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RESEARCH ARTICLE

DIVERSITY AND DISTRIBUTION OF BIRDLIFE ACCORDING TO VEGETATION TYPE AND SEASONS IN TWO DIFFERENT AREAS IN THE EQUATORIAL CLIMATE OF THE CONGO BASIN REGION: THE MOUANKO MANGROVE AND THE EDEA II EVERGREEN FOREST IN CAMEROON (LITTORAL, REGION)

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Abstract

In Cameroon, bird studies are increasingly well-known and often quite long-established. In recent years, several studies have been conducted in various areas across the country. To further update knowledge about Cameroonian avifauna, a study was carried out in the evergreen forest of Edea II and the mangrove of Mouanko,in the Sanaga-Maritime department, Littoral Region. The Japanese mist netting method was used to capture birds between December 2022 and December 2024. PAST (v5.2.1), R Studio (v4.1.2), and Excel (2016) software were used to perform statistical analyses on the distribution and diversity of avifauna in thesetwo areas within the department. A total of 643 individuals were captured, belonging to 10 orders, 28 families, 59 genera, and 92 species.Our results showed that passerines were more abundant (83.2%) than non-passerines (16.8%). The most abundant and diverse familywas the Pycnonotidae, with 7 genera and 12 species. The calculated diversity indices indicated that the avifauna of the overall study area is quite diverse (H' = 3.81), and our results show no dominance of any single species (1-λ = 0.95), with an equal distribution of individuals within each species (J' = 0.83). It should be noted that the evergreen forest was more abundant and diverse than that of the mangrove (S=87 and H'=3.70 vs S=47 and H'=3.64).

Similarly, the avifauna of the evergreen forest was more abundant and diverse in the first year than in the second, while the opposite was true for the mangrove. Furthermore, the analysis of avifauna distribution according to

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seasons showed no significant difference (p=0.14), whereas vegetation showed a significant difference (p=0.0019), indicating that the habitats are not similar.

Introduction:-

Cameroon is located in the Congo Basin region in which the climate is a mixture of equatorial and tropical climate, with the northern part under the tropical climate while the southern part is under the equatorial climate (Suchel,1988; Nguembock, 2008). Cameroon is also one of the countries in the world which presents a very great diversity of vegetation, at least nine different types of vegetation (equatorial forest, Guinean savannah, savannah forest mosaic, Sudanese savannah,mandara, sahel, floodplain, and mountainous region), and often this vegetation appearsmore abundant in mountain than in plain regions (Letouzey, 1985; Stuart, 1986;Nguembock, 2008; Nguembock et al.,2020).Only contrary to mountains, the plain is a biogeographical domain without relief and we mainly find in Cameroon the northern lowlands, some parts of the southern Cameroonian, and Adamawa plateau; the Mouanko and Edea II plains belongs to the coastal plains and contrary to the northern lowlands, it is covered in places with rich forest vegetation (Letouzey, 1985; Stuart, 1986; Nguembock et al.,2020).

Birds play a variety of roles: pollination, seed dispersal, regulation of insect populations, biological indicators of habitat health, and more. In tropical regions, these roles are even more pronounced due to species richness and the complexity of ecological interactions (Green et al., 2002; Green and Elmberg, 2014; Amano et al., 2018; BirdLife International, 2022; Kafando et al., 2023). The spatial distribution of bird species, their reproductive success, and their survival are influenced by the availability of key resources, including food, water, vegetation cover, and weather conditions (Lee et al., 2012; Adhikari et al., 2020). It is also worth noting that the seasonality is an important factor influencing avian diversity and the availability of key resources (Katuwal et al., 2016).

Cameroon has a great diversity of birds with 974 species distributed among 27 orders and 105 families (Lepage, 2024). Furthermore, in Cameroon, it is documented that there are also 11 endemic bird species (*Ploceusbannermani* Chapin, 1932; *Tauracobannermani* Bates, 1923; *Telophoruskupeensis*Serle, 1951; *Apalis Bamendae* Bannerman, 1922; *Platysteiralaticincta* Bates, 1926; *Ploceusbatesi* Sharpe, 1908; *Turdoidesgilberti* Serle, 1949; *Melichneutesrobustus* Bates, 1909; *Laniariusatroflavus* Shelley, 1887; *Pternistiscamerunensis* Alexander, 1909; *Zosteropsmelanocephalus*, Gray, 1862) (Fotso et al., 2001; Lepage, 2024).In the Sanaga-Maritime department where the areas in which our study was conducted, this geographical area presents a rich diversity with 339 species of birds (resident and migratory) distributed in 22 orders and 74 families (Lepage, 2024).

Furthermore, several studies have been conducted on birds in Cameroon (Louette, 1981; Nguembock et al., 2017, 2020; Mahamat, 2023; Nguembock et al., 2023; Azang et al., 2024). However, very few studies have been carried out in the coastal plain, particularly in the Sanaga-Maritime department (Louette, 1981; Fotso et al., 2001; Tchana, 2020). Yet, this ecosystem has ecological, biological, and economic importance (MINEPDED, 2017). The impact of human activities on the floristic structure of mangroves in the Cameroonian estuary is reflected in variations in density, tree height, and individual diameter depending on the degree of disturbance (MINEPDED, 2017).

