SALAMANDRA **46**(3) | 167–179 | 20 August 2010 | ISSN 0036–3375

A Tarzan yell for conservation: a new chameleon, *Calumma tarzan* sp. n., proposed as a flagship species for the creation of new nature reserves in Madagascar

Philip-Sebastian Gehring[1], Maciej Pabijan[1,6], Fanomezana M. Ratsoavina[1,4,5],
Jörn Köhler[2], Miguel Vences[1] & Frank Glaw[3]

[1] Division of Evolutionary Biology, Zoological Institute, Technical University of Braunschweig, Spielmannstr. 8, 38106 Braunschweig, Germany
[2] Department of Natural History – Zoology, Hessisches Landesmuseum Darmstadt, Friedensplatz 1, 64283 Darmstadt, Germany
[3] Zoologische Staatssammlung München, Münchhausenstr. 21, 81247 München, Germany
[4] Département de Biologie Animale, Université d'Antananarivo, BP 906. Antananarivo, 101, Madagascar.
[5] Grewcock´s Center for Conservation Research, Omaha´s Henry Doorly Zoo, 3701 South 10th Street, Omaha, NE 68107-2200, U.S.A.
[6] Department of Comparative Anatomy, Institute of Zoology, Jagiellonian University, ul. Ingardena 6, 30-060 Kraków, Poland

Corresponding author: Philip-Sebastian Gehring, e-mail: sebastiangehring@web.de

Manuscript received: 23 June 2010

Abstract. We describe *Calumma tarzan* sp. n., a morphologically distinct chameleon species of the *Calumma furcifer* species group from rainforest fragments in the Anosibe An'Ala region of central eastern Madagascar. Males and females of this species differ from all other species of the *Calumma furcifer* group by its rostral crests, which are fused anteriorly to form a spade-like ridge that slightly projects beyond the snout tip (less than 1 mm), by a unique stress colouration with a pattern of bright yellow and green, and by significant genetic divergence as assessed by an analysis of sequences of a fragment of the mitochondrial ND4 gene. We suspect that *Calumma tarzan* might be restricted to a rather small and fragmented distribution range and we consider the IUCN conservation status of "Critically Endangered" as adequate for this species. Moreover, we propose *Calumma tarzan* as a flagship species for the establishment of new protected areas in central-eastern Madagascar and suggest that biological surveys be carried out in the largely unexplored forest fragments of the region.

Key words. Squamata, Chamaeleonidae, *Calumma tarzan*, new species, forest fragments, Madagascar.

Introduction

Madagascar is an island that is recognized as one of the richest biodiversity centers with many microendemic taxa and with one of the highest rates of natural habitat loss worldwide (Myers et al. 2000). Current conservation priorities in Madagascar are focused on multitaxonomic approaches and no doubts exist that these rather than single-taxon approaches are critical for identifying and protecting areas likely to promote the persistence and conservation of a maximum number of different species (e.g., Kremen et al. 2008). Another concept to increase awareness and publicity for an area is to choose a charismatic or impressive species that attracts popular support ("flagship species", e.g. Williams et al. 2000) to represent a habitat or ecosystem in need of conservation, in order to successfully leverage the conservation of all species contained therein. In Madagascar, lemurs are typically used as flagship species for conservation activities, besides a few other representatives of Madagascar's enigmatic fauna such as the tomato frog *Dyscophus antongilii* in Maroantsetra (Tessa et al. 2007), or some charismatic species of birds (Rabearivony et al. 2010). However, especially the herpetofauna of Madagascar contains more species of striking and colourful appearance (e.g. Glaw et al. 2010, Vieites et al. 2010), with a high recognition value and with great potential to obtain people's sympathies (e.g. Wollenberg et al. in press).

One of the greatest problems for nature conservation in Madagascar is the ongoing rapid fragmentation of forest habitats and the unstable situation of forests even in some major protected areas due to poor governance and undermined judicial control (e.g. D'Cruze et al. 2008, Randriamalala & Liu 2010). Recently, illegal large-scale logging of rosewood within protected areas in the wake of the political crisis in 2009 created international awareness and protests (Randriamalala & Liu 2010). In many regions of the island, the forest has been reduced to very small, patchy fragments that are often more or less disturbed. These fragments are no longer suitable for the protection of large mammals (e.g., lemurs of the genera *Propithecus* or *Indri*) and, as a consequence, they are often neglected in the delimitation of protected areas. However, a large portion of the Malagasy fauna (including several chameleon species) is at least somewhat tolerant to forest disturbance (e.g., Jenkins et al. 1999, 2003, Rabearivony et al. 2007), and it would therefore be feasible to preserve major portions of the highly microendemic Malagasy fauna by also protecting small fragments with partly degraded buffer zones.

Madagascar is the center of chameleon species diversity (Brygoo 1971, 1978), with many species being restricted to primary forest habitats. The three Malagasy genera *Brookesia*, *Calumma*, and *Furcifer* include approximately 40% of the world's known chameleon species, including the largest and the smallest representatives. They are popular and enigmatic components of the Malagasy herpetofauna for ecotourists (Wollenberg et al. in press), qualifying them as ideal flagship species for conservation activities.

The genus *Calumma* is currently composed of 30 species, which are distributed in the humid rainforests and montane regions of eastern and central Madagascar (Glaw & Vences 2007). A further species (*C. tigris*) is endemic to the continental Seychelles islands, but this species shows little external similarity to any Malagasy species group and its affinities to *Calumma* are currently under study (T. Townsend et al. unpublished data). In contrast to the genus *Furcifer*, in which only a few new species have been discovered in recent times (Glaw et al. 2009), nine new species of *Calumma* have been described in the last 15 years and a further four taxa have been elevated to species rank (Böhme 1997, Andreone et al. 2001, Raxworthy & Nussbaum 2006).

According to Andreone et al. (2001), the *Calumma furcifer* species group currently consists of the following species: *Calumma furcifer* (Vaillant & Grandidier, 1880), *C. gastrotaenia* (Boulenger, 1888), *C. marojezense* (Brygoo, Blanc & Domergue, 1970), *C. andringitraense* (Brygoo, Blanc & Domergue, 1972), *C. peyrierasi* (Brygoo & Domergue, 1974), *C. guillaumeti* (Brygoo, Blanc & Domergue, 1974), *C. glawi* Böhme, 1997, *C. vatosoa* Andreone, Mattioli, Jesu & Randrianirina, 2001, and *C. vencesi* Andreone, Mattioli, Jesu & Randrianirina, 2001. With the exception of the two poorly known and more morphologically divergent species *C. peyrierasi* and *C. vatosoa*, these species represent a rather homogeneous group with only subtle interspecific differences in external morphology, but often with rather strong differences in hemipenis morphology (e.g. Böhme 1997, Andreone et al. 2001).

In the following, we describe a new species in the *Calumma furcifer* species group from the Anosibe An'Ala region that differs by morphology, life colouration and genetic differentiation from all other species in the group. Moreover, with the recent discovery of this unique new chameleon species from one of Madagascar's most deforested areas, we want to (1) highlight the potential of protecting small forest remnants in the network of protected areas, (2) draw attention to an area that still remains largely unstudied, and (3) create publicity for a species that is probably already on the brink of extinction.

