

ASSESSMENT OF SPECIES COMPOSITION, MORPHOLOGICAL CHARACTERISTICS AND CONSERVATION THREATS OF BATS WITHIN LOKOJA METROPOLIS IN KOGI STATE

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Cite this article as: Yusuf, A. A., Tanko, D., and Ogbe, K. U. (2026). Assessment of species composition, morphological characteristics and conservation threats of bats within Lokoja Metropolis in Kogi State. *Journal of Interdisciplinary Postgraduate Research*, 1(4), 36–47.

Abstract

This study assessed bat species composition, morphological characteristics and conservation threats within Lokoja Metropolis, Kogi State, Nigeria. Field surveys were conducted across eight urban sites between June and October 2025. Data were collected through mist netting, using nets of 12 m by 2.7 m with 36 mm mesh, at three rooftop survey sites during nocturnal sampling sessions from 18:00 to 23:00 and 04:00 to 06:30 hours, and through camera based dislodgement counting at five treetop survey sites. Morphological measurements were recorded for captured individuals, while threats were assessed through direct observation, community interviews and review of land use change evidence. A total of 255 bats representing two taxa were detected: *Eidolon helvum* (Pteropodidae), with 180 individuals representing 70.59 percent of the catch, and *Scotophilus nigrita* (Vespertilionidae), with 75 individuals representing 29.41 percent. *Eidolon helvum* was detected only at the sampled treetop sites and *Scotophilus nigrita* only at the sampled rooftop sites. Because mist netting was applied at rooftop sites and camera counting at treetop sites, this complete separation is confounded with survey method and is reported as a feature of the sampling design rather than as evidence of ecological partitioning. Species diversity was low, with a Shannon-Wiener index of 0.606, a Pielou evenness of 0.874 and a Simpson dominance of 0.585, placing the assemblage well below the range reported for forest and savannah habitats in the region. Sex composition differed significantly between the two taxa, $\chi^2(1) = 11.12$, $p < 0.001$ with continuity correction. *Eidolon helvum* was male biased at a ratio of 1.57 to 1 and *Scotophilus nigrita* female biased at 1 to 1.68, and each departed significantly from parity. Seven threat categories were documented under the IUCN Unified Threat Classification System, of which habitat loss and urban expansion, roost disturbance and vegetation clearance were assessed as of high overall severity. The study concludes that the recorded richness of two species is a minimum estimate constrained by method, that the urban assemblage of Lokoja is impoverished and dominated by two ecologically flexible generalists, and that roost protection in both built structures and mature trees is the intervention most likely to retain what remains.

Keywords: bat species composition; morphological characteristics; conservation threats; urban ecology; *Eidolon helvum*; *Scotophilus nigrita*; Lokoja Metropolis

1. Introduction

Biodiversity worldwide is under pressure from human activity (Joppa et al., 2016), including climatic change, the intensification and industrialisation of land use in agricultural areas and forests, and expanding urbanisation (Liu et al., 2020). The past three decades in particular have seen an unprecedented rate of urban growth and an increase in the spatial extent of urban land cover. The global human population is projected to rise by close to two billion, with the greater part of that growth occurring in urban communities (United Nations, 2018). Urban and suburban areas are consequently expected to expand into surrounding native ecosystems, exposing them to the effects of human activity (Angel et al., 2011) and intensifying impacts already evident in cities, among them local biodiversity loss (McKinney, 2006) and habitat loss, fragmentation and species endangerment (Liu, He and Wu, 2016).

Modelling of global biodiversity trends has shown consistent declines since the systematic collection of population data began more than fifty years ago (WWF, 2020). Urban environments differ from surrounding natural habitats in ways that matter ecologically. Cities generate high levels of noise and artificial light, carry large areas of impervious surface, support simplified and frequently non native vegetation, and present a fragmented mosaic in which patches of habitat are separated by hostile matrix. These conditions act as a filter, progressively excluding specialist and disturbance sensitive species while retaining those able to tolerate or exploit the altered environment (Piano et al., 2020).

The effects of urbanisation are not confined to dense city centres. Urban growth is accompanied by the conversion of surrounding land into lower density suburbs and peri urban settlement, so that the ecological footprint of a city extends well beyond its built core. Studies in urbanised landscapes have reported reduced invertebrate diversity, which propagates upward to affect insect predators including small mammals, birds and bats (Piano et al., 2020).

Bats are among the most species rich groups of mammals occurring in urban areas. Consuming up to their own body mass in insects nightly, insectivorous species provide a substantial pest regulation service, while frugivorous species disperse seed and pollinate across distances few other vertebrates match. More than 1,400 extant species are currently recognised, representing a considerable share of global mammalian diversity (Happold and Happold, 2013). Urbanisation nevertheless exacts a cost, and many bat species have undergone severe population decline where roosts have been lost and foraging habitat simplified (Russo and Ancillotto, 2015).

Two features of bat biology make them particularly informative subjects for urban assessment. First, they are roost obligate: unlike many urban adapters they cannot persist without discrete structures, whether cavities in buildings or stands of mature trees, that satisfy specific microclimatic and structural requirements. The presence of a bat assemblage therefore reports on the availability of a resource that is easily destroyed and slow to replace. Second, they are long lived and slow reproducing for their body size, so populations recover slowly from loss and a decline detected late is difficult to reverse.

Despite this, the urban bat fauna of north central Nigeria remains poorly documented. Lokoja, the capital of Kogi State, has grown rapidly since its designation in 1991, with construction extending into formerly vegetated land and mature trees removed from both public and private compounds. No published inventory of its bat assemblage exists, which means that neither the current composition nor the direction of change can be established. The present study addresses that gap. Its objectives are to determine the species composition and relative abundance of bats across urban survey sites in Lokoja Metropolis, to document the morphological characteristics distinguishing the recorded taxa, to quantify the diversity structure of the assemblage, and to identify and rank the conservation threats operating at each site.

