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Diversity and distribution of birds in a Congo Basin wetland: the upstream part of the Nyong River valley in Cameroon along two Regions (Centre and East)

Abstract

Several studies have recently been carried out on the avifauna of Cameroon and have made it possible to update the data for certain regions; however, no recent study has been carried out on the upper valley of the Nyong River, which is a wetland, and therefore the data remains quite old. We carried out a study on the avifauna of this valley and birds were sampled over a period of one year using the mist-netting method. The collected data were analyzed using PAST bio statistical software for the diversity and distribution of the avifauna. A total of 268 individuals belonging to 69 bird species were captured, with a high proportion of passerines (73%) compared with non-passerines. The high diversity of the avifauna is supported by estimated values of diversity indexes which show an absence of supremacy of one species (H'=3.64) and an equal distribution of individuals in their environment (J'=0.86). With the value of the Simpson diversity index of 0.96, our result confirms high diversity within the upper valley of the Nyong River avifauna but it also reveals the abundance of this avifauna. In addition, the Kruskal-Wallis test value of 0.04 showed a significant difference in the distribution of relative abundances of taxa at the areas investigated and that different could be justified by a difference in the physiognomy of their vegetation. This study confirms that the composition as well as the structure of the upper valley of the Nyong River as observed in the field play a main role in the diversity of bird species due to the presence of feeding, resting and nesting areas. Based on our distribution and diversity analysis, the pattern of variation in distribution of birds in this wetland appears to lean on environmental factors and particularly the vegetation, which played the main role with a mixture of poor and good dispersers, migratory and vagrant due to presence of lush vegetation all year round.

Keywords: avifauna, upstream valley, Nyong River, wetland, diversity, distribution

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Introduction

Cameroon's forests have one of the most diverse fauna in sub-Saharan Africa.[1] They are thus home to the fifth highest faunal diversity on the African continent and 92 % of their ecosystems.[2] Of the forest ecosystems found in Cameroon, wetlands are among the most productive as in the rest of the world;[3] they provide multiple ecosystem services among them cultural (leisure activities, ecotourism sites, etc.), energy (availability of nutritional resources, fresh water, etc.), regulatory (protecting against erosion, maintaining hydrological regimes, etc.) and trophic (nutrient cycling, productive environments, etc.). Otherwise, wetlands are recognized as ecotones that are essential to the functioning of the catchment areas in which they are located but they also appear vital to the survival of humankind providing the water and productivity on which the associated flora and fauna depend on their survival.[3]

Currrently, there are around 2493 Wetlands of International Importance in the world be 1126 in Europa, 438 in America, 429 in Africa, 420 in Asia and 85 in Oceania which cover an area of approximately 256 786 063 hectares.[4] More precisely, three types of wetlands are identified around the world, continental wetlands (2023), marine or coastal wetlands (1015) and artificial wetlands (895). In Africa, of the 429 wetlands identified, there are around 366 inland wetlands, 148 marine or coastal wetlands and 138 artificial wetlands.[4] All these wetlands are found in 172 stakeholders which have ratified the Convention and among the countries of the African continent, there is Cameroon.[4] Moreover, Cameroonian wetlands cover a surface area of 827 060 hectares be 1.78% of the total surface of country and to Cameroon, around seven wetlands of international importance have been identified to date (Table 1). On the other hand, wetlands are refuges for many species of fauna (feeding, hibernation and play areas, etc.) and constitute a great reservoir for biodiversity where many endemic, rare and vulnerable bird species are found in these lands.[5–7] Thus around the world, bird species in the following families are associated with wetlands be Gaviidae, Pelecanidae, Phalacrocoracidae, Anhimidae, Anhingidae, Anatidae, Aramidae, Ardeidae, Balaenicipitidae, Burhinidae, Scopidae, Ciconiidae, Threskiornithidae, Phoenicopteridae, Gruidae, Rallidae, Heliornithidae, Eurypygidae, Jacanidae, Rostratulidae, Dromadidae, Haematopodidae, Ibidorhynchidae, Podicipedidae, Recurvirostridae, Glareolidae, Charadriidae, Scolopacidae, Pedionomidae, Thinocoridae, Laridae and Rynchopidae except a few waterbirds.[3]

Thus to Cameroon, there are 104 bird's species for the Waza Logone Floodplain, 215 bird species in the biome of the Sangha river and 30 000 birds in the Rio Del Rey estuary.[8–10] It is also documented that Cameroonian wetlands are home to endangered bird species such as: *Balearica pavonina* (VU), *Trigonoceps occipitalis* (CR), *Psittacus erithacus* (EN) at the Rio Del Rey Estuary; but also endemic birds including *Picathartes oreas*, *Ploceus batesi* and *Bradypterus grandis*.[9–12] It also found in Cameroonian wetlands many migratory birds including intra-African migrants (*Ciconia abdimii*, *Egretta garzetta*) and Palaearctic migrants (*Pelecanus onocrotalus*).[11] Among Cameroonian wetlands with potential diversity of bird but not investigated, there is the Nyong River's valley. The Nyong catchment,

with a surface area of 27 800 km^2, is entirely forested.[13] It is the second largest river within Cameroon, covering 1/4 of the country's tributary area of the Congo Basin (Sangha) and it is approximately 400 km long and 70 km wide on average.[13] This valley is made up of land at altitudes of between 628 m and 657 m, and is made up of three morphological units: the upper marshy valley with a flat bottom, the middle marked by presence of waterfalls, and the lower narrow with a steep slope. As the whole of the south of the country, it has a Guinean equatorial climate.[14,15]

