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Exemples of habitats where pitfall traps were placed on the Guinean and Liberian Nimba: gallery forest and swamp, camp 4 (Liberia).

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# Shrews (Mammalia, Eulipotyphla) from a biodiversity hotspot, Mount Nimba (West Africa), with a field identification key to species

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**ABSTRACT**

In this study, we collected 226 shrew specimens originating from 16 localities on the Guinean and Liberian sides of Mount Nimba. We surveyed all major vegetation zones from 400 to 1600 m above sea level (asl), including forest and savannah habitats. We recorded 11 species, whose identifications were confirmed by genetic analyses and classical morphometrics. Furthermore, we provide cytogenetic data for five of these species. The shrew community at Mount Nimba is composed of a mix of both savannah- and forest-dependent species, which is related to the peculiar position of Mount Nimba situated at the transition between lowland rainforest to the south and Guinean woodlands to the north. We recorded 11 species of shrews in syntopy in lowland rainforest, seven in edaphic savannah and mountain forest, and five in high-altitude savannah at 1600 m asl. Based on morphometric analyses, we show that these syntopic species separate along a size axis, allowing species to occupy different ecological niches, which we speculate allows them to access different food resources. We also highlight that *Crocidura theresae* Heim de Balsac, 1968 from Mount Nimba has a different karyotype from that described in Côte d’Ivoire. Finally, we develop a novel identification key for shrews from Mount Nimba using external characters and standard body measurements, allowing it to be used in the field on live specimens. In total 12 shrew species are now known from Mount Nimba, which highlights its exceptional position as a tropical African biodiversity hotspot.

**KEY WORDS**

Soricidae,  
*Crocidura*,  
*Suncus*,  
community,  
cytogenetics,  
barcoding,  
morphometrics,  
morphology,  
Africa,  
Guinea,  
Liberia,  
biosphere reserve.

**RÉSUMÉ**

*Musaraignes (Mammalia, Eulipotyphla) d’un point chaud de biodiversité, le mont Nimba (Afrique de l’Ouest), avec une clef d’identification des espèces.*

Dans cette étude, nous avons collecté 226 spécimens de musaraignes dans 16 localités des versants guinéen et libérien du mont Nimba. Nous avons exploré les zones majeures de végétation de 400 à 1600 m d’altitude, incluant les habitats de forêt et de savanne. Nous dénombrons 11 espèces dont les identifications ont été confirmées par analyses génétiques et de morphométrie classique. De plus, nous présentons des données cytogénétiques pour cinq espèces. La communauté des musaraignes du mont Nimba est composée d’un mélange d’espèces savaniques et forestières. Ceci est à mettre en relation avec la position particulière du mont Nimba qui est situé à la transition entre la forêt de plaine au sud et la savanne guinéenne au nord. Nous avons capturé 11 espèces en syntopie dans la forêt de plaine, sept dans les savannes édaphiques et la forêt de montagne et cinq dans la savanne d’altitude à 1600 m. À partir des analyses morphométriques nous montrons que les espèces syntopiques se séparent le long d’un axe de taille, ce qui permet aux espèces d’occuper des niches écologiques variées et suggère que cela facilite l’accès à des ressources alimentaires distinctes. Nous montrons que *Crocidura theresae* Heim de Balsac, 1968 du mont Nimba possède un karyotype différent de ceux décrits en Côte d’Ivoire. Finalement, nous présentons une clef d’identification des musaraignes du mont Nimba utilisant les caractères externes et les mesures corporelles standard afin de permettre son utilisation sur le terrain pour des spécimens vivants. Au total, 12 espèces de musaraignes sont maintenant connues au mont Nimba, ce qui met en évidence sa situation exceptionnelle en tant que point chaud de biodiversité en Afrique tropicale.

**MOTS CLÉS**

Soricidae,  
*Crocidura*,  
*Suncus*,  
communauté,  
cytogénétique,  
barcoding,  
morphométrie,  
morphologie,  
Afrique,  
Guinée,  
Liberia,  
réserve de biosphère.

**INTRODUCTION**

Eulipotyphla Waddell, Okada & Hasegawa, 1999, which includes shrews (family Soricidae G.Fischer, 1814), hedgehogs (Erinaceidae G.Fischer, 1814), moles (Talpidae G.Fischer, 1814) and solenodons (Solenodontidae Gill, 1872), represents the third most diverse order within Mammalia after Rodentia Bowdich, 1821 and Chiroptera Blumenbach, 1779 (Hutterer 2005). The Soricidae comprises 25 genera and 448 species (Burgin & He 2018). Within Africa, both shrew diversity and endemism are high in the Guineo-Congolian rainforest block (Kasangaki *et al.* 2003; Nicolas *et al.* 2005; Gambalemoke

*et al.* 2008; Igbokwe *et al.* 2019). The western part of this forest block, which forms the Upper Guinea rainforest zone, has been identified as one of 25 biodiversity hotspots in the world (Myers *et al.* 2000). It harbours numerous endemic species and an exceptional diversity, which is far from being exhaustively known. For example, many cryptic species of small mammals have been recently recognized and described in this region (Nicolas *et al.* 2009; Denys & Aniskine 2012; Jacquet *et al.* 2012; Monadjem *et al.* 2013, 2016; Decher *et al.* 2015; Hutterer *et al.* 2019; Monadjem *et al.* 2021). There are currently 16 species of soricid shrews described from the Upper Guinean rain forest (Burgin & He 2018), some of which are of

conservation concern, e.g. *Crocidura nimbae* Heim de Balsac, 1956, *C. buettikoferi* Jentink, 1888, *C. grandiceps* Hutterer, 1983 that are listed as globally “Near Threatened” (IUCN, 2019), or have restricted geographical ranges, e.g. *C. nimbasilvanus* Hutterer, 2003 (Jacquet *et al.* 2013). Furthermore, some species are of socioeconomic importance being hosts for hantaviruses (Klempa *et al.* 2007; Kang *et al.* 2011).

The diversity of small mammals, and especially of shrews, is promoted by factors acting as biogeographical barriers such as different vegetation zones (Jacquet *et al.* 2014), rivers (Stanley & Esselstyn 2010; Jacquet *et al.* 2013), or mountains (Stanley & Olson 2005; Stanley & Esselstyn 2010). Mount Nimba, which is situated at the triple frontier point between Guinea, Liberia and Côte d’Ivoire, constitutes one of the three highest West African mountains (1752 m above sea level). Mount Nimba has been subject to several surveys aimed at understanding the structuring of its plant and animal communities (see Coe 1975 and references therein). Stratification of the vegetation is observed along the elevational gradient, with lowland forest up to 600 m, mid-elevation forest between 600 and 1200 m and edaphic altitude savannah above 1200 m. This latter habitat is known to offer isolation conditions for both plant and animal species owing to its distinct climate and vegetation characteristics (Coe 1975; Lamotte & Roy 2003). For this reason, Mount Nimba may act as a biodiversity promoter (White 1981). Moreover, it is situated in the ecotone zone between rainforest and savannah, which is high in diversity (Fahr & Kalko 2011), and is known to play an important role in speciation processes (Schilthuizen 2000).

Mount Nimba houses several endemic or near-endemic species including the toad *Nimbaphrynoïdes occidentalis* (Angel, 1943), the afrosoricid *Micropotamogale lamottei* Heim de Balsac, 1954 the rodent *Dendromus lachaisei* Denys & Aniskine, 2012, and the bats *Hipposideros lamottei* Brosset, 1984 and *Neoromicia roseveari* Monadjem, Richards, Taylor & Stoffberg, 2013 (Denys & Aniskine 2012; Monadjem *et al.* 2013, 2016, 2019). Furthermore, the two shrews *Crocidura nimbae* and *Crocidura nimbasilvanus* are near-endemics occurring on this mountain and in surrounding areas (Mamba *et al.* 2021).

The shrews of Mount Nimba have been the subject of several historical surveys (Heim de Balsac 1958; Coe 1975; Verschuren & Meester 1977). Highlighting the uniqueness of this mountain, five species of the genus *Crocidura* Wagler, 1832 have their type locality in Mount Nimba: *C. nimbae* Heim de Balsac, 1956, *C. juvenetae* Heim de Balsac, 1958, *C. obscurior* Heim de Balsac, 1958, *C. theresae* Heim de Balsac, 1968 and *C. nimbasilvanus* Hutterer, 2003. In total, two genera and 12 species are currently known from the massif: the five previously-mentioned species, plus *C. buettikoferi* Jentink, 1888, *C. grandiceps* Hutterer, 1983, *C. douceti* Heim de Balsac, 1957, *C. muricauda* (Miller, 1900), *C. olivieri* (Lesson, 1827) and *Suncus megalurus* (Jentink, 1888) (Heim de Balsac, 1958; Hutterer, 2005). Other species that may occur include *C. crossei* Thomas, 1895 and *C. lamottei* Heim de Balsac, 1968, both of which were previously reported from nearby regions (Decher *et al.* 1997; Grubb *et al.* 1998; Jacquet *et al.* 2012). On the Ivorian side of Mount Nimba, *C. eburnea* Heim de

Balsac, 1958 was described from Mount Tonkouï as a subspecies of *C. obscurior* before being recently elevated to full species level following detailed molecular analysis (Jacquet *et al.* 2014). Two other species, *C. poensis* (Fraser, 1843) and *C. denti* Dollman, 1915 are often described as being present from the vicinity of Mount Nimba (Wilson & Mittermeier 2018) but recent molecular studies show that they probably represent misidentifications (Dambry *et al.* 2016; Nicolas *et al.* 2019). Eleven of the 12 species recorded from Mount Nimba were recently validated through an integrative taxonomic approach using morphological and molecular data (Dubey *et al.* 2008; Jacquet *et al.* 2012).

Cytogenetic analyses have also been successfully employed to assess the validity of shrew species and to explore intra- and inter-specific variability (Meylan & Vogel 1982; Schlitter *et al.* 1999). Several cytogenetic studies have been conducted in West Africa, especially in Côte d’Ivoire and Burkina Faso (Meylan 1967, 1971; de Hondt 1974; Meylan & Vogel 1982; Maddalena & Ruedi 1994; Baskevitch *et al.* 1995; Lavrenchenko *et al.* 1997; Schlitter *et al.* 1999), however many gaps remain in our knowledge of the intra- and inter-specific variability in the karyotypes of shrews in West Africa, and no karyotypes have been published for shrews at Mount Nimba.

Despite progress made with resolving the taxonomy and systematic relationships of West African shrews, little is known about their ecological requirements and morphological variability. Morphometric analyses are useful in describing the variability within and between species, and have been used to demonstrate that in species-rich shrew communities such as those in African rainforests, species are typically ordered along a size gradient (Hutterer *et al.* 1987; Brosset 1988; Churchfield *et al.* 1999). It has been suggested that this assists partitioning access to food resources, allowing these species to co-exist sympatrically or even syntopically (Hutterer *et al.* 1987).

A serious challenge to research on West African shrews is the difficulty with species identification. Indeed, tools allowing rapid and accurate identification of species in the field are totally lacking; even the most recent and comprehensive synthesis of African mammals ‘Mammals of Africa’ does not present characters for distinguishing different species of the super-diverse genus *Crocidura* (Happold & Happold 2013). To complicate matters, the morphology of shrews may vary with environmental factors (Rácz & Demeter 1998; Wójcik *et al.* 2000, 2003). As a result, the identification of species in the field is challenging even for specialist taxonomists, especially owing to the paucity of available external characters (e.g. fur and skin colour, tail length and thickness, quantity and length of tail vibrissae) for the discrimination of species (Heim de Balsac 1956, 1958, 1968; Hutterer & Happold 1983). An identification key was presented by Hutterer & Happold (1983) for Nigerian shrews but is mostly inapplicable to the Upper Guinea rainforest, since species composition is different. Given the important status of Mount Nimba (Monadjem *et al.* 2016), the development of an identification key based on external and morphometric characters would be highly useful.

The aim of this paper is to synthesize our recent work on shrew diversity at Mount Nimba by: 1) providing a faunal



list with information on habitat and ecological requirements; 2) describing karyotypes of Mount Nimba shrews and comparing them with those available for other West African localities in the literature; 3) exploring the morphological variability within and between species in order to understand how diverse communities are structured; and 4) providing a new identification key easily usable in the field. We have at our disposal a valuable collection of genotyped specimens that represents a unique opportunity to update our knowledge on the distribution, ecology, and morphology of shrew taxa from this biodiversity hotspot.

## MATERIAL AND METHODS

### STUDY AREA AND BIOLOGICAL MATERIAL

Mount Nimba is an isolated massif of about 40 kilometers length, composed of Precambrian rocks, situated at the triple frontier point between Guinea, Liberia and Côte d'Ivoire. It is sometimes considered as a range constituted of different peaks all situated on the Guinean side: Mount Richard Molard (1752 m), Mount Sempéré (1682 m), Mount Leclerc (1577 m), Mount Pierré Richaud (1670 m), Mount Tô (1675 m). This range is partially protected under the name: Mount Nimba Strict nature reserve and Mount Nimba Biosphere reserve and world heritage that is found in Guinea and Côte d'Ivoire and includes only Mount Richard Molard known as Mount Nimba.

In 2003, Liberia proclaimed the East Nimba Nature Reserve (ENNR) covering most of the Liberian part of the mountain, whose management costs are currently subsidized by ArcelorMittal that views it as a possible offset site for its operations. In contrast, the entire Guinean and Ivorian parts of the mountain were protected from 1944 onwards. The Mount Nimba Strict Nature Reserve (La Réserve naturelle intégrale du Mont Nimba), was initially established by the former French colonial government in 1943 by Order no. 4190 SE/F in Côte d'Ivoire and subsequently by decree in Guinea in 1944 (JO-RF, 1944). In 1980 the Guinean portion of the Strict Nature Reserve was proclaimed a Biosphere Reserve. The Mount Nimba Strict Nature has been recognised as a single transboundary 'Natural World Heritage Site' (NWS) by UNESCO since 1981 (Cote d'Ivoire section) and 1982 (Guinea section) (Granier & Martinez 2011). Nevertheless, this ecosystem is currently threatened by intensive human activities like cacao, coffee, rubber and oil palm cultures, forestry and iron ore exploitation.

During biodiversity inventories performed from 2008 to 2013, we trapped shrews at several localities on the Guinean and Liberian sides of Mount Nimba. During the dry (February-March 2008, December 2009-January 2010, December 2010-January 2011) and wet (October 2008) seasons, 153 shrew specimens were trapped using Sherman and pitfalls traps at five localities in Guinea (Table 1). In 2011 and 2013 we collected 73 additional shrews at 11 localities in Liberia, in the ArcelorMittal concession including the ENNR. We surveyed all habitats encountered on this mountain, i.e., lowland and

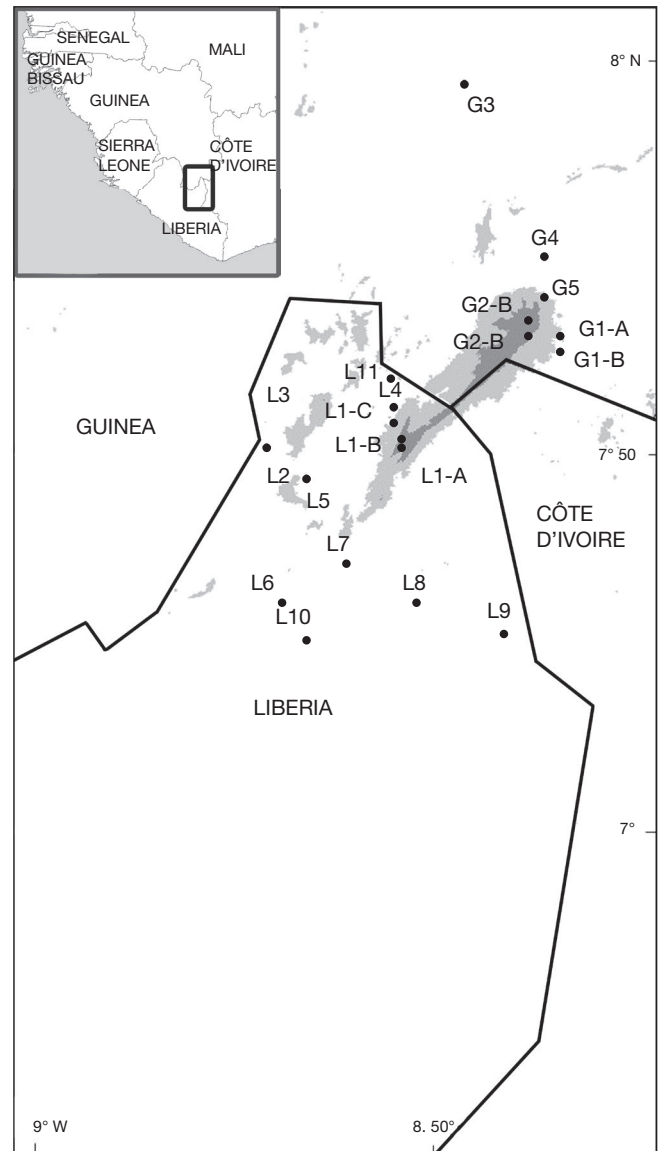


FIG. 1. — Detail of the trapping localities at Mount Nimba with respect to elevation. Sampling sites are shown in black circles. Light and dark grey shading refer to areas above 600 m and 1000 m, respectively. Names of localities used in this work as follows: **G**, Guinea; **L**, Liberia, Gbié: **G1-A, B**; Gouan: **G2-A, B**; Seringbara: **G3**; Gblayougouma **G4**; Ziéla: **G5**; East Nimba Nature Reserve **L1-A, B, C**; Bentor: **L2**; Bonlah: **L3**; Yekepa: **L4**; Tailings: **L5**; Camp4: **L6**; Liabala: **L7**; Gbapa: **L8**; Zolowee: **L9**; Grassfield: **L10**; Border (Yekepa): **L11**.

montane forests, secondary forests and agroecosystems from 400 to 1350 m, as well as edaphic savannahs at altitudes of 500-600, 1200 and 1600 m. (Figs 1; 2).

