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A NEW SPECIES OF *POLYPEDATES* (ANURA: RHACOPHORIDAE) FROM GUNUNG MURUD, SARAWAK (NORTHWESTERN BORNEO)

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***ABSTRACT.* –** A new species of rhacophorid of the genus *Polypedates* is described from Gunung Murud, Sarawak State, north-western Borneo. *Polypedates chlorophthalmus*, new species is compared with congeners from Borneo and other parts of southeast Asia. The new species is diagnosable in showing the following combination of characters: SVL 62.1 mm in the unique holotype; snout rounded, not projecting beyond mandible; head slightly wider than long; canthus rostralis sloping; no dermal flap along forearm; supracloacal fold absent; skin not co-ossified to cranial bones, median lingual process absent; supratympanic fold distinct; dorsum brown, with a thin dark gray line at back of forehead, nearly converging at the axilla, lacking dark lines; lower flanks and anterior edge of thighs with dark blotches; throat with dark pigmentation; and iris bright green.

***KEY WORDS.* –** *Polypedates*, new species, *Polypedates chlorophthalmus*, Rhacophoridae, systematics, new species, Borneo.

INTRODUCTION

The genus *Polypedates* (Anura: Rhacophoridae), as defined by Brown and Alcala (1994), is known to contain 16 nominal species, of which 10 occur in southeast Asia (Glaw et al., 2000; Frost, 1985, also the internet version, Frost, 2004; Iskandar & Colijn, 2000). The members of the genus are distributed from southern China, Sri Lanka and southwestern and northeastern India south to Indo-China and Indo-Malaya (Frost, 1985). Of these, four species have been reported from Borneo (Inger & Stuebing, 1997; Inger & Tan, 1996).

The herpetofauna of Gunung Murud, the highest mountain in Sarawak (2,423 m ASL), has been poorly sampled. The present day knowledge of the fauna derives from the collections made by the Swedish naturalist and adventurer, Eric Georg Mjöberg (1882–1938), Curator of the Sarawak Museum, in 1922. Mjöberg's herpetological collections were published by Smith (1925), and Mjöberg (1925) himself described this expedition in detail, enumerating collection localities. We commenced long-term field work in Gunung Murud, Sarawak, since 2003, with the goal of inventorying the herpetological diversity of the mountain range, collecting a number of novelties in the process.

A new species of *Polypedates*, which does not match any of the described species of the genus from Borneo or from any other part of south-east Asia, is here described, based on the recent collections from Gunung Murud. The species is allocated to *Polypedates* for showing the following characters considered diagnostic for the genus, according to the concept of Liem, 1970 (see also Inger, 1966): fingers free of webbing; tips of digits disk-like, with circummarginal grooves; vomerine teeth present; eyes large, with horizontal pupil; dermal tarsal and anal folds absent; and dorsum dark brown. Although the genus *Polypedates* has been considered synonymous with *Rhacophorus* by some authorities, based on morphology (e.g., Dubois, 1986; 1992) or acoustic data (Matsui & Wu, 1994), phylogenies of the group, based on a reanalysis of data in Liem (1970) show support for the validity of the genus (see Channing, 1989; Wilkinson & Drewes, 2000; Wilkinson et al., 2002).

MATERIAL AND METHODS

The holotype was collected at ca. 2100 h, photographed in life, fixed in formalin ca. 4 h after collection and subsequently washed in water and transferred to 70% ethanol about 8 weeks after collection. The following measurements were taken with Mitutoyo™ dial vernier calipers (to the nearest 0.1 mm), 4 months after collection: snout-vent length (SVL, from tip of snout to vent); tibia length (TBL, distance between surface of knee to surface of heel, with both tibia and tarsus flexed);

head length (HL, distance between angle of jaws and snout-tip); head width (HW, measured at angle of jaws); head depth (HD, greatest transverse depth of head, taken posterior of the orbital region); eye diameter (ED, horizontal diameter of eye); interorbital distance (IO, least distance between upper eyelids; internarial distance (IN, distance between nostrils); eye to snout distance (E-S, distance between anterior-most point of eyes and tip of snout); eye to nostril distance (E-N, distance between anterior-most point of eyes and nostrils); axilla to groin distance (A-G, distance between posterior edge of forelimb at its insertion to body to anterior edge of hindlimb at its insertion to body); body width (BW, greatest width of body); and tympanum diameter (TD, vertical and horizontal). Color notes were taken from Fujichrome Velvia 50 ASA 35 mm slide transparency film, and compared with color swatches of F. B. Smith (1975; 1981). Sex was determined through dissection to examine the gonads.

