Ecology and Evolutionary Biology
2023; 11(5): 55-65
http://www.sciencepublishinggroup.com/j/eeb
doi: 10.11648/j.bio.20231105.11
ISSN: 2575-3789 (Print); ISSN: 2575-3762 (Online)

Food Habit, Spatial, and Dietary Niche Overlap of Three Sympatric Insectivorous Bats (Chiroptera) in the West Region of Cameroon

Manfothang Dongmo Ervis[1, *], Bakwo Fils Eric-Moise[2], Manga Mongombe Aaron[2], Tchuenguem Fohouo Fernand-Nestor[3]

[1]Department of Forestry, Faculty of Agronomie and Agricultural Science (FASA), University of Dschang, Dschang, Cameroon
[2]Department of Biological Sciences, Faculty of Sciences, University of Maroua, Maroua, Cameroon
[3]Department of Biological Sciences, Faculty of Science, University of Ngaoundéré, Ngaoundéré, Cameroon

Email address:

manfothang@yahoo.com (Manfothang Dongmo Ervis)
[*]Corresponding author

To cite this article:

Manfothang Dongmo Ervis, Bakwo FILS Eric-Moise, Manga Mongombe Aaron, Tchuenguem Fohouo Fernand-Nestor. Food Habit, Spatial, and Dietary Niche Overlap of Three Sympatric Insectivorous Bats (Chiroptera) in the West Region of Cameroon. *Ecology and Evolutionary Biology*. Vol. 11, No. 5, 2023, pp. 55-65. doi: 10.11648/j.bio.20231105.11

Received: June 5, 2023; **Accepted**: July 13, 2023; **Published**: September 27, 2023

Abstract: We studied the diet and the overlap of diet and spatial niches of three common insectivorous bats: *Hipposideros fuliginosus, Rhinolophus landeri* and *Chaerephon pumilus* in the West region of Cameroon from December 2016 to November 2018. Bats were captured using standard mist netting and fecal analyses carried out. Five fecal pellets were randomly chosen from each bat, moisten with water and separated into fine pieces and observed under a binocular microscope. The result reveals that these species fed mainly on coleopterans, lepidopterans and hemipterans. Diet of these bats exhibited a high level of overlap, with the highest value between *C. pumilus* and *R. landeri*, with an overlap percentage of 76.6%, followed by *H. fuliginosus* and *R. landeri*, with an overlap percentage of 69.2%. The lowest overlap, with a percentage of 28.2% is between *C. pumilus* and *H. fuliginosus*. Also, communities of the *R. landeri* are spatially distant from those of *C. pumilus* and *H. fuliginosus* with the lowest spatial overlap between the pair *C. pumilus* and *R. landeri* followed by *R. landeri* and *H. fuliginosus*. Our results show that these three species consume the similar types of insect prey, but they take different proportions. Moreover, resource partitioning by these insectivorous bats is likely to occur in accordance with the abundance and seasonal availability of insect prey. Furthermore, our results provide baseline data for several insectivorous bats in Cameroon whose dietary and spatial co-existence has never been studied.

Keywords: West Region, Cameroon, Bat, Niche, Co-existence, Overlap

1. Introduction

Mechanisms that enable niche differentiation to ensure species coexistence and maintain biodiversity of ecosystems have long intrigued community ecologist. Coexisting species are known to avoid competitive exclusion by separating niche or partitioning resources such as habitat or diet [44]. Therefore, one way to investigate how species coexistence occurs is by measuring niche parameters such as niche overlap and comparing them among species [45]. When sympatric species have similar ecological requirements, there is niche overlap which is the region of niche spaces shared by two or more species [19]. Indeed, species can only coexist locally and maintain diversity in an ecosystem if they reduce competitive interactions and avoid complete overlap by partitioning critical resources such as using different resources: shelter, food or space or alternately by using the same resource in different ways [76].

The vegetation of the West region originally consisted of mid-elevation Atlantic evergreen forest in the oceanic slope, periforest savannahs on the Tikar plain and the Bamoun plateau and semi-deciduous forest in the Mbam and Ndé valleys [28, 55]. This vegetation has undergone profound transformation, via anthropogenic activities such as urbanization and agricultural expansion that are major drivers behind species loss through habitat destruction and fragmentation [26, 53]. The intensification of agriculture is one of such drivers that have significantly expanded in the West region of Cameroon in recent years [87]. This gradual transformation of natural habitat significantly reduces the hunting range and roosting sites for bats, leading to massive movement of species to preferred habitats [77]. These species gatherings lead to intra and interspecific competitions within their community. Bats population decline in an environment is related to unavailability of resources [57].

In order to limit competition, bat communities divide resources in four ways: spatial separation [81, 79, 49, 24]; vertical selection in relation to flight height [46, 20, 89]; specialization in diet [46, 94, 23, 3] and finally a difference in hunting time [17, 78, 21].

A number of studies have been conducted on the dietary and spatial partition among bats [5, 61]. Insectivorous bats can partition space based on wing morphology and echolocation call. Frugivorous bats can partition habitat within a site based on foraging height: ground level, canopy level, and above the canopy [58]. Several studies have shown habitat preference as a means of resource partitioning [5, 61]. Other studies have focused on dietary partitioning [36, 84, 4, 32, 11]. Some of these studies show evidence of partitioning [31, 36, 32], while other show no evidence of dietary partitioning [4, 18, 27, 13].

In Africa, the only studies on resource sharing between different species of bats have focused on the bats diet [72, 4, 70, 69]. These studies interpret the differences between diet as a consequence of sharing space and, indirectly, as a demonstration of the principle of competitive exclusion. While these studies provide information on the diet of bats in Africa, very little information is currently published on the diet of bats in Cameroon [9, 14]. Moreover, no study shows how different species of bats in coexistence use their spatial and food resources.

Our study on spatial and dietary niche overlap between the three species of insectivorous bats is therefore important in order to estimate both their separation and their importance. The identification of interspecific differences is an adaptive value in the context of niche separation [5]. Our study will therefore be limited to a simplified subset of the guild of insectivorous bats, the one defined by our three species *Hipposideros fuliginosus* (Hipposideridae), *Chaeraphon pumilus* (Molossidae) and *Rhinolophus landeri* (Rhinolophidae). These three sympatric species occur in most of the habitats of the West region of Cameroon. It therefore essential to understand the mechanisms that allow the sharing of resources between the three species of insectivores. We will compare two important dimensions of their ecological niche: i) the use of food resources, through fecal analysis; (ii) the size and overlap of their food niche; iii) and the use of space, by spatial niche overlap. These data will serve as a foundation to ensure the conservation of this group, which may allow verification and enhancement of their potential use as a local biological control agent.

