Comparative studies on the diversity and relative abundance of waterbird species in three southwest Ethiopian wetlands

Numeri Awash
Wolaita Sodo University
Wondimagegnehu Tekalign (wondimagegnehubeyene@gmail.com)
Wolaita Sodo University

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Abstract

Wetlands are significant habitats for avian populations, and knowledge of the diversity and other ecological aspects of waterbirds contribute a lot to the management of the ecosystem. The present study was conducted based on comparative studies on the diversity and relative abundance of waterbird species in the three wetlands of southwest Ethiopia. The point count method was utilized in this study. For the data analysis, the Shannon-Weaver 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 of the 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. There is no statistically significant difference between seasons in the species diversity of waterbirds ($p > 0.05$). Since the existence of waterbirds is based on a wetland ecosystem; human activities very near to the wetland should be controlled for their sustainable conservation.

Introduction

Wetlands are among the most productive ecosystems in the world, rich in biodiversity and harboring many globally threatened species (Getzner 2002). Wetlands 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 completely reliant 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).

Wetland birds 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, and the avian communities have been given emphasis by many of the scholars studying species diversity (Sarah et al. 2020). 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). Waterbird diversity is sensitive to climate, and understanding how they respond to climate is needed to enhance their diversity and conservation (Arruda et al. 2018; Xiuzhong et al. 2021). Nearly all waterbirds have a distinct preference for wet habitats and shorelines.

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 waterbird 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), and avifauna along with different types of agroforestry system (Yasin and Tekalign 2022). In Ethiopia, the wetlands are frequently assumed as wastelands and believed to pose difficulties to farming expansion, human and animal health associated with pests, and disasters such as floods, diseases like malaria, and schistosomiasis (Senteba 2007). Like other parts of sub-Saharan African countries, 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 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 (*Corvues crassirostris*). Although many prior pieces of research have been carried out on the wetlands, none of them has been done on the waterbirds that inhabit them. Therefore, this study aimed to study the diversity and abundance of waterbirds in the Awetu, Hurri, and Loga wetlands, in southwest Ethiopia.

Materials And Methods

The study area

Awetu, Hurri, and Loga wetlands are located around Gomma district, Oromia Regional State. Gomma District is found at 08^0 43" 00' to 07^0 39"30'N Latitude and 36^0 22" 00' to 36^0 49" 00'E Longitude with an elevation of 1636 meters above sea level. The Gomma district has a total area of 86469ha (864.69 km^2). The woreda 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 district, 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 of coffee (*Coffee arabica*) 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 3310 ha (33.1 km^2). Awetu and Hurri wetlands are dominated by marshes and swamps with different water levels at 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 also 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 wetlands are home to several species of waterbirds, including bird species such as the Black-crowned crane

(*Balearica pavonina*), Hadad ibis (*Bostrychia hagedash*), and endemic bird species such as the Banded Barbet (*Lybius undatus*).

The average monthly maximum and minimum temperatures of the study area are recorded in March (30C^{o}) and October (10C^{o}), respectively (Figure 2), the average monthly maximum and minimum rainfall of the study area was recorded in September (233 mm) and December (0.3mm), respectively (Figure. 3), and the highest and lowest average relative humidity recorded are in September (77%) and February (37%), respectively (Figure. 4).

Methods

A reconnaissance survey was conducted for a week in January 2020 to get well 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 habitat heterogeneity (Buckland et al. 2001). Three different habitat types were selected, namely: Awetu, Hurri, and Loga wetlands.

The point count method was used to study the abundance and diversity of birds 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. 2, 2, and 1 counting blocks were used for the Awetu, Hurri, and Loga wetlands, respectively. For each counting block, 4, 4, and 2 transect lines were used, and 6, 6, and 4 point counts were used for each wetland habitat, respectively. In a five-minute bird count (FMBC), activities, diversity, abundance, and locations of birds were recorded at each point. A colored polygene sheet was used to mark each count 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). The observation was made using binoculars by standing in the middle of the point transect and observing steadily up to a distance of 30 meters. Shimele and Bekele (2008) say that each point transects will be 100 m away from the roadside to avoid edge effect and 300 m away from each other to avoid double counting of the same individual species in different transect lines. To minimize disturbance during the count, a waiting period of 3 to 5 minutes prior to the count was applied (Hosteler and Main 2001; Sutherland 2000).

