VERTEBRATE ZOOLOGY

70 (3): 333 – 347
2020

SENCKENBERG

© Senckenberg Gesellschaft für Naturforschung, 2020.

Two new microhylid frog species of the genus *Xenorhina* Peters, 1863 from the Raja Ampat Islands, Indonesia

Rainer Günther[1,*], Stephen J. Richards[2], Burhan Tjaturadi[3] & Keliopas Krey[4]

[1] Museum für Naturkunde, Herpetologie, Invalidenstr. 43, 10115 Berlin, Germany — [2] South Australian Museum, North Terrace, Adelaide, South Australia, 5000, Australia — [3] Center for Environmental Studies, Sanata Dharma University (CESSDU), Yogyakarta, Indonesia — [4] Department of Biology, Faculty of Mathematics and Natural Sciences, University of Papua, Manokwari, Indonesia — * Corresponding author; email: rainer.guenther@mfn.berlin

Submitted March 17, 2020.
Accepted July 6, 2020.
Published online at www.senckenberg.de/vertebrate-zoology on August 4, 2020.
Published in print Q3/2020.

Editor in charge: Raffael Ernst

Abstract

Two new species of the asterophryine microhylid genus *Xenorhina* are described from the Raja Ampat archipelago off the western tip of New Guinea. Both are medium-sized (snout-urostyle length 29.9 – 35.2 and 28.5 – 39.5 mm), semi-fossorial frogs that call from hidden positions within the litter or under the soil surface. The two new species are morphologically similar but they have different advertisement calls. Although they are probably closely related, genetic studies are required to confirm this. The first species is known only from Salawati Island, a land-bridge island that was connected to the New Guinea mainland during the last glacial period. The second species is currently known only from Waigeo Island, an oceanic island long isolated from New Guinea that is separated from nearby Salawati by a major biogeographic barrier, the narrow but deep Sagewin Strait. Description of these two species appears to be another example of differentiation across this barrier, and brings the total number of *Xenorhina* known from New Guinea and surrounding islands to 34.

Kurzfassung

Zwei neue Arten der Froschgattung *Xenorhina* (Microhylidae, Asterophryinae) vom Raja Ampat Archipel westlich von Neuguinea werden beschrieben. Beide Arten sind mittelgroß (Schnauze-Urostyl-Länge 29,9 – 35,2 und 28,5 – 39,5 mm), haben eine grabende Lebensweise und rufen von Positionen im Falllaub oder im Erdboden. Beide Arten haben eine sehr ähnliche Morphologie, zeigen jedoch deutliche Unterschiede in ihren Rufen. Sie sind wahrscheinlich eng miteinander verwandt, was später auch durch genetische Untersuchungen bestätigt werden soll. Die erste Art wurde bisher nur auf der Insel Salawati gefunden, einer Landbrückeninsel, die während der letzten Eiszeit mit Neuguinea verbunden war. Die zweite Art ist gegenwärtig nur von Waigeo bekannt, einer ozeanischen und von Neuguinea lange isolierten Insel , die trotz der gegenwärtigen Nachbarschaft zu Salawati niemals mit dieser Insel verbunden war. Mit der Beschreibung dieser beiden neuen Arten erhöht sich die Anzahl der von Neuguinea und benachbarten Inseln beschriebenen *Xenorhina*-Arten auf 34.

Key words

Amphibia, bioacoustics, morphology, New Guinea, Salawati Island, taxonomy, Waigeo Island.

Introduction

The asterophryine microhylid frog genus *Xenorhina* is endemic to the New Guinea region, where 32 species occur at altitudes between sea level and more than 3,000 m a.s.l. (Zweifel, 1972; Blum & Menzies, 1989; Menzies, 2006; Frost, 2020). Most *Xenorhina* have small, pointed heads, short legs, and have reduced (or entirely lack) terminal discs on their fingers and toes, reflecting a fossorial or terrestrial lifestyle (Zweifel, 1972; Menzies, 2006). Just three species, *X. arboricola* Allison & Kraus, 2000, *X. macrodisca* Günther & Richards, 2005 and *X. varia* Günther & Richards, 2005 have large finger discs and are known to be at least partly arboreal

ISSN 1864-5755 | eISSN 2625-8498 | DOI: 10.26049/VZ70-3-2020-06

(Allison & Kraus, 2000; Günther & Richards, 2005; Menzies, 2006).

Xenorhina, including all species previously referred to *Xenobatrachus* Peters & Doria, 1878 (see Frost *et al*., 2006 and Köhler & Günther, 2008), is confined predominantly to the central and western parts of New Guinea Island (Menzies, 2006). Only one species, *X. varia*, has not been reported from mainland New Guinea; it has to date been recorded only from nearby Yapen Island (Günther & Richards, 2005), a land-bridge island that was connected to New Guinea during recent glacial periods (Wikramanayake *et al.,* 2002). One other species, *X. oxycephala* (Schlegel, 1858), could occur on both mainland New Guinea and Yapen Island (Price, 1994). However, according to molecular data (12S rRNA gene and 16S rRNA gene) presented by Günther (2010) the present taxon *X. oxycephala* probably includes more than one species. Here we describe two new species of *Xenorhina* from the Raja Ampat Islands off western New Guinea based on a combination of unique morphological and acoustic characters. These belong to the group of fossorial *Xenorhina* lacking vomerine spikes, and represent only the second and third known members of the genus that are endemic to New Guinea's small satellite islands.

Material and methods

Most frogs were located at night by their advertisement calls. Representative specimens were photographed in life, and specimens were euthanized in an aqueous chlorobutanol solution 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 SVLs presented for members of the genus in some papers; **TL** – tibia length: external distance between knee and tibio-tarsal articulation (referred to herein also as 'shank') some measurements of TL from the literature use a method introduced by Zweifel (1972) that produces shorter tibiae 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 edge of sole; **T4D** – transversal diameter of disc of 4th toe; **T1D** – transversal diameter of tip of first toe; **F3L** – length of 3rd finger: from tip of 3rd finger to proximal edge of palm; **F3D** – transversal diameter of tip of 3rd finger; **F1D** – transversal diameter of tpi of first finger; **HL** – head length, from tip of snout to posterior margin of tympanum; **HW** – 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.

Sex was determined mainly by observations of calling and/or the presence of vocal slits (males), or absence of vocal slits and/or presence of eggs (females); some specimens were dissected in order to inspect their gonads. Advertisement calls were recorded with a Sony WM-D6C Professional Walkman tape recorder and a Sennheiser ME66 shotgun microphone and analysed with Avisoft-SAS Lab Pro software. Air temperatures adjacent to calling males were recorded using a rapid-reading digital thermometer. Terminology and acoustic analysis procedures mostly follow Köhler *et al.* (2017). Colour of animals in life was described from digital photographs, and of preserved specimens from direct observations. Most colours were determined according to a colour matching system used in Europe that is created and administrated by the German RAL gGmbH (RAL non-profit LLC).

Measurements are presented as arithmetic means ± Standard Deviation. Statistical calculations were done with the program Statgraphics Centurion Version 15.2.14 (Statpoint Technologies, Inc., Warrenton, Virginia, USA). All p-values are calculated by the non-parametric Mann-Whitney (Wilcoxon) Test for comparison of medians. All specimens are stored in the collection of the Museum Zoologicum Bogoriense (MZB) in Cibinong (Bogor), Indonesia and bear registration numbers of that institution. Abbreviations for other institutions mentioned are: American Museum of Natural History, New York (AMNH); Bernice P. Bishop Museum, Hawaii (BPBM); Institut Royal des Sciences Naturales de Belgique, Brussels (IRSNB); Museo Civico di Storia Naturale di Genova, Genoa (MSNG); Museum of Comparative Zoology, Harvard (MCZ); Museum für Naturkunde, Berlin (ZMB); National Museum of Natural History now Naturalis Biodiversity Center, Leiden (RMNH); South Australian Museum, Adelaide (SAMA); University of Papua New Guinea, Port Moresby (UP); Zoological Museum Amsterdam now Naturalis Biodiversity Center, Leiden (ZMA). FN SJR is the field number of Stephen Richards. MZB always means in the following text MZB Amph.

