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## BIRDS OF THE DUMP: A STUDY ON DIVERSITY, ABUNDANCE AND THREATS IN LANDFILLS OF TIGRAY REGION, ETHIOPIA

T. B. Weldemariam\* & A. W. Alembrhan

Ethiopian Biodiversity Institute, Mekelle Biodiversity Center, Mekelle, Tigray region, Ethiopia  
Department of Biology, College of Natural and Computational Science, Aksum University,  
Axum, Tigray region, Ethiopia

\* Corresponding author

E-mail: tesfahunegnyw@yahoo.com

T. B. Weldemariam (<https://orcid.org/0000-0002-0277-7476>);

A. W. Alembrhan (<https://orcid.org/0000-0002-3516-7500>)

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**Birds of the dump: A study on diversity, abundance and threats in landfills of Tigray region, Ethiopia. Weldemariam, T. B. & Alembrhan, A. W.** —Birds inhabit all habitats, including dumpsites. Most bird research has mainly focused on protected areas, while landfills have been much less studied. Our study was conducted to collect baseline data on the diversity, abundance and threats of avifauna in waste landfills of the Tigray region, Ethiopia, from November 2019 to March 2020. Seven landfill sites in towns with different geographical settings (Maychew, Adwa, Axum, Shire, Sheraro, Humera and Wolkayt) were selected. The point count technique was used to survey the birds. Moreover, interviews and field observations were also conducted to identify threats to birds. Diversity indices and Two-way ANOVA were used to analyze the data. A total of 2,985 individual birds belonging to 96 species, 32 families and 11 orders were recorded. Family Accipitridae was the most dominant (24 species), followed by Muscicapidae (8 species) and Columbidae (7 species). Hooded Vulture (17.17%) was the most abundant species, followed by Tawny Eagle (8.32%) and Pied Crow (5.46%). The Humera landfill site had the highest bird abundance, while the Maychew landfill had the lowest. A higher abundance of birds was recorded during the morning than in the afternoon. Humera landfill had the highest species diversity index ( $H' = 3.56$ ), followed by Wolkayt ( $H' = 3.51$ ) and Maychew landfills ( $H' = 3.49$ ). Maychew landfill had the highest species evenness ( $E = 0.778$ ), whereas Shire landfill had the lowest species diversity and species evenness ( $H' = 2.89$ ;  $E = 0.439$ ). Activities of waste collectors, free-rang-

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ing domestic animals and waste burning were considered disturbing factors; at the same time, electrocution, hunting and disposal of pollutant wastes were identified as threats to birds. Waste landfills of the region support a diversity of birds. Therefore, bird conservation action is required, such as proper management of landfills. The impact of discarded waste on the long-term survival of birds, especially threatened species, should also be investigated.

**Key words:** dumpsite, bird diversity, threatened bird species, Tigray region of Ethiopia.

## Background

Ethiopia is an important region with a high degree of bird diversity and endemism, due to its diverse altitudinal ranges, climatic conditions, geographical features, and soil variability (Lavrenchenko & Afework, 2017). The country is home to one of Africa's richest avifauna, with over 900 bird species, including 19 endemics and 39 globally threatened species (Weldemariam, 2016; Lepage, 2022). Additionally, the country serves as a vital stopover for millions of migratory birds crossing the Sahara Desert (Şekercioğlu, 2012). The region is crucial for the birds' rest and refueling during their long journeys.

Nowadays, many bird species worldwide are threatened by habitat modification and disturbance (Evans et al., 2018; Wolff et al., 2018). These changes often result from human activities, leading to loss of nesting sites, food resources, and overall habitat quality. In Africa including Ethiopia, bird diversity is declining primarily due to the loss and fragmentation of foraging habitats and nesting sites, driven by urbanization, agricultural expansion, industrialization, and logging (Shimelis & Afework, 2008; Girma et al., 2014).

