

# Nine new species of microhylid frogs from the Muller Range in western Papua New Guinea (Anura, Microhylidae)

RAINER GÜNTHER<sup>1</sup>, STEPHEN J. RICHARDS<sup>2</sup> & CHRIS DAHL<sup>3</sup>

<sup>1</sup> Museum für Naturkunde, Invalidenstr. 43, 10115 Berlin, Germany — <sup>2</sup> Herpetology Department, South Australian Museum, North Terrace, Adelaide, South Australia, and Conservation International, Cairns, Queensland, Australia — <sup>3</sup> New Guinea Binatang Research Center, Madang, Papua New Guinea and University of South Bohemia and Biology Center of the Academy of Sciences of the Czech Republic, Branisovska 31, 370 05, Ceske Budejovice, Czech Republic

Accepted 01.xi.2013.

Published online at [www.senckenberg.de/vertebrate-zoology](http://www.senckenberg.de/vertebrate-zoology) on 30.iv.2014.

## Abstract

We describe nine new species of microhylid frogs in the genera *Austrochaperina*, *Cophixalus*, *Copiula*, *Hylophorbus*, *Oreophryne* and *Xenorhina* from the Muller Range in western Papua New Guinea. Each of the new species differs from congeners by a suite of morphological and acoustic characters. The discovery of so many new species during a survey of short duration (three weeks) and limited geographical coverage suggests that many additional species remain to be detected within this poorly known mountainous region.

## Kurzfassung

Vom Muller Range, einem Gebirgsstock im Westen von Papua New Guinea, werden neun neue Froscharten aus der Familie Microhylidae beschrieben. Es handelt sich um Vertreter der Gattungen *Austrochaperina*, *Cophixalus*, *Copiula*, *Hylophorbus*, *Oreophryne* und *Xenorhina*. Jede der neuen Arten unterscheidet sich von ihren Gattungsverwandten durch eine Reihe artspezifischer morphologischer und bioakustischer Merkmale. Die Entdeckung von so vielen neuen Arten in einer Zeitspanne von nur drei Wochen und auf einer relativ kleinen Fläche lässt vermuten, dass noch viele weitere neue Arten in dieser abgelegenen und wenig bekannten Gebirgsregion leben.

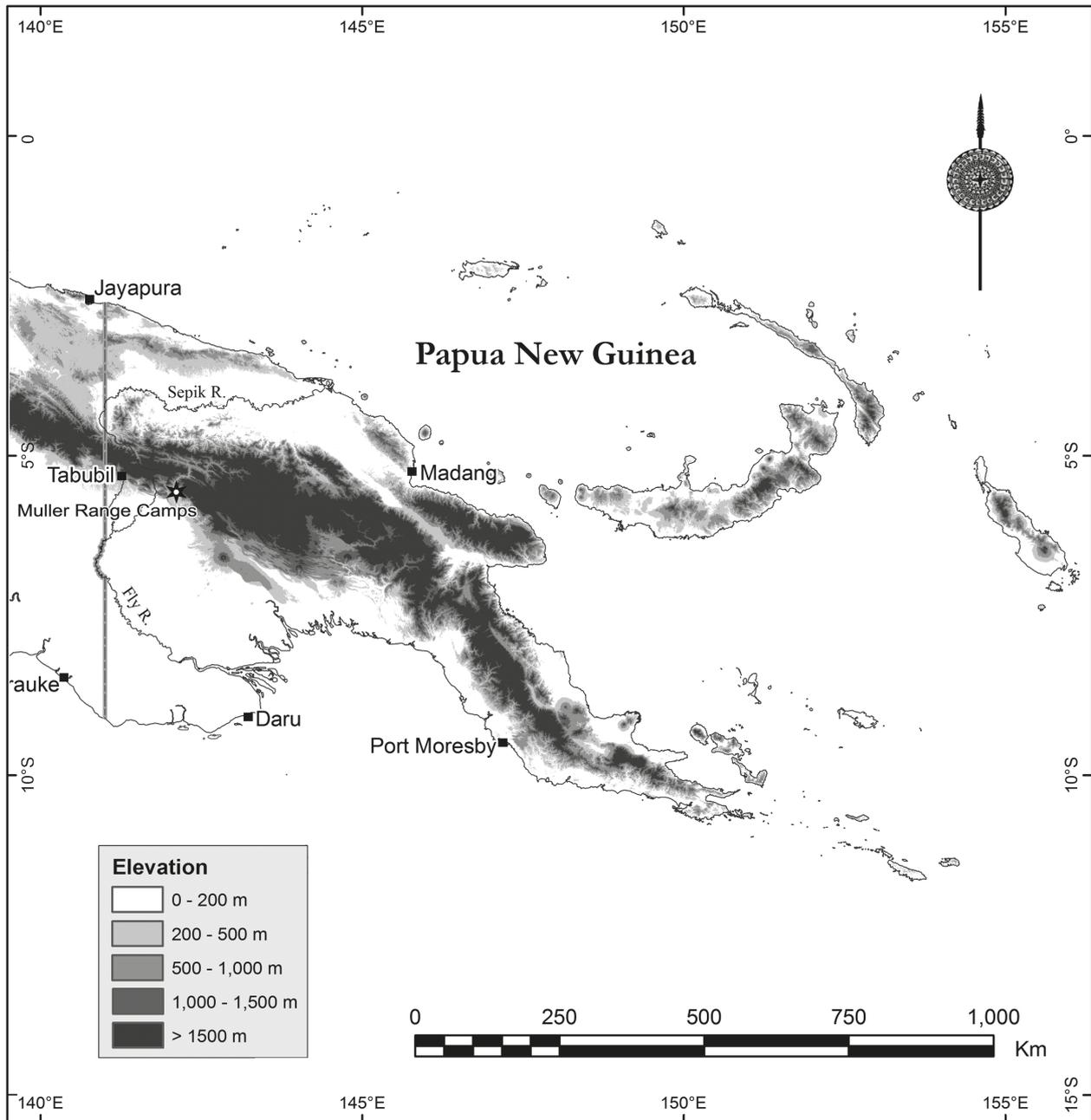
## Key words

Amphibia, Anura, Microhylidae, *Austrochaperina*, *Cophixalus*, *Copiula*, *Hylophorbus*, *Oreophryne*, *Xenorhina*, new species, Papua New Guinea.

## Introduction

The rugged and sparsely populated Muller Range of western Papua New Guinea straddles Western and Southern Highlands Provinces in the upper Strickland River basin (Fig. 1 and Fig. 2). The Muller Range is a predominantly limestone environment that has been included in a World Heritage nomination, ‘The sublime karsts of Papua New Guinea’. The region has been on the World Heritage Tentative List since 2006.

Although the spectacular karst cave systems of the Muller Range have been the subject of intensive speleological investigations (JAMES & DYSON 1980), the biodiversity of the region has been poorly documented and until recently only three species of frogs were known from this mountain range (KRAUS & ALLISON 2009). KRAUS & ALLISON (2009) described a new species of microhylid frog in each of the genera *Albericus*, *Cophixalus* and



**Fig. 1.** Map of Papua New Guinea showing the location (star) of the two Muller Range camps. Due to their close proximity, both sites are covered by the same symbol.

*Oreophryne* from the Muller Range, and increased the number of microhylid frogs known from there to nine.

In 2009 Conservation International undertook a Rapid Assessment Program (RAP) biodiversity survey in the Muller Range to obtain more information about the region's poorly-known biodiversity (RICHARDS & GAMUI 2011). That survey documented many new species of plants and animals including the microhylid frog *Oreophryne oviprotector* (e.g. TAKEUCHI 2010, GÜNTHER *et al.* 2012), and nine additional species of microhylid frogs that are described here.

## Material and methods

Most frogs were detected at night by tracking their advertisement calls. Some females were also encountered with the aid of head-torches, and a small number of individuals were collected from beneath stones and logs on the forest floor. Frogs were euthanised with chlorobutanol, fixed in 10 % formalin in the field for 1–2 days, and transferred to 75 % ethanol for permanent storage. Samples of liver tissue were extracted from up to five specimens of each species and stored in 95 % ethanol to permit future DNA analysis. Clearing and double staining of one specimen



**Fig. 2.** View from Gugusu camp at 500 m asl to the higher slopes of the Muller Range.

of some species as osteological preparations according to a modified method of DINGERKUS & UHLER (1977) was carried out to identify their generic allocation. Sex was determined by inspection of gonads and of secondary sex characters (presence of vocal slits).

Measurements of SUL, TL and TaL to the nearest 0.1 mm were made with a digital calliper; all others were made with an ocular micrometer in a dissecting microscope:

<b>SUL</b>	snout-urostyle length, from tip of snout to distal tip of urostyle bone (SUL and snout-vent length differ insignificantly, but SUL is more accurately measured);
<b>TL</b>	tibia length, external distance between knee and heel (calliper gently pressed);
<b>TaL</b>	length of tarsus, external distance, tarsal and heel joints held at right angles;
<b>L4T</b>	length of fourth toe, from tip of toe to proximal end of inner metatarsal tubercle;
<b>L3F</b>	length of third finger, from tip of finger to proximal end of inner metacarpal tubercle;
<b>F3D</b>	transverse diameter of third finger disc;
<b>F1D</b>	transverse diameter of first finger disc;
<b>T4D</b>	transverse diameter of fourth toe disc;
<b>T1D</b>	transverse diameter of first toe disc;
<b>HL</b>	head length, from tip of snout to posterior margin of tympanum;
<b>HW</b>	head width, taken in the region of the tympana;
<b>END</b>	distance from anterior corner of orbital opening to centre of naris;
<b>IND</b>	internarial distance between centres of nares;
<b>ED</b>	eye diameter, from anterior to posterior corner of orbital opening;

<b>EST</b>	distance from anterior margin of orbital opening to snout tip;
<b>TyD</b>	horizontal diameter of tympanum;
<b>SL</b>	snout length, from an imaginary line connecting the centres of the eyes to snout tip.

Calls were recorded in the field with a Marantz PMD-661 Digital Recorder and a Sennheiser ME66 microphone and analysed with Avisoft-SAS Lab Pro software. Specimens are housed in the herpetological collections of the Papua New Guinea National Museum and Art Gallery (PNGNM), the South Australian Museum, Adelaide (SAMA), and in the Museum für Naturkunde, Berlin (ZMB) and bear registration numbers of these institutions.

### Material compared

*A. archboldi*, AMNH 66719, holotype; AMNH 66720, AMNH 66722–25, paratypes; *A. blumi*, UPNG 9529-31, 9534, 9537; *Austrochaperina derongo*, paratypes MCZ A-132891, A-132913, A-132914, A-132918, A-132978 and A-132999; *A. guttata*, MCZ A-132843–45; *A. macrorhyncha*, RMNH 4630, holotype; ZMA 5747, 5750–54 (syntypes of *Chaperina punctata*), MCZ A-9383; *A. mehelyi*, MCZ A-28406; *A. novaebritanniae* MCZ A-73085–86.

Frogs of the genus *Cophixalus* that were studied are listed in the papers by RICHARDS, JOHNSTON & BURTON (1992); GÜNTHER (2003a, 2006a) and RICHARDS & OLIVER (2007, 2010), those of the genus *Copiula* by GÜNTHER (2002a and 2002b) and those of the genus *Hylophorbus* by GÜNTHER (2001) and RICHARDS & OLIVER (2007). Specimens of the

genus *Oreophryne* are listed in the papers by RICHARDS & ISKANDAR (2000); GÜNTHER, RICHARDS & ISKANDAR (2001); GÜNTHER (2003b and 2003c); ZWEIFEL, COGGER & RICHARDS (2005); and GÜNTHER *et al.* (2009). Moreover, three paratopotypes of *O. notata* ([AMNH A-81196-97](#) and [A-81199](#)) were examined. Material of the genus *Xenorhina* is listed by GÜNTHER (2010).

Original descriptions of new species, taxonomic revisions and field guides were also consulted.

## Abbreviations of collections

<b>AMNH</b>	American Museum of Natural History, New York, USA;
<b>BMNH</b>	The Natural History Museum (formerly British Museum of Natural History), London, UK;
<b>MCZ</b>	Museum of Comparative Zoology, Harvard University, Cambridge, USA;
<b>RMNH</b>	National Museum of Natural History, Naturalis, Leiden, The Netherlands;
<b>SAMA</b>	South Australian Museum, Adelaide, Australia;
<b>PNGNM</b>	Papua New Guinea National Museum and Art Gallery, PNG;
<b>ZMA</b>	Zoologisch Museum, Universiteit van Amsterdam;
<b>ZMB</b>	Museum für Naturkunde Berlin (formerly Zoologisches Museum Berlin).

## *Austrochaperina alexanderi* sp. nov.

**Holotype.** [SAMA R65094](#) (FN: [SJR 12026](#)), adult male, *coll.* S. RICHARDS and C. DAHL, Sawetau Camp, Muller Range, Western Province, Papua New Guinea (05°39.397' S, 142°18.277' E; 1600 m asl) on 13 September 2009.

**Paratypes.** [SAMA R65091](#) (FN: [SJR 12016](#)), [SAMA R65092](#) (FN: [SJR 12017](#)), [SAMA R65093](#) (FN: [SJR 12025](#)), [ZMB 79520](#) (FN: [SJR 12045](#)). Collectors and collection locality same as for holotype, all paratypes collected 12–13 September 2009. For sex of paratypes see Table 1.

**Diagnosis.** With a snout-urostyle length of 42.4–44.4 mm in four adult males and of 36.1 mm in a subadult male the new species belongs to the large-sized *Austrochaperina*. It differs from all other large-sized species by its big eyes (ED/SUL 0.127–0.147) and small tympanum (TyD/ED 0.26–0.30), a pale postocular stripe that reaches the scapular region, and by its advertisement call with most notes between 100 and 120 ms long and a repetition rate between 1.8 and 2.4 notes/s.

**Description of the holotype.** Adult male (Fig. 3); for body measurements and ratios see Table 1. Small longitudinal incision on left side of abdomen. Head almost as wide as body. Snout subelliptical in dorsal view and acute in profile. Nostrils directed laterally and closer to

snout tip than to eyes. Canthus rostralis gently rounded and straight between eye and nostril when seen from above. Loreal region slightly angular and shallowly concave. Distance between nares distinctly greater than distance between eye and naris (END/IND 0.71). Tongue elongate and widened posteriorly, half free laterally and posteriorly, and without a posterior indentation. Palatal ridge without denticles. Elongate vocal slit on each side of the tongue near corner of mouth. Tympanic annulus scarcely visible, its horizontal diameter less than one third of eye diameter (TyD/ED 0.27). Supratympanic skin fold clearly expressed. There is a depression that runs from tympanum to insertion of forearm. Eye large (ED/SUL 0.135) with horizontal pupil. Forelimbs of moderate size, fingers short with expanded tips (F3D/SUL 0.045). All fingers with terminal grooves, no trace of webbing. No distinct palmar or subarticular tubercles. Relative length of fingers 3 > 4 > 2 > 1 (Fig. 3b). Hind limbs well developed. Discs of toes 2, 3, and 4 clearly broader than penultimate phalanges, those of toes 1 and 5 only slightly wider than penultimate phalanx, all with terminal grooves. Metatarsal tubercles and subarticular tubercles absent. Relative length of toes 4 > 3 > 5 > 2 > 1, no webbing (Fig. 3c). Skin of all dorsal and ventral surfaces smooth.

**Colouration in preservative.** Ground colour of all dorsal and lateral surfaces grey-brown with inconspicuous mottling consisting of irregular small dark brown blotches and stipples. Some lighter spots only on fingers and toes. Area around tympanum reddish-brown. Conspicuous is a light grey longitudinal stripe from posterior edge of eye to scapular region that is bordered by dark brown spots on both sides and broadened posteriorly. Ventral surfaces off-white with grey-brown mottling, denser on throat, chest, thighs, tarsi, palms and soles, and less dense on abdomen. Some areas on forearms, lower arms, tibiae, fingers and toes are unpigmented. Snout tip with pale cap.

**Colouration in life.** All dorsal and lateral surfaces uniform grey with a yellowish hue and a few scattered small dark blotches. Conspicuous is the honeycombed structure of the skin, the pale postocular stripe, the pale snout tip and the rubiginous colour of the tympanum. Iris golden-silvery with dense blackish veining and orange zone in the middle of the anterior and posterior iris. Colour of all ventral surfaces (except soles and palms) is off-white with a dense grey mottling (Fig. 3d). Soles and palms dark grey, fingers and toes lighter grey.

**Morphological variation in the type series.** The type series consists of four adult males and one subadult male for which measurements and body ratios are listed in Table 1. Differences in overall colouration of dorsal surfaces among the preserved types are minor. They concern mainly the intensity of dark brown mottling which is less dense in the holotype and very dense in [SAMA R65092](#). Intensity of mottling is highest in [SAMA R65091](#) and



**Fig. 3.** Holotype of *Austrochaperina alexanderi* sp. nov. in life; (a) dorsolateral view, (b) ventral view of right hand, (c) ventral view of right foot, (d) ventral view.

lowest in the holotype and SAMA R65093. All specimens exhibit a pale postocular stripe that is bordered by dense rows of dark brown spots, and a whitish rostral cap. Ventral surfaces in all specimens are off-white and vary from sparsely pigmented (SAMA R65091) to strongly pigmented (SAMA R65093) by grey-brown stipples, mottles and areas.

**Distribution and ecological notes.** All specimens of this species were encountered along a short stretch of moderately slow-flowing but clear stream that emerged from the limestone substrate adjacent to Sawetau Camp and disappeared back into the limestone just ~50 m downstream. Males were calling from the ground adjacent to the stream after rain at night. No individuals were seen more than 2 m from the stream edge.

**Vocalization.** The advertisement call consists of a series of pulsed notes (Fig. 4). Call duration lasts from a few seconds to more than one minute. A conspicuous feature of the call is the irregular duration of internote intervals in many segments. The number of notes in calls was 11–118 and mean note repetition rate in 5 calls from two males (the holotype and a calling male observed that escaped) was 2.0 notes/s, range 1.8–2.4 notes/s. Mean note length in the calls of the first male was 112 ms (SD 5.4), range 102–126 ms,  $n=43$ ; mean length of internote intervals was 385 ms (SD 99.9), range 290–625 ms,  $n=42$  and mean of pulse number per note was 9.2 (SD 1.2), range 8–12,  $n=43$ . Mean note length in the calls of the second male was 106 ms (SD 8.4), range 86–117 ms,  $n=35$ ; mean of internote intervals was 306 ms (SD 101), range 211–777 ms,

**Table 1.** Body measurements and body ratios of the type series of *Austrochaperina alexanderi* sp. nov. SAMA R65094 is the holotype; all types (except the subadult R65091) are adult males. In all tables measurements are in mm; abbreviations are explained in “Material and methods”.

