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## RESEARCH ARTICLE

### Bird Diversity in Nensebo Moist Afromontane Forest Fragment, South Eastern Ethiopia.

Ziyad Jamal<sup>1</sup>, Zerihun Girma<sup>2</sup> and Girma Mengesha<sup>2,3,\*</sup>

<sup>1</sup>Department of Natural Resource Management, Arsi University, Assela, Ethiopia

<sup>2</sup>Department of Wildlife and Protected Area Management, Hawassa University, Hawassa, Ethiopia

<sup>3</sup>Addis Zoo Park, Addis Ababa, Ethiopia

#### Abstract:

#### Background:

Birds are one component of biodiversity. Ethiopia is rich in biodiversity resources. The avian diversity record is far from complete. There is no scientifically documented information on bird species composition and abundance at Nensebo forest. The objective of the study was to assess species composition, relative abundance and distribution of birds at Nensebo forest in southern Ethiopia.

#### Methods:

We employed a stratified random sampling technique with our study area stratified into two dominant habitat types: moist Afromontane forest and modified habitat. Within strata, we established 20 transect lines of 1km length and 0.25km width to sample 27.75% of the study area. We used line transect count methods aided by binoculars to estimate avian species diversity and distribution. We employed quantitative biodiversity indices, such as Shannon wiener diversity indexes to compare species diversity among habitat types and two way ANOVA to analyze the effect of season and habitat on bird species richness and abundance.

#### Results:

A total of 105 bird species consisting of 1 endemic, 8 near endemic, 1 globally threatened and 9 Palearctic migrants were recorded in Nensebo forest. Species richness and abundance varied between habitat types in Nensebo forest with mean species richness greater in modified habitat (mean= 4.70 ±1.65) as compared to moist Afromontane forest habitat (mean= 3.95 ±4.12, F=94.66 P<0.001). Additionally, modified habitat (Shannon diversity index= 4.131) harbored higher diversity of birds as opposed to Afromontane forest habitat (Shannon diversity index=3.79).

#### Conclusion:

The Nensebo forest has high avian species diversity including several endemic and endangered species revealing the importance of this site for bird conservation. Although we found that habitat heterogeneity favored bird species diversity, moist Afromontane habitat is critical for forest obligate species. Hence, sustainable bird conservation strategies including land use planning should be initiated for this area.

**Keywords:** Avian species, Habitat heterogeneity, Species abundance, Species richness, Afromontane habitat, Biodiversity.

#### Article History

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## 1. INTRODUCTION

Due to easy detectability and ease of study, birds are well-known species to the scientific community [1]. However, despite the fact that birds are well studied, new species are periodically being discovered in relatively unexplored regions of tropical and sub-tropical rainforests [2, 3]. Forests are known to be home to about 75% of avian species (>5,000

species) [4]. Within these habitats, avian species provide a wide range of ecosystem functions and services, such as pollination and seed dispersal. For example, over 920 species of birds pollinate plants [5], while within some tropical forests, up to 90% of the tree species are dispersed by animals, mainly mammals and birds [6]. However, the extinction of forest birds, mainly caused by forest loss, fragmentation and degradation, has been escalating over the last few decades [7]. Particularly, about 86% of globally threatened bird species are known to be at risk due to deforestation [8]. As a result, there is a need to document bird species diversity over unexplored remote

\* Address correspondence to this author at the Department of Wildlife and Protected Area Management, Hawassa University, Hawassa, Ethiopia, Email: zeru75@yahoo.com

regions of the world.

While several studies have focused on characterizing bird species composition and abundance of specific regions around the world [9 - 13], documentation of global avian diversity is still incomplete. Particularly, in Ethiopia, much of the remote areas remain unexplored in terms of avian diversity, thus, making Ethiopian avian checklists far from complete. Ethiopia is known for its rich bird diversity [14]. According to Birdlife International (2018) [8] Ethiopia is home for 819 species of birds, out of which, 35 are globally threatened and 17 are endemic to the country. Additionally, ~237 Palearctic and inter African migratory bird species have been recorded from Ethiopia (BLI 2018) [8]. Ethiopia has 68 important bird areas (10,794,408 ha) and 4 endemic bird areas (BLI 2018) [8].

Various studies in Ethiopia have characterized bird species diversity in protected areas [10, 15 - 17]. However, reports of bird species diversity outside protected areas in Ethiopia are very limited [18, 19]. About 17.62% of Ethiopia land mass coverage is protected (United Nations Environmental Protection- World Conservation Monitoring Center (UNEP-WCMC) 2019) [20]. However, a large proportion of important bird areas of Ethiopia lie outside protected areas, where information on bird species diversity is sparse. Most of these areas are also highly fragmented, located in human dominated landscapes that are often threatened by anthropogenic impacts. As a result, there is a need to document bird species diversity outside protected areas as a step towards the completion of avian records of Ethiopia, as well as provide important information for sustainable conservation of bird diversity and their habitats within this region.

Nensebo forest, one of the important bird areas of Ethiopia, is a patch of moist Afromontane forest partly connected to the Bale Mountains National Park (BMNP). However, with continued human encroachment, the wildlife corridor between the Nensebo forest and the BMNP has been reduced. Despite the importance of this region, there has been no scientifically documented information on bird species composition and abundance for this region, despite the need of this information for management actions and sustainable conservation for this region. Therefore, this study was implemented to investigate species diversity, abundance and distribution of birds at Nensebo forest.

