Article de recherche **Rev. Cong. Sci. Technol., Vol 03, No.04, pp. 391-403 (2024)**

OPEN ACCESS

Revue Congolaise des Sciences & Technologies

ISSN : 2959-202X (Online); 2960-2629 (Print)

http://www.csnrdc.net/

REVUE CONGOLAISE DES SCIENCES ET TECHNOLOGIES

Avifauna of the Hunting Area and Reserve of Bombo-Lumene, Kinshasa, Democratic Republic of Congo: Diversity and Distribution in Different Habitats

[Avifaune du domaine et réserve de chasse de Bombo-Lumene, Kinshasa, République Démocratique du Congo : Diversité et distribution dans différents habitats]

Ngandu Lendo Michel[1,3*], Liyandja Dja Liyandja Tobit[2,4], Kisasa Kafutshi Robert[1] & Punga Kumanenge Julien[3]

[1]*Ornithology Research Unit, Department of Biology, Faculty of Sciences and Technologies, University of Kinshasa, P.O. Box 190, Kinshasa, Democratic Republic of Congo*

[2]*Department of Biology, Faculty of Sciences and Technologies, University of Kinshasa, P.O. Box 190, Kinshasa, Democratic Republic of Congo*

[3]*Behavioural Ecology Research Unit, Department of Biology, Faculty of Sciences and Technology, University of Kinshasa, P.O. Box 190, Kinshasa, Democratic Republic of Congo*

[4]*Department of Biological Sciences, University of Toronto Scarborough, Toronto, ON M1C 1A4, Canada.*

Abstract

Despite holding the most diverse assemblage of birds in the Afrotropics, ornithological surveys in the Democratic Republic of Congo's network of reserves are notably rare. In this paper we provide the first well detailed inventory of bird species of Bombo-Lumene and their distribution across different habitats based on mist-netting specimens collection in three different habitats conducted between February and December 2023. We documented a total of 113 species, distributed in 34 families and 5 orders, including the threatened *Cossypha heinrichi*. As elsewhere in the country, Passeriformes, with over 80 species and 20 families, are the most represented species in Bombo-Lumene. We found that savanna and forest habitats hold the most diverse species communities whereas human transformed habitats such as thickets hold the least diverse communities. Overall, ecology indices based on species abundance suggest that assessed habitats in Bombo-Lumene are in good ecological health. Our results confirm the status of Important Bird Area (IBA) of the Bombo-Lumene protected area in Africa. Ethnic conflicts, increasing demand for land used in agriculture and human settlement, and poaching are the primary local threats on biological diversity of Bombo-Lumene in general and of its bird diversity in particular. Further surveys and studies in the reserve, covering all habitat types and an extended surface area of the reserve, are highly recommended to better capture its bird species composition and update strategies and policies for the conservation of these extremally diverse communities.

Keywords: Bird diversity, Habitat, Protected areas, Kinshasa, Central Africa.

Résumé

Bien que le réseau de réserves de la République Démocratique du Congo abrite l'assemblage d'oiseaux le plus diversifié de la région afrotropicale, les études ornithologiques y sont particulièrement rares. Dans cet article, nous fournissons le premier inventaire détaillé des espèces d'oiseaux de Bombo-Lumene et de leur distribution dans différents habitats, basé sur la collecte de spécimens au filet japonais dans trois habitats différents, réalisée entre février et décembre 2023. Nous avons récolté un total de 113 espèces, réparties dans 34 familles et 5 ordres, y compris *Cossypha heinrichi*, une espèce menacée. Comme ailleurs, les Passeriformes sont les plus représentés avec plus de 80 espèces et 20 familles. Nous avons constaté que les habitats de savane et de forêt abritent les communautés d'espèces les plus diversifiées, tandis que les habitats transformés par l'homme, tels que les fourrés, abritent les communautés les moins diversifiées. Dans l'ensemble, les indices écologiques basés sur l'abondance des espèces suggèrent que les habitats évalués à Bombo-Lumene sont en bonne santé écologique. Nos résultats confirment le statut de Zone Importante pour la Conservation des Oiseaux (ZICO) de l'aire protégée de Bombo-Lumène en Afrique. Les conflits ethniques, la demande croissante de terres utilisées pour l'agriculture et les installations humaines, et le braconnage sont les principales menaces locales pour la diversité biologique de Bombo-Lumène en général et pour la diversité de ses oiseaux en particulier. D'autres enquêtes et études dans la réserve, couvrant tous les types d'habitats et une surface étendue de la réserve, sont fortement recommandées pour mieux saisir la composition des espèces d'oiseaux et m0ettre à jour les stratégies et les politiques pour la conservation de ces communautés extrêmement diversifiées.

Mots-clés : Diversité des oiseaux, Habitat, Zones protégées, Kinshasa, Afrique centrale.

*Auteur correspondant: Michel L. Ngandu, (michka.ngandu@gmail.com). Tél.: (+243) 819 907 242 ;
ID : https://orcid.org/0009-0006-5489-8372; Reçu le 09/10/2024; Révisé le 18/11/2024 ; Accepté le 02/12/2024
DOI: https://doi.org/10.59228/rcst.024.v3.i4.106

1. Introduction

With an immense surface area of 2,345,410 km^2, the Democratic Republic of Congo (DRC), located almost entirely in the Congo Basin (CB), is the largest country in Sub-Saharan Africa (Demey & Louette, 2001). The country comprises a wide variety of habitats including the lowland swamp-forests of the cuvette centrale, the montane forests of the Albertine Rift highlands in the eastern Congo, the woodlands, grasslands, and savannas of the Katanga, Kwango, and Kasai plateaus, and the *Rhizophora* mangrove forest of the outer estuary of the Congo River (Demey & Louette, 2001). Thanks to its immensity, its variety of habitats, and climate variations, the country hosts an extremely diverse avian fauna estimated to 1,192 species including 20 endemic species (Lepage, 2024a) and charismatic species such as *Afropavo congensis* Chapin, 1936 and *Psittacus erithacus* Linnaeus, 1758.

Despite being relatively well documented in the past (Chapin, 1932–1954), the current diversity status of the avifauna of the country remained poorly documented and monitoring work has been neglected. By extension, data-driven policies, for protected areas and sustainable management strategies both in- and outside protected areas, are largely limited. While there have been some recent studies in specific sites (Voelker et al., 2013; Kisasa & Punga, 2024; King & Chamberlan, 2013) including in some protected areas (Liyandja et al., 2015; Murhabale et al., 2020; Jones & Jamie, 2023), these studies have been sporadic leaving the actual population and trends of avian species of several protected areas of the D.R. of Congo poorly known.

The protected area of Bombo-Lumene, comprises of a hunting area and a core reserve, is part of a network of about 29 protected areas established across the Democratic Republic of Congo (Inogwabini et al., 2005) to promote the conservation of the country's biodiversity. This protected area, which offers a diversity of landscapes (that includes range of natural and human-dominated ecosystems), is listed as one of the most Important Bird Areas (IBAs) in sub-Saharan Africa and the Democratic Republic of Congo (Demey & Louette, 2001). Yet, its avifauna remains poorly documented and ornithological studies in the area very scarce. Further, the area where Bombo-Lumene is located, is not exempted from ethnic conflicts related to land ownership between tribes such as Teke and Yaka, militia conflicts known as Mobondo, and poaching that have significantly affected the natural habitats and mission of this protected area. In this paper, we provide an inventory of bird species of Bombo-Lumene, their distribution across different habitats, and document the current characteristics of their communities in this touristic site.

2. Material et methods

2.1. Study Area

The protected area (PA) of Bombo Lumene, comprises of a hunting area and a reserve (figure 1), covers a surface area of about ca. 3 500 Km^2 and extends between 15.8406° and 16.2619° E and 4.2767° and 4.9000° S in western D.R. Congo.

The protected area has been established respectively in 1968 (hunting area) and in 1976 (reserve), for both natural protection and touristic purposes, and is currently managed by the Congolese Institute for Nature Conservation (ICCN).

