

Extending the known distribution of Nicosia's chameleon, *Furcifer nicosiai* Jesu, Mattioli & Schimmenti, 1999 (Squamata: Chamaeleonidae)

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The genus *Furcifer* Fitzinger, 1843 includes 24 species of chameleons, most of which are endemic to Madagascar (Glaw and Vences, 2007; Uetz et al., 2020). *Furcifer nicosiai* Jesu, Mattioli & Schimmenti, 1999 is a medium-sized species belonging to the *Furcifer verrucosus* (Cuvier, 1829) phenetic group (Glaw and Vences, 2007). Although slightly smaller, *F. nicosiai* is morphologically similar to *Furcifer oustaleti* (Mocquard, 1894), whose subadults can be mistaken with adults of this species (Glaw and Vences, 2007).

With Tsingy de Bemaraha as the type locality of *F. nicosiai* (Jesu et al., 1999), the species was thought to have a distribution limited to western Madagascar, with, until now, only a few additional records in the Melaky

region (Fig. 1, white circles; Table 1) (Randrianantoandro et al., 2008; Raselimanana, 2008; Bora et al., 2010; Randriamoria, 2011; Brown et al., 2014; Goodman et al., 2018). *Furcifer nicosiai* habitat encompasses dense sub-humid and dry forests of low elevation, between 57–571 m above sea level ~ a.s.l. (Bora et al., 2010).

Several records within the Menabe region (within the Paysage Harmonieux Protégé de Menabe Antimena, about 60 km south of Tsingy de Bemaraha) refer to a population of *F. nicosiai* that appears to have some morphological differences to the population from the type locality. A molecular characterisation is needed to assess the taxonomic identity of these populations, but for consistency we here continue to assign them to this species (Raselimanana, 2008; Randrianantoandro et al., 2010; Eckhardt et al., 2019) (Fig. 1, white circles; Table 1). In this area, where two populations of *F. nicosiai* were recently studied, the species was found roosting at 1.8 to 3.5 m height on tree and shrub branches (2.5 cm diameter at breast height) (Fig. 2F–G). These populations were associated with native western deciduous forest with low levels of human impact, with many lianas and an extensive tree canopy cover.

Here we summarise the data on *F. nicosiai* distribution and report on a significant range extension (300 km) for the species. The new records are the results of multiple surveys in Tsaranoro Forest, Makay Massif, Dabara Forest, and Kirindy Mitea National Park (Fig. 1; Table 1). We collected five tissue samples and 25 specimens that were fixed in 10% formalin or 90% ethanol and preserved in 70% ethanol for long-term storage. Specimens were deposited in the herpetological collections of the Zoologische Staatssammlung, Munich, Germany (ZSM), the American Museum of Natural History, New York City, USA (AMNH), Mention Zoologie et Biodiversité Animale, Domaine des Sciences et Technologies, Université d'Antananarivo, Antananarivo, Madagascar

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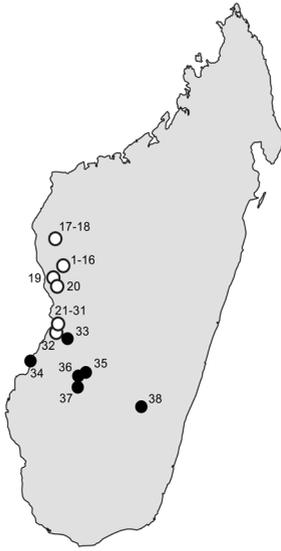


Figure 1. Geographical distribution of *Furcifer nicosiai* in Madagascar: 1–16. Tsingy de Bemaraha National Park (Jesu et al., 1999; Randrianantoandro et al., 2008; Raselimanana, 2008; Bora et al., 2010; Brown et al., 2014; Goodman et al., 2018); 17–18. Paysage Harmonieux Protégé de Beanka (Randriamoria, 2011; Goodman et al., 2018); 19. Paysage Harmonieux Protégé du Complexe Tsimembo Manambolomaty (Goodman et al., 2018); 20. Paysage Harmonieux Protégé du Complexe Lac-Forêt Ambondrombe (Goodman et al., 2018); 21–31. Paysage Harmonieux Protégé de Menabe Antimena (Raselimanana, 2008; Randrianantoandro et al., 2010; Brown et al., 2014; Goodman et al., 2018; Eckhardt et al., 2019); 32. Andranomena Special Reserve (Goodman et al., 2018); 33. Dabara forest; 34. Kirindy Mitea National Park; 35. Makay 1 (Base camp); 36. Makay 2 (Dry forest camp); 37. Makay 3 (Camp 1-Antsoha Forest); 38. Tsaranoro. White circles, previously known distributional records of *F. nicosiai*; Black circles, new distributional records for *F. nicosiai*. Locality numbers follow the numeration in Table 1.