We used 180 Sherman traps baited with a mixture of wheat, oil, peanuts, dryfish and palm nuts to capture small mammals. Each line consisted of 20 to 40 traps at 5 m intervals. In addition, we used pitfall trap lines that consisted of 20 buckets (10 l) 5 m apart and linked with a plastic sheet drift fence 40 cm tall. Our total sampling effort was 4532 bucket-nights for the pitfalls and 9515 trap-nights for Shermans and tomahawks.

Animals were autopsied immediately after capture, following the guidelines of the American Society of Mammalogists (Sikes *et al.* 2016). We took the following standard external

TABLE 1. — Description of all trapping devices and trapping sites sampled for shrews on Mount Nimba from 2008 to 2013. Abbreviations: ENNR, East Nimba Nature Reserve; PF, pitfall traps; SH, Sherman live traps.

Locality	Habitat	Elevation (m asl)	Latitude	Longitude	Trap type
Guinea					
Gbié	Gallery forest	552-621	7.65	-8.33	SH & PF
	Savannah	595-649	7.63	-8.33	SH & PF
Gouan	Gallery forest	1176-1212	7.67	-8.37	SH & PF
	Savannah	1201-1236	7.65	-8.37	SH
	Altitude savannah	1616-1642	7.67	-8.37	SH & PF
	Mare d'hivernage				
Seringbara	Secondary forest	589-600	7.97	-8.45	SH & PF
Gblayougouma	Field, secondary forest and houses	477	7.75	-8.35	SH & PF
Ziéla	Secondary and gallery forest	477-581	7.70	-8.35	SH & PF
Liberia					
ENNR	Secondary savannah	1350	7.51	-8.53	SH
	Primary mid- to high-elevation forest	1065-1190	7.52	-8.53	PF
	Primary lowland rainforest	690	7.54	-8.54	SH
Bentor	Primary lowland rainforest	420	7.51	-8.70	PF
Bonlah	Disturbed forest edge	450	7.57	-8.66	SH
Yekepa	Swamp in peri-urban area	515	7.56	-8.54	PF
Tailings	Primary lowland forest	475-495	7.47	-8.65	SH & PF
Camp4	Gallery forest and swamp	491-517	7.44	-8.66	SH & PF
Liabala	Secondary forest in front of the village	478	7.40	-8.58	PF
Gbapa N & S	Secondary forest	441-474	7.46	-8.49	SH & PF
Zolowee	Houses, <i>Hevea</i> Plantation	458-473	7.43	-8.38	SH
Grassfield	Edaphic savannah, secondary forest	427-518	7.38	-8.65	SH
Border (Yekepa)	Edaphic savannah, secondary forest	542-569	7.57	-8.84	SH

measurements: head and body length (HB), tail length (T), ear length (E) and hindfoot length without claw (HF). We also recorded weight, sex, and reproductive state. Skulls were either prepared in the field, at the Muséum national d'Histoire naturelle (MNHN) in Paris, France, or in the Durban Natural Science Museum, Durban (DM), South Africa. Eleven craniodental measurements were taken adapted from Dippenaar (1977) and Hutterer & Kock (2002) (Fig. 2) using a Mitutoyo caliper (Mitutoyo, Kawasaki, Japan) with a precision of 0.01 mm. All specimens are housed in the mammal collections of the MNHN under catalogue numbers [MNHN-ZM-2012-1051](#) to [2012-1205](#), [2014-899](#) to [2014-942](#) and at the DM under the numbers 13176-13204 (Appendices 1; 2; 3). Guinean species identification was based on an integrative taxonomic approach using morphological and molecular data (Jacquet *et al.* 2012). Based on genetic data the morphospecies *C. muricauda* could represent a complex of species (Jacquet *et al.* 2012), but pending revision of this species we take the conservative approach and consider it as a single species. The Liberian specimens were barcoded by two of us (A.L., J.G.B.) using cytochrome b partial sequences and identified using BLAST (“Basic Local Alignment Search Tool”) on the NCBI website (<http://blast.ncbi.nlm.nih.gov/Blast.cgi>; option “megablast”).

#### CYTOGENETIC ANALYSES

Fifteen specimens were used for standard cytogenetic analysis, which were directly conducted in the field by Vladimir Aniskine and Morlaye Sylla ([MNHN-ZM-2012-1051](#), [MNHN-ZM-2012-1053](#), [MNHN-ZM-2012-1069](#), [MNHN-ZM-2012-1070](#) and [MNHN-ZM-2012-1071](#) for *C. buetikoferi*; [MNHN-ZM-2012-1076](#) and [MNHN-ZM-2012-1077](#)

for *C. grandiceps*; [MNHN-ZM-2012-1087](#), [MNHN-ZM-2012-1088](#) and [MNHN-ZM-2012-1091](#) for *C. juvenetae*; [MNHN-ZM-2012-1153](#), [MNHN-ZM-2012-1154](#), [MNHN-ZM-2012-1156](#) and [MNHN-ZM-2012-1164](#) for *C. olivieri*; and [MNHN-ZM-2012-1168](#) and [MNHN-ZM-2012-1171](#) for *C. theresae*). Metaphase chromosome preparations were obtained by the standard colchicine method following the protocol of Lee & Elder (1980). We compared our data with those from other cytogenetic surveys in West Africa (Meylan 1967, 1971; de Hondt 1974; Meylan & Vogel 1982; Lavrenchenko *et al.* 1997; Baskevitch *et al.* 1995; Schlitter *et al.* 1999).

#### MORPHOMETRIC ANALYSES

We performed univariate statistics on the external and craniodental measurements on all the newly collected specimens from Mount Nimba (Fig. 3; Appendices 1, 2). Means, standard deviations and ratios were calculated for weight and external measurements (HB, T, E and HF lengths) for 141 adult specimens in order to provide diagnostic characters between species and to quantify the morphometric variability within them. Similarly, we calculated standard statistics using eleven craniodental measurements (Fig. 3) (a: condyle-incisive length, b: nasal width, c: interorbital width, d: occipital greatest width, e: greatest maxillary width, f: upper tooth row length, g: height of the skull at M2 level, h: greatest braincase height, i: mandibular length, j: lower tooth row length, k: greatest length between extremities of the coronoid and angular processes) for 122 specimens, which had intact skulls.

We then tested for sex- and species-related differences using ANOVAs (Analysis of Variance) and MANOVAs (Multiple





FIG. 2. — Examples of habitats where pitfall traps were placed on the Guinean and Liberian Nimba: **A**, gallery forest and swamp, camp 4 (Liberia); **B**, pitfall, altitude savannah with *Loudetia kagerensis*, Mare d'hivernage site (1642 m) (Guinea); **C**, pitfall, Selingbala (Guinea): mesophyllous secondary forest; **D**, pitfall, Gbie (Guinea): gallery forest with *Parinari excelsa* Sabine, 1824, *Carapa procera* DC., 1824 and *Pseudospondias microcarpa* (A. Rich.) Engl., 1883, *Maranthochloa purpurea* (Ridl.) Milne-Redh.



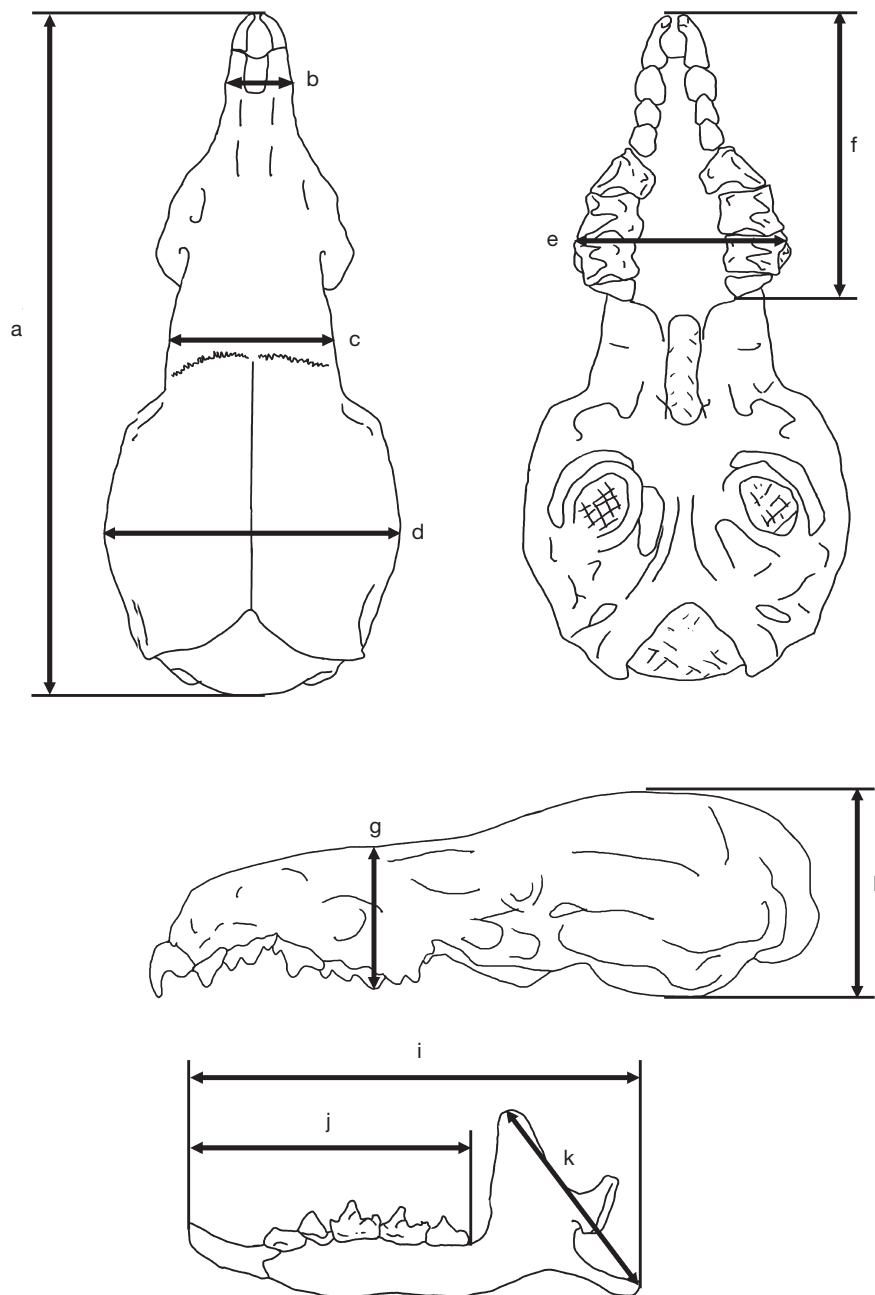


FIG. 3. — Craniodental measurements used for morphometric analyses adapted from Dippenaar (1977) and Hutterer & Kock (2002): **a**, condyle-incisive length; **b**, nasal width; **c**, interorbital width; **d**, occipital greatest width; **e**, greatest maxillary width; **f**, upper tooth row length; **g**, height of the skull at M2 level; **h**, greatest braincase height; **i**, mandibular length; **j**, lower tooth row length; **k**, greatest length between extremities of the coronoid and angular processes.

Analysis of Variance). Morphometric differences between species were also tested with CVA (Canonical Variate Analysis) using R version 2.9.0 (R Core Team, 2015) on log-transformed data. To obtain sufficient coverage for all our species, we added supplementary specimens from surrounding regions (Ziama Mt, Zouguepo, forest and savannahs of South eastern Guinea, i.e. Appendix 3) and Ivory Coast for the rarest species (*C. nimbae*, *C. nimbasilvanus*, *C. douceti*, *C. eburnea*).

Finally, we performed CVA on 41 specimens of *C. buettikoferi*, 12 *C. denti*, 5 *C. eburnea*, 7 *C. nimbae*, 15 *C. muricauda*, 39 *C. obscurior*, 19 *C. olivieri*, 19 *C. grandiceps*, 29 *C. juvenetae*, 11 *C. nimbasilvanus*, and 39 *C. theresae*. We included intact (unbroken skulls) type series specimens described by Heim de Balsac (1958) from our region (Appendix 3). Nearly all of the specimens that we used for morphometric analyses have also been molecularly barcoded.

TABLE 2. — Seasonal trapping success in localities and habitats where pitfall trap lines were installed. The habitat and elevation of each site is also presented. Abbreviation: ENNR, East Nimba Nature Reserve.

Locality	Habitat	Elevation (m asl)	Trapping effort (trap-nights)		Trapping success (specimens/trap nights * 100)	
			Dry season	Wet season	Dry season	Wet season
Gbié	Savannah	600	240	322	2.92	7.14
Seringbara	Forest	400-600	440	550	1.59	1.63
Gouan	Forest	1000-1200	480	140	3.96	5
Ziéla	Forest, houses	600	120	–	8.3	–
Mare d'hivernage	Savannah	1600	120	140	7.5	14.3
Total Guinea			1400	1152	3.71	5.12
ENNR	Forest, savannah	690-1350	130	–	3.08	–
Bentor	Forest	420	60	–	18.33	–
Yekepa	Swamp	515	60	–	1.67	–
Tailings	Forest	500	100	–	3.00	–
Camp 4	Swamp, forest	500	280	–	3.57	–
Liebala	Forest	478	240	–	7.5	–
Gbapa	Forest	500	60	–	5	–
Total Liberia			1980	–	5.34	–

TABLE 3. — Seasonal trapping success in localities and habitats where Sherman traps were installed. The habitat and elevation of each site is also presented. Abbreviation: ENNR, East Nimba Nature Reserve.

Locality	Habitat	Elevation (m asl)	Trapping effort (trap nights)		Trapping success (specimens/trap nights * 100)	
			Dry season	Wet season	Dry season	Wet season
Gbié	Gallery forest, savannah	600	550	1140	1.09	0.7
Gouan	Forest	1200	840	1025	0.12	0.39
Mare d'hivernage	Savannah	1600	450	930	1.11	0.54
Seringbara	Forest	600	1000	1090	0.0	0
Gblayougouma	Village	500	222	–	0	–
Ziéla	Gallery Forest	500	1209	30	0.5	3.33
Total Guinea			4271	4215	0.42	0.43
ENNR	Forest	600	88	–	2.27	–
ENNR	Forest	1000-1300	88	–	1.14	–
Bonlah	Forest	450	44	–	2.27	–
Tailings	Forest	500	215	–	2.79	–
Zolowee	Houses	500	90	–	2.22	–
Grassfield	Savannah	600	144	–	2.78	–
Gbapa	Swamp, forest	500	180	–	1.67	–
Camp4	Forest	500	90	–	2.22	–
Border, Yekepa	Forest, savannah	500	90	–	2.36	–
Total Liberia			1029	–	2.33	–

CONSTRUCTION OF AN IDENTIFICATION KEY

To assist in the identification of shrew species occurring on Mount Nimba we developed a dichotomous key that could be usable in the field and could work on live animals. Therefore, we used, as far as possible, external characters visible or measurable in the field. However, in a few instances reference to craniodental features was necessary to ensure accurate identifications. To take intraspecific variability into account, especially when few specimens of a species, like *C. douceti*, *C. eburnea* and *C. nimbasilvanus*, were collected, we used additional shrew specimens of the same species housed in the collections of the Muséum national d'Histoire naturelle, among which were 10 type specimens described from Mount Nimba and neighbouring regions (Appendix 3).

ABBREVIATIONS

*Institutions*

DM Durban Natural Science Museum, Durban;  
 MNHN Muséum national d'Histoire naturelle, Paris.

*Measurements*

HB Head and body length;  
 TL tail length;  
 HF hindfoot length;  
 E ear length;  
 TL/HB ratio of tail length on head and body length;  
 W weight.

RESULTS

TRAPPING RESULTS AND ECOLOGICAL DATA

Trapping success per locality and device for both the dry and wet seasons are presented in Tables 2 and 3. In Guinea, with pitfall traps, the overall trapping success was better in the wet than in the dry season. In the case of the edaphic and high-altitude savannahs (600 and 1600 m; Gbié and Mare d'hivernage), the trapping success was more than doubled between the dry and wet season (Table 2). There was great variability in capture success rate between pitfall sites, with the



TABLE 4. — Diversity, relative abundance, and habitats of shrew species from Guinean and Liberian sides of Mount Nimba. Abbreviations: **NI**, total number of individuals; **RA**, relative abundance.

