The Zoologist

2025. Vol. 27: 63-71. http://dx.doi.org/10.4314/tzool.v27i1.9 Print ISSN 1596 972X, Online ISSN 2992-4030

Bird species diversity along the metropolitan stretch of River Kaduna amidst increasing anthropogenic activities

Agbo, B. O.*[1], Joseph, S. G.[2], Zubairu, G. P.[1 a] and Saleh, Y.[2]

[1]Department of Biological Science, Faculty of Life Science

[2]Department of Geography, Faculty of Environmental Science, College of Computing, Engineering and Sciences, Kaduna State University (KASU), PMB 2339 Tafawa Balewa Way, Kaduna, Nigeria

*Correspondence author: Boniface O. Agbo. boniface.agbo@kasu.edu.ng

Received: 20 November, 2024
Revised: 26 December, 2025
Accepted: 28 December, 2025

Keywords: Anthropogenic activities, Bird diversity, Land use/cover, River Kaduna.

© 2025 **Zoological Society of Nigeria**

This is an Open Access article distributed under the terms of Creative Commons Attribution License 4.0 (CC BY-NC-SA

Abstract

The rate at which natural ecosystems are being replaced by urban environments is evolutionarily unprecedented. Over the past four decades, the city of Kaduna has undergone continuous structural reformation resulting from urban renewal projects. The influence of this trend on communities and populations of urban biota is an aspect of ecology that deserves exploration. River Kaduna originates from the Kaduna-Vom (K-Vom) on the Jos Plateau basin. Two kilometres transects in four purposively selected stations were marked along the metropolitan stretch of the River Kaduna to observe human activities and estimate environmental variables influencing bird population and were routinely surveyed over a four-month period (March to June 2019). The bird species and number of individuals were recorded, alongside environmental variables and associated anthropogenic activities. Additionally, satellite imagery was analyzed to account for spatial distributions of and extent of land-use/land-cover patterns across the study area. A total of 19, 056 individual birds were recorded, representing 115 species 52 families, with Shannon diversity index (*H'*) of 4.00. Bird-type associations relevant to habitats were categorized into aquatic (25%) and terrestrial (75%) birds. This study highlights that anthropogenic pressures and urbanization both have immediate and long-term impacts on birds and humans.

Introduction

Urbanization is rapidly increasing world-over (Awoyemi and Ibanez-Alamo 2023; Awoyemi *et al* 2024, 2025). The rate at which natural ecosystems are being replaced by urban environments is evolutionarily unprecedented. The force of this trend on communities and populations of urban biota is an aspect of ecology deserving exploration (Marzluff *et al* 2001; Ido *et al* 2008). Human activities influence the natural world in ways that result in negative consequences on humans and other living organisms on earth (UN 2016; Cresswell *et al* 2019; BirdLife 2020).

Increase in human population is linked to increasing anthropogenic activities that is exacerbating global biodiversity crisis (Aguilera 2019). Overfishing, hunting and land development are among the chief drivers of this extinction revolution. It has been predicted that if the current trends continue most regions of the developing world would hold urban and rural settlers within the next ten years (Montgomery *et al* 2013; UN 2016; Awoyemi *et al* 2023). Furthermore, within the next 20-30 years, nearly two-third of the global population is expected to reside in urban areas (Awoyemi *et al* 2025). The impact of this development is worth considering, given the sustainability of biodiversity at both local and global scales.

River Kaduna attracted several concerns due to the intensity of human activities along its metropolitan stretch and banks. Past studies have addressed various ecological and environmental aspects of the river; Ologunorisa *et al* (2021) studied its hydro-climates, Asibor and Akpofure (2019) evaluated its biodegradation capacity, Okafor and Ogbu (2018) assessed the impact of climate change on fresh water availability, Ogbozige *et al* (2017) examined water quality, Suleiman (2016) catalogued fish diversity, Yusuf *et al* (2008) monitored the pollution levels, and Jeb and Aggarwal (2008) modeled the hazards that could be associated with flooding of the river. Due to the Kaduna urban renewal projects, it is imperative to consider an ecological investigation of this important watershed. In this study, avifauna was used as bio-indicators (Ezealor 2002; Cresswell *et al* 2019) to evaluate environmental health of the River Kaduna. We hypothesized that, highly active anthropogenic sites that were well exposed or easily accessible as foot paths to access resources from the river and its bank, would hold fewer bird population (Braimoh *et al* 2018), and on the contrary, areas along the stretch of the river that were consequently not easily accessed by humans i.e. having less human traffic and activities would hold a high bird population.

Materials and methods

Study area

The study was conducted along Kaduna River, situated at longitude N10º 28' 00" and latitude E007º 35' 00". The river originates from the Sherri Hills (Ologunorisa *et al* 2021) on the Jos Plateau. It is navigable by light crafts

between the months of July to October when the rainy season is at its peak. The upper floodplains are utilized for swamp rice cultivation, while the southern plains serve as major agricultural sites for rice and sugarcane production. In addition, it is beneficial for local transportation, fishing, and irrigation farming (Kaduna State Bureau of Statistics (KDBS), 2017). Four sampling stations were purposively chosen along the metropolitan stretch of the Kaduna River (Figure 1); the coordinates of sampled transects are shown in (Table 1).

