Original study

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Small mammals of a West African hotspot, the Ziama-Wonegizi-Wologizi transfrontier forest landscape

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Abstract: The Upper Guinea rainforest zone in West Africa is considered a biodiversity hotspot and contains important habitats for threatened and endemic mammals, yet this region remains poorly known particularly for small mammals. The aim of this study was to survey small mammals in a Liberian and Guinean cross-border conservation area, the Ziama-Wonegizi-Wologizi landscape. We recorded a total of 52 small mammal species, including 26 bats, 15 rodents, 10 shrews, one otter-shrew, of which one rodent species was new to science (*Colomys* sp. nov.). We also documented the first country records of the bats *Chaerephon aloysiisabaudiae*, *Pseudoromicia brunnea* and *Pipistrellus inexspectatus* from Guinea, and the shrews *Crocidura douceti* and *Crocidura grandiceps* from Liberia. Furthermore, we recorded the recently described bat *Nycticeinops happoldorum* from Wologizi and Ziama, and we documented the presence of *Micropotamogale lamottei* at Wologizi, which represents the fourth known locality for this globally threatened species. Finally, the forests of Wologizi and Ziama support numerous threatened species. The results of our survey demonstrate the importance of this region for small mammals and support the creation of a transboundary protected area that will encompass the entire forest landscape.

Keywords: Afrosoricida; Chiroptera; Eulipotyphla; Rodentia; Upper Guinea rainforest.

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1 Introduction

Tropical rainforests are highly diverse and comprise a disproportionate number of global biodiversity hotspots (Bakarr et al. 2004; Carr et al. 2015; Myers et al. 2000), yet knowledge about these forests is poor compared to temperate zone biomes (Burgess et al. 2004). This is particularly true of African rainforests which have received little attention, including the Upper Guinea rainforest zone (Bakarr et al. 2001; Bakarr et al. 2004; Carr et al. 2015). Located in West Africa, the Upper Guinea region is a recognised biodiversity hotspot that extends from Guinea and Sierra Leone in the west to Togo in the east (Bakarr et al. 2001). A large number of mammal species occur here, many of which are endemic (Coe, 1975; Denys and Aniskine 2012; Fahr et al. 2006; Grubb et al. 1998; Monadjem and Fahr 2007).

Within the Upper Guinea rainforest are a number of key localities that serve as sites of exceptional importance particularly with respect to endemism; one of these being the border zone between Guinea and Liberia, an area that includes Mt. Nimba (Coe et al. 1975; Lamotte and Roy 2003). Indeed, two species of freshwater crabs (*Liberonautes lugbe* and *L. nimba*), a dragonfly (*Paragomphus kiautai*), and one of the world's viviparous frog species (*Nimbaphrynoides occidentalis*), are all endemic to Mt. Nimba (Lamotte and Roy 2003; Sandberger et al. 2010). Plant species diversity is also high, with a significant number of plants endemic to Mt. Nimba (Marshall and Hawthorne 2013; Wieringa and Poorter 2004). Furthermore, this area is one of the most important hotspots for African bats (Monadjem et al. 2016), with several small mammal species (*Micropotamogale lamottei*, *Hipposideros lamottei*, *Hipposideros marisae*, *Rhinolophus ziama*) having highly restricted global distributions centred on the border zone between Guinea and Liberia (Fahr et al. 2002; Fahr 2013d; Monadjem et al. 2013a; Rosevear 1965).

One explanation for this high diversity in the border zone between Liberia and Guinea has to do with biome transitions in West Africa, moving from forest in the south to savanna in the north (Fahr and Kalko 2011). Hence, it is predicted that other areas within this transition zone should be equally species rich as Mt. Nimba. For example, the Wonegizi and Wologizi mountain ranges (both in Liberia), and Ziama forest (in Guinea) lie in the same transition zone as Mt. Nimba, but these forests have not been surveyed to the same extent. To illustrate this point, only seven species of bats have been documented in Wologizi forest (Monadjem and Fahr 2007). However, some important small mammals have been reported from this region including the threatened Nimba otter-shrew (*M. lamottei*) and the poorly known Ziama horseshoe bat (*R. ziama*) both of which are known from Ziama forest, and the latter also from Wonegizi forest (Decher et al. 2016; Fahr et al. 2002; Heim de Balsac 1954; Monadjem et al. 2019a).

Currently, the Upper Guinea rainforest region is at risk from numerous threats. Much of the area has witnessed massive deforestation in the past few decades, primarily caused by slash-and-burn agricultural expansion, mining and illegal timber harvesting (Hoke et al. 2007). By the early 2000s just 15–20% of this forest zone remained, almost half of it in Liberia (Bakarr et al. 2004). Furthermore, following many years of civil conflict in parts of the region, it has been suggested that the lawlessness and human displacement caused by armed conflict has led to accelerated deterioration of the environment (Decher et al. 2010; Glew and Hudson 2007; Hanson et al. 2009). The goal of this study was to survey the small mammal fauna of a relatively unexplored part of the Upper Guinea rainforest, the Ziama-Wonegizi-Wologizi landscape (hereafter referred to as ZWW).

2 Materials and methods

The study area included the Wologizi National Forest and the Ziama Man Biosphere Reserve (hereafter referred to as Wologizi and Ziama, respectively). The Wologizi Forest is situated in north-western Lofa County (Liberia), near the border with Guinea. This forest consists of seasonal moist evergreen and semi-deciduous trees, with open riverine forest habitats (Hoke et al. 2007). It stretches from the Wologizi Mountains eastwards to the Wonegizi Mountains, which constitutes an important corridor between the two (Monadjem and Fahr 2007). Together with Mt. Nimba, the Wologizi and Wonegizi Mountains form the most extensive montane region in Liberia, which includes Liberia's highest peak, Mt. Wutewe (1424 m) at Wologizi (Hoke et al. 2007). Annual precipitation at Wologizi forest is approximately 2500 mm and the annual mean temperature is 24.9 °C (Monadjem and Fahr 2007). The Ziama Forest is a classified forest located in south-eastern Guinea (Guinée Forestière, Région Administrative de N'Zérékoré) bordering Liberia close to the Wonegizi Mountains. This forest is dominated by montane grasslands in the highlands, with adjacent plains dominated by bush-tree savanna (Fahr et al. 2006). Annual precipitation at Ziama forest, varies between 1700 and 2000 mm, with a long dry season lasting five to six months (November to April) (Fahr et al. 2006). The Ziama Forest was designated a Forest Reserve in 1932, and then a Biosphere Reserve in 1981 (Nicolas et al. 2009). By contrast, Wologizi Forest has no legal protection status.

The survey took place between 12 May 2019 and 22 June 2019, which coincided with the start of the wet season that mostly extends from April to November, with a pronounced dry season in December to February (Coe 1975; Hoke et al. 2007). We conducted surveys at three separate sites within each of the two forests (Wologizi in Liberia and Ziama in Guinea), the locations being 15–30 km apart (Figure 1). We

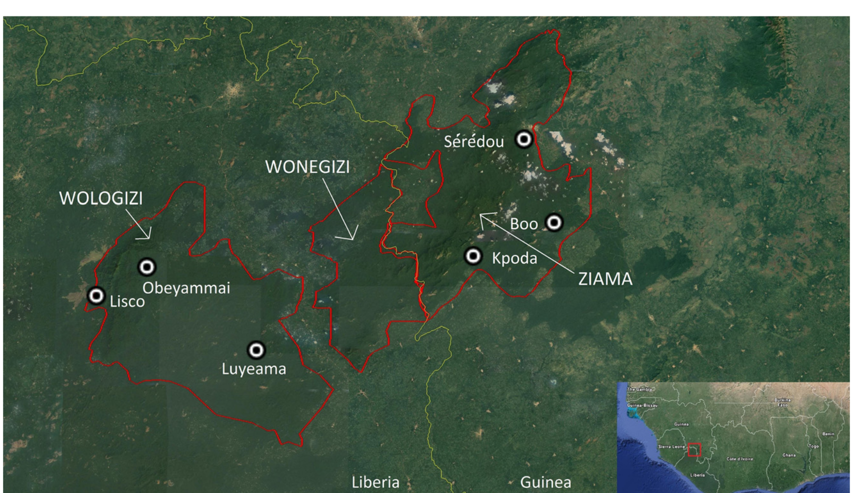

Figure 1: Map of the study area, including the Wologizi National Forest (Luyeama, Obeyammai, Lisco) and the Ziama Man Biosphere Reserve (Sérédou, Boo, Kpoda). The boundary of the Wonegizi National Forest is also shown here but was not surveyed in this study.

selected the sites to maximize the number of habitats and elevational zones as possible within the constraint of difficulty of access of much of the area.

