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DIVERSITY OF BIRDS IN HIGHLAND RESERVOIRS AND ADJOINING AREAS OF TIGRAY, NORTHERN ETHIOPIA: IMPLICATION FOR CONSERVATION

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Diversity of Birds in Highland Reservoirs and Adjoining Areas of Tigray, Northern Ethiopia: Implication for Conservation. Weldemariam, T. B., Alembrhan, A. W. & Kalayu, M. A. — Avian diversity is among the key components of the earth's biodiversity that serve as unique barometers for environmental change. Bird diversity in unprotected habitats such as reservoirs in the Tigray region is less known. A study was conducted to assess the avian diversity in highland reservoirs of the Tigray region, particularly at Maygundi and Maysye reservoirs and their adjoining habitats from August 2022 to March 2023, covering both wet and dry seasons. A line transects and point count methods aided by binoculars were used to estimate avian species diversity and distribution. Biodiversity indices and Two-way ANOVA were used to analyze the data. A total of 1,813 individual birds belonging to 151 species, 17 orders and 51 families were recorded during the study period. Egyptian goose was the most abundant species (19.58 %), followed by Little Grebe (10. 86 %), Eurasian Coot (7.00 %), Ruff and Yellow Mantle Widowbird (3.31 % for each). A significant variation in the number of bird species between wet and dry seasons ($F = 1225$, $df = 1$, $P = 0.02$) and between reservoirs ($F = 484$, $df = 1$, $P = 0.03$) was observed. However, there was no significant difference in abundance of birds between wet and dry seasons in both reservoirs ($P > 0.05$). Maysye reservoir had high bird species diversity ($H' = 3.66$), while Maygundi reservoir had the lowest ($H' = 3.24$). The study shows that sedimentation and habitat destruction due to anthropogenic activities, including the expansion of settlements; agriculture and livestock grazing were the main threats to bird diversity. The highland reservoirs and their adjoining habitats support high avian species diversity including endemic and endangered species revealing the importance of the sites for bird conservation. Therefore, urgent conservation measures are recommended for long-term bird conservation.
Key words: Avifauna, conservation, highland reservoir, war zone, wetland, Ethiopia.

Introduction

Ethiopia is distinguished as the eastern Afro-montane and the horn of Africa biodiversity hotspot that holds a substantial number of worldwide ecological zones with a high highland and a central mountain range separated by the Great Rift Valley (Yalden, 1983; Conservation International, 2011). The country has a wide range of altitudes, from 126 meters below sea level (m. a. s. l.) in the Afar depression to 4,620 m. a. s. l. in the Semien Mountains, i. e., Ras Dejen, resulting in the country hosting a high faunal diversity with a high degree of endemism (Husen et al., 2012; Ethiopian Biodiversity Institute (EBI), 2015). As a result, IUCN has nominated Ethiopia as one of the eight pilot countries where BIODER 2030 will be implemented (Mekbeb et al., 2022). Birds inhabit all habitat types on the planet, from the lowest desert to the highest mountains, and are key indicators of the health and stress of the ecosystem. Ethiopia hosts more than 2,970 species of wildlife, of which 926 species are birds belonging to 27 orders and 155 families. Of the total number of bird species, 665 species are resident, 30 are migratory and 37 are nonmigratory species (Weldemariam, 2016; Weldemariam et al., 2020).

Currently, Ethiopia has announced approximately 73 important bird areas to conserve birds of the country (Mengistu, 2003; Shimelis and Afework, 2009; Weldemariam, 2016). However, due to habitat loss caused by human-induced factors many species of birds are found outside of their natural and stable habitats in unprotected areas such as reservoirs and wetlands. Man-made highland reservoirs found at an average of 1100 m. a. s. l. have been described to attract more bird species than naturally formed highland reservoirs (Kiros et al., 2014). The creation of an artificial highland reservoir is considered an important measure since it can deliver a new habitat for bird communities when all habitat requirements are suitable. Globally, wetlands are still being degraded and there is a need to assess and monitor bird populations since their diversity and activities indicate the quality and status of the ecosystem (Aerts et al., 2008; Girma et al., 2017).

In Ethiopia, there have been limited surveys on bird diversity, abundance and threats, particularly diversity of water birds is in its infancy; hence, there is an imperative need to collect data on the diversity of bird communities in unprotected water bodies, such as reservoirs and wetlands to improve bird conservation concerns. In Ethiopia's Tigray region the diversity and abundance of birds is very little known due to long-lasting war in the region, and the war using bioweapons, poisonous chemicals and drones that cause a decline in biodiversity. The majority of available evidence shows that in most war zones, populations are dropping, rather than these areas serving as refuges for wildlife. More than 80 reservoirs have been constructed in the Tigray region, primarily for hydropower, irrigation, fishing, livestock watering, and other human uses. Few studies have revealed that these reservoirs are also suitable for foraging, roosting, nesting and breeding sites of both migratory and resident aquatic birds and area considered as alternative promising sites for high bird diversity of the region (Tsehaye et al., 2007; Kiros et al., 2014). So far, however, only 10 of the 80 reservoirs in the eastern and south-eastern zones of Tigray have been surveyed to document the diversity of bird species they contain (Kiros et al., 2014). The avian diversity of other highland reservoirs in the region, such as the Maygundi and Maysye reservoirs in the central zone, is not known. Therefore, the present study aims to assess the avian diversity of the Maygundi and Maysye reservoirs and their adjacent areas in the Tigray region of northern Ethiopia. Documenting the diversity of the avifauna in these highland reservoirs will provide a valuable primary source of data and assist in the development of a sound management plan for the future.

Material and Methods

Study area

The study was conducted in the central zone of the Tigray region particularly in Laelay Maichew district at Maygundi (38°47′44″ N Latitude and 14°02′ N 38°46″ E Longitude and Maysye reservoirs and their adjoining areas (38°47′44″ N Latitude and 14°03′37″ E Longitude) (fig. 1), with an average altitude of 2007 m. a. s. l., which have habitat heterogeneity including aquatic ecosystems for avian diversity and distribution. These reservoirs are mainly used for irrigation and livestock drinking. The mean annual temperature of the reservoirs is 20 °C and their mean annual rainfall is 638 mm, and the pattern of rainfall distribution is unimodal with a long rainy season between June and September (Tsehaye et al., 2007). However, Tigray's lands cover, wildlife, natural resources and biodiversity in general are intentionally damaged as battlefields frequently by genocidal war. However, people are making the most serious effort at conservation. Munitions and chemical agents exert both immediate and residual effects, both direct and indirect on biodiversity.

