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RESEARCH ARTICLE

THE ROLE OF GULLELE BOTANICAL GARDEN FOR BIRD CONSERVATION IN ADDIS ABABA, ETHIOPIA

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ABSTRACT: This study was carried out to investigate the role of the Gullele Botanical Garden for avian conservation. Data on bird species diversity and abundance were collected during the dry (January to February 2021) and wet seasons (July to August 2021). The study area was stratified into three dominant habitat types namely nature reserve forest, modified scenic garden and infrastructure development area. A stratified survey technique was employed using systematically established line transects in the three habitat types. A total of 90 bird species belonging to 12 orders and 37 families were identified in the study area. Among the habitat types, the highest bird diversity was observed in the modified scenic garden habitat (H' = 3.54), followed by the infrastructure development area (H' = 3.29). Modified scenic garden habitat had the highest species richness (67) followed by infrastructure development area (58) and nature reserve forest (28). Community similarity was high between modified habitat and infrastructure development areas during the study. Gullele Botanical Garden supports two endemic and 11 near-endemic bird species shared with Eritrea suggesting its ecological importance in avian fauna conservation. This study is the first detailed investigation regarding the diversity of bird species in the Botanical Garden providing valuable information on the significance of managed habitats with indigenous tree species to support different bird species.

Key words/phrases: Bird diversity, Botanical garden, Relative abundance, Species richness.

INTRODUCTION

Ethiopia is considered as one of the richest centres of biodiversity resources in the world where the large altitudinal range of the country is believed to contribute to the richness (Moore *et al*., 2002; Motuma Tolera *et al*., 2008). In this regard, the country is home to 864 bird species with 19 endemics and 14 endemics shared with Eritrea (Alemneh Amare, 2015; Rabira Gonfa *et al.*, 2015). Diversified bird species are protected through *in-situ*

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conservation (Bernard *et al*., 2014). However, *ex-situ* conservation is also implemented in the protection, restoration, and rehabilitation of degraded ecosystems and also in the recovery of threatened species (IBC, 2005; 2007).

Botanical gardens are among the *ex-situ* conservation techniques that play a great role in plant conservation (Primack and Miller-Rushing, 2009). Botanical gardens are also important for the conservation of bird species because it provides suitable habitats associated with vegetation structures suitable for birds (Tsegaye Gadisa *et al*., 2015). Botanical gardens are also important for conducting research and educating society about avian diversity and behaviour under various climate change scenarios (Gordo, 2007).

In Ethiopia, the Gullele Botanical Garden was established in 2010 at Gullele and Kolfe-Keranyo sub-cities through Proclamation No. 18/2009. It was established with a vision to see the centre as an exemplary garden for education, ecotourism and centre for the Ethiopian plant species. The place also serves as a research and nurturing site for endangered plant species. The botanical garden has a large altitudinal difference with diverse plant compositions having the potential to support diverse bird species and other wild animals (Kios Development Consulting, 2012).

It is known that bird species diversity and distribution are determined by a habitat type where each habitat has a specific set of micro-environments suitable for bird species (Girma Mengesha and Afework Bekele, 2008). Degrees of habitat disturbance and habitat patch size influence bird species richness and abundance (Bibi and Ali, 2013; Tsegaye Gadisa *et al*., 2015; Kang *et al*., 2015). Vegetation structure is the principal determinant factor of avian species richness and distribution (Shimelis Aynalem and Afework Bekele, 2008; Tsegaye Gadisa *et al*., 2015). Further, forest stand structure is important for birds because it can directly influence the availability and quality of breeding by providing food, nesting material and cover from predators (Whittingham and Evans, 2004; Solomon Chanie and Dereje Tesfaye, 2015).

Monitoring of birds provides valuable information on ecological health and can be a vital tool for developing awareness (Kremen *et al*., 1994; Addisu Asefa *et al*., 2016). In this regard, the importance of local landscapes for the conservation of avifauna can only be underscored by understanding the structure of the bird community of the area. Knowledge regarding the abundance and diversity of birds in the Gullele Botanical Garden is

important for taking conservation decisions and enhancing understanding of the actual potential of the garden. Therefore, this study was aimed at investigating the avian species diversity and abundance in Gullele Botanical Garden, Adds Ababa.

MATERIALS AND METHODS

Description of the study area

Gullele Botanical Garden is located in Addis Ababa city at 38°41′30″ to 38°44′00″ E; and 9°4′0″ to 9°5′30″ N (Fig. 1), covering an altitudinal range of 2,600 to 2,960 meters above sea level (Ensermu Kelbessa, 2005). The study area covers 936 hectares, which is characterized by the highland ecosystem and modified habitat with a landscape exhibiting undulated topography. The area exhibits a bimodal rainfall pattern. The major rainy season lasts from June to September with a smaller rainy season in March and April, the remaining months of the year are fairly dry. The mean annual rainfall and temperature in the area are 1,156 mm and 16.4°C, respectively (https://weatherspark.com/download/100668/Download-Addis-Ababa-Ethiopia-Weather-Data).