Specimens compared

Xenorhina adisca Kraus & Allison, 2003 (MZB Amph.8403, holotype);
X. arboricola (BPBM 13745 and 13747, paratypes);
X. arndti Günther, 2010 (ZMB 74629–31, type series);
X. bidens van Kampen, 1909 (ZMA 5705, holotype);

- *X. bouwensi* (De Witte, 1930) (IRSNB 1019, holotype, plus several specimens collected by R. Günther between 1998–2008 and stored in the ZMB collection); *X. bidens* van Kampen, 1909 (ZMA 5705, holotype);
- *X. eiponis* Blum & Menzies, 1989 (AMNH 128234, paratype);
- *X. gigantea* van Kampen, 1915 (ZMA 5702, lectotype; ZMA 5703, paralectotype);
- *X. lanthanites* (Günther & Knop, 2006) (ZMB 69557–61, type series);
- *X. macrodisca* (MZB Amph.10916, holotype);
- *X. macrops* van Kampen, 1913 (ZMA 5725, lectotype; ZMA 5726–5728, paralectotypes);
- *X. mehelyi* (Boulenger, 1898) (MSNG 29112, holotype);
- *X. minima* Parker, 1934 (ZMA 5818, holotype; ZMA 5817, paratype);
- *X. ocellata* van Kampen, 1913 (ZMA 5815–16, syntypes);
- *X. ophiodon* (Peters & Doria, 1878) (MSNG 29129, lectotype);
- *X. oxycephala* (RMNH 2280A and 2280B, syntypes, plus several specimens collected by R. Günther between 1998–2008 and stored in the ZMB collection);
- *X. parkerorum* Zweifel, 1972 (MCZ 81678, holotype; RMNH 16619, paratype);
- *X. tillacki* Günther, Richards & Dahl, 2014 (SAMA R65067–68, ZMB 79532, type series);
- *X. varia* (ZMB 65133–37, type series).

Additional morphometric and other data were extracted from original species descriptions and/or recompiled treatises, particularly Zweifel (1972) and Blum & Menzies (1989).

Specimens were assigned to the genus *Xenorhina* on the basis of the following combination of features: jaw symphygnathine; clavicles and procoracoids absent; body squat, head small, triangular, with small eyes; skin of dorsal surfaces with some tubercles, cutaneous tubercles on eyelids absent; tips of toes 2–5 expanded and with circum-marginal grooves; life style subterrestrial.

Xenorhina salawati sp. nov.

ZOOBANK urn:lsid:zoobank.org:act:78BB50FB-19AD-4E77-9BD0-892827E4F08F

Figs. 1–7, 10

Holotype. MZB Amph.12132 (FN SJR 7727), adult male, collected at Weybya camp, Salawati Island, Raja Ampat Islands, West Papua Province, Indonesia (00°57.383′S, 130°47.060′E; 75 m a.s.l.) on 24/06/2005 by S. Richards, B. Tjaturadi and K. Krey.

Paratypes. MZB Amph.12126 (FN SJR 7726), adult male; MZB Amph.12134 (SJR 7732), subadult female, same data as for holotype; MZB Amph.12121 (FN SJR 7767), adult or subadult, sex undetermined; MZB Amph.12122 (FN SJR 7766), adult female; MZB Amph.12124 (FN SJR 7773), probably male; MZB Amph.12125 (FN SJR 7774), adult male, same data as holotype but collected on 25/06/2005.

Diagnosis. A medium-sized *Xenorhina* (males 29.9–34.3 mm SUL, females 29.1–35.2 mm SUL, Table 1); vomerine spikes absent; legs moderately short (TL/SUL 0.45–0.47); all fingers and toe 1 without expanded discs, toes 2–5 with small but distinctly expanded discs (T4D/SUL 0.047–0.052); eye-naris distance greater than internarial distance (END/IND 1.17–1.41); tympanum about same diameter as eye (TyD/ED 0.86–1.07). Dorsal surfaces uniform reddish or bluish in life, ventral surfaces unspotted yellow or dark brown with whitish spots. Advertisement calls uttered in series lasting 5.6–12.05 s, calls per series 10–23, call length 52–87 ms, repetition rate 1.72–2.15 calls/s.

Description of the holotype. Measurements are summarized in Table 1. Head in region of tympana broader than long (HL/HW 0.80), with weak constriction at neck; snout acuminate from above and protruding in profile; loreal region oblique, no canthus rostralis, nostrils near tip of snout, directed more lateral than dorsal, visible from above but not from below; eye-naris distance greater than internarial distance (END/IND 1.17); tympanum clearly visible in preservative, its diameter less than that of eye (TyD/ED 0.86); supratympanic fold weakly expressed, extending from posterior corner of eye, across dorsal corner of tympanum to insertion of foreleg; shank of medium length (TL/SUL 0.45); fingers moderately short, not webbed; tips of fingers not expanded but fingers 2 and 3 with clear circum-marginal grooves, fingers 1 and 4 with only traces of grooves; relative lengths of fingers 3>4=2=1; all toe tips with circum-marginal grooves, those on toes 2–5 ending in discs clearly wider than penultimate phalanges, tip of toe 1 not broadened into disc; toes not webbed, relative lengths 4>3>5>2>1; plantar, palmar and subarticular tubercles absent except for moderately large metatarsal tubercle. Body laterally with some distinct tubercles in life and in preservative; dorsal surfaces of extremities, middle of dorsum and all ventral surfaces smooth. Tip of snout with several tiny depressions.

Colour in life. Dorsal surface of head, body and extremities uniform light reddish-brown with two semi-circular light yellowish lumbar spots (Fig. 1a), lower flanks with off-white and dark brown network of patches; dark brown patches also below eye, along supratympanic ridge, around vent and adjacent region and on anterior and posterior extremities; tubercles on lateral surfaces of body and on dorsal surfaces of extremities whitish on brown base; throat, belly and partly ventral surfaces of extremities uniform light melon-yellow (RAL 1028); throat covered by grey-brown network (Fig. 1b). Conspicuous are two zinc-yellow (RAL 1018) longitudinal stripes on abdomen forming ‘pear-shape’. Tip of snout grey with several tiny dark grey indentations (sensory pits?); lower surface of hand (Fig. 1c) and foot (Fig. 1d) predominantly different tones of grey. Anal region, proximal posterior of thigh and entire posterior tarsi predominantly dark brownish grey (Fig. 1e). Iris blackish with golden inner margin.

Colour in preservative. Colour of dorsal surfaces has changed from reddish brown to beige and that of ventral surfaces from melon-yellow to creamy white. Dark skin regions are same colour as in life. Lumbar spots are less pronounced than in life.

Fig. 1. Holotype (MZB 12132) of *Xenorhina salawati* sp. n. in life, (**a**) dorsolateral view, (**b**) ventral view, (**c**) ventral view of right hand, (**d**) ventral view of right foot, (**e**) rear view of thighs and of right tarsus.

Morphological variation in the type series. For measurements of all types see Table 1. The two smallest female paratypes (MZB 12121 and MZB 12134) have very small eggs in their ovaries and their maturity (adult or subadult) is uncertain. However, there appear to be no differences in body size or in body ratios between sexes (Table 1). Dorsal colouration in life within the paratype series is either different tones of reddish brown similar to the holotype (MZB 12132, Fig. 1a), or may be bluish as in MZB 12125 (Fig. 2); and ventral surfaces are

Table 1. Body measurements and body ratios of the type series of *Xenorhina salawati* sp. n. MZB 12132 is the male holotype; MZB 12124, 12125, 12126 are adult males, MZB 12122 is an adult female and 12121 and 12134 are probably subadult females. All measurements in mm; for explanation of abbreviations see "Material and methods".