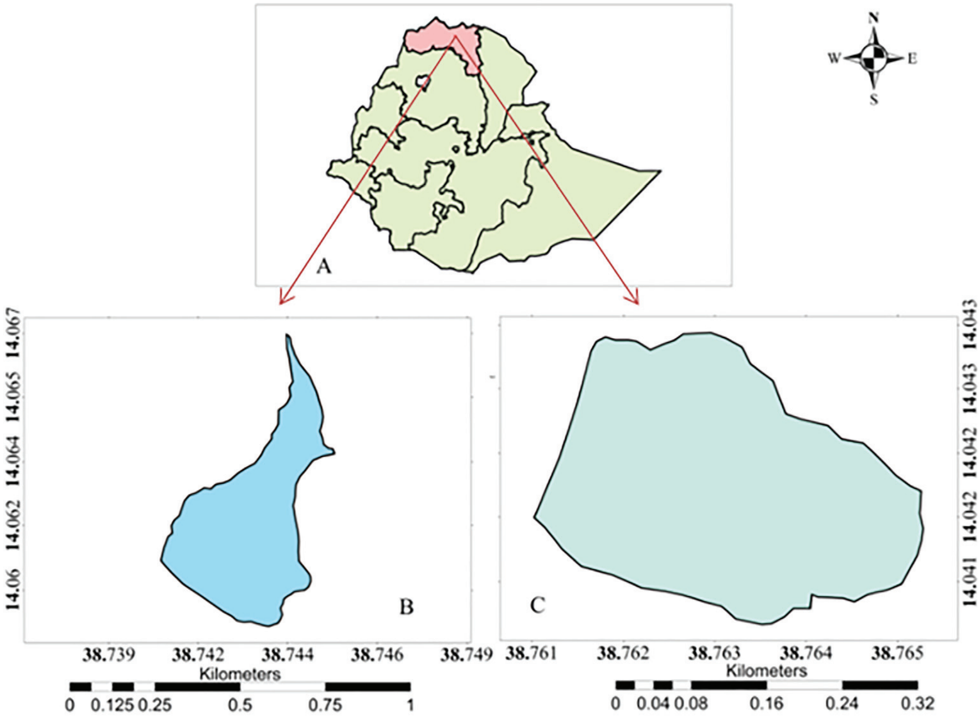

Fig. 1. Map of Ethiopia with regions (A), Maysye reservoir (B) and Maygundi reservoir (C).

Materials used

Various materials were used during the field survey such as GPS (Garmin72), binoculars (8 × 40), field guides for birds, digital camera, data sheets, notebook, pen, rulers and field tents.

Method of data collection

To study birds, two habitat types including reservoir and adjoining terrestrial habitats for both reservoirs were selected. Birds were monitored using the line transect and point count methods depending on the habitat types and suitability of the method (Bibby et al., 2000). Sampling sites were randomly established from each habitat type to make results representative of the whole study area (Bibby et al., 1998). Twenty sample points were established along the periphery of the reservoirs and were used as birds counting stations. In the selected counting stations, all observed birds were identified and counted with the help of binocular. Likewise, eight transect lines consist 26 counting stations were set to identify and count the birds in nearby terrestrial habitat of the study area (Bibby et al., 1992; Gibbons & Gregory, 2006). At each counting station, we observed for a period of 15 min to ensure that cryptic species were included by walking slowly along transects. Birds were counted as seen, heard and in flight were also recorded. Field data were collected from August to October 2022 (wet season) and from January to March 2023 (dry season). Birds were counted every two weeks twice a day in the early morning (6:00–10:00) and in the late afternoon (16:00–22:00) when the activities of birds were high (Shimelis & Afework, 2008). The identification and categorization of birds into their respective taxonomic groups was performed based on field guide books (Redman et al., 2009). The observations were made using binoculars and spotting scopes, and the images were captured using a digital camera. Photographs were taken to identify and count the birds that were not easily identified in the field.

Statistical analysis

Biodiversity indices were used to analyze the bird species diversity: the Shannon-Weiner diversity index (H′) (Shannon & Wiener, 1949). The formula is $H' = \sum (Pi\ ln\ Pi)$, where Pi = proportion of the i^{th} species and *In* = natural logarithm. Shannon–Wiener evenness index (*E*) ($E = H' / H_{max}$, where H′ = Shannon–Wiener diversity index; and $H_{max} = \ln S$ = natural logarithm of the total number of species (*S*) (Kathleen et al., 2005; Sohil & Sharma, 2020) was used to calculate the species evenness of birds. In addition, Simpson's similarity index (SI) ($SI = 2\,C/A + B$, where A = number of species that found in site A, B = number of species found in site B, and C = number of common species that found in site A and B) was used to evaluate the similarity between habitats with reference to species composition. Two-way ANOVA was used to test the significant variation in bird species richness and abundance between habitat types and seasons. PAST software (Hammer et al., 2001) was used to prepare the species accumulation curve to assess the adequacy of the sampling effort of birds during the study. Differences were considered statistically significant at $P < 0.05$.

Results

Species diversity

A total of 1,813 individual birds belonging to 151 species, 17 orders and 51 families were recorded in the study area (table 3). Order Passeriformes was the most dominant, represented by 20 families and 65 species, followed by order Charadriiformes (6 families, 21 species) and Pelecaniformes (4 families, 13 species), respectively (fig. 2). In the two reservoirs, a total of 694 and 1,119 individual birds were recorded during the wet and dry seasons, respectively. Maygundi reservoir had 332 and 439 individual birds during the wet and dry seasons, respectively, while the Maysye reservoir recorded 362 and 680 individuals, respectively. With respect to bird distribution across the reservoirs, 771 individual birds were recorded in the Maygundi reservoir and 1042 individuals were recorded in Maysye reservoir. In this study, four endemic species to Ethiopia including Blue Winged Goose, *Cyanochen cyanopterus* (Rüppell, 1845), Abyssinian Catbird, *Sylvia galinieri* (Guérin-Méneville, 1843), Ethiopian Cisticola, *Cisticola lugubris* (Rüppell, 1840), and White-Winged Cliff-Chat, *Monticola semirufus* (Rüppell, 1837), were recorded. Rouget's Rail, *Rougetius rougetii* (Guérin-Méneville, 1843), Banded Barbet, *Lybius undatus* (Rüppell, 1837), Black-Winged Lovebird, *Agapornis taranta* (Stanley, 1814), and Wattled Ibis, *Bostrychia carunculata* (Rüppell, 1837), were near-endemic (endemic to Ethiopia and Eritrea). In addition, globally threatened species such as Egyptian Vulture, *Neophron*

