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Description of a new *Xenorhina* species (Anura, Microhylidae) from northwestern Papua New Guinea

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Abstract

We describe a new species of the asterophryine microhylid genus *Xenorhina* from the lowlands of northwestern Papua New Guinea. It is a medium-sized species (SUL of two males 29.2 and 29.9 mm; of four females 29.9–33.0 mm) that can be distinguished from congeners by having a single short, triangular odontoid spike (palatal tooth) on each vomeropalatine bone, moderately short legs (TL/SUL 0.40–0.44) and ventral surfaces heavily spotted with reddish-brown blotches or reticula. The advertisement call comprises 7–10 loud, melodious hooting notes lasting 141–165 ms and produced at a repetition rate of 2.19–2.35 notes/s. Description of this species brings to 41 the number of *Xenorhina* known from New Guinea and surrounding islands.

Key words

Amphibia, New Guinea, Sepik River Basin, new species, advertisement call, taxonomy, ecofaunistics

Introduction

The asterophryine microhylid genus *Xenorhina* Peters, 1863 currently contains 40 named species of generally squat, short-legged frogs with narrow snouts and small eyes, all of them confined to the New Guinea region (Zweifel 1972; Blum and Menzies 1989; Menzies 2006; Frost 2021; Günther and Richards 2021). Most members of the genus are fossorial or terrestrial (Menzies and Tyler 1977), but three species (*X. arboricola* Allison and Kraus, 2000, *X. macrodisca* Günther and Richards, 2005 and *X. varia* Günther and Richards, 2005) are mainly arboreal. Recent studies of *Xenorhina* have improved knowledge of the genus in western (Günther and Richards 2005; Günther and Knop 2006; Günther et al. 2020) and southern (Günther et al. 2009; Kraus 2011; Günther and Richards 2021) New Guinea. By contrast, knowledge of the *Xenorhina* fauna of northern Papua New Guinea remains relatively scant, the most recent taxonomic treatment of material from the region being the description of *Xenorhina zweifeli* (Kraus and Allison, 2002) nearly two decades ago.

During a study of the beta diversity of frogs across the extensively forested lowlands of the Sepik River catchment in northern Papua New Guinea (Dahl et al. 2009, 2013), one of the authors (CD) encountered an unnamed *Xenorhina* with a striking pattern of spots and reticulations

across the venter. It belongs to a group of *Xenorhina* that exhibits a single enlarged odontoid spike on each vomeropalatine bone but differs from all congeners by its bold ventral pattern, unique advertisement call and a suite of mensural characters. The new species is known from two locations approximately 150 km apart in the vast lowlands of the Sepik River catchment in northwestern Papua New Guinea, and its description brings to 41 the number of described species in the genus.

Material and methods

Male frogs were located at night by their advertisement calls; females were encountered while digging for calling males. Specimens were euthanized in an aqueous chlorobutanol solution (Gamble 2014) and subsequently fixed in 5 % formalin. All specimens were transferred to 70 % ethanol within two days of fixation. The following measurements were taken with a digital calliper (> 10 mm) or with a binocular dissecting microscope fitted with an ocular micrometer (< 10 mm) to the nearest 0.1 mm from preserved specimens: **SUL** – snout-urostyle length from tip of snout to posterior tip of urostyle bone; **SUL** is generally slightly shorter than snout-vent length (**SVL**). As the measurement error is higher in the latter, we prefer to use the former. Both measurements are sufficiently similar (unpublished data) that, where relevant, we compare our **SUL** measurements with **SVL**s presented for members of the genus in some papers; **TL** – tibia length: external distance between knee and tibio-tarsal articulation (referred to herein as 'shank'); some measurements of **TL** from the literature use a method introduced by Zweifel (1972) that took measurements from the fold of skin on the knee to the heel, producing shorter tibia lengths; we extrapolate these to standard measurements using known ratios of differences between the two techniques; **TaL** – length of tarsus: external distance between tibio-tarsal and tarsal-metatarsal joints held at right angles; **T4L** – length of 4th toe: from tip of toe to proximal end of inner metatarsal tubercle; **T4D** – transversal diameter of disc of 4th toe; **T1D** – transversal diameter of disc of first toe; **F3L** – length of 3rd finger: from tip of 3rd finger to proximal edge of palm; **F3D** – transversal diameter of disc of 3rd finger; **F1D** – transversal diameter of disc of first finger; **HL** – head length, from tip of snout to posterior margin of tympanum; **HW** – maximum head width, taken in the region of the tympana; **SL** – snout length, from an imaginary line connecting the centres of the eyes to tip of the snout; **EST** – distance from anterior corner of orbital opening to tip of snout; **END** – distance from anterior corner of orbital opening to centre of naris; **IND** – internarial distance between centres of nares; **ED** – eye diameter, from anterior to posterior corner of orbital opening; **TyD** – horizontal diameter of tympanum.

Absence of clavicles and procoracoids was veryfied by CT scans. Sex was determined by observations of calling, presence of vocal slits and/or testes (males), or absence of vocal slits and/or presence of eggs (females). Advertisement calls were recorded with a Sony TCM-5000 Tape Recorder and a Sennheiser ME66 shotgun microphone and analysed with Avisoft-SAS Lab Pro software. Air temperature adjacent to the calling male was recorded using a rapid-reading digital thermometer. Terminology and acoustic analysis procedures mostly follow Köhler et al. (2017). Accordingly, and following Günther et al. (2020), we consider the multi-note vocalisations of this species to be 'call series' containing multiple single calls (= notes). However, we note that these call series could equally be considered a single call containing multiple single notes. Colour of the holotype in life was described from digital photographs, and of preserved specimens from direct observations. Most colours were determined according to a colour matching system created and administrated by the German RAL GmbH (https://en.wikipedia.org/wiki/RAL_colour_standard). When it was not possible to find an exact match between observed colours and RAL colour numbers, the most similar RAL number was chosen.