The entire protected area is located in the province of Kinshasa and experiences a tropical savanna climate, of type Aw4 following Köppen-Geiger's classification (Peel et al., 2007), characterized by two main seasons: a longer wet season of about eight months (from mid-September to mid-May) and a shorter dry season of about four months (from mid-May to mid-September).

The wet season is interrupted by a short period of reduced precipitation between mid-January and mid-February. The region receives an annual rainfall that varies between 1,250 and 1,600 mm (Bultot, 1971).

The surface area covered by the Bombo-Lumene protected area is situated on the Batèké plateau (650 and 700 m a.s.l.) predominated by the presence of acidic, dry, and lessivated sandy soils (Nsombo et al., 2016). Because of its sandy soils, the vegetation of Bombo-Lumene is mainly composed of shrub and herbaceous savannas (Vermeulen & Lanata, 2006).

Shrub savannas are dominated by species such *Hymenocardia acida*, *Crossopteryx febrifuga*, *Annona senegalensis*, and *Vitex madiensis* whereas herbaceous savannas are dominated by *Loudetia demeusii*, *Ctenium newtonii*, and *Laudelphia lanceolata* (Vermeulen & Lanata, 2006; Habiyaremye et al., 2011).

The PA of Bombo-Lumene is drained by the Mayi-Ndombe River system which includes several tributaries such as the Bombo, the Lumene, the Buti-Butiene or Muti-Mutiene, and the Lufimi rivers.

The banks of those rivers are principally covered by degraded secondary riparian forests dominated by relic species such as *Millettia laurentii*, *Dracaena nitens*, and *Pentatclethra eetveldeana* (Nsombo et al., 2016). Our study was carried out in the northern part of the PA of Bombo-Lumene in 3 characteristic habitats (figure 1).

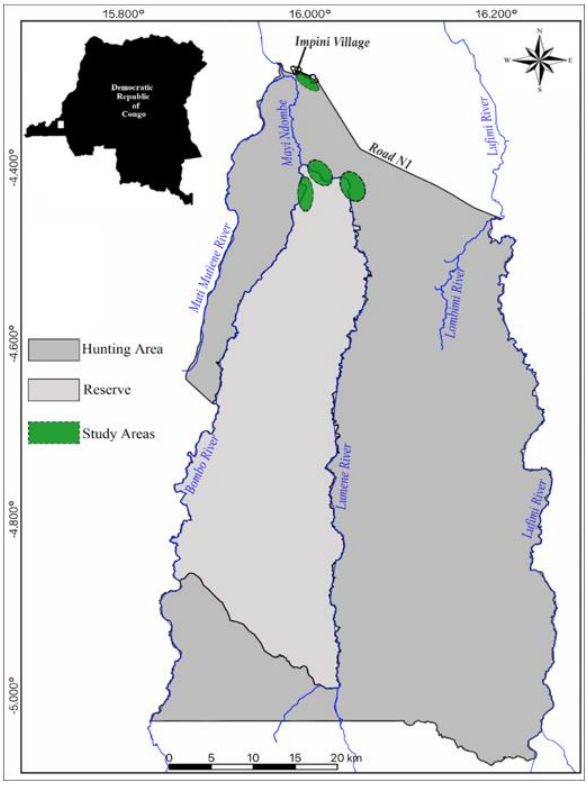

Figure 1. Map of the Bombo-Lumene protected Area showing survey site and its location in the Democratic Republic of Congo.

2.2. Habitat characterization

Because of the heterogeneity of habitat types in the study area, we used a stratified random sampling method. For that, we used the description of Habiyaremye et al. (2011) to stratify the study area into three main habitats: forested habitats, savannas, and thickets. Forests are habitats characterized by the presence of trees with more than 20 m in height with closer crowns than those of savannas, and the absence of the grassy stratum. In the forests, we included semi-deciduous dense forests and riparian forests. Savannas are habitats characterized by the presence of grassy stratum, the absence of trees, or presence of trees with less than 20 m in height, very disjointed crowns, and very thin overall canopy. In savannas, we included grassy savannas, shrubby savannas, and wooded savannas (Habiyaremye et al., 2011). Thickets are principally characterized by human planted vegetation.

2.3. Sampling and Species Identification

The list of species reported in this study is based on collections made between February and December 2023. Birds were captured monthly in different habitats (forests, savannas, and thickets) within the protected area using five 12 m x 2.5 m and 30 mm-mesh mist nets. In total, we sampled 43 different locations (16 in savannas, 6 in thickets, and 21 in forests) near the Impini village and the ICCN station within both the hunting area and reserve of Bombo-Lumene (table 1). Each visit lasted five days and netting activities were conducted during four consecutive days from approximately 7:00 to 17:00 each day.

We visited the nets three times per day to align with the daily activity patterns of most nesting birds. Captured specimens were photographed, leg banded, and realised in their natural habitat after species identification. Geographical coordinates for each location were recorded using a Garmin GPS (GPSMap 60CSx) receptor. Sampling stations were selected based on vegetation types and anthropogenic activities.

Table 1 lists geographical coordinates of each netting location and its type of habitat. Specimens were collected with permission of the Congolese Institute for the Conservation of Nature (ICCN)/General Direction (permit 1113/ICCN/DG/HMK/03/011/2022).

For species identification, we consulted numerous publications including (Mackworth & Grant, 1960; Borrow & Demey, 2001; Sinclair & Ryan, 2010), and the Birds of Africa series (Fry et al., 1982–2004). Phylogenetic classification (Sibley & Ahlquist, 1990; Lecointre & Le Guyader, 2001) has brought about significant changes at the level of bird orders, families, genera, and species.

In this study we follow the recent classification of Lepage (2007) and Gill & Donsker (2013). Many species have undergone changes in name or systematic position, or both. Thus, bird names and their systematic positions were updated as indicated in table 2 before generating a comprehensive list of species collected in the Bombo-Lumene hunting area.

Table 1. Geographical coordinates and habitats of netting locations at the Bombo-Lumene

Site Number	Latitude (°)	Longitude (°)	Habitat	Localisation in Bombo-Lumene
1	-4,290523	15,987407	Semi-deciduous dense forests	Hunting area (near Impini)
2	-4,289523	15,987837	Wooded savanna	Hunting area (near Impini)
3	-4,289406	15,989418	Grassy savannas	Hunting area (near Impini)
4	-4,427129	16,000838	Riparian forests	Reserve
5	-4,414903	15,9991203	Riparian forests	Reserve
6	-4,4357505	15,996621	Riparian forests	Reserve
7	-4,4103567	15,996309	Riparian forests	Reserve
8	-4,414903	16,0183296	Riparian forests	Reserve
9	-4,400795	16,006929	Riparian forests	Reserve
10	-4,412081	16,0297303	Riparian forests	Reserve
11	-4,402519	16,006148	Riparian forests	Reserve
12	-4,293173	15,991741	Thicket	Hunting area (near Impini)
13	-4,298112	15,9970899	Wooded savanna	Hunting area (near Impini)
14	-4,298543	15,999472	Shrubby savanna	Hunting area (near Impini)
15	-4,301267	15,997441	Grassy savannas	Hunting area (near Impini)
16	-4,405262	16,019735	Riparian forests	Hunting area
17	-4,4072999	16,0223902	Riparian forests	Hunting area
18	-4,407143	16,027388	Riparian forests	Hunting area
19	-4,423861	16,015806	Grassy savannas	Reserve
20	-4,405972	16,036139	Wooded savanna	Hunting area
21	-4,406301	16,0391203	Riparian forests	Hunting area
22	-4,405497	16,033674	Riparian forests	Hunting area
23	-4,407339	16,040663	Riparian forests	Hunting area
24	-4,398722	16,039833	Wooded savanna	Hunting area
25	-4,414694	16,043306	Shrubby savannas	Reserve
26	-4,414726	16,047144	Thicket	Hunting area
27	-4,422028	16,068889	Shrubby savannas	Hunting area
28	-4,423611	16,069694	Shrubby savannas	Hunting area
29	-4,413276	16,047261	Semi-deciduous dense forests	Hunting area
30	-4,44	16,068861	Semi-deciduous dense forests	Hunting area

31	-4,4435	16,065944	Semi-deciduous dense forests	Hunting area
32	-4,442944	16,065667	Semi-deciduous dense forests	Hunting area
33	-4,4475	16,065083	Semi-deciduous dense forests	Hunting area
34	-4,416813	16,053698	Thicket	Hunting area
35	-4,417019	16,053854	Thicket	Hunting area
36	-4,416921	16,053903	Thicket	Hunting area
37	-4,418283	16,0532003	Thicket	Hunting area
38	-4,423695	16,067167	Shrubby savannas	Hunting area
39	-4,415972	16,064167	Shrubby savannas	Hunting area
40	-4,411083	16,061278	Shrubby savannas	Hunting area
41	-4,4037778	16,058917	Shrubby savannas	Hunting area
42	-4,403944	16,076	Shrubby savannas	Hunting area
43	-4,423251	16,049944	Shrubby savannas	Hunting area

2.4. Data Analysis

We used simple descriptive statistics and different diversity indices to analyze the data. Species abundance, based on number of captured individuals in each habitat type, was used to calculate species relative frequencies (Rf) in that habitat type.