Reg.-No.	**MZB 12121**	**MZB 12122**	**MZB 12124**	**MZB 12125**	**MZB 12126**	**MZB 12132**	**MZB 12134**	**Mean ±SD**
SUL	29.1	35.2	30.7	29.9	31.4	34.3	29.1	
TL	13.4	16.0	14.4	13.5	14.5	15.3	13.6	
TaL	8.6	10.6	9.7	8.4	9.6	10.5	8.9	
T4L	13.3	14.8	14.1	12.6	14.4	15.2	13.5	
T4D	1.5	1.8	1.6	1.5	1.5	1.6	1.5	
T1D	1.0	1.2	1.1	0.8	0.8	1.0	0.9	
F3L	7.0	8.6	7.8	6.9	8.1	8.6	7.8	
F3D	0.9	1.2	1.0	0.9	0.9	1.1	0.9	
F1D	0.7	1.0	0.8	0.8	0.8	0.9	0.7	
HL	11.6	12.7	11.7	11.2	11.5	12.2	11.5	
HW	12.3	16.5	15.0	13.4	14.1	15.3	13.0	
END	3.2	3.8	3.0	3.1	3.3	3.5	3.3	
IND	2.4	3.1	2.5	2.2	2.7	3.0	2.5	
SL	4.8	6.0	4.7	4.7	4.8	5.4	5.2	
EST	4.8	5.7	4.9	4.6	4.8	5.0	4.7	
ED	2.3	2.8	2.5	2.2	2.4	2.9	2.6	
TyD	2.2	3.0	2.6	2.3	2.2	2.5	2.7	
TL/SUL	0.46	0.45	0.47	0.45	0.46	0.45	0.47	0.46±0.009
TaL/SUL	0.30	0.30	0.32	0.28	0.31	0.31	0.31	0.30±0.012
T4L/SUL	0.46	0.42	0.46	0.42	0.46	0.44	0.46	0.45±0.019
T4D/SUL	0.052	0.051	0.052	0.050	0.048	0.047	0.052	0.050±0.002
T1D/SUL	0.034	0.034	0.036	0.027	0.025	0.029	0.031	0.031±0.004
F3L/SUL	0.24	0.24	0.25	0.23	0.26	0.25	0.27	0.25±0.013
F3D/SUL	0.031	0.034	0.033	0.030	0.029	0.032	0.031	0.031±0.002
F1D/SUL	0.024	0.028	0.026	0.027	0.025	0.026	0.024	0.026±0.001
T4D/F3D	1.67	1.50	1.60	1.67	1.67	1.45	1.67	1.60±0.093
T1D/F1D	1.43	1.20	1.38	1.00	1.00	1.11	1.29	1.20±0.174
HL/SUL	0.40	0.36	0.38	0.37	0.37	0.36	0.40	0.38±0.017
HW/SUL	0.42	0.47	0.49	0.45	0.45	0.45	0.45	0.45±0.021
HL/HW	0.94	0.77	0.78	0.84	0.82	0.80	0.88	0.83±0.060
END/SUL	0.110	0.108	0.098	0.104	0.105	0.102	0.113	0.106±0.005
IND/SUL	0.082	0.088	0.081	0.074	0.086	0.087	0.086	0.083±0.005
END/IND	1.33	1.23	1.20	1.41	1.22	1.17	1.32	1.27±0.086
ED/SUL	0.079	0.080	0.081	0.074	0.076	0.085	0.089	0.081±0.005
TyD/SUL	0.076	0.085	0.085	0.077	0.070	0.073	0.093	0.080±0.008
TyD/ED	0.96	1.07	1.04	1.05	0.92	0.86	1.04	0.99±0.079
SL/SUL	0.165	0.170	0.153	0.157	0.153	0.157	0.179	0.162±0.009
EST/SUL	0.165	0.162	0.160	0.154	0.153	0.146	0.162	0.159±0.013

melon-yellow as in the holotype or dark brown with whitish spots as in MZB 12124 (Fig. 3). In preservative colour of dorsal surfaces varies from beige to brown-beige and of abdomen from unspotted ivory-white to brownish with ivory-white spots. Throat is unspotted ivory-white to more or less heavily flecked with brown. All specimens exhibit a more or less pronounced mid-dorsal stripe that may extend onto the hind limbs, and most specimens show light lumbar spots that are less pronounced in preservative than in life. Most specimens have a grey snout tip and the grey colour is more pronounced in preservative than in life.

Distribution and ecological notes. *Xenorhina salawati* is a semi-fossorial species that is currently known only from a single location at an altitude of about 50 m a.s.l. near the north coast of Salawati Island (Fig. 10), where males called from within the humus layer under leaf litter in lowland rainforest (Fig. 4) at night. Females and non-calling males were found sitting on the forest floor at night.

Vocalization. Four call series from MZB 12126 and four from MZB 12132 (holotype) recorded at an air temperature of 25 °C were analysed. Calls of both specimens are similar to each other and are therefore pooled

Fig. 2. Dorsolateral view of *Xenorhina salawati* (MZB 12125) with bluish dorsal surfaces, light yellowish middorsal and femoral lines and weakly developed lumbar spots. — **Fig. 3.** *Xenorhina salawati*, ventral view of MZB 12124 in life.

Fig. 4. Lowland rainforest habitat at the type locality of *Xenorhina salawati*.

in the following analyses. Average length of call series (± SD) 8.08 ± 2.3 s, range 5.6 – 12.05 s (n = 8). Average number of calls per series 15.2 ± 5.4, range 10 – 23 with mean repetition rate of 1.89 ± 0.16, range 1.72 – 2.15 calls/s. Mean call duration 72 ± 6.6 ms, range 52 – 87 ms (n = 122); mean duration of call intervals 478 ± 67 ms, range 379 – 618 ms (n = 114). Calls are unpulsed, of approximately equal length and approximately equal intervals, but intervals between first and last calls of a series may be slightly longer. A rise in volume and pitch of calls is evident during first half of each series, sometimes extending over entire call series (Fig. 5). Calls start abruptly at high amplitude, reach maximum amplitude soon after start, and amplitude then decreases slowly until end of call. All calls have harmonic structure with six to eight harmonics between 0.20 and 3.90 kHz (Fig. 6, below). First harmonic clearly dominant, with peak at 0.5 kHz (Fig. 7). Calls frequency modulated, with frequencies decreasing slightly during each call.

Etymology. The specific epithet *salawati* is a geographical proper name, a noun in nominative singular case, and refers to the island of Salawati situated west of the Vogelkop Peninsula in Indonesian New Guinea. Salawati is so far the only collection site of this new species.

Comparisons with other species. *Xenorhina* includes a group of species with one or more spikes on the

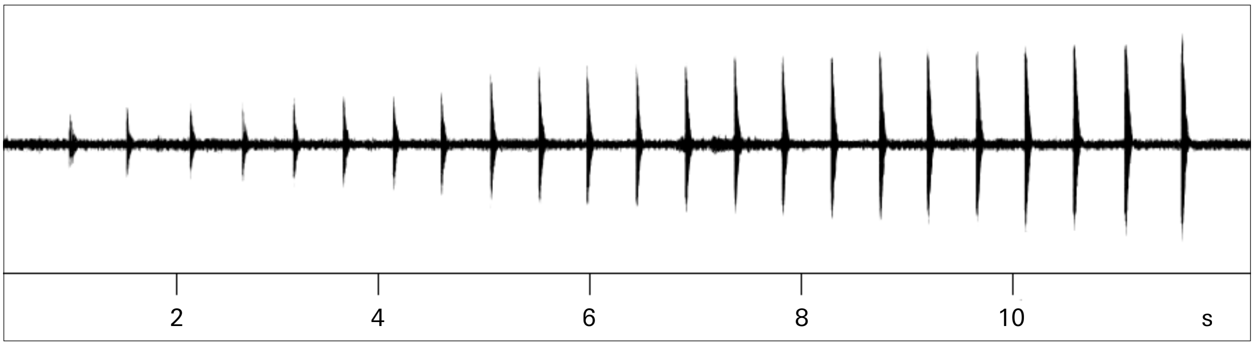

Fig. 5. Oscillogram of a complete advertisement call series with 23 single calls from the holotype of *Xenorhina salawati* sp. n.