Materials and methods

Most specimens were collected at night during the rainy season, using torches and headlamps to detect roosting chameleons in the vegetation. The type specimens were collected, anesthetized and killed by injection with chlorobutanol, fixed with 90% ethanol and stored in 70% ethanol. Specimens dealt with in this paper were subsequently deposited in the collection of the Zoologische Staatssammlung München (ZSM), Munich, Germany and in the collection of the Université d'Antananarivo, Département de Biologie Animale (UADBA), Antananarivo, Madagascar. Tissue samples of additional specimens were taken by tail clipping freshly collected specimens and stored in 98% ethanol at the Technical University of Braunschweig, Zoological Institute, Braunschweig, Germany. FGMV, FGZC, PSG and MPFC refer to field numbers of F. Glaw/M. Vences, F. Glaw, P.-S. Gehring, and M. Pabijan respectively. Locality coordinates were recorded with GPS receivers.

Morphological measurements were taken with digital callipers to the nearest 0.1 mm by P.-S. Gehring. Definition of measurements and the description scheme of the holotype largely follow Andreone et al. (2001). Snout-vent length is abbreviated SVL.

Mitochondrial DNA variation was studied in five specimens of the new species, including the holotype, one paratype and three individuals sampled in the forest fragments at Tarzanville and Ambatofotsy. Additionally, we incorporated available tissue samples from other species of the *C. furcifer* species group. Tissue samples of *C.* cf. *tarzan* were collected by FR in a forest fragment close to Marolambo in May 2009. Tissue samples of *C.* cf. *vencesi* were collected by MV, FR and David R. Vieites in the Makira forest in north-eastern Madagascar in February 2008. Tissue samples of *C.* cf. *marojezense* were collected in a forest fragment (Ambodivoahangy) along the Antainambalana river valley in north-eastern Madagascar by PSG, FG, JK, MP and FR in April 2010. Since the taxonomical identification of these latter specimens is not yet assured, our specific assignment is tentative. Data on three described species of the *C. furcifer* group are missing from our analysis: *C. guillaumeti*, *C. peyrierasi* and *C. vatosoa*. After extraction of total genomic DNA, using different standard protocols, fragments of the NADH dehydrogenase subunit 4 gene (ND4) were PCR-amplified using the primers ND4 (5' CAC CTA TGA CTA CCA AAA GCT CAT GTA GAA GC 3') and LeutRNA (5' CAT TAC TTT TAC TTG GAT TTG CAC C 3'), following standard protocols (see Arévalo et al. 1994). After purification (EXOSAP), the fragments were resolved on an automated DNA sequencer (ABI 3130 XL Applied Biosystems). Sequences were validated and aligned manually with the software CodonCode Aligner (CodonCode Corporation). Genbank accession numbers of the newly resolved DNA sequences are HM776645 (FGZC 4510), HM776649 (FGZC 4514), HM776650 (PSG 2114), HM776651 (MPFC 40), and HM776652 (MPFC 97) for *Calumma tarzan*; HM776646 (PSG 1377), HM776647 (PSG 1376), and HM776648 (PSG 1341) for *C.* cf. *tarzan* from Marolambo; HM776656 (FGMV 2001.590) for *C. andringitraense*; HM776659 (FGMV 2002.321) for *C. glawi*; HM776658 (FGMV 2002.987) for *C. gastrotaenia*; HM776653 (MPFC 110) and HM776657 (FGMV 2001.240) for *C. furcifer*; HM776660 (ZCMV 11275) for *C.* cf. *vencesi*; HM776654 (PSG 2364) and HM776655 (PSG 2350) for *C. marojezense*; and HM776661 (FGMV 2002.1221) for *C. boettgeri*. A neighbor joining tree was constructed in Mega 4.0 (Tamura et al. 2007) based on distances calculated with the Tamura-Kumar modification of the LogDet method (Tamura & Kumar 2002) due to the compositional heterogeneity between *Calumma gastrotaenia*, *C. glawi* and *C. tarzan* sp. n. Support values for nodes were generated by bootstrapping (10000 replicates). A maximum parsimony analysis with unordered and equally weighted characters was carried out in PAUP 4.0b10 (Swofford 2003). A heuristic search was conducted with 100 random taxon stepwise addition sequences and tree bisection reconnection (TBR) branchswapping. The topology was reconstructed using the 50% majority rule consensus with support values assessed by 10000 bootstrap pseudoreplicates. We also applied a model-based analysis in a Bayesian framework. Model selection was carried out in MrModelTest v2.3 (Posada & Crandall 1998, Nylander 2004). The Akaike information criterion used in this software selected GTR+I+G as the best-fit model of nucleotide substitution. We implemented this model in MrBayes v3.1.2, and programmed two runs with four chains that were run for a total of 5 million generations and sampled every 100 generations. The two runs converged into a stationary distribution after 10000 generations, for which reason we discarded the first 25% of the generations as burn-in, leaving 37500 generations from which parameter values were summarized and a majority rule consensus tree was produced with posterior probabilities calculated as the frequency of samples recovering each clade (Huelsenbeck & Ronquist 2001).

Systematics

Calumma tarzan sp. n.

Figs. 1–5

Holotype: ZSM 219/2010 (FGZC 4510), adult male with incompletely everted hemipenes, collected in the forest fragment near Tarzanville (19°19'50.3" S, 48°13'22.5" E, 847 m above sea level), Moramanga Province, central eastern Madagascar, on 12 April 2010 by P.-S. Gehring, F. Glaw, J. Köhler, K. Mebert, E. Rajeriarison & F. M. Ratsoavina.

Paratypes: UADBA uncataloged (FGZC 4511), UADBA uncataloged (FGZC 4513), ZSM 221/2010 (FGZC 4515), three adult males; UADBA uncataloged (FGZC 4405), UADBA uncataloged (FGZC 4512), ZSM 220/2010 (FGZC 4499), and ZSM 222/2010 (FGZC 4514), four adult females; UADBA uncataloged (FGZC 4519), one juvenile specimen, all with same collection data as the holotype.

Additional material: Additional tissue samples (without corresponding voucher specimens) for genetic analyses were available from a population of *C. tarzan* from the type locality Tarzanville (19°19'50.3" S, 48°13'22.5" E, 847 m a.s.l.), PSG 2114, 2116, 2117, 2130, 2133, 2138, 2139, 2142, 2151; from a forest fragment less than one kilometer north of Tarzanville (19°19.461' S, 48°13.193' E, 881 m a.s.l.), PSG 2178–2181; and from Ambatofotsy approximately 25 km southeast of Tarzanville (19°32'35.2" S, 48°18'59.5" E, 907 m a.s.l.), MPFC 38–42, 45, 94. In 2009, FR collected tissue samples from several juveniles of an unidentified chameleon species of the *C. furcifer* group in a forest fragment close to Marolambo (20°03'27.3" S, 48°11'00.0" E, 670 m a.s.l.), which in our analyses turned out to represent the sister group to *C. tarzan* and we therefore assign this population to *C.* cf. *tarzan* (PSG 1341–1343, 1351, 1368, 1376–1378, 1386).

