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Comparison of bird assemblage structures and diversity patterns between seasons among the three Ethiopian wetlands

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Abstract

Wetlands are significant habitats for avian populations, and knowledge of the diversity and other ecological aspects of bird species contribute to the management of the ecosystem. The present study was based on comparative studies of the diversity and relative abundance of bird species in the three wetlands of southwest Ethiopia. The point count method was utilized in this study. For the data analysis, the Shannon-Wiener diversity index, independent sample t-test, and similarity index were employed. A total of 46 bird species under 11 orders and 30 families were identified. The species diversity and relative abundance were higher in all three wetlands during the wet season. The Loga wetland had the highest diversity (H' = 3.089), whereas the lowest diversity (H' = 2.643) was recorded in the wetland of Hurri. During the dry season, the highest and the lowest diversity were also recorded in the Loga wetland (H' = 2.738) and the Hurri habitat (H' = 2.283), respectively. Seasonal differences in the species diversity of bird species are not statistically significant ($p > 0.05$). Since the existence of bird species is reliant on a wetland ecosystem; human activities very close to the wetland should be controlled for their sustainable conservation.

1. Introduction

Wetlands are among the most productive ecosystems in the world, rich in biodiversity and harboring many globally threatened species (Getzner 2002). These areas play critical ecosystem roles such as biodiversity conservation, hydrological balance, and human welfare (Woldemariam et al. 2018). A wide variety of birds use wetland habitats for all or part of their lives (Patra et al. 2010). Wetland birds are extremely diverse, reflecting early anatomical and physiological adaptation to this unique but rich habitat (Milton 2003). There are two categories of wetland birds: wetland specialists and generalists. Wetland specialists are birds that are entirely dependent on aquatic habitats and cannot survive in any other environment. Generalists, on the other hand, are birds that visit and rely on wetland habitats for food, shelter, and perching (Wetlands International 2012).

Waterbirds are an important component of the biotic community of wetland ecosystems (Green and Elmberg, 2014). They are good indicators of terrestrial and aquatic ecosystem pollution (Rajashekara and Venkatesha 2010). They differ widely in their species composition and relative abundance within a community (Milton 2003).

Elucidating the patterns of species diversity and their abundance across different locations is a vital purpose of community ecology. Many scholars studying species diversity (Sarah et al. 2020) have given emphasis to the avian communities. One of the main priorities in animal conservation is checking their populations to find the best strategies for their sustainable survival (Rajashekara and Venkatesha 2010).

According to Hillman (1993), there are 77 wetlands in Ethiopia and Eritrea with an entire coverage of 13,699 km^2, or 1.14% of the overall land area of the two countries. Mengistu (2003) described that there are 245 bird species in Ethiopia. Despite the rich bird species in Ethiopia, due to enormous habitat degradation, fragmentation, and loss, the survival of many bird species, including wetland birds (Shimelis and Bekele 2008), along with different types of agroforestry systems, is threatened (Yasin and Tekalign 2022). In Ethiopia, the wetlands are frequently considered to be wastelands and are believed to pose obstacles to farming expansion, cause an increase in risks to human and animal health, and be associated with disasters such as floods, with consequent pests and resulting diseases like malaria and schistosomiasis (Senteba 2007). Like other parts of sub-Saharan Africa, most of the Ethiopian wetlands are at risk of habitat degradation and habitat loss due to population growth and other factors such as on-site and off-site management problems, cultivation of wetlands, and the occurrence of drought (Mekonnen and Aticho 2011). Wetland bird species' diversity and abundance have been threatened due to various anthropogenic activities (Isaac et al. 2019).

The number of species present and how evenly the individuals are distributed among these species determine how diverse the avian species are (Isaac et al., 2019). According to Ali et al. (2016), the number of species present during various seasons is the only difference between bird assemblages. They showed that wetland managers should be extremely concerned about the sharp loss in species diversity as well as the seasonal persistence of dominant assemblages. The movement of birds, the availability of food, the suitability of the habitat, a wetland's geo-physiological structure, and its size all affect the diversity and distribution patterns (Akosim et al., 2008).

The wetlands of the study area and their surroundings are a haven for several bird species, including the black-crowned crane (*Balearica pavonina*) and the thick-billed raven (*Corvus crassirostris*). There was no prior research carried out on the bird species inhabiting the wetlands. One of the biggest threats to the wetlands is the expansion of farming activities nearby to produce crops like maize and sorghum, brick production, animal grazing, and the presence of large Eucalyptus tree plantations, which are changing the chemical and physical characteristics of the wetlands' areas. The diversity and assemblage structure of the bird species in the region between the dry and rainy seasons may then be impacted by this. Understanding the state of the species can help with the management of ecosystems and the services they provide. Bird species have a significant functional role in wetlands (Arruda et al. 2018). Bird species diversity and assemblage vary with the seasons and types of habitat. The assemblage of bird species and the diversity of seasons and habitat types are impacted by anthropogenic activities close to habitats. Therefore, the purpose of this study was to address the issues surrounding the variations in bird species diversity and assemblage structure between the dry and wet seasons in the three wetlands in southwest Ethiopia, as well as their underlying causes.

