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Community Structure, Conservation Status, and Functional Groups of Bird Species in Mbeya Range Forests, Tanzania

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Abstract:

The Mbeya range forest reserves (MRFRs) of the southern highland of Tanzania are an important hotspot for biodiversity conservation. However, its avian biodiversity has hardly ever been studied. Thus, for the first time, this study presents the inventory of bird species from MRFRs, demonstrating community structure, functional group, and conservation status. The study was carried out in four forest areas (i.e., Idugumbi, Kawetire, Mount Loleza, and Muvwa) within the MRFRs. The bird survey was carried out monthly between March 2018 and June 2018. Standardised line and point counts, as well as mist netting, were used to collect data. A total of 1052 individual birds, representing 41 species and 22 families, were recorded. Relative abundance, Shannon and Simpson species diversity, and species richness were high in Idugumbi forest and lowest in Kawetire forest. Species diversity differed significantly between the four forest areas. Moreover, Idugumbi and Muvwa had relatively low species composition dissimilarity compared to other forest areas. Different bird functional groups, i.e., insectivores, granivores, nectarivores, carnivores, frugivores, or combinations of these, were recorded in MRFRs. The insectivores were twice as abundant as granivores and nectarivores. The multi–layered vegetation structure of native plants in the Idugumbi forest appears to benefit and contribute to bird communities. The study reveals that MRFRs are an important hotspot for bird species that require ecological monitoring and protection. As a result, appropriate land–use practices near MRFRs should be followed to ensure long–term avian conservation.

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INTRODUCTION

Birds are a very diverse and vital component of forest ecosystems [1,2]. Their presence or absence indicates the ecological conditions of the forest ecosystem health [3-5], because they respond swiftly to any habitat change [4,6]. Though bird inventories are one of the steps in understanding forest biodiversity, little attention has been given to African avifauna, particularly in sub-Saharan African forests. Preceding studies have demonstrated that forests are vital ecosystems for conserving and protecting avifauna [7,8]. They provide various ecosystem services, including habitats and water for birds [3]. However, rapid global population growth and rapid development pose a threat to the resilience of natural forest ecosystems and bird species [7,9]. Birds are an acknowledged group of animals that are often used as proxies for other elements of biodiversity [10]. For instance, they are an important indicator of forest ecosystem health [3,11]. The European Union and most European countries, for instance, use birds as an indicator of sustainable biodiversity conservation [3,4]. Birds are vulnerable to anthropogenic changes when the ecosystem is health is transformed [4,7]. When the composition and structure of forests change, forest–dependent birds usually change [11,12]. These changes can negatively modify the community structure and composition of bird species. Further, when these changes persist, some bird species become endangered [8, 9]. Thus, management of forest ecosystems is essential to ensure the survival of forest avifauna.

Previous studies have shown that human development is associated with habitat loss, deforestation, degradation, and fragmentation [4,8]. These processes alter natural habitats [13], bird populations, species composition, and their functional groups [5]. In this study, the functional group refers to the taxonomic composition of bird diets [5,14]. For instance, a bird species that eats insects is classified in the functional group as an insectivore, one that eats fruits is classified as a frugivore, and one that feeds on flower nectar is classified as a nectarivore [5, 15]. Also, bird species that feed on seeds, grains, fruits, and nuts are classified as granivores, and those that prey on amphibians, reptiles, birds, and mammals are classified as carnivores, or sometimes a mixture of these [5,15,16].

Anthropogenic activities that cause fragmentation and habitat loss, according to Chace and Walsh [17], Chiari *et al*. [18], and Sandström *et al*. [19], have a negative impact on bird communities. Chowfin and Leslie [3] and Sodhi *et al*. [8] also pointed out that the decrease in species richness and abundance of birds in forests is due to habitat loss. Severe habitat degradation and/or loss due to human activities may lead to local extinctions of bird species [20-22]. As a result, most threatened bird species across the world have been listed by the International Union for Conservation of Nature (IUCN) on the red list as critically endangered (CR), endangered (EN), or vulnerable (VU). Thus, the avian functional group is an essential trait that affects birds' contributions to ecosystem integrity [5,10,15,16]. Accordingly, keeping forests intact would benefit bird species and maintain their functional diversity and ecosystem services.

There are about 12 endemic bird species in Tanzania. Respectively, about 56, 200, and 800 species are global conservation concerns, regular migrants, and resident species [23]. And most of these species live in forests [23]. The forest ecosystem forms one of the most important habitats for bird species in the country [1,24]. However, assessment of bird community structure in these forests is rarely carried out. Most of these forests, i.e., the Mbeya range forest reserves (MRFRs), receive little conservation attention from local government authorities. Like any other forest in the country, the MRFRs have suffered a long history of conversion by humans [25,26]. Anthropogenic changes associated with forest disturbances due to grazing, charcoal production, poles and firewood collection in MRFRs may have severe consequences for bird community structure. Invasive species, non–native plants, and shrub encroachment all pose risks to the MRFR's ecosystem health [26]. The current status of MRFRs is displeasing as it is becoming one of the most threatened ecosystems in Tanzania. In an effort to protect MRFRs from deforestation and forest degradation, the Tanzania Forest Services (TFS) implemented conservation measures. Prior to TFS to protect the MRFRs, most natural habitats in the forests were already affected by anthropogenic activities. For instance, some forests in MRFRs were cleared for timber, fuelwood, charcoal production, crop and grazing, and the development of infrastructure, i.e., houses and roads [26].