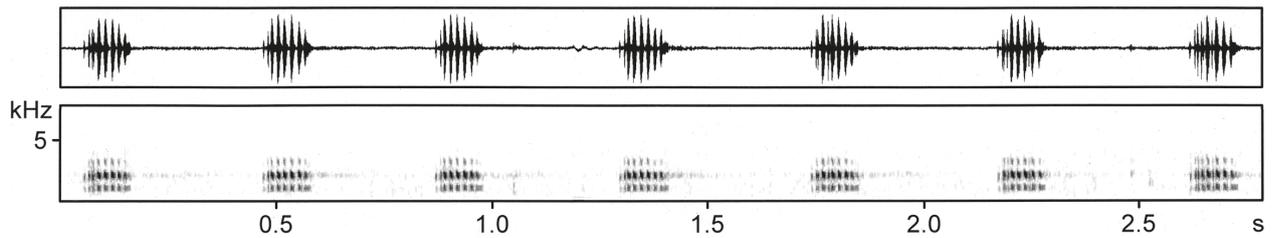
Reg.-No.	SAMA R65091	SAMA R65092	SAMA R65093	SAMA R65094	ZMB 79520	Mean ± SD
SUL	36.1	42.4	44.1	44.4	42.5	
TL	17.4	18.4	20.0	20.2	19.7	
TaL	10.8	12.1	12.4	12.7	12.5	
L4T	19.1	20.5	21.8	22.3	20.8	
T4D	1.9	2.3	2.5	2.3	2.2	
L3F	10.4	11.7	12.0	12.5	12.1	
F3D	1.6	1.8	1.9	2.0	2.0	
F1D	1.2	1.6	1.5	1.4	1.4	
T1D	1.3	1.7	1.7	1.5	1.7	
HL	12.4	14.1	14.8	13.9	14.0	
HW	14.4	15.4	17.0	16.7	16.3	
SL	6.4	6.8	8.0	7.5	6.6	
END	3.0	3.2	3.3	3.2	2.7	
IND	4.1	4.7	4.8	4.5	4.6	
ED	5.2	5.7	5.7	6.0	5.4	
TyD	1.5	1.5	1.7	1.6	1.5	
EST	5.0	5.6	5.7	5.2	5.0	
TL/SUL	0.48	0.43	0.45	0.45	0.46	0.45 ± 0.02
TaL/SUL	0.30	0.29	0.28	0.29	0.29	0.29 ± 0.007
T1D/F1D	1.08	1.06	1.13	1.07	1.21	1.11 ± 0.06
T4D/SUL	0.053	0.054	0.057	0.052	0.052	0.054 ± 0.002
T4D/F3D	1.19	1.28	1.31	1.15	1.10	1.21 ± 0.09
F1D/F3D	0.75	0.89	0.79	0.70	0.65	0.76 ± 0.09
HL/SUL	0.34	0.33	0.34	0.31	0.33	0.33 ± 0.01
HL/HW	0.86	0.92	0.87	0.83	0.86	0.87 ± 0.03
SL/SUL	0.177	0.160	0.181	0.169	0.155	0.168 ± 0.01
END/IND	0.73	0.68	0.69	0.71	0.59	0.68 ± 0.05
ED/SUL	0.144	0.134	0.129	0.135	0.127	0.134 ± 0.006
TyD/ED	0.29	0.26	0.30	0.27	0.29	0.28 ± 0.02

$n=34$  and mean of pulse number per note was 7.8 (SD 0.8), range 7–9,  $n=35$ . Fundamental frequency is at 1.1 kHz and dominant frequency at 2.2 kHz (Fig. 5). Depending on sound volume of the recording there are more or less upper harmonic bands. First pulses and last pulses of a note usually have a lower volume than the remaining ones. Calls were recorded at an air temperature of 17.5 °C.

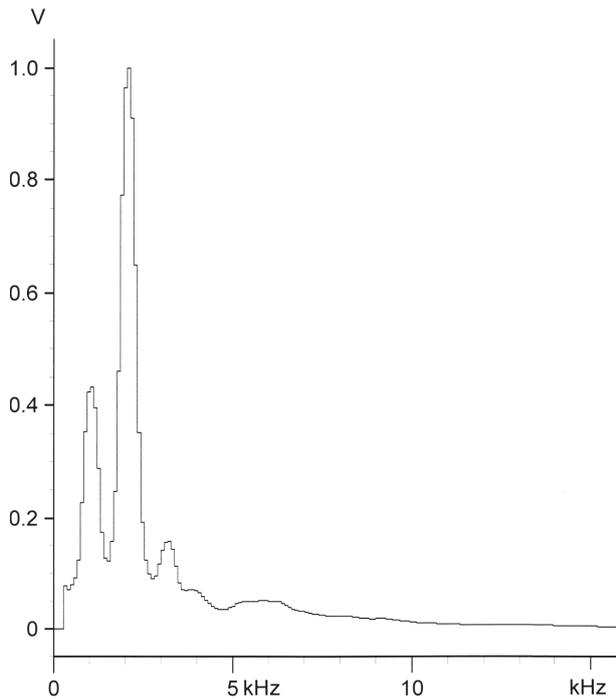
**Etymology.** The species name is dedicated to the senior author’s grandson ALEXANDER WERNER. English name: Alexander’s Land Frog; German name: Alexanders Landfrosch.

**Comparison with other species.** Species of approximately the same size as *A. alexanderi* are *A. derongo*, *A. guttata*, *A. hooglandi*, *A. palmipes* and *A. rivularis*. Six paratypes of *A. derongo* (studied by us) are smaller (SUL does not achieve 40 mm) than *A. alexanderi*; they further differ in having smaller eyes (ED/SUL 0.095–0.113 vs. 0.127–0.144), larger tympana (TyD/ED 0.34–0.40 vs.

0.26–0.30), smaller discs on the fourth toe (T4D/SUL 0.039–0.050 vs. 0.052–0.057), and advertisement calls have shorter notes in *A. derongo* (70–77 ms according to ZWEIFEL 2000) than in *A. alexanderi* (86–126 ms). *A. guttata* has distinctly patterned dorsal surfaces, longer shanks (mean TL/SUL 0.48 vs. 0.45), smaller eyes (ED/SUL 0.095–0.122), larger tympana (TyD/ED in the holotype 0.51) and advertisement calls with a repetition rate of 7 notes/s. *A. hooglandi* differs by having a different colour pattern (“dark middorsal region abruptly differentiated from paler lateral areas and with reddish shades prominent, especially laterally and on the groin and thighs”, ZWEIFEL 2000, page 35), distinctly smaller eyes, finger discs and toe discs and different advertisement calls (7.0–9.3 notes/s according to ALLISON & KRAUS 2003). *A. palmipes* differs conspicuously from *A. alexanderi* by its extensively webbed toes. *A. rivularis* seems closely related to *A. alexanderi*. It differs mainly by smaller eyes (ED/SUL 0.096–0.124 vs. 0.127–0.147), smaller finger discs (F3D/SUL 0.031–0.044 vs. 0.042–0.047 in *A. alexanderi*), smaller toe discs (T4D/



**Fig. 4.** Wave form (above) and spectrogram (below) of 7 notes of an advertisement call of *Austrochaperina alexanderi* sp. nov. (SAMA R65094).



**Fig. 5.** Power spectrum of one advertisement call section of *Austrochaperina alexanderi* sp. nov.

SUL 0.039–0.054 vs. 0.052–0.057), by lacking a pale postocular stripe and by its advertisement calls. The overwhelming majority of call notes of *A. rivularis* have a length of between 60 and 80 ms and those of *A. alexanderi* of between 95 and 115 ms. Dominant frequency is at 2.7 kHz in the first species (ZWEIFEL 2000) and at 2.2 kHz in the second one.

### *Austrochaperina laurae* sp. nov.

**Holotype.** SAMA R65097 (FN: SJR 12029), adult male, coll. S. RICHARDS and C. DAHL, Sawetau Camp, Muller Range, Western Province, Papua New Guinea (05° 39.397' S, 142° 18.277' E; 1600 m asl) on 12 September 2009.

**Paratypes.** SAMA R65095 (FN: SJR 10996), SAMA R65096 (FN: SJR 10999), SAMA R65098 (FN: SJR 12039), SAMA R65099 (FN: SJR 12047), SAMA R65100 (FN: SJR 12067), ZMB 79521 (FN: SJR 12046), ZMB 79522 (FN: SJR 12068). Collectors and collection site as for holotype, all collected 12–14 September 2009.

**Diagnosis.** With a snout-urostyle length of 26.9–29.6 mm in five adult males and 28.2–35.2 mm in three adult females this new species belongs to the medium sized group (or to the group of “small species” when following ZWEIFEL 2000) in the genus. Species that are clearly smaller than *A. laurae* are *A. blumi*, *A. gracilipes*, *A. kosarek*, *A. mehelyi*, *A. novaebritanniae*, *A. polysticta* and *A. yelaensis*. The new species can be readily distinguished from all other species except *A. hooglandi* and *A. septentrionalis* by its orange-red hidden surfaces of groin and thighs in life. With a size of 35.1–45.3 mm *A. hooglandi* is clearly larger than *A. laurae*; and *A. septentrionalis* differs in size of finger discs (F3D/SVL 0.022–0.028 in *A. septentrionalis* versus 0.027–0.042 in *A. laurae*), of toe discs (T4D/SVL 0.031–0.040 in *A. septentrionalis* versus 0.041–0.052 in *A. laurae*) and eye-diameter (ED/SVL 0.098–0.110 in *A. septentrionalis* versus 0.108–0.127 in *A. laurae*). Moreover, the advertisement call of *A. septentrionalis* has a duration of about eight seconds and a repetition rate of 9.3–9.6 notes/s, whereas that of *A. laurae* has a mean duration of two seconds and a repetition rate of 6.6–7.4 notes/s.

**Description of the holotype.** Adult male with a snout-urostyle length of 27.4 mm (Fig. 6). For measurements and body ratios see Table 2. Small longitudinal incision on left side of abdomen. Head in the region of the tympana as wide as the remaining body. Snout subelliptical in dorsal view and acute in profile. Nostrils laterally directed and closer to snout tip than to eyes. Canthus rostralis gently rounded and straight between eye and nostril. Loreal region slightly angular and shallowly concave. Distance between nares distinctly greater than distance between eye and naris (END/IND 0.68). Tongue moderately wide, elongate, half free laterally and posteriorly, and without a posterior indentation. Palatal ridges scarcely developed. Elongate vocal slit on each side of the tongue. Tympanum clearly visible, its horizontal diameter slightly more than half eye diameter (TyD/ED 0.53), supratympanic skin fold weak. Eye of medium size (ED/SUL 0.124), with horizontal pupil. Forelimbs of medium size, fingers short, their tips not (finger 1) or only scarcely (fingers 2–4) broader than penultimate phalanges (Fig. 6b). All fingers with terminal grooves, no trace of webbing. No distinct palmar or sub-articular tubercles. Relative length of fingers 3 > 4 > 2 > 1. Hind limbs more robust than fore limbs. Discs of toes 2, 3, and 4 clearly broader than penultimate phalanges,



**Fig. 6.** Holotype of *Austrochaperina laurae* sp. nov. in life; (a) dorsolateral view, (b) ventral view of left hand, (c) ventral view of left foot, (d) ventral view.

those of toes 1 and 5 only slightly wider than penultimate phalanx, all with terminal grooves. Metatarsal tubercles and subarticular tubercles absent. Relative length of toes  $4 > 3 > 5 > 2 > 1$ , no webbing (Fig. 6c). Skin of dorsum and lateral surfaces with many small and indistinct longitudinal ridges. Ventral surfaces smooth.

**Colouration in preservative.** All dorsal surfaces uniform brown; only tarsi, forearms, digits and toes with lighter flecks or areas. Ventral surfaces off-white with grey-brown marbling that is less dense on abdomen and extremities and more dense on chest and throat. This colour pattern extends also onto lower flanks.

**Colouration in life.** All dorsal surfaces brown with a more or less semitransparent grey veil. Small off-white

spots are on all body parts, especially on flanks, extremities and below eye and tympanum. Lower flanks are covered by larger off-white spots. Iris golden to orange with a dark grey-brown reticulum. Conspicuous is a white rostral cap. Colour of all ventral surfaces (except soles and palms) is yellowish with a dense grey marbling. Soles and palms darker grey, fingers and toes lighter grey. Groin, anterior and posterior sides of thighs, and proximal inside of shank salmon red (Fig. 6c and 6d).

**Morphological variation in the type series.** The type series consists of five adult males and three adult females for which measurements and body ratios are listed in Table 2. Although sample size is relatively small, and there is some overlap in snout-urostyle length between males and females, the overlap is minimal and the latter are gener-

**Table 2.** Body measurements and body ratios of the type series of *Austrochaperina laurae* sp. nov. SAMA R65097 is the holotype. SAMA R65095, R65096, R65100 and ZMB 79522 are adult males; R65098, R65099 and ZMB 79521 are adult females.

Reg.-No.	SAMA R65095	SAMA R65096	SAMA R65097	SAMA R65098	SAMA 65099	SAMA 65100	ZMB 79521	ZMB 79522	Mean ± SD
SUL	26.9	27.0	27.4	31.2	35.2	29.2	28.2	29.6	
TL	11.1	12.0	12.0	14.1	14.3	13.6	13.4	13.1	
TaL	8.2	8.1	8.2	9.4	9.6	9.1	8.9	8.7	
L4T	12.6	13.4	13.1	14.2	15.2	14.0	13.0	13.2	
T4D	1.2	1.4	1.2	1.6	1.5	1.3	1.3	1.2	
L3F	6.3	5.9	6.1	7.6	7.3	7.4	7.0	6.8	
F3D	0.8	0.9	0.8	1.3	1.0	0.8	1.0	0.8	
F1D	0.5	0.5	0.4	0.6	0.7	0.6	0.5	0.5	
T1D	0.6	0.6	0.5	0.7	1.0	0.6	0.6	0.6	
HL	10.0	9.7	9.2	10.5	10.5	10.1	9.8	9.4	
HW	11.0	11.5	10.4	11.7	12.9	11.9	11.0	10.7	
SL	4.4	4.1	4.3	4.5	5.0	4.8	4.6	4.4	
END	2.0	2.2	2.1	2.2	2.6	2.2	2.3	2.2	
IND	3.2	3.0	3.1	3.3	3.5	3.1	3.2	3.0	
ED	3.2	3.3	3.4	3.6	3.8	3.7	3.5	3.5	
TyD	1.7	1.5	1.8	1.6	1.5	1.6	1.4	1.9	
EST	2.5	3.9	3.9	3.4	4.2	3.7	3.3	3.2	
TL/SUL	0.41	0.44	0.44	0.45	0.41	0.47	0.48	0.44	0.44 ± 0.02
TaL/SUL	0.30	0.30	0.30	0.30	0.27	0.31	0.32	0.29	0.30 ± 0.01
T1D/F1D	1.20	1.20	1.25	1.17	1.43	1.00	1.20	1.20	1.21 ± 0.12
T4D/SUL	0.045	0.052	0.044	0.051	0.043	0.045	0.046	0.041	0.046 ± 0.004
T4D/F3D	1.50	1.56	1.50	1.23	1.40	1.63	1.30	1.50	1.45 ± 0.13
F1D/F3D	0.63	0.56	0.50	0.46	0.70	0.75	0.50	0.63	0.59 ± 0.10
HL/SUL	0.37	0.36	0.34	0.34	0.30	0.35	0.35	0.32	0.34 ± 0.02
HL/HW	0.91	0.84	0.88	0.90	0.81	0.85	0.89	0.88	0.87 ± 0.03
SL/SUL	0.164	0.152	0.157	0.144	0.142	0.164	0.163	0.149	0.154 ± 0.009
END/IND	0.63	0.73	0.68	0.67	0.79	0.65	0.72	0.73	0.70 ± 0.05
ED/SUL	0.119	0.122	0.124	0.115	0.108	0.127	0.124	0.118	0.120 ± 0.006
TyD/ED	0.53	0.45	0.53	0.44	0.43	0.43	0.40	0.54	0.47 ± 0.06

ally larger. No differences in body ratios between the sexes were detected. Differences in dorsal colouration of all preserved types are minor. They concern only the shade of brown colour. One specimen (ZMB 79521) exhibits some irregular whitish blotches on posterior dorsum. One of the male specimens (ZMB 79522) exhibits not only the lightest dorsal colour but does not have a whitish rostral cap, in contrast to all other males. All three females also do not have a whitish rostral cap. Ventral surfaces vary from strongly pigmented (holotype and SAMA R65098) to distinctly less pigmented (SAMA R12047). There is a clear tendency in all specimens that throat and chest are more strongly pigmented than abdomen, inferior thighs and inferior upper arms. Tympanum is distinctly lighter than its surrounding in all type specimens.

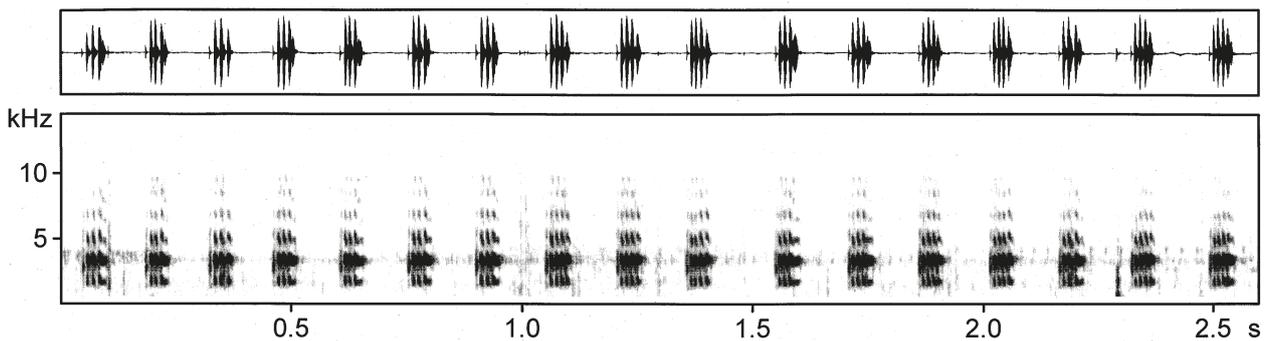
**Distribution and ecological notes.** This species was abundant in extremely wet and mossy forest surrounding Sawetau Camp at 1,600 m asl in the Muller Range of Western Province, Papua New Guinea (Fig. 7). All specimens that were not vocalising were collected from the forest floor at night, usually after rain. In contrast, calling males were all found on elevated perches on mossy

logs between 15 and 50 cm above the ground where they called from semi-exposed positions. The new species is currently known only from the type locality.

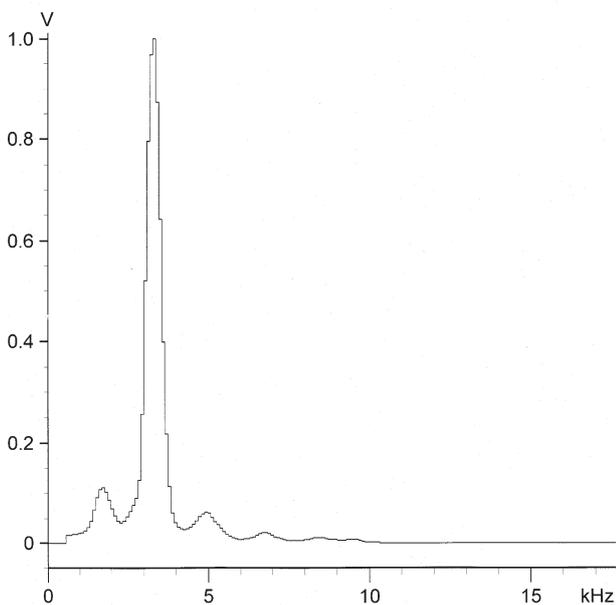
**Vocalization.** The advertisement calls, recorded at air temperatures of 17.8–18.0 °C, consist of a long series of pulsed notes (Fig. 8). Length of calls varied from 0.91–2.54 s, mean 1.97 (n=18). Mean note repetition rate in 18 calls from three males (SAMA R65095, R65096, R65097), was 7.0 notes/s (SD 0.20), range 6.6–7.4 notes/s. Mean of 16 means of note length was 57 ms (SD 3.9), range of means 51–62 ms. Absolutely shortest note was 34 ms and absolutely longest note was 68 ms. Mean of 16 means of internote intervals was 94 ms (SD 6.1), range of means 86–104 ms. Absolutely shortest interval was 75 ms and absolutely longest interval was 140 ms. Mean of means of pulse number per note was 5.3 (SD 0.9), range of means 4.3–6.9 pulses/note. Absolutely lowest number of pulses/note 4 and absolutely highest number 8 pulses/note. Fundamental frequency is at 1.6 kHz and dominant frequency at 3.2 kHz (Fig. 9). Depending on sound volume of the recording there are more or less upper harmonic bands.



**Fig. 7.** Forest interior at Sawetau Camp, 1600 m asl in the Muller Range, habitat of *Austrochaperina alexanderi* sp. nov. and *A. laurae* sp. nov.



**Fig. 8.** Wave form (above) and spectrogram (below) of 17 notes of an advertisement call of *Austrochaperina laurae* sp. nov. SAMA R65097.



**Fig. 9.** Power spectrum of an advertisement call section of *Austrochaperina laurae* sp. nov.

**Etymology.** The species name is dedicated to the senior author’s granddaughter LAURA WERNER. English name: Laura’s Land Frog; German name: Lauras Landfrosch.

**Comparison with other species.** Comparisons with some other species are already made in the “Diagnosis”. Here we consider species of comparable size, for which the colour in life is unknown. The only specimen of *A. adamantina* has, according to ZWEIFEL (2000), “dorsum tan with indistinct darker mottling”, a character that does not apply to the uniform brown colouration of *A. laurae*. *Austrochaperina adamantina* also differs from *A. laurae* in the following characters: HW/SVL in *A. adamantina* 0.34, in *A. laurae* 0.36–0.43; END/SVL in *A. adamantina* 0.073, in *A. laurae* 0.074–0.081; IND/SUL in *A. adamantina* 0.098, in *A. laurae* 0.099–0.119 and F3D/SUL in *A. adamantina* 0.041, in *A. laurae* 0.027–0.042. *A. aquilonia* differs from *A. laurae* mainly by dorsal (grey-brown with darker brown spotting and mottling versus uniform brown) and ventral colouration (“pale with faint indication of darker patterning” versus a strong

ventral pattern) and by its small finger discs; F3D/SVL 0.021–0.026 in *A. aquilonia* and 0.027–0.042 in *A. laurae*. *A. archboldi* is somewhat larger (males more than 30 mm SVL versus less than 30 mm in *A. laurae*), has a mottled dorsum and smaller tympana (TyD/ED in five specimens of the type series [including holotype] of *A. archboldi*, measured by us, ranges between 0.34–0.39 and in eight types of *A. laurae* between 0.40 and 0.54. *A. parkeri* is known only from the holotype collected near Lae in the Morobe Province. This species has a smaller head, a less projecting snout, no supratympanic fold and smaller eyes (ED/SVL 0.105 vs. 0.108–0.127) compared to *A. laurae*.

