BMC Zoology

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Assessment of bird diversity and abundance in Mai-Nigus artificial reservoir and surrounding semi-forest in Tigray Region, Northern Ethiopia

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Abstract

Background Artificial reservoirs are alternative habitats for bird diversity, and knowledge of the diversity and abundance of bird species contribute to the management of the ecosystem. This study was conducted to investigate the species diversity and abundance of birds in Mai-Nigus reservoir and its surrounding semi-forest from July 2022 to March 2023. Point count method with a total of fifteen count stations at an interval of 50 m radius was used to study the diversity and abundance of bird species in the semi-forest habitat while total count employed on the reservoir.

Results A total of 123 bird species comprising endemic and globally threatened species were identified. Order Passeriformes had the highest number of species followed by Charadriiformes and Pelecaniformes. Family Scolopacidae was the most abundant followed by Ardeidae, Ploceidae and Anatidae. Bird species richness and abundance were not significantly varied across seasons and habitats ($P > 0.05$). The highest species diversity (H´=3.96) were recorded in the Semi-forest during the wet season, whereas the least was recorded from reservoir during the dry season (H´=2.66). The highest and lowest species evenness of birds was recorded in Semi-forest (E = 0.725) and reservoir (E = 0.448) during the dry season, respectively. Most birds that inhabited the area had frequent relative abundance followed by uncommon and common species.

Conclusion Mai-Nigus reservoir and surrounding habitat host high bird diversity and this requires critical conservation concerns for the long-term survival of birds.

Keywords Anthropogenic threat, Artificial reservoir, Diversity, Indicator bird, Waterbirds

Background

Ethiopia is one of the African countries comprising the highest diversity of living organisms with high level of endemism [1–3]. The diverse habitat types, altitudinal ranges, climatic conditions and soil types contribute the country hosting enormously diverse bird species [3, 4]. About 881 species of birds have been enumerated from Ethiopia, of which 18 species are endemic to the country and 10 species are shared with Eritrea [4–6]. The government of Ethiopia has identified 73 important bird areas to conserve various terrestrial and aquatic birds as well as other organisms [7, 8].

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Birds are critical components of the ecosystem due to their roles in various ecological functions, including pollination, seed dispersal, pest control, energy flow and nutrient cycling [9–11]. Avian diversity is often used as an indicator of overall biodiversity and ecosystem health [10]. Besides, they are used as source of food, sources of spiritual and artistic inspirations and source of tourist attractions due to their distinctive body structure, colour, calls, songs and other activities such as courtship display [12–14]. Birds are among the best studies elements of the earth's biodiversity; however quantified information of birds in Ethiopia is still in its infancy due to lack of trained professionals and this leads to an obstacle in conservation [15–17]. Patterns of distribution and abundance of birds are strongly related to environmental factors, which determine their occurrence and activity [15]. Bird species diversity, abundance and distribution are highly influenced by seasonality as season affects the availability of food and cover of birds, which in turn affects their breeding success and survival [18, 19]. Globally, biodiversity has been changed due to habitat destruction and modification and these factors are identified as major causes of large-scale declines in several species of wildlife including bird fauna [15, 20, 21].

Despite the rich bird assemblages in Ethiopia, survivals of endangered bird species is lying on thin line due to various threats such as habitat fragmentation, degradation and loss [15, 22]. Mostly, agricultural land expansion, livestock encroachment, deforestation, indiscriminate fire and others have been identified as the major cause of birds' habitat degradation, fragmentation and loss in Ethiopia ultimately affecting the survival of birds [20, 23]. Now a day, high numbers of bird species inhabit newly formed unprotected habitat types such as reservoirs and urban areas out of their natural habitats [24–26]. In Ethiopia many reservoirs have been constructed for irrigation, fishing, hydropower, livestock drinking, washing and other human uses [24, 27]. In addition, artificial reservoirs are also considered as alternative promising sites for the breeding, feeding and nesting of several aquatic birds [27, 28]. Most of the previous studies on birds of the country were focused on the forest birds [8, 14]. However, studies conducted on aquatic birds in artificial reservoirs are few in number, which are sporadic and disjointed in nature [28–30]. Hence, this shows that in Ethiopia's bird diversity in artificial reservoirs has been mistreated compared to the protected areas and the reason for this could be the lack of scientific data on the diversity and abundance of waterbirds therein.