Table 1: Coordinates of sampled transects along the Metropolitan stretch of River Kaduna between March-June 2019

Transect	Transect Name	Start Coordinate	Stop Coordinate
w	Malali Water Works	N10º 33' 43", E007º 29' 17"	N10º 33' 38", E007º 29' 15"
x	Sir Patrick Yakowa Way- Bridge	N10º 30' 45", E007º 27' 69"	N10º 30' 36", E007º 27' 75"
y	River Kaduna Bridge through the city-centre	N10º 29' 94", E007º 25' 34"	N10º 29' 91", E007º 25' 28"
z	Nariya Village Stream	N10º 29' 90", E007º 22' 95"	N10º 29' 75", E007º 22' 81"

Bird survey

The line transect bird census technique (Bibby *et al* 2000) was employed in this study. This method involves walking a predetermined route at a consistent pace and recording all birds observed or heard within a fixed distance radius of 100 m on either side of the transect line as determined by the observer(s). At each station, a 2 km transect was established along the bank of the river, and extends to 5m and 10m from the river course in difficult terrain. The start and end points of the transects were geo-referenced using a Garmin 64® Global Positioning System (GPS) at the four sampling stations (**w**, **x**, **y** and **z)**. Two transects were routinely survey per day during two-time intervals (6:30 – 7:30 am and 8:30 - 9:30 am) with an hour interval to travel between stations. Surveys were carried out twice weekly during the sampling periods (March to June, 2019). Additionally, each transects was subdivided into five 400 m segments to facilitate observations and estimation of environmental variables and human activities that may influence bird populations. Birds were detected with the aid of 8 × 42 Olivon pair of binoculars, and species identification was aided with the field guide to the Birds of Western Africa (Borrow and Demey, 2014). All birds observed, whether perched, in flight or acoustically detected were recorded along each transect.

Anthropogenic and environmental variables estimation

Environmental variables including vegetation clearing, logging, farming, building, soil harvesting, erosion and pollution were qualitatively estimated both at the beginning and midpoint of each sampling month (Ringim and Harry 2017).

Landsat imagery from 1990 to 2020 were used to estimate the extent of Land-Use/Land-Cover (LULC) influence on vegetation, non-vegetation and the water bodies of the North and South Local Government Areas (LGAs) of Kaduna State. These two LGAs were selected for the analysis because the areas under investigations were largely situated within their boundaries. The analysis was conducted at the Geographic Information System Laboratory of the Federal University of Technology (FUT) Minna. Three sets of satellite data were used: Landsat Thematic Mapper (TM) of 1990, Landsat Enhanced Thematic Mapper Plus (ETM+) 2000 and Operational Land Imager (OLI). These dataset were downloaded from the Nigerian Airspace Research and Development Agency Office (NASRDA). All satellite imagery from the two LGAs were geo-referenced to ensure spatial accuracy. The Level 1 classification of distinct land categorization was used to classify built-up, vegetation, cultivated area, bare surface and water body (Anderson *et al* 1976). The total area coverage of each class was estimated, and results were visualized using histograms and percentage distribution tables.

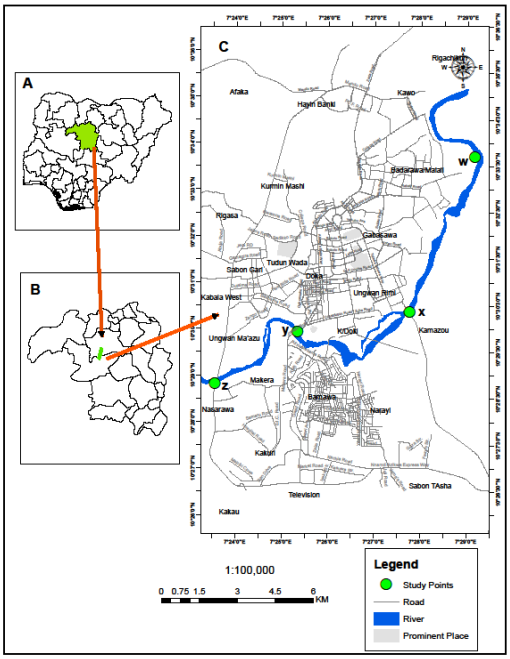

Figure 1. Map of study area showing sampling stations (C); inserted are maps of Nigeria showing Kaduna State (A), Kaduna North and Kaduna South Local Government Areas (B).

Data analysis

All data generated from the survey were analysed using the R Statistical package version 4.2.1 (R Core Team, 2022). Bird species diversity was calculated using Shannon-Wiener diversity index (Shannon, 1949).

$$H' = -\sum \left(\frac{ni}{N} \times ln\frac{ni}{N}\right)$$

Where ***ni*** is the number of individuals of species ***i***, and ***N*** is the total number individuals recorded.

Descriptive statistics are presented as Mean ± SD. One-way ANOVA was used to test whether bird abundance differ from one sampling station to another. Kruskal Wallis test was used to check the differences in the mean bird abundance at different sampling stations. Tukey's test was used to further separate sampling stations- pairs that bird abundance was lowest and highest. *T*-test was used to compare means between bird-types classified based on habitat. Chi-Square (X^2) test was estimated from percentage scores of estimated anthropogenic and environmental variables, while LULC magnitudes were summarized using percentages and presented in tabular forms.

Results

A total of 19,056 individual birds were recorded within the four sampling locations along the spread of the river in Kaduna Metropolis. The number of individual birds were highest at stations **z** and **y**. Additionally, the Shannon-Wiener diversity index (*H'*) was highest at station **x** (3.92) and lowest at station **y** (3.76) (Table 2). The average numbers of birds observed were 21.5%, 25.0%, 21.9% and 31.5% in sampling areas **w**, **x**, **y** and **z** respectively (Figure 2). Bird abundance varied significantly between the four transects in this study (ANOVA, $F_{3,1643}$ = 4.69 p<0.01; Kruskal Wallis chi-squared = 10.91, df =3, p-value = 0.012) with the lowest bird abundance been detected on transect **w** and highest on transect **z** (Tukey, mean difference = 3.97, p<0.001). A total of 115 bird species representing 52 families were identified and these were classified into aquatic and terrestrial habitats at a percentile of 29:71 (Figure 3). Also, bird abundance varied significantly between the two bird-types based on habitats (t_{1358} = 5.60, p < 0.001). According to the International Union for the Conservation of Nature (IUCN), all 115 species were categorized as least concern (IUCN, 2020; Table 3).

Bird relationship with environment amidst different estimated intensity of anthropogenic footprints varied from stations **x** and **z** with 0 % of building compared to stations **y** and **z** with 0 % of logging activities (Table 4). Anthropogenic activities comparison amongst **w**, **x**, **y** and **z** revealed χ^2 = 79.03, df = 18, p = 0.0001, R^2 = - 0.35.

