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Seasonal use of remnant forest fragments by understorey forest birds in the Uluguru Mountains, Tanzania: a conservation priority

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Forest fragmentation can lead to extinctions of some species at local levels and is eroding bird diversity at an increasing rate. While there is information on the distribution of forest bird species in most of the Eastern Arc Mountain forests, some forests, particularly the smaller fragments, have not been adequately surveyed. Using mist netting we surveyed avifauna in some of the poorly known forests (12.5–25 ha) located 320–1 300 m above sea level in the Uluguru Mountains in order to address their conservation importance. Proportions of seasonal altitudinal migrants were significantly higher in these lower-altitude forests during the cold season than the hot season. The results suggest that these forests support bird species of conservation concern, most of which are forest dependent and some of which make seasonal movements between high-altitude montane forests and lowland/foothill forests. These forests are important cold-season habitat of altitudinal migrants and further fragmentation should be halted as a matter of regional and global priority.

Utilisation saisonnière des parcelles rémanentes de forêt par les oiseaux de sous-bois de la montagne Uluguru en Tanzanie: une priorité de préservation

La fragmentation des forêts peut conduire à l'extinction de certaines espèces à l'échelle locale et érode la diversité aviaire à une vitesse croissante. Tandis que l'on trouve des informations sur la distribution des différentes espèces aviaires forestières pour la majorité des forêts de l'Arc montagneux oriental, certaines forêts, en particuliers les fragments les plus petits, n'ont pas été suffisamment étudiés. A l'aide de filets japonais, nous avons étudié l'avifaune de certaines de ces forêts peu connues (12,5 ha – 25 ha), situées entre 320 m et 1 300 m d'altitude dans les montagnes Uluguru, afin de déterminer leur niveau de préservation. La proportion de migrateurs saisonniers d'altitude s'est révélée bien plus importante dans ces forêts de basse altitude lors de la saison froide que durant la saison chaude. Les résultats suggèrent que ces forêts abritent des espèces aviaires dont la situation de conservation est préoccupante, dépendantes pour la plupart des forêts et dont certaines effectuent des migrations saisonnières entre les forêts montagneuses de haute altitude et les forêts de plaines/contreforts. Ces forêts sont un habitat de saison froide d'importance pour les migrateurs d'altitude et l'arrêt de leur fragmentation devrait être une priorité aussi bien régionale que globale.

Keywords: altitudinal gradient, altitudinal migration, bird distribution, conservation, fragmentation, mist-netting

Introduction

Tropical forests are facing alarming rates of forest fragmentation and some are already archipelagos of small fragments (Gascon et al. 2000). As forests become fragmented into smaller fragments there is a reduction in the number of species and increase in the possibility of local extinction of bird species (Newmark 1991; Turner 1996). This is particularly so for forest-dependent species whose survival depends on the presence of the forest (Newmark 1991).

In the Uluguru Mountains, as in the other Eastern Arc Mountains, lowland forests have been fragmented by agricultural practices leading to few remaining forest fragments at the mid and low altitudes (Burgess et al. 2002). A continuous forest spanning the entire altitudinal gradient is lacking and the forest fragments constitute inland 'islands' surrounded by a 'sea' of farmland. Given that forest fragmentation can dramatically impede the movements of many species (Lawrence and Goosem 2008; Newmark et al. 2010) it is possible that loss of the forest in the lower altitudes in the Uluguru Mountains has already affected movements of birds that make seasonal altitudinal movements.

In the Uluguru Mountains there are two main seasons: the cold season from April to September, and the hot season from October to May. As the forest birds move from high- to low-altitude forests during the cold season and to montane and upper-montane forests during the hot season to breed, the forest in which they move through should ideally be intact and contiguous (Werema 2007).