We surveyed small mammals belonging to four different orders: bats (Chiroptera); rodents (Rodentia); shrews (Eulipotyphla); and otter-shrews (Afrosoricida). We captured bats with mist nets (12 × 2.5 m, with 16 mm mesh size, Ecotone, Poland) erected between sunset and 9–11 pm. We deployed nets at suitable bat flight pathways such as streams, gaps between vegetation in the forest, near fruiting trees, or at suspected roosting sites (hollow trees, caves, or crevices). We shifted the location of nets each night and searched for roosting sites during daytime.

We captured rodents using Sherman live traps (7.6 × 9.5 × 30.5 cm, H. B. Sherman Live Traps. Inc, Tallahassee, Florida) set up in line transects consisting of 50–100 traps, with traps set approximately 5 m apart. Each trapline covered as many microhabitats as possible, with at least 200 m distance between traplines at each site. We baited traps with a mixture of peanut butter, oatmeal, palm nuts and raisins, with traps remaining active between four and five consecutive nights at each site. We checked traps twice a day to ensure captured individuals did not remain in traps for long periods of time. We captured *Cricetomys* species using Tomahawk traps in line transects consisting of 10 traps, with traps set approximately 10 m apart. Tomahawk traps were also baited with a mixture of peanut butter, oatmeal, palm nuts, and raisins, with traps remaining active between four and five consecutive nights at each site. The traps were checked daily to ensure captured individuals did not remain in traps for long periods of time. We captured shrews in pitfall traps that were set along transects, each one consisting of 10 buckets (50 cm in depth) spaced 5 m apart and connected with a plastic drift fence. We deployed pitfall traps near rivers and checked them twice a day.

We captured otter-shrews using funnel traps made of mesh wire (Monadjem et al. 2019a). We deployed 50–100 funnel traps along small rivers and streams, with traps remaining active for four consecutive nights. We checked traps twice a day, typically early in the morning and during the night. We handled all captured small mammals in accordance with the guidelines of the American Society of Mammalogy for the ethical and safe treatment of mammals (Sikes 2016). We collected voucher specimens of each species and deposited them in the Eswatini National Museum of Natural History at the Department of Biological Sciences (University of Eswatini, Eswatini) for identification and future reference. We removed the skull from each vouchered specimen, which was then cleaned and stored dry; the rest of the specimen was preserved as a wet specimen in 70% ethanol. Furthermore, we took tissue samples from all captured animals and deposited them in the biobank collections of the South African National Biodiversity Institute, Pretoria, South Africa.

To identify the species to which specimens belonged, we examined each specimen morphologically, and some specimens were further analyzed genetically. We took standard external measurements and weights for all small mammal specimens, which included head-body length, tail length, hindfoot length, ear length and body mass. Furthermore, we also measured the forearm length of bats. We then took several craniodental measurements including for bats: greatest skull length, condyle-incisive length, zygomatic breadth, mastoid breadth, greatest breadth of braincase, narrowest breadth of skull, length of upper toothrow, width across canines, width across upper molars and mandibular length (see Monadjem et al. 2019b for definitions). For rodents and shrews we took: greatest skull length, condyle-incisive length, zygomatic breadth, bimaxillary width (shrews only), upper toothrow (shrews only), length of upper cheekteeth row (rodents only), greatest width across upper molars and mandibular length (Nicolas et al. 2010; Stanley et al. 2000). We did not take all these craniodental measurements for each specimen, but only selected those that could not readily be identified based on other characters. We also noted other features such as the colour and patterning of the fur, shape of nose-leaf, and scales on tail. We then compared our measurements and other features with those in identification guides (e.g. Happold 2013; Happold and Happold 2013; Monadjem et al. 2010, 2015). For pipistrelle-like bats, we followed the taxonomy of Monadjem et al. (2020a).

For all the shrews, some rodents (*Praomys*/*Mastomys*), and some bats (*Hipposideros* cf. *ruber*) and pipistrelloid bats (*sensu* Monadjem et al. 2013b), we also conducted genetic analyses. Genetic identification of the shrews, pipistrelloid bats and *Praomys*/*Mastomys* rodent species were based on sequencing of a region of the Cytochrome *b* (cyt *b*) gene; the details for bats have been published elsewhere (Monadjem et al. 2020a,b), and are repeated here. DNA was extracted from tissue samples using the Quick-DNA™ Miniprep Plus Kit (Zymo Research) following the manufacturer's protocol. For PCR amplification of the cyt *b* region, 2.5 µl of template DNA was used for PCR reactions in a total volume of 15 µl (6.25 µl *Taq* DNA Polymerase 2x Master Mix (Amplicon), 0.5 µl of each primer L14724 (5′- CGAAGCTTGATATGAAAAACCATCGTTG-3′) and H15149 (5′-GCCCCTCAGAATGATATTTGTCCTCA-3′), 0.75 µl BSA and 4.5 µl double-distilled water). The temperature profile was as follows: an initial denaturation at 95 °C for 5 min, 35 cycles of 95 °C for 30 s, 45–50 °C for 30 s, and 72 °C for 1 min, followed by a final extension at 72 °C for 10 min.

In addition, for shrews a region of small subunit ribosomal RNA (16S rRNA) was amplified. For PCR amplification of 16S the following protocol was used: 2.5 µl of template DNA was used for PCR reactions in a total volume of 15 µl (6.25 µl *Taq* DNA Polymerase 2x Master Mix (Amplicon), 0.5 µl of each primer 16SA (5′-CGCCTGTTTAACAAAAACAT-3′) and 16SB (5′-CTCCGGTTTGAACTCAGATCA-3′) (Palumbi et al. 1991; Xiong and Kocher 1991) and 5.25 µl double-distilled water). The temperature profile was as follows: an initial denaturation at 95 °C for 5 min, 35 cycles of 95 °C for 30 s, 55–60 °C for 30 s, and 72 °C for 1 min, followed by a final extension at 72 °C for 10 min. Successful PCR products were purified with Exonuclease I and FastAP (Thermo Fisher Scientific Inc.). Gene fragments were sequenced in both directions using the BigDye® Terminator v3.1 Cycle Sequencing Kit and visualized on a 3500 Genetic Analyzer (Applied Biosystems). Sequence chromatograms were edited and assembled using Sequencing Analysis Software v.6.0 (Applied Biosystems).

Alignment of these sequences for phylogenetic analysis was achieved using MEGA ver. 7 (Kumar et al. 2016). A substitution model of sequence evolution that best fitted the data was estimated in jModelTest ver. 2.1.10 (Posada 2009). To estimate support for internal nodes, 1000 bootstrap replications were run using the same program (Felsenstein 1985; Kumar et al. 2016). Maximum likelihood (ML) (Felsenstein 1981) analysis was conducted using MEGA ver. 7 (Kumar et al. 2016).