2. Materials and Methods

2.1. Study Site

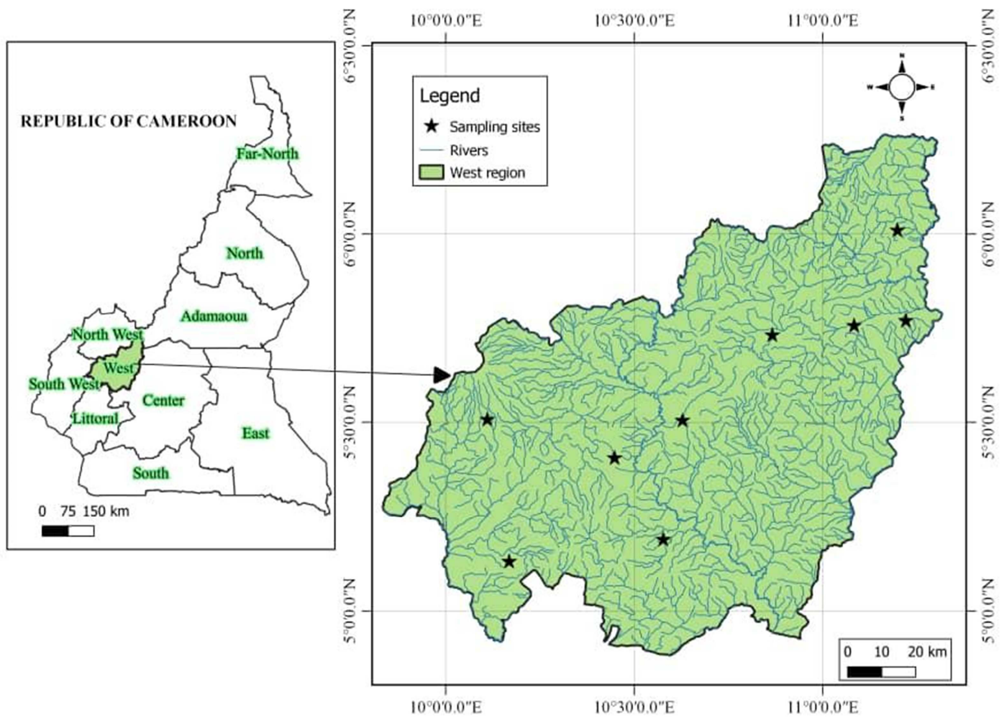

Figure 1. *Location of the West region with Cameroon.*

The West region of Cameroon is located between latitude 5° and 6° north and longitude 10 ° and 11° east. Its surface area represents 3% of the Cameroonian territory (13, 892 km^2). This region with the adjacent North West region is part of the western highlands of Cameroon [87]. These uplands are characterized by a succession of stepped plateau and limited by an escarpment of tectonic origin offering a particularly rugged topography with slopes approaching 40° (Figure 1). The plateaus of altitudes higher than 1000 m are observed along the SSW-NNE oriented volcanic massifs, forming the Cameroon Volcanic Line [73]. The climate is humid tropical with two seasons: a dry season of four to five months (November to March) and a rainy season of seven to eight months (mid-March to October). Annual rainfall varies between 1,673 to 2,092 mm depending on the year with an average of 1,814.6 mm. Due to altitude; the average annual temperature is between 19° C and 21°C [62, 87].

2.2. Capture, Identification and Fecal Collection

Bats were captured from December 2016 to November 2018 in monofilament nylon mist nets (12 m × 2.5 m; mesh, 40 mm) based on prior knowledge of bats activities (small streams, dip ponds, cultivated farms, clearings, cave openings and tree hollows were targeted). Mist nets were deployed at each site (9 sites; Table 1) between 6 pm to 12 midnight and checked every 15 minutes. Age, sex, forearm length, mass, reproductive status, and species name were recorded for all bats captured. Morphometric measurements from each captured bat were used for the identification of each species using the keys [75, 35, 63, 33]. After external measurements were recrded, each bat was placed separately in a small cloth bag for atleast two hours to collect feces for dietary analysis [70, 71], after which the bats were released. The fecal samples were labeled and stored in a plastic vials containing 70% ethanol until fecal analyses were carried out.

Table 1. *Geographical coordinates, habitat and length of net and number of nets used in parentheses.*

Sites	Longitudes	Latitudes	Altitudes	Habitat sampled	Length and number of nets
Site 1	N05.28827	E010.34107	1018m	Savannah	12 m (4)
Site 2	N05.23221	E010.25615	1541m	Deep-pond in cultivated farm	12 m (4)
Site 3	N05.45719	E010.48457	1146m	Deep-pond in savannah	12 m (3)
Site 4	N05.11560	E010.34504	1057m	Savannah	12 m (4)
Site 5	N05.56656	E011.12457	720m	Cultivated farm	12 m (4)
Site 6	N05.45855	E011.17421	676m	Forest	12 m (3)
Site 7	N05.33669	E010.04458	1800 m	Cultivated farm	12 m (3)
Site 8	N05.25269	E011.00114	752 m	Forest	12 m (3)
Site 9	N05.56656	E011.12457	720m	Cultivated farm	12 m (4)

2.3. Fecal Analyses

Five fecal pellets from each individual bat were selected randomly [93], and put in a petri dish containing a little amount of water (1-2 ml). The fecal pellets were carefully broken into little pieces with the help of fine dissecting needles under stereo-binocular microscope [70, 11]. The separated parts of insects were observed under the microscope. Parts such as legs, wings, antenna, abdomens and mouth parts were identified according to the guidelines and identification keys provided [95, 15, 82, 65]. We visually estimated the percentage frequency of prey items in the diet among individuals for each species, and estimated the percentage volume of prey items in pellets from each individual bat. The percentage volume was then expressed as the sum of individual pellet volumes divided by the total volume of feces examined, multiplied by 100 [95].

2.4. Statistical Analyses

The Fisher's Exact Test for Count Data was used to detect a possible intraspecific variation of the numbers according to the seasons and habitats. In order to use the percentage volume values in the normalized margin, all data was transformed into angular data before analysis using the R version 3.4.1 [66] statistical software. The ANOVA test was used to compare the abundance of different insect orders in the feces of the three bat species at the 5% significance level. Finally, the multiple comparison test (LSD) was used to show where the significant difference lies. The Generalized Linear Model (GLM. 25) was used in order to test the effect of season on the diet.

2.5. Niche Size Analyses

We assessed the importance of niche size (B) using Levins' Measure [56]: $B = 1 / \Sigma P_i^2$, with P as the percentage volume of each insect order consumed and equivalent to the inverse of the Simpson index [46]. In addition, the value of B was standardized (B *) between 0 and 1.0 according to the method of Hurlbert [37]: $B^* = B - 1 / n - 1$, where n corresponds to the number of insect orders consumed by each bat species.

2.6. Niche Overlap Analyses

In order to understand community organization, we measured the overlap in resources use among the different species in the community guild. The niche dimensions commonly used to better understand the sharing of resources among species is the calculation of overlap between food and space (or microhabitat). Niche overlap (Ô) between bat species pairs was evaluated with Pianka's index [64], where p_i is the proportion resources i is of the total resources used by each species (j and k).

$$\hat{O}_{jk} = \frac{\sum_i^n P_{ij} P_{ik}}{\sqrt{\sum_i^n P_{ij}^2 \sum_i^n P_{ik}^2}}$$

This measure of overlap ranges from 0 (no resources used in common) to 1.0 (complete overlap).