Despite the establishment of around 73 important bird areas in Ethiopia, habitat loss due to human activities has displaced many birds from their original habitats (Wondimagegnehu & Afework, 2008). Currently, numerous species have adapted to artificial habitats such as farmlands, grazing lands, and urban areas, including abattoirs, landfills, sewage ponds, home gardens, urban parks, sacred sites, and restaurants (Getachew et al., 2016; Yrgalem et al., 2019; Mebrat & Bezawork, 2021). Urbanization encompasses the environmental changes associated with urban development, characterized by increased human habitation, higher per capita energy consumption, and extensive landscape modification. It results in extensive modification of the natural environment and creates a system that does not depend principally on local natural resources to persist. The development and the continual expansion of urban areas have not only destroyed natural habitats, but also have drastically changed the environmental and ecological conditions of these areas. Consequently, species that have settled in these new man-made ecosystems are exposed to considerable alternations in environmental conditions (Partecke et al., 2005). While urban development poses significant threats, urban habitats can also play a crucial role in conserving various species, including birds (Malekian et al., 2021). Urban environments provide birds with considerable quantities of food and roosting sites especially in gardens and parks (Yrgalem et al., 2019; Hussen & Wondimagegnehu, 2022). Some species could be attracted to such areas since it introduces new exploitable resources such as water, ornamental plants and grasses (Posa & Sodhi, 2006). Now days, many birds have adapted to life in urban areas and look for food in gardens, farms and rubbish dumps (Morgan, 2004).

In Ethiopia, open dumping remains the primary method for waste disposal, driven by high costs of proper waste management, lack of infrastructure, and insufficient law enforcement. This has led to the establishment of large-scale landfills in major cities and suburbs. These landfills are important urban landscapes that support a significant number of bird species (Mehra et al., 2017; Arnold et al., 2021; Weldemariam & Alembirhan, 2023), consisting of municipal waste from homes, institutions, and industries. The organic waste within these sites serves as a food resource, attracting a wide range of birds and providing crucial roosting and feeding areas (Arnold et al., 2021). While landfills enhance populations of scavengers like vultures, eagles, buzzards, and kites (Seyoum & Bezawork, 2018; Beselam et al., 2022), they can also negatively impact biodiversity by reducing populations of sensitive species and exposing them to harmful contaminants (Plaza & Lambertucci, 2017).

Bird conservation efforts in Ethiopia have largely focused on protected areas such as national parks and forests (Kassahun et al., 2019; Teklay et al., 2020; Tamenut et al., 2021), while the avifauna in urban landfills is poorly understood, with research limited to a few cities like Addis Ababa, Dire Dawa, Wolkite, and Bahir Dar (Getachew et al., 2016; Mebrat & Bezawork, 2021; Seyoum & Bezawork, 2018; Abeba et al., 2020). Given the lack of comprehensive surveys on bird diversity and threats in urban settings, particularly in the Tigray region, there is an urgent need to gather data on urban bird communities and this will enhance conservation efforts and landfill management for long-term conservation. This study aims to establish baseline data on species diversity, abundance and threats to avifauna in landfill sites across various urban areas in Tigray, ultimately proposing conservation measures for waste-dependent birds before they face extinction.

## Methods

### Study Area

The study took place in the Tigray region, northern Ethiopia. Tigray region is located at 12°3'25" to 15°1'18" N latitude and 36°43'30" to 41°38'30" E longitude (Fig. 1). The estimated area of the region is 80,000 square km. The altitudinal ranges of Tigray region varies from 500 to 4000 meters above sea level (m.a.s.l), and as a result of the distinguished altitudinal and topographic variations, there are various agro-ecological niches or microclimates within short distances of the region (Amare, 1996). Tigray goes to the African drylands, which is regularly known as the Sudano-Sahelian region. The region is mostly distinguished by a sparse and uneven distribution of seasonal rainfall and frequent occurrence of drought. The average rainfall of the region ranges from 200 to 1000 mm in the northeast lowlands and southwestern highlands, respectively. In Tigray, most of the rainfall occurs from the beginning of June to September; however, in some parts a short rainy season occurs during the spring season, mainly in the months of March, April and May. The average temperature of Tigray is 18 °C and varies with respect to the altitudinal ranges and seasons; for instance, in the highland areas in the months of November to January, the temperature falls to 5 °C, while during the summer sea-