Particularly, above 80 reservoirs have been made since 1990s to combat drought in Ethiopia's Tigray region. Studies by Kiros et al. [15] and Tsehaye et al. [27] revealed that artificial reservoirs of the region exhibit a peculiar biodiversity in waterbirds. However, this exploration was not extended to all artificial reservoirs of the region [15]. Bird diversity of the reservoirs located in central and northwestern zones has not yet been explored and this is true for the Mai-Nigus reservoir which is found in the central zone of Tigray. Hence, in newly created habitats like the Mai-Nigus artificial reservoir, studying avian diversity can provide valuable insights into the ecological processes of colonization, adaptation, and community structure development. It also helps to test the diversity and complexity of habitats around the Mai-Nigus artificial reservoir significantly contribute to higher avian species richness and abundance compared to surrounding terrestrial areas. Therefore, the study was aimed to assess information on the bird diversity and abundance of the Mai-Nigus artificial reservoir and its adjoining habitat for better understanding of the habitat suitability for birds and subsequently for future protection and management of such vital area.

Materials and methods

Description of the study area

This particular study was conducted in Mai-Nigus reservoir and its adjoining habitat found in the central zone at Laelay-maychew district particularly in Dura village of Tigray region, northern Ethiopia. The reservoir is located at 14° 11' 76" N latitude and 39° 16' 01" E longitude (Fig. 1). It is found nearby (~6 km west) to the ancient historical town of Axum, and at 251 km and 1006 km far away from Mekelle city, the capital city of Tigray region and Addis Ababa, the capital city of Ethiopia, respectively. The average altitude of the reservoir is 2,056 m above sea level (m.a.s.l) with an average temperature of 20.6 °C [31]. Its mean annual rainfall is 663 mm, and the pattern of its rainfall distribution is uni-modal, which mostly occurs from June to September. Mai-Nigus reservoir is an engineered aquatic habitat designed primarily for water storage and irrigation purposes with a total area of 40 hectares [27]. Constructed to address water scarcity issues and enhance agricultural productivity, the reservoir has inadvertently created a new ecosystem that supports a diverse range of flora and fauna such as phytoplankton, zooplankton, fish and fish-eating avian species [27]. The surrounding habitats, comprising a mix of semi-forest including church forest, human settlement, and agricultural fields, further contribute to the ecological complexity of the area. The reservoir is highly interfered with human activities like irrigation and livestock drinking mainly during the dry season.