3. Results

From December 2016 to November 2018, we captured 100 bats belonging to these three species: 38 individuals of *Rhinolophus landeri* (Family Rhinolophidae), 33 individuals of *Chaerephon pumilus* (Family Molossidae) and 29 of *Hipposideros fuliginosus* (Family Hipposideridae). This corresponds to a capture success of 0.60 individuals per night and a capture effort of 164.8 nets per night (Table 2). The Fisher's Exact Test for Count Data showed statistically significant differences in the variation of individual bat between the nine capture sites and between habitats (P< 0.05). Figure 2 shows the distribution and spatial abundance of the three species in the West region of Cameroon. We observed that bat communities of *R. landeri* species are spatially distant from those of *C. pumilus* and *H. fuliginosus*. Adjustment of the spatially observed distributions to theoretical Pianka values shows that the average of the spatial overlap index between the three species is very low (Ô = 0.23), proving that the species have separate spatial niches. According to the theoretical values of the Pianka index, the lowest spatial overlap is between the pair *C. pumilus* / *R. landeri* (Ô = 0.01), followed by *R. landeri* / *H. fuliginosus* (0.03). However, the largest spatial overlap is between *C. pumilus* / *H. fuliginosus* (Ô = 0. 65). A degree of overlap greater than (Ô < 0.5), even in the absence of interactions between species, means that the species use or share the same spatial niche.

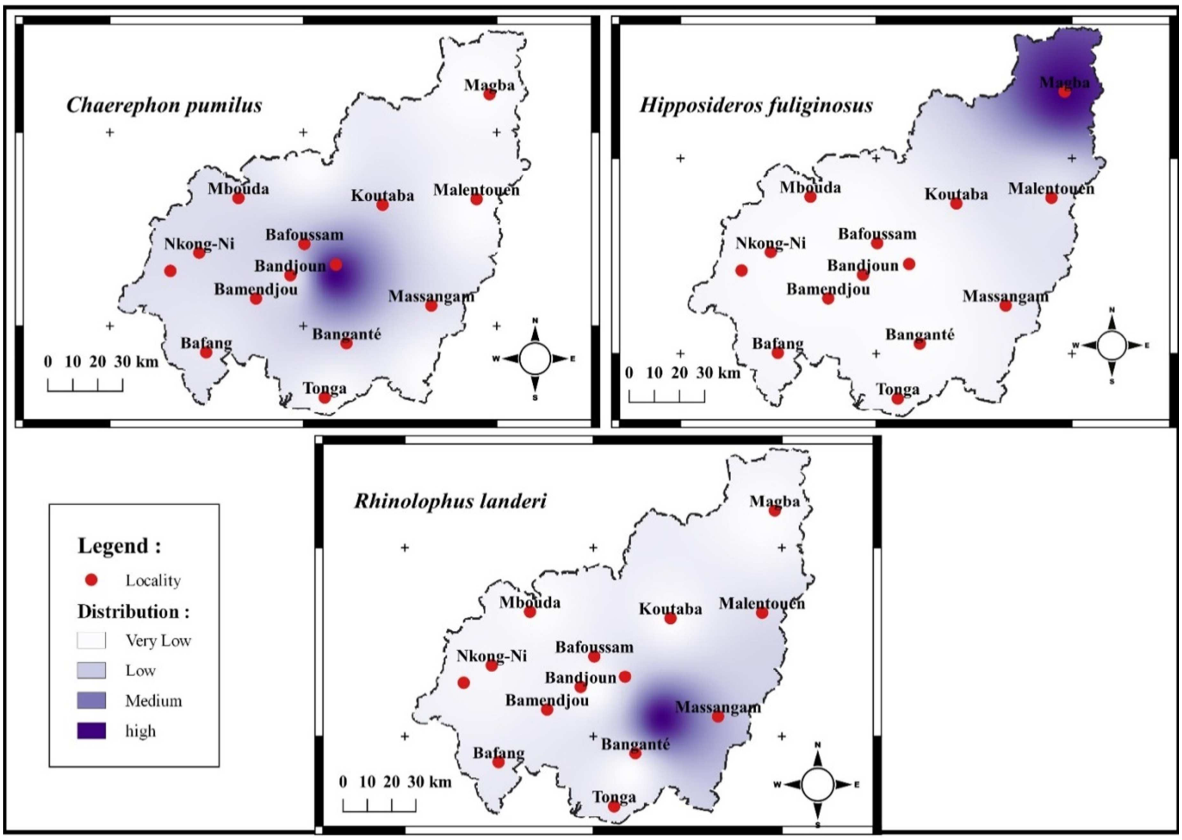

Figure 2. *Distribution of three insectivorous bat species in the West region of Cameroon.*

Table 2. *Sampling Effort, Capture Success, and Specific Abundance of Three Insectivorous Bats Captured in the West Region of Cameroon.*

Numbers of individuals per study site										
Species	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**	**Total**
Chaerephon pumilus	23	4	3	3	0	0	0	0	0	33
Hipposideros fuliginosus	0	0	0	1	20	0	0	3	5	29
Rhinolophus landeri	0	0	0	0	2	6	1	29	0	38
Total	23	4	3	4	22	6	1	32	5	100
Capture effort	20	20	16.2	20	20	16.2	16.2	16.2	20	164.8
Capture success	1.15	0.2	0.18	0.2	1.1	0.37	0.06	1.97	0.25	0.60

Table 3. *Volume, Percentage Volume and Frequency of Different orders of Insects Consumed by C. Pumilus, H. Fuliginosus and R. Landeri.*

Insect orders	*Chaerephon pumilus*			*Hipposideros fuliginosus*			*Rhinolophus landeri*		
	Volume	%volume	Frequency	Volume	%volume	Frequency	volume	% volume	Frequency
Diptera	221	7.70	1	0	0	0	213	10.4	37/38
Lepidoptera	529	18.30	1	82	8.2	1	585	28.6	1
Hemiptera	768	26.50	32/33	162	16.3	1	208	10.2	36/38
Hymenoptera	74	2.6	32/33	152	15.3	1	109	5.3	1
Coleoptera	1268	43.8	1	480	48.2	1	751	36.7	1
Orthoptera	0	0	0	94	9.4	1	145	7.1	1
Unidendified	33	1.1	20/33	26	2.6	17/29	37	1.7	27/38
Total	2893	100		996	100		2048	100	
Number of pellets	165			145			190		

Chaerephon pumilus (Cretzschmar, 1826): Nineteen males and 14 females of this species were captured with four individuals caught in natural forest and 29 in the savannah area. Also, this species is widely distributed at elevations between 1000 m to 1750 m in the West region of Cameroon. The species is listed as Least Concern in the IUCN Red List and its population trend is unknown [59]. The little free-tailed bat uses variable intensity calls for detection of a wide variety of prey that are consumed in flight.

Rhinolophus landeri (Martin 1838): Twenty one males and 16 females were caught at two habitat types during the surveys. We caught 37 individuals in natural forest and one in the cultivate farm. This species occupies altitudes ranging from 720 m up to 1800 m (site 7) in the region. The species is listed as LC in the IUCN Red List and its population trend is unknown [38]. This species is a clutter foragers which is highly selective for certain prey.

Hipposideros fuliginosus (Temminck 1853): This species was recorded in both the cultivate farms (24) and the savannah (5) in the region. Twenty nine individuals (nine females and eight males) were caught. During these surveys, the individuals were caught from elevations ranging from 720 m to 1250 m. This species is listed as LC in the IUCN Red List and its population trend is unknown [60]. This species forages by slow-hawking.

