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Research Paper

Assessment of species diversity and spatial distribution of bats along an ecological transect in the Yangambi Biosphere Reserve (YBR), Tshopo province, Democratic Republic of Congo (DRC)

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Summary
This work aims to assess the species diversity and spatial distribution of bats along an ecological transect in the Yangambi Biosphere Reserve (YBR), which is located between the Congo River to the south and the Aruwimi River to the north and west. This reserve covers an area of 225,000 hectares (0.771°N, 24.527°E; 400 m altitude) andis characterized by a remarkable biodiversity, although subject to increasing anthropogenic pressures. The study is based on bat specimens collected during field campaigns carried out in May, July, August, November and December 2023, and in January and February 2024 and in May 2025. Captures were made using mist nets and harp traps installed in various types of habitats along the transect. Observation plots were set up to ecologically characterize each site based on topographical and environmental criteria. A total of 574bats representing 45 species were captured, belonging to 23 identified genera and 7 families. The maximum peak activity was observed at 7 pm (113 individuals), followed by slightly lesser peaks at 9 pm (96) and 8 pm (63). This twilight and post-twilight phase is dominated by several YBR families. Between 12 am and 5 am, activity stabilizes at a moderate level (24–44 individuals per hour). The lowest activity was noted at 2 am (4 individuals) and 6 am (2 individuals), marking the end of outings. Ahigh occurrence of bats was observed along streams, followed by primary mixed forests, showingthat bat distribution is strongly influenced by habitat type, which plays a key role in population concentration. In other words, habitat availability and structure are determining factors for the abundance of captures while monodominant primary forests appear as the least productive habitat in terms of captures, suggesting that these factors strongly influence the distribution of captured specimens. Functional analysis reveals a vertical structuring of communities: Hipposideridae and

Vespertilionidae dominate insectivores in the lower to middle strata, while Pteropodidae, frugivores or nectarivores, exploit the upper floors, taking advantage of the floristic richness. The Megadermatidae, Molossidae, Nycteridae and Rhinolophidae families, although less frequent, enrich functional diversity through specific hunting strategies. The heterogeneous distribution of sampling effort among the 12 sites, with high representativeness at Bonde Moke and Ilokonda 2 (high diversity), contrasts with Mawate and Point Zéro (reduced diversity), highlighting the importance of taking this difference into account in the ecological interpretation of the results.

Keywords: *Assessment, species diversity, distribution, ecological transect, Yangambi landscape, DRC*

Résumé:
Le présent travail vise à évaluer la diversité spécifique et la distribution spatiale des chauves-souris le long d'un transect écologique dans la Réserve de Biosphère de Yangambi **(***RBY), qui est située entre le fleuve Congo au sud et la rivière Aruwimi au nord et à l'ouest. Cette réserve couvre une superficie de 225 000 hectares (0,771°N, 24,527°E ; 400 m d'altitude), elle se caractérise par une biodiversité remarquable, bien que soumise à des pressions anthropiques croissantes. L'étude s'appuie sur des spécimens de chauves-souris collectés lors de campagnes de terrain réalisées en mai, juillet, août, novembre et décembre 2023, puis en janvier, février 2024 et enfin en mai 2025. Les captures avaient été effectuées au moyen de filets japonais et de pièges-harpes installés dans divers types d'habitats le long de transect. Des placettes d'observation ont été aménagées pour caractériser écologiquement chaque site à partir de critères topographiques et environnementaux. Au total, 574 individus représentant 45 espèces de chauves-souris ont été capturés, dont 23 genres identifiés et 7 familles. Le pic maximal est observé à 19 h (113 individus), suivi de 21 h (96) et 20 h (63). Cette phase crépusculaire et post-crépusculaire est dominée par plusieurs familles de la RBY. Entre 00 h et 05 h, l'activité se stabilise à un niveau modéré (24–44 individus par heure). Les plus faibles activités sont notées à 02 h (4 individus) et 06 h (2 individus), marquant la fin des sorties. Les cours d'eau révèlent une forte prédominance des chauves-souris, suivie des forêts primaires mixtes, ce qui montre la distribution des chauves-souris est fortement influencée par un habitat qui joue un rôle clé dans la concentration des populations. Autrement dit, la disponibilité et la structure de l'habitat sont des facteurs déterminants pour l'abondance des captures tandis que les forêts primaires monodominantes apparaissent comme l'habitat le moins productif en termes de captures ce qui suggère que ces facteurs influencent fortement la distribution des spécimens capturés. L'analyse fonctionnelle révèle une structuration verticale des communautés : les Hipposideridae et Vespertilionidae dominent les insectivores dans les strates inférieures à moyennes, tandis que les Pteropodidae, frugivores ou nectarivores, exploitent les étages supérieurs, profitant de la richesse floristique. Les familles Megadermatidae, Molossidae, Nycteridae et Rhinolophidae, bien que moins fréquentes, enrichissent la diversité fonctionnelle par des stratégies de chasse spécifiques. La répartition hétérogène de l'effort d'échantillonnage entre les 12 sites, avec une forte représentativité à Bonde Moke et Ilokonda 2 (diversité élevée), contraste avec Mawate et Point Zéro (diversité réduite), soulignant l'importance de tenir compte de cette disparité dans l'interprétation écologique des résultats.*
Mots clés : Evaluation, diversité spécifique, distribution, transect écologique, paysage de Yangambi, RDC

I. Introduction

Assessing the species diversity and spatial distribution of bats provides an essential foundation for understanding the ecological dynamics of an ecosystem (Voigt and Kingston, 2016) in the context of global changes (García-García *et al.*, 2014). In the Yangambi Biosphere Reserve (from here on YBR), bats perform major ecological functions, including pollination, seed dispersal (Muscarella and Fleming, 2007), regulation of insect populations (Kunz *et al.*, 2011), and contribution to the regeneration of Congo Basin forests (Hekkala *et al.,* 2023). However, both their diversity and spatial distribution are currently threatened (Jung *et al.,* 2012) by multiple anthropogenic pressures (Thompson *et al.,* 2019), such as habitat destruction and fragmentation (Meyer *et al*., 2008), pollution (Shipley *et al.,* 2019), illegal hunting (van Vliet*et al.,* 2023), and especially climate change (Haest *et al.,* 2021). These factors, often synergistic, reduce the genetic diversity and adaptive capacity of bats (Razgour *et al.,* 2021) in the Yangambi landscape, thus increasing the risks of local or regional extinctions (Hohenlohe *et al.,* 2021). Although ecological fragmentation, induced by the exploitation of plant and animal resources, profoundly modifies the distribution of frugivorous, insectivorous or nectarivorous species (Webala *et al.,* 2019),it also intensifies interspecific competition for food resources and roosting sites (Clare *et al.,* 2011), which forces some species to expand their ecological niche or adopt more generalist diets (Sippola *et al.,* 2025). These adjustments alter the balance of bat communities in the reserve and cause an altitudinal or latitudinal redistribution of species (Voigt and Holderied, 2012). In this context, the analysis of the specific diversity and spatial distribution of bats along an ecological transect appears to be a relevant methodological approach to study the responses of species to environmental constraints (Campbell *et al.,* 2007, Mace *et al.,* 2012). This approach allows us to better identify anthropization gradients and to understand the mechanisms of niche sharing and reduction of interspecific conflicts (Paltrinieri*et al.,* 2025). Furthermore, some bats can adjust their behavior in interaction with temperature variations to optimize their thermoregulation (Klingbeil and Willig, 2009), although these adaptive responses remain poorly documented due to insufficient time series (Chang *et al.,* 2019). In addition, changes in the climate regime, particularly in temperature and precipitation, are likely to modify the geographical distribution and specific diversity of bats in this region in the long term (Brown *et al.,* 1997). Finally, due to their sensitivity to environmental changes and their position in the trophic chain (Maslo *et al.,* 2022), bats are excellent bioindicators of the health of forest ecosystems (Kolkert *et al.,* 2020), as are diurnal raptors (Dardanelli and Bellis, 2021). Their role as umbrella species (Fialas *et al.,* 2025) justifies their use as priority targets in conservation strategies (Korine and Pinshow, 2004). Thus, this study is part of a spatio-temporal approach aimed at characterizing bat assemblages in the Yangambi landscapeand guiding sustainable biodiversity management strategies in the forests of the Congo Basin (Charbonnier *et al.,* 2014).

