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Birds' Diversity in Kalfou Forest Reserve and Its Peripheral Zone, Far North, Cameroon

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Abstract

The Far North Region of Cameroon is home to a great diversity of bird species, which unfortunately remains very little explored. This work was initiated to establish an inventory of birds and the factors affecting their diversity and distribution for sustainable management in the Kalfou Forest Reserve (KFR) and its periphery. Two methods were used for sampling, linear strip transects from which direct counts and indirect observations were made and the mist netting to complement the first. In total, 2525 birds were observed, including 149 species, belonging to 20 orders and 55 families. Accipitridae had the greatest number of species (11). The species richness was greater in the KFR (117 species) compared to the periphery (95 species). The specific richness was higher in wooded savannah compared to other habitats. Shannon index was significantly higher in the KFR (3.99) compared to that obtained in the periphery (3.80). The value of the Simpson index was higher on the outskirts of the KFR than on the periphery. The indices of species diversity were greater in the wooded savannah compared to other vegetation types. The seasons had no influence on bird diversity. Among the human activities encountered, the pressure indices were more important for grazing (7.3 contacts/km). Human activities have resulted in a significant decrease in specific richness. Six endangered species were encountered, four belonging to the Accipitridae family. The greater bird diversity in the reserve compared to the periphery shows that protected areas are a long-term solution for biodiversity conservation.

Keywords

Bird Diversity, Habitats, Bird Species, Human Activities, Conservation, Kalfou

1. Introduction

Birds represent the most used animal group for environmental monitoring, next to the large mammals and are becoming more and more important in our environment, because they are being used to monitor the health of our planet [1]. Moreover, birds have undeniable ecological values which include the dissemination of seeds, the pollination of plants and their intervention in the various food chains of natural environments [2]. They are not only a source of aesthetic pleasure through their acoustics, and bring colour to our existence. They are also uplifting economic growth, providing income through ecotourism and thus motivation for conservation [3]. Birds have also a cultural significance in myths, legends, symbols, rituals (such as the ceremonial use of feathers), art and names [4]. Despite their ecosystem, cultural, economic and aesthetic roles, birds are unfortunately confronted with multiple threats in their natural environments nowadays as a result of unsustainable land use patterns and direct predation [5].

The direct drivers of biodiversity loss are linked to the type of economy which depends on natural resources, and land use changes which require increasing conversion of ecosystems [6]. Most threats to birds are caused by human activities, the most important ones are the expansion and intensification of agriculture, affecting 1091 globally threatened bird species (74%); logging, affecting 734 species (50%); invasive alien species, which threaten 578 (39%) species; and hunting and trapping, which endanger 517 species (35%) [7]. Climate change is an increasingly serious threat currently affecting 33% of threatened bird species globally and often exacerbating existing threats [7]. In Cameroon continuous conversion of forests, decreased from 22.5 million ha in 1975 to 19 million ha in 2005, corresponding to an annual loss of 100,000 ha, with a rate of 0.48%/year [8]. Observable consequences of the depletion of forest ecosystems include changes in landscapes, fragmentation of their habitat and consequently the migration or extinction of certain bird species [9]. In the Kalfou Forest Reserve (KFR), crop farms, despite a negligible hold of 193 ha, are experiencing an increasing rate of 0.11%, and although this activity is marginal at the moment, it is increased to the detriment of the woody cover (around 90 ha) exacerbated by wild tree logging [10]. The main activities carried out outside this protected area focus on agriculture, animal husbandry and hunting.

Protected areas provide places for shelter, food and reproduction of animals, fight against climate change, preservation of certain cultural values, etc. [11]. The KFR was not a wildlife reserve when it was created in 1933, although today

it is home to iconic large mammals such as elephants and giraffes as well as birds [12]. What attracts a large number of poachers to the area is added deforestation, and strong pastoral and agricultural activity. The Far North Region to which the KFR belongs is home to several Important Bird Areas [13]. This avian fauna is known globally through field reports and modeling of their spatial distribution [14] [15]. The fieldwork carried out in the Region is very old and is concentrated in the Waza area and the flood zone of the Logone River [16] [17] [18]. The KFR has never been the subject of an avifauna inventory, despite the presence of a large number of bird species. This study is a contribution to updating the ornithological database of the area, and at the same time makes it possible to assess the impact of habitat types on the specific richness, diversity and distribution of birds. Understanding the diversity and distributions of species of birds and other organisms is important in terms of understanding adaptability, survival and extinction rates of species and providing knowledge that can be used to protect particular species of birds, and other components of biodiversity that are correlated with them [19]. However, there are many challenges to extrapolating diversity patterns based on field studies to large spatial scales [20]. This research assessed and explored baseline data sets to test hypotheses about changes in species richness and diversity to answer the following research questions: 1) Which sectors or sites are habitats to a high number of bird species in KFR? 2) Are there any significant variations of species richness and diversity of birds across habitats? 3) Do anthropogenic activities have an impact on the specific richness and diversity of birds?

2. Materials and Methods

2.1. Study Area

Kalfou subdivision is located between 10˚4' and 10˚26' latitude (North), and between 14˚50' and 15˚10' longitude (East), in the Mayo-Danay Division, Far North Region (**Figure 1**). It is limited to the North by the Moulvoudaye Sub Division, to the South by Kar-hay Sub Division, to the East by Yagoua Sub Division and to the West by Guidiguis Sub Division.