(UADBA), and the University of Michigan Museum of Zoology, Ann Arbor, USA (UMMZ). Field collection numbers are coded as follows: ACZCV (Angelica Crottini Zoological Collection Voucher), ELO (field series of Elodie A. Courtois), and RAN (field series of Ronald A. Nussbaum). All individuals were assigned to *F. nicosiai* through morphological examination of the collected specimens based on the original species description (Jesu et al., 1999).

Based on the IUCN Red List guidelines (IUCN Standards and Petitions Committee, 2019), and considering the new distributional records, we recommend and propose a new evaluation of the current

conservation status of the species. We computed the Area of Occupancy (AOO), using a grid cell width of 2 km, and the Extent of Occurrence (EOO) with GeoCAT (Bachman et al., 2011). When precise occurrences (from published data or new distributional records) within protected areas were not available, we assumed that the species occurs in the entire legally protected surface (Table 1).

The Tsaranoro Forest is located in the administrative region of Haute Matsiatra, in south-central Madagascar, ca. 32 km south from the town of Ambalavao and only ca. 4 km away from the western entrance of Andringitra National Park. Tsaranoro Forest is a small fragment of semi-deciduous dry forest (46 ha) managed by the local association Tantely, that is managing the forest using selective logging practices and maintaining natural habitat integrity (Gabriel et al., 2018). This forest fragment is surrounded by villages, rice fields, and pastures and it is located at an elevation of ca. 900–1000 m a.s.l., at the foothill of a granitic outcrop that extends in elevation up to 1600 m a.s.l. (Gould and Andrianomena, 2015). This area was surveyed on the night of 6 December and in the morning of 7 December 2018, where three individuals of *F. nicosiai* (UADBA-uncatalogued [ACZCV 0795], ZSM 319/2018 [ACZCV 0780], and ZSM 320/2018 [ACZCV 0778]) were found roosting at high position within the inner and dense portion of the forest (Fig. 2C; Table 1).

The Makay sandstone Massif is located in the Atsimo Andrefana region, immediately north and west of the town of Beroroha, ranging in elevation from 250 to 1034 m a.s.l. The area encompasses numerous deep canyons with gallery forest, surrounded by an arid savannah and isolated from the nearest forests by at least 50 km (Rakotondravony and Goodman, 2011). The remaining forests in Makay Massif are mostly composed of degraded vegetation heavily disturbed by human activities (slash-and-burn agriculture, fires, and grazing). The closest protected areas are Isalo National Park (ca. 100 km to the south) and Zombitse-Vohibasia National Park (ca. 125 km to the south-west) (Rakotondravony and Goodman, 2011). This area was surveyed between November 2009 and January 2010. A few individuals of *F. nicosiai* were observed and some collected at three different sites: Makay 1 (Base camp) (tissues samples ELO 019, ELO 024, ELO 036, and ELO 049), Makay 2 (Dry forest Camp) (tissue sample ELO 042), and Makay 3 (Camp 1-Antsoha Forest) (AMNH R165387, AMNH R165388, AMNH R165390, AMNH R165391, and AMNH R165392) (Fig. 2D–E; Table 1). All these

Table 1. List of localities where *Furcifer nicosiai* is reported with information on coordinates, elevation, presence within protected area (if applicable), and original reference. Localities distribution is represented in Fig. 1. Protected areas are coded as follows: (A) Tsingy de Bemaraha National Park; (B) Paysage Harmonieux Protégé de Beanka; (C) Paysage Harmonieux Protégé du Complexe Tsimembo Manambolomaty; (D) Paysage Harmonieux Protégé du Complexe Lac-Forêt Ambondrombe; (E) Paysage Harmonieux Protégé de Menabe Antimena; (F) Andranomena Special Reserve; (G) Kirindy Mitea National Park.