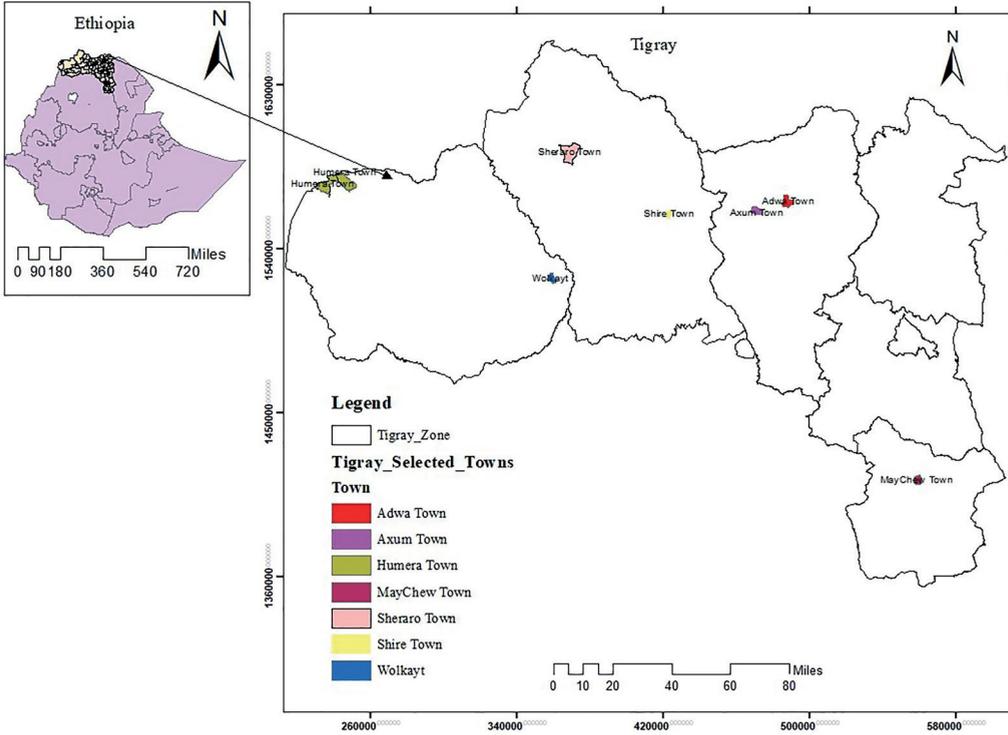


Fig. 1. Map of the study area

son in the lowland western parts of the region, particularly around Humera, the temperature reaches 40 °C. According to Ethiopian Statistic Service (Ethiopian Statistic Service, 2022) the estimated population of Tigray region is 5,738,996. In Tigray region, there is rapid growth of urban areas due to the continuous movement of people from rural to urban areas. As a result, open dumping is the most common problem in the region, and these waste dumping sites attract various species birds but their diversity and abundance were not determined. For this case, this study was conducted in landfill sites found in four highly populated administrative zones of the region include south, central, northwestern and western.

### Method of data collection

Data were collected from 05 November 2019 to 30 March 2020. Prior to the actual data collection, a preliminary survey was conducted to obtain basic information about the location of the landfill sites and their bird potential as well as to decide on the survey design. We selected seven landfill sites found at different geographical locations (both highland and lowland areas) for the study in different towns of Tigray including Maychew, Adwa, Axum, Shire, Sheraro, Humera and Wolkayt (Fig. 2). Urban areas often contain sizeable pockets of dumped wastes in active landfills and are considered alternative habitats for various wildlife including birds; hence, the aforementioned towns were selected purposively based on the flight path in which migratory and resident birds concentrate.

A point count technique was employed for the bird survey (Sidra et al., 2013). During the point count method, suitable locations or observation points



**Fig. 2.** Representatives of the landfill sites in Tigray region, Ethiopia

were selected and birds were identified and counted from a fixed position within a 50 m radius for a specific period of 15 minutes at every point (Alembrihan et al., 2024). All birds observed within this 50 m radius were recorded and counted. A total of six to ten point count stations were established in each landfill site depending on their size and maximum distance where observation of birds was possible. To minimize disturbance during counts, a waiting period of 3 to 5 minutes prior to counting was applied. Stations were surveyed for birds every two weeks twice a day (in the early morning 6:00–10:00 A.M. and in the afternoon 4:00–6:00 P. M.) when the activities of birds were prominent (Shimelis & Afe-work, 2008). Data including bird species, number, survey time (morning and afternoon) and survey town were recorded. Birds were physically observed using (10 x 50) binoculars. GPS readings were used to locate the points for the bird counting methods and record the locations of the study landfills.

The personal field observations were also carried out to gather information related to threats to bird species within the study landfills. A determined, methodical, and careful approach was taken to observe and record information regarding the threats to bird species, utilizing surveillance checklists. A camera was employed to capture images of both the bird species and the anthropogenic practices in the landfills.

