# Bird Diversity and Anthropogenic Impacts in the Southern Lake Chad Wetlands, Cameroon

**Wansang Daksala[1*], Kougoum Piebeng Ghislain Noé[1], Kondasso Lea Taiga[2]**
**Bakwo Fils Eric Moise[3]**

[1]*Department of Biological Sciences, Faculty of Science, University of Maroua, Maroua, Cameroon, BP 814, Maroua, BP Cameroon*
[2]*Department of Environmental Sciences, Higher Intitute of Agriculture, Forestry, Water and Environment of Belabo, University of Bertoua, Belabo, Cameroon, BP: 416 Bertoua, Cameroon*
[3]*Department of Biological Science, Faculty of water and Environment, University of Ebolowa, Ebolowa, Cameroon, BP 118, Ebolowa, Cameroon*
[*]Corresponding Author Email: dwansang@gmail.com

*Abstract*: This study, conducted in the southern part of Lake Chad (Far North Region, Cameroon), assessed bird diversity and conservation status using data collection methods along linear transects and Japanese net captures. A total of 213 species belonging to 24 orders and 67 families were recorded. Species richness was higher in the dry season (210 species) than in the rainy season (193 species), and higher around water points (98 species). The Shannon index was higher in the rainy season (H' = 2.1283 bits) than in the dry season (H' = 1.8149 bits), indicating greater diversity during the rainy season. Nine types of human activities were identified, with pollution being highest in the dry season (44.72 signs/km) and grazing predominant in the rainy season (24.63 signs/km). These activities negatively affected avian diversity in the dry season and rainy season). Conservation measures are needed to preserve this rich but threatened birdlife.

*Keywords*: Birds, Lake Chad, Cameroon, Diversity, Anthropogenic.

## 1. INTRODUCTION

Wetlands are highly diverse ecological systems that support a wide range of biological diversity and provide numerous services to human societies (Garba et al., 2025 ; Walakira et al., 2024 ; Aissaoui, 2012). The Cameroonian part of Lake Chad, located in the Far North region, was designated a Ramsar site in 2008 (Gbetkom, 2020). Of all the components of wetland biodiversity, birdlife is the most important element that gives meaning to aquatic environments. Indeed, wetlands are not only biodiversity hotspots, but also provide a large number of ecosystem services to society by contributing to the maintenance and improvement of water quality, the regulation of hydrological regimes, and the regulation of the local and global climate (Robinson et al., 2025). These ecosystems are a privileged habitat for many species of water birds (Green and Elmberg, 2014).

However, birds are considered to be good ecological indicators for these wetlands because they respond quickly to environmental changes on several spatial scales (Parchizadeh and Williams, 2018)., birds are a zoological group that can be easily used for ecological diagnosis,

leading to conservation strategies that benefit other species of flora and fauna (BirdLife International. 2018). Despite well-known biodiversity conservation functions, wetlands are subject to intense land use changes that alternately alter the composition, structure, and diversity of bird communities (Thapa and Saund, 2012). This globally important wetland is seriously threatened by heavy population pressure and climate change. In addition, the Lake Chad area faces serious eutrophication problems that are reducing the lake's surface area (Ranger, 2016). Throughout Lake Chad, several factors contribute to its degradation and thus to the loss of avian biodiversity, namely anthropogenic factors (extensive agriculture, logging, crafts, excessive harvesting of medicinal plants and wild honey, vegetation fires, overgrazing, urbanization) resulting mainly from population growth on the one hand, and natural factors such as the drying up of the lake (climate change) on the other (Trolliet, 2014). The available knowledge on birdlife in this area is still fragmentary and is based on localized inventories and often unsystematic data. There is therefore a lack of quantitative and spatially extensive research capable of establishing causal links between anthropogenic factors and the structure

of bird communities in this semi-arid region of Cameroon (BirdLife International, 2018). The study will contribute to a fundamental approach for assessing the consequences of different uses of ecosystems in this part of the country on bird communities and, more broadly, on biodiversity.

## 2. MATERIALS AND METHODS

### 2.1. Study site

This study was conducted in the southern part of Lake Chad, in Cameroon, located in the Far North region between approximately 10°30′ and 13°30′ N and 12°30′ and 16°00′ E (Figure 1), within the Sudanian-Sahelian ecological zone characterized by a semi-arid climate with a short rainy season (July–September) and a long dry season (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2023). Annual rainfall is generally low and variable, while temperatures remain high throughout the year, often averaging above 30 °C, with higher relative humidity near the water body, especially during the rainy season (Britannica, 2024). Lake Chad is an extremely shallow wetland, with average depths generally less than 4 m and strong seasonal and interannual fluctuations linked to inflows from the Chari–Logone river system and regional climate variability (Gbetkom, 2022). Recent analyses based on remote sensing show that, despite a marked reduction in its surface area since the 1960s, the lake exhibits a complex hydrological dynamic with phases of contraction and expansion of surface water over the past decade, including temporary increases observed after wetter years (Pham-Duc

et al., 2022). The vegetation in the Cameroonian part of the lake consists of a mosaic of aquatic and terrestrial formations, including floating and emergent macrophytes such as Cyperaceae, Typha, Phragmites, and Pistia in flooded areas, as well as wooded and shrub savannas dominated by *Acacia spp*., *Balanites aegyptiaca, Ziziphus mauritiana, and Hyphaene tebaica*(doum palm) formations, whose spatial distribution varies according to water gradients and the recent dynamics of water levels (Gbetkom, 2020; UNESCO, 2023).