Diagnosis: A medium-sized green chameleon (snout-vent length 61–72 mm, total length 119–150 mm) with a characteristic rostral profile, consisting of the rostral crests which are fused anteriorly to form a spade-like ridge that slightly projects beyond the snout tip (less than 1 mm), and a distinct colour pattern in life, consisting of a green to bright yellow ground colouration (with dark transversal bands when stressed) and a brown to blackish casque and neck in males. The following combination of characters leads us to assign the new species to the *C. furcifer* group: the small to moderate adult body size, the absence of occipital lobes (although small rudimentary lobes are present in males of *C. glawi*), a very low casque, absence of gular and ventral crests, and a more or less uniformly green colouration usually with a dark line running through the eyelids, and a broad brownish mid-ventral band that is bordered by a narrower white band on each side (except for *C. peyrierasi* that has only a single whitish ventral band). *Calumma tarzan* differs from all the other species in this group by the unique "spade-like" rostral profile (the two rostral crests unite anteriorly on the snout forming a rectangular ridge when viewed from above instead of a pointed snout tip in most other species of the group), and the blackish-brown casque and neck in males. Beside these unique characteristics, males of *C. tarzan* differ from those of *C. furcifer* by the absence of a dorsal crest and the absence of a bifid rostral appendage; from *C. gastrotaenia* by the much lower casque, absence of a dorsal crest and absence of a white lateral band; from *C. guillaumeti* by the lower casque, the absence of a dorsal crest and absence of a white lateral band; from *C. andringitraense* by a lower casque and the absence of a white lateral band with two rows of white spots along the flanks; from *C. glawi* by the absence of occipital lobes and absence of a yellow lateral band; from *C. marojezense* by the absence of a white lateral band and presence of only one light spot on the flank (instead of two); from *C. peyrierasi* by a much lower casque, the absence of a dorsal crest and absence of reddish inner sides of legs; from *C. vatosoa* by the absence of a parietal crest, absence of a vein-like dorsal pattern and absence of a large orange spot at mid-flank; from *C. vencesi* by the absence of a nuchal fold and absence of a dorsal crest. The females of *C. tarzan* differ from the females of the other species (as far as they are known and with the possible exception of *C. furcifer*) by the rectangular rostral profile which, however, is less pronounced than in the males. In addition, *C. tarzan* differs from *C. andringitraense*, *C. furcifer, C. gastrotaenia, C. glawi* and *C. marojezense* by substantial genetic differentiation (Fig. 7).

Description of the holotype: Adult male, in good condition, both hemipenes incompletely everted; SVL 72.0 mm; tail length 77.8 mm; further morphological measurements are provided in Table 1 (characters according to Tables 1 and 2 in Andreone et al. 2001). Head without rostral appendage, but with a unique "spade-like" rostral profile, the two rostral crests uniting anteriorly into a thickened

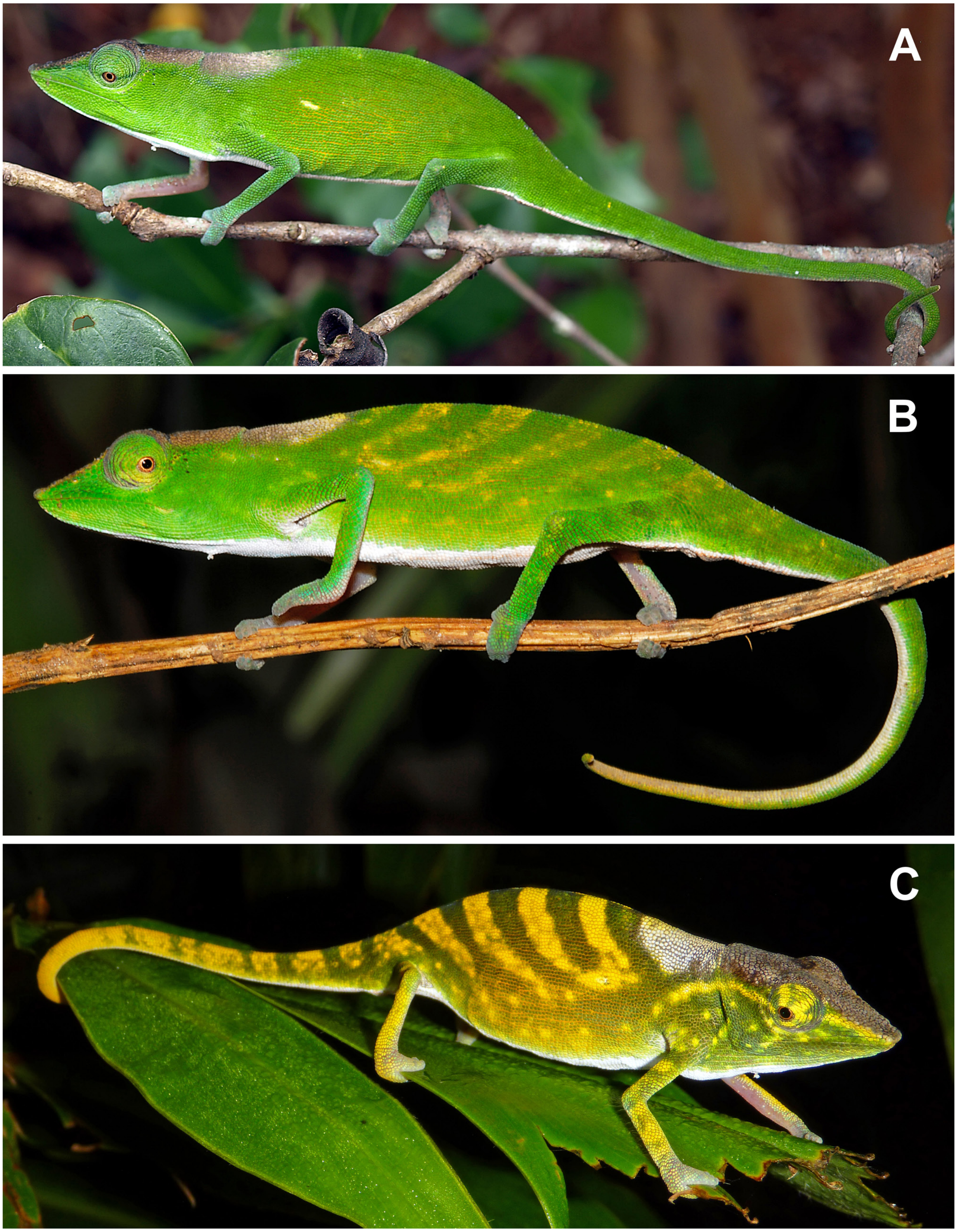

Figure 1. Male holotype of *Calumma tarzan* sp. n. (ZSM 219/2010) in life. (A) Lateral view when relaxed, (B) moderate stress colouration, and (C) stress colouration fully developed.

ridge, forming together a rectangular ridge in dorsal view that slightly (clearly less than 1 mm) projects beyond the snout tip; rostral crests almost parallel, but slightly diverging posteriorly, distance between anterior tips 3.5 mm; parietal crest entirely absent; supra-orbital crest rounded in lateral view and formed by a single, rather smooth row of tubercles; lateral crest moderately distinct, smooth in lateral view; temporal crest indistinct, both crests fusing posteriorly; parietal crest absent; no traces of occipital lobes; no traces of gular and ventral crests; dorsal crest absent. Body laterally compressed with fine homogeneous scalation, except in the vicinity of the cranial crests and neck region where scales are slightly larger; axillary pits distinct, deeply recessed; limbs and tail with homogeneous scalation, tail without dorsal crest, feet without tarsal spines; tail base moderately swollen.