More generally, the diversity, abundance and distribution of birds are also influenced by foraging opportunities at suitable nesting sites within various land cover types, including forests, shrublands, grasslands, wetlands, agricultural land, and urban areas (Price et al. 2014; Hu et al. 2017). However, in different regions of Cameroon, data are virtually non-existent for several ecosystems. This is the case for the Mouanko mangrove area and the Edea II evergreen forest, where several gaps remain, notably the lack of accurate and up-to-date data, particularly, the species present, their abundance, their migratory regime, and their sensitivity to human disturbances.In this study, we primarily pursued two objectives: firstly, we studied in depth the avifauna of these different areas, the diversity and composition of bird populations in the Mouanko and Edea II areas. Secondly, we analysed the distribution of birds according to seasons and habitats (evergreen forest and mangrove), comparing the different areas andthereby highlighting revealing trends and patterns.

Materials and Methods:-

Description of the study sites:-

Several study areas were investigated: Yoyo I (Os2) (N 03°64.889' E 09° 64.761') and Yoyo II (Os1) (N 03°66.635' E 09° 64.183') in the commune of Mouanko. In the commune of Edea II, the study areas were Ekite (Os3) (N 03° 80.356', E 10° 08.678') and Malimba (Os4) (N 03°84.920', E 10° 10.724') (Figure 1). These communes are located in the Sanaga-Maritime department of the Littoral Region. The climate of the Sanaga-Maritime department is equatorial, with four seasons (two dry seasons and two rainy seasons). Average annual rainfall varies between 3,000 and 4,000 mm (CWCS, 2004), and average monthly temperatures range from 24.6°C to 28.7°C (Suchel, 1988; Fometé and Tchanou, 1998). The terrain is relatively flat, characterized by coastal plains, hills, and riverine areas, with elevations ranging from 0 to 120 m, the highest point being at Olombe (Nlomo, 2000, cited in Kouam 2012). The vegetation found is Atlantic evergreen rainforest, which occupies a coastal strip extending up to 200 km inland (Figure 2). It includes firstly the coastal forest on sandy plains, with locally particularly dense mangrove forest and tall stands (Figure 2). This area is heavily affected by forestry operations, but also by industrial plantations (oil palm, rubber) and food crops (Letouzey, 1985; Oliry 1986; Ajonina, 2010).

Investigation of the Mouanko and Edea II avifauna:-

During the bird survey in the Mouanko and Edea II sites, we used the mist-netting method, employing dark-coloured nylon nets with three vertical pockets running horizontally along the length of the net. This method is suitable for capturing small and medium-sized birds such as passerines. Our mist nets were fixed with the mounting poles, which had been chosen carefully, and the choice of an appropriate mist-netting site was important for the capture success. In order to ensure the capture success, we mainly identified their preferred flight paths, feeding areas, roosting and shaded sites. Generally, we started our capture very early in the morning (5:00 a.m.) and we finished very late in the evening (sometimes 6:30 p.m.). In order to avoid a skew in our bird survey, we used the same seven (7) mist nets in our different field mission and we captured in the same transects across the different seasons. Furthermore, we conducted eight (8)field missions (of three days each for a total of 64 field surveys) over 24months (December 2022 to December 2024). Thus, eight linear transects, 1000 m long and 100 m wide, were used, comprising four in Mouanko and four in Edea II (Figure 1). To avoid cases of recapture, no transect was made twice in the same season. The identification manuals used were those of Borrow and Demey (2004, 2015).The captured and identified birds were then released at or near the capture sites.

Analysis of diversity and composition of the avifauna in the Mouanko and Edea II:-

Method for the calculation of abundance and occurrence of avifauna of Mouanko and Edea II:-

We used Excel program in order to calculate the relative abundance and the occurrence. We entered data and ran the software until the results were obtained.

Estimation of specific richness and calculation of the sampling effort:-

The estimate of species richness was calculated from estimators including Jackknife 1 and Jackknife 2, Chao 1, Ace and Boostrap. 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:

$$\mathbf{E} = \left(\frac{\text{Number of observed species}}{\text{Number of estimated species}}\right)100$$

Diversity indexes:-

Shannon index (**H'**):Shannon's diversity index represents the measure of the sum of degree of the uncertainty when it suggests prediction 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 maximum value $\log_2 S$ only when all species are represented by the same number of individuals. This index is determined by the following relationship:

$$\mathbf{H'} = -\sum_{i=1}^{s} \mathbf{P_i \log_2(P_i)}$$

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 v5.2.1 software program.

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. 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**); both have also been called the Simpson index in the ecological literature. In our study, the Simpson index was calculated with the PAST v 5.2.1 software.

Analysis of distribution of the avifauna in the Mouanko and Edea II:-

Equity index: the Equitability index measures the distribution of individuals within species independently of specific richness. Its value varies from 0 (dominance of one species) to 1 (equal distribution of individuals within species).

Thus, the Equitability index of Pielou (J') is determined by the following formula:

$$J = \frac{H'}{H'max} = \frac{-\sum_{i=1}^{s} P_i \log_2(P_i)}{\log_2(S)}$$

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 v5.2.1software.All these indexes have been obtained with a confidence threshold of 95%.

Comparison of the two sites with Permanova and pairwise Mann-Whitney tests:-

Shapiro-Wilk test:-

Before choosing the appropriate tests to compare the distribution of taxa within the habitats investigated, the Shapiro-Wilk test

- if $p \geq 0.05$: the distribution is considered normal;
- if $p < 0.05$: the distribution is considered non-Gaussian.

Mann-Whitney U test:-

Since the distribution did not follow a normal distribution and only two habitat types were observed (mangrove and evergreen forest), the Mann-Whitney U test was used to compare the distribution of taxa according to two environmental parameters (vegetation and seasons) between the two habitat types, under the following hypotheses:
H0: the distributions are identical;
H1: the distributions are different.