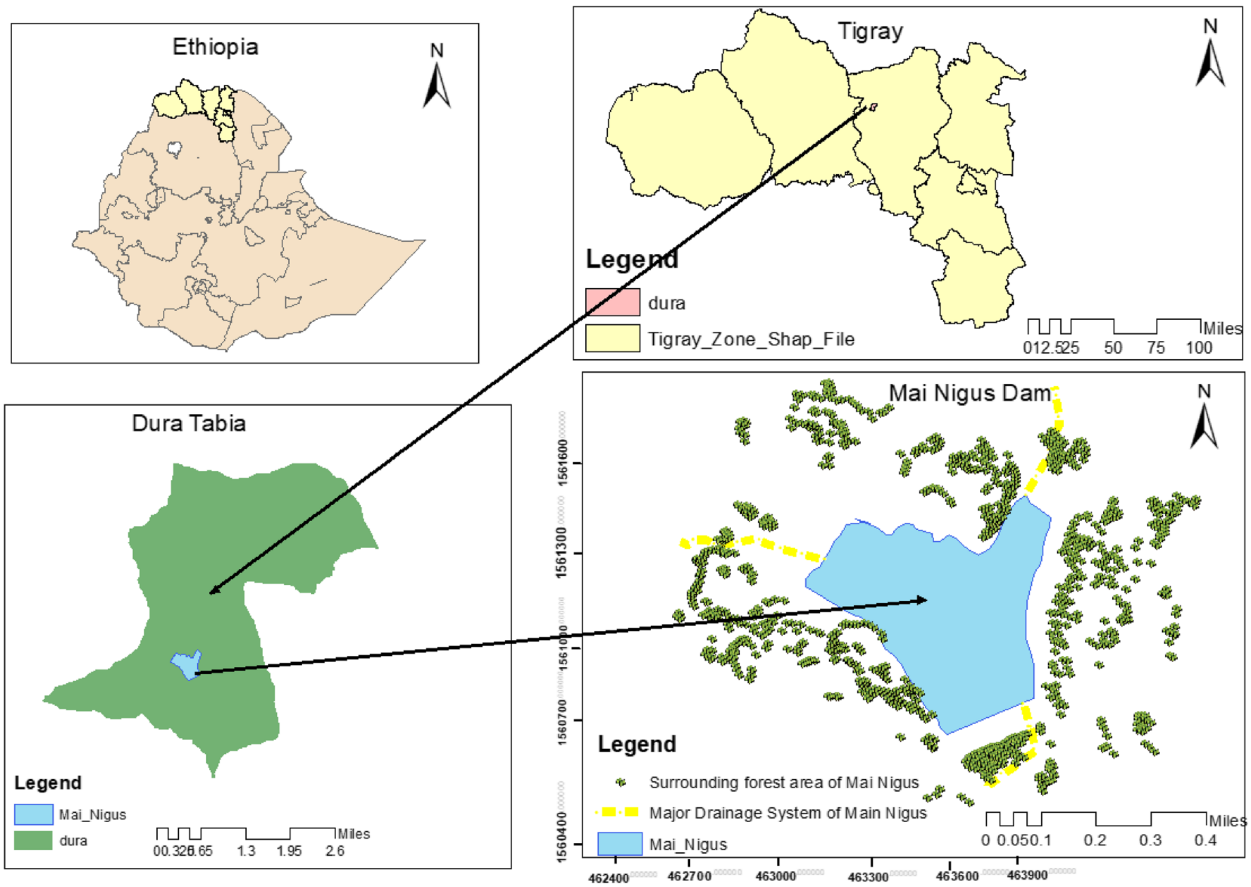

Fig. 1 Map of the study area

Bird survey

A preliminary survey was carried out in the first week of July 2022 in the study area, to gather baseline information like topographic features, habitat types and bird status. This led to the selection of two habitat types – the reservoir and the adjoining semi-forest for the study (Fig. 2). Based on the habitat type and suitability, total count and point transect techniques were employed to study birds [15, 32, 33]. In the semi-forest habitat type point count method, which is a systematic exploration in a fixed area and time interval was used [34]. During the point count method, fifteen point count stations or observation points were established systematically and birds were identified and counted from a fixed position within a 50 m radius for a specific period of 15 min at every point [35]. All birds seen or heard within this 50 m radius were recorded [34]. To minimize the double counting problem, point stations were intentionally set at a distance of 50 m intervals [20]. Due to the inaccessibility of implementing the point count technique, a total count technique was

Fig. 2 Habitat types selected for the present study: reservoir (left) and semi-forest (right) photo by Alembrhan A

employed to study birds in the reservoir [15]. Total count was used wherever possible by walking around the proximate areas or from specific vantage points to count birds. Birds on the open water were counted by moving to all directions of the reservoir. However, birds crossing the middle of the reservoir were identified and counted on their destination sides. In both habitats, a waiting period of five minutes was made to reduce disturbance and then identification and counting was carried out for 15 min [28].

Field data collection was conducted from July to October 2022 (wet season) and from January to March 2023 (dry season). Birds were identified and counted three days per month twice a day in the early morning (6:00–10:00 AM) and in the late afternoon (4:00–6:00 PM) when the bird activity was peak [20] using binocular (10×50). Appropriate coloured field guides were used to identify birds to their species level [36, 37]. Moreover, photographs were also taken to identify the birds that were not easily identified in the field by checking with the field guides. GPS reading were employed to locate the bird counting points and record the locations of the study area.

Data analysis

Data were analyzed using the PAST software, version 3.26 and Microsoft Excel program. PAST software [38] was used to calculate Shannon-Wiener diversity index (*H'*). Evenness index (E) was used to calculate the species evenness of birds [39]. Simpson's similarity index (SI) was used to evaluate the similarity between habitat types in terms of their species composition and its was calculated using this formula; $SI = \frac{2C}{A+B}$ where, A is the number of bird species that found in site A, B is the number of species in site B, and C is the number of common species in sites A and B [40]. Relative abundance (RA) of bird species was determined as the ratio between the number of individuals counted for a species and the total number of individuals of all species counted in percentage. $R\,(\%) = \frac{n}{N}$ x 100, where n is the number of individuals counted for a species and N is the total number of individuals of all species counted during the study period [25]. The relative abundance rank of bird species was computed using the number of individual birds of a species counted in a given area per day. For instance a species numbering 201 to 1000 individuals per day is categorized under abundant, 51 to 200 is very common, 21 to 50 is common, 7 to 20 is Frequent, 1 to 6 is uncommon and a species with 1 to 6 individuals per season is rare [41, 42]. Kolmogorov-Smirnov test was used to test the data normality and then Two-way ANOVA was used to test the significant variation of bird species richness and abundance between habitat types and seasons.

Results

Species composition of birds

A total of 123 bird species belonging to 15 orders, 42 families and 84 genera were recorded during the study period (Appendix 1). From all the identified bird species, Order Passeriformes (35%) had the highest number of species followed by order Charadriiformes (17.1%) and order Pelecaniformes (11.4%), respectively. The majority of bird species are of the family Scolopacidae (12 species) followed by Ardeidae (9 species) and Ploceidae and Anatidae (8 species for each). Of the bird species recorded 3 species were endemic to Ethiopia; Wattled Ibis (*Bostrychia carunculata*), Abyssinian Catbird (*Parophasma galinieri*) and Abyssinian Woodpecker (*Dendropicos abyssinicus*) and three species were near-endemic (endemic to Ethiopia and Eritrea) include Rouget's Rail (*Rougetius rougetii*), White-winged Cliffchat (*Thamnolaeasemirufa*) and Black-winged Lovebird (*Agapornis taranta*) (Appendix 1). In addition, one vulnerable species, the Abyssinian Ground-Hornbill (*Bucorvus abyssinicus*) and three near-threatened species such as Rouget's Rail (*Rougetius rougetii*), Eurasian Curlew (*Numenius arquata*) and Great Snipe (*Gallinago media*) were also recorded. Out of the total 123 bird species recorded, 87 species were recorded during the wet season and 58 species were recorded during the dry season. Among these 22 species were observed during both seasons, 65 species only during the wet season and 36 species were recorded only during dry the season.