2. Materials And Methods

2.1. The study area

Awetu, Hurri, and Loga wetlands are located around Gomma woreda (equivalent to a district), Oromia Regional State. Gomma woreda has an elevation of 1636 meters above sea level and is located at 08^{o} 43' ' 00' to 07^{o} 39" 00'N Latitude and 36^{o} 22" 00' to 36^{o} 49" 00'E Longitude. The woreda has a total area of

864.69 km^2 (Fig. 1). It is bordered by Gumay and Gera Wereda to the west; Mana Woreda to the east; Limu Kosa Woreda and Buno Bedele Zone to the north; and Seka Chokesra to the south. Aggaro town, which is the capital city of the woreda, is located 390 km from Addis Ababa on the way through Jimma.

Specifically, the three wetlands are found around Keta Muduga, which is the place where the foundation for coffee (*Coffee arabica*) production in Ethiopia was laid. Awetu wetland is the largest (14.4 km^2) of the wetlands, followed by Hurri (11.7 km^2), and Loga is the smallest (7 km^2). The three wetlands have a total surface area of 33.1 km^2. Awetu and Hurri wetlands are dominated by marshes and swamps with different water levels in different seasons, whereas the coastal area of Loga wetland is covered by different types of vegetation. The water sources of the Awetu, Hurri, and Loga wetlands are the Awetu, Hurri, and Loga Rivers, respectively. The littoral areas of the wetlands are covered with grass species, including *Sporobolus pyramidalis* and *Hyparrhenia rufa*. Eucalyptus tree plantation and brick production were commonly observed practices around the Awetu and Loga wetland habitats. However, livestock grazing and farming activities were the main activities in the Hurri wetland habitat.

The study area's average monthly maximum and minimum temperatures are recorded in March (30°C) and October (10°C), respectively. The study area's average monthly maximum and minimum rainfall are recorded in September (233 mm) and December (0.3 mm), respectively, and the highest and lowest average relative humidity recorded are in September (77%) and February (37%), respectively (NMSA, 2019) (Fig. 2).

2.2. Methods

A reconnaissance survey was conducted for a week in January 2020 in order to become acquainted with the study area. The area was divided into sampling strata and units that cover the whole area, and walking transects were placed using a stratified random sampling technique based on the size and wetland habitat heterogeneity (Buckland et al. 2001). Three different wetlands were selected, namely: Awetu, Hurri, and Loga wetlands.

The point count method was used to study the bird assemblage structure and diversity in the study area (Manley et al. 2006; Lambert et al. 2009). Data was recorded by distributing points in the given habitat and selecting points from the distributed points on a random basis. Two, two, and one counting blocks were used for the Awetu, Hurri, and Loga wetlands, respectively. For each counting block, four, four, and two transect lines were used, and six, six, and four-point counts were used for each wetland habitat, respectively. With the help of a GPS (Garmin GPSMAP 64s) and flagging tape, a total of 16 points were set up. Locations in each habitat were at least 25 meters away from the surrounding forest boundary, and all points were spaced apart by 30 to 50 meters (Perfecto et al. 2003). A laser meter was used to measure the distance and angle between the observer and the birds. Activities such as diversity, abundance, and locations of birds were recorded at each point. A colored polygene sheet was used to mark each counted block. The radius of point counting blocks was set at bands based on the bird’s detectability test during the reconnaissance survey (Norvell et al. 2003; Rosenstock et al. 2002).

Data collection was carried out from January 2020 to July 2020, both during the dry (February to April) and wet (May to July) seasons, following the work of Amare (2005). Three trips were made to the research region each month. In order to reduce disturbance during point counts, a waiting interval of five minutes was utilized for transportation and bird adjustment before the count, and a further ten minutes were employed for bird observation (Hosteler and Main 2001; Sutherland 2000). Species were visually and acoustically recognized within a 30-meter radius using binoculars (8 x 30 and 8 x 40) and/or the human eye during each 10-minute sample interval. During point counts, certain audio recordings were used for identifying purposes later. Birds flying overhead within the point radius were not counted (Perfecto et al. 2003). The current sampling period's time and weather were noted during bird adjustment phases. Each point was 100 m away from the roadside to avoid the edge effect and 300 m away from each other to avoid double counting of the same individual species in different transect lines (Shimelis and Bekele 2008).

Data collection was performed during the morning from 06:00 to 09:00 hr and in the afternoon from 15:00 to 17:00 hr when the activity of birds becomes prominent (Tsigereda 2011). Bird species names and populations were counted during the survey through direct observation. Both the time it took to complete each transect and the anticipated perpendicular distance from the transect lines were noted. Using common bird field guides, the birds were identified and grouped into their appropriate taxonomic groups (Redman et al., 2009; 2011). For more assurance, a picture of the birds was also shot with a digital camera. The sounds of the birds were also used to identify them.