## 2. MATERIALS AND METHODS

### 2.1. Study Area

Nensebo forest is found in Nensebo woreda (district) in the West Arsi Zone of Oromia Regional state of Ethiopia (Fig. 1). Nensebo woreda is situated between 6°10' - 6°40' N longitudes and 39°0' - 39°40' E latitudes (Fig. 1). Nensebo woreda is located at 407 km from Addis Ababa and 134.5 km from Shashemene, the capital city of West Arsi zone. Nensebo woreda is bordered by 8 woredas (Kokosa, Dodola, Adaba, Bensa, Girja, Meda Welabu, Chire and Harena Buluk) administered under four administrative zones (West Arsi, Bale, Borena and Sidama zones) and shared between two regional states (Oromia Regional State and South Nations and Nationa-

lities People Regional State, SNNPRS) (Fig. 1).

Nensebo woreda is characterized by a mountainous landscape having an altitude range between 1500 m a.s.l to 3700 m a.s.l. The Nensebo woreda exhibits bimodal rainfall pattern, with the annual rainfall range between 900 to 1100 mm and with a temperature that varies between a minimum of 15 °C and a maximum 22 °C (NWAO 2012) [21].

Nensebo forest is a moist Afromontane forest jointly managed by the community and Oromia Forest and wildlife Enterprise. Nensebo forest is part of Bale Mountains Eco-region known for its rich biodiversity and high level of endemism. Nensebo forest is one of the remnant moist Afromontane forests in the southeastern part of Ethiopia that exists in human dominated landscape [22]. The total area of Nensebo forest is 11,350 ha, comprised of both relatively intact moist Afromontane forest and modified Afromontane forest.

The moist Afromontane forest was characterized by dominant stands of the indigenous tree species such as *Croton macrostachys*, *Strychnos spinosa*, *Clematis longicauda*, *Prunus africana* and *Millettia ferruginea* [22]. The forest occurred over mountain slopes, valleys and remote inaccessible areas. The level of disturbance was minimal, there were no settlements or cultivation, and hardly any livestock grazed in the area. Modified moist Afromontane forest (habitat) occurs relatively at lower altitudes (1882-2153 m asl) in close proximity to human settlement and cultivation areas. Modified habitat is characterized by sparse stands of moist Afromontane characteristic tree species with mild crop cultivation (mainly 'enset' and coffee), intense livestock grazing and sparse human settlements [23]. The modified habitat is a heterogeneous habitat that provides diverse feeding guilds including fruiting tree crops such as coffee, as well as cereal crops such as barley and wheat. At the present, the modified habitat harbors perching trees *Croton macrostachys* and *Millettia ferruginea* and shrubs that provide good nesting grounds [22].

### 2.2. Sampling Design

We used line-transect methods to document the avian community due to better probability of detection, relatively easy accessibility of the study area and to cover a large sample area [24]. Based on vegetation types and altitudinal range, we first stratified the study area into two dominant habitat types; namely moist Afromontane forest and modified habitat. We then systematically generated sampling transects in a geographic information system (GIS) using ArcGIS software v. 10.1 (ESRI 2012) [25] representing the two dominant habitat types. We employed a stratified sampling technique in which transect placement was proportional to the area of the habitat types and represents each of the habitat types [15, 24]. Accordingly, we established a total of 20 transect lines, of which six transects were in modified habitat while the remaining fifteen (15) transects were in moist Afromontane forest (Fig. 2). The distance between two adjacent transects was 1 km and the length of each transect line was 1km with a maximum width of 0.25km. To avoid edge effects, we spaced transect lines 0.5km from the roadside (edge of the forest). Over the two dominant habitat types, established transects covered ~ 27.75% (3150 ha) of the study area.