Table 2: Abundance and diversity indices of birds at the four stations along the metropolitan stretch of River Kaduna during the study period (n=19,056)

Sampling Stations	Number of Birds (*N*[$\ddot{x}$±SD])	Diversity Index (*H'*)
W	400 (10.25±9.6)	3.85
X	448 (10.64±15.4)	3.92
Y	371 (11.27±15.6)	3.76
Z	428 (14.04±19.3)	3.77

N = Number of individual birds, $\ddot{x}$ = Average number of birds, SD = Standard Deviation and *H'* = Shannon-Wiener Diversity Index

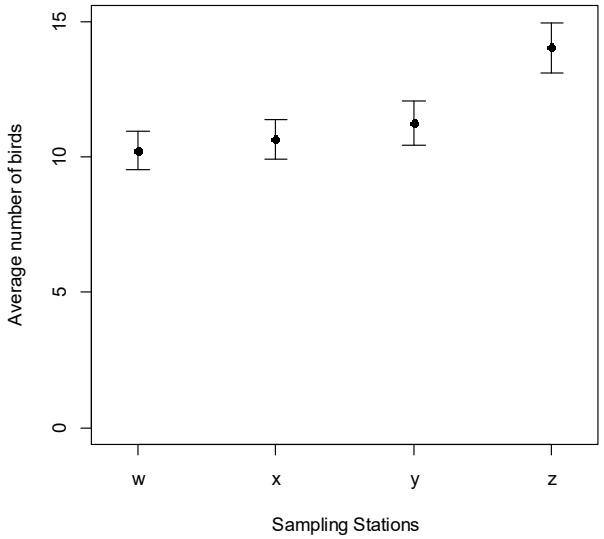

Figure 2. Average birds per sampling station along the metropolitan stretch of the River Kaduna during the study period

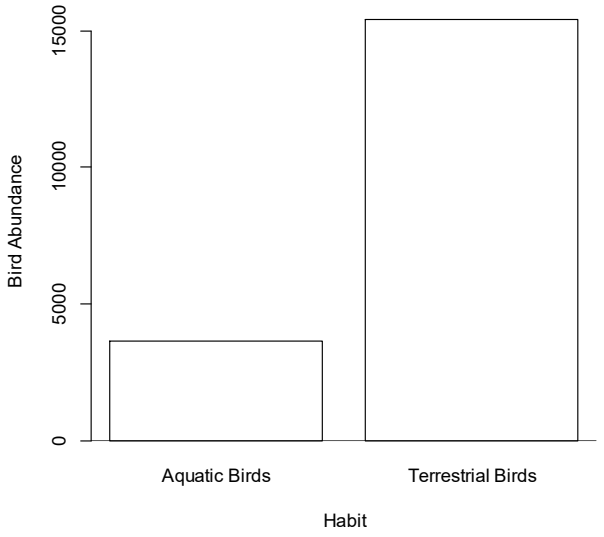

Figure 3. Difference in bird-type abundance along the metropolitan stretch of the River Kaduna during the study period

Classifications of analyzed Land Use/Land Cover (LULC) for Kaduna North and South Local Government Areas

The magnitude of LULC change over the past 30 years (1990 - 2020) showed a drastic lose in vegetation cover. Built-up areas had an annual rate of change of ±111.4% while cultivated land had the annual decline of -23.12%. The era experienced a further increase in bare surface and a decrease in the water body by approximately -0.39 km^2 representing -6.14% of the total change (Table 5; Figure 5).

Table 3: Bird species checklist on the four sampling stations along the metropolitan stretch of River Kaduna during the study