We calculated relative frequencies using the following mathematical expression: Rf = (ni/N) x 100, where ni is the total number of captured individuals of species i and N is the total number of individuals of all captured species in the protected area. Based on relative frequency values, Thiollay (1986) defined the following species categories: dominant species (D), when Rf ≥ 5%; regular species (Re), when 1% < Rf ≤ 5%; rare species (RS), when 0.2% < Rf ≤ 1%; and accidental species (AS) when Rf ≤ 0.2%.

To evaluate species diversity in different habitats, we calculated the Shannon-Weiner index and Pielou's evenness index using respectively the following expressions: $H' = -\sum_{i=1}^{s} p_i * ln\, p_i$ and $J' = H'/ln\, S$. Where p_i=ni/N, S is the number of species captured in that habitat (species richness), H' is the Shannon-Weiner index, and J' the evenness index.

We conducted multivariate analysis, primarily correspondence analysis (CA), to investigate possible correlations between habitat type and bird community assemblages. A one-way ANOVA test was also used to analysis community differences between habitats. For these analyses, we use the package FactoMineR (Lê et al., 2008) in R3.4.1. (R Core Team, 2013).

3. Results

3.1. Avian Fauna Composition

We captured 592 individuals within the protected area (Hunting area and Reserve) of Bombo-Lumene during our sampling campaigns. Those individuals belong to 113 avian species distributed across 71 genera, 35 families, and five orders. The most representative order is Passeriformes with 28 families, followed by Piciformes with 3 families, Coraciiformes with 2 families, and the least represented orders are Columbiformes and Cuculiformes with 1 family each (Table 2).

The order Passeriformes, with 84% of captured species, is significantly the most species-rich order in Bombo-Lumene. The remaining orders are less represented and accounted for only 16% [Coraciiformes (7%), Piciformes (5%), Columbiformes (3%), and Cuculiformes (1%)] of captured species (table 2).

Table 2. List of avian species collected from the Bombo-Lumene Protected Area with their conservation status.

Taxa	Specimens	SC	Rf(%)	CS
Columbiformes (1)				
Columbidae (3)				
Streptopelia semitorquata (Rüppell, 1837)	1	LC	0,17	AS
Turtur afer (Linnaeus, 1766)	2	LC	0,34	RS
Turtur tympanistria (Temminck, 1809)	3	LC	0,51	RS
Coraciiformes (2)				
Alcedinidae (4)				
Halcyon badia Verreaux & Verreaux, 1851	2	LC	0,34	RS
Halcyon chelicuti (Stanley, 1814)	2	LC	0,34	RS
Halcyon albiventris (Scopoli, 1786)	1	LC	0,17	AS
Ispidina picta (Boddaert, 1783)	41	LC	6,93	D
Meropidae (4)				
Merops apiaster Linnaeus, 1758	4	LC	0,68	RS
Merops breweri (Cassin, 1859)	2	LC	0,34	RS
Merops hirundineus Lichtenstein, 1793	1	LC	0,17	AS
Merops pusillus Müller, 1776	12	LC	2,03	Re
Cuculiformes (1)				
Cuculidae (1)				
Cuculus solitarius Stephens, 1815	1	LC	0,17	AS
Passeriformes (28)				
Acrocephalidae (3)				
Iduna natalensis (Smith, 1847)	1	LC	0,17	AS
Hippolais icterina (Vieillot, 1817)	3	LC	0,51	RS
Acrocephalus sp.	2	LC	0,34	RS
Alaudidae (1)				
Mirafra rufocinnamomea (Salvadori, 1866)	1	LC	0,17	AS
Cisticolidae (7)				
Camaroptera brevicaudata (Cretzschmar, 1830)	33	NE	5,57	D
Cisticola erythrops (Hartlaub, 1857)	3	LC	0,51	RS
Cisticola bulliens Lynes, 1930	2	LC	0,34	RS
Eremomela scotops Sundevall, 1850	5	LC	0,84	RS
Eremomela salvadorii (Reichenow, 1891)	3	NE	0,51	RS
Prinia subflava (Gmelin, 1789)	12	LC	2,03	Re
Schistolais leucopogon (Cabanis, 1875)	5	LC	0,84	RS
Dicruridae (2)				
*Dicrurus coracinus** (Verreaux & Verreaux, 1851)	1	LC	0,17	AS
*Dicrurus ludwigii** (Smith, 1834)	1	LC	0,17	AS
Emberizidae (1)				
Emberiza cabanisi (Reichenow, 1875)	3	LC	0,51	RS
Estrildidae (12)				
Clytospiza monteiri (Hartlaub, 1860)	3	LC	0,51	RS
Estrilda melpoda (Vieillot, 1817)	3	LC	0,51	RS
Glaucestrilda perreini (Vieillot, 1817)	2	LC	0,34	RS
Lagonosticta rhodopareia (Heuglin, 1868)	2	LC	0,34	RS
Lagonosticta rubricata (Lichtenstein, 1823)	9	LC	1,52	Re
*Mandingoa nitidula** (Hartlaub, 1865)	1	LC	0,17	AS
Nigrita canicapillus (Strickland, 1841)	1	LC	0,17	AS
*Paludipasser locustella** Neave, 1909	1	LC	0,17	AS
Pyrenestes ostrinus (Vieillot, 1805)	7	LC	1,18	Re
Pytilia afra (Gmelin, 1789)	1	LC	0,17	AS
*Pytilia melba** (Linnaeus, 1758)	1	LC	0,17	AS
Spermestes cucullata (Swainson, 1837)	3	LC	0,51	RS
Fringillidae (2)				
Crithagra mozambica (Müller, 1776)	6	LC	1,01	Re
Crithagra atrogularis (Smith, 1836)	2	LC	0,34	RS
Hyliidae (1)				
Hylia prasina (Cassin, 1855)	2	LC	0,34	RS
Hyliotidae (1)				
Hyliota flavigaster Swainson, 1837	2	LC	0,34	RS
Hirundinidae (1)				
Petrochelidon rufigula (Barboza du Bocage, 1877)	1	LC	0,17	AS
Malaconotidae (3)				
Bocagia minuta (Hartlaub, 1858)	1	LC	0,17	AS
Laniarius leucorhynchus (Hartlaub, 1848)	1	LC	0,17	AS
*Chlorophoneus bocagei** (Reichenow, 1894)	1	LC	0,17	AS
Monarchidae (4)				
Terpsiphone batesi Chapin, 1921	3	LC	0,51	RS