Gullele Botanical Garden has a nature reserve forest, modified habitat for a scenic garden and an infrastructure development area. The nature reserve forest is dominated by *Eucalyptus globulus*, *Eucalyptus saligna*, and *Eucalyptus viminalis* at the lower elevation to upper elevation including river valleys. There are also scattered indigenous species such as *Juniperus procera*, *Prunus africanus*, *Hagenia abyssinica*, *Podocarpus falcatus*, *Olea europea* and *Alophylus abyssinicus*. The modified habitat for the scenic gardens is dominated by *Juniperus procera* trees and other indigenous tree species managed as plantation forests. There are also common shrubs including *Erica arborea*, *Rosa abyssinica*, *Hypericum revolutum*, and the endemic *Jasminum stan* and herbs like *Helichrysum*, *Trifolium* and *Thymus* species and the giant herbs of the forest *Solanecio gigas* at the steep sides of the valleys. The infrastructure development area is dominated by buildings with ornamental plants, nursery sites, medicinal plant sites, man-made wetlands, man-made ponds, and recreation sites for tourists.

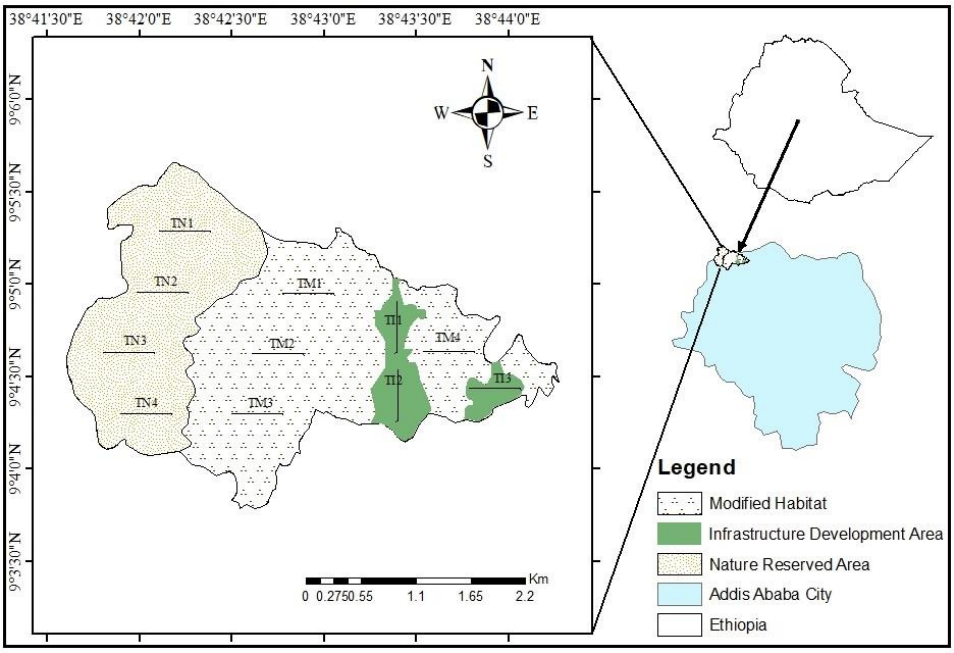

Fig. 1. Map of the Gullele Botanical Garden's major habitat classification.

Data collection

A preliminary survey was conducted during mid-January 2021 to be familiarized with the topography and the habitat types of the study area. A stratified random sampling design was used to study bird species composition and relative abundance. The study site was stratified into three dominant habitat types namely nature reserve forest (315.68 ha), modified habitat for the scenic garden (537.87 ha) and infrastructure development area (72.45 ha). A total of 11 sampling line transects were systematically generated using ArcGIS V10.5 (ESRI, 2012).

Sampling line transects were established in each habitat type where four sampling line transects each were laid in the nature reserve forest and in the modified habitat while three sampling line transects were laid in the infrastructure development area (Fig. 1). The length of line transects was one kilometre for nature reserve forest and modified habitat for scenic garden and 200 meters in the infrastructure development area each with a width of 100 meters. To avoid double counting, line transects were spaced at 500 meters in all habitat types (Bibby *et al*., 1998; Sutherland, 2006). Following Yosef Mamo *et al*. (2016), Chao 1 richness estimator was computed to determine sampling adequacy. This estimator computes the

total number of species (observed plus not observed during the survey though present in the area) expected to be present in a particular area (Colwell *et al*., 2012). Thus, the ratio of observed richness to Chao 1 estimated richness gives the proportional number of species recorded during the survey relative to the expected total number of species (Colwell, 2013).

The survey covered the dry (January to February 2021) and wet seasons (July to August 2021). Data was collected early in the morning from 6:00 to 10:00 am and late in the afternoon from 3:00 to 6:30 pm when birds are more active (Bibi and Ali, 2013). Each transect line was visited each month three times and a total of 12 times visited the study area. Rainy and cloudy days were avoided because such types of climatic conditions significantly affect the activities of birds and make the identification of bird species difficult (Bibby *et al*., 1998). During the survey, bird species observed, the number of individuals, time of observation, vegetation (habitat) characteristics and activity of birds were carefully recorded. In addition, auxiliary data such as latitude and longitude, elevation, slope and aspect were recorded using GPS (Garmin 76). Birds were detected with naked eyes and with the help of binoculars (Nikon 10*50). Plumage pattern, size, shape, colour, songs, and calls were used for bird identification (Bibby *et al*., 1998; Sutherland, 2006; Shimelis Aynalem and Afework Bekele, 2008). Identifications of species were confirmed by using the field guidebook (Redman *et al*., 2009). Furthermore, photographs and videos were taken to identify species difficult to confirm in the field.