Ongoing habitat alterations in MRFR may affect birds' dispersal ability and their role in forest ecosystem functions, e.g., insect pest control (insectivores), seed dispersal (frugivores and granivores), and pollination (nectarivores) [12,22]. Furthermore, the changes in the forest ecosystem may lead to dissimilarities in bird

species compositions, diversity, abundance, and functional groups [20,22,27]. In MRFRs, habitat fragmentation represents the key threat to bird diversity as it affects their roosting and nesting sites. This may further affect the population's ability to reproduce, and therefore, increase the species' vulnerability. Although information concerning community structure and the IUCN conservation status of forest avifauna is available, little work has been done in most places in Tanzania. For instance, there is no study that has been carried out to assess the community structure (i.e., abundance, diversity, and species composition) of bird species in MRFRs. Further, there is no data concerning the IUCN conservation status and functional groups of bird species. The goal of this study was to assess community structure, IUCN conservation status, and functional groups of birds in MRFRs. The specific objectives were to: (1) inventory the bird species, (2) determine the community structure of birds, (3) assess bird functional groups, and (4) assess the IUCN conservation status of birds in MRFRs.

MATERIALS AND METHODS

Study Site

The research was carried out in the Mbeya region (8°51′18″ S, 33°25′15″ E), in south–western Tanzania [25]. Loleza Peak (2656 m), Mbeya Peak (2565 m), Nyanuwa Peak (2332 m), and Pungulumo peak (1909 m) [25-26] comprise the Mbeya range (2818 m peak). The MRFRs are endowed with species of birds, insects, and plants [25]. In addition, it provides ecosystem services such as food, medicine, and fuelwood that support local people's livelihoods [26]. Common plant species in MRFRs include *Albizia gummifera* (J.F. Gmel.) C.A. Sm, *Albizia versicolar* Welw. Ex Oliv, *Allophylus sp*, *Trichilia prieuriana* A. Juss, *Trilepisium madagascariense* DC, *Acacia albida* Delile, *Brachystegia boehmii* Taub, *Brachystegia manga* De Wild, *Brachystegia spiciformis* Benth, *Combretum molle* R. Br ex G. Don, *Cussonia arborea* Hochst, *Pterocarpus angolensis* DC, *Uapaca kirkiana* Mull.Arg., *Faurea saligna* Harv, and *Erica spp*, *Hyperhenia spp, Panicum sp, Sacciolepsis spp, Brevifolia spp,* and *Protea spp*. Also, there are exotic tree species such as Eucalyptus *spp.,* Pinus *spp*., and *Mangifera indica*.

Four study areas in MRFRs, i.e., Idugumbi (8° 53' 45" S, 33° 20' 10E), Kawetire (8° 50' 55" S, 33° 30' 3" E), Mount Loleza (8° 53' 27" S, 33° 26' 143" E), and Muvwa (8° 52' 48" S, 33° 18' 11" E) were selected for bird species inventory. The Idugumbi forest area is characterized by fewer human disturbances. It is dominated by native vegetation trees varying in size, height, and canopy cover, as well as a well–established understory flora. Muvwa and Mt. Loleza forest areas experience more anthropogenic disturbances, e.g. livestock grazing, fire incidences, forest gaps, stumps, logging, charcoal production, firewood and pole collection, and uncontrolled tourism activities. Mt. Loleza forest, which is located in urban areas, borders Mbeya Zonal Referral Hospital (MZRH) and households that use the forest resources. Kawetire is the plantation forest that borders the Mt. Loleza forest. It is dominated by non-native trees (*Cuppressus lustanica, Eucalyptus maidenii, Pinus patula, Pinus canariensis,* and *Pinus radiate*). It has poor understory flora and limited multi-layered vegetation. It is also subjected to anthropogenic activities such as livestock, agriculture, and roadways.

Bird Population Survey

A bird survey was carried out in Idugumbi, Kawetire Mt. Loleza, and Muvwa, located in MRFRs. The survey was conducted using standardised line and point counts, mist netting [5,12,15], and opportunistic searches to collect data on bird species, diversity, relative abundance, and functional groups. A two-person team walked continuously along several transects (3 km) in each of the four sites. Birds observed on both sides of the transect line were counted and recorded. Another team of two people conducted a point count. During the point count, the team walked along the transect at an interval of every 50 m and stopped after 10 minutes to count every bird individual and species. In order to avoid interference, observations were made using binoculars at least 30 m from the birds. Further, observations were conducted from different localities in each area. All birds were identified at species level.

Bird population surveys were conducted four times (March 1–15, April 1–15, May 1–15, and June 1–15) in 2018. The surveys started in the morning (08:00 h), usually in the absence of rain. We allowed at least a two-day break between consecutive visits to the same site. Moreover, in order to minimize the possibility of double recordings, count points were at least 100 m apart. In addition, bird species were identified using a 15-m mist net (36 mm mesh). Two mist nets were fixed and stretched between two poles in different locations, and were positioned at ground level (0–3m). The nets were opened at 08:00 h and closed at 18:30 h. They

were monitored every two hours. The nets were left for 2 days in the same place before being relocated. To enable individual identification, birds caught in mist nets were ringed with aluminium bands [5]. Furthermore, birds were assigned to different functional groups based on a combination of factors or preferred diet [16]. The functional groups were assessed by observing the type of food the birds eat and supplemented by a literature review. They were classified as insectivores, nectarivores, frugivores, granivores, carnivores (raptors and piscivores), or a combination of these.