2.3. Data analysis

All the recorded bird species were statistically analyzed using various parameters like Shannon Index (H') (Shannon and Weaver 1949), Species Evenness (E), Species Abundance, and Richness. The number of individuals recorded for each bird species was statistically evaluated using the Species Diversity Index (H'). The values range between 0, indicating low community complexity, and 4 and above, indicating high community complexity.

- **Relative Density**

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Where H' = diversity index; Pi = the proportion of each species in the sample; and ln

pi = the natural logarithm of this proportion.

Abundance: Using the work of Bull (1974), the abundance of bird species in the study area was computed by using the number of individual birds of particular species in the study area as a percentage of the total bird population of a given area.

$$\text{Abundance} = \frac{\text{Total number of individuals in all sampling units}}{\text{Total number of occurrence sampling units}}$$

$$\text{Evenness} = \frac{H}{H_{max}}$$

Where, H=Shannons Diversity Index, and H_{max} = maximum diversity possible.

Richness

The number of species per sample is a measure of richness. The more species present in the sample, the "richer" the sample becomes. Margalef's index was used as a simple measure of species richness.

Margalef's index = (S-1/In N)

Where S = the total number of species, N = the total number of individuals in the sample, and In = natural logarithm.

The bird species with populations of between 51 and 200 individuals were termed "very common," whereas those with populations of between 21 and 50 individuals were considered common species. Bird species were termed "frequent" if they had a population of between 7 and 20 individuals per day, whereas those observed between 1 and 6 were called "uncommon". Correspondingly, birds with 1–6 individuals per season were described as rare. Besides, bird species are also classified as wetland specialists for those species that eat a limited diet and occupy a much narrower niche, while wetland generalists are for those species that can feed on a wide variety of things and thrive in various environments.

A statistically independent sample t-test was employed to estimate the seasonal and spatial effects on bird species' abundance and distribution. The similarity among habitats and seasons in terms of bird species composition was evaluated using the Similarity Index (SI) = 2C/A + B) (Sorenson 1948).

Where SI denotes the Similarity Index, A denotes the number of species found in site A, B denotes the number of species found in site B, and C denotes the number of species found in both sites A and B. A sample correlation analysis of bird species was done using Pearson chi-square with a 5% significance level.

3. Result

3.1. Species diversity

During the study period, a total of 2,588 individual birds, including 46 species, 11 orders, and 30 families, were recorded in the study area. Of the 11 orders, the order Passeriformes is represented by the highest number of species (N = 17). On the other hand, the lowest number of species was recorded in the orders of Columbiformes, Cuculiform, and Coliforms, with a single species each. Of the total avian species recorded in the study area, two species are endemic to Ethiopia. Thick-billed Raven (*Corves crassirostris*) and Banded Barbet (*Lybus undates*), 13 pale arctic migrant species, 24 residents, and the remaining seven species were partially migrant (Annex 1).

During the wet season, a total of 57 bird species were recorded from the three wetland habitats. Among them, 32 were wetland specialists and 26 were wetland generalists. During the dry season, 41 bird species were recorded from the three wetland habitats. Of those, 23 were wetland specialists and the remaining were wetland generalist bird species.

In general, overall bird species diversity was higher during the wet season in all habitats. Loga wetland has the highest species diversity in both wet (H' = 3.089) and dry (H' = 2.738) conditions. On the other hand, the lowest species diversity is found in the Hurri habitat in both wet (H' = 2.643) and dry (H' = 2.283), respectively. The species' evenness (E) during the dry season was 0.9131, 0.9520, and 0.9665 for Awetu, Hurri, and Loga wetland habitats, respectively (Table 1). There is no statistically significant difference between the wet (Mean = 0.16802, SD = 0.111767) and dry seasons (Mean = 0.18420, SD = 054151) (two-tailed) bird species diversity in the wetland habitats (t = -0.857, df = 97, p = 0.393).

Table 1
The diversity of bird species in the study area during the wet and dry seasons

Wetland	Season	NS	NI	RI	H'	H'/Hmax
Awetu	Dry	13	336	2.1	2.342	0.9131
	Wet	18	483	2.8	2.706	0.9363
Hurri	Dry	11	218	1.9	2.283	0.9520
	Wet	16	416	2.5	2.643	0.9531
Loga	Dry	17	408	2.7	2.738	0.9665
	Wet	23	727	3.3	3.089	0.9853

NS = Number of species; NI = Number of individuals; RI = Richness; H' = Shannon-Weaver diversity index; H'/H'max = Evenness, H'max = ln(S).

3.2. Similarity Index

3.2.1. Bird species' similarity between seasons

The highest (SI = 0.65) similarity of bird species between the wet and dry seasons was observed at Loga and less similarity (SI = 0.58) at Awetu wetland (Table 2).