The climate of the study area is tropical Sudano-Sahelian type with a long dry season, the harmattan blows from October to March. Southerly winds appear in June before bringing rain in August and especially in September. The average rainfall varies between 500 mm to 800 mm and the annual precipitation is concentrated mainly over 3 months (from August to October). Average temperatures are around 30˚C, with very significant thermal differences (7.7˚C annual average).

The vegetation of Kalfou is quite varied. Depending on the season, the landscape is characterized by wooded, grassy savannah and small thorny steppes on plots not occupied by dwellings and fields. The dominant herbaceous species are: *Pennisetum purpureum*, *Andopogon* sp., *Hyparhenya rufa*, *Chromolaena odorata*, *Mimosa* sp. and many other grasses.

The marshy areas located at the edge of certain neighbourhoods are mainly

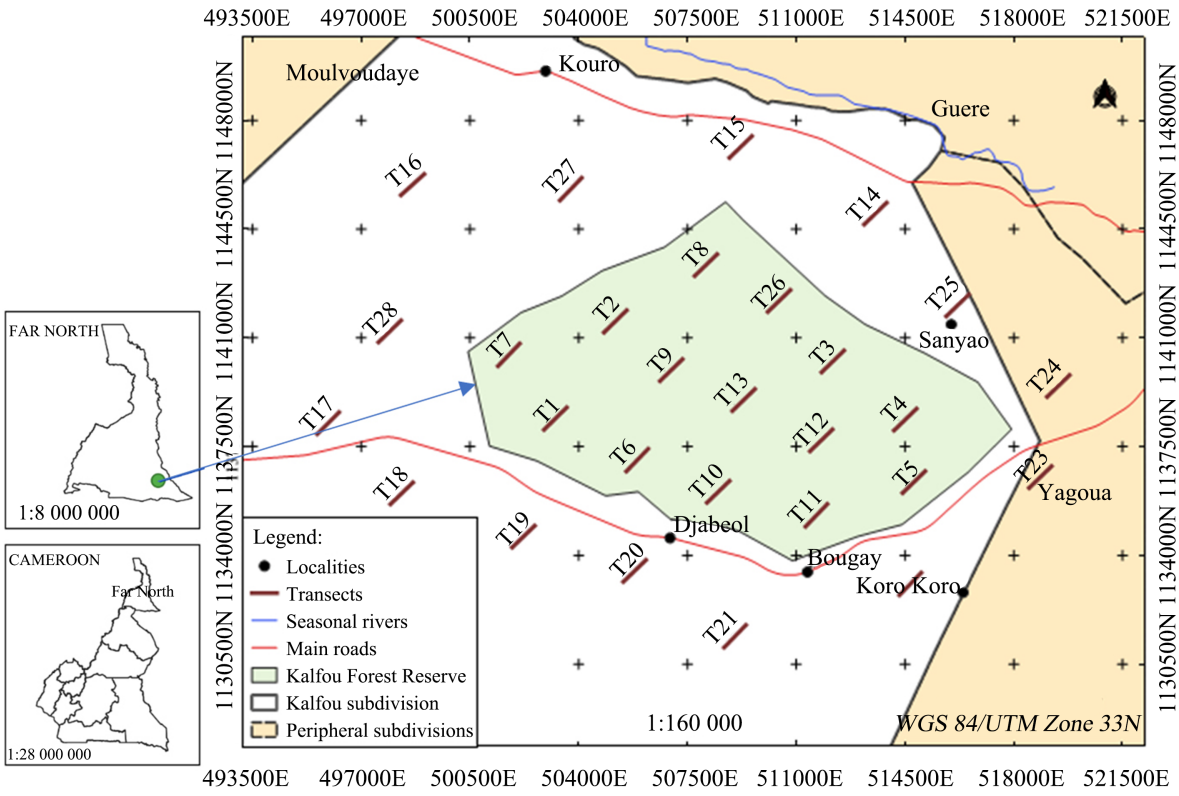


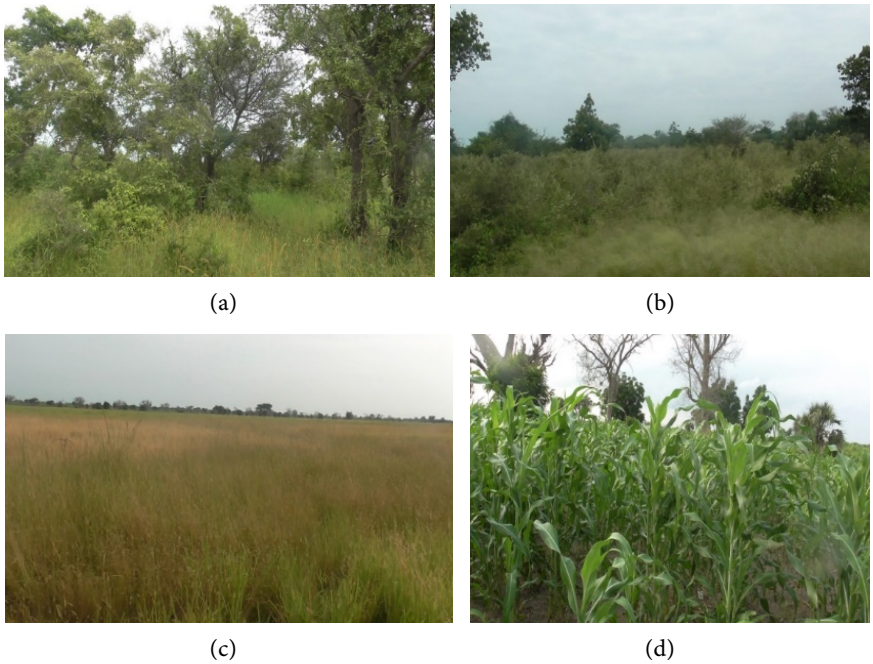
Figure 1. Map showing the location of the Kalfou Forest Reserve (KFR) and transect lay out.