### Data analysis

Statistical analysis was conducted using Statistical Product and Service Solutions (SPSS) Version 22.0 software. Two-way analysis of variance (ANOVA) was used to test the significant variation in bird species composition and abundance across landfills and time of counting. Species accumulation curve and Canonical correspondence analysis (CCA) were used to assess the adequacy of the sampling effort of the survey and the association of dominant bird species among different landfills, respectively. Paleontological Statistics (PAST) software version 4.03 (Hammer et al., 2001) was used to prepare the species accumulation curve and CCA. P value less than 0.05 was considered as statistically significant.

The Shannon-Wiener diversity index ( $H'$ ) was used to compute the species diversity of bird species (Shannon & Weaver, 1949). It was calculated as follows:

$$H' = - \sum (P_i - \ln P_i),$$

where  $P_i$  is proportion of the  $i^{\text{th}}$  species and  $\ln$  is natural logarithm. The Shannon-Wiener evenness index ( $E$ ) was used to calculate the species evenness of birds in the area (Kathleen et al., 2005).

The formula is:

$$E = H' / H_{max}$$

where  $H'$  is Shannon–Wiener diversity index and  $H_{max}$  is  $\ln S$ , which is natural logarithm of the total number of species ( $S$ ). Simpson's similarity index (SI) was used to evaluate the bird community similarities among landfill sites in relation to the composition of species (Jeffery et al., 2004).

$$SI = 2C / A + B,$$

where  $A$  is the number of species found at site  $A$ ,  $B$  is number of species found at site  $B$ , and  $C$  is number of common species found at sites  $A$  and  $B$ . 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. The collected data was presented using descriptive statistical methods. Results from the numerical data were summarized through tables, figures and bar graphs.

## Results

### Species composition of birds and sampling adequacy

A total of 2,985 individual birds of 96 species belonging to 32 families and 11 orders were recorded during the study period (Table S1). The order Passeriformes had the highest number of species ( $n = 42$ ), followed by order Accipitroformes ( $n = 24$ ) and order Columbiformes ( $n = 5$ ), whereas both order Coliiformes and Anseriformes has the least number of species ( $n = 1$  for each). Family Accipitridae had the highest number of species (24 species), accounting for 25.5%, followed by Muscicapidae (with 8 species) and Columbidae (7 species), while some families were represented by a single species. From the total species recorded, two species, the Thick-billed Raven, *Corvus crassirostris* and Abyssinian, Slaty-flycatcher, *Melaenornis chocolatinus* are endemic to Ethiopia and Eritrea. Globally threatened species such as Hooded Vulture, *Necrosyrtes monachus*, White-backed Vulture, *Gyps africanus*, White-headed Vulture, *Trigonoceps occipitalis* and Rueppell's Griffon, *Gyps rueppellii* (critically endangered), Egyptian Vulture, *Neophron percnopterus*, Lappet-faced, Vulture *Torgos tracheliotos* and Steppe Eagle, *Aquila nipalensis* (endangered), Greater Spotted Eagle, *Aquila clanga* and Martial Eagle, *Polemaetus belliosus* (Vulnerable), and Crowned Hawk-eagle, *Stephanoaetus coronatus*, Lammergeier, *Gypaetus barbatus* and Bateleur, *Terathopius ecaudatus* (Near-threatened) were also recorded. The species accumulation curve for all landfill sites (Fig. 3) fully reached the asymptote, which shows the completeness of the survey and no more sampling effort is needed to explore all expected bird species of the study area.

Additional data on the list of bird species and their relative abundance and IUCN conservation status at landfills in the Tigray region of northern Ethiopia are presented in Table S1, which is available on the Zenodo website at <https://doi.org/10.5281/zenodo.18311078>.

### Distribution and abundance of birds

From a total of 96 identified species, 60 bird species were recorded from the Humera landfill site, 47 species from Sheraro, 42 species from Axum and the least was from