Locality number	Locality name	Latitude	Longitude	Elevation (m a.s.l.)	Administrative Region	Protected area	Reference	Notes
1	Trano Passage, Antsingy Forest †	18.7167°S	44.7167°E	120–130	Melaky	A	Jesu et al., 1999; Brown et al., 2014	
2	Andolombazimba 1	19.1483°S	44.8283°E	100	Melaky	A	Raselimanana, 2008	
3	Andolombazimba 2	19.1403°S	44.8283°E	59	Melaky	A	Bora et al., 2010	
4	Andranongidro	18.7417°S	44.7117°E	120	Melaky	A	Raselimanana, 2008	
5	Andranopasazy 1	18.7086°S	44.7172°E	146	Melaky	A	Randrianantoandro et al., 2008; Bora et al., 2010	
6	Anjaha	18.6572°S	44.8221°E	403	Melaky	A	Randrianantoandro et al., 2008; Bora et al., 2010	
7	Ankilogoa	19.1311°S	44.8089°E	57	Melaky	A	Bora et al., 2010	
8	Ankily	18.6692°S	44.7811°E	286	Melaky	A	Randrianantoandro et al., 2008; Bora et al., 2010	
9	Antranopasazy 1 (Camp 1)	18.7086°S	44.7189°E	148	Melaky	A	Brown et al., 2014	
10	Antranopasazy 2	18.708°S	44.7164°E	136	Melaky	A	This study	
11	Bendrao 1	18.7972°S	44.8603°E	427	Melaky	A	Bora et al., 2010	
12	Manambolo	19.1333°S	44.8333°E	220	Melaky	A	This study	
13	Ranotsara	19.0356°S	44.7747°E	65	Melaky	A	Bora et al., 2010	
14	Ankazomanga	18.7364°S	44.9139°E	571	Melaky	-	Randrianantoandro et al., 2008; Bora et al., 2010	Nearby (A)
15	Antsalo	18.6817°S	44.6258°E	103	Melaky	-	Bora et al., 2010	Nearby (A)
16	Bendrao 2 (Forest Camp 3)	18.7844°S	44.8603°E	439	Melaky	-	Brown et al., 2014	Nearby (A)
17	Beanka 1	18.0236°S	44.5022°E	220	Melaky	B	Randriamoria, 2011	
18	Beanka 2	18.0519°S	44.5181°E	320	Melaky	B	Randriamoria, 2011	
19	Camp Kimby	18.8725°S	44.24°E	6	Melaky	C	This study	
20	Lac-Forêt Ambondrombe	-	-	-	Melaky	D	Goodman et al., 2018	Coordinates not available
21	Ampataka	20.0897°S	44.5485°E	20	Menabe	E	Randrianantoandro et al., 2010	
22	Ankidroadroa	19.75°S	44.6167°E	120	Menabe	E	Raselimanana, 2008	
23	Ankoraobato	20.1049°S	44.6162°E	67	Menabe	E	Randrianantoandro et al., 2010	
24	Kiboy	19.805°S	44.6386°E	113	Menabe	E	Randrianantoandro et al., 2010	
25	Kirindy 1	20.075°S	44.6722°E	61	Menabe	E	Brown et al., 2014	
26	Kirindy 2	20.0845°S	44.5526°E	29	Menabe	E	Randrianantoandro et al., 2010	
27	Kirindy 3 CNFEREF (north)	20.0523°S	44.6337°E	49	Menabe	E	Randrianantoandro et al., 2010	
28	Kirindy 4 CNFEREF (south)	20.0729°S	44.6629°E	76	Menabe	E	Randrianantoandro et al., 2010	
29	Kirindy forest 5	20.05°S	44.65°E	30–60	Menabe	E	Eckhardt et al., 2019	
30	Marofandilia	20.1016°S	44.6087°E	57	Menabe	E	Randrianantoandro et al., 2010	
31	Tsitakabasia	19.8035°S	44.6301°E	102	Menabe	E	Randrianantoandro et al., 2010	
32	Andranomena	-	-	-	Menabe	F	Goodman et al., 2018	Coordinates not available
33	Dabara forest	20.3741°S	44.8476°E	180	Menabe	-	This study	
34	Kirindy forest (Belo)	20.9349°S	43.8804°E	5	Menabe	G	This study	
35	Makay 1 (Base camp)	21.2229°S	45.3252°E	493	Atsimo Andrefana	-	This study	
36	Makay 2 (Dry forest camp)	21.3116°S	45.1284°E	593	Atsimo Andrefana	-	This study	
37	Makay 3 (Camp 1-Antsoha Forest)	21.5959°S	45.1144°E	268	Atsimo Andrefana	-	This study	
38	Tsaranoro	22.0851°S	46.7755°E	974	Haute Matsiatra	-	This study	

† Type locality

chameleons were found roosting on tree branches at 2–6 m height in primary deciduous forest. During these surveys, many other forests and sites were studied, but *F. nicosiai* appears to be restricted to relatively large and intact blocks of deciduous forest on the eastern side of the Makay Massif and was never found in secondary forest, or degraded habitats.