### 2.2. Data collection using the transect method

The data was collected from January 8 to March 21, 2024, for the dry season and from June 13 to October 16, 2024, for the rainy season. The geo-referenced satellite images obtained showed the different variations in land use, namely plantation areas, wooded areas, dwellings, water points, and grassy areas. This was done in order to compare the diversity between the two (02) seasons and between habitats. A total of 80 linear transects, each 1 km long, were defined. The transects were oriented horizontally, with a spacing of at least approximately 1.5 km between them (Figure 2). The starting points of each transect and their coordinates were recorded using QGIS version 12.3 software to facilitate their location and orientation in the field. As part of this study, the 1-km transects were established and evenly distributed according to habitat type, with 16 transects per habitat. A total of five (transects corresponding to each habitat type were randomly selected for the placement of Japanese nets.
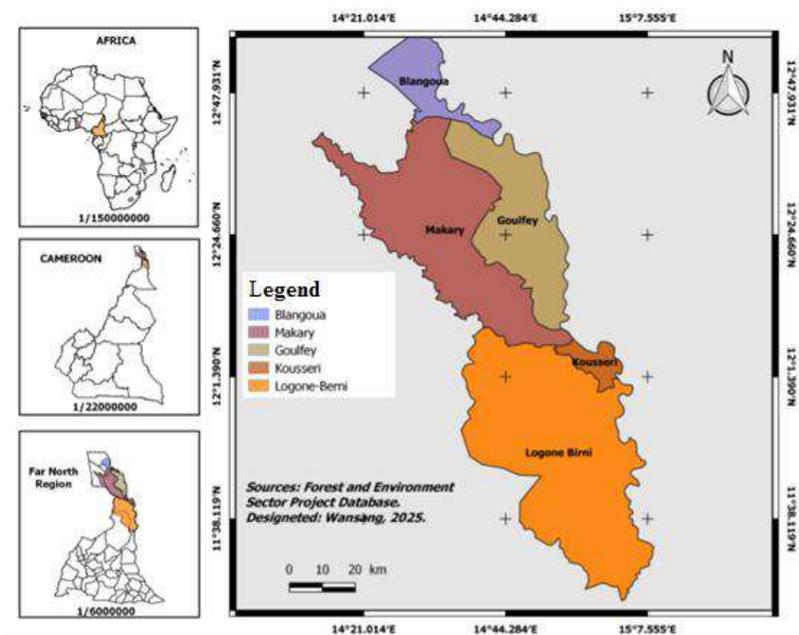


**Figure 1:** Study area and land use in the study area

At water points, were placed at the edge of an area considered likely to be used by birds. The inventory team arrives early in the morning (around 6 a.m.) at or near the sampling point and/or in the evening from 3 :30 p.m. onwards, to increase the chances of encountering birds, as most wild birds are most active during these periods (Kougoum et al., 2024). Each of these transects was surveyed during each season.

## 2.3. Data collection using the Japanese net capture method

In order to confirm or correct certain identifications, Japanese net captures were also carried out during the same period, on the same transects, to capture passerines (Figure 3). Twenty-five (25) transects out of the 80 used, at a rate of 5 per habitat type, were selected for the installation of nets. The Japanese nets, which were 3 m high, with a mesh size of 2 cm and a length of 12 m, were set up vertically very early in the morning between 5 :30 and 6 :00 a.m. and in the evening between 4 :00 and 5 :30 p.m. by attaching their rings to two stakes at least 3.5 m high and fixed to the ground. These nets were initially placed by observing the probable direction of the birds' movement in order to increase the chances of capture. The various measurements are recorded on a form, including the length of the beak, tarsus, tibia, wing, wingspan, total length of the bird, weight, and other morphological characteristics (color of plumage, shape of legs, toes, beak, etc.).

## 2.4. Identification of bird species in the southern part of Lake Chad, Cameroon

Bird identification equipment consists of a pair of binoculars for remote bird observation, a telescope, a bird identification guide for perfect bird recognition. the species through its morphological characteristics and scientific name, a camera for taking images of birds without doubt of identification in the field (Figure 4). The bird nomenclature is that used in the work of Borrow and Demey (2014).

### 2.5. Data analysis

**2.5.1. Species richness estimate : Species richness was calculated as described by Blondel (1975).**

Species richness estimate (E) = (species observed) / (species estimated) x 100

### 2.5.2. Shannon-Wiener diversity index (H')

This index was calculated according to each type of habitat and according to the seasons and expressed in Binary Digit Units (Bits). $H = \sum p_i \log_2(p_i)$

$\log_2$= logarithm to base 2; $N_i$ = number of observations of a species i; N = total number of observations; $p_i$ is the probability that a species i is present in a survey. In Practice, $p_i = N_i N-1$

-If H' ° (H < 3) then H' is weak, which implies that the environment is not very diverse (case of specialized
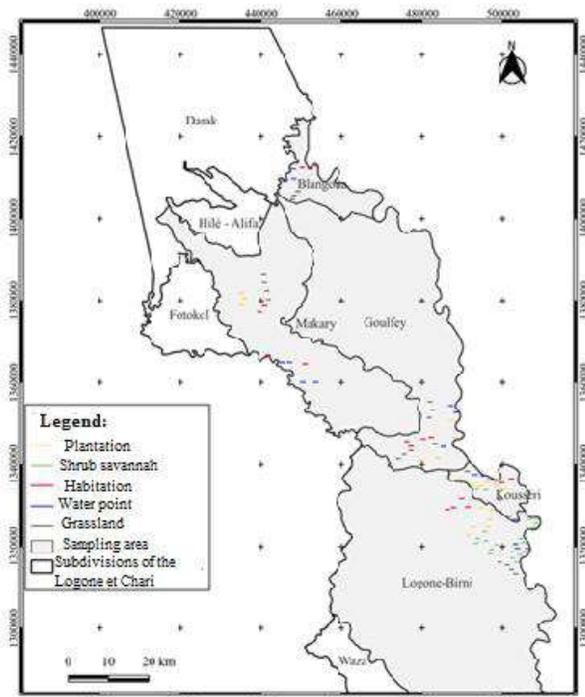


**Figure 3:** Taking measurements of a bird captured with a mist net



**Figure 2:** Lay out of transects in the sampling area

**Figure 4:** Group of birds in the study area

environments where we generally note the dominance of a single species or a small number of species species across all species in the community.