II. METHODS

2.1. Study area and experimental design

This work was carried out in the YBR, located in the Tshopo province of the DRC **[Figure 1, (c)]**, 100 km west of the city of Kisangani (Kyale Koy *et al.,* 2019). The climate is continental equatorial, type Af according to the Köppen classification. The annual averages of precipitation and temperature are respectively 1830 mm and 25.0 °C (Likoko *et al.,* 2019).The reserve is bordered to the southwest by the Congo River **[Figure 1, (a)]**; it is crisscrossed by tributaries, the main ones being the Aruwimi (to the north) and Lindi (to the east) rivers. The soils of the Yangambi plateau are predominantly ferralsols (Luambua *et al.,* 2022). The vegetation of the reserve includes mature mixed forest, mature *Gilbertiodendron dewevrei* (De Wild.) J. Léonard forest and anthropized stands (fallow land and secondary forests), a consequence of slash-and-burn agriculture, which is the main activity of local populations (Mangaza *et al.,* 2022).

The reserve and its periphery include the Yangambi agglomeration as well as various villages (Koy and Ngonga, 2017) and camps distributed along the river and the roads within or around its boundaries (Likoko *et al.,* 2019). In addition to the houses built from sustainable materials in Yangambi center, the riverside villages and camps of the YBRare characterized by housing built from materials found in the forest.(van Vliet*et al.,* 2023). The roads that cross or border the reserve allow the movement of the population within the region and towards the largeurban areas, including Kisangani, Yangambi, Isangi, and Bengamisa (Van Vliet *et al.,* 2022). However, some are currently only passable on foot or two-wheeled vehicles. The dominant crops are cassava, rice, maize, peanuts, and plantain (Ebuy *et al.,* 2016). Perennial crops such as cocoa, rubber, oil palm, and coffee were introduced during the colonial era by the l'Institut national pour L'étude agronomique du Congo belge [National Institute for Agronomic Studies of the Belgian Congo], now the Institut national pour l'étude et la recherche agronomique [National Institute for Agronomic Studies and Research]. The old plantations date from the 1940s and 1960s and are still being exploited.

For the bat inventory in the YBR, a strategy was developed by combining the topographic gradient of a habitat along a mega transect course using a stream as a starting point. Based on non-destructive vegetation methods, 18 permanent plots were installed and arranged. This bat monitoringschemewas replicated at each bat inventory site. Habitat descriptions were carried out within these 18 plots for each research site. The plots had a main length of 1000 m, spaced at 200 m intervals using the Euclidean distance from the stream as a reference point. The habitat description was carried out in plots of 100 m^2 i.e. 5 mx 20 m at a space of 200 m from each other **[Figure 1, (b)]** and finally, the inventory of trees or lianas with dbh (diameter at breast height) ≥ 5 cm in the different capture sites was carried out to list the number of species and/or plant families in the various sites. The GPS points (geographic coordinates) for each plot were taken and then introduced into open access digital cartographic data (RGC, 2010) (Mande *et al.,* 2023) with our own field surveys, using QGIS 2.8.

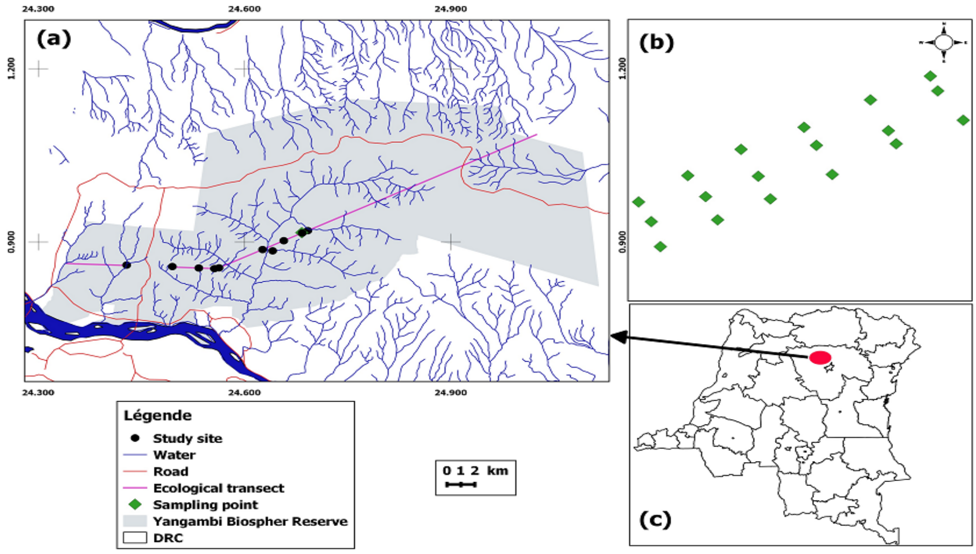

Figure 1. Research site location. **(a)** Distribution of different sampling sites along a transect in the Yangambi Biosphere Reserve;**(b)** representation of the18 nested sampling points of (20 × 5 m) spaced 200 m apart at each sampling siteand (c) location of the Yangambi Biosphere Reserve in the Democratic Republic of Congo.

2.2. Bat sampling

The bats were captured at Bonde Moke (May 2023); Ikoo 1, Lobilo and Watu (July-August 2023); Bongale, Ilokonda 1 and Osobisa (November-December 2023); Ikoo 2, Moni and Point Zéro (January-February 2024) and finally at Ilokonda 2 and Mawate (May 2025). We used a set of 8 traps per site: six nylon mist nets (ecotone, Poland) (2 of each type: **1**: mesh: 14x14 mm, levels: 5, length: 10 m, height: 2.5 m; **2**: mesh: 30x30 mm, levels: 4, length: 12 m, height: 3.2 m; **3**: mesh: 20x20 mm, levels: 4, length: 9 m, height: 3.2 m. The elevation of the nets depended on the available forest paths and varied from 1 to 7 m above ground. Furthermore, two harp traps (iron and aluminum poles, 150 cm x 150 cm capture surface brand Thailand)were placed at an elevation of 3.5 meters approximately. Bats trying to cross the system were stopped by rows of vertical nylon lines of the harp trap and fell directly into the pocket below. This type of trap limits the stress of the bats but covers a smaller sampling area (approximately 2.25 m²) compared to the mist net, so the harp trap is placed in a fairly closed environment (paths, trails, transects, streams and so on). Unfortunately, the use of mist nets and harp traps excludes the capture of species that fly high in the trees or above the canopy, e.g. Molossidae, which have a completely different morphology (Festa *et al.,* 2022).

To standardize the capture effort, the surveys were collected over four successive nights for each capture site (e.g. Bonde Moke, Bongale, Ikoo, Ilokonda 1, Ilokonda 2, Mawate, Lobilo, Osobisa and Watu including, 4 nights times 8 traps times 12 hours times 9 sites, an effort of 3,456 trap nights hours for this research which took place between 2023 and 2025. A trap night refers to a mist net or harp trap open for 12 hours after sunset (18:00-06:00). The sampling time was set according to the time slot of the bats' exit, so that the sampling duration of 4 hours corresponding to an event is identical for all events at a site: early evening (18:00-22:00), middle of the night (22:00-02:00) and early morning (02:00-06:00) according to Central African Time (UTC+02:00). During each event, traps were checked at least every 30 minutes. Captured bats were individually placed in cloth bags (30 × 40 cm) before being subjected to morphometric measurements and identified by referring to the identification key to East African bats by Patterson and Webala (2012).