The Kirindy Mitea National Park is located on the coastline of the Menabe region. It incorporates a wide variety of lowland habitats (0–40 m a.s.l.) including mangroves, brackish flats, littoral forest, dry spiny thicket, and dry deciduous forest (Goodman et al., 2018). One individual (UMMZ 228149) was collected in coastal deciduous forest on 1 April 2001 (Table 1).

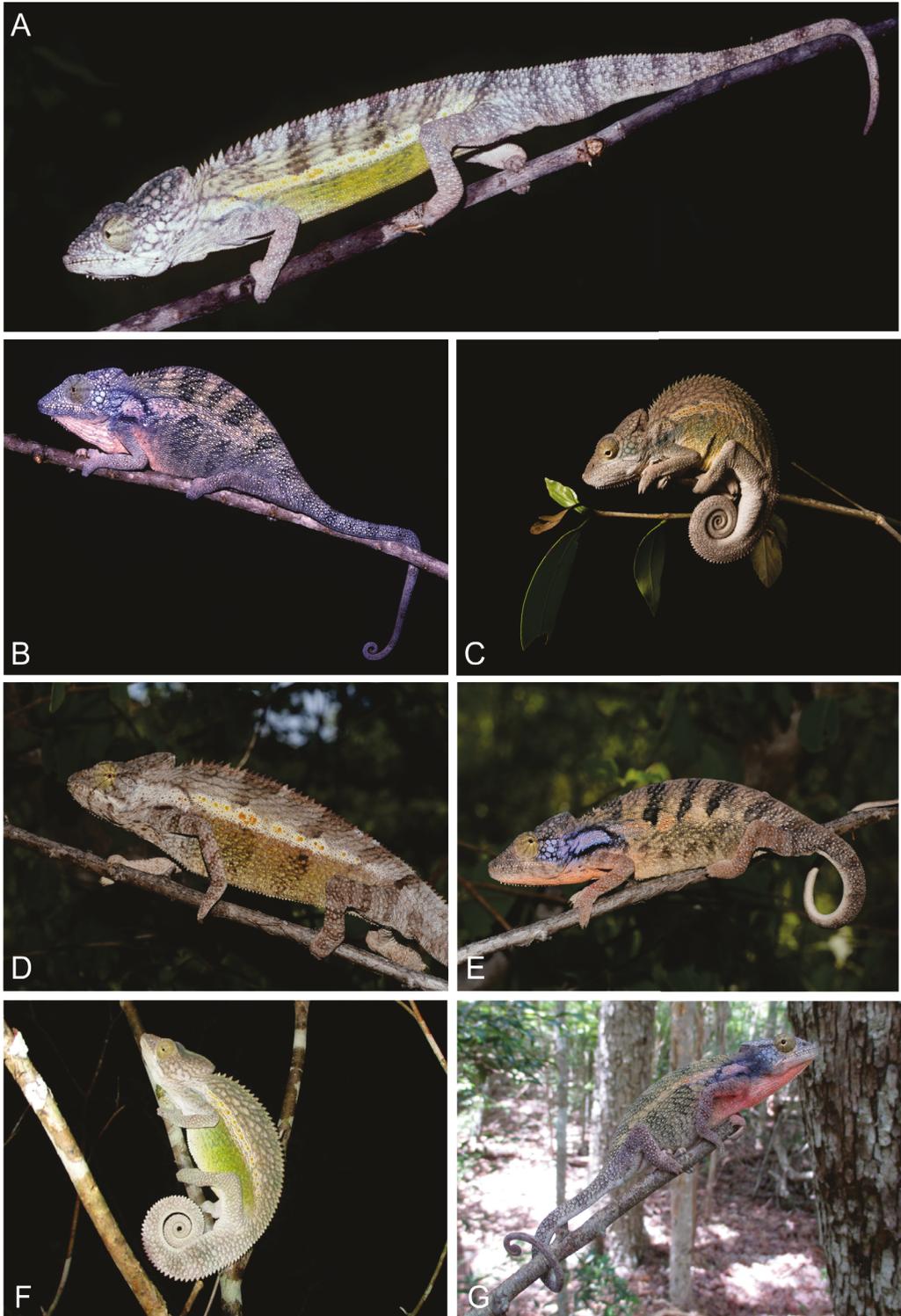


Figure 2. Individuals of *Furcifer nicosiai* collected in Dabara Forest (A) male, (B) female; (C) male from Tsaranoro; (D) male and (E) female from Makay Massif; (F) male and (G) female from Kirindy CNFEREF (Paysage Harmonieux Protégé de Menabe Antimena). Photos by C. J. Raxworthy (A–B, D–E), J. Lobón-Rovira (C), and M. Raselimanana (F–G).

The Dabara Forest is a fragmented dry deciduous forest in the Menabe region, ca. 30 km south-east of the Andranomena Special Reserve and ca. 23 km north-east of Kirindy Mitea National Park. This unprotected forest has become heavily degraded over the past 30 years, and it is not certain if a population of *F. nicosiai* still survives in this region. Eight individuals (UMMZ 215696, UMMZ 215697, UMMZ 215698, UMMZ 215699, and UMMZ 215701; UADBA: RAN 51417, RAN 51510, and RAN 51512) of *F. nicosiai* were collected at night roosting on tree branches at 2–6 m height on 27–28 January 1996 (Fig. 2A–B; Table 1). The original forest at this site included large trees up to 20 m in height and had an extensive closed canopy.

This study considerably increases the distribution of *F. nicosiai* (Fig. 1, black circles). Tsaranoro Forest currently represents the highest elevational record for the species (974 m a.s.l.), which was previously reported up to 571 m a.s.l. in Tsingy de Bemaraha National Park (Bora et al., 2010). The current total areas of Extent of Occurrence (EOO) and Area of Occupancy (AOO) are estimated to be 57,367 km² and 412 km², respectively. The large difference in surface area between these distributions reflects the highly fragmented habitat of this species, with most populations now confined to isolated relict patches of native forest.

