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ORIGINAL RESEARCH

Unique bird diversity in an Ethiopian church forest

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Abstract

Today, most of Ethiopia's church forests are small forest patches surrounded by a degraded and anthropogenically modified landscape, mostly arable land. Nevertheless, these forest islands may still provide valuable habitats for typical forest species. It remains questionable whether these habitat remnants provide sufficient resources for forest species to successfully reproduce and persist in the long run. In this study, we assessed bird species based on point-counts in and around Tara Gedam Church Forest in northern Ethiopia. We observed birds in typical natural evergreen Afromontane forest (forest interior and forest edge) and in anthropogenic habitats, the semi-natural shrublands, agricultural land, and Eucalyptus tree plantations. We assigned ecological and behavioural characteristics to each of the bird species observed. Our results point to a specific bird community restricted to the forest interior and characterized by forest generalists and forest specialist birds. Along the forest edge, a mix of forest generalists and species of the open landscape can be found, creating mixed communities with high species overlap. The highest number of species was observed at the forest edge and in semi-natural shrubland, where both, openland and forest species were found. On the other hand, the total number of species in the forest interior was comparatively low, with insectivorous and frugivorous typical forest species. Our results underline the fact that even small forest remnants are important for the conservation of forest species, which do not evade surrogate forest habitats.

Keywords Habitat size · Habitat type · Birds · Traits · Species richness · Species community structure · Surrogate habitat · Forest specialist · Indicator species

Introduction

Worldwide, natural habitats are under severe pressure, as they are converted into agricultural land, tree plantations and settlements on a large scale (Jantz et al. 2015; Maxwell et al. 2016). The demand for cash crops, local demographic pressure and the resulting settlement

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Extended author information available on the last page of the article of land with subsistence farming cause severe transformations and the destruction of natural habitats (Williams 2013; Teucher et al. 2020). This trend particularly affects tropical forests, which have been heavily destroyed during the past decades (Hoang and Kanemoto 2021), especially due to the need for timber for houses and wood as primary source of energy, being perpetual in most countries of Subsahara Africa (Antonínová et al. 2020). As a consequence, resources of the remaining natural forest ecosystems have been excessively used resulting in their overexploitation. This particularly affects small remnant forest patches which are under protection due to cultural reasons and for the conservation of biodiversity (Zegeye 2022).

Ethiopia is particularly negatively affected by severe and large-scale deforestation. Most of the former natural forest has been converted into arable land or pastures. Due to overstocking and the sporadic but very heavy rainfalls, a large part of the landscape of Ethiopia has been degraded and is characterised by severe soil erosion today. A major proportion of Ethiopia's forest exists in the high mountain regions (Kelbessa and Demissew 2014) and is internationally recognised as part of the Eastern Afromontane Biodiversity Hotspot (Mittermeier et al. 2011; Mechalu 2017). Most of the already small forest remnants are continuously shrinking and degrading due to anthropogenic pressure, such as selective logging, collection of dead wood, grazing activities or hunting (Mechalu 2017). The fragmentation and isolation of dry evergreen Afromontane forests in the northern Ethiopia highlands represent a particular case. Human population pressure coupled with the suitability of the forests for agricultural use made this forest severely affected by destruction, which ultimately led to the fragmentation of formerly interconnected forests into small forest patches (Rodrigues et al. 2004; Cordeiro et al. 2007). This applies particularly to the Amhara region in Northern Ethiopia (Wassie et al. 2010).

The long-term persistence of species in such small and degraded habitat remnants is uncertain. Reduced habitat size frequently leads to an increase of negative edge effects and, subsequently, lower habitat quality (Galán-Acedo et al. 2021). This drives the extinction probability of extant local populations of species (Maseko et al. 2020). In addition, effects from demographic and environmental stochasticity are particularly high in such small and isolated populations, hence also triggering local extinctions (Melbourne and Hastings 2008). Furthermore, re-colonisation from neighbouring populations after local extinction is very unlikely in such highly fragmented habitats (Rutt et al. 2020). As a result, a gradual loss of the original species diversity is taking place with a successive vanishing of species, particularly of specialist species in need of specific forest structures and resources for their survival.