2. Materials and Methods

2.1 Description of the Study Area

The research was conducted in Lokoja Metropolis, the capital of Kogi State in north central Nigeria. Lokoja lies at the confluence of the Rivers Niger and Benue, a position that gives the city a distinctive combination of riparian vegetation, rocky inselberg terrain associated with Mount Patti, and expanding built up land. The climate is tropical with a wet season extending from April to October and a dry season from November to March, and the surrounding vegetation is Guinea Savannah. The spatial distribution of survey sites is shown in Figure 1.

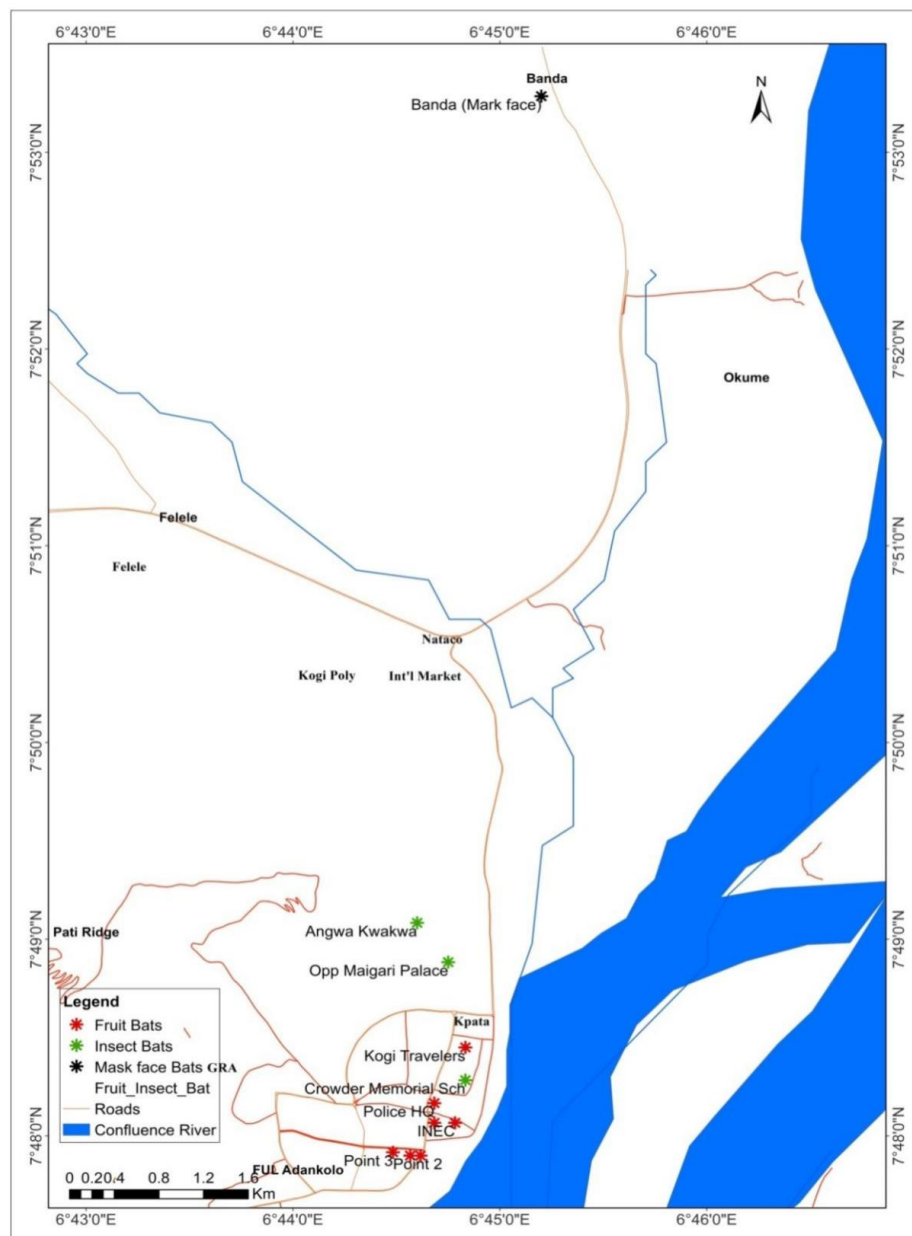


Figure 1: Map of Lokoja Metropolis showing the distribution of bat survey sampling sites. Markers distinguish sites at which fruit bats and insectivorous bats were recorded, against the road network and the confluence of the Rivers Niger and Benue. Source: GIS Laboratory, Federal University Lokoja (2026).

2.2 Research Design

The study adopted a descriptive field survey design combining direct capture with observational methods to assess bat occurrence, morphology and conservation status across an urban gradient. Field data collection was conducted exclusively during the wet season, from June to October 2025, so that surveys coincided with the period of maximum bat activity, when insect prey abundance and fruit availability are both at their seasonal peak.

2.3 Site Selection and Habitat Classification

Eight survey sites were identified through purposive sampling guided by reconnaissance surveys conducted before formal data collection began. Sites were selected to represent three habitat categories along the urban gradient:

- **Habitat A:** densely built up areas within the urban core, characterised by high impervious surface cover, artificial lighting, heavy human traffic and built structures offering roosting opportunity in roof voids and wall cavities.
- **Habitat B:** transitional areas on the fringe of the urban core, with a mixture of residential buildings, scattered tree cover, cultivated farmland and remnant patches of vegetation.
- **Habitat C:** areas retaining significant natural vegetation, including stands dominated by *Azadirachta indica*, *Mangifera indica* and *Terminalia* spp.

Classification of each site was based on three criteria assessed during reconnaissance: land use class, recorded as built up, mixed or vegetated; degree of canopy cover, estimated visually and classified as sparse at below 25 percent, moderate at 25 to 60 percent, or dense at above 60 percent; and degree of urbanisation, assessed from the intensity of human activity, impervious surface coverage, artificial lighting and proximity to the urban core.

2.4 Mist Netting for Insectivorous Bats

Insectivorous bats roosting within built structures were captured using mist nets measuring 12 metres in length and 2.7 metres in height, with a mesh size of 36 mm, deployed around fascia boards, eaves and roof access points. Nets were operated during two nocturnal windows, from 18:00 to 23:00 hours to capture the evening emergence and from 04:00 to 06:30 hours to capture the pre dawn return. Nets were monitored continuously and captured individuals were removed promptly, held individually in cloth bags, processed and released at the point of capture.