S/No.	Family	Bird Species	Common Name	Status	IUCN	Feeding Guild	W	X	Y	Z
1	Accipitridae	*Accipiter badius*	Shikra	RB	LC	Carnivore	٧	٧	٧	*
2	Acrocephalidae	*Acrocephalus schoenobaenus*	Sedge Warbler	PW	LC	Insectivore	٧	٧	٧	٧
3	Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	P	LC	Insectivore	٧	٧	٧	٧
4	Jacanidae	*Actophilornis africanus*	African Jacana	RB	LC	Insectivore	٧	٧	٧	٧
5	Apodidae	*Apus affinis*	Little Swift	RB	LC	Insectivore	٧	٧	٧	٧
6	Apodidae	*Apus pallidus*	Pallid Swift	PW	LC	Insectivore	*	٧	٧	٧
7	Ardeidae	*Ardea cinerea*	Grey Heron	RB/PW	LC	Carnivore/piscivore/insectivore	٧	٧	٧	٧
8	Ardeidae	*Ardea intermedia*	Intermediate Egret	RB	LC	Carnivore/piscivore/insectivore	٧	٧	*	٧
9	Ardeidae	*Ardea melanocephala*	Black-headed Heron	AB	LC	Carnivore/piscivore/insectivore	٧	*	*	٧
10	Ardeidae	*Ardeola ralloides*	Squacco Heron	PW/RB	LC	Carnivore/piscivore/insectivore	٧	٧	٧	٧
11	Pycnonotidae	*Atimastillas flavicollis*	Yellow-throated Leaflove	RB	LC	Frugivore/Insectivore	*	٧	*	*
12	Ardeidae	*Bubulcus ibis*	Cattle Egret	AB	LC	Insectivore	٧	٧	٧	٧
13	Ardeidae	*Butorides striata*	Green-backed Heron	RB	LC	Insectivore	٧	٧	٧	٧
14	Cisticolidae	*Camaroptera brachyura*	Grey-backed Camaroptera	RB	LC	Insectivore	٧	٧	٧	٧
15	Cuculidae	*Centropus senegalensis*	Senegal Coucal	RB	LC	Carnivore/insectivore	٧	٧	٧	٧
16	Alcedinidae	*Ceryle rudis*	Pied Kingfisher	RB	LC	Carnivore/piscivore/insectivore	٧	٧	٧	٧
17	Nectariniidae	*Chalcomitra senegalensis*	Scarlet-chested Sunbird	RB	LC	Nectirivore/insectivore	٧	٧	٧	٧
18	Charadriidae	*Charadrius forbesi*	Forbe's Plover	RB	LC	Carnivore	*	*	٧	٧
19	Cuculidae	*Chrysococcyx caprius*	Didric Cuckoo	RB	LC	Insectivore	٧	*	٧	٧
20	Cuculidae	*Chrysococcyx klaas*	Klaas's Cuckoo	RB	LC	Insectivore	٧	*	٧	٧
21	Cisticolidae	*Cisticola galactotes*	Winding Cisticola	RB	LC	Insectivore	٧	٧	٧	٧
22	Cisticolidae	*Cisticola natalensis*	Croaking Cisticola	RB	LC	Insectivore	*	*	*	٧
23	Cuculidae	*Clamator jacobinus*	Jacobin's Cuckoo	AB	LC	Insectivore	*	*	٧	٧
24	Columbidae	*Columba guinea*	Speckled Pigeon	RB	LC	Granivore	٧	٧	٧	٧
25	Coraciidae	*Coracias abyssinicus*	Abyssinian Roller	AB	LC	Insectivore	٧	٧	*	٧
26	Coraciidae	*Coracias naevius*	Rufous-crowned Roller	RB	LC	Insectivore	٧	*	*	*
27	Laniidae	*Corvinella corvina*	Yellow-billed Shrike	RB	LC	Insectivore	٧	٧	٧	٧
28	Corvidae	*Corvus albus*	Pied Crow	RB	LC	Omnivore	٧	٧	٧	٧
29	Muscicapidae	*Cossypha albicapillus*	White-crowned Robinchat	R	LC	Insectivore	*	*	٧	*
30	musophagidae	*Crinifer piscator*	Western Grey Plantain-eater	RB	LC	Frugivore/insectivore	٧	٧	٧	٧
31	fringillidae	*Crithagra mozambica*	Yellow-fronted Canary	RB	LC	Granivore	*	٧	٧	٧
32	Cuculidae	*Cuculus gularis*	African Cuckoo	A	LC	Insectivore	٧	٧	*	٧
33	Apodidae	*Cypsiurus parvus*	African Palm Swift	R	LC	Insectivore	٧	٧	٧	٧
34	Anatidae	*Dendrocygna viduata*	White-faced Whistling Duck	RB	LC	Omnivore	٧	٧	٧	٧
35	Picidae	*Dendropicos fuscescens*	Cardinal Woodpecker	RB	LC	Insectivore	٧	*	*	*
36	Dicruridae	*Dicrurus adsimilis*	Fork-tailed Drongo	RB	LC	Insectivore	٧	٧	*	٧
37	Ardeidae	*Egretta garzetta*	Little Egret	RB/PW	LC	Carnivore	٧	٧	٧	٧
38	Accipitridae	*Elanus caeruleus*	Black-shouldered Kite	RB	LC	Carnivore	٧	٧	٧	٧

S/No.	Family	Bird Species	Common Name	Status	IUCN	Feeding Guild	W	X	Y	Z
39	Cisticolidae	*Eremomela pusilla*	Senegal Eremomela	RB	LC	Insectivore	٧	٧	٧	٧
40	Estrildidae	*Estrilda troglodytes*	Black-rumped Waxbill	RB	LC	Insectivore	*	*	*	٧
41	Ploceidae	*Euplectes franciscanus*	Northern Red Bishop	RB	LC	Granivore	٧	٧	٧	٧
42	Ploceidae	*Euplectes hordeaceus*	Black-winged Bishop	RB	LC	Granivore	٧	*	*	*
43	Coraciidae	*Eurystomus glaucurus*	Broad-billed Roller	AB	LC	Insectivore	٧	*	*	٧
44	Falconidae	*Falco alopex*	Fox Kestrel	RB	LC	Carnivore	*	٧	٧	٧
45	Falconidae	*Falco ardosiaceus*	Grey Kestrel	RB	LC	Carnivore	*	٧	*	*
46	Falconidae	*Falco biarmicus*	Lanner's Falcon	RB	LC	Carnivore	*	٧	*	*
47	Falconidae	*Falco naumanni*	Lesser Kestrel	PW	LC	Carnivore	*	*	*	٧
48	Falconidae	*Falco tinnunculus*	Common Kestrel	RB/PW	LC	Carnivore	٧	٧	٧	٧
49	Alaudidae	*Galerida cristata*	Crested Lark	RB	LC	Insectivore	٧	٧	٧	٧
50	Rallidae	*Gallinula angulata*	Lesser Moorhen	AB	LC	Omnivore	٧	٧	٧	٧
51	Rallidae	*Gallinula chloropus*	Common Moorhen	RB/P	LC	Omnivore	٧	٧	٧	٧
52	Passeridae	*Gymnoris dentata*	Bush Petronia	AB	LC	Insectivore	٧	*	*	٧
53	Alcedinidae	*Halcyon leucocephala*	Grey-headed Kingfisher	AB	LC	Piscivore/insectivore	٧	٧	٧	٧
54	Alcedinidae	*Halcyon senegalensis*	Woodland Kingfisher	AB	LC	Piscivore/insectivore	٧	٧	٧	٧
55	Hirundinidae	*Hirundo aethiopica*	Ethiopian Swallow	RB	LC	Insectivore	٧	٧	*	٧
56	Hirundinidae	*Hirundo smithii*	Wire-tailed Swallow	RB	LC	Insectivore	٧	٧	٧	٧
57	Cisticolidae	*Hypergerus atriceps*	Oriole Warbler	RB	LC	Insectivore	*	٧	*	*
58	Indicatoridae	*Indicator indicator*	Greater Honeyguide	RB	LC	Insectivore	٧	٧	٧	*
59	Ardeidae	*Ixobrychus minutus*	Little Bittern	RB/PW	LC	Carnivore/piscivore	*	٧	٧	*
60	Accipitridae	*Kaupifalco monogrammicus*	Lizard Buzzard	RB	LC	Carnivore	*	*	*	٧
61	Estrildidae	*Lagonosticta senegala*	Red-billed Firefinch	RB	LC	Granivore	٧	٧	٧	٧
62	Sturnidae	*Lamprotornis caudatus*	Long-tailed Glossy Starling	RB	LC	Omnivore	٧	٧	٧	٧
63	Sturnidae	*Lamprotornis chloropterus*	Lesser Blue-eared Starling	RB	LC	Omnivore	٧	٧	٧	٧
64	Sturnidae	*Lamprotornis purpureus*	Purple Glossy Starling	RB	LC	Omnivore	٧	٧	٧	٧
65	Malaconotidae	*Laniarius barbarus*	Yellow-crowned Gonolek	R	LC	Insectivore	٧	٧	٧	٧
66	Motacillidae	*Macronyx croceus*	Yellow-throated Longclaw	RB	LC	Insectivore	٧	*	*	*
67	Muscicapidae	*Melaenornis edolioides*	Northern Black Flycatcher	RB	LC	Insectivore	٧	*	٧	٧
68	Meropidae	*Merops pusillus*	Little Bee-eater	RB	LC	Insectivore	٧	*	٧	*
69	Picidae	*Mesopicos goertae*	Grey Woodpecker	RB	LC	Omnivore	٧	٧	٧	*
70	Phalacrocoracidae	*Microcarbo africanus*	Long-tailed Comorant	RB	LC	Carnivore/piscivore/insectivore	٧	٧	٧	٧
71	Accipitridae	*Milvus migrans parasitus*	Yellow-billed Kite	AB	LC	Omnivore	٧	٧	٧	٧
72	Motacillidae	*Motacilla flava*	Yellow Wagtail	PW	LC	Insectivore	*	*	٧	٧
73	Ardeidae	*Nycticorax nycticorax*	Black-crowned Night Heron	PW/RB	LC	Carnivore	٧	*	*	*
74	Oriolidae	*Oriolus auratus*	African Golden Oriole	AB	LC	Frugivore/insectivore	٧	٧	٧	٧
75	Accipitridae	*Pandion haliaetus*	Osprey	PW	LC	Carnivore	*	*	٧	*
76	Phoeniculidae	*Phoeniculus purpureus*	Green Wood-hoopoe	RB	LC	Insectivore	٧	٧	٧	٧
77	Ploceidae	*Ploceus cucullatus*	Village Weaver	RB	LC	Granivore	٧	٧	٧	٧
78	Ploceidae	*Ploceus heuglini*	Heuglin's Masked Weaver	RB	LC	Granivore	٧	٧	*	٧
79	Ploceidae	*Ploceus luteolus*	Little Weaver	RB	LC	Granivore	*	٧	٧	٧
80	Ploceidae	*Ploceus vitellinus*	Vitelline Masked Weaver	RB	LC	Granivore	٧	٧	٧	٧