Data collection was performed during the morning from 06:00 to 11:00 hr and in the afternoon from 15:00 to 18:00 hr when the activity of birds becomes prominent (Tsigereda 2011). The identification and categorization of birds into their respective taxonomic groups was done by using field guide books (Redman et al. 2011).

Data analysis

The bird species diversity of the study area was determined by the Shannon-Weaver diversity index (Shannon and Weaver 1949).

H' = -Σ Pi lnPi Where H’ = diversity index; Pi = the proportion of each species in the sample, and lnpi = natural logarithm of this proportion.

The relative abundance of bird species in the study area was computed by using the number of individual birds recorded in the study area, and the frequency of bird occurrence and comparative abundance was determined by following the work of Bull (1974). The bird species found between 51 and 200 individuals were termed “very common,” whereas those found 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.

A statistically independent sample t-test was employed to estimate the seasonal and special effects on waterbird 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 community with habitat quality was done using Pearson chi-square with a 5% significance level.

Result

Species composition

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 (Table 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 generalist bird species. 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 high 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 at Hurri habitat in both wet (H' = 2.643) and dry (H' = 2.283), respectively. The species' evenness during the dry season was 0.9131, 0.9520, and 0.9665 for Awetu, Hurri, and Loga wetland habitats, respectively (Table 2). There is no statistically significant difference between the wet (Mean =.16802, SD =.111767) and dry seasons (Mean=.18420, SD=054151) (t = -.857, p =.393) (two-tailed). This showed that there is no statistically significant difference between the dry and wet seasons in species diversity of waterbirds in the study habitat.

Similarity Index

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 3).

Bird species' similarity between habitats

Avian species showed similarity 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 (Table 4).

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 high (Figure 5).

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 scored 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 scores between the dry (Mean = 24.00, SD = 10.03) and wet seasons (Mean = 30.29, SD = 12.85; t = -1.684, P =.012; two-tailed). This showed that there is variation between the dry and wet seasons in the relative abundance of waterbirds in Hurri wetland. However, there is no statistically significant difference between the dry and

wet seasons in the relative abundance of waterbirds in Awetu and Loga wetland habitats. The results also showed that there is a significant difference in the relative abundance between habitats in the dry season ($F = 4.53$; $p < 0.05$); whereas, there is no significant difference in the relative abundance of waterbirds between habitats in the wet season ($F = .782$; $P > 0.05$).

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 waterbirds 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). Thirty-one species of waterbirds belonging to 14 families have been identified in the waterways along the Cauvery Basin at Kumbakonam, Tamil Nadu, India (Veeramani and Usha 2018). Of the 11 orders, the order Passeriformes is represented by the highest number of species (n = 17). Such a higher representation of perching birds or songbirds is necessary as 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, the occurring of residents and migrant bird species in a significant number of twenty-four and thirteen is an indication that the area is an ideal habitat for resident bird species and a stopover for migrant bird species in order to forage, loaf, rest, and refuel their energy. In a similar study that was carried out around Jimma town of Boye Kitto and Kofe wetlands, 107 species of water birds were recorded (Mekonnen and Aticho 2011). A 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 might be due to the high species richness in this wet season. During the wet season, the Loga habitat had the highest diversity, whereas the lowest diversity was recorded in the Hurri wetland habitat. Moreover, the highest evenness record was from the Loga habitat, whereas the lowest was from the Awetu wetland habitat. Similarly, during the dry season, the highest and lowest diversity were recorded in the Loga and Hurri habitats, respectively. During the dry season, the highest evenness was recorded from the Loga wetland, whereas the lowest was recorded from the Awetu wetland habitat.