Comparative materials examined are listed in Appendix I. Sources of additional data on character states and distribution of congeneric species include the following works: Alcala and Brown (1998), Ahl (1931), Berry (1975), Boulenger (1882; 1912), Bourret (1942), Hoffmann (1995), Inger (1966), Inger & Stuebing (1989; 1997), Iskandar (1998), Malkmus et al. (2002), Taylor (1962), Wolf (1936), and et al. (1991). Museum abbreviations, where available (indicated with an asterisk), follow Leviton et al. (1985). These include:
Forest Research Institute Malaysia, Kepong, Malaysia (FRIM)
Philippines National Museum, Manila, Philippines (PNM*)
Sarawak Biodiversity Centre, Semenggoh, Sarawak, Malaysia (SBC)
Sabah Parks Zoological Museum, Gunung Kinabalu, Sabah, Malaysia (SP)
Biology, Universiti Brunei Darussalam, Bandar Seri Begawan, Brunei Darussalam (UBD)
Raffles Museum of Biodiversity Research, National University of Singapore, Singapore (ZRC; the abbreviation used in Leviton et al., 1985, is USDZ*). Specimens with ID–field numbers are being accessioned with this collection, apart from the types of the present species; and
Zoological Survey of India, Kolkata, India (ZSI*).

SYSTEMATICS

Polypedates chlorophthalmus, new species
(Figs. 1-3)

***Material examined.* –** Holotype – **ZRC 1.11531 –** Sarawak Biodiversity Centre Zoological Museum (field number ID–8017) from an unnamed stream ca. 0.8 km NE of Samling Camp at Ravenscourt, 04º 05'14.1"N 115º 28' 42.7" E, Lawas Division, Sarawak; 1,351 m ASL, at middle elevations of Gunung Murud, East Malaysia (Borneo), coll. I. Das, 16 Oct.2003. Adult female.

***Diagnosis.* –** A medium-sized (SVL 62.1 mm) species of *Polypedates*, diagnosable from congeneric species in showing the following combination of characters: SVL 62.1 mm in the unique holotype; snout rounded, not projecting beyond mandible; head slightly wider than long; canthus rostralis sloping; no dermal flap along forearm; supracloacal fold absent; skin not co-ossified to cranial bones, median lingual process absent; supratympanic fold distinct; dorsum brown, with a thin dark gray line at back of forehead, nearly converging at the axilla, lacking dark lines; lower flanks and anterior edge of thighs with dark blotches; throat with dark pigmentation; and iris bright green.

***Description of the holotype (adult female).* –** A medium species of *Polypedates*, SVL 62.1 mm; body elongate, with a narrow waist; head slightly broader than long (HW/HL ratio 1.04); snout elongate, rounded at the tip, not exceeding level of mandible in lateral view and vertical in dorsal view; nares oval, laterally positioned, nearer tip of snout than to eye (E-N/E-S ratio 0.74); internarial distance greater than distance from anterior margin of eye to nostril (IN/E-N ratio 0.72); eye large (ED/HL ratio 0.39); pupil horizontal; its diameter greater than eye to nostril distance (ED/E-N ratio 1.07); canthal ridge distinct; skin of forehead free, not co-ossified to the nasal, sphenethmoid or frontoparietal elements of the cranium; pineal ocellus present; interorbital width greater than upper eyelid width (IO/UE ratio 2.22); canthus rostralis sloping; loreal region vertical; maxillary teeth present; a weak 'W'- shaped notch (= symphysial knob) on anterior edge of mandible; mouth extends to posterior corner of eye; tongue subtriangular, smooth, bifid apically, lacking a median lingual process, free posteriorly for a third its length; choanae located close to anterior of palate; vomerine ridges large, in two oblique series, beginning at inner front edge of choana, and separated by a distance ca. 0.5 of their own length; pupil horizontal; no rictal gland at posterior corner of mouth, but 2–3 small tuberculate structures present; tympanum distinct; its vertical diameter greater than horizontal diameter; supratympanic fold distinct, extending from the posterior corner of eyelid to above insertion of forearm; no dermal flap along forearm or tarsus; supracloacal fold absent; postcloacal tubercles absent; dorsum, including upper eyelids and upper surfaces of limbs smooth; abdomen and inner side of thighs with weak glandular structures.