Distribution and abundance of birds

In this study, species distribution was varied between habitat types during the wet and dry seasons (Table 2). From the total bird species recorded, 70 species were recorded in the reservoir and 113 species in the semi-forest. Of these, 10 species were recorded in the reservoir and 53 species were recorded in the semi-forest. Sixty bird species were recorded in both habitat types. Moreover, 51 and 32 species were recorded in the reservoir, and 72 and 51 species were recorded in the semi-forest during the wet and dry season, respectively. During the study period, a total of 3,572 individual birds were counted, of which 1,921 individuals were recorded during the wet season and 1,651 individuals were recorded during the dry season. The higher number of bird abundance was recorded in the reservoir habitat of 1,852 individuals, while the lower was recorded in the semi-forest habitat of 1,720 individuals. Based on the ANOVA analysis, there was no significant difference in number of bird species and abundance across seasons and habitat types ($P > 0.05$). Abundance score and ordinal scale of birds estimated by encounter rate showed that most bird

Table 1 Relative abundance rank of birds in Mai-Nigus reservoir during the wet and dry seasons

Habitat type	Season	Rank					
		Rare	Uncommon	Frequent	Common	Very Common	Abundant
Reservoir	Wet	7	15	22	6	1	–
	Dry	3	6	14	8	–	1
Semi-forest	Wet	6	34	32	7	–	–
	Dry	7	14	27	3	–	–

species, 22 species were found within the ordinal rank of "frequent" during the wet season on the reservoir and 34 species within "uncommon" during the wet season on the semi-forest habitat. Least number of birds was recorded as "very common" and "abundant" ($n=1$ species for each) during the wet and dry seasons from reservoir habitat (Table 1). From the total 123 species recorded, Egyptian goose (*Alopochen aegyptiaca*) accounted the highest relative abundance (12.7%) followed by Spur-winged lapwing (*Vanellus spinosus)* (4.54%) and Ruff (*Calidris pugnax*) (4.34%), whereas Greater spotted eagle (*Clanga clanga*) and Double-toothed barbet (*Lybius bidentatus*) were with the least relative abundance (Appendix 1).

Bird species diversity and evenness

Bird species diversity was higher during the wet season in both habitats compared to the dry season. The highest diversity of bird species was recorded in the semi-forest habitat (H' = 3.96) during the wet season while the lowest diversity of species was found in the reservoir (H' = 2.66) during the dry season (Table 2). Across both seasons, higher values of Shannon's diversity index was recorded in the semi-forest (H' = 4.28) than in the reservoir (H' = 3.40). The highest species evenness was found in the semi-forest habitat during the dry season (E = 0.725) and wet season (E = 0.665). Between both seasons, the higher species evenness was recorded from the semi-forest (E = 0.637) than reservoir (E = 0.427) (Table 2).

Bird species similarity index

Among 87 species which were recorded during the wet season, 79 and 51 species were recorded in the semi-forest and reservoir habitats, respectively. Forty three species were common to both habitats. A total 58 species were also recorded during the dry season. Among them 51 species were found in the semi-forest, 32 species on the reservoir and 25 species were common to both habitats. The similarity index of bird species between two habitats showed variations between wet and dry seasons. Accordingly, more species similarly was observed during the wet season in the reservoir and semi-forest (SI = 0.662) while the least similarity was observed between the two habitats during the dry season (SI = 0.602) (Table 3). The overall bird community similarity of the reservoir and semi-forest habitats was SI = 0.656, which is > 50%, and this indicated that there is high similarity of bird species between these two habitats.

Table 2 Bird species diversity between two habitats during wet and dry seasons

Habitat type	Season	No. of species	Abundance	H´	E
Reservoir	Wet	51	887	3.46	0.625
	Dry	32	965	2.66	0.448
	Both	70	1,852	3.40	0.427
Semi-forest	Wet	79	1,034	3.96	0.665
	Dry	51	686	3.61	0.725
	Both	113	1,720	4.28	0.637

Where *H´* Shannon-Wiener diversity Index, *E* Evenness

Table 3 Bird species similarity between two habitat types during wet and dry seasons

Habitat type	Simpson's similarity index (SI)		
	Season	Reservoir	Semi-forest
Reservoir	Wet	-	0.662
	Dry	-	0.602
	Both	-	0.656
Semi-forest	Wet	0.662	-
	Dry	0.602	-
	Both	0.656	

Discussion

High avian species (123) consisting endemic and globally threatened species were recorded in the study area. This proved that the Mai-Nigus reservoir and its adjoining habitat are very crucial for bird conservation. An area with sufficient food sources and diverse vegetation structure or the presence of diverse habitats supports variety of bird species [43, 44]. The observed richness of birds in the area might be due to the availability of numerous aquatic organisms such as fishes, snails, amphibians,

aquatic insects and vegetation structures in and around the reservoir that provide wide range of foraging, roosting and nesting sites for the birds. However, the number of bird species of the area might be above the recorded ones this might due to different limitations of the present study such as survey duration, anthropogenic factors and ecological data gaps.