Measurements are presented as arithmetic means ± Standard Deviation. Specimens are deposited in the collections of the South Australian Museum, Adelaide, Australia (SAMA) and the Museum für Naturkunde, Berlin (ZMB). One paratype (SJR3914) will be repatriated to the Papua New Guinea National Museum (PNGNM). SJR is the field number of Stephen Richards. Abbreviations for other institutions mentioned are: American Museum of Natural History, New York, U.S.A. (AMNH); Bernice P. Bishop Museum, Hawaii, U.S.A. (BPBM); Institut Royal des Sciences Naturales de Belgique, Brussels (IRSNB); Museo Civico di Storia Naturale di Genova, Genoa, Italy (MSNG); Museum of Comparative Zoology, Harvard, U.S.A. (MCZ); Museum Zoologicum Bogoriense, Cibinong, Indonesia (MZB); National Museum of Natural History, now Naturalis Biodiversity Center, Leiden, The Netherlands (RMNH); University of Papua New Guinea, Port Moresby (UP); Zoological Museum Amsterdam, now Naturalis Biodiversity Center, Leiden, The Netherlands (ZMA).

Specimens examined for comparative purposes are listed in Appendix 1. Additional morphometric and other data were extracted from original species descriptions and/or recompiled treatises, particularly Zweifel (1972), Blum and Menzies (1989), Kraus and Allison (2002) and Menzies (2006).

Systematics

Specimens were assigned to the genus *Xenorhina* on the basis of the following combination of features: jaw symphygnathine (maxillae meeting in front of the premaxillae); clavicles and procoracoids absent; a conspicuous spike present on each vomeropalatine bone; body squat; head small, triangular, with small eyes; life style subterrestrial.

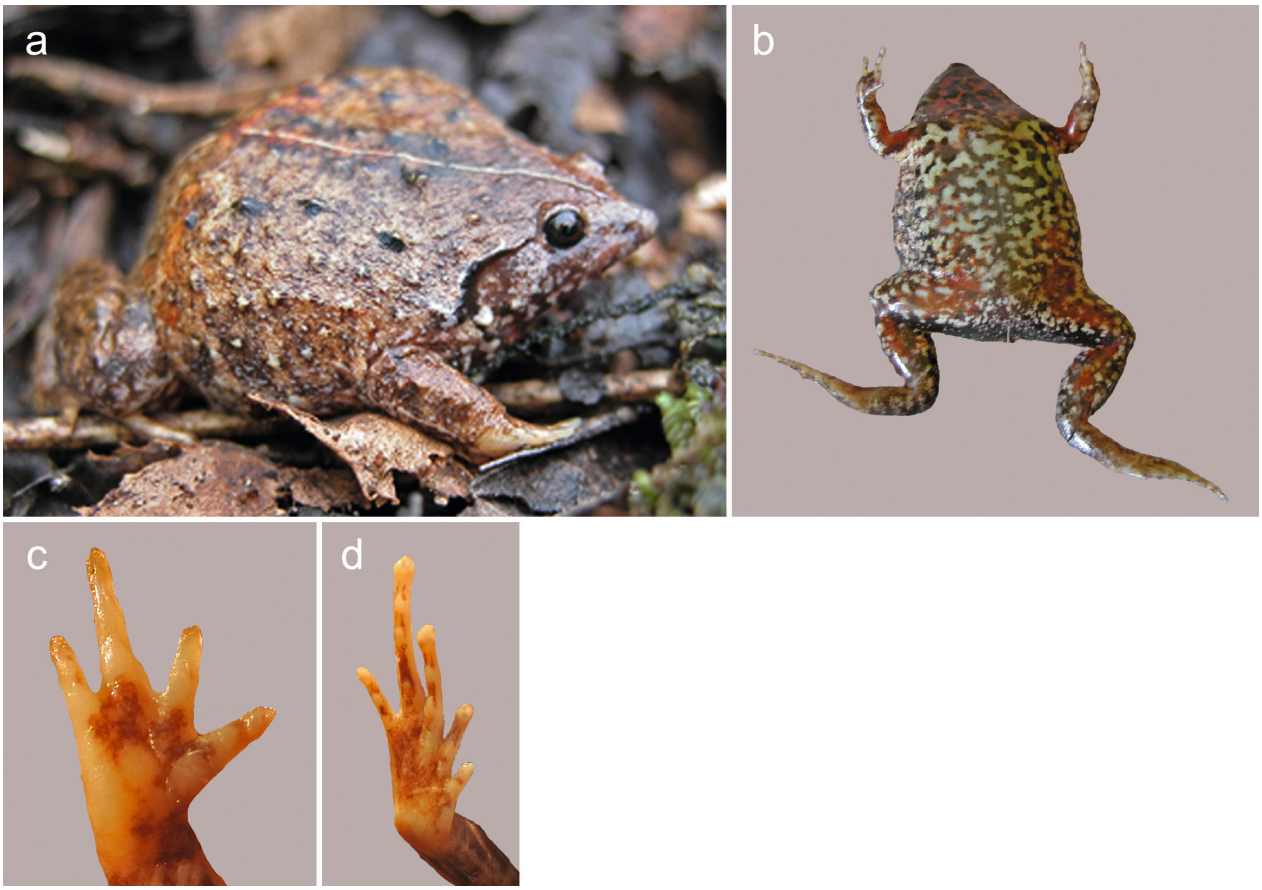

Figure 1. Holotype (SAMA R71741) of *Xenorhina ventrimaculata* sp. nov. (a) dorsolateral view in life, (b) ventral view in life; (c) ventral view of right hand of preserved specimen, (d) ventral view of right foot of preserved specimen.

Xenorhina ventrimaculata sp. nov.

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Holotype. SAMA R71741 (SJR 3689), adult male, collected adjacent to Utai Village, West Sepik (Sandaun) Province, Papua New Guinea (3.3875°S, 141.5853°E; 210 m a.s.l.) on 29/05/2004 by C. Dahl.

Paratypes. ZMB 91632 (SJR3694), adult male, same details as holotype but collected on 31/05/2004; SAMA R71742 (SJR3872), adult female, collected at Yapsiei Village, West Sepik (Sandaun) Province, Papua New Guinea (4.6284°S, 141.0962°E; 180 m a.s.l.) on 25/06/2004 by C. Dahl; SAMA R71743 (SJR3887), ZMB 91633 (SJR3888), PNGNM (SJR3914), same details as for SAMA R71742, but SAMA R71743 and ZMB 91633 (SJR3888) collected on 27/06/2004 and PNGNM (SJR3914) collected on 01/07/2004.