Species	Guinea NI	Guinea RA (%)	Liberia NI	Liberia RA (%)	Habitat	Altitude (m asl)
<i>Crociodura obscurior</i> Heim de Balsac, 1958	36	23.5	7	9.6	Lowland gallery forest, secondary forest, mountane forest	400-600, 1200
<i>Crociodura</i> sp. ( <i>obscurior/eburnea</i> )	0	0.0	5	6.8	Lowland secondary forest, gallery forest	400-600, 1600
<i>C. eburnea</i> Heim de Balsac, 1958	0	0.0	12	16.4	Lowland gallery forest	400-600
<i>C. juvenetae</i> Heim de Balsac, 1958	23	15.0	8	11	Lowland gallery forest, secondary forest, mountane forest	600, 1200
<i>C. theresae</i> Heim de Balsac, 1968	23	15.0	4	5.5	Lowland gallery forest, savannah	600, 1600
<i>C. buettikoferi</i> Jentink, 1888	22	14.4	9	12.3	Lowland gallery forest, secondary forest, mountane forest	400-600, 1200
<i>C. olivieri</i> (Lesson, 1827)	13	8.5	15	20.5	Savannah	1600
<i>C. grandiceps</i> Hutterer, 1983	11	7.2	5	6.8	Bush, fallow, lowland gallery forest, secondary forest, mountane forest	400-600, 1200
<i>C. muricauda</i> (Miller, 1900)	7	4.6	5	6.9	Houses, swamp, lowland gallery forest, secondary forest, mountane forest	600
<i>C. douceti</i> Heim de Balsac, 1958	1	0.6	0	0.0	Edaphic savannah	600-1200
<i>C. nimbasilvanus</i> Hutterer, 2003	1	0.6	1	1.4	Mountain gallery forest, lowland gallery forest, savannah	600
<i>Suncus megalura</i> (Jentink, 1888)	16	10.6	2	2.7	Lowland secondary forest	400-1200
Total	153	100	73	100	Lowland forest, gallery forest, secondary forest, mountane forest	Savannah 600, 1600

best results from primary lowland forest at Bentor, which was alongside a medium-sized river, and in the Mare d'hivernage (high-altitude savannah). With Sherman traps, capture success was always low and similar in the dry and wet seasons, in the different habitats of Guinea (Table 3). The best results were obtained in gallery forests at 600 m (Ziela) and in the high-altitude savannah at 1600 m (Mare d'hivernage). No specimens were trapped in houses in the Guinean side. In Liberia best trapping success was obtained in Tailings (lowland forest) and Grassfield (edaphic savannah). A single individual of *C. grandiceps* was found in a house in Zolowee village in Liberia in 2013.

Of the 226 specimens captured in this study, 209 (92%) belong to the genus *Crociodura* and 17 (8%) to the genus *Suncus* Ehrenberg, 1832 (Table 4). The genus *Crociodura* was represented by 10 species, and *Suncus* by one species. We collected mostly the same species on both sides of Mount Nimba with the exceptions of *C. eburnea* (Liberian side only) and *C. douceti* (Guinean side only). We did not trap *C. nimbae*, which was previously recorded from Mount Nimba by Heim de Balsac (1958). *Suncus megalura* (Jentink, 1888) was trapped in both Liberia and Guinea. In the Guinean side, the most abundant species in our sampling was *C. obscurior*, which represented 23.5% of all captured specimens. *Crociodura buettikoferi*, *C. theresae* and *C. juvenetae* each represented about 15% of all captures.

We trapped one specimen of *C. douceti* and two *C. nimbasilvanus*. In Liberia, the most abundant species was *C. olivieri* (20.3%), followed by *C. eburnea* and *C. obscurior* (16.4%), *C. buettikoferi* (12.2%) and *C. juvenetae* (10.3%). A few specimens of *C. theresae*, *C. grandiceps*, *C. muricauda* and *C. nimbasilvanus* were also captured.

The lowland primary and gallery forests between 400 and 800 m harboured all shrew species that we recorded from Mount Nimba (11 species, two genera) (Table 5; Appendixes 4; 5). By comparison, only seven species (of both genera) were recorded in montane forests between 1000 and 1200 m (*S. megalura*, *C. muricauda*, *C. grandiceps*, *C. olivieri*, *C. buettikoferi*, *C. juvenetae*, *C. obscurior*) and five species (of both genera) were encountered in high-altitude edaphic savannahs at 1200-1600 m (*S. megalura*, *C. theresae*, *C. juvenetae*, *C. obscurior*, *C. buettikoferi*). The lowland edaphic savannah hosted *S. megalura*, *C. muricauda*, *C. grandiceps*, *C. olivieri*, *C. theresae*, *C. juvenetae* and *C. obscurior*. Among the species restricted to lowland primary, secondary, and gallery forests were *C. nimbasilvanus*, *C. douceti* and *C. eburnea*.

#### KARYOTYPES

The three males and two females of *C. buettikoferi* displayed the same karyotype with diploid number  $2n = 52$  and fundamental number of autosomes  $N_{Fa} = 66$  (Fig. 4A). The autosomal set comprised three pairs of small meta-submetacentric

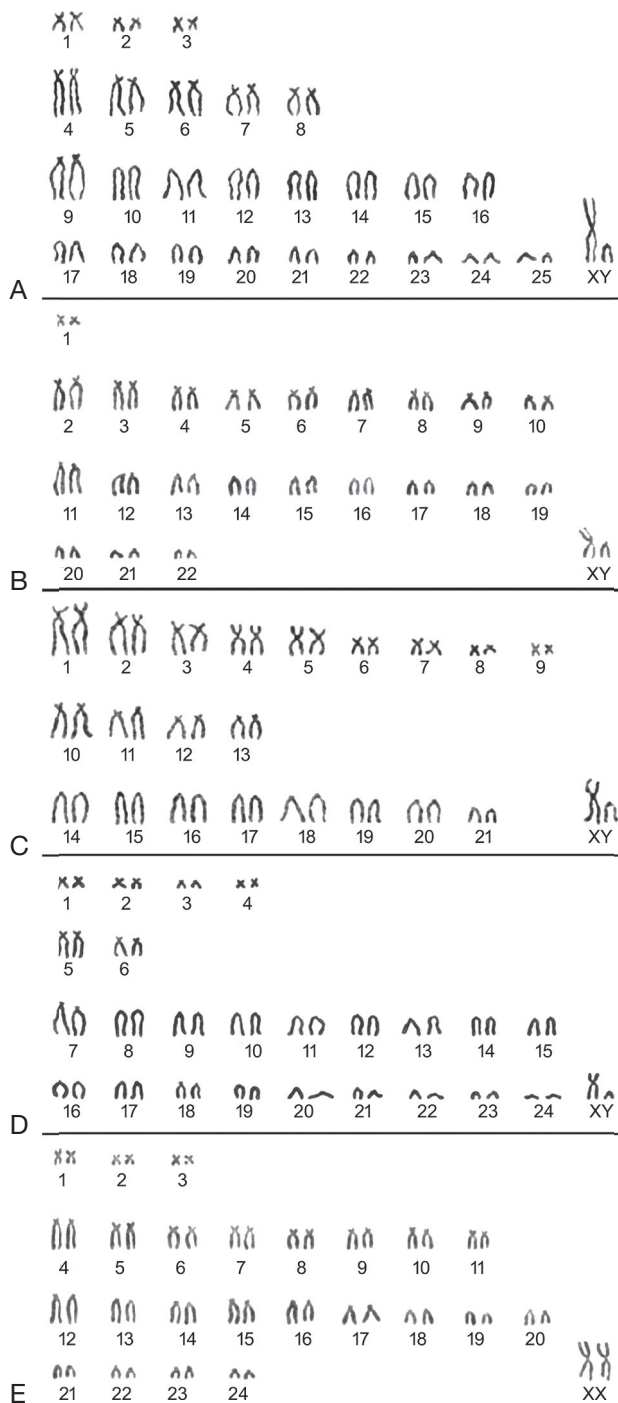


FIG. 4. — Standard karyotypes from Mount Nimba shrews: **A**, male *C. buettikoferi* Jentink, 1888 MNHN-ZM-2012-1071, 2n = 52, NFa = 66; **B**, male *C. grandiceps* Hutterer, 1983 MNHN-ZM-2012-1077, 2n = 46, NFa = 64; **C**, male *C. juvenetae* Heim de Balsac, 1958 MNHN-ZM-2012-1091, 2n = 44, NFa = 68; **D**, male *C. olivieri* (Lesson, 1827) MNHN-ZM-2012-1164, 2n = 50, NFa = 60; **E**, female *C. theresae* Heim de Balsac, 1968 MNHN-ZM-2012-1171, 2n = 50, NFa = 70.

(1<sup>st</sup>-3<sup>rd</sup>), five pairs of subtelocentric (4<sup>th</sup>-8<sup>th</sup>) and 17 pairs of acrocentric chromosomes (9<sup>th</sup>-25<sup>th</sup>) decreasing in size. The X and Y chromosomes were constituted respectively of the largest metacentric and an acrocentric element similar in size to the 19<sup>th</sup> pair of autosomes.

The two males of *C. grandiceps* had 2n = 46 and NFa = 64 (Fig. 4B). The karyotype comprised one pair of small metacentric (1<sup>st</sup>), nine pairs of subtelocentric (2<sup>nd</sup> - 10<sup>th</sup>) and 12 pairs of acrocentric chromosomes (11<sup>th</sup>-22<sup>nd</sup>) decreasing in size. The X was a large-sized metacentric chromosome and the Y was acrocentric and similar in size to the 17<sup>th</sup> pair of autosomes.

The three *C. juvenetae* specimens displayed identical karyotypes with 2n = 44 and NFa = 68 (Fig. 4C). The autosomal set comprises nine pairs of large to small metacentric and submetacentric chromosomes (1<sup>st</sup>-9<sup>th</sup>), four subtelocentric pairs (10<sup>th</sup>-13<sup>th</sup>) and eight acrocentric pairs (14<sup>th</sup>-21<sup>st</sup>). The X and Y chromosomes were easily recognizable and represented a large-sized metacentric and an acrocentric slightly higher in size than the 21<sup>st</sup> pair of autosomes, respectively.

The three males and the female of *C. olivieri* were characterized by 2n = 50 and NFa = 60 (Fig. 4D). The karyotypes consisted of four small meta-submetacentric pairs (1<sup>st</sup>-4<sup>th</sup>), two medium-sized subtelocentric pairs (5<sup>th</sup>-6<sup>th</sup>) and 18 acrocentric pairs of chromosomes (7<sup>th</sup>-24<sup>th</sup>) decreasing in size. The X and Y chromosomes were metacentric and small acrocentric, respectively.

The male and the female of *C. theresae* displayed the same karyotype with 2n = 50 and NFa = 70 (Fig. 4E). The karyotype contained three pairs of small bi-armed autosomes similar in size (1<sup>st</sup>-3<sup>rd</sup>), eight subtelocentric pairs (4<sup>th</sup>-11<sup>th</sup>) and 13 acrocentric pairs (12<sup>th</sup>-24<sup>th</sup>) progressively decreasing in size. The X chromosome was a large-sized metacentric and the Y was acrocentric and similar in size to the 21<sup>st</sup> pair of autosomes (data not shown).

MORPHOMETRIC DATA

Shrew species occurring on Mount Nimba differed in external body measurements (F = 15.596, P < 0.001), in body weight (F = 135.8, P < 0.001) and in craniodental measurements (F = 3.7812, P < 0.001). Some sexual dimorphism was detected (F = 1.8896, P = 0.120, F = 0.661, P = 0.120 and F = 1.9245, P = 0.070, respectively), but we preferred to keep male and female specimens pooled for the remaining analyses due to relatively low sample sizes.

The CVA performed on the four body measurements (Fig. 5) showed that most of the variability was recovered on axis 1, representing 70.5 % of the total variability (Appendices 4; 5). The highest loadings on axis 1 were HB, HF, E. Axis 2 represented 26% of the variability and the highest loading was TL (Appendix 4). The CVA on external measurements allowed discrimination of *C. muricauda* and *S. megalura* from all other species along the second axis with regards to their long tail length (Fig. 5). *Crociodura douceti* was also partially differentiated along axis 2. Along axis 1 we observed an opposition between the smallest species (negative side of the axis) *C. obscurior*, *C. eburnea*, *C. douceti* and the largest (positive side) *C. nimbasilvanus*, relatively well differentiated. Medium-sized species like *C. juvenetae*, *C. theresae*, *C. buettikoferi*, *C. nimbae* were situated in the centre of axis 1. *Crociodura olivieri* and *C. grandiceps* were two large-sized species, the former being larger than the latter.

TABLE 5. — Means ± standard deviations of standard external measurements for each collected shrew species from Mount Nimba only. Species are ordered by increasing weight.

Species	Weight (g)	HB (mm)	TL (mm)	HF (mm)	TL/HB
<i>C. obscurior</i> Heim de Balsac, 1958	3.8 ± 0.6	56.0 ± 4.5	33.7 ± 2.5	9.3 ± 0.9	0.61 ± 0.08
<i>C. eburnea</i> Heim de Balsac, 1958	3.9 ± 0.9	63.62 ± 4.5	36.15 ± 3.4	9.94 ± 0.4	0.57 ± 0.07
<i>C. douceti</i> Heim de Balsac, 1958	4	103	57	11	0.55
<i>C. muricauda</i> (Miller, 1900)	5.0 ± 0.5-6	63.5 ± 5	83.1 ± 18.3	11.8 ± 0.7	1.31 ± 0.3
<i>S. megalura</i> (Jentink, 1888)	6.5 ± 1.6	68.8 ± 5.3	80.3 ± 7.4	14.3 ± 0.9	1.17 ± 0.10
<i>C. juvenetae</i> Heim de Balsac, 1958	6.6 ± 1.3	70.3 ± 5.9	48.3 ± 3.7	11.4 ± 1.3	0.69 ± 0.06
<i>C. theresae</i> Heim de Balsac, 1968	12.3 ± 2.4	85.1 ± 6.5	52.3 ± 4.1	13.9 ± 1.2	0.62 ± 0.07
<i>C. buettikoferi</i> Jentink, 1888	14.4 ± 3.2	91.0 ± 8.1	59.0 ± 4.2	15.3 ± 0.7	0.65 ± 0.06
<i>C. grandiceps</i> Hutterer, 1983	18.7 ± 6.1	103.3 ± 9.1	74.1 ± 11.0	18.8 ± 2.3	0.72 ± 0.11
<i>C. olivieri</i> (Lesson, 1827)	27.2 ± 5.6	119.6 ± 8.0	76.8 ± 5.8	19.3 ± 1.4	0.65 ± 0.06
<i>C. nimbasilvanus</i> Hutterer, 2003	48.5 ± 51	137 - 148	117 - 120	25 - 25	0.81 - 0.85

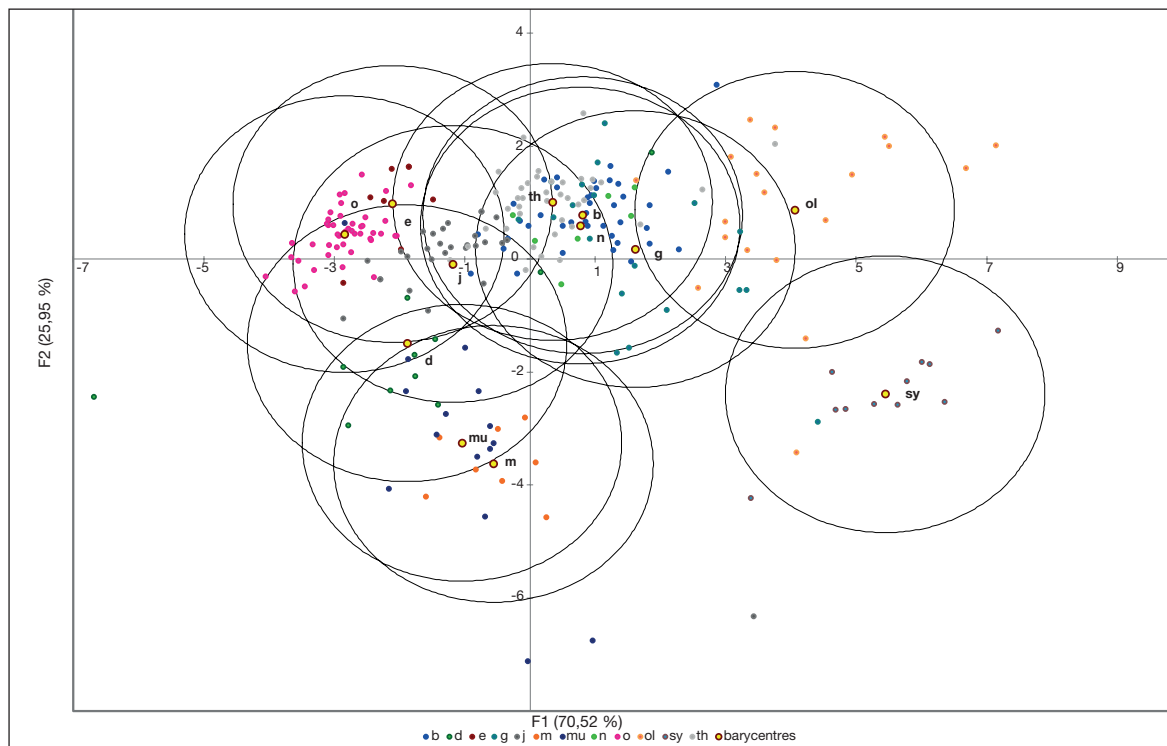


FIG. 5. — Plot between the two first axes of the CVA performed upon four external body measurements (head and body, tail, hindfoot, and tail lengths) for 252 shrew specimens from Mount Nimba, Ziama and surrounding areas. Each species is represented by a color dot. **Yellow dots** indicate class barycenter and ellipses at 0.05% confidence; **b**, *C. buettikoferi* Jentink, 1888; **d**, *C. douceti* Heim de Balsac, 1958; **e**, *C. eburnea* Heim de Balsac, 1958; **g**, *C. grandiceps* Hutterer, 1983; **j**, *C. juvenetae* Heim de Balsac, 1958; **m**, *S. megalura* (Jentink, 1888); **mu**, *S. megalura* (Jentink, 1888); **n**, *C. nimbae* Heim de Balsac, 1956; **o**, *C. obscurior* Heim de Balsac, 1958; **ol**, *C. olivieri* (Lesson, 1827); **sy**, *C. nimbasilvanus* Hutterer, 2003; **t**, *C. theresae* Heim de Balsac, 1968.

Calculation of means and standard deviations for external body measurements (Table 5) also showed that most values did not overlap between species, which appeared to be size calibrated when considering only the Mount Nimba specimens. A continuum from the smallest to the largest species was observed, each being replaced in turn by another slightly larger species. The smallest species were *C. obscurior*, *C. eburnea* and *C. douceti* that were followed by five slightly larger species *C. juvenetae*, *C. muricauda*, *S. megalura*, *C. theresae* and *C. buettikoferi*. Next were *C. grandiceps*, *C. olivieri* and *C. nimbasilvanus*, which were the largest species. *Crociodura muricauda* and *S. megalura* are further differentiated from all other species by their long tails, where tail to head-body ratio is greater than 1.0 (Table 5).