colonized by Maranthaceae and Zynziberaceae. In the study area we found the wooded savannah, shrub and a grassy savannah. The woody plant composition of KFR is mainly made up of *Balanites aegyptiaca*, *Sclerocarya birrea*, *Kigelia africana* and *Sterculia setigera* [10].

Agriculture and livestock breeding are the most practiced activities in the study area. In Kalfou, we also meet hunters, loggers, traders, fishermen and artisans.

2.2. Field Work and Data Collection

Planning of sampling. The field work for this study was carried out from July 01 to October 30, 2020 (4 months, rainy season), and December 18, 2020 to March 30, 2021 (3 months, dry season). The georeferenced satellite images, obtained from the Google Earth Pro 7.1 software, made it possible to see the different variations in land use (vegetation, fields and houses). This made it possible to place the transects to cover the different habitats in the study area. Thus, a total of 28 line transects, 100 m wide and 1000 m long were used, of which 14 were inside the reserve and 14 outside (**Figure 1**). This was done in order to compare the diversity between the two sites, habitats (**Figure 2**) and seasons. The spacing between transects was at least 1000 m. The starting points of each transect and their coordinates were recorded using QGIS software version 3.12 to facilitate their location and orientation in the field. The same transects were followed in the dry season and in the rainy season.



(a) (b)

(c) (d)

Figure 2. Different types of habitats in KFR and its periphery. (a) = Wooded savannah, (b) = shrub savannah, (c) = Grassland and (d) = Plantation.

Use of the strip transect method and data collection. The band transect method has been used to determine the species composition and to estimate the relative frequency of bird species [21] [22] [23]. Data collection consisted of silently walking the line (1 km) and noting all birds seen or heard in a 50 m band either side of the transect line. The inventory team arrives early in the morning (approximately 6 am), at or near the sampling point and/or in the evening from 3 h 30 pm, to increase the chances of contact with the birds because the peak activity of most wild birds occurs during these periods [24]. Various information's collected during the transects were noted on a data collection sheet. The main data contained in the collection sheet were: the coordinates of the contact points where the bird is seen in the transect; the common and/or scientific name of the bird species encountered is reported; the group's workforce; anthropogenic activities (poaching, planting, camping, deforestation, and grazing were noted); the type of habitats or vegetation type in which the bird species was observed (woodland savannah, shrub savannah, grassy savannah and plantations).

Mist netting. Mist net catches were also carried out during the same period, on the same transects, to capture passerines, but also to confirm or correct certain identifications. Sixteen (16) transects among the 28 used, with 4 per habitat type were chosen for the installation of the nets. The black-coloured net, 3 m high, with a mesh of 2 cm each and 12 m in length, was placed vertically very early in the morning between 4 h 30 am and 6 h 00 am, by hanging its rings on two stakes of at least 3.5 m high, and fixed to the ground. They were placed by first observing the likely direction of movement of the birds to increase the chances of capture. These nets were placed 250 m apart, in open areas on or near

transects. The composition of this team varied according to the activities. They were 8 when switching to the mist net catches, with the additional 4 people in charge of guarding the nets (far in a shelter or hidden in the vegetation) against cattle, herders and farmers.

Identification and determination of the migratory status of bird species. The West African Birds Identification Guide has been used for the identification of avifauna in the field [14]. It was also used to determine the migratory status of each bird species. In order to facilitate the observations, we used the Olympus brand binoculars (10 × 50) and a Panosonic HC-V131 camera. Birds caught in mist nets, which could not be identified in the field, were transported individually in small cotton bags to the camp. The various measurements were noted including the length of the beak, tarsus, tibia, wing, wingspan, total length of the bird, weight, etc., as well as other morphological characteristics (color plumage, shape of legs, feet, beak, etc.). The captured and identified birds were then released at or near the capture sites.

2.3. Data Analysis

Estimation of specific richness and calculation of the sampling effort. Data on bird species was used to produce rarefaction curves according to habitat types and the sectors of the study area. The estimate of species richness was calculated from estimators including Jackknife 1 and Jackknife 2 [25], Chao 2 [26] and Boostrap [27]. These estimates took into account the number of species and their abundance by habitat and, by sector of the study area and throughout the study area. This made it possible to determine the estimated average number of species in the study area and to calculate the sampling effort.