Based on our analyses of fecal pellets, six insect orders. (Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera and Orthoptera) were identified in the droppings of these bats. We recorded a total of 5,937 insect fragments (Table 4), among which 5,841 prey items were identified and 96 were not. The mean number of prey taxa per pellet was 11.71 ± 5.05 (n = 500), with a minimum of seven. Coleopterans accounted for the majority of identified preys, followed by lepidopterans and dipterans. Based on both the percentage volume and percentage frequency of contents in the fecal pellets examined, coleopterans occurred with a percentage of 43.8% (38.42 ± 11.16), 48.2% (16.55 ± 5.42), 36.7% (19.76 ± 6.77) in *C. pumilus*, *H. fuliginosus*, *R. landeri* respectively. The second most frequently consumed group of insects belonged to the order Lepidoptera: *C. pumilus* (18.3%; 16.03 ± 6), *H. fuliginosus* (8.2%; 2.82 ± 1.55) and *R. landeri* (28.6%; 15.39 ± 5.66). Other important prey were from the order Diptera: *C. pumilus* (26.5%; 23.27 ± 9.36), *H. fuliginosus* (16.3%; 5.58 ± 2.06), *R. landeri* (10.2%; 5.47 ± 4.06).

Table 4. *Niche sizes of the three bat species in the West Region of Cameroon.*

Species	Order of insects consumed (n)	Levins Index (B)	B standardized (B*)
Chaerephon pumilus	5	3.305	0.57
Hipposideros fuliginosus	5	3.230	0.55
Rhinolophus landeri	6	3.93	0.58

3.1. Diet of Rhinolophus Landeri

We recorded 2,048 insect fragments from the fecal pellets of this species, among which 2,011 items were identified and 37 were not. This diet was dominated by Coleoptera (36.7%; 19.76 ± 6.77) and Lepidoptera (28.6%; 15.39 ± 5.66), other taxa with lower occurrence were Hemiptera (10.4%; 5.60 ± 3.73), Diptera (10.2%; 5.46 ± 4.06), Orthoptera (7.1%; 3.81 ± 2.12) and Hymenoptera (5.3%; 2.86 ± 2.19). This was the only species for which we identified six insect orders.

3.2. Diet of Chaerephon Pumilus

We did not observe any Orthoptera fragments in the fecal pellets of this species. We recorded a total of 2,893 insect fragments from 165 fecal pellets, among which 2860 items were identified and 33 were not. The percentage volume of Coleoptera (43.8%; 38.42 ± 11.16) was higher than in the diet of the other two species. Dipterans and lepidopterans were the second most common prey items: 26.5% (23.27 ± 9.36) and 18.3% (16.03 ± 6) respectively. Other insect orders were Hemiptera (7.7%; 6.69 ± 4.23) and Hymenoptera (2.6%; 2.24 ± 1.32).

3.3. Diet of Hipposideros Fuliginosus

The diet of *H. fuliginosus* consisted mainly of Coleoptera (48.2%; 16.55 ± 5.42), Diptera (16.3%; 5.58 ± 2.06), Hymenoptera (15.3%; 5.24 ± 2.6), Orthoptera (9.4%; 3.24 ± 2.92) and Lepidoptera (8.2%; 2.82 ± 1.55). The amount of hymenopterans was higher than in the diet of other species. *Hipposideris fuliginosus* fed very little on Lepidoptera compared to all other species. A total of 996 insect fragments were recorded from fecal pellets (n = 145), among which 970 items were identified and 26 were not. This species was the only one in which we did not find any insect fragments of the order Hemiptera.

3.4. Comparison of Diet of These Three Species

We observed a statistically significant differences in the percentage volume of food items between the three insectivorous bat species (P < 0.05): Coleoptera (F = 42.10), Lepidoptera (F = 20.10), Diptera (F = 19.10), Hemiptera (F = 10.2), Hymenoptera (F = 5.70) and Orthoptera (F = 4.00). These proofs that the proportion of consumed prey were not the same in all three species. Additionally, the percentage volume of Coleoptera between *C. pumilus* and *R. landeri* differ statistically significantly (P <0.0001 ***), likewise for the percentage volume of Diptera between *Hipposideros fuliginosus* and *Chaerephon pumilus* (P<0.000001 ***).

Multiple comparison test (LSD) between the species, showed a statistically significant difference in the orders consumed at 5% level between the two seasons (estimate = -1.304 ± 0.902, z = -1.444, P = 0.148). Indeed, we observed the highest difference between the consumption of the lepidopterans in all three species according to the seasons. Also, this highest variation in lepidopterans consumption was observed in *H. fuliginosus*, which consumed mainly Lepidoptera in the rainy season. The Generalized Linear Model (GLM. 25) summarizes the potential effects of seasonable variable on the observed total insect's orders consumed. Consumption of Hymenoptera, Lepidoptera and Diptera was positively correlated with seasonal variation (estimate = 0.264 ± 0.123, z = 2.140, P = 0.0323), (estimate = -0.142±0.05, z = -2.623, P= 0.00872) and (estimate = 0.083±0.037, z = 2.205, P= 0.02746) respectively. However, percentage volume of Coleoptera, Hemiptera and Orthoptera did not vary statistically significantly with seasonal variation (estimate = 0.045±0.025, z = 1.767, P=0.07719), (estimate = 0.004±0.085, z= 0.049, P=0.9609) and (estimate = -0.08±0.121, z= -0.662, P= 0.50822) respectively.

3.5. Niche Sizes and Niche Overlap

The Levins' measures of niche size of these three species coexisting in the study area were close: 0.56, 0.55 and 0.58 for *C. pumilus*, *H. fuliginosus*, *R. landeri* respectively (Table 5). These three values are slightly greater than 0.50 which corresponds to the generalist category.

Table 5. *Pianka's Measure of Dietary Niche Overlap Between the three Bat Species.*

Comparison of diet overlap	Pianka index (Ô)	Percentage overlap (%)
Chaerephon pumilus & *Hipposideros fuliginosus*	0.209	28.2%
Chaerephon pumilus & *Rhinolophus landeri*	0.881	76.6%
Hipposideros fuliginosus & *Rhinlophus. landeri*	0.7	69.2%
Pianka's index (mean of observed index)	0.66	

According to Pianka's index (Table 5), the three species have a high average (Ô = 0.66) meaning similarity in dietary preference. The highest overlap is between *C. pumilus* and *R. landeri* (Ô = 0.881) with an overlap percentage of 76.6%, followed by *H. fuliginosus* and *R. landeri* (Ô = 0.7) with an overlap percentage of 69.2%. The lowest overlap, with a percentage of 28.2% is between *C. pumilus* and *H. fuliginosus* (Ô = 0.294). The upward hierarchical classification of prey similarity consumed by the three bat species, based on the overlapping matrix of food niches is presented in Figure 3.