Novel cyt *b* sequences were generated for all shrew samples (Supplementary Table S1). However, visual inspection of the chromatograms identified double peaks in both the forward and reverse strands for several samples. Double peaks are polymorphic sequences that can occur due to amplification of distinct genomes, either between mitochondria (heteroplasmy) or between mitochondria and nuclear genomes (numts) (Song et al. 2008). Thus, sequences with double peaks were excluded and the final dataset included 23 shrew samples generated here which were added to 57 ingroup and three outgroup sequences obtained from GenBank. As numts were suspected for cyt *b*, novel 16S sequences were additionally generated for 48 shrew samples (this study) and were added to 68 ingroup and two outgroup sequences obtained from GenBank (Supplementary Table S1). Closely related species were included as outgroups as the accuracy of phylogenetic reconstruction may decrease when more distant outgroups are used (Schneider and Cannarozzi 2009). The model selected for cyt *b* was General Time Reversal (GTR) plus Gamma (G) and Invariable sites (I) and for 16S was Tamura-Nei (TN) plus Gamma (G) and this was used for ML (Felsenstein 1981) analyses implemented in MEGA ver. 7 (Kumar et al. 2016).

Novel cyt *b* sequences for 13 *Praomys* and *Mastomys* samples were generated in this study, and added to 12 ingroup (EU053855, EU740804-EU740806, EU740689, EU740691, EU740695, EU740698, GU144664-6, JQ735657 and JQ735656) and one outgroup sequence (*Rattus norvegicus*, EU349782) obtained from GenBank (Supplementary Table S1). The model selected was GTR plus G and I, and this was used for Maximum Likelihood (ML) (Felsenstein 1981) analyses implemented in MEGA ver. 7 (Kumar et al. 2016).

Finally, novel cyt *b* sequences of six *H. cf. ruber* samples were generated in this study and added to 17 ingroup (EF584226, EU934455, EU934452, EU934475, EU93477, FJ347977, FJ347985, FJ347989, FJ347994, FJ347995, HQ343240, HQ343242, HQ343248, HQ343255, HQ343265, HQ343266 and MH713752) obtained from GenBank (Supplementary Table S1). The model selected was Hasegawa-Kishino-Yano (HKY) plus G and this was used for ML (Felsenstein 1981) analyses implemented in MEGA ver. 7 (Kumar et al. 2016).

Smoothed species accumulation curves were generated for bats, rodents, and shrews captured at Wologizi and Ziama, using the program EstimateS, Version 9.0 (Colwell 2013). These sample-based rarefaction curves were calculated with the 'Mao Tau' function (Colwell et al. 2004). The IUCN Red List status is based on the most recent update available at www.iucnredlist.org (IUCN 2020). Finally, capture effort for bats was calculated as the total net hours per site as 12 m net equivalents, whereas for rodents it was calculated as the total number of Sherman traps and Tomahawk traps per night at each site. Shrew and otter-shrew capture efforts were calculated as the total number of pitfall traps and funnel traps per night at each site, respectively (Table 1).

3 Results

A total of 218 individuals of small mammals belonging to 52 species were captured during the survey, including 26 species of bats, 15 rodents, 10 shrews, and one otter-shrew species (Table 2, Supplementary Table S1). Similar numbers of species were recorded in Wologizi (Liberia) and Ziama (Guinea), totalling 19 and 20 species of bats, 10 and 12 species of rodents, and seven and eight species of shrews, respectively, while the single species of otter-shrew was only recorded from Wologizi (Table 2). Our aim was to keep sampling effort consistent across the sites, but there was some variation for logistical reasons out of our control, and ranged from 12 to 18 net hours for bats, 800–1200 Sherman trap nights for rodents, 40–60 Tomahawk trap nights for *Cricetomys* species, 40–60 pitfall trap nights for shrews and 400–600 funnel trap nights for otter-shrews (Table 1).

The species accumulation curves for bats, rodents, and shrews at both Wologizi and Ziama all appeared to be tapering off although none of them had yet reached an asymptotic plateau (Figure 2). This was particularly evident for rodents at Wologizi and shrews at Ziama which had curves that had tapered off to a large degree; in contrast,

Table 1: The locations of the six survey sites in Wologizi and Ziama forests at which small mammals were captured; also included is the trapping effort for each trap type.

Site	Latitude	Longitude	Altitude (m)	Dates	Bats (net hours)	Rodents (Sherman trap nights)	Rodents (Tomahawk trap nights)	Shrews (pitfall trap nights)	Otter-shrews (funnel trap nights)
Wologizi (Liberia)									
Luyeama	8.02503°N	9.70683°W	422	12–16 May	12	800	40	40	400
Obeyammai	8.14983°N	9.87963°W	609	18–22 May	12	800	40	40	400
Lisco	8.10386°N	9.95792°W	559	24–29 May	15	1,000	50	50	500
Ziama (Guinea)									
Sérédou	8.35806°N	9.29607°W	613	3–7 June	12	800	40	40	400
Boo	8.23072°N	9.24673°W	563	9–14 June	15	1,000	50	50	400
Kpoda	8.17680°N	9.37177°W	534	15–21 June	18	1,200	60	60	600

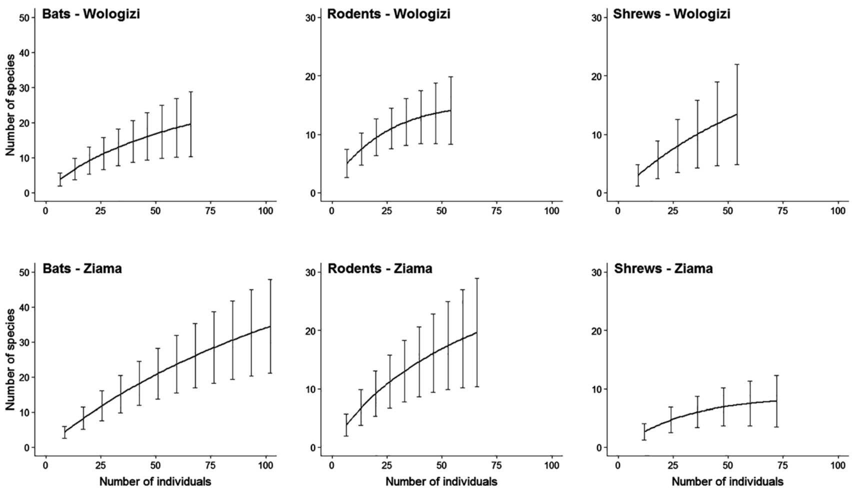

Figure 2: Sample-based species accumulation curves with standard deviations (±SD) for bat, rodent, and shrew species from Wologizi and Ziama Forests.

the species accumulation curves for bats at both sites remained on an upward trend (Figure 2).

In the following section, we present an annotated checklist of small mammal species recorded during this survey.

3.1 Order Chiroptera

3.1.1 Family Pteropodidae

Three pteropodid species were recorded during the survey.

3.1.1.1 *Myonycteris angolensis smithi* (Thomas 1908)

A single female was captured from Sérédou (Guinea). This species has been recorded from the Liberian and Guinean sides of Mt Nimba (Denys et al. 2013; Monadjem et al. 2016). It is restricted to montane forests in this region of West Africa (Coe 1975; Wolton et al. 1982). We follow Nesi et al. (2013) in placing this species in the genus *Myonycteris*.

3.1.1.2 *Myonycteris leptodon* (Andersen 1908)

Six individuals were captured, two females and one male from Sérédou (Guinea) and a single female from Luyeama, Obeyammai, and Lisco (Liberia) respectively. This species has been previously recorded from the Liberian and Guinean side of Mt Nimba (Coe 1975; Denys et al. 2013; Fahr et al. 2006; Monadjem et al. 2016; Verschuren 1977; Wolton et al. 1982). We also followed Nesi et al. (2013) in recognising the West African taxon *M. leptodon* as a separate species from *Myonycteris torquata*, which occurs further east of Africa.