Statistical Data Analysis

The overall bird abundance in the four forest areas was compared using one-way ANOVA with a Tukey post hoc test. The species diversity was compared using the diversity t-test. Species diversity indices, i.e. the Shannon and Weiner index (*H'*), Simpson's diversity index (*D*), the Evenness (*E*), and Margalef community diversity index (*d*) [28,29] were computed and compared between the study areas. Furthermore, bird species composition among the four areas was compared using the Bray–Curtis dissimilarity index (in a range of 0 (similar) to 1 (dissimilar)). The Kruskal–Wallis test was used to compare the numbers of bird species across different functional groups (i.e., insectivore, nectarivore, frugivore, granivore, carnivore), followed by Dunn's post hoc test. Origin software version 9.0 SR1 and Paleontological Statistics software (PAST) version 2.17 [30] were used to analyze the data. Homogeneity of variance and normality were tested using Levene's test and the Kolmogorov-Smirnov test, respectively. Statistical significance was defined as $p < 0.05$.

RESULTS

Birds' Community Structure and IUCN Conservation Status

A total of 1052 bird individuals representing 41 species and 22 families were recorded in MRFRs during this study (Tables **1** and **2**). Among these species, none of them were found on the IUCN Red List of Threatened Species. All identified bird species in MRFRs are in the least concerning (LC) category according to IUCN (Appendix A: Table **A.1**). The most abundant bird species (with > 50 individuals) observed in MRFRs during the survey consisted of *Pycnonotus barbatus* (Family: Pycnonotidae), *Cisticola chiniana* (Family: Cisticolidae), and *Lagonosticta senegala* (Family: Estrildidae). The least abundant bird species (with 10 individuals) consisted of *Ardea melanocephala* (Family: Ardeidae), *Cinnyris mediocris* (Nectariniidae), *Streptopelia decipiens* (Family: Columbidae) and *Scopus umbretta* (Family: Scopidae) (Table **2**). Examples of the bird species caught by MRFRs are shown in Figure **1**.

Overall, 34 (26.563%) species were recorded in Idugumbi, 32 (25%) in Muvwa, 29 (22.656%) in Kawetire, and 33 (25.781%) in Mt. Loleza (Table **3**; Appendix B: Table **B.1**). Moreover, a high number of birds were recorded from the Idugumbi forest area with 319 individuals, relative abundance (30.323%), diversity ($H = 3.427$, $D = 0.965$), evenness ($E = 0.905$), and species richness ($d = 5.724$) compared to other study areas (Table **3**). Kawetire had the lowest relative abundance (20.057%), diversity ($H = 3.187$, $D = 0.953$) and species richness ($d = 5.232$) (Table **3**; Appendix B: Table **B.1**). It was also found that diversity indices increased proportionally with the number of bird species in the study areas (Table **3**; Appendix B: Table **B.1**).

Species diversity was statistically significant different ($p < 0.05$) between study areas (Table **4**). For instance, Shannon species diversity differed between Muvwa and Idugumbi ($p = 0.003$), Idugumbi and Kawetire ($p = <0.001$) and Mt. Loleza and Kawetire ($p = 0.026$) (Table **4**). Also, Simpson species diversity differed between Muvwa and Idugumbi ($p = 0.022$), Idugumbi and Kawetire ($p = 0.002$) and Mt. Loleza and Kawetire ($p = 0.026$) (Table **4**). However, overall bird abundance did not differ significantly across the four study areas ($F(2,_{27}) = 1.725$, $p = 0.165$, Figure **2**). Moreover, study areas had dissimilar bird species compositions (Figure **3**). Idugumbi and Muvwa had low species composition dissimilarity (Bray–Curtis = 0.5331, Figure **3**, Table **5**).

Functional Groups of Bird Species

The functional groups of bird species recorded from MRFRs consist of insectivores, granivores, nectarivores, carnivores, frugivores, and combinations of these (Table **6**, Appendix B: Table **B.1**). About 42.53% of species were insectivores, 19.54% granivores, 13.79% nectarivores, 12.64% frugivores, 8.05% carnivores, and 3.45% generalists (Table **6**). Two families of generalist bird species, Passeridae (i.e., *Passer domesticus*) and Scopidae (i.e., *Scopus umbretta),* were recorded during this study (Table **6**). But, several functional groups (I = insectivore;

Table 1: List of Bird Species Observed from four Study Areas in Mbeya Range Forest Reserves