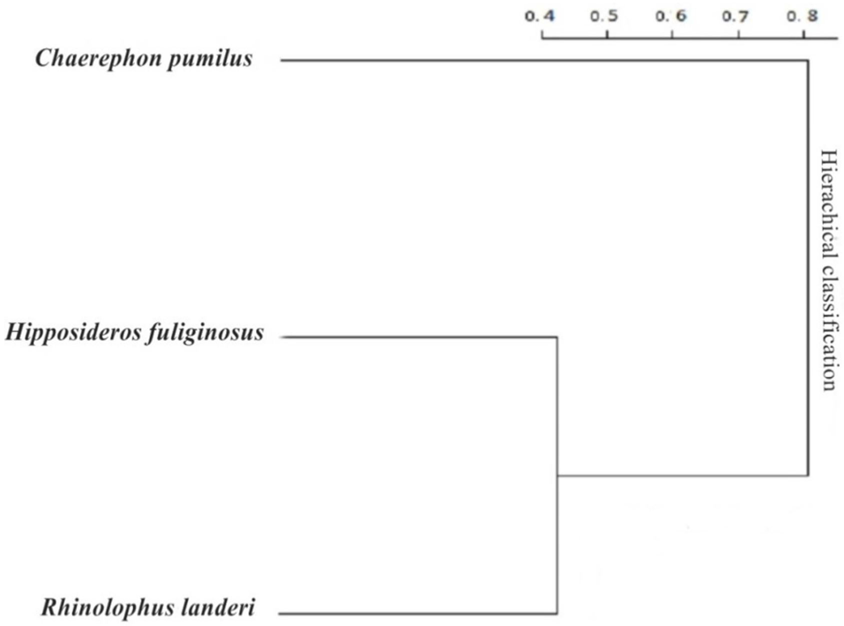

Figure 3. *Ascending Hierarchical Classification of Species Consuming Insect Orders, Based on the Overlapping Matrix of Niche.*

4. Discussion

These three species of bats are widely distributed in the West region of Cameroon. Insectivorous bats provide important ecological services such as insect pest control and the regulation of nocturnal insect populations [92]. These functions suggest that their absence would impoverish the ecosystems of which they are part of, and may even lead to its collapse [48]. Several favorable habitats exist for these bats species in the West region of Cameroon. It is interesting to note that, these species have been recorded previously in several other ecosystems in Cameroon [75, 6-8].

Our analyses provide baseline information about the diet of three bat species from the West region of Cameroon. Six insects orders with large percentage volume differences were observed in the diets of some species, but small differences were observed in the diets of *C. pumilus* and *R. landeri* as concerns dipterans. Coleoptera, Lepidoptera and Diptera were the most common food items occurring in all the analyzed pellets. Coleopterans were the preferred food items of some molossids in the Far North region of Cameroon [14]. The author [1] further pointed out that, most African insectivorous bats mainly feed on lepidopterans and coleopterans. Our results are in line with studies [68, 70, 92], which showed the predominance of coleopterans in the diet of bats. These findings also corroborate studies in Madagascar [69, 71] that showed that several species of bats mainly feed on coleopterans. The information should be interpreted carefully as diets of bats largely depend on the environment and the season [85, 54, 96, 70, 69, 71]. It is therefore difficult to use such information to make generalizations about one species [92].

The percentage volume of the Order Coleoptera was highest for the majority of identified prey. This abundance of Coleoptera fragments in the fecal pellets of *R. landeri*, *C. pumilus* and *H. fuliginosus* could be attributed to the abundance and wide distribution of coleopterans in the study area. Indeed, the Order Coleoptera is the most abundant insects in the world with nearly 350,000 to 400,000 species described [22]. They are present in all major habitats with the exception of the polar and marine environments. Another reason for the consumption of beetles is related to their relative larger size which makes flight slower, thus facilitating capture by insectivorous bats [16]. Our results show that lepidopterans were another frequently consumed group of insects prey. These results are similar to those obtained by the authors [74, 83] who noted the prevalence of moth scale in the feces of *Rhinolophus beddomei* and *Rhinolophus pusillus*. Coleopterans and lepidopterans appeared to be the most important insect orders in bats' diet [52]. Our results reveal that family Diptera is the third preferred prey for these species. These results are similar to those of the author [83] who found that dipterans were the third resources used by *Rhinolophus rouxii*, *Rhinolophus pusillus*, *Rhinolophus lepidus* and *Rhinolophus beddomei* in India, while the research [92] found high numbers of dipterans in the diet of *Taphozous longimanus* in Thailand. According to Bogdanowicz et al. (1999), Weterings and Umponstira (2014), bats that feed on a large number of dipterans are often small in size and have high frequency echolocation calls [12, 91]. The low consumption of hymenopterans and orthopterans can be explained by the adaptation of the diet of these three species according to their environments. Bat's diet was potentially related to preponderance of available prey, habitat and the time when prey are hunted [69].

When comparing the percentage volumes and frequencies of occurrence of prey items for these species, we observed a variation in the amount of prey items consumed by these three species. *Chaerephon pumilus* consumes mainly coleopterans, dipterans and lepidopterans. These results are similar to those obtained by the authors [4, 13], who also showed that these three Orders were among the common prey consumed by *C. pumilus*. However, we did not find any fragments of orthopterans in their fecal pellets, this contrast with findings [13] that showed that 0.02% of Orthoptera fragments were present in the diet of *C. pumilus* in the far north region of Cameroon, and concluded that orthopterans were probably accidental prey in the diet of this bat. *Rhinolophus landeri* feeds on the six orders of insects: Coleoptera and Lepidoptera were the most common. The presence of six orders in their diet, with Hymenoptera in small quantities shows that this species is able to capture all types of prey, even insects that remain attached to leaves. Indeed, the ability to extract prey from vegetation has also been reported in the family Rhinolophidae [11]. In Zimbabwe, [30] found 92% of Lepidoptera and Orthoptera fragments the diet of *R. landeri* while [43] in Sudan found that the diet of this species consisted mainly of small Coleoptera. For *H. fuliginosus*, our result shows that this species feeds on five insect orders (Coleoptera, Lepidoptera, Diptera, Hymenoptera and Orthoptera), with a marked preference for coleopterans. *Hipposideros fuliginosus* feeds on other insect orders, but not hemipterans which are also present in the study area. The hypothesis that the small amount or absence of any fragments orders in the fecal pellets of a bat species may be due to the fact that some orders spend a short time in the digestive tract of bats and are defecated faster than other insect orders [70]. In addition, the diet of *H. fuliginosus* is closely related to their hunting pattern which favors the capture of medium-sized flying insects such as moths and coleopterans [33].

The dietary study of these three insectivorous bats are important for understanding insect-prey preferences, it also provides a good estimate of preferred prey [51]. The values of the Levins' measure classifies these three bat species in the generalist category and shows that despite the phenotypic differences, these three species show a convergent evolution with regard to diet. This convergent evolution within this community makes it possible to question or verify the hypothesis on the similarity limit of bat species with respect to a particular insect group. A high niche overlap (Pianka's index, Ô

= 0.66) between the three species highlights that despite differences in specific hunting techniques among the three species (e. g. capture of prey in flight or glean prey from the leaf surface) [40], these species adapt their food habit according to their environments. Indeed, the authors [10, 70] suggest that, generalist bats punctually exploit abundant prey in their environment.

The variation in echolocation calls frequencies represent adaptations to different forage microhabitats [67]. Bats of the family Rhinolophidae and Hipposideridae typically emit long constant frequency (FM-CF-FM) echolocation calls with a high duty cycle that allows them to exploit prey resources around and within dense vegetation [86]. Indeed species that are active in cluttered habitats use low intensity echolocation calls [42] when bats foraging in open environments they use narrowband calls consisting of shallow, long duration frequency modulated (FM) calls [29]. Hipposiderids bats are known to be flexible in their hunting behavior, they use high duty cycle echolocation that are better able to prey on airborne insects from perches and therefore detect the echoes of fluttering insects in the cluttered background [50, 2]. This echolocation behavior observed in foraging bats is the most important ecological factor which define various foraging habitats [80].