### *Cophixalus viridis* sp. nov.

**Holotype.** SAMA R65104 (FN: SJR 10998), adult male *coll.* S. RICHARDS and C. DAHL, Sawetau Camp, Muller Range, Western Province, Papua New Guinea (05°39.397' S, 142°18.277' E; 1,600 m asl) on 12 September 2009.

**Paratypes.** SAMA R65103 (FN: SJR 10997), SAMA R65105 (FN: SJR 12023), SAMA R65107 (FN: SJR 12098), ZMB 79523 (FN: SJR 12037) ZMB 79524 (FN: SJR 12057), PNGNM 24043 (FN: SJR 12038), PNGNM 24044 (FN: SJR 12044); same collectors and collection site as for holotype, all collected 12–16 September 2009. ZMB 79524 is now an osteological preparation. For sex of the paratypes see Table 3.

**Diagnosis.** With a snout-urostyle length of 15.8 to 16.2 mm in three adult males and 18.1 to 20.1 mm in five adult females the new species belongs to the small-sized species of the genus. Along with small body size a combination of the following characters is diagnostic: (1) predominantly green colouration of all dorsal and lateral surfaces in life, (2) W-shaped mark on dorsum, (3) tympanum in males smaller than in females, (4) snout in profile acuminate, (5) call lasts 4–5 seconds and contains 80–100 one-pulse notes.

**Description of the holotype.** Adult male (Fig. 10) with small vocal slits. Measurements are presented in Table 3. Longitudinal incision on left side of abdomen. Head at its widest point as wide as body. Snout in profile short, protruding and angular (=acute), in dorsal view truncate with rostral keel (=mucronate). *Canthus rostralis* well defined, slightly curved. Loreal region marginally concave and slightly angular. Internarial distance longer than eye-naris distance (END/IND 0.89). Tympanic annulus visible, horizontal diameter of tympanum one third of eye diameter. No supratympanic, post-tympanic or dorsolateral folds. Some tubercles on dorsal tibiae, posterior tarsi and dorsolateral surfaces of dorsum. All remaining dorsal, lateral and ventral surfaces smooth.

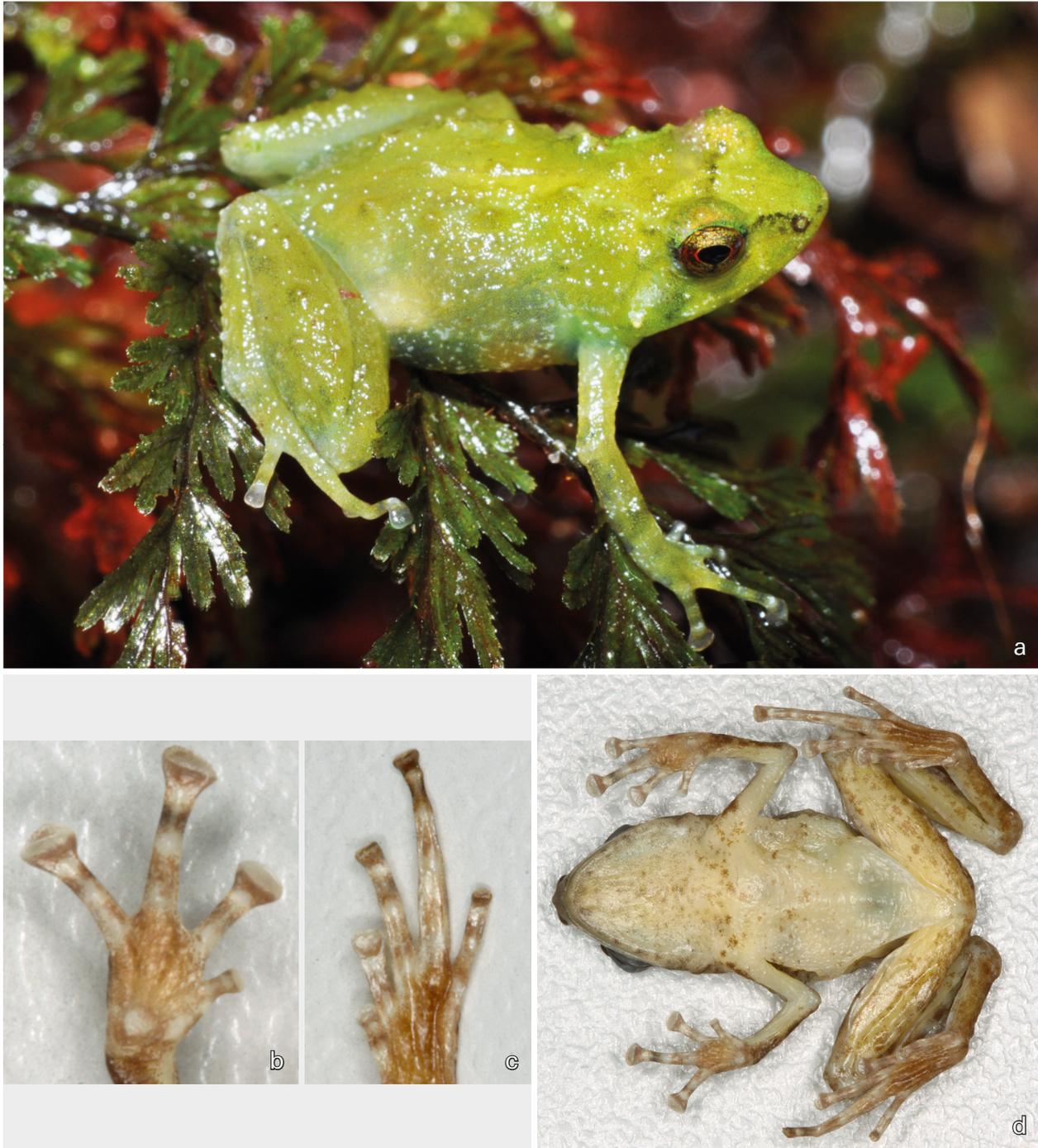
Fingers unwebbed, their relative lengths  $3 > 4 > 2 > 1$ , all subarticular tubercles as well as palmar and plantar tubercles, except inner metatarsal tubercle, very indistinct.

Discs on fingers 2–4 prominent and expanded, that of finger 1 small, barely exceeding width of phalanx. Discs of all fingers, including finger 1, with distinct circum-marginal grooves (Fig. 10b). Toes unwebbed, their relative lengths  $4 > 3 > 5 > 2 > 1$ . Discs on toes 2–4 twice as wide as penultimate phalanx, discs on toes 1 and 5 only scarcely wider than penultimate phalanx (Fig. 10c).

**Colouration in preservative.** Basal colouration of dorsal surfaces of head, body and extremities light-brown. This colouration is overlain by a number of blackish markings consisting of: W-shaped marking in scapular region, whose distal outlines reaches the eyes; a thin transverse blotch between eyes that is bordered anteriorly by an off-white area; and additional scattered smaller dark brown blotches on various body parts. Off-white areas are to be found inside the W-shaped mark and dorsally on snout. Conspicuous are a broad dark canthal stripe from nostril to eye that is bordered inferiorly by an off-white blotch, and a broad off-white stripe, bordered by blackish spots, from posterior edge of eye including tympanum to axillary region. Upper lateral surface of torso of the same brown colour as dorsal surfaces and becoming lighter ventrally. All ventral surfaces with off-white base colouration, overlain by tiny brown spots forming loose clumps (Fig. 10d). These clumps are almost absent on abdomen, upper- and fore-arms and tibiae, they are rare on chest, and more dense on remaining lower surfaces. There is a dark brown band though vent opening.

**Colouration in life.** All dorsal surfaces are green (Fig. 10a). There is a barely visible and discontinuous dark canthal stripe and interocular stripe as well as a golden patch on each eyelid and an indistinct whitish patch in the inguinal region. Green colour becomes dark grey towards ventral surfaces. Superior parts of iris golden with slight venation, middle iris dark orange with a blackish half ring and inferior iris again golden with massive blackish venation.

**Morphological variation in the type series.** Mensural variation for the type series is shown in Table 3. There are clear differences in tympanum size between males (TyD/ED 0.30–0.33) and females (0.36–0.48). However basic colour and colour pattern elements of all preserved types are fairly uniform and resemble the holotype. Characteristic elements are a grey-brown to reddish-brown dorsum, a narrow blackish interocular stripe, a dark brown W-shaped mark in the scapular region that includes lighter areas, a blackish canthal stripe, an off-white stripe, bordered by blackish areas, from posterior edge of eye through tympanum, dorsal surface of snout lighter than dorsum. Base colour of ventral surfaces of all specimens off-white. Degree of mottling on venter relatively consistent with a tendency in all specimens for more mottling on throat, thighs, tarsi, palms and soles and less on abdomen, fore and upper arm and tibiae. All paratypes were substantially green dorsally in life.

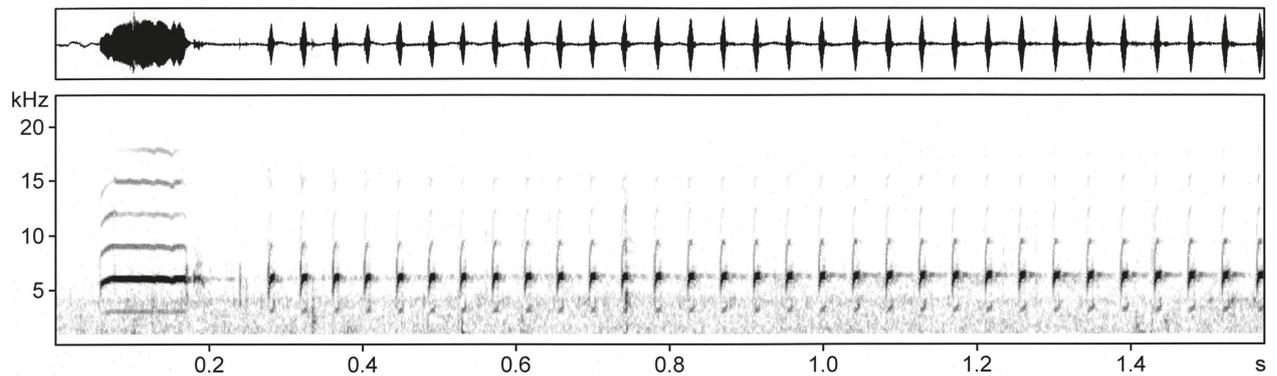


**Fig. 10.** Holotype of *Cophixalus viridis* sp. nov.; (a) dorsolateral view in life, (b) ventral view of right hand of preserved specimen, (c) ventral view of left foot of preserved specimen, (d) ventral view of preserved specimen.

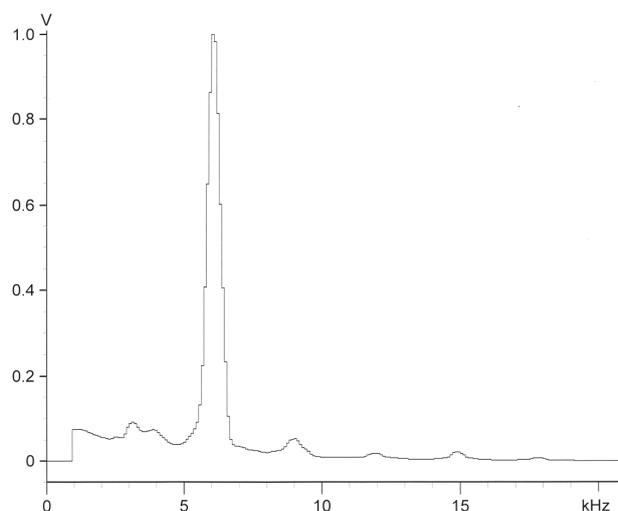
It was striking that all living specimens exhibited well developed and more or less pointed tubercles, especially on dorsal surfaces of hind legs and on dorsolateral back, but that these tubercles vanished in preserved specimens completely or nearly completely.

**Vocalization.** One advertisement call from SAMA R65103 and two from R65105 were recorded at a temperature of 17.8 °C. The first mentioned call is 4.4 s long and contains 89 notes. The first, or introductory note dif-

fers significantly in both length and structure from all following ones (Fig. 11). Its duration is 114 ms and the first internote interval is 104 ms long. Pulses in the first note follow very fast one after another, resulting in the banding pattern shown in the spectrogram. “Normal” notes in the first call contain one pulse and have a mean length of 8.7 ms, SD 0.51, range 8–10 ms. Internote intervals are between 33 and 37 ms, mean 34.7 ms, SD 1.17. The first call of SAMA R65105 has a duration of 4.43 s and contains 84 notes. Although no distinct introductory note



**Fig. 11.** Wave form (above) and spectrogram (below) of the first section of an advertisement call of *Cophixalus viridis* sp. nov. (SAMA R65105).

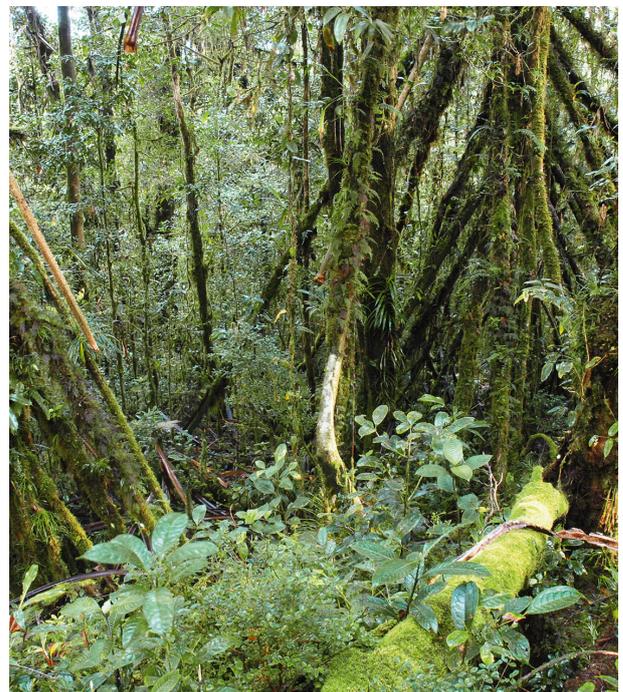


**Fig. 12.** Power spectrum of an advertisement call section of *Cophixalus viridis* sp. nov.

could be discerned, this could reflect the poor quality of the recording because all calls heard in the field were noted to have this introductory note. Mean note length in this call is 7.9 ms, SD 0.84, range 6–10 ms. Average internote interval length is 39.2 ms, SD 2.0, range 36–42 ms. The second call from R65105 lasts 5.14 s and contains 98 notes. Duration of the introductory note is 149 ms and that of the first interval is 44 ms. Average note duration is 8.9 ms, SD 0.64, range 8–10 ms and average internote interval duration is 39.3 ms, SD 2.66, range 35–45 ms. There is a tendency for notes and internotes to become a little longer toward the end of calls. Note repetition rate (without introductory notes) is between 18.8 and 21.2 notes/s.

The frequency pattern of the spectrogram and the power spectrum (Fig. 12) shows the fundamental frequency at 3 kHz, the dominant frequency at 6 kHz and four following harmonics with decreasing energy at 9, 12 and 15 kHz. All notes except the introductory one start with a high amplitude and continue with a slowly decreasing amplitude.

**Distribution and ecological notes.** All specimens of this species were found perched on low vegetation, less



**Fig. 13.** Wet, mossy forest interior at Sawetau Camp, 1600 m asl in the Muller Range. Male *C. viridis* called from the low, broad leaves in the foreground.

than 1 m high, in wet mossy forest (Fig. 13). No specimens were observed on the ground and, although most tree-trunks and branches in the forest were covered with moss, this species was never found sitting in moss, but always on the leaves of broad-leaved shrubs. Males called only very sporadically, usually no more than once every 5 minutes.

**Etymology.** The species name *viridis* is a Latin adjective and means green. It refers to the (unusual for species of this genus) colour of all dorsal surfaces of the new species. English name: Green Rainforest Frog; German name: Grüner Regenwaldfrosch.

**Comparison with other New Guinean species.** *Cophixalus viridis* differs from *C. balbus*, *C. biroi*, *C. caverniphilus*, *C. cheesmanae*, *C. clapporum*, *C. cryptotypanum*,

**Table 3.** Body measurements and body ratios of the type series of *Cophixalus viridis* sp. nov. SAMA R65104 is the male holotype. SAMA R65103 and R65105 are males, all other paratypes are females.

Reg.-No.	SAMA R65103	SAMA R65104	SAMA R65105	SAMA R65107	PNGNM 24043	PNGNM 24044	ZMB 79523	ZMB 79524	Mean ± SD
SUL	16.0	15.8	16.2	18.4	18.5	18.7	18.1	20.1	
TL	8.1	8.1	7.9	9.7	9.3	9.2	9.0	9.6	
TaL	5.4	5.1	5.0	6.4	5.9	6.0	6.1	6.5	
L4T	8.5	8.2	8.1	10.0	9.1	9.4	9.5	9.8	
T4D	0.8	0.7	0.9	0.9	1.0	1.0	0.9	1.0	
L3F	4.7	4.8	5.0	5.3	5.3	5.4	5.2	5.3	
F3D	0.9	1.0	1.1	1.3	1.2	1.3	1.1	1.2	
F1D	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	
T1D	0.4	0.4	0.4	0.5	0.5	0.6	0.5	0.5	
HL	6.0	5.5	5.8	6.3	6.8	6.6	6.5	6.6	
HW	6.5	6.1	6.5	7.0	6.9	7.4	6.8	6.8	
SL	2.9	2.8	3.1	3.5	3.5	3.4	3.2	3.3	
END	1.5	1.6	1.8	1.8	1.8	1.8	2.0	1.8	
IND	2.0	1.8	1.9	2.1	2.1	2.3	2.0	2.1	
ED	2.3	2.2	2.4	2.5	2.6	2.5	2.2	2.7	
TyD	0.7	0.7	0.8	0.9	1.1	1.2	1.0	1.0	
EST	2.2	2.3	2.5	2.6	2.7	2.9	2.9	2.5	
TL/SUL	0.51	0.51	0.49	0.53	0.50	0.49	0.50	0.48	0.50 ± 0.02
TaL/SUL	0.34	0.32	0.31	0.35	0.32	0.32	0.34	0.32	0.33 ± 0.01
T1D/F1D	1.00	1.00	1.00	1.25	1.00	1.50	1.25	1.25	1.16 ± 0.19
T4D/SUL	0.050	0.044	0.056	0.049	0.054	0.053	0.050	0.050	0.051 ± 0.004
T4D/F3D	0.89	0.70	0.82	0.69	0.83	0.77	0.82	0.83	0.79 ± 0.07
F1D/F3D	0.44	0.40	0.36	0.31	0.42	0.31	0.36	0.33	0.37 ± 0.05
HL/SUL	0.38	0.35	0.36	0.34	0.37	0.35	0.36	0.33	0.34 ± 0.04
HL/HW	0.92	0.90	0.89	0.90	0.99	0.89	0.96	0.97	0.93 ± 0.04
SL/SUL	0.181	0.177	0.191	0.190	0.189	0.182	0.177	0.164	0.181 ± 0.009
END/IND	0.75	0.89	0.95	0.86	0.86	0.78	1.00	0.86	0.87 ± 0.08
ED/SUL	0.144	0.139	0.148	0.136	0.141	0.134	0.122	0.134	0.137 ± 0.008
TyD/ED	0.30	0.32	0.33	0.36	0.42	0.48	0.45	0.37	0.38 ± 0.06

*C. cupricareus*, *C. kairiensis*, *C. monosyllabus*, *C. nubicola*, *C. parkeri*, *C. riparius*, *C. tetzlaffi* and *C. verrucosus* by its much smaller size (SUL < 20 mm vs. > 20 mm). Of the species within or approximately the same size range it differs from *C. albolineatus*, *C. amabilis*, *C. ateles*, *C. bewaniensis*, *C. desticans*, *C. humicola*, *C. iovaorum*, *C. kethuk*, *C. pictus*, *C. pipilans*, *C. shellyi*, *C. sphagnicola* and *C. tenuidactylus* by having a distinct circum-marginal groove on the first finger. From those species of similar size that also have a distinct groove on the first finger, or for which this character is not reported, *C. viridis* differs in the following characters: from *C. daymani* in having a snout that is mucronate in dorsal view and angular in profile (vs. bluntly rounded) and in having longer legs (SUL/TL 0.48–0.53 vs. less than 0.44 in *daymani*); from *C. interruptus* it differs in lacking a dark sub-ocular blotch, and in its different advertisement call (first note of call longer than remaining notes, which form a very fast series of pulses vs. a moderately slow sequence of similar notes); from *C. linnaeus* it differs in lacking a dark sub-ocular blotch and in having a dorsum that is not irregularly mottled with dark brown; from *C. melanops* by lacking dark lateral surfaces of the face; from *C. misimae* by lacking a dark lateral band; from *C. nexipus* by lack-

ing basal webbing between the toes; from *C. phaeobalius* it differs in lacking a dark sub-ocular blotch, and in its different advertisement call (> 80 notes vs. 3–7 notes); from *C. pulchellus* by lacking a boldly patterned dorsum; from *C. tagulensis* by having feet free of webbing; from *C. timidus* by lacking a yellow blotch in groin and 1–4 yellow spots each side of pectoral region; from *C. variabilis* by lacking heavily melanised ventral surfaces; and from *C. wempi* by lacking prominent tubercles along the tarsus and on each eyelid (GÜNTHER 2003a, 2006, 2010a, KRAUS & ALLISON 2006, 2009, RICHARDS & OLIVER 2007, 2010, GÜNTHER & RICHARDS 2011, KRAUS 2012).

