii* Wolf, 1936: 170.
- Rhacophorus hosi* Inger, 1954: 385.
- Rhacophorus hosei* Inger, 1966: 304.
- Philautus hosei* Liem, 1970: 68.
- Philautus hosii* Inger, 1985: 529.
- Polypedates chlorophthalmus* Das, 2005: 266. – new synonymy.

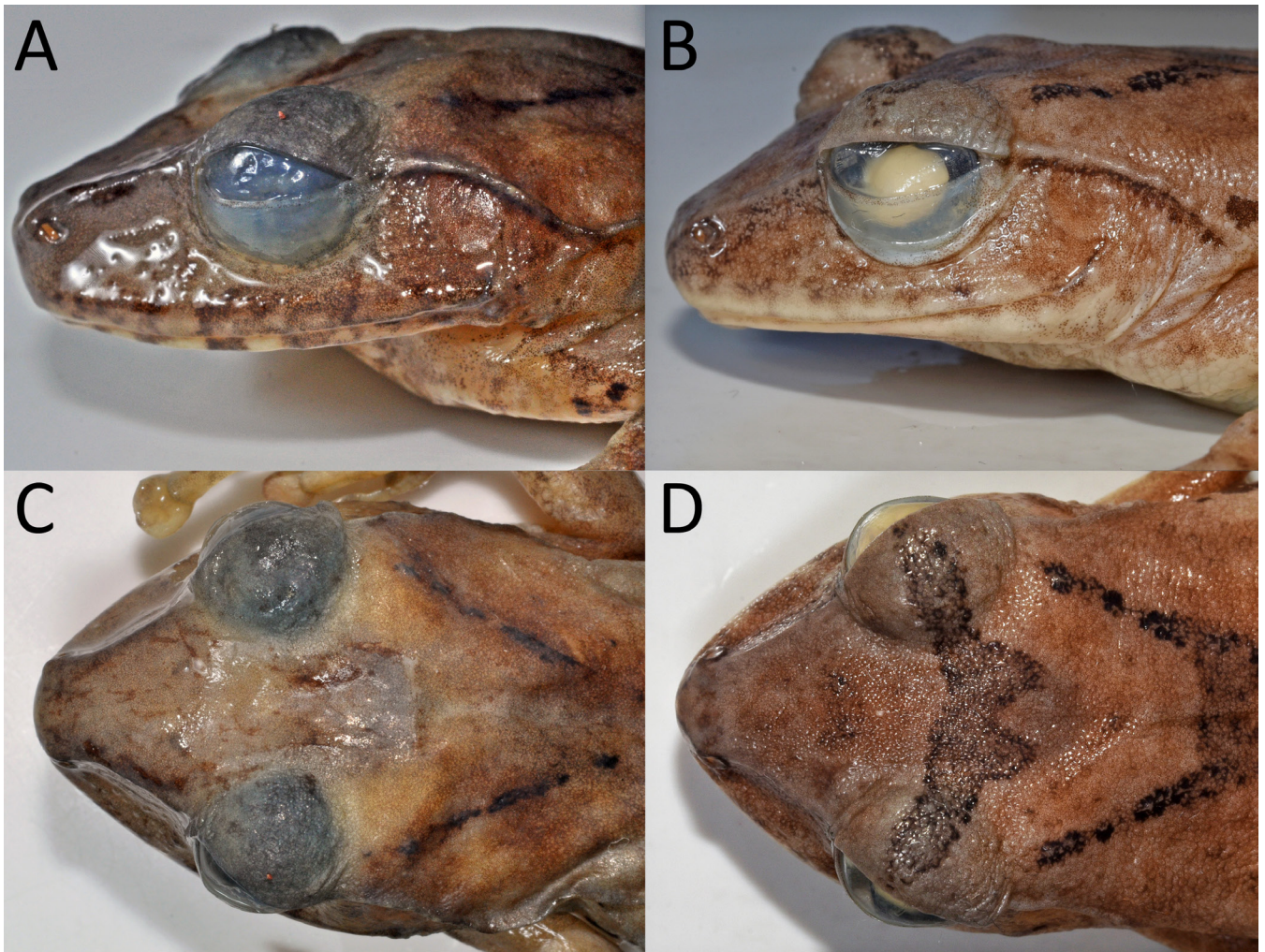


Fig. 2. Lateral view of the head of the holotype of A, *Polypedates chlorophthalmus* (ZRC 1.11531) and B, an adult female *Philautus hosii* (SMNS 13628). Dorsal view of the head of the holotype of C, *Polypedates chlorophthalmus* (ZRC 1.11531) and D, an adult female *Philautus hosii* (SMNS 13628).