Wing morphology (e. g. forearm length) is another factors determine where bats forage [1]. It determines flight style and different foraging strategies [88, 39]. For example, bats with large, broad and rounded tips wings such as rhinolophid fly slowly with considerable manoeuvrability and hunt in cluttered environments [33]. In comparison, *H. fuliginosus* with relatively short forearm length (FA: 47-36), forages by slow-hawking, indicating that this bat forages mainly in densely cluttered forest [33]. Moreover, fast-flying molossid such as *C. pumilus* exploit insects in the open-space, because there may encounter high metabolic costs when foraging in edge-space habitats (forest gaps) [90].

5. Conclusion

Our study reveals that in the West region of Cameroon, these three insectivorous bat species feed on six insect Orders (Coleoptera, Hemiptera, Diptera, Lepidoptera, Hymenoptera and Orthoptera). The order Coleoptera (42.09%) is the most consumed prey item by the three bat species. We also observed that the composition of the diet varies from one species to another and between seasons. This makes it possible to advance the hypothesis according to which the three species of bats present in the West region of Cameroon use different modes of hunting and could hunt several orders of insects within their habitat. The spatial coexistence between these species is found in prey selection, habitat selection and the niche size of each species. All these factors could mitigate an important overlap and at the same time remedy the effects of exclusive competition between them.

Acknowledgments

We are grateful to the VBD-LABEA laboratory of the University of Dschang Cameroon for making available their laboratory for fecal analyses. We also indebted to IDEA WILD for their valuable help with catching material.

References

[1] Aldridge, H., Rautenbach, I. 1987. Morphology, echolocation and resource partitioning in insectivorous bats. *The Journal of Animal Ecology*, 56: 763–778.

[2] Altringham, J. D. 2011. Bats from evolution to conservation, 2nd edition. *Oxford University Press*, Oxford, 319 pp.

[3] Andreas, M., Reiter, A., Benda, P. 2011. Prey Selection and Seasonal Diet Changes in the Western Barbastelle Bat (Barbastella barbastellus). *Acta Chiropterologica*, 14: 81–92.

[4] Andrianaivoarivelo, A. R., Ranaivoson, N., Racey, P. A., Jenkins, R. K. B. 2006. The diet of three synanthropic bats (Chiroptera: Molossidae) from eastern Madagascar. *Acta Chiropterologica,* 8 (2): 439–444.

[5] Arlettaz, R. 1999. Habitat selection as a major ressource paritioning mechanism between the two sympatric sibling bat species *Myotis myotis* and *Myotis blyhtii*. *J. Anim. Ecol,* 68 460-471.

[6] Atagana, P. J., Bakwo Fils, E. M., Mbeng, D. W., Tsague, K. J. A., Kekeunou, S. 2018. The bat fauna of the Mpem and Djim National Park, Cameroon (Mammalia Chiroptera). *Biodiversity Journal*, (9): 241-254.

[7] Backwo Fils, E. M. 2009. Inventaire des chauves-souris de la réserve de biosphère du Dja, cameroun. *Vespère,* (2): 71-85.

[8] Bakwo Fils, E. M., Bol A Anong, D., Badoana, T. D., Guieké, B., Tsala, D. E., Kuate, F. A. 2014. Diversity of bats of the Far North Region of Cameroon–with two first records for the country. *Biodiversity,* 15 (1): 16-22.

[9] Bakwo Fils, E. M. 2010. The Bats of Cameroon: proving the benefits of the forgoten fruit bats. *Bats*, 28: 11–13.

[10] Belwood, J. J., Fenton, M. B. 1976. Variation in the diet of *Myotis lucifugus* (Chiroptera: Vespertilionidae). *Canadian Journal of Zoology*, 54: 1674-1678.

[11] Benarbia, A. & Fentrouci, B. 2017. Caractérisation Morphométrique, de quelques espèces de la chauves-sauries en Algérie Occidentale et Application Bioinformatique en Génétique. Mémoire de Master en Génétique: Gestion et amélioration et ressources biologiques, UNIVERSITE de TLEMCEN.

[12] Bogdanowicz, W., Fenton, M. B., Daleszczyk, K. 1999. The relationships between echolocation calls, morphology and diet in insectivorous bats. *Journal of Zoology*, 247: 381–393.

[13] Bohmann, K., Monadjem, A., Noer, C. L., Rasmussen, M., Zeale, M. R. K., Clare, E., Jones, G., Willerslev, E. & Gilbert, M. T. P. 2011. Molecular Diet Analysis of Two African Free-Tailed Bats (Molossidae) Using High Throughput Sequencing. PloS one, 6e21441.

[14] Bol A Anong, A. G. 2013. Investigations sur le régime alimentaire de trois Chauves-souris insectivores de la région de l'Extrême-Nord Cameroun: Mémoire présenté en vu de l'obtention d'un MASTER II à l'Université de Maroua-Cameroun.

[15] Borror & White. 1970. Clé d'identification des ordres d'insectes adultes. Gilles Bourbonnais / Cégep de Sainte-Foy.

[16] Brigham, R. M., Randeus, G., Saunders. 1990. The diet of big brown bats in relation to insect availability in southern Alberta, Canada. *Northwest Science*, 64: 7-10.

[17] Brown, J. H. 1968. Activity patterns of some neotropical bats. *Journal of Mammalogy*, 49: 754-757.

[18] Burles, D. W., Brigham, R. M., Ring, R. A., Reimchen, T. E. 2008. Diet of two insectivorous bats, *Myotis lucifugus* and *Myotis keenii*, in relation to arthropod abundance in a temperate Pacific Northwest rainforest environment. *Canadian Journal of Zoology*, 86: 1367–1375.

[19] Colwell RK, Futuyma DJ. On the measurement of niche breadth and overlap. *Ecology,* 52: 567-576.

[20] De Jong, J. 1994. Habitat use, home-range and activity pattern of the northern bat, *Eptesicus nilssoni,* in a hemiboreal coniferous forest. *Mammalia*, 58: 535-548.

[21] Delaval, M. 2004. Impacts des perturbations d'origine anthropique sur les peuplements de chauves-souris en Guyane Française. THESE de DOCTORAT de l'UNIVERSITE PARIS 6.

[22] Delvare, G. & Aberlanc, H. P. 1989. Les insectes d'Afrique et d'Amérique-Tropicale. Clés pour la reconnaissance des familles. CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement), Montpellier, 302 pp.

[23] Dodd, L. E., Lacki, M. J., Rieske, L. K. 2008. Variation in moth occurrence and implications for foraging habitat of Ozark big-eared bats. *Forest Ecology and Management*, 255: 3866–3872.

[24] Downs, N. C., Racey, P. A. 2006. The use by bats of habitat features in mixed farmland in Scotland. *Acta Chiropterologica*, 8: 169-185.

[25] Emrich, M. A. 2013. Structure of an Ensemble of Insectivorous Bats. Electronic Thesis and Dissertation Repository. 1332. https://ir.lib.uwo.ca/etd/1332.

[26] Estrada, A. & Coates-Estrada, R. 2002. Bats in continuous forest, forest fragments and in an agricultural mosaic habitat-island at Los Tuxtlas, Mexico. Biological Conservation Vol. 103, Iss. 2, pp. 237-245.

[27] Feldhamer, G. A., Carter, T. C., John, O., The, S., Midland, A., Whitaker, J. O. 2009. Prey Consumed by Eight Species of Insectivorous Bats from Southern Illinois. *The American Midland Naturalist,* 162: 43–51.

[28] Felix, J. 1950. Géographie des dénudations et dégradation des sols au Cameroun. Ministère Français d'outre Mer. *In Bulletin scientifique*, Vol. III, n° 127.