### *Copiula annanoreenae* sp. nov.

**Holotype.** SAMA R65109 (FN: SJR 12091), adult male, coll. S. RICHARDS and C. DAHL, Sawetau Camp, Muller Range, Western Province, Papua New Guinea (05° 39.397' S, 142° 18.277' E; 1600 m asl) on 16 September 2009.

**Paratypes.** None.



**Fig. 14.** Holotype of *Copiula annanoreenae* sp. nov. in life, (a) dorsolateral view, (b) ventral view of right hand, (c) ventral view of right foot, (d) ventral view.

**Diagnosis.** A small terrestrial species, SUL of the single male 22.0 mm. Dorsal surfaces in life grey-brown, in preservative dark brown, which becomes paler laterally. A whitish stripe from snout tip, along canthus rostralis and including upper eyelid, and a broad dark brown lateral stripe from behind eye to middle of flank. Belly and inferior thighs and arms in life yellow with a few dark grey blotches; chest and throat grey with whitish blotches. Advertisement call long, lasting up to more than 100 seconds. Duration of notes 55–75 ms, length of inter-note intervals very variable, mean repetition rate 2.5–2.8 notes/s, dominant frequency at 4.3 kHz. Conspicuous is that notes are uttered in dyads over large parts of the call.

**Description of the holotype** (all measurements in mm). Adult male (Fig. 14) with the following measurements

and ratios: SUL 22.0, TL 11.1, TaL 7.5, L4T 12.0, L3F 5.1, F3D 0.6, F1D 0.4, T4D 1.0, T1D 0.5, HL 7.9, HW 8.6, END 1.8, IND 2.7, EST 2.9, ED 2.6, TyD 1.3, SL 3.7; TL/SUL 0.50, TaL/SUL 0.34, T4D/SUL 0.045, T4D/F3D 1.66, F1D/F3D 0.67, T1D/F1D 1.25, HL/SUL 0.36, HL/HW 0.92, END/IND 0.67, ED/SUL 0.118, TyD/ED 0.50, SL/SUL 0.168. Longitudinal incision on left side of abdomen. Head small and triangular with a roundish snout tip, clearly projecting in profile. Nostrils directed laterally and somewhat closer to tip of snout than to eyes, distance between nares distinctively greater than distance between eye and naris. Canthus rostralis well defined and gently rounded, angled outwards only in the region of nares. Loreal region angled and concave (especially directly above maxillary). Tongue fairly narrow, broadened posteriorly and without indentation. Vocal slits long and

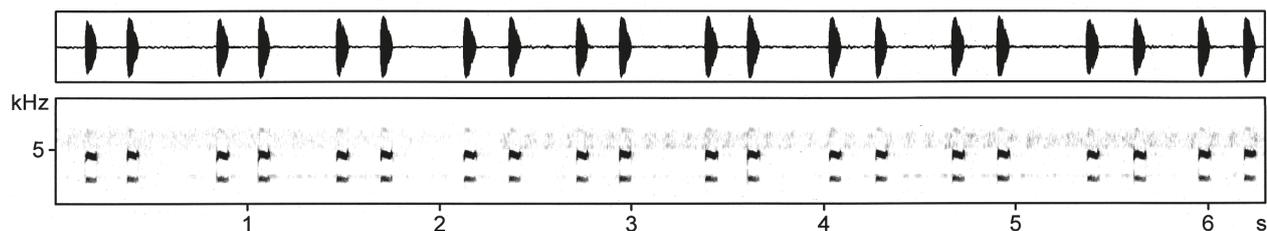


Fig. 15. Wave form (above) and spectrogram (below) of a section of an advertisement call of *Copiula annanoreenae* sp. nov.

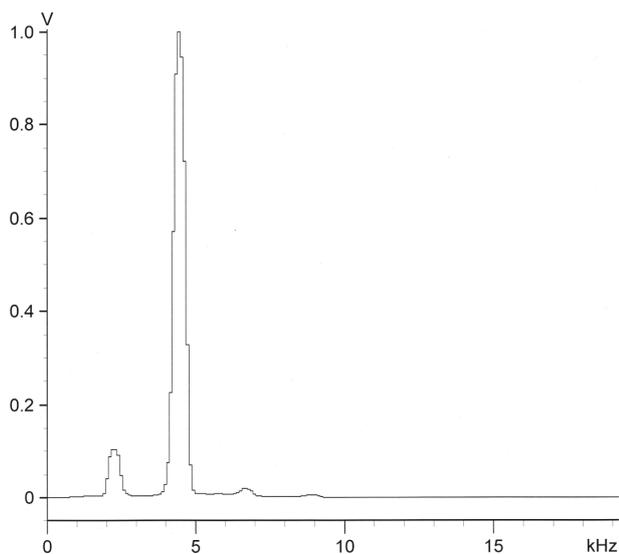


Fig. 16. Power spectrum of an advertisement call section of *Copiula annanoreenae* sp. nov.

close to dentary. Palatal fold low and without denticles. Supratympanic fold and tympanic annulus clearly visible. Eye rather small with horizontal pupil. Fore limbs short with short fingers, their relative lengths  $3 > 4 > 2 > 1$ , tip of finger 1 not, and tips of fingers 2, 3 and 4 scarcely broader than penultimate phalanx, subarticular and palmar tubercles absent (Fig. 14b). Hind limbs long and muscular, toes medium sized, disc of toe 1 not wider than penultimate phalanx, that of toe 5 scarcely wider than penultimate phalanx and those of toes 2–4 distinctly broader than penultimate phalanges; subarticular tubercles only slightly indicated, inner metatarsal tubercle long and oval, no outer metatarsal tubercle. Relative length of toes  $4 > 3 > 5 > 2 > 1$ , no webbing, all finger tips and toe tips with circummarginal grooves (Fig. 14c). Dorsal and ventral surface of body, head and extremities smooth. A whitish coloured and thickened stratum corneum on tip of snout.

**Colouration in preservative.** Dorsum dark brown and unspotted. Upper flanks lighter brown. Lower flanks and inferior hind legs with a reticulum of brown and off-white flecks. Undersides of hands and feet nearly uniform grey-brown. Commencing on tip of snout, a broad blackish lateral stripe extends along loreal region, below eye, above tympanum and reaches to anterior flank.

Tympanum uniform lighter brown. Rostral cap and upper canthal region whitish. Dorsal surfaces of hind legs of the same brown colour as dorsum but with a few blackish spots. Ground colour of forelegs lighter brown but stronger mottled. Ventral surface of tibia and tarsus off-white and strongly mottled with irregular brown blotches. The same concerns the posterior side of thighs. Ventral surface of thighs off-white with less blotches than posterior side. Belly and posterior chest off-white with only a few small and irregular grey-brown markings. Throat and anterior chest with off-white flecks on grey-brown background. Above vent a blackish spot is bordered dorsally by a whitish spot.

**Colouration in life.** There are only a few deviations from colour in preservative. Colour of all dorsal surfaces is lighter; whitish cantho-rostral stripe which commences on tip of snout and extends behind eye is much more distinct; colour of iris is orange with dense blackish venation; tip of urostyle yellowish (instead of whitish); basic colour of abdomen, of underside of thighs, of underside of upper arms and of forearms yellowish and basic colour of throat grey (Fig. 14d).

**Etymology.** This species is dedicated to the senior author's granddaughter ANNA NOREEN GÜNTHER. English name: Anna Noreen's Mehely Frog; German name: Anna Noreens Mehelyfrosch.

**Distribution and ecological notes.** The sole known specimen of this species was calling from within moss and litter on the forest floor, on the steeply sloping edge of a limestone sinkhole at night after rain. The species is so far known only from the type locality.

**Vocalization.** The advertisement call consists of a long series of short peeping notes (Fig. 15). Duration of three recorded calls, recorded at a temperature of 17.4 °C, was 81 s, 101 s and 25 s. It is characteristic that notes over most parts of the calls are grouped to dyads. Mean note length was  $63 \pm 4.4$  ms, range 55–75 ms,  $n=65$ . Mean duration of intervals within a dyad was  $174 \pm 16.5$  ms, range 149–224 ms,  $n=65$ . Most intervals between dyads last 0.3–0.4 s. Breaks of up to 1.5 s may occur within a call. Repetition rate in the three calls analysed was 2.6, 2.6 and 2.8 notes/s. Most notes reach their maximum amplitude rather quickly, amplitude remains more or less stable in the first part of the note and then drops gradually.

Notes are unpulsed and exhibit only weak frequency modulation. Fundamental frequency is around 2.3 kHz, dominant frequency (coincidental with first harmonic) is around 4.5 kHz (Fig. 16). There are further harmonic bands up to a level of 15 kHz.

**Comparison with other species.** *C. annanoreenae* can be differentiated from *C. major* and *C. fistulans* by its much smaller size and from *C. minor*, a species known only from Milne Bay in far-eastern PNG, by its broader snout tip and very different call which lasts less than 2 s in *C. minor* (vs. more than 25 s in *C. annanoreenae*) and is not produced in dyads. According to our measurements of four males and one subadult from AMNH, *C. oxyrhina* has a larger body size (all four males were larger than 25 mm) and smaller eyes than the new species (ED/SUL 0.096–0.104 in the former and 0.118 in the latter). Moreover their calls are quite different; note repetition rate in *C. oxyrhina* is about 5–6 notes/s with a dominant frequency at 2 kHz (MENZIES & TYLER 1977) vs. 2.6–2.8 notes/s and 4.5 kHz in *C. annanoreenae*. *C. obsti* is morphologically very similar to *C. annanoreenae*. Its body size is somewhat shorter (does not reach 22 mm in males) and eye-size is smaller (ED/SUL 0.099–0.110 versus 0.118). However, *C. obsti* has a completely different advertisement call. Its call lasts up to 5 s, mean note length is 27 ms (63 ms in *C. annanoreenae*), repetition rate is 17 notes/s, dominant frequency is at 5.6 kHz and all notes exhibit a strong frequency modulation. *C. exspectata* and *C. pipiens* also differ mainly in their advertisement calls from the new species. Both utter much shorter and frequency modulated notes that are not grouped into dyads and that have a repetition rate of about 10 notes/s. *Copiula tyleri* is morphologically similar to the new species but two paratypes of *C. tyleri* differ from the new species in body ratios HL/SUL (0.29–0.33 in the former vs. 0.36 in the latter), HL/HW (0.86–0.88 vs. 0.92), END/SUL (0.071–0.076 vs. 0.082) and ED/SUL (0.098–0.114 vs. 0.118). Moreover, the tympanum of *C. annanoreenae* is not unpigmented as reported for *C. tyleri*, the head laterally is darker and ground colour of entire abdomen as well as ventral surfaces of thighs and forearm and upper arm is yellow, not greyish white as in *C. tyleri*. Furthermore, the calls of the two species are very different. The call of *C. tyleri* is a ‘rapid unmodulated trill’ (MENZIES 2006) lasting only about 1 s.

### *Copiula lennarti* sp. nov.

**Holotype.** SAMA R64992 (FN: SJR 10922), semiadult female, coll. S. RICHARDS and C. DAHL, Gugusu Camp, Muller Range, Western Province, Papua New Guinea (05°43.751' S, 142°15.797' E; 515 m asl) on 08 September 2009.

**Paratypes.** SAMA R64990 (FN: SJR 10903); SAMA R64991 (FN: SJR 10914), SAMA R64993 (FN: SJR 10927), SAMA 64994

(FN: SJR 10932), ZMB 79525 (FN: SJR 10934). Collectors and collection site as for holotype, except SAMA R64990 collected by PIOTR NASKRECKI; all paratypes collected 6–8 September 2009. Sex of the specimens is presented in Table 4.

**Diagnosis.** *Copiula lennarti* is a typical representative of its genus and with adult males at least up to 33.8 mm SUL and females up to 38.5 mm SUL it belongs, with *C. fistulans* and *C. major*, among the three largest species of the genus. It differs from *C. fistulans* by a broader and more obtuse snout tip (especially in ventral view), by longer shanks and larger toe discs, and from the latter by shorter shanks, wider toe discs and different head proportions (see below). Unfortunately, no calls of this species were heard.

**Description of the holotype.** Subadult female (Fig. 17), for measurements see Table 4. Longitudinal incision on left side of abdomen and on right side of body dorsolaterally. Head small, body and extremities medium sized. Snout projecting, its tip fairly broad and gently rounded in dorsal view. Canthus rostralis distinct and straight up to nostril, then curved outward. Loreal region slightly concave and slightly angled, nostrils directed laterally and situated immediately behind snout tip. Eyes small, pupil horizontally elliptical. Tympanum large, more than ½ size of eye, clearly demarcated and lighter than its surroundings. Supratympanic fold weakly expressed and reaching to arm insertion. Tongue fairly narrow, tapering posteriorly, with weak indentation and about half-free laterally and posteriorly; no vomerine teeth, prepharyngeal ridge denticulate. Fore limbs moderately long with relatively short fingers and poorly developed discs, in order of length 3 > 4 > 2 > 1 (Fig. 17b). Hind limbs more muscular, toes rather long with discs broader than finger discs, toes in order of length 4 > 3 > 5 > 2 > 1 (Fig. 17c). Subarticular tubercles as well as inner metatarsal and inner metacarpal tubercle poorly developed. No webbing between fingers or toes, skin smooth on all body surfaces.

**Colouration in preservative.** Dorsal surface of body, head and extremities uniform grey-brown. Superior loreal region dark brown which fades inferiorly. No white canthal and/or superciliary stripe, rostral cap scarcely developed. An irregular blackish stripe, which is clearly demarcated above by the grey-brown dorsal colour and fades into brown inferiorly, commences on posterior edge of eye, proceeds above tympanum and along flanks and reaches (and includes) a lumbar spot, which is clearly visible from above. Irregular brownish spots and stripes are to be found on anterior and posterior surfaces of upper and forearm as well as on thighs and shanks. A dense brownish reticulum covers inferior tarsi, forearms and posterior thighs. Conspicuous is a row of blackish spots above vent. Underside of abdomen and thighs unspotted off-white, throat and chest off-white with brownish patches that consist of numerous stipples.



**Fig. 17.** Holotype of *Copiula lennarti* sp. nov.; (a) dorsolateral view in life, (b) ventral view of left hand of preserved specimen, (c) ventral view of left foot of preserved specimen, (d) ventral view of preserved specimen.



**Fig. 18a.** Paratype SAMA R64990 of *Copiula lennarti* in life which shows faintly mottled dorsal surfaces.



**Fig. 18b.** Ventral surface of paratype SAMA R64990 of *Copiula lennarti* sp. nov. in life.

**Table 4.** Body measurements and body ratios of the type series of *Copiula lennarti* sp. nov. SAMA R64992 is the holotype. SAMA R64991 and R64994 are adult males; R64992 and R 64993 are adult females; R64990 and ZMB 79525 are subadults.

Reg.-No.	SAMA R64990	SAMA R64991	SAMA R64992	SAMA R64993	SAMA R64994	ZMB 79525	Mean ± SD
SUL	31.3	32.2	32.3	38.5	33.8	28.5	
TL	16.7	17.4	17.4	20.4	18.2	15.2	
TaL	10.0	10.4	10.5	12.6	10.7	9.0	
L4T	14.8	16.3	16.5	18.6	17.0	13.5	
T4D	1.5	1.5	1.4	1.7	1.5	1.3	
L3F	7.3	7.5	7.4	9.3	7.7	6.1	
F3D	0.8	1.1	0.9	1.3	1.1	1.0	
F1D	0.7	0.7	0.8	1.1	0.7	0.6	
T1D	0.8	0.8	0.9	1.2	0.9	0.8	
HL	9.4	10.1	9.6	11.3	10.5	9.5	
HW	12.2	13.2	12.5	14.0	12.2	11.4	
SL	5.1	5.7	5.5	6.0	5.6	4.7	
END	2.8	2.8	3.0	3.0	2.5	2.6	
IND	3.7	3.6	3.7	4.3	3.6	3.3	
ED	2.7	3.0	3.0	3.2	3.1	2.7	
TyD	2.0	1.9	1.7	2.1	1.9	1.8	
EST	4.1	4.3	4.4	4.7	4.5	3.6	
TL/SUL	0.53	0.54	0.54	0.53	0.54	0.53	0.54 ± 0.005
TaL/SUL	0.32	0.32	0.33	0.33	0.32	0.32	0.32 ± 0.005
T1D/F1D	1.14	1.14	1.13	1.09	1.29	1.33	1.19 ± 0.10
T4D/SUL	0.048	0.054	0.043	0.044	0.044	0.046	0.047 ± 0.004
T4D/F3D	1.88	1.36	1.33	1.31	1.36	1.20	1.41 ± 0.24
F1D/F3D	0.88	0.64	0.89	0.85	0.64	0.60	0.75 ± 0.14
HL/SUL	0.30	0.31	0.30	0.29	0.31	0.33	0.31 ± 0.01
HL/HW	0.77	0.77	0.77	0.81	0.86	0.83	0.81 ± 0.04
SL/SUL	0.163	0.177	0.170	0.156	0.166	0.165	0.166 ± 0.007
END/IND	0.76	0.78	0.81	0.70	0.69	0.79	0.76 ± 0.05
ED/SUL	0.086	0.093	0.093	0.083	0.092	0.095	0.090 ± 0.005
TyD/ED	0.74	0.57	0.57	0.66	0.61	0.67	0.64 ± 0.07

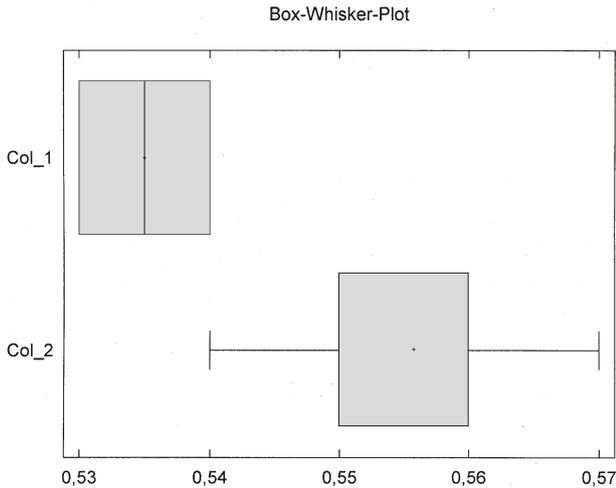
**Colouration in life** is similar to that in preservative. Dorsal surfaces light reddish-brown. Whitish canthal and superciliary stripe present. Axillary region, ventral sides of thighs, shanks as well as groin orange. Abdomen and underside of arms unspotted yellow, throat and chest yellow with grey blotches and mottling (Fig. 17d). Iris reddish-orange with dark venations.