Data analysis

Species richness, Shannon diversity index, Sorenson's similarity index and relative abundance of species were computed (Colwell, 2013). Species richness was computed in EstimateS version 9.1 software (Colwell, 2013) for each of the three habitat types. As the treatments (habitat types) differed in sample size (i.e., number of individual birds recorded in each treatment category), both rarefaction of the observed number of species and extrapolation methods were used to calculate species richness and compare between respective treatments.

Species diversity was computed using the Shannon-Weiner diversity index ($H^I = -\sum PilnPi$; where Pi: The proportion of the i^{th} species to total abundance value $Pi = ni/Ni$. ln Pi: the natural logarithm of Pi). The value ranges between zero and four, zero indicating low species diversity and four indicating high species diversity.

Following Addisu Asefa (2014), relative abundance of each species in each habitat type was calculated using a formula: RA*i* = N*i*/Tn*i*, where, RA*i* = relative abundance of species *i*; N*i* = number of individual birds (abundance) of species *i* recorded in a particular habitat; and Tn*i* = the total number of individual birds recorded in that habitat. Based on these RA values, each species was classified into four relative abundance categories. For each abundance category >0.75, 0.51−0.75, 0.25−0.50, and <0.25 the following abundance score was given: 1 - Abundant, 2 - Common, 3 - Uncommon and 4 - rare, respectively.

A Chi-square test was used to compare the difference in the number of species classified in each relative abundance category for each season and combined using SPSS version 20. Sorensen's similarity index compares the similarity of bird species composition between habitat types both within and across seasons.

RESULTS

Species composition

A total of 2,521 individual birds representing 90 bird species belonging to 37 families and 12 orders were recorded during the study period. Of these, 67 species were recorded in modified habitats for scenic gardens; 58 species in infrastructure development areas and 28 species in nature reserved forests (Table 1). The highest number of bird species was recorded in the order Passeriformes (62 species). Of the total bird species recorded in Gullele Botanical Garden, two species were endemic to Ethiopia, namely Abyssinian Catbird (*Parophasma galinieri*) and Yellow-fronted parrot (*Poicephalus flavifrons*). In addition, 11 endemic bird species shared with Eritrea such as Black-winged Lovebird (*Agpornis taranta*), Abyssinian Forest Oriole (*Oriolus monacha*), Thick-billed Raven (*Corvus crassirostris*), White-collared Pigeon (*Columba albitorques*), Abyssian Slaty-Flycatcher (*Melaenornis chololatinus*), Ruppell's Robin Chat (*Myrmecocichla melaena*), Ethiopian Cisticola (*Cisticola lugubris*), Abyssinian woodpecker (*Dendropicos abyssinicus*), White-winged Cliff Chat (*Thamnolaea semirufa*), Wattled Ibis (*Bostrychila carunculata*), and White-backed Black Tit (*Parus leuconotus*) were recorded (Table 1).

Table 1. Bird species observed and relative abundance at Gullele Botanical Garden.

Family	Common name	Scientific name	IUCN conservation status	MS	Abundance per habitat						RA (%)	Rank
					IDA		MH		NRF			
					DS	WS	DS	WS	DS	WS		
FRINGILLIDAE	Brown-rumped Seedeater	*Serinus tristriatus*	LC	RS	63	94	66	31	10	20	11.27	1
ZOSTEROPIDAE	Montane White-eye	*Zosterops poliogastrus*	LC	RS	8	6	41	85	2	19	6.39	2
NECTARINIIDAE	Tacazze Sunbird	*Nectarinia tacazze*[HB]	LC	RS	7	51	16	54	-	3	5.20	3
PLOCEIDAE	Baglafecht Weaver	*Ploceus baglafecht*[HB]	LC	RS	3	55	2	48	-	14	4.84	4
FRINGILLIDAE	Streaky Seedeater	*Serinus striolatus*[HB]	LC	RS	6	45	12	33	2	20	4.68	5
TURDIDAE	Mountain Thrush	*Turdus abyssinicus*	LC	RS	11	7	29	69	-	1	4.64	6
PASSERIDAE	Swainson's Sparrow	*Passer swainsonii*	LC	RS	7	41	13	43	-	9	4.48	7
PYCNONOTIDAE	Common Bulbul	*Pycnonotus barbatus*	LC	RS	16	45	19	15	-	14	4.32	8
TURDIDAE	Moorland Chat	*Cercomela sordida*[HB]	LC	RS	11	46	24	12	3	11	4.24	9
TIMALIIDAE	Abyssinian Catbird	*Parophasma galinieri*[E,HB]	LC	RS	17	8	19	46	7	7	4.13	10
COLUMBIDAE	White-collared Pigeon	*Columba albitorques*[NE,HB]	LC	RS	-	-	-	80	-	-	3.17	11
MUSCICAPIDAE	Abyssinian Slaty-Flycatcher	*Melaenornis chocolatinus*[NE,HB]	LC	RS	11	15	10	-	3	28	2.66	12
COLUMBIDAE	Dusky Turtle-Dove	*Streptopelia lugens*[HB]	LC	RS	14	26	7	14	-	-	2.42	13
MUSCICAPIDAE	African Dusky-Flycatcher	*Muscicapa adusta*	LC	RS	8	29	5	19	-	-	2.42	13
FRINGILLIDAE	African Citril	*Serinus citrinelloides*[HB]	LC	RS	1	-	-	32	-	19	2.06	14
CORVIDAE	Pied Crow	*Corvus albus*	LC	RS	1	11	12	27	-	-	2.02	15
COLUMBIDAE	Red-eyed Dove	*Streptopelia semitorquata*	LC	(NM)	1	2	-	31	-	10	1.75	16
MUSCICAPIDAE	Ruppell's Robin Chat	*Myrmecocichla melaena*[NE,HB]	LC	RS	1	6	4	27	-	3	1.63	17
ZOSTEROPIDAE	Abyssinian White-eye	*Zosterops abyssinicus*	LC	RS	4	10	4	15	-	8	1.63	17