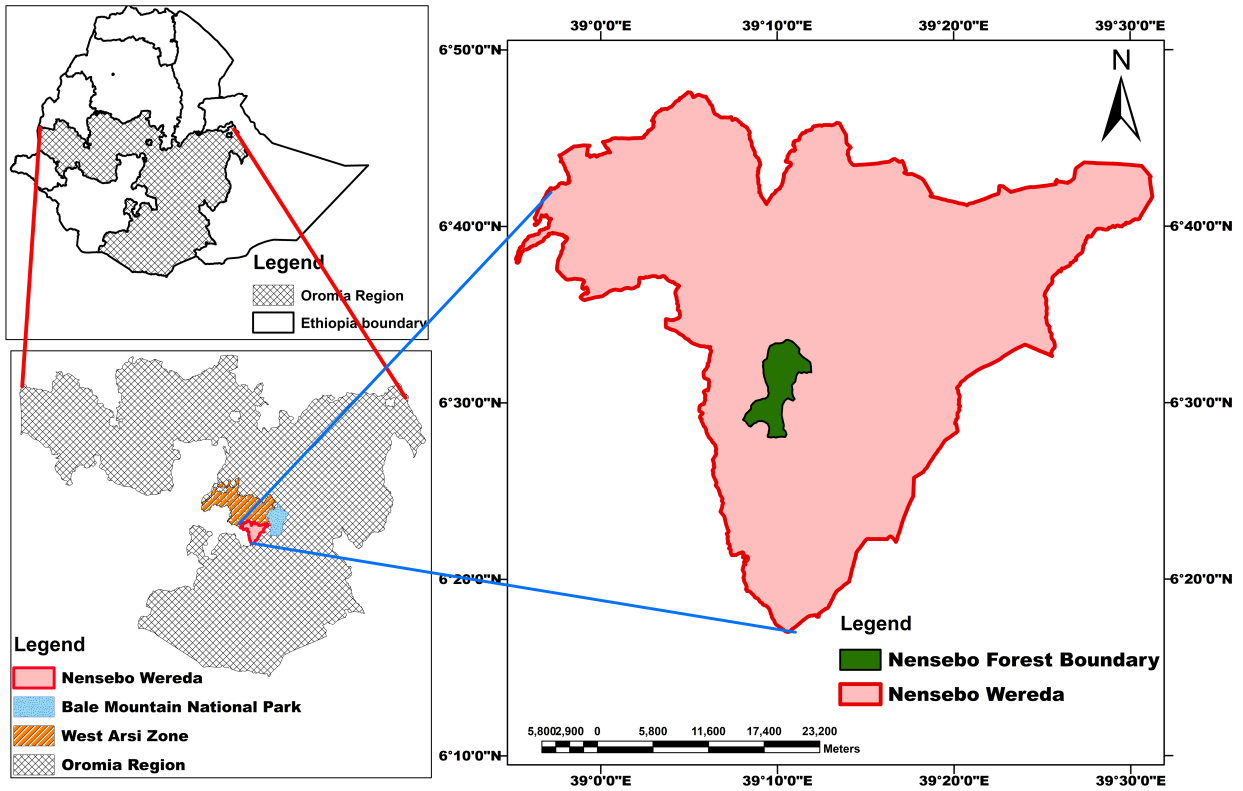


Fig. (1). Location map of study area.

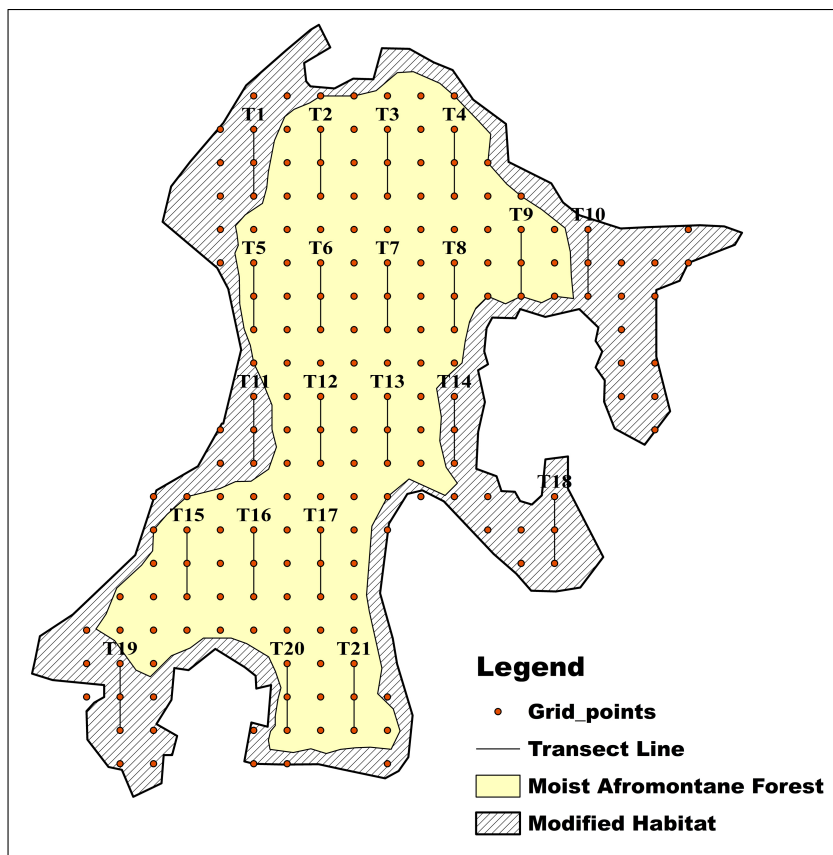


Fig. (2). Line transect layout of the Nensebo forest.

### 2.3. Data Collection

We carried out data collection from August 2017 to January 2018, covering both wet and dry seasons. We conducted ground monitoring (walking on foot along transect lines) to survey bird species diversity in the study area. We recorded all birds (number of individuals and species) seen (with the naked eye and aided by binoculars (10x500)) while traversing transect lines. For further confirmation of species identification, we used digital sound recorders to record bird sounds, as well as digital photo cameras to take pictures of the birds. We counted birds when they were active during early morning hours (06:30 – 10:00 AM) and late afternoon hours (from 15:30 – 18.00 PM). We avoided bird counting during unfavorable weather (strong wind, cold or rain) conditions. We identified bird species using key taxonomic and behavior features, such as plumage pattern, size, shape, color, songs and calls [26] with the aid of guide book Redman *et al.* [27].

### 2.4. Data Analysis

We computed Shannon-Wiener diversity index ( $H'$ ) and evenness [28] for each habitat type to compare diversity among the two dominant habitat types. We calculated Shannon-Wiener diversity index using the formula: Shannon's index ( $H'$ )' =  $\sum (pi) (\ln pi)$ , where,  $i$  = the proportion of the species relative to the total number of species ( $pi$ ) multiplied by the natural logarithm of this proportion ( $\ln pi$ ) and the final product multiplied by -1. Similarly, we calculated species evenness by the formula: Evenness ( $E$ ) =  $H'/H_{max}$ , where,  $H_{max}$  is defined as  $\ln(S)$  and species richness ( $S$ ) is defined by:  $S = \sum n$ , where  $n$  is the number of species in the community. We calculated relative abundance of bird species using the formula (%) =  $n/N \times 100$ , where  $n$  is the number of individuals of particular species recorded and  $N$  is the total number of individuals of the species. We then used a two-way analysis of variance (ANOVA) to analyze the effect of season and habitat on bird species richness and abundance.