Terpsiphone rufocinerea Cabanis, 1875	4	LC	0,68	RS
Terpsiphone sp.	9	LC	1,52	Re
Terpsiphone rufiventer (Swainson, 1837)	4	LC	0,68	RS
Muscicapidae (8)				
Cercotrichas leucophrys (Vieillot, 1817)	5	LC	0,84	RS
Cossypha natalensis Smith, 1840	4	LC	0,68	RS
Cossypha heinrichi Rand, 1955	1	VU	0,17	AS
Cossypha heuglini Hartlaub, 1866	2	LC	0,34	Ra
Cossypha niveicapilla (Lafresnaye, 1838)	3	LC	0,51	Ra
Muscicapa striata (Pallas, 1764)	3	LC	0,51	Ra
Alethe castanea (Cassin, 1856*)*	3	LC	0,51	Ra
*Myioparus plumbeus** (Hartlaub, 1858)	1	LC	0,17	AS
Nectariniidae (13)				
Anthreptes rectirostris (Shaw, 1812)	2	LC	0,34	RS
Chalcomitra amethystina (Shaw, 1812)	2	LC	0,34	RS
Chalcomitra fuliginosa (Bechstein, 1811)	1	LC	0,17	AS
Chalcomitra rubescens (Vieillot, 1819)	1	LC	0,17	AS
Cinnyris cupreus (Shaw, 1812)	6	LC	1,01	Re
*Cyanomitra bannermani** Grant & Mackworth-Praed, 1943	1	LC	0,17	AS
Cinnyris chloropygius (Jardine, 1842)	1	LC	0,17	AS
*Cinnyris batesi** Ogilvie-Grant, 1908	4	LC	0,68	RS
Cinnyris venustus (Shaw, 1799)	1	LC	0,17	AS
Cyanomitra olivacea (Smith, 1840)	14	LC	2,36	Re
Cyanomitra sp.	2	LC	0,34	RS
Cyanomitra verticalis (Latham, 1790)	9	LC	1,52	Re
Deleornis fraseri (Jardine & Selby, 1843)	1	LC	0,17	AS
Nicatoridae (1)				
Nicator chloris (Valenciennes, 1826)	1	LC	0,17	AS
Oriolidae (1)				
Oriolus oriolus (Linnaeus, 1758)	1	LC	0,17	AS
Passeridae (1)				
Gymnoris superciliaris Blyth, 1845	2	LC	0,34	RS
Paridae (1)				
Melaniparus rufiventris (Barboza du Bocage, 1877)	8	LC	1,35	Re
Pellorneidae (1)				
Illadopsis fulvescens (Cassin, 1859)	2	LC	0,34	RS
Platysteiridae (6)				
Batis minor Erlanger, 1901	1	LC	0,17	AS
Batis sp.	1	LC	0,17	AS
*Platysteira albifrons** Sharpe, 1873	1	NT	0,17	AS
Platysteira cyanea (Müller, 1776)	5	LC	0,84	RS
Platysteira castanea Fraser, 1843	3	LC	0,51	RS
Platysteira peltata Sundevall, 1850	1	LC	0,17	AS
Ploceidae (7)				
Euplectes hordeaceus (Linnaeus, 1758)	1	LC	0,17	AS
Euplectes macroura (Gmelin, 1789)	60	LC	10,14	D
Euplectes ardens (Boddaert, 1783)	8	LC	1,35	Re
Ploceus bicolor Vieillot, 1819	2	LC	0,34	RS
Ploceus nigricollis (Vieillot, 1805)	15	LC	2,53	Re
*Ploceus xanthops** (Hartlaub, 1862)	2	LC	0,34	RS
Quelea erythrops (Hartlaub, 1848)	5	LC	0,84	RS
Phylloscopidae (1)				
Phylloscopus sibilatrix (Bechstein, 1793)	1	LC	0,17	AS
Pycnonotydae (10)				
Atimastillas flavicollis (Swainson, 1837)	1	LC	0,17	AS
Bleda syndactylus (Swainson, 1837)	3	LC	0,51	RS
Chlorocichla falkensteini (Reichenow, 1874)	1	LC	0,17	AS
Chlorocichla simplex (Hartlaub, 1855)	2	LC	0,34	RS
Eurillas curvirostris (Cassin, 1859)	3	LC	0,51	RS
Eurillas latirostris (Strickland, 1844)	28	LC	4,73	Re
Eurillas virens (Cassin, 1857)	58	LC	9,8	D
Neolestes torquatus Cabanis, 1875	6	LC	1,01	Re
Phyllastrephus scandens Swainson, 1837	9	LC	1,52	Re
Pycnonotus tricolor (Hartlaub, 1862)	30	NE	5,07	D
Remizidae (1)				
*Anthoscopus flavifrons** (Cassin, 1855)	1	LC	0,17	AS
Sylviidae (1)				
Sylvia borin (Boddaert, 1783)	2	LC	0,34	RS
Turdidae (2)				
Neocossyphus poensis (Strickland, 1844)	3	LC	0,51	RS
Stizorhina fraseri (Strickland, 1844)	5	LC	0,84	RS
Vangidae (1)				
Bias musicus (Vieillot, 1818)	1	LC	0,17	AS
Zosteropidae (1)				
Zosterops senegalensis Bonaparte, 1850	1	LC	0,17	AS
Piciformes (3)				
Indicatoridae (1)				
*Indicator conirostris** (Cassin, 1856)	2	LC	0,34	RS
Lybiidae (1)				
Pogoniulus bilineatus (Sundevall, 1850)	20	LC	3,38	Re
Picidae (4)				
Campethera nivosa (Swainson, 1837)	3	LC	0,51	RS
Campethera cailliautii (Malherbe, 1849)	1	LC	0,17	AS
Campethera caroli (Malherbe, 1852)	7	LC	1,18	Re
Campethera sp.	1	LC	0,17	AS

Legend: LC: Least Concern, NE: Not Evaluated, NT: Near Theatened, VU: Vulnerable, Rf: Frequency, CS: Conservation status, SC: species category.

At family level, the avian fauna of Bombo-Lumene is predominated by Nectariniidae and Estrildidae, which are the most speciose families with respectively 13 (~12%) and 12 (~11%) species. They are followed by Pycnonotidae with 10 (~9%) species, Muscicapidae with 8 species (7%), Ploceidae and Cisticolidae with 7 species (6%) each, and Platysteiridae with 6 species (5%).

The remaining families are represented by less than 5 species (figure 2). Additionally, in table 2, we provided conservation status (CS) of each encountered species as assessed by the IUCN list of threatened species in 2021 (IUCN, 2021), their relative frequency (Rf) in the entire sample (not by habitat type), and species category (SC) based on the relative frequency.

Overall, 95% of species captured in Bombo-Lumene have been assessed as least concerned (LC) and 3% of species were listed as not evaluated (NE).

The species *Platysteira albifrons*, assessed as near threatened (NT), and *Cossypha heinrichi*, assessed as vulnerable (VU), were the only species with higher extinction risk status.

On the other hand, based on their relative frequencies in the entire sampling, 50% of the species capture in Bombo-Lumene are estimated as rare (RS), 31% as accidental (AS), 15% as regular (Re), and only 4% were estimated as dominant (D) species (table 2).

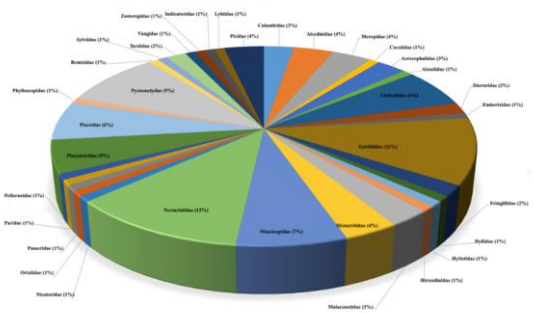

Figure 2. Relative representation of each family in Bombo-Lumene.

3.2. Diversity Indices and Species Distribution by Habitats

Our results support that savanna habitats have both the highest species richness (S=60) and the highest value for the Shannon-Weiner diversity index (H'=3.37).

The forested habitats have the second highest species richness (S=58) and the second highest value for the Shannon-Weiner index (H'=3.35). The lowest values for both the species richness (S=25) and Shannon-Weiner index (2.9) were observed in the thickets (table 3).

In opposite, the highest value of Pielou's evenness index was observed in thickets and the lowest in savanna and forest (table 3). Overall, natural habitats (savannas and forests) are the most diverse habitats in Bombo-Lumene and artificial habitats (thickets) the least diverse.