Table 1 Wetlands of international importance found in Cameroon

Wetlands / Ramsar sites	Location	Surface (ha)	Registration date	Site number
Barombi Mbo Crater Lake	South-West Region near Kumba	415	08/10/2006	1643
Rio Del Rey Estuary	South-West Region on the border between Cameroon and Nigeria	165 000	20/05/2010	1908
Cameroon part of the Sangha river	Adamaoua Region (where the river rises)	6200	02/02/2008	1739
Cameroon part of the Ntem river	South Cameroon Region	39 848	05/06/2012	2067
Cameroon part of Lake Chad	Far North Region	12 500	02/02/2010	1903
Waza Logone Floodplain	Far North Region	600 000	20/03/2006	1609
Ebogo wetland	Centre Region	3 097	06/05/2012	2068

First studies on the Nyong were carried out at eight main stations: Abong-Mbang, Ayos, Mbalmayo (Table 2, Figure 1), Akonolinga, Olama, Kaya, Eséka and Dehane which are characterised by vast swampy areas, fully flooded grass corridors and flooded forest up to 3 km wide.[16] These sites have been the subject of relatively old ornithological studies and a total of 137 bird species belonging to 39 families have been identified including 123 bird species in Abong-Mbang, 22 in Ayos and 19 in Mbalmayo (Table 3).[17,18] It is documented that the relationships between biodiversity and an ecosystem within the environment is often related to the food-web structure found in these habitats.[19,20] Only bird surveys carried out in the Nyong River valley of Cameroon have not provided information on relationships between birds and their living environment particularly on the principle of taxa distribution in their environment as well as conditions of their abundance. [17,18,21] In this study, we mainly followed two purposes: firstly, we thoroughly investigated the avifauna of this wetland and secondly, we tried to explore the diversity, abundance and distribution within the avifauna of this valley to suggest hypotheses on their patterns of distribution as well as reasons of their diversity or abundance if it is established in their biotic environment.

Table 2 Surface area and location of the study sites of the upper Nyong River valley in East and Centre Regions[16]

Nyong River at	Surface area (Km^2)	East longitude	North latitude	Elevation (m)
Abong-Mbang	965	13° 10'	3° 59'	657
Ayos	5 300	12° 31'	3° 53'	654
Mbalmayo	13 555	11° 30'	3° 31'	634

Table 3 Avifauna of the upper Nyong River valley (Abong-Mbang, Ayos and Mbalmayo) according to Germain et al.[17] and Good[18]

Family	Species	Good[18]	Germain et al.[17]
Accipitridae	*Accipiter melanoleucus*	1 and 3	/
	Gymnogenys typus	1 and 3	/
	Gypohierax angolensis	1	/
	Kaupifalco monogrammicus	1	/
	Machaerhamphus alcinus anderssoni	1	/
	Milvus migrans	1 and 3	/
	Stephanoaetus coronatus	3	/
Alcedinidae	*Ceryle rudis*	2	/
	Corythornis cristata	1	/
	Halcyon badia	1	/
	Halcyon malimbica	3	/
	Halcyon senegalensis	1	/
Anatidae	*Nettapus auritus*	2	/
	Plectropterus gambensis	2	/
	Pteronetta hartlaubii	1 and 3	/
Ardeidae	*Ardea goliath*	2	/
	Ardea melanocephala	1	/
	Bubulcus ibis	1	/
	Butorides striatus	1	/
Bucerotidae	*Bycanistes sharpii*	1	/
	Bycanistes subcylindricus	1	/
	Ceratogymna atrata	1	/
	Tockus fasciatus	1	/

Table 3 Continued...

Family	Species	Good[18]	Germain et al.[17]
Capitonidae	*Buccanodon duchaillui*	1	/
	Gymnobucco bonapartei	1	/
	Lybius bidentatus	1	/
	Pogoniulus leucolaimus	1	/
Ciconiidae	*Sphenorhynchus abdimii*	1	/
Coliidae	*Colius striatus*	1	/
Columbidae	*Culumba unicincta*	1	/
	Streptopelia semitorquata	1	/
	Turtur afer	1	/
	Tympanistria tympanistria	1	/
	Vinago calva	1	/
Coraciidae	*Eurystomus afer*	1	/
Corvidae	*Corvus albus*	1	/
Cuculidae	*Centropus anselli*	1	/
	Centropus monachus	1 and 3	/
	Ceuthmochares aereus	3	/
	Chrysococcyx cupreus	1 and 2	/
	Cuculus clamosus	1	/
	Lampromorpha caprius	1	/
	Lampromorpha klaasi	1	/
Dicruridae	*Dicrurus sharpei*	1	/
Fringillidae	*Serinus mozambicus*	1	/
Heliornithidae	*Podica senegalensis*	1	/
Hirundinidae	*Hirundo abyssinica*	/	2 and 3
	Hirundo nigrita	/	3
	Hirundo rustica	1	/
	Lillia abyssinica	1	/
	Lillia senegalensis	1	/
	Psalidoprocne petiti	1 and 2	/
Indicatoridae	*Melignothes conirostris*	1	/
Jacanidae	*Actophilornis africanus*	2 and 3	/
Laniidae	*Dryophoneus bocagei*	1	/
	Malaconotus cruentus	1	/
	Tchagra australis	1 and 3	/
Meropidae	*Aerops albicollis*	1	/
	Merops apiaster	1	/
	Melittophagus mülleri	1	/
	Melittophagus variegatus	1, 2 and 3	/
Micropodidae	*Cypsiurus parvus*	1	/
	Micropus affinis	1 and 2	/
	Micropus sladeniae	1 and 2	/
	Telacanthura ussheri	1	/
Motacillidae	*Motacilla aguimp*	1	/
	Budytes flavus	1	/
	Motacilla flava	1	1, 2 and 3
Muscicapidae	*Elminia longicauda*	1	/
	Fraseria cinerascens	/	1, 2 and 3
	Fraseria ocreata	/	1, 2 and 3
	Hypodes cinerea	1	/
	Muscicapa cassini	/	1, 2 and 3
	Muscicapa striata	1	/
	Platysteira cyanea	1	/
	Terpsiphone viridis	/	2 and 3
	Trochocercus nitens	1	/