Diagnosis. A species of *Xenorhina* characterized by the unique combination of: medium size (SUL of two males 29.2–29.9 mm; of four females 29.9–33.0 mm); vomeropalatines each with one short triangular odontoid spike; legs moderately short (TL/SUL 0.40–0.44); all fingers and toe 1 without, and toes 2–5 with, expanded terminal discs; eye-naris distance greater than internarial distance (END/IND 1.10–1.21); tympanum about same size as eye (TyD/ED 0.95–1.16); dorsal surfaces in life different tones of brown with small blackish spots; ventral surfaces light ivory heavily spotted with reddish-brown blotches or reticula; advertisement calls uttered in series containing 7–10 loud hooting calls = notes each lasting 141–165 ms and produced at a rate of 2.19–2.35 calls/s.

Description of the holotype. Adult male with vocal slits, calling when collected. Measurements are summarized in Table 1, a dorsolateral view in life is shown in Fig. 1a and ventral surfaces in life in Fig.1b. Head broader than long (HL/HW 0.81); snout acuminate from above and below, distinctly protruding in profile; vomeropalatines each with one short, triangular and acuminate odontoid spike; loreal region oblique, no canthus rostralis; nostrils near tip of snout, directed dorsolaterally, visible from above but not from below; eye-naris distance greater than internarial distance (END/IND 1.21); tympanum visible in life and preservative, its diameter slightly less than that of eye (TyD/ED 0.95); supratympanic fold weakly expressed, extending from behind eye to behind tympanum; fingers moderately short, not webbed; tips of all fingers with barely detectable circum-marginal grooves, tips not wider than penultimate phalanges; subarticular and metacarpal tubercles barely visible; relative lengths of fingers 3>4>2>1 (Fig. 1c); shank short (TL/SUL 0.42); all toe tips with circum-marginal grooves and, with exception of toe 1, tips wider than penultimate phalanges; toes not webbed, most subarticular tubercles and oval inner metatarsal tubercle moderately well defined; relative lengths

Table 1. Body measurements and body ratios of the type series of *Xenorhina ventrimaculata* sp. nov. SAMA R71741 is the male holotype, others are paratypes. All measurements are in mm; M = male; F = female; for explanation of other abbreviations see "Material and methods".

Reg.-No.	SAMA R71741	ZMB 91632	SAMA R71742	SAMA R71743	ZMB 91633	PNGNM (SJR3914)	Mean ± SD
Sex	M	M	F	F	F	F	
SUL	29.2	29.9	33.0	32.0	29.9	31.4	
TL	12.2	11.9	13.8	13.8	13.2	13.3	
TaL	7.6	8.1	9.0	9.3	8.7	8.9	
T4L	12.0	12.1	13.4	14.2	13.3	13.8	
T4D	0.9	0.9	1.0	1.0	1.1	0.9	
T1D	0.5	0.5	0.7	0.7	0.6	0.7	
F3L	6.1	5.3	6.6	6.0	5.9	6.0	
F3D	0.4	0.5	0.7	0.7	0.6	0.6	
F1D	0.4	0.45	0.5	0.5	0.5	0.6	
HL	9.2	7.9	8.0	9.1	11.0	8.6	
HW	11.4	11.2	11.3	10.6	11.0	10.8	
END	2.3	2.3	2.4	2.4	2.2	2.2	
IND	1.9	2.0	2.1	2.1	2.0	2.0	
SL	4.0	3.9	3.9	3.6	3.5	3.8	
EST	3.2	3.1	3.3	3.5	3.2	3.1	
ED	2.0	2.0	2.1	1.9	2.1	2.1	
TyD	1.9	2.2	2.0	2.2	2.0	2.1	
TL/SUL	0.42	0.40	0.42	0.43	0.44	0.42	0.42±0.013
TaL/SUL	0.26	0.27	0.27	0.29	0.29	0.28	0.27±0.012
T4L/SUL	0.41	0.40	0.41	0.44	0.44	0.44	0.42±0.018
T4D/SUL	0.031	0.030	0.030	0.031	0.037	0.029	0.031±0.003
T1D/SUL	0.017	0.017	0.021	0.022	0.020	0.022	0.020±0.002
F3L/SUL	0.21	0.18	0.20	0.19	0.20	0.19	0.20±0.010
F3D/SUL	0.014	0.017	0.021	0.022	0.020	0.022	0.019±0.003
F1D/SUL	0.014	0.015	0.015	0.016	0.017	0.019	0.016±0.002
T4D/F3D	2.25	1.80	1.40	1.40	1.20	1.50	1.70±0.297
T1D/F1D	1.25	1.11	1.40	1.40	1.20	1.17	1.26±0.121
HL/SUL	0.32	0.26	0.24	0.28	0.27	0.27	0.27±0.026
HW/SUL	0.39	0.37	0.34	0.33	0.37	0.34	0.36±0.023
HL/HW	0.81	0.71	0.71	0.86	0.75	0.80	0.77±0.060
END/SUL	0.079	0.077	0.073	0.075	0.074	0.070	0.075±0.003
IND/SUL	0.065	0.067	0.064	0.066	0.067	0.064	0.066±0.001
END/IND	1.21	1.15	1.14	1.14	1.10	1.10	1.14±0.040
ED/SUL	0.068	0.067	0.064	0.059	0.070	0.067	0.066±0.004
TyD/SUL	0.065	0.074	0.061	0.069	0.067	0.067	0.067±0.004
TyD/ED	0.95	1.10	0.95	1.16	0.95	1.00	1.02±0.090
SL/SUL	0.137	0.130	0.118	0.113	0.117	0.121	0.123±0.009
EST/SUL	0.110	0.104	0.100	0.109	0.107	0.099	0.105±0.005

of toes 4>3>5>2>1 (Fig. 1d). Body laterally with numerous irregularly shaped and irregularly arranged tubercles; dorsally posterior of head with four regularly spaced longitudinal tubercle rows (two paravertebral and two dorsolateral); dorsal surfaces of head, limbs, and all ventral surfaces without tubercles; tip of snout smooth.