## 3. RESULTS

### 3.1. Species Composition and Relative Abundance

A total of 105 species were recorded from the Nensebo forest (Table 1). Out of the recorded species, 41 and 8 species exclusively occurred in the moist Afromontane and modified habitats, respectively, whereas 56 species were present in both habitat types. Among the recorded species, 8 near endemic

(endemic to Ethiopia and Eritrea) species, namely Wattled ibis (*Bostrychia carunculata*), Thick-billed raven (*Corvus crassirostris*), Black-winged love bird (*Agapornis taranta*), Ethiopian cisticola (*Cisticola lugubris*), Abyssinian oriole (*Oriolus monacha*), Abyssinian slaty flycatcher (*Chocolatina ficedula*), Abyssinian woodpecker (*Abyssinicus phylloscopus*) and Banded barbet (*Lybius undatus*) were recorded. Out of the near endemic species recorded, Ethiopian cisticola occurred exclusively in the moist Afromontane forest, whereas other species were present in both habitat types. The endemic Yellow-fronted parrot (*Poicephalus flavifrons*) exclusively occurred in the moist Afromontane forest habitat. Furthermore, the globally threatened Semi collared flycatcher (*Semi torquata*) was confined in the moist Afromontane forest habitat (Table 1).

Within the Nensebo forest, *Sylviidae* (10 species) was the most dominant family followed by *Accipitridae* (8 species), *Columbidae* (7 species) and *Cisticolidae* (6 species) (Table 1). Among the recorded bird species, 96 birds were resident whereas 6 were Palearctic migrant species and 3 were inter-African migrants (Table 1). Inter-African migrants were confined in moist Afromontane forest, whereas most of the Palearctic migrants occurred in the modified habitat. Higher species richness and abundance were recorded during the wet season than the dry season in both habitat types (Table 1).

Abyssinian oriole (6.92%) was the most abundant bird species within the Nensebo forest (Table 2). Abyssinian oriole (9.95%) and Yellow-bellied waxbill (*Coccyzygia quartinia*) (5.52%) were the most abundant species in the moist Afromontane forest and modified habitat respectively (Table 2).

### 3.2. Diversity and Distribution

Species richness varied among habitat types, with greater mean species richness recorded in the modified habitat ( $4.70 \pm 1.65$ ) as compared to the moist Afromontane habitat ( $3.95 \pm 4.13$ ;  $F_{1,18} = 94.657$   $P < 0.001$ ; (Table 3). Similarly, greater mean species abundance was observed in the modified habitat ( $32 \pm 4.10$ ) as compared to the moist Afromontane habitat ( $25 \pm 7.54$ ), although differences were not significant ( $F_{1,18} = 0.853$ ;  $P = 0.368$ ; (Table 3). Similarly, the highest avian species diversity was recorded from the modified habitat during both dry ( $H' = 4.17$ ) and wet ( $H' = 3.99$ ) seasons (Table 4). Modified habitat also had the highest bird species evenness during both dry ( $E = 0.957$ ) and wet ( $E = 0.910$ ) seasons (Table 4).

**Table 1. Bird species recorded at Nensebo forest**

Order	Family	Common Name	Scientific Name	Species Abundance			RA (%)	AF	MH	Rank
				Wet season	Dry season	Total				
–	–	–	–							
Passeriformes	Oriolidae	Abyssinian oriole	<i>Oriolus monacha</i> <sup>a</sup>	68	46	74	6.9	+	+	1 <sup>st</sup>
Passeriformes	Turdidae	Mountain thrush	<i>Turdus olivaceus</i>	34	14	48	4.5	+	+	2 <sup>nd</sup>
Passeriformes	Zosteropidae	Montane white eye	<i>Zosterops poliogastrus</i>	23	12	35	3.3	+	+	3 <sup>rd</sup>
Passeriformes	Passeridae	Swainsons sparrow weaver	<i>Passer swainsonii</i>	22	11	33	3.1	+	+	4 <sup>th</sup>
Passeriformes	'Sturnidae	Red winged starling	<i>Onychognathus morio</i>	17	13	30	2.8	+	+	5 <sup>th</sup>
Passeriformes	Fringillidae	Streaky seed eater	<i>Serinus striolatus</i>	22	7	29	2.7	+	+	6 <sup>th</sup>
Passeriformes	Estrildidae	Yellow bellied waxbill	<i>Coccyzygia quartinia</i>	19	10	29	2.7	+	+	6 <sup>th</sup>

(Table 1) cont.....