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Table 3 Continued...

Family	Species	Good[18]	Germain et al.[17]
Musophagidae	*Corythaeola cristata*	1	/
	Turacus persa	1	/
Nectariniidae	*Cinnyris cyanolaema*	1	/
	Cinnyris minulla	1	/
Oriolidae	*Oriolus brachyrhynchus*	1	3
Phasianidae	*Francolinus squamatus*	1	/
Picidae	*Campethera caroli*	1	/
	Dendropicos fuscescens	1	/
	Verreauxia africana	1	/
Plataleidae	*Hagedashia hagedash*	1 and 2	/
Plocéidae	*Estrilda astrild*	1 and 2	1
	Estrilda atricapilla	1	/
	Estrilda melpoda	/	1
	Estrilda nonnula	1	/
	Euplectes afra	1	/
	Euplectes hordeaceus	1	3
	Hyphanturgus nigricollis	1	/
	Hypochera camerunensis	1	/
	Lagonosticta rubricata	1	/
	Melanopteryx nigerrimus	1 and 2	/
	Neisna melpoda	1	/
	Neisna subflava	1	/
	Nigrita bicolor	3	/
	Nigrita canicapilla	1	/
	Nigrita luteifrons	1	/
	Parmoptila woodhousei	1	/
	Passer griseus	1	1 and 3
	Plesiositagra cucullata	1	/
	Ploceus aurantius	/	3
	Ploceus nigerrimus	/	3
	Spermestes cucullata	1	/
	Vidua macroura	1	/
	Xanthophilus aurantia	1, 2 and 3	/
Prionopidae	*Sigmodus rufiventris*	1	/
Psittacidae	*Agapornis pullarius*	1	/
	Psittacus erithacus	1	/
Pycnonotidae	*Andropadus curvirostris*	3	/
	Atimastillas simplex	1	/
	Eurillas virens	1	/
	Pycnonotus barbatus	1	1 and 3
	Pyrrhurus scandens	1, 2 and 3	/
	Stelgidillas gracilirostris	1	/
	Thescelocichla leucopleura	1	1 and 3
Rallidae	*Crecopsis egregia*	1	/
	Himantornis haematopus	1	/
	Limnocorax flavirostra	2	/
	Porphyrula alleni	2	/
	Sarothura elegans	1	/
	Sarothura pulchra	1	/
Sturnidae	*Lamprocolius purpureiceps*	1	/
	Lamprocolius splendidus	1	/
	Poeoptera lugubris	1	/

Table 3 Continued...

Family	Species	Good[18]	Germain et al.[17]
Sylviidae	*Bathmedonia rufa*	3	/
	Calamaecetor rufescens	1	/
	Camaroptera brevicaudata	1	/
	Camaroptera superciliaris	1	/
	Cisticola anonyma	1	/
	Cisticola erythrops	1	/
	Cisticola galactotes	1 and 2	1, 2 and 3
	Eremomela badiceps	1	/
	Notiocichla baeticata	1, 2 and 3	/
	Phylloscopus trochilus	1, 2 and 3	/
	Prinia subflava	1	/
	Schoenicola brevirostris	1, 2 and 3	/
Timaliidae	*Illadopsis fulvescens*	1	/
Trogonidae	*Apaloderma narina*	1	/
Turdidae	*Cossypha cyanocampter*	1	/
	Saxicola torquata	2	1, 2 and 3
	Turdus olivaceus	1	/
Total: 39	146	137	18