Family	Common name	Scientific name	IUCN conservation status	MS	Abundance per habitat						RA (%)	Rank
					IDA		MH		NRF			
					DS	WS	DS	WS	DS	WS		
CORVIDAE	Thick-billed Raven	*Corvus crassirostris*[NE,HB]	LC	RS	-	15	7	8	-	10	1.59	18
PSITTACULIDAE	Black-winged Lovebird	*Agpornis taranta*[NE,HB]	LC	RS	3	-	7	21	-	3	1.35	19
NECTARINIIDAE	Variable Sunbird	*Cinnyris venustus*	LC	AM	-	15	-	14	-	3	1.27	20
CISTICOLIDAE	Ethiopian Cisticola	*Cisticola lugubris*[NE]	LC	RS	-	-	-	-	-	31	1.23	21
CISTICOLIDAE	Tawny-flanked Prinia	*Prinia subflava*	LC	RS	4	5	7	14	-	-	1.19	22
COLIIDAE	Speckled Mousebird	*Colius striatus*	LC	RS	4	17	9	-	-	-	1.19	22
APODIDAE	Alpine Swift	*Tachymarptis melba*	LC	NM	3	22	-	-	-	-	0.99	23
MEROPIDAE	Little Bee-eater	*Merops pusillus*	LC	RS	5	14	6	-	-	-	0.99	23
ORIOLIDAE	Black-headed Oriole	*Oriolus larvatus*[HB]	LC	RS	-	-	16	-	9	-	0.99	23
ESTRILDIDAE	Yellow-bellied Waxbill	*Coccopygia quartinia*	LC	RS	4	8	11	-	-	-	0.91	24
APODIDAE	White-rumped Swift	*Apus caffer*	LC	NM	-	19	-	-	-	-	0.75	25
HIRUNDINIDAE	Rock Martin	*Ptyonoprogne fuligula*	LC	(NM)	-	3	5	11	-	-	0.75	25
PARIDAE	White-backed Black Tit	*Parus leuconotus*[NE]	LC	RS	-	-	16	2	-	-	0.71	26
MALACONOTIDAE	Common Fiscal	*Lanius collaris*	LC	RS	1	-	14	2	-	-	0.67	27
ACCIPITRIDAE	Augur Buzzard	*Buteo augur*	LC	RS	1	2	8	4	-	-	0.60	28
HIRUNDINIDAE	Plain Martin	*Riparia paludicola*	LC	(NM)	-	12	-	3	-	-	0.60	28
ACCIPITRIDAE	Hooded Vulture	*Necrosyrtes monachus*	CR	RS	-	5	3	6	-	-	0.56	29
ESTRILDIDAE	Red Cheeked-Cordon bleu	*Uraeginthus bengalus*	LC	RS	-	2	10	-	-	-	0.48	30
NUMIDIDE	Helmeted Guineafowl	*Numida meleagris*	LC	RS	-	-	-	12	-	-	0.48	30
THRESKIORNITHIDE	Wattled Ibis	*Bostrychia*	LC	RS	-	6	-	-	-	6	0.48	30