3.1.1.3 *Scotonycteris occidentalis* (Hayman 1947)

One female was captured from Boo (Guinea). This species has been previously recorded from Wologizi (as *Scotonycteris zenkeri*) (Fahr 2013c; Monadjem and Fahr 2007) and Mt Nimba in Liberia (Coe 1975; Monadjem et al. 2016; Verschuren 1977; Wolton et al. 1982). We follow Hassanin et al. (2015) in recognizing *S. occidentalis* as a distinct species restricted to the Upper Guinea rainforest.

3.1.2 Family Hipposideridae

Four hipposiderid species were recorded during the survey.

3.1.2.1 *Doryrhina cyclops* (Temminck 1853)

One male was captured in a cave from Luyeama (Liberia). This species has been previously recorded from Mt Nimba in Liberia (Monadjem et al. 2013a, 2016; Verschuren 1977; Wolton et al. 1982) and Ziama forest in Guinea (Fahr et al. 2006). It has also been previously recorded to the west of Wologizi from Kasewe Forest Reserve (Grubb et al. 1998), and Seli River valley (Decher et al. 2010), both in central Sierra Leone. We follow Foley et al. (2017) in recognizing *Doryrhina* as a distinct genus separate from *Hipposideros*.

3.1.2.2 *Hipposideros jonesi* (Hayman 1947)

Three males were captured, two from Luyeama (Liberia) and one from Sérédou (Guinea). This species has been previously recorded to the west of Wologizi from the Seli River valley in Sierra Leone (Decher et al. 2010), and from Ziama forest in Guinea (Fahr et al. 2006).

3.1.2.3 *Hipposideros marisae* (Aellen 1954)

Three individuals were captured from a cave in Lisco (Liberia), one female and two males. This species has been

Table 2: Overview of the species of small mammals (bats, rodents, shrews, and otter-shrews) captured at six sampling sites in Wologizi (Liberia) and Ziama (Guinea) forests, including their conservation status.

Order/Family/Species		Wologizi			Ziama		
	IUCN red list	Luyeama	Obeyammai	Lisco	Sérédou	Boo	Kpoda
Chiroptera							
Pteropodidae							
Myonycteris angolensis	LC				1		
Myonycteris leptodon	LC	1	1	1	3		
Scotonycteris occidentalis	LC					1	
Hipposideridae							
Doryrhina cyclops	LC	1					
Hipposideros jonesi	NT	2			1		
Hipposideros marisae	VU			3			
Hipposideros cf. *ruber* C1	LC	2				1	
H. cf. *ruber* D1	LC			1			2
H. cf. *ruber* (lineage not assigned)	LC	4	1	10	3	12	2
Rhinolophidae							
Rhinolophus (simulator) alticolus	LC				1	1	
Rhinolophus guineensis	EN		1		2		
Rhinolophus ziama	EN	1			1		
Nycteridae							
Nycteris grandis	LC					1	
Molossidae							
Chaerephon aloysiisabaudiae	LC						2
Mops leonis	LC		2				2
Vespertilionidae							
Glauconycteris poensis	LC			1		1	
Mimetillus moloneyi	LC		4				
Myotis bocagii	LC		2				
Afronycteris nana	LC					3	
Nycticeinops bellieri	NE	1					
Nycticeinops happoldorum	NE		1	1			4
Pseudoromicia brunnea	NT		1		2		1
Pseudoromicia roseveari	EN	1	3				3
Pipistrellus cf. *inexspectatus*	DD						1
Pipistrellus nanulus	LC		3	2			3
Scotophilus nux	LC		1				
Unidentified specimens							2
Miniopteridae							
Miniopterus nimbae	LC	2	1	2			1
Miniopterus villiersi	NT	1		4			3
Rodentia							
Sciuridae							
Funisciurus pyrropus	LC	1					
Gliridae							
Graphiurus lorraineus	LC			1	1		
Graphiurus nagtglasii	LC				1		
Nesomyidae							
Cricetomys cf. *emini*	LC	1	1				1
Cricetomys gambianus	LC						1
Muridae							
Colomys sp. nov.	LC			1			1
Dephomys defua	LC				1		
Hybomys trivirgatus	LC			1			
Hylomyscus simus	LC	1	1	1	1		
Lophuromys sikapusi	LC		1			3	
Malacomys edwardsi	LC		1	1		1	
Mastomys erythroleucus	LC					1	

Table 2: (continued)

Order/Family/Species	IUCN red list	Wologizi			Ziama		
		Luyeama	Obeyammai	Lisco	Sérédou	Boo	Kpoda
Mus setulosus	LC					2	
Praomys rostratus	LC	2	1	4	6	5	
Anomaluridae							
Anomalurus derbianus	LC	1					
Eulipotyphla							
Soricidae							
Crocidura buettikoferi	NT					2	
Crocidura douceti	LC			1			
Crocidura eburnea	LC		4	1		5	1
Crocidura grandiceps	NT		1		1		
Crocidura jouvenetae	LC	1	5		8	2	
Crocidura muricauda	LC	1	1		3	2	3
Crocidura nimbae	NT					1	
Crocidura nimbasilvanus	LC		1				
Crocidura obscurior	LC		1	1			1
Crocidura olivieri	LC				1		
Unidentified specimens			1	1		1	
Afrosoricida							
Potamogalidae							
Micropotamogale lamottei	VU			1			

The latest IUCN Red List status (downloaded in February 2020 from www.iucnredlist.org) is presented. Red List categories: LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered, DD = data deficient, NE = not evaluated.

previously recorded from Mt Nimba on both the Guinean and Liberian sides (Monadjem et al. 2016), and from Ziama forest in Guinea (Fahr et al. 2006).

3.1.2.4 *Hipposideros cf. ruber* (Noack 1893)

We captured a total of 38 individuals belonging to this species complex from all six sites; up to three cryptic species may co-occur sympatrically in West Africa (Monadjem et al. 2013a; Vallo et al. 2008). Six individuals were captured from Luyeama (Liberia), one male from Obeyammai (Liberia), 11 individuals from Lisco (Liberia), three from Sérédou (Guinea), 13 from Boo (Guinea), and four from Kpoda (Guinea) (Table 2). We sequenced six individuals, three of which belonged to lineage C1 and three to D1 (Supplementary Figure S2). Lineages C1 and E1 had previously been reported from Mt. Nimba (Monadjem et al. 2013a), but lineage D1 is reported for the first time from Liberia and Guinea, although it has recently been recorded from Sierra Leone (Weber et al. 2019). This species complex has been widely reported from West African rainforest sites (Fahr et al. 2006; Grubb et al. 1998), but it is not clear how many different species it represents.

3.1.3 Family Rhinolophidae

Three rhinolophid species were recorded during the survey, all of which are endemic to the Upper Guinea rainforest zone.

3.1.3.1 *Rhinolophus (simulator) alticolus* (Sanborn 1936)

Two individuals were captured, one female from a cave in Boo (Guinea) and a single male from Sérédou (Guinea). This species has been previously recorded from the Guinean side of Mt Nimba (Brosset 1985; Denys et al. 2013), and Ziama forest in Guinea (Fahr et al. 2006). It has also been previously recorded in Nigeria and Cameroon (Happold 1987). The taxon *alticolus* may represent a distinct species from *R. simulator* (Csorba et al. 2003; Fahr et al. 2006; Rosevear 1965).

3.1.3.2 *Rhinolophus guineensis* (Eisentraut 1960)

Three individuals were captured, one female from Obeyammai (Liberia) and a single male and female from Sérédou (Guinea). This species has been previously recorded from the Guinean side of Mt Nimba (Brosset 1985;

Denys et al. 2013; Monadjem et al. 2016), and in Sierra Leone (Decher et al. 2010; Grubb et al. 1998). It has also been previously recorded from Ziama forest in Guinea (Fahr et al. 2006).