The plot between the two first axes of the CVAs and on the 11 cranio-dental measurements (Fig. 5) allowed good discrimination between the 11 species of our data set (Fig. 6, Appendices 6; 7). Most of the variability was recovered on axis 1 (86.5%). All variables were highly correlated with this axis, indicating a size relationship (Appendix 6). On axis 2 (5.5%), the best correlated variables were nasal width (b), occipital height (h) and molar height (g). *Crociodura nimbae* could be distinguished from all other species on this. The three smallest shrews (*C. obscurior*, *C. eburnea*, and *C. douceti*) can be distinguished on the negative side of axis 1, with the mean-sized species *C. megalura* + *C. muricauda* + *C. juvenetae*, followed by the medium-large species *C. theresae* + *C. grandiceps* + *C. buettikoferi* and finally



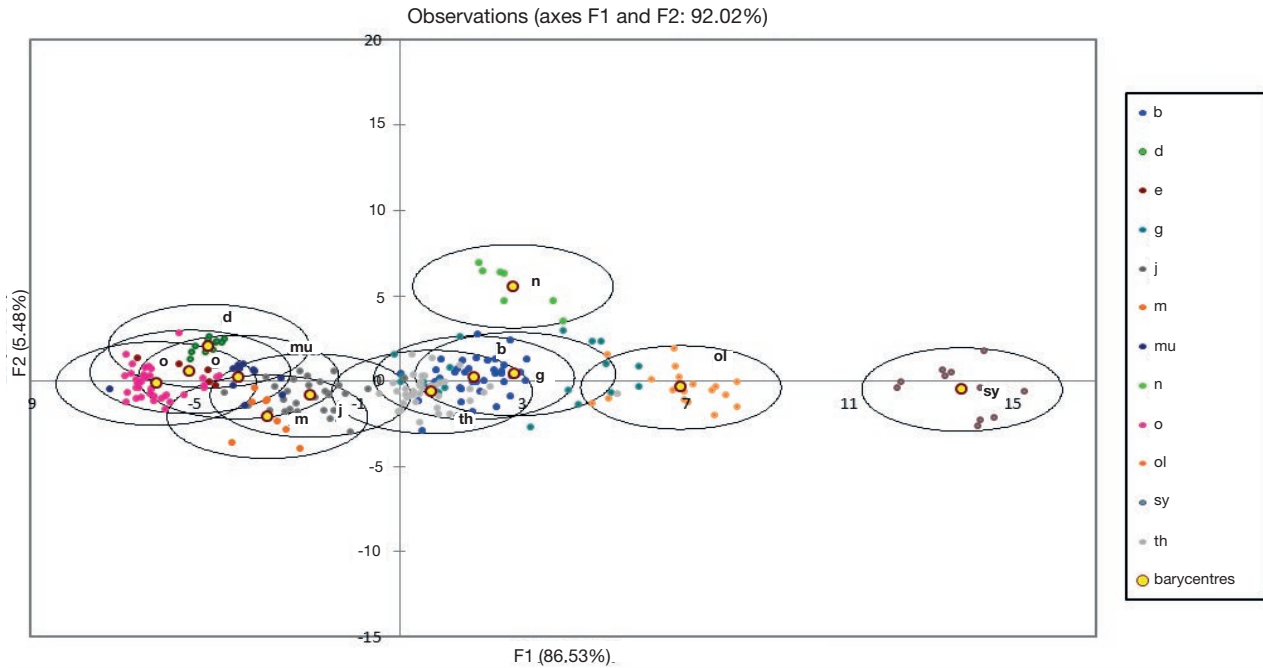


FIG. 6. — Plot between the two first axes of the CVA performed upon 11 craniodental measurements for 244 shrew specimens from Mount Nimba, Ziama and surroundings. Each species is represented by a color dot. In yellow class barycenter and ellipses at 0.05% confidence: **b**, *Crocidura buettikoferi* Jentink, 1888; **d**, *C. douceti* Heim de Balsac, 1958; **e**, *C. eburnea* Heim de Balsac, 1958; **g**, *C. grandiceps* Hutterer, 1983; **j**, *C. juvenetae* Heim de Balsac, 1958, *C. muricauda* (Miller, 1900); **mu**, *S. megalura* (Jentink, 1888); **n**, *C. nimbae* Heim de Balsac, 1956, **o**, *C. obscurior* Heim de Balsac, 1958; **ol**, *C. olivieri* (Lesson, 1827); **sy**, *C. nimbasilvanus* Hutterer, 2003; **t**, *C. theresae* Heim de Balsac, 1968.

TABLE 6. — Means and standard deviations for craniodental measurements on sequenced specimens from Mount Nimba based on newly recovered specimens. All measurements in millimeters. All measurements by CD. Abbreviations for measurements see Figure 2. For authorships of the species, see Table 5.

Species	a	b	c	d	e	f	g	h	i	j	k
<i>C. obscurior</i>	15.7 ± 0.7	1.9 ± 0.2	3.8 ± 0.2	7 ± 0.4	4.7 ± 0.2	6.8 ± 0.3	3.3 ± 0.2	4.2 ± 0.3	9.7 ± 0.5	6.3 ± 0.4	4.1 ± 0.4
<i>C. eburnea</i>	16.4 ± 1.1	2.0 ± 0.3	3.8 ± 0.2	7.2 ± 0.5	5 ± 0.4	7.6 ± 0.4	3.4 ± 0.1	4.9	10.4 ± 0.4	6.9 ± 0.4	4.4 ± 0.8
<i>C. douceti</i>	17.2	2	3.72	7.5	4.8	7.55	3.7	4.8	10.9	6.9	4.2
<i>C. muricauda</i>	18.5 ± 1.3	2.1 ± 0.2	3.8 ± 0.4	7.7 ± 0.6	5.2 ± 0.4	7.8 ± 0.6	3.9 ± 0.5	5.1 ± 0.8	11 ± 0.8	7 ± 0.6	4.5 ± 0.4
<i>S. megalura</i>	18.7 ± 0.3	2.3 ± 0.2	4.4 ± 0.2	7.9 ± 0.2	5.6 ± 0.2	7.9 ± 0.3	4.3 ± 0.2	5.3 ± 0.3	11.3 ± 0.5	7.2 ± 0.3	5.4 ± 0.3
<i>C. juvenetae</i>	20 ± 1.1	2.4 ± 0.2	4.2 ± 0.3	8 ± 0.6	6.1 ± 0.4	8.8 ± 0.6	4.1 ± 0.4	4.7 ± 0.4	12.6 ± 0.8	8.2 ± 0.5	5.6 ± 0.7
<i>C. theresae</i>	22.5 ± 0.5	2.6 ± 0.3	5.0 ± 0.2	9.3 ± 0.4	7 ± 0.3	9.9 ± 0.3	5.0 ± 0.4	5.9 ± 0.4	14.2 ± 0.4	9.1 ± 0.3	6.2 ± 0.5
<i>C. buettikoferi</i>	24 ± 0.8	2.7 ± 0.2	5.4 ± 0.4	9.8 ± 0.6	7.3 ± 0.3	10.6 ± 0.3	4.9 ± 0.3	6.2 ± 0.5	15.6 ± 0.6	9.9 ± 0.4	7 ± 0.5
<i>C. grandiceps</i>	26.7 ± 2	2.9 ± 0.3	5.6 ± 0.4	10. ± 0.9	7.9 ± 0.8	12.1 ± 1.3	5.8 ± 0.8	6.5 ± 0.7	17.2 ± 1.7	10.4 ± 1.7	7.8 ± 1.7
<i>C. olivieri</i>	29.9 ± 1.0	3.4 ± 0.4	5.7 ± 0.2	11.3 ± 0.4	9.1 ± 0.4	13.6 ± 0.4	6.2 ± 0.5	7 ± 0.4	19.6 ± 0.7	12.4 ± 0.3	8.6 ± 0.6
<i>C. nimbasilvanus</i>	36.8 ± 0.7	4.3 ± 0.6	7.8 ± 0.5	13.6 ± 0.7	11.6 ± 0.7	17.4 ± 0.01	8.3 ± 0.7	8.1 ± 1.4	24.9 ± 0.9	15.4 ± 0.7	10.1 ± 0.5

on the opposite positive side, the two largest species, *C. olivieri* and *C. nimbasilvanus*. We obtained a total of 83.6% of correctly classified specimens with the highest scores (100%) for three species *C. olivieri*, *C. nimbae* and *C. nimbasilvanus*. The worst scores were obtained for *C. grandiceps* (52.6%) and *C. eburnea* (40%) for which some specimens were incorrectly classified and regrouped by the analysis inside *C. theresae*, *C. buettikoferi* and *C. obscurior* variability ranges (Appendix 7).

The same observations about size classes were made for craniodental measurements for only those species present at Mount Nimba (Table 6) with *C. obscurior* being the smallest shrew and *C. nimbasilvanus* the largest. *Crocidura nimbae*, which was not captured during this study, is a relatively large shrew with skull proportions close to other medium- to large-sized species such as *C. grandiceps*, *C. buettikoferi* and *C. theresae* (Appendices 4, 5).

#### Identification key

The identification key, based mostly on visual and microscope morphology plus external measurements, was tested by one of us (FJ) based on Guinean and Liberian specimens from Mount Nimba and type specimens housed in MNHN. In order to facilitate identifications in the field we used for each step one external qualitative or quantitative character. Qualitative characters were indicated in Heim de Balsac's (1956, 1958) descriptions and through our observations. Quantitative characters are provided in Tables 5, 6. For *C. eburnea* and *C. obscurior* we were unable to find any external characters that allowed us to differentiate them, which resulted in our decision to pool these two species in the dichotomous key presented below.

IDENTIFICATION KEY FOR SHREW SPECIES PRESENT AT MOUNT NIMBA  
(abbreviations see Material and methods)

1. Tail skin naked and ringed; four pairs of maxillary unicuspid ..... *S. megalura* (Jentink, 1888)
- Tail skin hairy or non ringed, three pairs of maxillary unicuspid ..... 2
  
2. Ratio TL/HB > 1 ..... *C. muricauda* (Miller, 1900)
- Ratio TL/HB < 1 ..... 3
  
3. HB < 70 mm ..... 4
- HB > 110 mm ..... 5
- HB between 70 and 110 mm ..... 6
  
4. Ratio TL/HB < 0.8 ..... *C. obscurior/eburnea* Heim de Balsac, 1958
- Ratio TL/HB between 0.8 and 1 ..... *C. douceti* Heim de Balsac, 1958
  
5. HB > 130 mm ..... *C. nimbasilvanus* Hutterer, 2003
- HB between 110-130 mm, brownish, black hairs ..... *C. olivieri* (Lesson, 1827)
  
6. HF > 17 mm ..... *C. grandiceps* Hutterer, 1983
- HF < 17 mm ..... 7
  
7. Proportion of tail covered by vibrissae > 50%; fur color brown ..... 8
- Proportion of tail covered by vibrissae < 50%; fur color black ..... *C. buettikoferi* Jentink, 1888
  
8. End of tail with visible skin, spare hairs ..... *C. theresae* Heim de Balsac, 1968
- Hair covering at end of tail ..... 9
  
9. HF > 14 mm ..... *C. nimbae* Heim de Balsac, 1956
- HF < 14 mm ..... *C. juvenetae* Heim de Balsac, 1958

## DISCUSSION

### SHREW DIVERSITY, HABITAT ASSOCIATIONS AND CONSERVATION ISSUES

During our extensive surveys we were able to capture all shrew species previously recorded from Mount Nimba and surrounding areas (Heim de Balsac 1958, 1974; Coe 1975; Verschuren & Meester 1977; Churchfield *et al.* 2004; Nicolas *et al.* 2009), except for *C. nimbae*. On the Liberian side of Mount Nimba, Coe (1975) collected only two species: *C. occidentalis* (Pucheran, 1855) – now named *C. olivieri* and *C. poensis* (Fraser, 1843) (now named *C. buettikoferi*). Despite extensive tracts of rainforest remaining at Mount Nimba (Monadjem *et al.* 2016), and despite our relatively high sampling effort, we were still unable to capture *C. nimbae*, suggesting either that it is very rare, or that it selects a very specific habitat that we did not sample as already suggested by Heim de Balsac (1958) in his original description. *Crocidura nimbae* was recently trapped by Nicolas *et al.* (2009) in Ziama forest, where it represented only 0.4% of the captures. More recently, it has again been recorded from Ziama, by a single specimen (Mamba *et al.* 2021). These two studies confirm the rarity of *C. nimbae*.

We confirm here for the first time that *C. eburnea* occurs on the Liberian side of Mount Nimba and that it is sympatric with *C. obscurior* in that region. Its absence on the Guinean side of Mount Nimba (Jacquet *et al.* 2014) and more generally in western parts of Eastern Guinea, despite extensive sampling, needs to be verified by further studies, but may be related to the relatively drier conditions there.

Of the shrews that occur at Mount Nimba, three species are currently classified as “Near Threatened”: *Crocidura buettikoferi*, *C. grandiceps* (13.7 and 7.1% of all captures, respectively) and *C. nimbae* (no captures during our study). We captured a single specimen of the rare *C. douceti*, whose conservation status is currently “Least Concern” (IUCN, 2019). This species has been rarely captured since its original description in 1984. In Ziama forest Nicolas *et al.* (2009) reported a low relative abundance at 5.9%, and Mamba *et al.* (2021) recorded a single individual from Wologizi forest in Liberia. Based on these observations, we suggest that the conservation status of this species be re-appraised. To date, there is no IUCN assessment for the two most recently recognised species, *C. eburnea* and *C. nimbasilvanus*. We captured two specimens of *C. nimbasilvanus* and 12 specimens of *C. eburnea*.

The 12 species of shrews currently known at Mount Nimba may be an underestimate because the high genetic divergence between the two lineages of *C. muricauda* (Jacquet *et al.* 2012) may represent cryptic species and requires further investigation.

When compared with the shrew diversity of the Upper Guinea rainforest zone, which harbours 16 species (Burgin & He 2018) we did not record the following species in our study: *C. nimbae*, *C. crossei*, *C. lamottei*, *C. nigeriae* and *C. wimmeri*. *Crocidura nimbae* was recovered in S Sierra Leone, N Liberia and SW Côte d’Ivoire in Taï National Park (Churchfield *et al.* 2004, Hutterer 2005) and Dodo-Cavally forest reserve (Decher *et al.* 2005) as well as in Ziama forest (Nicolas *et al.* 2009, Mamba *et al.* 2021) and in Mount Nimba in Zougépo (Heim de Balsac 1958). It is not clear whether *C. crossei* is present in West Africa because formerly it was treated as conspecific

with *C. jowenetae*, which is now considered as a distinct valid species. *Crocidura lamottei* was described from Lamto (Côte d'Ivoire) and does not occur in forested environments. *Crocidura wimmeri* is classified as Critically Endangered and was collected only in Adiopodoume and Banco National Park near Abidjan (Côte d'Ivoire) in a secondary forest (Kadjo *et al.* 2013, Vogel *et al.* 2014). *Crocidura nigeriae*, described from Nigeria, is supposed to be also present in SE Côte d'Ivoire and NE Ghana (Burgin & He 2019) but a recent phylogenetic study concluded that West African specimens attributed to this species should be renamed (Nicolas *et al.* 2009, 2020). According to Heim de Balsac (1971) *C. denti* could be present on Mount Loma (Sierra Leone) but these specimens most probably represent misidentifications (Dambry *et al.* 2016).

The species associations we report here are like those previously published, even though their abundances vary. The three forest-dwelling species *C. obscurior* (excluding *C. eburnea*), *C. jowenetae* and *C. buettikoferi* were also trapped in the high-elevation savannah (at 1600 m asl) during both wet and dry seasons. Furthermore, our study revealed that most species from Mount Nimba live in syntopy, sharing the same habitat. The lowland primary and secondary forests at 600 m asl harboured 11 shrew species representing two genera (Table 7). This species richness is similar to that reported in other West African (Churchfield *et al.* 2004; Nicolas *et al.* 2009; Mamba *et al.* 2021) and Central African (Brosset 1988; Nicolas *et al.* 2005) rainforests. Nevertheless, some more species rich communities have been recorded in the rainforests of the Central African Republic. For example, Ray & Hutterer (1996) found four genera and 16 species in Kongana, Barrière & Nicolas (2000) reported five genera and 18 species in Ngotto forest, and Barrière *et al.* (2005) reported two genera and 14 species in the north of the country. Similarly, Van de Perre *et al.* (2019) reported 22 species of shrews in the Kisangani area of the Democratic Republic of Congo, of which four were without a scientific name.