The results of the ANOVA test suggest that bird's communities, in Bombo-Lumene, varied significantly (F= 5.57, *p-value*= 0.004, d*f*=2) between habitat types during our study (table 4).

Table 3. Diversity indices calculated in different habitats

	Forest	Savanna	Thicket
S	58	60	25
H'	3,35	3,38	2,94
J'	0,82	0,82	0,91
H'max	4,060443011	4,094344562	3,218875825
Rmax	0,8250331285	0,825528958	0,9133623538

Table 4. ANOVA single factor results

ANOVA: Single Factor						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	279,4041298	2	139,7020649	5,573848495	0,004155259409	3,022601302
Within Groups	8421,451327	336	25,06384324			
Total	8700,855457	338				

To prevent significant influence from differences in counts across habitats, we only included, in the correspondence analysis (CA), species with a count of more than two specimens.

The analyses revealed patterns in bird species distribution and established association between species and habitat types in Bombo-Lumene. All variation in the dataset were captured by only two axes which accounted respectively for 76.8% and 23.2% of variation in the dataset. The first axis (76.8%) opposes forested habitats to savannas and thickets whereas the second axis (23.2%) opposes natural habitats (forests and savannas) to artificial habitats (thickets).

Overall, the CA supports that species such as *Cossypha natalensis* (Can), *Cossypha niveicapilla* (Cni), *Cyanomitra olivacea* (Col), *Eurillas latirostris* (Ela), *Eurillas virens* (Evi), *Neocossyphus poensis* (Npo), *Terpsiphone batesi* (Tba), *Terpsiphone rufiventer* (Tru), *Terpsiphone rufocinerea* (Trf), and *Terpsiphone* sp.1 (Tsp1) are strongly associated with forested habitats whereas species such as *Clytospiza monteiri* (Cmo), *Euplectes ardens* (Ear), *Euplectes macroura* (Ema), *Merops apiaster* (Map), *Merops pusillus* (Mpu), *Neolestes torquatus* (Nto), and *Quelea erythrops* (Qer) are strongly associated with savannas (figure 3).

On the other hand, species such as *Platysteira cyanea* (Pcy), *Cinnyris cupreus* (Ccu), and *Lagonosticta rhodopareia* (Lrh) are slightly associated with thickets whereas *Ispidina picta* (Ipi), *Cyanomitra verticalis* (Cvr), *Pyrenestes ostrinus* (Pos), and *Pycnonotus tricolor* (Ptr) were present in all habitats and did show little habitat preference.

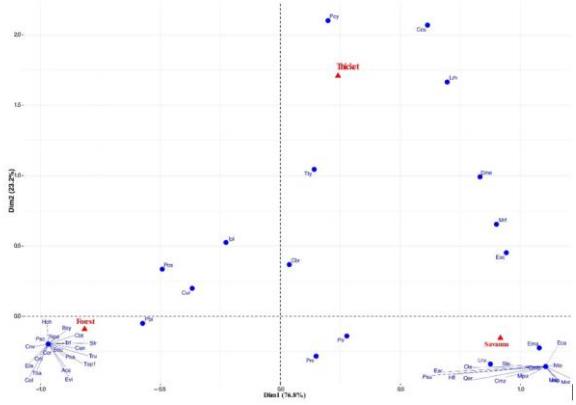

Figure 3. Biplot of the first and second axes of the correspondence analysis showing association between species and habitat types in Bombo-Lumene.

4. Discussion

4.1. Species Composition, Diversity, and threats

Birds are of great values as bioindicators of natural ecosystems' health and are among the most fascinated organisms worldwide (Maznikova et al., 2024).

They are also one of the most diverse vertebrate groups, adapted to all types of habitats around the globe, and have evolved a panoply of dietary, behavioural, and morphological adaptions (Tietze, 2019). Since a very long time, birds are used as a source of food (Cooper, 1995), clothing, and cultural artefacts inspirations and material (Frie, 2018).

All these usages, coupled with the current climate crisis and land use increasing demand constitute existential risks to many bird species. With significant human population growth, Kinshasa, the capital of the Democratic Republic of Congo (DRC), and its surround regions have experienced a significant loss of natural habitats due to rapid and poorly controlled urbanization since the country's independence in 1960 (Nsokimieno et al., 2010).

Despite these concerning trends in habitats loss, very few studies (Punga & Ifuta, 2015; Kisasa & Aloni, 2011; Kisasa et al,. 2020; Tshisuku et al., 2021) on bird species have been conducted in Kinshasa province rendering the monitoring of bird species status in the region almost impossible. Punga & Ifuta (2015) reported, based on eight years' observations across different habitats within the city of Kinshasa, the presence of about 131 bird species distributed across 40 families and 16 orders.

Their study has been conducted in the highly urbanized/populated portion of Kinshasa province (the city of Kinshasa) where natural habitats have been highly degraded and has explored higher number of habitat types.

On the contrary, the present study has been conducted in a protected area where we explored three pristine and relatively less degradation habitats. The comparison of the two studies provides a preliminary understanding of the impact of uncontrolled urbanization on bird communities in the region.

We reported the presence of 113 bird species (refer to Figures 4-7 in the appendix) in 34 families and 5 orders in a relatively small portion of the Bombo-Lumene protected area during a time span of only ten months. These species account for 20.9% and 9.5% of the total bird species respectively known from the province of Kinshasa (about 541 species) and the Democratic Republic of Congo (about 1192 species) (Lepage, 2024a, b).

In comparison to other protected area of the Democratic Republic of Congo, which have been recently surveyed, Bombo-Lumene ranks after the Salonga National Park with 174 reported species (Jocque & Mertens, 2022), the Biosphere Reserve of Luki with 136 species (Liyandja et al., 2015), and the Itombwe Nature Reserve with 126 reported species (Murhabale et al., 2021). Nine species including *Anthreptes rectirostris*, *Bleda syndactylus*, *Campethera nivosa*, *Eurillas latirostri*, *Eurillas virens*, *Hylia prasina*, *Pogoniulus bilineatus*, *Terpsiphone rufiventer*, and *Stizorhina fraseri* have been reported as common in these four protected areas.

Their wide geographic ranges suggest that these species have wider niche breadth and more frequent dispersal. Among species reported in the present study, 65 were not reported by Punga & Ifuta (2015) and Ifuta et al. (2002) in the city of Kinshasa (see table 2, bolded names).

The absence of these species in the latter studies may reflect the impact of habitat degradation in the City of Kinshasa. Indeed, the majority of the species not reported in these two studies, such as *Halcyon badia*, *Halcyon chelicuti*, *Dicrurus ludwigii*, *Dicrurus coracinus*, *Cossypha heinrichi*, *Alethe castanea*, *Muscicapa striata*, *Bias musicus*, *Indicator conirostris*, *Stizorhina fraseri*, *Neocossyphus poensis*, *Eurillas latirostris*, *Eurillas curvirostris*, *Bleda syndactylus*, *Platysteira castanea*, *Platysteira albifrons*, and *Illadopsis fulvescens*, are confined to forests, gallery forests, woodlands, savannas, and forest edges (Sinclair & Ryan, 2010).

These types of habitats have been lost long ago in the highly urbanized/populated portion of Kinshasa. Hence, the pristine habitats of Bombo-Lumene play a role of refugia for birds in the region and the increasing demand in land use, for both agriculture and dwelling, represent a major threat for their conservation. Of the 65 species not reported by Punga & Ifuta (2015) and Ifuta et al. (2002), only 13 (see table 2, names with *) are not reported in the check list of the birds of Kinshasa (Lepage, 2024a).

These species are potential new records for the region. Conversely, numerous species reported by Punga & Ifuta (2015) and Ifuta et al. (2002) are absent from the present study.

Several reasons can account for the absence of these species in our list including the number of explored habitats, the time span of this study, the sampling methods, and habitat difference between study areas.

Indeed, Punga & Ifuta (2015) identified 11 more orders than did the present study. Among these orders not reported in here, representatives of Charadriiformes, Gruiformes, and Pelecaniformes are generally found in wetlands a type of habitat we did not explore. Representatives of Strigiformes are generally nocturnal and these of Accipitriformes, Apodiformes, Bucerotiformes, Falconiformes, and Psittaciformes are generally associated with canopy strata.