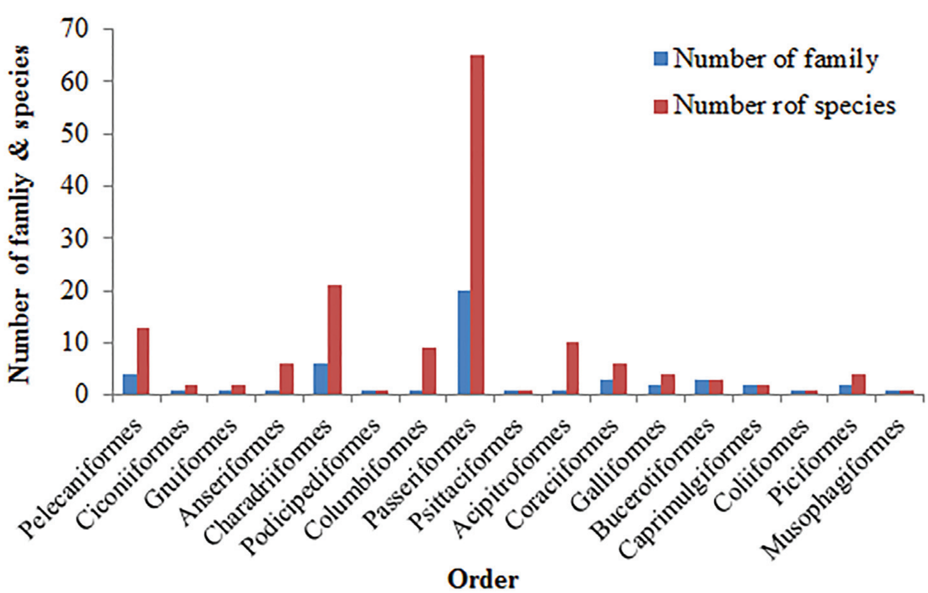

Fig. 2. Bird orders with number of families and species in Maygundi and Maysye reservoirs, Tigray, Ethiopia.

Table 1. Bird species diversity between Maygundi and Maysye reservoirs during the wet and dry seasons

Reservoirs	Season	S	N	D	H′	E
Maygundi	Wet	56	332	0.11	2.82	0.32
	Dry	45	439	0.09	2.96	0.43
	Both	81	771	0.08	3.24	0.32
Maysye	Wet	93	362	0.08	3.42	0.33
	Dry	70	680	0.09	3.27	0.38
	Both	140	1042	0.07	3.66	0.28

Note. S — species richness; N — abundance; D — dominance; H′ — Shannon–Wiener diversity index; E — species evenness.

percnopterus (Linnaeus , 1758), Lappet-faced Vulture, *Torgos tracheliotos* (Forster , 1791), *Sylvia galinieri* (Guérin-Méneville, 1843), *Rougetius rougetii*, Cassin's Hawk-eagle, *Aquila africana*, and Martial Eagle, *Polemaetus bellicosus* (Daudin, 1800), were also recorded.

The study showed variations in species diversity between reservoirs and seasons (table 1). During both seasons the highest bird species diversity (H′ = 3.66) was recorded in the Maysye reservoir and the lowest was recorded in Maygundi reservoir (H′ = 3.24). Similarly, the bird species diversity was higher during the wet season than during the dry season in both habitats. Maysye reservoir had higher species diversity in both the wet (H′ = 3.42) and dry (H′ = 3.27) seasons, while the Maygundi reservoir had lower species diversity in both the wet (H′ = 2.82) and dry (H′ = 2.96) seasons. Higher species evenness was recorded during the dry season in both reservoirs than during the wet season (table 1). The species accumulation curve for both reservoirs and nearby wetlands has fully reached the asymptote line, indicating the completeness of the survey and adequacy of sampling effort. This implies that no more sampling effort is needed to explore all the expected bird species of the study reservoir and its adjoining habitat (fig. 3).

Species similarity indices

Avian species similarity across reservoirs ranged from 0.28 to 0.67. During the wet season the highest species similarity (SI = 0.67) was recorded between the Maygundi and Maysye reservoirs. The lowest species similarity (SI = 0.28) was recorded during the dry season in both reservoirs. The overall similarity index was SI = 0.64, which is greater than 50 %, indicating that there is high similarity of bird species between the two reservoirs (table 2).

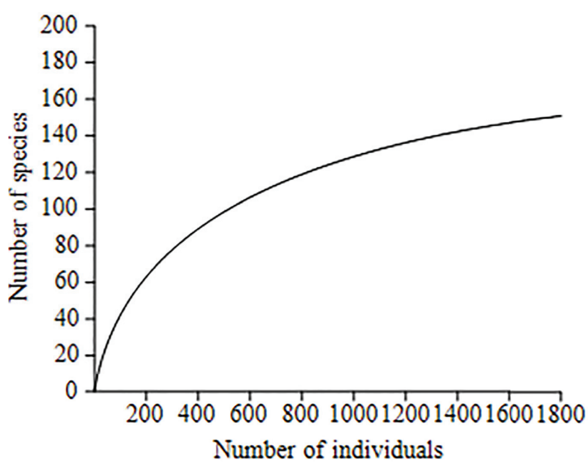

Fig. 3. Species accumulation curve of bird species in Maygundi and Maysye reservoirs.

Table 2. Bird species similarity between Maygundi and Maysye reservoirs during the wet and dry seasons

Simpson's similarity index (SI)			
Reservoir	Season	Maygundi	Maysye
Maygundi	Wet	–	0.67
	Dry	–	0.28
	Both	–	0.64
Maysye	Wet	0.67	–
	Dry	0.28	–
	Both	0.64	–

Distribution and Abundance

In the present study, the bird species distribution varied between reservoirs during the wet and dry seasons (table 1). Of the total bird species recorded, 140 species were observed from Maysye reservoir and 81 species were from Maygundi. Of these, 69 species were found only in the Maysye reservoir, 10 species were observed only in the Maygundi reservoir, and 71 species were observed common to both reservoirs. During the wet season, 56 bird species were recorded from the Maygundi reservoir and 93 species were recorded from the Maysye reservoir. Likewise, during the dry season, 45 species from Maygundi and 70 species from Maysye were recorded. Two-way ANOVA showed that there was significant variation in the number of species between the wet and dry seasons ($F = 1225$, $df = 1$, $P = 0.02$) and between reservoirs ($F = 484$, $df = 1$, $P = 0.03$). A total of 1,813 individual birds were counted during this study period. Of these, 694 individuals were recorded during the wet season, and 1,119 individuals were detected during the dry season. A higher number ($N = 362$) of individual birds was recorded from the Maysye reservoir and a lower number ($N = 332$) was recorded from Maygundi reservoir during the wet season. Similarly, higher ($N = 680$) and lower ($N = 439$) numbers of individual birds were recorded from the Maysye and Maygundi reservoirs during the dry season, respectively (table 1). There was no significant difference in the abundance of birds between the wet and dry seasons in both reservoirs during the study period ($P > 0.05$). Of the total identified bird species, Egyptian goose was the most abundant species, constituting 19.58 %, followed by Little Grebe (10. 86 %), Eurasian Coot (7.00 %), Ruff and Yellow Mantle Widowbird (3.31 % for each), while some species were represented by a single individual (0.05 %) (table 3).