We could compare these species abundance data to those of other surveys led in Tai forest (Churchfield *et al.* 2004), in Haute Dodo and Cavally forests (Decher *et al.* 2005) and in Zياما forest (Nicolas *et al.* 2009; Mamba *et al.* 2021) (Fig. 6). In Taï and Zياما forests, *C. obscurior* + *C. eburnea*, *C. jowenetae* and *C. buettikoferi* were abundant, while *C. douceti*, *C. nimbae* and *C. nimbasilvanus* were rare. All were typical forest-dwelling species and were trapped in gallery or secondary forests on Mount Nimba. The relative abundance of the species *C. olivieri*, *C. grandiceps* and *S. megalura* are higher in Mount Nimba than in other studies (Fig. 7). *Crocidura obscurior* + *C. eburnea*, *C. muricauda* dominate in Taï and in Zياما. In Dodo/Cavally it is *C. obscurior* + *eburnea*, *C. jowenetae* and *C. theresae* that dominate the community. *Crocidura theresae* has been recorded from Guinean savannahs, mixed forest and savannah areas and rice fields (Verschuren & Meester 1977; Hutterer 2005; Wilson & Mittermeier 2018), while *C. olivieri* and *S. megalura* were encountered in a wide variety of forest and savannah habitats (Hutterer 2005). *Crocidura grandiceps* is associated with primary rain forests (Hutterer 1983; Grubb *et al.* 1998), but has also been recorded from small scattered

forest fragments surrounded by savannahs in Ghana (Hutterer 2005), and in our study a single individual was trapped in a house. Several authors have reported a synanthropic behavior of *C. olivieri* (Heim de Balsac 1968, 1974; Heim de Balsac & Barloy 1966; Verschuren & Meester 1977, Nicolas *et al.* 2020), but we did not trap this species in houses. *Crocidura eburnea* is found in lowland forests up to 600 m. We did not capture it in montane forest or in high-elevation savannah, which is in contrast to *C. obscurior* that was found at all elevations and in all vegetation types. The peculiar composition of the shrew community at Mount Nimba compared with other West African forests can be explained by the geographic location of this mountain at the ecotone zone between rain-forest and Guinean woodland. Mount Nimba thus harbours a mixed shrew community composed of both savannah and forest-dwelling taxa.

*Crocidura muricauda* is less abundant on Mount Nimba (5.3 % of all captures) than in Zياما and Tai National Parks forests (respectively 19.35 & 21.5 %) (Fig. 7). Heim de Balsac (1958) had already noticed the scarcity of this forest-dwelling species on Mount Nimba (four specimens out of more than 100 shrew specimens). Nicolas *et al.* (2009) observed that in Zياما *C. muricauda* is a typical forest species: it was much more abundant at sites with high understorey density, high canopy height and cover, and high density of stems and trees, than in logged or agricultural landscapes. Both lowland and montane forests in the Nimba Mountains are of variable states of integrity, ranging from relatively intact to highly degraded by anthropogenic activities (seasonal fires across the entire range, mining in two localised areas, and logging and clearance for agriculture in the lowlands). This may explain the relative rarity of *C. muricauda* on Mount Nimba. None of the forest-dwelling shrew species on Mount Nimba appeared to be restricted to primary habitat. These results are congruent with those of the long-term study of Nicolas *et al.* (2009) in Zياما Man Biosphere Reserve forest who demonstrated that shrew communities were not significantly affected by agricultural activities and that their diversity was similar in primary and secondary forests.

At Mount Nimba, the shrew community in montane forest (1000-1350 m asl) was not different from that in lowland forest except in terms of diversity with seven species instead of 11; demonstrating that the shrew community in montane forest may be a subset of that in lowland forest (Table 7). However, for logistics reasons our trapping efforts concentrated mostly on lowland forest (6750 Trap nights) compared to montane forest (2573 trap nights). The edaphic savannah (from 1200 to 1600 m asl), which is peculiar to the Guinean side of Mount Nimba, harboured five species, *C. obscurior*, *C. jowenetae*, *C. theresae*, *C. buettikoferi* and *S. megalurus*. Only two species, *C. obscurior* and *C. theresae*, were recorded from this habitat by Heim de Balsac (1958), Verschuren & Meester (1977) and Lamotte & Roy (2003). *Crocidura theresae* was found in grassland savannahs, bush between 600 and 1600 m by Verschuren & Meester (1977). The altitude savannah biotope does not seem to promote isolation for shrews, as no endemic taxon was identified, suggesting that this vegetation



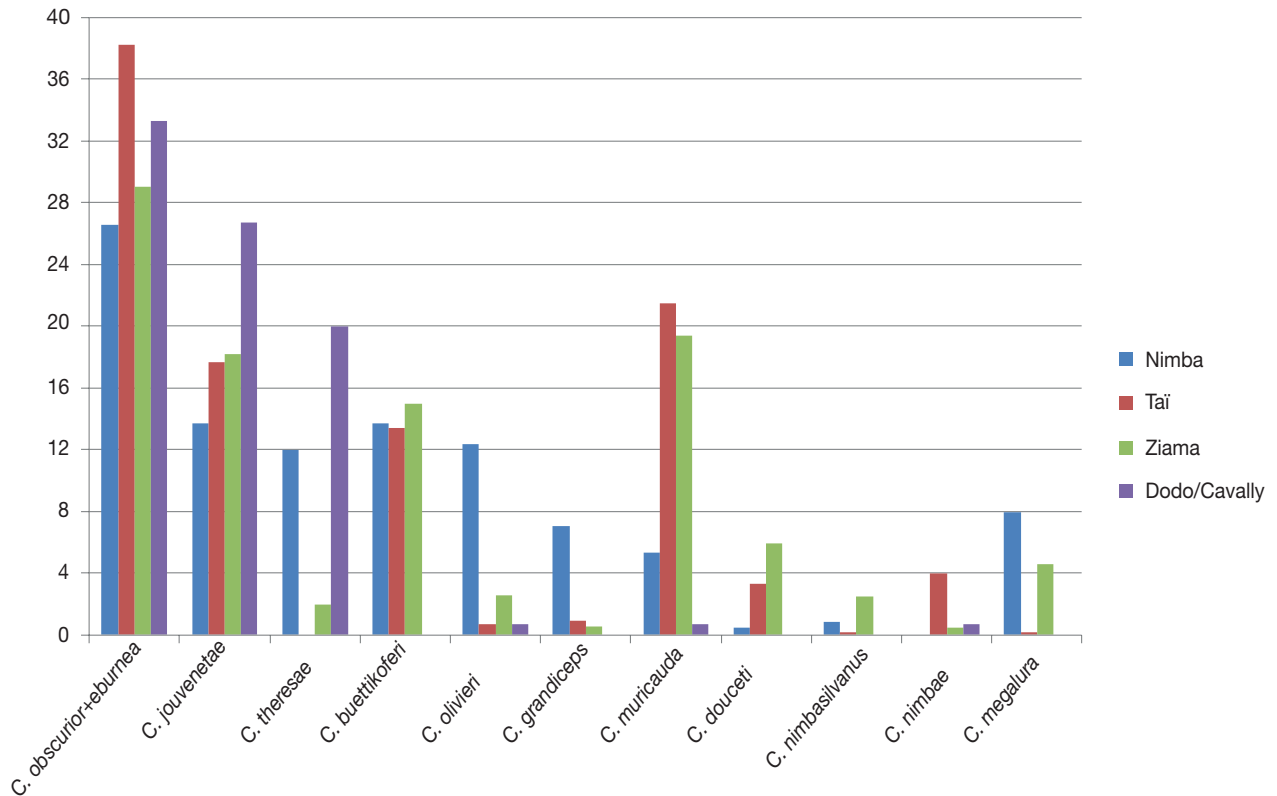


FIG. 7. — Comparison of the relative abundance (%) on y axis) of shrew species between four different surveys. Nimba this work (N = 226), Taï: Churchfield *et al.* (2004) (N = 553), Zياما: Nicolas *et al.* (2009) (N = 2571), Dodo-Haut Cavally: Decher *et al.* (2005) (N = 15). For authorships of the species, see Table 5.

is relatively recent in origin. Our results suggest that shrews demonstrate habitat plasticity at Mount Nimba, as suggested by Verschuren & Meester (1977). Some species like *C. eburnea* and *C. douceti* or *C. nimbasilvanus* were found only in lowland forests. They all corresponded to species trapped in low abundance despite relatively intense trapping on the Guinean side of the Mount in this environment. *Crocidura douceti* is known in relict and gallery forest as well as anthropogenic environments in Taï National Park (Churchfield *et al.* 2004) but was considered as a forest shrew of low density by Heim de Balsac (1958). The holotype of *C. eburnea* comes from Mt Tonkouï situated at 1200 m asl, which could indicate that the species is also living in montane forest of Nimba range region. *Crocidura nimbasilvanus* is more common in closed environments according to Nicolas *et al.* (2009) but was captured in low abundance in Zياما forests. According to Burgin & He (2018), *C. nimbae* is found in submontane and lowland forest but was known by a few specimens in Zougoupo Nimba lowland forest (Heim de Balsac 1958).

#### CYTOGENETIC CHARACTERIZATION OF MOUNT NIMBA SHREWS

Cytogenetic analyses in mammals showed that there is extensive karyotypic diversity among extant species and that many closely related species or even populations possess different karyotypes indicating that chromosomal differentiation often occurs during, or shortly after cladogenesis (Dobigny *et al.*

2017). Thus, descriptions of mammalian karyotypes serve an important role for characterizing chromosomal rearrangements, which provide information on genetic barriers to gene flow and ultimately on the processes involved in speciation. In this paper we provide cytogenetic data for five of the 11 captured species. For each species several individuals were studied in order to test for intraspecific variability but a remarkable result of this study is that karyotypes of all species are stable. In the following paragraphs we compare our data with previously published data from the same or closely related species.

The standard karyotype of *C. buettikoferi* is characterized by  $2n = 52$  and  $NFa = 66$ . Our results are in good agreement with the report of Meylan (1971) and Meylan & Vogel (1982) from Côte d'Ivoire (as *C. poensis pamela* Dollman, 1915). The authors identified 17 pairs of acrocentric decreasing in size, five pairs of subtelocentric and three pairs of small meta/submetacentric chromosomes. The X and Y chromosomes are a large-sized metacentric and a small acrocentric, respectively. It is important to note that *C. buettikoferi* from Mount Nimba has very small short arms at the 9<sup>th</sup> pair of autosomes, the same as *C. olivieri* (7<sup>th</sup>) and *C. theresae* (12<sup>th</sup>). With a significant chromosome contraction, those arms are barely noticeable. In addition, they are C-positive and vary in size, so we consider this pair of autosomes as acrocentric.

The karyotype of *C. grandiceps* is  $2n = 46$  and  $NFa = 64$ . This is in agreement with data previously published by Meylan & Vogel (1982) in Côte d'Ivoire, as *C. cf. nimbae*.

TABLE 7. — Elevational distribution of newly collected shrews of Mount Nimba.

Species	400-600 m Lowland primary and secondary forest	600 m Edaphic savannah	800-1400 m Mountain forest	1600 m Altitude savannah
<i>C. obscurior</i> Heim de Balsac, 1958				
<i>C. eburnea</i> Heim de Balsac, 1958				
<i>C. juvenetae</i> Heim de Balsac, 1958				
<i>C. theresae</i> Heim de Balsac, 1968				
<i>C. buettikoferi</i> Jentink, 1888				
<i>C. grandiceps</i> Hutterer, 1983				
<i>C. muricauda</i> (Miller, 1900)				
<i>C. douceti</i> Heim de Balsac, 1958				
<i>C. olivieri</i> (Lesson, 1827)				
<i>C. nimbasilvanus</i> Hutterer, 2003				
<i>S. megalura</i> (Jentink, 1888)				

Our specimens of *C. juvenetae* are characterized by  $2n = 44$  and  $NFa = 68$ . The first karyotype of *C. juvenetae* was described from Côte d'Ivoire by Meylan (1971) with  $2n = 44$  and  $NFa = 62$ . Variation in the short arms of several pairs of chromosomes can result from difficulties in categorizing chromosomes and homologous pairs, which can be considered as acrocentric or subtelocentric (see Fig. 2 in Meylan, 1971). The chromosome formula  $2n = 44$  and  $NFa = 62$  was described for *C. crossei* (*juvenetae*) *ebriensis* from Côte d'Ivoire (Meylan & Vogel 1982), but the taxonomic status of these specimens still needs to be assessed and they could be a synonym of *C. juvenetae* (Hutterer 2005). In the same work, Meylan & Vogel (1982) described the karyotype of *C. cf. planiceps* from Côte d'Ivoire, which also displayed  $2n = 44$ , but differed by  $NFa = 68$ . The five *C. juvenetae* investigated in our study display the same standard formula as *C. cf. planiceps*. According to Wilson & Mittermeier (2018) the species *C. planiceps* Heller, 1910 is known from Nigeria and Uganda. Thus the taxonomic status of the *C. cf. planiceps* specimens from Côte d'Ivoire needs to be re-evaluated. However, an integrative study combining morphological, molecular and cytogenetic data is now required to review the phylogeography and taxonomy of the species *C. juvenetae*.

Cytogenetic (Meylan 1967, 1971; de Hondt 1974; Meylan & Vogel 1982; Baskevitch *et al.* 1995; Lavrenchenko *et al.* 1997) and molecular studies (Quérouil *et al.* 2005; Dubey *et al.* 2007, 2008; Jacquet *et al.* 2015) have led to the unification of a high number of large-sized shrews under the name *C. olivieri* (Hutterer 2005; Burgin & He 2018). A summary of the various available karyotypic data for *C. olivieri* was presented by Schlitter *et al.* (1999). The first karyotype of *C. olivieri* was described by Meylan (1967) under the name *C. occidentalis kivu* Osgood, 1910 from Democratic Republic of Congo with  $2n = 50$  and  $NFa = 62$ . Later surveys from various parts of Africa revealed the same karyotype for all forms that are currently considered conspecific to *C. olivieri* (Meylan 1971 from Côte d'Ivoire; de Hondt, 1974 from Egypt; Meylan & Vogel 1982 from Mali, Cameroon, Nigeria and Burkina Faso; Baskevitch *et al.* 1995 from Ethiopia). The formula we describe here from Mount Nimba ( $2n = 50$ ,  $NFa = 60$ ) is in

agreement with these previous surveys. However, some differences exist in categorizing acrocentric/subtelocentric largest pair of autosomes. In the first studies, this pair is considered as acrocentric (Meylan 1967, 1971). In later papers, it is attributed to the subtelocentric (De Hondt 1974; Meylan & Vogel 1982; Maddalena *et al.* 1987; Lavrenchenko *et al.* 1997; Schlitter *et al.* 1999). In our study we adhere to the terms of Meylan (1967, 1971). We consider this pair of autosomes as acrocentric because its very small short arms are C-positive and can vary in size, while the short arms of the other two pairs of subtelocentrics are C-negative and dimensionally stable (Aniskin, unpubl. data).

The diploid number of *C. theresae* from Mount Nimba is the same as *C. olivieri* ( $2n = 50$ ), but the karyotype differs by the fundamental number of autosomes ( $NFa$ ). In our study the karyotype of *C. theresae* comprises 11 pairs of bi-armed autosomes and 13 acrocentric pairs, with  $NFa = 70$ . Our results show some differences with the karyotype of *C. theresae* from Côte d'Ivoire by Meylan (1971), who identified 15 pairs bi-armed autosomes and nine acrocentric pairs, with  $NFa = 78$ . Additional analyses combining morphological, molecular and cytogenetic data is now required to review the phylogeography and taxonomy of this species.

#### MORPHOMETRIC CHARACTERISTICS OF SHREWS FROM MOUNT NIMBA

Some species could not readily be discriminated with certainty based on morphometric analyses. This is particularly the case for *C. eburnea* and *C. obscurior* for which external and craniodental measurements overlapped significantly (Tables 5, 6), demonstrating their status as sibling species. The two holotypes have distinct sizes (Appendix 3), with *C. eburnea* slightly smaller, but this difference disappears when additional specimens are included in the analysis. In the original description, Heim de Balsac (1958) highlighted some dental differences between these taxa like a more developed P3 and paracone of P4. These characters were not validated as diagnostic by Jacquet *et al.* (2014), who instead demonstrated that both species are small sized ones (body length 50-65 mm) with a uniform dark pigmentation of the skin and the fur (Jacquet *et al.* 2014).

The morphometric analyses based on weight, external and craniodental measurements show that sympatric shrew species from Mount Nimba can be classified along a size gradient from the tiny *C. obscurior*-*C. eburnea* to the giant *C. nimbasilvanus*. This is congruent with the size range theory of Brosset (1988), who demonstrated that within a shrew community composed of 11 species from Makokou forest (Gabon), each species was replaced by another along a size gradient. All species were syntopic and showed the same activity periods. This suggests that species-rich shrew communities in African rain forests partition resources in this way, decreasing interspecific competition and allowing coexistence of multiple species (Hutterer *et al.* 1987; Brosset 1988; Churchfield *et al.* 1999; Goodman *et al.* 2001).

The morphometric analyses also reveal an important intraspecific uniformity for most species. External measures are thus often used to define diagnostic characters and to build identification keys (Hutterer & Happold 1983) (Appendices 4; 5). A notable exception is found between the smallest species *C. eburnea* and *C. obscurior* which are impossible to separate by external size characters (Jacquet *et al.* 2014).

#### MORPHOLOGICAL IDENTIFICATION KEY

We developed an identification key based as much as possible, on both body measurements (head & body, tail and hindfoot lengths, tail / head + body length ratio) and external characters (fur and skin color, tail hairiness, quantity and length of tail vibrissae). The same characters were used by Hutterer & Happold (1983) to build a key for Nigerian shrews. Our key needs to be tested in the future on other west African sites and be amended by the missing taxa once they have been well described using an integrative taxonomic approach *sensu* Taylor *et al.* (2019).

#### CONCLUSION

Our surveys on the Guinean and Liberian slopes of Mount Nimba has allowed us to better understand the biodiversity and ecological requirements of shrews at this unique mountain. We collected 11 species of shrews in total, which confirmed the high diversity of shrews on Mount Nimba, especially in lowland forests (11 species) compared to the edaphic savannah from 1200 to 1600 m (five species). Only three species known in the western parts of the Upper Guinea rainforest zone were not captured in our study: *C. nimbae*, *C. wimmeri* and *C. lamottei*. The shrew community at Mount Nimba combines a mixture of both savannah (*Crocidura theresae*, *C. olivieri*, *S. megalurus*) and forest-dwelling species (*C. buetikoferi*, *C. obscurior*, *C. eburnea*, *C. jowenetae* and *C. nimbasilvanus*). This highlights the importance of Mount Nimba for the conservation of shrews, as has been demonstrated for bats (Monadjem *et al.* 2016). We also described for the first time karyological data of shrews from Mount Nimba. Our results were congruent with previous data, except for *C. theresae*, for which differences with a karyotype described from Côte d'Ivoire were highlighted, maybe owing to cryptic vari-

ability. Morphometric analyses based on external body and craniodental measurements revealed that shrew species from Mount Nimba can be classified along an increasing size gradient, congruently with the size range theory of Brosset (1988). Based on body measurements and external characters, we developed an identification key of shrews from Mount Nimba, which can be easily used in the field and on live animals.

