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## Beautiful bright belly: A distinctive new microhylid frog (Amphibia: *Stumpffia*) from eastern Madagascar

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### Abstract

We describe a new red-bellied species of the microhylid frog genus *Stumpffia* from the Andasibe region (18°56' S, 48°25' E, ca. 900 m elevation) in central-eastern Madagascar. *Stumpffia kibomena* sp. nov. differs from all other described *Stumpffia* species in coloration, morphology, and by genetic differentiation in the mitochondrial 16S rRNA gene ( $\geq 8.6\%$  uncorrected p-distance to all other nominal species of the genus). It is furthermore distinguished from most other *Stumpffia* species by its advertisement calls. The new species is reliably known only from a few specimens collected in the Andasibe region and based on the limited knowledge we suggest its IUCN Red List classification as "Data Deficient".

**Key words:** Amphibia, Anura, Cophylinae, Madagascar, Microhylidae, *Stumpffia kibomena* sp. nov.

### Introduction

Within the Malagasy microhylid subfamily Cophylinae two major ecological groups can be distinguished: arboreal species with dilated finger tips and terrestrial species, usually without terminal finger discs (Andreone *et al.* 2005). Terrestrial cophylines include the genera *Madecassophryne*, *Rhombophryne*, *Stumpffia* and most species of the genus *Plethodontohyla* (Wu 2003). Species of *Stumpffia* are relatively well characterized by small to very small body size (adult snout-vent length 10–28 mm) and the absence of maxillary and vomerine teeth (Guibé 1978; Blommers-Schlösser & Blanc 1991; Köhler *et al.* 2010), a character combination shared only with *Madecassophryne*. As primarily terrestrial frogs, most *Stumpffia* species have no terminal finger discs, although exceptions with well developed finger discs are known from *Stumpffia helenae* (Vallan 2000) and several cave dwelling species from karstic habitats (Köhler *et al.* 2010). The majority of *Stumpffia* species form a well-supported monophyletic group sister to *Rhombophryne* but *S. helenae* is only poorly supported in this clade, and some yet undescribed lineages from south-eastern Madagascar might represent a phylogenetically independent radiation of miniaturized cophylines (Wollenberg *et al.* 2008).

*Stumpffia* currently contains 15 described taxa (Köhler *et al.* 2010; Klages *et al.* 2013; Ndriantsoa *et al.* 2013), which are generally characterized by tiny distribution ranges. In Madagascar, a high degree of miniaturization and microendemism is paralleled by a high species diversity in some organism groups (Wollenberg *et al.* 2011; Glaw *et al.* 2012). Thus it is not surprising that many undescribed species and lineages of *Stumpffia* have been identified (Glaw & Vences 2007; Wollenberg *et al.* 2008; Vieites *et al.* 2009; Perl *et al.* 2014). Most of the undescribed species are morphologically similar to each other as well as to described taxa and their taxonomic description requires a careful revision of the genus, which is currently in progress.

In this paper we describe a new red-bellied species that can be distinguished easily from all other *Stumpffia*

species and all other cophylines. This species was discovered, and identified as a new taxon, as early as 1995. However, no DNA sequences for molecular analysis could be obtained until recently, and the DNA sequences now available confirm this form as representing a new species with strong molecular divergence to all other nominal species of the genus.

## Material and methods

Morphological measurements were taken by F. G. with calipers to the nearest 0.1 mm. Calls were recorded using a Tensai portable tape recorder (RCR-3222) with external Vivanco EM 238 microphone and analyzed with the sound-analysis system MEDAV Spekto 3.2. Temporal call parameters are given in milliseconds (ms) as range, followed by mean  $\pm$  standard deviation and number of analyzed units (n) in parentheses. Type specimens are deposited in NMBE (Naturhistorisches Museum Bern, Switzerland) and ZFMK (Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany).

Toe clips of three specimens with SVL of 18.0–21.5 mm (sample numbers 012, 019, and 020 from Andasibe), captured on 18 December 2013 and 25 January 2014 on road at Andasibe (between 18.93805°S/48.41424°E and 18.93548°S/48.41431°E) by the NGO Mitsinjo, were used for DNA extraction. The corresponding frogs were photographed (one or two of the specimens shown in Fig. 1 A–B) and released after tissue sampling. Total genomic DNA was extracted from the tissue samples using proteinase K digestion (10 mg/ml concentration) followed by a standard salt extraction protocol (Bruford *et al.* 1992). A fragment of the mitochondrial 16S rRNA gene was amplified using standard protocols and with primers 16SL3 and 16SAH (Vences *et al.* 2003; see Vences *et al.* 2010 for exact methodology applied). All newly obtained sequences were deposited in GenBank (accession numbers KM881483–KM881485) and compared with sequences from previous works (Wollenberg *et al.* 2008; Klages *et al.* 2013; Ndriantsoa *et al.* 2013). Uncorrected pairwise distances among sequences (p-distances) were computed with MEGA 5 (Tamura *et al.* 2011).