2.3. Data processing and analysis

Bat body biomass was measured using Pesola brand precision balances, whose capacities varied between 10 g and 200 g, depending on the size of the bat specimens. Morphometric measurements were obtained using a high-precision caliper (0.01 mm), allowing the measurement of forearm length (FA), foot length (Foot), ear length (Ear) and tail length (Tail) in insectivorous species, which were used for the taxonomic identification of the bats, based on the determination key of Patterson and Webala (2012). Data analysis was conducted using Excel 2016 software for the organization and processing of the collected information and the production of tables and graphs. The PAST software (Hammer *et al.,* 2001) was used for the calculation of diversity indices, including Shannon indices (H'), Simpson indices (D), dominance and equitability indices (EQ), in order to characterize the structure of bat assemblages.

III. Results

Figure 2 illustrates the variation in the number of bats and the number of species captured during the night, suggesting that each hourly reading corresponds to one or more species active during that time slot. Activity begins at 6 pm and continues until 6 am, with well-marked peaks of activity between 7 pm and 9 pm. Captures are highest in the early evening, with a peak of 113 individuals and 23 species around 7 pm, followed by a second maximum of 96 individuals and 27 species around 9 pm. After midnight, numbers decrease sharply, reaching a minimum of 12 individuals and 4 species around 2 am. A slight recovery is observed between 3 am and 4 am (44 individuals and 17 species), before a gradual decline until dawn (6 am), when only 2 individuals and 2 species are captured. The general trend shows maximum bat activity in the early night, followed by a gradual decrease with some fluctuations before dawn.

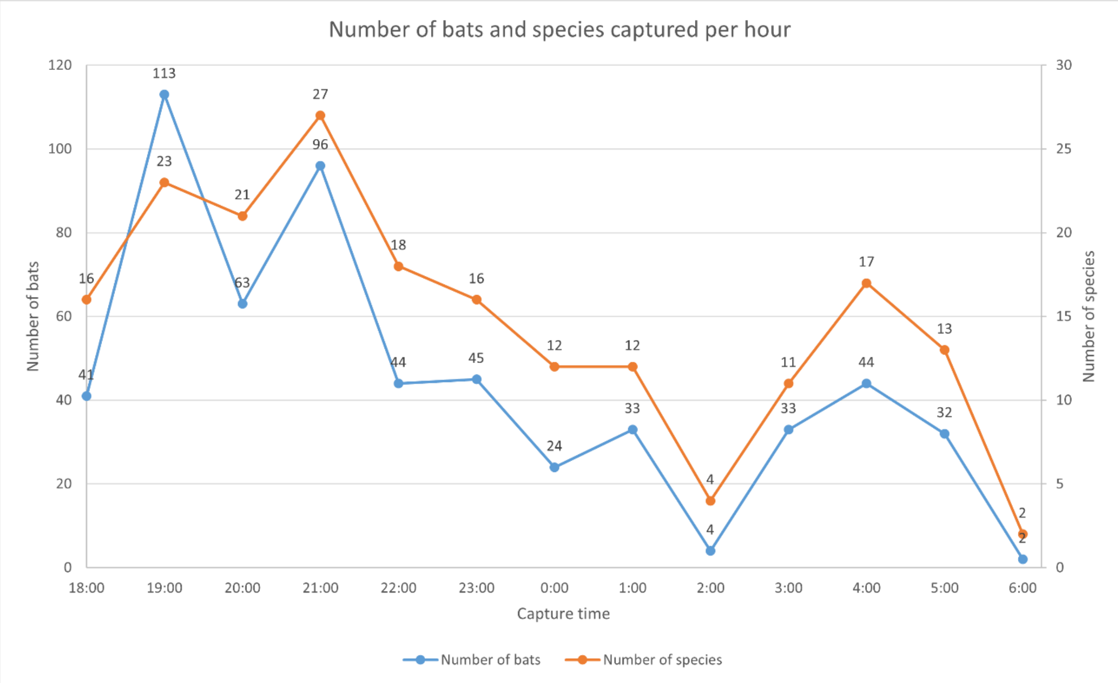

Figure 2. Activity level of captured bats and species during this study.

Table 1. Diversity, species richness and relative abundance of bats along an ecological transect of the RBY.

Family	Genus	Species	Number of bats	Relative abundance
Hipposideridae	*Doryrhina*	*Doryrhina camerunensis*	2	0.35%
		Doryrhina cyclops	10	1.91%
	Hipposideros	*Hipposideros beatus*	27	4.70%
		Hipposideros caffer	17	2.96%
		Hipposideros fuliginosus	1	0.17%
		Hipposideros ruber	1	0.17%
		Hipposideros sp	2	0.35%
	Macronycteris	*Macronycteris gigas*	14	2.44%
Megadermatidae	*Lavia*	*Lavia frons*	1	0.17%
Molossidae	*Chaerephon*	*Chaerephon bemmeleni*	3	0.52%
		Chaerephon major	6	1.05%
		Chaerephon nigeriae	15	2.61%
		Chaerephon sp	1	0.17%
	Mops	*Mops nanulus*	10	1.74%
		Mops pumilus	1	0.17%
		Mops sp	3	0.52%
Nycteridae	*Nycteris*	*Nycteris grandis*	1	0.17%
		Nycteris hispida	2	0.35%
Pteropodidae	*Casinycteris*	*Casinycteris argynnis*	17	2.96%
	Epomops	*Epomops franqueti*	64	11.15%
	Hypsignathus	*Hypsignathus monstrosus*	3	0.52%
	Megaloglossus	*Megaloglossus woermanni*	49	8.54%
	Myonycteris	*Myonycteris torquata*	131	22.82%
	Scotonycteris	*Scotonycteris bergmansi*	19	3.31%
Vespertilionidae	*Afronycteris*	*Afronycteris nanus*	81	14.11%
	Glauconycteris	*Glauconycteris argentata*	1	0.17%

		Glauconycteris beatrix	13	2.26%
		Glauconycteris curryae	18	3.14%
		Glauconycteris gleni	2	0.35%
		Glauconycteris humeralis	2	0.35%
		Glauconycteris poensis	1	0.17%
		Glauconycteris sp	8	1.39%
		Glauconycteris superba	5	0.87%
		Glauconycteris variegata	3	0.52%
	Kerivoula	*Kerivoula cuprosa*	4	0.70%
		Kerivoula lanosa	2	0.35%
		Kerivoula sp	5	0.87%
	Laephotis	*Laephotis capensis*	3	0.52%
	Mimetillus	*Mimetillus moloneyi*	2	0.35%
	Myotis	*Myotis bocagii*	2	0.35%
		Myotis sp	1	0.17%
	Neoromicia	*Neoromicia sp*	1	0.17%
	Pseudoromicia	*Pseudoromicia tenuipinnis*	1	0.17%
	Scotophilus	*Scotophilus dinganii*	14	2.44%
Rhinolophidae	*Rhinolophus*	*Rhinolophus alcyone*	4	0.70%
Total: 7	23	*45*	574	100.00