2.5 Camera Based Estimation of Tree Roosting Bats

Tree roosting bats associated with stands of *Azadirachta indica*, *Mangifera indica* and *Terminalia* spp. were surveyed using a camera based dislodgement count method. At sunset, prior to the commencement of the evening departure flight, roosting aggregations were photographed and recorded using a Samsung Galaxy Z Fold 5 5G smartphone camera. Counts were conducted across all three tree species at each treetop survey site to permit comparison of fruit bat abundance between locations. The photographic and video records provided a visual dataset from which species identification and population estimates were subsequently derived under controlled viewing conditions.

The use of two distinct methods, one at rooftop sites and one at treetop sites, was dictated by the physical accessibility of the roosts concerned. Its consequence for interpretation is substantial and is addressed explicitly in Sections 3.3 and 4.2.

2.6 Species Identification

Captured and photographed bats were identified through detailed morphological examination using peer reviewed identification keys and regional taxonomic resources, principally Happold and Happold (2013). The diagnostic characters applied were body size and overall shape, assessed against size classes established in regional field guides; fur colour and texture, including dorsal and ventral coat colour, pattern and surface texture; ear shape, size and tragus characteristics; nose structure, with attention to the presence, shape and size of nose leaves, which are diagnostic in families such as Hipposideridae and Rhinolophidae; wing membrane colouration and attachment points along the body and hind limbs; and distinctive facial markings and head shape.

2.7 Morphological Measurements

External measurements were recorded for captured individuals. Head length, measured from the tip of the snout to the back of the skull, serves as a proxy for overall body size and cranial development. Ear lobe length, measured from the base of the ear to its tip, is taxonomically significant because ear dimensions correlate with echolocation strategy. Forearm length, measured from elbow to wrist, is the single most widely used external measurement in bat taxonomy. Body length was measured from the snout to the base of the tail or uropatagium. Claw length, measured from base to tip of the hind claw, reflects roosting grip adaptation in frugivorous species. Hind limb length was measured from hip joint to ankle, upper limb length from shoulder to elbow, and lower limb length from knee to ankle. Sex was determined by external examination of the genitalia and recorded for every individual.

2.8 Assessment of Conservation Threats

Threats were assessed concurrently with population surveys through three complementary methods applied systematically at every site. Direct field observation documented active construction, vegetation clearance, artificial lighting installations and evidence of pesticide application. Community interviews, conducted as informal structured discussions with residents, building occupants and community members, gathered qualitative information on persecution, hunting and historical change at each location. Review of land use change evidence recorded ongoing construction, freshly cleared vegetation, tree stumps and newly exposed bare ground.

Seven threat categories were assessed and classified under the IUCN Unified Threat Classification System: habitat loss and urban expansion (Category 1); roost disturbance (Category 6); direct persecution (Categories 6 and 8); artificial light at night (Category 9); pesticide and insecticide use (Category 9); vegetation clearance (Category 1); and bushmeat hunting (Category 5). Severity at each site was categorised qualitatively as High, denoting an immediate and extensive threat likely to cause population level impact without intervention, Moderate, or Low.

2.9 Diversity Indices and Statistical Analysis

Relative abundance of each species was computed as

$$RA_i = (n_i / N) \times 100 \quad (1)$$

where n_i is the number of individuals of species i and N the total number of individuals recorded. Species diversity was quantified using the Shannon-Wiener index

$$H' = -\sum_{i=1}^S p_i \ln p_i \quad (2)$$

in which $p_i = n_i/N$ is the proportional abundance of species i and S the number of species recorded. Evenness was computed using the Pielou index

$$J' = H' / \ln S \quad (3)$$

and dominance using the Simpson index

$$D = \sum_{i=1}^S p_i^2 \quad (4)$$

Associations between categorical variables were tested using the chi square statistic

$$\chi^2 = \sum (|O_{ij} - E_{ij}| - 0.5)^2 / E_{ij} \quad (5)$$

where O_{ij} and E_{ij} are observed and expected frequencies. The continuity correction of 0.5 was applied throughout, as is conventional for tables with one degree of freedom. Departure of each species sex ratio from parity was tested by the same statistic against an expectation of equal numbers of males and females. Significance was assessed at $\alpha = 0.05$.

2.10 Ethics, Permits and Declarations

Animal handling and release followed the field protocol described above, including prompt removal from nets, individual holding bags, rapid processing and release at the point of capture. No individual was retained. Community interviews were conducted with verbal consent and responses are reported in aggregate.

3. Results

3.1 Species Composition and Relative Abundance

A total of 255 individual bats representing two taxa were recorded across the eight urban survey sites between June and October 2025. *Eidolon helvum* (Pteropodidae) accounted for 180 individuals, or 70.59 percent of the total, and *Scotophilus nigrita* (Vespertilionidae) for 75 individuals, or 29.41 percent (Table 1, Figure 2).

Table 1: Species composition and relative abundance of bats recorded at urban survey sites in Lokoja Metropolis, June to October 2025

Bat species	Family	Survey site type	Total individuals	Relative abundance (%)
<i>Eidolon helvum</i> (fruit bat)	Pteropodidae	Treetop	180	70.59
<i>Scotophilus nigrita</i> (insectivorous bat)	Vespertilionidae	Rooftop	75	29.41
Total			255	100.00

Note. $N = 255$ individuals. Source: field survey data (2025).