S/N	Scientific name	Family	No. of bird individuals recorded in four study areas			
			Idugumbi	Muvwa	Kawetire	Mt. Loleza
1	*Cyanomitra olivacea* Smith	Nectariniidae	6	0	2	4
2	*Terpsiphone viridis* Müller	Monarchidae	8	0	3	10
3	*Phylloscopus sibilatrix* Bechstein	Phylloscopidae	3	12	0	0
4	*Dendropicos goertae* Statius Muller	Picidae	7	5	4	1
5	*Lamprotornis superbus* Rüppell	Sturnidae	8	5	10	9
6	*Stiphrornis erythrothorax* Hartlaub	Muscicapidae	9	11	7	5
7	*Bubulcus ibis* Bonaparte	Ardeidae	11	8	0	5
8	*Pogoniulus simplex* Fischer et Reichenow,	Lybiidae	9	4	0	2
9	*Corvus albus* Statius Muller	Corvidae	12	7	0	9
10	*Phylloscopus ruficapilla* Sundevall	Phylloscopidae	7	11	14	0
11	*Onychognathus morio* Linnaeus	Sturnidae	10	3	0	13
12	*Cisticola chiniana* Smith	Cisticolidae	23	10	18	5
13	*Estrilda astrild* Linnaeus	Estrildidae	9	3	0	0
14	*Spilopelia senegalensis* Linnaeus	Columbidae	13	15	7	3
15	*Passer domesticus* Linnaeus	Passeridae	7	8	13	11
16	*Phylloscopus inornatus* Blyth	Phylloscopidae	7	0	3	14
17	*Zosterops anderssoni* Shelley	Zosteropidae	15	17	0	7
18	*Pycnonotus barbatus* Desfontaines	Pycnonotidae	13	22	16	17
19	*Streptopelia capicola* Sundevall	Columbidae	6	13	0	6
20	*Ploceus subaureus* Smith	Ploceidae	16	9	8	8
21	*Merops pusillus* Statius Muller	Meropidae	11	7	4	2
22	*Prinia subflava* Gmelin	Cisticolidae	8	12	0	5
23	*Lamprotornis unicolor* Shelley	Sturnidae	4	0	10	8
24	*Muscicapa striata* Pallas	Muscicapidae	9	0	2	12
25	*Lagonosticta senegala* Linnaeus	Estrildidae	14	21	9	6
26	*Egretta garzetta* Linnaeus	Ardeidae	11	6	9	13
27	*Anthus lineiventris* Sundevall	Motacillidae	7	5	3	0
28	*Lagonosticta rubricata* Lichtenstein	Estrildidae	9	11	13	14
29	*Lagonosticta rhodopareia* Heuglin	Estrildidae	3	4	9	0
30	*Cossypha heuglini* Hartlaub	Muscicapidae	14	3	6	9
31	*Nectarinia famosa* Linnaeus	Nectariniidae	13	6	5	0
32	*Chalcomitra senegalensis* Linnaeus	Nectariniidae	5	3	0	7
33	*Spermestes bicolor* Fraser	Estrildidae	10	9	0	5
34	*Scopus umbretta* Gmelin	Scopidae	2	0	5	0
35	*Iduna similis* Richmond	Acrocephalidae	0	14	11	9
36	*Streptopelia decipiens* Hartlaub & Finsch	Columbidae	0	2	0	5
37	*Hirundo rustica* Boddaert	Hirundinidae	0	3	7	5
38	*Cinnyris mediocris* Shelley	Nectariniidae	0	4	3	0
39	*Chalcomitra amethystina* Shaw	Nectariniidae	0	0	5	10
40	*Ardea melanocephala* Vigors & Children	Ardeidae	0	0	1	4
41	*Lanius excubitoroides* Prévost & Des Murs	Laniidae	0	0	4	6

Table 2: Abundant (>50 Individuals) and Least Abundant (<10 Individuals) Bird Species Recorded from Mbeya Range Forest Reserve

Bird species		Number of individuals	Relative abundance (%)
Scientific name	**Family**		
Pycnonotus barbatus	Pycnonotidae	68	6.46
Cisticola chiniana	Cisticolidae	56	5.32
Lagonosticta senegala	Estrildidae	50	4.75
Ardea melanocephala	Ardeidae	5	0.48
Cinnyris mediocris	Nectariniidae	7	0.67
Streptopelia decipiens	Columbidae	7	0.67
Scopus umbretta	Scopidae	7	0.67

Figure 1: Some of the bird species caught using mist net in Mbeya range forest reserve.

Table 3: Species Richness, Abundance, Relative Abundance and Diversity Indices of Birds Recorded from Mbeya Range Forest Reserve

Forest area (Study site)	Species richness	No. of individuals	Relative abundance (%)	Shannon index (*H*)	Simpson index (*D*)	Evenness index (*E*)	Margalef index (*d*)
Idugumbi	34	319	30.323	3.427	0.965	0.905	5.724
Muvwa	32	273	25.951	3.291	0.957	0.84	5.526
Kawetire	29	211	20.057	3.187	0.953	0.835	5.232
Mt. Loleza	33	249	23.669	3.363	0.962	0.875	5.6
Total number of individuals			1052				
Total number of species			41				

Table 4: Diversity *t* Test Summary of Shannon and Simpson Species Diversity for the Four Study Areas in Mbeya Range Forest Reserves. Asterisk (*) on *p*–Value Indicates Significant Difference at p < 0.05

Sites comparison	Shannon diversity			Simpson diversity		
	t-value	DF	*p*–value	*t*–value	DF	*p*–value
Muvwa vs Idugumbi	2.9766	515	0.003*	-2.297	484	0.022*
Muvwa vs Kawetire	1.8531	454	0.065	-1.003	441	0.316
Muvwa vs Mt. Loleza	1.4472	521	0.148	-1.306	511	0.192
Idugumbi vs Kawetire	4.8051	377	<0.001*	-3.151	337	0.002*
Idugumbi vs Mt. Loleza	1.4572	503	0.146	-1.002	507	0.317
Mt. Loleza vs Kawetire	-3.2609	424	0.001*	2.237	384	0.026*

