Description of a new microhylid frog species of the genus *Xenorhina* (Amphibia: Anura: Microhylidae) from the Fakfak Mountains, far western New Guinea

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> Abstract

Based on morphological, bioacoustic, and molecular traits, a new species in the microhylid genus *Xenorhina* is described. It was recently discovered in the Fakfak Mountains, northwestern corner of the Bomberai Peninsula, Papua Province, Indonesia. This new species has no vomero-palatine spikes. According to molecular traits of the 12S and 16S rRNA genes, the new taxon is most closely related to a syntopic *Xenorhina* cf. *oxycephala*. It belongs to the smallest species in its genus and to those with the longest hind legs. Its advertisement call consists of a series of melodious notes lasting 5–6 seconds; mean note length 77 milliseconds, mean internote interval length 438 ms, and mean repetition rate 2.1 notes per second. The new species is fossorial and it occurs in primary and secondary rain forest at an elevation of from 400 m to 900 m a.s.l.

> Kurzfassung

Basierend auf morphologischen, bioakustischen und molekularen Merkmalen wird eine neue Art der Gattung *Xenorhina* beschrieben. Sie wurde kürzlich in den Fakfak-Bergen, nordwestlicher Zipfel der Bomberai Halbinsel, Papua Provinz von Indonesien, entdeckt. Die neue Art hat keine vomero-palatine Stacheln. Gemäß molekularer Charakteristika der 12S und 16S rRNA Gene ist das neue Taxon am nächsten verwandt mit einer syntopen *Xenorhina* cf. *oxycephala*. Es gehört zu den kleinsten Arten seiner Gattung und zu jenen mit den längsten Hinterbeinen. Seine Rufe bestehen aus Serien melodischer Silben und dauern 5–6 Sekunden. Die mittlere Silbenlänge beträgt 77 Millisekunden, die mittlere Zwischensilbendauer 438 Millisekunden, und die mittlere Silbenwiederholungsrate 2,1 Silben pro Sekunde. Die neue Art lebt in der oberen Bodenschicht in primären Regenwäldern, in Höhen von 400 m bis 900 m über dem Meeresspiegel.

> Key words

Amphibia, Anura, Microhylidae, *Xenorhina*, new species, Papua Province, Indonesia, New Guinea.

Introduction

According to the results of recent molecular studies by FROST *et al*. (2006) and KÖHLER & GÜNTHER (2008), the genus name *Xenobatrachus* has to be considered as a junior synonym of *Xenorhina* because no stringency was found for a separation of both groups into different monophyletic taxa. There is one important feature to discriminate between *Xenorhina* and the former members of *Xenobatrachus* which can be still used in determination practice: the latter posseses vomero-palatine spikes (lacking in *Xenorhina* old sense). *Xenorhina* species without vomero-palatine spikes are *X. oxycephala* (SCHLEGEL, 1858), *X. bouwensi* (WITTE, 1930), *X. minima* (PARKER, 1934), *X. similis* (ZWEIFEL, 1956), *X. parkerorum* ZWEIFEL, 1972, *X. eiponis* BLUM & MENZIES, 1988 "1989", *X. arboricola* ALLISON & KRAUS, 2000, *X. adisca* KRAUS & ALLISON, 2003, *X. varia* GÜNTHER & RICHARDS, 2005 and *X. macrodisca* GÜNTHER & RICHARDS, 2005. There are 19 *Xenorhina* species with vomero-palatine spikes (ZWEIFEL, 1972; BURTON, 1986; BLUM & MENZIES, 1988 "1989"; GÜNTHER & KNOP, 2006; MENZIES, 2006; FROST, 2010). The genus is endemic to the mainland of New

Guinea, and only the offshore island Yapen is presently known to be settled by three species (PRICE, 1994; GÜNTHER & RICHARDS, 2005; GÜNTHER & KNOP, 2006).

Together with native friends I collected some specimens of a hitherto unknown *Xenorhina* species in September 2008 in the Fakfak Mountains, located on the "throat" of the Vogelkop Peninsula in western Indonesian New Guinea, which is scientifically described in this paper.

