International Journal of Zoology and Applied Biosciences **ISSN: 2455-9571**
Volume 7, Issue 6, pp: 24-31, 2022
https://doi.org/10.55126/ijzab.2022.v07.i06.004
http://www.ijzab.com

Research Article

SPECIES RICHNESS AND ABUNDANCE OF SMALL MAMMALS FROM NIMBA REGION, NORTHEASTERN LIBERIA

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Article History: Received 17th August 2022; Accepted 21st October 2022; Published 4th November 2022

ABSTRACT

This study was carried out in a biodiversity hotspot within the Nimba region located in the northeastern part of Liberia. The Nimba region is known to harbor exceptional fauna diversity. However, the small mammal communities in Nimba region are poorly documented. The aim of this study was to determine the species richness and relative abundance of rodents and shrews in five sites: Bento, East Nimba, Gangra-Yuelliton, Tokadeh and Vayampah. A total of 244 individual of small mammals comprising 18 species were trapped on 4,375 trap nights. Rodent species recorded include: *Arvicanthis rufinus*, *Dephomys defua*, *Grammomys buntingi*, *Graphiurus lorraineus*, *Hybomys planifrons*, *Hybomys trivirgatus*, *Hylomyscus simus*, *Lemniscomys striatus*, *Lophuromys sikapusi*, *Malacomys edwardsi*, *Mastomys erythroleucus*, *Mus muscoloides*, *Mus setulosus* and *Praomys rostratus*. Shrew species were *Crocidura eburnea*, *Crocidura jouvenetae*, *Crocidura muricauda* and *Crocidura obscurior*. The most dominant species was *Hylomyscus simus* (22.95%), followed by *Praomys rostratus*, *Crocidura muricauda* and *Crocidura eburnea*. The highest species richness was recorded at Gangra-Yuelliton and lowest at Tokadeh. Diversity indexes were higher at East nimba (H' = 2.01; 1-D = 0.82) and Gangra-Yuelliton (H' = 2.00; 1-D = 0.83) and lower at Tokadeh (H' = 1.57; 1-D = 0.75). Similarity index revealed high resemblance in species composition between Bento and Vayampah. The lowest similarity was observed between Tokadeh and Gangra-Yuelliton. This study highlighted the high biological diversity of small mammal communities in Liberia's Mount Nimba region. Thus, this zoological group should now be taken into account in the biodiversity conservation strategies of Mount Nimba.

Keywords: Small mammal community, Rodentia, Shrew, Diversity index, Rainforest, West Africa.

INTRODUCTION

Mount Nimba area located at the triple frontier point between Guinea, Liberia and Côte d'Ivoire, forms part of the Guinean forests of West Africa biodiversity hotspot. This indicates that as well as having great biodiversity, it is also considered to be an area where the biodiversity is under threat (Conservation International, 2001; Arcelor Mittal, 2010). The Nimba region is known to harbor several species of conservation concern and also a large number of endemic or near-endemic species, which include several small mammal species, such as shrews *Crocidura nimbae*, *Crocidura goliath nimbasilvanus*, *Crocidura jouvenetae*, *Crocidura obscurior*, *Crocidura eburnea* (Jacquet *et al*., 2012; Denys *et al*., 2021), rodent *Dendromus lachaisei* (Denys and Aniskine, 2012), bats *Hipposideros lamottei*, *Neoromicia roseveari* (Monadjem *et al*., 2016) and the Afrosoricid *Micropotamogale lamottei* (Monadjem *et al*., 2019).

Despite this exceptional biological diversity, the rainforest of Nimba region is one of the most threatened

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Upper Guinea forests, with large plantations of cash crops (cocoa, coffee, rubber, and oil palm cultures), mining and illegal timber extraction (Arcelor Mittal, 2010; Enaruvbe *et al*., 2019). Deforestation and fragmentation of natural habitats can cause serious dysfunctions within ecosystems, such as the reduction in species diversity and increased risk of extinction of forest-specialist species, as these species require specific habitat structure and quality (Bregman *et al*., 2014; Ofori *et al*., 2015; Skupien *et al*., 2022). Forest fragmentation alter also habitat structure, which affects the community structure of small mammal species (Lema and Magige, 2018; Ssuuna *et al*., 2020).