- If H' ° (3 ≤ H < 4) then H' can be assumed to be average, which implies that the environment is relatively rich in species.

- If H' ° (H ≥ 4) then H' can be assumed to be high. Here the study station or the environment presents favorable conditions for the installation of many species, but the number of individuals per species is low

To determine the differences in diversity between bird communities according to habitat type and season, the Jaccard similarity index was used.

### 2.6.3. Anthropogenic factors

This was based primarily on determining the anthropogenic disturbance index. The team reported the anthropogenic pressure indices encountered at each sampling point. These indices were grouped into categories : transhumance (any presence of domestic livestock), camping, poaching (any physical presence of poachers, poaching camps.), fishing, agricultural occupation (fields or human occupation), logging (harvesting of dead wood/fuel, logging sites), etc. To compare the intra-annual variability of species richness and diversity, we used the chi-square ($\chi^2$) test and the diversity t-test, respectively. The nonparametric Kruskall-Wallis test was used to compare species richness between habitat types. General linear model was also used to determine the effect of human activities on the avifauna of the study area based on kilometer abundance indices. The probability threshold used for statistical analyses corresponding to a confidence level of 95.0%. Statistical tests were performed using PAST 4.03 and XLstat software.

## 3. RESULTS AND DISCUSSION

### 3.1. Overall species richness

The 80 transects carried out in the study area recorded 213 species. These birds are divided into 24 orders and 67 families. Among the orders, Passeriformes is the order with the largest number of families (27 families), representing 39.70%, followed by Bucerotiformes (11 families) and Pelicaniformes (4 families). Orders such as Strigiformes, Psittaciformes, Podicipediformes, Musophagiformes, Falconiformes, Cuculiformes, Columbiformes, Coliiformes, Ciconiiformes, Caprimulgiformes, Apodiformes, and Accipitriformes are the least represented, with only one family each. Most diverse families in terms of number of species are Accipitripidae with 19 species and Ardeidae with 16 species. Of the 68 families recorded, 29 each represent 0.79% (one species) (Table 1). According to

the IUCN, three (03) species have been classified as vulnerable (*Aquila rapax ; Circaetus beaudouini ; Balearica pavonina)*, two (02) as near threatened (*Circus macrourus ; Ciconia episcopus*) and One (01) Critically Endangered (*Necrosyrtes monachus*).

### 3.2. Sampling success

The cumulative richness of bird species based on 80 surveys was carried out (Figure 5). Taking into account the species richness in the different habitats of the study area, the estimators Chao2 (261.335), Jackknife1 (221.464), Jackknife2 (237.202), and Bootstrap (231.906) give us an average of 238 species. As the number of species observed is 213, the estimators show that 25 species were not encountered in this study area. Considering the number of estimated species and those sampled, the sampling effort for study is 88.26%.

The results of counts carried out in the southern part of Lake Chad highlight a particularly high level of avian diversity. The abundance of individuals observed confirms the ecological importance of this ecosystem for both resident and migratory birds. The species richness represents approximately 22.3% of all known bird species in Cameroon (954 species) and 56.2% of Far North region (379 species) (Lepage, 2019; Languy, 2019). These proportions demonstrate the central role of this wetland in maintaining national and regional avian diversity.

The values observed are similar to those obtained in other wetlands in West Africa. Odoukpe et al. (2014) recorded 216 species in two seasons in a wetland in Côte d'Ivoire, confirming the high ecological productivity of these environments. In contrast, Kougoum et al. (2024), in the Kalfou Forest Reserve and surroundings, recorded a much lower species richness (124 species). This difference could be explained by the ecological contrasts between the two sites : the Lake Chad area is a vast wetland recognized as a Ramsar site, characterized by the presence of permanent water bodies favorable to waterfowl and Palearctic migratory birds (Gbetkom, 2020). Conversely, the Kalfou Reserve does not have such aquatic habitats, which limits its capacity to support water-dependent species.

Wetlands play a crucial role in the life cycle of birds, as breeding, wintering, and migratory stopover sites. Chokri (2024) emphasized that these environments are home to a wide variety of waterbirds, providing critical habitats for many migratory species. The probabilistic estimators applied in this study suggest a total species richness of around 237 species, which is higher than the estimate by Kougoum et al. (2024) in Kalfou (184 species) using the

**Table 1:** Distribution of specific richness by order and by family

| Orders | Families | Species | IUCN status |
|---|---|---|---|
| Accipitriformes | Accipitridae | *Accipiter badius* | LC |
| | | *Accipiter minullus* | LC |
| | | *Aquila rapax* | VU |
| | | *Aquila wahbergi* | LC |
| | | *Butastur rufipennis* | LC |
| | | *Buteo auguralis* | LC |
| | | *Chelictinia riocourii* | VU |
| | | *Circaetus beaudouini* | VU |
| | | *Circaetus cinereus* | LC |
| | | *Circus macrourus* | NT |
| | | *Circus pygargus* | LC |
| | | *Elanus caeruleus* | LC |
| | | *Hieraaetus spilogaster* | LC |
| | | *Lophaetus occipitalis* | LC |
| | | *Melierax metabates* | LC |
| | | *Micronisus gabar* | LC |
| | | *Milvus migrans* | LC |
| | | *Necrosyrtes monachus* | CR |
| | | *Polyboroides typus* | LC |
| | Pandionidae | *Pandion haliaetus* | LC |
| Anseriformes | Anatidae | *Alopochen aegyptiaca* | LC |
| | | *Anas hottentota* | LC |
| | | *Dendrocygna bicolor* | LC |
| | | *Dendrocygna viduata* | LC |
| | | *Plectropterus gambensis* | LC |
| | | *Sarkidiornis melanotos* | LC |
| | | *Thalassornis leuconotus* | LC |
| Apodiformes | Apodidae | *Apus affinis* | LC |
| | | *Cypsiurus parvus* | LC |
| Bucerotiformes | Bucerotidae | *Tockus erythrorhynchus* | LC |
| | | *Tockus nasutus* | LC |
| | Upupidae | *Upupa epops* | LC |
| Caprimulgiformes | Caprimulgidae | *Caprimulgus inornatus* | LC |
| | | *Macrodipteryx longipennis* | LC |
| Charadriiformes | Burhinidae | *Burhinus capensis* | LC |
| | | *Burhinus senegalensis* | LC |
| | Charadriidae | *Charadrius hiaticula* | LC |
| | | *Charadrius marginatus* | LC |
| | | *Vanellus crassirostris* | LC |
| | | *Vanellus senegallus* | LC |
| | | *Vanellus spinosus* | LC |
| | | *Vanellus superciliosus* | LC |
| | | *Vanellus tectus* | LC |