Materials and methods

Frogs were collected at night after locating them by their advertisement calls. All specimens were photographed in life the next day, anaesthetised with chlorobutanol and subsequently fixed in 2 % formalin. Tissue probes from the thigh muscle were taken from one specimen (ZMB 74631) and stored in 96 % ethanol to enable later DNA sequencing, before fixing the animal in formalin. All specimens were later transferred to 75 % ethanol in the museum collection. One specimen (ZMB 74631) was cleared and stained as an osteological preparation according to a method modified from DINGERKUS & UHLER (1977).

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 only:

SUL snout-urostyle length from tip of snout to distal tip of urostyle bone; SUL is about one to two mm shorter than the snout-vent length (SVL). As the measurement error is higher in the latter, I prefer to use the former. In general, both measurements are more or less identical and are used interchangeably in this paper;
TL tibia length: external distance between knee and ankle;
TaL length of tarsus: external distance, tarsal and ankle 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;
F3L length of third finger;
F3D transversal diameter of disc of 3rd finger;
T1L length of first toe, distal of the inner metatarsal tubercle;
MTL length of the inner metatarsal tubercle;
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 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.

Advertisement calls were recorded under natural conditions with a Sony Digital Audio Tape (DAT) Walkman TCD-D 100 and a Sennheiser microphone MKE 300 and analysed with Avisoft-SAS Lab Pro software. All specimens are currently stored in the Museum für Naturkunde Berlin (ZMB) and bear registration numbers of this institution. Part of the type series will be transferred to the Museum Zoologicum Bogoriense (MZB) after completion of my studies.

Material compared: one paratype of *Xenorhina eiponis* stored in the American Museum of Natural History (AMNH 128234); two paratypes of *X. arboricola* stored in the Bernice P. Bishop Museum Honolulu (BPBM 13745 and 13747); two syntypes of *X. oxycephala* from the National Museum of Natural History, Leiden (RMNH 2280A and 2280B); the holotype of *X. bouwensi* stored in the collection of the Institut Royal des Sciences Naturales de Belgique, Brussels (IRSNB 1019); the type series of *X. varia* (Museum für Naturkunde Berlin, ZMB); the holotype of *X. macrodisca* (Museum Zoologicum Bogoriense, MZB Amph. 10916); and some specimens of *X. bouwensi* and *X. oxycephala* collected by R. Günther in recent years and stored in the ZMB collection. Moreover, morphometric and other data, published by the authors mentioned above, were appraised.

Figure 7 is by BJÖRN STELBRINK (ZMB), all others are by the author.

Xenorhina arndti sp. nov.

Figs. 1–9 and Tab. 1

Holotype. ZMB 74629 (field number = FN 7925), adult male, collected by R. GÜNTHER and A. PIAHAR on 11 September 2008, 6 km direct line NNE of Fakfak town, near the Fakfak-Kokas road, Bomberai Peninsula (neck of Vogelkop), Papua Province, Indonesia, 2°53′S and 132°18′E, elevation 500 m a.s.l. (Fig. 1).
Paratypes. ZMB 74630 (FN 7930) and ZMB 74631 (FN 7875). Both paratypes are adult males, both were collected about 13 km direct line NNE of Fakfak town, near the Fakfak-Kokas road, 2°44′S and 132°19′E, elevation 860 m a.s.l. Collectors were the same as for the holotype. ZMB 74631 was collected on 8 September and ZMB 74630 was collected on 12 September 2008.

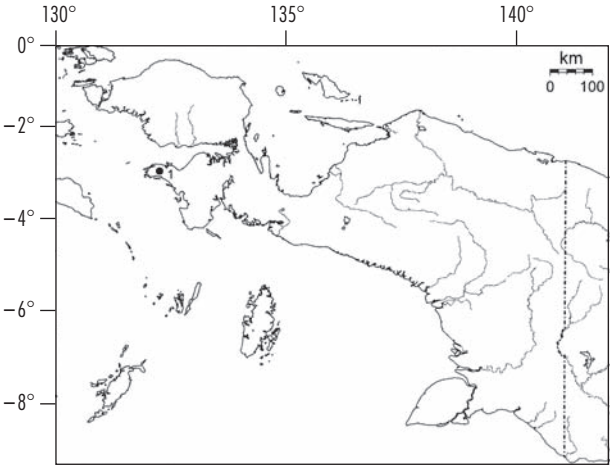

Fig. 1. Map of Papua Province, Indonesia with type locality (1) of *Xenorhina arndti* sp. nov.