Out of the total bird species recorded six species; Wattled Ibis (*Bostrychia carunculata*), Rouget's Rail (*Rougetius rougetii*), Abyssinian Catbird (*Parophasma galinieri*), Black-winged Lovebird (*Agapornis taranta*), Abyssinian Woodpecker (*Dendropicos abyssinicus*) and White-winged Cliff-chat (*Thamnolaea semirufa*) are endemic to Ethiopia and shared with the neighbor country Eritrea. This is accordance with findings of several authors who reported many endemic and near-endemic species in different areas of Ethiopia [45–47]. The presence of high number of near-endemic bird species in the area might be due to its proximity to Eritrea (~ 60 km) and similarity in ecological and climatic conditions.

In the present study higher bird species richness and abundance were recorded during the wet season than during the dry season. This variation could be the availability of various food sources, habitat conditions and birds breeding season. For example in relation to heavy rainfall aids in production of insects and fishes that are used as food sources for birds which mainly happen during the wet season [48]. The finding of this study is in accordance with the idea that bird species richness and abundance are influenced by local resources and vegetation composition [45]. Besides, during the wet season the productivity and yield of habitats increase as many of the invertebrates and fishes breed and the herbs become more productive on which the birds depend; as a result, the richness and abundance of birds increase [47]. However, this is in contrast to the findings of various authors who reported that the species richness and abundance of bird species was higher during the dry season due to availability high food items such as fruits and flowering plants in the area [29, 30, 46].

The semi-forest habitat had high bird species richness. This might be due to the presence of wide array of vegetation types that provide different habitat types for many bird species as well as its wide area might contribute to inhabit by diverse bird species. In contrast, the reservoir had high bird abundance. This could be related with high productivity of the reservoir habitat and associated characteristics. The availability of food materials, high productivity level, adequate shelter and breeding habitats are important factors that determine the bird species richness and abundance of an area [49].

Abundance score and ordinal scale of birds revealed that most bird species of the study area found within the ordinal rank of "frequent". The possible reasons for this could be the availability of food sources, visibility of birds in the reservoir, quality of the reservoir and the surrounding habitat to harbor high number of individuals of a species. This finding agrees to Ayalew et al. [33] and Yenew and Dessalegn [46] who reported more frequent bird species. However, this finding is contrary to other authors who reported more rare species [28], common species [30] and uncommon species [47, 50]. Based on their reasons, the occurrence of more rare and uncommon species of birds may be related with their behavior and habitat condition. Breeding habitat, wide home range, niche of a species and habitat degradation are the main factors which lead to the presence of uncommon birds in a given area [51]. From the total bird species recorded, Egyptian Goose (*Alopochen aegyptiaca*) was the most abundant species. This might be related with its ability to inhabit and feed in both terrestrial and aquatic habitats. This finding concurs with many authors who reported high abundance of the species from localities of the country [15, 24, 28]. The occurrence of relatively high number of Pink-backed Pelican (*Pelecanus rufescens*) and Great White Pelican (*Pelecanus onocrotalus*) in this study indicates the presence of fishes in the reservoir and it can also be due to their piscivore diet.

The diversity index result indicated that the highest diversity and evenness of bird species were recorded in the semi-forest habitat during both wet and dry seasons. The species diversity increased during the wet season in both habitats that the dry season. This could be due to the presence of large number of individuals of Egyptian goose during the dry season which affects the Shannon-Weiner diversity index calculation. In addition, complex habitat types may support high number of species compared to habitat types with simple structure, since there are more niches delivering various types of nesting and feeding resources. This finding contradicts to Alemayehu and Dereje [28] who reported that bird species diversity and species evenness were higher in dam than its surrounding habitat. Moreover, Amare and Girma [21] also reported the highest birds' species diversity and species evenness in Lake Hawasa unlike to adjoining habitats. Bird species similarity analysis between the reservoir and semi-forest habitat types showed that more species similarity was observed during the wet season while the least similarity was observed between the two habitats during the dry season. This is in accordance with authors who recorded that higher similarity of bird species observed between two habitats during the wet season than during

the dry season [33, 47]. In this study, the overall bird species similarity between reservoir and semi-forest was high. This high similarity of bird species between the two habitats could be attributed to the existence of the semi-forest habitat close to the reservoir. Closed habitats can share similar species since they are geographically close which allows individuals to move from one habitat to another easily.