**Morphological variation in the type series.** Variation in measurements and ratios is shown in Table 4. Dorsal colour in the preserved specimens varies from light grey-brown to dark grey-brown. An irregular blackish or dark brownish stripe in all but one specimen extends from side of head to inguinal region where it forms a conspicuous lumbar spot. This stripe may be continuous or interrupted and in one specimen (ZMB 79525) ends in the middle of the flank. Only in this specimen and in SAMA R64990 (Fig. 18a) the dorsal surfaces are not uniform but faintly mottled. Most specimens exhibit a fine mid-dorsal line, mostly dark on head and/or anterior back and light on posterior back. Colouration of ventral surfaces is, in all but one specimen, like that of the holotype; only SAMA R64990 has nearly no dark mottling on the throat (Fig. 18b).

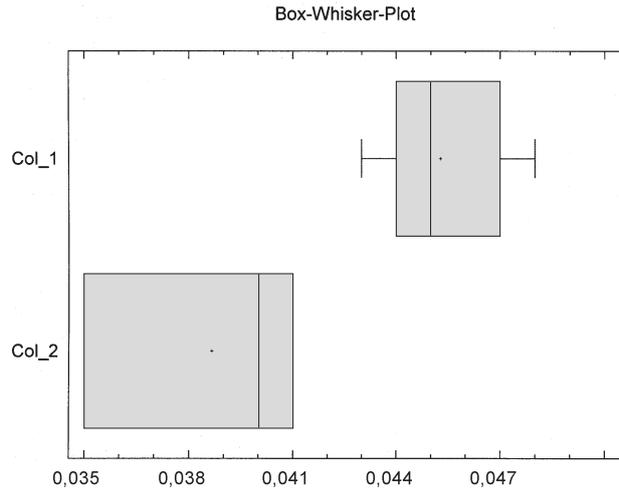
**Distribution and ecological notes.** All specimens of this species were found on the forest floor at night after rain, on a ridge at the base of the Muller Range, Western Province, PNG. It is currently known only from the type locality.

**Etymology.** The specific epithet is dedicated to the senior author's grandson LENNART GÜNTHER. English name: Lennart's Mehely Frog; German name: Lennarts Mehelyfrosch.

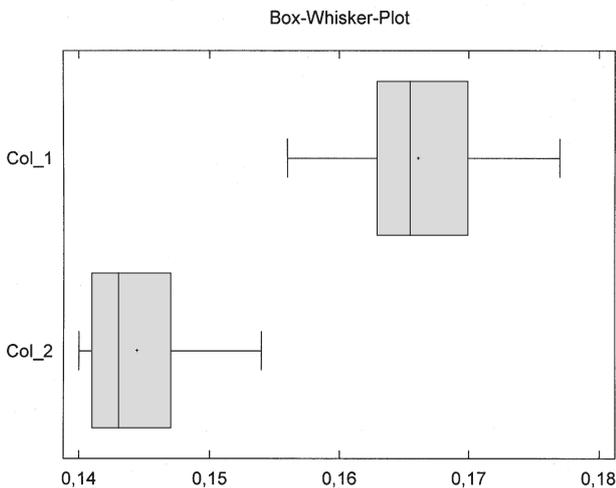
**Comparison with other species.** All other *Copiula* species, except *C. fistulans* and *C. major*, are much smaller than *C. lennarti*. The largest female of *C. oxyrhina* was about 30 mm SUL (MENZIES & TYLER 1977); all other species do not reach 30 mm snout-vent-length. *C. lennarti* differs from *C. major* in several morphological features. Most conspicuous are an off-white colouration of all ventral surfaces of the latter in fixative whereas the throat of five from six specimens of *C. lennarti* exhibits grey-brown blotches of irregular shape. The following body ratios also differentiate these species: TL/SUL 0.53–0.54, mean 0.535, SD 0.005, n=6 in *C. lennarti* and 0.54–0.57, mean 0.556, SD 0.009, n=7 in *C. major*, t=4.6 and p=0.0008 (Fig. 19); T4D/SUL 0.043–0.048,



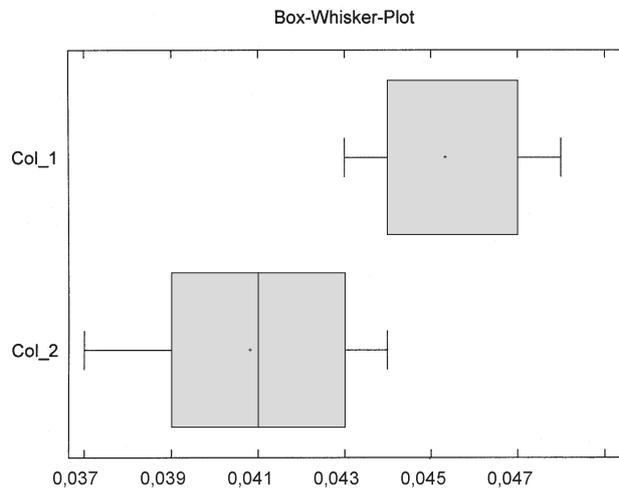
**Fig. 19.** Box-Whisker-Plot of the ratio TL/SUL in *Copiula lennarti* sp. nov. (Col\_1) and in *C. major* (Col\_2).



**Fig. 20.** Box-Whisker-Plot of the ratio T4D/SUL in *Copiula lennarti* sp. nov. (Col\_1) and in *C. major* (Col\_2).



**Fig. 21.** Box-Whisker-Plot of the ratio SL/SUL in *Copiula lennarti* sp. nov. (Col\_1) and in *C. major* (Col\_2).



**Fig. 22.** Box-Whisker-Plot of the ratio T4D/SUL in *Copiula lennarti* sp. nov. (Col\_1) and in *C. fistulans* (Col\_2).

mean 0.045, SD 0.002,  $n=6$  in *C. lennarti* and 0.035–0.041, mean 0.039, SD 0.003,  $n=7$  in *C. major*,  $t=5.1$ ,  $p=0.0004$  (Fig. 20); HL/HW 0.77–0.86, mean 0.80, SD 0.04,  $n=6$  in *C. lennarti* and 0.8478–0.90, mean 0.88, SD 0.02,  $n=7$  in *C. major*,  $t=4.5$ ,  $p=0.0009$ ; ED/SUL 0.083–0.095, mean 0.090, SD 0.005,  $n=6$  in *C. lennarti* and 0.077–0.089, mean 0.083, SD 0.005,  $n=7$  in *C. major*,  $t=2.8$ ,  $p=0.02$ ; and SL/SUL 0.156–0.177, mean 0.166, SD 0.007,  $n=6$  in *C. lennarti* and 0.140–0.154, mean 0.144, SD 0.005,  $n=7$  in *C. major*,  $t=6.6$ ,  $p=0.00004$  (Fig. 21). The medians of all these body ratios were also significantly different.

Morphologically, *C. fistulans* is most similar to the new species but that species, which is known only from far north-eastern Papua New Guinea, differs by the following characters: The snout tip is more acuminate (especially in ventral view) and the whitish stripe from snout tip, along canthus rostralis and including upper eyelid is more pronounced in *C. fistulans*. Shanks are significantly

longer in *C. lennarti*, (TL/SUL 0.53–0.54, mean 0.535, SD 0.005,  $n=6$ ) than in *C. fistulans*, (0.47–0.53, mean 0.50, SD 0.024,  $n=5$ ,  $t=3.32$ ,  $p=0.009$ ), and discs of toe 4 are wider in *C. lennarti* (T4D/SUL 0.043–0.048, mean 0.045, SD 0.002,  $n=6$ ) than in *C. fistulans*, (0.037–0.044, mean 0.041, SD 0.003,  $n=5$ ,  $t=3.11$ ,  $p=0.013$ , Fig. 22).

### *Hylophorbus sigridae* sp. nov.

**Holotype.** SAMA R65001 (FN: SJR 10925), adult female, coll. S. RICHARDS and C. DAHL, Gugusu Camp, Muller Range, Western Province, Papua New Guinea (05°43.751' S, 142°15.797' E; 515 m asl) on 08 September 2009.

**Paratypes.** SAMA R64998 (FN: SJR 10904), SAMA R64999 (FN: SJR 10905), SAMA R65000 (FN: SJR 10906), SAMA R65003

(FN: [SJR 10937](#)), [SAMA R65004](#) (FN: [SJR 10986](#)), [ZMB 79526](#) (FN: [SJR 10930](#)), [ZMB 79527](#) (FN: [SJR 10931](#)), [ZMB 79528](#) (FN: [SJR 10957](#)), collection data as for holotype, all collected 6–9 September 2013. Sex of each paratype is listed in Table 5.

**Diagnosis.** With a snout-urostyle length of between 21.2 and 23.6 mm in five adult males and 23.9 and 24.2 mm in three adult females the new species is among the three smallest members of the genus. From the only two other species of similarly small size it can be distinguished from *H. richardsi* by presence of a ‘wavy’ blackish lateral band (Fig. 24a) and that species’ completely different advertisement call, that contains less than one call (or note) per second (vs. a very fast train of about 19 short notes lasting nearly 2 seconds); and from *H. atrifasciatus* by a shorter black lateral band and having a lumbar ocellus (absent in *atrifasciatus*).

**Description of the holotype.** Adult female (Fig. 23) with dorsolateral incision on right body side and small longitudinal incision on left side of abdomen (see Table 5 for key measurements and ratios). Mature or nearly mature, unpigmented eggs are visible behind the incision. Head somewhat narrower than body, as wide as long (HL/HW 0.95), snout truncate in dorsal view, angled anteriorly in profile. Tongue broad and long, not clearly forked posteriorly. Prepharyngeal ridge prominent and serrated. Loreal region slightly concave, canthus rostralis roundish, nostrils directed laterally and close to tip of snout. Internarial distance clearly larger than distance from nostril to anterior edge of eye (END/IND 0.57). Eyes moderately large (ED/SUL 0.132). Tympanum moderately large with distinct annulus (TyD/ED 0.59). Supratympanic fold weakly expressed and interrupted posteriorly. In preservative, skin on all dorsal and ventral surfaces smooth. Fingers unwebbed, long, their relative lengths  $3 > 4 > 2 > 1$ ; finger 1 only marginally shorter than 2 (Fig. 23b). Subarticular and metacarpal tubercles scarcely developed, circum-marginal grooves on all finger discs present; discs on all fingers wider than penultimate phalanges. Toes unwebbed, their relative lengths  $4 > 3 > 5 > 2 > 1$ , subarticular tubercles indistinct but better developed than on fingers, inner metatarsal tubercle prominent and ovoid, no outer metatarsal tubercle. Discs on toes 2–4 at least twice as wide as penultimate phalanges (clearly wider than on fingers), those on toes 1 and 5 less wide and all toes with circum-marginal grooves (Fig. 23c).

**Colour in preservative.** Base colour of back and dorsal surfaces of hind legs middle-brown, that of forelegs and head lighter brown. Back immaculate, head with some dark brown blotches and a light inter-ocular band, hind legs and forelegs with some dark brown blotches and stripes. Two vaguely expressed light dorsolateral stripes present. Side of head dark brown with light brown diagonal stripe. In lateral view there is a blackish stripe extending from behind eye, including upper part of tympanum and reaching to middle of body; the upper part of this

stripe merges gradually into the colour of the dorsum and its undulating lower part is sharply bordered by a grey-white line that merges into the colour of the flank. Grey-white flanks are covered by some irregular dark brown blotches that reach the groin and continue as a dark reticulum on anterior thighs. Anteriorly the light lateral area reaches to the eye. Dark brown lumbar blotches are clearly separated from dark lateral stripe. Surface of abdomen and ventral surface of upper arm and partly of lower arm off-white and fleckless. Throat and chest strongly mottled with dark brown (Fig. 24d). Underside of lower arm as well as anterior and posterior thighs, tibiae and posterior tarsus including palms and soles with extensive brown areas. Ventral surfaces of thighs off-white with a weak brown reticulum.

**Colour in life** (Fig. 23a) is much like that in preservative. Especially conspicuous are an alternating white and red-orange pattern on the upper eyelid; a large blackish sub-ocular patch; a ventrally undulating blackish lateral stripe that reaches to middle of body and is bordered below, beginning behind the tympanum, by a white line; a dark lumbar spot bordered posteriorly by a yellow patch; yellow patches on anterior and superior thighs.

**Variation in the preserved paratypes.** For mensural variation see Table 5. Overall colour, as well as presence and distribution of specific colour patterns, is very similar to the holotype in all preserved paratypes. Colour of dorsum varies from lighter to darker brown. It is uniform in all specimens except SAMA R64999, where the dorsum exhibits a distinct brown reticulum on a paler background. The same specimen also differs from all others by lacking a pale interocular stripe. Light dorsolateral stripes occur in all specimens but their intensity is variable. The blackish lateral stripe may be solid or broken into a series of blotches. The extent to which the stripe extends posteriorly is also variable, though in no specimen does it reach the lumbar blotch which has an elongate but irregular shape in most specimens. Dorsal surface of thighs varies from faintly spotted to intensely banded. Posterior sides of shanks with a conspicuous blackish longitudinal stripe in all specimens. Lower surface of upper arm and part of inner surface of forearm off-white and without spots in all specimens. Ventral surface of forearm including palms and fingers completely dark brown or with only a few light areas. Throat off-white and more or less densely mottled with dark brown. A whitish blotch that is bordered anteriorly by a dark brown sub-ocular area from posterior end of mandible to insertion of upper arm is characteristic for most specimens. Chest generally more intensively pigmented than throat or anterior abdomen.

Information on colour of the ventral surfaces of the holotype in life is not available, so we here describe the ventral colouration of one paratype (SAMA R64998) that is otherwise similar to the holotype (Fig. 24) as follows: ventral surfaces of posterior abdomen and extremities yellow, that of anterior abdomen, chest and throat off-white to yellowish. Posterior abdomen and



**Fig. 23.** Holotype of *Hylophorbus sigridae* sp. nov.; (a) dorsolateral view in life, (b) ventral view of left hand of preserved specimen, (c) ventral view of left foot of preserved specimen, (d) ventral view of preserved specimen.

inferior upper arms without flecks, anterior abdomen covered by a grey reticulum; chest with two solid blackish blotches and throat with a dense reticulum of dark grey colour. Lower lip with a continuous row of blackish spots that are interrupted by a white spot posteriorly. Inferior thighs, shanks and tarsi with a dark grey reticulum, which is sparsely reticulated in the centre and more dense on anterior and posterior surfaces. Ventral surfaces of fingers, palms, toes and soles densely pigmented with dark grey-brown.

**Distribution and ecological notes.** Gugusu Camp is in foothill rainforest on a low ridge at the base of the Muller

Range. All animals were encountered on the forest floor (Fig. 25) at night, most commonly after rain. Males called from semi-exposed positions such as the base of tree buttresses at night, while females were encountered hopping or sitting exposed on the litter. *Hylophorbus sigridae* is known only from the type locality in the foothills of the Muller Range.

**Vocalization.** The advertisement call consists of a very fast train of short, rather melodious notes (Fig. 26). Five calls from SAMA R65000 recorded at an air temperature of 23 °C were analysed. Mean duration of these calls is 1.86 s, range 1.76–1.97 s. Calls contain on average

**Table 5.** Body measurements and body ratios of the type series of *Hylophorbus sigridae* sp. nov. SAMA R 65001 is the holotype; SAMA R64999, R65001, R65003, ZMB 79527 and ZMB 79528 are adult males; SAMA R 65004 and ZMB 79526 are adult females and SAMA R 64998 is a subadult female. ZMB 79527 was cleared and double stained as an osteological preparation.

Reg.-No.	SAMA R64998	SAMA R64999	SAMA R65000	SAMA R65001	SAMA 65003	SAMA 65004	ZMB 79526	ZMB 79527	ZMB 79528	Mean ± SD
SUL	21.6	23.1	23.5	24.2	23.6	23.9	24.1	21.2	23.1	
TL	13.1	13.0	13.2	13.7	13.6	13.9	13.9	12.9	13.5	
TaL	7.7	7.8	7.9	8.1	8.1	7.5	8.1	7.7	8.0	
L4T	12.6	12.3	13.0	13.3	12.9	13.5	13.2	11.9	13.2	
T4D	0.9	1.2	1.1	1.2	1.2	1.3	1.3	1.0	1.0	
L3F	5.7	5.7	5.6	5.7	5.6	6.0	6.0	5.6	5.5	
F3D	0.6	0.7	0.6	0.8	0.7	0.8	0.7	0.5	0.5	
F1D	0.5	0.5	0.6	0.6	0.6	0.8	0.5	0.4	0.5	
T1D	0.7	0.6	0.7	0.7	0.7	0.6	0.7	0.6	0.6	
HL	8.0	8.2	7.9	8.0	8.1	8.0	7.8	7.5	7.7	
HW	7.6	8.3	8.2	8.4	8.3	8.2	8.1	7.5	8.1	
SL	3.1	3.4	3.5	3.9	3.8	4.0	3.5	2.8	3.4	
END	1.6	1.7	1.7	1.6	1.7	1.8	1.6	1.6	1.7	
IND	2.3	2.7	2.7	2.8	2.5	2.7	2.7	2.3	2.5	
ED	2.7	2.9	2.8	3.2	3.0	3.1	3.2	2.7	2.9	
TyD	1.8	1.5	1.7	1.9	2.0	2.0	1.9	1.6	1.7	
EST	2.5	2.7	2.8	2.8	2.7	2.4	2.6	2.2	2.6	
TL/SUL	0.61	0.56	0.56	0.57	0.58	0.58	0.58	0.61	0.58	0.58 ± 0.02
TaL/SUL	0.36	0.34	0.34	0.33	0.34	0.31	0.34	0.36	0.35	0.34 ± 0.02
T1D/F1D	1.40	1.20	1.17	1.17	1.17	1.33	1.40	1.50	1.20	1.28 ± 0.13
T4D/SUL	0.042	0.052	0.047	0.050	0.051	0.054	0.054	0.047	0.043	0.049 ± 0.004
T4D/F3D	1.50	1.71	1.83	2.25	1.71	1.63	1.86	2.0	2.0	1.83 ± 0.23
F1D/F3D	0.83	0.71	1.0	0.75	0.86	0.75	0.71	0.8	1.0	0.82 ± 0.11
HL/SUL	0.37	0.35	0.34	0.33	0.34	0.33	0.32	0.35	0.33	0.34 ± 0.02
HL/HW	1.05	0.99	0.96	0.95	0.98	0.98	0.96	1.00	0.95	0.98 ± 0.03
SL/SUL	0.144	0.147	0.149	0.161	0.161	0.167	0.145	0.132	0.147	0.150 ± 0.01
END/IND	0.70	0.63	0.63	0.57	0.68	0.67	0.59	0.69	0.68	0.65 ± 0.05
ED/SUL	0.125	0.126	0.119	0.132	0.127	0.130	0.133	0.127	0.126	0.127 ± 0.004
TyD/ED	0.67	0.52	0.61	0.59	0.67	0.65	0.59	0.56	0.59	0.61 ± 0.05



**Fig. 24.** Paratype SAMA R64998 of *Hylophorbus sigridae* sp. nov., ventral view in life.



**Fig. 25.** Forest interior at Gugusu Camp, 500 m asl, in the Muller Range where *Hylophorbus sigridae* called from the ground in positions such as hidden among the buttress roots of this tree.

19 notes, range 18–20 notes. Mean of means of note length 37.2 ms, range of means 36.4–37.9 ms, absolutely shortest note 22 ms and absolutely longest note 42 ms; mean of means of inter-note length 64.3 ms, range of

means 62.6–65.9 ms, absolutely shortest inter-note interval 51 ms and absolutely longest interval 99 ms. Mean note repetition rate 10.2 notes/s, range 10.2–10.3 notes/s. “Normal” notes contain 25–30 pulses. Notes exhibit a

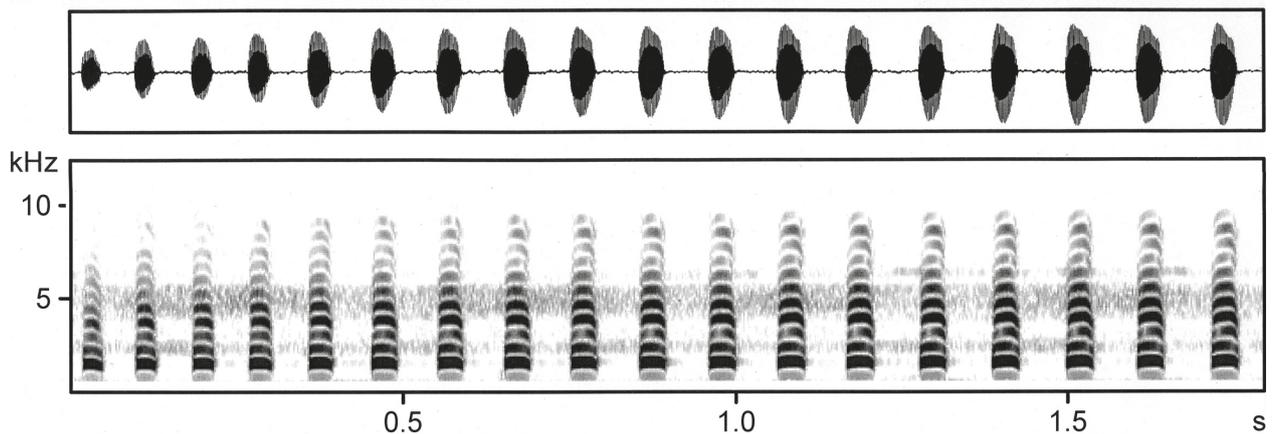


Fig. 26. Wave form (above) and spectrogram (below) of an advertisement call of *Hylophorbus sigridae* sp. nov. consisting of 18 notes.