Furcifer nicosiai is listed as Endangered (EN) under criteria B1ab(iii) of the IUCN Red List (Jenkins et al., 2011; IUCN Standards and Petitions Committee, 2019). The main threats to the species are ongoing habitat destruction due to expanding agriculture, fire, and logging. These factors, in combination with the known species distribution at the time of the assessment (limited to Tsingy de Bemaraha National Park and estimated in 1566 km² EOO), were considered enough to classify this species into one of the highest threat categories (Jenkins et al., 2011).

Most of our reports are from small fragments of forest outside legally protected areas (Dabara Forest, Tsaranoro Forest, and Makay Massif; although part of the latter is currently in the process of becoming formally protected) and are subject to a variety of threats, which include fires and deforestation for agriculture and logging (Rakotondravony and Goodman, 2011; Gould and Andrianomena, 2015; Gabriel et al., 2018). All these threats are shared by many dry forests in western Madagascar, even within legally protected areas (Raselimanana, 2008; Whitehurst et al., 2009; Randriamoria, 2011; Zinner et al., 2014; Eckhardt et al., 2019). Nonetheless, these records reflect a significant

increase in EOO and AOO for *F. nicosiai*, which justifies the proposed re-evaluation of its conservation status concerning its vulnerability to extinction.

The newly estimated AOO (412 km²) meets criterion B requirements of threatened categories (AOO < 2000 km²), and the taxon can also qualify for subcriterion b(iii), given the above-mentioned threats and conditions that question habitat quality for most of its distributional range (IUCN Standards and Petitions Committee, 2019). Nevertheless, to the best of available knowledge, the species is not eligible for any other subcriterion, and we consequently propose to list *F. nicosiai* within the Near Threatened category. The presence of some populations in protected areas, as well as the discovery of new populations in different regions of western and central Madagascar, suggest that new localities could be identified in other patches of dry deciduous forest in western Madagascar, possibly further reducing extinction risk. Nevertheless, we stress that future molecular and ecological studies improving our knowledge on species genetic diversity and biology, especially characterising population viability and trends, intraspecific variation, and connectivity among localities, may qualify the species for additional subcriteria and make it eligible for threatened categories.

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