Hemipenes small, both most likely incompletely everted (total length on right side 4.8 mm, on left side 5.5 mm). The general morphology (Fig. 6) differs from that of other species in the *Calumma furcifer* group (see drawings and descriptions in Böhme 1997 and Andreone et al. 2001) and is therefore difficult to interpret and perhaps partially an artifact. The truncus, especially in asulcal view, is covered with numerous distinct papillae (unknown from the other species) whereas calyces are not recognizable (present in the other species). Apex with one distinct and one indistinct pair of rotulae, without clearly recognizable structures in the area between the four rotulae, which are typical for the other species of the *C. furcifer* group (see Böhme 1997).

In life, when relaxed, the male holotype (Fig. 1) exhibited a rather light green colouration with a yellow ground colour during the day. Starting at the snout, the casque and roughly the anterior third of the dorsum were covered with black to charcoal-colour delimited by a sharp line along the casque and the lateral crest to the rostral crest and on to the upper tip of the snout (Fig. 2). Along the back in posterior direction the blackish colour faded to whitish-grey. One single, small, light yellowish spot (1.4 mm in diameter) on the anterior flanks. No visible light lateral band, which is in contrast to most other species of the *C. furcifer* group. A dark horizontal line through the eyelid, extending horizontally in a posterior direction to the insertion of the forelimbs. Belly whitish-green, with a broad, grey-brown longitudinal band from the throat to the cloaca broadest midventrally (3.4 mm) and narrower towards the forelimbs, where it fades out in irregular turquoise and whitish spots. This broad band is fringed by an indistinct reddish line that is bordered on either side with a white band ca. 1 mm wide. These bands merge with the white ground colour of the throat at level of the insertion of forelimbs. The pattern of a central brown band bordered with a narrow white band on either side continues onto the tail, but fades within the first half of the tail. The inner mucous integument of the mouth is darkly pigmented; axillary pockets are whitish. Iris copper-coloured. After being handled, the holotype showed a unique stress colouration (Fig. 1) unknown from other species of the *C. furcifer* group. The yellow ground colour became prominent and interrupted the green colouration by oblique transversal bands on body and tail. Several irregular yellow spots appeared on head, flanks, and extremities. The eyelids became almost completely yellow and the tail almost completely yellow with transversal dark green bands. There was no change in the dark colouration of the head, but the greyish patch on the shoulders became more whitish. In preservative, the holotype faded and the green colouration almost disappeared, changing into greyish-blue. Dark colouration of the head indistinguishable from the dark dorsal colouration of the flanks and the back. Dorsum dark bluish, turning into lighter shades ventrally. One single light spot on each flank, axillary pockets white. Ventrally, the medioventral band has faded to grey, still bordered by two narrow white bands, composed of irregular dark spots on the throat extending until the anterior half of the tail.

Figure 2. Head and neck of a male *Calumma tarzan* sp. n. in dorsal view, showing the characteristic brownish colour pattern and the spade-like ridge projecting beyond the snout tip.

Variation: Description of the female paratype ZSM 222/2010 (FGZC 4514): Adult female, in good condition, but with a longitudinally cut venter; SVL 61.4 mm; tail 57.9 mm; further morphological measurements are provided in Table 1. Head without rostral appendage, but with a characteristic "spade-like" rostral profile, less pronounced than in the male; the two rostral crests unite anteriorly on the snout into a thickened ridge, forming together a rectangular ridge in dorsal view that very slightly projects beyond the snout tip; rostral crests almost parallel, but slightly divergent posteriorly, distance between anterior tips 1.9 mm; parietal crest entirely absent; supra-orbital crest rather indistinct; lateral crest distinct, smooth in lateral view; temporal crest indistinct, both crests fuse posteriorly; parietal crest absent; no traces of occipital lobes; no traces of gular and ventral crests; dorsal crest absent. Body laterally compressed with fine homogeneous scalation except on the

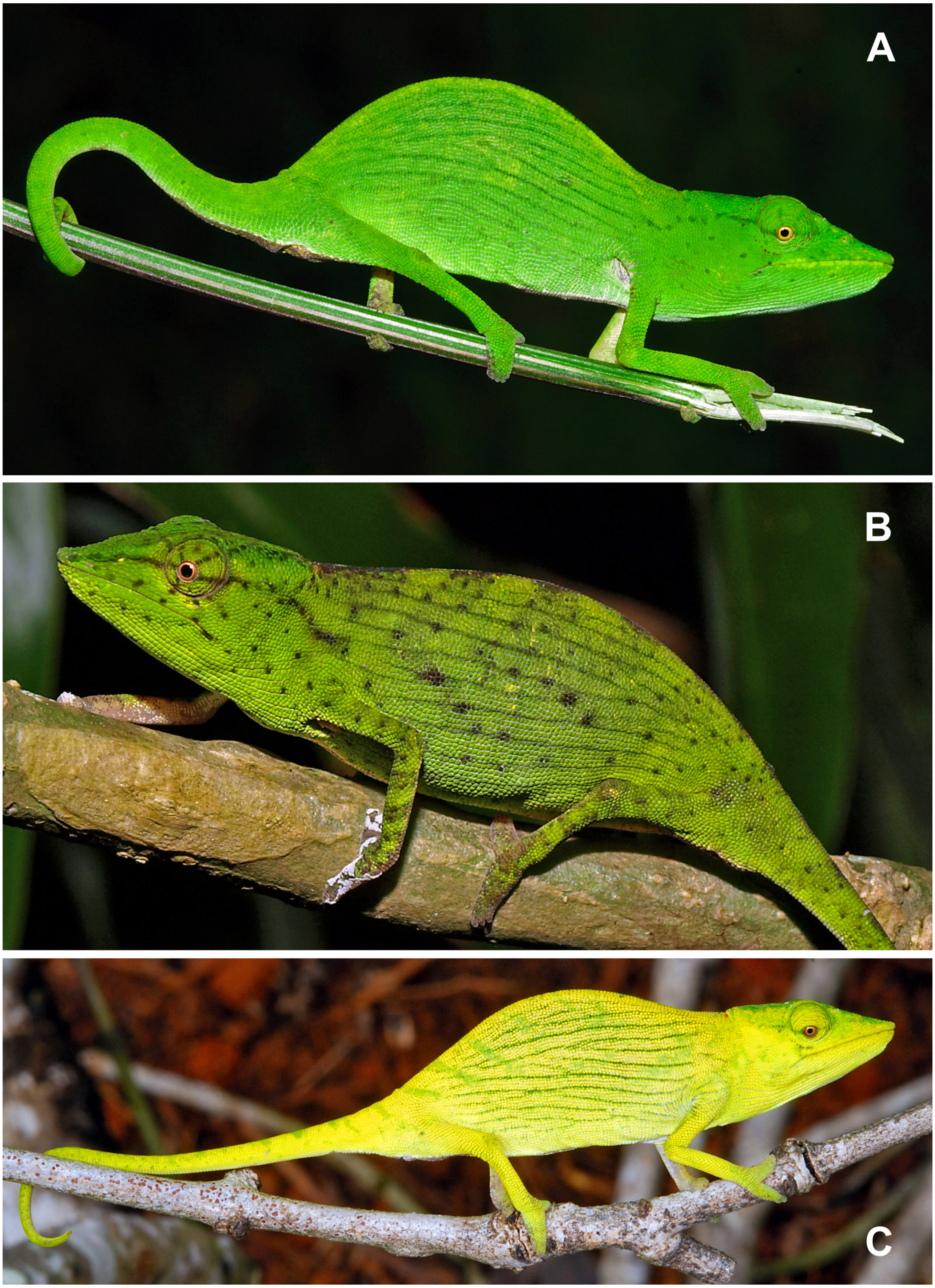

Figure 3. Female paratype of *Calumma tarzan* sp. n. (ZSM 222/2010) in life. (A) Lateral view when relaxed, and (B, C) differently developed stress colourations.

head, which is covered with slightly larger scales; axillary pits distinct; limbs and tail with homogeneous scalation, tail without dorsal crest, feet without tarsal spines; tail base not swollen.