Table 2
The overall similarity (SI) of bird species within habitats during the wet and dry seasons

Wetland	Wet	Dry	Common species	SI (Similarity Index)
Awetu	18	13	9	0.58
Hurri	16	11	8	0.59
Loga	23	17	13	0.65

3.2.2. Bird species' similarity between habitats

Avian species showed similarities between Awetu and Hurri, Awetu and Loga, and between Hurri and Loga wetland habitats. During the wet season, bird species similarity was higher (SI = 0.55) between Hurri and Loga wetlands. Besides, a higher species similarity (SI = 0.4) was recorded between Awetu and Loga wetlands during the dry season (Tables 3 and 4).

Table 3
Compares the similarity of bird species' habitats during the wet and dry seasons

Wetland	Season					
	Wet			Dry		
	Number of species	SI	%	Number of species	SI	%
Awetu wetland with Hurri	4	0.18	18	5	0.31	31
Awetu wetland with Loga	7	0.32	32	6	0.38	38
Hurri wetland with Loga	11	0.50	50	5	0.31	31

Table 4
One-way ANOVA test for bird species variation between habitats in the dry and wet seasons

Season	Habitat	Number	Mean value	SD	F	Sig.
Wet	Awatu	18	0.1566	0.039	0.201	0.819
	Hurri	16	0.1650	0.059		
	Loga	24	0.1786	0.165		
	Total	58	0.1680	0.112		
Dry	Awatu	13	0.194	0.040	3.86	0.043*
	Hurri	11	0.207	0.063		
	Loga	17	0.161	0.050		
	Total	40	0.183	0.054		

3.3. Relative abundance

A total of 1135, 819, and 634 individual birds were recorded from Loga, Awetu, and Hurri wetlands in both the wet and dry seasons. The highest number (N = 727) of individual birds was recorded from Loga wetland and the least (N = 416) from Hurri during the wet season. Similarly, during the dry season, the highest (N = 408) and the least (N = 218) number of individual birds were recorded from Loga and Hurri, respectively. In general, in all habitats of the present study, bird species abundance during the wet season was higher (Fig. 3) (Table 5).

Table 5
Independent sample t-test for the relative abundance of bird species in the study habitat

Habitat	Season	N	Mean	SD	t	df	Sig (2-tailed)
Awatu	Dry	13	25.84	8.754	-0.278	29	0.783
	Wet	18	26.83	10.391			
Hurri	Dry	17	24.00	10.030	-1.684	39	0.012*
	Wet	24	30.29	12.850			
Loga	Dry	11	19.81	9.703	-1.078	23	0.292
	Wet	14	24.92	13.141			

During the wet season, the status of the local occurrences varied: common for 15, frequent for 14, uncommon for 12, and rare for 10 bird species. Among bird species recorded during the dry season, 15 species were recorded as common, 10 species were frequent, 7 species were uncommon, and 8 species were observed rarely (Table 5). At Hurri wetland, there is a significant difference in records between the dry (Mean = 24.00, SD = 10.03) and wet seasons (Mean = 30.29, SD = 12.85; t = -1.684, P = 0.012; two-tailed). This showed that there is variation between the dry and wet seasons in the relative abundance of bird species in the Hurri wetland. However, there is no statistically significant difference between the dry and wet seasons in the relative abundance of bird species in Awetu and Loga wetland habitats. The results also revealed that there is a significant difference in relative abundance between wetlands during the dry season ($F = 4.53$; $P < 0.05$), but no difference in relative abundance between wetlands during the wet season ($F = 0.782$; $P > 0.05$) (Fig. 4) (Table 6).

Table 6
Independent t-test for comparing relative abundance in dry and wet seasons

Season	Habitat	N	Mean value	SD	F	Sig.
Dry	Awatu	14	26.50	8.75	4.530	0.030*
	Hurri	16	23.31	9.94		
	Loga	11	19.81	9.70		
	Total	41	23.46	9.61		
Wet	Awatu	18	26.83	10.39	0.782	0.463
	Hurri	24	30.29	12.85		
	Loga	16	25.75	12.91		
	Total	58	27.96	12.12		

4. Discussion

In the present study, a total of 46 bird species under 11 orders and 30 families were recorded from the three wetland habitats. A total of 64 species and 17 families of birds were recorded across the wetlands of eastern Uganda (Sarah et al. 2020). From the Afro-tropical highland wetlands of the Awi zone and Wombera hotspot areas, Northwestern Ethiopia, 84 species and 23 families were recorded (Tesfahunegny 2016). A total of 103 avian species belonging to 47 families and 14 orders were recorded in Lake Hawassa and part of the Eastern Wetland habitats, Southern Ethiopia, during the wet and dry seasons (Gibru and Mengesha 2021). Ninety-five species were recorded from the wetland areas of Tropical Maharashtra, India (Wagh and Prathmesh 2020). Of the 11 orders, the order Passeriformes is represented by the highest number of species (N = 17). The order Passeriformes is the largest and most diverse order of birds, comprising over half of the world's known bird species (Sibley and Monroe 1990).