Small mammals are the most diverse group of the African mammalian fauna (Denys *et al*., 2001). They are essential components of the forest ecosystems. They play important roles in seed and fungus dispersals (Wang and Ives, 2017; Stephens and Rowe, 2020; Benedek *et al*., 2021), soil aeration through digging and burrowing (Wilske *et al*., 2015), and are known to be an important food sources for many mammal predators, including raptors, snakes and small carnivores (Angelici and Luiselli, 2005). In addition, their reduced longevity, offset by strong population dynamics, enables them to react quickly to environmental conditions changes and habitat fragmentation (Manning and Edge, 2008). Thus, the species richness and abundance of small mammals are regularly used to measure the level of disturbance of different tropical forests (Avenant, 2011; Ademola *et al*., 2022; Skupien *et al*., 2022). Several studies have been conducted on mammalian diversity in Nimba rainforests in Liberia. Most of these studies were focused on large mammals (Bene *et al*., 2013), bats (Monadjem *et al*., 2013; Monadjem *et al*., 2016), shrews (Verschuren and Meester, 1977; Denys *et al*., 2021) and Nimba otter-shrew (Decher *et al*., 2016; Monadjem *et al*., 2019). Thus, species composition and abundance of small mammals in Nimba region in Liberia remind poorly documented. The aim of this study was to gather information on species richness, abundance, and composition of small mammal communities in five locations of the northern Nimba region in Liberia.

MATERIALS AND METHODS

Study area

Nimba region is located in the northeastern part of Liberia and shares borders with the Republic of Côte d'Ivoire in the East, and the Republic of Guinea in the Northwest. The Nimba region covers an area of 2,300 km^2. The most distinctive landforms of Nimba region are the Nimba Range of mountains. These are dominated by a ridge which runs 40 km in a north-east to south-west direction along the Guinean- Ivorian border. The mountains' highest point is 1752 m above sea level. In Nimba region the significant but isolated peaks of Tokadeh, Beeton and the twin peaks of Gangra and Yuelliton lie to the west of the main Nimba ridge. Rivers Khan and Dayea drain the area with many creeks. The local climate is tropical with an average annual rainfall of about 1800 mm. The region is characterized by two climatic seasons: the rainy season starts in May and end in October, and the dry seasons' starts in November and end in April. The annual mean temperature varies between 23˚C and 27.5˚C. The biodiversity of the Nimba region is considered to be of global importance. Indeed, this region harbors numerous species of conservation concern and also a large number of endemic species (Arcelor Mittal, 2010; Enaruvbe *et al*., 2019). Rodents and shrews were inventoried in five separate locations including Bento, East Nimba (reserve), Grangra-Yuelliton, Tokadeh and Vayampah, in the northern part of Nimba region in Liberia (Figure 1). Small mammals were captured in primary forests at three sites including Bento, East Nimba (reserve) and Vayampah, while at Grangra-Yuelliton and Tokadeh, animals were caught in secondary forests. However, the secondary forest of Grangra-Yuelliton was less disturbed than that of Tokadeh.

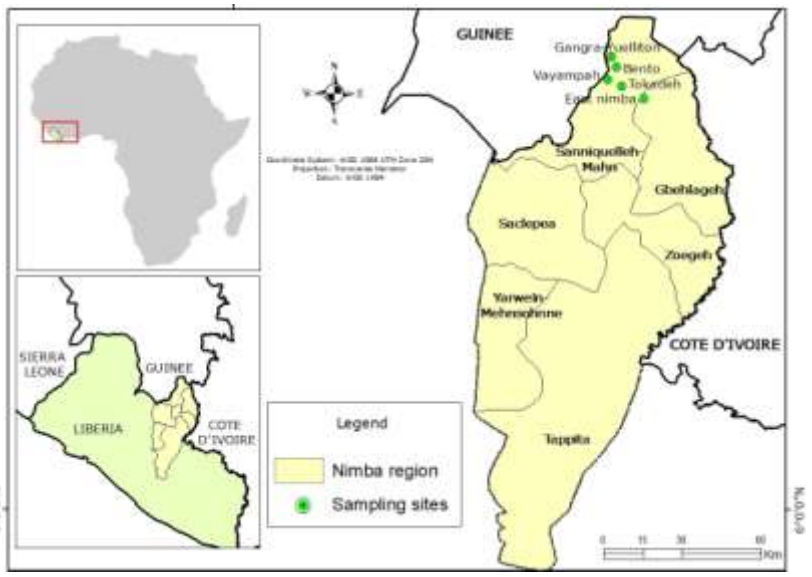

Figure 1. Location of sampling sites in northern Nimba region in Liberia.