## Results

### *Stumpffia kibomena*, sp. nov.

Figs. 1, 2

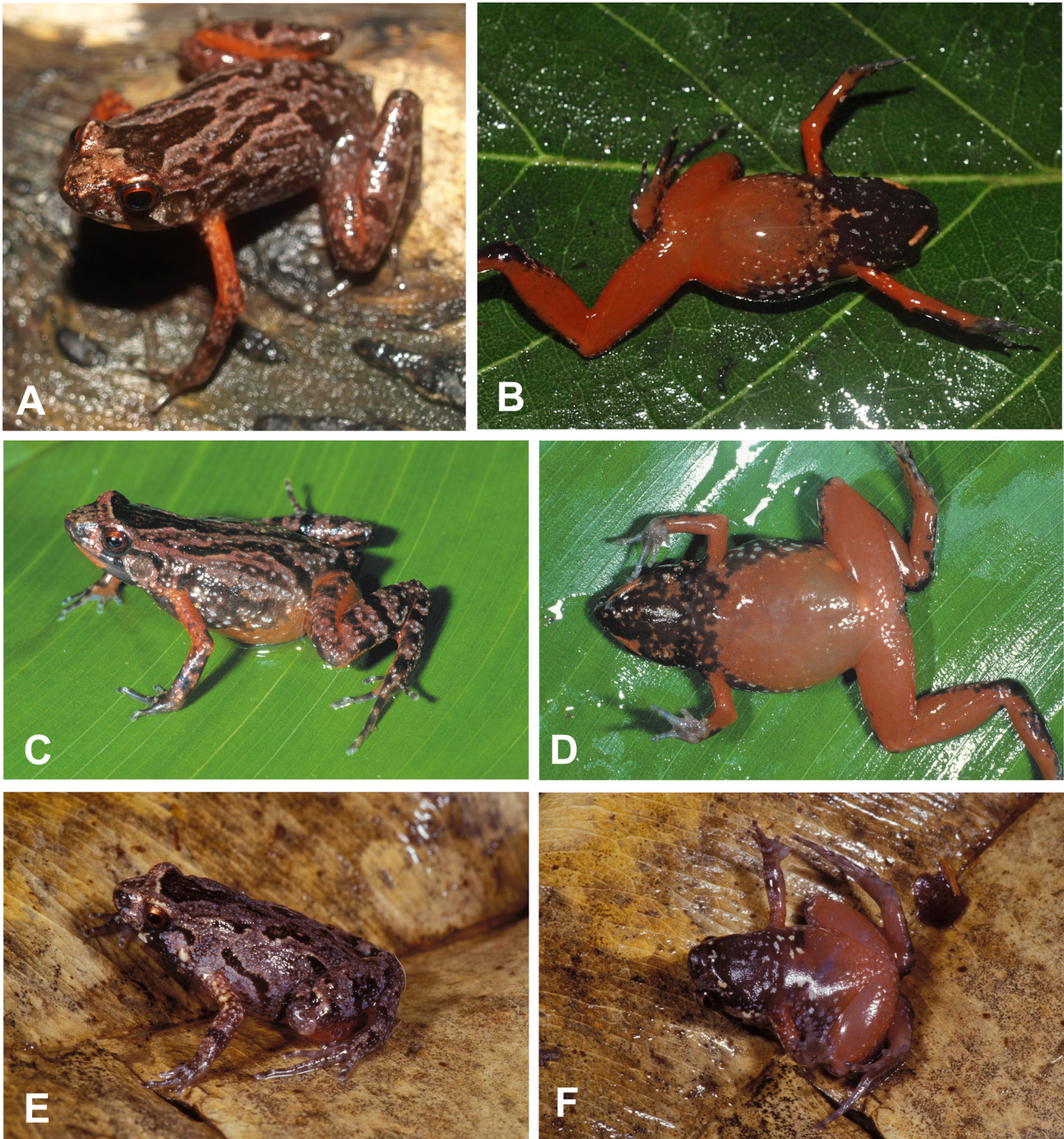
**Remark.** This species has been previously referred to as *Stumpffia* sp. (Andasibe) by Vences *et al.* (2006: 39) and as *Stumpffia* sp. “kibomena” by Glaw & Vences (2007: 130).