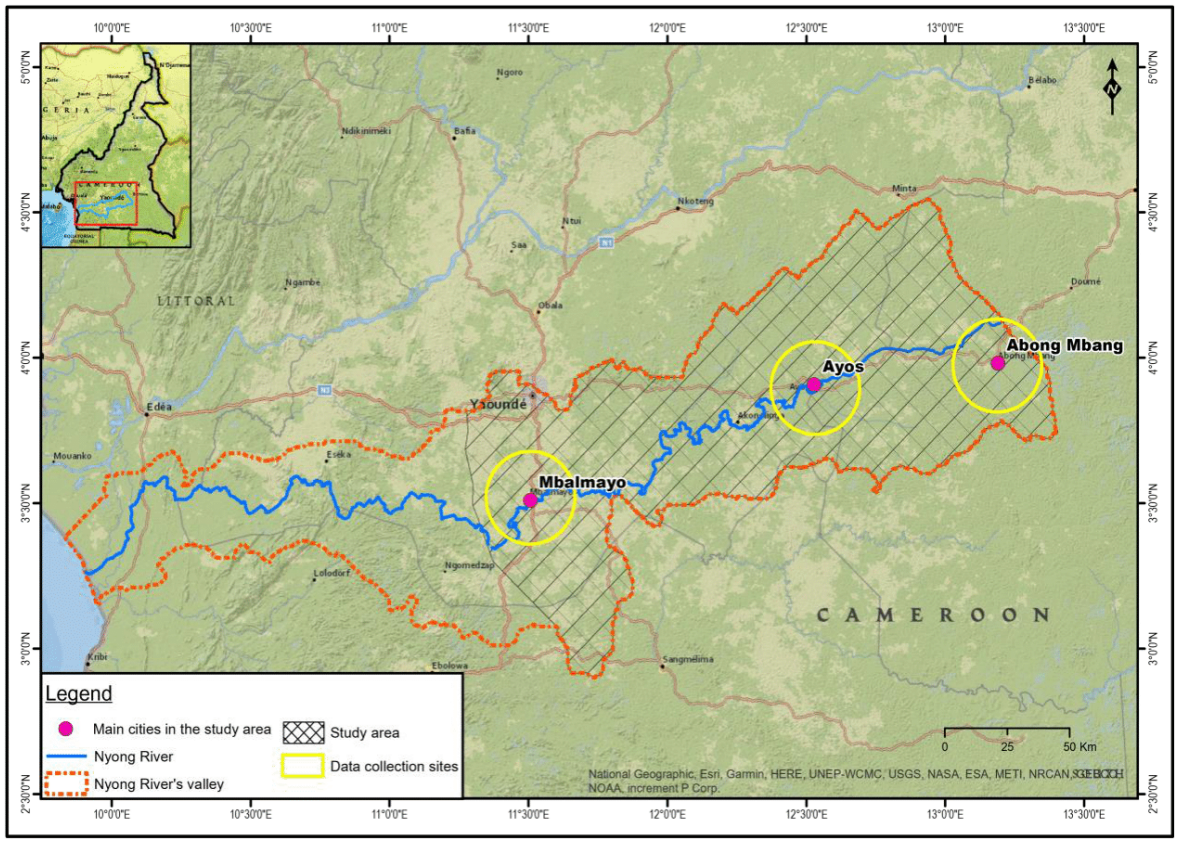

Figure 1 Nyong River valley.

Material and methods

Investigation of the upstream part of the Nyong River valley avifauna

To investigate the avifauna, we used the mist-netting method, which is suitable for catching small to medium-sized wild birds such as passerines. According to this method, an inconspicuous mesh net is erected vertically on poles and deployed in areas of high activity to intercept birds as they go about their normal daily routines. In our captures, we used dark coloured nylon nets and smaller mesh for smaller species. Our mist nets have a series of 3 pockets running horizontally along the length of the net; they were fixed with the mounting poles which had been chosen carefully and the choice of a suitable mist-netting site was important for the capture success. Thus, to ensure the capture success, we identified their preferred flight paths, feeding areas, roosting and shaded sites. Generally, we

start catching very early in the morning (5:00 AM) and we finish very late in the evening (sometimes 6:30 PM). In order to avoid a skew during the survey, we used the same five mist nets in our different field missions and we did nine (9) field missions (of 03 days each for a total of 27 field surveys) during one year (november 2020 to october 2021). To avoid cases of recapture, no transect was made twice. The identification manuals used were those of Borrow and Demey.[22,23]

Method for the calculation of the relative abundance and occurrence of avifauna in the upstream part of the Nyong River valley

We use Excel program[24] in order to calculate the relative abundance and the occurrence. We input data and ran software until the obtaining of the results.

Methods for the measure of the distribution of the upstream part of the Nyong River valley avifauna in keeping with their environment

Diversity indexes

Shannon index (H'): The Shannon's diversity index represents the measure of the sum of degree of the uncertainty when it suggests predicting to which species would belong to an individual taken by chance in a collection of S species and N individuals. H' = 0 if the community has only one species; H' takes the maximal value $\log_2 S$ only when all species are represented by the same number of individuals. This index is determined by the following relationship:

$$H' = -\sum_{i=1}^{S} (p_i x \text{Log}_2 p_i)$$

Where pi = proportion of individuals of the species "i" (Pi=ni/N); S = total number of species of the sample. ni = number of individuals of the species "i"; N = total number of individuals of the sample. The Shannon index (H') increases when the number of the species of the community grows and, theoretically, it can reach elevated values. The value of H' varies from 1 to $\log_2 S$. In our study, the Shannon index was calculated with the PAST v3.16 software.[25]