Table 1 presents the assessment of species diversity and spatial distribution of bats along an ecological transect in the YBR, which illustrates the mechanisms of species distribution. Hipposideridae mainly capture slow-flying and highly maneuverable insectivorous species, specialized in hunting in closed environments, typically dense forests. The dominant species, *Hipposideros beatus* and *Hipposideros caffer*, are distinguished by a constant frequency echolocation, perfectly adapted to the detection of immobile prey in a cluttered environment. Their moderate abundance reflects a stable but targeted exploitation of these habitats, which translates an ecological selectivity of resources (insects or habitats). The family Megadermatidae, represented here only by *Lavia frons*, is rare in the sampling. This bat, both carnivorous and insectivorous, adopts a hunting strategy by hanging in wait, in semi-open or wooded areas. Its low observation frequency could reflect habitat degradation or an affinity for microhabitats that are poorly represented in the study area. Among the Molossidae, the identified species, including *Chaerephon nigeriae* and *Mops nanulus*, are adapted to open environments and the upper or intermediate layers of the canopy. Their fast, straight flight makes them effective for capturing insects at high altitudes, generally after dusk. Their intermediate abundance underlines their ecological role in regulating flying insect populations, as well as their ability to exploit fragmented habitats or habitats subject to anthropogenic disturbance. The Nycteridae, represented by *Nycteris grandis* and *Nycteris hispida*, remain infrequent in captures. These discrete and crepuscular species, with slow and silent flight, usually frequent dense forests or plant galleries. Their rarity can be explained by avoidance behaviors or difficult detection by the capture methods used in this study. On the other hand, Pteropodidae constitute the most abundant family, both in number of individuals and biomass. Essentially frugivorous or nectarivorous, with flagship species such as *Hypsignathus monstrosus*, *Myonycteris torquata*, *Epomops franqueti,* etc., these bats play a major ecological role in pollination and seed dispersal. They mainly exploit the upper and intermediate layers of vegetation, and benefit from the floristic richness of the YBR as well as a high availability of plant resources. Their abundance also testifies to their ecological flexibility in the face of habitat mosaics, including secondary forests, edges and cultivated environments. The Vespertilionidae family, for its part, is distinguished by a remarkable specific richness and an extensive functional diversity. *Afronycteris nanus* is the dominant species, followed by several representatives of the genus *Glauconycteris*. These insectivores, with varied flight abilities, occupy a wide spectrum of forest strata, from the canopy to the undergrowth. Their adapted echolocation and behavioral plasticity reflect a fine ecological partitioning, favoring coexistence in a complex and multistratified environment. Finally, the Rhinolophidae are represented by *Rhinolophus alcyone*, a strictly insectivorous species, with slow and precise flight, perfectly adapted to dense forests thanks to its constant frequency echolocation. Its low abundance probably reflects strict ecological selectivity. Overall, the specific and functional composition of the observed bats reflects a community finely structured along distinct ecological axes. The frugivores and nectarivores of the Pteropodidae dominate the upper or intermediate strata, reflecting a high availability of plant resources in the forests. The Hipposideridae and Vespertilionidae, rich in specialized insectivores, reveal a structural heterogeneity favorable to niche diversification. The Nycteridae, Molossidae, and Rhinolophidae, although less frequent, make a complementary functional contribution. This organization suggests a sophisticated ecological balance, in which each group takes advantage of distinct niches in terms of space, resources, and behaviors, thus ensuring the stability and resilience of the YBR.

Table 2. Overview of bat captures at different sites along an ecological transect in the RBY.

Species	Bonde Moke	Bongale	Ikoo 1	Ikoo 2	Ilokonda 1	Ilokonda 2	Lobilo	Mawate	Moni	Osobisa	Zero point	Watu	Grand Total
Afronycteris nanus	16	1	1	13	18	11	2		4	2		13	81
Casinycteris argynnis	1			1		5	1	1			7	1	17
Chaerephon bemmeleni									3				3
Chaerephon major				1					5				6
Chaerephon nigeriae									15				15
Chaerephon sp									1				1
Doryrhina camerunensis	1					1							2
Doryrhina cyclops	4		1	1	2	2				1			11
Epomops franqueti	3	1	1	1	6	6	18	22	1		3	2	64
Glauconycteris argentata	1												1
Glauconycteris beatrix	5	3	2			1						2	13
Glauconycteris curryae				8		4						6	18
Glauconycteris gleni		1			1								2
Glauconycteris humeralis				1								1	2
Glauconycteris poensis	1												1
Glauconycteris sp				4	1				3				8
Glauconycteris superba	1	1	2			1							5
Glauconycteris variegata	1											2	3
Hipposideros beatus	3	4	1	4	1	4	4			1		5	27
Hipposideros caffer	7	1	1	2	6								17
Hipposideros fuliginosus	1												1
Hipposideros ruber									1				1
Hipposideros sp	2												2
Hypsignathus monstrosus				1		2							3
Kerivoula cuprosa		2		1								1	4
Kerivoula lanosa				1								1	2
Kerivoula sp				1		4							5
Laephotis capensis	1	1										1	3
Lavia frons			1										1
Macronycteris gigas	9								3		1	1	14
Megaloglossus woermanni	3			1			7	1	20		16	1	49
Mimetillus moloneyi	1	1											2
Mops nanulus						1			9				10
Mops pumilus						1							1
Mops sp									3				3
Myonycteris torquata	22		2	1	3	23	4	39		1	33	3	131
Myotis bocagii												2	2
Myotis sp						1							1
Neoromicia sp	1												1
Nycteris grandis						1							1
Nycteris hispida										1		1	2
Pseudoromicia tenuipinnis	1												1
Rhinolophus alcyone		1				1				2			4

Species	Bonde Moke	Bongale	Ikoo 1	Ikoo 2	Ilokonda 1	Ilokonda 2	Lobilo	Mawate	Moni	Osobisa	Zero point	Watu	Grand Total
Scotonycteris bergmansi			2	1	2	3	5	3	2	1			19
Scotophilus dinganii	1				10	2						1	14
Grand Total	86	17	14	43	50	74	41	66	70	9	60	44	574
Number of species per site	22	11	10	9	10	19	7	5	13	7	5	17	45

Table 2 presents 12 sampling sites in the YBR, according to the localities studied. The sampled sites are Bonde Moke (22 species / 86 specimens, followed by Ilokonda 2 (19/74), Moni (13/70), Mawate (5/66) and Point Zéro (5/60). This high representativeness suggests that these localities were considered as priorities for data collection, probably due to their accessibility, ecological diversity or strategic importance in the sampling protocol. At an intermediate level, we find Ilokonda 1 (10/50), Watu (17/44), Ikoo 2 (17/43) and Lobilo (7/41), indicating significant, but less sustained, inventory or biological monitoring activity. On the other hand, localities such as Bongale (11/17), Ikoo 1 (10/14) and especially Osobisa (7/9) show the lowest numbers. The most species-diverse sites are Bonde Moke, Ilokonda 2, Ikoo 2 and Watu. Some sites, such as Mawate (5 species), Point Zéro (5) or Osobisa (7), have a lower species diversity. The analysis reveals the presence of a set of very poorly represented species, generally observed by only one or two individuals. These rare species contribute little to the total abundance but enrich the overall specific diversity of the local communities. Among them are notably *Doryrhina camerunensis* (2 individuals), *Glauconycteris argentata* (1), *Hipposideros fuliginosus* (1), *Nycteris grandis* (1) and *Pseudoromicia tenuipinnis* (1). Other uncommon species include *Glauconycteris beatrix*and *Kerivoula cuprosa* (observed at Bongale) and *Lavia frons* (at Ikoo 1), *Scotonycteris bergmansi* (at Osobisa and Watu), and *Hipposideros beatus* (in very low numbers at Osobisa). Their sporadic occurrence could reflect either a naturally low density, occasional passage or undersampling. These infrequent species nevertheless play an important role in maintaining the functional and genetic diversity of bat communities in the studied landscape. Additionally, several rare species, such as *Glauconycteris argentata*, *Hipposideros fuliginosus*, *Lavia frons*, *Nycteris grandis*, *Pseudoromicia tenuipinnis* are represented by only 1 to 2 individuals. The heterogeneous distribution of sampling effort reflects a differentiated strategy according to geographical areas. It may reflect specific ecological objectives, habitat diversity or conservation issues specific to each locality. This imbalance should be taken into account in the interpretation of biodiversity data to avoid bias in the analysis of species richness or in the assessment of the spatial distribution of species.