S/No.	Family	Bird Species	Common Name	Status	IUCN	Feeding Guild	W	X	Y	Z
81	Pluviandae	*Pluvianus aegyptius*	Egyptian Plover	RB	LC	Insectivore	٧	٧	٧	*
82	Ramphastidae	*Pogoniulus chrysoconus*	Yellow-fronted Tinkerbird	RB	LC	Frugivore/insectivore	٧	٧	*	٧
83	Ramphastidae	*Pogonomis dubius*	Bearded Barbet	RB	LC	Frugivore/insectivore	٧	٧	٧	٧
84	Psittacidae	*Poicephalus senegalus*	Senegal Parrot	RB	LC	Omnivore	٧	*	٧	٧
85	Cisticolidae	*Prinia subflava*	Tawny-flanked Prinia	RB	LC	Insectivore	٧	٧	٧	٧
86	Psittacidae	*Psittacula krameri*	Rose-ringed Parakeet	RB	LC	Omnivore	٧	٧	٧	٧
87	Phasianidae	*Pternistis bicalcaratus*	Double-spurred Francolin	RB	LC	Omnivore	٧	٧	٧	٧
88	Corvidae	*Ptilostomus afer*	Piapiac	RB	LC	Frugivore/insectivore	٧	٧	٧	٧
89	Pycnonotidae	*Pycnonotus barbatus*	Common Bulbul	RB	LC	Frugivore/insectivore	٧	٧	٧	٧
90	Ploceidae	*Quelea quelea*	Red-billed Quelea	RB	LC	Granivore	*	٧	*	٧
91	Phoeniculidae	*Rhinopomastus aterrimus*	Black Scimitarbill	RB	LC	Insectivore	٧	*	٧	*
92	Rostratulidae	*Rostratula benghalensis*	Greater Painted-snipe	RB	LC	Carnivore	٧	٧	٧	٧
93	Estrildidae	*Spermestes cucullata*	Bronze Mannikin	RB	LC	Granivore	٧	٧	٧	٧
94	Columbidae	*Streptopelia semitorquata*	Red-eyed Dove	RB	LC	Granivore	٧	٧	٧	٧
95	Columbidae	*Streptopelia senegalensis*	Laughing Dove	RB	LC	Granivore/insectivore	٧	٧	٧	٧
96	Columbidae	*Streptopelia vinacea*	Vinaceous Dove	RB	LC	Granivore/insectivore	٧	٧	٧	٧
97	Macrosphenidae	*Sylvietta brachyura*	Northern Crombec	RB	LC	Insectivore	٧	٧	٧	٧
98	Malaconotidae	*Tchagra senegalus*	Black-crowned Tchagra	RB	LC	Insectivore	٧	*	*	٧
99	Monarchidae	*Terpsiphone viridis*	African Paradise Flycatcher	AB/RB	LC	Insectivore	٧	*	٧	٧
100	Bucerotidae	*Tockus erythrorhynchus*	Northern Red-billed Hornbill	RB	LC	Frugivore/insectivore	٧	٧	٧	٧
101	Bucerotidae	*Tockus nasutus*	African Grey Hornbill	AB	LC	Frugivore/insectivore	٧	٧	٧	٧
102	Scolopacidae	*Tringa glareola*	Wood Sandpiper	P	LC	Carnivore/insectivore	٧	٧	٧	٧
103	Scolopacidae	*Tringa ochropus*	Green Sandpiper	P	LC	Carnivore/insectivore	٧	٧	٧	٧
104	Scolopacidae	*Tringa stagnatilis*	Marsh Sandpiper	PW	LC	Carnivore	٧	٧	٧	٧
105	Leiothrichidae	*Turdoides plebejus*	Brown Babbler	RB	LC	Frugivore/insectivore	٧	٧	٧	٧
106	Turdidae	*Turdus pelios*	African Thrush	RB	LC	Insectivore	٧	٧	٧	٧
107	Columbidae	*Turtur abyssinicus*	Black-billed Wood Dove	RB	LC	Granivore	٧	٧	٧	٧
108	Estrildidae	*Uraeginthus bengalus*	Red-cheeked Cordon-Bleu	RB	LC	Granivore	٧	٧	٧	٧
109	Charadriidae	*Vanellus senegallus*	African Wattled Lapwing	RB	LC	Insectivore	٧	*	*	*
110	Charadriidae	*Vanellus spinosus*	Spur-winged Lapwing	RB	LC	Insectivore	٧	٧	٧	٧
111	Charadriidae	*Vanellus tectus*	Black-headed Lapwing	RB	LC	Insectivore	٧	*	*	*
112	Viduidae	*Vidua chalybeata*	Village Indigobird	RB	LC	Granivore	٧	*	٧	٧
113	Viduidae	*Vidua macroura*	Pin-tailed Whydah	R	LC	Ganivore	٧	*	*	٧
114	Rallidae	*Zapornia flavirostra*	Black Crake	RB	LC	Carnivore/piscivore/insectivore	٧	٧	٧	*
115	Zosteropidae	*Zosterops senegalensis*	Yellow White-eye	RB	LC	Insectivore	٧	٧	٧	٧