This study indicated that the wetlands support a large number of bird species, including two endemic species, the Thick-billed Raven (*Corves crassirostris*) and the Banded Barbet (*Lybius undatus*). In addition to this, resident and migrant bird species occur in a significant number, which provides an indication that the area is a satisfactory habitat for resident bird species and a stopover for migrant bird species that can forage, loaf, rest, and refuel their energy. In a similar study that was carried out around Jimma town of BoyeKitto and Kofe wetlands, 107 species of water birds were recorded (Mekonnen and Aticho 2011). The species composition of birds in different seasons was also determined for the study areas. In general, overall bird species diversity was highest during the wet season in all habitats. This is due to the high species richness in this wet season.

According to Borgesio (2004), wetland habitats provide ample food resources such as frogs, worms, and insects to many bird species. This study, however, found that among the three wetland habitats, the highest species diversity was recorded in the Loga wetland habitat. Further, the presence of a variety of vegetation around this wetland is probably a contributing factor. Smith (1992) described how food resources are one of the key factors in determining the species diversity in a particular area. On the other hand, in the Hurri wetland habitat, relatively less bird diversity was observed. This might be due to more anthropogenic activities taking place around this wetland habitat. For this reason, birds do not get an adequate place for nesting and breeding. Meyer and Turner (1992) described how the conversion of wetlands for agriculture and industrial ports affects the nesting and breeding sites of many bird species.

The result of species diversity analysis revealed that species composition is different among areas and months because of habitat differences, seasonal movement patterns, local and regional habitat changes, large-scale population changes, and climatic conditions (Ericiaet al., 2005). The present study revealed that the seasonal occurrence of bird species in the three wetlands was different. In general, most bird species were locally common.

A total of 1626 individuals of 57 species of birds were observed during the wet season and 962 individuals of 41 species during the dry season in the three types of habitats of the study area (Table 2). The decline in global bird diversity has been linked to a number of anthropogenic factors, including pollution (Gordon et al. 1998), water fluctuation (Riffell et al., 2001; Timmermans et al., 2008), habitat and landscape configuration, and the influence of the surrounding physiographic matrix (Czech and Parsons 2002). The seasonal occurrence of bird species in the three wetlands was different. This difference might be due to the availability of food resources, habitat conditions, breeding season, as well as the migratory behavior of bird species (Mengesha and Bekele 2008). In a similar way, Gaston and Blackburn (2009) explained that the distinct seasonality of rainfall and seasonal variation in the abundance of food resources resulted in seasonal changes in the abundance of birds. Furthermore, the temporal decoupling of food resources and bird numbers, variable climate harshness in different regions, or individuals' inability to reach isolated areas all have an impact on the migratory bird population (Telleria et al. 2009).

In general, wetlands are important feeding and breeding areas for birds. Farmers around the wetlands cultivate the area during both the wet and dry seasons, with crops such as maize and sorghum becoming the dominant crops in the study areas. At present, the unusually high level of human encroachment has led to a reduction in the size of the wetlands, which has resulted in many areas being under permanent cultivation. Ultimately, this could eliminate the bird's habitat unless concerned bodies are involved in conservation measures. To conserve the wetlands and the avian population of the study area, a management plan should be prepared emphasizing an avenue for the sustainable utilization of the resources of the wetland without jeopardizing its continued ecological values and function. As with all ecological studies, our study also has some shortcomings during data collection and analysis.

5. Conclusion

The result of this study showed that the Awetu, Hurri, and Loga wetland habitats are more productive avian habitats since they are home to a variety of bird species. Among these bird species, some are globally threatened, as well as some are endemic to Ethiopia. A total of 46 bird species were recorded in the three different wetland habitats during both the wet and dry seasons. The highest diversity of bird species was recorded in the Loga wetland area, whereas the lowest diversity of bird species was recorded in the Hurri wetland. The presented study also revealed that the species composition of birds between seasons is not statistically significant. However, there is variation in the relative abundance of bird species among seasons and habitats. Currently, although the wetlands support several bird populations, anthropogenic activities near the wetlands are shrinking the habitat available for birds, which ultimately will seriously affect birds' abundance and the survival of the wetlands in the area. A management plan should be developed that focuses on the long-term use of the wetlands.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki, which provides guidance for researchers to protect research subjects. The study was approved by the Institutional Research Review Board (IRB) of Wolaita Sodo University. Consent to participation isn't applicable to the present article.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

There is no conflict of interest between the authors regarding this paper.

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Authors' contributions

Numeri Awash designed the research, collected data, organized the data on the computer, did the analysis, interpretation, and identification, and wrote the draft manuscript.