Family	Common name	Scientific name	IUCN conservation status	MS	Abundance per habitat						RA (%)	Rank
					IDA		MH		NRF			
					DS	WS	DS	WS	DS	WS		
		carunculata[NE]										
COLUMBIDAE	Speckled Pigeon	*Columba guinea*	LC	RS	1	9	-	-	-	-	0.40	31
MALACONOTIDAE	Black-crowned Tchagra	*Tchagra senegala*	LC	RS	-	-	5	-	2	3	0.40	31
SYLVIIDAE	Willow Warbler	*Phylloscopus trochilus*	LC	NM	10	-	-	-	-	-	0.40	31
PLOCEIDAE	Spectacled Weaver	*Ploceus nigricollis*	LC	RS	-	-	9	-	-	-	0.36	32
ACCIPITRIDAE	Black Kite	*Milvus migrans*	LC	AM	1	-	7	-	-	-	0.32	33
ACCIPITRIDAE	Yellow-billed Kite	*Milvus aegyptius*	LC	AM	2	-	6	-	-	-	0.32	33
ESTRILDIDAE	Bronze Mannikin	*Lonchura cucullata*	LC	RS	-	-	-	8	-	-	0.32	33
ORIOLIDAE	Abyssinian Forest Oriole	*Oriolus monacha*[NE,HB]	LC	RS	-	-	8	-	-	-	0.32	33
TURDIDAE	Cyprus Wheatear	*Oenanthe cypriaca*	LC	NM	8	-	-	-	-	-	0.32	33
VIDUIDAE	Village Indigobird	*Vidua chalybeate*	LC	RS	-	5	-	-	-	3	0.32	33
COLUMBIDAE	African Collard Dove	*Streptopelia roseogrisea*	LC	(NM)	-	-	7	-	-	-	0.28	34
MUSCICAPIDAE	Pied Wheatear	*Oenanthe pleschanka*	LC	NM	4	-	3	-	-	-	0.28	34
PHASIANIDAE	Erckel's Francolin	*Pternistis erckelii*	LC	RS	-	3	-	4	-	-	0.28	34
PSITTACIDAE	Yellow-fronted Parrot	*Poicephalus flavifrons*[E, HB]	LC	RS	-	2	5	-	-	-	0.28	34
ESTRILDIDAE	Red-billed Firefinch	*Lagonostica senegala*	LC	RS	-	-		-	-	-	0.24	35
SYLVIIDAE	Brown Parisoma	*Parisoma lugens*	LC	RS	-	-	6	-	-	-	0.24	35
ESTRILDIDAE	Zebra Waxbill	*Sporaeginthus subflavus*	LC	RS	-	-	-	-	5	-	0.20	36
MALACONOTIDAE	Ethiopian Boubou	*Laniarius aethiopicus*[HB]	LC	RS	-	-	2	3	-	-	0.20	36
PLOCEIDAE	Speke's Weaver	*Ploceus spekei*[SM]	LC	RS	-	-	5	-	-	-	0.20	36
SYLVIIDAE	Cinnamon Bracken Warbler	*Bradypterus cinnamomeus*[HB]	LC	RS	-	-	3	2	-	-	0.20	36

Family	Common name	Scientific name	IUCN conservation status	MS	Abundance per habitat						RA (%)	Rank
					IDA		MH		NRF			
					DS	WS	DS	WS	DS	WS		
CISTICOLIDAE	Grey-backed Camaroptera	*Camaroptera brachyura*	LC	RS	2	-	-	2	-	-	0.16	37
VIDUIDAE	Pin-tailed Whydah	*Vidua macroura*	LC	RS	-	4	-	-	-	-	0.16	37
ACROCEPHALIDE	Dark-capped Yellow Warbler	*Chloropeta natalensis*	LC	RS	-	3	-	-	-	-	0.12	38
APODIDAE	Common Swift	*Apus apus*	LC	NM	3	-	-	-	-	-	0.12	38
MEROPIDAE	Blue-breasted Bee-eater	*Merops variegatus*	LC	RS	2	-	1	-	-	-	0.12	38
MOTACILLIDAE	Plain-backed Pipit	*Anthus leucophrys*	LC	RS	-	-	3	-	-	-	0.12	38
MUSCICAPIDAE	Pale Flycatcher	*Bradornis pallidus*	LC	RS	-	-	3	-	-	-	0.12	38
PLOCEIDAE	Village Weaver	*Ploceus cucullatus*	LC	AM	-	-	3	-	-	-	0.12	38
TURDIDAE	White-winged Cliff Chat	*Thamnolaea semirufa*[NE]	LC	RS	2	-	1	-	-	-	0.12	38
ACCIPITRIDAE	Long-crested Eagle	*Lophaetus occipitalis*	LC	RS	-	-	-	2	-	-	0.08	39
ACCIPITRIDAE	Tawny Eagle	*Aquila rapax*	VU	N	-	2	-	-	-	-	0.08	39
CISTICOLIDAE	Red-fronted Warbler	*Urorhipis rufifrons*	LC	RS	2	-	-	-	-	-	0.08	39
FALCONIIDAE	Peregrine Falcon	*Falco peregrinus*	LC	(NM)	-	-	1	-	-	1	0.08	39
MACROSPHENIDE	Red Faced Crombec	*Sylviett whytii*	LC	RS	-	-	-	-	-	2	0.08	39
MOTACILLIDAE	White Wagtail	*Motacilla alba*	LC	NM	-	-	-	1	-	1	0.08	39
MOTACILLIDAE	Yellow Wagtail	*Motacilla flava*	LC	NM	-	-	2	-	-	-	0.08	39
PHASIANIDAE	Moorland Francolin	*Scleroptila psilolaema*	NT	RS	2	-	-	-	-	-	0.08	39
PICIDAE	Abyssinian Woodpecker	*Dendropicos abyssinica*[E, HB]	LC	RS	-	-	2	-	-	-	0.08	39
SYLVIIDAE	Garden Warbler	*Sylvia borin*	LC	NM	2	-	-	-	-	-	0.08	39
TURDIDAE	Abyssinian Ground Thrush	*Zoothera plaggiae*[HB]	LC	RS	-	-	2	-	-	-	0.08	39
ANATIDAE	African Black	*Anas sparsa*	LC	RS	1	-	-	-	-	-	0.04	40