The Tara Gedam Church Forest is a remnant of evergreen Afromontane forest in northern Ethiopia and covers an area of 875 ha (Tessfa et al. 2020). The forest patch is located in the South Gondar Zone (Amhara National Regional State) close to Addis Zemen town and grows at an altitude of about 2300 m asl. The region is characterized by uni-modal rainfall (with strong rains from June to August and a dry season from December to April). The Tara Gedam Church Forest is conserved since the presence of the monastery in the 17th century and is protected as State Forest since 1979 (Gedefaw and Soromessa 2014). Inside the forest are houses of monks and nuns, churches, and a school. It provides typical forest resources such as timber for house construction and wood as energy source for cooking, but also serves as pasture for cattle grazing. Thus, despite the existence of tall old trees, the forest is highly disturbed.

To investigate the ecological value of this forest remnant, we recorded bird species inside the natural forest, along the forest edge, and in two open land habitat types around the forest, namely semi-natural shrubland and agricultural land, as well as Eucalyptus tree plantations. We performed point-counts during the dry season in the year 2023. For this purpose, observation points were visited several times and all bird species were visually and acoustically assessed. The observed bird species were grouped according to their ecological and behavioural traits. Based on these data we seek to answer the following questions:

1. Do typical forest bird species still occur in the Tara Gedam Church Forest?
2. Do species numbers and species composition in the forest differ compared to the adjacent anthropogenically modified habitats?
3. Do tree plantations represent potential surrogate habitats for typical forest species?
4. Does ecological performance determine species´ specific responses to habitat types and the transformation of natural into anthropogenically modified habitats?

Materials and methods

Study area

Our study area covers Tara Gedam forest and the surrounding landscape. The study area is located close to Addis Zemen town, northeast of Lake Tana in northern Ethiopia (Fig. 1). The forest is located at an altitude of about 2300 m asl. We collected bird data in the following habitat types: Natural forest interior (FI), Forest edge (FE), Shrubland (mainly without natural vegetation) (SL), Plantation (mainly Eucalyptus trees) (PL), and agricultural land (mainly fields of maize, or grazing areas) (AL). Distances between single observation points were at least 100 m from each other to minimize the effects of autocorrelation (Fig. 1). In our analyses, we combine forest interior and forest edge as forest, and plantation, shrubland, and agricultural land as non-forest habitats.

Bird surveys were conducted using the point count technique according to Bibby et al. (1998). Observation points were established inside the respective habitat type, surrounded by the respective ecosystem, to minimize potential edge effects. This did not apply for the forest edge points, which were intentionally positioned at the forest-open land ecotone. During point counts, all birds heard and seen in a radius of about 50 m were recorded and noted. Point counts were undertaken during morning (6–10 am) and during later afternoon (4–6 pm) for 10 min at each point. Birds flying from behind were not recorded to avoid double counts. This procedure was repeated four times during the dry season. All birds observed were classified into the following guilds: Feeding behaviour (frugivore, granivore, insectivore, nectivore, carnivore, omnivore, necrophagous), and habitat preference, i.e. forest dependency (forest specialist, forest generalist, forest visitor, non-forest species). All raw data are given in Table A1 of Appendix A.