Permanova test:-

This is a non-parametric multivariate test used to compare biological communities between different sites, seasons, or treatments. It tests whether the differences between groups are significantly greater than those within groups. It is based on the distances between samples (Anderson, 2001) and relies on the dissimilarity matrix. A multivariate permutation analysis of variance (Permanova) was used to test differences in composition per survey between climatic seasons. A Permanovawas also used to test differences in avian composition per survey based on vegetation type (evergreen forest and mangrove). If the communities within the groups are different, F-value is high and $P < 0.05$). If the communities are very similar, F-value is low and $P > 0.05$. In our study, these three tests have been done with the PAST v5.2.1 software; we entered data as described in the user guide and ran software until the results were obtained.

Results:-

Specific Richness of the avifauna of the Mouanko and the Edea II:-

Research work in the forest (Edea II) and mangrove (Mouanko) areas helped to obtain 643 individuals captured with Japanese nets. These 643 individuals were distributed among 10 orders, 28 families, 59 genera and 92 species (Table I).Of the taxa inventoried, 83.20% belong to the order Passeriformes and 16.8% to non-Passeriformes (Accipitriformes, Charadriiformes, Coliiformes, Columbiformes, Coraciiformes, Cuculiformes, Passeriformes, Piciformes, Strigiformes, Suliformes) (Table I).

The Table II shows that the occurrence frequencies of the species captured in the study area varied from 1.6% to 68.8%. Only one regular species was recorded: *Eurillasvirens* (68.8%). four (04) species were considered incidental: *Eurillaslatirostris* (42.2%), *Ploceusnigricollis* (48.4%), *Cyanomitraolivacea* (26.6%) and *Pycnonotus barbatus* (28.1%). The accidental species were *Buccanodonduchaillui* (7.8%), *Chlorocichlafalkensteini* (7.8%), *Cinnyrischloropygius* (9.4%), *Camaropterabrachyura* (12.5%), *Cossyphaniveicapilla* (14.1%), and *Chlorocichla simplex* (15.6%). The rare species were the most numerous totalling 60 species (*Accipiter castanilius*, *Acrocephalusarundinaceus*, *Alethecastanea*, *Chrysococcyxklaas*, *Pogoniulusatroflavus*, *Eurillasgracilis*, *Hyliaprasina*, *Cisticolabulliens, Sylviettadenti, Alcedoquadribrachys, Psalidoprocnenitens, Gymnobuccobonapartei, Turturafer, Hirundorustica, Phyllastrephusicterinus*, *Tringastagnatilis, Fraseriacinerascens,* etc.) (Table II).

The capture of taxa using mist nets allowed for the inventory of 643 individuals belonging to 92 species across different sites. The Edea II forest area yielded 272 individuals grouped into 80 species (2023) and 170 individuals grouped into 39 species (2024). Meanwhile, the Mouanko mangrove area yielded 121 individuals belonging to 44 species in 2023 and 80 individuals grouped into 41 species in 2024. The most abundant species were *Eurillasvirens* with 108 individuals (16.80%), *Eurillaslatirostris* (6.38%), *Cyanomitraolivacea* (4.67%). The least abundant species were *Accipiter castanilius*, *Alethediademata*, and *Cisticolaanonymus*, each at 0.16% (Table II). Of the 92 species captured using Japanese nets, four (04) are Palearctic migrants (*Acrocephalusarundinaceus, Hirundorustica*, *Saxicolarubetra*, and *Tringastagnatilis*), whereasseven (07) are intra-African migrants (*Cecropissemirufa, Cecropisabyssinica, Halcyon leucocephala, Ispidinapicta, Meropsalbicollis, Psalidoprocnepristoptera, and Terpsiphoneviridis*) (Table II).

Sampling effort:-

Taking into account the specific richness at the different sectors of the study area, the estimators: Chao1 (105.92), Jackknife1 (117.5), Jackknife2 (127.83), Ace (110.11) and Bootstrap (104.09) gave an average of 113.09 species, which corresponds to approximately 113 species. The number of species observed being 92, the estimators therefore show that 21 species (113 estimated -92 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 81.41%.

Diversity indices:-

Birddiversity across different study areas:

The Table III, the data shows the diversity indices for the different sites within the area. The Simpson index is 0.94 in the Edea II forest area; 0.96 in the Mouanko area; and 0.95 across the entire study area. The Shannon index values are 3.7, 3.64, and 3.81 in the Edea II, Mouanko, and overall study areas, respectively. The Pielou evenness index is 0.81 in Edea II; 0.92 in Mouanko; and 0.83 for the entire site. The species richness of the different sites is 80, 39, and 87 in the forest environments (Edea II 2023, 2024, and overall forest), 44 and 41 in the mangrove (2023 and 2024), and 92 in the study area.

Bird diversity indices by season:-

Regarding the seasons, the short dry season was the most diverse species (forest 2023, 2024 and mangrove 2023) and the most abundant in individuals (forest 2023 and 2024). The lowest diversity was observed in the forest in 2024 during the long dry season (LDS) (H=2.02), followed by the short rainy season (SRS) in the 2024 forest (H'=2.27). Conversely, in the mangrove, the lowest diversity was observed during the short rainy season in 2024 (H=1.63), followed by the short rainy season in 2023 (SRS) (H'=2.29).

Analysis of distribution of the avifauna in the Mouanko and Edea II:-

Regarding the overall Evenness index,in 2023 the Equitability index was 0.86 in forest while it was 0.90 in mangrove; however, in 2024 it was 0.80 in forest while it was 0.95 in mangrove (Table III).