Description of ZRC 1.11531 (holotype of *Polypedates chlorophthalmus* Das, 2005). Character states in the original description (D) that differ from the results of the re-examination are given in square brackets.

Adult female (Fig. 1); body large, SVL 59.9 mm [D: 62.1], body moderately slender with narrow waist, widest posterior to head; head large (HL/SVL 0.39), slightly longer than wide (HW/HL 0.93) [D: slightly broader than long (HW/HL 1.04)]; snout elongate and long (SL/HL 0.45), subacuminate in dorsal view, rounded in lateral view, slightly projecting beyond lower jaw [D: not exceeding level of mandible] in lateral view, wider than long (SL/EE 0.91) (Fig. 2); canthus rostralis distinct, slightly concave (Fig. 2); loreal region almost vertical, slightly concave (Fig. 2); nostrils oval, directed anterolaterally, situated close to tip of snout (EN/NS 2.55, EN/SL 0.72 [D: 0.74]), separated from each other by distance much smaller than distance between eye and nostril (NN/EN 0.64 [D: 0.72]) (Fig. 2); eyes directed anterolaterally, protruding, moderately large (ED/HL 0.31); pupil horizontal; eye diameter shorter than snout length (ED/SL 0.70), and subequal to eye-to-nostril distance (ED/EN 0.98 [D: larger, ED/EN 1.07]); interorbital distance slightly

greater than upper eyelid (IO/EW 1.05 [D: interorbital distance greater than upper eyelid width, IO/EW 2.22]) and wider than internarial distance (IO/NN 1.38) (Fig. 2); skin of forehead free, not co-ossified to nasal, sphenethmoid or frontoparietal elements of cranium; pineal ocellus present; tympanum distinct, oval, its vertical diameter greater than horizontal diameter, half diameter of eye (TD/ED 0.51), separated from eye by about half its diameter (ET/TD 0.54) (Fig. 2); mouth extends to level of centre of tympanum [D: to posterior corner of eye]; upper jaw with dentition; teeth on premaxilla larger than those on maxilla; choanae elongate, located far anterolaterally at margins of roof of mouth (Fig. 3); vomerine teeth in two highly elevated, large, broad, posteromedially directed ridges at anterior edge of choanae, separated from each other by about one-fourth length of individual ridge (Fig. 3); mandibular symphysis weakly thickened to bony knob; tongue subtriangular, bifid apically, lacking median lingual process, free distally for about one-third its length.

Dorsal side of trunk, head, and limbs shagreened [D: dorsum, including upper eyelids and upper surfaces of limbs smooth] (Fig. 1); supratympanic fold distinct, curved, running from



Fig. 3. Palmar view of the right manus of the holotype of A, *Polypedates chlorophthalmus* (ZRC 1.11531) and B, an adult female *Philautus hosii* (SMNS 13628). Plantar view of the left foot of the holotype of C, *Polypedates chlorophthalmus* (ZRC 1.11531) and D, an adult female *Philautus hosii* (SMNS 13628). Ventral view of the roof of the mouth of the holotype of E, *Polypedates chlorophthalmus* (ZRC 1.11531) and F, an adult female *Philautus hosii* (SMNS 13628), showing shape of choanae and vomer processes and teeth.

posterior corner of eye to level of forelimb insertion (Fig. 2); ventral side of head and limbs smooth, abdomen and postaxial sides of thighs areolate (Fig. 1).