**Cont...**

**Table 1:** Distribution of specific richness by order and by family

| Orders | Families | Species | IUCN status |
|---|---|---|---|
| | Glareolidae | Glareola cinerea | LC |
| | Jacanidae | Actophilornis africana | LC |
| | | Microparra capensis | LC |
| | Laridae | Larus cirrocephalus | LC |
| | | Rynchops flavirostris | NT |
| | | Sterna albifrons | LC |
| | Pluvianidae | Pluvianus aegyptius | LC |
| | Recurvirostridae | Himantopus himantopus | LC |
| | Rostratulidae | Rostratula benghalensis | LC |
| | Scolopacidae | Calidris alpina | LC |
| | | Calidris minuta | LC |
| | | Gallinago gallinago | LC |
| | | Lymnocryptes minimus | LC |
| | | Philomachus pugnax | LC |
| | | Tringa nebularia | LC |
| | | Tringa totanus | LC |
| | Sternidae | Sterna caspia | LC |
| | Turnicidae | Ortyxelos meiffrenii | LC |
| | | Turnix sylvaticus | LC |
| Ciconiiformes | Ciconiidae | Anastomus lamelligerus | LC |
| Ciconiiformes | Ciconiidae | *Anastomus lamelligerus* | LC |
| | | *Ciconia episcopus* | LC |
| | | *Leptoptilos crumeniferus* | LC |
| | | *Leptoptilos senegalensis* | LC |
| | | *Mycteria ibis* | LC |
| Coliiformes | Coliidae | *Urocolius macrourus* | LC |
| Columbiformes | Columbidae | *Columba guinea* | LC |
| | | *Oena capensis* | LC |
| | | *Streptopelia abyssinicus* | LC |
| | | *Streptopelia decipiens* | LC |
| | | *Streptopelia roseogrisea* | LC |
| | | *Streptopelia senegalensis* | LC |
| | | *Streptopelia vinacea* | LC |
| | | *Turtur abyssinicus* | LC |
| Coraciiformes | Alcedinidae | *Ceryle rudis* | LC |
| | | *Ceyx pictus* | LC |
| | | *Halcyon chelicuti* | LC |
| | | *Halcyon leucocephala* | LC |
| | | *Halcyon senegalensis* | LC |
| | | *Megaceryle chelicuti* | LC |
| | | *Megaceryle maxima* | LC |
| | Coraciidae | *Coracias abyssinicus* | LC |
| | | *Coracias naevius* | LC |
| | | *Eurystomus glaucurus* | LC |

**Cont...**

**Table 1:** Distribution of specific richness by order and by family

| Orders | Families | Species | IUCN status |
|---|---|---|---|
| | Meropidae | *Merops albicollis* | LC |
| | | *Merops apiaster* | LC |
| | | *Merops nubicus* | LC |
| | | *Merops orientalis* | LC |
| | | *Merops persicus* | LC |
| | | *Merops pusillus* | LC |
| Cuculiformes | Cuculidae | *Centropus senegalensis* | LC |
| | | *Chrysococcyx caprius* | LC |
| | | *Cuculus gularis* | LC |
| | | *Oxylophus levaillanti* | LC |
| Falconiformes | Falconidae | *Falco ardosiaceus* | LC |
| | | *Falco biarmicus* | LC |
| Galliformes | Numidae | *Numida meleagris* | LC |
| | Phasianidae | *Francolinus clappertoni* | LC |
| Gruiformes | Gruidae | *Balearica pavonina* | VU |
| | Rallidae | *Amaurornis flavirostra* | LC |
| | | *Crex egregia* | LC |
| | | *Gallinula angula* | LC |
| Musophagiformes | Musophagidae | *Crinifer piscator* | LC |
| Otidiformes | Otididae | *Eupodotis senegalensis* | LC |
| | | *Lissotis melanogaster* | LC |
| Passeriformes | Acrocephalidae | *Acrocephalus arundinaceus* | LC |
| | | *Acrocephalus rufescens* | LC |
| | | *Acrocephalus schoenobaenus* | LC |
| | | *Acrocephalus scirpaeus* | LC |
| | Alaudidae | *Eremopterix leucotis* | LC |
| | | *Galerida cristata* | LC |
| | Buphagidae | *Buphagus africanus* | LC |
| | Cisticolidae | *Camaroptera brachyura* | LC |
| | | *Cisticola galactotes* | LC |
| | | *Cisticola juncidis* | LC |
| | | *Cisticola ruficeps* | LC |
| | | *Cisticola marginatus* | LC |
| | | *Prinia subflava* | LC |
| | Corvidae | *Corvus albus* | LC |
| | | *Ptilostomus afer* | LC |
| | Dicruridae | *Dicrurus adsimilis* | LC |
| | Estrildidae | *Estrilda melpoda* | LC |
| | | *Euodice cantans* | LC |
| | | *Lagonosticta senegala* | LC |
| | | *Pytilia melba* | LC |
| | | *Spermestes cucullatus* | LC |
| | | *Uraeginthus bengalus* | LC |