Although the reservoir and its surrounding harbor high bird species, it is highly threatened by various anthropogenic factors include irrigation, overgrazing, agricultural encroachment, unregulated use of agrochemicals, human settlement and land degradation. The regional government constructed the reservoir mainly for irrigation purpose; as a result, farmers extensively use water for irrigation and livestock drinking during the dry season. This leads in the reservoir, specifically to late March, water level falls and most of the birds move from the reservoir to elsewhere and this may be the possible reason for less species richness during the dry season.

Conclusion

The research result confirmed that there are 123 species of birds in the area among which 6 are endemic and near endemic to Ethiopia and 4 are globally threatened species. The presence of high number of species suggests that Mai-Nigus artificial reservoir and its adjoining semi-forest habitat are important conservation areas of birds. The highest species richness was recorded in semi-forest habitat while the highest abundance in reservoir. This indicates that both habitats provide the necessary requirements such as food, water, nesting and breeding sites to birds. Despite the fact that the reservoir and its surrounding habitat are home to numerous bird populations, high human pressure from the surrounding area with intensive irrigation, agricultural expansion, livestock grazing and settlement are putting pressure and becoming major threats of the birds and their habitat. Therefore, implementing long-term monitoring plans by engaging local communities to mitigate the human impacts, and restoring such habitats for the protection of bird species are crucial steps for the effective conservation of avian diversity in this important ecological area.

Appendix

Table 4 Bird species and their abundance in Mai-Nigus reservoir during wet and dry seasons

Order	Family	Common name	Scientific name	Season			RA
				Wet	Dry	Total	
Anseriformes	Anatidae	Egyptian Goose	*Alopochen aegyptiaca*	87	365	452	12.7
		African Pygmy-Goose	*Nettapus auratus*	0	43	43	1.2
		Tufted Duck	*Aythya fuligula*	56	0	56	1.6
		White-backed Duck	*Thalassornis leuconotus*	0	39	39	1.1
		Knob-billed Duck	*Sarkidiornis melanotos*	0	32	32	0.9
		Hottentot Teal	*Spatula hottentota*	0	12	12	0.33
		Southern Pochard	*Netta erythrophthalma*	0	53	53	1.5
		Green-winged Teal	*Anas crecca*	0	11	11	0.31
Charadriiformes	Charadriidae	Three-banded Plover	*Charadrius tricollaris*	16	0	16	0.45
		Kittlitz's Plover	*Charadrius pecuarius*	13	0	13	0.4
		Ringed Plover	*Charadrius hiaticula*	21	0	21	0.59
		Little Ringed Plover	*Charadrius dubius*	10	0	10	0.28
		Spur-winged Lapwing	*Vanellus spinosus*	46	116	162	4.54
	Burhinidae	Spotted Thick-knee	*Burhinus capensis*	35	0	35	0.98
	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	21	0	21	0.59
		Marsh Sandpiper	*Tringa stagnatilis*	9	0	9	0.25
		Green Sandpiper	*Tringa ochropus*	0	20	20	0.56
		Common Snipe	*Gallinago gallinago*	62	0	62	1.74
		African Snipe	*Gallinago nigripennis*	72	0	72	2.01
		Jack Snipe	*Lymnocryptes minimus*	60	0	60	1.68