Diagnosis. A typical representative of its genus, with a small head, acuminate snout, small eyes (average ED/SUL 0.077), and a rather uniform colour. With a snout-urostyle length of between 23.8 and 27.8 mm in three males, the new species belongs to the small members of its genus. Circum-marginal grooves present on all finger and toe discs, discs of all toes wider than corresponding penultimate phalanges, discs of all fingers not wider than penultimate phalanges; lacking vomero-palatine spikes. Of those species lacking vomero-palatine spikes, only *Xenorhina adisca, X. bouwensi,* and *X. minima* are of a size similar to the new species. *Xenorhina adisca* has no discs on fingers and toes; *X. bouwensi* has shorter tibiae (mean of TL/SUL 0.44, mean in *X. arndti* 0.49), a higher ratio of T4D/F3D (mean in *X. bouwensi* 2.06, mean in *X. arndti* 1.64), and different advertisement calls; *X. minima* has no discs on fingers and toes and shorter legs than the new species. *Xenorhina arndti* seems to spend most of its life underground, and its advertisement call consists of a chain of musical notes and is uttered from small holes in the ground.

Description of the holotype. For measurements see Tab. 1. Head in the region of the tympana broader than long (HL/HW 0.82) and merging seamlessly into the wider body; snout acuminate from above and slightly protruding 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, nearly as large as the eye (TyD/ED 0.95); supratympanic fold extends from posterior corner of eye, touches the dorsal margin of tympanum and reaches up to insertion of foreleg; tibia very long for the genus (ratio TL/SUL 0.51); fingers rather short; no webbing between fingers and toes (Figs. 2 and 3); all finger tips with circum-marginal grooves, tips as wide as, or even narrower, than corresponding penultimate phalanges; all toe tips with discs wider than corresponding penultimate phalanges; relative length of fingers 3>2>4>1; relative length of toes 4>3>5>2>1; except for a rather large metatarsal tubercle, no distinct subarticular, plantar or palmar tubercles present. Body sides in life and in preservative with some distinct tubercles, a few tubercles also on dorsum and on dorsal surfaces of extremities; all ventral surfaces smooth. Tip of snout smooth and not pustulose, as, for example, in *Xenorhina lanthanites*.

Colour in life. Dorsal surface of head, body and extremities uniform brown, lower flanks white with a brownish network. Conspicuous is a dark brown supratympanic ridge (Fig. 4). A whitish mid-dorsal line extends from eye level to urostyle and further as a broken line along the posterior thighs. Anal region blackish; lower tarsi, anterior and posterior tibiae, knee-region, and dorsal surfaces of fingers and toes exhibit a pattern of irregular dark brown and whitish spots. Throat brown with irregular darker and lighter spots; snout tip from below dark brown; chest and belly cream-coloured with some irregular white spots (Fig. 5). Iris nearly circular, blackish with a few golden speckles and a golden inner margin. Colour of the animal in preservative differs only slightly from that in life.

Morphological characters of the paratypes. For measurements of the paratypes see Table 1. While paratype ZMB 74630 exhibits a light brown dorsal colour and a similar arrangement of the colour pattern as the holotype, the dorsal surfaces of paratype ZMB 74631, as in the holotype, are darkish brown, but in life this brown colour as well as all dorsal and lateral light areas were more or less covered by blue (Fig. 6). With exception of the brownish margin of the throat, all other ventral surfaces in ZMB 74630 were whitish. The distribution of darker pigments on ventral surfaces of ZMB 74631 was more like that in the holotype, but basic colour was not cream-coloured but a light orange. Both paratypes have a fine yellowish middorsal line.

Osteology. Unfortunately, the bone-and-cartilage preparation was only partly successful. Consequently, various osteological characters cannot now be properly appraised. However, the genus traits and a lack of vomero-palatine spikes could clearly be assessed.

Molecular evidence. According to B. Stelbrink and T. von Rintelen (pers. comm., September 2010) DNA isolation and PCR were done using the protocol of Köhler & Günther (2008). Forward and reverse strands were aligned using Codon-Code Aligner v.3.0.3. (CodonCode Corporation, Dedham, MA,

Fig. 2. Ventral view of right hand of the holotype of *Xenorhina arndti* sp. nov.