Key:
٧ = present; * = absent; A = Afrotropical visitor; B = Breeding evidence; P = Palearctic visitor; R = Resident; W=Most winter (Dowsett, 2018).
AB = Afrotropical visitor with Breeding evidence
RB = Resident with Breeding evidence
PW = Palearctic visitor present Most winter
IUCN: International Union for the Conservation of Nature (Red List Category of Threatened Species)
LC = Least Concern

Table 4: Estimated scores and percentages of anthropogenic/environmental variables at the four sampling stations along the metropolitan stretch of River Kaduna during the study period.

Variables	Station W	(%)	Station X	(%)	Station Y	(%)	Station Z	(%)
Building	10	10	0	0	2	2	0	0
Erosion	14	13	12	16	21	23	5	8
Farming	28	27	12	16	29	33	26	42
Logging	5	5	2	3	0	0	0	0
Sand harvesting	10	10	21	28	17	19	5	8
Vegetation clearing	20	20	22	29	13	15	14	23
Pollution	15	15	6	8	7	8	12	19
Grand Total		**100**		**100**		**100**		**100**

Table 5: Magnitude and percentage of change in Land Use/Land Cover (LULC) between 1990 and 2020

LULC Class	1990 Extent (km^2)	2020 Extent (km^2)	Magnitude of Change (km^2)	Percentage Change (%)	Annual Rate of Change (%)
Built Up	21.55	81.54	59.99	278.4	111.4
Vegetation	62.72	21.53	-41.19	-65.67	-26.27
Cultivated Area	53.8	22.71	-31.09	-57.79	-23.12
Bare Surface	6.65	19.36	12.71	606	242.4
Water Body	2.54	2.15	-0.39	-15.35	-6.14
Total	**147.21**	**147.3**	**145.4**	**1023.2**	**409.3**

Source: GIS Laboratory, Federal University of Technology, Minna.