In life dorsal surfaces of head, body and extremities mostly ochre-brown (RAL 8001); posterior back with extended daffodil yellow (RAL 1007) flecks; tubercles on dorsum mainly black-brown (RAL 8022) with light ivory (RAL 1015) apices; a black-brown stripe runs along supratympanic ridge. Ventral surfaces mostly light ivory (RAL 1015) with beige-grey (RAL 7006) reticulation and diffuse orange-brown (RAL 8023) spots on extremities and both sides of abdomen; throat orange-brown with black-brown spots. Iris predominantly blackish.

In preservative ground colour of dorsal surfaces of head, back and extremities beige (RAL 1001) with some inconspicuous brown-beige (RAL 1011) spots. Supratympanic ridge and cutaneous tubercles partly (especially on their bases) black-brown; rear of thighs predominantly fawn-brown (RAL 8007). Basic colour of ventral surfaces light ivory; flecks on chest, abdomen, and extremities beige-brown; throat light ivory with mahogany-brown

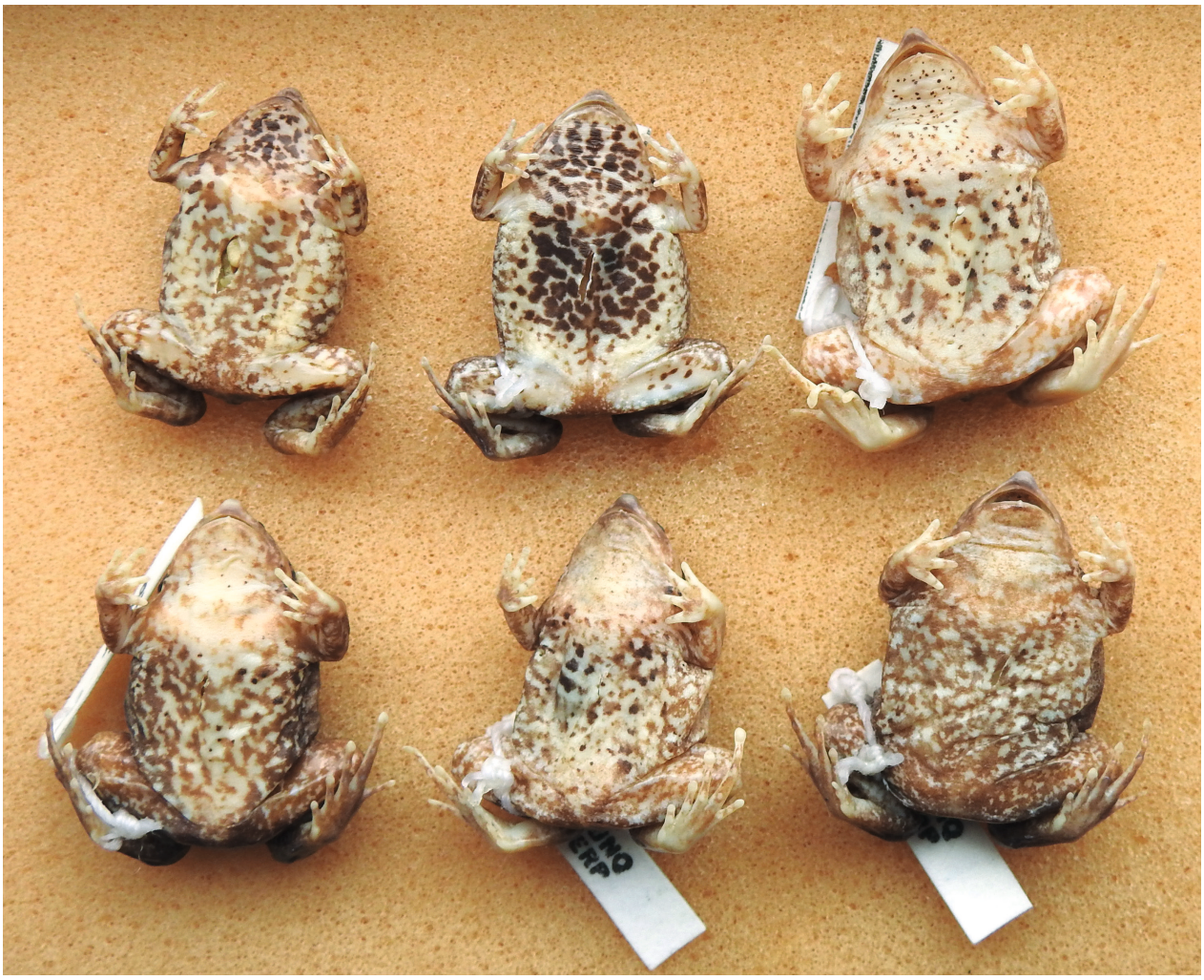

Figure 2. Ventral view of the preserved type series of *Xenorhina ventrimaculata* sp. nov. Top row: left holotype SAMA R71741, middle ZMB 91632, right SAMA R71742; bottom row: left PNGNM (SJR 3914), middle ZMB 91633, right SAMA R71743.

(RAL 8016) flecking. Narrow light ivory middorsal line from between eyes to cloaca continues on to rear of hind limbs and is vaguely detectable on abdomen.

Morphological variation. Measurements and proportions of most paratypes show limited variation (Table 1). Two males measure 29.2 and 29.9 mm and four females 29.9–33.0 mm SUL, indicating that sexual size dimorphism is slight. Ground colour of the dorsal surfaces in preservative of SAMA R71742 and ZMB 91633 is beige, as in the holotype, but in the remaining types is light mahogany brown. All paratypes except ZMB 91632 have a narrow light ivory middorsal line; none exhibits lumbar spots. Most specimens have variable numbers of small blackish dorsal and/or dorsolateral spots closely associated with cutaneous tubercles. Tip of snout is light grey and smooth in all specimens. Colouration of ventral surfaces in all specimens is light ivory covered with beige brown (e.g. PNGNM [SJR 3914]) to mahogany brown (e.g. ZMB 91632) spots or reticula (Fig. 2). Size and extent of pigment spots on throat varies from almost unspotted (PNGNM [SJR 3914]) to extensively covered with small (SAMA R71742) or large ZMB 91632 spots.