Order	Family	Common name	Scientific name	Season			RA
				Wet	Dry	Total	
		Great Snipe[d]	*Gallinago media*	29	0	29	0.08
		Eurasian Curlew[d]	*Numenius arquata*	41	0	41	1.15
		Whimbrel	*Numenius phaeopus*	9	1	10	0.28
		Stone Curlew	*Burhinus oedicnemus*	15	21	36	1.01
		Ruff	*Calidris pugnax*	56	99	155	4.34
		Temminck's Stint	*Calidris temmincki*	0	36	36	1.01
	Rostratulidae	Greater Painted-Snipe	*Rostratula benghalensis*	0	14	14	0.39
	Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	6	0	6	0.17
		Pied Avocet	*Recurvirostra avosetta*	10	0	10	0.28
Pelecaniformes	Ardeidae	Cattle Egret	*Bubulcus ibis*	74	51	125	3.5
		Little Egret	*Egretta garzetta*	37	23	60	1.68
		Greater White Egret	*Egretta alba*	8	6	14	0.39
		Gray Heron	*Ardea cinerea*	17	26	43	1.2
		Goliath Heron	*Ardea goliath*	68	43	111	3.11
		Purple Heron	*Ardea purpurea*	3	0	3	0.08
		White-backed Night-Heron	*Gorsachius leuconotus*	0	56	56	1.57
		Squacco Heron	*Ardeola ralloides*	0	8	8	0.22
		Dwarf Bittern	*Ixobrychus sturmii*	0	22	22	0.62
	Scopidae	Hamerkop	*Scopus umbretta*	2	4	6	0.17
	Threskiorithidae	African Sacred Ibis	*Threskiornis aethiopicus*	59	0	59	1.65
		Wattled Ibis[a]	*Bostrychia carunculata*	40	0	40	1.11
	Pelecanidae	Pink-backed Pelican	*Pelecanus rufescens*	54	37	91	2.55
		Great White Pelican	*Pelecanus onocrotalus*	35	48	83	2.32
Suliformes	Anhingidae	African Darter	*Anhinga rufa*	4	23	27	0.76
Passeriformes	Sturnidae	Greater Blue-eared Glossy-Starling	*Lamprotornis chalybeus*	37	18	55	1.54
	Pycnonotidae	Common Bulbul	*Pycnonotus barbatus*	16	9	25	0.7
	Turdidae	Groundscraper Thrush	*Psophocicchla Litsitsirupa*	14	0	14	0.39
		Song Thrush	*Turdus philomelos*	8	0	8	0.22
	Fringillidae	White-rumped Seedeater	*Serinus leucopygius*	9	0	9	0.25
	Estrildidae	Common Waxbill	*Estrilda astrild*	11	0	11	0.31
		Red-cheeked Cordon-Bleu	*Uraeginthus bengalus*	34	0	34	0.95
		Blue-cheeked Cordon-Bleu	*Uraeginthus angolensis*	23	0	23	0.64
	Muscicapidae	Mocking Cliff-chat	*Thamnolaea cinnamomeiventris*	18	0	18	0.5
		White-winged Cliff-chat[b]	*Thamnolaea semirufa*	0	15	15	0.42
		Spotted flycatcher	*Muscicapa striata*	16	0	16	0.46
		Abyssinian Slaty Flycatcher	*Melaenornis chocolatinus*	0	21	21	0.59
		African Dusky Flycatcher	*Muscicapa adusta*	0	9	90	0.25
		Spotted Morning-Thrush	*Cichladusa guttata*	25	0	25	0.7
		African Stonechat	*Saxicola torquatus*	0	3	3	0.08
	Malaconotidae	Black-crowned Tchagra	*Tchagra senegala*	6	0	6	0.17
	Laniidae	Greater Gray Shrike	*Lanius excubitor*	7	0	7	0.2
		Common Fiscal	*Lanius collaris*	32	27	59	1.65
		Gray-backed Fiscal	*Lanius excubitoroides*	14	0	14	0.39
	Buphagidae	Yellow-billed Oxpecker	*Buphagus africanus*	8	0	8	0.22
	Alaudidae	Singing Bushlark	*Mirafra cantillans*	17	0	17	0.48
		Crested Lark	*Galerida cristata*	10	0	10	0.28
		Flappet Lark	*Mirafra rufocinnamomea*	12	0	12	0.34
		Thekla Lark	*Galerida theklae*	6	0	6	0.17