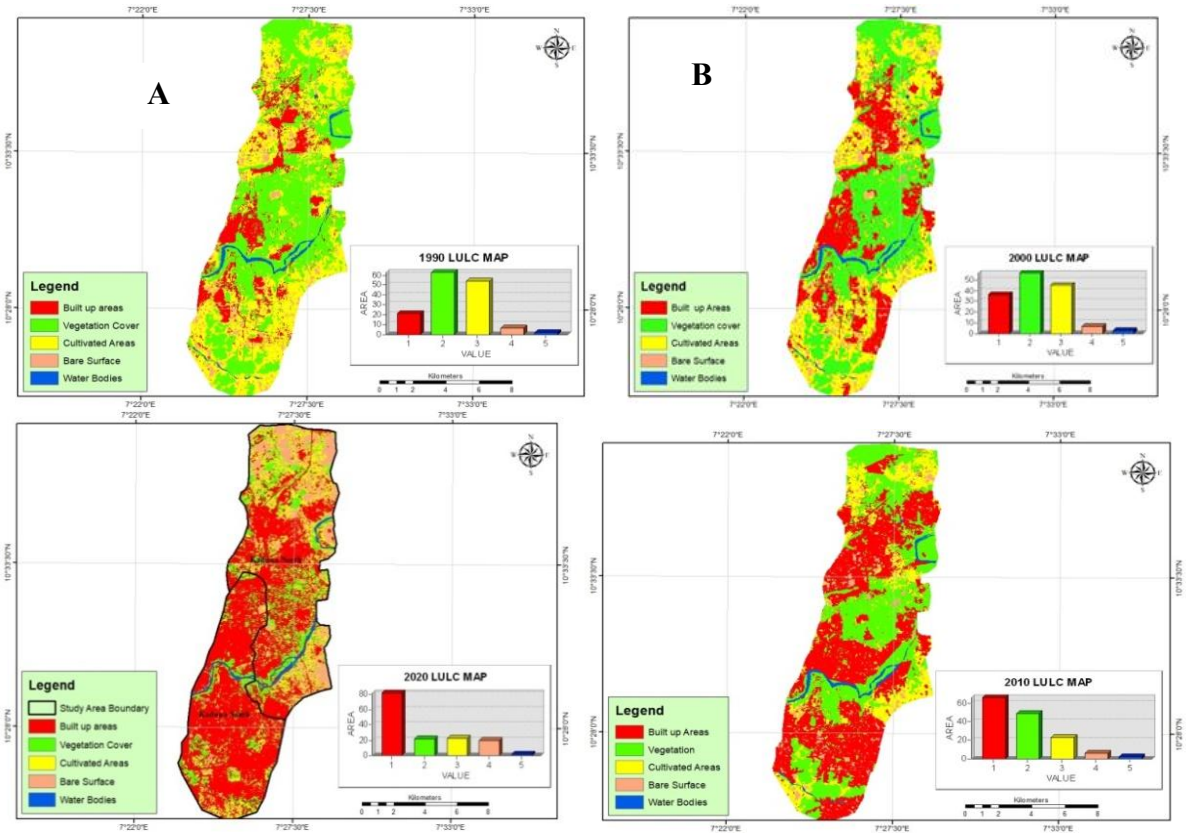

Figure 5. Periodical satellite imagery classification of Land Use/Land Cover (LULC)L distributions of Kaduna North and South LGAs generated from LandSat 5 TM ; a: 1990-2000; b: 2000-2010; c: 2010-2020; d: 1990-2020.
Source: GIS Laboratory, Federal University of Technology, Minna.

Discussion

Urban landscapes are living mosaics where natural ecosystems and human activity converge shaping both biodiversity and human well-being. Along the metropolitan stretch of the River Kaduna, bird communities serve as sensitive indicators of these dynamics, reflecting the pressure of urban expansion, cultivation and infrastructural development. As anthropogenic activities intensify, the resilience or decline of avifaunal diversity provides critical insight into the health of the ecosystem and sustainability of the environment we share.

The bird abundance ranked highest to lowest from stations **z**, **x**, **y** and **w**; overall, more birds were recorded at station **z** than at the other sampling stations (see Table 2). In addition to reducing the level of disturbance, stations **x** and **z** may be considered environmentally healthier than **w** and **y**. Despite human activities, the mechanism fostering bird diversity in relations to various habitats remains largely unclear (Hung *et al* 2020). Areas with higher ecological diversity perhaps are psychologically beneficial to humans (Hedblom *et al* 2014), as they are indicators of human well-being (Fuller *et al* 2007, Luck *et al* 2011) or the health of the environment (Ezealor 2002).

As hypothesized, active anthropogenic sites (Table 1) were expected to have more disturbances in agreement with Braimoh *et al* (2018) leading to negative relationship between bird abundance (Table 2) as a result of intensified activity with anthropogenic footprints (Table 4). At whatever level anthropogenic activity influences the environmental, it threatens biota at perceptible or temporary-concealed manner across the metropolitan stretch of the River Kaduna. Human population growth which forms the basis of anthropogenic activity intensification in an area is closely is associated with land use change (Cresswell *et al* 2019). The dynamic process of how bird population change may be better understood if change in human population density per area is focused at, rather than absolute human population growth.

Further results from this study revealed five categories of Land Use/Land Covers spanning thirty years; built-ups land, vegetation cover, cultivated areas, bare surfaces and water bodies. A steady increase in built-up area coverage underscored the intensifying human activity and urban expansion, consistent with the findings of Saleh *et al* (2014), who noted that urbanization profoundly alters land-use patterns. As the growing human population drives the demands for more housing and urban areas, more areas are converted for cultivation and sustenance, leading to more damage to the environment. These increasing populations promote disturbances, causing a lack of suitable foraging and nesting sites for birds, which may explain the lower abundance and diversity recorded at the stations located near high-traffic areas (i.e. stations **x** and **y**).

Urban renewal projects through their environmental and social impact assessment frameworks, often underscore biodiversity conservation together with the sustainable human development. Nevertheless, these projects also opened new access roads and increase connectivity, thereby exacerbating noise, air and industrial pollutions that may disrupt bird flight, foraging, nesting and breeding along the stretch of the rivers and their surroundings.

The LULC imagery is a true reflection of the rapid urbanization that is responsible for replacement of nature and avifaunal habitats in the metropolitan area with buildings, roads and other infrastructure. The expansion of urban areas has also resulted in widespread vegetation clearance, exposing affected areas to direct windstorms and intense sunlight. Additionally, plastics and other domestic wastes were observed clogging the drainage channels and water pathways, flowing into the river. Flood predictions by Jeb and Aggarwal (2008) involving serious urban renewal projects have been observed to influence population around the city centers.

Conclusion

This study combined avifaunal assessment along the metropolitan stretch of Kaduna River and remotely sensed spatiotemporal LULC trends in Kaduna North and South Local Government Areas to reveal the effects of rapid urbanization and structural reformations in Kaduna metropolis. Though bird diversity seemed to be coping well with the changes, periodic assessments are recommended to keep abreast the influence of structural reforms in the River Kaduna corridor across the metropolis of Kaduna State. The long-term impacts of these changes may manifest in alterations in seasonal patterns and livelihood in general.

Accordingly, establishing a baseline inventory at the onset of projects, followed by periodic monitoring is recommended. The development of strategies to mitigate emerging environmental health concerns, and the proposal of measurable indicators to evaluate progress are essential. These efforts not only foster adaptive learning but also provide a foundation for reassessing the same areas in the future to determine whether conservation and development goals are being achieved.

Conflict of interest

The authors declare no conflict of interest.

References

Awoyemi, A.G. and Ibanez-Alamo, J.D. 2023. Status of urban ecology in Africa: A systematic review. *Land Urbanplan. 233*: 104707.

Awoyemi, A.G., Ibanez-Rueda, N., Guardiola, J. and Ibanez-Alamo, J.D. 2024. Human-nature interactions in Afrotropics: Experiential and cognitive connections among urban residents in southern Nigeria. *Ecol. Econ. 218*:108105.

Awoyemi, A.G., Alabi, T.R. and Ibanez-Alamo, J.D. 2025. Remotely sensed spectral indicators of birds taxonomic, functional and phylogenetic diversity across Afrotropical urban and non-urban habitats. *Ecol. Ind. 170*: 112966.

Aguilera, J. 2019. The Numbers are just horrendous, almost 30,000 species face extinction because of

human activity. time.com/5629548/almost-30000-species-face-extinction-new-report/July 18.