Vocalization. Eight call series from the holotype recorded at an air temperature of 26.0°C were analysed. Data are presented as range and Mean±SD. Call series contain 7–10 calls (= notes) (mean 9.1±1.13; n=8) lasting 3.2–4.5 s (mean 3.98±0.48 s; n=8) at a repetition rate of 2.19–2.35 calls/s (mean 2.29±0.06; n=8). Call (= note) duration is 141–165 ms (mean 151.6±4.36 ms; n=73), with call intervals of 262–498 ms (mean 322.5±46.7 ms; n=65). Calls are unpulsed and the first call in most series is slightly longer than subsequent ones. Call intervals tend to become longer during the course of each series, and the last interval is clearly greater than preceding ones. Unlike many other *Xenorhina* species, neither volume (Fig.3, upper) nor pitch of calls (Fig. 3, lower) increase during the series. Calls start abruptly at maximum amplitude, and amplitude decreases rapidly at the very beginning and then gradually until end of call (Fig. 3, upper). Frequency decreases slightly at the very end of each call (Fig. 3, lower), where this pattern is most evident in the upper harmonics). All calls have four well-defined harmonics, with maximum energy at 0.85 kHz, 1.70 kHz, 2.55 kHz and 3.40 kHz. The first harmonic with peak at 0.85 kHz is clearly the dominant one (Fig. 4).

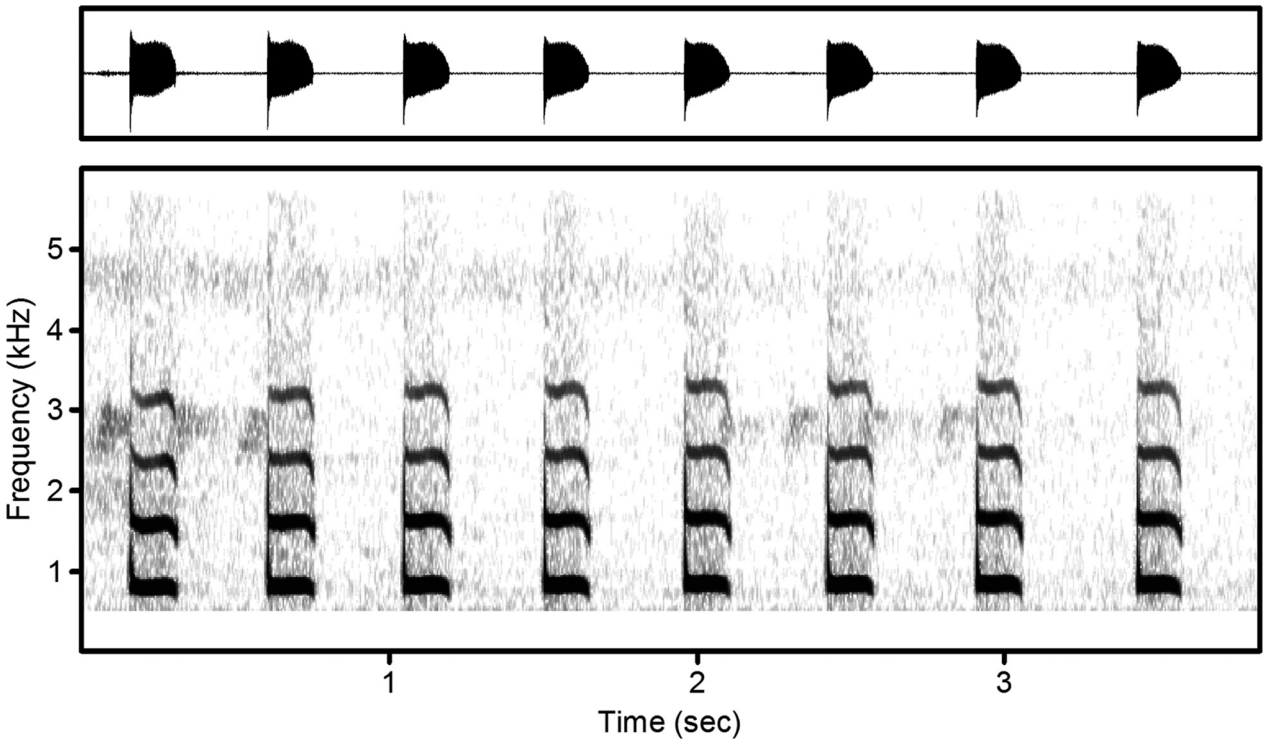

Figure 3. Waveform (upper) and spectrogram (lower) of a complete advertisement call series with eight calls from the holotype (SAMA R71741) of *Xenohrina ventrimaculata* sp. nov. Spectrogram parameters: FFT length 512; Frame size 75 %; Window Flat-Top; Bandwidth 117 Hz; Resolution 23 Hz; Overlap 87.5 %. Sampling rate conversion from 22050 Hz to 12000 Hz. Basic noise was deleted up to 500 Hz.

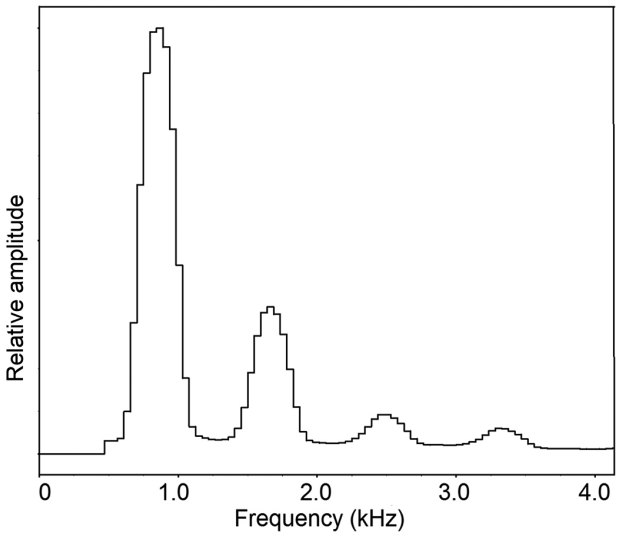

Figure 4. Amplitude spectrum of the advertisement call series shown on Fig. 3

Distribution and ecological notes. *Xenorhina ventrimaculata* sp. nov. is known with certainty from two locations approximately 150 km apart in the lowlands of the Sepik River basin in northwestern Papua New Guinea (Fig. 5). An additional male specimen (SAMA R71744) from Wamangu Village, about 300 km northeast of the type locality (Fig. 5), closely resembles this species in its ventral colouration but is substantially larger than the two male types (39.5 mm vs. 29.2 and 29.9 mm SUL) and further differs in a number of body ratios. We refrain from including it in the type series and consider the taxonomic status of the Wamangu population to be uncertain pending the collection of additional information.