[29] Fenton, M. 1990. The foraging behaviour and ecology of animal-eating bats. *Canadian Journal of Zoology,* 68: 411–422.

[30] Fenton, M. B. 1975. Observations on the Biology of some Rhodesian bats, including a key to the Chiroptera of Rhodesia. *Life Sciences Royal Ontario Museum*, University of Toronto, 104: 1 – 27.

[31] Findley, J., Black, H. 1983. Morphological and dietary structuring of a Zambian insectivorous bat community. *Ecology*, 64: 625–630.

[32] Fukui, D., Okazaki, K., Maeda, K., 2009. Diet of three sympatric insectivorous bat species on Ishigaki Island, Japan. *Endangered Species Research*, 8: 117–128.

[33] Happold, M. & Happold, D. C. D. 2013. Mammals of Africa Volume IV: Hedgehogs, shrews and bats. Bloomsbury Publishing, London 800 pp.

[34] Hardin, G. 1960. The competitive exclusion principle. *Science*, 131, 1292–1297.

[35] Hayman, R. W. & Hill, J. E. 1971. The Mammals of Africa: An identification manual. Part2. Order Chiroptera. Smithsonian Institution Press. Washington, D. C 73 pp.

[36] Hickey, M. B. C., Acharya, L., Pennington, S. 1996. Resource partitioning by two species of vespertilionid bats (*Lasiurus cinereus* and *Lasiurus borealis*) feeding around street lights. *Journal of Mammalogy*, 77: 325–334.

[37] Hurlbert, S. H. 1978. The measurement of niche overlap and some relatives. *Ecology*, 59: 67–77.

[38] Jacobs D. (S.), F. P. D., Cotterill, P. J., Taylor, A, Monadjem. 2008an. *Rhinolophus landeri.* In IUCN 2009: IUCN Red List of Threatened Species. Version 2009. 2.www.iucnredlist.org.

[39] Jacobs, D., Barclay, R. 2009. Niche differentiation in two sympatric sibling bat species, Scotophilus dinganii and Scotophilus mhlanganii. *Journal of Mammalogy*, 90: 879–887.

[40] Jones, G. & Rydell, J. 2003. Attack and defense interaction between echolocating bats and their prey. In Bat ecology, eds. T. H. Kunz & M. B. Fenton, pp. 301-345. The University of Chicago Press, Chicago.

[41] Kalko, E. 1995. Insect pursuit, prey capture and echolocation in pipestirelle bats (Microchiroptera). *Animal Behaviour,* 50: 861–880.

[42] Kalko, E. K. V. 2004. Neotropical leaf-nosed bats (Phyllostomidae):"Whispering" bats or candidates for acoustic survey. Proceedings of a Workshop on Identification and Acoustic Monitoring of Bats, M. Brigham, G. Jones, and EKV Kalko, eds. Austin, TX: Bat Conservation International.

[43] Kock, D. 1969. Die Fledermaus-Fauna des Sudan (Mammalia, Chiroptera). Abhandlungen der Senckenbergischen naturforschenden Gesellschaft, 521: 1–238.

[44] Kotler, B. P., Brown, J. S. 1988. Environmental heterogeneity andthe coexistence of desert rodents. *Annual Review of Ecologyand Systematics,* 19: 281–307.

[45] Krebs, C. J. 1971. Ecological methodology. 2nd ed. Boston: Addison Wesley Longman.

[46] Krebs, C. J. 2014. Ecological methodology. 3rd edition, in preparation with online text. Available from: http://www zoology.ubc.ca/~krebs/books.html.

[47] Krull, D., Schumm, A., Metzner, W., Neuweiler, G. 1991. Foraging areas and foraging behavior in the notch-eared bat, *Myotis emerginatus* (Vespertilionidae). *Behavioral Ecology and Sociobiology*, 28: 247-253.

[48] Kunz, T. H., Braun de Torrez, E., Bauer, D., Lobova, T., Fleming, T. H. 2011. Ecosystem services provided by bats. Annals of the New York Academy of Sciences 1223: 1-38.

[49] Kunz, T. H. & Fenton, B. B. 2005. Bat ecology, University of Chicago Press, Chicago, Ill.

[50] Kunz, T. H. & Fenton, M. B. (eds.) 2003. Bat ecology. University of Chicago Press, Chicago, Illinois, 778 pp.

[51] Kunz, T. H., Whitaker Jr, J. O. 1983. An evaluation of fecal analyses for determining food habits of insectivorous bats. *Canadian Journal of Zoology*, 61: 1317-1321.

[52] Kurta, A., Whitaker Jr, J. O. 1996. Diet of endangered Indiana bat, *Myotis sodalis* in Michigan. *Bat Research News*, 37: 139.

[53] Lawer, E. A., Darkoh, E. L. 2016. Effects of agroecosystems on insect and insectivorous bat activity: a preliminary finding based on light trap and mist net captures. *Turkish Journal of Zoology*, 40: 423-432.

[54] Leelapaibul, W, Bumrungsri, S, Pattanawiboon, A. 2005. Diet of wrinkle-lipped free-tailed bat (*Tadarida plicata* Buchannan, 1800) in central Thailand: insectivorous bats potentially act as biological pest control agents. *Acta Chiropterologica*, 7: 111–119.

[55] Letouzey, R. 1968. Etude phytogéographique du Cameroun. Lechevalier, Paris. 508 p.

[56] Levins, R. 1968. Evolution in changing environments. Princeton University Press, Princeton.

[57] Lino, A., Fonseca, C., Goiti, U., Pereira, M. J. R. 2014. Prey selection by *Rhinolophus hipposideros* (Chiroptera, Rhinolophidae) in a modified forest in Southwest Europe. *Acta Chiropterologica*, 16 (1): 75–83.

[58] Menzel, J., Menzel, M., Kilgo, J. 2005. Effect of habitat and foraging height on bat activity in the coastal plain of South Carolina. *Journal of Wildlife Management*, 69: 235–245.

[59] Mickleburgh, S., Hutson, A. M., Racey, A. P., Ravino, J., Bergmans, W., Cotterill, D. P. F. & Gerlach, J. 2008dr. *Tadarida pumila*. In IUCN 2009: IUCN Red List of Threatened Species. Version 2009. 2. www.iucnredlist.org.

[60] Monadjem, A., Juste, J., Bergmans, W., Mickleburgh, S., Hutson, A. M., Fahr, J. 2017c. *Hipposideros fuliginosus*. The IUCN Red List of Threatened Species 2017: e. T10134A22090466.http://dx.doi.org/10.2305/IUCN. UK. 2017-2. RLTS. T10134 A22090466.

[61] Nicholls, B. & Racey, P. 2006. Habitat selection as a mechanism of resource partitioning in two cryptic bat species *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus*. Ecography, 29: 697–708.

[62] Olivry, J. C. 1976. Régimes Hydrologiques en Pays Bamiléké (Cameroun). Thèse Présentée à l'Université des Sciences et Techniques du Languedoc pour obtenir le grade de Docteur de Spécialité (Géologie Appliquée, mention Hydrologie) 3e Cycle.

[63] Patterson, B. D., Webala, P. W. 2012. Keys to the East African Bats. *Fieldiana: Life and Earth Sciences* (Museum of Natural History) 60p.

[64] Pianka, E. R. 1973. The structure of lizard communities. *Annual Review of Ecology and Systematics*, 4: 53–74.