Adwa (36 species) (Table 2). Hooded Vulture, Common Buzzard, Tawny Eagle, Cattle Egret and Little Egret were recorded in all landfill sites. Egyptian Vulture, White-headed Vulture and Pied Crow were observed in six landfill sites. Most of the identified bird species were observed from three and four landfills. Of these, 676 individual birds were counted from Humera landfill, 623 from Axum, 570 from Shire, 316 from Sheraro, 278 from Adwa, 265 from Wolkayt and 257 birds from Maychew landfills (Table 2). However, there was no significant variation in the abundance of birds across landfills ( $F = 3.6783, p = 0.069, df = 6$ ). The total number of counts varied among species. Hooded Vulture was the most abundant species, constituting 17.17% of the total number of counts, followed by Tawny Eagle (8.32%) and Pied Crow (5.46%), respectively, and Greater blue-eared Starling and Fork-tailed Drongo (0.14%) were the least abundant species (Table 1). In all landfill sites, a higher number of birds (2,179 individuals) were counted during the morning hours than in the afternoon (806 individuals). A significant variation in abundance of birds was observed between the morning and afternoon hours ( $F = 28.2315, p = 0.0018, df = 1$ ) (Fig. 4).

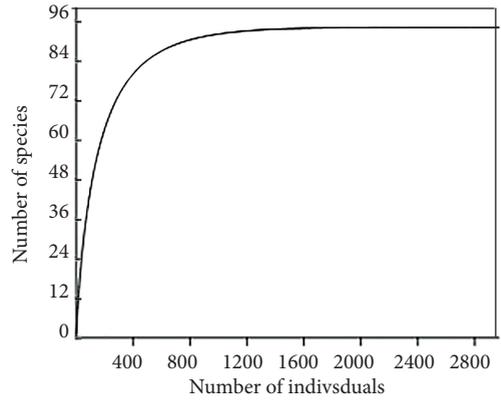


Fig. 3. Species accumulation curve of birds in landfills of Tigray region, Ethiopia

Based on canonical correspondence analysis (CCA), some dominant bird species, such as Hooded Vulture, Tawny Eagle, Pied Crow, White-backed Vulture, Griffon Vulture and Egyptian Goose, showed a high association with the Shire landfill site. Common Buzzard and Common Fiscal showed associations with the Axum landfill site. Pied Crow showed high association with Shire landfill. Shire, Axum and Adwa landfill sites were found to be the suitable sites for Cattle egret. White-headed Vulture also displayed a high relationship with Humera and Wolkayt landfills (Fig. 5).

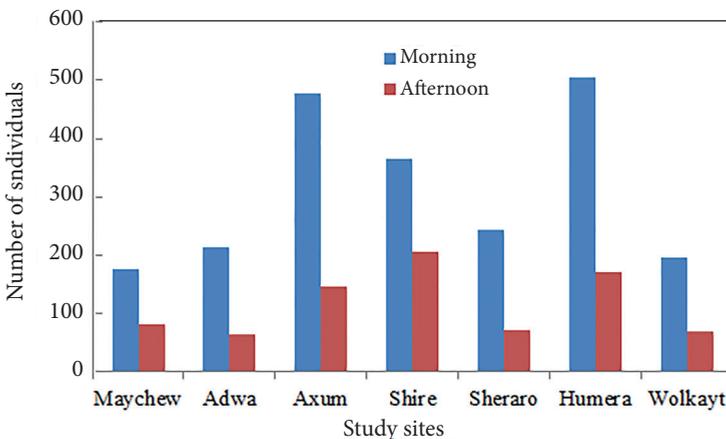
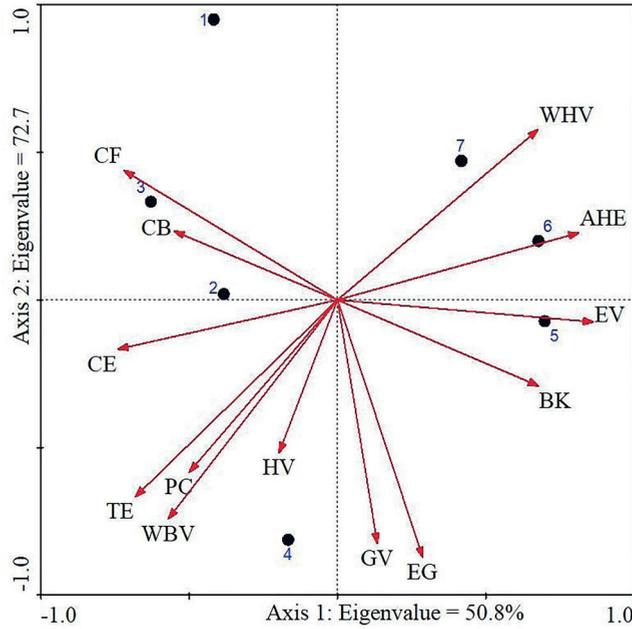