Discussion

In this study, a total of 151 species belonging to 17 orders and 51 families were recorded in the highland reservoirs. This implies that the highland reservoirs support a high diversity of avian species due to various ecological resources. The number of bird species recorded in these reservoirs is relatively in agreement with reports of previous studies from other localities of Ethiopia. This coincides with the result of Weldemariam (2016), who recorded approximately 2985 individual birds belonging to 84 species, 48 genera and 23 families with 4 endemic species in the Afro-tropical highland wetlands of the Awi zone and Wombera hotspot areas, northwestern, Ethiopia. Jemal et al. (2020) recorded about 105 bird species consisting of one endemic, eight near endemic, one globally threatened and nine Palearctic migrants in Nensebo forest, southern Ethiopia. Hailu and Bezawork (2022) reported

Table 3. Bird species and number of individuals in Maygundi and Maysye reservoirs and surrounding areas during the wet and dry seasons

Order	Family	Common name	Scientific name	Reservoir				T	RA (%)
				Maygundi		Maysye			
				W	D	W	D		
1	2	3	4	5	6	7	8	9	10
Pelecaniformes	Ardeidae	Grey Heron	*Ardea cinerea*	2	2	15	4	23	1.27
		Purple Heron	*Ardea purpurea*	2	2	3	3	10	0.55
		Goliath Heron	*Ardea goliath*	1	0	1	7	9	0.49
		Squacco Heron	*Ardeola ralloides*	0	5	0	9	14	0.77
		Little Egret	*Egretta garzetta*	1	6	1	23	31	1.71
		Greater White Egret	*Ardea alba*	1	0	4	0	5	0.27
		Cattle Egret	*Bubulcus ibis*	8	6	3	13	30	1.65
	Scopidae	Hamerkop	*Scopus umbretta*	4	0	2	0	6	0.33
	Threskiornithidae	Sacred Ibis	*Threskiornis aethiopicus*	0	3	0	0	3	0.16
		Wattled Ibis [NE]	*Bostrychia carunculata*	0	0	6	4	10	0.55
		African Spoonbill	*Platalea alba*	0	0	0	4	4	0.22
	Pelecanidae	Great White Pelican	*Pelecanus onocrotalus*	4	6	2	0	12	0.66
		Pink-backed Pelican	Pelecanus rufescens	0	0	3	0	3	0.16
Ciconiiformes	Ciconiidae	Black Stork	*Ciconia nigra*	0	6	2	0	8	0.44
		Yellow Billed Stork	*Mycteria ibis*	0	0	4	0	4	0.22
Gruiformes	Rallidae	Rouget's Rail [NE]	*Rougetius rougetii*	1	0	1	0	2	0.11
		Eurasian Coot	*Fulica atra*	65	59	3	0	127	7.00
Anseriformes	Anatidae	White-Backed Duck	*Thalassornis leuconotus*	1	2	1	0	4	0.22
		Tufted Duck	*Aythya fuligula*	0	8	0	2	10	0.55
		Egyptian Goose	*Alopochen aegyptiacus*	74	56	67	158	355	19.58
		Blue Winged Goose [E]	*Cyanochen cyanopterus* [E]	0	21	10	24	55	3.03
		Fulvous Whistling-Duck	*Dendrocygna bicolor*	1	0	1	0	2	0.11

1	2	3	4	5	6	7	8	9	10
		Common Pochard	*Aythya ferina*	0	0	0	14	14	0.77
Charadriformes	Rostratulidae	Painted-Snipe	*Rostratula benghalensi*	0	0	2	0	2	0.11
	Charadriidae	Black-Winged Lapwing	*Vanellus melanopterus*	20	3	1	0	24	1.32
		Spur-Winged Lapwing	*Vanellus spinosus*	4	9	4	17	34	1.87
		Senegal Lapwing	*Vanellus lugubris*	0	0	2	0	2	0.11
		African Wattled Lapwing	Vanellus senegallus	0	0	0	6	6	0.33
		White-Fronted Plover	*Charadrius marginatus*	0	0	1	0	1	0.05
		Caspian Plover	*Charadrius asiaticus*	0	0	0	4	4	0.22
		Little Ringed Plover	*Charadrius dubius*	1	0	1	0	2	0.11
		Kittlitz's Plover	*Charadrius pecuarius*	0	18	0	3	21	1.16
		Kentish Plover	*Charadrius alexandrinus*	0	0	0	14	14	0.77
	Scolopacidae	Ruff	*Philomachus pugnax*	0	52	0	8	60	3.31
		Dunlin	*Calidris alpina*	0	0	0	12	12	0.66
		Common Greenshank	*Tringa nebularia*	0	0	0	7	7	0.38
		Stone-Curlew	*Burhinus oedicnemus*	41	0	0	7	48	2.65
		Marsh Sandpiper	*Tringa stagnatilis*	2	0	0	1	3	0.16
		Temminck's Stint	Calidris temminckii	0	0	0	10	10	0.55
	Burhinidae	Senegal Thick-knee	*Burhinus senegalensis*	1	4	22	3	30	1.65
		Spotted Thick-knee	*Burhinus capensis*	0	0	1	0	1	0.05
	Laridae	Little Tern	*Sternula albifrons*	2	0	3	0	5	0.27
		Bridled Tern	*Sterna anaethetus*	1	0	2	0	3	0.16
	Jacanidae	African Jacana	*Actophilornis africanus*	1	0	0	0	1	0.05
Podicipediformes	Podicipedidae	Little grebe	*Tachybaptus ruficollis*	0	76	19	102	197	10.86
Columbiformes	Columbidae	African Collared Dove	*Streptopelia roseogrisea*	1	0	1	0	2	0.11
		Ring-Necked Dove	*Streptopelia capicola*	0	2	1	3	6	0.33
		African Mourning Dove	*Streptopelia decipiens*	0	7	1	0	8	0.44
		Dusky Turtle-Dove	*Streptopelia lugens*	0	0	1	0	1	0.05