Sampling effort (E) was made to assess the percentage of species sampled:

$$E = \frac{\text{Number of observed species}}{\text{Number of estimated species}} \times 100$$

Diversity indices. The Shannon-Wiener index (H') combines both the number of species and the distribution of species according to their abundances. It was calculated to compare the diversity according to the type of vegetation and the sectors of the study area. $H' = \sum p_i \log_2 (p_i)$. Where $\log_2$ = logarithm in base 2; N_i = number of observations of a species i; N = total number observations; p_i is the probability that species is present in a survey. In practice, $p_i = N_i/N$.

Pielou equity (evenness) index **(E)**. It reflects the degree of diversity reached by a stand. It provides information on how individuals are distributed within species. Its value results from the ratio of the Shannon diversity index **(H')** to the value of the theoretical maximum diversity (H_{max}). It is calculated by the following formula:

$$E = H'/H_{max},$$

where H' is the Shannon index, $H_{max} = \log_2 S$ with S being the total number of species. $E = H'/\log_2 S$. This index varies between 0 and 1. It tends towards 1 when

the species have identical abundances in the stand or when each species is represented by the same number of individuals, and towards 0 when the majority of individuals belong to a single species.

The Simpson index (*D*) is a formula to calculate a probability, that is to say the probability that two individuals selected randomly in a given environment are of the same species. It is expressed by the formula:

$$D = \sum N_i \left(N_i - 1\right) / N\left(N - 1\right)$$

D: Simpson's index, N_i: Number of individuals of the given species, *N*: Total number of individuals. The index varies between 0 and 1. The closer it gets to 0, the higher the chances of obtaining individuals of different species.

The Whittaker dissimilarity index [28] was used to compare the different avian communities in the samples (habitats, seasons and sectors of the study area).

PAST software version 4.03 was used for the various statistical analyses. The $\chi 2$ test was used to compare the species richness between sectors and between different habitats in the study area. The t-diversity test was used to compare the bird diversity of different sectors of the study area. The general linear model was used to see the effect of human activities (pastoralism, deforestation, plantation, Poaching and Camp) on relative abundance, including kilometric indices of abundances of different species of birds. The probability threshold retained for the analyses is $p = 0.05$ (confidence level of 95.0%).

The relationships between the different dependent variables describing bird diversity, namely species richness, abundance, and degree of threat, were analysed using the generalized linear model. The application of GLM to the data made it possible to know about the levels of the indices of threats which have an effect on the diversity of birds.

3. Results

3.1. Specific Richness of the Study Area

In the study area, 2525 individuals of 149 bird species were identified, belonging to 20 orders subdivided into 55 families (Table 1). From Table 1, it emerges that the Passeriformes constitute the most dominant order in terms of number of families (24), ahead of Bucerotiformes, Charadriiformes, Coraciiformes, Pelecaniformes and Piciformes, with each having three (03) families. Caprimulgiformes and Galliformes with 2 families, while the other orders only had one family. The family of Accipitripidae contained the largest number of species (14 species), or 9.4% of 149 species recorded. The most represented species of this family were: Pallid Harrier (*Circus macrourus*), Black Kite (*Milvus migran*) and African Harrier-hawk (*Polyboroides typus*). The other families were also most represented are: Columbidae, Muscicapidae and Ploceidae had each 8 species, Estrildidae (7 species) and Sylviidae (6 species). The Ploceidae family was the largest in terms of individuals (699 birds) followed by the Columbidae (229).

Table 1. Distribution of specific richness by order and by family.

Orders	Famillies	Number of species	Abondance
Accipitriformes	Accipitridae	14	39
Anseriformes	Anatidae	3	22
Bucerotiformes	Bucerotidae	3	96
	Phoeniculidae	2	14
	Upupidae	1	12
Caprimulgiformes	Apodidae	1	8
	Caprimulgidae	2	4
Charadriiformes	Charadriidae	1	18
	Scolopacidae	1	2
	Turnicidae	2	14
Coliiformes	Coliidae	1	8
Columbiformes	Columbidae	8	229
Coraciiformes	Alcedinidae	4	59
	Coraciidae	3	14
	Meropidae	5	86
Cuculiformes	Cuculidae	5	56
Falconiformes	Falconidae	4	8
Galliformes	Numididae	1	8
	Phasianidae	1	5
Gruiformes	Rallidae	1	2
Musophagiformes	Musophagidae	1	2
Otidiformes	Otididae	1	4
Passeriformes	Buphagidae	1	12
	Campephagidae	1	6
	Cisticolidae	2	72
	Corvidae	2	31
	Dicruridae	1	79
	Emberizidae	1	3
	Estrildidae	7	78
	Hirundinidae	4	18
	Laniidae	2	15
	Malaconotidae	2	7
	Monarchidae	1	5

Continued

	Muscicapidae	8	51
	Nectariniidae	4	52
	Oriolidae	1	4
	Paridae	1	2
	Passeridae	5	94
	Ploceidae	8	699
	Pycnonotidae	1	4
	Sturnidae	5	170
	Sylviidae	6	64
	Leiotrichidae	1	38
	Turdidae	1	9
	Viduidae	2	114
	Zosteropidae	1	2
Pelecaniformes	Ardeidae	3	79
	Ciconiidae	1	3
	Scopidae	1	2
Piciformes	Lybiidae	4	16
	Indicatoridae	1	2
	Picidae	2	9
Psittaciformes	Psittacidae	2	72
Pterocliformes	Pteroclidae	1	2
Strigiformes	Tytonidae	1	1
Total (20)	55	149	2525

Threatened species according to IUCN, encountered in the study area belong to 3 families: Bucerotidae (*Bucorvus abyssinicus*, Abyssinian Ground-Hornbill, Vulnerable (VU)), *Falconidae* (*Falco vespertinus*, Red-footed Falcon, Near Threatened (NT)) and Accipitripidae. The latter is the most endangered and contains 4 species: *Aquila rapax*, VU; *Circaetus beaudouini*, VU; *Circus macrourus* (Pallid Harrier, NT) and *Necrosyrtes monachus* (Hooded Vulture, CR, Critically Endangered).