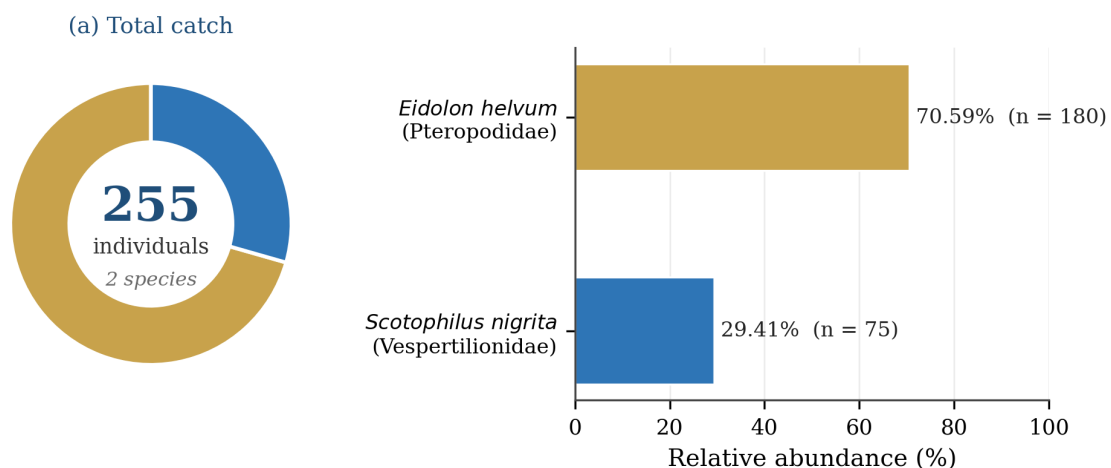


Figure 2: Composition of the recorded assemblage. Panel (a) shows the total catch of 255 individuals across two species; panel (b) the relative abundance of each taxon.

3.2 Distribution of Bat Species Across Survey Sites

Table 2 presents site by site abundance across all eight survey sites. Among the three rooftop sites, Crowther Memorial Staff Quarters recorded the highest insectivorous bat count at 33 individuals, representing 44.00 percent of rooftop captures, followed by Mai-geri Palace with 29 individuals at 38.67 percent and Angwan Kwakwa with 13 individuals at 17.33 percent. Among the five treetop sites, the location opposite the Federal Teaching Hospital recorded the highest fruit bat count at 53

individuals, or 29.44 percent of treetop records, and the Former Kogi Travelers Lodge the lowest at 19 individuals, or 10.56 percent.

Table 2: Site by site bat abundance across all urban survey sites in Lokoja Metropolis, June to October 2025

Survey site	Site type	Species recorded	Individuals	% of site type total
Crowther Memorial Staff Quarters	Rooftop	<i>Scotophilus nigrita</i>	33	44.00
Mai-geri Palace	Rooftop	<i>Scotophilus nigrita</i>	29	38.67
Angwan Kwakwa	Rooftop	<i>Scotophilus nigrita</i>	13	17.33
Rooftop subtotal			75	100.00
Former NITEL (Post Office) Building	Treetop	<i>Eidolon helvum</i>	26	14.44
INEC Office	Treetop	<i>Eidolon helvum</i>	37	20.56
Police Headquarters	Treetop	<i>Eidolon helvum</i>	45	25.00
Former Kogi Travelers Lodge	Treetop	<i>Eidolon helvum</i>	19	10.56
Opposite Federal Teaching Hospital	Treetop	<i>Eidolon helvum</i>	53	29.44
Treetop subtotal			180	100.00
Grand total			255	

Note. Percentages are calculated within each survey site type. Source: field survey data (2025).

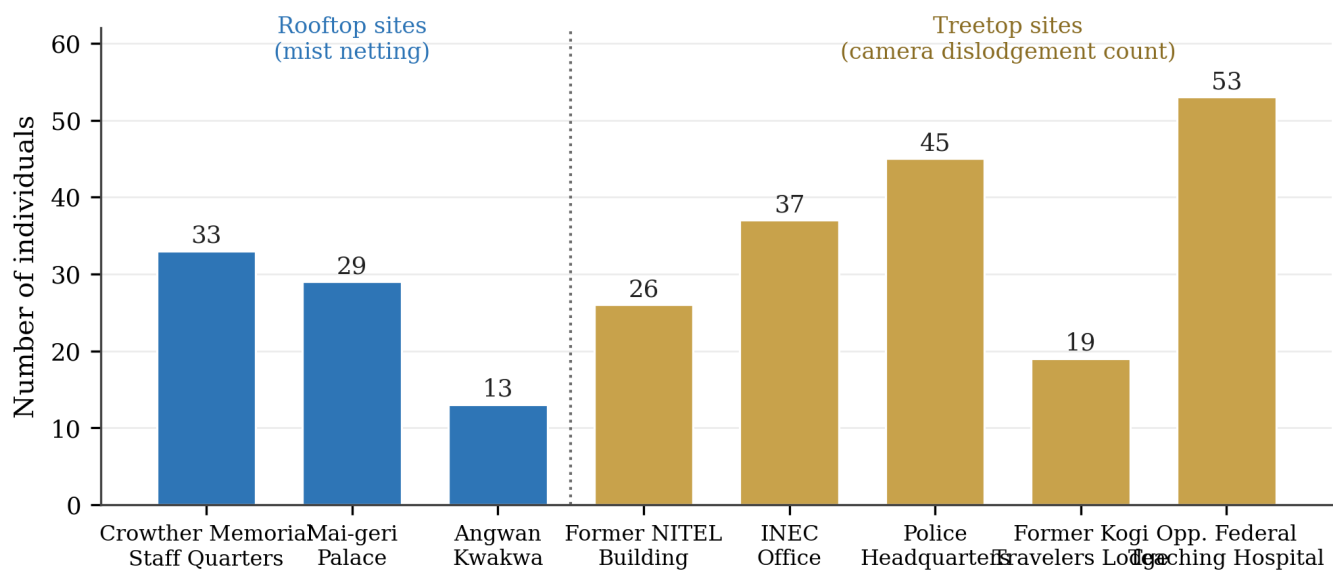


Figure 3: Bat abundance across all eight urban survey sites. Rooftop sites, surveyed by mist netting, are shown in blue and treetop sites, surveyed by camera dislodgement count, in gold. The dotted line separates the two survey methods.

3.3 Association Between Species and Site Type

Table 3 presents the two by two contingency table of species against survey site type. The table shows complete separation, with zero counts in both off diagonal cells. A chi square test on such a table necessarily returns a large statistic, and the value is tied arithmetically to the sample size rather than to any ecological signal.