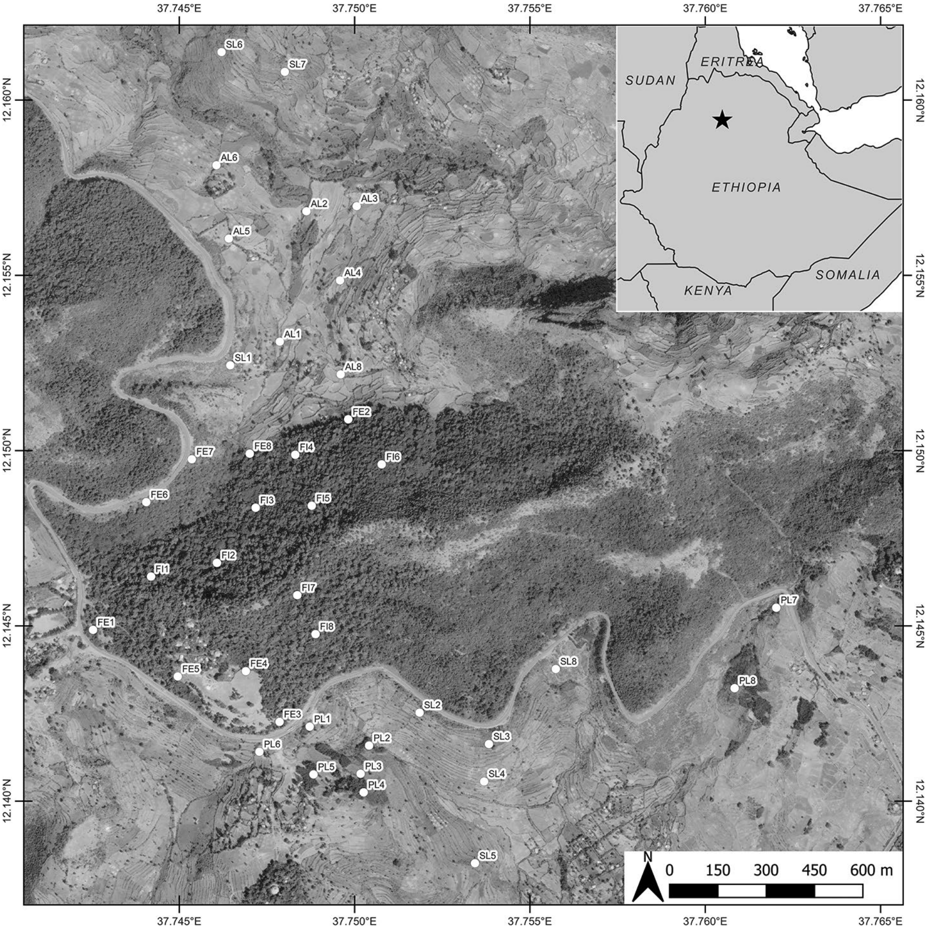

Fig. 1 Study area in northern Ethiopia (star in small inlet map), and the observation points used for point-counting of birds. Abbreviations: FI: forest interior, FE: forest edge, PL: plantation, AL: agricultural land, SL: shrubland

Statistics

We used summary tables of bird occurrences and record numbers in the five habitat types. The Chao1 estimator (Chao 1984) served to estimate species richness. We estimated community evenness from the Pillou index $E = E^H/S$, where H is the Shannon diversity and S the species richness. Two-way cluster analysis (Ward method) in combination with principal coordinates analysis and two-way Permanova (Bray-Curtis similarities) served to infer significant differences in species composition across habitat types.

Table 1 Summary data of bird counts, observed and estimated (Chao1) richness, evenness, and overlap between the five habitats. Upper triangle: species jointly occurring. Lower triangle: proportion of overlap in richness (Jaccard similarity). Restricted to: number of species restricted to on habitat type or group of habitat types

Variable	FI	FE	PL	AL	SL
Records	393	392	210	319	465
Species richness	39	50	36	46	59
Species richness	64		59		59
Chao1	46	52	37	46	60
Chao1	66		59		60
Evenness	0.45	0.74	0.74	0.73	0.64
Restricted to	8	9	3	12	15
Restricted to	23		17		15
Overlap	**FI**	**FE**	**PL**	**AG**	**SL**
FI		25	15	13	21
FM	0.39		23	22	29
PL	**0.25**	0.37		23	26
AG	**0.18**	**0.30**	0.40		30
SR	**0.27**	**0.36**	**0.38**	**0.40**	

FI: forest interior, FE: forest edge, PL: plantation, AL: agricultural land, SL: shrubland

Significant differences in species overlap are given in bold type (Permanova, Jaccard similarity, Bonferroni corrected $P<0.01$)

Table 2 Summary table of species richness of 11 bird guilds across five habitat types