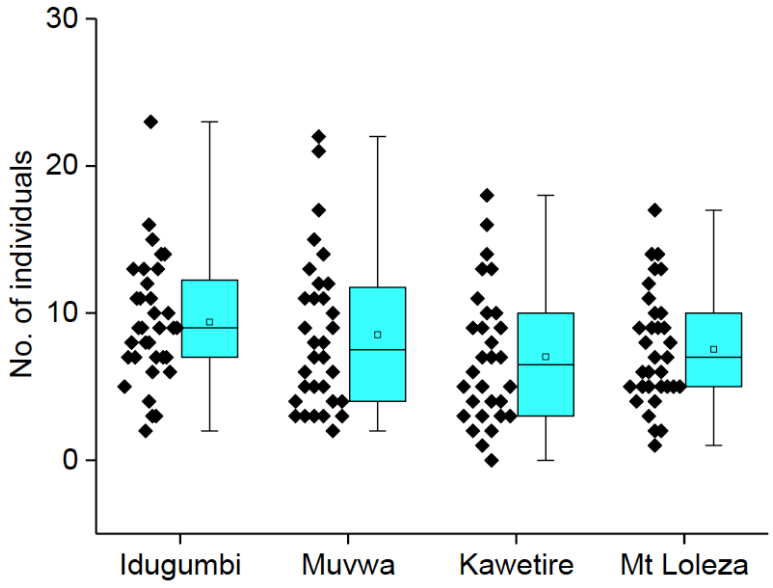

Figure 2: Number of birds recorded from the study areas i.e. Idugumbi, Muvwa, Kawetire and Mt. Loleza. Boxplots with data on the left show the mean (a square within boxes) and ranges from 25% and 75% quartile, and the tips of the whiskers indicate the 5th and 95th percentiles. The number of birds was not statistically significant different between areas (Tukey's HSD test at p = 0.05).

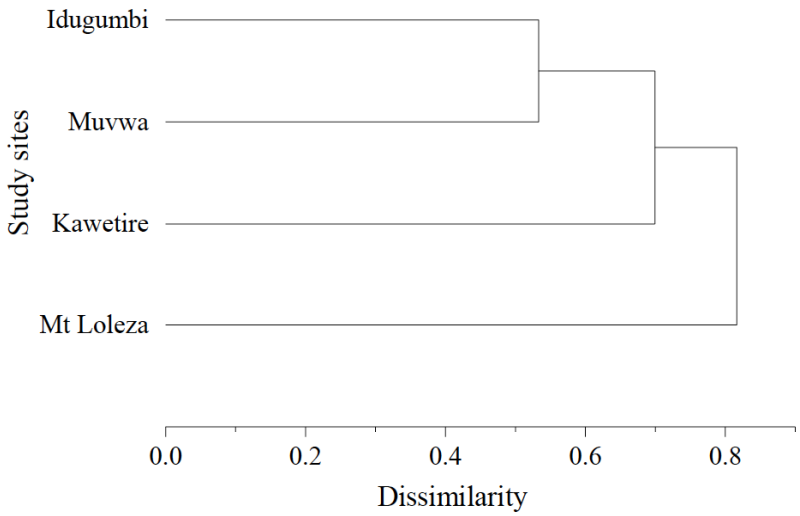

Figure 3: Dissimilarity dendrogram of the overall bird community in four study areas (Bray–Curtis index) as per the current study.

Table 5: Bray–Curtis Species Dissimilarity Index Summary for the Four Forest Areas Surveyed in Mbeya Range Forest Reserve from March 2018 to June 2018. Note: 0 Represents Similarity (100% Similarity) while 1 Represents 100% Dissimilarity

	Idugumbi	Muvwa	Kawetire	Mt. Loleza
Idugumbi	0	0.5331	0.7473	0.8085
Muvwa		0	0.6517	0.9085
Kawetire			0	0.7321
Mt. Loleza				0

Table 6: Functional Group (I = Insectivore; G = Granivore; N = Nectarivore C = Carnivore; F = Frugivore; M = Generalist; PC = Possible Combination) of Bird Species Recorded from Mbeya Range Forest Reserves

S/N	Family	Functional group of bird species						
		I	G	N	C	F	M	PC
1	Acrocephalidae	1	0	0	0	0	0	-
2	Ardeidae	3	0	0	3	0	0	IC
3	Cisticolidae	2	0	1	0	0	0	IN
4	Columbidae	2	3	1	0	1	0	IGNF
5	Corvidae	1	1	0	1	1	0	IGCF
6	Estrildidae	3	5	0	0	0	0	IG
7	Hirundinidae	1	0	1	0	0	0	IN
8	Laniidae	1	0	0	0	0	0	-
9	Lybiidae	1	1	0	0	1	0	IGF
10	Monarchidae	1	0	0	0	0	0	-
11	Meropidae	1	0	0	0	0	0	-
12	Motacillidae	1	0	0	0	0	0	-
13	Nectariniidae	4	0	5	2	1	0	INCF
14	Muscicapidae	3	0	0	1	1	0	ICF
15	Passeridae	1	1	0	0	1	1	IGFM

(Table 6). Continued.