Simpson index (λ): The Simpson index represents the proportion of abundance of the species "i". This index measures the degree of concentration when individuals are classified into types.[25] It is determined by the following relationship:

$$\lambda = \sum_{i=1}^{S} \frac{n_i (n_i - 1)}{n(n-1)}$$

Where ni = number of individuals of the species "i"; n = total number of individuals of the sample. Nevertheless, the most popular of such indexes have been the inverse Simpson index (1/λ) and the Gini-Simpson index (1 – λ) and both have also been called the Simpson index in the ecological literature. In our study, the Simpson index was calculated with the PAST v3.16 software.[25]

Equitability index: The Equitability index measures the distribution of individuals within species independently to the specific richness. Its value varies from 0 (supremacy of one species) to 1 (equal distribution of individuals within species). Thus, the Equitability index of Pielou (J') is determined by the following formula: *J' = H'/H' max; H'* = Shannon index*; H' max* = $\log_2 S$ (S = the total number of species). In our study, the Equitability index was calculated with the PAST v3.16 software.[25] All these indexes have been obtained with a confidence threshold of 95%.

Comparison of the three sites with Kruskal-Wallis and pairwise Mann-Whitney tests

Before choosing the appropriate tests to compare the distribution of taxa within the habitats investigated, the Shapiro-Wilk normality test for relative abundance have been done at the threshold probability value of p=0.05. Then, if the probability obtained is below the threshold value, the conclusion is that the data do not follow a normal distribution.

The Kruskal-Wallis test have been used to compare the distribution of taxa within the habitats investigated. If the result is below the threshold probability of p=0.05, the conclusion is that there is a significant difference between the distribution of taxa; but if the result is above, the conclusion is that difference between the distribution is no significant. For the first case (significant difference), an associated Mann-Whitney U test is used to determine the level of difference between the pairs of habitats studied. In our study, these tree tests have been done with the PAST v3.16 software;[25] we input data as explained in the user guide and ran software until the obtaining of the results.

Results

Abundance and occurrence of the upper Nyong River valley avifauna

From the field surveys, a total of 268 individuals divided into five (05) orders, 22 families, 43 genera and 69 species were captured. By site, 60 specimens were obtained in Mbalmayo, 107 in Ayos and 101 in Abong-Mbang (Table 4).

Table 4 Familial abundance, number of genera and number of species of the upper Nyong River valley avifauna

Order	Family	Number of genera	Number of species	Absolute abundance	Relative abundance (%)
Columbiformes	Columbidae	1	1	13	4.85
Coraciiformes	Alcedinidae	1	1	8	2.99
Coraciiformes	Meropidae	1	1	8	2.99
Passeriformes	Acrocephalidae	1	1	3	1.12
Passeriformes	Cisticolidae	4	8	24	8.96
Passeriformes	Estrildidae	6	8	20	7.46
Passeriformes	Fringillidae	1	1	2	0.75
Passeriformes	Hyliidae	1	1	3	1.12
Passeriformes	Macrosphenidae	1	1	1	0.37
Passeriformes	Malaconotidae	1	1	1	0.37
Passeriformes	Muscicapidae	3	6	7	2.61
Passeriformes	Nectariniidae	4	10	39	14.55
Passeriformes	Phylloscopidae	1	1	2	0.75

Table 4 Continued...

Order	Family	Number of genera	Number of species	Absolute abundance	Relative abundance (%)
Passeriformes	Plastyteiridae	2	2	5	1.87
Passeriformes	Ploceidae	3	11	81	30.22
Passeriformes	Pycnonotidae	6	7	43	16.04
Passeriformes	Sylviidae	1	1	1	0.37
Passeriformes	Turdidae	1	1	1	0.37
Passeriformes	Viduidae	1	1	1	0.37
Piciformes	Lybiidae	1	3	3	1.12
Piciformes	Picidae	1	1	1	0.37
Strigiformes	Strigidae	1	1	1	0.37
Total: 05	22	43	69	268	100

Familial abundance, number of genera and number of species of the upper Nyong River valley avifauna

Of the 22 bird's families recorded, the most represented are Ploceidae (30.22%), Pycnonotidae (16.04%) and Nectariniidae (14.55%) (Table 4). We found that 73% of the captures were from the passerine families and 27% from non-passerine. The most diverse families are: Estrildidae (six genera and eight species), Pycnonotidae (six genera and seven species), Cisticolidae (four genera and eight species), Nectariniidae (four genera and ten species), Ploceidae (three genera and eleven species) and Muscicapidae (three genera and six species) (Table 4).

Specific abundance and occurrence of the upper Nyong River valley avifauna

Of the 69 species caught, the most abundant were: *Ploceus cucullatus* (11.94%) and *Eurillas virens* (8.58%). Analysis reveals that the species most frequently captured were: *Eurillas virens* (FO=44.44%), *Ploceus cucullatus* (FO=37.04%) and *Turtur tympanistria* (FO=29.63%) (Figure 2, Table 5). Of this avifauna (Figure 3), four (04) migratory species were captured (Figure 4).