Trapping procedures

Field surveys were conducted from June to August 2012 in five sites in northern Nimba region in Liberia. Small mammals were sampled using Sherman live traps (H.B. Sherman Traps, Inc., Tallahassee, FL, USA) and pitfall traps with drift fences. One trap line contained of 105 Sherman live traps spaced at 5 m intervals, and one pitfall line of 20 buckets spaced at 5 m intervals were established in each sampling site. Sherman live traps were baited with the pulp of palm nut (*Elaeis guineensis* Jacq.). Sherman and pitfall traps were set for seven consecutive nights per sampling site. Traps were checked early in the morning. These trapping procedures follow the Guidelines of the American Society of Mammalogists (Sikes *et al*., 2016).

Species identification

Because of the existence of several sibling species, the identification of most small mammal species is not possible by external morphological characters only. Thus, all the captured specimens were euthanized and preserved at the Laboratory of Zoology and Animal Biology at "Félix Houphouët-Boigny" University (Côte d'Ivoire). Species identification was based on external measurements (head and body length, tail length, hind-foot length, and ear length) analyses, and were confirmed for several specimens, by molecular analysis (cytochrome b gene sequencing). Rodents and shrews were named according to the current taxonomy and nomenclature (Happold and Happold, 2013; Monadjem *et al*., 2015).

Data analysis

For each sampling site, species richness (S) was calculated, which corresponds to the total number of small mammal species sampled. The relative abundance (RA) of individual species was computed as the ratio of the number of a particular species to the total number of all individuals captured in a site, RA = (ni/N) x 100; with, ni = number of individuals of each species i, N = total number of individuals captured. Trap success was calculated as the ratio of the number of individuals captured to the total trap-nights in a site multiplied by 100. Species accumulation curves were constructed for small mammals caught at each sampling site, using PAST Software v.4.04 (Hammer *et al*., 2001). The expected species richness of each sampling site was estimated with Choa 2, Jacknife 1, Jacknife 2, and Bootstrap. Shannon-Wiener index (H'), Simpson index of diversity (1-D), and Equitability index (J) were also calculated with PAST Software v. 4.04. Similarity among trapping sites was compared using the Sorensen's coefficient, the following formula was used (Begum *et al*., 2021):

$$QC = \frac{2a}{2a + b + C}$$

where:

QC = Sorensen similarity coefficient.
a = Number of species in sample A and sample B (joint occurrences).
b = Number of species in sample B but not in sample A.
c = Number of species in sample A but not in sample B.

RESULTS AND DISCUSSION

In 4,375 trap nights, 244 individuals of small mammals were recorded in the five sampling sites. Captured specimens belonged to three families (Gliridae, Soricidae and Muridae) and 18 species (One species of Gliridae, four species of Soricidae and 13 species of Muridae). Species richness ranged from 6 to 12 across different sites. Overall trapping success was 5.57% with a range from 3.08% to 8.45% (Table1). The estimation of the total species richness (Choa 2 = 23.6 ± 5.43; Jacknife 1 = 24.4 ± 2.99; Jacknife 2 = 27.85 and Bootstrap = 20.85) were all higher than those observed in the field, suggesting that the species richness value was not high enough (Table 2). The species accumulation curves for the five sampling sites showed that those of Bento and Tokadeh approached the asymptote, while those of East Nimba, Gangra-Yuelliton and Vayampah were still increasing (Figure 2), indicating that more species could be recorded with a higher sampling effort in these three sites.

Table1. Small mammal species recorded in the different sampling sites of northern Nimba region of Liberia. Values in brackets () show percentage composition.