In the Uluguru and other Eastern Arc Mountains, altitudinal migrations of birds have been discussed by Stuart (1983),

Stuart and Jensen (1985), Stuart et al. (1993), Burgess and Mlingwa (2000), Cordeiro et al. (2006) and Werema (2007, 2015, 2016a, 2016b). These migrations involve the annual movement of some or all individual birds in a population between breeding and non-breeding grounds that differ in altitude (Stuart 1983). Breeding grounds are normally at high altitudes and the birds spend the non-breeding season in the low altitudes (Dowsett-Lemaire 1989; Burgess and Mlingwa 2000). These altitudinal migrants are forest-dependent species and the influence of forest fragmentation on their seasonal movements is not well understood. While there is background information on the distribution of forest birds in the Uluguru Mountains (Stuart and Jensen 1985; Svendsen and Hansen 1995), the extensive loss of forest in low- and mid-altitudes and fragmentation (Burgess et al. 2002) suggests an urgent need to undertake avifaunal studies in those forest fragments.

The present research questions were (1) which forest bird species are using these forest fragments? (2) Due to seasonal altitudinal migrations of some forest birds, are there seasonal differences in abundance and diversity of forest birds in these forest fragments? (3) What proportion of the species found in these fragments are seasonal altitudinal migrants? Through these questions we then discuss the implications of seasonal altitudinal distribution and seasonal changes of forest birds in the fragmented landscapes of the Uluguru Mountains. We use the results of this study to address the conservation role of the remnant forest fragments in the lower altitudes as cold-season non-breeding habitats for seasonal altitudinal migrants.

Materials and methods

Study area

The study area is along an altitudinal gradient on the eastern slopes of the Uluguru Mountains, central-eastern Tanzania. These mountains form one of the component blocks of the Eastern Arc Mountains and are recognised for a high degree of endemic vertebrate and plant taxa (Burgess et al. 2002, 2007; Rovero et al. 2014). For example, among the Eastern Arc Mountains of Tanzania, the Uluguru Mountains rank second in the number of endemic vertebrate species (Rovero et al. 2014). Due to extensive forest loss in the Uluguru Mountains, mainly as a result of agriculture (Burgess et al. 2002), the lowest altitudes of the forest vary along the mountain range. Most of the forest is found above 1 000 and 1 500 m above sea level [asl] in the northern and southern sections of the Uluguru Mountains, respectively. There are few remaining forest fragments, particularly on the eastern side of the Uluguru Mountains, some of which are now protected as forest reserves. Among these, we selected three that were both small in size and poorly surveyed ornithologically but also located at varying altitudes. Their sizes and mean altitudes above sea level are Milawilila (12.8 ha, 350 m), Kisewe (15.6 ha, 550 m) and Kilomwe (25 ha, 1 300 m) (see Figure 1). These forests are believed to have been part of a larger forest that covered the entire altitudinal gradient from 220 to 2 500 m in the Uluguru Mountains (Pócs 1976). All these forests now fall within a farmland matrix and are locally protected by their respective village governments.

The eastern Uluguru Mountains receive more than 3 000 mm of rainfall annually (Burgess et al. 2002). Most rain falls during April and May. In July and August precipitation is reduced, especially on lower slopes and in the foothills. Heavy rainfall in April is normally associated with a decrease in temperatures leading to a cold season that continues until September. From October onwards temperatures rise leading to a hot season that ends in March.

Understorey bird sampling

Understorey mist netting was used to examine the avifauna at each of the three forest sites. We used mist nets because they provide an efficient and reliable estimate of relative abundance of birds (Karr 1981). Fifteen mist-nets (12 m, 2.6 m high, 16 mm mesh, four shelves) were used at each forest site in January and July 2011 during the hot and cold seasons, respectively. The nets were erected forming a net line (total length 180 m) for 36 daylight hours, and operated from dawn to dusk for three consecutive days. Net locations and sampling effort were maintained during each season. All birds captured in mist nets were ringed and then released at site of capture.

Vegetation sampling

To assess habitat quality for understorey birds in each forest fragment, a 280-m-long transect with 10 equally spaced 10 m $\times$ 10 m plots was established. This transect ran through the mist net locations and was conducted after the mist nets were removed. The first sample plot in each transect was randomly located and the following nine plots were then laid down 20 m apart along the transect. Within each plot, trees of at least 10 cm diameter at breast height (dbh $\geq$ 10 cm) were counted and identified to species level. Within each 10 m $\times$ 10 m plot, a 5 m $\times$ 2 m subplot was laid down at one of the corners. In each subplot, numbers of shrubs with dbh $\leq$ 10 cm were counted and determined to species level.