Comparison of the two sites with the Shapiro-Wilk, Mann-Whitney U and Permanova tests:-

By applying the Shapiro-Wilk test to our data, we obtained for each habitat type, a p-value below the 5% threshold, confirming that the data collected did not follow a normal distribution; thus, the null hypothesis is rejected. The Mann-Whitney U test confirms the existence of a significant difference between the abundance distributions of the two bird samplesfrom the two investigated habitats (Edea II evergreen forest and Mouanko mangrove) because p is less than 0.05 (0.021) (Table IV).

Furthermore, the Permanova test shows that the analysis of the avifauna distribution according to seasons showed no significant difference (p=0.14)nor the interaction between these two environmental parameters (p=0.73), whereas the vegetation showed a significant difference (p=0.0019) between these two habitat types (Table V).

Discussion:-

The study conducted in the study area showed a high representation of passerines (83.20%) compared to non-passerines (16.80%) (**Table I).** This result is similar to previous research conducted in Cameroon across the various habitats investigated, including forest, savanna, and mountain areas (Louette, 1981; Fotso et al., 2001; Nguembock et al., 2017, 2019a, 2019b; Tchana, 2020; Nguembock et al., 2020; Kendeg, 2021; Mahamat, 2023; Odoukpe et al., 2023; Azang et al., 2024). This high abundance of passerine birds can be explained primarily by their short incubation period, allowing them to multiply rapidly during the breeding season, especially when food resources are readily available. Secondly, by their strong representation on the globe (Noske and Franklin, 1999; Auer et al., 2007).

The largest families were the Pycnonotidae, followed by the Nectariniidae and Alcedinidae, which were the most prevalent. This result corroborates the findings of several authors (Fatcheu, 2018; Kendeg, 2021; Azang et al., 2024) whose work has shown that forests are a favorable environment for birds. Furthermore, families such as the Pycnonotidae and Nectariniidae prefer open areas and secondary forests, primarily due to the availability of their food resources (Akinsola and Oluseye, 2004; Okosodo et al., 2016). Furthermore, of the 28 families identified, the most diverse were the Pycnonotidae (7 genera and 12 taxa), followed by the Lybiidae (6 genera and 9 taxa), Muscicapidae (6 genera and 8 taxa), Cisticolidae, and Estrildidae (4 genera and 5 taxa). This result is similar to those of Tchana (2020), Kendeg (2021), and Azang et al. (2024), which demonstrate that rainforests are highly diverse due to the presence of numerous resources such as food availability, varied microhabitats (canopy, lianas, epiphytes, etc.), understory, forest soil and others they contain.

Specific presentation of the birdlife of the study area:-

The Edea II site (2023) was the most abundant and diverse. However, in 2024, Edea II was less diverse (39) and less abundant (170). Meanwhile, the Mouanko area in 2023 was less abundant (121) than Edea II but more diverse (44) than Edea II (2024). The Mouanko area in 2024 was also more diverse (41) than the forest in 2024 but the least abundant (80). Overall, the evergreen forest area of Edea II was more diverse and more abundant than the mangrove area of Mouanko. This result corroborates the work of Essayas and Bekele (2011), who state that the abundance of birds in the forest is due to the diverse habitats it offers to different species. This could be attributed to the greater and more varied presence of food, nesting, and play resources that evergreen forests provide compared to mangroves. Regarding landscape composition, the forest ecosystem, particularly evergreen forest, with its shrubsand undergrowth, has a positive impact on birdlife (Wang, 2024). The results of our analyses showed *Eurillasvirens* (68.8%) as a regular species, and several accessory species including *Eurillaslatirostris* (42.2%), *Ploceusnigricollis* (48.4%); *Cyanomitraolivacea* (26.6%) and *Pycnonotus barbatus*(28.1%). This result is similar to that of Azang et al. (2024), who conducted an inventory in the rainforests of the upper Nyong River valley. This could be explained by the presence of diverse habitats (evergreen rainforests, agricultural areas, etc.) that provide sufficient resources for all taxa (Azang et al., 2024).

Diversity indices and distribution of the study area:-

The diversity indices obtained indicated that the study area is diverse. Generally, a Simpson index value of 0.95 indicates an absence of any one species dominating the others. This result is similar to that of Bunza et al. (2021), who conducted a study in swamp forests and mangroves with varied habitats in Nigeria. This finding corroborates the work of Nguembock et al. (2023) and Azang et al. (2024), who carried out their studies in the Central,and Central and Eastern Regions of Cameroon, respectively. Similarly, MacArthur and MacArthur (1961) emphasize the importance of forest habitats for preserving birdlife, as they provide complex community structures, abundant food resources, and suitable nesting sites, while mitigating anthropogenic disturbances. A value of 3.81 for the Shannon index confirms the diversity of the study area (Table III). This result is similar to that of several authors (Tchana, 2020; Abassa, 2021; Nguembock et al., 2023; Mahamat, 2023; Nubuya et al., 2023; Azang et al., 2024). This diversity could be explained by low competition between taxa due to the presence of varied habitats and diverse and abundant resources in the forest and mangrove zone. The Pielou Evenness Index value of 0.83 indicates an even distribution of individuals among the taxa. This result corroborates those of several authors (Abassa, 2021; Bunza, et al., 2021; Nguembock et al., 2023; Mahamat, 2023; Nubuya et al., 2023; Azang et al., 2024), and could explain the diversity of habitats and resource abundance, such as the presence of readily available water (rivers, streams, and the sea) and food resources, are important factors.