**Holotype.** ZFMK 60007 (Fig. 2), adult male, collected near Andasibe (18°56' S, 48°25' E), ca. 900 m elevation, central-eastern Madagascar, by F. Glaw on 17 January 1995.

**Paratypes.** NMBE 1044940, adult male, collected in An'Ala forest (18°55' S, 48°29' E, ca. 850 m elevation), east of Andasibe, central-eastern Madagascar, by D. Vallan on 14 February 1997; NMBE 1034211 (Fig. 1 E–F), probably adult male, collected near Andasibe (18°55' S, 48°25' E, ca. 950 m elevation), central-eastern Madagascar, by D. Vallan on 13 February 1995.

**Diagnosis.** The new species is assigned to the genus *Stumpffia* on the basis of its small size, absence of vomerine and maxillary teeth, phenetic similarities to other species in the genus, and molecular phylogenetic relationships. It is a small-sized terrestrial cophyline frog, but one of the larger *Stumpffia* species, adult snout-vent length (SVL) 17.1–21.2 mm. Five toes and four fingers (no digital reduction). Tympanum distinct and large (63–88% of eye diameter). No maxillary teeth, no vomerine teeth, tips of fingers and toes not dilated, third toe longer than fifth, tibiotarsal articulation reaching the eye if hindlimb is adpressed along body, tympanum distinct, dorsal skin relatively smooth, ventral side of belly, hindlegs and arms almost uniformly bright red (largely uniform yellowish after ten years in preservative), throat black.

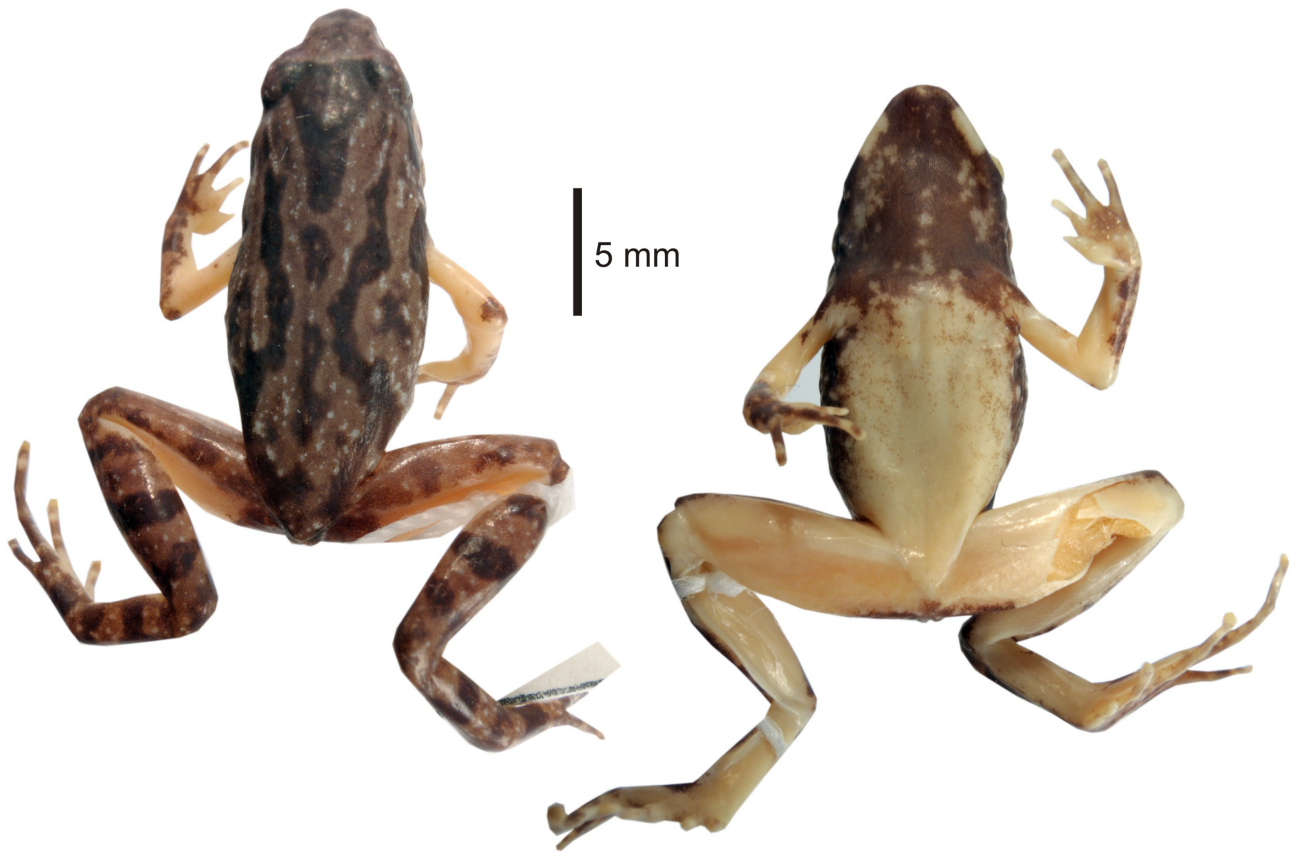
*Stumpffia kibomena* differs from all other terrestrial cophyline species without dilated finger tips as follows: from all *Plethodontohyla* and *Rhombophryne* by the absence of vomerine teeth (vs. presence) and by smaller SVL (except for the small-sized *Rhombophryne minuta* and *R. mangabensis* with a SVL of 20–24 mm); from *Madecassophryne truebae* by relatively smooth dorsal skin (versus granular), a larger tympanum (tympanum/eye 0.6