Wondimagegnehu Tekalign: proposed the research concept, read the draft, reviewed, edited, supervised, and validated the final manuscript.

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Figures

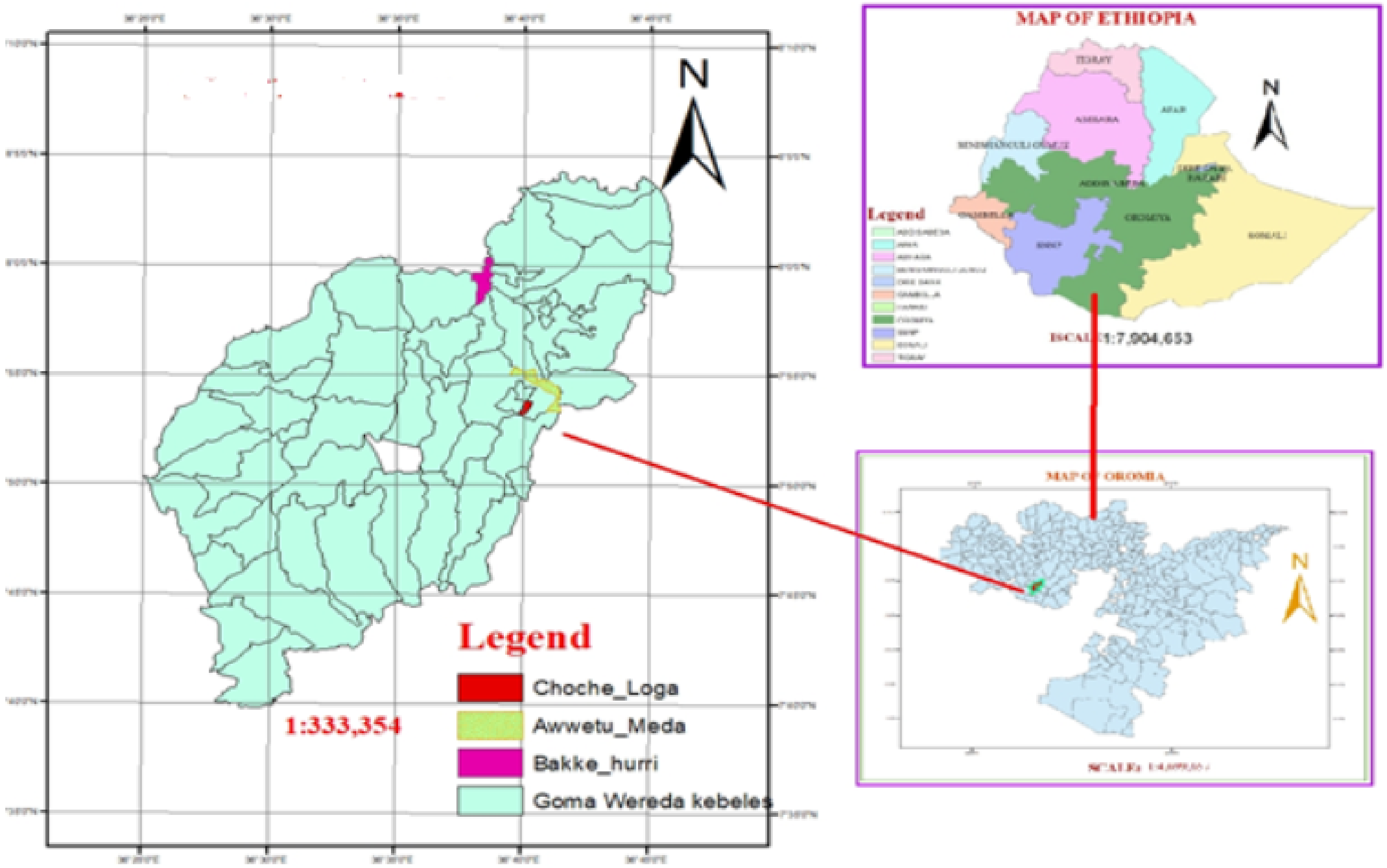