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. This might be due to the fact that compared to other habitats; the presence of multiple food resources and anthropogenic activities in this habitat is very limited. Further, the presence of a variety of vegetation around this wetland is also 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 (Ericia et al. 2005). The present study revealed that the seasonal occurrence of waterbird species in three wetlands was different. In general, most bird species were locally common.

A total of one thousand six hundred twenty-six individuals of fifty-seven species of birds were observed during the wet season and nine hundred sixty-two individuals of forty-one species during the dry season in the three types of habitats of the study area (Table 2). The Loga wetland habitat had the highest number of individuals during both the wet and dry seasons as this habitat supplied a variety of food resources and the presence of good surface water. In addition, the littoral areas of the Loga wetland are covered by different vegetation. As a result, water birds were able to find alternative food sources, whereas, the lowest number of individuals was recorded from the Hurri wetland. This is due to more human activities taking place near this wetland habitat. The decline in the 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 waterbird 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 the three welands being 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. Crops such as maize and sorghum were becoming the dominant crops in the study areas. At present, the unusually high level of reduction in the size of the wetlands has led to many areas being under permanent cultivation. Ultimately, this could eliminate the bird’s habitat unless concerned bodies are involved in the alternative conservation measure. 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.

Conclusion

The result of this study showed that the Awetu, Hurri, and Loga wetland habitats are more productive habitats since they are home to a variety of waterbird species. Among these bird species, some are globally threatened, as well as 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 waterbirds 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 waterbirds among seasons and habitats. Currently, although the wetlands support several bird populations, anthropogenic activities going on near the wetlands are shrinking the available habitats for birds, which ultimately will seriously affect birds' abundance and survival in the wetlands of the area. To conserve the wetlands and the avian population of the study area, a management plan should be prepared emphasizing the sustainable utilization of the wetlands.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki that 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

All authors agreed to make this original research work public.

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Competing interests

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

Data availability

The datasets generated and analyzed during the current study are included in the body of this paper.

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Tables

Table 1 is available in the Supplementary Files section.

Table 2

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

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

Table 3

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
	Dry	17	408	2.7	2.738	0.9665
Loga	Wet	23	727	3.3	3.089	0.9853

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

Wetland	Wet	Dry	Common species	SI (Similarity Index)	% SI
Awetu	18	13	9	0.58	58
Hurri	16	11	8	0.59	59
Loga	23	17	13	0.65	65

Table 4

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

Wetland	Season					
	Wet			Dry		
	Number of species	SI	%	No. of species	SI	%
Awetu with Hurri wetland	4	0.18	18	5	0.31	31
Awetu with Loga wetland	7	0.32	32	6	0.38	38
Hurri with Loga wetland	11	0.50	50	5	0.31	31

Table 5

Bird species’ local occurrence status during wet and dry seasons

Order	Number of Species		Common		Frequent		Uncommon		Rare	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Anseriform	11	9	4	4	4	3	1	1	2	1
Columiforms	1	0	0	0	0	0	1	0	0	0
Coliforms	1	1	0	0	0	0	1	0	0	1
Cuculiforms	1	1	0	0	0	0	1	0	0	1
Pelecaniforms	8	6	2	1	2	1	1	1	1	2
Passeriformes	17	17	6	6	5	6	3	3	3	2
Piciforms	2	2	1	1	1	0	1	0	0	0
Coraciiform	5	3	2	11	0	1	11	1	0	0
Charadriformes	4	4	0	1	1	0	0	0	1	0
Ciconiform	2	1	0	1	0	0	1	0	1	0
Gruiformes	2	1	0	0	0	0	1	1	1	0