Fore-and upper arm short and thick; fingers long and thin, lacking webbing; relative length of fingers (longest to shortest): 3 > 4 > 2 > 1; finger tips dilated, with circummarginal grooves; width of disk on finger III less than tympanum diameter; subarticular tubercles prominent, rounded, numbering one on first, second and fourth fingers, two on third finger; palmar tubercles indistinct; hind limbs relatively long and thin, meeting each other and overlapping slightly when folded right angle to body; toes long and thin; webbing on toe I to top of subarticular tubercle; toe II to distal subarticular tubercle (inner) and base of disk (outer); toe III to distal subarticular tubercle (inner) and base of disk (outer); toe IV distal subarticular tubercle, reaching base of disk as a narrow sheath (both outer and inner); and toe V to slightly below base of disk; relative length of toes (longest to shortest): 4 > 5 > 3 > 2 > 1; toe tips rounded, with circummarginal grooves; subarticular tubercles well developed, rounded, numbering one on first and second toes (Fig. 3); two on third and fifth toes; and three on fourth toe; large, elongated inner metatarsal tubercle; outer metatarsal tubercle absent; disks

on fingers wider than those on toes; heel lacks postaxial fold or calcar.

***Colour.* –** In life, the dorsum is russet (# 34), with numerous smoke gray (# 44) blotches; a vandyke brown (# 121) line at back of forehead, commencing from posterior of upper eyelid, converging medially a little ahead of the posterior end of the suprascapula, but failing to meet each other; lips barred with walnut brown (# 221B) and yellow ochre (# 123C); flanks with a few vandyke brown (# 121) blotches; the iris of eye apple green (# 61); pupil black; tympanic fold on the inferior aspect edged with walnut brown (# 221B); tongue yellowish-pink, unpigmented; bars on limbs and webbing vandyke brown (# 121); and venter pale horn color (# 92). In preservative, gray-brown dorsally, with a darker gray line in scapular region; dark lips barred with pale gray; fore and hind limbs gray brown with darker bars; webbing pale gray; throat and pectoral regions with extensive gray mottling; flanks of body with small, gray-black blotches; undersurfaces of limbs grayish-yellow with dark gray variegations; digits of arms and legs yellowish-gray.

***Measurements (in mm).* –** SVL 62.1; HL 19.8; HW 20.6; HD 11.1; BW 19.7; TBL 38.0; TD (vertical) 3.9; TD (horizontal) 2.9; ED 7.7; UE 5.5; IN 5.2; IO 12.2; E-S 9.7; E-N 7.2; E-T 2.3; A-G 31.9.

Fig. 1. Lateral view of holotype of *Polypedates chlorophthalmus*, new species in life (SBC ZRC 1.11531).

Fig. 2. Close-up of head of the holotype of *Polypedates chlorophthalmus*, new species ZRC 1.11531, showing bright green iris. Marker = 5 mm.

***Etymology.* –** The new species is named for its remarkable green iris, from the Greek for green-eyed.

***Ecological notes.* –** The holotype was found on vegetation, ca. 0.8 m above a granite boulder at the edge of a forest stream. It was a gravid female, containing large and small unpigmented ova, assumed to represent multiple clutches. The males, call and larval stages of the new species remain unknown. The following species of anuran amphibians were found sympatric with the new species: *Ansonia* sp., *Meristogenys whiteheadi* and *Rhacophorus angulirostris.* Because of the relative inaccessibility of the site, follow-up visits to collect additional specimens have not been possible.

***Comparisons*. –** Anuran eye coloration is known to be of systematic importance (see review in Glaw & Vences, 1997), and two south-east Asian anuran species has been described recently on the basis of iris coloration - *Philautus erythrophthalmus* Stuebing & Wong (2000) and *Leptobrachium* sp. Ohler et al., 2004 (both known only from the respective holotypes, from Sabah, Malaysia [Borneo] and Laos, respectively). In possessing bright green iris, the new species from Gunung Murud can be separated from all other south-east Asian species of *Polypedates*. Additionally, *Polypedates chlorophthalmus*, new species, can be differentiated from *P. colletti* (Boulenger, 1890) (range: southern Thailand, Peninsular Malaysia, the Natuna Islands, Sumatra and Borneo), on the basis of the following characters