Anderson, J.R., Hardy, E.E., Roach, J.T. and Witmer, R.E. 1976. *A land use land cover classification system for use with remote sensor data*. Geological survey professional paper. U.S. Government printing office, Washington DC 964pp.

Asibor, G. and Akpofure, R. 2019. Investigation of biodegradation capacity of Kaduna River, Nigeria. *British J. of Env. Sci.* (*7*)*3*: 53-61.

Bibby, J.C., Burgess, N.D. Hill, D.A. and Mustoe, S.H. 2000. *Bird Census Techniques*, second ed. Academic Press, London, 302pp.

BirdLife International 2020. *Our post 2020 vision.* http://www.birdlife.org/magazine/april-june-2020.

Borrow, N. and Demey, R. 2014. *Birds of Western Africa*. Christopher Helm, London, 592pp.

Braimoh, B., Iwajomo, S., Wilson, M., Chaskda, A., Ajang, A. and Cresswell, W. 2018. Managing human distance: factors influencing flight-initiation distance of birds in a West African nature reserve. *Ostrich*, 89:59-69.

Cresswell, W., Kazeh, N. W. and Patchett, R. 2019. Local human population increase in the non-breeding areas of long-distance migrant bird species is only weakly associated with their declines, even for synanthropic species. *Div. Dist.* 00:1-12. Doi: 10.1111/ddi.13006.

Dowsett, R.J. 2018. Nigerian Checklist: African Bird Club. Retrieved from https//www.africanbirdclub.org/sites/default/files/15_NigerianList_Dowsett.pdf; Accessed 3 March 2020.

Ezealor, A.U. 2002. *Critical Sites for biodiversity conservation in Nigeria*. Nigerian Conservation Foundation. Lagos Nigeria. P65.

Ido, T., Zvika, A. and Burt, P. K. 2008. Foraging behavior of urban birds: Are human commensals less sensitive to predation risk than their nonurban counterparts? *Condor 110*(*4*):772-776. https://doi.org/10.1525/cond.2008.8572.

Jeb, D.N. and Aggarwal, S.P. 2008. Flood inundation hazard modelling of the River Kaduna using remote sensing and Geographic Information Systems. *J. Appl. Sci. Res. 4*(*12*): 1822-1833.

Marzluff, J.M., McGowan, K.J., Donnelly, R. and Knight, R.L. 2001. *Causes and consequences of expanding American Crow populations*. pp. 332-363. *In*: Avian ecology and conservation in an Urbanizing World (J.M. Marzluff, R. Bowman and R. Donnelly, eds.), Kluwer Academic Press, Norwell, MA.

Montgomery, M.R., Stren, R., Cohen, B. and Reed, H.E. 2013. Cities transformation: Demographic change and its implications in developing world. https://doi.org/10.4324/9781315065700.

Ogbozige, F.J., Adie, D.B. and Abubakar, U.A. 2017. Water quality assessment and mapping using inverse distance weight interpolation: A case of River Kaduna Nigeria. *Nig. J. Tech. 37*(*1*):249-261.

Okafor, G.C. and Ogbu, K.N. 2018. Assessment of the impact of Climate change on the freshwater availability of Kaduna River basin. *J. Wat. Land Dev. 38*:105-114. https://doi.org/10.2478/jwld-2018-0047.

Ologunorisa, T. E., Durowoju, O. S. and Akinbobola, A. 2021. Hydroclimatology of the Kaduna River Basin. *Amer. J. Clim. Chan. 10:* 353-369.

Suleiman, B. 2016. Catalogue of Fishes of Kaduna River, Kaduna, Nigeria. 19p.

Ringim, A. S. and Harry, H. Jr. 2017. Is the population in the Hadejia-Nguru Wetlands under Threat? *W. Afr. J. Appl. Ecol. 25*(*2*):69-84.

Fuller, R.A., Irvine, K.N., Devine-Wright, P., Warren, P.H. and Gaston, K.J. 2007. Psychological benefits of greenspace increase with biodiversity. *Biol. Lett. 3*: 390-394, https://doi.org/10.1098/rsbl.2007.0149.

IUCN (2020). IUCN Red List of Threatened Species. www.iucnredlist.org. Accessed 12 April 2020

Kaduna State Bureau of Statistics (2017). *Kaduna State Agricultural Structure Survey (KASS)*. 43pp. https://kdbs.ng/app/uploads/2018/02/KASS-STRUCTURE-SURVEY.pdf

Luck, G.W., Davidson, P., Boxall, D. and Smallbone, L. 2011. Relations between urban bird and plant communities and human well-being and connection to nature. *Conserv. Biol*. *25*, 816-826, https://doi.org/10.1111/j.1523-1739.2011.01685.x.

Hedblom, M., Heyman, E., Antonsson, H. and Gunnarsson, B. 2014. Bird song diversity influences young people's appreciation of urban landscapes. *Urban For*. *Urban Green*. *13:* 469-474, https://doi.org/10.1016/j.ufug.1014.04.002.

Hung-Ming, T., Meng-Wen, F. and Chie-Jen, J.K. 2020. *Nature*. https://doi.org/10.1038/s41598-020-58202-4.

R. Core Team. 2022. A language and environment for statistical computing. R Foundation for statistical computing, Vienna, Australia. https://www.r.project.org. Accessed 28 December 2025.

Saleh, Y., Badr, A.M., El-Banna, F. and Shahata, A. 2014. Agricultural land-Use change and disappearance of farmlands in Kaduna Metropolis Nigeria. *Sci. World J.* 9(*1*):1-7.

Shannon, C. E. 1949. *The Mathematical Theory of Communication*. The University of Illinois press, Champaign, IL, USA, 117pp.

United Nations (UN). 2016. *Urbanization and development: Emerging futures.* World Cities Report 2016. Nairobi: United Nations.

Yusuf, R.O., Durojaiye, A.O. and Salawudeen, T.A. 2008. Pollution monitoring along Kaduna River. *Intl. J. Env. Sci. 4*(*4*): 76-82.

ORCID
Boniface O. Agbo: https://orcid.org/0009-0002-3496-4257