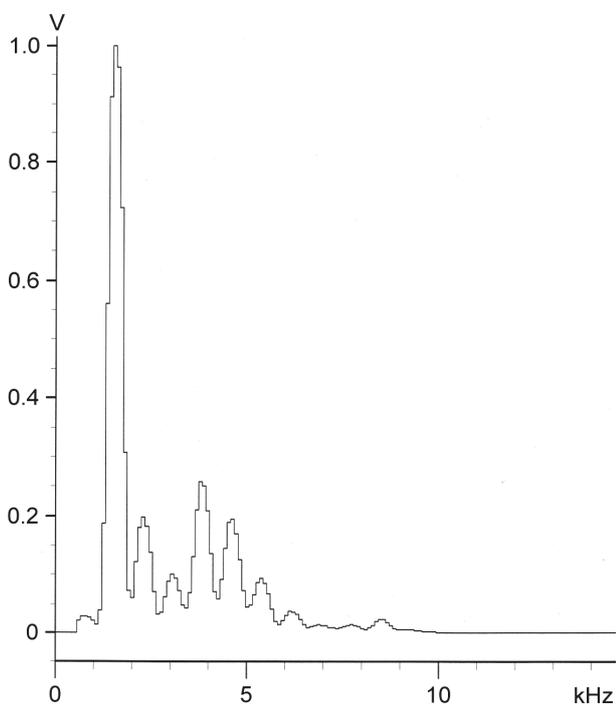


Fig. 27. Power spectrum of an advertisement call of *Hylophorbus sigridae* sp. nov.

harmonic structure with more than eight harmonics on spectrograms (Fig. 26, below). Fundamental frequency is about 0.8 kHz and dominant frequency is at 1.6 kHz (Fig. 27). After the dominant frequency harmonics 4 and 5 contain the most energy.

**Etymology.** The species name is dedicated to the senior author's daughter SIGRID WERNER. English name: Sigrid's Mawatta Frog; German name: Sigrids Mawattafrosch.

**Comparison with other species.** There are only two other *Hylophorbus* species of similar size to the new species; all others are significantly larger. Of the larger species only *H. picoides* has a similar black lateral band, but it has completely different advertisement calls. *Hylophorbus richardsi* is comparable in size to the new

species but it has no lateral band and calls consisting of single, slowly repeated notes (vs. a very fast train of notes) while *H. atrifasciatus* has a conspicuously long lateral band and lacks a lumbar spot (KRAUS 2013).

### *Oreophryne albomaculata* sp. nov.

**Holotype.** SAMAR65135 (FN: SJR 12089), adult male, coll. S. RICHARDS and C. DAHL, Sawetau Camp, Muller Range, Western Province, Papua New Guinea (05°39.397' S, 142°18.277' E; 1600 m asl) on 15 September 2009.

**Paratypes.** None.

**Diagnosis.** A small-sized *Oreophryne* (SUL of male holotype 17.7 mm) with moderately short legs (TL/SUL 0.46), moderately-sized finger and toe discs (T4D/SUL 0.045), and finger discs clearly wider than toe discs. Eyenaris distance shorter than internarial distance (END/IND 0.79). No webs between toes. All dorsal surfaces greenish with many irregular off-white flecks in life which disappeared in preservative. Loreal region with a whitish inverted U-shaped mark. Connection between procoracoid and scapula cartilaginous. Advertisement call is a chain of melodious peeps or whistles. Calls last from 4.0–4.7 seconds with mean note length of 97 ms and a repetition rate of between 4.1 and 4.3 notes per second. The dominant frequency is at 4.2 kHz.

**Description of the holotype.** Adult male (Fig. 28) with following measurements and body ratios: SVL 17.7, TL 8.2, TaL 5.8, L4T 8.2, L3F 5.3, F3D 1.1, F1D 0.6, T4D 0.8, T1D 0.6, HL 6.3, HW 7.0, END 1.5, IND 1.9, EST 2.2, ED 2.6, TyD 0.7, SL 3.0; TL/SUL 0.46, TaL/SUL 0.33, T4D/SUL 0.045, F1D/F3D 0.55, F3D/SUL 0.062, T4D/F3D 0.73, HL/SUL 0.36, HL/HW 0.90, END/IND 0.79, ED/SUL 0.147, TyD/ED 0.27, SL/SUL 0.169, IND/SUL 0.107. There are cuts in chest and anterior abdomen, and a bluish hue of some body parts was caused by al-cian blue staining. Head slightly broader than long, weak

constriction at neck region. Snout truncate with a small cusp in dorsal, and round in lateral, view. Canthus rostralis straight, loreal region oblique and slightly concave, nostrils lateral and very close to tip of snout. Eyes large, eye-naris distance smaller than internarial distance. Tongue long and broad, without posterior notch. Prepharyngeal ridge fairly short, vocal slits present. Tympanum small, supratympanic fold weakly expressed. Forelegs long and slender, fingers long, their relative lengths  $3 > 4 \approx 2 > 1$ . Tips of fingers 2–4 rounded and wide (about twice the width of penultimate phalanges), all with terminal grooves. Metacarpal and subarticular tubercles feebly developed (Fig. 28b). Hind limbs also slender and with long toes, their relative length  $4 > 5 > 3 > 2 > 1$  on left foot and  $4 > 3 > 5 > 2 > 1$  on right foot, no webs between toes. Toe tips narrower than finger tips, all with terminal grooves (Fig. 28c). Metatarsal and subarticular tubercles on toes weakly developed. Glandular ridges in the scapular region have the shape of a W in life but disappeared in preservative, all other dorsal and ventral surfaces are smooth.

**Colouration in preservative.** Basic colour of all dorsal surfaces is off-white. Irregular dark brown markings are more dense on head, across middle of back, on thighs and shanks. Conspicuous are a broad whitish interocular band that is interrupted centrally and bordered by intense stippling, a large whitish postocular patch that extends on upper arm and whitish lumbar spots that are also bordered by more intense pigmented areas. Loreal region also off-white with some smaller and larger dark spots. Ventral surfaces off-white, throat with few regularly distributed dark brown dots, abdomen with irregular groups of dots, more dense groups of dots on thighs, shanks, lower arms and soles of feet.

**Colouration in life.** Ground colour of most dorsal surfaces moss green, that of anterior back brown-green and that of flanks grey-green. All dorsal surfaces covered with irregular off-white spots. Largest spots between eyes, between eye and insertion of upper arm including anterodorsal area of proximal upper arm, on flanks, on posterior tarsus and above angle. Right lumbar spot split into two and left lumbar spot divided into three parts. Inverted U-mark on left loreal region more clearly pronounced than on right side. W-shaped ridges in scapular region indicated by rows of whitish spots. Ventral surfaces of head, chest, abdomen and thighs whitish and covered with inconspicuous dark grey dots (Fig. 28d).

**Distribution and ecological notes.** The holotype and only collected specimen was calling from approximately 3 m above the ground at night, in a tree in wet, mossy forest at an elevation of 1,600 m asl. Several other specimens were heard calling at the type locality (Fig. 29) but were too high to capture. This species is known only from the type locality.

**Vocalization.** Advertisement call is a series of unpulsed peeps (Fig. 30). Four calls of the holotype were analysed.

Air temperature during recording was 16.3 °C. Call length was 4.0–4.7 s, mean 4.4 s, number of notes was 17–20 per call, and note repetition rate was 4.1–4.3 notes per s (mean 4.2 notes per s). Notes start explosively, show a slight sound modulation in the course of the note, and cease quickly. There is no frequency modulation in the course of each note. Mean note length varies from 95 to 99 ms (mean of means 97 ms) and mean inter-note interval length varies from 148 to 161 ms (mean of means 153 ms). Total range of note length 77–122 ms (first note was always shorter than the following ones), total range of inter-note interval length 128–338 ms. Last interval in all cases the longest. Total number of analysed notes is 67 and total number of inter-note intervals is 63. Fundamental frequency is at 2.1 kHz and dominant frequency at 4.2 kHz. There are some harmonics above the dominant band, most pronounced of these is the first band at 6.2 kHz (Fig. 31).

**Etymology.** The specific epithet “*albomaculata*” is a composed Latin adjective of feminine gender; *albus*, -a, -um means white and *maculatus*, -a, -um means spotted or speckled. It refers to the colouration of the holotype. English name: Speckled Cross Frog; German name: Weißfleckenbergkröte.

**Comparison with other species.** *Oreophryne albomaculata* belongs to a group of species that share a combination of the following characters: (a) procoracoid connected to the scapula by a cartilaginous bridge, (b) size of males (in most cases) not larger than 23 mm, (c) ratio TL/SUL more than 0.43, (d) no webs between toes, (e) finger tips and toe tips with distinctly expanded discs, (f) inverted U- or O-shaped loreal mark, (g) peeping advertisement calls. Besides *O. albomaculata* the following species belong to this group: *O. asplenicola*, *O. notata*, *O. pseudasplenicola* and *O. streiffeleri*. None of these species exhibits a greenish ground colouration covered with numerous whitish flecks as is characteristic for the holotype of *O. albomaculata*. Future biochemical investigations must show whether the mentioned species belong indeed to a monophyletic group.

*O. asplenicola* is slightly but distinctly larger (five males measure 19.3–21.2 mm) than the new species and has different head proportions: HL/SUL 0.30–0.31 vs. 0.36 in *O. albomaculata*; HL/HW 0.77–0.85 vs. 0.90, END/IND 0.95–1.00 vs. 0.79 and ED/SUL 0.128–0.139 vs. 0.147. Moreover, note length is distinctly shorter and internote interval length is greater in *O. asplenicola* and repetition rate is 2.1–2.7 notes/s in *O. asplenicola* and 4.1–4.3 notes/s in the new species.

Comparisons to *O. notata* are based on our study of three paratopotypes of this species, of observations in the field and consideration of the original description by ZWEIFEL (2003). Basic colour of *O. notata* is brown and there are no conspicuous whitish flecks on dorsal surfaces. Although the number of specimens measured is low, the great number of differences in body ratios support our opinion of specific distinctness. We found the



**Fig. 28.** Holotype of *Oreophryne albomaculata* sp. nov. in life; (a) dorsolateral view, (b) ventral view of right hand, (c) ventral view of right foot, (d) ventral view.



**Fig. 29.** Moss-covered trees at Sawetau Camp, 1600 m asl in the Muller Range. Several male *O. albomaculata* spec. nov. were heard calling from high in these trees.

following differences with no overlapping of the values (own measurements): T4D/SUL in *O. albomaculata* 0.045, in *O. notata* 0.051–0.059; T4D/F3D 0.73 vs. 0.79–0.86; F1D/F3D 0.55 vs. 0.57–0.71; T1D/F1D 1.00 vs. 0.70–0.88; HL/SUL 0.36 vs. 0.30–0.33; HL/HW 0.90 vs. 0.73–0.88; END/IND 0.79 vs. 0.88–0.90; TyD/ED 0.27 vs. 0.29–0.41; IND/SUL 0.107 vs. 0.095–0.102; END/SUL 0.085 vs. 0.086–0.089. Moreover, dominant frequency of the *notata*-calls is according to ZWEIFEL 3.5–3.6 kHz, that of the new species is at 4.2 kHz.

*O. pseudasplenicola* differs from the new species by colouration, as it lacks the white spotting, by its shorter shanks (TL/SUL 0.40–0.43 vs. 0.46), shorter head (HL/SUL 0.27–0.32 vs. 0.36) and a different ratio END/IND 0.90–1.00 vs. 0.79. Moreover, note length is greater in *O. pseudasplenicola* (range of means 111–128 ms

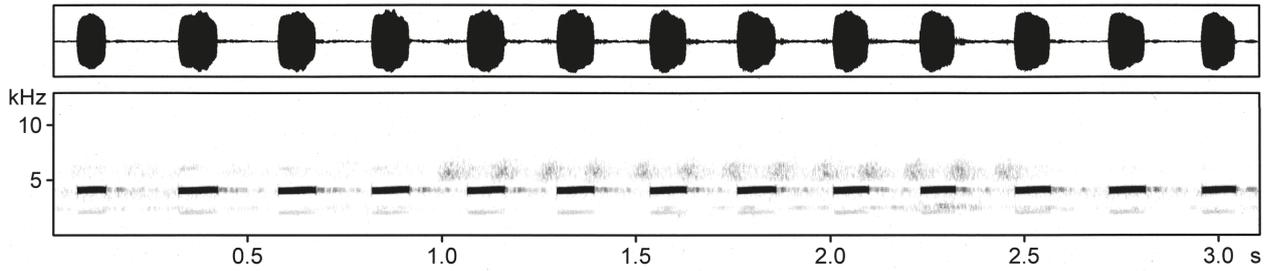


Fig. 30. Wave form (above) and spectrogram (below) of an advertisement call section of *Oreophryne albomaculata* sp. nov.

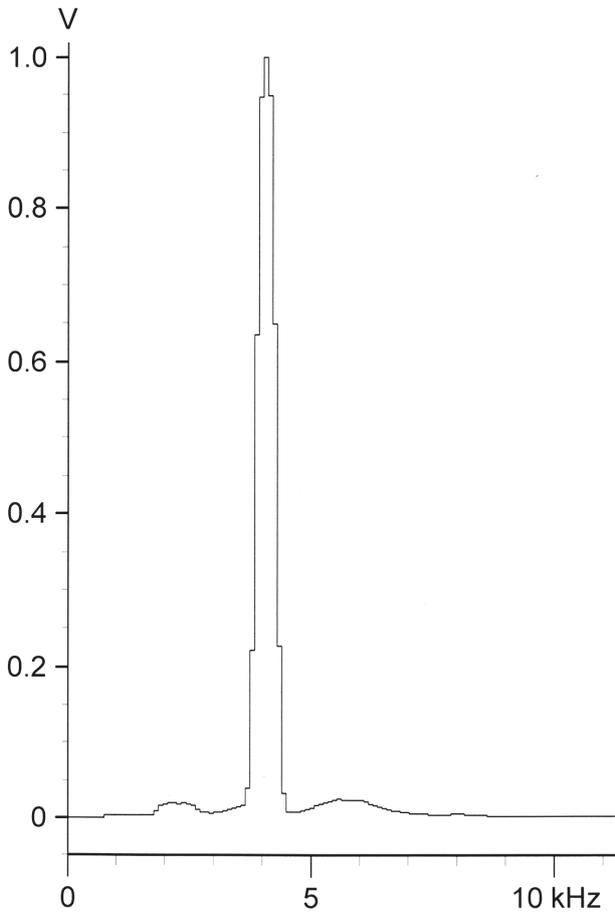


Fig. 31. Power spectrum of an advertisement call section of *Oreophryne albomaculata* sp. nov.

vs. 95–99 ms), internote intervals are longer (range of means 633–754 ms vs. 148–161 ms) and note repetition rate is lower (1.3–1.4 vs. 4.1–4.3 notes/s).

*O. streiffeleri* is bigger than *O. albomaculata* (SUL of seven males more than 20 mm), and has broader toe discs (T4D/SUL 0.062–0.073 vs. 0.045). Other ratios showing differences include: T4D/F3D (0.86–1.00 vs. 0.73), HL/SUL (0.28–0.32 vs. 0.36), HL/HW 0.74–0.83 vs. 0.90), END/IND 0.85–0.95 vs. 0.79), ED/SUL 0.112–0.128 vs. 0.147) and TyD/ED (0.31–0.45 vs. 0.27). It also has different advertisement calls. Mean note length in *O. streiffeleri* varies from 148 to 161 ms, mean internote interval length varies from 241–278 ms and note repetition rate varies from 2.5–2.6 notes/s.

### *Oreophryne curator* sp. nov.

**Holotype.** SAMA R65139 (FN: SJR 12020), adult male, *coll.* S. RICHARDS and C. DAHL, Sawetau Camp, Muller Range, Western Province, Papua New Guinea (05°39.397' S, 142°18.277' E; 1600 m asl) on 14 September 2009.

**Paratypes.** SAMA R65136 (FN: SJR 12083), SAMA R65137 (FN: SJR 10993), SAMA R65138 (FN: SJR 12001), SAMA R65140 (FN: SJR 12021), SAMA R65141 (FN: SJR 12024), SAMA R65142 (FN: SJR 12028), SAMA R65143 (FN: SJR 12031), SAMA R65144 (FN: SJR 12034), SAMA R65145 (FN: SJR 12048), SAMA R65146 (FN: SJR 12055), SAMA R65147 (FN: SJR 12060), SAMA R65148 (FN: SJR 12062), SAMA R65149 (FN: SJR 12093), SAMA R65150 (FN: SJR 12094), ZMB 79529 (FN: SJR 12036), ZMB 79530 (FN: SJR 12043), now an osteological preparation, ZMB 79531 (FN: SJR 12080). Collectors and collection site as for holotype, all paratypes collected 12–16 September 2009. SAMA R65136–37, R65140–41, –45 and –47 are adult males, SAMA R65146, –48, –49 and –50 are adult females, SAMA R65142–44 are subadult and R65138 is a juvenile. All three ZMB-specimens are adult males.

**Diagnosis.** A species of the genus *Oreophryne* with a snout-urostyle length in adult males (n=10) from 20.5–24.8 mm and in adult females (n=4) from 28.3–28.9 mm. Cartilaginous connection between procoracoid and scapula; no webs between fingers, basal webs in some specimens present and mainly between toes 3 and 4 and between toes 4 and 5; fifth toe somewhat longer than third or of equal size; finger discs clearly wider than toe discs (mean ratio T4D/F3D 0.82). Average proportions TL/SUL 0.45, HL/HW 0.85, ED/SUL 0.144, TyD/ED 0.27, and END/IND 0.89. Dorsal colouration extremely variable: different tones of green, yellow or brown, uniform or spotted. Advertisement call is a rattle of more than 2.5 seconds, mean note length 26–28 ms and repetition rate 12.3–13.4 notes per second. Dominant frequency at 3.0 kHz.

**Description of the holotype.** Adult male (Fig. 32) with SUL of 23.4 mm and the following measurements and ratios: TL 10.5, TaL 7.2, T4L 11.9, T4D 1.2, F3L 8.0, F3D 1.6, T1D 1.0, F1D 1.0, HL 8.2, HW 9.6, END 2.0, EST 3.1, IND 2.2, ED 3.3, TyD 0.9, SL 4.3; TL/SUL 0.45, TaL/SUL 0.31, T4D/SUL 0.051, T4D/F3D 0.75, F3D/SUL 0.068, F1D/F3D 0.63, T1D/F1D 1.0, HL/SUL 0.35, HL/HW 0.85, END/IND 0.91, ED/SUL 0.141, TyD/ED 0.27, SL/SUL 0.184, END/SUL 0.085, IND/SUL 0.094.



**Fig. 32.** Holotype of *Oreophryne curator* sp. nov. in life; (a) dorsolateral view, (b) ventral view of right hand, (c) ventral view of right foot, (d) ventral view.

Longitudinal cut on left side of anterior abdomen. Head broader than long, snout truncate with a small cusp from above, and truncate with rounded edge in profile. Nostrils directed anterolaterally and very close to tip of snout, distance between nares less than distance between eye and naris (END/IND 0.91). Canthus rostralis roundish and not curved, loreal region slightly concave and slightly skewed. Tongue broad and long, posteriorly not bifurcate. Prepharyngeal ridge with distinct denticles. Long vocal slits on both sides of mouth floor. Tympanum small, partly covered by skin (TyD/ED 0.27), no prominent supratympanic fold. Legs moderately long. Fingers unwebbed and with broad and grooved terminal discs, their relative lengths  $3 > 4 \approx 2 > 1$ . Discs of fingers about twice as wide as penultimate phalanges (Fig. 32b). Metacarpal and subarticular tubercles on fingers scarcely

visible. All toes with wide and grooved terminal discs, finger discs clearly wider than toe discs (T4D/F3D 0.75). No webs between toes present and no prominent metatarsal or subarticular tubercles. Relative lengths of toes  $4 > 5 > 3 > 2 > 1$  (Fig. 32c). Skin smooth on all surfaces.