Species	Bento (%)	East nimba (%)	Gangra-Yuelliton (%)	Tokadeh (%)	Vayampah (%)	Relative abundance (%)
Soricidae						
Crocidura eburnea Heim de Balsac, 1958	4 (7.01)	1 (2.56)	17 (22.97)	4 (14.81)	4 (8.51)	30 (12.3)
Crocidura jouvenetae Heim de Balsac, 1958	0	0	0	0	1 (2.13)	1(0.41)
Crocidura muricauda (Miller, 1900)	6 (10.53)	7 (17.95)	10 (13.52)	7 (25.92)	6 (12.76)	36 (14.75)
Crocidura obscurior Heim de Balsac, 1958	6 (10.53)	1 (2.56)	7 (9.47)	2 (7.41)	1 (2.13)	17 (6.97)
Muridae						

Arvicanthis rufinus (Temminck, 1853)	0	0	2 (2.7)	0	0	2 (0.82)
Dephomys defua (Miller, 1900)	4 (7.01)	0	0	0	1 (2.13)	5 (2.05)
Grammomys buntingi (Thomas, 1911)	0	0	1 (1.35)	0	0	1 (0.41)
Hybomys planifrons (Miller, 1900)	0	2 (5.13)	0	0	0	2 (0.82)
Hybomys trivirgatus (Temminck, 1853)	0	1 (2.56)	0	0	0	1 (0.41)
Hylomyscus simus (G.M. Aellen and Coolidge, 1930)	21 (36.84)	12 (30.77)	2 (2.7)	2 (7.41)	19 (40.42)	56 (22.95)
Lemniscomys striatus (Linnaeus, 1758)	0	0	1 (1.35)	0	0	1 (0.41)
Lophuromys sikapusi (Temminck, 1853)	1 (1.76)	3 (7.7)	3 (4.05)	0	3 (6.38)	10 (4.1)
Malacomys edwardsi Rochebrune, 1885	6 (10.53)	1 (2.56)	1 (1.35)	0	7 (14.9)	15 (6.14)
Mastomys erythroleucus (Temminck, 1853)	0	0	0	0	1 (2.13)	1 (0.41)
Mus musculoides Temminck, 1853	0	1 (2.56)	19 (25.67)	0	0	20 (8.2)
Mus setulosus Peters, 1876	0	4 (10.26)	0	2 (7.41)	0	6 (2.46)
Praomys rostratus (Miller, 1900)	9 (15.79)	6 (15.39)	10 (13.52)	10 (37.04)	4 (8.51)	39 (15.98)
Gliridae						
Graphiurus lorraineus Dollman, 1910	0	0	1 (1.35)	0	0	1 (0.41)
Total	57	39	74	27	47	244
Number of species (S)	8	11	12	6	10	18
Trap success (%)	6.51	4.45	8.45	3.08	5.37	5.57

Table 2. Estimation of total small mammal species richness in all sampling sites.

		Standard Deviation
Species richness (S):	18	
Chao 2:	23.6	5.43
Jackknife 1:	24.4	2.99
Jackknife 2:	27.85	
Bootstrap:	20.85	

Table 3. Diversity indexes of small mammal species in five sampling sites of northern Nimba region of Liberia.

Sites	Species richness (S)	Shannon index (H')	Simpson index (1-D)	Equitability (J)
Bento	8	1.81	0.79	0.87
East nimba	11	2.01	0.82	0.83
Gangra-Yuelliton	12	2.00	0.83	0.80
Tokadeh	6	1.57	0.75	0.88
Vayampah	10	1.83	0.77	0.79

Table 4. Pairwise Sorensen similarity coefficient between sampling sites.

Sites	Bento	East nimba	Gangra-Yuelliton	Tokadeh	Vayampah
Bento	-	0.73	0.70	0.71	0.88
East nimba	0.73	-	0.69	0.70	0.66
Gangra-Yuelliton	0.70	0.69	-	0.55	0.63
Tokadeh	0.71	0.70	0.55	-	0.62
Vayampah	0.88	0.66	0.63	0.62	-