1	2	3	4	5	6	7	8	9	10
		Blue-spotted Wood Dove	*Turtur afer*	0	0	1	0	1	0.05
		Namaqua Dove	*Oena capensis*	0	1	0	8	9	0.49
		Lemon Dove	*Columba larvata*	0	0	0	7	7	0.38
		Spackled Pigeon	*Columba guinea*	0	2	0	0	2	0.11
		Bruce's Green Pigeon	Treron waalia	0	12	0	0	12	0.66
Passeriformes	Ploceidae	Black-Headed Weaver	*Ploceus melanocephalus*	17	0	1	0	18	0.99
		Northern Red Bishop	*Euplectes franciscanus*	1	0	1	0	2	0.11
		Yellow Bishop	*Euplectes capensis*	3	0	5	0	8	0.44
		African Paradise Monarch	*Terpsiphone viridis*	0	0	1	0	1	0.05
		Black-Winged Bishop	*Euplectes hordeaceus*	0	0	1	0	1	0.05
		Spectacled-fronted Weaver	*Sporopipes frontalis*	1	0	1	0	2	0.11
		Baglafetch Weaver	*Ploceus baglafecht*	0	0	0	2	2	0.11
		Yellow Mantle Widowbird	*Euplectes macroura*	1	0	59	0	60	3.31
	Sylviidae	Abyssinian Catbird [E]	*Parophasma galinieriE*	0	0	1	0	1	0.05
		Eurasian Blackcape	*Sylvia atricapilla*	0	0	0	3	3	0.16
	Fringillidae	African Citril	*Serinus citrinelloides*	0	0	1	0	1	0.05
		Yellow-Rumped Seed Eater	*Crithagra xanthopygia*	1	0	1	0	2	0.11
		Grosbeak-Canary	Serinus donaldsoni	0	0	1	0	1	0.05
	Platysteiridae	Eastern Black-Headed Batis	*Batis minor*	0	0	1	2	3	0.16
	Nectariniidae	Bronze Sunbird	Nectarinia kilimensis	0	0	1	0	1	0.05
		Beautiful Sunbird	*Cinnyris pulchellus*	0	0	1	0	1	0.05
		Variable Sunbird	*Cinnyris venustus*	1	0	1	0	2	0.11
		Malachite Sunbird	*Nectarinia famosa*	0	0	0	2	2	0.11
	Laniidae	Long-Tailed Fiscal	*Lanius cabanisi*	1	0	1	0	2	0.11
		Northern Fiscal	*Lanius humeralis*	0	0	1	3	4	0.22
	Malaconotidae	Black-Crowned Tchagra	*Tchagra senegala*	0	0	1	0	1	0.05
		Ethiopian Boubou	*Laniarius aethiopicus*	0	2	0	3	5	0.27

1	2	3	4	5	6	7	8	9	10
		Northern Puffback	*Dryoscopus gambensis*	0	0	0	2	2	0.11
	Vangidae	White helmetshrike	*Prionops plumatus*	0	0	1	0	1	0.05
	Corvidae	Pied Crow	*Corvus albus*	1	0	1	3	5	0.27
		Cape Crow	*Corvus capensis*	0	0	1	3	4	0.22
	Cisticolidae	Pectoral-Path Cisticola	*Cisticola brunnescens*	0	0	0	3	3	0.16
		Ethiopian Cisticola [E]	*Cisticola lugubris*	0	0	0	2	2	0.11
		Singing Cisticola	*Cisticola cantans*	0	1	0	2	3	0.16
		Green-Backed Camaroptera	Eremomela canescens	0	0	0	3	3	0.16
	Estrildidae	Red-Billed Firefinch	*Lagonosticta senegala*	15	9	14	10	48	2.65
		African Firefinch	*Lagonosticta rubricate*	6	10	10	11	37	2.04
		Cut-Throat Finch	*Amadina fasciata*	0	0	0	6	6	0.33
		Common Waxbill	*Estrilda astrild*	2	3	3	3	11	0.61
		Red-rumped Waxbill	*Estrilda charmosyna*	3	3	2	3	11	0.61
		African Silverbill	*Lonchura cantans*	0	0	0	34	34	1.87
		Red-Cheeked Cordian Blue	*Uraeginthus bengalus*	1	0	1	0	2	0.11
		Blue-Cheeked Cordian Blue	*Uraeginthus angolensis*	4	3	1	15	23	1.27
	Pcynonotidae	Common Bulbul	*Pycnonotus barbatus*	1	2	1	2	6	0.33
	Sturnidae	Bronze-Tailed Starling	*Lamprotornis chalcurus*	0	0	6	0	6	0.33
		Greater Blue-eared Starling	*Lamprotornis chalybaeus*	0	0	0	20	20	1.10
		Lesser Blue-eared Starling	*Lamprotornis chloropterus*	0	0	0	6	6	0.33
	Viduidae	Village Indigo Bird	*Vidua chalybeate*	1	0	1	0	2	0.11
	Alaudidae	Thekla Lark	*Galerida theklae*	0	0	0	2	2	0.11
		Greater Short-Toed Lark	Calandrella brachydactyla	0	0	0	2	2	0.11
	Motacillidae	Plain-Backed Pipit	*Anthus leucophrys*	0	0	0	2	2	0.11
		Tawny Pipit	*Anthus campestris*	0	0	0	2	2	0.11
		Yellow Wagtail	*Motacilla flava*	0	0	0	10	10	0.55
	Emberizidae	Cinnamon-Breasted Bunting	*Emberiza tahapisi*	0	0	0	5	5	0.27

1	2	3	4	5	6	7	8	9	10
	Muscicapidae	Mocking Cliff-Chat	*Thamnolaea cinnamomeiventris*	0	4	6	0	10	0.55
		Rueppell's Black-Chat	*Myrmecocichla melaena*	0	0	1	3	4	0.22
		White-Winged Cliff-Chat [E]	*Thamnolaea semirufa*	0	1	1	0	2	0.11
		Familar Chat	*Cercomela familiaris*	0	0	0	3	3	0.16
		Siberian Stonechat	*Saxicola maura*	0	0	0	2	2	0.11
		Common Chiffchaff	*Phylloscopus collybita*	0	2	0	0	2	0.11
		Northern Wheatear	*Oenanthe oenanthe*	0	0	1	0	1	0.05
		Abyssinian Wheatear	*Oenanthe lugubris*	1	0	1	0	2	0.11
		Collared Flycatcher	Ficedula albicollis	0	0	1	0	1	0.05
		Pale Flycatcher	*Bradornis pallidus*	0	0	0	3	3	0.16
		African Dusky Flycatcher	*Muscicapa adusta*	1	3	0	0	4	0.22
		Spotted Flycatcher	*Muscicapa striata*	0	2	0	0	2	0.11
		African Paradise Flycatcher	*Terpsiphone viridis*	0	0	0	4	4	0.22
		Spotted Flycatcher	*Muscicapa striata*	0	2	0	0	2	0.11
	Passeridae	Northern Grey-Headed Sparrow	*Passer griseus*	1	0	0	0	1	0.05
	Turdidae	African Thrush	*Turdus pelios*	0	0	2	0	2	0.11
Psittaciformes	Psittaculidae	Black-Winged Lovebird [NE]	*Agapornis taranta*	1	0	1	0	2	0.11
Acipitroformes	Accipitiridae	Cassin's Hawk-Eagle	*Aquila Africana*	1	0	1	0	2	0.11
		Long-Crested Eagle	*Lophaetus occipitalis*	0	0	1	0	1	0.05
		Martial Eagle	*Polemaetus bellicosus*	3	0	1	0	4	0.22
		Lappet-Faced Vulture	*Torgos tracheliotus*	0	0	1	0	1	0.05
		Egyptian Vulture	*Neophron percnopterus*	4	0	1	0	5	0.27
		Common Buzzard	*Buteo buteo*	2	1	1	0	4	0.22
		Gabar Goshawk	*Micronisus gabar*	1	0	1	0	2	0.11
		Yellow-Billed Kite	*Milvus(migrans) aegyptius*	0	0	0	2	2	0.11
		Black Winged Kite	*Elanus caeruleus*	0	0	0	2	2	0.11
		Black Kite	Milvus migrans	0	6	0	6	12	0.66