Figure 1

A map of the study area

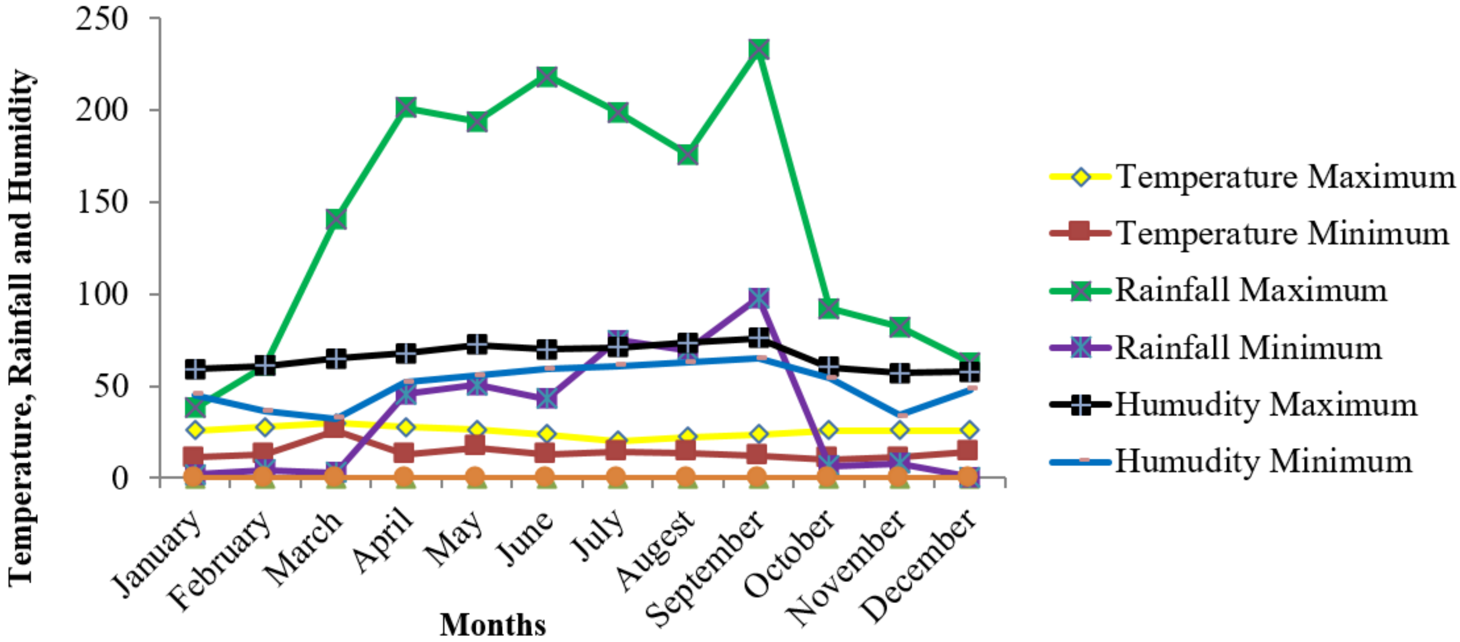

Figure 2

The average monthly maximum and minimum temperatures, rainfall, and humidity

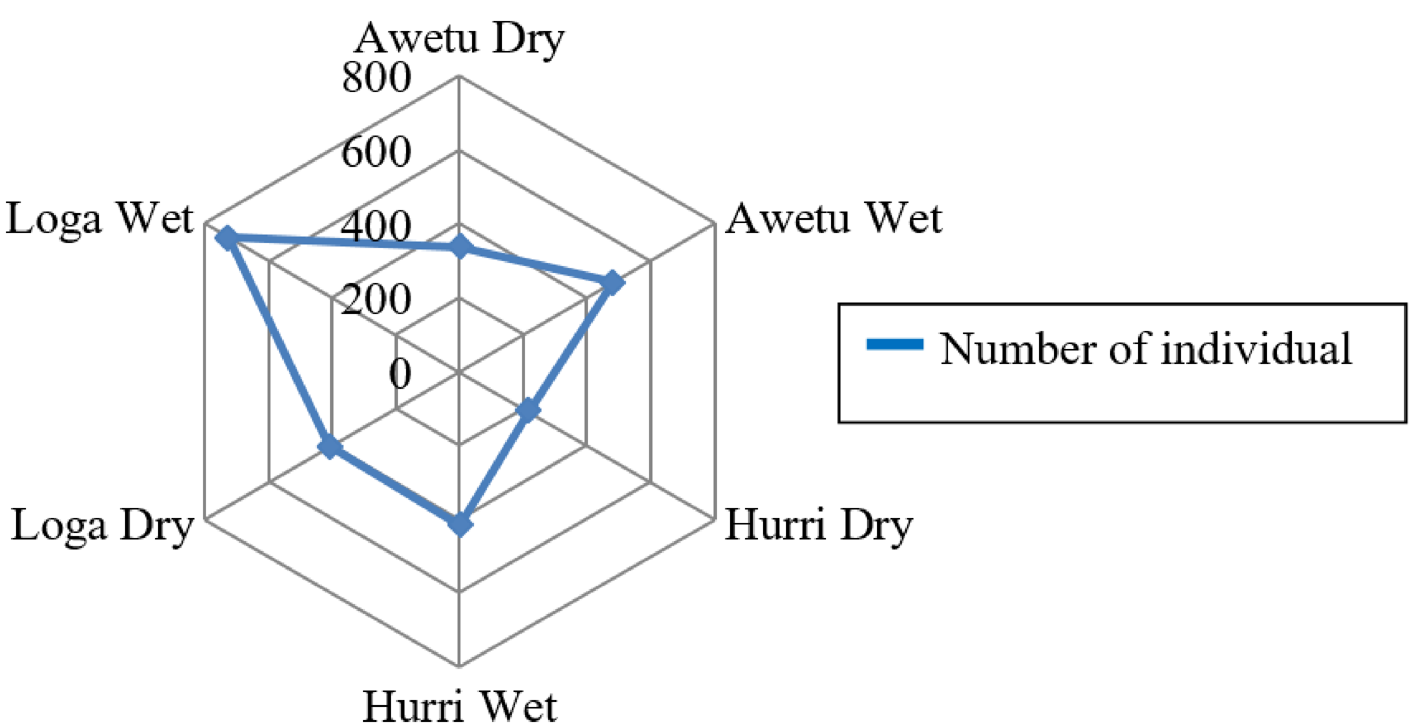

Figure 3