Family	Common name	Scientific name	IUCN conservation status	MS	Abundance per habitat						RA (%)	Rank
					IDA		MH		NRF			
					DS	WS	DS	WS	DS	WS		
	Duck											
CISTICOLIDAE	Stout Cisticola	*Cisticola robustus*[HB]	LC	RS	-	-	1	-	-	-	0.04	40
COLUMBIDAE	African Mourning Dove	*Streptopelia decipiens*	LC	RS	-	-	1	-	-	-	0.04	40
FALCONIIDAE	Lesser Kestrel	*Falco naumanni*	LC	RS	-	-	1	-	-	-	0.04	40
MONARCHIDAE	African Paradise-Flycatcher	*Terpsiphone viridis*	LC	AM	1	-	-	-	-	-	0.04	40
MOTACILLIDAE	Grassland Pipit	*Anthus cinnamomeus*	LC	(NM)	-	-	1	-	-	-	0.04	40
MOTACILLIDAE	Grey Wagtail	*Motacilla cinerea*	LC	NM	1	-	-	-	-	-	0.04	40
MOTACILLIDAE	Long-billed Pipit	*Anthus similis*	LC	RS	-	-	1	-	-	-	0.04	40
MOTACILLIDAE	Tree Pipit	*Anthus trivialis*	LC	NM	-	-	-	-	1	-	0.04	40
STURNIDAE	Lesser Blue-eared Starling	*Lamprotornis chloropterus*	LC	RS	1	-	-	-	-	-	0.04	40
TURDIDAE	Northern Wheatear	*Oenanthe oenanthe*	LC	AM	1	-	-	-	-	-	0.04	40

Key: E = Endemic; NE = Near Endemic; CR = Critically Endangered; VU = Vulnerable; NM = Northern or Palearctic Migrant; (NM) = Northern Migratory with resident sub species; AM = Africa Migrant; N = Nomadic; RS = Resident; IDA = Infrastructure Development Area; MH = Modified Habitat; NRF = Nature Reserve Forest; MS = Migratory Status; RA = Relative Abundance

In addition, Gullele Botanical Garden supports 20 Afro-Tropical highland biomes restricted bird species including the Abyssinian Catbird (*Parophasma galinieri*), Black-headed Oriole (*Oriolus larvatus*) and Abyssinian Slaty-flycatcher (*Melaenornis chocolatinus*). Somali-Massi biome restricted birds Speke's Weaver *Ploceus spekei* was also recorded in the area. Of the recorded species 66 were resident birds with one critically endangered species, Hooded Vulture *Necrosyrtes monachus* and a near-threatened species, Moorland francolin *Scleroptila psilolaema*. The remaining 23 bird species were migratory. Tawny Eagle (*Aquila rapax*) is the only vulnerable and nomadic bird species in this study area.

The 90 bird species recorded showed different feeding guilds of which insectivores were dominant (45.56%) followed by granivores (20%) (Fig. 2).

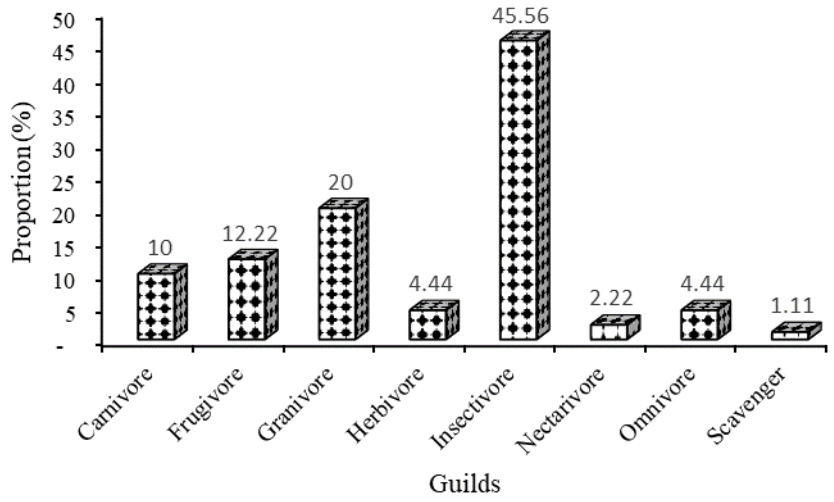

Fig. 2. The proportion of birds by trophic guild type in Gullele Botanical Garden.