S/N	Family	Feeding guild of bird species						
		I	G	N	C	F	M	PC
16	Phylloscopidae	3	0	1	0	0	0	IN
17	Picidae	1	0	0	0	0	0	-
18	Ploceidae	1	1	1	0	0	0	IGN
19	Sturnidae	3	3	2	0	3	0	IGNF
20	Zosteropidae	1	1	0	0	1	0	IGF
21	Pycnonotidae	1	1	1	0	1	0	IGCF
22	Scopidae	1	0	0	1	0	1	ICM
	Total	37 (43%)	17 (18%)	13 (14%)	8 (10%)	11(12%)	2(3%)	-

G = granivore; N = nectarivore C = carnivore; F = frugivore; M = generalist; PC = possible combination) combinations such as INCF, ICF, IGFM, IGF, and IN were also observed in MRFRs (Table **6**). Moreover, the number of bird species differed significantly between functional groups (H = 34.38, p 0.00001). Further analysis using Dunn's multiple comparison indicated a significant difference in the number of bird species between insectivore and granivore, insectivore and nectarivore, insectivore and carnivore, insectivore and frugivore, and insectivore and generalist (Table **7**). All other pairs were not statistically significantly different in terms of the overall number of bird species (Table **7**).

Table 7: Dunn's Multiple Comparison of Overall Number of Bird Species in Six Functional Groups Recorded from Mbeya Range Forest Reserves. Asterisk (*) on *p*–Value Indicates Significant Different at p < 0.05

Functional group	*p*–value
Insectivore vs Granivore	< 0.0001*
Insectivore vs Nectarivore	< 0.0001*
Insectivore vs Carnivore	< 0.0001*
Insectivore vs Frugivore	< 0.0001*
Insectivore vs Generalist	< 0.0001*
Granivore vs Nectarivore	0.6789
Granivore vs Carnivore	0.2217
Granivore vs Frugivore	0.7797
Granivore vs Generalist	0.0263*
Carnivore vs Frugivore	0.3461
Carnivore vs Generalist	0.3171
Frugivore vs Generalist	0.0521

DISCUSSION

Despite being the first study to inventory bird species in MRFRs, it described the community structure, functional groups, and IUCN conservation status of birds. Based on the findings of this study, it may be established that MRFRs are biologically richer in terms of bird species. This could be due to the habitat heterogeneity of the Mbeya range forests. Habitat heterogeneity is a vital ecological determinant of species richness [15,24]. Moreover, heterogeneous vegetation that provides abundant food resources and suitable roosting and breeding sites seems to attract birds in MRFRs [5,15]. Compared to other forest areas in MRFRs, Idugumbi had a high number of bird species, abundance, diversity, evenness, and Margalef index. This could be facilitated by an intact ecosystem structure with fewer prevailing anthropogenic disturbances [8,20]. Aside from being densely forested, Idugumbi has a dense tree cover, abundant understory flora, and a multi–layered floral structure that benefits bird communities. Thus, high native tree diversity, multi-layered vegetation structure, and fewer human disturbances may have influenced high bird abundance and species composition in Idugumbi. Further, this might have contributed to the significant difference in species diversity between Idugumbi and other study areas in MRFRs. Apart from Idugumbi, Muvwa forest area also showed a high relative abundance of birds. This could be due to its natural vegetation structure dominated by large tree cover of different heights and canopy sizes. Because of this, Idugumbi and Muvwa forests show less dissimilarity in terms of bird species compositions. In general, both Idugumbi and Muvwa forest areas are less disturbed. These findings are supported by previous studies that claim that birds tend to occupy heathy forests [4,7]. Furthermore, Dale *et al*.

[11] highlighted that forest bird species are more affected when habitat is lost or the forest ecosystem structure is altered. When such changes persevere, some bird species composition and/ or abundance may decrease [8,9] and eventually become threatened [10,11]. Because of this, bird species have been used as environmental indicators [3,4]. In view of that, monitoring bird species composition in MRFRs may serve as biological indicator for the ecosystem health of the forest reserves.

The rapid increase in the global human population and swift development have threatened natural forest ecosystem resilience and bird species [7,9]. Urbanization, including the development of MZRH and household infrastructures nearby the Mt. Loleza forest reserve, threatens its ecosystem structure. Also, roadways and uncontrolled picnic activities in the Mt. Loleza forest jeopardize the ecosystem's health. These anthropogenic deeds have opened and fragmented the forest compared to other forest areas in the MRFRs. It also has limited native plant species mixed with invasive non-native tree species such as Eucalyptus *spp.* and Pinus *spp*. In general, the Mt. Loleza forest has several degraded forest patches. These could be the reasons for the low relative abundance of birds in Mt. Loleza compared to Idugumbi and Muvwa [19,22]. Apart from Mt. Loleza forest, the lowest relative abundance of birds was observed in Kawetire forest. This might be due to limited plant diversity, lack of multi–layered vegetation structure, poor canopy cover, and understory vegetation [27]. The poor forest ecosystem structure of Kawetire does not offer suitable breeding and roosting sites or diverse food sources for birds [8,11]. This forest differs from other forest areas because it is dominated mostly by non-native plants, i.e., *C. lustanica, E. maidenii, P. patula, P. canariensis,* and *P. radiate*.