[65] Pokhrel, S., Budha, P. B. 2014. Key to Identify Insects from Droppings of Some Insectivorous Bats of Nepal. *Journal of Institute of Science and Technology*, 19 (1): 129-136.

[66] R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

[67] Rubsamen R, G. Neuweiler, G. Marimuthu 1999. Ontogenesis of tonotopy in inferior colliculus of a hipposiderid bat reveals postnatal shift in frequency-place codeJ Comp Physiol [A], 165, pp. 755-769.

[68] Rakotoarivelo, A. A., Ranaivoson, N., Ramilijaona, O. R., Kofoky, A. F., Racey, P. A., Jenkins, R. K. B. 2007. Seasonal food habits of five sympatric forest microchiropterans in western Madagascar. *Journal of Mammalogy*, 88: 959-966.

[69] Rakotondramanana, C. F., Rajemison, B., Goodman, S. M. 2015. Comportement alimentaire des communautés de chauves-souris animalivores de Kirindy (CNFEREF) et d'Antsahabe, Madagascar: répartition, partage et disponibilité de niche alimentaire. *Malagasy Nature*, 9: 68-87.

[70] Ramasindrazana, B., Rajemison, B., Goodman, S. M. 2012. Bioécologie des chauves-souris du Parc National de Tsimanampetsotsa. 2. Variation interspécifique et saisonnière du régime alimentaire. *Malagasy Nature*, 6: 117-124.

[71] Rasoanoro, M., Ramasindrazana, B., Rajemison, B., Razafimahatratra, E., Goodman, S. M. 2015. Préférence alimentaire des chauves-souris de Kianjavato, région de Vatovavy-Fitovinany, Madagascar. *Malagasy Nature*, 9: 58-67.

[72] Razakarivony, V., Rajemison, B., Goodman, S. M. 2005. The diet of Malagasy Microchiroptera based on stomach contents. *Acta Chiropterologica*, 9: 312-316.

[73] Rivière, Y. 2000. Paysages et Agroforets en Pays Bamiléké (Ouest-cameroun) Mémoire de stage « en Gestion des Systemes Agro-Sylvo-Pastoraux en Zones Tropicales ». Universite de Dschang Cameroun.

[74] Robinson, M. F., Stebbings, R. E. 1993. Food of the serotine bat, *Eptesicus serotinus*. Is faecal analysis a valid qualitative and quantitative technique? *J. Zool Lond*, 231: 239-248.

[75] Rosevear, D. R. 1965. The Bats of West Africa, Trustees of the British Museum (Natural History), London 401p.

[76] Russell, P. J., Wolfe, S. L., Hertz, P. E., Starr, C., Fenton, M. B., Addy, H., Maxwell, D., Haffie, T. & Davey, K. 2010. Biology: Exploring the Diversity of Life. Thomson Brooks/Cole.

[77] Russo, D., Cistrone, L., Garonna, A. P., Jones, G. 2010. Reconsidering the importance of harvested forests for the conservation of tree-dwelling bats. *Biodiversity and Conservation,* 19: 2501–2515.

[78] Rydell, J., Entwistle, A. C., Racey, P. A. 1996. Timing of foraging flights of three species if bats in relation to insect activity and predation risk. *OIKOS*, 76: 243-252.

[79] Safi, K., Kerth, G. 2004. A Comparative Analysis of Specialization and Extinction Risk in Temperate-Zone Bats. *Conservation Biology*, 18: 1293-1303.

[80] Schnitzler, H. U. & Kalko, E. K. V. 1998. How echolocating bats search and find food. Pages 183–196 in Kunz TH, Racey PA, eds. Bat Biology and Conservation. Washington (DC): Smithsonian Institution Press.

[81] Schnitzler, H. -U., Moss, C. F., Denzinger, A. 2003. From spatial orientation to food acquisition in echolocating bats. *Trends in Ecology & Evolution*, 18: 386–394.

[82] Scholtz, C. H. & Holm, E. 1989. Insects of Southern Africa. Buttterworths, Johannesburg, 502 pp.

[83] Selva Ponmalar, S., Juliet Vanitharani. 2014. Insect pest management by the horse shoe bats (*Rhinolophus* species) in the forest ecosystem of Kalakad Mundanthurai Tiger Reserve, India. *Scrutiny International Research Journal of Biological and Environmental Science* (SIRJ-BES), 1: 5.

[84] Siemers, B. M., Swift, S. M. 2006. Differences in sensory ecology contribute to resource partitioning in the bats *Myotis bechsteinii* and *Myotis nattereri* (Chiroptera: Vespertilionidae). *Behavioral Ecology and Sociobiology*, 59: 373–380.

[85] Srinivasulu, B., Srinivasulu, C. 2005. Diet of the black-bearded tomb bat *Taphozous melanopogon* Temminck, 1841 (Chiroptera: Emballonuridae) in India. *Zoos' Print Journal,* 20: 1935–1938.

[86] Taylor, P. J. 2000 Bats of southern Africa. University of Natal Press, Pietermaritzburg.

[87] Temgoua, L. F. 2011. Déterminants socio-économiques et écologiques de la plantation d'arbres producteurs de bois d'œuvre et d'artisanat dans l'Ouest du Cameroun. Thèse de Doctorat en « Géographie tropicale », Université Michel de Montaigne Bordeaux 3.

[88] Vaughan, T. A. 1970. Flight patterns and aerodynamics. Biology of Bats 1 (ed W. A. Wimsatt), pp. 195–216. Academic Press, New York.

[89] Verboom, B., Huitema, H. 1997. The importance of linear landscape elements for the pipistrelle *Pipistrellus pipistrellus* and the serotine bat *Eptesicus serotinus. Landscape Ecology*, 12: 117-125.

[90] Voigt, C. C. & Holderied, M. W. 2012. High manoeuvring costs force narrow-winged molossid bats to forage in open space. *Journal of Comparative Physiology*, 182B: 415–424.

[91] Weterings, R., Umponstira, C. 2014. Bodyweight-forearm ratio, cranial morphology and call frequency relate to prey selection in insectivorous bats. *Electronic Journal of Biology*, 10: 21–27.

[92] Weterings, R., Wardenaar, J., Dunn, S., Umponstira, C. 2015. Dietary analysis of five insectivorous bat species from Kamphaeng Phet, Thailand. *Raffles Bulletin of Zoology,* 63: 91–96.

[93] Whitaker Jr, J. O. 1988. Food habits analysis of insectivorous bats. In Ecological and Behavioral Methods for the Study of Bats. T. H, Kunz, Ed: 171–189. Smithsonian Institution Press. Washington, DC. 32.

[94] Whitaker Jr, J. O. 1994. Food availability opportunistic versus selective feeding in insectivorous bats. *Bat Research News*, 35: 75-77.

[95] Whitaker Jr, J. O., McCracken, G. F., Siemers, B. M. 2009. Food habits analysis of insectivorous bats. In Ecological and behavioral methods for the study of bats, 2nd edition, eds. TH Kunz and S Parsons, pp. 567–592. The Johns Hopkins University Press, Baltimore.

[96] Zhang, L., Jones, G., Rossiter, S., Ades, G., Liang, B., Zhang, S. 2005. Diet of flatheaded bats, Tylonycteris pachypus and T. robustula, in Guangxi, south China. *Journal of Mammalogy*, 86: 61–66.