1	2	3	4	5	6	7	8	9	10
Coraciiformes	Alcedinidae	Pied Kingfisher	*Ceryle rudis*	1	0	1	0	2	0.11
		Malachite Kingfisher	*Alcedo cristata*	1	0	1	0	2	0.11
	Coraciidae	Eurasian Roller	*Coracias garrulus*	0	0	1	0	1	0.05
	Meropidae	White Fronted Bee-Eater	*Merops bullockoides*	1	0	1	0	2	0.11
		Blue-breasted Bee-eater	*Merops variegatus*	0	0	1	0	1	0.05
		White-Throated Bee-Eater	*Merops albicollis*	1	0	1	0	2	0.11
Galliformes	Phasianidae	Clapperton's Francolin	*Francolinus clappertoni*	0	0	1	0	1	0.05
		Scaly Francolin	*Francolinus squamatus*	0	0	1	0	1	0.05
		Erckee's Francolin	*Francolinus erckelii*	0	0	0	1	1	0.05
	Numididae	Helmeted Guineafowl	*Numida meleagris*	0	3	0	0	3	0.16
Bucerotiformes	Phoeniculidae	Black-Billed Wood-Hoopoe	Phoeniculus somaliensis	3	0	14	0	17	0.94
	Bucorvidae	Abyssinian Ground Hornbill	*Bucorvus abyssinicus*	0	0	0	2	2	0.11
	Bucerotidae	Northern Red-Billed Hornbill	*Tockus erythrorhynchus*	0	3	0	2	5	0.27
Caprimulgiformes	Caprimulgidae	Montane Nightjar	Caprimulgus poliocephalus	0	0	0	1	1	0.05
	Apodidae	Little Swift	*Apus affinis*	10	1	1	0	12	0.66
Coliiformes	Coliidae	Speckled Mousebird	*Colius striatus*	0	2	0	6	8	0.44
Piciformes	Picidae	Nubian Woodpecker	*Campethera nubica*	0	8	0	0	8	0.44
	Lybiidae	Banded Barbet [NE]	*Lybius undatus*	0	0	1	0	1	0.05
		Black Billed Barbet	*Lybius guifsobalito*	0	0	1	0	1	0.05
		Red-Faced Barbet	*Tricholaema diademata*	0	0	1	0	1	0.05
Musophagiformes	Musophagidae	Easter Plantain-Eater	*Crinifer zonurus*	1	0	1	0	2	0.11

Note. W — wet; D — dry; T — total; RA — relative abundance; E — endemic to Ethiopia; NE — near endemic (endemic to Ethiopia and Eritrea).

a total of 90 bird species belonging to 12 orders and 37 families with two endemic and 11 near- species from Gullele Botanical Garden, central Ethiopia. Variation in the number of bird species and abundance across different localities might be due to differences in the availability of food sources, nesting habits of birds, levels of human disturbance, climatic conditions, and other ecological constraints. Moreover, the number of survey routes/points, length of time spent on observation and size of the study area also lead to variation. Manthey et al. (2022) noted that taxon-specific characteristics and extrinsic climatic and geological forces may both shape population differentiation and speciation. Monitoring the population dynamics of threatened avian species requires a landscape-scale understanding of their distribution over time (Rowe et al., 2023; Santini et al., 2023). However, detection is inherently low for rare, widely distributed and cryptic species. Such scenario development for major policy instruments, such as the convention on biological diversity, could help shift national and international priorities away from the growth imperative and towards enhancing biodiversity and human well-being (Weldemariam & Getachew, 2017; Otero et al., 2020; Teklay et al., 2020).

From the total identified orders, the order Passeriformes was the most dominant with the highest number of species, while Podicipediformes, Psittaciformes, Coliiformes and Musophagiformes had the least number of species. This result is consistent with the reports of several authors who reported a high number of bird species belonging to the order Passeriformes (Alemayehu & Dereje, 2021; Hailu & Bezawork, 2022; Manthey et al., 2022; Rowe et al., 2023). In this study, Egyptian goose was the most abundant species, which might be associated with its ability to feed in agricultural lands and water bodies and is a generalist bird that can inhabit both terrestrial and aquatic habitats. This is in line with the results of various authors (Kiros et al., 2014; Hadis et al., 2020; Alemayehu & Dereje, 2021).

In highland reservoirs population differentiation and speciation are complex and shaped by interactions of earth's pattern, biological variables and patterns of avian species-specific traits (Manthey et al., 2022; Santini et al., 2023). These might be affected through limnological characteristics, biological and morpho-edaphic variables of the highland reservoirs on water bird species richness and distribution (Tsegazeabe, 2023). In both reservoirs, bird species richness and abundance were higher during the dry season than during the wet season. Semi-arid slopes in the highland reservoirs, with small forest relics on sacred grounds, scattered fields in a matrix of degraded grazing land, and forest rehabilitation areas, which are enclosures where grazing and cutting are forbidden for sustainable conservation. During the wet season, swamp flowering plants flourished and as a result, food was plentiful for birds in the highland reservoirs. However, during the dry season, deciduous trees defoliate and in the absence of food, many species of birds are restricted to specific habitats where sufficient resources are available (Jemal et al., 2020). The outcome of this result agrees with Nyssen (2023), who suggested that by mid-September, near the end of the rainy season, Tigray's landscapes are green, with large spots of bright yellow herbs locally called Meskel flowers/gilgile meskel that attract and support diverse avian species. In highland reservoirs structurally complex vegetation buffers the influence of seasonality and there is a great stability in resource availability, which allows bird species to occur as residents throughout the year. The avian species richness of different feeding guilds might respond differently to changes in vegetation structure and complexity across highland ecosystems.