Figures

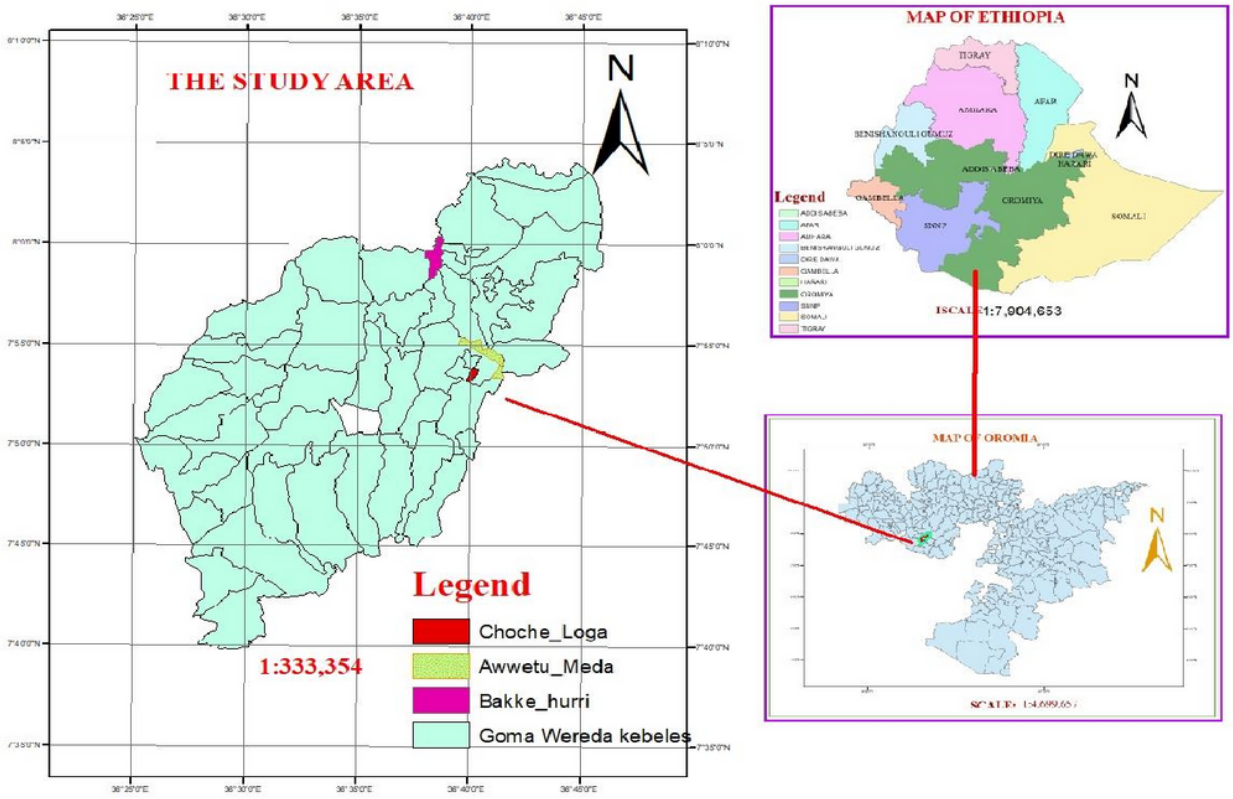

Figure 1

A map of the research area

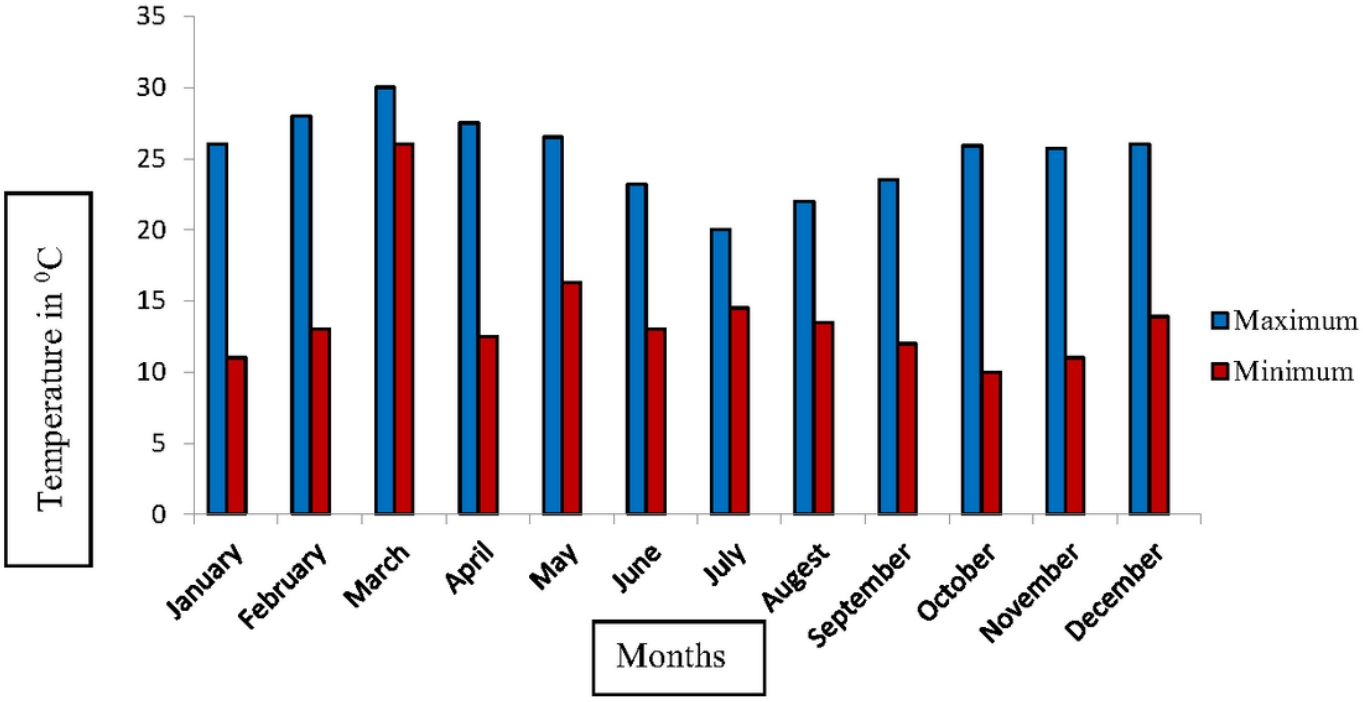

Figure 2