The latter groups were not collected in Bombo-Lumene as our nets were only set during daytime and no canopy net was deployed. Galliformes species have recently been reported in Bombo-Lumene (Tshisuku et al. 2021) however, these species are rarely caught in mist nets. *Colius striatus*, one of the two Coliiformes known from the Kinshasa region, is not reported in the present study neither.

Obviously, our study does not capture the totality of bird species diversity in Bombo-Lumene but represents an important baseline documentation that

can be used for monitoring and conservation of bird species in this protected area.

4.2. Diversity Indices and Species Distribution by Habitats

Diversity indices are essential in assessing and diagnosing the ecological health of ecosystems (Daly et al., 2018). It's generally accepted that healthier ecosystems have higher diversity indices values (Bell et al., 2005).

In this study, the ecological diversity indices, calculated based on species abundance, reveal that in all type of habitats the Shannon-Weiner (forest: 3.35, savanna: 3.38, and thicket: 2.94) and the evenness (forest: 0.83, savanna: 0.83, and thicket: 0.91) indices are approaching their maximum values which are respectively 4.06, 4.09, and 3.22 for the Shannon-Weiner index in each habitat and 1 for the evenness index.

These results reflect an excellent distribution of species abundance and the good ecological health of assessed habitats in the Bombo-Lumene protected area. It should be noted that the good ecological health of these habitats is more likely a result of the conservation status of Bombe-Lumne. Similar values of diversity indices were reported in different protected areas outside of D.R. Congo (Desalegn et al., 2020; Esayas & Bekele, 2011).

Overall, the highest numbers of bird species (S) were observed in savanna and forest habitats (60 and 58 respectively) whereas the least species diversity was observed in thicket habitats (refer to table 5 in the appendix).

This pattern of highest species diversity in forest and savanna habitats and lowest diversity in human transformed habitats has been well documented in other African countries (Akogwu & Ihuma, 2012; Derebe et al., 2023; Desalegn et al., 2020; Esayas & Bekele, 2011).

Bird species distribution patterns are results of numerous environmental factors such as floristic diversity and structure (N'Zala et al., 1997; Yabi et al., 2017; Burel & Baudry, 1999; Punga & Kisasa, 2024), food availability (Laurence, 2006; Kisasa, 2012), soil quality for nest excavation (Kisasa & Aloni, 2011), and anthropogenic factors such as land use (Kisasaa, 2012; Akogwu & Ihuma, 2012; Rodríguez, 2007).

Our results of the correspondence analysis confirm the association between habitat types and bird communities' composition and diversity in Bombo-Lumene.

This distribution pattern based on habitat quality largely support the usage of bird species as indicators of ecosystems health on which their reproductive success depends. Therefore, protecting various forest and savanna habitats of this site, threatened by anthropogenic activities, where bird species find refugia, largely contributes to the conservation of their diversity.

5. Conclusion

The avifauna of the Bombo-Lumene protected area, in the southeast of the province of Kinshasa in the Democratic Republic of Congo, is characterized by a high species diversity despite various threats related to ethnic conflicts, land use, and poaching.

This avifauna represents over 9 % of the total bird species known from the Democratic Republic of Congo and contains species of various ecological statuses. Such a high level of bird diversity is likely a result of both the area's extensive habitat diversity and its protected status.

Thanks to its status as a protected area, the different vegetational formations of the reserve are well preserved and still provide suitable habitat for bird species in the region.

It's therefore very important to keep preserving these habitats from degradation to maintain the avifauna diversity in this protected area. The present study, which reports more than 110 bird species in Bombo-Lumene, represents a solid baseline documentation that can be used in conservation and monitoring of bird species in the reserve.

However, we are convinced that our study likely overlooked several resident species because of limited number of explored habitats and sampling methods. Further investigations throughout different habitats of the reserve are recommended to better capture its species composition and their distribution in different habitats.

Furthermore, studies on demography, population's structure, biology, and ecology of the reserve's charismatic species are needed to improve policies and strategies for their conservation. Additionally, it is crucial to investigate the impact of ethnic conflicts, poaching, and the increasing demand

for land use for agriculture, within and around this site, on these species.

References

Akogwu, S.A., Ihuma, J.O., & Manu, S. (2012). Survey of abundance and diversity of avian species in Assop Forest Reserve and surrounding farmlands in Jos, Nigeria. *International Journal of Advanced Biological Research*, 2 (*3*), 506–514.

Bell, T., Newman, J.A., Silverman, B.W., Turner, S.L., & Lilley, A.K. (2005). The Contribution of species richness and composition to bacterial services. *Nature*, *436*, 1157–1160. https://doi.org/10.1038/nature03891

Burel, F. & Baudry, J. (1999). *Ecologie du paysage. Concepts, méthodes et applications*. Paris: Technique & Documentation, pp. 359.

Cooper, J.E. (1995). The role of birds in sustainable food production. *Biodiversity and Conservation*, *4*, 266–280. https://doi.org/10.1007/BF00055973

Daly, A.J., Baetens, J.M., & De Baets, B. (2018). Ecological diversity: measuring the unmeasurable. *Mathematics*, *6* (*7*), 119. https://doi.org/10.3390/math6070119

Demey, R. & Louette, M. (2001). *Democratic Republic of Congo*. In: Fishpool, L.D.C., & Evans, M.I. (eds.), *Important Bird Areas in Africa and associated islands: priority sites for conservation*. Newbury and Cambridge, UK: Pisces Publications and BirdLife International, pp. 199–218.

Derebe, Y., Derebe, B., Kassaye, M., & Gibru, A. (2023). Species diversity, relative abundance, and distribution of avifauna in different habitats within Lewi Mountain, Awi zone, Ethiopia. *Heliyon*, *9* (*6*), e17127. https://doi.org/10.1016/j.heliyon.2023.e17127

Desalegn, T., Aynalem, S., & Tassie, N. (2020). Diversity, abundance and habitat association of avifauna in Menagesha Amba Mariam and Gara Medhanialem forest , in Oromia Region, Ethiopia. *International Journal of Avian & Wildlife Biology*, *5* (*1*), 61–70. https://doi.org/10.15406/ijawb.2020.05.00175

Esayas, K., & Bekele, A. (2011). Species composition, relative abundance and distribution of the avian fauna of Entoto Natural Park and escarpment, Addis Ababa. *Ethiop. J. Sci*, *34* (*2*), 113–122.

Frie, A.C. (2018). Insignia of power: bird imagery on artefacts of hierarchy and ritual in Iron Age Dolenjska (SE Slovenia). *Documenta Praehistorica*, *45*, 166–178. https://doi.org/10.4312/dp.45.13

Fry, C.H. (2004). Malimbus. In Fry, C.H., & Keith, S. (eds.). *The birds of Africa, vol. VII: sparrows to buntings*. London: Christopher Helm, pp. 77–97.

Fry, H.C., Keith, S., & Urban, E.K. (2004). *The birds of Africa*. Vols. I–VII. London: Academic Press and Christopher Helm, pp. 1982–2004.

Fry, H.C., Keith, S., Lack, P.C., de Naurois, R., Prigogine, A., & Urban, E.K. (1997). *Turdidae, thrushes*. In Urban, E.K., Fry, C.H., & Keith, S. (eds.). *The birds of Africa*, vol. V: thrushes to puffback flycatchers. London: Academic Press, pp. 1–56.

Gill, F., & Donsker, D. (2013). *The Birds of Democratic Republic of Congo*. IOC World Bird List. (ed.), Version 4.3. Accessed November 04, 2014. http://www.the-birds.net/aves/republique.democratique.du.congo.html.

Habiyaremye, M.F., Nlandu, L., & Malio, N. (2011). *Habitats de la Réserve et Domaine de chasse de Bombo-Lumene (R.D.C). Lexique Kiteke des plantes observées dans ces milieux*. Institut Congolais pour la Conservaion de la Nature, 144p.