Species diversity

The Shannon diversity index showed higher bird diversity (3.54) in the modified habitat during the dry season. Comparison of species diversity between seasons showed a significant difference (χ^2 = 10.666, DF = 2, P = 0.0052) where dry season diversity was significantly lower than the wet season in nature reserved forest and significantly higher in modified habitat and infrastructure development areas. The modified habitat supports higher bird species richness (67 species) compared to the other habitats (Table 2).

Table 2. Shannon-Weiner diversity index (SWI, H') and Chao-1 mean values for the three habitat types in both seasons.

Habitat	No. of species dry (wet)	No. of individuals dry (wet)	SWI (H')	H_{max}	Chao-1
Infrastructure development area	44 (38)	253 (670)	3.12 (3.14)	3.78 (3.64)	53.75 (38)
Nature reserve forest	10 (25)	44 (249)	2.08 (2.87)	2.3 (3.22)	10 (26.5)
Modified habitat	56 (36)	497 (800)	3.54 (3.13)	4.03 (3.58)	60.67 (36)
Overall	74 (54)	794 (1719)	3.57 (3.42)	4.3 (3.99)	85.67 (54)
Pooled Season					
Infrastructure development area	58	931	3.29	4.06	60.55
Nature reserve forest	28	293	2.96	3.33	31
Modified habitat	67	1297	3.54	4.2	73
Overall	90	2521	3.64	4.5	94.58

Relative abundance

Relative abundance of birds during the wet and dry seasons showed that more than half of the recorded species were rare while about 10% were abundant (Fig. 3). The most abundant species in all habitat types were the Brown-rumped Seedeater (*Serinus tristriatus*) and Montane White Eye (*Zosterops poliogastrus*). There was no significant difference in species' relative abundance among the three habitat types both during the wet (χ^2 = 0.44565, DF = 6, P = 0.99844) and dry seasons (χ^2 = 2.5067, DF = 6, P = 0.86771).

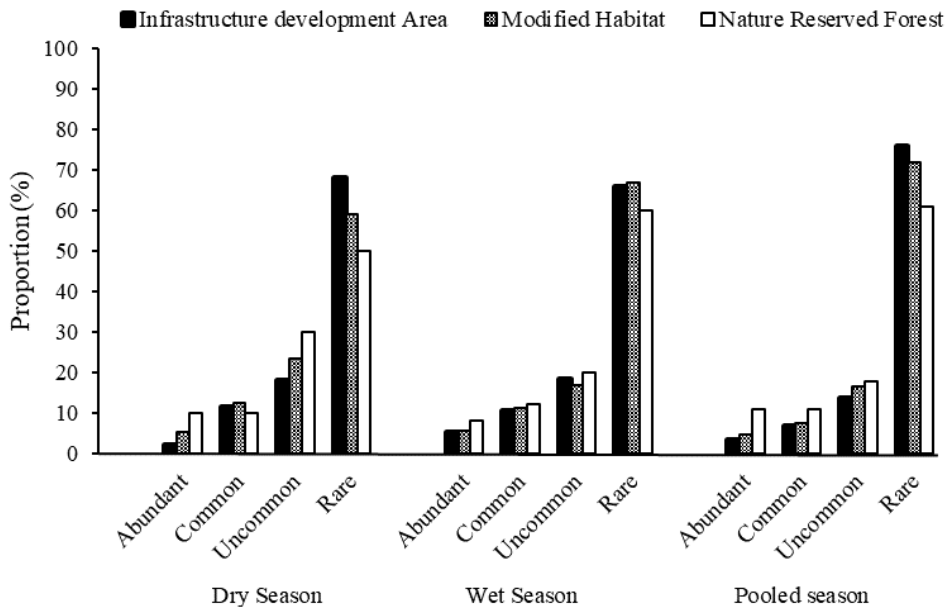

Fig. 3. Relative abundance of birds in different habitats.

Community similarity

Species similarity was higher between infrastructure development area and modified habitat for the scenic garden during the dry (56%) and wet (65%) seasons. The lowest similarity was recorded between the infrastructure development area and the nature reserve forest habitats (22%) (Table 3).

Table 3. Percentage of Sorenson's species similarity index between the three habitat types.

Habitat type	Dry season			Wet season		
	Infrastructure development area	Nature reserved forest	Modified habitat	Infrastructure development area	Nature reserved forest	Modified habitat
Infrastructure development area	1	22	56	1	57	65
Nature reserved forest		1	24		1	59
Modified habitat			1			1

DISCUSSION

Gullele Botanical Garden supports a total of 90 bird species. This is more than 10% of the country's recorded bird species. Of the total bird species recorded in the study area, three bird species were endemic to Ethiopia and 10 bird species were regional endemics shared with Eritrea. The number of species recorded in the Gullele Botanical Garden is higher than a previous record of 55 bird species (Kios Development Consulting, 2012). The number of bird species reported in this area is also greater compared to what has been reported by Addisu Asefa (2018) from similar adjacent habitats, Entoto Mountain Forest, where only 49 bird species were recorded. This may be the movement of bird species into the botanical garden from the adjacent areas attributed to its ecological factors (Lameed, 2011; Tadashi, 2015; Sato *et al*., 2020). It is known that the principal determinant factor of avian species richness and distribution correlates with vegetation structure (Shimelis Aynalem and Afework Bekele, 2008; Tsegaye Gadisa *et al*., 2015).