Table 3: Contingency table of observed bat species by survey site type

Survey site type	<i>Eidolon helvum</i>	<i>Scotophilus nigrita</i>	Total
Rooftop	0	75	75
Treetop	180	0	180
Total	180	75	255

Note. The complete separation reflects the observed sampling structure. Because mist netting was applied at rooftop sites and camera counting at treetop sites, species and method are confounded and the table is not interpreted as a test of ecological independence.

This separation must be read with care. Mist netting was deployed at rooftop sites and camera based counting at treetop sites, so survey method and site type are perfectly confounded. A mist net set at fascia board height cannot sample a canopy roost, and a dislodgement count directed at a tree crown cannot detect bats within a roof void. The pattern in Table 3 is therefore a property of the sampling design as much as of the bats, and it is reported here as an observation rather than as evidence of strict ecological partitioning between the two species.

3.4 Sex Composition

Table 4 presents sex composition. *Eidolon helvum* was male biased, with 110 males to 70 females, a ratio of 1.57 to 1, while *Scotophilus nigrita* was female biased, with 28 males to 47 females, a ratio of 1 to 1.68. The difference in sex composition between the two taxa is statistically significant, $\chi^2(1) = 11.12$, $p < 0.001$ with continuity correction. Each species also departs significantly from parity when tested separately: *Eidolon helvum*, $\chi^2(1) = 8.45$, $p = 0.004$; *Scotophilus nigrita*, $\chi^2(1) = 4.32$, $p = 0.038$ (Figure 4).

Table 4: Sex composition of bat species recorded in Lokoja Metropolis

Species	Male	Female	Total	Male to female ratio	Departure from parity
<i>Eidolon helvum</i> (fruit bat)	110	70	180	1.57 : 1	$\chi^2 = 8.45$, $p = 0.004$
<i>Scotophilus nigrita</i> (insectivorous bat)	28	47	75	1 : 1.68	$\chi^2 = 4.32$, $p = 0.038$
Total	138	117	255	1.18 : 1	

Note. All chi square statistics incorporate the Yates continuity correction with one degree of freedom. Source: field survey data (2025).

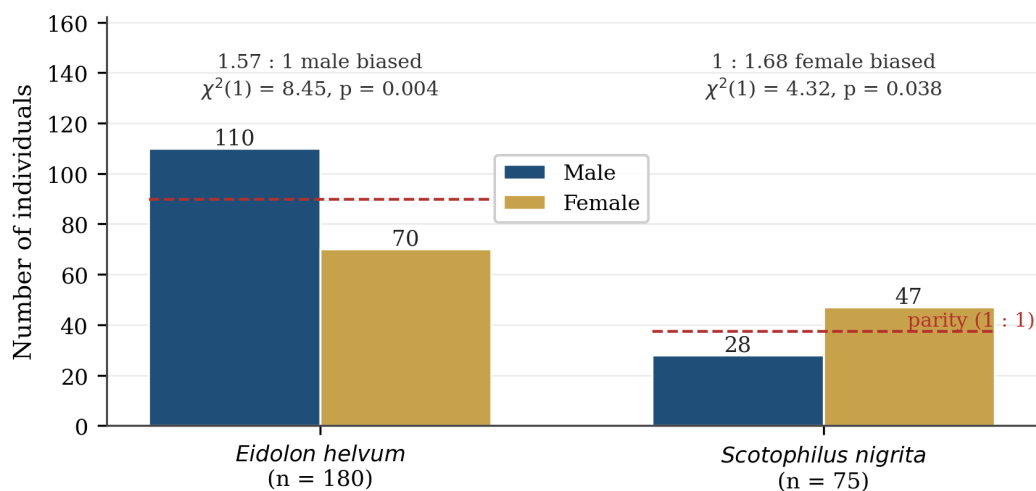


Figure 4: Sex composition of the two recorded taxa. Broken horizontal lines mark the parity expectation of equal numbers of males and females. The two species depart from parity in opposite directions.

3.5 Morphological Characteristics

Table 5 compares external measurements between the two recorded taxa. *Eidolon helvum* exceeded *Scotophilus nigrita* on every measurement recorded for both species, most markedly in forearm length, at 42.0 cm against 16.0 cm, and body length, at 20.0 cm against 7.5 cm. A projecting tail was recorded in *Scotophilus nigrita* but not in *Eidolon helvum*, which is consistent with the familial distinction between Vespertilionidae and Pteropodidae (Figure 5).

Table 5: Comparative morphological measurements of the two recorded bat taxa

Measurement	Fruit bat, observed (cm)	Insectivorous bat, observed (cm)	Larger taxon	Taxonomic significance
Head length	6.0	2.5	Fruit bat	Elongated fox like muzzle distinguishes Pteropodidae
Ear lobe length	3.0	1.0	Fruit bat	Medium sized upright ears in frugivores; correlates with echolocation strategy
Wing or forearm length	42.0	16.0	Fruit bat	Principal diagnostic measurement in bat taxonomy
Body length	20.0	7.5	Fruit bat	Substantial size difference between families
Claw length	2.0	not recorded	Fruit bat	Longer claws adapted for canopy roosting grip
Hind limb length	10.0	5.0	Fruit bat	Extended hind limbs support suspended roosting posture
Upper limb length	6.0	3.0	Fruit bat	Component of overall wing structure
Lower limb length	12.0	not recorded	Fruit bat	Extended tibia supports the plagiopatagium
Tail length	absent	3.0	Insectivorous bat	A projecting tail was recorded only in the vespertilionid

Note. Values are observed measurements reported in the source dataset. Because dispersion statistics and per individual sample sizes were not recorded, no inferential comparison of means is undertaken. Source: field survey data (2025).