The average monthly maximum and minimum temperatures in the study area

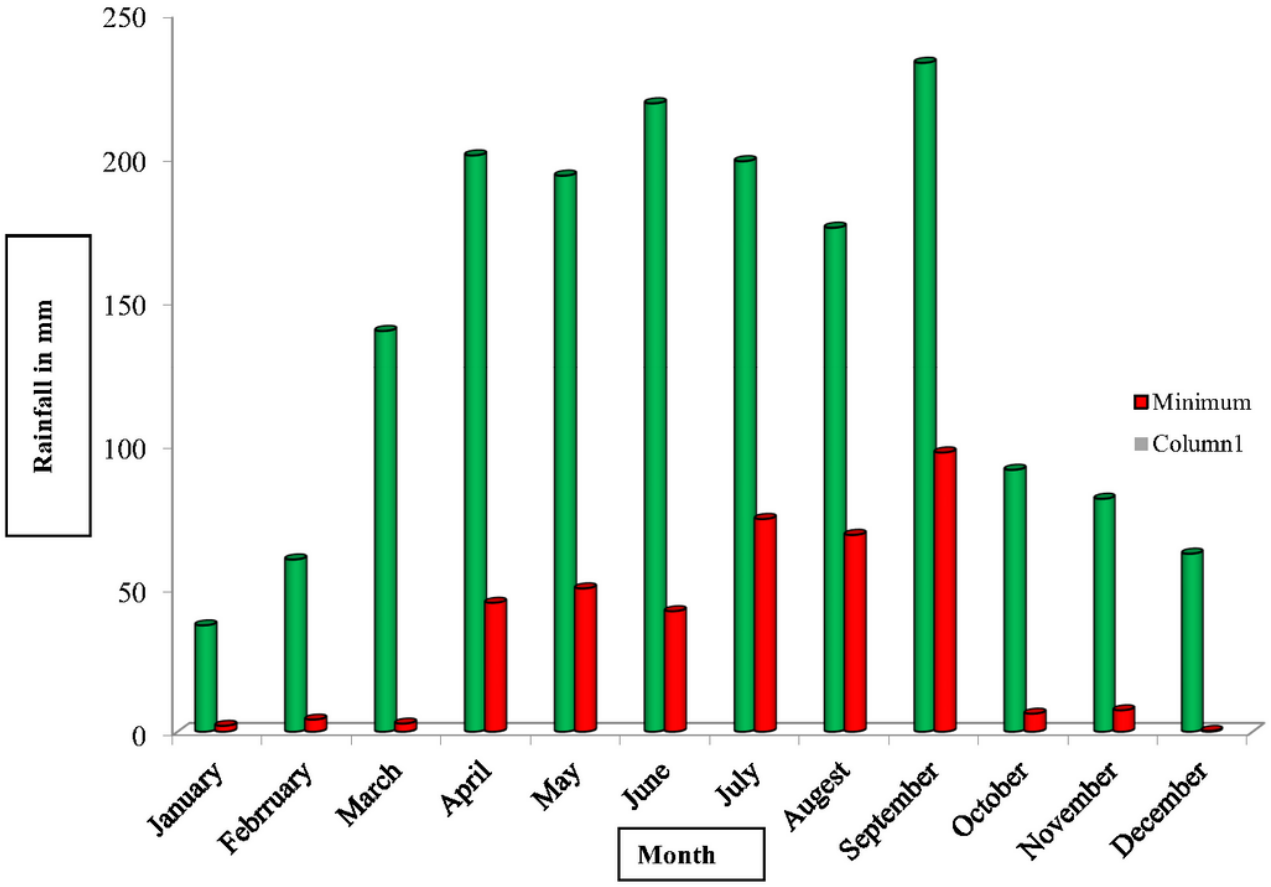

Figure 3

The average monthly maximum and minimum