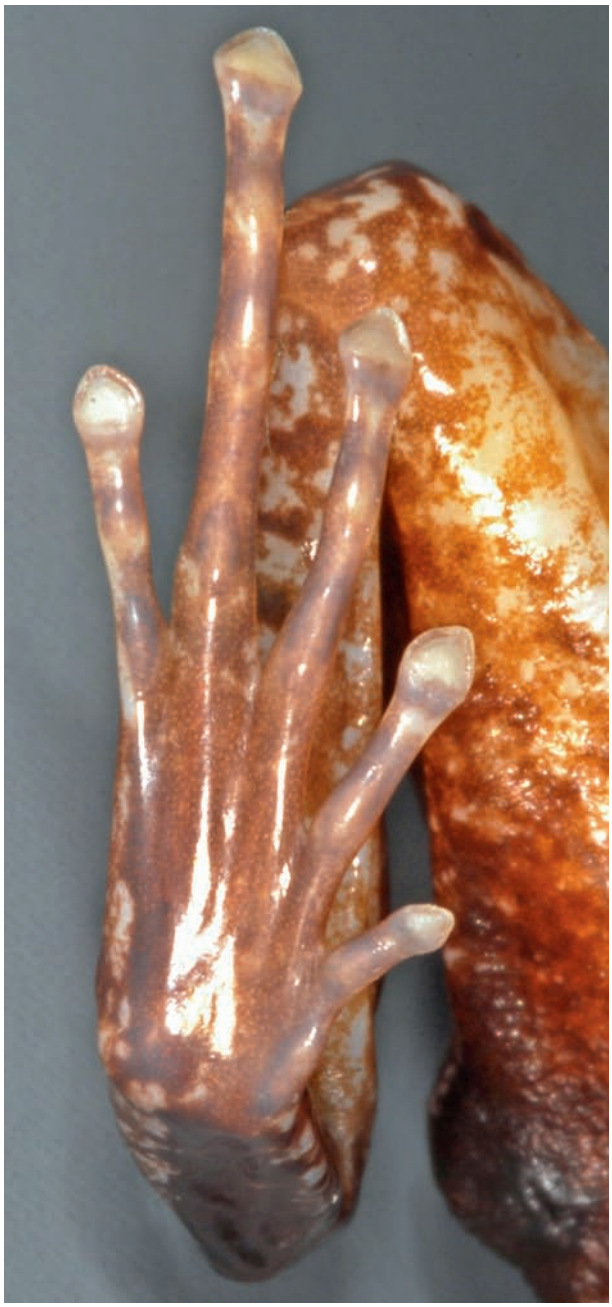

Fig. 3. Ventral view of right foot of the holotype of *Xenorhina arndti* sp. nov.

USA) and corrected by eye. Sequences were aligned using MAFFT (KATOH & TOH, 2008) and optimised using ALISCORE (MISOF & MISOF, 2009). Phylogenetic analysis (Bayesian inference) was accomplished as conducted by GÜNTHER, STELBRINK & RINTELEN (2010).

The analysis of 480 base pairs of the 16S rRNA gene and 680 bp of the 12S rRNA gene revealed that the new species (ZMB 74631) is a sister taxon of *Xenorhina* cf. *oxycephala* (ZMB 74628 and ZMB 74640) that occurs syntopically in the Fakfak Mountains. *Xenorhina* cf. *oxycephala* (ZMB 69562) from the Wondiwoi Mountains, located about 260 km W of the Fakfak Mountains, is obviously a sister taxon of *X. varia* (ZMB 65133, ZMB 65136 and ZMB 65137) from Yapen Island, while *X.* cf. *oxycephala* from Yapen Island is a sister taxon of *X. varia* + *X.* cf. *oxycephala* from the Wondiwoi Mountains (Fig. 7). All *X.* cf. *oxycephala* specimens were determined on the basis of external morphology, using the holotypes and the key by ZWEIFEL (1972) as a reference. According to the molecular characters, shown above, it is very doubtful that *X. oxycephala* inhabits areas in New Guinea as large as, for example, suspected by ZWEIFEL (1972) and MENZIES (2006). More detailed molecular and behavioural (mating calls) studies should be conducted to answer the question of whether *X. oxycephala* in the present sense shows an extreme polymorphism in its mitochondrial genes or whether it consists of several taxa.