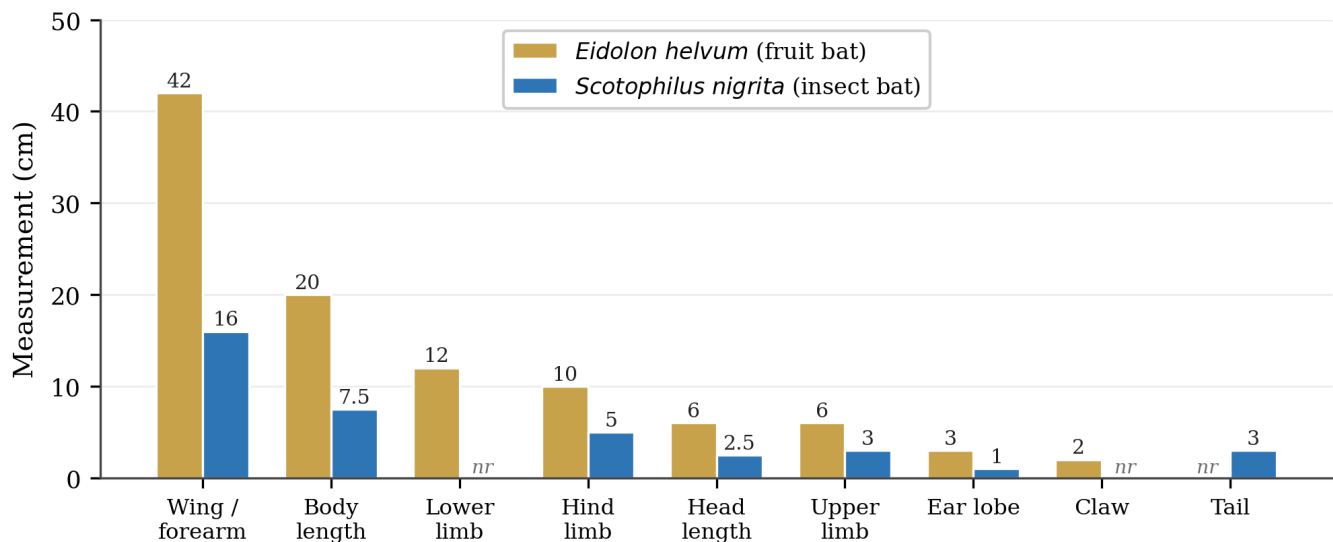


Figure 5: Comparative external measurements of the two recorded taxa, ordered by magnitude in the fruit bat. Measurements not recorded for a taxon are marked nr. The tail is the single measurement on which the insectivorous bat exceeds the fruit bat.

3.6 Species Diversity and Community Structure

Diversity indices computed for the combined dataset are presented in Table 6 and Figure 6. The Shannon-Wiener index returned 0.606, the Pielou evenness index 0.874 and the Simpson dominance index 0.585.

Table 6: Diversity indices for the urban bat assemblage of Lokoja Metropolis

Index	Symbol	Value	Interpretation
Species richness	S	2	Minimum estimate, constrained by survey method
Shannon-Wiener diversity	H'	0.606	Low relative to forest and savannah assemblages
Pielou evenness	J'	0.874	Relatively even proportional split between the two taxa
Simpson dominance	D	0.585	Moderate dominance by a single species

Note. Indices computed from equations (2) to (4). Source: authors' computation from field survey data (2025).

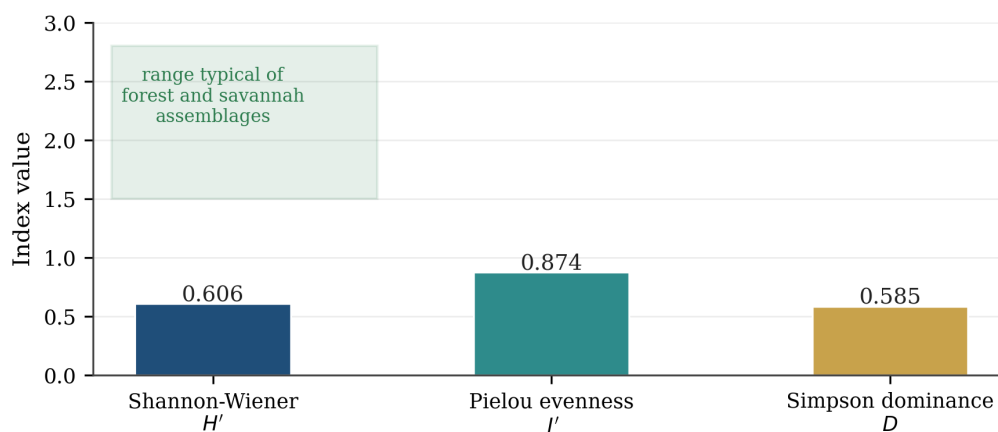


Figure 6: Diversity indices for the Lokoja urban bat assemblage. The shaded band indicates the range of Shannon-Wiener values typically reported for forest and savannah bat assemblages in the region, against which the urban value of 0.606 is markedly low.

3.7 Conservation Threats

Seven threat categories were documented across the eight survey sites and are summarised in Table 7 and Figure 7. Habitat loss and urban expansion was assessed as of high severity at both rooftop and treetop sites and is the single most pervasive threat recorded. Roost disturbance was high at rooftop sites, where building renovation destroys occupied roof voids, and moderate at treetop sites. Vegetation clearance was high at treetop sites, where removal of mature trees eliminates roosting substrate outright, and low at rooftop sites. Artificial light at night was high at rooftop sites and low at treetop sites, reflecting the concentration of street and security lighting in the built core.

Table 7: Conservation threats to bats across urban survey sites in Lokoja Metropolis

Threat category	Rooftop sites	Treetop sites	Overall severity	Conservation implication
Habitat loss and urban expansion	High	High	High	Most critical threat across all site types
Roost disturbance	High	Moderate	High	Building renovation destroys occupied roof voids
Vegetation clearance	Low	High	High	Removal of mature trees eliminates roosting substrate
Artificial light at night	High	Low	Moderate	Suppresses emergence and foraging in <i>Scotophilus nigrita</i>
Pesticide and insecticide use	Moderate	Low	Moderate	Reduces invertebrate prey for insectivorous bats
Direct persecution	Moderate	Moderate	Moderate	Disease stigma drives deliberate killing and roost eviction
Bushmeat hunting	Low	Moderate	Low to moderate	Fruit bats occasionally harvested for food and traditional medicine

Note. Threat categories classified under the IUCN Unified Threat Classification System. Severity assessed qualitatively from direct observation, community interviews and land use change evidence. Source: field survey data (2025).