rainfall in the study area

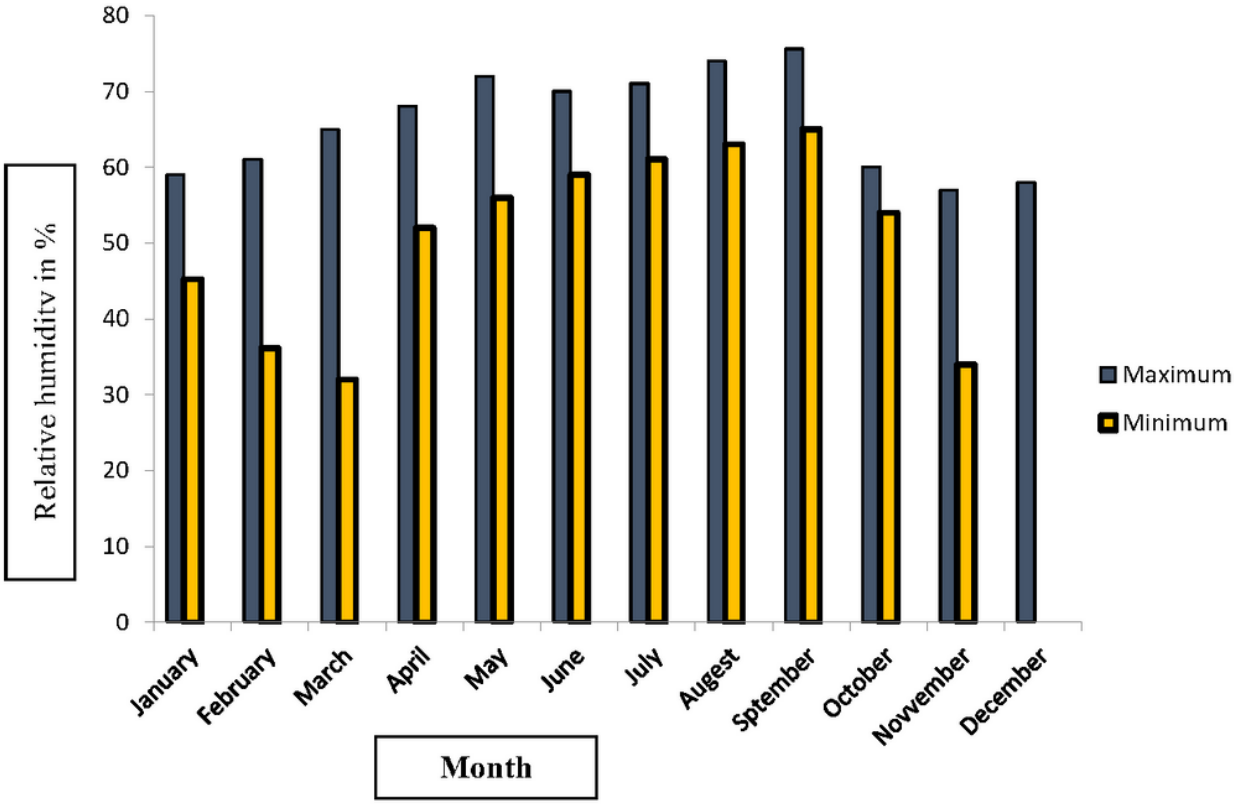

Figure 4

The study areas highest and lowest average relative humidity levels