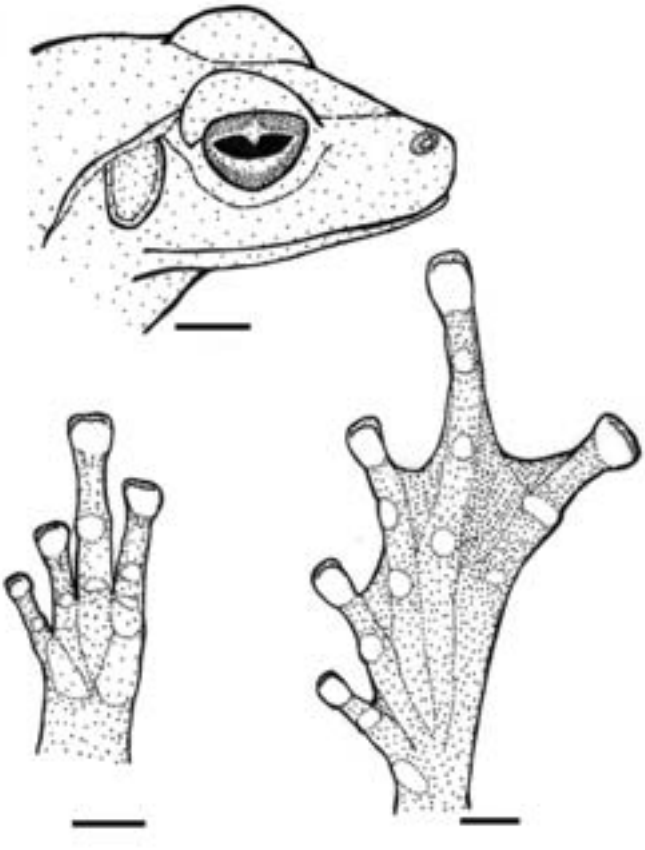

Fig. 3. Head (3.1), hand (3.2) and feet (3.3) of holotype of *Polypedates chlorophthalmus*, new species ZRC 1.11531. Markers = 5 mm.

diagnostic of the latter species: snout acute; canthal ridge indistinct; fingers basally webbed; webbing on toe IV to distal subarticular tubercle on outer edge and to beyond median subarticular tubercle on inner edge; lips unbarred, but with scattered dark pigments; and a distinct X-shaped mark on dorsum. *Polypedates leucomystax* (Gravenhorst, 1829) (as currently understood, comprises a complex of sibling species, see Narins et al., 1998; north-eastern India and southern China, south to Indo-Malaya and Indo-China, to the Philippines and Timor), differs from the new species in possessing head longer than broad; snout tip subacute, exceeding level of mandible; canthus rostralis vertical; iris dark brown; dorsum typically with four narrow, dark stripes or plain or with mottled coloration in individuals from the Bornean population; lips lacking dark bars, and throat and lower flanks and anterior edge of thighs lacking dark pigmentation. *Polypedates macrotis* (Boulenger, 1891) (Peninsular Malaysia, Sumatra, the Mentawai Archipelago, Borneo, the Natuna Islands, and islands of the southern Philippines), differs from the new species in showing snout that projects beyond mandible; a dark broad temporal stripe; lips unbarred; iris yellowish-gray; skin of forehead ossified to frontoparietal bones in adult females; and two to four, white, postcloacal tubercles present. The last Bornean species of the genus, *P. otilophus* (Boulenger, 1893) (Borneo and Sumatra), is diagnosable from the new species from Murud in being larger (SVL in adult females to 97 mm); has a serrated crest over the tympanum; skin co-ossified to bony elements of cranium; spiny protuberances at posterior of jaws (in adults); webbing on feet reaches median subarticular tubercle; a calcar on heel and frequently, on elbow; dorsum of body and hind limbs with numerous thick and thin dark longitudinal lines; throat unpatterned; and iris yellow.

The new species from Gunung Murud is compared with all other known congeners from south-east Asia, listing only opposing suite of characters:
Polypedates dennysii (Blanford, 1881) (southern China and Myanmar, assigned to *Rhacophorus* by Wilkinson et al., 2002), iris yellow; SVL to 120 mm; toes webbed to base of digits; and dorsum green, with isolated pale blotches on dorsal surface and flanks; *P. dugretei* David, 1871 (southern China and Vietnam: preliminary molecular data presented by Yang & Lin, 1997 support the placement of this nominal species in the genus *Rhacophorus*, although Wilkinson & Drewes, 2000, retain it in *Polypedates*, pending further studies), iris yellowish-brown; dorsum green with reddish-brown blotches; toe IV with two phalanges free of web; and fingers basally webbed; *P. feae* Boulenger, 1893 (southern China, Myanmar, Thailand and Vietnam), SVL to 125 mm; head as long as wide; dorsum green; and fingers with webbing; *P. insularis* Das, 1995 (Great Nicobar Island, India), dorsum typically with an hour-glass marking; iris yellow; toe webbing to base of disks of all toes, except toe IV; vomerine teeth separated by a distance equal to their own; and skin on forehead completely free; *P. megacephalus* Hallowell, "1860" 1861 (revived from the synonymy of *P. leucomystax* by Matsui et al., 1986; see also Inger et al., 1999: southern China, Thailand, Laos and Vietnam), iris yellow; dorsum brown with a dark hour-glass mark on scapular region; a dark canthal region; and toe IV with two phalanges free of web; and *P. mutus* (Smith, 1940) (southern China, Myanmar), head longer than wide; dorsum brown a dark interorbital bar and spots or four longitudinal stripes; a dark hour-glass shaped mark on dorsum; iris yellow; and outer edges of thighs with bright yellow blotches.