Passeriformes	ploceidae	Baglafaecht weaver	<i>Ploceus baglafaecht</i>	16	7	26	2.4	+	+	8 <sup>th</sup>
Passeriformes	Oriolidae	Black headed oriole	<i>Oriolus larvatus</i>	13	3	26	2.4	+	-	8 <sup>th</sup>
Passeriformes	Muscicapidae	Abyssinian slaty flycatcher	<i>Melaenornis chocolatina</i> <sup>a</sup>	16	9	25	2.3	+	+	10 <sup>th</sup>
Passeriformes	Muscicapidae	Semi collared flycatcher	<i>Ficedula semitorquata</i> <sup>f</sup>	22	3	25	2.3	+	-	10 <sup>th</sup>
Passeriformes	Nectariniidae	Variable sun bird	<i>Cinnyris venustus</i>	16	7	23	2.1	+	+	12 <sup>th</sup>
Passeriformes	'Pycnonotidae	Common bulbul	<i>Pycnonotus barbatus</i>	12	10	22	2.1	+	+	12 <sup>th</sup>
Trogoniformes	Trogonidae	Narina's Trogon	<i>Apaloderma narina</i>	15	5	20	1.9	+	+	14 <sup>th</sup>
Passeriformes	Viduidae	Pin tailed whydah	<i>Vidua macroura</i>	16	4	20	1.9	+	+	14 <sup>th</sup>
Passeriformes	Muscicapidae	Rupels robin chat	<i>Cossypha semirufa</i>	11	9	20	1.9	+	+	14 <sup>th</sup>
Passeriformes	Corvidae	Thick billed raven	<i>Corvus crassirostris</i> <sup>a</sup>	12	7	19	1.8	+	+	17 <sup>th</sup>
Piciformes	Indicatoridae	Greater honey guide	<i>Indicator indicator</i>	16	2	18	1.7	+	-	17 <sup>th</sup>
Passeriformes	Estrildidae	Red billed fire finch	<i>Lagonosticta senegala</i>	14	4	18	1.7	+	+	17 <sup>th</sup>
Passeriformes	Monarchidae	African dusky flycatcher	<i>Muscicapa adusta</i>	9	7	16	1.5	+	+	20 <sup>th</sup>
Passeriformes	Sylviidae	Cinnamon bracken warbler	<i>Bradypterus cinnamomeus</i>	14	2	16	1.5	+	-	20 <sup>th</sup>
Passeriformes	Fringillidae	African citril	<i>Serinus citrinelloides</i>	9	6	15	1.4	+	+	22 <sup>th</sup>
Galliformes	phasianidae	Chestnut naped francolin	<i>Pternistis castaneicollis</i>	11	4	15	1.4	+	+	22 <sup>th</sup>
Passeriformes	Cisticolidae	Ethiopian cisticola	<i>Cisticola lugubris</i> <sup>a</sup>	13	2	15	1.4	+	-	22 <sup>th</sup>
Passeriformes	Cisticolidae	Green backed cameroptera	<i>Camaroptera brachyura</i>	6	9	15	1.4	+	-	22 <sup>th</sup>
Psittaciformes	Psittaculidae	Black winged love bird	<i>Agapornis taranta</i> <sup>a</sup>	10	4	14	1.3	+	+	26 <sup>th</sup>
Psittaciformes	Nectariniidae	Collared sun bird	<i>Hedydipna collaris</i>	12	2	14	1.3	+	-	26 <sup>th</sup>
Columbiformes	Columbidae	Red eyed dove	<i>Streptopelia semitorquata</i>	10	4	14	1.3	+	+	26 <sup>th</sup>
Passeriformes	Monarchidae	*African paradise flycatcher <sup>AM</sup>	<i>Terpsiphone viridis</i>	9	4	13	1.2	+	-	29 <sup>th</sup>
Passeriformes	Fringillidae	Brown rumped seed eater	<i>Crithagra tristriatus</i>	8	5	13	1.2	+	+	29 <sup>th</sup>
Piciformes	Indicatoridae	Lesser honeyguide	<i>Indicator minor</i>	9	4	13	1.2	+	-	29 <sup>th</sup>
Accipitriformes	Accipitridae	Lesser spotted eagle	<i>Aquila pomarina</i>	8	4	12	1.1	+	+	32 <sup>th</sup>
Cuculiformes	Cuculidae	*Levaillant's cuckoo <sup>AM</sup>	<i>Clamator levaillantii</i>	9	2	11	1.0	+	-	33 <sup>th</sup>
Passeriformes	Fringillidae	Yellow crowned canary	<i>Crithagra mozambicus</i>	11	0	11	1.0	+	-	33 <sup>th</sup>
Passeriformes	Cisticolidae	Tawny flanked prinia	<i>Prinia subflava</i>	6	4	10	0.9	+	+	35 <sup>th</sup>
Cuculiformes	Musophagidae	White cheeked turaco	<i>Tauraco leucotis</i>	4	6	10	0.9	+	+	35 <sup>th</sup>
Piciformes	Picidae	Abyssinian wood pecker	<i>Dendropicos abyssinicus</i>	4	5	9	0.8	+	+	37 <sup>th</sup>
Passeriformes	Sylviidae	Brown wood warbler	<i>Phylloscopus umbrovirens</i> <sup>a</sup>	7	2	9	0.8	+	-	37 <sup>th</sup>
Passeriformes	Laniidae	Common fiscal	<i>Lanius collaris</i>	7	2	9	0.8	+	+	37 <sup>th</sup>
Coliiformes	Collidae	Speckled mouse bird	<i>Colius striatus</i>	5	4	9	0.8	+	+	37 <sup>th</sup>
Psittaciformes	Psittacidae	Yellow fronted parrot	<i>Poicephalus flavifrons</i> <sup>b</sup>	7	2	9	0.8	+	-	37 <sup>th</sup>
Passeriformes	Passeridae	Bush petronia	<i>Petronia dentata</i>	6	2	8	0.7	+	+	42 <sup>th</sup>
Columbiformes	Columbidae	Dusky turtle dove	<i>Streptopelia lialugens</i>	2	6	8	0.7	+	+	42 <sup>th</sup>
Passeriformes	Buphagidae	Red billed oxpecker	<i>Buphagus erythrorhynchus</i>	4	4	8	0.7	+	+	42 <sup>th</sup>
Piciformes	Indicatoridae	Scaly throated honey guide	<i>Indicator variegatus</i>	8	0	8	0.7	+	+	42 <sup>th</sup>
Coraciiformes	Alcedinidae	Wood land kingfisher	<i>Halcon senegalensis</i>	3	5	8	0.7	+	-	42 <sup>th</sup>
Passeriformes	Sylviidae	Wood warbler	<i>Phylloscopus sibilatrix</i>	6	2	8	0.7	+	-	42 <sup>th</sup>
Falconiformes	Accipitridae	Augur buzzard	<i>Buteo augur</i>	4	3	7	0.7	+	+	42 <sup>th</sup>
Cuculiformes	Sylviidae	Brown parisoma	<i>Parisoma lugens</i>	5	2	7	0.7	+	-	42 <sup>th</sup>
Piciformes	Picidae	Eastern grey wood pecker	<i>Dendropicos goertae</i>	5	2	7	0.7	+	-	42 <sup>th</sup>
Piciformes	Picidae	Nubian wood pecker	<i>Campethera nubica</i>	5	2	7	0.7	+	-	42 <sup>th</sup>
Columbiforme	Columbidae	*Tambourine dove <sup>AM</sup>	<i>Turtur tympanistria</i>	6	1	7	0.7	+	-	42 <sup>th</sup>
Cuculiformes	Cuculidae	African emerald cuckoo	<i>Chrysococcyx cupreus</i>	4	2	6	0.6	+	-	53 <sup>th</sup>
Piciformes	Lybiidae	Banded barbet	<i>Lybius undatus</i> <sup>a</sup>	3	3	6	0.6	+	+	53 <sup>th</sup>
Passeriformes	Hirundinidae	*Barn swallow <sup>NM</sup>	<i>Hirundo rustica</i>	2	4	6	0.6	+	+	53 <sup>th</sup>
Passeriformes	Sylviidae	Black start	<i>Cercomela melanura</i>	6	0	6	0.6	+	+	53 <sup>th</sup>
Passeriformes	Estrildidae	Common waxbill	<i>Estrilda astrild</i>	6	0	6	0.6	+	+	53 <sup>th</sup>
Passeriformes	Buphagidae	Grey cuckoo shrike	<i>Coranica caesia</i>	4	2	6	0.6	+	-	53 <sup>th</sup>