**Cont...**

**Table 1:** Distribution of specific richness by order and by family

| Orders | Families | Species | IUCN status |
|---|---|---|---|
| | Fringillidae | *Serinus leucopygius* | LC |
| | Hirundinidae | *Delichon urbicum* | LC |
| | | *Hirundo aethiopica* | LC |
| | | *Hirundo daurica* | LC |
| | | *Hirundo rustica* | LC |
| | | *Petrochelidon preussi* | LC |
| | | *Hirundo senegalensis* | LC |
| | | *Riparia cincta* | LC |
| | | *Riparia paludicola* | LC |
| | Indicatoridae | *Indicator indicator* | LC |
| | Laniidae | *Lanius collurio* | LC |
| | Malaconotidae | *Nilaus afer* | LC |
| | | *Tchagra senegalus* | LC |
| | Motacillidae | *Anthus cervinus* | LC |
| | | *Macronyx croceus* | LC |
| | | *Motacilla flava* | LC |
| | Muscicapidae | *Muscicapa aquatica* | LC |
| | | *Saxicola torquatus* | LC |
| | Nectariniidae | *Chalcomitra senegalensis* | LC |
| | | *Cinnyris pulchellus* | LC |
| | | *Hedydipna platura* | LC |
| | Passeridae | *Passer domesticus* | LC |
| | | *Passer griseus* | LC |
| | | *Passer luteus* | LC |
| | | *Petronia dentata* | LC |
| | | *Plocepasser superciliosus* | LC |
| | | *Sporopipes frontalis* | LC |
| | Phylloscopidae | *Phylloscopus bonelli* | LC |
| | Ploceidae | *Bubalornis albirostris* | LC |
| | | *Euplectes franciscanus* | LC |
| | | *Euplectes hordeaceus* | LC |
| | | *Ploceus cucullatus* | LC |
| | | *Ploceus heuglini* | LC |
| | | *Ploceus luteolus* | LC |
| | | *Ploceus vitellinus* | LC |
| | | *Quelea quelea* | LC |
| | Pycnonotidae | *Pycnonotus barbatus* | LC |
| | Sturnidae | *Lamprotornis caudatus* | LC |
| | | *Lamprotornis pulcher* | LC |
| | | *Lamprotornis purpureus* | LC |
| | Sylviidae | *Hippolais pallida* | LC |
| | | *Hippolais (pallida) opaca* | LC |
| | | *Hippolais icterina* | LC |

**Table 1:** Distribution of specific richness by order and by family

| Orders | Families | Species | IUCN status |
|---|---|---|---|
| | Timaliidae | *Cercotrichas leucophrys* | LC |
| | | *Cercotrichas podobe* | LC |
| | | *Turdoides plebejus* | LC |
| | Turdidae | *Oenanthe deserti* | LC |
| | | *Oenanthe isabellina* | LC |
| | | *Oenanthe oenanthe* | LC |
| | | *Phoenicurus phoenicurus* | LC |
| | | *Turdus pelios* | LC |
| | Viduidae | *Vidua chalybeata* | LC |
| | | *Vidua macroura* | LC |
| Pelicaniformes | Ardeidae | *Aigretta ardesiaca* | LC |
| | | *Ardea alba* | LC |
| | | *Ardea cinerea* | LC |
| | | *Ardea melanocephala* | LC |
| | | *Ardea purpurea* | LC |
| | | *Ardeola ralloides* | LC |
| | | *Bubulcus ibis* | LC |
| | | *Butorides striada* | LC |
| | | *Egretta garzetta* | LC |
| | | *Egretta intermedia* | LC |
| | | *Ixobrychus sturmii* | LC |
| | | *Lxobrychus minutus* | LC |
| | | *Nycticorax nycticorax* | LC |
| | Scopidae | *Scopus umbretta* | LC |
| | Threskiornithidae | *Bostrychia hagedash* | LC |
| | | *Platalea leucorodia* | LC |
| | | *Plegadis falcinellus* | LC |
| | | *Threskiornis aethiopica* | LC |
| Piciformes | Capitonidae | *Lybius dubius* | LC |
| | | *Lybius minor* | LC |
| | Picidae | *Dendropicos obsoletus* | LC |
| Podicipediformes | Podicipedidae | *Tachybaptus ruficollis* | LC |
| Psittaciformes | Psittacidae | *Psittacula krameri* | LC |
| Pterocliformes | Pteroclidae | *Pterocles exustus* | LC |
| | | *Pterocles quadricinctus* | LC |
| Strigiformes | Strigidae | *Bubo(africanus) cinerascens* | LC |
| | | *Glaucidium perlatum* | LC |
| | | *Ptilopsis leucotis* | LC |
| Suliformes | Anhingidae | *Anhinga rufa* | LC |
| | Phalacrocoracidae | *Microcarbo africanus* | LC |
| | | *Phalacrocorax africanus* | LC |

*Legend: LC=Least Concern ; NT=Near Threatened ; VU=Vulnerable ; CR=Critically Endangered ; IUCN=International Union for Conservation of Nature*

same estimation tools. This difference corroborates the hypothesis of greater habitat heterogeneity in the Lake Chad area, favoring increased species diversity. Although the accumulation curve obtained indicates a satisfactory estimate of species richness, additional sampling would be necessary to identify rare or undetected species. In the same ecological gradient, the nearby Waza National Park (WNP) is home to around 370 bird species, including more than 71 species of water birds, of which around 20 are migratory (BirdLife International, 2018 ; MINFOF, 2020). This park, which enjoys protected status, preserves an exceptional wealth of fauna and flora (Gbetkom, 2022). A comparison between the WNP and the southern part of Lake Chad illustrates the impact of the level of protection on the diversity observed.