**FIGURE 1.** *Stumpffia kibomena* sp. nov. in life, in dorsolateral and ventral view, respectively. (A–B) One or two individuals (not collected) from Andasibe used for DNA sequencing (photos: D. Edmonds); (C–D) female specimen from An’Ala (photos: F. Glaw); (E–F) male paratype NMBE 1034211 from near Andasibe (photos: D. Vallan).

versus 0.2), and ventral colour pattern. *S. kibomena* differs from all other *Stumpffia* species as follows: from *S. helenae*, *S. staffordi*, *S. be*, *S. hara* and *S. megsoni* by non-dilated finger tips (vs. slightly to strongly dilated); from *S. analamaina*, *S. madagascariensis*, *S. miery*, *S. pygmaea*, *S. tetradactyla*, and *S. tridactyla* by larger size (SVL 17–21 mm vs. 10–15 mm); from *S. psologlossa* (SVL 14–16 mm) by larger size, and unpulsed notes of advertisement calls (vs. pulsed notes); from *S. gimmeli* (SVL of adult specimens 15–18 mm) by larger size and dorsal coloration (compare colour photographs in Glaw & Vences 2007). *Stumpffia kibomena* mostly resembles *S. grandis* (SVL 19–25 mm) and *S. roseifemoralis* (SVL 19–22 mm). It differs from *S. roseifemoralis* (Fig. 3 E–F) by dorsal coloration and ventral coloration (throat black and belly uniformly bright red vs. throat light and belly yellowish-grey marbled with light brown). It differs from *S. grandis* (Fig. 3 C–D) by ventral coloration (belly

uniformly bright red vs. belly bluish-grey marbled with black). In addition, *S. kibomena* differs from all described *Stumpffia* species by a bright red ventral surface of belly, legs and arms in life and a high note repetition rate of 1.3 notes per second which is higher than in all other described species in which advertisement calls are known. It differs from all described *Stumpffia* species except *S. grandis* in having a blackish throat. Furthermore, *S. kibomena* differs from all described *Stumpffia* species by significant genetic differentiation in the mitochondrial 16S gene ( $\geq 8.6\%$  uncorrected pairwise sequence divergence, see below).