Chace and Walsh (2006) showed that birds respond to changes in vegetation composition and structure, which influence their food resources. The habitats were ranked as follows: forest (2023) was the most diverse (H = 3.9; J = 0.86), followed by mangrove (2024) (H = 3.77; J = 0.95), followed by mangrove (2023) (H = 3.6; J = 0.90), and forest (2024) was the least diverse (H = 3.03; J = 0.79). Overall, forest (H = 3.70; J = 0.81) was more diverse than mangrove (H = 3.64; J = 0.92), but there was a slightly more even distribution of birds in forest compared to mangrove. These results are similar to those of several authors (Abassa, 2021; Bunza, et al., 2021; Nguembock et al., 2023; Mahamat, 2023; Nubuya et al., 2023; Azang et al., 2024). Louette (1981), and Earnst and Holmes (2012) state that the distribution of birds is linked to vegetation (Table III).

Comparison of the two sites with Permanova and pairwise Mann-Whitney tests:-

The results of the analysis performed with the test Mann-Whitney U tests in the different site comparisons (evergreen forest vs. mangrove) showed a significant difference (Table IV). Similarly, analyses performed with two-way PERMANOVA revealed a significant difference between the habitats (evergreen forest vs. mangrove). This demonstrates a slight but significant variation in community structure. These results indicate overall heterogeneity across the entire study site (Table V). This could be due to the fact that the birds share the same biotopes and move throughout the study area, as well as the presence of year-round available resources and the absence of intraspecific competition between taxa. It should also be noted that the presence of evergreen vegetation throughout the year would provide permanent refuge for the different birds. Thus, Telleria and Santos (1994) emphasized that habitat structure influences species distribution. Furthermore, habitat size (Willis, 1979), feeding patterns (Marone, 1991) and floristic composition (Wiens and Rotenberry, 1981) also have an impact on species distribution.

Similarly, analyses carried out with Permanova, taking into account seasonal variations across different sites, showed no significant differences in the forest and mangrove areas (Table V). This could be due to the availability of resources (food, nesting sites, shelter, etc.) throughout the year. The equatorial climate with four seasons is favourable to the flourishing of birds year-round. This contrasts with findings from subtropical monsoon climates, which force some species to migrate, particularly in winter, or reduce their movements in summer (Nepali et al., 2021). Likewise, our results differ from those of Zean (2022) conducted in Ivory Coast, where the dry season appears to be the least favourable. Indeed, the dry season also coincides with the drying out of annual plants bordering bodies of water and the occurrence of bushfires (Poilecot and Loua, 2009); seasonal bird populations vary very little within each site. Similarly, several authors have demonstrated that seasonal variations influence bird abundance and distribution (Katuwal et al., 2016; Nepali et al., 2021; Zean, 2022). Furthermore, the results of our work show that the seasons do not correlate with the distribution of birdlife in the evergreen forest and the mangrove. These results are similar to those of several authors (Lefebvre, 1994; Lefebvre and Poulin, 1997; Mohd-Azlan, 2014) who show that few resources change drastically from one season to the next, that populations are stable, and that mangroves are used.

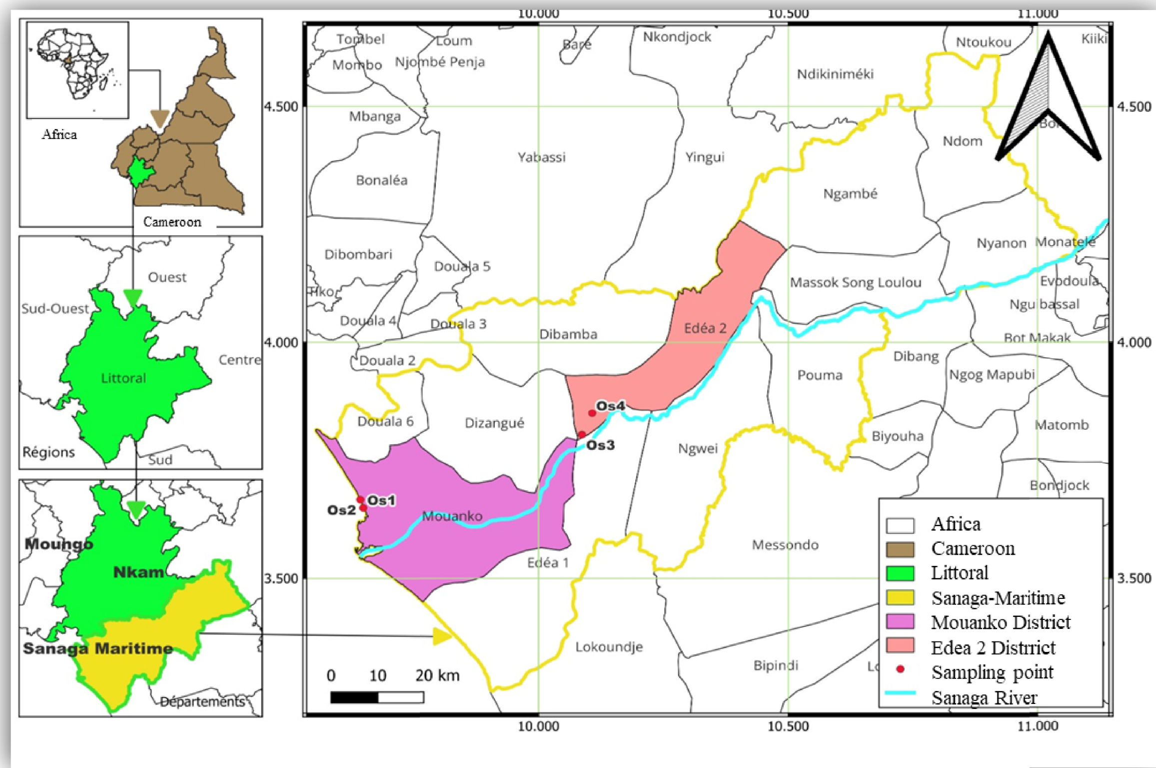

Fig 1: Geographical location of the study site.