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## APPENDICES

APPENDIX 1. — Shrew specimens from Guinean Mount Nimba collected and used in this study with MNHN collection and field numbers, habitat, sex, weight (g) and external body measurements (mm). Expedition number: 1, February-March 2008, 2, October 2008 and 3, December 2009-January 2010 (used for Table 5 and 6). Abbreviations: Alt. savannah, Altitude savannah and see Material and methods.

Collection number (MNHN-ZM-)	Field number	Species	Locality	Habitat	Altitude (m asl)	Mission		W	HB	TL	HF	E	Specimens used for morphometric analyses	
						number	Sex						Body measures	Skull distances
2012-1051	G221	<i>C. buettikoferi</i>	Gbié	Gallery forest	573	2	M	17	96	59	15	7	×	×
2012-1052	G227	<i>C. buettikoferi</i>	Gbié	Gallery forest	612	2	M	14	83	62	15	7	×	×
2012-1053	G241	<i>C. buettikoferi</i>	Gbié	Gallery forest	612	2	F	9	86	56	14	7	×	×
2012-1054	G248	<i>C. buettikoferi</i>	Gbié	Gallery forest	552	2	M	15	96	60	15	7	×	×
2012-1055	GBE90	<i>C. buettikoferi</i>	Gblayougouma	Secondary forest	477	3	M	14	91	60	17	8	×	—
2012-1056	N320	<i>C. buettikoferi</i>	Gouan	Gallery forest	1212	1	F	19	98	64	16	9	×	×
2012-1057	N323	<i>C. buettikoferi</i>	Gouan	Gallery forest	1212	1	M	19	78	57	17	9	×	×
2012-1058	NIMII01	<i>C. buettikoferi</i>	Gouan	Alt. savannah	1616	2	M	10	75	54	15	7	×	×
2012-1059	NIMII02	<i>C. buettikoferi</i>	Gouan	Alt. savannah	1616	2	F	10	77	57	15	7	×	—
2012-1060	NIMII07	<i>C. buettikoferi</i>	Gouan	Alt. savannah	1616	2	F	18	100	56	15	8	×	×
2012-1061	NIMII12	<i>C. buettikoferi</i>	Gouan	Alt. savannah	1616	2	F	10	82	56	15	8	×	×
2012-1062	NIMII17	<i>C. buettikoferi</i>	Gouan	Alt. savannah	1616	2	F	14	93	53	15	7	×	×
2012-1063	NIMII18	<i>C. buettikoferi</i>	Gouan	Alt. savannah	1616	2	F	12	90	64	15	7	×	×
2012-1064	NIMII20	<i>C. buettikoferi</i>	Gouan	Gallery forest	1206	2	F	15	101	60	16	8	×	×
2012-1065	NIMII21	<i>C. buettikoferi</i>	Gouan	Gallery forest	1206	2	F	16	99	62	15	7	×	×
2012-1066	NIMII59	<i>C. buettikoferi</i>	Gouan	Gallery forest	1176	2	M	15	98	68	16	8	×	×
2012-1067	NIMII72	<i>C. buettikoferi</i>	Gouan	Alt. savannah	1616	2	M	17	95	61	15	7	×	×
2012-1068	N71	<i>C. buettikoferi</i>	Serengbara	Secondary forest	600	1	F	13	86	52	15	7	×	×
2012-1069	SER160	<i>C. buettikoferi</i>	Serengbara	Secondary forest	589	2	M	18	96	58	15	8	×	×
2012-1070	SER184	<i>C. buettikoferi</i>	Serengbara	Secondary forest	589	2	F	10	86	55	15	7	×	×
2012-1071	SER185	<i>C. buettikoferi</i>	Serengbara	Secondary forest	589	2	M	14	98	57	16	8	×	×
2012-1072	N329	<i>C. buettikoferi</i>	Ziéla	Gallery forest	581	1	F	18	99	66	16	7	×	×
2012-1074	ZIE256	<i>C. buettikoferi</i>	Ziéla	Gallery forest	581	—	I	—	—	—	—	—	—	×
2012-1075	SER156	<i>C. douceti</i>	Serengbara	Secondary forest	589	2	I	—	—	—	—	—	—	×
2012-1076	G209	<i>C. grandiceps</i>	Gbié	Gallery forest	612	2	M	14	104	84	20	9	×	×
2012-1077	G220	<i>C. grandiceps</i>	Gbié	Gallery forest	573	2	M	12	92	53	15	7	×	×
2012-1078	N172	<i>C. grandiceps</i>	Gbié	Gallery forest	608	1	F	13	95	56	14	7	×	×
—	N191	<i>C. grandiceps</i>	Gbié	Savannah	649	1	F	12	106	72	19	8	×	—
2012-1079	N217	<i>C. grandiceps</i>	Gouan	Gallery forest	1212	1	M	30	102	73	21	11	×	×
2012-1080	N266	<i>C. grandiceps</i>	Gouan	Gallery forest	1212	1	F	16.5	96	85	18	8	×	×
2012-1081	N305	<i>C. grandiceps</i>	Gouan	Gallery forest	1212	1	M	23	95	85	19	8	×	×
2012-1082	NIMII63	<i>C. grandiceps</i>	Gouan	Gallery forest	1206	2	F	23	99	77	20	9	×	×
2012-1083	ZIE10	<i>C. grandiceps</i>	Ziéla	Secondary forest	477	3	F	16	117	80	20	10	×	—
2012-1084	ZIE40	<i>C. grandiceps</i>	Ziéla	Secondary forest	477	3	M	25	118	114	21	11	×	—
2012-1085	ZIE41	<i>C. grandiceps</i>	Ziéla	Secondary forest	477	3	F	21	112	70	20	11	×	—
2012-1086	G212	<i>C. juvenetae</i>	Gbié	Gallery forest	552	2	F	9	79	53	10	7	×	×
2012-1087	G214	<i>C. juvenetae</i>	Gbié	Gallery forest	552	2	F	6	70	47	12	7	×	×
2012-1088	G218	<i>C. juvenetae</i>	Gbié	Gallery forest	552	2	F	6	71	46	11	6	×	×
2012-1089	G224	<i>C. juvenetae</i>	Gbié	Gallery forest	612	2	F	5	70	49	12	7	×	×
2012-1090	G226	<i>C. juvenetae</i>	Gbié	Gallery forest	612	2	M	8	76	51	10	7	×	×
2012-1091	G229	<i>C. juvenetae</i>	Gbié	Gallery forest	552	2	M	8	75	49	10	7	×	×
2012-1092	G232	<i>C. juvenetae</i>	Gbié	Gallery forest	552	2	F	5	69	44	10	6	×	×
2012-1093	N177	<i>C. juvenetae</i>	Gbié	Savannah	649	1	M	8	74	50	13	7	×	×
2012-1094	N178	<i>C. juvenetae</i>	Gbié	Savannah	649	1	F	7	80	49	12	8	×	×
2012-1095	N267	<i>C. juvenetae</i>	Gouan	Gallery forest	1212	1	M	6.5	73	46	12	7	×	×
2012-1096	N280	<i>C. juvenetae</i>	Gouan	Alt. savannah	1642	1	F	5	61	46	10	6	×	×
2012-1097	NIMII29	<i>C. juvenetae</i>	Gouan	Gallery forest	1176	2	F	7	69	48	8	6	×	×
2012-1098	N288	<i>C. juvenetae</i>	Gouan	Alt. savannah	1642	1	I	—	—	—	—	—	—	×
2012-1099	N1	<i>C. juvenetae</i>	Serengbara	Secondary forest	589	1	M	—	75	56	12.5	9	×	×
2012-1100	N2	<i>C. juvenetae</i>	Serengbara	Secondary forest	589	1	M	6.5	56	48	12.5	7	×	×
2012-1101	N34	<i>C. juvenetae</i>	Serengbara	Secondary forest	589	1	M	7	68	56	13.5	7.5	×	×
2012-1102	N35	<i>C. juvenetae</i>	Serengbara	Secondary forest	589	1	F	4	60	40	12	8.5	×	×
2012-1103	N4	<i>C. juvenetae</i>	Serengbara	Secondary forest	589	1	M	5.5	65	49	12.5	9	×	×
—	N322	<i>C. juvenetae</i>	Gouan	Gallery forest	1212	1	F	7	70	47	12	7	×	—
2012-1104	SER150	<i>C. juvenetae</i>	Serengbara	Secondary forest	589	2	M	8	67	46	12	7	×	×
2012-1105	SER151	<i>C. juvenetae</i>	Serengbara	Secondary forest	589	2	F	8	75	51	12	7	×	×
2012-1106	SER152	<i>C. juvenetae</i>	Serengbara	Secondary forest	589	2	F	6	73	45	11	7	×	×
2012-1107	SER155	<i>C. juvenetae</i>	Serengbara	Secondary forest	589	2	F	6	71	47	11	7	×	×
2012-1108	G205	<i>C. muricauda</i>	Gbié	Gallery forest	552	2	I	—	—	—	—	—	—	×
2012-1109	N156	<i>C. muricauda</i>	Gbié	Savannah	649	1	F	6	69	82	13	7	×	×
2012-1110	N228	<i>C. muricauda</i>	Gouan	Gallery forest	1212	1	F	5	61	73	11	7	×	×
2012-1111	N232	<i>C. muricauda</i>	Gouan	Gallery forest	1212	1	M	5.5	66	81	12	7	×	×

Appendix 1. — Continuation.

Collection number (MNHN-ZM-)	Field number	Species	Locality	Habitat	Altitude (m asl)	Mission		Specimens used for morphometric analyses						
						number	Sex	W	HB	TL	HF	E	Body measures	Skull distances
2012-1112	N319	<i>C. muricauda</i>	Gouan	Gallery forest	1212	1	F	5	53	76	12	7	×	×
2012-1113	N238	<i>C. muricauda</i>	Gouan	Gallery forest	1212	1	I	—	—	—	—	—	—	×
2012-1114	N263	<i>C. muricauda</i>	Gouan	Gallery forest	1212	1	I	—	—	—	—	—	—	×
2012-1115	G236	<i>C. nimbasilvanus</i>	Gbié	Gallery forest	552	2	M	51	148	120	25	14	×	×
2012-1116	G193	<i>C. obscurior</i>	Gbié	Gallery forest	552	2	F	4	57	37	10	6	×	×
2012-1117	G194	<i>C. obscurior</i>	Gbié	Gallery forest	552	2	F	4	59	33	10	6	×	—
2012-1118	G206	<i>C. obscurior</i>	Gbié	Gallery forest	612	2	F	3	58	34	10	—	—	×
2012-1119	G225	<i>C. obscurior</i>	Gbié	Gallery forest	612	2	F	4	64	32	8	7	×	×
2012-1120	G228	<i>C. obscurior</i>	Gbié	Gallery forest	612	2	M	3	52	37	9	6	×	×
2012-1121	N179	<i>C. obscurior</i>	Gbié	Savannah	649	1	M	4	60	33	10	6	×	×
2012-1122	GBE89	<i>C. obscurior</i>	Gblayougouma	Secondary forest	477	3	M	4	59	33	11	6	×	—
2012-1123	N219	<i>C. obscurior</i>	Gouan	Gallery forest	1212	1	M	5	57	33	10	6	×	—
2012-1124	N237	<i>C. obscurior</i>	Gouan	Gallery forest	1212	1	F	3.5	58	33	8	7	×	×
2012-1125	N239	<i>C. obscurior</i>	Gouan	Alt. savannah	1642	1	M	3	58	30	8	6	×	×
2012-1126	N282	<i>C. obscurior</i>	Gouan	Gallery forest	1212	1	M	4	50	33	9	7	×	×
2012-1127	N294	<i>C. obscurior</i>	Gouan	Gallery forest	1212	1	M	3	47	35	10	5	×	×
2012-1128	N296	<i>C. obscurior</i>	Gouan	Gallery forest	1212	1	M	3.5	49	39	9	5	×	×
2012-1129	N307	<i>C. obscurior</i>	Gouan	Gallery forest	1212	1	M	4	48	35	10	6	×	—
2012-1130	NIMII06	<i>C. obscurior</i>	Gouan	Alt. savannah	1616	2	M	4	59	29	8	6	×	×
2012-1131	NIMII09	<i>C. obscurior</i>	Gouan	Alt. savannah	1616	2	M	5	60	37	10	6	×	×
2012-1132	NIMII15	<i>C. obscurior</i>	Gouan	Gallery forest	1176	2	M	3	54	34	10	6	×	×
2012-1133	NIMII16	<i>C. obscurior</i>	Gouan	Gallery forest	1176	2	F	4	60	30	10	6	×	×
2012-1134	NIMII25	<i>C. obscurior</i>	Gouan	Alt. savannah	1616	2	M	4	56	32	9	6	×	×
2012-1135	NIMII41	<i>C. obscurior</i>	Gouan	Gallery forest	1176	2	F	3	57	35	9	6	×	×
2012-1136	N72	<i>C. obscurior</i>	Serengbara	Secondary forest	589	1	F	3	51	32	9	5	×	×
—	SER145	<i>C. obscurior</i>	Serengbara	Secondary forest	589	2	F	3	46	38	8	6	×	—
2012-1137	SER153	<i>C. obscurior</i>	Serengbara	Secondary forest	589	2	F	4	56	34	8	6	×	×
2012-1138	SER154	<i>C. obscurior</i>	Serengbara	Secondary forest	589	2	M	4	58	35	9	6	×	×
2012-1139	SER157	<i>C. obscurior</i>	Serengbara	Secondary forest	589	2	F	4	56	32	8	5	×	×
2012-1140	SER158	<i>C. obscurior</i>	Serengbara	Secondary forest	589	2	M	4	58	35	8	6	×	×
—	SER171	<i>C. obscurior</i>	Serengbara	Secondary forest	589	2	F	4	55	35	9	6	×	—
2012-1141	ZIE24	<i>C. obscurior</i>	Ziela	Secondary forest	477	3	M	4	54	35	10	6	×	—
2012-1142	ZIE38	<i>C. obscurior</i>	Ziela	Secondary forest	477	3	M	4	59	32	11	6	×	—
2012-1143	ZIE39	<i>C. obscurior</i>	Ziela	Secondary forest	477	3	F	4	63	31	10	6	×	—
2012-1145	ZIE47	<i>C. obscurior</i>	Ziéla	Secondary forest	477	3	F	4	58	31	9	6	×	—
2012-1146	ZIE48	<i>C. obscurior</i>	Ziéla	Secondary forest	477	3	M	5	61	37	10	7	×	—
2012-1148	N281	<i>C. obscurior</i>	Gouan	Gallery forest	1212	1	I	—	—	—	—	—	—	×
2012-1149	N295	<i>C. obscurior</i>	Gouan	Gallery forest	1212	1	I	—	—	—	—	—	—	×
2012-1150	N312	<i>C. obscurior</i>	Gouan	Alt. savannah	1642	1	I	—	—	—	—	—	—	×
2012-1151	N316	<i>C. obscurior</i>	Gouan	Alt. savannah	1642	1	I	—	—	—	—	—	—	×
2012-1152	G201	<i>C. olivieri</i>	Gbié	Savannah	596	2	F	26	123	65	19	10	×	×
2012-1153	G203	<i>C. olivieri</i>	Gbié	Gallery forest	552	2	M	10	103	73	18	9	×	×
2012-1154	G208	<i>C. olivieri</i>	Gbié	Gallery forest	552	2	F	27	119	103	17	7	×	×
2012-1155	G239	<i>C. olivieri</i>	Gbié	Gallery forest	573	2	M	31	116	81	20	12	×	×
2012-1156	G243	<i>C. olivieri</i>	Gbié	Gallery forest	612	2	M	24	114	80	18	8	×	×
2012-1157	N162	<i>C. olivieri</i>	Gbié	Gallery forest	621	1	F	33	122	89	22	10	×	×
2012-1158	N201	<i>C. olivieri</i>	Gbié	Gallery forest	608	1	F	24	123	76	20	8	×	×
2012-1159	GBE57	<i>C. olivieri</i>	Gblayougouma	Secondary forest	477	3	M	35	132	73	20	11	×	—
2012-1160	GBE59	<i>C. olivieri</i>	Gblayougouma	Secondary forest	477	3	F	24	120	73	18	9	×	—
2012-1161	N321	<i>C. olivieri</i>	Gouan	Gallery forest	1212	1	M	30	124	80	22	8	×	×
2012-1162	NIMII57	<i>C. olivieri</i>	Gouan	Gallery forest	1176	2	F	16	111	78	18	11	×	×
2012-1163	NIMII58	<i>C. olivieri</i>	Gouan	Gallery forest	1176	2	M	34	132	—	20	10	—	×
2012-1164	SER159	<i>C. olivieri</i>	Serengbara	Secondary forest	589	2	M	22	116	78	20	9	×	×
2012-1167	G200	<i>C. theresae</i>	Gbié	Gallery forest	573	2	M	23	92	53	15	7	×	×
2012-1168	G202	<i>C. theresae</i>	Gbié	Savannah	595	2	M	10	84	51	12	7	×	×
2012-1169	G238	<i>C. theresae</i>	Gbié	Gallery forest	573	2	F	13	83	47	12	7	×	×
2012-1170	G242	<i>C. theresae</i>	Gbié	Gallery forest	612	2	F	13	88	45	12	7	×	×
2012-1171	G244	<i>C. theresae</i>	Gbié	Savannah	595	2	F	15	89	49	14	8	×	×
2012-1172	N155	<i>C. theresae</i>	Gbié	Savannah	628	1	F	10	90	54	15	8	×	×
2012-1173	N157	<i>C. theresae</i>	Gbié	Savannah	628	1	M	75	89	60	14	7	×	×
2012-1174	N164	<i>C. theresae</i>	Gbié	Gallery forest	608	1	F	10	97	48	12	7	×	×
2012-1176	N240	<i>C. theresae</i>	Gouan	Alt. savannah	1642	1	F	12.5	82	50	13	8	×	×
2012-1177	N241	<i>C. theresae</i>	Gouan	Alt. savannah	1642	1	F	9	86	51	14	7	×	×
2012-1178	N250	<i>C. theresae</i>	Gouan	Alt. savannah	1642	1	M	—	83	54	14	7	×	×