Forelimbs moderately thick [D: short and thick]; hand large (HND/SVL 0.34); fingers long and slender, lacking webbing (Fig. 3); relative length of fingers: $I < II < IV < III$; tips of fingers enlarged into broad oval disks, each with circummarginal groove; subarticular tubercles prominent, rounded, numbering one on Fingers I and II, two on Fingers III and IV [D: one on first, second and fourth fingers, two on third finger] (Fig. 3); proximal tubercles on Fingers III and IV smaller than distal tubercles and tubercles on Fingers I and II (Fig. 3); thenar tubercle small, about one-third length of metacarpal of Finger I in palmar view, oval, low; inner and

outer palmar tubercle subequal in shape and size to thenar tubercle, on proximal part of metacarpals of Fingers III and IV [D: palmar tubercles indistinct] (Fig. 3); supernumerary small tubercles present on metacarpals.

Hindlimbs long and slender (LEG/SVL 1.96); tibiofibula long (TFL/SVL 0.62), longer than thigh (TFL/THL 1.10); heels without flap, fold, or calcar, overlapping each other considerably when knees flexed and thighs held perpendicularly to median plane [D: meeting each other and overlapping slightly]; foot large (FOT/SVL 0.52), shorter than tibiofibula (FOT/TFL 0.84); toes long and slender, relative length $I < II < V < III < IV$; tips of toes enlarged into broad oval disks, each with circummarginal groove, smaller than disks on fingers; subarticular tubercles

Table 1. Morphometrics, ratios, and extent of toe webbing of *Philautus hosii* females. For abbreviations, see Material and Methods.

specimen	ZRC 1.11531 (holotype of <i>Polypedates chlorophthalmus</i> Das, 2005)	SMNS 13628
origin	Gunung Murud, Sarawak, 1,351 m a.s.l.	Gunung Mulu, Sarawak, 100 m a.s.l.
SVL	59.94	54.64
TFL	37.35	32.02
THL	34.07	28.01
TarL	50.97	42.31
FOT	31.25	27.16
LEG	117.56	98.22
HND	20.51	17.33
HW	21.63	19.83
HL	23.25	20.97
EN	7.49	6.36
NS	2.94	2.61
SL	10.39	9.44
NN	4.79	4.39
EE	11.40	10.17
IO	6.59	5.73
EW	6.29	5.90
ED	7.31	7.23
TD	3.71	3.36
ET	2.00	1.49
HW/SVL	0.361	0.363
HL/SVL	0.388	0.384
HW/HL	0.930	0.946
SL/HL	0.447	0.450
SL/EE	0.911	0.928
EN/NS	2.548	2.437
EN/SL	0.721	0.674
NN/EN	0.640	0.690
ED/HL	0.314	0.345
ED/SL	0.704	0.766
ED/EN	0.976	1.137
IO/EW	1.048	0.971
IO/NN	1.376	1.305
TD/ED	0.508	0.465
ET/TD	0.539	0.443
HND/SVL	0.342	0.317
LEG/SVL	1.961	1.798
TFL/SVL	0.623	0.586
TFL/THL	1.096	1.143
FOT/SVL	0.521	0.497
FOT/TFL	0.837	0.848
webbing	I1.5/2III1+/2+III1+/2+IV2/1+V	I1.25/2III1+/2+III1+/2+IV2/1+V

well developed, rounded, prominent, numbering one on Toes I and II, two on Toes III and V, and three on Toe IV (Fig. 3); distal subarticular tubercles on Toes III–V and tubercles on Toes I and II slightly larger than proximal tubercles on Toes III and V and penultimate tubercle on Toe IV (Fig. 3); proximal tubercle on Toe IV smaller than all other subarticular tubercles and less distinct; pedal webbing formula **I1.5/2III1+/2+III1+/2+IV2/1+V** [D: **I2-2III1+/2+III1+/2+IV2/1.25V**] (Fig. 3); narrow dermal flap on

postaxial side of Toe V from proximal end of metatarsus to disk; inner metatarsal tubercle very prominent and elongate, large, about length of Metatarsal I (Fig. 3); outer metatarsal tubercle absent.