(a)

(b)

Fig 2: Different types of habitats (a)=Evergreen forest(Edea II) and (b)=mangrove(Mouanko)

Table I: orders, families, genera, species and absolute abundance of the study area

Orders	Families	Genres	Species	Abundances
Accipitriformes	1	1	1	1
Charadriiformes	1	1	1	2
Coliiformes	1	1	1	2
Columbiformes	1	1	2	9
Coraciiformes	2	4	7	64
Cuculiformes	1	1	1	2
Passeriformes	17	41	67	535
Piciformes	2	7	10	25
Strigiformes	1	1	1	1
Suliformes	1	1	1	2
Total	**28**	**59**	**92**	**643**

Table II: Frequency of occurrences and biogeographical statuses

No.	Species	Occurrence forest	Occurrence mangrove	Frequency of occurrence %	Absolute abundance forest	Absolute abundance mangrove	Total Absolute abundance	Total relative abundance% (RA%)	biogeographical status (Borrow and Demey, 2015)	IUCN status (2025)	MINF OF status (2020)
1	*Accipiter castanilius* Bonaparte, 1853	1	0	1.6%	1	0	1	0.16%	S	LC	B
2	*Acrocephalusarundinaceus* Linnaeus, 1758	1	2	4.7%	1	3	4	0.62%	P	LC	C
3	*Acrocephalusrufescens* Sharpe and Bouvier, 1877	1	2	4.7%	1	3	4	0.62%	S	LC	C
4	*Alcedoquadribrachys* Bonaparte, 1850	1	1	3.1%	1	1	2	0.31%	S	LC	C
5	*Alethecastanea*Cassin, 1856	2	0	3.1%	2	0	2	0.31%	S	LC	C
6	*Alethediademata* Bonaparte, 1850	1	0	1.6%	1	0	1	0.16%	S	LC	C
7	*Bledanotatus* Cassin, 1856	7	1	12.5%	30	1	31	4.82%	S	LC	C
8	*Buccanodonduchaillui* Cassin, 1855	2	3	7.8%	2	3	5	0.78%	S	LC	C
9	*Butoridesstriata* Linnaeus, 1758	0	2	3.1%	0	2	2	0.31%	S	LC	C
10	*Camaropterabrachyura*Vieillot, 1821	5	3	12.5%	8	5	13	2.02%	S	LC	C
11	*Cecropisabyssinica*Guérin-Méneville, 1843	1	0	1.6%	1	0	1	0.16%	M	LC	C
12	*Cecropissemirufa*Sundevall, 1850	2	0	3.1%	2	0	2	0.31%	S/M	LC	C
13	*Chamaetylaspoliocephala* Bonaparte, 1850	1	0	1.6%	1	0	1	0.16%	S	LC	C
14	*Chlorocichlafalkensteini*Reichenow, 1874	2	3	7.8%	2	4	6	0.93%	S	LC	C
15	*Chlorocichlaflaviventris* Smith, 1834	2	2	6.3%	3	2	5	0.78%	S	LC	C
16	*Chlorocichla simplex*Hartlaub, 1855	6	4	15.6%	8	6	14	2.18%	S	LC	C
17	*Chrysococcyxklaas* Stephens, 1815	2	0	3.1%	2	0	2	0.31%	S	LC	C
18	*Cinnyrisbatesi* Ogilvie-Grant, 1908	6	5	17.2%	11	7	18	2.80%	S	LC	C
19	*Cinnyrischloropygius*Jardine, 1842	3	3	9.4%	5	4	9	1.40%	S	LC	C