Guild	FI	FE	PL	AL	SL	FI+FE	PL+AL+SL	Overlap forest - non forest	Overlap forest - plantation	Re-stricted to forest	Total
Forest generalists	15	15	10	10	16	22	20	15	10	7 (31%)	27
Forest specialists	4	1	0	0	0	4	0	0	0	4 (100%)	4
Forest visitors	17	24	18	22	27	27	35	17	10	10 (37%)	45
Non-forest species	3	10	8	14	16	11	28	9	5	2 (18%)	30
Birds of prey	3	3	2	1	0	5	2	1	1	4 (80%)	6
Carrion eaters	0	2	2	0	0	2	2	1	1	1 (50%)	3
Frugivores	7	10	7	10	12	13	13	10	6	3 (23%)	16
Granivores	0	4	5	11	7	4	14	4	3	0 (0%)	14
Insectivores	28	29	19	22	38	38	48	24	13	14 (37%)	62
Nectarivores	0	1	0	2	2	1	3	0	0	1 (100%)	4
Omnivores	1	1	1	0	0	1	1	1	1	0 (0%)	1
Total	39	50	36	46	59	64	83	41	25	23 (36%)	106

Percentages refer to the percentage of forest species not recorded elsewhere

FI: forest interior, FE: forest edge, PL: plantation, AL: agricultural land, SL: shrubland. Forest includes FI and FE, non-forest PL, AL, and SL

Results

We recorded a total of 1779 individuals belonging to 106 species in the five habitat types analysed (Tables 1 and 2). Chao1 estimator pointed to three additional, so far undetected species (Table 1); in turn, more than 95% of the occurring species should have been spotted. Evenness of the species dominance order was high, except for forest interior (E = 0.45, Table 1). Three species were dominant, and cluster analysis identified them as being mainly forest dwelling: *Oriolus monacha* (118 records), *Tauraco leucotis* (41), and *Dryoscopus gambensis* (40). In turn, the frugivore *Agapornis taranta* was found to be specific to forest edge, agricultural land, and shrubland. The carrion eater *Gyps ruepellii* appeared to be specific to plantations, among two other bird species (Fig. 2).

Only a small number of habitat generalist species occurred in all five habitat types (9 of the 106 species, i.e. 8.5% of all species), all of them being forest visitors. 23 species (22% of total richness) were restricted to forest interior or forest edge, eight of them occurring only in forest interior. In turn, 41 species (i.e. 64% of the forest inventory) overlapped between forest and non-forest habitats (Table 2), and as many as 83 species were found in habitats outside the natural forest (78% of all species). Of the 64 species observed in the forest and at its edges, only 25 (39% of the forest inventory) were also detected in plantations. With 36 recorded and 37 estimated species, plantations were the most impoverished habitat type in terms of species (Tables 1 and 2), and only three species (*Bucorvus abyssinicus*, *Gyps africanus*, *Rhinopomastus minor*) were exclusively recorded there.

