Description of a new microhyrid 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

> Key words

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 possesses 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. parkeri* 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 & KNOB, 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 Dingkerus & 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 Naturelles 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.
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, USA).
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The genetic distance (uncorrected p-distance) of Xenorhina arndti sp. nov. to Xenorhina bouwensi is 11.6 %, to X. lanthanites 7.2 %, 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 Xenorhina arndti sp. nov. to X. bouwensi is about 20 %, to X. bouwensi (ZMB 65133, ZMB 65136, and ZMB 65137) from Yapen Island.

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 Xenorhina arndti sp. nov. to X. bouwensi is about 20 %, to X.
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-
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...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 and 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”.

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don, 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.

**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.

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. ophiu-

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

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