The habitat at the type locality at Utai is secondary lowland forest, where both the holotype and paratype ZMB 91632 were calling from beneath leaf litter after rain at night. At Yapsiei this species was found in primary lowland forest, where all specimens were found between 1.5–3.0 cm beneath the soil surface when attempting to locate calling males. The local name for this species at Utai is *Mopepe*.

Etymology. The specific epithet is an adjective compound of two Latin words. Venter is a substantive and means belly or underside of the body and maculata is a feminine adjective meaning flecked or spotted. The specific epithet refers to the conspicuously spotted ventral surfaces of most specimens of the new species.

Comparisons with other species. *Xenorhina* includes a group of species with one or more distinct odontoid spikes on each vomeropalatine bone (formerly allocated to the genus *Xenobatrachus*) and another group lacking spikes on the vomeropalatines. *Xenorhina ventrimaculata* sp. nov. belongs to the former group and we compare it here only with other *Xenorhina* species of a similar size (25–38 mm SUL) that have a single odontoid spike on the vomeropalatines. Note that the terms call and note are used synonymously.

Xenorhina fuscigula (Blum & Menzies, 1989) has shorter legs than *Xenorhina ventrimaculata* sp. nov.

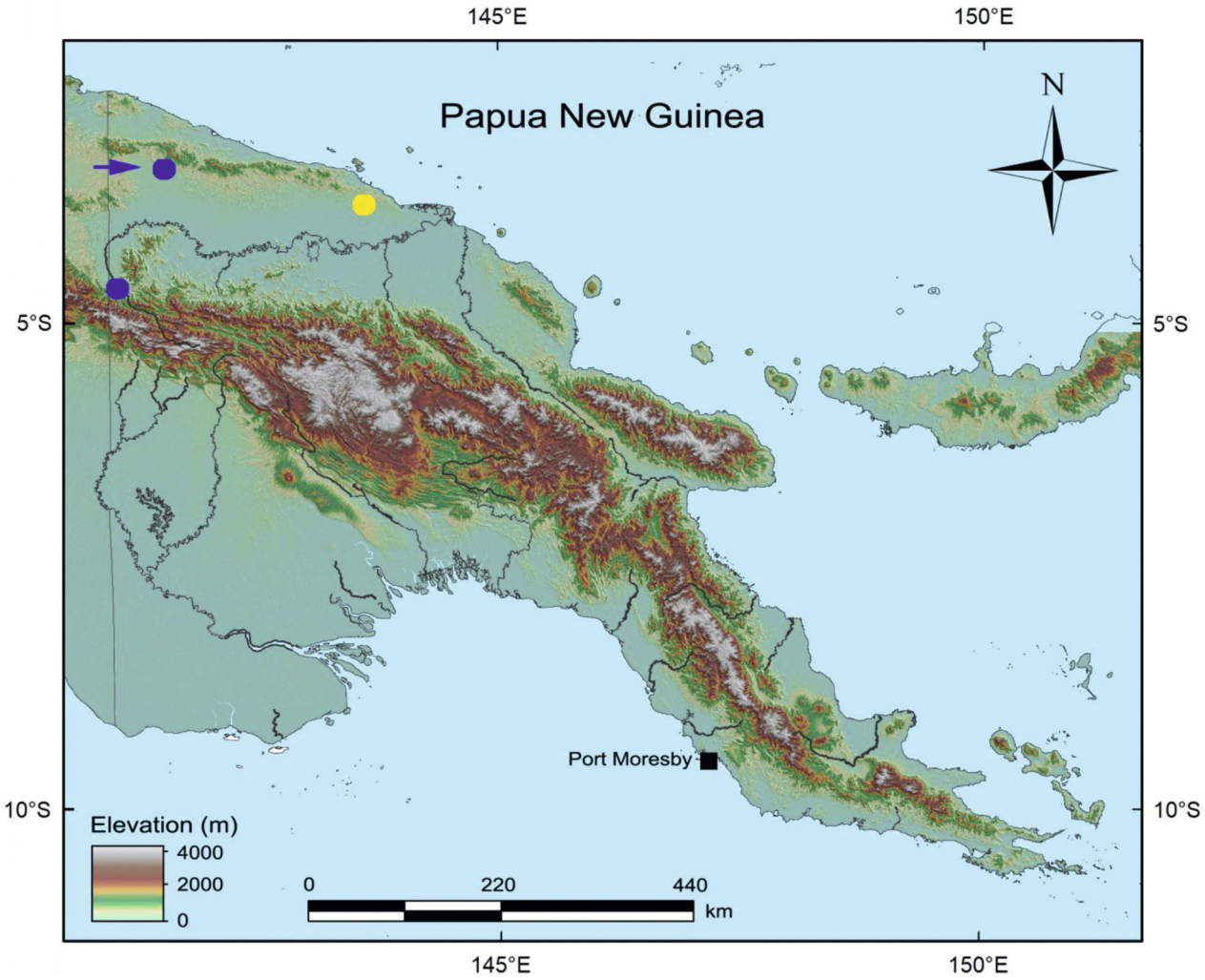

Figure 5. Distribution of *Xenorhina ventrimaculata* sp. nov. (blue circles); the arrow indicates the type locality. The yellow circle shows the collection locality of a morphologically similar but much larger specimen that is not included in the type series (see text).

(TL/SUL < 0.33 vs. > 0.40), a smaller internarial distance (IND/SUL < 0.64 vs. > 0.64), a smaller eye-naris distance (END/SUL 0.064–0.074 vs. 0.070–0.081), a shorter fourth toe (T4L/SUL 0.34–0.41 vs. 0.40–0.44) and its call is a single note (vs. 7–10 notes in *Xenorhina ventrimaculata* sp. nov.).

Xenorhina huon (Blum & Menzies, 1989) has shorter legs (TL/SUL < 0.38 vs. > 0.40), a ventral colour pattern varying from dark pigmentation near-absent to near-complete dense covering (see Fig. 71 in Zweifel 1972 [as *Xenobatrachus rostratus* (Méhely, 1898)]) and no mid-dorsal line (vs. mid-dorsal line present in almost all specimens of *Xenorhina ventrimaculata* sp. nov.).