(Table 1) cont.....

Passeriformes	Turdidae	Ground scraper thrush	<i>Psophocichla litsipsirupa</i>	4	2	6	0.6	-	+	53 <sup>th</sup>
Passeriformes	Sylviidae	Little rush warbler	<i>Bradypterus baboecala</i>	4	2	6	0.6	+	-	53 <sup>th</sup>
Passeriformes	Muscicapidae	Northern black flycatcher	<i>Melaenornis edolioides</i>	6	0	6	0.6	+	+	53 <sup>th</sup>
Coraciiformes	Coraciidae	Abyssinian roller	<i>Coracias abyssinicus</i>	5	0	5	0.5	+	+	53 <sup>th</sup>
Apodiformes	Apodidae	African black swift	<i>Apus barbatus</i>	3	2	5	0.5	+	-	53 <sup>th</sup>
Columbiformes	Columbidae	Black billed wood dove	<i>Turtur abyssinicus</i>	4	1	5	0.5	+	-	53 <sup>th</sup>
Passeriformes	Buphagidae	Black cuckoo shrike	<i>Campephaga flava</i>	3	2	5	0.5	+	-	53 <sup>th</sup>
Accipitriformes	Buphagidae	Lesser white throat	<i>Sylvia curruca</i>	5	0	5	0.5	+	+	53 <sup>th</sup>
Cuculiformes	Cuculidae	Red chested cuckoo	<i>Cuculus solitarius</i>	5	0	5	0.5	+	-	53 <sup>th</sup>
Passeriformes	Cisticolidae	Red faced cisticola	<i>Cisticola erythrops</i>	3	2	5	0.5	+	-	53 <sup>th</sup>
Ciconiiformes	Threskiornithidae	Silvery checked hornbill	<i>Bycanistes brevis</i>	3	5	5	0.5	+	+	53 <sup>th</sup>
Cuculiformes	Paridae	White winged black tit	<i>Parus leucomelas</i>	4	1	5	0.5	+	-	53 <sup>th</sup>
Accipitriformes	Cisticolidae	Yellow breasted apalis	<i>Apalis flavida</i>	5	0	5	0.5	+	-	53 <sup>th</sup>
Pelecaniformes	Timaliidae	Abyssinian cat bird	<i>Parophasma galinieri<sup>b</sup></i>	3	1	4	0.4	-	+	72 <sup>th</sup>
Piciformes	Lybiidae	Black billed barbet	<i>Lybius guifsobalito</i>	4	0	4	0.4	+	+	72 <sup>th</sup>
Columbiformes	Columbidae	Ring necked dove	<i>Streptopelia capicola</i>	2	2	4	0.4	+	+	72 <sup>th</sup>
Accipitriformes	Accipitridae	Rupels vulture	<i>Gyps rueppellii</i>	0	4	4	0.4	+	+	72 <sup>th</sup>
Falconiformes	Accipitridae	*Tawny eagle <sup>NM</sup>	<i>Aquila rapax</i>	3	1	4	0.4	+	-	72 <sup>th</sup>
Pelecaniformes	Threskiornithidae	Wattled ibis	<i>Bostrychia carunculata<sup>a</sup></i>	2	2	4	0.4	+	-	72 <sup>th</sup>
Falconiformes	Accipitridae	White backed vulture	<i>Gyps africanus</i>	4	0	4	0.4	+	+	72 <sup>th</sup>
Passeriformes	Sylviidae	Willow warbler	<i>Phylloscopus trochilus</i>	0	4	4	0.4	+	+	72 <sup>th</sup>
Passeriformes	Cisticolidae	Buff-bellied warbler	<i>Phyllolais pulchella</i>	0	3	3	0.3	+	-	80 <sup>th</sup>
Passeriformes	Sylviidae	Dark caped yellow warbler	<i>Chloropeta natalensis</i>	2	1	3	0.3	+	-	80 <sup>th</sup>
Passeriformes	Motacillidae	*Yellow wagtail <sup>NM</sup>	<i>Motacilla flava</i>	3	0	3	0.3	+	+	80 <sup>th</sup>
Passeriformes	Estrildidae	African fire finch	<i>Lagonosticta rubricata</i>	0	2	2	0.2	+	-	81 <sup>th</sup>
Columbiformes	Columbidae	African olive pegenion	<i>Columba arquatrix</i>	0	2	2	0.2	+	-	81 <sup>th</sup>
Coraciiformes	Alcedinidae	African pigmy kingfisher	<i>Ceyx pictus</i>	2	0	2	0.2	+	+	81 <sup>th</sup>
Passeriformes	Sylviidae	*Black cap <sup>NM</sup>	<i>Sylvia atricapilla</i>	0	2	2	0.2	-	+	81 <sup>th</sup>
Piciformes	Platysteiridae	Black headed batis	<i>Batis minor</i>	0	2	2	0.2	+	-	81 <sup>th</sup>
Columbiformes	phoeniculidae	Black- billed wood hoopoe	<i>Phoeniculus somaliensis</i>	2	0	2	0.2	+	+	81 <sup>th</sup>
Cuculiformes	Cuculidae	Blue headed coucal	<i>Centropus monachus</i>	0	2	2	0.2	+	-	81 <sup>th</sup>
Passeriformes	Sylviidae	*Common redstart <sup>NM</sup>	<i>Phoeniculus phoenicurus</i>	2	0	2	0.2	+	+	81 <sup>th</sup>
Coraciiformes	Bucerotidae	Crowned hornbill	<i>Tockus alboterminatus</i>	2	0	2	0.2	+	+	81 <sup>th</sup>
Columbiformes	Threskiornithidae	Hadada ibis	<i>Bostrychia hagedash</i>	2	0	2	0.2	+	+	81 <sup>th</sup>
Passeriformes	'Malaconotidae	Northern puff back	<i>Dryoscopus gambensis</i>	0	2	2	0.2	+	-	81 <sup>th</sup>
Passeriformes	Nectariniidae	Takazze sun bird	<i>Nectarinia tacazze</i>	0	2	2	0.2	-	+	81 <sup>th</sup>
Ciconiiformes	Ciconiidae	Woolly-necked stork	<i>Ciconia episcopus</i>	0	2	2	0.2	+	+	81 <sup>th</sup>
Passeriformes	Turdidae	Abyssinian ground thrush	<i>Zoothera piaggiae</i>	0	1	1	0.1	-	+	96 <sup>th</sup>
Falconiformes	strigidae	Cape eagle owl	<i>Bubo capensis</i>	0	1	1	0.1	-	+	96 <sup>th</sup>
Passeriformes	Corvidae	Fan tailed raven	<i>Corvus rhipidurus</i>	1	0	1	0.1	+	+	96 <sup>th</sup>
Falconiformes	strigidae	Greyish eagle owl	<i>Bubo cinerascens</i>	1	0	1	0.1	+	+	96 <sup>th</sup>
Pelecaniformes	Ardeidae	Little egret	<i>Egretta garzetta</i>	0	1	1	0.1	+	-	96 <sup>th</sup>
Accipitriformes	Accipitridae	Lizzard buzzard	<i>Kaupifalco monogrammicus</i>	0	1	1	0.1	+	-	96 <sup>th</sup>
Passeriformes	Muscicapidae	Mocking cliff chat	<i>Thamnolaea cinnamomeiventris</i>	1	0	1	0.1	+	+	96 <sup>th</sup>
Columbiformes	Columbidae	Namaqua dove	<i>Oena capensis</i>	0	1	1	0.1	-	+	96 <sup>th</sup>
Accipitriformes	Accipitridae	Pallied harrier <sup>NM</sup>	<i>Circus macrourus</i>	0	1	1	0.1	-	+	96 <sup>th</sup>
Accipitriformes	Accipitridae	Yellow billed kite	<i>Milvus(migrans) aegyptius</i>	0	1	1	0.1	+	-	96 <sup>th</sup>