3.1.3.3 *Rhinolophus ziama* (Fahr et al. 2002)

Two females were captured, one from Luyeama (Liberia) and the other from Sérédou (Guinea). This species was previously only known from just three specimens in Ziama in Guinea, and a single specimen from Wonegizi in Liberia (Fahr et al. 2002). It was subsequently recorded from the Seli River valley in Sierra Leone (Decher et al. 2010).

3.1.4 Family Nycteridae

One nycterid species was recorded during the survey.

3.1.4.1 *Nycteris grandis* (Peters 1865)

One female was captured from a cave in Boo (Guinea). This species has been previously recorded from the Guinean and Liberian sides of Mt Nimba (Aellen 1963; Monadjem et al. 2016; Wolton et al. 1982), as well as from Sierra Leone (Decher et al. 2010; Grubb et al. 1998) and Ziama forest in Guinea (Fahr et al. 2006).

3.1.5 Family Molossidae

Two molossid species were recorded during the survey.

3.1.5.1 *Chaerephon aloysiisabaudiae* (Festa 1907)

Two males were captured from Kpoda (Guinea). This record represents a significant westward range extension for this species, and a new record for Guinea (Fahr 2013b). Both specimens were captured in mist nets erected across the same stream and less than 1 m above the water surface, presumably as they came down to drink. Forearm lengths were 49.8 and 50.0 mm, greatest skull lengths were 21.0 and 21.2 mm, and both had russet pelage typical of this species (Figure 3).

3.1.5.2 *Mops leonis* (Thomas 1908)

Four females were captured, two from Obeyammai (Liberia) and two from Kpoda (Guinea). This species has been previously recorded from Mt Nimba on both the Guinean and Liberian sides (Denys et al. 2013; Monadjem et al. 2016). This species is widely distributed in the Afrotropical forest zone from Sierra Leone to eastern Democratic Republic of Congo and may be distinct from the species *Mops brachypterus*, which is restricted to coastal East Africa and possibly western Uganda (Monadjem et al. 2010; Thorn and Kerbis Peterhans, 2009).

Figure 3: Photograph of *Chaerephon aloysiisabaudiae* from Kpoda (Guinea) showing the russet pelage typical of this species.

3.1.6 Family Vespertilionidae

Eleven vespertilionid species were recorded during the survey, including seven pipistrelloids (sensu Monadjem et al. 2013b) in the genera *Afronycteris*, *Pseudoromicia*, *Nycticeinops* and *Pipistrellus*.

3.1.6.1 *Glauconycteris poensis* (Gray 1842)

Two individuals were captured, one male from Boo (Guinea), and one female from Lisco (Liberia). This species has been previously recorded from Mt Nimba in Liberia (Monadjem et al. 2016), and Ziama Forest in Guinea (Fahr et al. 2006) and occurs widely in the tropical rainforest belt of Africa (Hassanin et al. 2018).

3.1.6.2 *Mimetillus moloneyi* (Thomas 1891)

Four individuals were captured from Obeyammai (Liberia), all females. This species has been previously recorded from both the Guinean and Liberian side of Mt Nimba (Monadjem et al. 2016), and from Ziama Forest in Guinea (Fahr et al. 2006).

3.1.6.3 *Myotis bocagii* (Peters 1870)

Two individuals were captured from Obeyammai (Liberia), one male and one female. The female was captured from inside the leaves of a banana tree. This species, which has a wide African distribution, has been previously recorded from Sierra Leone (Decher et al. 2010; Grubb et al. 1998), and on the Liberian side of Mt Nimba (Monadjem et al.

2016). It has also been previously recorded from Ziama Forest in Guinea (Fahr et al. 2006).

3.1.6.4 *Afronycteris nana* (Peters 1852)

A single male and two females were captured from Boo (Guinea). This species, which has a wide distribution across sub-Saharan Africa, has been previously recorded from the Liberian and Guinean side of Mt Nimba (Brosset 1985; Fahr et al. 2006; Monadjem et al. 2016; Wolton et al. 1982), and from Ziama Forest in Guinea (Fahr et al. 2006). We follow Monadjem et al. (2020a) in recognising the newly described genus *Afronycteris*; this species was previous placed in the genus *Neoromicia*.

3.1.6.5 *Pseudoromicia brunnea* (Thomas 1880)

Four individuals were captured, one female from Obeyammai (Liberia), one male from Kpoda (Guinea), and a male and female from Sérédou (Guinea). This species has been previously recorded from the Liberian side of Mt Nimba (Monadjem et al. 2013b, 2016). This is the first record of this species from Guinea (Fahr 2013a). We follow Monadjem et al. (2020a) in recognising the newly described genus *Pseudoromicia*; this species was previous placed in the genus *Neoromicia*.

3.1.6.6 *Pseudoromicia roseveari* (Monadjem et al. 2013)

Seven individuals were captured, two males and one female from Kpoda (Guinea), a single female from Luyeama (Liberia), and two males and a female from Obeyammai (Liberia). This recently described species, has been previously recorded from the Liberian side of Mt Nimba (Monadjem et al. 2013b), and in north-eastern Guinea (Decher et al. 2015). The species is currently only known from the Upper Guinea rainforest zone. We follow Monadjem et al. (2020a) in recognising the newly described genus *Pseudoromicia*; this species was previous placed in the genus *Neoromicia*.

3.1.6.7 *Nycticeinops bellieri* (De Vree 1972)

One female was captured from Luyeama (Liberia). This species has been previously recorded from the Liberian side of Mt Nimba (as *Hypsugo bellieri*) (Monadjem et al. 2013b, 2016), and from Ziama Forest in Guinea (Fahr et al. 2006). This species is restricted to the Upper Guinea rainforest. We follow Monadjem et al. (2020a) in placing this species in the genus *Nycticeinops*; this species was previous placed in the genus *Parahypsugo*, which itself was only recently described (Hutterer et al. 2019).

3.1.6.8 *Nycticeinops happoldorum* (Hutterer et al. 2019)

Six individuals of this newly described species (Hutterer et al. 2019) were captured, three females and a male from Kpoda (Guinea), and one female from each of Obeyammai (Liberia) and Lisco (Liberia). This species (as *Neoromicia* sp.) has been previously recorded from the Liberian side of Mt Nimba (Monadjem et al. 2013b) and the Simandou range in Guinea (Hutterer et al. 2019). We follow Monadjem et al. (2020a) in placing this species in the genus *Nycticeinops*; this species was previous placed in the genus *Parahypsugo*.

3.1.6.9 *Pipistrellus cf. inexspectatus* (Aellen 1959)

A single female was captured from Kpoda (Guinea). This species closely resembles *Pipistrellus inexspectatus* in external appearance (bicoloured fur) and size (forearm length = 34.0 mm), as well as craniodental measurements (greatest skull length = 13.0 mm, length from canine to third molar = 4.60 mm, and width across the third molar = 5.30 mm). However, this individual did not have a white trailing edge to the wing membrane and therefore it is not clear whether it represents *P. inexspectatus*. Rosevear (1965) suggested that this white training edge may be variable in this species. If demonstrated to be *P. inexspectatus*, this would be a new record for Guinea.

3.1.6.10 *Pipistrellus nanulus* (Thomas 1904)

Eight individuals were captured, two males and three females from Obeyammai and Lisco (Liberia), and two females and a male from Kpoda (Guinea). This species has been previously recorded from the Liberian side of Mt Nimba (Hill 1982; Monadjem et al. 2013b, 2016; Wolton et al. 1982) and south-eastern Guinea (Fahr et al. 2006).