Individual (N) bird count in the study habitats

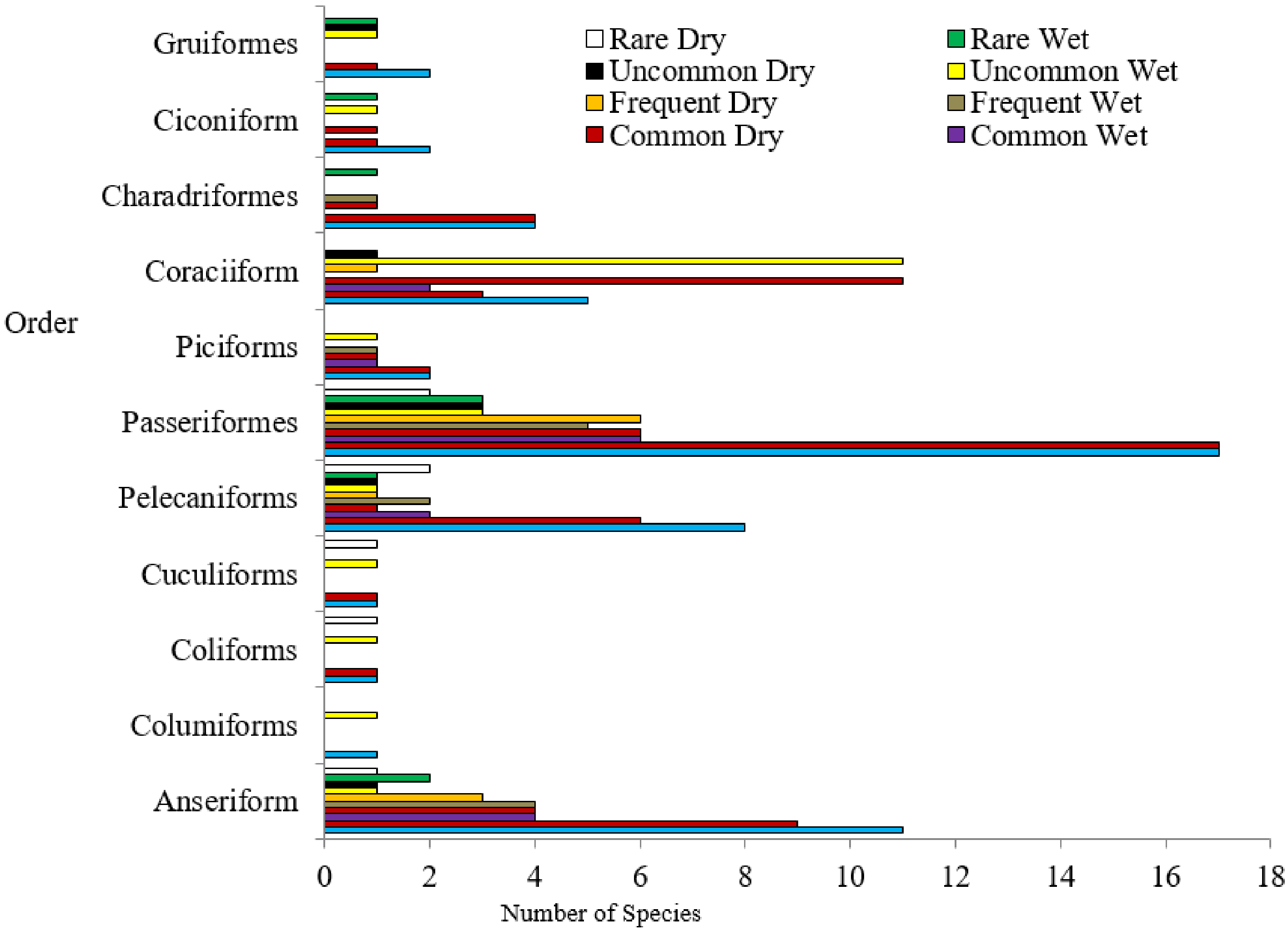

Figure 4

Bird species' local occurrence status during wet and dry seasons

Supplementary Files

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- Annex1.docx