Most of the species encountered in Kalfou are sedentary (S) and represented by 93 species (62.42%); followed by sedentary and migratory species (S/M) (24 species, 16.11%); Palearctic (P) (9 species, 6.04%) and Migrator (M) comprising six (07) species (4.70%). The following statuses presented a single species: M/O (*Eurystomus glaucurus*-Broad-billed Roller), M/P/O (*Merops persicus*-Blue-cheeked Bee-eater), M/P/S (*Milvus migrans*-Black Kite) and S/M/O (*Oena ca-*

pensis-Namaqua Dove). Two species were occasionally present: *Emberiza tahapisi*-Cinnamon-breasted Bunting and *Tringa totanus*-Common Redshank.

Individual rarefaction curves. The different rarefaction curves (Figure 3) showing the evolution of species richness as a function of species abundance increase, but without reaching an asymptote (Figure 3(a)). This shows that there are still species to be identified in the study area. Of the 149 species counted in the study area, the KFR contained 117 species of birds, on the other hand the peripheral zone holds 95 species (Figure 3(b)).

The species richness observed in the KFR was significantly higher ($\chi 2$ = 7.9109; df = 1; p = 0.0049), compared to that of the peripheral zone. Figure 3(d) shows that 140 species were encountered in the dry season compared to 129 in the rainy season. The species richness of the dry season was significantly higher ($\chi 2$ = 4.6222; df = 1; p = 0.0316) compared to that of the rainy season. The