The genetic distance (uncorrected p-distance) of *Xenorhina arndti* sp. nov. to *X. bouwensi* is 11.6 %, to *X. lanthanites* 10.5 %, to *X.* cf. *oxycephala* (ZMB 69562) 7.2 %, to *X.* cf. *oxycephala* (ZMB 74628 and ZMB 74640) 4.8 %, to *X.* cf. *oxycephala* (ZMB 74635) 8.1 %, and to *X. varia* 12.3–12.5 % for the 12S rRNA gene. For the 16S rRNA gene, the genetic distance of *X. arndti* sp. nov. to *X. bouwensi* is about 20 %, to *X.*

Fig. 4. Dorsolateral view of the holotype of *Xenorhina arndti* sp. nov. in life.

Fig. 5. Ventral surfaces of the holotype of *Xenorhina arndti* sp. nov. in life.

Fig. 6. Paratype (ZMB 74631) of *Xenorhina arndti* sp. nov. with bluish colouration.

lanthanites 18.0 %, to *X*. cf. *oxycephala* (ZMB 69562) 10.9 %, to *X*. cf. *oxycephala* (ZMB 74628 and ZMB 74640) 7.7 %, to *X*. cf. *oxycphala* (ZMB 74635) 13.6 %, and to *X*. *varia* 10.9 %.

Distribution and ecological notes. All specimens of the type series were collected at between 500 m and 860 m a.s.l. near the road from Fakfak town to Kokas, Fakfak Mountains, Bomberai Peninsula, Papua Prov-

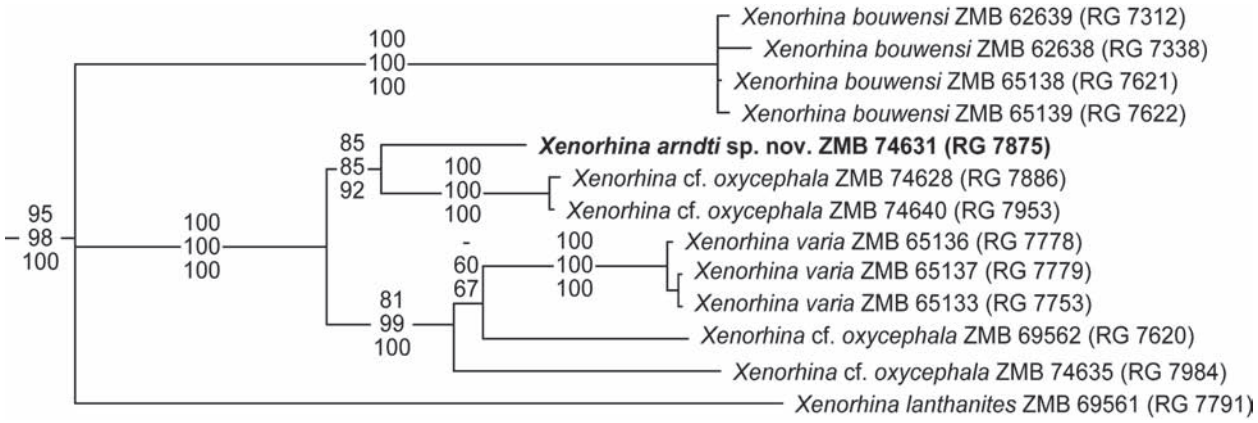

Fig. 7. Bayesian phylogram of the concatenated data set (12S rRNA and 16S rRNA).The numbers on branches are maximum parsimony bootstrap values, maximum likelihood bootstrap values, and posterior probabilities of Bayesian inference (from top to bottom).