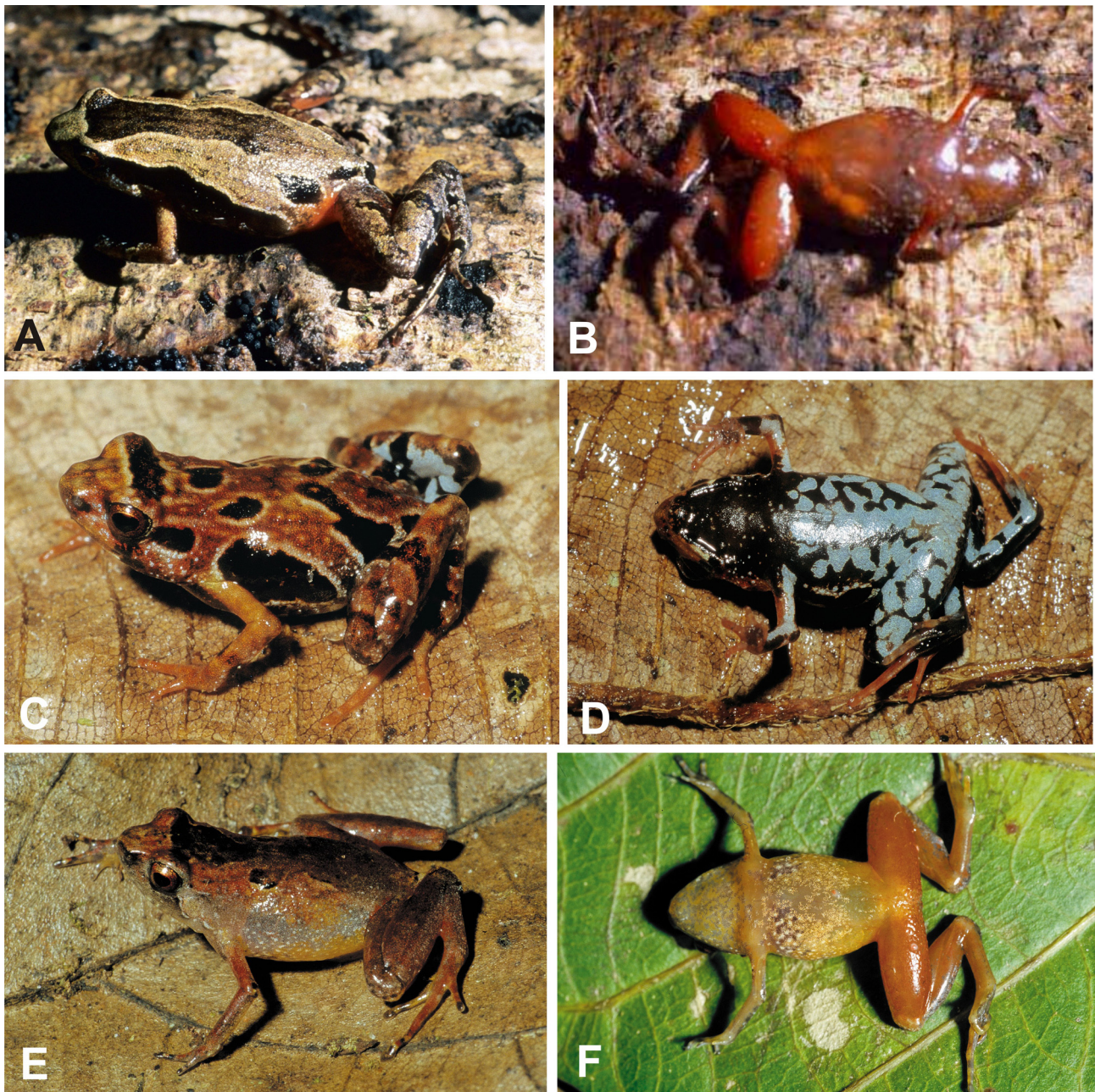
**FIGURE 2.** *Stumpffia kibomena* sp. nov., preserved male holotype (ZFMK 60007) in dorsal and ventral view (photos: M. Franzen).

**Description of holotype.** Specimen in good state of preservation, fixed in concentrated ethanol and stored in 70% ethanol. After several years in preservative, a tissue sample was taken from the left thigh (but did not result in successful DNA extraction). Body elongated; head wider than long, not wider than body; snout roughly rounded in dorsal and lateral views; nostrils directed laterally, not protuberant, nearer to tip of snout than to eye; canthus rostralis moderately distinct; loreal region almost flat; tympanum distinct, about 63% of eye diameter; supratympanic fold indistinct; tongue elongated, slender, free posteriorly and not notched; maxillary teeth absent; vomerine teeth absent; choanae rounded. Forelimbs slender; subarticular tubercles single, very indistinct; outer metacarpal tubercle not recognizable, a distinct protuberance at base of first finger which probably represents the nuptial pad; hand without webbing; relative length of fingers  $1 < 2 < 4 < 3$ , fourth finger slightly longer than second; finger tips not expanded into discs. Hind limbs slender; tibiotarsal articulation reaching the eye when hind limb adpressed along body; tibia length 50% of SVL; lateral metatarsalia strongly connected; inner metatarsal tubercle small; outer metatarsal tubercle absent; no webbing between toes; relative length of toes  $1 < 2 < 5 < 3 < 4$ ; fifth toe distinctly shorter than third. Skin on dorsum relatively smooth, without distinct dorsolateral folds. Ventral skin smooth.