Order	Family	Common name	Scientific name	Season			RA
				Wet	Dry	Total	
	Motacillidae	Plain-backed Pipit	*Anthus leucophrys*	7	0	7	0.2
		Mountain Wagtail	*Motacilla clara*	0	16	16	0.45
	Sylviidae	Abyssinian Catbird[a]	*Parophasma galinieri*	5	0	5	0.14
	Nectariniidae	Malachite Sunbird	*Nectarinia famosa*	7	0	7	0.2
		Beautiful Sunbird	*Nectarinia pulchella*	13	0	13	0.36
		Variable Sunbird	*Cinnyris venustus*	7	0	7	0.2
		Scarlet-chested Sunbird	*Chalcomitra senegalensis*	0	7	7	0.2
	Ploceidae	Black-headed Weaver	*Ploceus cucullatus*	19	22	41	1.15
		Spectacled Weaver	*Ploceus ocularis*	0	27	27	0.76
		Parasitic Weaver	*Anomalospiza imberbis*	0	19	19	0.53
		Baglafecht Weaver	*Ploceus baglafecht*	0	16	16	0.45
		Yellow-mantled Widowbird	*Euplectes macrocercu*	105	0	105	2.94
		Red-collared Widowbird	*Euplectes ardens*	41	0	41	1.15
		Black Bishop	*Euplectes gierowii*	37	0	37	1.04
		Black-winged Red Bishop	*Euplectes hordeaceus*	20	0	20	0.56
	Corvidae	Pied Crow	*Carvus albus*	10	0	10	0.28
	Cisticolidae	Green-backed Camaroptera	*Camaroptera brachyura*	9	0	9	0.25
		Red-faced Cisticola	*Cisticola erythrops*	0	12	12	0.34
		Singing Cisticola	*Cisticola cantans*	0	9	9	0.25
Gruiformes	Rallidae	Eurasian Coot	*Fulica atra*	61	0	61	1.71
		Red-knobbed Coot	*Fulica cristata*	0	15	15	0.42
		Rouget's Rail[a,d]	*Rougetius rougetii*	5	0	5	0.14
Acipitroformes	Accipitiridae	Black Goshawk	*Accipiter melanoleucus*	11	0	11	0.31
		Lizard Buzzard	*Kaupifalco monogramicus*	4	0	4	0.11
		Common Buzzard	*Buteo buteo*	0	9	9	0.25
		Black Kite	*Milvus migrans*	0	22	22	0.62
		Yellow-billed Kite	*Milvus aegyptius*	0	6	6	0.17
		Montagu's Harrier	*Circus pygargus*	0	10	10	0.28
		Greater Spotted Eagle	*Clanga clanga*	0	2	2	0.06
Bucerotiformes	Bucerotidae	Hemprich's Hornbill	*Tockus hemprichii*	6	0	6	0.17
		African Gray Hornbill	*Lophoceros nasutus*	0	12	12	0.34
	Phoeniculidae	Black-billed Wood-hoopoe	*Phoeniculus somaliensis*	0	25	25	0.7
	Bucorvidae	Abyssinian Ground- Hornbill[c]	*Bucorvus abyssinicus*	4	0	4	0.11
Coraciiformes	Alcedinidae	Pied Kingfisher	*Ceryle rudis*	16	13	29	0.81
	Meropidae	White-throated Bee-eater	*Merops albicollis*	7	0	7	0.2
		Blue-breasted Bee-eater	*Merops variegatus*	7	0	7	0.2
	Coraciidae	European Roller	*Coracias garrulus*	3	0	3	0.08
		Rufous-crowned Roller	*Coracia naevius*	8	0	8	0.22
Ciconiiformes	Ciconiidae	Yellow-billed Stork	*Mycteria ibis*	4	0	4	0.11
		Abdim's Stork	*Ciconia abdimii*	5	0	5	0.14
		Black Stork	*Ciconia nigra*	0	7	7	0.2
		White Stork	*Ciconia ciconia*	6	0	6	0.17
Coliiformes	Coliidae	Speckled Mousebird	*Colius stariatus*	12	7	19	0.53
Columbiformes	Columbidae	Mourning Collared-Dove	*Streptopelia decipiens*	16	0	16	0.45
		Ring-necked Dove	*Streptopelia capicola*	23	26	49	1.37
		Dusky Turtle-Dove	*Streptopelia lugens*	9	0	9	0.25
		Tambourine Dove	*Turtur tympanistria*	0	6	6	0.17
		Speckled Pigeon	*Columba guinea*	12	15	27	0.76
		Bruce's Green-Pigeon	*Treron waalia*	6	0	6	0.17

Order	Family	Common name	Scientific name	Season			RA
				Wet	Dry	Total	
		Namaqua Dove	*Oena capensis*	0	13	13	0.36
Piciformes	Picidae	Abyssinian Woodpecker[a]	*Dendropicos abyssinicus*	5	0	5	0.14
	Lybiidae	Double-toothed Barbet	*Lybius bidentatus*	0	2	2	0.06
Galliformes	Phasianidae	Scaly Francolin	*Pternistis squamatus*	3	0	3	0.08
		Erckel's Francolin	*Pternistis erckelii*	0	22	22	0.62
Psittaciformes	Psittaculidae	Black-winged Lovebird[b]	*Agapornis taranta*	10	0	10	0.28

Where, [a]Endemic species, [b]Near-endemic, [c]Vulnerable, [d]Near-threatened, *RA* relative abundance

Abbreviations

ANOVA Analysis of variance
GPS Global Positioning System
P Probability
PAST Paleontological Statistics

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40850-024-00215-x.

Supplementary Material 1.

Acknowledgements

We would like to express our thanks to Aksum University and Ethiopian Biodiversity Institute, Mekelle Biodiversity Center for the facilities and financial support. Authors also sincerely thank to the local communities around Mai-Nigus reservoir for their delivery necessary information and hospitality during data collection such as giving orange, guava and roasted maize.

Authors' contributions

A.A proposed the research idea. A.A, K.M and W.T collected the data and identified birds; A.A, K.M and B.F generated and analyzed the results; A.A, A.G and T.M interpreted the results and wrote the paper. All authors contribute, read and approved the final manuscript.

Funding

The study did not receive any specific financial support but performed by the willingness of authors using the perdiem from Aksum University and Mekelle Biodiversity Center.

Availability of data and materials

All the data generated and analyzed during this manuscript preparation are available on the hands of the corresponding author.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The study was approved by Research and Publication Directorate office of Aksum University and permission was obtained from the local government. Consent to participation is not applicable since no respondents were participated in this research work. All methods used in this study were performed in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 23 April 2024 Accepted: 4 September 2024
Published online: 14 September 2024

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