Foot Note: (a, Near Endemic c, endangered b, Endemic e, near threatened NM, Northern Migratory AM, Inter-African migrant; AF, Afrontane Forest MH, modified habitat + sign indicates presence of the species in that habitat, while - sign indicates absence of the species in that habitat; RA is relative abundance)

**Table 2. Top five ranking abundant species among two habitat types and across the study area based on percent relative abundance (RA) in Nansebo forest, 2017-2018.**

Species	Moist Afromontane		Modified		Across the Study Area	
	RA (%)	Rank	RA (%)	Rank	RA (%)	Rank
Abyssinian oriole	9.95	1 <sup>st</sup>	-	-	6.92	1 <sup>st</sup>
Mountain thrush	4.19	2 <sup>nd</sup>	4.91	2 <sup>nd</sup>	4.49	2 <sup>nd</sup>
Montane white eye	3.27	4 <sup>th</sup>	-	-	3.27	3 <sup>rd</sup>
Swaisons sparrow weaver	3.40	3 <sup>rd</sup>	4.29	4 <sup>th</sup>	3.08	4 <sup>th</sup>
Red-winged starling	3.01	5 <sup>th</sup>	-	-	2.80	5 <sup>th</sup>
Yellow-bellied waxbill	-	-	5.52	1 <sup>st</sup>	2.71	6 <sup>th</sup>
Rupels robin chat	-	-	4.91	3 <sup>rd</sup>	1.87	7 <sup>th</sup>
Thick-billed raven	-	-	3.68	5 <sup>th</sup>	1.78	8 <sup>th</sup>