For measurements of ZSM type specimens see Table 1. Specimens deposited in UADBA were not available for detailed examination. Females of *C. tarzan* have a distinctly less swollen tail base.

Concerning colouration in life, males in a relaxed state were rather uniform in their colour patterns. The brown colour on the head and neck can extend posteriorly on the dorsal ridge to midbody. Depending on agitation, several irregular dark spots on the head, flanks, and the extremities can be visible, as well as dark oblique transversal bands and a more pronounced dark horizontal line through the eyelid which can extend further posteriorly than in a relaxed state. The yellow spot on the flank can be surrounded by a dark line.

Life colouration of the females is uniformly light green (in a relaxed state) to bright yellow with a network of darker horizontal stripes and irregular darker spots on the flanks in a stressed state (Fig. 3, photographed during the day). A dark horizontal line through the eyelid is also present in females.

Juveniles showed more or less the same colouration as the females; uniformly light green to yellow, although the light spot on the flanks was clearly recognizable in juvenile males (Fig. 4, photographed at night).

Etymology: The species was discovered in a small rainforest fragment very close to the village formerly known as Tarzanville (since recently called Ambodimeloka, meaning "place of the curve"). Therefore, we dedicate the new species to the fictional forest man "Tarzan" in the hope that this famous name will promote awareness and conservation activities for this apparently highly threatened new species and its habitats, in the mid-altitude rainforest. We consider this epithet as an invariable noun in apposition.

Distribution, habitat and habits: *Calumma tarzan* is known only from its type locality (a forest fragment of about 1.5 km in length and less than 0.3 km in width), another small and degraded rainforest fragment just less than one kilometer north of Tarzanville (19°19.461' S, 48°13.193' E, 881 m a.s.l.) and from Ambatofotsy (19°32'35.2" S, 48°18'59.5" E, 907 m a.s.l.), a forest fragment (of ca. 6 km in length and 1.5 km in width) proposed as a potential protected area, located approximately 25 km southeast of Tarzanville (Fig. 8).

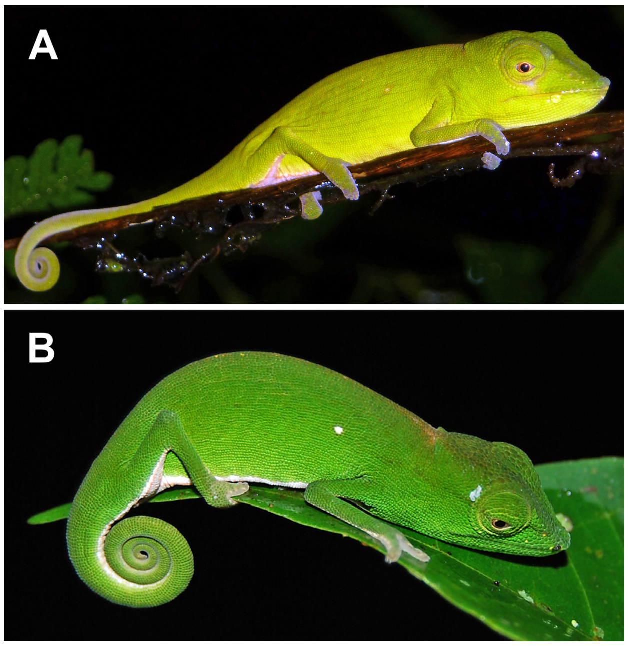

Figure 4. Juveniles of (A) *Calumma tarzan* sp. n. from the type locality, and (B) *Calumma* cf. *tarzan* from the Marolambo region.

The forests surrounding these three known localities comprise a total area of less than 10 km^2 and are situated along the slopes of the Manambolo river valley, which runs from north to south before discharging into the Mangoro river. All voucher specimens were collected inside the forest fragment close to Tarzanville.

A survey in 2009 in a small forest fragment in the Marolambo area some 50 km south of Ambatofotsy and situated south of the Mangoro river (Fig. 8) yielded juveniles of an unidentified form of the *C. furcifer* group, showing persuasive similarities with *C. tarzan* (Fig. 4b) which therefore may also be assignable to the new species. Only tissue samples and no voucher specimen were collected from this population. We here tentatively refer to this Marolambo population as *C.* cf. *tarzan*. Further studies and adult specimens are necessary to assess the taxonomic status of this population.

All known localities of *C. tarzan* are within an altitudinal range of ca. 800–910 m above sea level. All individuals were found in mid-April. At that time they were relatively abundant and found roosting in the vegetation at night, ca. 1–4 m above the forest floor. Small and probably recently

Table 1. Biometric measurements (in mm) of available type specimens of *Calumma tarzan* sp. n. from the forest fragment close to Tarzanville. Definition and selection of characters according to Andreone et al. (2001); abbreviations as follows: SVL, snout-vent length; TL, tail length; HL, head length; HD, head depth; HW, head width; SD, socket diameter (measured horizontally); AGD, axilla-groin distance; HT, holotype; PT, paratype.

Voucher number	Status	Sex	SVL	TL	HL	HD	HW	SD	AGD
ZSM 219/2010	HT	male	72.0	77.8	19.4	12.6	9.6	5.1	38.0
ZSM 220/2010	PT	female	60.6	58.3	20.0	12.4	8.8	4.1	32.3
ZSM 221/2010	PT	male	68.1	72.4	21.6	12.1	9.2	5.6	39.4
ZSM 222/2010	PT	female	61.4	57.9	19.9	12.2	8.7	4.6	34.3

Figure 5. Adult female of *Calumma tarzan* sp. n. (UADBA/FGZC 4405), found hanging dead in a tree at the type locality.

hatched juveniles were much more common than adults and seemingly perching at lower positions (mostly ca. 1–2 above the forest floor). One female (ZSM 222/2010) contained three large eggs (diameters 11.0 x 6.3, 10.7 x 6.2, and 10.7 x 6.3 mm). Another female (FGZC 4405) was found at night hanging head down dead in a tree, attached with the tip of the tail to a twig (Fig. 5). Although it apparently had died at most a few hours before (its colour was still similar to that in life), many large unidentified insect larvae were found in its body the next morning, suggesting that the larvae had already infected the living chameleon and might have caused its death.

Molecular differentiation and phylogenetic relationships: The alignment of partial DNA sequences of the ND4 gene consisted of 17 sequences with 537 aligned nucleotide positions. A total of 191 nucleotides were variable, 134 of which were parsimony informative. The heuristic search in the MP analysis produced a single most parsimonious tree with a length of 376 (consistency index, CI=0.628; retention index, RI=0.702). The BI runs resulted in identical topologies and very similar likelihood estimates (mean ln*L*= -2193.10).