Table 5 Specific abundance and occurrence of the upper Nyong River valley avifauna

Species	Common name	Absolute abundance	Relative abundance (%)	Occurrence	Frequency of occurrence (%)
Acrocephalus baeticatus	African Reed-warbler	3	1.12	3	11.11
Andropadus curvirostris	Plain Greenbul	1	0.37	1	3.7
Camaroptera brachyura	Bleating Camaroptera	9	3.36	6	22.22
Camaroptera chloronata	Olive –green Camaroptera	1	0.37	1	3.7
Camaroptera superciliaris	Yellow-browed Camaroptera	1	0.37	1	3.7
Chorocichla simplex	Simple Greenbul	1	0.37	1	3.7
Cinnyris batesi	Bates's Sunbird	8	2.99	6	22.22
Cinnyris chloropygius	Olive-bellied Sunbird	3	1.12	3	11.11
Cinnyris coccinigastrus	Splendid Sunbird	1	0.37	1	3.7
Cinnyris cupreus	Copper Sunbird	2	0.75	1	3.7
Cinnyris minullus	Tiny Sunbird	2	0.75	2	7.41
Cinnyris reichenowi	Northern Double-collared Sunbird	1	0.37	1	3.7
Cisticola brachypterus	Short-winged Cisticola	2	0.75	2	7.41
Cisticola bulliens	Bubbling Cisticola	5	1.87	3	11.11
Cisticola galactotes	Rufous-winged Cisticola	1	0.37	1	3.7
Cossypha niveicapilla	Snowy-crowned Robin-chat	1	0.37	1	3.7
Criniger chloronotus	Eastern Bearded Greenbul	1	0.37	1	3.7
Crithagra mozambica	Yellow-fronted Canary	2	0.75	1	3.7
Cyanomitra obscura	Olive Sunbird	14	5.22	3	11.11
Cyanomitra olivacea	Olive Sunbird	5	1.87	4	14.81
Deleornis fraseri	Fraser's Sunbird	1	0.37	1	3.7
Dendropicos fuscescens	Cardinal Woodpecker	1	0.37	1	3.7
Dyaphorophyia castanea	Chestnut Wattle-eye	3	1.12	2	7.41
Estrilda astrild	Common Waxbill	1	0.37	1	3.7
Estrilda melpoda	Orange-cheeked Waxbill	2	0.75	2	7.41
Estrilda nonnula	Black-crowned Waxbill	8	2.99	4	14.81
Euplectes afer	Yellow-crowned Bishop	2	0.75	2	7.41
Euplectes ardens	Red-collared Widowbird	13	4.85	7	25.93
Euplectes gierowii	Black Bishop	2	0.75	1	3.7
Euplectes hordeaceus	Black-winged Bishop	1	0.37	1	3.7
Euplectes macroura	Yellow-mantled Widowbird	10	3.73	6	22.22

Table 5 Continued...

Species	Common name	Absolute abundance	Relative abundance (%)	Occurrence	Frequency of occurrence (%)
Eurillas latirostris	Yellow-whiskered Greenbul	9	3.36	7	25.93
Eurillas virens	Little Greenbul	23	8.58	12	44.44
Hedydipna collaris	Collared Sunbird	2	0.75	2	7.41
Hylia prasina	Green hylia	3	1.12	3	11.11
Ispidina picta	African Pygmy Kingfisher	8	2.99	6	22.22
Lagonosticta rubricata	African firefinch	1	0.37	1	3.7
Lonchura bicolor	Black-and-white Mannikin	2	0.75	2	7.41
Merops variegatus	Blue-breasted Bee-eater	8	2.99	6	22.22
Muscicapa caerulescens	Ashy Flycatcher	1	0.37	1	3.7
Muscicapa striata	Spotted Flycatcher	1	0.37	1	3.7
Muscicapa tessmanni	Tessmann's Flycatcher	2	0.75	1	3.7
Nigrita bicolor	Chestnut-breasted Nigrita	1	0.37	1	3.7
Phyllastrephus albigularis	White-throated Greenbul	1	0.37	1	3.7
Phylloscopus herberti	Black-capped Woodland-warbler	2	0.75	1	3.7
Platysteira cyanea	Brown-throated Wattle-eye	2	0.75	2	7.41
Ploceus cucullatus	Village Weaver	32	11.94	10	37.04
Ploceus intermedius	Lesser Masked Weaver	1	0.37	1	3.7
Ploceus nigerrimus	Vieillot'sBlack Weaver	8	2.99	3	11.11
Ploceus nigricollis	Black-necked Weaver	1	0.37	1	3.7
Ploceus ocularis	Spectacled Weaver	4	1.5	3	11.11
Pogoniulus bilineatus	Yellow-rumped Tinkerbird	1	0.37	1	3.7
Pogoniulus scolopaceus	Speckled Tinkerbird	1	0.37	1	3.7
Pogoniulus subsulphureus	Yellow-throated Tinkerbird	1	0.37	1	3.7
Prinia subflava	Tawny-flanked Prinia	1	0.37	1	3.7
Pycnonotus barbatus	Common Bulbul	7	2.61	4	14.81
Quelea erythrops	Red-headed Quelea	7	2.61	4	14.81
Saxicola rubicola	European Stonechat	1	0.37	1	3.7
Saxicola torquatus	Common Stonechat	1	0.37	1	3.7
Schistolais leucopogon	White-chinned Prinia	4	1.5	4	14.81
Scotopelia bouvieri	Vermiculated Fishing owl	1	0.37	1	3.7
Spermestes cucullata	Bronze Mannikin	1	0.37	1	3.7
Spermophaga haematina	Western Bluebill	4	1.5	3	11.11
Stizorhina fraseri	Rufous Flycatcher-thrush	1	0.37	1	3.7
Sylvia borin	Garden Warbler	1	0.37	1	3.7
Sylvietta virens	Green Crombec	1	0.37	1	3.7
Tchagra australis	Brown-crowned Tchagra	1	0.37	1	3.7
Turtur tympanistria	Tambourine Dove	13	4.85	8	29.63
Vidua macroura	Pin-tailed Whydah	1	0.37	1	3.7
Total	/	268	100	/	/

Ploceus cucullatus Statius Muller, 1776 *Eurillas virens* Cassin, 1858 *Turtur tympanistria* Temminck,1809

Figure 2 The most abundant and frequently caught species of avifauna in the upper Nyong River valley.