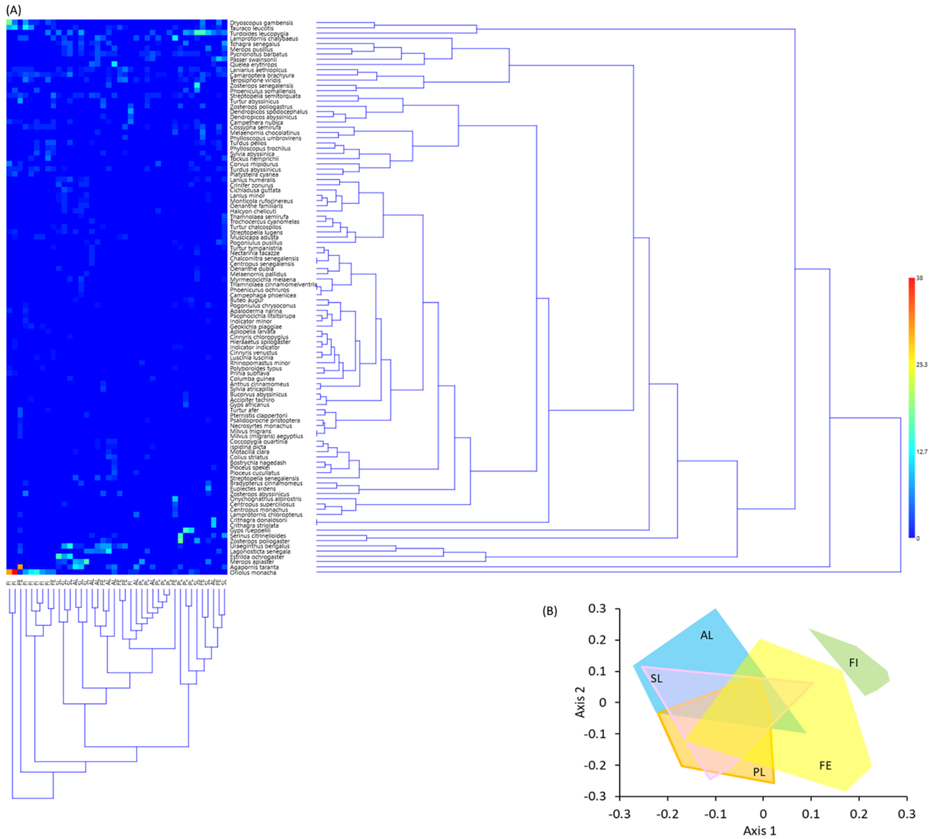

Fig. 2 **(A)** Ward two-way cluster analysis based on species total records including heat map (red: strong, blue weak associations). **(B)** First two axes of principle coordinates analysis (Bray-Curtis similarities of records). FI: forest interior, FE: forest edge, PL: plantation, AG: agricultural land, SL: shrubland

Species overlap among the five habitat types was moderate and did not exceed 40% (Table 1). It was lowest (18%) between forest interior and agricultural land (13 overlapping species, Table 1). Among the highest species overlap (39%) occurred between forest interior and forest edge (25 species, Table 1). Similarly high overlaps (38–40%) were recorded for all combinations between shrubland, plantations, and agricultural land (Table 1). Consequently, cluster and principal coordinates analyses did not clearly detect habitat specific bird communities (Fig. 2A). However, the analyses separated forest interior from all other habitat types, while forest edges were intermediate between forest interior on the one hand and open landscapes and plantations on the other (Fig. 2). Hence, forest edge species composition was a mix of forest interior and non-forest species, exhibiting substantial overlap with all other habitats (Table 1).

Permanova detected significant differences in guild composition among the five habitat types (Table 3). Species known to be forest specialists were indeed exclusively found in the forest (Table 2). Forest generalists and visitors occurred in most other habitats, too (Table 2). 11 of the 60 non-forest species were also recorded in the forest (Table 2). With respect to feeding ecology, we found 23% of the frugivorous and 37% of the insectivorous species to be restricted to the forest (Table 2). However, 10 of the frugivores (77%) and 24 of the insectivorous (39%) forest species were also found outside the forest (Table 2). Seven of the nine Accipitridae species occurred in the forest (78%), while only four species (44%) were found also or exclusively outside (Table 2).

Discussion

The species composition analysed for this natural forest in northern Ethiopia clearly differed from species compositions found in all other habitats assessed. Typical forest species were found nearly exclusively in the forest interior and not in any other habitat type. Even along the forest edge, we found only one typical forest specialist. This coincides with other studies on the habitat preferences of bird species in Afrotropical forest environments (Mulwa et al. 2012, 2021). For Tara Gedam Church Forest, Tessfa et al. (2020) also showed strongest difference in bird species composition between the forest and the open agricultural landscape. Furthermore, the community observed along the forest edge consists of a mix of forest generalists and inhabitants of open land species and is intermediate between the forest interior and the mostly open anthropogenic ecosystems.