**Colouration in preservative.** Basic colour of dorsal surfaces of body and extremities middle-brown; a dark brown and ill-defined vertebral stripe from occiput to cloaca and an ill-defined dorsolateral stripe of the same colour on each side from eyelid to lumbar region including a faint lumbar spot; a conspicuous vertebral line from snout tip to posterior of body that continuous on rear thigh, shank and tarsus; a pale fleck anteriorly between eyes; a few scattered white spots on dorsum, light brown flanks covered with numerous irregular dark brown spots



Fig. 33. Paratype of *Oreophryne curator* sp. nov. in life with predominantly grey dorsum.



Fig. 34. Paratype of *Oreophryne curator* sp. nov. in life with large orange blotches on dorsum.



Fig. 35. Paratype of *Oreophryne curator* sp. nov. in life with grey-green ground colour and irregular brownish blotches.

and mottling. Dorsal surfaces of extremities also mottled with some lighter and darker areas. Loreal and subocular region uniform dark brown, a pale stripe from posterior edge of eye to insertion of upper arm that is bordered by dark brown areas dorsally and ventrally. Ventral surfaces of throat, chest and abdomen off-white with a dense pattern of irregular brown areas, ventral surfaces of extremities stronger pigmented than remaining undersides,

Table 6. Body ratios of the type series (n=10 adult males, 4 adult females and 4 subadults) of *Oreophryne curator* sp. nov.

Ratio	Mean	Standard-Deviation	Range
TL/SUL	0.45	0.01	0.43 –0.47
TaL/SUL	0.31	0.01	0.29 –0.33
HL/SUL	0.34	0.02	0.31 –0.37
HL/HW	0.85	0.04	0.81 –0.92
SL/SUL	0.177	0.01	0.161–0.198
T4D/SUL	0.054	0.008	0.044–0.066
T4D/F3D	0.82	0.09	0.70 –1.00
T1D/F1D	0.93	0.09	0.71 –1.07
F1D/F3D	0.70	0.05	0.58 –0.77
END/IND	0.89	0.10	0.77 –1.04
ED/SUL	0.144	0.008	0.131–0.157
TyD/ED	0.27	0.05	0.18 –0.35

conspicuous is a discontinuous whitish line on upper and lower arm.

**Colouration in life.** Dorsal surfaces yellow-grey with a distinct light yellow vertebral line that continuous on hind limbs; this line is bordered by a dark brown strip that becomes paler laterally and there are some orangish tubercles on upper flanks and on shanks, a yellowish line from nostril along canthus rostralis and upper eye lid broadened to an irregular patch in the tympanal region and is bordered there dorsally by an isolated dark brown patch and ventrally by a dark brown area that is part of the dark brown “loreal mask”. There is a broad, slightly paler inter-orbital bar. Flanks and extremities with a few grey-brown flecks, upper and lower part of iris silvery with blackish venation, middle part orange, inguinal region orange. Lower surfaces off-white with a dense grey-brown stippling and a few yellowish stripes and spots (Fig. 32d).

**Morphological variation in the type series.** There are 10 adult male paratypes with a snout-urostyle length (including the holotype) of 20.5–24.8 mm, mean 23.3±1.24 mm, and four adult female paratypes with SUL of 28.3–28.9 mm, mean 28.6±0.25 mm. Three subadult males measure 18.9–19.3 mm and one subadult female 23.4 mm. One specimen of 14.0 mm is juvenile, its sex could not be determined. Because there are no conspicuous differences between adult sexes and subadults in body ratios, these were merged in Table 6.

Ground colour of dorsal surfaces of the preserved specimens varies from off-white to dark brown and patterning from a few stippled areas to extensive dark brown areas as in the holotype. Dorsally snout is paler than other dorsal surfaces in most specimens. Three out of 17 specimens have a conspicuous whitish middorsal line that continuous on hind legs. Loreal and subocular region are in most specimens more strongly pigmented than surrounding areas and there is a pale postocular patch, bordered superiorly and inferiorly by darker areas, and a

pale interocular bar in almost all type specimens. Some specimens have irregular scattered whitish spots on dorsum and most exhibit some inconspicuous tubercles and ridges on dorsal and lateral surfaces. Ventral surfaces are off-white, but patterning varies strongly: there are specimens with a few evenly distributed stipples, in others stipples are arranged in more or less dense blotches and stripes. Light areas dominate in almost all specimens over dark brown or dark grey pigmented areas.

Colouration of dorsal surfaces of living specimens was also very variable (see Figs. 32a, 33, 34, 35 and 38). We found as basic colour different tones of green, grey, yellow-orange and brown. Patterning was not or only scarcely expressed in lighter specimens, while specimens with darker basic colour exhibited as a rule a more striking dark brown pattern, in some cases also with a conspicuous whitish middorsal line. Almost all specimens had a whitish line on the top of the snout tip that continued along the canthus rostralis, the upper eyelid and the supratympanic fold. A pale postocular stripe was also characteristic for most specimens. Ventral surfaces were mostly off-white with an inconspicuous dark grey stippling, inguinal region in most specimens orange. No specimen showed clearly expressed lumbar ocelli or an obvious hourglass-shaped figure on the back.

**Vocalization.** Four calls from two specimens (one call from SAMA R65140 and three calls from SAMA R65137) were analysed. As all call parameters from both males are very similar, they are treated together here. Advertisement calls are rattles of 2.6–3.2 s duration (Fig. 36). They contain 32–41 pulsed notes. Notes consist of six to eight pulses, seldom less. First pulse with maximum amplitude, amplitude decreasing toward the end of note. Mean of means of note length is  $27.3 \pm 0.96$  ms, total range 12–39 ms ( $n=151$ ). Mean of means of internote-interval length is  $51.6 \pm 2.7$  ms, total range 30–70 ms ( $n=147$ ). Note repetition rate in four calls varied from 12.3–13.4, mean  $13.1 \pm 0.51$  notes per s. Most sound energy is concentrated between 2 and 5 kHz, with dominant frequency at 3 kHz (Fig. 37). Temperature during recording was 16.5–18.5 °C.

**Distribution and ecological notes.** This species was abundant in the wet, mossy forest at 1,600 m altitude in the Muller Range. Despite this abundance, specimens were difficult to capture due to the elevated positions of their calling and perching sites. Most males called from at least 5 m above the ground, and often much higher, in moss-covered trees after rain at night. One male, SAMA R65147, was observed guarding a clutch of eggs on the underside of a leaf just ~30 cm above the ground on a steep hillside above camp. The male straddled the clutch with its body each night, and was seen in the same position over several days (Fig. 38).

**Etymology.** The specific epithet “curator” is a Latin noun in apposition and means protector or guardian and refers to the fact that the males of this species guard the eggs of

their mates. English name: Minder’s Cross Frog; German name: Wächterbergkröte.

**Comparisons with other species.** We are not aware of any other species of *Oreophryne* that shows such a high non-ontogenetic variability in colouration as *O. curator*. An important character that distinguishes *Oreophryne curator* from many other congeners is the cartilaginous connection between the procoracoid and the scapula. *Oreophryne* species with this character may again be subdivided on the basis of their advertisement calls into two distinct groups, those with a peeping call and those with a rattling call. The new species belongs to the latter group. We now compare our new species to all *Oreophryne* with a rattling advertisement call and a cartilaginous connection procoracoid-scapula and to those species from which these characters are unknown.

*O. alticola*, *O. brevicrus*, *O. brevirostris*, *O. geminus*, *O. habbemensis*, and *O. terrestris* all have a TL/SUL ratio of less than 0.43, they are smaller (most males are less than 20 mm), have narrower finger and toe discs and live in higher altitudes than the new species.

*O. anamiatoi* has smaller eyes (ED/SUL 0.110–0.130 vs. 0.131–0.157); a lower END/IND ratio (0.72–0.86 versus more than 0.86), a more uniform brown dorsal colouration, a “venter with a dense array of dark-brown flecks” and different calls. Advertisement calls of *O. anamiatoi* are shorter (less than 2.3 s), contain less notes (17–22 vs. more than 26 in *O. curator*), note duration is greater (mean 57 ms vs. 27 ms), repetition rate is slower (about 9 vs. 13 notes/s) and dominant frequency is about 2.5 vs. 3.0 kHz in *O. curator* (KRAUS & ALLISON 2009).

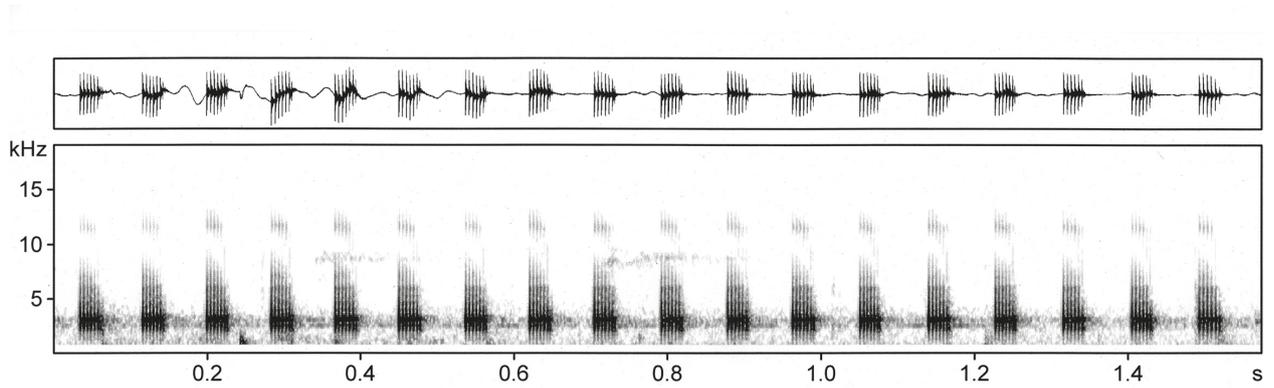
*O. clamata* is a smaller species (males 18.5–20.4 mm SUL), its dorsal surfaces are not so variably coloured, its ratio T4D/F3D is distinct (0.62–0.66 vs. 0.70–1.00 in *O. curator*) and its calls are shorter (0.58–1.41 s) with a higher note repetition rate (16.3–18.4 notes/s).

*O. crucifer* is known only from two syntypes (ZMA 5819–20) collected in the Went Mountains and along the Setekwa River, now Papua Province of Indonesia. In contrast to *O. curator*, this species exhibits lumbar ocelli and an hourglass-shaped figure on the back. The new species differs from ZMA 5819 also in some body ratios: T4D/SUL (0.043–0.066 vs. 0.068) and END/IND (0.77–0.104 vs. 1.25).

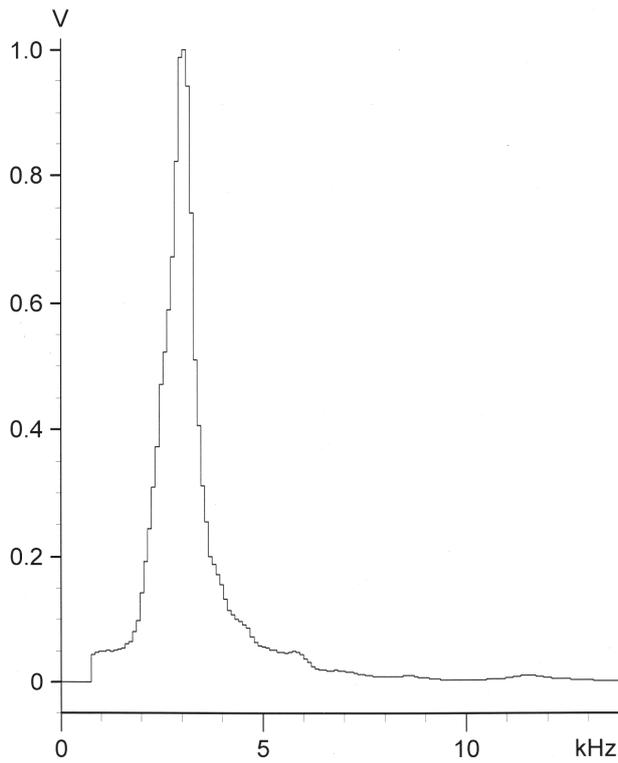
*O. flava* occurs according to MENZIES (2006) in the central highlands of western New Guinea between 1800 m and 2900 m asl. Six specimens of this species, including the holotype (ZMA 5823), were compared. *O. flava* is smaller than the new species and has a smaller disc on the fourth toe (T4D/SUL 0.039–0.044 vs. 0.044–0.066 and T4D/F3D 0.62–0.69 vs. 0.71–1.00).

*O. idenburgensis* with body length of males and females up to 45 mm is clearly a larger species than the new one.

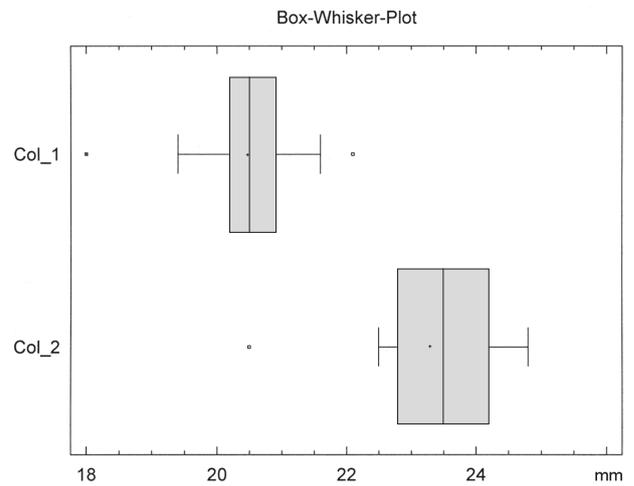
The (female) holotype of *O. kampeni* (BMNH 1947. 2.1214) with a SUL of 23.0 mm (and so with a smaller body size than *O. curator*), has conspicuous webs between toes (not present or inconspicuous in *O. curator*),



**Fig. 36.** Wave form (above) and spectrogram (below) of an advertisement call section of *Oreophryne curator* sp. nov.



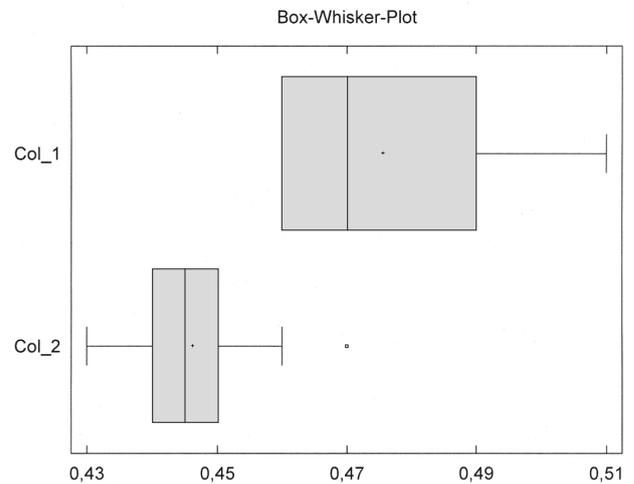
**Fig. 37.** Power spectrum of an advertisement call section of *Oreophryne curator* sp. nov.



**Fig. 39.** Box-Whisker-Plot of snout-urostyle length (SUL) in mm of 19 *Oreophryne oviprotector* males (Col\_1) and 10 *O. curator* sp. nov. males (Col\_2).



**Fig. 38.** Male of *Oreophryne curator* sp. nov. (SAMA R65147) protecting eggs of its mate.



**Fig. 40.** Box-Whisker-Plot of ratio TL/SUL in *Oreophryne oviprotector* (Col\_1) (n=25) and *O. curator* sp. nov. (Col\_2) (n=18).

fifth toe shorter than third (vice versa in the new species), ratio TL/SUL 0.42 (vs. 0.43–0.47), ratio T4D/SUL 0.043 (vs. 0.044–0.066) and ratio T4D/F3D 0.67 (vs. 0.75–1.00).

According to MENZIES (2006), the advertisement call notes of *O. loriae* have a length of 200–300 ms, and with this clearly differ from the shorter notes (means 26–28 ms) of *O. curator*.

*O. minuta* has a much smaller body (males up to 11.5 mm SVL) and no discs on fingers and toes (RICHARDS & ISKANDAR 2000).

*O. moluccensis* has toes one-third webbed vs. only traces of or no webbing in the new species.

*O. oviprotector* is significantly smaller than the new species (Fig. 39). Nineteen males measured 18.0–22.1 mm SUL (mean 20.4 mm) and six females measured 21.7–27.1 mm (mean 23.3 mm). In contrast 10 males of *O. curator* measured 20.5–24.8 mm (mean 23.3 mm) and four females 28.3–28.9 mm (mean 28.6 mm). Both species also differ highly significantly ( $t=6.3$  and  $p=0.0000005$ ) in the length of tibia (ratio TL/SUL in *O. oviprotector* 0.46–0.51, in *O. curator* 0.43–0.47, Fig. 40). Moreover, colouration and calls are different. Advertisement calls of *O. oviprotector* last less than one second, total range of note length is 9–14 ms, notes contain as a rule three pulses and repetition rate varies from 26.0 to 27.7 notes/s (GÜNTHER *et al.* 2012).

*O. waira* is smaller (SUL of six adult males 17.8–18.9 mm, of two adult females 18.6 and 21.0 mm) than the new species and never has uniform green, yellow or grey dorsal surfaces. Moreover, its calls are much shorter (mean of 31 calls from four different males 0.48 s) with only 6–11 notes and a repetition rate of 15–19 notes/s vs. 12.3–13.4 notes/s in *O. curator*.

*O. wolterstorffi* has conspicuous webs on toes vs. only basal or no webs in *O. curator*.

### *Xenorhina tillacki* sp. nov.

**Holotype.** SAMA R65068 (FN: SJR 10947); adult male, *coll.* S. RICHARDS and C. DAHL, Gugusu Camp, Muller Range, Western Province, Papua New Guinea (05°43.751' S, 142°15.797' E; 515 m asl) on 08 September 2009.

**Paratypes.** SAMA R65067 (FN: SJR 10920), ZMB 79532 (FN: SJR 10866). Same data as holotype except ZMB 79532 collected on 4 September 2009. Both paratypes are adult males.

**Diagnosis.** With a snout-urostyle length of between 18.2 and 21.7 mm in three adult males and the possession of two spikes on each vomero-palatine bone the new species differs clearly from all species without spikes and belongs to the smallest species of the genus. Only *Xenorhina anorbis*, *X. lanthanites* and *X. brachyrhyncha* are similar in size and have vomero-palatine spikes. However all three have only one spike. Advertisement

call of the new species consists of a long series of short piping notes. Average note length is 70 ms with a dominant frequency of about 0.9 kHz; note repetition rate is 3.3–3.6 notes per second.

**Description of the holotype.** An adult male (Fig. 41). For measurements see Table 7. Head in the region of the tympana broader than long (HL/HW 0.86) and merging seamlessly into the wider body. Snout acuminate from above and rounded in profile. Loreal region oblique, no canthus rostralis. Nostrils near tip of snout, directed dorsolaterally, visible from above but not from below. Internarial distance smaller than eye diameter. Tympanum clearly visible and large (TyD/ED 0.88), supratympanic fold extends from posterior corner of eye, touches the dorsal margin of tympanum and reaches up to insertion of foreleg, its posterior half more strongly expressed than its anterior half. Tibia of medium length for the genus (ratio TL/SUL 0.44). Fingers rather short, no webbing between fingers and toes (Figs. 41b and 41c). All finger tips with scarcely visible circum-marginal grooves, tips as wide as, or even narrower than, corresponding penultimate phalanges. First finger longer than fourth, relative length of fingers  $3 > 2 > 1 > 4$ . Tips of toes 2, 3, 4 and 5 with discs wider than corresponding penultimate phalanges that of toe 1 as wide as penultimate phalanx. All toe tips with clearly expressed circum-marginal grooves. Relative length of toes  $4 > 3 > 5 > 2 > 1$ , no distinct subarticular, plantar or palmar tubercles present. Body sides in life and in preservative with some white-capped tubercles, but no tubercles on extremities or ventral surfaces. Tip of snout with a few tiny holes in life but fairly smooth in preservative.