Xenorhina lacrimosa Günther & Richards, 2021 is larger than *Xenorhina ventrimaculata* sp. nov. (SUL of five adult males 34.5–41.0 mm vs. 29.2–29.9 mm in two male *Xenorhina ventrimaculata* sp. nov. and 34.3 mm in one female *X. lacrimosa* vs. 29.9–33.0 mm in four female *Xenorhina ventrimaculata* sp. nov.). *Xenorhina lacrimosa* also has wider discs on fourth toes (T4D/SUL 0.036–0.043 vs. 0.029–0.037), wider discs on first toes (T1D/SUL 0.023–0.027 vs. 0.017–0.022), a greater END/IND ratio (1.18–1.48 vs. 1.10–1.21); and a call repetition rate of 0.20–0.27 calls/s vs. 2.2–2.4 calls/s in *Xenorhina ventrimaculata* sp. nov.

Xenorhina mehelyi (Boulenger, 1898) has longer legs (TL/SUL > 0.44 vs. < 0.44), larger eyes (ED/SUL 0.067–0.079 vs. 0.056–0.070) and advertisement calls containing about 17 calls (vs. 7–10 calls in *Xenorhina ventrimaculata* sp. nov.) with call intervals of 1500 ms on average (Blum and Menzies 1988) (vs. 323 ms on average) and a mean repetition rate of 0.6 calls/s in *X. mehelyi* (vs. 2.3 calls/s in *Xenorhina ventrimaculata* sp. nov.).

Xenorhina schiefenhoeveli (Blum & Menzies, 1989) has shorter legs (TL/SUL < 0.40 vs. > 0.40), larger eyes (ED/SUL 0.071–0.081 vs. 0.056–0.070), and call series containing more than 100 (vs. 7–10) shorter calls (about 100 ms on average vs. about 150 ms on average).

Xenorhina subcrocea (Menzies & Tyler, 1977) has longer legs (TL/SUL > 0.44 vs. < 0.44), a smaller internarial distance (IND/SVL 0.059 vs. 0.064–0.067), a higher END/IND ratio (1.26–1.33 vs. 1.10–1.23), larger eyes (ED/SUL 0.071–0.072 vs. 0.056–0.070), shorter calls (64–69 ms vs. 141–165 ms) with shorter call intervals (154–285 ms vs. 262–498 ms) and a lower dominant frequency (0.40 vs. 0.85 kHz).

Xenorhina tumulus (Blum & Menzies, 1989) is slightly smaller than *Xenorhina ventrimaculata* sp. nov. (SVL of three males 26.0–28.7 mm vs. 29.2–29.9 mm SUL in two males), has short, round palatine spikes (vs. triangular

spikes with pointed tips), ventrum pinkish mottled with brown (vs. light ivory mottled with reddish-brown), rear of thighs very dark (vs. not dark), and call series with up to 17 (vs. 7–10), shorter (100 ms vs. > 140 ms) calls.

Xenorhina wiegankorum Günther & Richards, 2021 is larger than *Xenorhina ventrimaculata* sp. nov. (SUL of five adult males 32.0–35.7 mm vs. 29.2–29.9 mm in two male *Xenorhina ventrimaculata* sp. nov.); has longer shanks (TL/SUL 0.44–0.47 vs. 0.40–0.44); longer tarsi (TaL/SUL 0.29–0.31 vs. 0.26–0.29); longer fourth toes (T4L/SUL 0.45–0.47 vs. 0.40–0.44); wider discs on first toes (T1D/SUL 0.023–0.030 vs. 0.017–0.022); wider discs on third fingers (F3D/SUL 0.020–0.028 vs. 0.014–0.022); wider discs on first fingers (F1D/SUL 0.020–0.025 vs. 0.014–0.019); longer call series (13.8–18.1 s vs. 3.2–4.5 s) with shorter calls (60–104 ms vs. 141–165 ms) having a lower dominant frequency (0.55 kHz vs. 0.85 kHz), and produced at a slower repetition rate (1.71–2.15 vs. 2.19–2.35).

Xenorhina woxvoldi Günther & Richards, 2021 has shorter legs than *Xenorhina ventrimaculata* sp. nov. (TL/SUL 0.36 vs. 0.40–0.44); wider discs on fourth toes (T4D/SUL 0.038–0.040 vs. 0.029–0.037); wider discs on third fingers (F3D/SUL 0.024–0.027 vs. 0.014–0.022); wider discs on first finger (F1D/SUL 0.020–0.021 vs. 0.014–0.019); a shorter distance between eye and naris (END/SUL 0.056–0.060 vs. 0.070–0.079), a lower END/IND ratio (0.80–0.90 vs. 1.10–1.21); and shorter calls = notes (37–84 ms vs. 141–165 ms) produced at a higher repetition rate (4.0–4.5 calls/s vs. 2.19–2.35 calls/s).

Xenorhina zweifeli (Kraus & Allison, 2002) is larger than *Xenorhina ventrimaculata* sp. nov. (SVL of 10 specimens 33.2–38.0 mm vs. SUL of six specimens 29.2–33.0 mm), has a smaller internarial distance (IND/SVL 0.052–0.063 vs. 0.064–0.067), ventral surfaces sparsely flecked (vs. intensively spotted), and advertisement calls consisting of a single note repeated at irregular intervals with lengths of 207–380 ms (vs. 7–10 calls repeated in rapid succession with lengths of 141–165 ms).

Discussion

The Sepik River in northern Papua New Guinea is the country's largest river system, and the river and its associated floodplains and lakes bisect a vast expanse of relatively uniform lowland tropical rainforest (Novotny et al. 2007). Few studies of amphibians have been conducted in these lowland forest habitats, and a large proportion of the fauna remains undescribed. For example, Austin et al. (2008) reported that 42% of 33 species encountered during an intensive survey at Utai on the western edge of the Sepik catchment were undescribed or unidentifiable and Dahl et al. (2013) reported a similar result (nearly 40%) for 44 frog species encountered at five sites across the catchment.