In fact, before the establishment of the study area as a botanical garden, the number of birds recorded were only 52 species (Kios Development Consulting, 2012), which is found to be much lower compared to the present bird record (90 species). The higher bird species richness indicates the positive effect of protecting habitat and the suitability of the botanical garden in providing ecological requirements of birds.

Afro-Tropical Highland Biomes restricted and Somali-Massi Biome restricted bird species were recorded in the study area among which most were recorded in modified habitats and infrastructure development areas. Although species used plantation forests, most near-endemic bird species recorded in this study were primarily Afro-Tropical Highland Biomes restricted species that prefer natural forests. In fact, birds move from plantation areas towards the natural forest and vice versa in search of food, water, and cover (Whittingham and Evans, 2004; Solomon Chanie and Dereje Tesfaye, 2015) and hence birds were recorded more in modified habitat.

In terms of geographical occurrence, the majority of bird species recorded were residents. Critically endangered and vulnerable species such as the Hooded Vulture and Tawny Eagle, respectively, were recorded in the GBG suggesting its ecological importance as a refuge for these species. On the other hand, this botanical garden supports insectivores and granivores species. This could be due to the emergence of insects coinciding with the year-round availability of water that attracts insectivores and availability of seeds in the modified habitats.

The nature reserve area supported less number of species during the dry season compared to wet season. The area is dominantly covered by homogenous exotic plant species having poor floristic complexity and hence less bird diversity. On the other hand, the infrastructure development area and modified habitat were visited by more number of bird species. It is known that forest stand structure is important for birds because it can directly influence the availability and quality of food, nesting material, and cover from predators (Whittingham and Evans, 2004; Anderson *et al*., 2015; Solomon Chanie and Dereje Tesfaye, 2015), and hence bird diversity. Hence, the modification of habitats for the botanical garden has an important role in supporting more bird species and their conservation.

The modified habitat for the scenic garden had almost insignificant exotic species as the vegetation structure had changed from plantation area to the natural forest with indigenous species. This may have resulted in higher vegetation complexity and floristic composition of the habitat (Schlossberg and King, 2008; Tsegaye Gadisa *et al*., 2015). In addition, minimal disturbance with high vegetation layer, availability of food, a refuge from predators might have contributed to the high number of bird species in the modified habitat. The nature reserve forest showed significantly lower diversity than the two habitat types suggesting low community complexity.

The relative abundance of bird species in the study area showed that most of the bird species were rare. Colwell *et al*. (2012) pointed out that the detectability of bird species in a given habitat such as forest is usually less than 100% and this may have resulted in skewed results to rare species. Besides, in nature reserve forest, only one bird species (Brown-rumped Seedeater *Serinus tristriatus*) was grouped as abundant. This might be due to the impact of exotic plants (*Eucalyptus globulus*, *Eucalyptus saligna*, and *Eucalyptus viminalis*) on the ecosystem. The planted fast-growing exotic trees suppress the growth of nearly all the indigenous woody and herbaceous plants and severely reduce the floral and faunal diversity of the area.

Between habitats, bird species similarity of nature reserve forests when compared with the modified habitat and infrastructure development area was less than 30% during the dry season. However, during the wet season, more than 50% of the species were similar between all habitat types. The species similarity of modified habitat and infrastructure development area is less during the dry season than wet season. This result indicates that different bird species need their specific habitats associated with the season for their survival, reproduction, source of food, and protection from the enemy (Nabaneeta and Gupta, 2010). Among the three habitats, bird species similarity was highest between modified habitat and infrastructure development areas. Burgess *et al*. (2002) and Rodríguez-Estrella (2007) noted that the more complex or denser habitats tend to contain more similar species because complex vegetation provides a stable food supply and shelter. Lameed (2011) has also noted that the similarity of bird species composition between habitats indicates a tendency for similar habitats to have similar species composition. In addition, Şekercioğlu *et al*. (2004) noted that foraging modes of birds are important factors in birds' habitat selection. Therefore, species of the same guild would select the same habitat features. Hence, the similarity in bird species between modified habitat and infrastructure development areas could be attributed to these factors.

CONCLUSION

The present study revealed that Gullele Botanical Garden supports a variety of bird species including endemic and regionally endemic species. In addition, the garden supports Afro-Tropical Highland Biomes restricted bird species. Most of the birds in the study area were locally rare, and this indicates the Gullele Botanical Garden is important for local visitor bird species. The variation in the number of individual species and their

distribution in the study area are directly related to the types of habitats as different bird species have specific needs for their survival, source of food, reproduction, and protection from predation. Compared to a nature reserve forest that is dominated by exotic plant species, modified habitat and infrastructure development areas supported more bird species. This ecological study on the diversity of bird species in Gullele Botanic Garden provides first-hand information for managers to make effective conservation decisions that take birds into consideration.

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