Habitat loss and urban expansion	High	High	High
Roost disturbance	High	Moderate	High
Vegetation clearance	Low	High	High
Artificial light at night	High	Low	Moderate
Pesticide and insecticide use	Moderate	Low	Moderate
Direct persecution	Moderate	Moderate	Moderate
Bushmeat hunting	Low	Moderate	Low to moderate
	Rooftop sites	Treetop sites	Overall severity

Figure 7: Threat severity matrix across rooftop and treetop survey sites. The complementary pattern is notable: lighting and roost disturbance dominate in the built core, while vegetation clearance and hunting dominate at tree roosts, so that no single intervention protects both groups.

4. Discussion

4.1 An Impoverished Urban Assemblage

The recorded assemblage of two species, with a Shannon-Wiener index of 0.606, is markedly depauperate. Values reported for forest and savannah habitats in West Africa are substantially higher, and the regional species pool documented by Happold and Happold (2013) contains many taxa that might reasonably be expected to occur in the vicinity of Lokoja. The contrast is consistent with the environmental filtering that characterises urban faunas, in which the gradient from natural to built habitat progressively excludes specialists while retaining generalists tolerant of disturbance, noise, light and simplified vegetation (Piano et al., 2020; Russo and Ancillotto, 2015).

The identity of the two survivors supports that reading. *Eidolon helvum* is a highly mobile, colonial frugivore that migrates over continental distances and roosts in large trees in settlements across Africa (Richter and Cumming, 2006). *Scotophilus nigrita* is a synanthropic vespertilionid that readily occupies buildings. Neither is a habitat specialist, and both are among the taxa most commonly retained where urbanisation has removed more sensitive species. What the Lokoja assemblage illustrates is therefore not simply reduced richness but a specific kind of reduction, namely the loss of the ecologically particular and the retention of the ecologically flexible.

The evenness value requires comment because it is easily misread. A Pielou index of 0.874 appears high and might be taken to indicate a balanced community. It does not. Evenness is computed relative to the logarithm of richness, and with only two species even a split as uneven as 71 to 29 yields a high value. The index is informative about proportional balance within the recorded set, not about the health of the assemblage, and reporting it without that qualification would invite an unduly favourable interpretation. The Simpson dominance value of 0.585 conveys the same information in a less misleading direction.

4.2 Method, Not Ecology, Explains the Species Separation

The most important interpretive issue in this study concerns the complete separation shown in Table 3. Every *Eidolon helvum* was recorded at a treetop site and every *Scotophilus nigrita* at a rooftop site, and a chi square test on that table returns a very large statistic. It would be straightforward, and wrong, to present this as evidence of strict ecological partitioning.

The difficulty is that survey method and site type are perfectly confounded. Mist nets were set at fascia board and eave height at rooftop sites; camera based dislodgement counts were directed at tree crowns at treetop sites. Each method is capable of detecting only the taxon it was deployed against. A fruit bat roosting in a crown above a surveyed building would not enter a net set at roof level, and an insectivorous bat emerging from a roof void adjacent to a surveyed tree would not appear in a canopy photograph. The zero cells in Table 3 therefore record what the methods could not detect at least as much as what the bats did not do.

The authors of the source dataset are to be credited for flagging this rather than exploiting the apparently dramatic statistic, and the present analysis follows that lead. The methodological implication for subsequent work is specific: both methods should be applied at every site, so that detection is decoupled from habitat and the question of partitioning can actually be tested. Until that is done, the correct statement is that each species was detected where its roost type was surveyed, and nothing stronger.

The same reasoning bears on the richness estimate. Two methods targeting two roost types will recover the taxa using those roost types. Bats roosting in culverts, bridges, rock crevices on Mount Patti, or in foliage rather than crowns were not sampled at all, and acoustic survey, which detects free flying individuals irrespective of roost, was not employed. The richness of two species is consequently a minimum, and almost certainly an underestimate, of the true urban bat fauna of Lokoja.

4.3 Spatial Variation and the Structural Basis of Roost Selection

Among rooftop sites, Crowther Memorial Staff Quarters carried the largest insectivorous aggregation, which is plausibly attributable to the structural characteristics of the older staff quarters buildings. Such structures typically offer a greater number of undisturbed roof crevices, ceiling voids and accessible entry points than newer construction, and these are the features vespertilionid bats require for colony formation (Kunz and Lumsden, 2003). The lower count at Angwan Kwakwa is consistent with higher human activity and more intense artificial lighting, both of which suppress emergence and shorten foraging time in light averse species (Stone, Jones and Harris, 2009).

Among treetop sites, the location opposite the Federal Teaching Hospital carried the largest fruit bat aggregation, which corresponds to the presence of well established mature tree stands. *Eidolon helvum* preferentially roosts in large, structurally stable trees offering vegetative cover and sufficient height for predator detection (Richter and Cumming, 2006). The lowest treetop count, at the Former Kogi Travelers Lodge, coincided with ongoing building demolition and vegetation disturbance at that location.

Taken together these observations point to a single underlying variable. Abundance tracked roost quality and the absence of disturbance rather than position along the urban gradient as such. A heavily built site with intact old roofs held more bats than a less built site with active construction. This matters for conservation practice because it identifies the operative resource: it is not greenness in the abstract that retains bats in Lokoja, but specific structures, whether architectural or arboreal, that persist undisturbed across seasons.

4.4 Divergent Sex Ratios and What They May Indicate

The two taxa departed from parity in opposite directions, *Eidolon helvum* male biased at 1.57 to 1 and *Scotophilus nigrita* female biased at 1 to 1.68, and the difference between them is significant. Two explanations merit consideration and they are not mutually exclusive.

The first is biological. Many temperate and tropical vespertilionids form maternity colonies in which females aggregate in warm, sheltered cavities during gestation and lactation while males roost separately and more diffusely. Roof voids provide precisely the thermal stability such colonies require, so a female biased catch from building roosts during the wet season, which coincides with the reproductive period, is what the maternity colony hypothesis would predict. For *Eidolon helvum*, male bias within a sampled portion of a large colonial roost may reflect spatial sorting within the colony, since males and females of this species do not distribute randomly through a roost tree.