Table 3. Overview**of captured bats according to habitat type**

Species	Watercourse	Mixed primary forest	Monodominant primary forest	Secondary forest	Grand Total
Afronycteris nanus	73	8			81
Casinycteris argynnis		10		7	17
Chaerephon bemmeleni	3				3
Chaerephon major	2	4			6
Chaerephon nigeriae	5	10			15
Chaerephon sp		1			1
Doryrhina camerunensis	1	1			2
Doryrhina cyclops	5	5			10
Doryrhina cyclops	1				1
Epomops franqueti	9	44	8	3	64
Glauconycteris argentata	1				1
Glauconycteris beatrix	13				13
Glauconycteris curryae	18				18
Glauconycteris gleni	2				2
Glauconycteris humeralis	2				2
Glauconycteris poensis	1				1
Glauconycteris sp	7	1			8

Species	Watercourse	Mixed primary forest	Monodominant primary forest	Secondary forest	Grand Total
Glauconycteris superba	5				5
Glauconycteris variegata	3				3
Hipposideros beatus	25	2			27
Hipposideros caffer	16	1			17
Hipposideros fuliginosus	1				1
Hipposideros ruber	1				1
Hipposideros sp	2				2
Hypsignathus monstrosus	2	1			3
Kerivoula cuprosa	4				4
Kerivoula lanosa	2				2
Kerivoula sp	5				5
Laephotis capensis	3				3
Lavia frons		1			1
Macronycteris gigas	10	3		1	14
Megaloglossus woermanni	17	16		16	49
Mimetillus moloneyi	2				2
Mops nanulus	6	4			10
Mops pumilus		1			1
Mops sp	2	1			3
Myonycteris torquata	21	57	20	33	131
Myotis bocagii	2				2
Myotis sp	1				1
Neoromicia sp	1				1
Nycteris grandis	1				1
Nycteris hispida		2			2
Pseudoromicia tenuipinnis	1				1
Rhinolophus alcyone	3	1			4
Scotonycteris bergmansi	4	13	2		19
Scotophilus dinganii	13	1			14
Grand Total	296	188	30	60	574
Number of species	41	23	3	5	

Table 3 indicates that captures are dominated at streams (296), followed by primary mixed forests (188), whereas secondary forests (60) and monodominant primary forests (30) present relatively low abundances. More than half of the recorded individuals (51.6 %) were captured at streams, and primary mixed forests constitute the second most representative habitat, with nearly a third of captures (32.8%). In contrast, secondary forests only shelter a modest proportion of individuals (10.5%), while monodominant primary forests appear to be the least preferred habitat in terms of captures, with only 5.2%. These results suggest that habitat availability and structure strongly influence the distribution of captured specimens.

Table 4. Diversity indices of different bat sampling sites along an ecological transect

	Bonde Moke	Bongale	Ikoo 1	Ikoo 2	Ilokonda 1	Ilokonda_2	Lobilo	Mawate	Moni	Osobisa	Zero point	Watu
Taxa (S)	22	11	10	17	10	19	7	5	13	7	5	17
Individuals	86	17	14	43	50	74	41	66	70	9	60	44

Dominance (D)	0.13	0.13	0.11	0.15	0.21	0.14	0.26	0.46	0.16	0.16	0.39	0.14
Simpson (1-D)	0.87	0.87	0.89	0.85	0.79	0.86	0.74	0.54	0.84	0.84	0.61	0.86
Shannon (H)	2.47	2.23	2.24	2.31	1.86	2.39	1.61	0.94	2.13	1.89	1.15	2.4
Equity (EQ)	0.8	0.93	0.97	0.81	0.81	0.81	0.83	0.59	0.83	0.97	0.71	0.85

Species richness is particularly high at Bonde Moke (22 species) with a very high population size (86 individuals), associated with low dominance (0.13), high diversity (Simpson = 0.87; Shannon = 2.47) and good evenness (0.80). Conversely, Mawate is distinguished by high abundance (66 individuals) but low species richness (5 species), very high dominance (0.46), very low diversity (Shannon = 0.94) and low evenness (0.59), indicating a high concentration of individuals in few species. Sites such as Watu, Ilokonda 2, Ikoo 2 and Bongale show a high and balanced diversity (Shannon > 2.3; Simpson > 0.85; EQ > 0.80), reflecting a good distribution of individuals among many species. In contrast, Lobilo, Point Zéro and Ilokonda 1 show lower diversity (Shannon < 2.0) with marked dominance (D ≥ 0.21), suggesting less balanced communities. Overall, these data reveal a clear spatial structuring, contrasting rich and diverse sites with others that are poor and dominated by a few species.