Data analysis

Birds in the study area were divided into two groups: forest-dependent and non-forest-dependent species (Stuart and Jensen 1985; Romdal 2003). Forest-dependent species were further divided into forest specialists (FS species), which are 'true' forest birds of the interior undisturbed forest; and those which are in most cases found in forest strips, gaps and edges (FE species) but may also occur in undisturbed forest. Non-forest-dependent species (NF species) are birds that are found mainly in the farmland matrix, but also enter the forest (Newmark 1991). Forest-dependent species were further grouped into two categories: altitudinal migrants and non-altitudinal migrants. Altitudinal migrants are those species that have been found to make seasonal altitudinal movements in the Eastern Arc Mountains (Stuart 1983; Stuart and Jensen 1985; Burgess and Mlingwa 2000; Werema 2007, 2015a, 2015b). Non-altitudinal migrants are forest-dependent species that have not been recorded to undertake seasonal altitudinal movements.

Given that the focus of the study was to census forest-dependent species, five non-forest-dependent species captured in mist nets were excluded from analysis.

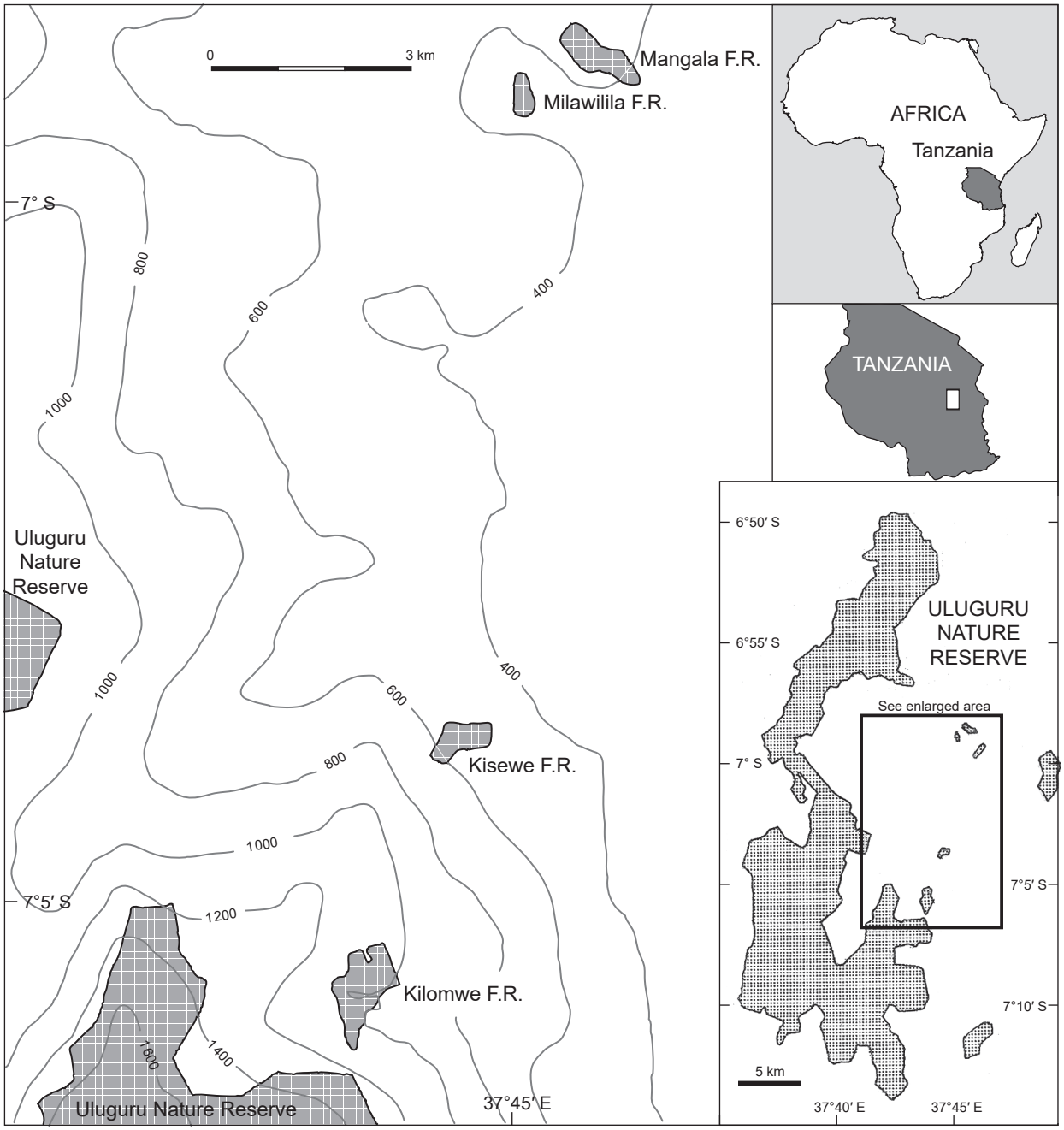


Figure 1: Location of the study sites in the Uluguru Mountains, Tanzania. The larger Uluguru Nature Reserve is located at the top of the mountains in the higher altitudes

These were Black Saw-wing *Psalidoprocne pristoptera*, Brown-hooded Kingfisher *Halcyon albiventris*, Common Bulbul *Pycnonotus barbatus*, Tropical Boubou *Laniarius ferrugineus* and White-browed Robin Chat *Cossypha heuglini*.

Although some species, such as Bar-tailed Trogon *Apaloderma vittatum* and Green Barbet *Buccanodon olivavea*, can forage in the mid and upper strata of the canopy (Newmark 1991), they are also known to forage in the understorey layer (Romdal 2003). Therefore, for simplicity we consider all captures of forest birds as understorey birds. Same-season recaptures were excluded from analysis, whereas those recaptured in the subsequent season were included in analysis.