Although the forest interior was unique in terms of community composition, species richness was comparatively low. Hence, only 39 species were observed in the forest interior, while for example 50 species were found along the forest edge and even 59 in shrubland. In general, comparatively low numbers of species but most of them being specialists have already been found earlier in undisturbed ecosystems like natural tropical forests (Mulwa et al. 2021), most likely due to more homogenous habitat structures. This differs in ecosystems characterised by disturbances and the resulting coexistence of different structures and

Table 3 Two-way Permanova separated birds with specific habitat requirements and food type among the five habitat types

Variable	df	F
Habitat	3	1.18*
Food	6	1.52***
Interaction	18	0.35

Permutation significances: *: $P<0.05$; ***: $P<0.001$

resources, which can quickly accelerate the accumulation of species, as demonstrated for butterflies (see Gaigher et al. 2021). In addition, the Tara Gedam Church Forest is a forest patch of limited size. Thus, only a fraction of the original structural and resource diversity – as provided by an intact large forest block – is available. This is of particular relevance as diversity and relative abundance of birds strongly depend on a variety of food resources, vegetation structures and the availability of diverse nesting material (Gil-Tena et al. 2007; Deppe and Rotenberry 2008, Girma Mengesha and Afework Bekele 2008, Wilcoxen et al. 2015, Tessfa et al. 2020).

Principle coordinates and cluster analysis revealed the mediating position of the forest edge community between forest interior and open land habitats including plantations. Indeed, species composition at forest edges was ecologically very diverse. Thus, numerous forest generalists and forest visitors were found here, as well as open land species. However, the typical forest specialist species were missing at the forest edge. This underlines the negative edge effects for such forest specialists and highlights the negative effects of habitat fragmentation as shown in various studies (Kurosawa and Askins 1999; Pardini et al. 2009; Poulin and Villard 2011). However, an accumulation of species richness and abundance, and the missing of forest specialists along the forest edge has been also observed in previous studies and for different groups of organisms (Mulwa et al. 2021, Gaigher et al. 2021). Thus, these ecotones provide numerous ecological niches, resulting in a high total number of species, but in parallel, these habitats seem to be too disturbed for species with specific ecological demands, and thus exclusively found in intact forest interior (Poulin et al. 2011).

Numerous nectivorous and frugivorous species were observed in the forest, while the bird community in anthropogenic landscapes were dominated by omnivorous and granivorous species, as also observed in other Afrotropical forests (e.g. Ulrich et al. 2016, 2018). This has also been confirmed in previous studies, and even in forest islands characterised by heavy anthropogenic disturbance, where omnivorous species show great persistence, while frugivorous and nectivorous forest specialists rapidly disappear (Ulrich et al. 2016, 2018).

Our results strongly underline the fact that remnants of Afromontane forest are highly crucial for the conservation of the overall species diversity, as highlighted by the existence of a number of forest specialist species in the Tara Gedam Church Forest. The comparatively low number of species found inside the forest suggests that such a small habitat size may not support the persistence of numerous species. This study also demonstrates once more that habitats with forest-like habitat structures, such as Eucalyptus plantations in our case, are no surrogates for typical forest species, as already shown for birds and other taxa (cf. Habel et al. 2018; Schmitt et al. 2020). In Eucalyptus plantations, we observed only 36 bird species in our study, none of which being a typical forest specialist. In general, Eucalyptus plantations are already known to be particularly negative for bird diversity because the allelopathic effects where their leaves negatively affect the understory vegetation; this in turn negatively affects insect diversity and subsequently the occurrence of many (insectivorous) bird species (Esayas and Bekele 2011).

The availability of resources is one of the factors determining the distribution and accumulation of species in different habitats (Borghesio and Laiolo 2004; Tessfa et al. 2020). However, the observations made in our study were limited to the dry season. A comparison with the situation during the rainy season is unfortunately not possible on the basis of these collected data. Tesfahun and Ejigu (2022) showed that the increased frequency of fruiting and flowering trees in forests (both well synchronized with seasonality) contributed to the presence of more bird species. Thus, their occurrence accumulates where many sources are available (Fleming 1992). Similarly, bird diversity in farmland also strongly depends on resource availability (e.g. *Triticum asestivum*, *Zea mays*) (Tsegaye Megersa et al. 2016, Tessfa et al. 2020). Even though our study is just a small snapshot covering a short period of time (the end of the dry season, one single forest patch), the results strongly underline the great value of the remaining forest remnants in Ethiopia for biodiversity conservation.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10531-024-02842-9.

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Author contributions J.C.H., T.S. and M.T. developed the study design, A.G. and M.M. collected and compiled the data, W.U. did statistical analyses, all contributed while interpreting the results and writing this article.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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