IV. Discussion

Assessment of bat diversity along an ecological transect in the YBR reveals remarkable richness, with 574 bat specimens recorded, distributed over 45 species, covering 23 genera and 7 families. This diversity reflects a complex ecosystem (Campbell *et al.,* 2007), relatively well preserved in some areas, although locally affected by anthropogenic pressures and fragmentation. The taxonomic composition is dominated by Vespertilionidae, followed by Pteropodidae and Hipposideridae, a structure consistent with the observations of Mande *et al.* (2023), who describe the Congo Basin forests as important refuges for bat diversity, particularly among species adapted to vertical stratification. Genera such as *Glauconycteris*, *Hipposideros* and *Myonycteris* illustrate an ecological specialization of resources (fruits, nectars or insects), likely influenced by height gradients, microhabitat complexity and resource availability. This species richness is consistent with Cosson *et al.* (1999), who indicate that secondary or regenerating forests can maintain high diversity, especially among insectivores and frugivores. The observed abundance structure shows the dominance of a few species, of which *Myonycteris torquata*, *Afronycteris nanus*, *Epomops franqueti* and *Hipposideros beatus* are considered as multi-habitat specialists. These habitats are frequently used by several coexisting species. This pattern follows a log-normal model typical of tropical communities, as described by Flipo (2018). However, the dominance of some species could reflect local disturbances such as fragmentation, habitat loss or modification of food resources (Sippola *et al.,* 2025). Bat activity is concentrated in the early night, with two peaks between 7 pm and 9 pm, reflecting an adaptation to the abundance of nocturnal insects and fruits. After midnight, captures decrease before resuming moderately between 3 am and 4 am, depending on trophic guilds. Some species are crepuscular, while others exploit late periods to reduce interspecific competition. These results are consistent with Blažek *et al.* (2021), who highlight the influence of environmental conditions and habitats, including anthropogenic ones. In Yangambi, the presence of open areas, streams, and forest edges likely heightens early peaks in activity. Thus, the behavioral plasticity of bats illustrates a trade-off between foraging opportunities, energy saving, risk avoidance, and roost availability. This temporal organization reflects opportunistic ecological structuring (Clare *et al.,* 2011), often observed during events of high trophic availability, such as mass caterpillar emergences, as documented by Blažek *et al.* (2021). Moreover, recent work such as Einav *et al.* (2024) has highlighted the importance of acoustic stimuli in triggering hunting activity, particularly in semi-desert environments, suggesting that analogous mechanisms could be at work in the YBR. The acoustic and trophic functional traits of the observed species reflect strong ecological specialization. *Hipposideros beatus* and *H. caffer* (Hipposideridae) use constant frequencies to detect immobile prey in dense habitats (Chang *et al.,* 2019), while the rarity of *Lavia frons* (Megadermatidae) could indicate strict selectivity for certain poorly represented microhabitats. This phenomenon supports the principle of competitive exclusion (Hardin, 1960), as illustrated by Preatoni *et al.* (2011) in the Alps. Molossidae such as *Chaerephon nigeriae* and *Mops nanulus* show an affinity for open environments. Their role in regulating night-flying insect populations is well documented, particularly in agricultural systems such as cotton plantations (Kolkert *et al.,* 2020). Vespertilionidae, particularly *Afronycteris nanus*, express a large morpho-functional variability, which illustrates their ability to occupy various canopy levels. This niche differentiation (Novella-Fernandez *et al.,* 2020), is based on specific microhabitat preferences (Ashrafi *et al.,* 2013) and has been widely described in morphologically close species such as *Pipistrellus pipistrellus*and *P. pygmaeus* in temperate regions (Nicholls and Racey, 2006). Pteropodidae dominate both in biomass and abundance. Their central role in pollination and seed dispersal is confirmed by Boyles *et al.* (2011), who emphasize their ecological and economic value in tropical agriculture. The floristic richness of the YBR supports this abundance, as demonstrated by Taberlet *et* *al.* (2018) via environmental DNA analyses. As for Nycteridae and Rhinolophidae, their low representativeness could be due to avoidance behaviors or under-detection related to the sampling method, a bias already highlighted by Legendre *et al.* (1997). This spatial variation influences species representation and must be considered in data interpretation. Bat distribution is strongly influenced by resource availability and the structural complexity of habitats. Streams, rich in insects and fruits, constitute ecological corridors favorable to various guilds, which confirm that structured habitats increase chiropteran diversity (Klingbeil and Willig, 2009). Mixed primary forests, with their mosaic of niches, favor species coexistence via resource partitioning (Chang *et al.,* 2019). Conversely, monodominant forests, poor in resources and homogeneous, limit functional diversity (Cosson *et al.,* 1999). Secondary forests, which are less stable, mainly host opportunistic species (Meyer *et al.,* 2008). Finally, the high activity near water highlights the importance of bats in insect regulation and ecosystem services (Maslo *et al.,* 2022). Diversity indices show that Bonde Moke and Ilokonda 2 have balanced and rich communities, while Mawate and Point Zéro reveal a more marked dominance of a few species. This imbalance could result from anthropogenic disturbances or increased fragmentation, resulting in a simplification of assemblages and a decrease in ecological resilience (Kolkert *et al.,* 2020). The strong specific dominance observed at Mawate and Point Zéro contrasts with the high equitability of other sites, which illustrate a heterogeneous community structure. According to Klingbeil and Willig (2009), this pattern is common in disturbed habitats, where a few tolerant generalist species outcompete specialist species, such as *Myonycteris torquata* and *Epomops franqueti*, which are dominant at Mawate and Point Zéro. Conversely, sites with high equitability reflect a more homogeneous distribution of individuals between species, often linked to a stable and complex environment (Willig *et al.,* 2007). These authors emphasize that structural complexity increases available niches and reduces competition, explaining coexistence in equitable sites and dominance in simplified sites. Taken together, these results indicate that along an ecological transect, there is an exceptionally rich, ecologically diverse, and strategically organized bat community along functional and temporal gradients. However, this diversity remains vulnerable to anthropogenic threats and habitat fragmentation. The combination of taxonomic, functional, and acoustic analyses establishes the YBR as a priority area for the conservation of Afrotropical bats, particularly in the context of rapid ecological change. These results call for strengthening long-term monitoring efforts and integrating conservation approaches based on species functionality.

V. Conclusion

The study conducted in the YBR reveals a remarkably diverse and ecologically well-structured bat community, with 45 species distributed in 7 families. Vespertilionidae, Pteropodidae and Hipposideridae largely dominate, driven by the abundance of *Myonycteris torquata*, *Epomops franqueti*, *Megaloglossus woermanni*, *Afronycteris nanus*, *Hipposideros beatus,* etc.The spatial distribution of species along the transect highlights significant heterogeneity between localities: some sites, such as Mawate or Point Zéro, exhibit strong specific dominance, while other sites display greater evenness. These contrasts reflect the combined influence of habitat structure, human pressure and ecological connectivity. The low detection of families such as Nycteridae or Rhinolophidae suggests sensitivity to fragmentation or sampling biases. This spatial variability, both taxonomic and functional, highlights the importance of multi-scale monitoring, combining field methods, genetic analyses and acoustic tools. The YBR is confirmed as a hotspot of bat diversity in Central Africa, which requires adaptive conservation strategies in the face of increasing environmental pressures.

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References

[1]. Blažek, J., Konečný, A., & Bartonička, T. (2021). Bat aggregational response to pest caterpillar emergence. Scientific Reports, 11, 13634. https://doi.org/10.1038/s41598-021-93104-z

[2]. Boyles, J. G., Cryan, P. M., McCracken, G. F., & Kunz, T. H. (2011). Economic importance of bats in agriculture. Science, 332(6025), 41–42. https://doi.org/10.1126/science.1201366

[3]. Brown, G. W., Nelson, J. L. & Cherry, K. A. (1997). The influence of habitat structure on insectivorous bat activity in montane ash forests of the Central Highlands, Victoria. Australian Forestry, 60(2), 138–146. https://doi.org/10.1080/00049158.1997.10674709

[4]. Campbell, P., Schneider, C. J., Zubaid, A., Adnan, A. M. & Kunz, T. H. (2007). Morphological and Ecological Correlates of Coexistence in Malaysian Fruit Bats (Chiroptera : Pteropodidae). Journal of Mammalogy, 88(1), 105-118. https://doi.org/10.1644/06-MAMM-A-160R1.1

[5]. Chang, Y., Song, S., Li, A., Zhang, Y., Li, Z., Xiao, Y., Jiang, T., Feng, J. & Lin, A. (2019). The roles of morphological traits,

resource variation and resource partitioning associated with the dietary niche expansion in the fish-eating bat *Myotis pilosus*. Molecular Ecology, 28(11), 2944–2954. https://doi.org/10.1111/mec.15127

[6]. Charbonnier, Y., Barbaro, L., Theillout, A. & Jactel, H. (2014). Numerical and Functional Responses of Forest Bats to a Major Insect Pest in Pine Plantations. PLoS ONE, 9(10), e109488. https://doi.org/10.1371/journal.pone.0109488

[7]. Clare, E. L., Barber, B. R., Sweeney, B. W., Hebert, P. D. N. & Fenton, M. B. (2011). Eating local: influences of habitat on the diet of little brown bats (*Myotis lucifugus*). Molecular Ecology 20(8): 1772–1780. https://doi. org/10.1111/j.1365-294X.2011.05040.x

[8]. Cosson, J.-F., Pons, J.-M. & Masson, D. (1999). Effects of forest fragmentation on frugivorous and nectarivorous bats in French Guiana. Journal of Tropical Ecology, 15(4), 515-534. https://doi.org/10.1017/S026646749900098X

[9]. Dardanelli, S. & Bellis, L. M. (2021). Nestedness structure of bird assemblages in a fragmented forest in Central Argentina: the role of selective extinction and colonization processes. Animal Biodiversity and Conservation, 44(1): 17–29, https://doi.org/10.32800/abc.2021.44.0017

[10]. Ebuy, J., Mate J. P., Mukandama J. P. & Ponette, Q. (2016). Chute des litières et fertilité des sols sous plantations forestières dans le bassin du Congo : cas de la station I.N.E.R.A/Yangambi en R.D.C. 31:4843–4861. Journal of Animal &Plant Sciences, 31(1), 4843-4863, https://www.m.elewa.org/JAPS/2016/31(1)-November.html

[11]. Einav, A., Giladi, I., Schäckermann J. & Korine, C. (2024) Enhancing insectivorous bat activity through sound manipulation and assessing the contribution of small gaps in windbreaks in the hyper-arid Arava desert. Front. Conserv. Sci. 5:1491713: https://doi.org/10.3389/fcosc.2024.1491713