Our study adds to a growing effort to better document the frog fauna of northwestern Papua New Guinea and builds on important contributions to knowledge about patterns of species diversity and distributions (Kraus and Allison 2006; Austin et al. 2008; Dahl et al. 2009; Kraus 2010) and taxonomy (Allison and Kraus 2000; Kraus and Allison 2000, 2001, 2002; Richards 2007; Kraus 2013). Much of this effort has focused on frogs occupying the outlying north-coast ranges including the Bewani, Hunstein, Torricelli and Prince Alexander Mountains (e.g. Kraus and Allison 2002, 2006; Kraus 2013a,b). These mountain ranges are derived from offshore island arcs that have accreted onto the New Guinea mainland over the past 20 million years (Davies et al. 1997; Davies 2012) and the discovery and descriptions of numerous new frog species in these mountains, many with limited known distributions (e.g. Allison and Kraus 2000; Kraus and Allison 2000, 2001, 2002, 2009; Kraus 2013a,b), suggests that these accreted island arc systems have contributed to the generation of high levels of regional amphibian endemism.

The drivers of amphibian diversity in New Guinea's lowland forests are less well understood. Dahl et al. (2013) found that the Sepik River does not represent a major barrier to frog dispersal. In the absence of major topographical barriers most frog species documented in the lowlands and foothills north of New Guinea's central cordillera have broad distributions (Kraus and Allison 2006; Dahl et al. 2009, 2013; Kraus 2010). *Xenorhina ventrimaculata* sp. nov. appears to fit this pattern, with the two known sites being about 150 km apart. However, documenting the true extent of its distribution will require further survey effort in this underdocumented region of Papua New Guinea.

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Appendix 1

Specimens examined

Species	Location	Registration numbers
Xenorhina adisca Kraus and Allison, 2003	Indonesia: Papua Province: Tembagapura	MZB Amph.8403 (holotype)
Xenorhina arboricola Allison and Kraus, 2000	Papua New Guinea: West Sepik Province: Mt Menawa	BPBM 13747 (paratype)
Xenorhina arboricola	Papua New Guinea: West Sepik Province: Mt Hunstein	BPBM 13745 (paratype)
Xenorhina arndti Günther, 2010	Indonesia: Papua Province: Bomberai Peninsula	ZMB 74629–31 (type series)
Xenorhina bidens van Kampen, 1909	Indonesia: Papua Province: "Digul-Fluss"	ZMA 5705 (holotype)
Xenorhina bouwensi (De Witte, 1930)	Indonesia: West Papua Province: Arfak Mountains	IRSNB 1019 (holotype), plus several specimens collected by R. Günther between 1998–2008 and stored in the ZMB collection
Xenorhina eiponis Blum and Menzies, 1989	Indonesia: Papua Province: Eipomek Valley	AMNH 128234 (paratype)
Xenorhina gigantea van Kampen, 1915	Indonesia: Papua Province: Snow Mountains	ZMA 5702 (lectotype), ZMA 5703 (paralectotype)
Xenorhina lacrimosa Günther and Richards, 2021	Papua New Guinea: Western Province: Rentoul River	SAMA R71648 (holotype)
Xenorhina lacrimosa	Papua New Guinea, Western Province: upper Strickland River basin	SAMA R71647, ZMB 91129–30 (paratypes)
Xenorhina lacrimosa	Papua New Guinea, Western Province, Muller Range	SAMA R65069–72 (paratypes)
Xenorhina lanthanites (Günther and Knop, 2006)	Indonesia: Papua Province: Yapen Island	ZMB 69557–61 (type series)
Xenorhina macrodisca Günther and Richards, 2005	Indonesia: Papua Province: Wapoga River Headwaters	MZB Amph.10916 (holotype)
Xenorhina macrops van Kampen, 1913	Indonesia: Papua Province: Hellwig Mountains	ZMA 5725 (lectotype), ZMA 5726–5728 (paralectotypes)
Xenorhina mehelyi (Boulenger, 1898)	Papua New Guinea: Central Province: "Vikaiku", Angabunga River	MSNG 29112 (holotype)
Xenorhina minima (Parker, 1934)	Indonesia: Papua Province: Went Mountains	ZMA 5818 (holotype), ZMA 5817 (paratype)
Xenorhina ocellata van Kampen, 1913	Indonesia: Papua Province: Hellwig Mountains	ZMA 5815–16 (syntypes)
Xenorhina ophiodon (Peters and Doria, 1878)	Indonesia: Papua Province: Hatam, Arfak Mountains	MSNG 29129 (lectotype)
Xenorhina oxycephala Schlegel, 1858	Indonesia: Papua Province: Triton Bay	RMNH 2280A and 2280B (syntypes) (plus several specimens collected by R. Günther between 1998–2008 and stored in the ZMB collection)
Xenorhina parkerorum Zweifel, 1972	Papua New Guinea: Western Province: Imigabip	MCZ 81678 (holotype),
Xenorhina parkerorum Zweifel, 1972	Indonesia: Papua Province: Tenmasigin, Star Mountains	RMNH 16619 (paratype)
Xenorhina salawati Günther, Richards, Tjaturadi and Krey, 2020	Indonesia: West Papua Province: Salawati Island	MZB Amph.12121–22, 12124–26, 12132, 12134, (type series)
Xenorhina tillacki Günther, Richards and Dahl, 2014	Papua New Guinea: Western Province: Muller Range	SAMA R65067–68, ZMB 79532 (type series)
Xenorhina varia Günther and Richards, 2005	Indonesia: Papua Province: Yapen Island	ZMB 65133–37 (type series)
Xenorhina waigeo Günther, Richards, Tjaturadi and Krey, 2020	Indonesia: Papua Province: Waigeo Island	MZB Amph. 12119–20, 12123, 12127-31, 12133, 12155 (type series)
Xenorhina wiegenkorum Günther and Richards, 2021	Papua New Guinea: Western Province: Baia River	SAMA R71653 (holotype)
Xenorhina wiegankorum	Papua New Guinea: Western Province: upper Strickland River basin	SAMA R71654 (paratype)
Xenorhina wiegankorum	Papua New Guinea: Western Province: Rentoul River	ZMB 91132 (paratype)
Xenorhina woxvoldi Günther and Richards, 2021	Papua New Guinea: Hela Province: Karius Range	SAMA R71646 (holotype), ZMB91133 (paratype)