To identify understorey bird community assemblage similarities and potential species turnover along the altitudinal gradient, we used agglomerative hierarchical clustering based on the Sørensen dissimilarity index for binary data (on an absence–presence matrix of all species sampled). The index is between 0 and 1, where 0 means the two sites have the same species composition (that is they share all

the species) and 1 implies that the two sites do not share any species. This was carried out using Community Analysis Package 4 (Seaby and Henderson 2007).

Shannon–Wiener diversities were calculated for each site (Magurran 1988). Assuming equal captures between seasons, chi-square tests (Yates corrected) were used to compare the number of individuals captured between cold and hot seasons at each site and also during each season. The *z*-score test (*Z*) (Zar 2010) was used to assess the proportions of altitudinal migrants during the cold and hot seasons at each forest site.

To analyse vegetation structure, density of trees (number of trees per 100 m^2) and density of shrubs (number of shrubs per 10 m^2) were computed. Plant species diversity for each plot was computed using the Shannon–Wiener index (Magurran 1988) and mean diversity calculated based on a total of 10 plots in each forest fragment.

Throughout this paper the species nomenclature follows Stuart and Jensen (1985) except for the Uluguru Mountain Greenbul *Andropadus neumanni*, White-chested Alethe *Alethe fueleborni* and Forest Batis *Batis mixta*, for which we used Sinclair and Ryan (2003), and Rubeho Akalat *Sheppardia aurantiithorax*, which follows Beresford et al. (2004).

Results

Seasonal differences in understorey bird abundance

More individuals were captured at Kisewe (550 m) during the cold season than during the hot season ($\chi^2 = 5.240$, df = 1, $p < 0.025$; Figure 2, Table 1). At Kilomwe (1 300 m) there were significantly more individuals caught during the hot season than during the cold season ($\chi^2 = 5.240$, df = 1, $p < 0.025$; Table 1). At Milawilila (350 m) there was no difference in number of captures of birds ($\chi^2 = 2.408$, df = 1, $p > 0.05$; Table 1), though there was a trend towards higher captures during the cold season compared with the hot season.