The second explanation is methodological and must be weighed honestly. Mist netting captures individuals in flight at the roost entrance, and if the sexes differ in emergence timing or flight height the catch will not represent the colony. Camera based counting requires sex to be assigned from photographs, which is considerably less reliable than examination in the hand and may be biased towards whichever sex is more visible or more frequently positioned on the outer canopy. Given that the *Eidolon helvum* sex data derive from photographic assessment, the male bias recorded for that species should be treated as provisional. The finding is nevertheless worth reporting, since it generates a testable hypothesis for work using direct capture at tree roosts.

4.5 The Threat Profile and Its Structure

Seven threat categories were documented, and the three assessed as of high overall severity, namely habitat loss and urban expansion, roost disturbance and vegetation clearance, share a common property: each destroys roosts rather than merely degrading foraging conditions. This is the most consequential pattern in the threat data. Bats can adjust foraging behaviour, shift diet and travel further to feed, but they cannot manufacture a roost. Loss of a mature tree or the sealing of a roof void

during renovation removes a resource that took decades to form and that no behavioural flexibility can replace.

The threat profile is also structurally complementary across the two site types, as Figure 7 shows. Artificial light and roost disturbance bear most heavily on building roosting insectivores, while vegetation clearance and bushmeat hunting bear most heavily on tree roosting frugivores. No single intervention therefore addresses both groups. A lighting ordinance would benefit *Scotophilus nigrita* and do nothing for *Eidolon helvum*; a tree preservation order would do the reverse. Conservation planning for this assemblage must be explicitly dual tracked, and this is a point that a study reporting only aggregate threat scores would have missed.

Direct persecution, assessed as moderate at both site types, deserves separate mention because its driver is informational rather than economic. Community discussions attributed deliberate killing and roost eviction principally to disease stigma. Unlike habitat loss, which is driven by development pressure that conservation messaging cannot easily counter, persecution motivated by misapprehension is in principle tractable through public engagement, and it is therefore the threat on which modest effort may yield the largest proportional return.

4.6 Limitations

Several limitations qualify these findings and are stated plainly. The confounding of survey method with site type, discussed in Section 4.2, is the most serious and constrains every conclusion about species distribution. Surveys were conducted in a single wet season, so seasonal variation in abundance, migration of *Eidolon helvum*, and dry season roost occupancy are unobserved. No acoustic sampling was undertaken, which means that species detectable only in free flight, including many smaller insectivores, could not be recorded at all. Morphological measurements were reported as single observed values without dispersion or per individual sample sizes, so no inferential comparison of means between taxa was possible and Table 5 is necessarily descriptive. Threat severity was assessed qualitatively by field observation and interview rather than through quantified measurement of lighting intensity, canopy loss or pesticide application. Finally, the eight sites were purposively selected on the basis of known or suspected bat presence, so site level abundance figures describe occupied roosts rather than the metropolis as a whole.

5. Conclusion and Recommendations

This survey recorded 255 bats of two taxa across eight urban sites in Lokoja Metropolis. *Eidolon helvum* accounted for 70.59 percent of individuals and *Scotophilus nigrita* for 29.41 percent. Diversity was low, with a Shannon-Wiener index of 0.606, placing the assemblage well below values reported for forest and savannah habitats in the region. Sex composition differed significantly between the two taxa, each departing from parity in opposite directions. Seven threat categories were documented, of which habitat loss and urban expansion, roost disturbance and vegetation clearance were assessed as of high overall severity.

Two conclusions follow, one methodological and one substantive. Methodologically, the observed separation of species between site types is confounded with survey method and should not be read as ecological partitioning; the richness of two species is a minimum estimate rather than an inventory. Substantively, the Lokoja urban bat fauna is impoverished and composed of two generalists, and the threats bearing most heavily upon it are those that destroy roosts. Since roosts are the resource bats cannot substitute, their protection in both built structures and mature trees is the intervention most likely to retain the assemblage that remains.

The following recommendations are made.

1. **Apply both survey methods at every site in future work.** Mist netting and camera based counting, supplemented by acoustic recording, should be deployed at all sites so that detection is decoupled from roost type and species distribution can be tested rather than assumed.
2. **Extend survey across seasons.** Dry season sampling is required to establish whether the recorded assemblage is resident or seasonal, which bears directly on which roosts warrant year round protection.
3. **Protect mature roost trees.** Stands of *Azadirachta indica*, *Mangifera indica* and *Terminalia* spp. supporting known colonies should be identified and protected from clearance, since vegetation clearance was assessed as of high severity at treetop sites.
4. **Introduce roost aware renovation practice.** Building owners and contractors, particularly in older public quarters, should be advised to schedule roof works outside the reproductive period and to retain or replace access points where colonies are present.
5. **Moderate artificial lighting near known roosts.** Shielded, lower intensity and warmer spectrum lighting near occupied buildings would reduce the suppression of emergence documented for light averse species.
6. **Address disease stigma through public engagement.** Since persecution is driven by misapprehension rather than material interest, targeted community education offers a comparatively low cost route to reducing a moderate severity threat.
7. **Establish the present data as a baseline.** The diversity values reported here should be treated as a reference point against which subsequent change in the Lokoja bat assemblage can be measured.

Acknowledgements

The authors thank the residents, building occupants and community leaders of the surveyed communities for granting access to roost sites and for participating in the field discussions. The cartographic support of the GIS Laboratory, Federal University Lokoja, is gratefully acknowledged.

Conflict of Interest

The authors declare no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial or not for profit sectors.

Ethical Statement

All bats were handled in accordance with the field protocol described in the Methods, including prompt removal from nets, individual holding bags, rapid processing and release at the point of capture. No individual was retained or euthanised. Community interviews were conducted with verbal informed consent and responses are reported only in aggregate.

Authors Contributions

Yusuf Abdulrazak Adavize: conceptualisation, field data collection, species identification, formal analysis, writing of the original draft. **Dauda Tanko:** supervision, methodology, validation, review and editing. **Ogbe Kingsley Unekwu:** taxonomic verification, data curation, review and editing.

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