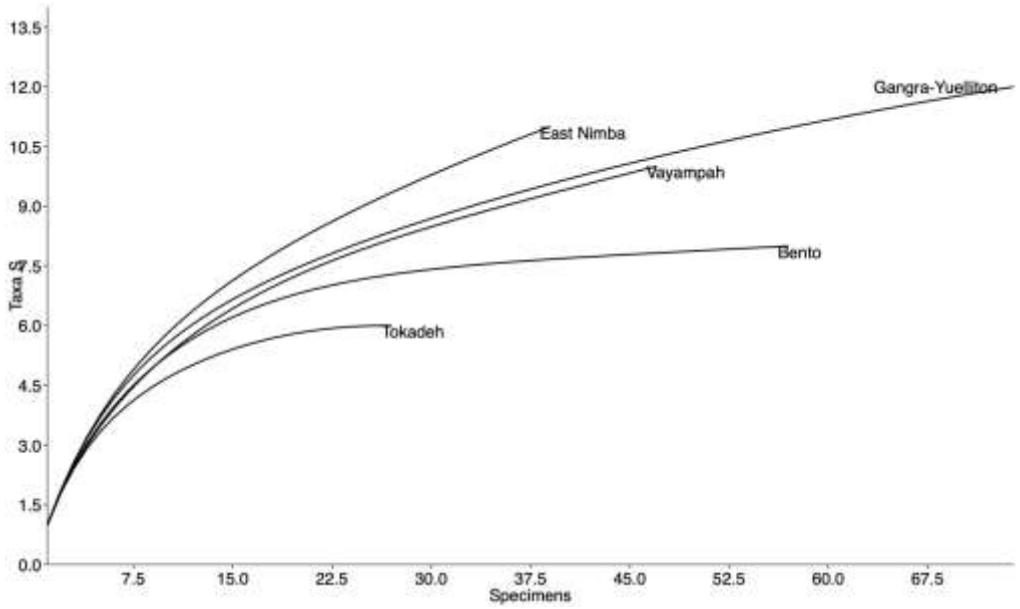

Figure 2. Species accumulation curves for the five study sites of northern Nimba region of Liberia.

Muridae represented 65.57% of the small mammals' community, while Soricidae accounted for 34.43% of the total captures. Overall, *Hylomyscus simus* was the most abundant species, with 56 (22.95%) individuals. Meanwhile, *Praomys rostratus* (39 individuals, 15.98%) was the second most dominant species, followed by *Crocidura muricauda* (36 individuals, 14.75%). During this study, the least frequently found species were *Crocidura jouvenetae*, *Grammomys buntingi*, *Hybomys trivirgatus*, *Lemniscomys striatus*, *Mastomys erythroleucus* and *Graphiurus lorraineus*, with one (0.41%) individual each (Table1). By sampling site, *Hylomyscus simus* was also the most abundant species at Bento, Vayampah and East Nimba with 21 (36.84%), 19 (40.42%) and 12 (30.77%) individuals respectively. *Mus muscoloides* was dominant at Gangra-Yuelliton site, followed by *Crocidura eburnea*, while *Praomys rostratus* was the most dominant species at Tokadeh. Simpson species diversity index showed higher diversity for East Nimba (0.82) and Gangra-Yuelliton (0.83). Shannon indexes 2.01 and 2.00 recorded at East Nimba and Gangra-Yuelliton respectively confirmed the greater diversity of small mammals in these two sites. The lowest Shannon index (1.57) was observed at Tokadeh. However, species equitability (J) was highest at Bento (0.87) and Tokadeh (0.88) (Table 3). The highest Sorensen similarity index (0.88) was between Bento and Vayampah, the second greatest value was recorded between Bento and East Nimba. The lowest similarity index (0.55) was between Tokadeh and Gangra-Yuelliton (Table 4).