[12]. Festa, F., Ancillotto, L., Santini, L., Pacifici, M., Rocha, R., Toshkova, N., Amorim, F., Benítez-López, A., Domer, A., Hamidovic, D., Kramer-Schadt, S., Mathews, F., Radchuk, V., Rebelo, H., Ruczynski, I., Solem, E., Tsoar, A., Russo, D. & Razgour, O. (2022). Bat responses to climate change: A systematic review. Biological Reviews, 98(1), 19–33. https://doi.org/10.1111/brv.12893

[13]. Fialas, P.C., Santini, L., Russo, D., Amorim, F., Rebelo, H., Novella-Fernandez, R., Marques, F., Domer, A., Vella, A., Martinoli, A., Figurek, A., Tsoar, A., Sandor, A., Ibáñez, C., Korine, C., Kerbiriou, C., Voigt, C., Mifsud, C., Jére, C., Dalhoumi, R., Preatoni, D., Hamidović, D., Tidenberg, E.-M., Çoraman, E., Mathews, F., Lison, F., Furmankiewicz, J., Petersons, G., Loumassine, H., Garin, I., Csősz, I., Liira, J., Juste, J., Julien, J.F., van der Kooij, J., Darija, J., Aihartza, J., Eldegard, K., Phelps, K., Olival, K.J., Kipson, M., Ancillotto, L., Lesínski, G., Barti, L., Cantú Salazar, L., Bosso, L., Rodrigues, L., Hamel, L., Uhrin, M., Mas, M., Cerekovic, N., Toshkova, N., Roche, N., Kalda, O., Aizpurua, O., Georgiakakis, P., Kanuch, P., Presetnik, P., Bilgin, R., McKay, R.A., Rnjak, D., Rnjak, G., Ruczýnski, I., Sørås, R., Robert, S., Aulagnier, S., Kramer-Schadt, S., Gazaryan, S., Bücs, S.-L., Yorulmaz, T., Stjernberg, T., Liukko, U.-M., Nistreanu, V., Vintulis, V., Radchuk, V., Puig-Montserrat, X., Bas, Y., Zagmajster, M., Zegarek, M., Zrnčić, V. & Razgour, O.(2025). Changes in community composition and functional diversity of European bats under climate change. Conservation Biology, 39(4), e70025. https://doi.org/10.1111/cobi.70025

[14]. Flipo, A. (2018). Etude et modélisation des habitats de chasse potentiels des chiroptères en Wallonie sur base de données acoustiques. Thèse de maîtrise, Université de Liège, Belgique: i-ix, 1-75, http://hdl.handle.net/2268.2/5119

[15]. García-García, J. L., Santos-Moreno, A. & Kraker-Castañeda, C. (2014). Ecological traits of phyllostomid bats associated with sensitivity to tropical forest fragmentation in Los Chimalapas, Mexico. Tropical Conservation Science 7(3), 457-474. https://doi.org/10.1177/194008291400700307

[16]. Haest, B., Stepanian, P. M., Wainwright, C. E., Liechti, F. & Bauer, S. (2021). Climatic drivers of (changes in) bat migration phenology at Bracken Cave (USA). Global Change Biology 27(4), 768–780, doi: 10.1111/GCB.15433

[17]. Hammer, Ø., Harper, D. A.T. & Ryan, P. D. (2001). Past: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica, vol. 4, issue 1, art. 4: 9pp., 178kb. http://palaeo-electronica.org/2001_1/past/issue1_01.htm.

[18]. Hardin, G. (1960). The competitive exclusion principle. Science, 131(3409), 1292–1297. https://doi.org/10.1126/science.131.3409.1292

[19]. Hekkala, A.-M., Jönsson, M., Kärvemo, S., Strengbom, J. & Sjögren, J. (2023). Habitat heterogeneity is a good predictor of boreal forest biodiversity. Ecological Indicators, 148, 110069. https://doi.org/10.1016/j.ecolind.2023.110069

[20]. Hohenlohe, P.A., Funk, W.C. & Rajora, O. P. (2021). Population genomics for wildlife conservation and management. Mol Ecol. 30(1), 62–82. https://doi.org/10.1111/mec.15720

[21]. Jung, K., Kaiser, S., Böhm, S., Nieschulze, J. & Kalko, E. K. V. (2012). Moving in three dimensions : Effects of structural complexity on occurrence and activity of insectivorous bats in managed forest stands. Journal of Applied Ecology, 49(2), 523-531. https://doi.org/10.1111/j.1365-2664.2012.02116.x

[22]. Kipute, D. D., Mampeta, S. W., Kahindo, J-M. M., Lelo, U. D. M., Sufo Kankeu, R., Sonwa, J. D., Joiris, V. D. & Mate, J.-P. M. (2021). Complexity of zoning management in biosphere reserves: the case of the Yangambi Biosphere Reserve in DRC. International Forestry Review 23(1), 55-67. https://doi.org/10.1505/146554821832140358

[23]. Klingbeil, B. T. & Willig, M. R. (2009). Guild-specific responses of bats to landscape composition and configuration in fragmented Amazonian rainforest. Journal of Applied Ecology, 46(1), 203-213. https://doi.org/10.1111/j.1365-2664.2008.01594.x

[24]. Kolkert, H., Andrew, R., Smith, R., Rader, R. & Reid, N. (2020). Insectivorous bats selectively source moths and eat mostly pest insects on dryland and irrigated cotton farms. *Ecology and Evolution*, 10(1), 371–388. https://doi.org/10.1002/ece3.5901

[25]. Korine, C. & Pinshow, B. (2004). Guild structure, foraging space use, and distribution in a community of insectivorous bats in the Negev Desert. Journal of Zoology, 262(2), 187-196. https://doi.org/10.1017/S0952836903004539

[26]. Koy, J.K., & Ngonga, A. M. M. (2017). Pratiques Traditionnelles de Conservation de la Nature à L'épreuve des Faits Chez Les Peuples Riverains de la Réserve de Biosphère de Yangambi (RDC). European Scientific Journal, 13(8), 328-356. https://doi.org/10.19044/esj.2017.v13n8p328

[27]. 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), 1-38. https://doi.org/10.1111/j.1749-6632.2011.06004.x

[28]. Kyale Koy, J., Wardell, D. A., Mikwa, J.-F., Kabuanga, J. M., Monga Ngonga, A. M., Oszwald, J. & Doumenge, C. (2019). Dynamique de la déforestation dans la Réserve de biosphère de Yangambi (République démocratique du Congo) : Variabilité spatiale et temporelle au cours des 30 dernières années. Bois & forets des tropiques, 341, 15–28. https://doi.org/10.19182/bft2019.341.a31752.

[29]. Legendre, P., Galzin, R. & Harmelin-Vivien, M. L. (1997). Relating behavior to habitat: solutions to the fourth-corner problem. Ecology, 78(2), 547–562. https://doi.org/10.2307/2266029

[30]. Likoko, B. A., Mbifo, N, Besango, L., Totiwe, T., Badjoko, D. H., Likoko, A. G., Botomo, A. D., Litemandia, Y. N., Posho, N. B., Alongo, L.S. & Boyemba, B. F. (2019). Climate change for Yangambi Forest Region, DR Congo. Journal of Aquatic Sciences and Oceanography, 1(2): 203.