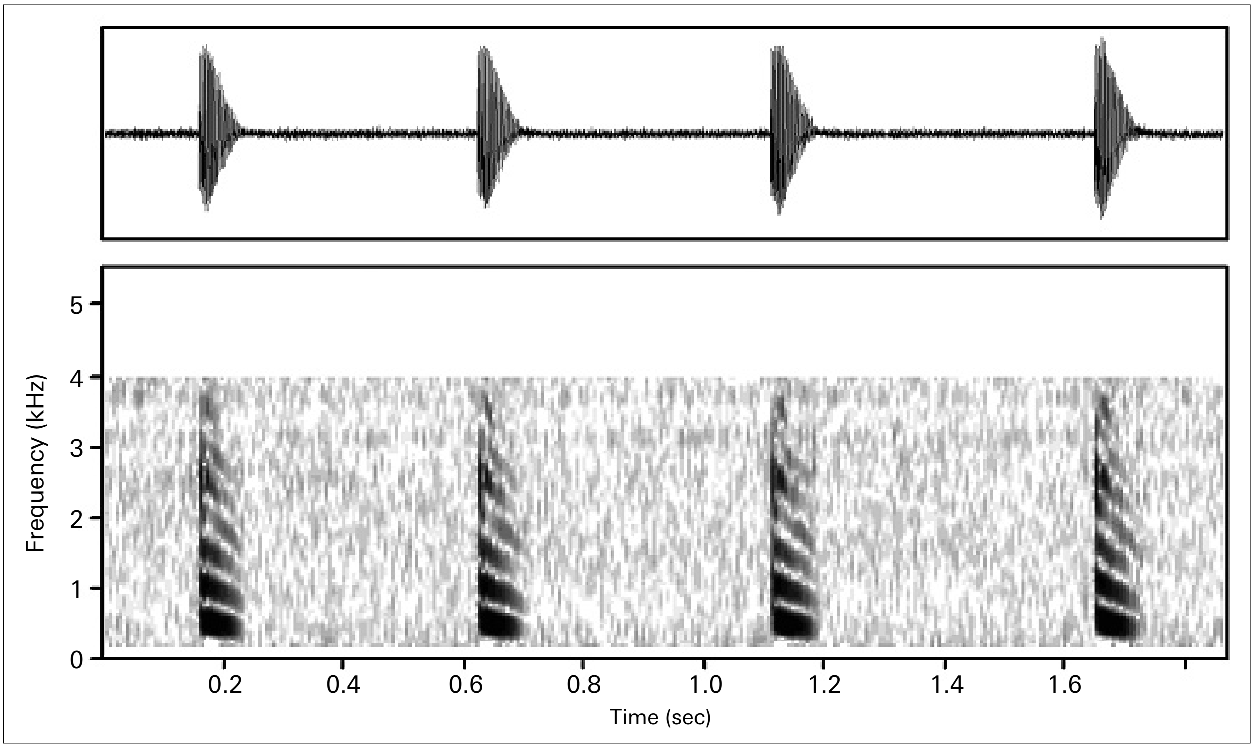

Fig. 6. Oscillogram (above) and spectrogram (below) of four advertisement calls of the holotype of *Xenorhina salawati* sp. n. Sampling rate conversion from 44 kHz to 12 kHz; spectrogram parameters: FFT length 256, Window FlatTop, sample units 64, Overlap 87.5 %.

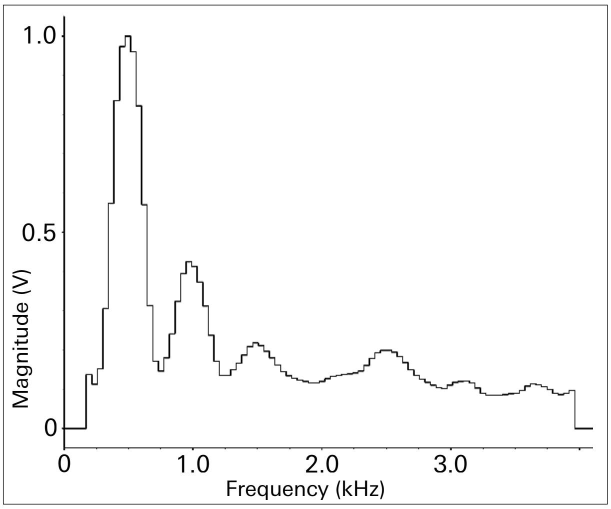

Fig. 7. Amplitude spectrum of four advertisement calls from *Xenorhina salawati* sp. n. Same parameters as in Fig. 6.

vomero-palatine bone (formerly allocated to the genus *Xenobatrachus*) and another group lacking spikes in this region. *Xenorhina salawati* belongs to the latter group and is compared here only with other species lacking vomero-palatine spikes.

Xenorhina adisca is smaller than *X. salawati* (18–24 mm vs. 29.1–35.2 mm SVL), has shorter legs (mean ratio TL/SVL 0.40 vs. 0.46) and lacks expanded discs on toes (vs. expanded discs on toes in the new species). *Xenorhina arboricola* is larger than the new species (SVL > 37.9 mm vs. maximum 35.2 mm SUL in *X. salawati*) and has strongly expanded finger discs (vs. not expanded in *X. salawati*). *Xenorhina arndti* is smaller than the new species (23.8–27.8 mm SVL vs. > 29.0 mm SUL), and further differs in having narrower finger tips (F3D/SVL 0.020–0.025 vs. 0.029–0.034), narrower toe tips (T4D/SVL 0.032–0.043 vs. 0.047–0.052) and a shorter internarial distance (IND/SVL 0.059–0.065 vs.

0.074–0.089). *Xenorhina bouwensi* and *X. brachyrhyncha* Kraus, 2011, are both smaller than *X. salawati* (< 23 mm SVL vs. > 29 mm SVL). *Xenorhina eiponis* has longer legs (TL/SVL 0.48–0.52 vs. 0.45–0.47) and a smaller ratio END/IND (1.03–1.16 vs. 1.17–1.41). *Xenorhina macrodisca* and *X. varia* have strongly expanded discs on fingers (vs. discs lacking in *X. salawati*). *Xenorhina minima* lacks expanded discs on toes (vs. present in *X. salawati*) and has shorter legs (TL/SVL < 0.40 vs. > 0.45 in *X. salawati*). *Xenorhina oxycephala* sensu Zweifel (1972) and Menzies (2006) is probably polyphyletic according to mitochondrial DNA-studies (Günther, 2010) but this "species" is larger than *X. salawati* (40–50 mm SVL vs. 29–35 mm SUL), slightly broadened discs on fingers (vs. discs absent in *X. salawati*) and smaller eyes (ED/SVL 0.060–0.067 vs. 0.074–0.089). *Xenorhina parkerorum* is much larger (SVL to 68 mm vs. 35.2 mm SUL in *X. salawati*), and *X. similis* (Zweifel, 1956) is also larger than *X. salawati* (up to 51 mm SVL vs. 35.2 mm SUL)) and has shorter legs (TL/SVL < 0.43 vs. > 0.43 in *X. salawati*).

Xenorhina waigeo sp. nov.

ZOOBANK urn:lsid:zoobank.org:act:75C7196E-E499-47D7-9A7F-8BA17FEE1B22

Figs. 8–13

Holotype. MZB Amph.12129 (field number = FN SJR 7661), adult male, collected at unnamed camp near Urbinasopen Village, Waigeo Island, Raja Ampat Islands, West Papua Province, Indonesia

Fig. 8. Holotype (MZB 12129) of *Xenorhina waigeo* sp. n. in life, (**a**) dorsolateral view, (**b**) ventral view, (**c**) ventral view of left hand, (**d**) ventral view of left foot.

Fig. 9. Dorsolateral view of *Xenorhina waigeo* (MZB 12131) with bluish-brown dorsal surfaces, a light yellowish middorsal line that continues on posterior extremities and weakly developed lumbar spots.

(00°20.231′S, 131°15.528′E; ~20 m a.s.l.) on 15/06/2005 by S. Richards, B. Tjaturadi and K. Krey.

Paratypes. MZB Amph.12119 (FN SJR 7637), adult female; MZB Amph.12120 (FN SJR 7662), adult male; MZB Amph.12123 (FN SJR 7633), probably male; MZB Amph.12127 (FN SJR 7635), adult male; MZB Amph.12128 (FN 7632), adult male; MZB Amph.12130 (SJR 7604), subadult female; MZB Amph.12131 (SJR 7621), adult male; MZB Amph.12133 (SJR 7603) adult female; MZB Amph.12155 (SJR 7634) juvenile, data same as for holotype except MZB Amph.12130, 12131 and 12133 collected on 12/06/2005, and MZB Amph.12119, 12123, 12127–8 and 12155 collected on 13/06/2005.

Diagnosis. A medium-sized *Xenorhina* (adult males 28.5–31.8 mm SUL, adult females 34.2–39.5 mm SUL; Table 2) without vomerine spikes; legs moderately long (TL/SUL 0.47–0.49); all fingers and toe 1 lacking expanded discs, toes 2–5 with small but clearly expanded discs (T4D/SUL 0.048–0.056); eye-naris distance equal to or greater than internarial distance (END/IND 1.00–1.32); tympanum scarcely visible in life, more visible in preservative, about same diameter as eye (TyD/ED 0.80–1.13). Dorsal surfaces in life different tones of beige or bluish brown; ventral surfaces pastel-yellow (RAL 1034), abdomen and posterior chest unspotted, throat, anterior chest and extremities more or less intensely spotted with grey-brown. Advertisement calls produced in short series, each comprising 2–6 calls and lasting 0.49–2.26 s. Length of calls 63–92 ms, repetition rate 2.49–4.08 calls/s.

Description of the holotype. An adult male, calling when collected. Measurements are presented in Table 2. Head in region of tympana broader than long (HL/HW 0.79), with weak constriction at neck; snout acuminate from above, protruding in profile; loreal region oblique, no canthus rostralis, nostrils near tip of snout, directed more lateral than dorsal, visible from above but not from below; eye-naris distance greater than internarial distance (END/IND 1.28); annulus of right tympanum visible in preservative, that of left tympanum mostly covered by skin, ear nearly same size as eye (TyD/ED 1.08); supratympanic fold weakly expressed, extending from posterior corner of eye, across dorsal corner of tympanum, to insertion of foreleg; shank of medium length (TL/SUL 0.48); fingers moderately short, not webbed, tips with circum-marginal grooves but not expanded; relative lengths of fingers 3>4=2=1; toes not webbed, all tips with circum-marginal grooves; toes 2–5 with terminal discs clearly wider than penultimate phalanges, toe 1 without expanded terminal disc; relative lengths of toes 4>3>5>2>1; subarticular, plantar and palmar tubercles weakly pronounced. Dorsolateral surfaces of body and dorsal surfaces of hind legs with numerous small tubercles; all ventral surfaces smooth. Tip of snout with some tiny depressions.