Fig. 4. Temporal variation in abundance of birds in landfills of Tigray region, Ethiopia



**Fig. 5.** Canonical correspondence analysis exhibiting association of dominant bird species: 1 — Maychew, 2 — Adwa, 3 — Axum, 4 — Shire, 5 — Sheraro, 6 — Humera, 7— Wolkayt landfills, HV — Hooded Vulture, TE — Tawny Eagle, WHV — White-headed Vulture; WBV — White-backed Vulture, EV — Egyptian Vulture, GV — Griffon Vulture, PC — Pied Crow, BK — Black Kite, AHE — African harrier Eagle, EG — Egyptian Goose, CB — Common Buzzard, CF — Common Fiscal, CE — Cattle Egret

**Table 2. Diversity indices of birds among landfills in urban areas of Tigray region, Ethiopia**

Diversity indices	Landfills						
	Maychew	Adwa	Axum	Shire	Sheraro	Humera	Wolkayt
S	42	36	46	41	47	60	44
N	257	278	623	570	316	676	265
H'	3.49	3.31	3.18	2.89	3.38	3.56	3.51
E	0.778	0.766	0.525	0.439	0.622	0.584	0.759

Note. S — Species richness, N — Total number of individuals (abundance), H'— Shannon-Wiener diversity index, E — Evenness index.

**Table 3. Bird species similarity between landfills of Tigray region, Ethiopia**

Landfills	Maychew	Adwa	Axum	Shire	Sheraro	Humera	Wolkayt
Maychew	–	0.41	0.705	0.506	0.404	0.373	0.349
Adwa	–	–	0.561	0.442	0.434	0.458	0.425
Axum	–	–	–	0.552	0.366	0.453	0.422
Shire	–	–	–	–	0.386	0.436	0.353
Sheraro	–	–	–	–	–	0.598	0.486
Humera	–	–	–	–	–	–	0.712
Wolkayt	–	–	–	–	–	–	–

## Species diversity and species similarity indices

The species richness, diversity, and evenness of birds varied among landfills (Table 2). Humera landfill site had the highest species richness (60 species), while Adwa landfill has the lowest species richness (36 species). In this study, Humera landfill had the highest species diversity index ( $H' = 3.56$ ), followed by Wolkayt ( $H' = 3.51$ ), and the lowest diversity index was observed in Shire landfill site ( $H' = 2.89$ ). Maychew had the highest species evenness ( $E = 0.778$ ), whereas Shire had the lowest species evenness ( $E = 0.439$ ). The analysis of species similarity among landfill sites indicated that the highest species similarity index was recorded between Humera and Wolkayt landfill sites ( $SI = 0.712$ ), followed by Maychew and Axum landfill sites ( $SI = 0.705$ ), and the lowest was obtained between Maychew and Wolkayt landfills ( $SI = 0.349$ ) (Table 3). The overall similarity of bird species among all landfills was 0.111, which is  $< 25\%$ , indicating that there is very less similarity among the study landfills.

Based on personal field observations, there are various negative impacts on birds, either directly (threats) or indirectly (disturbance). Activities of waste collectors, free-ranging domestic animals and waste firing we consider as the disturbing factors, at the same time, electrocution, hunting and disposal of pollutant wastes were identified threats to birds.

## Discussion

In Ethiopia, most of important bird areas have been affected by various human related activities, such as habitat destruction, agricultural expansion, industrialization, investment and overgrazing (Shimelis & Afework, 2008; Kiros et al., 2014). In the present study, a total of 96 bird species were recorded and this indicates the most bird species of the country are in risk in the long term survival since they are using the detrimental landfill sites. Landfills are among the modified habitats used as roosting and feeding sites of diverse species of birds and they provide organic food sources and various prey species, such as invertebrates, small mammals and birds, used as the main food source for many predator species (Yrgalem et al., 2019; Arnold et al., 2021). The number of bird species recorded in the present study was higher compared to previous studies conducted in urban areas of Ethiopia, such as Yrgalem et al. (2019), who identified 30 species from Wolkite town; Hiwot and Afework (2007); who identified 21 species from the Addis Ababa abattoir enterprise area; Seyoum and Bezawork (2018), who identified 17 species from Wolkite town; and Getachew et al. (2016), who identified 6 species from Ashewa local vulture restaurant, Dire Dawa city, however it was lower than that in the reports of Abeba et al. (2020), who recorded 186 species from Bahir Dar city. During this study, a total of 2,985 individual birds were counted, which relatively agrees with the report of Seyoum and Bezawork (2018), who counted 2,566 individuals from Wolkite town; however, this number is higher than the reports of Getachew et al. (2016) and Yrgalem et al. (2019), who counted 1,088 and 617 individual birds, respectively. The observed high species richness and abundance of birds in the area might be due to the availability of high organic food sources in landfills, and presence of various

landscapes such as building and vegetation structures in and around the landfills that provide wide range of foraging, roosting and nesting sites for the birds.