Among the species recorded in the study area, three endangered species, all birds of prey, and two near-threatened species were identified. This finding is consistent with the observations made by Kougoum et al. (2024) in the Kalfou Reserve, as well as by Adhikari et al. (2019) in Chitwan National Park in Nepal. The presence of these globally threatened species gives the southern Lake Chad area high biological value and makes it a priority site for conservation.

### 3.3. Spatio-temporal diversity of avifauna

Of the 213 species encountered in the area, shows that 98.59% (210 species) are in the dry season, compared to 193 species in the rainy season, or 91.07% of the total. Surveys conducted in the five habitat types enabled to encounter 98 species at water points, 88 species in the shrub savanna, 87 species in plantations, 77 species in grassy savanna, and 65 species in residential areas. The Krukall-Wallis test shows no significant difference between these different habitats. The cumulative species richness curves are logarithmic in nature, showing a quasi-asymptotic plateau after a certain number of surveys, beyond which the probability of encountering a new species becomes very low (Figure 6).

The avian diversity observed within habitats (Table 2) is relatively high (3.821 bits) at water points and lower in plantations (0.985 bits) according to the Shannon index. This

result shows that water point habitats are more diverse than other types of habitats. Comparing the Shannon indices of the different habitats in pairs, indicate that there is a highly significant difference between shrub savanna and plantation followd by plantations and grassy savannah, grassy savannah and water points, water points and residential areas, and grassy savannah and shrub savannah. Comparison of the Jaccard similarity index shows that there are differences between habitat types. The greatest similarity is
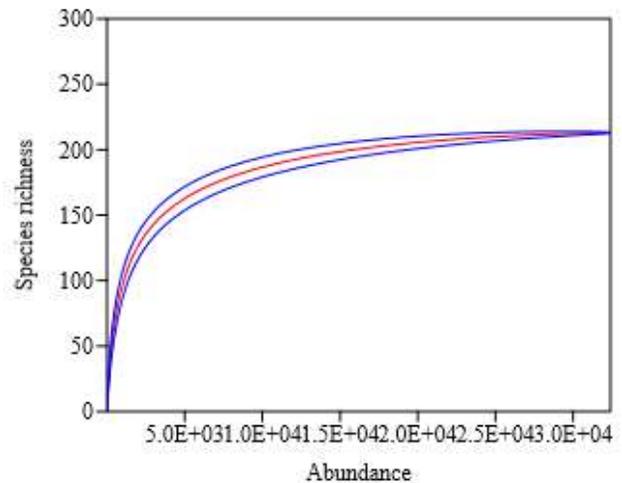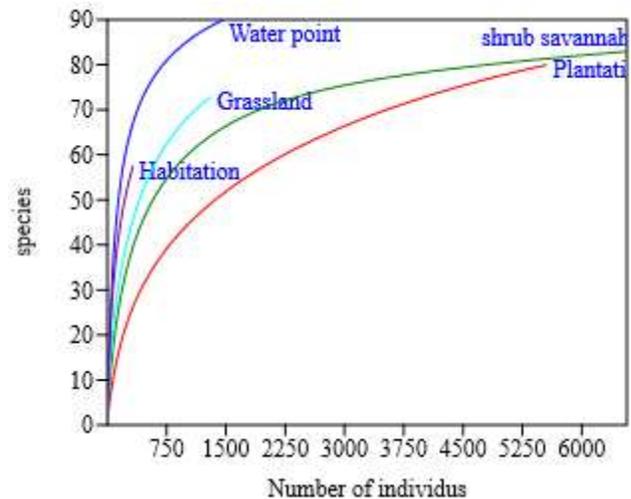


**Figure 5:** Global rarefaction curve



**Figure 6:** Rarefaction curves depending on habitats

**Table 2:** Diversity indices

|  | Shannon index | | | | Simpson index | | | |
|---|---|---|---|---|---|---|---|---|
|  | H' | T | Dl | P | D | T | Dl | P |
| Rainy season | 2.1283 | 11.432 | 32052 | 3.3101E-30 | 0.43261 | -12.246 | 32309 | 2.0951E-34 |
| Dry season | 1.8149 | | | | 0.5179 | | | |

*Legend: H'= Shannon index; T=diversity indices T; df = degree of freedom; P = probability; D = Simpson index*

between shrub savanna and plantation (78.66%). In contrast, there is little similarity between the residential area and the plantation (6.8%).

Although diversity is low during both seasons, the Shannon index in the rainy season (H' = 2.1283) is higher than in the dry season (H' = 1.8149). Comparison of the Shannon index between the two seasons showed a highly significant difference. The probability that two randomly selected individuals belonging to the same species is higher in the rainy season (D=0.43261) than in the dry season (D=0.5179) according to the Simpson index. This means that certain species are more dominant in the rainy season compared to the dry season.

### 3.4. Specific diversity of birds according to the seasons

The results indicate that bird species richness is higher during the dry season than during the rainy season. This trend has also been highlighted in several previous studies (Kougoum et al., 2024 ; Sadip et al., 2022 ; Nepali et al., 2021). Kougoum et al. (2024), mentiond that seasonal variation could be explained by increased availability and better access to food resources during the dry season, a period also marked by the arrival of many migratory species between October and March, which temporarily increases species richness. Conversely, heavy rainfall and flooding during the rainy season can disrupt aquatic habitats, leading to a decrease in the number of species present.