Colour in life. Dorsal surface of head, body and extremities almost uniform beige (RAL 1001); head laterally, anterior and posterior limbs, and area around vent with

Table 2. Body measurements and body ratios of the type series of *Xenorhina waigeo* sp. n. MZB 12129 is the male holotype; MZB 12120, 12123, 12127, 12128 and 12131 are male paratypes, MZB 12119, 12130 and 12133 are female paratypes and MZB 12155 is a juvenile paratype whose measurements were not considered in the calculations for Mean ± SD. All measurements in mm; for explanation of abbreviations see "Material and methods".

Reg.-No.	**MZB 12119**	**MZB 12120**	**MZB 12123**	**MZB 12127**	**MZB 12128**	**MZB 12129**	**MZB 12130**	**MZB 12131**	**MZB 12133**	**MZB 12155**	**Mean ± SD**
SUL	39.5	29.0	29.1	31.8	31.1	31.5	28.6	28.5	34.2	18.7	
TL	19.3	13.9	14.2	14.8	14.6	15.1	14.0	14.1	16.1	9.3	
TaL	12.1	9.1	9.0	8.8	9.4	10.0	9.3	8.7	10.7	7.0	
T4L	18.6	14.8	15.2	14.7	15.3	15.8	15.2	16.5	19.5	12.0	
T4D	2.1	1.4	1.5	1.6	1.6	1.5	1.5	1.4	1.9	1.0	
T1D	1.1	0.9	0.8	0.8	1.1	1.0	1.1	1.0	1.3	0.6	
F3L	10.3	7.4	7.0	7.1	6.7	7.5	7.0	7.5	8.8	4.6	
F3D	1.2	1.1	1.0	1.0	1.1	1.0	1.1	1.0	1.2	0.5	
F1D	1.1	0.9	0.8	0.8	0.8	0.8	0.8	0.7	1.0	0.4	
HL	14.5	10.7	10.1	10.5	11.5	11.6	11.0	10.2	11.7	7.4	
HW	15.3	14.4	13.2	13.4	14.5	14.6	13.5	13.5	11.9	7.4	
END	3.8	2.9	2.7	2.6	3.0	3.2	3.3	3.0	3.2	2.1	
IND	3.0	2.5	2.3	2.6	2.5	2.5	2.5	2.4	3.0	1.6	
SL	6.7	4.9	4.6	4.5	4.8	4.5	4.6	4.9	5.0	3.5	
EST	5.5	4.1	4.0	4.2	4.2	4.9	4.3	4.2	4.9	3.0	
ED	3.1	2.5	2.3	2.3	2.5	2.6	2.4	2.3	2.5	1.9	
TyD	3.5	2.0	1.9	2.5	2.5	2.8	2.0	2.1	2.6	1.3	
TL/SUL	0.49	0.48	0.49	0.47	0.47	0.48	0.49	0.49	0.47	0.50	0.48 ± 0.009
TaL/SUL	0.31	0.31	0.31	0.28	0.30	0.32	0.33	0.31	0.31	0.37	0.31 ± 0.014
T4L/SUL	0.47	0.51	0.52	0.46	0.49	0.50	0.53	0.58	0.57	0.64	0.51 ± 0.041
T4D/SUL	0.053	0.048	0.052	0.050	0.051	0.048	0.052	0.049	0.056	0.053	0.051 ± 0.003
T1D/SUL	0.028	0.031	0.027	0.025	0.035	0.032	0.038	0.035	0.038	0.032	0.032 ± 0.005
F3L/SUL	0.26	0.26	0.24	0.22	0.22	0.24	0.24	0.26	0.26	0.25	0.24 ± 0.017
F3D/SUL	0.030	0.038	0.034	0.031	0.035	0.032	0.038	0.035	0.035	0.027	0.034 ± 0.003
F1D/SUL	0.028	0.031	0.027	0.025	0.023	0.025	0.028	0.025	0.029	0.021	0.027 ± 0.002
T4D/F3D	1.75	1.27	1.50	1.60	1.45	1.50	1.36	1.40	1.58	2.00	1.49 ± 0.143
T1D/F1D	1.00	1.00	1.00	1.00	1.38	1.25	1.38	1.43	1.30	1.50	1.19 ± 0.190
HL/SUL	0.37	0.37	0.35	0.33	0.37	0.37	0.38	0.36	0.34	0.40	0.36 ± 0.017
HW/SUL	0.39	0.50	0.45	0.42	0.47	0.46	0.47	0.47	0.35	0.40	0.44 ± 0.047
HL/HW	0.95	0.74	0.77	0.78	0.79	0.79	0.81	0.76	0.98	1.00	0.82 ± 0.086
END/SUL	0.096	0.100	0.093	0.082	0.096	0.102	0.115	0.105	0.094	0.112	0.098 ± 0.009
IND/SUL	0.076	0.086	0.079	0.082	0.080	0.079	0.087	0.084	0.088	0.086	0.082 ± 0.004
END/IND	1.27	1.16	1.17	1.00	1.20	1.28	1.32	1.25	1.07	1.31	1.19 ± 0.108
ED/SUL	0.078	0.086	0.079	0.072	0.080	0.083	0.084	0.081	0.073	0.102	0.080 ± 0.005
TyD/SUL	0.087	0.069	0.065	0.079	0.080	0.089	0.070	0.074	0.076	0.070	0.077 ± 0.008
TyD/ED	1.13	0.80	0.83	1.09	1.00	1.08	0.83	0.91	1.04	0.68	0.97 ± 0.127
SL/SUL	0.170	0.169	0.158	0.142	0.154	0.143	0.161	0.172	0.146	0.187	0.157 ± 0.012
EST/SUL	0.139	0.141	0.137	0.132	0.135	0.156	0.150	0.147	0.143	0.160	0.142 ± 0.008

some dark brown spots (Fig. 8a). Tip of snout off-white with some tiny grey indentations. Dorsal and dorsolateral tubercles mostly lighter than surrounding skin. Ventral surfaces mostly pastel-yellow (RAL 1034) covered by tiny whitish flecks; throat covered by grey-brown flecks (Fig. 8b). Ventral surfaces of hands and feet show different tones of grey or grey-brown (Fig. 8c and 8d). Conspicuous are two zinc-yellow (RAL 1018) longitudinal stripes on abdomen forming 'pear-shape'. Iris golden with silvery specks and dark brown venation. Pale lumbar spot faintly indicated.

Colour in preservative. Colour of dorsal surfaces pale brown (RAL 8025) in preservative and that of ventral surfaces ivory (RAL 1014). Dark skin regions retain same colour as in life. No lumbar spot visible.

Morphological variation in the type series. Measurements of the type series are presented in Table 2. The only juvenile (MZB 12155) differed from all other paratypes (probably due to allometry) in the body ratios TL/SUL, TaL/SUL, F3D/SUL, F1D/SUL, T1D/F1D, T4L/SUL, T4D/F3D, HL/SUL, HL/HW, ED/SUL, TyD/ED,