In the present study, variation in species richness and abundance of birds among landfills was observed, in which Humera landfill site had the highest species richness and abundance, followed by Axum landfill, while Adwa landfill site had the lowest. This variation might be related to the environmental conditions, amount of available food sources, level of human disturbance, geographical locations and other ecological constraints across landfill sites. Humera and Axum landfill sites are found in large and highly populated towns, which can contribute to the use of highly dumped organic wastes as sources of food for many birds and various urban landscapes as roosting, resting and feeding sites. Beselam et al. (2022) and Massawe, 2017 stated that human activities in and around dumpsites have a great influence on the distribution pattern of bird species and that dump areas that are highly disturbed harbor a lower number of birds. According to various studies, the availability of food was reported as a main reason for the increase in the number of birds in a particular area (Getachew et al., 2016; Taylor et al., 2013). Moreover, other factors, such as the level of competition, climatic conditions and availability of roosting areas, have also been declared to have a significant impact on the abundance of birds (Getachew et al., 2016; Kassahun et al., 2019). Many researchers have suggested that various ecological pressures such as human disturbance, climatic conditions and the availability of food, water, and roosting and nesting sites can lead to variation in bird species and their abundance among different areas (Seyoum & Bezawork, 2018; Abeba et al., 2020).

Among the recorded bird species in the area, scavenging species were more abundant than other bird groups, which could be associated with their feeding habits and adaptation in disturbed habitats. From the identified bird species, Hooded vulture and Tawny eagle were found in all study landfill sites and were recorded as the most abundant species compared to other species, which is in line with the report of Getachew et al. (2016) from dumpsites of Dire Dawa City. Abeba et al. (2020) also reported that Hooded Vulture and Marabou Stork were more abundant species. The high abundance of these types of birds might be associated with their high resistance to human disturbances, generalist feeding habits, such as feeding on food scraps, offal and other locally dumped food sources, strong feeding preferences and high adaptation to the complex habitats of urban areas.

This study recorded two endemic bird species, which might be related to the exclusivity and uniqueness of the area and the diverse habitat types for the bird species. Similar studies have been recorded many bird species as endemic to Ethiopia and Eritrea (Yrgalem et al., 2019; Abeba et al., 2020). In addition, 12 globally threatened bird species were also recorded in this study, including Hooded Vulture, White-backed Vulture, White-headed Vulture, *Rueppell's Griffon*, Egyptian Vulture, and Lappet-faced Vulture. These threatened species are suffering as a result of the destruction of their habitat, roosting, feeding and breeding sites due to uncontrolled human activities, and this raises great conservation concerns for these threatened species in their natural and modified habitats, such as landfills.

Higher numbers of individual birds were counted during the morning hours than in the afternoon. This is in line with previous reports in Ethiopia (Seyoum &

Bezawork, 2018; Abeba et al., 2020). This temporal variation in individual birds might be related to the amount of food sources, and during our field work, we observed that wastes in the towns were usually discarded in the morning time, which could be the reason for the high number of individual birds in the morning than in the afternoon. In addition, the free-ranging domestic animals such as dogs and cats might also consume food scraps during the morning to midday; as a result, no food scraps remain until the afternoon. Thus, this indicates that food sources influence the number of bird occurrences at specific areas and times, and food sources are considered the main limiting factor for the distribution and abundance of birds. In addition, the daily activity pattern of birds is also associated with their foraging behavior, which might be affected by both biotic and abiotic factors, including predation, competition, food availability, habitat types and climatic conditions.