Colouration in preservative. Dorsum greyish light brown; large, dark grey, V-shaped pattern in scapular region; light brown labial region barred with darker spots; dorsal side of limbs light brown with faint dark crossbars; webbing pale

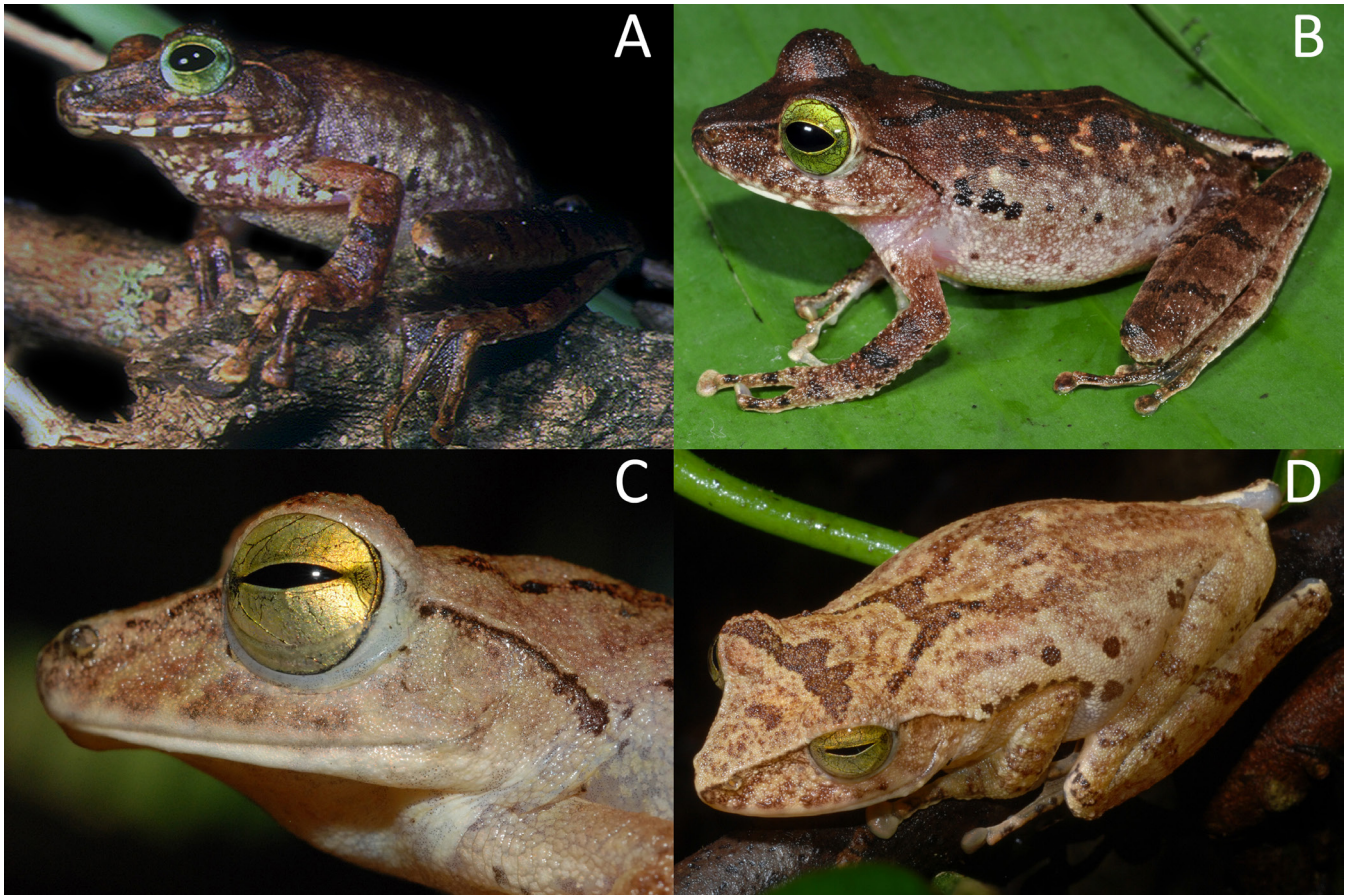


Fig. 4. A, holotype of *Polypedates chlorophthalmus* (ZRC 1.11531) from Gunung Murud, Sarawak, Malaysia, in life. B, adult male *Philautus hosii* (NMBE 1060413) from 950 m a.s.l. at Gunung Gading, Sarawak, Malaysia, in life. C, lateral view of the head of an adult female *Philautus hosii* (SMNS 13628) from Gunung Mulu National Park, Sarawak, Malaysia, in life. D, dorsolateral view of SMNS 13628, in life.

grey; ventral side of trunk and limbs cream-coloured; head, throat, and breast with marked medium brown mottling; abdomen with widely separated small brown dots; preaxial and postaxial sides of limbs with greyish brown mottling; digits of limbs yellowish grey.