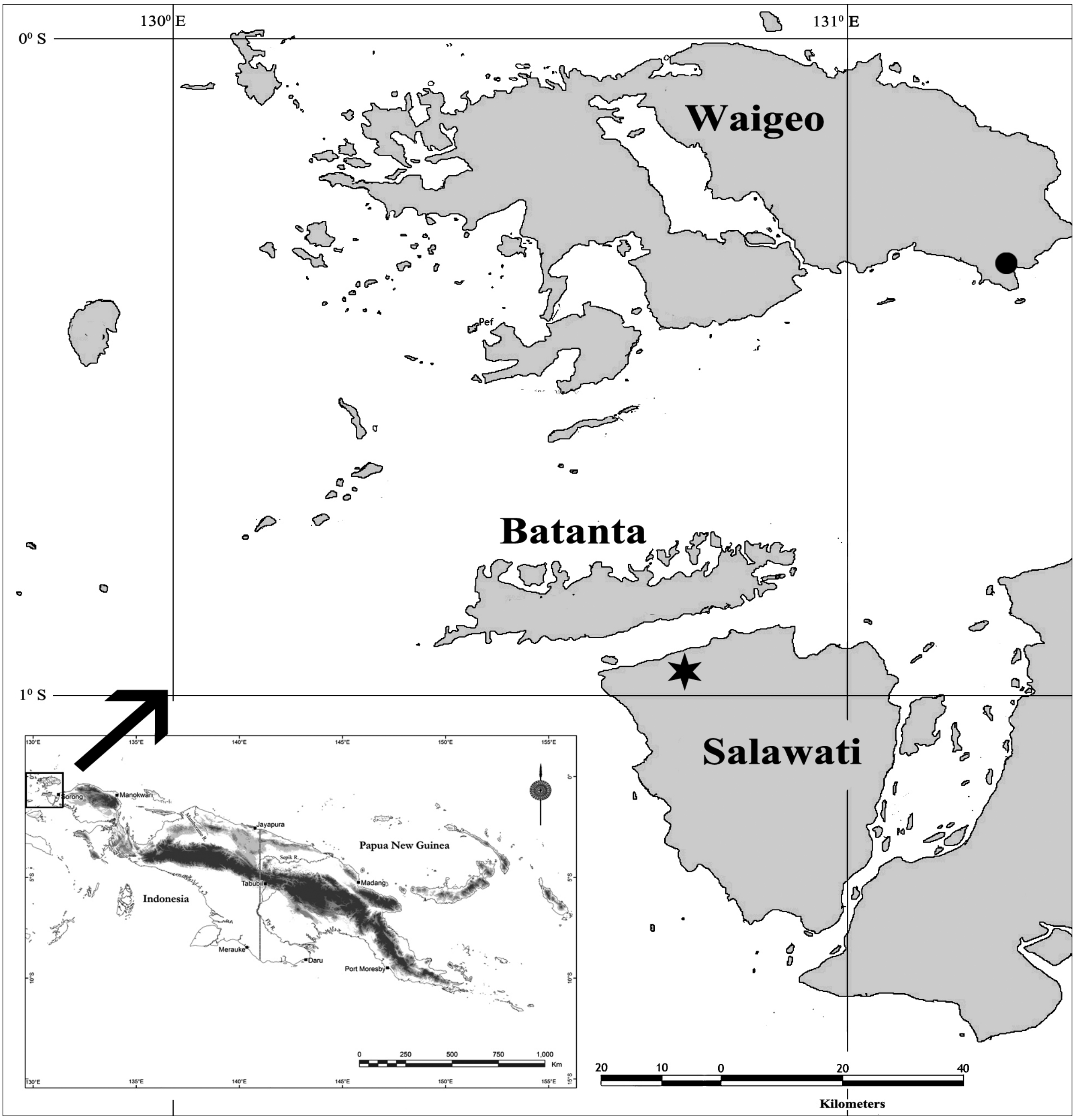

Fig. 10. Map showing type (and only known) localities for *Xenorhina salawati* (star) and *X. waigeo* (circle).

SL/SUL and EST/SUL so its measurements are not considered in the calculations of means in Table 2 nor discussed in the following text. Seven of ten specimens had brownish dorsal surfaces in life and three were blueish (Fig. 9). Five specimens, among them all blueish ones, exhibited a yellowish mid-dorsal line. Snout tip was grey in nearly all specimens and this colour is more strongly expressed in preserved specimens than in living ones.

Distribution and ecological notes. *Xenorhina waigeo* is a semi-fossorial species known only from one location on the southeastern tip of Waigeo Island in the Raja Ampat archipelago of West Papua Province, Indonesian New Guinea (Fig. 10). Males called from hidden positions below the soil surface, or under debris formed by rotting vegetation, in lowland rainforest at altitudes between sea level and 20 m a.s.l. (Fig. 11). Females and non-calling males were encountered on the forest floor at night.

Vocalization. Two call series from MZB 12129, 25 from MZB 12120 and four from an unvouchered specimen, all recorded at an air temperature of 25 °C, were analysed. Calls of the three specimens are similar and are pooled in the following analyses. In addition to the 31 call series, each comprising 2–6 calls, four single calls were heard. In most cases several call series are uttered in relatively rapid succession. Average length of call series 1.16 ± 0.55 s, range 0.49–2.26 s, n = 31; average number of calls per series 3.37 ± 1.27, range 2–6 calls per series, mean repetition rate 3.05 ± 0.47, range 2.49–4.08

Fig. 11. Saturated lowland rainforest along a trail at the type locality of *Xenorhina waigeo*.

calls/s; mean call duration 76 ± 6.1 ms, range 63 – 92 ms, n = 108; mean duration of call intervals 384 ± 77 ms, range 261 – 621 ms, n = 74. Calls are unpulsed, have approximately equal length and follow each other in approximately equal intervals, except last interval generally longest. Volume of calls increases during course of most series. Calls start abruptly at medium amplitude, reach maximum amplitude soon, after then amplitude decreases slowly until end of call. All calls have harmonic structure showing 6 – 8 harmonics between 0.25 and 3.8 kHz (Fig. 12, below). First harmonic is clearly dominant with its peak at 0.45 kHz (Fig. 13). Calls are not or only weakly frequency modulated.

Etymology. The specific epithet *waigeo* is a geographical proper name, a noun in nominative singular case, and refers to the island of Waigeo situated west of the Vogelkop Peninsula. Waigeo is the only known locality for this new species.

Comparisons with other species. *Xenorhina waigeo* belongs to the group of *Xenorhina* species without vomeropalatine spike(s) and it is compared only with species of this group in the following section.

Xenorhina adisca is smaller than *X. waigeo* (18 – 24 mm vs. 28.5 – 39.5 mm SVL in *X. waigeo*), has shorter legs (TL/SVL 0.39 – 0.40 vs. 0.47 – 0.50) and no expanded discs on toes (vs. expanded discs on toes in *X. waigeo*). *Xenorhina arboricola* has strongly expanded finger discs (vs. not expanded in *X. waigeo*). *Xenorhina arndti* is smaller (23.8 – 27.8 mm SVL vs. > 28.5 mm SUL), and further differs in having narrower finger tips (F3D/SVL 0.020 – 0.025 vs. 030 – 0.038 in *X. waigeo*), narrower toe tips (T4D/SVL 0.032 – 0.043 vs. 0.048 – 0.056) and a shorter internarial distance (IND/SVL 0.059 – 0.065 vs. 0.076 – 0.088). *Xenorhina bouwensi* is much smaller than *X. waigeo* (< 23 mm SVL vs. > 28.5 mm SUL). *Xenorhina eiponis* has longer legs (TL/SVL > 0.54 vs. < 0.50 in *X. waigeo*). *Xenorhina macrodisca* and *X. varia* have strongly expanded discs on fingers (vs. lacking in *X. waigeo*). *Xenorhina minima* lacks expanded terminal discs on toes (vs. present in *X. waigeo*) and has shorter legs (TL/SVL < 0.40 vs. > 0.45 in *X. waigeo*). *Xenorhina oxycephala* sensu Zweifel (1972) and Menzies (2006) is probably polyphyletic (Günther, 2010) but as currently defined is larger than *X. waigeo* (40 – 50 mm SVL vs. 28.5 – 39.5 mm SUL), has shorter legs (mean TL/SVL 0.42 vs. 0.48 in *X. waigeo*), slightly broadened discs on fingers (vs. discs absent in *X. waigeo*) and smaller eyes (ED/SVL 0.060 – 0.067 vs. 0.072 – 0.086 in *X. waigeo*). *Xenorhina parkerorum* is a much larger species (to 68 mm SVL vs. 28.5 – 39.5 mm SVL in *X. waigeo*), and *X. similis* is also bigger than *X. waigeo* (up to 51 mm SVL) and has shorter legs (TL/SVL < 0.42 vs. > 0.45 in *X. waigeo*).

Xenorhina waigeo is most similar to *X. salawati* to which it is probably closely related, although future genetic studies are required to confirm these species' relationships. However, there are substantial and consistent differences in advertisement calls that indicate the *Xenorhina* populations on Waigeo and Salawati islands are distinct species. At the same temperature call series of *Xenorhina salawati* consist of 10 – 23 calls with a repetition rate of 1.72 – 2.15 calls/s while those of *X. waigeo* consist of 2 – 6 calls, repetition rate 2.49 – 4.08 calls/s. Accordingly length of call series is much greater and repetition rate is lower in *X. salawati*. Moreover, calls from *X. salawati* are frequency modulated with higher frequencies at the beginning of each call and lower frequencies at the end of the call whilst call frequencies from *X. waigeo* do not exhibit this modulation (compare Figs. 6 and 12).