[31]. Luambua, N.K., Hubau, W., Salako, K.V., Amani, C., Bonyoma, B., Musepena, D., Rousseau, M., Bourland, N., Nshimba, H.S.M., Ewango, C., Beeckman, H. & Hardy, O.J. (2022). Spatial patterns of light-demanding tree species in the Yangambi rainforest (Democratic Republic of Congo). Ecology and Evolution, 11(24), 18691–18707, https://doi.org/10.1002/ece3.8443

[32]. Mace, G. M., Norris, K. & Fitter, A. H. (2012). Biodiversity and ecosystem services : A multilayered relationship. Trends in

Ecology & Evolution, 27(1), 19-26. https://doi.org/10.1016/j.tree.2011.08.006
[33]. Mande, C., Van Cakenberghe, V., Kirkpatrick, L., Laudisoit, A., De Bruyn, L., Gembu, G.-C. & Verheyen, E. (2023). Drivers affecting habitat use in Afrotropical hipposiderid and pteropodid bats. Biotropica, 55(5), 920-932. https://doi.org/10.1111/btp.13242
[34]. Mangaza, L., Makana, J.-R., Hubau, W., Sonwa, D., Batsi, G. & Fayolle, A. (2022). Impacts du changement d'utilisation des terres sur la biomasse et la diversité dans le paysage forestier de la réserve de biosphère de Yangambi en République démocratique du Congo. Bois et Forêts des Tropiques, 353, 61-73. https://doi.org/10.19182/bft2022.353.a36836
[35]. Maslo, B., Mau, R. L., Kerwin, K., McDonough, R., McHale, E. & Foster, J. T. (2022). Bats provide a critical ecosystem service by consuming a large diversity of agricultural pest insects. Agriculture, Ecosystems & Environment, 324, 107722. https://doi.org/10.1016/j.agee.2021.107722
[36]. Meyer, C. F. J., Fründ, J., Lizano, W. P. & Kalko, E. K. V. (2008). Ecological correlates of vulnerability to fragmentation in Neotropical bats. Journal of Applied Ecology, 45(1), 381-391. https://doi.org/10.1111/j.1365-2664.2007.01389.x
[37]. Muscarella, R. & Fleming, T. H. (2007). The Role of Frugivorous Bats in Tropical Forest Succession. Biological Reviews, 82(4), 573-590. https://doi.org/10.1111/j.1469-185X.2007.00026.x
[38]. Nicholls, B. & Racey, P. A. (2006). Habitat selection as a mechanism of resource partitioning in two cryptic bat species *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus*. Ecography, 29(5), 697–708. https://doi.org/10.1111/j.2006.0906-7590.04575.x
[39]. Novella-Fernandez, R., Ibañez, C., Juste, J., Clare, E. L., Doncaster, C. P. & Razgour, O. (2020). Trophic resource partitioning drives fine-scale coexistence in cryptic bat species. Ecology & Evolution, 10(24), 14122–14136. https://doi.org/10.1002/ece3.7004
[40]. Paltrinieri, L., Razgour, O., Santini, L., Russo, D., Aihartza, J., Aizpurua, O., Amorim, F., Ancillotto, L., Bidziński, K., Bilgin, R., Briggs, P., Cantù-Salazar, L., Ciechanowski, M., Cistrone, L., Dechmann, D.K.N., Eldegard, K., Fjelldal, M.A., Froidevaux, J., Furmankiewicz, J., Garin, I., Hamel, L., Ibáñez, C., Jankowska-Jarek, M., Juste, J., Korine, C., Lesiński, G., Leuchtmann, M., Martinoli, A., Mas, M., Mathews, F., McKay, R.A., Molenaar, T., Morris, C., Nistreanu, V., Olival, K.J., Pereswiet-Soltan, A., Péter, Á., Phelps, K., Pontier, D., Pope, L., Rebelo, H., Preatoni, D.G., Puig-Monserat, X., Roche, N., Ruczyński, I., Sándor, A.D., Sørås, R., Spada, M., Toshkova, N., van der Kooij, J., Voigt, C.C., Wikar, Z., Zapart, A., Zegarek, M. & Benítez-López, A. (2025). The effects of climate on bat morphology across space and time. Ecography, 2025(7), e07663. doi: 10.1002/ecog.07663
[41]. Patterson, B. D. & Webala, P. W. (2012). Keys to the bats (Mammalia: Chiroptera) of East Africa. Fieldiana Life and Earth Sciences, 6, 1– 60. https://doi.org/10.3158/2158-5520-12.6.1
[42]. Preatoni, D. G., Spada, M., Wauters, L. A., Tosi, G. & Martinoli, A. (2011). Habitat use in the female Alpine long-eared bat (*Plecotus macrobullaris*): does breeding make the difference? Acta Chiropterologica, 13(2), 355–364. https://doi.org/10.3161/150811011x624820
[43]. Razgour, O., Kasso, M., Santos, H. & Juste J. (2021). Up in the air: Threats to Afromontane biodiversity from climate change and habitat loss revealed by genetic monitoring of the Ethiopian Highlands bat. Evolutionary Applications 14(3), 794–806. https://doi.org/10.1111/eva.13161
[44]. Shipley, R., Wright, E., Selden, D., Wu, G., Aegerter, J., Fooks, A. R. & Banyard, A. C. (2019). Bats and viruses : emergence of novel lyssaviruses and association of bats with viral zoonoses in the EU. Tropical Medicine and Infectious Disease, 4(1), 31. https://doi.org/10.3390/tropicalmed4010031
[45]. Sippola, E. A., Johnson, J. S., Mammola, S., Apoznanski, G., Brila, I., Fernández Latapiat, I., Lundberg, P., Matlova, M., Nanni, V., Jackson, R. T., Perez-Jimenez, J., Sánchez-Navarro, S., Tena, E., Troitsky, T. S., Lilley, T. M. & Meierhofer, M. B. (2025). Impacts of bat use of anthropogenic structures on bats and humans. Conservation Biology, e70037. https://doi.org/10.1111/cobi.70037
[46]. Taberlet, P., Bonin, A., Zinger, L. & Coissac, E. (2018). Environmental DNA: for biodiversity research and monitoring (253 pp.). Oxford University Press. https://doi.org/10.1093/oso/9780198767220.001.0001
[47]. Thompson, T. Q., Bellinger, M. R., O'Rourke, S. M., Prince, D. J., Stevenson, A. E., Rodrigues, A. T., Sloat, M. R., Speller, C. F., Yang, D. Y., Butler, V. L., Banks, M. A. & Miller, M. R. (2019). Anthropogenic habitat alteration leads to rapid loss of adaptive variation and restoration potential in wild salmon populations. Proceedings of the National Academy of Sciences of the United States of America, 116(1), 177–186. https://doi.org/10.1073/pnas.1811559115
[48]. van Vliet, N., Gonzalez, A., Nyumu, J., Muhindo, J., Paemelaere, E., Cerutti, P. & Nasi, R. (2022). Reducing Wild Meat Sales and Promoting Local Food Security : Lessons Learnt from a Behavior Change Campaign in Yangambi, Democratic Republic of Congo. Ethnobiology and Conservation, 11. https://doi.org/10.15451/ec2022-04-11.09-1-14
[49]. van Vliet, N., Quintero, S., Muhindo, J., Nyumu, J., Cerutti, P.O., Nasi, R. & Rovero, F. (2023). Status of terrestrial mammals in the Yangambi Landscape, Democratic Republic of the Congo. Oryx, 57(6), 799–810, https://doi.org/10.1017/S0030605322001569
[50]. Voigt, C. C. & Holderied, M. W. (2012). High manoeuvring costs force narrow-winged molossid bats to forage in open space. Journal of Comparative Physiology B, 182(3), 415-424. https://doi.org/10.1007/s00360-011-0627-6
[51]. Voigt, C. C. & Kingston, T. (2016). Bats in the Anthropocene : Conservation of Bats in a Changing World. In: Springer International Publishing. https://doi.org/10.1007/978-3-319-25220-9
[52]. Webala, P. W., Mwaura, J., Mware, J. M., Ndiritu, G. G. & Patterson, B. D. (2019). Effects of habitat fragmentation on the bats of Kakamega Forest, western Kenya. Journal of Tropical Ecology, 35(6), 260-269. https://doi.org/10.1017/S0266467419000221