**Colouration in preservative.** Ground colour of all dorsal surfaces is cream-white. Large areas are more or less evenly interspersed with tiny dark brown dots. Additionally there are irregular dark brown spots, blotches and marbling distributed across all dorsal surfaces. Beginning on dorsal tip of snout and extending to posterior edge of eyes is an unspotted kite-shaped area. A short and broad stripe of the same colour that is bordered by blackish spots extends from each posterior eyelid in direction of the mid dorsum. A mid-dorsal line reaches to the cloacal opening, and is also pronounced on posterior thigh and on posterior tarsus, but not on tibia. This line is less intensively expressed in fixative than in life. Upper flanks are covered by irregular blackish blotches that are connected with each other. A small prominent, white and round spot is located below each tympanum. Lateral surfaces of head and tympana are more intensely pigmented than dorsal surfaces. Ventral surfaces exhibit a brown reticulum with many irregularly shaped whitish spots that are larger on the belly and smaller on the throat.

**Colouration in life.** The colouration of all dorsal and lateral surfaces was reddish grey with a very irregular pattern of whitish, light and dark grey, as well as brownish spots, blotches and marbling (Fig. 41a). Conspicuous features include a light grey dorsal surface of the snout,



**Fig. 41.** Holotype of *Xenorhina tillacki* sp. nov. in life; (a) dorsolateral view, (b) ventral view of left hand, (c) ventral view of left foot, (d) ventral view.

two stripes of the same colour behind the eyes and a whitish mid-dorsal line that continues on the posterior thigh and the tarsus. Ventral surfaces are brown with a dense pattern of irregular whitish blotches (Fig. 41d). Iris was golden with a dense blackish venation.

**Variation in the type series.** For variation in biometric characters see Table 7. SUL varies between 18.2 and 21.7 mm (mean 20.1 mm) and TL/SUL from 0.44–0.48 (mean 0.46) in three adult males. SAMA R65067 seems to be a colour copy of the holotype both in life and in preservative. ZMB 79532 exhibits in preservative a more uniformly dark greyish-brown dorsal colouration of the trunk and hind legs, with some dark brown spots especially on hind legs; snout and forelegs are coloured as in the above specimens but ventral surfaces less intensely

pigmented than in those specimens. Mid-dorsal line very faintly expressed. ZMB 79532 differs in life habitus considerably from the other two paratypes. Dorsal and lateral surfaces of its body and hind legs are uniform dark grey-brown and dorsum of snout and forelegs are conspicuously light (Fig. 42). It shows a couple of tiny holes on the tip of the snout in life, but a couple of slight pustules in preservative.

**Distribution and ecological notes.** *Xenorhina tillacki* was encountered only during and after heavy rain in foothill forest in the Muller Range, Western Province, Papua New Guinea. The type locality is on a low ridge at around 500 m asl, and all three specimens were found either in litter or hopping on a forest trail (Fig. 43). The holotype was tracked down by its call, which was uttered from the

**Table 7.** Body measurements and body ratios of the type series of *Xenorhina tillacki* sp. nov. SAMA R65068 is the holotype. All types are males.

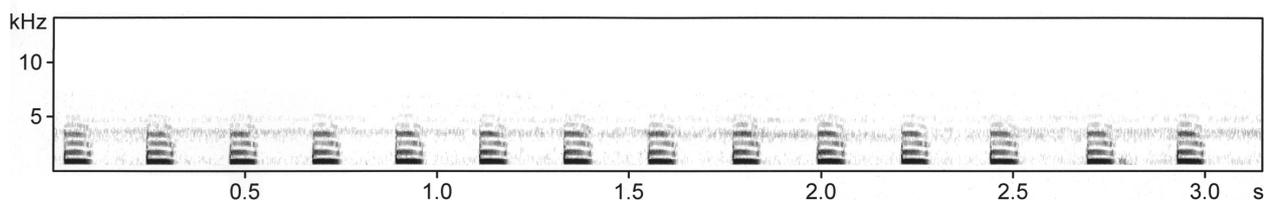
Reg.-No.	SAMA R65067	SAMA R65068	ZMB 79532	Mean
SUL	20.3	21.7	18.2	20.1
TL	9.1	9.5	8.7	
TaL	5.9	6.2	5.8	
L4T	9.7	10.2	9.0	
T4D	0.8	0.8	0.8	
L3F	4.2	4.2	3.8	
F3D	0.5	0.5	0.4	
F1D	0.4	0.3	0.3	
T1D	0.4	0.4	0.3	
HL	6.1	6.8	5.2	
HW	7.6	7.9	7.0	
SL	2.7	2.8	2.6	
END	1.7	1.7	1.6	
IND	1.3	1.3	1.2	
ED	1.7	1.7	1.5	
TyD	1.5	1.5	1.0	
EST	2.4	2.3	2.3	
TL/SUL	0.45	0.44	0.48	0.46
TaL/SUL	0.29	0.29	0.32	0.30
T1D/F1D	1.00	1.33	1.00	1.11
T4D/SUL	0.039	0.037	0.044	0.040
T4D/F3D	1.60	1.60	2.0	1.73
F1D/F3D	0.80	0.60	0.75	0.72
HL/SUL	0.30	0.31	0.29	0.30
HL/HW	0.80	0.86	0.74	0.80
SL/SUL	0.133	0.129	0.143	0.135
END/IND	1.31	1.31	1.33	1.32
ED/SUL	0.084	0.078	0.082	0.081
TyD/ED	0.88	0.88	0.67	0.81



**Fig. 42.** Male of *Xenorhina tillacki* sp. nov. (ZMB 79532) with predominantly dark coloured dorsal surfaces.



**Fig. 43.** Forest floor at Gugusu, 500 m asl in the Muller Range where *Xenorhina tillacki* spec. nov. called from the litter.



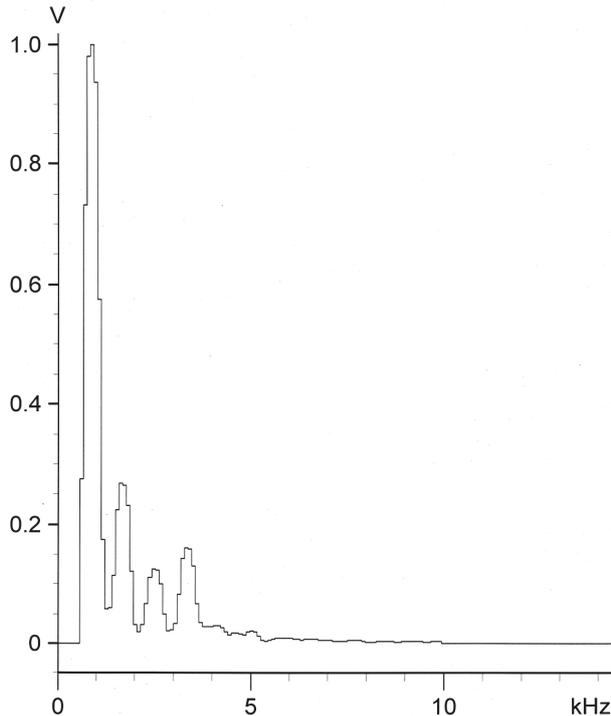
**Fig. 44.** Spectrogram of an advertisement call section of *Xenorhina tillacki* sp. nov.

surface layers of litter that had accumulated on the helipad clearing after heavy rain.

**Vocalization.** The advertisement call consists of long series of melodious piping notes (Fig. 44). Two calls produced by the holotype were recorded at an air temperature of 23 °C; they lasted 12 and 14 seconds. Note repetition rate was 3.6 notes/s in the first series and 3.3 notes/s in the second series. Note length varied from 58 to 77 ms (mean 70 ms, SD 4.16, n=80) and internote interval varied from 136–180 ms (mean 149 ms, SD 8.75, n=78). Dominant frequency and fundamental frequency are the same at around 0.9 kHz. Four upper harmonics (first and third most pronounced) appear in the power spectrum (Fig. 45).

**Etymology.** The specific name is gratefully dedicated to the senior author’s dear colleague and helper in many situations, the manager of the herpetological collection of the Museum für Naturkunde, Berlin, FRANK TILLACK, on the occasion of his 50<sup>th</sup> birthday at fifth June 2013. English name: Tillack’s Snouted Frog; German name: Tillacks Spitznasenfrosch.

**Comparison with other species.** Overall habitus, presence of two odontoid spikes on each vomero-palatine (Fig. 47) and a symphygnatine condition of the upper jaw clearly allocates the new species to the genus *Xenorhina*. Adult specimens of most of the 31 known species of this genus have a SVL of more than 25 mm (ZWEIFEL 1972, MENZIES & TYLER 1977, BLUM & MENZIES 1989, KRAUS

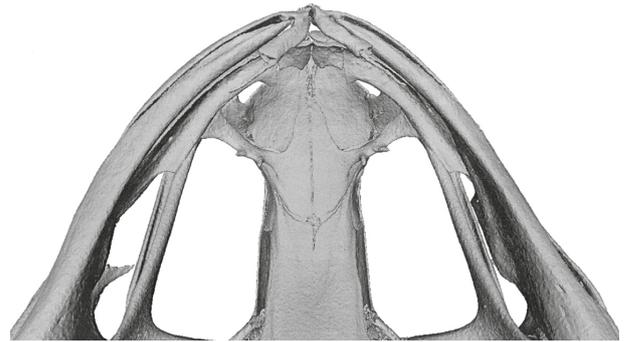


**Fig. 45.** Power spectrum of an advertisement call section of *Xenorhina tillacki* sp. nov.

& ALLISON 2002, MENZIES 2006, GÜNTHER 2010b). Only *X. anorbis*, *X. lanthanites* and *X. brachyrhyncha* have an SUL of less than 25 mm and vomero-palatine spikes. *X. anorbis* differs from *X. tillacki* by entirely lacking circum-marginal grooves on finger and toe discs, by much shorter tibiae (mean TL/SVL 0.29 according to an “older” measurement method which corresponds to less than 0.40 of the “new” method vs. 0.46) and by having a uniformly dull orange venter (MENZIES 2006). *X. lanthanites* differs from *X. tillacki* by the presence of only one vomero-palatine spike (vs. 2), by a more uniform colouration, by dorsal surfaces covered with many conspicuous tubercles and by the following different morphometric ratios T4D/SUL (0.027–0.036 vs. 0.037–0.044 in *X. tillacki*) and END/IND (0.94–1.20 vs. 1.31–1.33). Moreover, note and internote lengths are much longer and note repetition rate is slower in *X. lanthanites* (1.2–1.8 notes/s) than in *X. tillacki* (3.3–3.6 notes/s) (GÜNTHER & KNOP 2006). *X. brachyrhyncha* has only one odontoid spike, a shorter and broader snout (END/IND 1.06–1.13 vs. 1.31–1.33), a more uniform dorsal colouration and no white vertebral line.

### Acknowledgements

Fieldwork in Papua New Guinea by SJR was approved by the PNG National Research Institute and the PNG Department of Environment and Conservation. The Muller Range Rapid Assessment Program (RAP) biodiversity survey was a collaboration



**Fig. 46.** X-ray computed micro-tomography of the mouth roof of *Xenorhina tillacki* sp. nov. (SAMA R65067).

between Conservation International, A Rocha International, and the PNG Institute of Biological Research, and funding was provided by a grant from the HANS WILSDORF Foundation. Additional financial and logistical support was provided by Porgera Joint Venture (PJV) and SJR and CD are extremely grateful to PJV’s Environment and Community Affairs staff for wonderful assistance. The communities of Tobi in Western Province and Aluni in Southern Highlands Province generously allowed us to work on their land and freely shared their knowledge. ROSE SINGADAN and PAULUS KEI provided assistance at the University of PNG and we are also grateful to C. KOVACH and M. HUTCHINSON (South Australian Museum) who provided access to specimens in their care. SJR is also grateful to VICTORIA NIESI and the Conservation International-PNG team in Port Moresby who provided valuable logistical support and numerous other courtesies and to LISA CAPON who produced the map.

RG wishes to thank FRANK TILLACK (ZMB) for his various technical help especially with photographic work and KRISTIN MAHLOW (ZMB) for preparation of Figure 46.

### References

ALLISON, A. & KRAUS, F. (2003): A new species of *Austrochaperina* (Anura: Microhylidae) from northern Papua New Guinea. – *Journal of Herpetology*, **37**: 637–644.

BLUM, P. & MENZIES, J.I. (1989): Notes on *Xenobatrachus* and *Xenorhina* (Amphibia: Microhylidae) from the mountains of New Guinea with descriptions of nine new species. – *Alytes*, Paris, **7**: 125–163 (1988).

BURTON, T.C. (1990): The New Guinea genus *Copiula* MÉHELY (Anura: Microhylidae): a new diagnostic character and a new species. – *Transactions of the Royal Society of South Australia*, **114**: 87–93.

BURTON, T.C. & STOCKS, R. (1986): A new species of terrestrial microhylid frog from Papua New Guinea. – *Transactions of the Royal Society of South Australia*, **110**: 150–158.

DINGERKUS, G. & UHLER, L.D. (1977): Enzyme clearing of alcian blue stained whole small vertebrates for demonstration of cartilage. – *Stain Technology*, **52**: 229–232.

FRY, D.B. (1912): Description of *Austrochaperina* a new genus of Engystomatidae from north Australia. – *Records of the Australian Museum*, **9**(1): 87–106.

- GÜNTHER, R. (2001): The Papuan frog genus *Hylophorbus* (Anura: Microhylidae) is not monospecific: description of six new species. – *Russian Journal of Herpetology*, **8**(2): 81–104.
- GÜNTHER, R. (2002a): Westernmost records of the Papuan frog genus *Cophixalus* with descriptions of two new species (Amphibia, Anura, Microhylidae). – *Faunistische Abhandlungen* (Dresden), **23**(2): 35–58.
- GÜNTHER, R. (2002b): Beschreibung einer neuen *Copiula*-Art (Amphibia, Anura, Microhylidae) von der Insel Yapen im Nordwesten von Papua, Indonesien. – *Zoologische Abhandlungen* (Dresden), **52**: 77–86.
- GÜNTHER, R. (2003a): First record of the microhylid frog genus *Cophixalus* from western Papua, Indonesia, with descriptions of two new species (Anura, Microhylidae). – *Herpetozoa*, **16**(1/2): 3–21.
- GÜNTHER, R. (2003b): Three new species of the genus *Oreophryne* from western Papua, Indonesia. – *Spixiana*, **26**(2): 175–191.
- GÜNTHER, R. (2003c): Further new species of the genus *Oreophryne* (Amphibia, Anura, Microhylidae) from western New Guinea. – *Zoologische Abhandlungen* (Dresden), **53**: 65–85.
- GÜNTHER, R. (2006): Two new tiny *Cophixalus* species with reduced thumbs from the west of New Guinea (Anura: Microhylidae). – *Herpetozoa*, **19**(1/2): 59–75.
- GÜNTHER, R. (2010a): Another new *Cophixalus* species (Amphibia: Anura: Microhylidae) from western New Guinea. – *Bonn zoological Bulletin*, **57**(2): 231–240.
- GÜNTHER, R. (2010b): Description of a new microhylid frog species of the genus *Xenorhina* (Amphibia: Anura: Microhylidae) from the Fakfak Mountains, far western New Guinea. – *Vertebrate Zoology*, **60** (3): 217–224.
- GÜNTHER, R. & KNOP, R. (2006): A new species of *Xenobatrachus* (Anura, Microhylidae) with a striking resemblance to *Xenorhina bouwensi*. – *Zootaxa*, **1268**: 39–57.
- GÜNTHER, R. & RICHARDS, S. (2011): Five new microhylid frog species from Enga Province, Papua New Guinea, and remarks on *Albericus alpestris* (Anura, Microhylidae). – *Vertebrate Zoology*, **61**(3): 343–372.
- GÜNTHER, R., RICHARDS, S.J., BICKFORD, D. & JOHNSTON, G.R. (2012): A new egg-guarding species of *Oreophryne* (Amphibia, Anura, Microhylidae) from southern Papua New Guinea. – *Zoo-systematics and Evolution*, **88**(2): 223–230.
- GÜNTHER, R., RICHARDS, S.J. & ISKANDAR, D. (2001): Two new species of the genus *Oreophryne* from Irian Jaya, Indonesia (Amphibia, Anura, Microhylidae). – *Spixiana*, **24**(3): 257–274.
- GÜNTHER, R., RICHARDS, S., TJATURADI, B. & ISKANDAR, D. (2009): A new species of the microhylid frog genus *Oreophryne* from the Mamberano Basin of northern Papua Province, Indonesian New Guinea. – *Vertebrate Zoology*, **59**(2): 147–155.
- JAMES, J.M. & DYSON, H.J. (eds) 1980: Caves and karst of the Muller Range. – *Atea* 78. Newtown.
- KRAUS, F. (2011): New frogs (Anura: Microhylidae) from the mountains of western Papua New Guinea. – *Records of the Australian Museum*, **63**: 53–60.
- KRAUS, F. (2012). Papuan frogs of the genus *Cophixalus* (Anura: Microhylidae): new synonyms, new species, and a dichotomous key. – *Zootaxa*, **3559**: 1–36.
- KRAUS, F. (2013): A new species of *Hylophorbus* (Anura: Microhylidae) from Papua New Guinea. – *Current Herpetology*, **32**(2): 102–111.
- KRAUS, F. & ALLISON, A. (2002): A new species of *Xenobatrachus* (Anura: Microhylidae) from northern Papua New Guinea. – *Herpetologica*, **58**: 56–66.
- KRAUS, F. & ALLISON, A. (2006): Three new species of *Cophixalus* (Anura: Microhylidae) from southeastern New Guinea. – *Herpetologica*, **62**: 202–220.
- KRAUS, F. & ALLISON, A. (2009): New microhylid frogs from the Muller Range, Papua New Guinea. – *ZooKeys*, **26**: 53–76.
- MENZIES, J.I. (2006): The frogs of New Guinea and the Solomon Islands. – *Pensoft, Sofia-Moscow*, 346 pp.
- MENZIES, J.P. & TYLER, M.J. (1977): Systematics and adaptations of some Papuan microhylid frogs which live underground. – *Journal of Zoology*, London, **183**: 431–464.
- RICHARDS, S.J. & GAMUI, B. (editors) (2011): Rapid Biological Assessments of the Nakanai Mountains and the upper Strickland Basin: surveying the biodiversity of Papua New Guinea's sublime karst environments. – *RAP Bulletin of Biological Assessment* 60. Conservation International. Arlington, VA.
- RICHARDS, S.J. & ISKANDAR, D. (2000): A new minute *Oreophryne* (Anura: Microhylidae) from the mountains of Irian Jaya, Indonesia. – *The Raffles Bulletin of Zoology*, **48**(2): 257–262.
- RICHARDS, S.J., JOHNSTON, G.R. & BURTON, T.C. (1992): A new species of microhylid frog (genus *Cophixalus*) from the Star Mountains, central New Guinea. – *Science in New Guinea* **18**(3): 141–145.
- RICHARDS, S.J. & OLIVER, P. (2007): A new species of *Cophixalus* (Anura: Microhylidae) from Misima Island, Papua New Guinea. – *Pacific Science*, **61**(2): 279–287.
- RICHARDS, S.J. & OLIVER, P.M. (2010): A new scansorial species of *Cophixalus* (Anura: Microhylidae) from the Kikori River Basin, Papua New Guinea. – *Journal of Herpetology*, **44**(4): 555–562.
- TAKEUCHI, W. 2010: Additions to the rubiaceaceous flora of Papua New Guinea: *Psychotria stolonifera* and *P. ternatifolia*, two remarkable species from the Muller limestone. – *Phytotaxa*, **7**: 25–34.
- ZWEIFEL, R.G. (1972): Results of the Archbold Expeditions No. 97. A revision of the frogs of the subfamily Asterophryinae, family Microhylidae. – *Bulletin of the American Museum of Natural History*, **148**: 411–546.
- ZWEIFEL, R.G. (2000): Partition of the Australopapuan microhylid frog genus *Sphenophryne* with descriptions of new species. – *Bulletin of the American Museum of Natural History*, **253**: 1–130.
- ZWEIFEL, R.G. (2003): A new species of microhylid frog, genus *Oreophryne*, from Papua New Guinea. – *American Museum Novitates*, **3419**: 1–8.
- ZWEIFEL, R.G., COGGER, H.G. & RICHARDS, S.J. (2005): Systematics of microhylid frogs, genus *Oreophryne*, living at high elevations in New Guinea. – *American Museum Novitates*, **3495**: 1–25.