The ND4 gene sequences of *C. tarzan* showed a high divergence to all included taxa of the *C. furcifer* species group (Fig. 7). Six clades were highly supported by distance, discrete character, and model-based phylogenetic analyses (Fig. 7). Specimens assigned to *C. tarzan* from the type locality and Ambatofotsy formed a highly supported clade. No sequence variation was detected within *C. tarzan*. The sister group to *C. tarzan* was *C.* cf. *tarzan* from Marolambo, differing by an average of 18.3 nucleotide substitutions (3.5% uncorrected *p*-distance) and 2 aminoacid substitutions. The average divergence of *C. tarzan* from the other nominal species of the *C. furcifer* group included in our analysis was 58.5–73.0 substitutions (12.6–15.7% p-distance), but phylogenetic relationships between most of the other taxa incorporated into the analysis are unresolved. However, the main purpose of this tree is not to reliably establish relationships within this group, but to give an indication of the molecular differentiation between taxa.

Available names: Two junior synonyms are currently recognized in the *Calumma furcifer* species group and need to be discussed as possible earlier available names for *C. tarzan*: *Chamaeleon grandidieri* Mocquard, 1900 (synonymized with *C. gastrotaenia* by Werner 1902), was based on a single female holotype (MNHN 99416) from the surroundings of Suberbieville (today named Maevatanana according to Viette 1991) in central north-western Madagascar, which is an unusual locality for a species of the genus *Calumma* as these are mostly restricted to humid eastern Madagascar. The species was described in two different papers. One of the descriptions (Mocquard 1900a) is very short, comprising just seven lines, whereas the second (Mocquard 1900b) is much more detailed, and includes an illustration. According to these descriptions, the holotype had a SVL of 45 mm, a tail length of 43 mm, an axillary mite pocket, and a homogeneous pholidosis, but no casque, no dorsal, gular and ventral crests, and no crests on the head. An evaluation of the validity of this taxon is difficult since the original description of *C. gastrotaenia* was based on a male and a subadult (Boulenger 1888) and with the imprecise type locality "Madagascar". The status of *C. grandidieri* was not discussed or reassessed by recent authors who described new species in the *C. furcifer* group (Böhme 1997, Andreone et al. 2001). However, since the type locality of *C. grandidieri* is in a different biogeographic and climatic region than that of *C. tarzan*, it is highly unlikely that both taxa are conspecific.

Chamaeleon chauvini was described by Methuen & Hewitt (1913) based on a male holotype collected near Tamatave (today Toamasina). The authors considered this taxon as closely related to *C. furcifer* and mentioned the possibility that "it may eventually prove to be a juvenile of that species". From the description and the accompanying photograph of the holotype, a dorsal crest of small tubercles and a bony rostral process projecting about 1 mm beyond the upper lip and being bifid at the end, are evident. These two characters differ substantially from *Calumma tarzan* and agree entirely with *C. furcifer*, leaving no doubts that the synonymy of *C. chauvini* with *C. furcifer* is fully justified.

Discussion

Relationships

With *Calumma tarzan,* we add a new morphologically distinct chameleon species to the *C. furcifer* species group. Most species currently allocated to this group form a relatively homogeneous morphological group, whereas *C. peyrierasi* and *C. vatosoa* are morphologically more divergent, indicating that the phylogenetic relationships within this group and with other related groups (e.g., the *Calumma nasutum* group) are still poorly understood. Our phylogenetic analysis of the species group (Fig. 7) based on the ND4 gene fragment did not properly resolve relationships among the species studied either. Nevertheless, it became at least clear that the closest relative of *C. tarzan* is a barely studied population of morphologically similar chameleons from Marolambo which is distinctly differentiated genetically, however. Further studies may reveal that this Marolambo population either represents a separate species, or a differentiated but conspecific population of *C. tarzan*.

On a larger scale, recent molecular studies suggest that the genus *Calumma* is polyphyletic (e.g., Raxworthy et al. 2002, Townsend & Larson 2002). The relationships between the species groups are not yet sufficiently resolved and even the monophyly of several species groups in their current definition is still questionable. It is thus likely that a future partition of the genus *Calumma* will be necessary to properly reflect the phylogenetic history of these chameleons. In this case, only the clade including the type species of *Calumma*, *C. cucullatum*, is likely to retain its current generic name in the future. This type species was found to be the sister species of the *C. furcifer* group (*C. gastrotaenia, C. guillaumeti, andringitraense* and *marojezense*) by Raxworthy et al. (2002), suggesting that even a revised genus *Calumma* would include the species of the *C. furcifer* group.

Conservation

Several areas around the known distribution range of *C. tarzan* were surveyed but did not reveal additional localities for the new species: in forests around Niagarakely, situated north of Tarzanville and at a higher altitude (19°13.127' S, 48°13.930' E, 1034 m a.s.l.; Fig. 8), we found only a single specimen of *Calumma* cf. *gastrotaenia*. The forest remnants between the Manambolo and Mangoro river valleys are mostly above 900 m altitude and therefore are probably not populated by the new species. The same is true for the forests west of the Mangoro River, including an area east of Tsinjoarivo surveyed by us in 2010, in which *C. tarzan* was not recorded. Surveys in forest fragments of littoral forests in an area between Vatomandry, Mahanoro, and the estuary of the Mangoro River did not yield any *C. tarzan* or any other member of the *C. furcifer* group (Gehring et al. submitted).

Perhaps the best chances for discovering additional populations of *C. tarzan* may be in areas to the east and northeast of the type locality where small fragments of mid-altitude rainforests still exist (Fig. 8). The available data indicate that the distribution of *C. tarzan* is rather patchy. Although the real limits of its distribution still need to be assessed, this distinctive species was apparently not discovered earlier by other herpetologists or ecotourists, suggesting a relatively small range. Furthermore, its tolerance of habitat disturbance might be limited, and a high level of recent logging and degradation was evident in and around the known habitats.