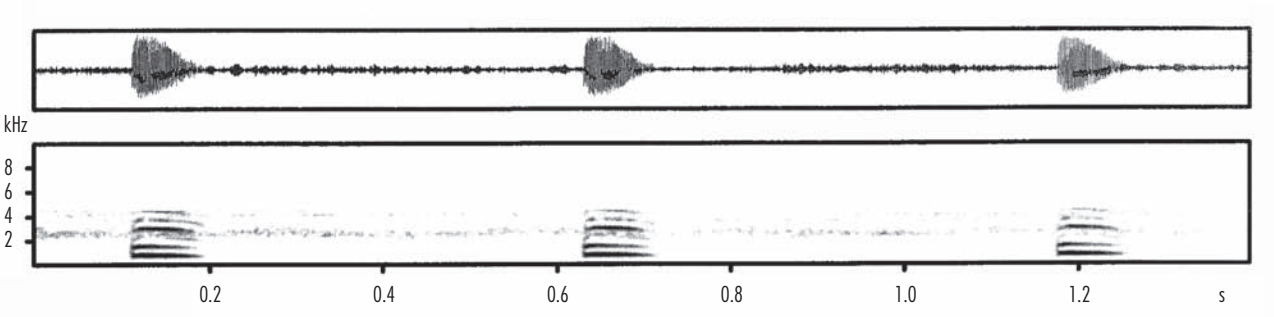

Fig. 8. Wave form (above) and spectrogram (below) of three notes from the middle section of an advertisement call from *Xenorhina arndti* sp. nov.

ince, Indonesia (Fig. 1). Besides the specimens that were collected, we heard only a few more calling in a sector between 400 m and 860 m a.s.l. These latter frogs were found at greater distances from one another, and calls were uttered rather infrequently. This situation could mean that the species is indeed rare, but it is also not impossible that we visited the area outside of the mating season. All three specimens uttered their calls from small holes at 5–15 cm beneath the ground surface. They inhabited primary and secondary rain forest with a greater or lesser developed understory.

Vocalisation. All calls were heard at between 6 and 10 p.m. Three complete calls of one male were analysed. All three have exactly 12 notes. Call duration was from 5.69 s to 5.80 s, mean 5.73 s. Note length was from 57 ms to 88 ms, and the mean of 31 notes was 77 ± 7.1 ms. Twenty-eight internote intervals ranged from 408 ms to 501 ms, mean 438 ± 26.2 ms. Mean note repetition rate was 2.1 notes per s, range 2.07–2.12 notes per s.

Notes are melodious and unpulsed. They start with maximum amplitude and decrease more or less consistently to the end (Fig. 8, above). The first note is the shortest and lowest of all notes. There is an increase in note length and audibility from note one to note five or six, then note length remains more or less stable. The audiospectrogram (Fig. 8, below) shows six harmonics with weak frequency modulation. According to the power spectrum (Fig. 9), the fundamental frequency band centres around 0.80 kHz und exhibits by far the most energy (dominant frequency). The following frequency bands decrease in energy and their main frequencies are around 1.50 kHz, 2.25 kHz, 3.0 kHz, 3.60 kHz and 4.40 kHz.

Comparison with other species. *Xenorhina arndti* sp. nov. differs from the majority of its congeners by lacking vomero-palatine spikes. From the congeners without vomero-palatine spikes, the species *X. arboricola* (SVL 38–41 mm), *X. eiponis* (SVL 35 mm), *X. macrodisca* (SVL 41 mm), *X. oxycephala* (SVL 40–50 mm), *X. parkerorum* (SVL 70 mm), *X. similis* (SVL about 50 mm), and *X. varia* (SVL 39 mm) are larger than the new species. In *X. eiponis*, which possibly overlaps in size, the discs of fingers and toes are of a similar size while in *X. arndti* toe discs are

Tab. 1. Body measurements and body ratios of the type series of *Xenorhina arndti sp. nov.* ZMB-No are the inventory numbers of the Museum für Naturkunde Berlin, FN are the author's field numbers. ZMB 74629 is the holotype, ZMB 74631 is now an osteological preparation. All three specimens are adult males. All measurements are in mm; abbreviations are explained in "Materials and methods".

ZMB-No **FN**	74629 7925	74630 7930	74631 7875	Mean
SUL	27.8	25.3	23.8	25.6
TL	14.1	12.3	11.2	
TaL	9.3	7.8	7.4	
T4L	13.5	11.1	10.1	
T4D	1.2	0.8	0.8	
F3L	6.0	5.2	5.4	
F3D	0.7	0.5	0.5	
HL	8.2	7.3	7.5	
HW	10.0	8.9	8.5	
END	2.5	2.3	2.3	
IND	1.8	1.5	1.4	
ED	2.1	1.9	1.9	
TyD	2.0	1.5	1.4	
Sl	3.8	3.1	3.6	
L1T	2.8	2.0	2.2	
LCint	1.4	0.9	0.8	
TL/SUL	0.51	0.49	0.47	0.49
TaL/SUL	0.33	0.31	0.31	0.32
T4L/SUL	0.49	0.44	0.42	0.45
T4D/SUL	0.043	0.032	0.034	0.036
F3L/SUL	0.22	0.21	0.23	0.22
F3D/SUL	0.025	0.020	0.021	0.022
T4D/F3D	1.71	1.60	1.60	1.64
HL/SUL	0.29	0.29	0.32	0.30
HW/SUL	0.36	0.35	0.36	0.36
HL/HW	0.82	0.82	0.88	0.84
END/IND	1.39	1.53	1.64	1.52
ED/SUL	0.076	0.075	0.080	0.077
TyD/ED	0.95	0.79	0.74	0.83
SL/SUL	0.137	0.123	0.151	0.137
Lcint/T1L	0.50	0.45	0.36	0.44