## Appendix 1. — Continuation.

Collection number (MNHN-ZM-)	Field number	Species	Locality	Habitat	Altitude (m asl)	Mission number	Sex	W	HB	TL	HF	E	Specimens used for morphometric analyses	
													Body measures	Skull distances
2012-1179	N252	<i>C. theresae</i>	Gouan	Alt. savannah	1642	1	M	12.5	82	60	13	8	×	×
2012-1180	N301	<i>C. theresae</i>	Gouan	Alt. savannah	1639	1	F	14	86	59	15	8	×	×
2012-1181	N302	<i>C. theresae</i>	Gouan	Alt. savannah	1642	1	F	12.5	93	51	13	8	×	×
2012-1182	N303	<i>C. theresae</i>	Gouan	Alt. savannah	1642	1	M	14	81.5	52	16	8	×	×
2012-1183	N311	<i>C. theresae</i>	Gouan	Alt. savannah	1642	1	M	16	86	60	13	8	×	×
2012-1184	N313	<i>C. theresae</i>	Gouan	Savannah	1236	1	M	15	87	50	14	7	×	×
2012-1185	NIMII122	<i>C. theresae</i>	Gouan	Gallery forest	1201	2	F	9	78	53	15	7	×	—
2012-1186	NIMII43	<i>C. theresae</i>	Gouan	Alt. savannah	1616	2	F	14	88	50	14	7	×	×
2012-1187	NIMII52	<i>C. theresae</i>	Gouan	Alt. savannah	1616	2	M	16	87	51	15	8	×	×
2012-1188	NIMII70	<i>C. theresae</i>	Gouan	Alt. savannah	1616	2	F	10	75	53	15	7	×	×
2012-1189	NIMII82	<i>C. theresae</i>	Gouan	Alt. savannah	1616	2	M	10	85	52	15	7	×	×
2012-1190	G237	<i>S. megalura</i>	Gbié	Gallery forest	552	2	F	7	76	82	14	7	×	×
2012-1191	N163	<i>S. megalura</i>	Gbié	Savannah	621	1	M	6	76	90	15	7	×	×
2012-1192	N242	<i>S. megalura</i>	Gouan	Alt. savannah	1642	1	F	5	67	84	14	7	×	×
2012-1193	N244	<i>S. megalura</i>	Gouan	Alt. savannah	1642	1	M	5.5	71	80	13	7	×	×
2012-1194	N292	<i>S. megalura</i>	Gouan	Alt. savannah	1642	1	M	5	63	75	13	7	×	×
2012-1195	N306	<i>S. megalura</i>	Gouan	Gallery forest	1212	1	M	6	60	83	15	7	×	×
2012-1196	NIMII03	<i>S. megalura</i>	Gouan	Alt. savannah	1616	2	M	8	68	87	15	7	×	—
2012-1197	NIMII04	<i>S. megalura</i>	Gouan	Alt. savannah	1616	2	M	8	75	81	15	7	×	—
2012-1198	NIMII08	<i>S. megalura</i>	Gouan	Alt. savannah	1616	2	F	8	70	70	14	7	×	—
2012-1199	NIMII10	<i>S. megalura</i>	Gouan	Alt. savannah	1616	2	F	6	68	83	13	7	×	—
2012-1200	NIMII11	<i>S. megalura</i>	Gouan	Alt. savannah	1616	2	F	5	68	80	15	7	×	—
2012-1201	NIMII26	<i>S. megalura</i>	Gouan	Alt. savannah	1616	2	F	7	71	82	15	7	×	—
2012-1202	NIMII40	<i>S. megalura</i>	Gouan	Alt. savannah	1616	2	F	3	57	60	13	6	×	—
2012-1203	NIMII54	<i>S. megalura</i>	Gouan	Alt. savannah	1616	2	F	8	71	88	14	7	×	—
2012-1204	NIMII55	<i>S. megalura</i>	Gouan	Alt. savannah	1616	2	F	9	72	84	15	7	×	—
2012-1205	NIMII56	<i>S. megalura</i>	Gouan	Alt. savannah	1616	2	F	8	68	76	15	7	×	—



APPENDIX 2. — Shrew specimens from Liberian Mount Nimba we collected and used in this study with DM and MNHN collection and field numbers, habitat, sex, weight (g) and external body measurements (mm). Expedition number: 1, December 2011; 2, February-March 2013. Abbreviations: see Material and methods.

Collection number (DM/ ou MNHN-ZM-)	Field number	Species	Locality	Habitat	Altitude (m)	Mission number	Sex	W	HB	TL	HF	E	Specimens used for morphometric analyses	
													Body measures	Skull distances
DM13179	AM2011_12_27_03	<i>C. theresae</i>	ENNR 11	Savannah	1350	1	M	11.5	83	55	14.9	8	×	×
DM13180	AM2011_12_27_02	<i>C. theresae</i>	ENNR 11	Savannah	1350	1	F	10.5	79	51	14.6	8	×	×
DM13176	AM2012_01_10_01	<i>C. nimbasilvanus</i>	Bentor 1	Lowland forest	420	1	M	48.5	137	117	24.6	14	×	×
DM13182	AM2012_01_10_02	<i>C. juvenetae</i>	Bentor 1	Lowland forest	420	1	F	7.2	76	50	12.7	9	×	×
DM13183	AM2011_12_29_01	<i>C. muricauda</i>	ENNR 15	Mountain forest	1064	1	F	4.5	64	90	11.9	7	×	×
DM13184	AM2012_01_11_02	<i>C. muricauda</i>	Bentor 1	Lowland forest	420	1	F	4.6	64	71	12.4	8	×	×
DM13190	AM2011_12_23_02	<i>C. muricauda</i>	Tailings 2	Lowland forest	475	1	?	4	61	58	12.1	9	×	×
DM13185	AM2012_01_09_03	<i>C. obscurior/ eburnea</i>	Bentor 1	Lowland forest	420	1	F	3.5	58	38	9.9	7	–	–
DM13186	AM2012_01_09_04	<i>C. eburnea</i>	Bentor 1	Lowland forest	420	1	F	4.8	62	37	10.6	8	×	×
DM13187	AM2011_12_30_01	<i>C. obscurior/ eburnea</i>	ENNR 15	Mountain forest	1064	1	F	2.9	62	35	10.3	7	×	–
DM13188	AM2012_01_11_03	<i>C. eburnea</i>	Bentor 1	Lowland forest	420	1	F	2.5	56	35	10.5	7	×	×
DM13196	AM2011_12_25_01	<i>C. obscurior/ eburnea</i>	Tailings 2	Lowland forest	475	1	M	2.7	51	39	10.1	6	–	–
DM13197	AM2011_12_28_01	<i>C. eburnea</i>	ENNR 14	Mountain forest	1188	1	F	3.3	64	29	10.7	7	×	×
DM13198	AM2012_01_09_05	<i>C. eburnea</i>	Bentor 1	Lowland forest	420	1	M	4.5	65	40	10.9	8	×	×
DM13199	AM2012_01_09_06	<i>C. eburnea</i>	Bentor 1	Lowland forest	420	1	M	4.1	65	40	10.7	8	×	×
DM13200	AM2012_01_02_01	<i>C. obscurior/ eburnea</i>	ENNR 15	Mountain forest	1064	1	M	3.8	65	38	11.0	7	×	–
DM13201	AM2012_01_09_02	<i>C. eburnea</i>	Bentor 1	Lowland forest	420	1	M	3.1	61	37	10.9	7	×	×
DM13202	AM2012_01_09_01	<i>C. obscurior/ eburnea</i>	Bentor 1	Lowland forest	420	1	M	3.1	61	35	10.9	8	–	–
DM13203	AM2011_12_23_01	<i>C. obscurior/ eburnea</i>	Tailings 2	Lowland forest	475	1	M	3.9	62	39	10.8	7	–	–
DM13177	AM2011_12_22_03	<i>C. olivieri</i>	Tailings 4	Lowland forest	494	1	M	29.5	122	79	20.8	12	×	×
DM13189	AM2011_12_22_01	<i>C. olivieri</i>	Tailings 4	Lowland forest	494	1	F	33	119	71	18.8	11	×	×
DM13204	AM2011_12_18_01	<i>C. olivieri</i>	Tailings 1	Lowland forest	381	1	F	25.5	109	75	20.0	13	×	×
Released		<i>C. olivieri</i>	Tailings 4	Lowland forest	494	1	M				20.7		–	–
Released		<i>C. olivieri</i>	Tailings 7	Lowland forest	467	1	?				21.5		–	–
Released		<i>C. olivieri</i>	ENNR 16	Lowland forest	690	1	M				21.0		–	–
Released		<i>C. olivieri</i>	Tailings 4	Lowland forest	494	1	F				20.7		–	–
Released		<i>C. olivieri</i>	Bonlah 2	Secondary forest	452	1	M				20.6		–	–
DM13181	AM2012_01_11_01	<i>C. buettikoferi</i>	Bentor 1	Lowland forest	420	1	M	17.5	97	69	16.0	11	×	×
DM13178	AM2012_01_05_01	<i>S. megalura</i>	Settlement 6	Secondary forest	515	1	M	6.1	70	87	15.3	9	×	×
2014-899	LB03	<i>C. buettikoferi</i>	Camp4	Gallery forest	516	2	F	12	98	56	15	9	×	–
2014-900	LB07	<i>C. buettikoferi</i>	Camp4	Gallery forest	515	2	F	14	105	58	15	10	×	–
2014-912	LB09	<i>C. grandiceps</i>	Camp4	Gallery forest	516	2	F	9	91	46	15	19	×	–
2014-913	LB12	<i>C. grandiceps</i>	Camp4	Gallery forest	516	2	F	13	98	53	15	9	×	–
2014-939	LB20	<i>C. olivieri</i>	Grassfield	Bush, fallow	498	2	F	16	110	65	17	10	×	–
2014-914	LB28	<i>C. grandiceps</i>	Zolowee	Houses	458	2	M	25	114	88	19	10	×	–
2014-934	LB38	<i>C. olivieri</i>	Grassfield	Savannah	476	2	M	33	119	72	17	10	×	–
2014-935	LB42	<i>C. olivieri</i>	Grassfield	Savannah	476	2	M	32	120	71	19	11	×	–
2014-936	LB54	<i>C. olivieri</i>	Grassfield	Bush, fallow	498	2	M	38	130	81	19	12	×	–
2014-925	LB59	<i>C. muricauda</i>	Liabala	Gallery forest	470	2	F	5	67	78	11	9	×	–
2014-918	LB60	<i>C. juvenetae</i>	Liabala	Gallery forest	470	2	F	7.5	74	44	10	8	×	–
2014-909	LB61	<i>C. eburnea</i>	Liabala	Gallery forest	470	2	F	4.2	68	32	10	6	×	–
2014-927	LB62	<i>C. obscurior</i>	Liabala	Gallery forest	470	2	M	3.6	60	35	9	7	×	–
2014-928	LB63	<i>C. obscurior</i>	Liabala	Gallery forest	470	2	F	3	62	38	9	7	×	–
2014-919	LB71	<i>C. juvenetae</i>	Liabala	Gallery forest	470	2	F	6.7	76	44	10	7	×	–
2014-929	LB75	<i>C. obscurior</i>	Camp4	Gallery forest	516	2	F	3	59	36	9	5	×	–
2014-920	LB76	<i>C. juvenetae</i>	Camp4	Gallery forest	516	2	F	6	77	55	11	7	×	–
2014-905	LB78	<i>C. buettikoferi</i>	Camp4	Gallery forest	516	2	M	15	100	68	14	7	×	–
2014-930	LB79	<i>C. obscurior</i>	Liabala	Gallery forest	470	2	F	3.5	60	38	8	6	×	–
2014-910	LB80	<i>C. eburnea</i>	Liabala	Gallery forest	470	2	F	5.5	71	40	9	6	×	–
2014-911	LB81	<i>C. eburnea</i>	Liabala	Gallery forest	470	2	F	5.5	70	34	9	5	×	–
2014-931	LB82	<i>C. obscurior</i>	Liabala	Gallery forest	470	2	F	4.5	68	35	8	6	×	–
2014-921	LB83	<i>C. juvenetae</i>	Liabala	Gallery forest	470	2	M	6.5	75	40	10	8	×	–
2014-906	LB106	<i>C. eburnea</i>	Camp4	Gallery forest	516	2	F	3.3	59	39	9	5	×	–
2014-917	LB108	<i>C. buettikoferi</i>	Liabala	Gallery forest	470	2	F	12	88	58	14	8	×	–
2014-907	LB109	<i>C. eburnea</i>	Liabala	Gallery forest	470	2	F	3.4	63	33	9	6	×	–
2014-941	LB115	<i>C. theresae</i>	Camp4	Gallery forest	516	2	M	8.6	78	54	14	7	×	–

## Appendix 2. — Continuation.

Collection number (DM/ ou MNHN-ZM-)	Field number	Species	Locality	Habitat	Altitude (m)	Mission number	Sex	W	HB	TL	HF	E	Specimens used for morphometric analyses	
													Body measures	Skull distances
2014-932	LB116	<i>C. obscurior</i>	Gbapa	Secondary forest	441	2	F	3.5	55	39	8	6	×	–
2014-901	LB122	<i>C. buettikoferi</i>	Gbapa	Gallery forest	460	2	F	12	96	64	14	8	×	–
2014-915	LB129	<i>C. grandiceps</i>	Zolowee	Houses	458	2	F	14	101	50	14	7	×	–
2014-902	LB130	<i>C. buettikoferi</i>	Liabala	Gallery forest	470	2	F	11	93	60	14	8	×	–
2014-937	LB131	<i>C. olivieri</i>	Gbapa	Gallery forest	474	2	M	23	113	78	14	9	×	–
2014-938	LB138	<i>C. olivieri</i>	Gbapa	Gallery forest	460	2	M	31	123	71	18	9	×	–
2014-922	LB142	<i>C. juvenetae</i>	Gbapa	Secondary forest	441	2	F	7.6	80	46	12	7	×	–
2014-923	LB143	<i>C. juvenetae</i>	Gbapa	Secondary forest	441	2	M	6	64	39	10	6	×	–
2014-903	LB150	<i>C. buettikoferi</i>	Camp4	Gallery forest	516	2	F	17	101	61	15	9	×	–
2014-926	LB151	<i>C. muricauda</i>	Liabala	Gallery forest	470	2	F	5	71	118	11	7	×	–
2014-916	LB152	<i>C. grandiceps</i>	Cap4_ marais	Swamp	491	2	F	17	94	58	16	8	×	–
2014-940	LB162	<i>C. olivieri</i>	Border	Savannah	542	2	F	30.4	135	73	18	10	×	–
2014-942	LB170	<i>C. theresae</i>	Border	Savannah	542	2	F	15	95	48	14	8	×	–
2014-924	LB171	<i>C. juvenetae</i>	Liabala	Gallery forest	470	2	M	5	71	48	10	5	×	–
2014-933	LB172	<i>C. obscurior</i>	Liabala	Gallery forest	470	2	F	3.5	64	38	10		×	–
2014-908	LB173	<i>C. eburnea</i>	Liabala	Gallery forest	470	2	F	3.5	65	36	9	5	×	–
2014-904	LB177	<i>C. buettikoferi</i>	Border	Secondary forest	569	2	F	13	94	59	13	8	×	–
	LB25	<i>S. megalura</i>	Camp4	Gallery forest	516	2	F	6.5	73	84	14	7	×	–

APPENDIX 3. — Shrew specimens from the Guinean and Ivorian surroundings of Mount Nimba used in this study with MNHN collection and field numbers (when available) for CVA analyses, sex, weight (g) and external body measurements (mm). Holotypes and paratypes in bold, Type specimens available in the collections of the Muséum National d'Histoire Naturelle, all described by Heim de Balsac in 1956 and 1958. \*Specimens initially described as subspecies of *C. bottegi* (Heim de Balsac 1959) but later elevated to full species level (Hutterer 2005, Jacquet *et al.* 2014). Abbreviations: see Material and methods.