**Table 3. Bird diversity in Nansebo forest among habitat types.**

Habitat Types	Diversity Measures						
	SRPH	MSRPT	SAPH	MSAPT	H'	H' max	Evenness
Moist Afromontane	96	3.95 ±4.13	764	25±7.54	3.795	3.970	0.956
Modified	53	4.70 ±1.65	163	32±4.10	4.131	4.564	0.905

SRPH: Species richness per habitat MSRPT: Mean species richness per transect SAPH: Species abundance per habitat MSAPT: Mean species abundance per transect, H'= Shannon's index diversity, Hmax= maximum Shannon's index diversity

**Table 4. Seasonal variation in bird diversity in Nansebo forest among the different habitat types.**

Habitat types	Season	Diversity Measures						
		BSRPH	BMSRPT	BSAPH	BMSAPT	H'	H' max	Evenness
Moist Afromontane	dry	78.0	5.2±1.02	221.0	14.73±2.437	3.620	3.761	0.963
	wet	82.0	5.5±2.47	554.0	36.93±1.931	3.670	3.989	0.920
Modified	dry	43.0	8.6±2.25	107.0	21.4±3.873	4.170	4.357	0.957
	wet	54.0	10.8±3.21	218.0	43.6±3.873	3.990	4.407	0.910

BSRPH: Bird species richness per habitat, BMSRPT: Bird mean species richness per transect, BSAPH: Bird species abundance per habitat, BMSAPT: Bird mean species abundance per transect.

#### 4. DISCUSSION

The bird diversity study at Nensebo forest revealed that this area supports high diversity of birds, including several endangered, endemic, and migratory species. The diverse plant assemblages and presence of modified habitats such as coffee based and 'enset' based agroforestry systems around the forest [22], could support rich bird diversity. The structure and complexity of habitat are the two main factors influencing avian community diversity [29, 30]. Vegetation diversity and structure influence microhabitat conditions, such as feeding guilds that can be used as predictors of bird species richness and abundance in forest ecosystems [30, 31]. The variations in abundance of bird species among seasons might also be related to the availability of food, habitat conditions and breeding season of the species [10, 32 - 34]. Plant species diversity and structure are influenced by complex geographical and environmental gradients, such as rainfall pattern, temperature, altitude, aspect [9, 29]. As a result, the rainfall variation between wet and dry seasons could create variations in vegetation diversity and abundance that ultimately lead to variations in bird species richness and abundance. During the wet season, flowering plants flourished and as a result, food was plentiful for birds in

almost all the habitats [22]. However, during the dry season, the deciduous trees defoliated and in the absence of food, many species of birds were restricted to specific habitat where sufficient resource was available. Furthermore, during the wet season, the surrounding agricultural lands are covered by crops that provide alternative temporary seasonal foraging and nesting opportunities to the birds [23]. This could decrease their abundance in their natural habitat during the wet season, particularly in the modified habitat type [15, 34, 35].

The higher diversity and evenness of bird species in the modified habitat than the moist Afromontane forest habitat could be due to variations in habitat heterogeneity. Modified habitat had more heterogeneous vegetation and vegetation strata as compared to moist Afromontane forest habitat that could provide several niches for birds promoting high bird species diversity per given area sampled. Particularly, cultivated fruiting trees and shrubs such as coffee and cultivated crops provide better foraging opportunities particularly during fruiting season, whereby high concentrations of birds were observed. Similar studies elsewhere in the world unanimously state that habitat heterogeneity promotes bird species diversity through providing increased feeding guilds and nesting op-

portunities [10, 16, 26, 32 - 36].

However, considering the overall species richness, the unmodified moist Afromontane forest harboured the highest richness due to its large size, better cover opportunity and little disturbance. Moreover, the habitat is home to 41 forest specialist bird species such as the yellow-fronted parrot, African paradise flycatcher (*Terpsiphone viridis*), Abyssinian oriole, black-headed oriole (*Oriolus larvatus*) and Ethiopian cisticola that exclusively occurred in this habitat type. For example, the Abyssinian oriole had the highest percent relative abundance in the moist Afromontane forest. It has been reported that Abyssinian oriole inhabits highland forests between 900 and 2000 m asl, where it optimally attains its favorite berries, fruits and caterpillars [37]. Similar observations have been made in a study carried out in Wondo Genet forest in Ethiopia [35] and Araninge, Kwamsisi, Gendagenda and Msbugwe forests in Tanzania [38], whereby forest specialists were only confined to the homogenous forest ignoring the heterogeneous habitats. As a result, the homogenous unmodified moist Afromontane forest is critical habitat for the survival of diverse forest specialist bird species.

#### CONCLUSION AND RECOMMENDATIONS

The Nensebo forest had high bird species diversity including endemic and endangered species revealing the importance of the site for bird conservation. Therefore, it can serve as good potential for bird watching tourism that can integrate economic gain with biodiversity conservation. This study has demonstrated that habitat heterogeneity favors bird species diversity. However, high concentration of bird species around cultivation and settlement areas can bring birds and human in close contact initiating human wildlife conflict. Birds could cause crop loss (economic loss) and in turn, retaliatory kills could happen. At present, the study revealed that the unmodified moist Afromontane forest is critical habitat for diverse forest specialist bird species. Hence, it is important to promote sustainable forest conservation and promote land use planning. Cultivation at close proximity of forest should be avoided and community awareness campaigns should be initiated to aware the local community about the importance of wildlife conservation in general and birds in particular.

#### ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

#### HUMAN AND ANIMAL RIGHTS

Not applicable.

#### CONSENT FOR PUBLICATION

Not applicable.

#### AVAILABILITY OF DATA AND MATERIALS

The data sets analyzed during the current study are available from the corresponding author (Z.G) upon request.

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#### CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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