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Figure 3 Some pictures of resident bird's species caught in the study area.

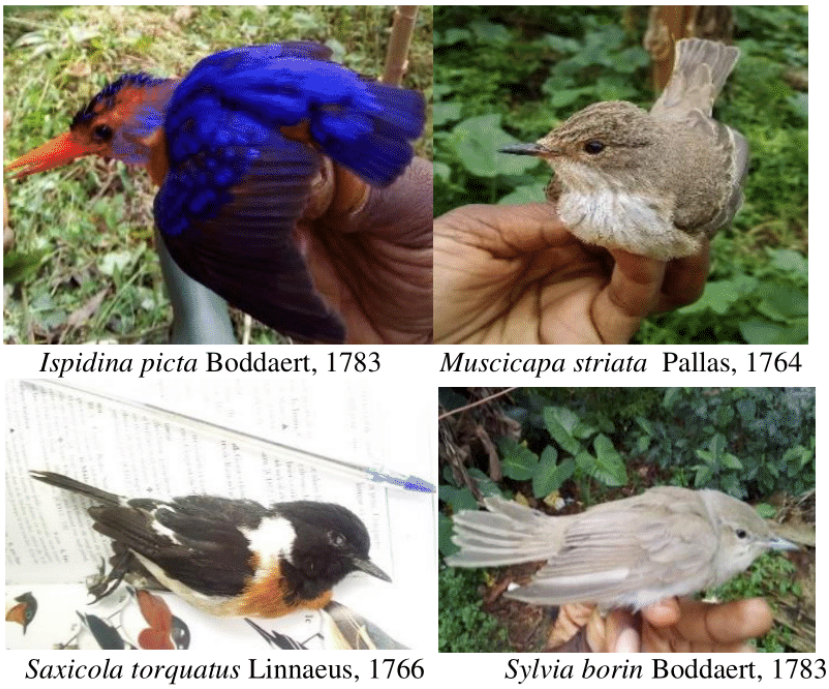

Figure 4 Migratory birds caught in the upper Nyong River valley.

Diversity indexes

The following table shows the diversity indexes values at the specific level by site and for the study area. Overall, the values for the entire study area are 0.96 for the Simpson index, 3.64 for the Shannon index and 0.86 for the Pielou equitability index (Table 6).

Table 6 Diversity indexes by site and for the entire study area

Indexes	Mbalmayo	Ayos	Abong-Mbang	Study area
Richness (S)	18	33	42	69
Number of individual	60	107	101	268
Simpson (λ)	0.87	0.93	0.94	0.96
Shannon (H)	2.43	3.04	3.28	3.64
Equitability (J)	0.84	0.87	0.88	0.86

Comparison between the three sites:

The Shapiro-Wilk normality test for relative abundance gave probability values of 0.55, 0.05 and 0.01 for Mbalmayo, Ayos and Abong-Mbang respectively (Table 7). Given that the probability value of the normality test at Abong-Mbang is below the threshold value (p=0.05), the overall conclusion is that the data do not follow a normal distribution.

Table 7 Result of the Shapiro-Wilk normality test for relative abundance

Site	Mbalmayo	Ayos	Abong-Mbang
Shapiro-Wilk normality test value per site	0.55	0.05	0.01

Comparison of relative abundance using the Kruskal-Wallis test and the pairwise Mann-Whitney test

A Kruskal-Wallis test value of 0.04 below the threshold probability (p=0.05), reveals a significant difference between the distribution of relative abundances of taxa in the different sites investigated (Table 8). And, the pairwise Mann-Whitney U test reveals that a significant difference was found between Mbalmayo and Ayos (p=0.01) (Table 9).

Table 8 Kruskal-Wallis Test of relative abundance

Calculated elements	H (chi²)	Probability
Value	6.46	0.04
Conclusion	Significant difference between median of the samples	

Table 9 Pairwise comparison of the Mann-Whitney U test

Sites	Abong-Mbang	Ayos	Mbalmayo
Abong-Mbang	/	0.25	0.17
Ayos	0.25	/	0.01
Mbalmayo	0.17	0.01	/