3.1.6.11 *Scotophilus nux* (Thomas 1904)

A single female was captured from Obeyammai (Liberia). This species has been previously recorded from the Liberian side of Mt Nimba (Monadjem et al. 2016; Wolton et al. 1982) and south-eastern Guinea (Fahr et al. 2006).

3.1.7 Family Miniopteridae

Two miniopterid species were recorded during the survey.

3.1.7.1 *Miniopterus nimbae* (Monadjem et al. 2019)

Six individuals were captured, one male from Kpoda (Guinea) and two males from Luyeama, two males from Lisco, and a single male from Obeyammai (Liberia). This recently described species appears to be endemic to the upland border zone between Guinea and Liberia (Monadjem et al. 2019b). It was previously referred to as *Miniopterus* aff.

inflatus (Fahr et al. 2006) and is known from the Liberian side of Mt Nimba (as *M. inflatus*) (Monadjem et al. 2016).

3.1.7.2 *Miniopterus villiersi* (Aellen 1956)

Eight individuals were captured, three males from Kpoda (Guinea), a single female and three males from Lisco (Liberia), and one male from Luyeama (Liberia). This species has been previously listed as a subspecies of *Miniopterus schreibersii* (Kuhl 1817; Wilson and Reeder 2005), however Monadjem et al. (2019b) demonstrated that it represents a distinct species restricted to the Upper Guinea rainforest zone. It has been previously recorded from Seli River valley in Sierra Leone (Decher et al. 2010) and from Ziama Forest in Guinea (Fahr et al. 2006).

3.2 Order Rodentia

3.2.1 Family Sciuridae

One sciurid species was recorded during the survey

3.2.1.1 *Funisciurus pyrropus* (F. Cuvier 1833)

One female was captured from Luyeama (Liberia). This species has been previously recorded from the Liberian side of Mt Nimba (Coe 1975), and from North Lorma (Wologizi mountains) in Liberia (Monadjem and Fahr 2007).

3.2.2 Family Gliridae

Two glirid species were recorded during the survey.

3.2.2.1 *Graphiurus lorraineus* (Dollman 1910)

Two individuals were captured, one female from Lisco (Liberia) and one male from Sérédou (Guinea). This species has been previously recorded from Mt Nimba (Heim de Balsac 1958), under the name *Graphiurus murinus spurrelli*.

3.2.2.2 *Graphiurus nagtglasii* (Jentink 1888)

One female was captured from Sérédou (Guinea). This species has been previously recorded from Mt Nimba (Heim de Balsac 1958), under the name *Graphiurus hueti nagtglasii*.

3.2.3 Family Nesomyidae

Two nesomyid species were recorded during the survey

3.2.3.1 *Cricetomys* cf. *emini*

Three females were captured using Tomahawk traps. Two females were captured from Luyeama and Obeyammai (Liberia) and one female was captured from Kpoda (Guinea). This species has been previously recorded from Sierra Leone in Seli River Valley (Decher et al. 2010). This unnamed species, which appears to be restricted to the Upper Guinea rainforest zone, has been shown to be genetically distinct from *C. emini* which occurs in the Congo basin (Olayemi et al. 2012).

3.2.3.2 *Cricetomys gambianus* (Waterhouse 1840)

One female was captured from Kpoda (Guinea) using Tomahawk traps. This species has been previously recorded from Seli River valley in Sierra Leone (Weber et al. 2019), and from the Liberian side of Mt Nimba (Coe 1975). This species has been reported to typically occur in grassland, woodland, and anthropogenic habitats in the northern savannas of West and Central Africa (Monadjem et al. 2015).

3.2.4 Family Muridae

Nine murid species were recorded during the survey

3.2.4.1 *Colomys* sp. nov.

Two males were captured from Lisco (Liberia) and Kpoda (Guinea). Previously, this species was known in West Africa by just a single specimen captured in Wonegizi in 1990 by R. W. Dickerman (Koopman et al. 1995). Dieterlen (2013) suggested that it may represent a new taxon, and recent genetic and morphological analyses support this hypothesis and a new taxon has recently been described (Giarla et al. 2020).

3.2.4.2 *Dephomys defua* (Miller 1900)

One male was captured from Sérédou (Guinea). This species has been previously recorded from Mt Nimba in Liberia (Coe 1975) and south-eastern Guinea (Roche 1971).

3.2.4.3 *Hybomys trivirgatus* (Temminck 1853)

One female was captured from Lisco (Liberia). This species has been previously recorded from the Liberian side of Mt Nimba (Coe 1975) and south-eastern Guinea (Roche 1971).

3.2.4.4 *Hylomyscus simus* (Allen and Coolidge 1930)

Four individuals were captured, one male from Sérédou (Guinea), one male from Luyeama, one female from Obeyammai, and one male from Lisco (Liberia). This species has been previously widely recorded in the Upper Guinea forest zone (Nicolas et al. 2020).

3.2.4.5 *Lophuromys sikapusi* (Temminck 1853)

Four individuals were captured, two females and one male from Boo (Guinea), and one female from Obeyammai (Liberia). This species has been previously recorded from Seli River valley in Sierra Leone (Decher et al. 2010; Weber et al. 2019), and from the Liberian side of Mt Nimba (Coe 1975). It has also been previously recorded from Mt Loma in Sierra Leone (Heim de Balsac 1971).

3.2.4.6 *Malacomys edwardsi* (Rochebrunne 1885)

Three individuals were captured, two males from each of Obeyammai and Lisco (Liberia) and one female from Boo (Guinea). This species has been previously recorded from Seli River valley in Sierra Leone (Decher et al. 2010; Weber et al. 2019), from the Liberian side of Mt Nimba (Coe 1975), and south-eastern Guinea (Roche 1971). It has also been previously recorded from the Atewa Range Forest Reserve, Eastern Region, Ghana (Weber and Fahr 2004).

3.2.4.7 *Mastomys erythroleucus* (Temminck 1853)

A single female of this species was confirmed by genetic analysis (Supplementary Figure S1) to be present at Boo (Guinea), where it was sympatric with *Praomys rostratus* (Table 2). This specimen was captured in a forest clearing that was being used for subsistence agriculture. The trap was alongside a maize field in grassland.

3.2.4.8 *Mus setulosus* (Peters 1876)

A single male and female were captured from Boo (Guinea). This species has been previously recorded from Sierra Leone (Decher et al. 2010; Grubb et al. 1998; Weber et al. 2019), and from the Liberian side of Mt Nimba (Coe 1975). It has also been previously recorded from Mt Loma in Sierra Leone (Heim de Balsac 1971).

3.2.4.9 *Praomys rostratus* (Miller 1900)

A total of 18 individuals were confirmed by genetic analysis to belong to this species (Supplementary Figure S1), making it the most caught rodent species in this survey. This included five males from Boo (Guinea), one female and five males from Sérédou (Guinea), three females and one male from Lisco (Liberia), one female from Obeyammai (Liberia), and two females from Luyeama (Liberia), and hence occurred at five of the six survey sites. This species has been previously recorded from Sierra Leone in Seli River Valley (Decher et al. 2010; Grubb et al. 1998; Weber et al. 2019). Previous work has shown that *P. rostratus* co-occurs with *Praomys tullbergi* (a morphologically similar species) at Ziama, and both have been captured in rainforest habitats although *P. rostratus* appears to be less restrictive in its habitat requirements (Akpatou et al. 2007; Nicolas et al. 2008). We could not confirm the presence of *P. tullbergi* in our study.

3.2.5 Family Anomaluridae

One anomalurid species was recorded during the survey.

3.2.5.1 *Anomalurus derbianus* (Gray 1842)

One individual was observed and photographed moving up one tree trunk and then gliding to a neighbouring tree at Luyeama (Liberia). This species has been previously recorded from Mt Nimba in Liberia (Coe 1975).