Ifuta, N.B., Kenawabo, T., Mampembe, L., Zambi, T., Palata, K., & Punga, K. (2002). Avian fauna of green species of Kinshasa and surroundings. *Les Cahiers de l'ISP*, *11*, 19–30.

Inogwabini, B.I., Ilambu, O., & Gbanzi, M.A. (2005). Protected areas of the Democratic Republic of Congo. *Conservation Biology*, *19* (*1*), 15–22. https://doi.org/10.1111/j.1523-1739.2005.00181.x

Jones, S., & Jamie, G. (2023). *Avifauna*. In Jocque, M., Mertens, J., Jamie, G., Jones, S., Mbende, M., Mpongo Iyomi, D.M., Nunes, M., Pett, B., Hamer, M., de Haas, M., Van Roie, M., & Van Noppen, M. (2023). *The Salonga National Park expedition: a rapid biodiversity assessment in the largest forest reserve in Africa, DRC*. Glabbeek, Belgium: Biodiversity Inventory for Conservation, pp. 131. https://doi.org/10.1007/978-981-13-2538-0_2128

King, T., & Chamberlan, C. (2013). Where does the savannah fauna of the Bateke Plateau come from? *Wild Conservation*, *1*, 10–16.

Kisasa, K.R., & Aloni, K.J. (2011). The impact of soil texture on the selection of nesting sites by the Malachite Kingfisher (Alcedinidae: Alcedo cristata Pallas 1764). *Ostrich*, *82* (*3*), 243–246. https://doi.org/10.2989/00306525.2011.616696

Kisasa, K.R. (2012). Diet of the Malachite Kingfisher *Alcedo cristata* during the breeding period in the Kinshasa area (Democratic Republic of Congo). *Malimbus journal*, *34*, 17–28.

Kisasa, K.R., Bansomire, C., Ngandu, L.M., & Malekani, D.V. (2020). Ectoparasites (Phthiraptera) de quelques oiseaux de la ville de Kinshasa. *Malimbus*, *42* (*1*), 1–6. http://www.malimbus.org/en/contents/tocm42.html

Kisasa, K.R., & Punga, K.J. (2024). The relative influence of habitat modification on bird assemblage in the University's domain of Notre Dame du Kasai in Kananga, D. R. Congo. *Revue Congolaise de Sciences et technologies*, *3* (*1*), 16–23. https://doi.org/10.59228/rcst.024.v3.i1.63

Laurence, D. (2006). *Sélection de l'habitat par les oiseaux forestiers et modernisation de leur distribution potentielle en chênaie et hêtraie ardennaises : impact de la composition et de la structure forestière*. Thèse de Doctorat, Gembloux, Faculté universitaire des Sciences agronomiques, 253 p.

Lepage, D. (2024a). Checklist of the birds of Kinshasa city. Avibase, the world bird database. Retrieved on May 31st, 2024, from. https://avibase.bsc-eoc.org

Lepage, D. (2024b). Checklist of the birds of Democratic Republic of Congo. Avibase, the world bird database. Retrieved on May 31st, 2024, from https://avibase.bsc-eoc.org.

Lê S., Josse, J., & Husson, F. (2008). FactoMineR: an R package for multivariate analysis. *Journal of Statistical Software*, *25* (*1*), 1–18. https://doi.org/10.18637/jss.v025.i01

Liyandja, T.L.D., Andersen, M.J., Oliveros, C.H., Kalemba, L.N., Bakambana, T.L., Marks, B.D., Kahindo, C., & Malekani, J.M. (2015). Birds of the man and biosphere reserve of Luki, Bas-Congo province, Democratic Republic of Congo. *Check List*, *11* (*5*), 1–15. https://doi.org/10.15560/11.5.1755

Louette, M., & Hasson, M. (2011). *Les oiseaux du Katanga: studies in Afrotropical zoology*. Tervuren: Royal Museum of Central Africa, p. 406.

Maznikova, V.N., Ormerod, S.J., & Gómez-Serrano, M.Á. (2024). Birds as bioindicators of river pollution and beyond: specific and general lessons from an apex predator. *Ecological Indicators*, *158*, 111366. https://doi.org/10.1016/j.ecolind.2023.111366

Murhabale, B.C., Bwanamudogo, I., Magadju, A., Tolbert, S., Bapeamoni, F., Kahindo, C., Marks, B.D., & Agenong'a, U. (2021). Birds of Burhinyi mountain forest, north of Itombwe nature reserve, Democratic Republic of Congo. *African Journal of Ecology*, *59* (*1*), 305–311. https://doi.org/10.1111/aje.12825

Nsokimieno, E.M.M., Shouyu, C., & Li Qin, Z. (2010). Sustainable urbanization's challenge in Democratic Republic of Congo. *Journal of Sustainable Development*, *3* (*2*), 242–254. https://doi.org/10.5539/jsd.v3n2p242

Nsombo, B.M., Lumbuenamo, R.S., Lejoly, J., Aloni, J.K., & Mafuka, P.M.M. (2016). Caractéristiques des sols sous savane et sous forêt naturelle sur le plateau des Batéké en République Démocratique du Congo. *Tropicultura*, *34* (*1*), 87–97.

N'Zala, D., Nongamani, A., & Moutsamboté, J.M. (1977). Diversité floristique dans les monocultures d'eucalyptus et de pins au Congo. *Cahier Agricultures*, 6, 169–174.

Peel, M.C., Finlayson, B.L., & McMahon, T.A. (2007). Updated world map of the Koppen-Geiger climate classification. *Hydrology Earth System Sciences*, *11* (*5*), 1633–1644. https://doi.org/10.1002/ppp.421

Punga, K.J., & Ifuta, S.N.B. (2015). Recent data on birds of Kinshasa in Democratic Republic of Congo. *Journal of Agricultural Science and Technology A*, *5*, 218–233. https://doi.org/10.17265/2161-6256/2015.03.011

R Core Team (2013). R: A language and environment for statistical computing. Vienna, Austria.: R Foundation for Statistical Computing. Retrieved from. http://www.r-project.org/

Rodríguez-Estrella, R. (2007). Land use changes affect distributional patterns of desert birds in the Baja California peninsula, Mexico. *Diversity and Distributions*, *13* (*6*), 877–889. https://doi.org/10.1111/j.1472-4642.2007.00387.x

Sinclair, I., & Ryan, P. (2010). *Birds of Africa south of the Sahara*. Cape Town: Struik Nature, 767p. ISBN 1770076239, 9781770076235

Tietze, D.T. (2019). *Bird species: how they arise, modify and Vanish*. Basel, Switzerland: Springer Open, p. 266. https://doi.org/10.2307/j.ctvpb3vwx.12

Tshisuku, M.J.V., Musibono, E.D., Lubini, A.C., & Ifuta, N.B.S. (2021). Preliminary study of the avifauna of the families Numididae and Phasianidae (Galliformes) of the Bombo-Lumene hunting area and reserve in Kinshasa (DR Congo). *World Journal of Advanced Research and Reviews*, *12* (*2*), 019–031. https://doi.org/10.30574/wjarr.2021.12.2.0529

Vermeulen, C., & Lanata, F. (2006). Le domaine de chasse de Bombo-Lumene: un espace naturel en péril aux frontières de Kinshasa. *Parcs et Reserves*, *61* (*2*), 4–8.

Voelker, G., Marks, B.D., Kahindo, C., Agenong'a, U., Bapeamoni, F., Duffie, L.E., Huntley, J.W., Mulotwa, E., Rosenbaum, S.A., & Light, J.E. (2013). River barriers and cryptic biodiversity in an evolutionary museum. *Ecology and Evolution*, *3* (*3*), 536–545.

Yabi, B.F, Olou, L.T., & Codjia, T-C. (2017). Influence des zones biogéographiques sur la diversité avienne des galéries forestières au Bénin, afrique de l'Ouest. *European Scientific Journal*, *13* (*6*), 410–438.