20	*Cinnyriscupreus* Shaw, 1812	3	2	7.8%	5	2	7	1.09%	S	LC	C
21	*Cinnyrissuperbus* Shaw, 1812	1	0	1.6%	2	0	2	0.31%	S	LC	C
22	*Cisticolaanonymus* Müller, 1855	1	0	1.6%	1	0	1	0.16%	S	LC	C
23	*Cisticolabulliens*Lynes, 1930	2	0	3.1%	2	0	2	0.31%	S	LC	C
24	*Clytospizamonteiri*Hartlaub, 1860	1	0	1.6%	1	0	1	0.16%	S	LC	C
25	*Coliusstriatus*Gmelin, 1789	2	0	3.1%	2	0	2	0.31%	S	LC	C
26	*Cossyphaniveicapilla*Lafresnaye, 1838	6	3	14.1%	8	4	12	1.87%	S	LC	C
27	*Crinigercalurus*Temminck, 1820	1	0	1.6%	1	0	1	0.16%	S	LC	C
28	*Cyanomitracyanolaema* Jardine and Fraser, 1852	3	0	4.7%	4	0	4	0.62%	S	LC	C
29	*Cyanomitraolivacea* Smith, 1840	12	5	26.6%	22	8	30	4.67%	S	LC	C
30	*Cyanomitraverticalis* Latham, 1790	1	2	4.7%	1	2	3	0.47%	S	LC	C
31	*Elminialongicauda*Swainson, 1838	1	0	1.6%	2	0	2	0.31%	S	LC	C
32	*Estrildamelpoda*Vieillot, 1817	2	0	3.1%	4	0	4	0.62%	S	LC	C
33	*Estrildanonnula*Hartlaub, 1883	2	1	4.7%	3	1	4	0.62%	S	LC	C
34	*Euplectesmacroura*Gmelin, 1789	1	2	4.7%	1	2	3	0.47%	S	LC	C
35	*Eurillasgracilis*Cabanis, 1880	2	0	3.1%	2	0	2	0.31%	S	LC	C
36	*Eurillaslatirostris* Strickland, 1844	19	8	42.2%	33	8	41	6.38%	S	LC	C
37	*Eurillasvirens* Cassin, 1857	28	16	68.8%	83	25	108	16.80%	S	LC	C
38	*Fraseriacinerascens*Hartlaub, 1857	1	0	1.6%	1	0	1	0.16%	S	LC	C
39	*Gymnobuccobonapartei*Hartlaub, 1854	1	0	1.6%	1	0	1	0.16%	S	LC	C
40	*Halcyon leucocephala* Müller, 1776	2	2	6.3%	4	2	6	0.93%	M	LC	C
41	*Halcyon malimbica* Shaw, 1812	5	4	14.1%	6	4	10	1.56%	S	LC	C
42	*Halcyon senegalensis* Linnaeus, 1766	2	5	10.9%	3	7	10	1.56%	S/M	LC	C
43	*Hirundorustica* Linnaeus, 1758	0	1	1.6%	0	1	1	0.16%	P	LC	C
44	*Hyliaprasina* Cassin, 1855	2	0	3.1%	2	0	2	0.31%	S	LC	C
45	*Ispidinapicta*Boddaert, 1783	7	4	17.2%	14	5	19	2.95%	M	LC	C
46	*Ketupapoensis* Fraser, 1854	1	0	1.6%	1	0	1	0.16%	S	LC	C
47	*Laniariusaethiopicus*Gmelin, 1789	1	0	1.6%	1	0	1	0.16%	S	LC	C
48	*Lybiusvieilloti* Leach, 1815	1	0	1.6%	2	0	2	0.31%	S	LC	C
49	*Malaconotuscruentus* Lesson, 1831	1	2	4.7%	1	2	3	0,47%	S	LC	C
50	*Meropsalbicollis*Vieillot, 1817	1	4	7.8%	1	6	7	1.09%	M	LC	C
51	*Meropspusillus* Müller, 1776	3	3	9.4%	7	3	10	1.56%	S	LC	C
52	*Muscicapasethsmithi*Someren, 1922	1	0	1.6%	1	0	1	0.16%	S	LC	C
53	*Muscicapastriata* Pallas, 1764	2	0	3.1%	2	0	2	0.31%	M	LC	C
54	*Neocossyphuspoensis*Strickland, 1844	8	2	15.6%	10	2	12	1.87%	S	LC	C
55	*Nicatorchloris*Valenciennes, 1826	1	0	1.6%	1	0	1	0.16%	S	LC	C
56	*Nicator vireo*Cabanis, 1876	0	3	4.7%	0	3	3	0.47%	S	LC	C
57	*Pardipicuscaroli* Malherbe, 1852	1	0	1.6%	2	0	2	0.31%	S	LC	C
58	*Passer griseus*Vieillot, 1817	1	2	4.7%	1	2	3	0.47%	S	LC	C
59	*Phyllastrephusicterinus* Bonaparte, 1850	2	0	3.1%	2	0	2	0.31%	S	LC	C
60	*Phyllastrephusxavieri*Oustalet, 1892	1	4	7.8%	1	4	5	0.78%	S	LC	C
61	*Platysteiracastanea* Fraser, 1843	4	0	6.3%	5	0	5	0.78%	S	LC	C
62	*Platysteirachalybea*Reichenow, 1897	1	0	1.6%	1	0	1	0.16%	S	LC	C
63	*Platysteiracyanea* Müller, 1776	4	4	12.5%	6	5	11	1.71%	S	LC	C

64	*Ploceuscucullatus* Müller, 1776	12	1	20.3%	18	2	20	3.11%	S	LC	C
65	*Ploceusnigerrimus*Vieillot, 1819	12	3	23.4%	15	4	19	2.95%	S	LC	C
66	*Ploceusnigricollis*Vieillot, 1805	3	28	48.4%	8	11	19	2.95%	S	LC	C
67	*Pogoniulusatroflavus*Sparrman, 1798	1	2	4.7%	2	2	4	0.62%	S	LC	C
68	*Pogoniulusbilineatus*Sundevall, 1850	2	0	3.1%	2	0	2	0.31%	S	LC	C
69	*Pogoniulusscolopaceus* Bonaparte, 1850	0	3	4.7%	0	6	6	0,93%	S	LC	C
70	*Pogoniulussubsulphureus* Fraser, 1843	1	0	1.6%	1	0	1	0.16%	S	LC	C
71	*Pogonornisbidentatus* Shaw, 1799	1	0	1.6%	1	0	1	0.16%	S	LC	C
72	*Priniasubflava*Gmelin, 1789	1	0	1.6%	1	0	1	0.16%	S	LC	C
73	*Psalidoprocnenitens* Cassin, 1857	1	0	1.6%	1	0	1	0.16%	S	LC	C
74	*Psalidoprocnepristoptera*Rüppell, 1840	1	2	4.7%	1	2	3	0.47%	S/M	LC	C
75	*Pycnonotus barbatus*Desfontaines, 1789	8	10	28.1%	12	17	29	4.51%	S	LC	C
76	*Saxicolarubetra* Linnaeus, 1758	2	3	7.8%	3	4	7	1.09%	P	LC	C
77	*Schistolaisleucopogon*Cabanis, 1875	1	0	1.6%	1	0	1	0.16%	S	LC	C
78	*Spermestes bicolor* Fraser, 1843	6	1	10.9%	12	1	13	2.02%	S	LC	C
79	*Spermophagahaematina*Vieillot, 1807	3	0	4.7%	5	0	5	0.78%	S	LC	C
80	*Sylviettadenti*Ogilvie-Grant, 1906	1	0	1.6%	1	0	1	0.16%	S	LC	C
81	*Sylviettavirens* Cassin, 1859	1	2	4.7%	1	2	3	0.47%	S	LC	C
82	*Tchagraaustralis* Smith, 1836	2	0	3.1%	2	0	2	0.31%	S	LC	C
83	*Tchagrasenegalus* Linnaeus, 1766	1	0	1.6%	1	0	1	0.16%	S	LC	C
84	*Terpsiphonebatesi* Chapin, 1825	3	0	4.7%	3	0	3	0.47%	S	LC	C
85	*Terpsiphonerufocinerea*Cabanis, 1875	2	0	3.1%	2	0	2	0.31%	S	LC	C
86	*Terpsiphoneviridis* Müller, 1776	1	5	9.4%	1	5	6	0.93%	S/M	LC	C
87	*Thescelocichlaleucopleura* Cassin, 1855	1	2	4.7%	1	2	3	0.47%	S	LC	C
88	*Tricholaemahirsuta*Swainson, 1821	1	0	1.6%	1	0	1	0.16%	S	LC	C
89	*Tringastagnatilis* Bechstein,1803	0	2	3.1%	0	2	2	0.31%	P	LC	C
90	*Turduspelios* Bonaparte, 1850	2	2	6.3%	2	2	4	0.62%	S	LC	C
91	*Turturafer* Linnaeus, 1766	2	0	3.1%	4	0	4	0.62%	S	LC	C
92	*Turturtympanistria*Temminck, 1809	4	0	6.3%	5	0	5	0.78%	S	LC	C
	Total	**/**	**/**	**100%**	**442**	**201**	**643**	**100%**	**/**	**/**	**/**