3.3 Order Eulipotyphla

3.3.1 Family Soricidae

Ten soricid species were recorded during the survey, all confirmed by genetic analysis (Figure 4 and Supplementary Figure S3).

3.3.1.1 *Crocidura buettikoferi* (Fraser 1842)

A male and a female, confirmed by genetic analysis (Figure 4), were captured, from Boo (Guinea). This species has been previously recorded from the Liberian side of Mt Nimba (Monadjem unpublished data). This species is in the "*poensis*" group and is endemic to the Upper Guinea rainforest zone (Nicolas et al. 2019).

3.3.1.2 *Crocidura douceti* (Heim de Balsac 1958)

A single male from Lisco (Liberia), was confirmed by genetic analysis to represent this poorly known species. As in *Crocidura muricauda*, it has a long tail and these two species are difficult to distinguish morphologically. It has previously been recorded from the Guinean side of Mt. Nimba (Jacquet et al. 2012), but this represents the first record of this species for Liberia.

3.3.1.3 *Crocidura eburnea* (Heim de Balsac 1958)

Eleven individuals were captured and confirmed by genetic analysis (Figure 4). Four males were captured from Obeyammai (Liberia), five individuals were captured from Boo (Guinea), a single male and female were captured from Kpoda (Guinea) and Lisco (Liberia) respectively. This species is genetically closely related to *Crocidura obscurior* (Jacquet et al. 2014), from which it cannot be readily distinguished on morphological grounds. These two species were captured sympatrically at Obeyammai (Liberia), Lisco (Liberia) and Kpoda (Guinea) (Table 2).

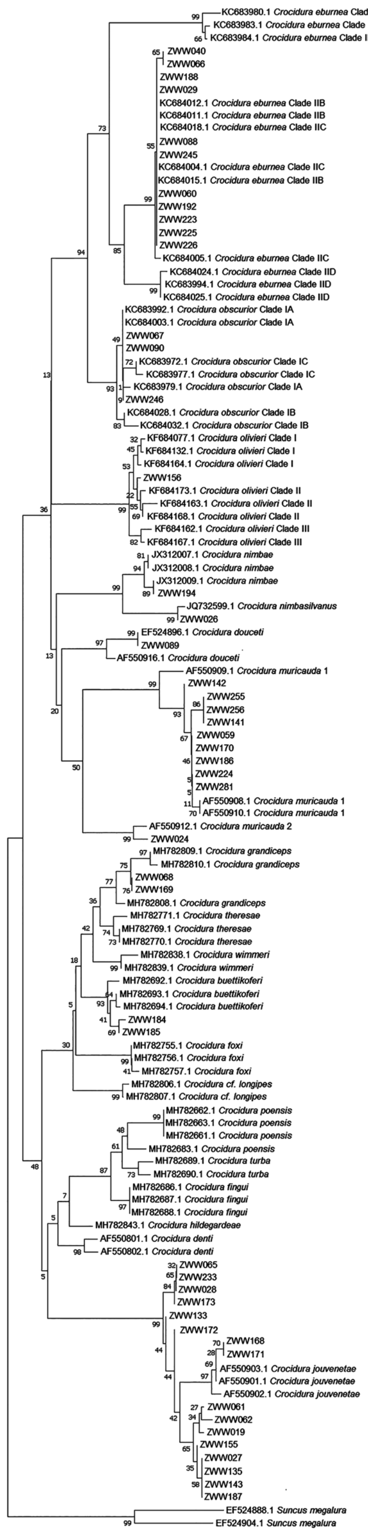

Figure 4: Phylogenetic tree of shrews based on a region of the small subunit ribosomal RNA (16S rRNA) inferred using the maximum likelihood method based on the Tamura-Nei (TN) model.

3.3.1.4 *Crocidura grandiceps* (Hutterer 1983)

Two specimens of this species were confirmed by genetic analysis from Obeyammai (Liberia) and Sérédou (Guinea) (Figure 4). This difficult to identify species belongs to the "*poensis*" group (Igbokwe et al. 2019; Nicolas et al. 2019). It co-occurs with another member of the "*poensis*" group *C. buettikoferi* in the ZWW landscape although the two species were not collected at the same site (Table 2). The Liberian record represents a new record from that country.

3.3.1.5 *Crocidura jouvenetae* (Heim de Balsac 1958)

Sixteen individuals were captured and confirmed by genetic analysis (Figure 4). Five individuals were from Obeyammai (Liberia), eight individuals from Sérédou (Guinea), a single female from Luyeama (Liberia), and a single male and female from Boo (Guinea). This species has been previously recorded from Seli River valley in Sierra Leone (Decher et al. 2010) and Guinean side of Mt Nimba (Jacquet et al. 2012).

3.3.1.6 *Crocidura muricauda* (Miller 1900)

Ten individuals (all confirmed by genetic analysis, Figure 4) were captured, two females from Boo (Guinea), a female and two males from Kpoda (Guinea), a female and two males from Sérédou (Guinea), a single female from Obeyammai (Liberia), and one male from Luyeama (Liberia). Of these, nine individuals cluster with the "*muricauda* 1" lineage and one with "*muricauda* 2" lineage (Jacquet et al. 2012). This species has been previously recorded from North Lorma (Wonegizi Mountains) in Liberia (Monadjem and Fahr 2007). It forms a species complex with at least two genetically divergent lineages occurring in West Africa (Jacquet et al. 2012), and is closely related to *C. douceti*, which was also captured during this survey (see below).

3.3.1.7 *Crocidura nimbae* (Heim de Balsac 1956)

A single female, confirmed by genetic analysis (Figure 4), was captured from Boo (Guinea). It has previously been recorded from a restricted area in eastern Sierra Leone, south-eastern Guinea, Liberia, and western Côte d'Ivoire and is listed as globally "Near-Threatened" (IUCN 2020; Jacquet et al. 2013).

3.3.1.8 *Crocidura nimbasilvanus* (Hutterer 2003)

A single female, confirmed by genetic analysis (Figure 4), was captured from Obeyammai (Liberia). This species has been recently described as a new species (Jacquet et al. 2013).

3.3.1.9 *Crocidura obscurior* (Heim de Balsac 1958)

Three individuals were captured and confirmed by genetic analysis (Figure 4) as belonging to this species. A single male from Lisco (Liberia), one female from Obeyammai (Liberia), and one male from Kpoda (Guinea). This species is closely related to *C. eburnea* from which it cannot be distinguished morphologically (see previous species account for more details).

3.3.1.10 *Crocidura olivieri* (Lesson 1827)

One male was captured from Sérédou (Guinea) and confirmed by genetic analysis (Figure 4). *C. olivieri* represents a species complex with at least three distinct and deeply divergent lineages occurring in West Africa (Jacquet et al. 2015). Our single specimen groups with Clade 1, which occurs widely in the Upper Guinea forest zone (Jacquet et al. 2015), including the Seli River valley in Sierra Leone (Weber et al. 2019).

3.4 Order Afrosoricida

3.4.1 Family Potamogalidae

One potamogalid species was recorded during the survey.

3.4.1.1 *Micropotamogale lamottei* (Heim deBalsac 1954)

A single female was captured from Lisco (Liberia). This species has been previously recorded from the Liberian side of Mt Nimba with a single record from Sérédou in the Ziama forest (Guinea) (Coe 1975; Decher et al. 2016; Monadjem et al. 2019a; Vogel 1983). This species is restricted to the upland areas surrounding the border zone between Guinea and Liberia centred on Mt. Nimba, with outlying records from Putu Hills (Liberia) (Decher et al. 2016; Monadjem et al. 2019a,b). Hitherto, this species has not been previously recorded from Wologizi forest (Liberia), but had been previously predicted to occur there (Monadjem et al. 2019a,b). This species is listed as Vulnerable (IUCN 2020).