The study shows that there is a diverse functional group of bird species in MRFRs. Insectivores (bird species that feed on insects, such as grasshoppers, ants, bees, beetles, termites, flies, butterflies, bugs, locusts, mosquitoes, dragonflies, wasps, etc., e.g. swallows, swifts, flycatchers), frugivores (fruit–eating specialists, such as some finches), nectarivores (birds that feed on flower nectar, such as sunbird. However, it was observed that MRFRs are rich in insectivore, granivore, and nectarivore bird species. Previous studies indicate that insectivores are the dominant guild of birds across the world [10,22]. This is similar to this study's findings that show insectivores are the most dominant functional groups of birds in MRFRs. Other earlier studies, for instance, Tchoumbou *et al*. [22] found insectivores prevailing in the Talangaye rainforest, Southwest Cameroon. Leo *et al*. [10] showed that half of the observed birds were insectivores in the Western Carpathians (in Poland) and in Slovakia.

Hence, to save bird species, insect diversity should be maintained as most bird species raise their young on insects. Nevertheless, ongoing anthropogenic activities, e.g., logging and forest fires in MRFRs, may affect insect diversity and other resources required by birds for living [2,21]. Despite the fact that frugivore birds are less abundant in MRFRs, they are still important as they disperse seeds [14]. Therefore, the findings of this study illustrate the importance of MRFRs as potential significant refuges for the specialized functional groups, such as insectivores, nectarivores, and granivores.

Overall, the difference in bird species composition, diversity, relative abundance, and functional groups in the four studied forest areas infers their dissimilarities in terms of habitat conditions. The study further shows the necessity for detailed bird inventories as there are many areas in Africa that are yet to be surveyed, particularly in Tanzania. In addition to revealing bird community structure, the study increases awareness of the importance of MRFRs for biodiversity conservation. Thus, conservation of MRFRs is imperative in order to protect bird species and their breeding and roosting sites.

CONCLUSION

The study emphasizes that appropriate land–use practices adjacent to MRFRs must be put in place to protect the forests. Protection of MRFR habitats could enhance the breeding and roosting sites of bird species. This is also beneficial for migratory and resident bird species [12]. In addition, conservation plans for MRFRs should be identified and prioritized, and sites used by birds should be protected to ensure their survival. Forest fires, as well as the harvesting of poles, fuelwood, and other forest products, may result in a loss of plant diversity in MRFRs. Therefore, the development of buffer zones should be made where villagers would be allowed to collect firewood, medicinal plants, and other forest products for their immediate needs. Nonetheless, they should be limited to such zones and not allowed to encroach on reserve areas, particularly on Mt. Loleza, where human activities predominate.

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DECLARATION OF COMPETING INTEREST

Authors declare that there is no competing interests with any one.

APPENDIX

Appendix 1:

Table A.1: Bird Species, IUCN Conservation Status and Functional Group

S/N	Common name	Scientific name	IUCN status	functional groups					
1	Olive sunbird	*Cyanomitra olivacea*	LC					Nectarivore	
2	African paradise flycatcher	*Terpsiphone viridis*	LC	Insectivore					
3	Brown wood warbler	*Phylloscopus sibilatrix*	LC	Insectivore					
4	African grey woodpecker	*Dendropicos goertae*	LC	Insectivore					
5	Superb starling	*Lamprotornis superbus*	LC	Insectivore		Granivore	Frugivore		
6	Forest robin	*Stiphrornis erythrothorax*	LC	Insectivore					
7	Mountain yellow warbler	*Iduna similis*	LC	Insectivore					
8	Cattle egret	*Bubulcus ibis*	LC	Insectivore	Carnivore				
9	Eastern green tinkerbird	*Pogoniulus simplex*	LC	Insectivore		Granivore	Frugivore		
10	Pied crow	*Corvus albus*	LC	Insectivore	Carnivore	Granivore	Frugivore		
11	Yellow-throated woodland warbler	*Phylloscopus ruficapilla*	LC	Insectivore					
12	Red-winged starling	*Onychognathus morio*	LC	Insectivore		Granivore	Frugivore	Nectarivore	
13	Rattling cisticola	*Cisticola chiniana*	LC	Insectivore				Nectarivore	
14	Common waxbill	*Estrilda astrild*	LC	Insectivore		Granivore			
15	Laughing dove	*Spilopelia senegalensis*	LC	Insectivore		Granivore			
16	House sparrow	*Passer domesticus*	LC	Insectivore		Granivore	Frugivore		Generalist
17	Amethyst sunbird	*Chalcomitra amethystina*	LC	Insectivore				Nectarivore	
18	Yellow-browed warbler	*Phylloscopus inornatus*	LC	Insectivore				Nectarivore	
19	Yellow white-eye	*Zosterops anderssoni*	LC	Insectivore		Granivore	Frugivore		