LC: Least concern
B: Specie under partial protection
M: Intra- African migrant**C:** Common specie
P: Palaearcticmigrant**S:** Resident

Table III: Bird diversity indices of Edea II and Mouanko

Habitats	seasons	years	Species	Individuals	Simpson_1-D	Shannon_H	Equity_J
Forest	**LRS**	2023	27	55	0.94	3.17	0.89
Forest	**LDS**	2023	25	49	0.96	3.29	0.95
Forest	**SRS**	2023	36	91	0.93	3.23	0.85
Forest	**SDS**	2023	47	77	0.98	3.91	0.94

Forest		**2023**	**80**	**272**	**0.96**	**3.90**	**0.86**
Forest	**LRS**	2024	18	50	0.91	2.68	0.87
Forest	**LDS**	2024	7	17	0.88	2.02	0.95
Forest	**SRS**	2024	12	46	0.87	2.27	0.86
Forest	**SDS**	2024	21	57	0.91	2.79	0.86
Forest		**2024**	**39**	**170**	**0.91**	**3.03**	**0.80**
Forest		**Total forest**	**87**	**442**	**0.94**	**3.70**	**0.81**
Mangrove	**LRS**	2023	13	26	0.89	2.48	0.88
Mangrove	**LDS**	2023	23	46	0.96	3.18	0.94
Mangrove	**SRS**	2023	9	15	0.90	2.29	0.92
Mangrove	**SDS**	2023	23	34	0.97	3.33	0.96
Mangrove		**2023**	**44**	**121**	**0.96**	**3.60**	**0.90**
Mangrove	**LRS**	2024	18	26	0.96	3.09	0.95
Mangrove	**LDS**	2024	19	28	0.96	3.12	0.95
Mangrove	**SRS**	2024	4	5	0.90	1.63	0.96
Mangrove	**SDS**	2024	18	21	0.99	3.25	0.98
Mangrove		**2024**	**41**	**80**	**0.98**	**3.77**	**0.95**
Mangrove		**Total mangrove**	**47**	**201**	**0.96**	**3.64**	**0.92**
Grand Total		**Grand Total**	**92**	**643**	**0.95**	**3.81**	**0.83**

LRS: Long rainy season
SRS: Short rainy season
LDS: Long dry season
SDS: Short dry season
Mann-Whitney test

Table IV: comparison of the Mann-Whitney test

	Forest evergreen	**mangrove**
Forest evergreen		0.021
mangrove	0.021	

Table V: Analysis of the structure of bird communities according to seasons and habitat using the Permanova test with 9999 permutations

Two-way PERMANOVA					
Source	**Sum of squares**	**Df**	**Mean square**	**F**	**p**
habitats	**0.36**	**1**	**0.36**	**9.70**	**0.0019**
seasons	**0.22**	**3**	**0.073**	**1.98**	**0.14**
Interaction	**0.065**	**3**	**0.021**	**0.58**	**0.73**
Residues	**0.29**	**8**	**0.037**		
Total	**0.94**	**15**			

Conclusion:-

This study allowed us to identify a total of 92 captured species. The families were highly representative of passerines (83.2%). It revealed that the avifauna of the Edea II and Mouanko area is very diverse and that there is a significant difference in the distribution of relative abundances of taxa across the different study sites. Regarding the species composition of the bird populations, our study revealed that the investigated habitats are not similar. This difference within the sites appears to be directly related to vegetation. Furthermore, no significant difference in the distribution of relative abundances of species according to the seasons was observed. This homogeneity is linked to the year-round availability of resources and a four-season equatorial climate that is very favourable to the flourishing of the taxa. The information can then be used to manage and improve bird conservation at local, regional and international levels, given that a large part of Mouanko and Edea II'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 authors declare that there are no conflicts of interest.

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