Discussion

Familial abundance of avifauna in the upstream part of the Nyong River valley

The results showed that the most diverse families are Estrildidae, Pycnonotidae, Cisticolidae, Nectariniidae, Ploceidae and Muscicapidae. This result is similar to the work of Nubuya et al.[26] who also found that Pycnonotidae, Nectariniidae and Ploceidae were among the most diverse families, noting that the wetland studied is one of the most diverse environments. Furthermore, they pointed out that this diversity could be favored by the proximity of the Benue River to the highly productive environment; they thus noted that this ecosystem was characterized by a wide variety of food resources, water availability, good vegetation cover, good breeding and nesting sites. According to our results, this would also apply to the Nyong River valley which globally presents the same characteristics. Hence the similarity with our study area, which also presents these characteristics. On the other hand, according to Good[18] the families Estrildidae and Pycnonotidae are made up of species which live mainly in forest vegetation. And this could also explain their presence in this study area. As for the presence of Ploceidae, it could be explained by their great capacity to colonize various environments as already revealed by several authors.[23,27,28]

Our results also revealed that Ploceidae (30.22%), Pycnonotidae (16.04%) and Nectariniidae (14.55%) were the most represented families and this result appeared similar to those of Kendeg[29] and Nubuya et al.[26] who highlighted that the riparian forest could serve as a refuge for these types of birds. Thus being in the same line with the results of these authors, we propose that conservation effort be focused on riparian forest and wetland habitats. It should also be noted according to our result that these families, all composed of passerines, confirm the high representativeness of Passeriformes (73%) compared to non-passerines (27%); this result thus corroborates the work of Lepage[30] in Nyong and So'o and could be explained by the fact that passerines alone make up more than half of the total number of known species in the world and thus have easily colonized in almost all environments. However, this result is different from that of Issiaka et al.[31] in the Niger River wetland; this may be due to the difference in sampling methods used. The latter used listening and observation points, whereas in this study we used nets instead. In addition, they worked on the banks of the river and during the period when Palaeartic migratory birds are abundant, whereas our study was carried out at the edge of the forest.

Specific abundance and occurrence of the upper Nyong River valley avifauna

According to our results, Ayos (107 individuals) was the most abundant site while the least abundant was Mbalmayo (60 individuals). The low abundance in Mbalmayo could be explained among other things, by intense logging activities which destroy habitats, plant cover and by extension, the forest, but also the uncontrolled extraction of sand, which disturbs the biotope of the taxa. Our result appears similar to that of Nubuya et al.[26] who state that habitats are destroyed by anthropogenic activities which affect the diversity of avifauna species. This study is also in agreement with Ntongani and Andrew[32] who reported that habitats little disturbed by humans supported more bird species and that the diversity as well as foraging sites favored high diversity of birds. More specifically, the species *Ploceus cucullatus* and *Eurillas virens* were the most abundant and frequently caught, in addition with *Turtur tympanistria* (Figure 2); based on their diets, this result indicates the presence of a wide diversity of resources in the study area and a diversified plant physiognomy (forest, semi-open environments, plains and grassy slopes). This result coroborates that of Tela et al.[33] who state that vegetation structure is the most proximate factor that determines species diversity. Otherwise based on Dajoz,[34] our results show that of the species captured: 55.07% are rare; 37.68% are accidental; and 7.25% are accessories; this result, which is in agreement with that of Lepage,[30] highlights a permanent food resource in the study zone.

Diversity indexes

Diversity indexes revealed that the study area is diverse. Overall, a value of 0.96 obtained for the Simpson's index indicates the absence of supremacy of one species over the others. This result is similar to that of Azang.[35] On this subject, Jetz and Rahbek[36] reveal that models of variation in species distribution use almost exclusively environmental factors. Likewise, Louette[21] states that the distribution of birds is directly linked to vegetation. A value obtained from the Shannon index of 3.64 reveals that the study area is diverse. This result is similar to those of several authors. [26,28,31,37] This diversity

could be explained by low competition between organisms due to the presence of diversified resources and microhabitats found in the upstream valley of the Nyong River. The value of 0.86 obtained for the Pielou equitability index indicates that there is an equal distribution of individuals within species. This result corroborates that of Issiaka et al.,[31] Mahamat[37] and Nguembock et al.,[38] it could be justified by the diversity of habitats encountered (aquatic grasslands, swamp forests, flooded forests, secondary forests, fallow land, etc.) and the abundance of food resources offered by the study area. Along the same lines, Akosim et al.[39] point out that the diversity patterns depend on food availability, habitat suitability, geophysiological structure of habitats and their size.

Comparison between the three sites

In comparison of the sites explored, the results showed a probability of 0.04 for the Kruskal-Wallis test, revealing a significant difference between the distribution of relative abundances of taxa in the different sites investigated. And the associated Mann-Whitney U test showed that there was a significant difference between Mbalmayo and Ayos (p=0.01). Mbalmayo presents vegetation influenced by its slightly uneven relief and by very marked human activity. This site is thus dominated by secondary forests of the humid equatorial type, alternating in places with palm groves.[40] However, Ayos reveals vegetation consisting of aquatic meadows, riperian forest and permanently flooded marshes which make access difficult and thus favour the stability of this ecosystem.[13]

Conclusion

This study allowed us to identify a total of 69 species captured. Families were highly representative of passerines (73%). This study revealed that the avifauna of the upper Nyong River valley is very diverse, and that there is a significant difference between the distribution of relative abundances of taxa in the different sites investigated. Concerning the specific composition of the avian populations, our study revealed that the habitats covered are not similar. And that difference within the sites appeared to be directly related to the vegetation.

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Conflicts of interest

The authors declared that there are no conflicts of interest.

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