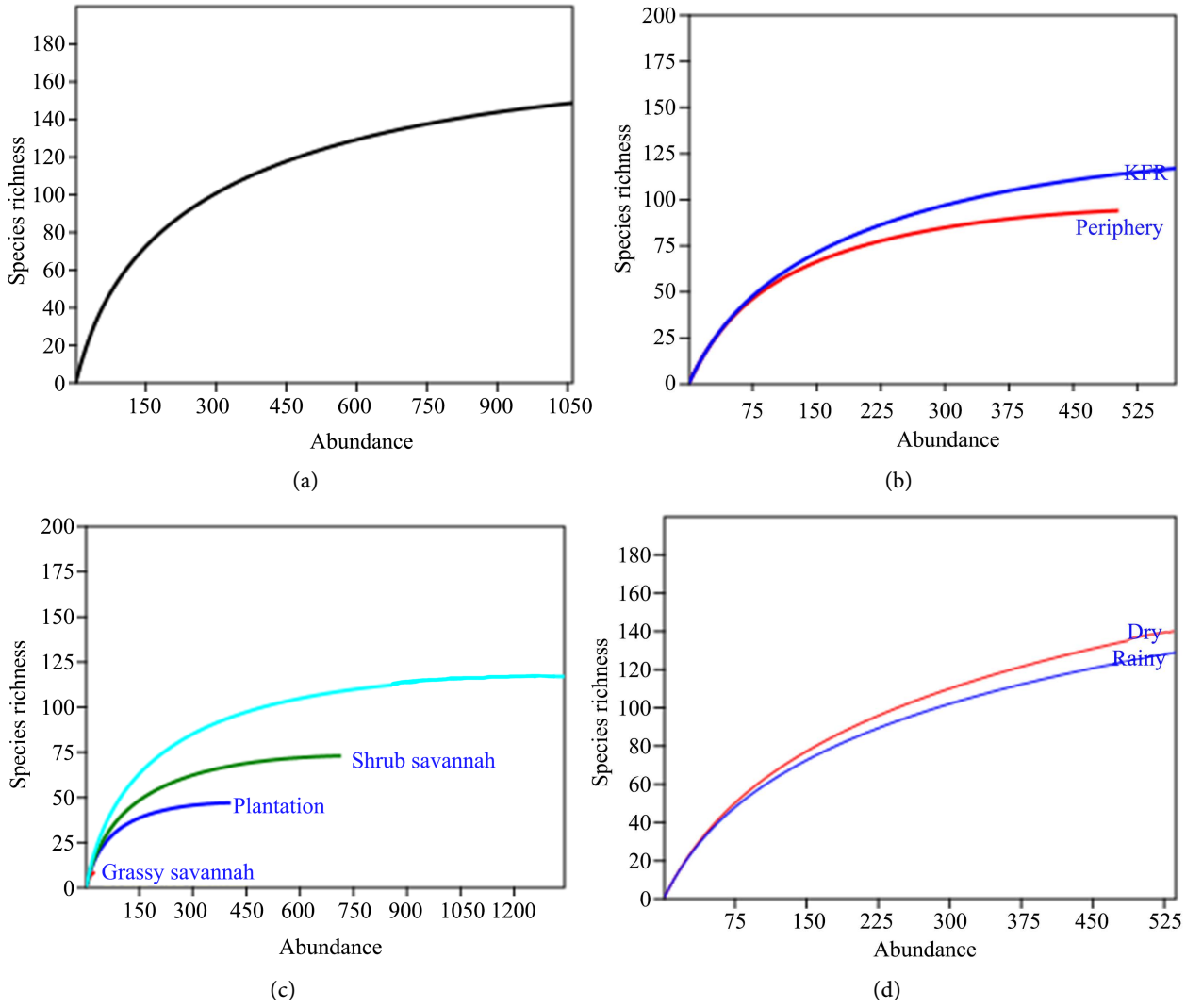


Figure 3. Individual rarefaction curves of bird species richness in the study area. (a) Global rarefaction curves; (b) Rarefaction curve between the Parc and its periphery; (c) Rarefaction curves according to the type of habitat; (d) Rarefaction curves of rainy and dry season.

wooded savannah contains the greatest number of species (117 species) against 73 species in the shrub savannah, 47 species in the cultivated areas (plantations) and 9 species in the grassy savannah (Figure 3(c)). Comparison of the specific composition of the 4 habitat types showed a highly significant difference ($\chi 2$ = 171.01; dl = 3; p = 7.41E−37).

Sampling effort. Taking into account the specific richness at the different sector of the study area, the estimators: Chao2 (178.69), Jackknife1 (192.5), Jackknife2 (192.5) and Bootstrap (170.75) gave an average of 183.61 species, which corresponds to approximately 184 species. The number of species observed being 149, the estimators therefore shows that 35 species (184 estimated − 149 species observed) were not encountered in this study area. Considering the number of estimated species and those sampled, the sampling effort for our study was 80.99% (or 149/184 × 100).

3.2. Comparison of Avian Diversity

Comparison of avian diversity according to sectors of the study area

The Shannon index (H') at the KFR (H' = 4.359 bits) is greater than that obtained at the periphery (H' = 4.243 bits) (Table 2). Comparison of the Shannon index between the periphery and the KFR showed a significant difference (p = 0.025). This result proves that the KFR has a high diversity compared to that of the periphery. The Simpson diversity index in the KFR is D = 0.017 against D = 0.018 in the peripheral area. No significant difference was observed (p > 0.05) in the comparison of the Simpson indices of the two areas. This assumes that the probability of two randomly selected individuals belonging to the same species was the same in the KFR and the periphery.

In addition, the value of the Whittaker index obtained by comparing the avian communities of the sectors of the study area gave a dissimilarity value of 0.41 (41%), corresponding to the difference in the specific composition of the two environments. In other words, the two sectors of the study area had a similar specific richness of 0.59, or 59% of the species in common.

Comparison of avifauna diversity according to the season

The Shannon index remains high (>4) irrespective of the type of season (Table 3). It was nevertheless higher in the dry season (H' = 4.501 bits) compared to that obtained in the rainy season (H' = 4.389 bits). However, no significant difference (p = 0.062) in bird diversity depending on the season was observed. The Simpson index (D) was higher in the rainy season (0.017) compared to that obtained in the dry season (0.0154). The comparison of the 2 dominance indices showed no significant difference (p = 0.174).

The Whittaker dissimilarity index between the 2 seasons is 10.78%, showing that the avian communities of the 2 seasons vary very little.

Comparison of avian communities according to the vegetation types. Table 4 shows that, for bird species, the diversity index varies from one habitat to another.

Table 2. Diversity according to sectors of the study area.

Indices	Shannon index				Simpson index			
Areas	***H'***	**t**	**df**	**p**	**D**	**t**	**df**	**p**
Peripheral	4.243	−2.239	1070.4	**0.025***	0.018	0.381	1070	0.704
KFR	4.359				0.017			

H' = Shannon index; t = t diversity test; df = degree of freedom; p = probability value; D = Simpson index; KFR: Kalfou Forest Reserve; * Significant.

Table 3. t diversity test according to the season.

	Shannon index				Simpson index			
	H'	**t**	**df**	**P**	**D**	**t**	**df**	**p**
Dry season	4.501	1.867	1071	0.062	0.015	1.359	1060	0.174
Rainy season	4.389				0.017			

Table 4. Diversity of bird community according to the type of habitat in the study area.

Habitats	Grassy savannah	Plantation	Shrub savannah	Wooded savannah
Taxa_S	9	47	73	117
Individuals	39	411	721	1354
Dominance_D	**0.153**	0.066	0.054	0.025
Simpson_1-D	0.847	0.934	0.946	**0.976**
Shannon_*H'*	2.029	3.268	3.582	**4.181**
Evenness_e^*H*/*S*	**0.845**	0.559	0.492	0.559

The higher index is presented by the number in bolt.

- Shannon diversity index (*H'*), it is higher in wooded savannah (*H'* = 4.181 bits), average in shrub savannah (*H'* = 3.582 bits) and in plantations (*H'* = 3.268 bits) and low in grassy savannah (*H'* = 2.029 bits). This result clearly shows that the wooded savannah is more diversified compared to the other types of vegetation, followed by the shrub savannah, then by the plantations. On the other hand, diversity is lower in grassy savannah.
- Simpson index (1 − *D*): It is higher in the wooded savannah (0.976) followed by shrub savannah (0.946) and plantations (0.934), grassy savannah has the lowest value (0.847). The Simpson indices show that the probability of randomly selecting two individuals of the same species is lower in wooded savannah compared to other types of habitats.
- Pielou evenness index (*E*). The grassy savannah presents the highest fairness (0.845) successively ahead of the wooded savannah (0.559), the plantations (0.559) and shrub savannah (0.492). The analysis of this result shows that the species present in grassy savannah have almost identical abundances given

that the Pielou evenness index gives a value which tends towards 1.