Measurements (in mm). Snout-vent length 21.2, maximum head width 6.7, head length from tip of snout to posterior edge of snout opening 5.1, horizontal tympanum diameter 1.2, horizontal eye diameter 1.9, distance between anterior edge of eye and nostril 1.9, distance between nostril and tip of snout 1.1, internarial distance 2.4, forelimb length (from limb insertion to tip of longest finger) 12.5, hand length, to the tip of the longest finger 5.0,

hind limb length (from the cloaca to the tip of the longest toe) 35.5, tibia length 10.6, foot length including tarsus 15.3, foot length 10.0, length of nuptial pad along inner finger 1.3.

Colour of holotype in preservative (Fig. 2). After ten years in 70% ethanol the dorsum was brown with distinct black markings. A black, triangular marking between eyes, extending posteriorly to a point between neck and middorsum (seen from lateral view until the insertion of forelimbs). Posterior to this point, elongated black markings form an interrupted narrow vertebral band. Lateral to this two further continuous narrow black bands extend posteriorly from insertion of arms, converge toward the vertebral band at middorsum, then diverge posteriorly toward the inguinal region. An elongated black spot present laterally above and behind insertion of arms and a smaller black spot above the tympanum. Distinct black bands present on tibia, tarsus and foot and (less distinctly) on lower arm and hand. The brown dorsal areas contain fine white dots. Cloacal region dark brown; throat dark brown, except for small irregular yellowish spots and two distinct yellowish spots of about 2 mm length on lower lip below eyes. Belly, and ventral parts of upper arm, lower arm, upper leg, lower leg, and foot yellowish. Colour in life unknown.



**FIGURE 3.** Comparative *Stumpffia* species in dorsolateral and ventral view. (A–B) *Stumpffia* aff. *kibomena* from Masoala (photos: J. E. Randrianirina); (C–D) *S. grandis* from its type locality Marojejy (photos: F. Glaw & M. Vences); (E–F) *S. roseifemoralis* from its type locality Marojejy (photos: F. Glaw & M. Vences).

**Variation.** Measurements (in mm) refer to NMBE 1044940, followed by NMBE 1034211 in parentheses. Specimens in good state of preservation, fixed in concentrated ethanol and stored in 70% ethanol. Snout-vent length 19.8 (17.1), maximum head width 6.9 (6.2), head length from tip of snout to posterior edge of snout opening 4.9 (4.3), tympanum distinct, horizontal tympanum diameter 1.4 (1.3), horizontal eye diameter 1.6 (1.6), distance between anterior edge of eye and nostril 1.7 (1.3), distance between nostril and tip of snout 0.8 (0.8), distance between both nostrils 2.4 (2.3), forelimb length (from limb insertion to tip of longest finger) 12.1 (11.5), hand length, to the tip of the longest finger 4.5 (4.4), hind limb length, from the cloaca to the tip of the longest toe 32.0 (29.5), tibia length 9.6 (9.3), foot length including tarsus 14.7 (14.8), foot length 8.9 (9.2), length of nuptial pad along inner finger 1.2 (indistinct). General morphology similar to the holotype. Tibiotarsal articulation reaching the eye if hind limb is adpressed along body. In preservative, the dorsal colour pattern of NMBE 1044940 is generally similar to that of the holotype. However, the lateral dark longitudinal markings on the back of NMBE 1044940 are in contact in the posterior part of the back, forming a large X-like structure. The dorsal pattern of NMBE 1034211 is much less distinct and contrasting, although the dark triangular marking between the eyes and dark longitudinal markings are recognizable. The ventral colour pattern of both paratypes agrees with the holotype. The dorsal and ventral coloration in life documented in Fig. 1 A–F. Dorsal ground colour brown to copper with a pattern of dark brown or black markings. Upper arms reddish to brown. All unmelanized ventral areas bright red. Throat largely black with reddish or grey spots and dots. A symmetrical, elongated reddish marking can be present on each side of the lower jaw. Flanks can show white spots. Ventral side of hands and fingers grey. Iris copper.