In this study, the highest bird species diversity index was observed in the Humera landfill site, and the lowest were observed in the landfill site found at Shire town. The highest and lowest species evenness was recorded in the Maychew and Shire landfill sites, respectively. Variations in food sources, nesting, foraging and roosting sites and the degree of human interference among landfills may be the reason for variations in the species diversity and evenness of birds. Habitat features and feeding behaviors of birds mostly lead to variation in species diversity and species evenness (Megersa et al., 2016). The highest species similarity index was recorded between the Humera and Wolkayt landfill site, which is probably due to their proximity and similar geographical conditions and resources since they are found in lowland parts of western Tigray. The overall species similarity among landfills was very low, which could be due to habitat-specific variations in feeding habits and the response of birds to human disturbances. This finding is in line with various authors who reported that animals that inhabit areas with similar environmental conditions are more similar to each other in terms of species richness and topographical structure than animals that inhabit areas with various environmental conditions (Megersa et al., 2016; Tamenut & Fasika, 2022).

In the landfills of the study region, birds were negatively affected by various anthropogenic factors, such as disturbance of garbage collectors, burning of waste, disposal of inedible waste and other harmful pollutants and pathogens, free movement of domestic animals such as dogs, cats and other livestock in the landfills, electrocution and hunting of birds. These and other related negative factors can affect the survival, distribution, diversity and abundance of birds in a given area. In most of the study landfills, the daily activities of waste collectors, burning of wastes and free-ranging dogs, cats and cattle were observed, and these activities can affect the feeding and other activities of birds. The presence of dogs and cats in landfills may cause the death of immature birds and disrupt feeding activities (Ogada et al., 2016). During this study, we observed that when there are high human pressures in and around landfills, most scavenging birds fly and stay in nearby forests, poles and buildings, and just when human activities decrease, birds come back and start feeding. In addition, the killing and hunting of birds for medicinal purposes were observed mainly in Humera town. Similar to this study, previous studies also identified different factors that threatened urban birds in different localities of Ethiopia. For example, Seyoum and Bezawork (2018) reported that garbage collectors and the presence of

domestic dogs, cats, and vehicles were identified as the main negative factors affecting bird behavior at the landfills of Wolkite, Ethiopia. Similarly, Getachew et al. (2016) also found that garbage collectors and free-roaming domestic dogs disrupt bird feeding activities at the landfills. According to Mebrat and Bezawork (2021), the major threats to Hooded Vultures in Addis Ababa abattoirs were shortages of food. In addition, Beselam et al. (2022) also mentioned that human disturbance and competition for food and resting with domestic and wild animals were the major negative factors to African white-backed Vultures. The most serious potential threat for the Egyptian Vulture in Ethiopia was poisoning and electrocution (Arkumarev et al., 2014). Birds such as the Egyptian vultures are susceptible to electrocution due to their habit of perching and roosting on powerline pylons.

## Conclusions and recommendations

The present study provides baseline information on the roles of landfills for bird conservation in urban areas of the Tigray region, northern Ethiopia. A high bird diversity (96 species), consisting of endemic and globally threatened species, was recorded, which demonstrates the importance of the studied landfills for bird conservation. Bird species richness and abundance varied spatially across landfill sites in different urban areas; this might be related to variations in food sources, climatic conditions, levels of human disturbance, and the availability of roosting and feeding sites. According to the findings, the Hooded Vulture had the highest abundance, followed by the Tawny Eagle and Pied Crow. The Thick-billed Raven and Abyssinian Slaty-flycatcher are endemic to Ethiopia and Eritrea. Many globally threatened bird species, such as the Hooded Vulture, White-backed Vulture, White-headed Vulture, Rueppell's Griffon, Egyptian Vulture, Lappet-faced Vulture, Steppe Eagle, Greater Spotted Eagle, and Martial Eagle, were also recorded in the area. The Humera landfill site had the highest bird abundance, followed by the Axum landfill, while the Maychew landfill had the lowest. Humera landfill had the highest species diversity index ( $H' = 3.56$ ), while Shire landfill had the lowest. Maychew landfill had the highest species evenness ( $E = 0.778$ ), followed by the Adwa and Wolkayt landfills. Various negative factors affecting birds were identified, including human disturbance, stray dogs, cats, cattle, waste burning, food shortage, electrocution, and hunting. Although the landfills of the region are highly disturbed, they harbor a large number of bird species.

Therefore, to safeguard the waste-dependent bird fauna in general, and globally threatened species in particular, conservation measures, such as proper management and protection of landfills, are critically recommended. Further investigations into the impact of dumped waste on the survival of birds are also recommended. Moreover, urban planners should consider the existence of bird fauna when selecting and designing landfill sites.

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