The present study showed that the northern Nimba region in Liberia harbors important small mammals' communities. A total of 18 species of small mammals were identified, including one glirid, four soricids and 13 murids. The current total species richness was higher than those recorded by previous studies carried out in west Africa. For example, Decher and Bahian (1999) collected 13 species in Ghana; Fichet-Calvet *et al*. (2009) recorded 17 species in Guinea, Akpatou *et al*. (2018) caught 17 species in Côte d'Ivoire and Weber *et al*. (2019) recorded 14 species in Sierra Leone. The species accumulation curves were still increasing for three sites (East nimba, Gangra-Yuelliton and Vayampah), suggesting that the species richness could be increased with more trapping effort in these sites. This indicates that the number of small mammal species in Nimba region is probably underestimated. This is supported by the species richness values estimated by Choa 2 = 23.6, Jacknife 1 = 24.4, Jacknife 2 = 27.85 and Bootstrap = 20.85, which were all higher than the total observed species in this study. The same pattern was observed by other authors (Ofori *et al*., 2016; Ssuuna *et al*., 2020; Begum *et al*., 2021). The greatest species richness (12 species) was recorded in the secondary forest at Gangra-Yuelliton while the lowest species richness (6 species) was observed in the most disturbance habitat from Tokadeh. This result could be attributed to the fact that forests with an intermediate level of disturbance tend to show higher values of species richness and diversity in comparison with those exposed to a high level of disturbance (Ssuuna *et al*., 2020). The small mammal diversity and distribution are influence by the habitat heterogeneity and the level of disturbance (Vera and Rocha, 2006; Mayamba *et al*., 2020). Among the habitats sampled, the secondary forest at Gangra-Yuelliton was more heterogeneous compared to the other habitats, this could justify the great diversity recorded. The Tokadeh site was more degraded by human activities, such as agriculture and mining, resulting in low diversity of small mammals.

The most common small mammal species in the Upper Guinea forests are *Hylomyscus simus* or *Praomys rostratus*

(Kadjo *et al*., 2013; Akpatou *et al*., 2018; Weber *et al*., 2019). In this study, the forest species *H. simus* (22.95% of the total captures) was the most abundant species. *Hylomyscus simus* species is widely distributed in the Upper Guinea forests (Nicolas *et al*., 2020). During this study, *H. simus* was trapped in all the five sampling sites. This confirms that *H. simus* lives in a variety of biotopes with a preference for primary and secondary forests (Happold, 2013; Monadjem *et al*., 2015). Another forest species *Praomys rostratus* was the second dominant species with 15.98% of the total captures in Nimba region. *P. rostratus* was also captured in all the five sampling sites. *P. rostratus* was often the most common small mammal species in rainforest habitats of West Africa (Fichet-Calvet *et al*., 2010; Weber *et al*., 2019; Mamba *et al*., 2021). *Crocidura muricauda* (14.75%) was the third most dominant species in this study area. It was also captured in all the sampling sites. Most small mammals recorded in Nimba forests were forest-specialist species (Monadjem *et al*., 2015; Happold and Happold, 2013; Mamba *et al*., 2021). However, some generalist species such as *Arvicanthis rufinus*, *Lemniscomys striatus* and *Mus muscoloides* were recorded. *Graphiurus lorraineus* is widely distributed in the West Africa rainforests (Monadjem *et al*., 2015), but it is rarely captured during small mammal surveys. For example, only one individual was caught in this study, Mamba *et al*. (2021) captured two specimens in Wologizi-Ziama transfrontier forest. *Graphiurus lorraineus* is highly arboreal (Happold, 2013). The trapping device for this study being set only on the ground could explain its low number of captures. Diversity and abundance of small mammal species are strongly associated with vegetation structure (Aviv and Douglas, 2020; Ssuuna *et al*., 2020; Ademola *et al*., 2022). The present results showed a great similarity between small mammal community from Bento and Vayampah. These primary forests represent refuges for forest dwelling small mammals such as *Praomys rostratus* and *Hylomyscus simus* in a region whose fauna habitats have been degraded by human activities.

CONCLUSION

This study has revealed that the northern Nimba region in Liberia harbors a high number of small mammal species. The small mammals' communities were dominated by forest species such as *Hylomyscus simus*, *Praomys rostratus*, *Crocidura muricauda* and *Crocidura eburnea*. Such forests deserve special attention for their conservation given the important roles played by small mammals in forest ecosystems.

ACKNOWLEDGMENTS

We would like to thank the local people from Bento, Vayampah, Yekepa and Zolowe for their technical support and successful contribution on the field surveys. We are grateful to the "Service de Systematique Moleculaire (UMS 2700 Acquisition et Analyse de Données pour l'Histoire naturelle, MNHN, Paris)", for molecular analyses. We thank V. Nicolas (MNHN) for assisting with the molecular identification of our specimens. Many thanks to N'CHO Odon Clement for his valuable contribution to improving the English on this paper. We are also grateful to BOGUI E. Bandama, for producing the map of sampling sites. We thank the two anonymous reviewers for their helpful comments on this paper.

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