Comparison of the Whittaker dissimilarity indices shows that there are differences in bird community between habitat types (Table 5). The greatest dissimilarity is found between grassy savannah and wooded savannah (0.921, *i.e.* 92.06% difference in bird species composition). On the other hand, there is a slight similarity between the 2 habitats types (7.94%). The lowest dissimilarity (0.442, or 44.2%) in terms of species composition was observed between shrub savannah and wooded savannah.

3.3. Threats Suffered by the Birds of the RFK and Its Peripheral Zone

Distributions of anthropogenic activities. Five (5) types of human pressures (pastoralism, deforestation, agriculture, poaching and camp) were identified in the KFR and its periphery. Pastoralism, was the most important human pressure recorded in our study site. Her PCMI was 7.39 for 28 km covered. It is justified on the ground by the presence of numerous breeders, cattle as well as the footprints of the oxen. Deforestation, the exploitation of woody plants is the second most common anthropogenic activity in the study area. Indeed, it is defined through the cutting of various woods, pruning for livestock and coal mining activities. Its PCMI is 2.96 for a total of 28 km of transects;

Impact of human activities on the avifauna of the RFK and its peripheral zone. Analysis of the results of the general linear model fitting Kilometric Indices of Abundance (KIA) to PCMI shows that there is a statistically significant relationship between KIA and the predictor variables at the 95.0% confidence level (model p = 0.0000). Overall, there is an increase in the kilometric abundance indices with the kilometric pressure contact indices. On the other hand, the specific richness is more important for the zones where the PCMI are lower than 0.5 (see the large number of points of the Figure 4) and weak beyond. Human activities in Kalfou, although resulting in a decrease in species richness, do not have a negative influence on the abundance of most of the species encountered.

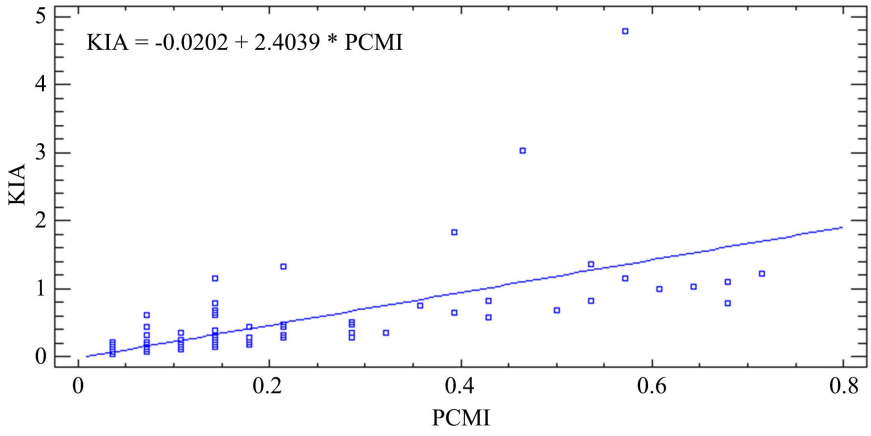


Figure 4. Global impact of human activities on bird's abundance. KIA: Kilometric Index of Abundance, PCMI: Pressure contact mileage index.

Table 5. Whittaker dissimilarity matrix on bird communities between habitat types.

Habitats*	Grassy savannah	Plantation	Shrub savannah	Wooded savannah
Grassy savannah	0	0.821	0.902	0.921
Plantation		0	0.5	0.573
Shrub savannah			0	0.442
Wooded savannah				0

4. Discussion

This number of bird species recorded in the study area was higher than the simulation of the specific richness made by [15] which estimates at 127, the number of species contained in the geographical area of Kalfou. Based on field data from this study, the estimators gave a number of 184 species, an estimate much higher than that of [15]. The difference between these two estimates would be attributed in the fact that Languy's estimates were mainly based on surveys and on previous data without fieldwork in the geographical area of Kalfou. Also, there exist 954 bird species in Cameroon grouped into 86 families, of which 55 families were represented in the KFR and its peripheral zone, which testifies to the importance of this zone in terms of avian fauna [15]. Most bird species in the area are also found in West Africa and part of East Africa [13]. The estimate of the richness of birds in the study area is reasonable as indicated by the result of the accumulation curve. The KFR despite its status of Forest Reserve, has avian biodiversity very close to certain National Parks. Its specific richness is similar to that of Mole National Park in Ghana where 131 species of birds have been recorded [29]. On the other hand, 379 birds species were identified of in the Waza area and in the flood zone of the Logone River, including more than 71 species of waterbirds, of which about twenty were migratory [17]. Indeed, the same authors point out that the presence of a watercourse in Waza area attracted species of aquatic birds, which was not the case with the RFK. Forest reserves, although initially created for the preservation of plant species, are home to many species of birds [30].