We compared the female holotype of *Polypedates chlorophthalmus* (ZRC 1.11531) in detail to a female *Philautus hosii* (SMNS 13628), collected near Camp 5 in Gunung Mulu National Park, Sarawak, at ca. 100 m a.s.l. (Figs. 1–3; Table 1). The two specimens are nearly identical in general appearance (Fig. 1), shape of snout (Fig. 2), hands and feet, extent of toe webbing (Fig. 2), presence and shape of hand and foot tubercles (Fig. 3), size and shape of vomerine teeth (Fig. 3), dorsal and ventral colouration and pattern (Fig. 1), and body proportions (Table 1). We therefore conclude that the two specimens are conspecific. Iris colouration is variable in *Philautus hosii* and some recently collected specimens exhibit a greenish-coloured iris, instead of the more typical golden iris (Fig. 4).

DISCUSSION

Philautus hosii was originally described by Boulenger (1895) as a member of the then catchall genus *Rhacophorus* that included all large members of the family bearing vomerine

teeth. It was transferred to *Philautus* by Liem (1970), a move followed by Dring (1987) on the basis of morphology, adult colouration, and bioacoustics, a scheme followed by Bossuyt & Dubois (2001), who allocated it to the subgenus *Gorhixalus*. More contemporary phylogenetic analyses show support for the generic allocation (e.g., Hertwig et al., 2013). Allocation to *Polypedates* for the Murud material was following the generic boundaries among rhacophorids of Liem (1970), who reported the presence of vomerine teeth, in addition to the large size, and webbing between the two outer metatarsals. The greenish iris pigmentation was then unknown for montane populations of *Philautus hosii* (e.g., Inger, 1966; Dring, 1987).

The female holotype of *Polypedates chlorophthalmus* (ZRC 1.11531) agrees with the description of the female holotype of *Philautus hosii* from the Pata River, North Sarawak, in all characters mentioned by Boulenger (1895), such as overall habitus, snout shape, tympanum size, vomerine teeth, webbing, dorsal and ventral colouration, except that the snout is longer than the eye diameter, not “as long as the diameter of the orbit”. It is unclear, however, how Boulenger (1895) defined and measured snout length and orbit diameter.

All examined characters [in brackets] are also within the range of female *Philautus hosii* as described by Inger (1966): SVL 51.0 to 62.0 mm [59.9]; head longer than broad; HW/SVL

0.34–0.37 [0.36]; HL/SVL 0.36–0.41 [0.39]; snout rounded in profile; nostril twice as far from eye as from tip of snout [EN/NS 2.55]; eye diameter equal to eye-nostril distance [ED/EN 0.98]; interorbital narrower than upper eyelid [as wide as upper eyelid IO/EW 1.05]; iris “greenish gold”; vomerine teeth in two oblique groups, beginning close to anterior border of choanae; webbing **I**₁+**2****III**₁+**2****III**₁+**2****IV**₂/**1**+**V**; one oval inner but no outer metatarsal tubercle.

Detailed comparison of ZRC 1.11531 with a female specimen of *Philautus hosii* (SMNS 13628) did not reveal any marked difference to this taxon in any of the examined characters. One of the diagnostic characters, the greenish-yellow iris is present only in live specimens. This character is variable in *Philautus hosii* and the colouration of the iris ranges from golden to greenish-yellow (Fig. 4). Our preliminary observations indicate that specimens from higher elevations are more likely to exhibit a greenish colouration of the iris. All morphological evidence points to the conclusion that *Polypedates chlorophthalmus* Das, 2005, is in fact conspecific with *Philautus hosii* (Boulenger, 1895), and therefore, should be regarded a junior synonym of the latter. The record from Gunung Murud at 1,351 m a.s.l. represents the highest locality from which *P. hosii* has been recorded. Although the species is more commonly encountered at lowland sites (e.g., Inger et al., 2017), we found it on several mountain tops in western Sarawak at 950 m (Gunung Gading) and 1,200 m (Gunung Penrissen).

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