Proportions of altitudinal migrants were significantly higher at each forest fragment during the cold season compared with the hot season (Milawilila: $Z = 2.71$, $p < 0.01$; Kisewe: $Z = 3.00$, $p < 0.01$; Kilomwe: $Z = 3.04$, $p < 0.01$; Figure 3). When altitudinal migrants were analysed separately, there were significantly more captures during the cold season than the hot season at Milawilia ($\chi^2 = 8.393$, df = 1, $p < 0.005$) and Kisewe ($\chi^2 = 15.123$, df = 1, $p < 0.0005$) but not Kilomwe ($\chi^2 = 3.6$, df = 1, $p > 0.05$). Examples of notable species that had more captures during the cold season are Little Greenbul *Andropadus virens*, Orange Ground-thrush *Zoothera gurneyi* and White-starred Forest-robin *Pogonocichla stellata* (Table 1). For example, nine individuals of Orange Ground-thrush were captured at Milawilila forest (350 m) during the cold season and none during the hot season. When non-altitudinal migrants were analysed separately between sites there were no differences in the number of captures between seasons at Milawilila ($\chi^2 = 1.282$, df = 1, $p > 0.25$) and Kisewe ($\chi^2 = 0.556$, df = 1, $p > 0.25$). At Kilomwe, the hot season had more captures than the cold season ($\chi^2 = 12.448$, df = 1, $p < 0.0005$).

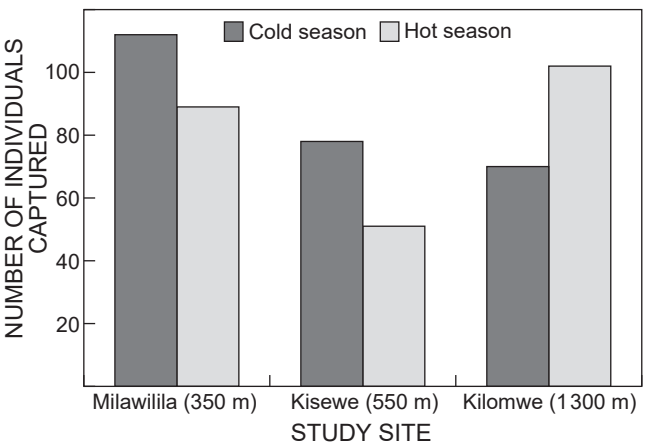


Figure 2: Number of individuals captured during each season along an altitudinal gradient

The dendrogram in Figure 4 separated the avian community structure into two major groups: lowland and montane communities. The bird community at Kilomwe at 1 300 m asl, for instance, was different from that of the lower-altitude forests that were sampled. Owing to the influence of seasons, cluster analysis separated avian communities at Milawilila and Kisewe into different clusters instead of grouping them together (Figure 4). Cluster analysis highlighted the differences in species composition among the sites and showed that low- and high-altitude understorey bird communities were clearly distinct.

Community composition, overall diversity and species distribution along an altitude gradient

In total, 502 individual birds of 41 forest species and five non-forest species were captured. Of these, 486 (96.8%) and 16 (3.2%) were forest-dependent and non-forest-dependent species, respectively. More individuals of forest species were captured at Milawilila (350 m) compared with the other two forest fragments (Table 1). This was reflected by the higher diversity of birds at Milawilila compared with the other two sites (Table 1). The most abundant species were Little Greenbul, Olive Sunbird *Nectarinia olivacea*, White-chested Alethe, Stripe-cheeked Greenbul *Andropadus milanjensis* and White-starred Forest-robin (see Table 1 for altitudinal ranges, forest affinities and migratory status of each species).

Of all species captured, Loveridge's Sunbird *Nectarinia loveridgei* and Uluguru Mountain Greenbul, which were caught at Kilomwe (1 300 m), are endemic to the Uluguru Mountains. The Rubeho Akalat was captured at Milawilila and is endemic to the Eastern Arc Mountains. Of the endemic and near-endemic birds found in the Uluguru Mountains forests (Burgess et al. 2007), only the Green Barbet (NE), Shelley's Greenbul *Andropadus masukuensis* (NE), Stripe-cheeked Greenbul (NE) and Forest Batis (NE) were captured. High-altitude montane species, such as Moustached Green Tinkerbird *Pogoniulus leucomystax*, Uluguru Mountain Greenbul, Olive Mountain Greenbul *Phyllastrephus placidus* and Olive Thrush *Turdus olivacea*, were only detected at 1 300 m. In a similar manner, the typical lowland species, such as Fisher's Greenbul *Phyllastrephus fischeri*, Grey-olive Greenbul *Phyllastrephus*