The species diversity indices showed that the higher species diversity of birds was found in the Maysye reservoir than in the Maygundi reservoir. This might be due to the availability of various food items, nesting sites, vegetation composition that delivers heterogeneous habitats for different bird species and its nature bordering farmlands that are considered as alternative feeding sites. Structurally, complex habitats might harbor a high number of species compared to habitats with simple structures, because there are more niches providing different types of nesting and foraging resources. This is in agreement with the findings of Alemayehu and Dereje (2021) that there was a high diversity of bird species at the Ansas Dam Debre Birhan Town, Ethiopia. The high bird diversity in reservoir habitats is probably due to its potential in edible aquatic organisms such as small fishes, frogs, tadpoles, insects and other invertebrates, and aquatic plants. Moreover, the high species diversity and abundance of birds in the reservoir indicate their attractiveness for water birds and good water quality. The overall bird species similarity between reservoirs during this study is high and this maximum similarity between these habitats might be recognised by the very close occurrence of the reservoirs. Moreover, the presence of similar climatic conditions between the two areas might lead to the occurrence of high similarities in the bird community. Habitats that are close to one another can share the same number of species because they are geographically close which allows individuals to move from one habitat to another.

Threats to avian fauna diversity in Ethiopia are underpinned by high human population pressure in the highland reservoirs of Tigray. Therefore, habitat heterogeneity is an important environmental determinant of variation in avian species richness in reservoirs. There is a need to sustain the achievements of highland reservoirs attained in promoting co-management and ecosystem sustainability. All productive land in the highlands has been transformed and the original vegetation that remains only does so because it is confined to the ecosystems that are extreme and defy human use and recover avian species diversity in Tigray which is highly similar to the reports of several studies (Santini et al., 2023; Aerts et al., 2006, 2008). Bird species composition and abundance varied in the two highland reservoirs and supports low bird diversity in highland reservoir near to extensive human settlements, agricultural activities and areas with degraded natural habitats. This result concurs with the finding of Asmare et al. (2023), who noted that areas highly affected by anthropogenic impacts such as logging, overgrazing, firewood collection and disturbance contribute to low bird diversity, but in some cases the modified habitats support and provide alternative forage, nesting and roosting sites. The most likely reason for macro ecological drivers might be due to many anthropogenic activities in the highland reservoirs and their surroundings. In reservoirs human encroachment is ever increasing and has adverse effects on the bird population. Anthropogenic activities such as clothes washing, the use of motorised vehicles, livestock, bathing, and waste dumping have contributed to the increase in environmental pollution. Cultivated plants in the villager's grounds and terraces attracted avian species. However, these birds have often died and become endangered due to pesticide poisoning, which discourages them from eating seeds and causes habitat loss.

Management and conservation implications

Although the studied reservoirs support high bird diversity, they are deteriorating due to various anthropogenic factors, including land cover change, agricultural expansion, human settlement, irrigation, sedimentation and other human activities (Kiros et al., 2014; Hadis et al., 2020), and there is an urgent need for conservation intervention in these unprotected habitats. Therefore, responsible organizations and other stakeholders with local communities should work in cooperation to conserve and manage the habitat of wildlife species (Hanson, 2009; BirdLife International, 2017). Facilitate contributing habitat restoration and supporting biodiversity protection with environmentally friendly practices. No conservation effort is given to these study areas to tackle problems of severe deforestation, sedimentation and land degradation from severe human pressure. Since, water is essential for various recreational values we need to work with the local people for the economy of water-based tourism, bird watching, fisheries and aquaculture, drinking and bathing, sanitation, and spiritual and symbolic purposes, among the myriad other uses described in this series.

Conclusion and Recommendation

A total of 151 bird species belonging to 17 orders and 51 families were recorded in this study. This means that upland reservoirs support a large number of bird species. Interestingly, some of the endemic and globally threatened bird species were found in the reservoirs, making them important conservation areas. However, these reservoirs, which support a high number of bird species, are threatened by the livelihood activities of local communities. Therefore, to increase the bird diversity in such a large freshwater area, an intensive conservation effort with harmonised and protected promising wintering sites should be undertaken. Similarly, for the long-term conservation of the avifauna around the highland reservoirs, continuous monitoring of bird species, targeted site improvement and awareness raising among the local community are recommended.

References

Aerts, R., Lerouge, F., November, E., Lens, L., Hermy, M. & Muys, B. 2008. Land rehabilitation and the conservation of birds in a degraded Afromontane landscape in northern Ethiopia. *Biodiversity and Conservation,* 17, 53–69.

Aerts, R., Maes, W., November, E., Negussie, A., Hermy, M. & Muys, B. 2006. Restoring dry Afromontane forest using bird and nurse plant effects: direct sowing of *Olea europaea ssp*. cuspidata seeds. *Forest Ecology and Management,* 230, 23–31.

Alemayehu, S. & Dereje, Y. 2021. Diversity, distribution and relative abundance of avifauna at Ansas Dam and surrounding farmland site Debre Birhan Town, Ethiopia. *Avian Biology Research*, **14** (1), 8–17.

Asmare, B. D., Derebe, Y. & Tamer, M. 2023. Diversity and relative abundance of bird species in the two habitat types of Dokima forest Awi zone, Ethiopia. *PLoS ONE,* 18(3): e0281595. https://doi. org/10.1371/journal.pone.0281595.

Bibby, C., Burgessand, J. & David, H. 1992. *Bird census techniques.* Academic Press, London.

Bibby, C., Jones, M. & Marsden, S. 1998. *Bird Surveys: Expedition Field Techniques*. The Expedition Advisory Center Royal Geographic Society, London.

Bibby, C. J., Burgess, N. D., Hill, D. A. & Mustoe, S. 2000. *Bird census techniques. 2nd edition*. Academic Press, London.

BirdLife International. 2017. *Spotlight on threatened birds*. Presented as part of the BirdLife State of the world's birds website. Available from: http://www.birdlife.org/datazone.

Conservation International. 2011. *Biodiversity Hotspots Revisited*. http://www. Biodiversity hotspots.org/xp/Hotspots/resources/maps.xml.

Ethiopian Biodiversity Institute (EBI). 2015. *Ethiopia's national biodiversity strategy and action plan 2015–2020.*

Gibbons, D. W. & Gregory, R. D. 2006. Birds. *In*: Sutherland, W. J., ed. *Ecological census techniques: a handbook. 2nd edition*. Cambridge University Press, Cambridge.

Girma, Z., Mengesha, G. & Asfaw, T. 2017. Diversity, relative abundance and distribution of avian fauna in and around Wondo Genet forest, South-central Ethiopia. *Research Journal of Forestry*, 11, 1–12.

Hadis, T., Afework, B. & Simeneh A. 2020. Significance of Gefersa Artificial Reservoir and its surrounding habitat for the conservation of avifauna, Northwestern Addis Ababa, Ethiopia. *Species*, **21** (67), 53–61.

Hailu, T. & Bezawork, A. 2022. The role of Gullele Botanical Garden for bird conservation in Addis Ababa, Ethiopia. *Ethiopian Journal of Biological Science,* **21** (1), 1819–8678.