4 Discussion

Our results show that the Ziama-Wonegizi-Wologizi (ZWW) rainforest landscape harbours a species-rich small mammal fauna. We confirmed the presence of 52 species of small mammals, including 26 bats (Chiroptera), 15 rodents (Rodentia), 10 shrews (Eulipotyphla), and one otter-shrew (Afrosoricida). We documented similar numbers of species at Wologizi and Ziama, probably reflecting the presence of similarly diverse habitats in these two forests, but species composition appeared to differ, underscoring the importance of conserving both forests within the ZWW rainforest landscape. A few specimens could not be identified to species level and potentially represent species not reported in this paper. This includes three shrews that could not be sequenced, and which were tentatively identified as *C. jouvenetae, C. eburnea* and *C. olivieri* (however, the presence of all three species was confirmed by genetic analysis from other specimens). Two bats could also not be identified to species based on morphological features and were not sequenced; one was tentatively identified as a *Neoromicia* species and the other as *Pipistrellus* species. All other specimens of small mammals were identified to species level by either molecular or morphological analysis.

Based on the results of our survey, we significantly increased the number of bat and terrestrial small mammal species known to occur in the Wologizi Forest. Previously, just seven species of bats had been documented from this forest (Monadjem and Fahr 2007), compared with the 19 species recorded in this study. However, there were several species of bats (*Nanonycteris veldkampii*, *M. torquata*, *Nycteris arge*, *Hipposideros fuliginosus*, *Hipposideros beatus*) that were documented from Wologizi in previous surveys (Monadjem and Fahr 2007), but not recorded during this study, increasing the total number of bats documented for this site to 24 species.

The number of bats documented from Ziama Forest for this study was less than previously documented for this area (20 vs 30 species, Fahr et al. 2006). However, we added four species (*P. brunnea*, *P. roseveari*, *N. happoldorum*, *C. aloysiisabaudiae*) that were not recorded previously, increasing the total number of bats recorded from Ziama to 34 species. Although the diversity of bats at Ziama is high, it still is relatively low compared with Mt. Nimba which currently stands at 59 species (Monadjem et al. 2016).

In addition, we documented several interesting bats from Wologizi and Ziama. For example, we report the first records of *P. brunnea*, *P.* cf. *inexspectatus*, and *C. aloysiisabaudiae* from Guinea (Fahr 2013a, 2013b; Monadjem et al. 2013b). We also documented important range extensions for several recently described and poorly known species. Wologizi represents the fourth known locality for the globally "Endangered" *R. ziama* (IUCN 2020). Furthermore, *N. happoldorum*, which was only described in 2019, was previously only known from Simandou

Mountains in Guinea and Mt. Nimba in Liberia (Hutterer et al. 2019); our recent records from Wologizi and Ziama, therefore, represent the third and fourth known localities for this species and a relatively significant range extension. We also report the occurrence of the *H.* cf. *ruber* lineage D1 from both Liberia and Guinea for the first time; previous records are from Senegal and Sierra Leone (Vallo et al. 2011; Weber et al. 2019).

Similarly, we also increased the number of rodent and shrew species known to occur in the region. Previously, five rodent and two shrew species had been documented from Wologizi Forest (Monadjem and Fahr 2007), compared with 10 rodents (*F. pyrropus*, *G. lorraineus*, *C.* cf. *emini*, *Colomys* sp. nov., *H. trivirgatus*, *H. simus*, *L. sikapusi*, *M. edwardsi*, *P. rostratus, A. derbianus*) and seven shrews (*C. douceti*, *C. eburnea*, *C. grandiceps, C. jouvenetae*, *C. muricauda*, *C. nimbasilvanus*, *C. obscurior*) from this study. Two of the shrew species represent new country records for Liberia: *C. douceti* and *C. grandiceps*. In addition, there are three rodent species (*Heliosciurus rufobrachium*, *Paraxerus poensis*, *Protoxerus stangeri*) that were recorded from Wologizi before (Monadjem and Fahr 2007), but not recorded during this survey, increasing the total number to 13 species. Roche (1971) recorded 28 species of rodents from Sérédou (Ziama Forest) over a three-year survey (Denys et al. 2009) compared with the 12 species recorded during this survey. This is similar to the total number of rodents recorded and published from Mt. Nimba which currently stands at 29 species (Coe 1975; Denys et al. 2009; Gautun et al. 1986), although recent unpublished surveys suggest that this figure is a gross under-representation (C. Denys and A. Monadjem, unpublished data). In any case, the rodent community in Ziama now represents one of the most diverse in West Africa.

We also documented an undescribed species of rodent during this survey, *Colomys* sp. nov. We captured one specimen each from Wologizi and Ziama. There is a single prior record of *Colomys* from the entire Upper Guinea forest region, at Wonegizi Mountains (Koopman et al. 1995). These three individuals are genetically and morphologically distinct from *Colomys goslingi* (Giarla et al. 2020). The nearest population of *Colomys* to the one at ZWW is from Cameroon, 2200 km to the east (Monadjem et al. 2015), demonstrating the relictual nature of this newly discovered population.

We were able to identify unequivocally 10 species of shrews from Wologizi and eight species from Ziama. Previously, just two species were known from Wologizi (Monadjem and Fahr 2007), both of which were also captured during this survey. The latter study did not use pitfall traps, which would explain the low species richness recorded. By comparison, an intensive and long-term pitfall study conducted at Ziama recorded 11 species (Nicolas et al. 2009), which is only slightly more than the diversity that we report.

Finally, we recorded the presence of the globally “Vulnerable” otter-shrew *M. lamottei* in Wologizi (IUCN 2020). This represents the third locality in Liberia, and the fourth globally for this threatened and highly range-restricted species (Monadjem et al. 2019a). This species was previously recorded from Ziama (Vogel 1983). Therefore, it is possible that it also occurs in the Wonegizi Mountains which lie between Wologizi and Ziama; hence, future surveys to this mountain range are suggested.

The small mammal community of the ZWW landscape was comprised almost entirely of forest-dwelling species, with only a few savanna species having been captured. For example, we captured *C. gambianus*, which is a savanna species (Olayemi et al. 2012), at just one site in Ziama, while the forest associated *C.* cf. *emini* (Olayemi et al. 2012) was captured from several sites in both Guinea and Liberia. Similarly, all but one of the shrews (*C. olivieri*) were forest dependent species. Bats dominated the number of small mammal species in this forested landscape, which is not unusual in the Upper Guinea forests (Monadjem and Fahr 2007; Weber et al. 2019). Most of the bats recorded were forest associated species, with some species (e.g. *R. guineensis, R. ziama, R. alticolus, H. jonesi, H. marisae, H.* cf. *ruber, D. cyclops, N. grandis, M. villiersi*) known to depend on caves as day roosts (Decher et al. 2010; Monadjem et al. 2016).

We captured several threatened species from Wologizi and Ziama forests during this survey. At Wologizi, we recorded three ‘Endangered’ (*R. guineensis, R. Ziama, N. roseveari*), two ‘Vulnerable’ (*H. marisae, M. lamottei*) and three ‘Near-Threatened’ (*H. jonesi*, *P. brunnea*, *M. villiersi*, *C. grandiceps*) small mammal species. Similarly, at Ziama we recorded the same three species as ‘Endangered’ and ‘Near-Threatened’ as well as a fourth species (*C. buettikoferi*) also ‘Near-Threatened’, but no ‘Vulnerable’ species. This demonstrates the importance of these two forests for the conservation of threatened small mammals.

In conclusion our results show that the ZWW landscape harbours a diverse small mammal assemblage, with several species endemic to the area. Furthermore, we recorded at least one species new to science (*Colomys* sp. nov.), and six new country records (see above). Hence, we have demonstrated that the ZWW landscape is of considerable importance for biodiversity conservation and should be highlighted for urgent and immediate protection.

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