Collection number (MNHN-ZM-MO-/MNHN-ZM-)	Field number	Species	Locality/ Country	Sex	W	HB	TL	HF	E	Specimens used for morphometric analyses	
										Body measures	Skull distances
1981-498	–	<i>C. theresae</i>	Nzérékoré, Mt Nimba	M	–	60	40	12	–	–	×
1981-499	–	<i>C. theresae</i>	Nzérékoré, Mt Nimba	F	–	–	–	–	–	–	×
1981-490	–	<i>C. juvenetae</i>	Ziéla, Mt Nimba	M	–	60	40	12	–	–	–
1981-492	–	<i>C. nimbae</i>	Zouguépo, Mt Nimba	F	–	90	57	17	–	–	×
1981-493	–	<i>C. nimbae</i>	Zouguépo, Mt Nimba	M	–	80	52	16	–	–	–
1981-494	–	<i>C. obscurior*</i>	Gouéla, Mt Nimba	M	–	50	37	10	–	–	–
1981-495	–	<i>C. obscurior*</i>	Ziéla, Mt Nimba	M	–	–	–	–	–	–	–
1981-482	–	<i>C. obscurior*</i>	Zouguépo, Mt Nimba	–	–	–	–	–	–	–	–
1981-483	–	<i>C. eburnea*</i>	Mt Toukoui (Côte d'Ivoire)	F	–	40	28	9	–	–	–
1981-496	–	<i>C. obscurior</i>	Altitude grassland, Mt Nimba	F	–	–	–	–	–	–	–
1984-1099	–	<i>C. douceti</i>	Adiopodoumé (Côte d'Ivoire)	F	–	55	50	11.5	–	–	–
2013-755	BH5	<i>C. buettikoferi</i>	Bhoita	M	17	97	67	17	10	×	×
2012-1436	CI418	<i>C. buettikoferi</i>	Touzouko (Côte d'Ivoire)	M	13	94	57	11	10	×	×
2013-770	FR47	<i>C. buettikoferi</i>	Franfina	F	17	100	57	17	10	×	×
2013-771	FR51	<i>C. buettikoferi</i>	Franfina	F	11	91	51	15	10	×	×
2013-772	FR53	<i>C. buettikoferi</i>	Franfina	M	13	92	58	16	10	×	×
2013-763	GUI137	<i>C. buettikoferi</i>	Gbetlaya	M	15	94	61	15	8	×	×
2013-773	GUI1374	<i>C. buettikoferi</i>	Gania	M	21	108	62	17	10	×	×
2013-774	GUI1431	<i>C. buettikoferi</i>	Gania	F	17	93	60	18	9	×	×
2013-742	GUI1448	<i>C. buettikoferi</i>	Tanganya	M	16	103	64	16	10	×	×
2013-743	GUI791	<i>C. buettikoferi</i>	Tanganya	M	11	92	51	17	9	×	×
2013-745	MK29	<i>C. buettikoferi</i>	Maikou	F	11	87	52	15	11	×	×
2013-747	MK33	<i>C. buettikoferi</i>	Maikou	M	14	98	66	17	9	×	×
2013-748	SA17	<i>C. buettikoferi</i>	Sangassou	M	15	93	67	10	9	×	×
2013-749	SA20	<i>C. buettikoferi</i>	Sangassou	M	16	106	75	17	9	×	×
2013-750	SA21	<i>C. buettikoferi</i>	Sangassou	M	14	100	60	16	10	×	×
2013-751	SA28	<i>C. buettikoferi</i>	Sangassou	M	16	102	68	16	9	×	×
2013-752	SA32	<i>C. buettikoferi</i>	Sangassou	F	14	96	62	16	10	×	×
2013-753	SA36	<i>C. buettikoferi</i>	Sangassou	M	16	102	70	17	10	×	×
2013-489	VN1379	<i>C. douceti</i>	Zogota	F	49	60	11	9	5	×	×
2017-28	PO953	<i>C. douceti</i>	Zogota	M	58	61	13	9	6	×	×
2017-31	P1556	<i>C. douceti</i>	Zogota	M	61	61	12	9	4	×	×
2017-47	P2687	<i>C. douceti</i>	Zogota	F	60	60	60	10	6	×	×
2017-37	P2274	<i>C. douceti</i>	Zogota	F	63	60	12	–	5	×	×
2017-69	P1572	<i>C. douceti</i>	Zogota	F	62	58	12	9	5	×	×
2017-70	P1612	<i>C. douceti</i>	Zogota	M	63	67	13	10	6	×	×
2017-107	P0958	<i>C. douceti</i>	Zogota	M	49	60	11	9	5	×	×
2017-108	PO967	<i>C. douceti</i>	Ziama	M	4	54	55	13	7	×	×
2017-115	P1097	<i>C. douceti</i>	Ziama	F	5	82	59	12	10	×	×
2017-117	P1233	<i>C. douceti</i>	Ziama	M	5	65	57	12	10	×	×
–	DV0056	<i>C. obscurior</i>	Ziama/Diecke	–	–	–	–	–	–	–	×
–	PO842	<i>C. eburnea</i>	Ziama/Diecke	M	4	56	41	11	8	×	×
–	PO955	<i>C. eburnea</i>	Ziama/Diecke	M	6	65	41	12	10	×	×
2013-777	BH20	<i>C. grandiceps</i>	Bhoita	F	22	109	82	16	13	×	×
2013-769	FR43	<i>C. grandiceps</i>	Franfina	M	16	95	64	17	9	×	×
2013-781	YRD14	<i>C. grandiceps</i>	Yerende	F	10	85	54	14	7	×	×
2012-1477	CI199	<i>C. juvenetae</i>	Gbaboube	F	8	82	50	12	7	×	×
2013-791	GUI919	<i>C. juvenetae</i>	Bantou	M	8	78	47	11	7	×	×
2013-805	GUI1336	<i>C. juvenetae</i>	Tanganya	F	11	66	45	11	6	×	×
2013-792	GUI157	<i>C. juvenetae</i>	Gbetlaya	M	7	79	52	12	9	×	×
2013-793	GUI816	<i>C. juvenetae</i>	Tanganya	M	6	74	49	11	8	×	×
–	BH22	<i>C. muricauda</i>	Bhoita	M	7	74	96	16	10	×	×
2013-589	VN1282	<i>C. muricauda</i>	Zogota	F	3	68	78	10	6	×	×
2013-569	VN1281	<i>C. muricauda</i>	Zogota	F	4.5	69	64	11	7	×	×
2013-571	VN1416	<i>C. muricauda</i>	Zogota	F	4	69	71	12	8	×	×
2017-438	PO872	<i>C. nimbae</i>	Ziama	F	22	92	61	16	10	×	×
2017-437	PO839	<i>C. nimbae</i>	Ziama	M	17	86	51	17	11	×	×
2017-412	P2963	<i>C. nimbae</i>	Ziama	F	25	100	62	17	12	×	×
2017-441	P2668	<i>C. nimbae</i>	Ziama	M	16	99	59	17	10	×	×
2017-440	P1597	<i>C. nimbae</i>	Ziama	F	21	102	60	16	10	×	×
2017-439	PO947	<i>C. nimbae</i>	Ziama	M	16	88	65	17	11	×	×
2017-443	P1829	<i>C. nimbae</i>	Ziama	F	12	85	55	15	11	×	×
2017-374	P0265	<i>C. nimbasilvanus</i>	Ziama	M	52	137	123	25	15	×	×



## Appendix 3. — Continuation.

Collection number (MNHN-ZM-MO-/MNHN-ZM-)	Field number	Species	Locality/ Country	Sex	W	HB	TL	HF	E	Specimens used for morphometric analyses	
										Body measures	Skull distances
2017-377	PO452	<i>C. nimbasilvanus</i>	Ziama	M	54	104	114	21	14	x	x
2017-378	PO461	<i>C. nimbasilvanus</i>	Ziama	M	53	136	115	25	15	x	x
2017-380	PO484	<i>C. nimbasilvanus</i>	Ziama	F	52	130	113	22	16	x	x
2017-382	PO594	<i>C. nimbasilvanus</i>	Ziama	F	63	129	117	23	15	x	x
2017-383	PO693	<i>C. nimbasilvanus</i>	Ziama	M	59	123	115	24	12	x	x
2017-384	PO747	<i>C. nimbasilvanus</i>	Ziama	F	62	122	104	24	17	x	x
2017-386	PO775	<i>C. nimbasilvanus</i>	Ziama	M	72	129	116	27	16	x	x
2017-388	PO792	<i>C. nimbasilvanus</i>	Ziama	F	39	122	112	23	15	x	x
—	DV0057	<i>C. eburnea</i>	Ziama/Diecke	—	—	—	—	—	—	—	x
—	OP831	<i>C. obscurior</i>	Ziama/Diecke	F	3	51	33	11	7	x	x
—	P1138	<i>C. obscurior</i>	Ziama/Diecke	F	4	57	35	10	8	x	x
—	P1142	<i>C. obscurior</i>	Ziama/Diecke	M	4	55	36	10	7	x	x
—	OP859	<i>C. obscurior</i>	Ziama/Diecke	M	4	58	33	11	7	x	x
2012-1530	CI294	<i>C. olivieri</i>	Sanguiebo	F	12	102	58	16	11	x	x
2012-1511	CI479	<i>C. olivieri</i>	Bakro	M	44	139	79	20	13	x	x
2013-845	BH56	<i>C. olivieri</i>	Bhoita	M	38	132	80	19	13	x	x
2013-846	BH57	<i>C. olivieri</i>	Bhoita	M	35	129	87	21	11	x	x
2013-848	GUI243	<i>C. olivieri</i>	Gagal	F	24	116	66	16	10	x	x
2013-834	GUI632	<i>C. olivieri</i>	Khoneya	M	26	125	68	18	10	x	x
2012-1494	CI424	<i>C. theresae</i>	Touzoukro	F	18	111	67	17	11	x	x
2013-909	BH45	<i>C. theresae</i>	Bhoita	M	15	97	56	15	8	x	x
2013-901	FR15	<i>C. theresae</i>	Franfina	M	11	89	51	14	9	x	x
2013-903	FR57	<i>C. theresae</i>	Franfina	F	9	91	58	15	10	x	x
2013-904	FR90	<i>C. theresae</i>	Franfina	F	9	91	53	14	10	x	x
2013-884	GUI782	<i>C. theresae</i>	Tanganya	F	11	91	53	9	8	x	x
2013-885	GUI792	<i>C. theresae</i>	Tanganya	M	10	93	55	14	10	x	x
2013-887	GUI826	<i>C. theresae</i>	Tanganya	M	9	90	56	15	10	x	x
2013-894	KD25	<i>C. theresae</i>	Kodoko	M	14	97	55	15	10	x	x
2013-895	KD27	<i>C. theresae</i>	Kodoko	M	14	100	65	15	10	x	x
2013-896	KD28	<i>C. theresae</i>	Kodoko	F	9	92	51	15	10	x	x
2013-897	KD31	<i>C. theresae</i>	Kodoko	M	12	92	55	14	10	x	x
2013-898	KD32	<i>C. theresae</i>	Kodoko	M	12	95	52	16	11	x	x
2013-899	KD33	<i>C. theresae</i>	Kodoko	M	11	92	53	16	10	x	x
2013-900	KD7	<i>C. theresae</i>	Kodoko	F	10	84	50	14	10	x	x
2013-906	MAC17	<i>C. theresae</i>	Macenta	F	9	86	60	15	9	x	x

APPENDIX 4. — Correlations between Variables and Factors of the CVA on external measurements. Abbreviations: see Material and methods.

	F1	F2	F3	F4
HB	0.950	0.199	-0.003	-0.240
TL	0.805	-0.564	-0.058	-0.177
HF	0.566	0.026	0.094	-0.819
E	0.748	-0.093	0.595	-0.278

APPENDIX 5. — Confusion matrix for classification predictions of the sample for the CVA on external measurements. Abbreviations: **b**, *Crocidura buettikoferi* Jentink, 1888; **d**, *C. douceti* Heim de Balsac, 1958; **e**, *C. eburnea* Heim de Balsac, 1958; **g**, *C. grandiceps* Hutterer, 1983; **j**, *C. juvenetae* Heim de Balsac, 1958, *C. muricauda* (Miller, 1900); **mu**, *S. megalura* (Jentink, 1888); **n**, *C. nimbae* Heim de Balsac, 1956, **o**, *C. obscurior* Heim de Balsac, 1958; **ol**, *C. olivieri* (Lesson, 1827); **sy**, *C. nimbasilvanus* Hutterer, 2003; **t**, *C. theresae* Heim de Balsac, 1968.

From/to	b	d	e	g	j	m	mu	n	o	ol	sy	th	Total	% correct
b	27	0	0	1	3	0	0	0	0	1	0	9	41	65.85%
d	1	8	0	0	1	0	0	0	0	0	0	1	11	72.73%
e	0	0	0	0	1	0	0	0	7	0	0	0	8	0.00%
g	7	0	0	6	0	0	0	1	0	2	1	2	19	31.58%
j	0	0	0	0	17	0	0	0	6	0	1	5	29	58.62%
m	0	0	0	0	0	2	6	0	0	0	0	0	8	25.00%
mu	0	1	0	0	1	2	10	0	1	0	0	0	15	66.67%
n	2	0	0	0	0	0	0	0	0	0	0	5	7	0.00%
o	0	0	0	0	0	0	0	0	45	0	0	0	45	100.00%
ol	0	0	0	1	0	0	0	1	0	15	1	1	19	78.95%
sy	0	0	0	0	0	0	0	0	0	0	11	0	11	100.00%
th	8	0	0	1	2	0	0	0	0	1	0	27	39	69.23%
Total	45	9	0	9	25	4	16	2	59	19	14	50	252	66.67%

APPENDIX 6. — Correlations between the variables and the axes, CVA on skull measurements. Abbreviations: **a**, condyle-incisive length; **b**, nasal width; **c**, inter-orbital width; **d**, occipital greatest width; **e**, greatest maxillary width; **f**, upper tooth row length; **g**, height of the skull at M2 level; **h**, greatest braincase height; **i**, mandibular length; **j**, lower tooth row length; **k**, greatest length between extremities of the coronoid and angular processes.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
a	0.995	0.045	-0.034	0.066	0.007	0.011	0.019	0.022	-0.029	0.021	0.016
b	0.941	-0.166	-0.037	-0.050	-0.114	0.006	0.139	0.117	-0.050	0.185	0.006
c	0.947	-0.041	0.253	-0.024	0.065	-0.134	0.035	0.051	0.057	0.042	0.071
d	0.964	0.067	0.122	0.041	0.059	0.146	0.096	0.067	-0.025	0.070	0.078
e	0.984	0.060	-0.008	0.052	-0.043	-0.020	0.114	-0.080	-0.056	-0.015	-0.021
f	0.986	-0.086	0.029	-0.026	-0.057	0.047	0.062	-0.061	-0.045	-0.041	0.051
h	0.922	0.048	0.212	0.174	-0.120	0.059	-0.047	0.191	-0.100	-0.032	-0.063
g	0.940	-0.170	0.093	0.167	0.042	0.055	-0.048	-0.085	-0.051	0.185	-0.012
i	0.992	0.089	-0.025	-0.018	0.027	0.003	-0.004	0.000	-0.071	0.029	-0.020
k	0.944	-0.106	-0.041	0.024	0.167	0.011	0.091	0.067	-0.219	-0.086	0.002
j	0.986	0.063	-0.036	-0.038	0.000	0.009	0.038	-0.006	0.064	-0.019	-0.120

APPENDIX 7. — Confusion matrix AFD skull measurements. Abbreviations: **b**, *Crocidura buettikoferi* Jentink, 1888; **d**, *C. douceti* Heim de Balsac, 1958; **e**, *C. eburnea* Heim de Balsac, 1958; **g**, *C. grandiceps* Hutterer, 1983; **j**, *C. juvenetae* Heim de Balsac, 1958, *C. muricauda* (Miller, 1900); **mu**, *S. megalura* (Jentink, 1888); **n**, *C. nimbae* Heim de Balsac, 1956, **o**, *C. obscurior* Heim de Balsac, 1958; **ol**, *C. olivieri* (Lesson, 1827); **sy**, *C. nimbasilvanus* Hutterer, 2003; **t**, *C. theresae* Heim de Balsac, 1968.

From/to	b	d	e	g	j	m	mu	n	o	ol	sy	th	Total	% correct
b	33	0	0	0	0	0	0	0	0	0	0	8	41	80.49%
d	0	11	0	0	0	0	0	0	1	0	0	0	12	91.67%
e	0	0	2	0	0	0	0	0	3	0	0	0	5	40.00%
g	2	0	0	10	0	0	0	0	0	2	0	5	19	52.63%
j	0	0	0	0	28	0	1	0	0	0	0	0	29	96.55%
m	0	0	0	0	0	7	1	0	0	0	0	0	8	87.50%
mu	0	0	0	0	1	0	12	0	2	0	0	0	15	80.00%
n	0	0	0	0	0	0	0	7	0	0	0	0	7	100.00%
o	0	1	1	0	0	0	2	0	35	0	0	0	39	89.74%
ol	0	0	0	0	0	0	0	0	0	19	0	0	19	100.00%
sy	0	0	0	0	0	0	0	0	0	0	11	0	11	100.00%
th	8	0	0	0	1	0	0	0	0	1	0	29	39	74.36%
Total	43	12	3	10	30	7	16	7	41	22	11	42	244	83.61%



APPENDIX 8. — Nimba shrews skins with field numbers: **A**, MNHN-ZM-2014-900 (LB07) *C. buettikoferi* Jentink, 1888 Camp 4; **B**, MNHN-ZM-2012-1079 (NIM217) *C. grandiceps* Hutterer, 1983 Gouan; **C**, MNHN-ZM-2012-1158 (NIM201) *C. olivieri* (Lesson, 1827) Gbié; **D**, MNHN-ZM-2012-1111 (NIM232) *C. muricauda* (Miller, 1900) Gouan; **E**, MNHN-ZM-2012-1180 (NIM 301) *C. theresae* Heim de Balsac, 1968 Gouan; **F**, MNHN-ZM-MO-1981-492 *C. nimbae* Heim de Balsac, 1956 Holotype Zouguepo; **G**, MNHN-ZM-MO-1981-483 *C. eburnea* Heim de Balsac, 1958 Mt Tonkui; **H**, MNHN-ZM-2012-1123 (NIM 219) *C. obscurior* Heim de Balsac, 1958 Gouan.