Hammer, O., Harper, D. & Ryan, P. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Paleontologia Electronica*, **4** (1), 1–9.

Hanson, T., Brooks, T. M. Da Fonseca, G. A., Hoffmann, M., Lamoreux, J. F., Machlis, G., Mittermeier, C. G., Mittermeier, R. A. & Pilgrim, J. D. 2009. Warfare in Biodiversity Hotspots. *Conservation Biology*, **23** (3),578–587.

Husen, A., Mishra, V. K., Semwal, K. & Kumar, D. 2012. Biodiversity Status in Ethiopia and Challenges. *In*: Bharati, K. P., Chauhan, A. & Kumar, P., eds. *Environmental Pollution and Biodiversity*. Discovery Publishing House Pvt Ltd. New Delhi, India, 31–79.

Jemal, Z., Girma, Z. & Mengesha, G. 2020. Bird Diversity in Nensebo Moist Afromontane Forest Fragment, South Eastern Ethiopia. *The Open Ornithology Journal*, 13, 1–9.

Kathleen, A., Nolan, K. & Callahan, J. E. 2005. The Shannon-Weiner species diversity index. *Beachcomber Biology*, 27, 334–338.

Kiros, W., Tsegazeabe, H., Solomon, K., Mokonen, T., Kibrom, F. & Meheretu, Y. 2014. Assessment of birds of the Arid water bodies in Tigray, Northern Ethiopia. *International Journal of Biodiversity and Conservation*, **6** (4), 333–341.

Manthey, J. D., Bourgeois, Y., Meheretu, Y. & Boissinot, S. 2022. Varied diversification patterns and distinct demographic trajectories in Ethiopian montane forest bird (Aves: Passeriformes) populations separated by the Great Rift Valley. *Molecular Ecology*, **31** (9), 2664–2678.

Mekbeb, T., Addisu, A. & Yila, D. 2022. Ambition for biodiversity BIODEV 2030. *National Biodiversity Threat Assessment: Ranking Major Threats Impacting Ethiopia's Biodiversity*. Accessed on February 2022.

Mengistu, W. 2003. Wetlands, Birds and important bird areas of Ethiopia. *In*: Abebe, Y. L. & Geheb, K., eds. Wetlands of Ethiopia. Proceedings of Seminar on the Resource and Status of Ethiopia's Wetlands. Gland, Switzerland: *International Union for conservation of Nature and Natural Resources*, 25–36.

Nyssen, J. 2023. Establishment of a modest Tigray botanical garden in Belgium — an illustration of the Afromontane vegetation, **1** (17).

Otero, I., Farrell, K. N., Pueyo, S., Kallis, G., Kehoe, L., Haberl, H., Plutzar, C., Hobson, P., García-Márquez, R., Rodríguez-Labajos, B., Martin, J. L., Erb, K. L., Schindler, S., Nielsen, J., Skorin, T., Settele, J., Essl, F., Gómez-Baggethun, E., Brotons, L., Rabitsch,W., Schneide, F. & Pe'er, G. 2020. Biodiversity policy beyond economic growth. *Conservation Letters*, 13, e12713. https://doi.org/10.1111/conl.12713.

Redman, R., Stevenson, T. & Fanshawe, J. 2009. *Birds of the Horn of Africa: Helm Field Guides*. London. Christopher Helm Press, 1–512.

Rowe Karen, M. C., Selwood Katherine, E., Bryant, D. & Baker-Gabb, D. 2023. Acoustic surveys improve landscape-scale detection of a critically endangered Australian bird, the plains-wanderer. *Wildlife Research.* https://doi.org/10.1071/WR22187.

Santini, L., Tobias, J. A., Callaghan, C., Gallego-Zamorano, J. & Benítez-López, A. 2023. Global patterns and predictors of avian population density. *Global Ecology and Biogeography*, 00, 1–16.

Shannon, C. E. & Weaver, N. 1949. *The Mathematical Theory of Communication*. The University of Illinois, Urbana, 117.

Shimelis, A. & Afework, B. 2008. Species composition, relative abundance, and distribution of bird fauna of riverine and wetland habitats of Infranz and Yiganda at the Southern tip of Lake Tana, Ethiopia. *Tropical Eco*logy, **49** (2), 199-209.

Shimelis, A. & Afework, B. 2009. Species composition, relative abundance and habitat association of the bird fauna of the montane forest of Zegie peninsula and nearby Islands, Lake Tana, Ethiopia. *Ethiopian Journal of Science*, 32, 45–56.

Sohil, A. & Sharma, N. 2020. Assessing the bird guild patterns in heterogeneous land use types around Jammu, Jammu, and Kashmir, India. *Ecological Processes,* **9** (1), 1–5.

Tsegazeabe, H. 2023. Limnological factors that affect waterbird assemblages in semi-arid reservoirs of Tigray National Regional State, northern Ethiopia. *Heliyon*, **9** (6), e17110. https://doi.org/10.1016/j.heliyon.2023.e17110.

Teklay, G., Zeyede, T. & Tesfay, T. 2020. Bird Diversity and Community Composition in Kafta Sheraro National Park, Tigray, Northern Ethiopia. *International Journal of Zoology,* https://doi.org/10.1155/2020/5016804.

Tsehaye, A., Tadesse, D., Declerck, S., Nyssen, J., Van der Gucht, K., Risch, S., Rousseaux, S., De Wit, J., Afework, M., Nigussie, H., Abreha, G., Poesen, J., Deckers, J., Vyverman, W. & De Meester, L. 2007. Ecological Atlas of Reservoirs in Tigray, Northern Ethiopia. Tigray Livelihood Papers No. 4 vol. 80, *VLIR-Mekelle University IUC Programme and Zala-Daget Project, Mekelle*, Ethiopia.

Weldemariam, T. & Getachew, M. 2017. Impact of Climatic Change on Avian Populations: Implication for Long Term Conservation in Wildlife Genetic Resources. *American Journal of Bioscience and Bioengineering*. **5** (1), 23–33.

Weldemariam, T. 2016. Bird Species Composition and Diversity in Wetlands of Awi zone and Wombera hotspot areas Northwestern, Ethiopia. *Journal of Zoology Studies*, **3** (5), 00–00.

Weldemariam, T., Demeke, D., Mengistu, W., Gebre Egziabeher, H. & Tadesse, H. 2020. Impact of wind energy development on birds and bats: the case of Adama wind farm, Ethiopia, *The Journal of Basic and Applied Zoology*, 81, 41. https://doi.org/10.1186/s41936-020-00171-1.

Yalden, D. 1983. The extent of high ground in Ethiopia compared to the rest of Africa. *SINET: Ethiopian Journal of Science*, 6, 35–38.

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