A series of specimens from the Masoala peninsula in north-eastern Madagascar (Fig. 3 A–B; MRSN-A 2602–2607), collected by J. E. Randrianirina on 27–31 January 2002 at a campsite locally known as “Ambohitsitondroina” (15°26.00’S, 49°57.34’ E, 1100 m above sea level) resembles *Stumpffia kibomena* by a uniformly yellowish ventral side in preservative (red in life), a blackish throat, a dark marking between the eyes extending onto the back, and similar size (SVL 19–23 mm), but is easily distinguished by coloration, especially the presence of a distinctly elongated black lateral marking that runs from the posterior edge of the eye to the posteriormost third of the flanks (absent in *S. kibomena*). Unfortunately, DNA sequences and call data are not yet available to clarify the taxonomic status of this population, and we tentatively assume that this population does not belong to *S. kibomena* but rather to a still undescribed species.

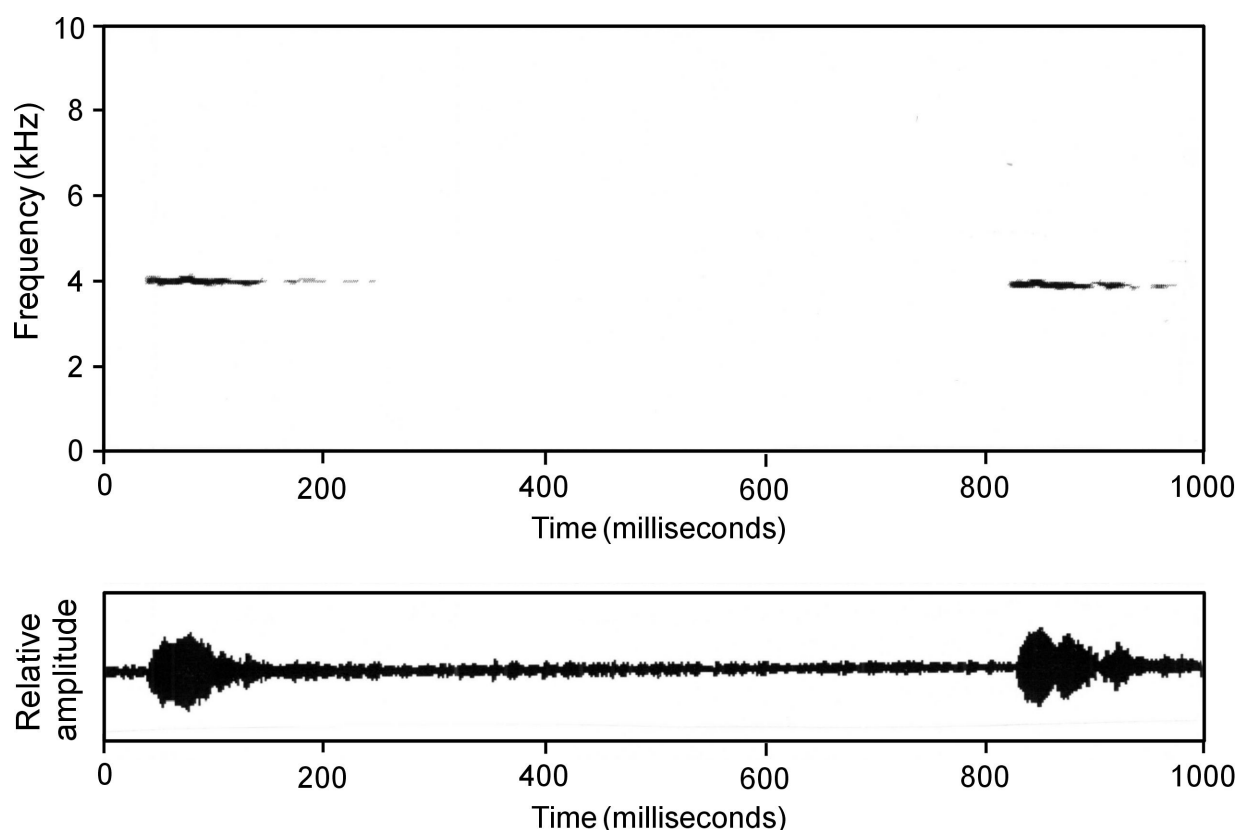
**Distribution.** *Stumpffia kibomena* is only known from the Andasibe region in central-eastern Madagascar at an altitudinal range between 900–950 m above sea level. The two principal localities have an airline distance of 8 km from each other. Other *Stumpffia* specimens with red ventral colour either belong to other undescribed species (e. g. *Stumpffia* sp. “Ranomafana”, see Glaw & Vences 2007: 130–131) or cannot be reliably identified with the data available.