However, the rainy season has a higher Shannon diversity index than the dry season. This result could be explained by a more balanced distribution of abundance among species, particularly due to the scarcity of migratory species during this period. The high species diversity during the rainy season would thus be linked to the lesser dominance of certain abundant species observed in the dry season. Habitat structure also plays a decisive role in the composition and organization of avian communities ( Earnst and Holmes, 2012, Krizler et al., 2022 ). In this study, a comparison of species richness and diversity in five habitat types (shrub savanna, residential areas, plantations, water areas, and grassy savanna) south of Lake Chad highlights a significant influence of habitat type on bird distribution. Previous studies confirm that avian diversity is closely linked to habitat structure and complexity (Kumar et al., 2017, Adhikari et al., 2019 ). The differences observed between habitats could therefore be due to variability in resource availability and the degree of anthropogenic disturbance. Water areas have the highest species diversity, followed by grassy savannahs, with which they share a strong similarity. This ecological proximity is probably

explained by comparable vegetation composition and environmental conditions, as the grassy savannahs south of Lake Chad are periodically flooded and offer food resources similar to those found at water points. The shrub savanna shows a notable similarity to plantation areas, a result consistent with  Krizler (2015) and can be attributed to analogous plant structures—trees and shrubs scattered across herbaceous cover—which promote similar ecological assemblages. Nevertheless, differences in management practices and the level of anthropization introduce significant variations between these two environments (Bett et al., 2016, Thakur et al., 2022 ).

The lowest similarity was observed between plantation areas and residential areas which is consistent with the observations of Gatesire et al. (2014) and SpringerLink. (2023), where reduced bird diversity in urban environments. Human infrastructure (roads, buildings, schools, and health facilities) in residential areas significantly alter natural habitats and limit the niches available to birdlife. These transformations explain the low diversity and dissimilarity observed in the inhabited areas of southern Lake Chad.

### 3.5. Human activities and impact on birdlife in the southern part of Lake Chad, Cameroon, according to the seasons

Analysis of data on indicators of human presence revealed nine (09) types of human pressure in the southern part of Lake Chad, Cameroon, including poaching, bush fires, grazing, deforestation, pollution, poisoning, agricultural activities, and fishing. The HIs for the various activities range from 0.04<HI<24.7 in the dry season to 0.04<HI<44.8 in the rainy season. Grazing has the highest IKA (24.63 signs/km) in the rainy season compared to other activities., pollution indicate highest IKA (44.72 signs/km) o in the dry season (Table 3). Comparing the IKAs of these different activities observed in the two seasons, there are significant differences between grazing (and fishing and very significant differences between activities related to pollution

### 3.6. Correlation and level of influence of human activities and bird presence

Depending on the distribution of bird species and human activities, overall, the species appear to be influenced by anthropogenic activities. To assess the impact of human activities on avifauna, Pearson correlation and determination coefficients were evaluated between the IKA of activities and the IKA of birds. It therefore appears that birds are strongly influenced and are negatively, highly, and significantly affected by human activities (r= -0.38 and p=0.00012446) in the dry season (Figure 7a) and

**Table 3:** Kilometer indices of abundance of human activities in the southern part of Lake Chad, Cameroon

| Type of threats | Activities | Frequency (n) rainy season | PCKI (n/80km) rainy season | Frequency (n) dry season | PCKI (n/80km) dry season |
|---|---|---|---|---|---|
| **Poaching** | Bird catch nets | 39 | 0,487 | 44 | 0,55 |
| | Hunter seen | 23 | 0,287 | 8 | 0,1 |
| | Gunshot | 26 | 0,325 | 0 | 0 |
| | Holes dug by hunters | 42 | 0,525 | 18 | 0,225 |
| | Pitfalls | 37 | 0,462 | 21 | 0,262 |
| | Torch/Battery/bulb | 7 | 0,087 | _ | - |
| | Cartridges | 6 | 0,075 | - | - |
| | Birds injured by the weapon | 27 | 0,337 | - | - |
| | **Total Poaching activities** | **206** | **2,575** | **91** | **1,1375** |
| **Bushfires** | Landscape consumed /ha | 6 | 0,075 | 13 | 0,16 |
| | **Total bushfire activity** | **36** | **0,45** | **6** | **0,075** |
| **Deforestation** | Pruning | 41 | 0,512 | 11 | 0,137 |
| | Trees felled | 256 | 3,2 | 256 | 3,2 |
| | Wood cutting | 63 | 0,78 | 36 | 0,45 |
| | Coal mining | 22 | 0,275 | 3 | 0,0375 |
| | **Total deforestation activities** | **306** | **3,825** | **457** | **5,712** |
| **Pasture** | Shepherds seen | 27 | 0,337 | 14 | 0,175 |
| | Sheep or goats seen | 629 | 7,862 | 370 | 4,625 |
| | Cattle seen | 882 | 11,025 | 328 | 4,1 |
| | Cattle tracks | 433 | 5,412 | 612 | 7,65 |
| | **Total pasture activities** | **1971** | **24,63** | **1234** | **15,425** |
| **Pollution** | Engine noise | 8 | 0,1 | 18 | 0,22 |
| | Fuel leaks into water | 8 | 0,1 | 18 | 0,22 |
| | Plastic waste | 1224 | 15,3 | 3435 | 42,9375 |
| | Chemical fertilizers | 27 | 0,337 | 11 | 0,13 |
| | Scarecrows | 15 | 0,187 | 89 | 1,11 |
| | Slaughterhouse | 1 | 0,012 | 1 | 0,012 |
| | Pesticides | 21 | 0,262 | 6 | 0,075 |
| | **Total pollution activities** | **1304** | **16,3** | **3554** | **44,425** |
| **Poisoning** | Poisoned water | 30 | 0,375 | 22 | 0,275 |
| | Potentially poisoned birds | 93 | 0,92 | 52 | 0,65 |
| | **Total poisoning activities** | **123** | **1,537** | **74** | **0,925** |
| **Electrocution** | Post or wires involved | 4 | 0,05 | 1 | 0,0125 |
| | Electrocuted birds | - | - | 3 | 0,0375 |
| | **Total electrocution activities** | **4** | **0,05** | **4** | **0,0375** |
| **Agricultural activities** | Fallow | 66 | 0,825 | 90 | 1,125 |
| | Cultivated fields | 73 | 0,912 | 250 | 3,125 |
| | New fields | 13 | 0,162 | 12 | 0,15 |
| | Farmers' Tracks | 2 | 0,025 | 8 | 0,1 |
| | **Total agricultural activities** | **154** | **1,925** | **360** | **4,5** |
| **Peaches** | Fishing nets | 67 | 0,837 | 128 | 1,6 |
| | Traps | 18 | 0,225 | 54 | 0,675 |
| | Fishermen | 47 | 0,587 | 162 | 2,025 |
| | Total fishing activities | **132** | **1,65** | **344** | **4,3** |