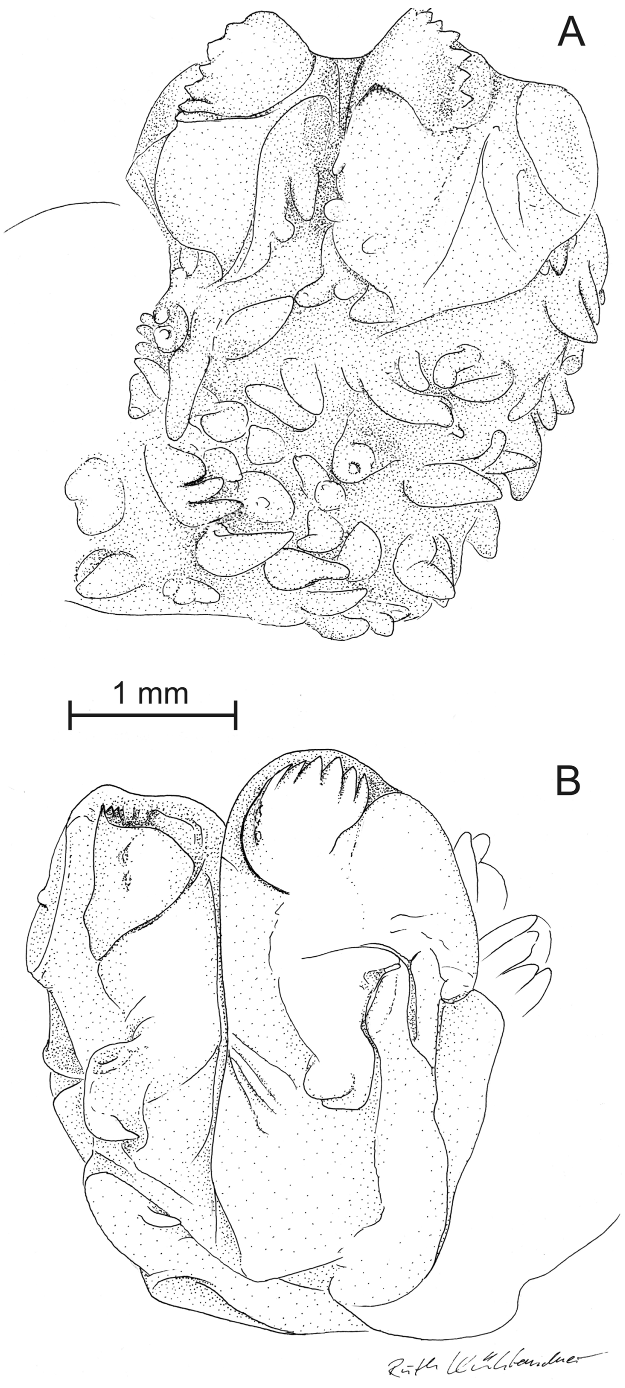

Figure 6. Left hemipenis of the holotype of *Calumma tarzan* sp. n., (A) asulcal view, (B) sulcal view. Note that the hemipenis is most likely not fully everted.

Using these data to assess the IUCN Conservation status, *C. tarzan* should be considered as "Critically Endan-

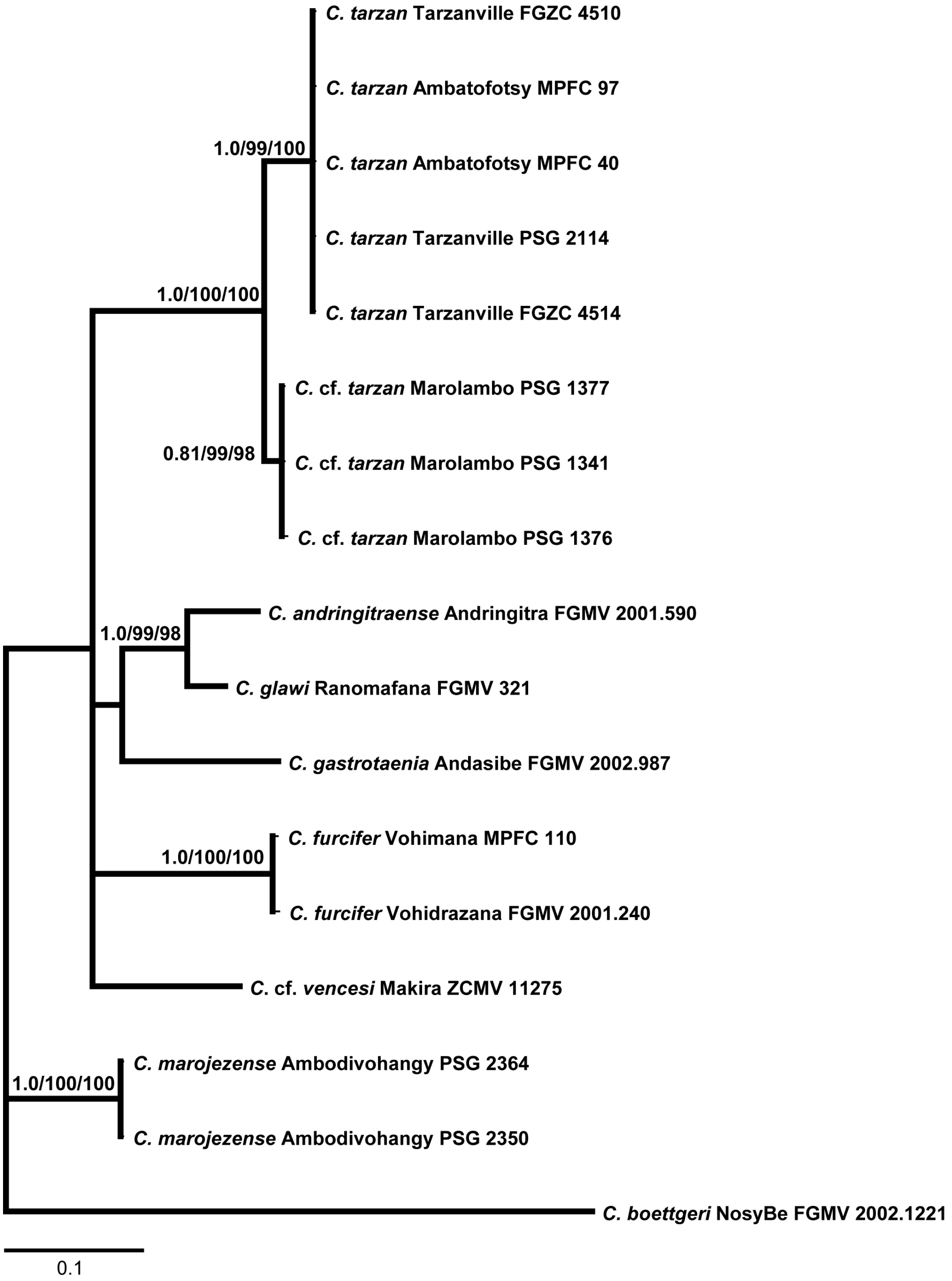

Figure 7. Bayesian phylogram of the *Calumma furcifer* species group, based on the mitochondrial ND4 gene (GTR+I+G model of nucleotide evolution). Values above nodes indicate Bayesian clade credibility (5 mio. generations), bootstrap support for the neighbor-joining analysis (10000 replicates), and bootstrap support for the maximum parsimony analysis (10000 replicates). Only values above 75% bootstrap support and 0.7 posterior probability are shown.

gered" because its Area of Occupancy (AOO) is probably less than 10 km^2, all individuals are in only two major locations, there is continuing decline in the extent and quality of much of its habitat, and none of the habitats are included in the network of protected areas yet. In the large area between Analamazoatra-Zahamena-Ankeniheny in the north and the Ranomafana National Park in the south, extending for about 250 km, no low- and mid-altitude ar-