The KFR and its peripheral zone had in common 64% of the avian specific richness and the diversity of birds observed in the peripheral area of the reserve was the greatest. The difference observed between the two bird communities could be due on the one hand to the fact that the peripheral area is less protected compared to the KFR which has the status of a protected area (PA). On the other hand, the KFR's terrain seemed to be more heterogeneous in plant and animal species diversity compared to its peripheral zone. This thus allowed an increase in avian diversity [31]. The comparison of the species richness between protected areas with areas not classified as PA showed that PAs have a higher specific richness compared to unclassified areas [32]. The KFR, according to this result showed that it continues to play its role in the maintenance of ecosystems,

in the protection of the avian fauna that it shelters compared to its peripheral zone not classified as protected area. This is a strong signal showing the importance of integrating unprotected areas into a rational land management plan for the sustainable conservation of bird species.

The observed avian diversity varied depending on the habitat, and it was greater in the wooded savannah. Several studies have showed that plant habitat types play an essential role in the structuring of bird communities [33]. Indeed, it has been shown that diversity is greater in stable, undisturbed environments, and weaker in environments which are subject to disturbances linked to human activity and various ecological constraints [32]. Vegetation cover was greater in wooded savannahs compared to other plant formations. Many studies already showed that the species richness and avian diversity decrease with the decrease in plant cover due to the fact that the destruction of the natural habitat left a depleted plant growth which in turn allowed only species often resistant generalists or resilient species to persist in this medium [34]. The same authors revealed that opening up the vegetation cover following environmental degradation can also expose birds to predators.

The estimate of 35 species not encountered in this study would be justified by the choice of the sampling period (only part of the dry and rainy seasons), and the sampling method (direct observation and use of mist nets only). Species richness and diversity of birds were greater in the dry season, compared to those in the rainy season, although no significant difference was observed. However, several authors have shown that the seasons greatly influence avian diversity and communities [35] [36], with more birds during the rainy season. This result can also be explained by the fact that the inventory work was carried out at the start of the dry season (availability of food, water resources, abundance of off-season crops), *i.e.* 4 months out of the 9 what is in our study area.

The various human activities carried out in the study area seem to have no effect on the specific richness and diversity of birds. However, it is known that the habitat degradation strongly affects bird communities [37] [38]. Human activities such as deforestation, the creation of plantations, poaching and grazing have negative impacts on avian fauna [39]. Some species seemed to be more tolerant of human activities, most of which were generalist. There are some species that would benefit from habitat degradation, while others would be negatively affected [40].

Our study showed the presence of birds with several phenological groups, most of which are sedentary (59.52%), migratory (13.49%) and Palaearctic (7.14%). Gajera *et al.* (2013) found the same result according to which sedentary birds are the most represented [41]. The biogeographical position and structure of habitats are some of the causes that favour the appearance of certain species of birds [41]. This study revealed that the study area is very important for migratory bird species in addition to sedentary birds. The search for food is thought to be the primary cause of bird migration [42] [43]. Some authors also claim that it is the bird's diet that determines in particular its sedentary or migratory charac-

ter. Indeed, the study area is heterogeneous in nature. It is full of insects like locusts, mosquitoes, flies, etc. serving as food for insectivore birds. This area has great floristic potential for nutrition, shelter and nesting birds. The presence of palearctic migrants in this study area showed that the environment is favourable for the protection of these species threatened by climate change and therefore constitutes a place of refuge for them [44].

Implications for Conservation

This ornithological inventory was the first to be carried out in the Kalfou Forest Reserve and its peripheral zone. The birds of the study area were mostly dependent on forest ecosystems which were degraded giving way to agro-ecosystems, pastoral practices and human habitation. It is known that the structure of vegetation and its level of disturbance play an important role in the diversity and distribution of species. The threats encountered on avifauna during this inventory were essentially grouped into five (05) types: agricultural activities, pastoral activities, deforestation, poaching and camping. The most common anthropogenic activity (threat) was that of pastoralism and the least encountered was camping. The high diversity of bird species observed within the Reserve showed that it is relatively more protected. There was also a strong diversity in the peripheral zone where there has been significant reforestation. To better conserve this bird diversity, the maintenance of ecosystems is highly desirable. The following actions can be undertaken within the Forest Reserve: anti-poaching, ban on grazing and reforestation. Several endangered species and migratory species were encountered both inside and outside the Reserve, which suggests that conservation efforts should not be limited only to protected areas but also consider unprotected areas with diverse species, with much more comprehensive action needed taken for migratory birds. This study also identified the various potential ecosystems for the valuation and conservation of birds that must be taken into account in the development and conservation plans of natural resources in order to identify with precision the areas for ornithological tourism.

5. Conclusion

The avifauna of the Kalfou area is rich and diverse. Monitoring aspects of biodiversity richness and diversity as well as species composition is important to manage ecosystem functions and services that benefit humanity. Our study explores data sets and ways in which species richness and diversity can be monitored across and between habitats, and seasons using species accumulation curves. This study also provides a tool to monitor bird spatio-temporal changes in the environment, and the information can then be used to manage and improve bird conservation at local, regional and international levels, given that a large part of Kalfou's avian fauna is common to much of West, Central and East Africa. Many migratory and Palearctic bird species are also found there.

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Conflicts of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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