*Legend: PCKI (Pressure Contact Kilometer Index)*

$y = -0{,}41445x + 2{,}2685$                                      $y = -0{,}42891x + 4{,}2387$
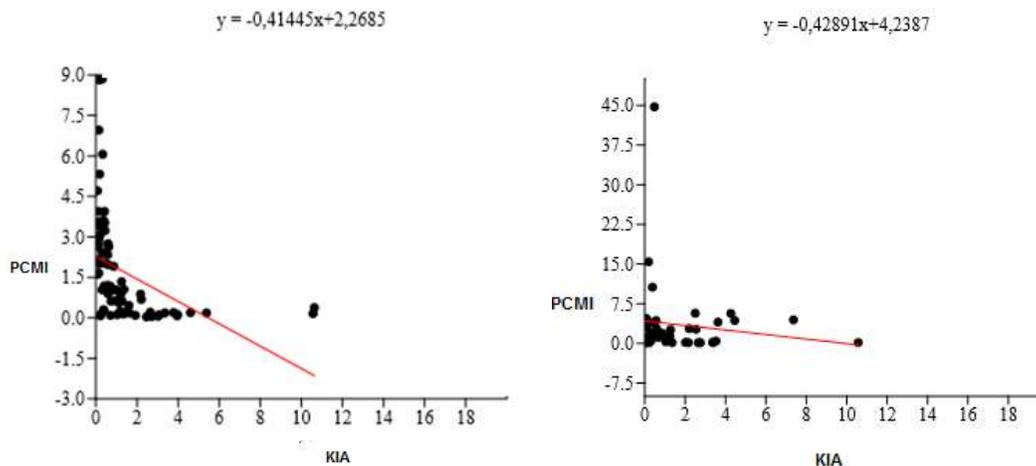


**Figure 7:** Correlation between the IKA values of anthropogenic activities and birds in the southern part of Lake Chad, Cameroon in the dry season (a) and in the rainy season (b)

significantly in the rainy season (r= -0.167 and p=0.42911) (Figure 7b).

The bird communities respond strongly to various pressures from human activities such as poaching, fishing, pastoralism, pollution, poisoning, deforestation, bush fires, electrocution, and agriculture. The values of the kilometer-based abundance indices (IKA) associated with these pressures vary according to the seasons, reflecting both the temporal and spatial influence of anthropogenic disturbances on avifauna.During the rainy season, pastoralism was most significant pressure. This situation can be explained by the influx of transhumant herders to the southern area of Lake Chad at this time of year, due to the increased availability of pasture and water sources (Rangé, 2016). In the dry season, these groups move and concentrate around the few remaining functional wetlands (Gbetkom, 2020), altering the distribution of pastoral pressure on habitats. In contrast, pollution was higher during the dry season, probably due to the intensification of economic and agricultural activities such as market gardening and off-season crops, as well as the increased use of motorized equipment and chemical inputs. These factors contribute to the degradation of environmental quality and the disruption of ecosystems frequented by birds. Similar trends were reported by Kougoum et al. (2023 ) in the Sena Oura and Zakouma national parks, where pastoralism was also the most frequent activity according to IKA surveys. However, contrary to their conclusions suggesting a limited impact of human activities on birdlife, the analyses from this study highlight a significant negative correlation between the intensity of anthropogenic pressures and bird abundance, both in the rainy and dry seasons. This difference could be linked to the protection status of the sites : in unprotected areas, pressures are generally stronger and less regulated, which amplifies the impacts on wildlife. Chavez-Lugo et al. (2024) also observed same trend where bird communities in unprotected environments are significantly influenced by human activities. The weaker correlation recorded during the rainy season could be explained by the greater availability of food resources and nesting habitats, which temporarily mitigates the effects of human disturbance. However, this buffering effect remains limited, as most of the pressures observed persist throughout the year. Overall, these results highlight the need for integrated management of the Lake Chad basin ecosystems.

## 4. CONCLUSION

The study conducted in the southern part of Lake Chad highlights remarkable avian diversity, with 213 species recorded, representing more than half of the region's total. Water areas have the greatest diversity, while anthropized environments are the poorest. The dry season is richer in species, particularly migratory species, while the rainy season has greater species diversity. Human activities (grazing, poaching, deforestation, fires, pollution) negatively affect bird communities. The presence of endangered species confirms the ecological importance of the site. Integrated habitat management, combining conservation, regulation of uses, and community participation, is essential to ensure the sustainability of biodiversity in southern Lake Chad.

### Authors' Contributions

Wansang Daksala: led the research, conducted the fieldwork, and prepared the manuscript. Kougoum Piebeng Ghislain Noé: conducted the fieldwork, performed the literature review. Kondasso Taiga Lea: interpreted and analyzed the data, reviewed the manuscript. Bakwo Fils Eric Moise: conducted the fieldwork, reviewed the manuscript.

### Conflict of Interest

The authors declare that they have no conflicts of interest related to the content of this manuscript.

### Statement on Generative AI and AI-Assisted Technologies in the Writing Process

The authors declare that no artificial intelligence tools were used to write this manuscript.

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