20	Common bulbul	*Pycnonotus barbatus*	LC	Insectivore		Granivore	Frugivore	Nectarivore	
21	Ring-necked dove	*Streptopelia capicola*	LC	Insectivore		Granivore	Frugivore	Nectarivore	
22	African golden weaver	*Ploceus subaureus*	LC	Insectivore		Granivore		Nectarivore	
23	Little bee-eater	*Merops pusillus*	LC	Insectivore					
24	Tawny-flanked prinia	*Prinia subflava*	LC	Insectivore					
25	Ashy starling	*Lamprotornis unicolor*	LC	Insectivore		Granivore	Frugivore	Nectarivore	
26	Spotted flycatcher	*Muscicapa striata*	LC	Insectivore					
27	Red-billed firefinch	*Lagonosticta senegala*	LC			Granivore			
28	Black headed heron	*Ardea melanocephala*	LC	Insectivore	Carnivore				
29	Little egret	*Egretta garzetta*	LC	Insectivore	Carnivore				
30	Striped pipit	*Anthus lineiventris*	LC	Insectivore					
31	African Firefinch	*Lagonosticta rubricata*	LC	Insectivore		Granivore			
32	Grey-backed fiscal	*Lanius excubitoroides*	LC	Insectivore					
33	Jameson's firefinch	*Lagonosticta rhodopareia*	LC	Insectivore		Granivore			
34	African mourning dove	*Streptopelia decipiens*	LC			Granivore			
35	Barn swallow	*Hirundo rustica*	LC	Insectivore				Nectarivore	
36	White browed robin chat	*Cossypha heuglini*	LC	Insectivore	Carnivore		Frugivore		
37	Malachite sunbird	*Nectarinia famosa*	LC	Insectivore				Nectarivore	
38	Scarlet chested sunbird	*Chalcomitra senegalensis*	LC	Insectivore	Carnivore			Nectarivore	
39	Black and white mannikin	*Spermestes bicolor*	LC			Granivore			
40	Eastern double collared sunbird	*Cinnyris mediocris*	LC	Insectivore	Carnivore			Nectarivore	
41	Hamerkop	*Scopus umbretta*	LC	Insectivore	Carnivore				Generalist

Appendix 2:

Table B.1: Bird Species, Families, Abundance and Relative Abundance

S/N	Scientific name	Family	No. of individuals recorded in four study sites				Abundance	Relative abundance
			Idugumbi	Muvwa	Kawetire	Mt. Loleza		
1	*Cyanomitra olivacea*	Nectariniidae	6	0	2	4	12	1.141
2	*Terpsiphone viridis*	Monarchidae	8	0	3	10	21	1.996
3	*Phylloscopus sibilatrix*	Phylloscopidae	3	12	0	0	15	1.426
4	*Dendropicos goertae*	Picidae	7	5	4	1	17	1.616
5	*Lamprotornis superbus*	Sturnidae	8	5	10	9	32	3.042

6	*Stiphrornis erythrothorax*	Muscicapidae	9	11	7	5	32	3.042
7	*Bubulcus ibis*	Ardeidae	11	8	0	5	24	2.281
8	*Pogoniulus simplex*	Lybiidae	9	4	0	2	15	1.426
9	*Corvus albus*	Corvidae	12	7	0	9	28	2.662
10	*Phylloscopus ruficapilla*	Phylloscopidae	7	11	14	0	32	3.042
11	*Onychognathus morio*	Sturnidae	10	3	0	13	26	2.471
12	*Cisticola chiniana*	Cisticolidae	23	10	18	5	56	5.323
13	*Estrilda astrild*	Estrildidae	9	3	0	0	12	1.141
14	*Spilopelia senegalensis*	Columbidae	13	15	7	3	38	3.612
15	*Passer domesticus*	Passeridae	7	8	13	11	39	3.707
16	*Phylloscopus inornatus*	Phylloscopidae	7	0	3	14	24	2.281
17	*Zosterops anderssoni*	Zosteropidae	15	17	0	7	39	3.707
18	*Pycnonotus barbatus*	Pycnonotidae	13	22	16	17	68	6.464
19	*Streptopelia capicola*	Columbidae	6	13	0	6	25	2.376
20	*Ploceus subaureus*	Ploceidae	16	9	8	8	41	3.897
21	*Merops pusillus*	Meropidae	11	7	4	2	24	2.281
22	*Prinia subflava*	Cisticolidae	8	12	0	5	25	2.376
23	*Lamprotornis unicolor*	Sturnidae	4	0	10	8	22	2.091
24	*Muscicapa striata*	Muscicapidae	9	0	2	12	23	2.186
25	*Lagonosticta senegala*	Estrildidae	14	21	9	6	50	4.753
26	*Egretta garzetta*	Ardeidae	11	6	9	13	39	3.707
27	*Anthus lineiventris*	Motacillidae	7	5	3	0	15	1.426
28	*Lagonosticta rubricata*	Estrildidae	9	11	13	14	47	4.468
29	*Lagonosticta rhodopareia*	Estrildidae	3	4	9	0	16	1.521
30	*Cossypha heuglini*	Muscicapidae	14	3	6	9	32	3.042
31	*Nectarinia famosa*	Nectariniidae	13	6	5	0	24	2.281
32	*Chalcomitra senegalensis*	Nectariniidae	5	3	0	7	15	1.426
33	*Spermestes bicolor*	Estrildidae	10	9	0	5	24	2.281
34	*Scopus umbretta*	Scopidae	2	0	5	0	7	0.665
35	*Iduna similis*	Acrocephalidae	0	14	11	9	34	3.232
36	*Streptopelia decipiens*	Columbidae	0	2	0	5	7	0.665
37	*Hirundo rustica*	Hirundinidae	0	3	7	5	15	1.426
38	*Cinnyris mediocris*	Nectariniidae	0	4	3	0	7	0.665
39	*Chalcomitra amethystina*	Nectariniidae	0	0	5	10	15	1.426
40	*Ardea melanocephala*	Ardeidae	0	0	1	4	5	0.475
41	*Lanius excubitoroides*	Laniidae	0	0	4	6	10	0.951

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