Appendixes

Figure 4. Representative bird species of Bombio-Lumene. (A) Turtur afer, (B) Halcyo badia, (C) Merops hirundineus, (D) Platysteira castanea, (E) Hippolais icterina, (F) Mirafra rufocinnamomea, (G) Eremomela scotops, (H) Dicrurus ludwuig

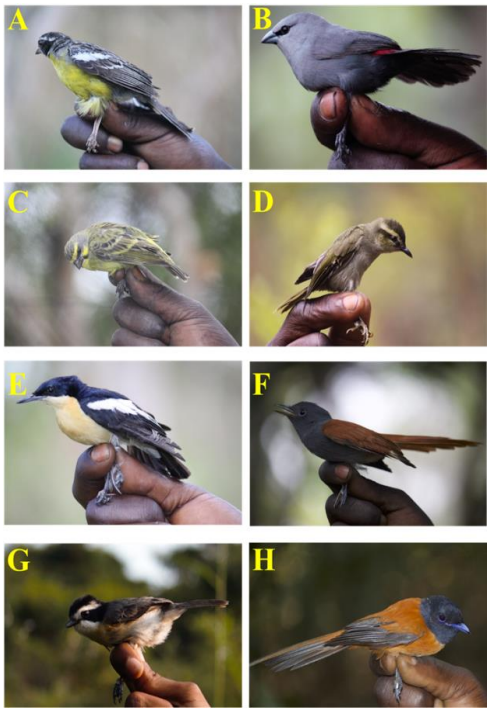

Figure 5. Representative bird species of Bombo-Lumene. (A) Emberiza flavigaster, (B) Glaucestrilda perreni, (C) Crithagra mozambica, (D) Hylia prasina, (E) Hyliota flavigaster, (F) Tersiphone batesi, (G) Cholorophoneus bocagei, (H) Tersiphone rufiventer.

Figure 6. Representative bird species of Bombo-Lumene. (A) Cossypha niveicapilla, (B) Cossypha heinrichi, (C) Cyanomitra olivacea, (D) Nicator chloris, (E) Oriolus oriolus, (F) Gymnoris superciliaris, (G) Melaniparus rufiventris, (H) Platysteira peltata.

Figure 7. Representative bird species of Bombo-Lumene. (A) Euplectes macroura, (B) Phylloscopus sibilatrix, (C) Neolestes torquatus, (D) Campethera caroli, (E) Stizorhina fraseri, (F) Bias musicus, (G) Zosterops senegalensis, (H) Indicator conirostris.

Table 5. Species distribution and abundance in different habitats

	Code	Forest	Savanna	Thicket
Turtur afer	Taf	1	1	0
Alethe castanea	Aca	3	0	0
Anthoscopus flavifrons	Afa	0	0	1
Anthreptes rectirostris	Are	2	0	0
Atimastillas flavicollis	Afl	1	0	0
Batis minor	Bmn	0	2	0
Batis sp	Bsp	0	0	1
Bias musicus	Bmu	1	1	0
Bleda syndactylus	Bsy	3	0	0
Bocagia minuta	Bmi	0	1	0
Camaroptera brevicaudata	Cbr	14	12	5
Campethera caillautii	Cca	1	0	0
Campethera caroli	Ccr	7	0	0
Campethera nivosa	Cnv	3	0	0
Campethera sp.	Casp	0	1	0
Cercotrichas leucophrys	Cle	0	5	0
Chalcomitra amethystina	Cam	0	0	2
Chalcomitra fuliginosa	Cfu	0	1	1
Chalcomitra rubescens	Cru	1	0	0
Chlorocichla falkensteini	Cfa	1	0	0
Chlorocichla simplex	Csi	0	2	0
Chlorocichla sp	Csp	1	0	0
Chlorophoneus bocagei	Cbo	0	1	0
Cinnyris batesi	Cba	4	0	0
Cinnyris chloropygius	Cch	0	1	0
Cinnyris cupreus	Ccu	0	2	3
Cinnyris venustus	Cve	0	1	0
Cisticola bulliens	Cbu	0	0	2
Cisticola erythrops	Cer	0	1	0
Cisticola sp	Csp	0	2	0
Clytospiza monteiri	Cmo	0	3	0
Cossypha heinrichi	Che	1	0	0
Cossypha heuglini	Chg	0	2	0
Cossypha natalensis	Can	4	0	0
Cossypha niveicapilla	Cni	3	0	0
Crithagra atrogularis	Cat	0	2	0
Crithagra mozambica	Cmz	0	8	0
Cuculus solitarius	Cso	0	0	1
Cyanomitra bannermani	Cba	1	0	0
Cyanomitra olivacea	Col	14	0	0
Cyanomitra sp	Csp	0	2	0
Cyanomitra verticalis	Cvr	6	2	1
Deleornis fraseri	Dfr	1	0	0
Dicrurus coracinus	Dco	0	1	0
Dicrurus ludwigii	Dlu	0	0	1
Emberiza cabanisi	Eca	0	3	0
Eremomela salvadorii	Esa	0	2	0
Eremomela scotops	Esc	0	4	1
Estrilda melpoda	Eme	0	2	1
Euplectes ardens	Ear	0	8	0
Euplectes hordeaceus	Eho	0	1	0
Euplectes macroura	Ema	0	59	2
Eurillas curvirostris	Ecu	3	0	0
Eurillas latirostris	Ela	21	0	0
Eurillas virens	Evi	50	0	0
Glaucestrilda perreini	Gpe	1	1	0
Gymnoris superciliaris	Gsu	0	0	2
Halcyon albiventris	Hal	1	0	0
Halcyon badia	Hba	2	0	0
Halcyon chelicuti	Hch	3	0	0
Hippolais icterina	Hic	0	3	0
Hylia prasina	Hpr	2	0	0
Hyliota flavigaster	Hfl	0	3	0
Iduna natalensis	Ina	0	1	0
Illadopsis fulvescens	Ifu	0	2	0
Indicator conirostris	Ico	1	1	0
Ispidina picta	Ipi	26	11	9
Lagonosticta rhodopareia	Lrh	0	2	2
Lagonosticta rubricata	Lru	1	8	0
Laniarius leucorhynchus	Lle	0	1	1
Mandingoa nitidula	Mni	1	0	0
Melaniparus rufiventris	Mrf	0	6	2
Merops apiaster	Map	0	4	0
Merops breweri	Mbr	2	0	0
Merops hirundineus	Mhi	0	0	1
Merops pusillus	Mpu	0	7	0
Merops sp	Msp	0	1	0
Mirafra rufocinnamomea	Mru	0	1	0
Muscicapa striata	Mst	0	3	0
Myioparus plumbeus	Mpl	2	0	0
Neocossyphus poensis	Npo	5	0	0
Neolestes torquatus	Nto	0	6	0
Nicator chloris	Nch	1	0	0
Nigrita canicapillus	Nca	0	0	1
Oriolus oriolus	Oor	1	0	0
Paludipasser locustella	Plo	1	0	0
Petrochelidon rufigula	Pru	0	1	0
Phyllastrephus scandens	Psc	9	0	0
Platysteira albifrons	Pal	1	0	0
Platysteira castanea	Pca	3	0	0
Platysteira cyanea	Pcy	1	1	3
Ploceus bicolor	Pbi	2	0	0
Ploceus nigricollis	Pni	6	7	0
Ploceus xanthops	Pxa	0	2	0
Pogoniulus bilineatus	Pbi	15	3	1
Prinia subflava	Psu	0	8	0
Pycnonotus tricolor	Ptr	10	15	1
Pyrenestes ostrinus	Pos	5	1	1
Pytilia afra	Paf	0	2	0
Pytilia melba	Pme	0	1	0
Quelea erythrops	Qer	0	3	0
Schistolais leucopogon	Sle	0	3	0
Spermestes cucullata	Scu	0	3	0
Stizorhina fraseri	Sfr	4	0	0
Streptopelia semitorquata	Sse	1	0	0
Sylvia borin	Sbo	2	0	0
Terpsiphone batesi	Tba	3	0	0
Terpsiphone rufiventer	Tru	4	0	0
Terpsiphone rufocinerea	Tru	4	0	0
Terpsiphone sp1	Tsp	10	0	0
Terpsiphone sp2	Tsp	1	0	0
Turtur tympanistria	Tty	1	1	1
Zosterops senegalensis	Zse	1	0	0