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APPENDIX I

List of comparative material examined

Polypedates colletti – DWNP A.0996, Interpretive Trail, Sungei Relau, Taman Negara, Pahang, Peninsular Malaysia; ID–7932, Gunung Santubong, Sarawak, Malaysia; PNM 7959 and 7964, Bako National Park, Sarawak, Malaysia; ID–7508–09, Long Asap, Belaga, Sarawak, Malaysia; ID–7495, Niah National Park, Sarawak, Malaysia; UBD 494 and 536, Batu Apoi, Temburong District, Brunei Darussalam; UBD 657, Tasek Merembun, Brunei Darussalam.

Polypedates insularis – ZSI A8731 (holotype), ZSI A8732–34 (paratopotypes), ca. 2 km E mouth of Galathea River, Galathea National Park, Great Nicobar, India; ZSI A8575, Campbell Bay, Great Nicobar, India; ZSI A8735–36 (paratypes), Shompen Hut, Great Nicobar, India; ZSI A8737–40 (paratypes), ca. 2 km E Kopen Heat, Great Nicobar, India.

Polypedates leucomystax – DWNP-A.0978–80, Sungei Relau, Taman Negara, Pahang, Peninsular Malaysia; PNM 7970, Gunung Penrissen, Sarawak, Malaysia; SBC A.00050, Gn. Ropih, Bau, Sarawak, Malaysia; SBC A.00169, Gn. Umbut, Bau, Sarawak, Malaysia; SBC A.00176–77, SBC A.00253, SBC A.00274, Gn. Tabai, Bau, Sarawak, Malaysia; SBC A.00199–201, Gn. Doya, Bau, Sarawak, Malaysia; SBC A.00235, Gn. Meraja, Bau, Sarawak, Malaysia; SBC A.00298, Gn. Podam, Bau, Sarawak, Malaysia; ZRC – 1.11090, Gunung Gading National Park, Sarawak, Malaysia; ZRC 1.7672, 1.7709, Kota Samarahan, Sarawak, Malaysia; SP 01189-93, Hutan Simpan, Mandamail, Pitas, Kudat, Sabah, Malaysia; UBD 05, 07–08, 73, Tasek Lama, Bandar Seri Begawan, Brunei Darussalam; UBD 552, Kampung Sungei Damit, Tutong, Brunei Darussalam; UBD 505 and 689, Batu Apoi, Temburong District, Brunei Darussalam; UBD 429, Jalan Menggis Dua, Bandar Seri Begawan, Brunei Darussalam; UBD 580, 588, Bukit Patoi, Temburong, Brunei Darussalam; ZRC 1.903, Ayer Rajah Campus, Singapore; ZRC 1.1347, Hindhide Drive, Singapore; ZRC 1.1498, Jurong, Singapore.

Polypedates macrotis— DWNP A.0994, Interpretive Trail, Sungei Relau, Taman Negara, Pahang, Peninsular Malaysia; DWNP A.1022–24, behind staff quarters, Sungei Relau, Taman Negara, Pahang, Peninsular Malaysia; PNM 7955, Gunung Gading National Park, Sarawak, Malaysia; ID–7555, Gunung Beremput, Sarawak, Malaysia; ID–7588, Gunung Gading National Park, Sarawak, Malaysia; ID–SWAK 19, Lambir Hills National Park, Sarawak, Malaysia; ID–7773, Pulau Balambangan, Sabah, Malaysia; SP 00920, Danum Valley Field Centre, Lahad Datu, Sabah, Malaysia; SP 20189, Ulu Padas, Long Pasia, Sabah, Malaysia; UBD uncat. (Chris Reading coll.), Batu Apoi, Temburong District, Brunei Darussalam.

Polypedates otilophus — SBC A.00022, Gn. Apin, Bau, Sarawak, Malaysia; SBC A.00170, Gn. Umbut, Bau, Sarawak, Malaysia; ZRC 1.3923, Gunung Buri, Sarawak, Malaysia; ZRC uncatalogued, Lambir Hills National Park, Sarawak, Malaysia; SP 02725, Tawau Hills Park, Sabah, Malaysia; SP 02425, Mahua Camp, Crocker Range National Park, Sabah, Malaysia; UBD 537, Batu Apoi, Temburong District, Brunei Darussalam.