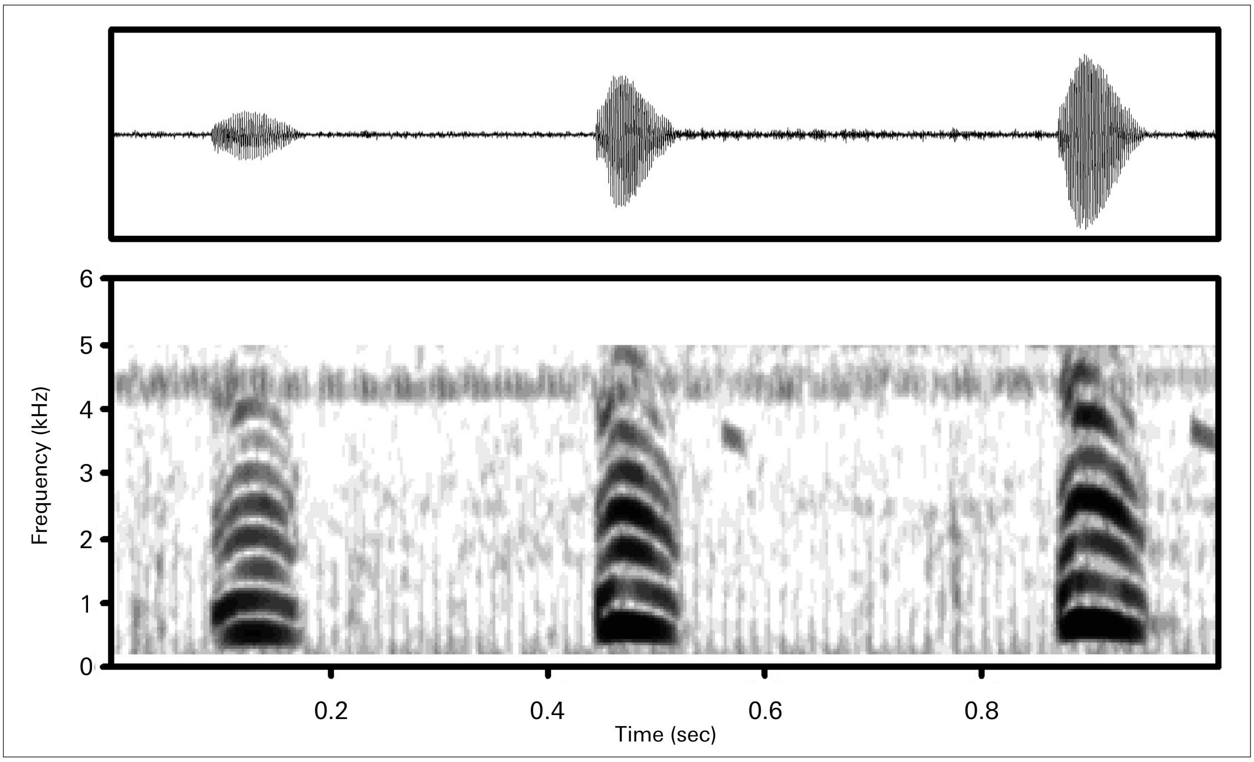

Fig. 12. Oscillogram (above) and spectrogram (below) of three advertisement calls of the holotype (MZB 12129) of *Xenorhina waigeo* sp. n. Sampling rate conversion from 44 kHz to12 kHz; spectrogram parameters: FFT length 256, Window FlatTop, sample units 64, Overlap 87.5 %.

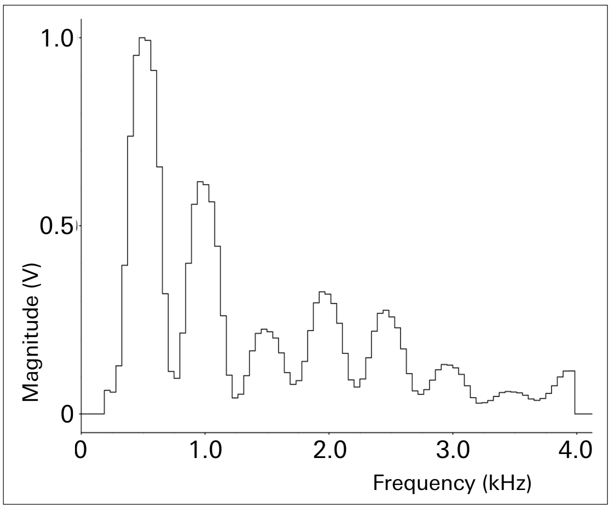

Fig. 13. Amplitude spectrum of the first advertisement call in Fig. 12. Same parameters as in Fig. 12.

Morphological differences between these species are slight but include: *Xenorhina salawati* has shorter legs (TL/SUL 0.45–0.47 vs. 0.47–0.49, p=0.002, Fig. 14), shorter 4th toes (0.42–0.46 vs. 0.46–0.57, p=0.002, Fig. 15), and a greater distance between eye and snout tip (EST/SUL 0.146–0.165 vs. 0.132–0.156, p=0.006, Fig. 16) than *X. waigeo*. In preservative four of seven *X. salawati* have lighter dorsal surfaces than all ten *X. waigeo*, the throat of most *X. salawati* is more strongly mottled than that of *X. waigeo*, and ventral surfaces of fingers and toes in most *X. salawati* are less intensely pigmented than in *X. waigeo*.

Discussion

The two species of *Xenorhina* described here bring to 34 the number of named *Xenorhina* species, and represent the first records of the genus from the Raja Ampat archipelago off western New Guinea. *Xenorhina salawati* is currently known only from Salawati, a land-bridge island that lies to the south of the Sorong Fault Zone where it occupies a common shallow water platform with the Vogelkop Peninsula at the western margin of the Australian Craton (Beehler, 2007). The faunal assemblage of Salawati is generally considered to be a depauperate subset of the nearby mainland, with little evidence of mammal (Helgen, 2007) or bird endemism. However, at least two frogs, *Cophixalus salawatiensis* Günther, Richards, Tjaturadi & Krey, 2015, and an undescribed *Litoria* species, and two geckos, *Cyrtodactylus irianjayaensis* Rösler, 2001 and a recently described *Lepidodactylus* species, are currently known only from this island (Günther *et al.*, 2015; Karkkainen *et al.*, 2020; S.J. Richards, K. Krey & B. Tjaturadi, in prep). It is possible that some or all of these species also occur on the adjacent mainland (Tallowin & Oliver, 2017; Karkkainen *et al.*, 2020) but it is also possible that, like Yapen

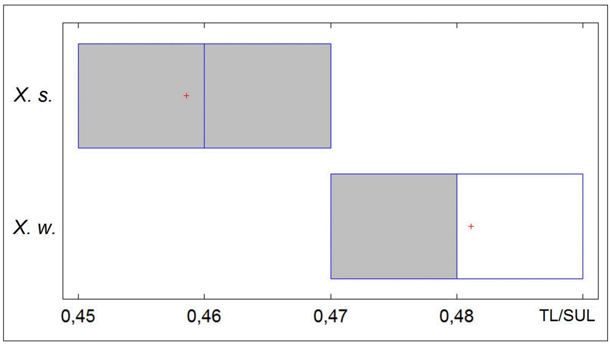

Fig. 14. Box-Whisker-Plot of the ratio "tibia-length/snout-urostyle length" (TL/SUL) in *Xenorhina salawati* (*X.s.*) compared to that of *X. waigeo* (*X.w.*).

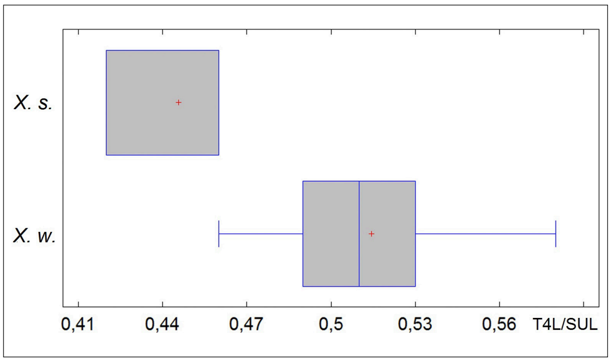

Fig. 15. Box-Whisker-Plot of the ratio "length of toe 4/snout-urostyle length" (T4L/SUL) in *Xenorhina salawati* (*X.s.*) compared to that of *X. waigeo* (*X.w.*).

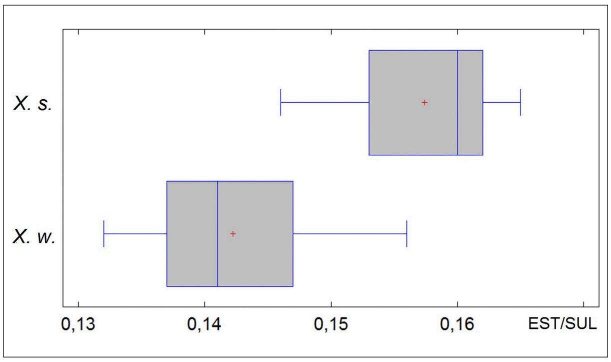

Fig. 16. Box-Whisker-Plot of the ratio "distance from anterior corner of orbital opening to tip of snout/snout-urostyle length" (EST/SUL) in *Xenorhina salawati* (*X.s.*) compared to that of *X. waigeo* (*X.w.*).