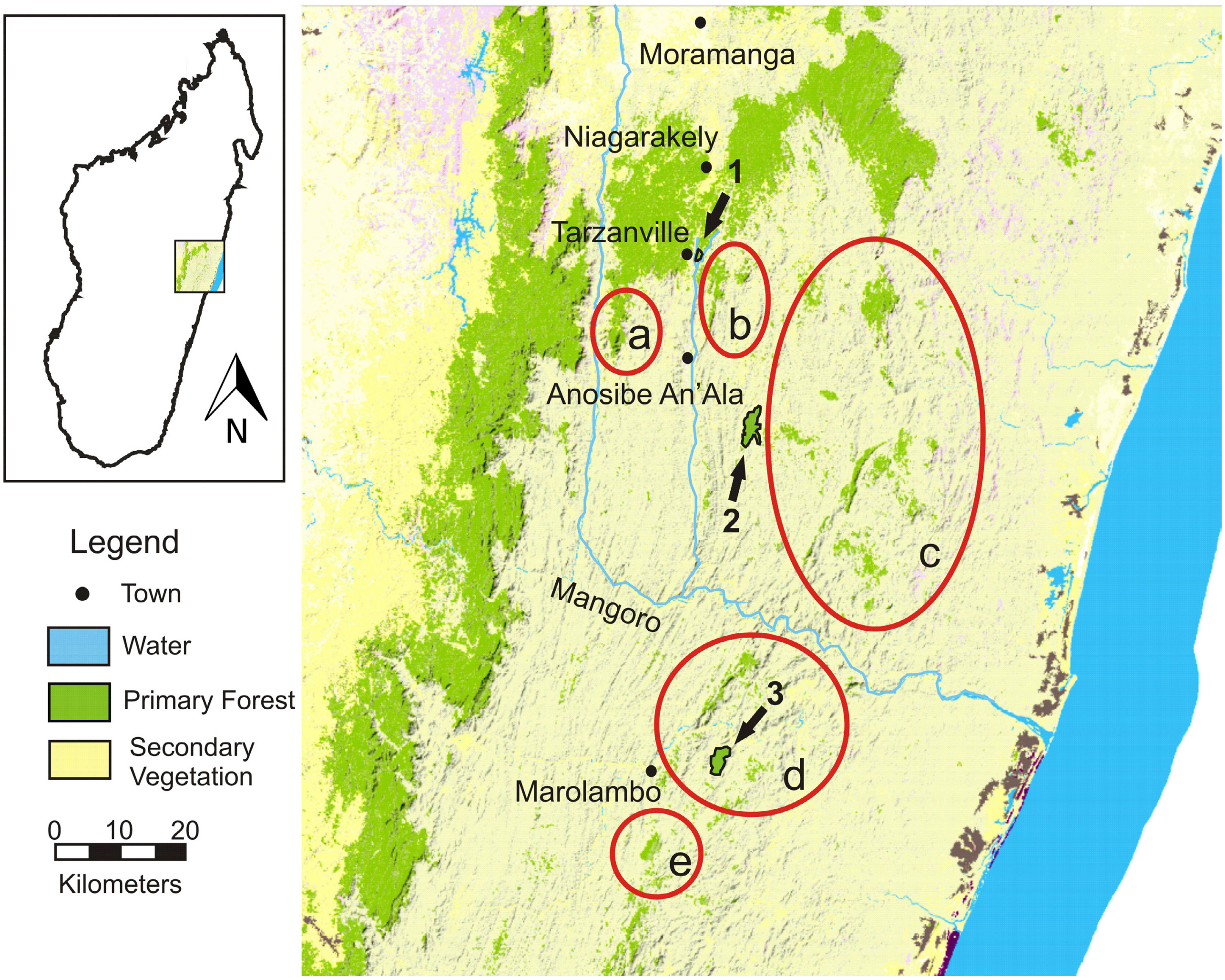

Fig. 8. Modified map of central eastern Madagascar taken from the Madagascar Vegetation Mapping Project (www.vegmad.org), showing the potential distribution range of *Calumma tarzan* and *Calumma* cf. *tarzan* in central eastern Madagascar. The known localities are indicated by arrows, 1) forest close to Tarzanville, 2) Ambatofotsy and 3) forest fragment close to Marolambo; potential localities are surrounded by red circles (a – d). Green colour represents remaining forest areas; bright yellow secondary vegetation; blue colour water bodies.

eas are protected or proposed for protection (Kremen et al. 2008), resulting in a major "reserve gap" in central eastern Madagascar. One reason for this situation might be that this area is not comprised of any large block of primary forest and therefore might appear less important for the conservation of larger animals such as diurnal lemurs. However, at least from a herpetological point of view, even tiny forest fragments can play a crucial role in the conservation of vital populations of different endangered amphibian and reptile species (see e.g. Vallan 2000) and this most likely also holds true for major parts of the invertebrate fauna of such fragments. Preserving small fragments seems of particular importance in areas where intensive slash-and-burn agriculture has destroyed most of the primary habitats, and where at the same time microendemic ranges of certain species were already identified (compare e.g. D'Cruze et al. 2007, Wollenberg et al. 2008). The forest fragments in the Anosibe An'Ala region may perfectly qualify as a conservation priority. This region has been (surprisingly) very poorly surveyed until now and recent discoveries suggest a significant degree of microendemism in this area, exemplified by the recently described *Phelsuma hoeschi* (Berghof & Trautmann 2009) or the presence of *Calumma* sp. aff. *gallus,* currently under description (P.-S. Gehring et al. unpublished data). The discovery of *Calumma tarzan* supports the assumption that this area may hold even more microendemic species. Two major conclusions should be drawn from this situation:

(1) The known habitats of this new chameleon, especially Ambatofotsy and the forest fragment at Tarzanville, should be placed under formal protection (either by the Malagasy government or NGOs) as soon as possible in order to ensure the survival of this splendid species and other locally endemic species expected to occur in these forest remnants, using *C. tarzan* as a flagship species. The forest near Tarzanville is very small and very close to the road connecting Moramanga and Anosibe An'Ala. Due to the small size of the fragment, its protection would not require exhaustive financial resources and ensure the survival of a vital population of *C. tarzan* and many other forest-dwell-

ing species. In addition, this forest could be interesting enough for the establishment of an ecotourist destination, due to its relatively easy accessibility from one of Madagascar's most famous and most visited nature reserves (only 2.5 hours drive from Moramanga and 3 hours from Andasibe). Even if only a limited number of tourists would visit this forest, the income generated by this ecotourism would probably be higher than that obtained by clearing the forest and planting rice or other crops on the slopes, as can be observed in the close vicinity of the habitat of *C. tarzan*. Conservation activities for this forest are urgent, as it is already exploited for precious timber, and recently established properties are already marking its edges. The second site that *C. tarzan* was recorded from, Ambatofotsy, encompasses approximately 9 km^2 on a forested plateau between 800–1060 m a.s.l. This forest patch is at present accessible only by foot and therefore more remote than the Tarzanville forest. Moreover, access is hampered by steep rock cliffs partly surrounding the forest, which have to some degree protected the site from logging. Due to its larger size, Ambatofotsy may be a stronghold for the species, especially in the event of continued habitat degradation at the type locality.

(2) Since we suspect that the level of microendemism in the above mentioned "reserve gap" may be strongly underestimated, biological inventory surveys should be carried out as soon as possible to improve our understanding of the biodiversity and biogeography of this region. These surveys should also include the small mid-altitude forest fragments east and southeast of Tarzanville, and the Marolambo region (see Fig. 8), as these areas have the highest potential of harbouring additional populations of *C. tarzan* or undescribed related taxa.

Acknowledgements

We are grateful to numerous colleagues, friends and organizations: Jason Lee Brown, Konrad Mebert, Emile Rajeriarison, Solohery Rasamison, and Francois Randrianasolo helped in the field, and Ruth Kühbandner prepared the hemipenis drawings. Richard Jenkins (Madagasikara Voakajy) drew our attention to the forest of Ambatofotsy, and the local NGO Mbarakaly (Anosibe An'Ala) helped with logistics. The work of PSG was supported by a project of the evolutionary biology funding initiative of the Volkswagen Foundation. FR was supported by a project of the Volkswagen Foundation in the program "Knowledge for Tomorrow – Cooperative Research Projects in Sub-Saharan Africa". MP is supported by a postdoctoral fellowship of the Alexander von Humboldt Foundation. Financial support was also provided by the "Wilhelm-Peters-Fonds" of the Deutsche Gesellschaft für Herpetologie und Terrarienkunde (DGHT). Research was carried out in the framework of established collaboration with the UADBA. We are grateful to the Malagasy authorities for providing research and export permits as well as to the German authorities for issuing import permits.

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