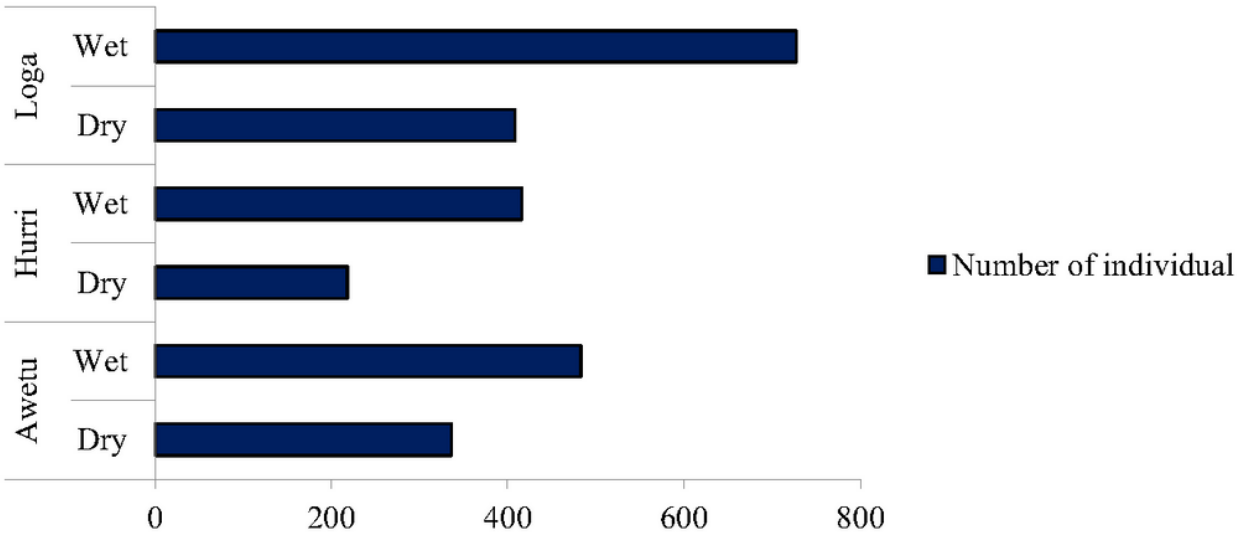

Figure 5

Individual (N) bird count in the study habitats

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.docx