Island (another land-bridge island to the north of New Guinea), Salawati supports a moderately diverse assemblage of endemic herpetofauna species.

Waigeo Island, the only known locality for *Xenorhina waigeo*, has a much longer history of isolation from mainland New Guinea (Polhemus, 2007) and this is reflected in high levels of invertebrate endemism (Polhemus & Allen 2007). At least one large reptile, *Varanus boehmei* Jacobs, 2003, is also currently known only from Waigeo (Jacobs, 2003), as is the Waigeo Brushturkey, *Aepypodius bruijnii* (Oustalet,1880), although that species is suspected to also occur on nearby Batanta Island (Beehler, 2007). Waigeo and Batanta are oceanic islands that lie to the north of the Sorong Fault Zone, separated from Salawati by the deep Sagewin Strait (Polhemus, 2007) so despite their proximity it is unlikely that Salawati was ever connected to these islands. In contrast Waigeo and Batanta were united into a single landmass in the late Pleistocene (Helgen, 2007), and several species including two birds of paradise (*Paradisea rubra* Daudin, 1800 and *Cicinnurus respublica* [Bonaparte, 1850]) and a cuscus (*Spilocuscus papuensis* [Desmarest, 1822]) occur only on these two islands and some smaller nearby islets (Beehler, 2007). None of these species occurs on Salawati. The recently described frog, *Cophixalus rajampatensis*, also follows this pattern being known only from Waigeo and Batanta islands; it has not been detected on Salawati despite intensive surveys there (Günther *et al.*, 2015).

Beehler (2007) noted that the Sagewin Strait separating Waigeo/Batanta from Salawati represents a major biogeographic discontinuity, and argued that many more species of plants and animals will be shown to have differentiated across this barrier. Although genetic data are currently unavailable to test their relationships, descriptions of the morphologically similar but acoustically divergent *Xenorhina salawati* and *X. waigeo* appear to provide further evidence for this assertion.

Acknowledgements

Fieldwork in the Raja Ampat Islands was supported by Conservation International and the South Australian Museum. We are most grateful to Yance de Fretes, Muhamad Farid and Jatna Supriatna of Conservation International for their organisational skills and support, and to Herlina Kafiar, Rizana Kurniati, Elias Kore, Sofia Roni, Arthur Tipawael and Adelina Werimon for assistance in the field. We are also extremely grateful to the Indonesian Institute of Sciences (LIPI) for their support and approval of specimen export, the Forestry Department, especially Kantor Sub BKSDA 2, Sorong and Directorate Jenderal PHKA, and to Lisa Capon who produced Figure 10 and Dan Polhemus who generously shared his expertise in the geological history of the New Guinea region. Linda Ford (then AMNH), Carla Kishinami (BPBM), George Lenglet (IRSNB), José Rosado (MCZ), Giuliano Doria (MSNG), Hellen Kurniati and Mumpuni (MZB), Pim Arntzen (RMNH), Carolyn Kovach and Mark Hutchinson (SAMA), Miguel Vences (then ZMA) and Frank Tillack and Mark-Oliver Rödel (ZMB) kindly provided access to specimens in their care.

References

Allison, A. & Kraus, F. (2000). A new species of frog of the genus *Xenorhina* (Anura: Microhylidae) from the north coast ranges of Papua New Guinea. *Herpetologica*, **56**, 285–294.

Beehler, B. M. (2007). Papuan terrestrial biogeography, with special reference to birds, pp. 196–206 *in*: Marshall, A. J. & Beehler,

B. M. (eds) *The Ecology of Indonesia Series. Volume 6. The Ecology of Papua, Part 1*. Singapore, Periplus Editions.

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*, **7**, 125–163 (1988).

Frost, D. R. (2020). Amphibian Species of the World: an online reference. Version 6.0 (Accessed on 23 February 2020). Available at http://research.amnh.org/herpetology/amphibia/index.html.

Frost, D. R., Grant, D., Faivovich, J., Bain, R. H., Haas, A., Haddad, C. F. B., De Sa, R. O., Channing, A., Wilkinson, M., Donnellan, S. C., Raxworthy, C. J., Campbell, J. A., Blotto, B. L. , Moler, P., Drewes, R. C., Nussbaum, R. A., Lynch, J. D., Green, D. M., Wheeler, W. C. (2006). *The amphibian tree of life. Bulletin of the American Museum of Natural History*, **297**, 8–370.

Günther, R. (2010). 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**, 217–224.

Günther, R. & Richards, S. J. (2005). Two new tree-dwelling species of the genus *Xenorhina* from New Guinea (Anura, Microhylidae). *Mitteilungen aus dem Zoologischen Museum in Berlin*, **81**, 167–176.

Günther, R., Richards, S. J., Tjaturadi, B. & Krey, K. (2015). Two new species of the genus *Cophixalus* from the Raja Ampat Islands west of New Guinea (Amphibia, Anura, Microhylidae). *Zoosystematics and Evolution,* **91**, 199–213.

Helgen, K. M. (2007). A taxonomic and geographic overview of mammals of Papua, pp. 689–749 *in*: Marshall, A. J. & Beehler, B. M. (eds) *The Ecology of Indonesia Series. Volume 6. The Ecology of Papua, Part 1*. Singapore, Periplus Editions.

Jacobs, H. J. (2003). A further new emerald tree monitor lizard of the *Varanus prasinus* species group from Waigeo, West Irian (Squamata: Sauria: Varanidae). *Salamandra*, **39**, 65–74.

Karkkainen, D. T., Richards, S. J., Kraus, F., Tjaturadi, B., Krey, K. & Oliver, P. (2020). A new species of small *Lepidodactylus* (Squamata: Gekkonidae) from Salawati Island, Indonesia. *Israel Journal of Ecology and Evolution*, 1–10, http://dx.doi.org/10.1163/22244662-bja10001.

Köhler, F. & Günther, R. (2008). The radiation of microhylid frogs (Amphibia: Anura) on New Guinea: a mitochondrial phylogeny reveals parallel evolution of morphology and life history traits and disproves the current morphology based classification. *Molecular Phylogenetics and Evolution*, **47**, 353–365.

Köhler, J., Jansen, M., Rodríguez, A., Kok, P. J. R., Toledo, L. F., Emmrich, M., Glaw, F., Haddad, C. F. B., Rödel, M-O. & Vences, M. (2017). The use of bioacoustics in anuran taxonomy: theory, terminology, methods and recommendations for best practice. *Zootaxa*, **4251**, 1–124.

Menzies, J. (2006). *The Frogs of New Guinea and the Solomon Islands*. Sofia-Moscow, Pensoft.

Polhemus, D. A. (2007). Tectonic geology of Papua, pp. 137–164 *in*: Marshall, A. J. & Beehler, B. M. (eds), *The Ecology of Indonesia Series. Volume 6. The Ecology of Papua, Part 1*. Singapore, Periplus Editions.

Polhemus, D. A. & Allen, G. R. (2007). Freshwater biogeography of Papua, pp. 207–245 *in*: Marshall, A. J. & Beehler, B. M. (eds) *The Ecology of Indonesia Series. Volume 6. The Ecology of Papua, Part 1*. Singapore, Periplus Editions.

Price, D. S. (1994). Observations on the ecology and vocalization of *Xenorhina oxycephala* (Schlegel), (Anura: Microhylidae) of New Guinea. *Science in New Guinea*, **20**, 141– 46.

Tallowin, O. & Oliver, P. (2017). *Cyrtodactylus irianjayaensis*. The IUCN Red List of Threatened Species 2017: e.T178473A21644437. https://dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T178473A21644437.en. Accessed March 11, 2020.

Wikramanayake, E., Dinerstein, E., Loucks, C. J., Olson, D. M., Morrison, J., Lamoreux, J., McKnight, M. & Hedao, P. (2002). *Terrestrial ecoregions of the Indo-Pacific: A conservation assessment.* Washington, Island Press.

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.

Zoobank Registration

at http://zoobank.org

This published work and the nomenclatural acts it contains have been registered in ZooBank, the online registration system for the International Commission on Zoological Nomenclature (ICZN). The ZooBank LSIDs (Life Science Identifiers) can be resolved and the associated information can be viewed through any standard web browser by appending the LSID to the prefix http://zoobank.org. The LSID for this publication is as follows:

urn:lsid:zoobank.org:pub:5E74091-5D4F-4BA5-A479-C48B-0C63F4E2