**Natural history.** The frogs were found during the day on the ground, in the leaf litter of primary rainforest, in eucalypt forest, in secondary fern scrub, as well as at night moving across a road, thus indicating that the habitat is rather variable. Calling males were heard in February and March during the rainy season, in the morning and in the afternoon. *S. kibomena* occurs sympatrically with at least two other species *Stumpffia* species (*S. aff. tridactyla* and *S. aff. grandis*).

**Advertisement calls.** Recorded on 20 March 1995 at 15:15 h and 24°C air temperature (no voucher specimen). The call (Fig. 4) is a single melodious note that is repeated after regular intervals. The specimen emitted regular series of 11–22 notes (n=5), with a note-repetition rate of 1.2–1.3 per second. Note duration was 70–76 ms (73±2 ms, n=9) and duration of intervals between notes was 770–813 ms (797±15 ms, n=9). The frequency range was 3900–4300 Hz. When searching for this characteristic call, we discovered several times specimens of *S. kibomena*. Unfortunately, we were not able to observe these specimens in the moment of sound production (with inflated vocal sac), so there remains a minimal uncertainty in the attribution of the calls to *S. kibomena*. Additional call recordings are available on a published audio soundguide (Vences *et al.* 2006).

**Molecular differentiation.** The three obtained 16S sequences of *S. kibomena* had identical haplotypes. The lowest pairwise uncorrected sequence divergence (p-distance) in the analyzed 16S fragment of *S. kibomena* to other nominal species is found in comparison to *S. grandis* (8.6%), while the distance to all other nominal species (including *S. roseifemoralis*, the only other described species with reddish ventral pigment) ranges between 14–19%. These high values are not unusual in *Stumpffia* (Ndriantsoa *et al.* 2013) and indicate a high genetic divergence between most of these small-sized cophyline species. A phylogenetic analysis will be published in a forthcoming comprehensive revision of the genus.

**Etymology.** The specific name is derived from the Malagasy words "kibo" (= venter) and "mena" (= red). It is used as noun in nominative singular, standing in apposition to the generic name.



**FIGURE 4.** Sonagram and oscillogram of two calls of *Stumpffia kibomena* sp. nov. (recorded on 20 March 1995 at 15:15 h and 24°C air temperature).

## Discussion

With the description of *S. kibomena* we add a distinctive though poorly known new species to the genus *Stumpffia*. Orange or red colour on belly and inguinal region is relatively common in terrestrial and arboreal cophyline microhylids and Madagascan treefrogs of the genus *Boophis* (Glaw *et al.* 2001; Vences *et al.* 2012). However, this colour is rarely as bright in life as in *Stumpffia kibomena* and rarely extending over such a large ventral area. Similar to the situation in red-bellied snakes from Madagascar (Glaw *et al.* 2014) the function of the red ventral colour remains poorly known, and might be interpreted either in the context of anti-predator defense or intraspecific signalling.

Phenetically, the new taxon is most similar to the similarly sized *S. roseifemoralis* and *S. grandis*. *Stumpffia roseifemoralis* is the only other described *Stumpffia* species with any reddish colour on the ventral surface (although much less distinct), but is not closely related genetically (see above). *Stumpffia grandis* is the only other described species with a black throat. Based on the drawing of *S. grandis* by Guibé (1978: Planche 64) and on topotypical material (Fig. 3 C–D) *S. grandis* has a dorsal colour pattern that is principally similar to *S. kibomena*. Both species also share a distinct black marking between the eyes, an elongated black spot along the flank posteriorly to the insertion of arms, and elongated black markings running from the posterior dorsum to the inguinal region. Judging from the phenetic similarities in size and colour pattern, *S. grandis* was expected to be closely related to *S. kibomena* and this assumption is confirmed by their close genetic relationships.

Despite many herpetological surveys in the rainforest areas of Madagascar between 1987 and 2014 we were able to hear or capture only few specimens of *S. kibomena*, whereas most other *Stumpffia* species from humid areas are relatively common and easy to find (e. g. Vences & Glaw 1991). Although this species is very conspicuous in ventral coloration it is apparently absent from the major herpetological collections encompassing material from

Madagascar. This might indicate that the habits of *S. kibomena* are rather cryptic or seasonal, or that the species is indeed rare and restricted to a relatively small distribution range. The presence of *S. kibomena* in the rather well-protected reserve Analamazaotra might assure its survival. Because *S. kibomena* is known only from two locations (situated close to each other) and a few specimens, we suggest its inclusion in the IUCN category "Data Deficient" (DD) according to the IUCN Red List criteria (IUCN 2001).

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