clearly wider than finger discs. *Xenorhina adisca* is smaller (SVL 18–24 mm) than *X. arndti* and has no discs on fingers and toes. *Xenorhina minima* has very short legs (TL/SVL < 0.40) and fingers and toes without discs. *Xenorhina bouwensi* differs from the new species by shorter tibiae. In 14 specimens of *X. bouwensi,* the ratio TL/SUL varies from 0.40–0.50, mean 0.44; *X. arndti* with a TL/SUL ratio of 0.47–0.51, mean 0.49, has, together with *X. eiponis, X. ophiodon,* and *X. obesus,* the longest hind legs in the genus (Günther & Knop, 2006; Menzies, 2006). Besides shorter tibiae, *X. bouwensi* also exhibits a greater ratio T4D/F3D (1.67–2.66, mean 2.06) than *X. arndti* (1.60–1.71, mean 1.64), has another structure of the advertisement call notes, has a more than 10 % genetic difference in the 12S gene, and has a more than 15 % difference in the 16S gene.

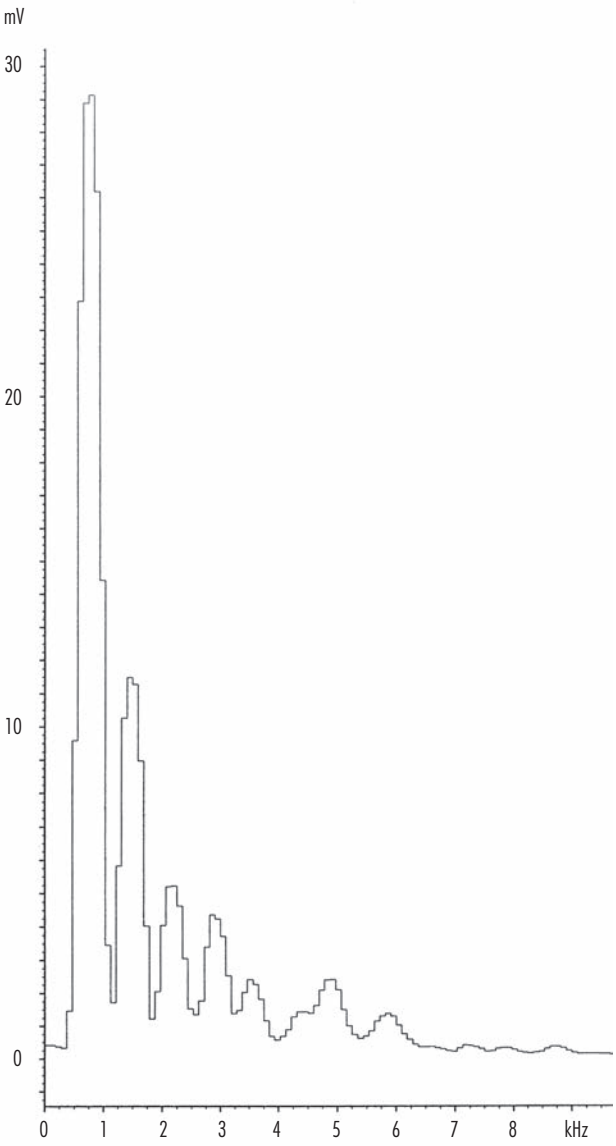

Fig. 9. Power spectrum of a single note of *Xenorhina arndti* sp. nov.

Etymology. The specific epithet is a patronym in genitive singular. With this specific name I acknowledge certain financial support and editorial assistance by my dear colleague Dr. Rudolf G. Arndt of The Richard Stockton College of New Jersey, Pomona (New Jersey/USA) for my studies on the herpetofauna of New Guinea in recent years.

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