Table 1: Number of captures of forest birds at Milawilila, Kisewe and Kilomwe. Earlier records in other forests in the Uluguru Mountains are based on Stuart and Jensen (1985), Svendsen and Hansen (1995) and Doggart et al. (2004). CS = cold season, HS = hot season; E, EAM – E, and NE = endemic, Eastern Arc Endemic, and Near-Endemic species, respectively (Burgess et al. 2007).* = Species known to be altitudinal migrants in the Uluguru Mountains (Stuart 1983; Stuart et al. 1993; Burgess and Mlingwa 2000; Werema 2007, 2015, 2016a, 2016b). FD = Forest dependency, FS = forest specialist species, FE = forest species that can be found in undisturbed forest, forest strips, gaps and edges

FD	Species	Milawilila (350 m)		Kisewe (550 m)		Kilomwe (1300 m)		Subtotals across all sites per species and season		Altitudinal range based on earlier records
		CS	HS	CS	HS	CS	HS	CS	HS	
FS	Lemon Dove *Aplopelia larvata**	3	1	0	0	1	0	4	1	300–2 220
FE	Tambourine Dove *Turtur tympanistria*	0	2	0	4	0	0	0	6	300–>2 100
FE	Narina Trogon *Apaloderma narina*	1	0	0	0	0	0	1	0	300–1 800
FS	Bar-tailed Trogon *Apaloderma vittatum**	1	0	2	1	0	0	3	1	300, 1 100–2 350
FE	Pygmy Kingfisher I*spidina picta*	3	4	0	2	0	0	3	6	–
FS	Green Barbet *Buccanodon olivaceum*[NE]	0	0	0	0	0	2	0	2	300–2 060
FS	Moustached Green Tinkerbird *Pogoniulus leucomystax*	0	0	0	0	0	6	0	6	1 200–2 500
FE	Yellow-rumped Tinkerbird *Pogoniulus bilineatus*	0	0	0	1	0	1	0	2	300–2 145
FE	Scaly-throated Honeyguide *Indicator variegatus*	0	0	1	1	1	1	2	2	300–1 800
FS	African Broadbill *Smithornis capensis*	2	1	1	0	0	0	3	1	300–1 800
FS	Square-tailed Drongo *Dicrurus ludwigii*	2	1	0	0	0	0	2	1	300–1 540
FS	Pale-breasted Illadopsis *Illadopsis rufipennis*	3	4	1	0	0	0	4	4	300–900
FS	Shelley's Greenbul *Andropadus masukuensis**[NE]	1	0	0	0	1	4	2	4	300–2 300
FS	Stripe-cheeked Greenbul *Andropadus milanjensis**[E]	5	0	17	1	3	3	25	4	250–2 145
FS	Uluguru Mountain Greenbul *Andropadus neumanni**[E]	0	0	0	0	1	0	1	0	1 050–2 640
FE	Little Greenbul *Andropadus virens**	32	16	22	3	34	25	88	44	200–1 800
FE	Nicator *Nicator chloris*	0	1	0	0	0	0	0	1	250–1 000
FE	Grey-olive Greenbul *Phyllastrephus cerviniventris*	3	4	3	3	0	0	6	7	300–1 500
FS	Yellow-streaked Greenbul *Phyllastrephus flavostriatus*	2	4	6	5	0	0	8	9	300–1 500
FS	Olive Mountain Greenbul *Phyllastrephus placidus*	0	0	0	0	1	4	1	4	1 200–>2 200
FS	White-chested Alethe *Alethe fuelleborni**	13	12	9	1	3	0	25	13	250–2 145
FE	Red-capped Robinchat *Cossypha natalensis*	1	16	3	7	0	0	4	23	300–1 800
FS	Olive-flanked Ground Robin *Dryocichloides anomalus*	0	0	0	0	0	1	0	1	1 430–2 610
FS	White-starred Forest Robin *Pogonocichla stellata**	5	0	6	6	2	1	13	7	300–2 600
FS	Rubeho Akalat *Sheppardia aurantiithorax*[EAM - E]	1	0	0	0	0	0	1	0	400
FS	Olive Thrush *Turdus olivaceus*	0	0	0	0	0	5	0	5	1 100–2 550
FS	Orange Ground Thrush *Zoothera gurneyi**	9	0	0	0	0	0	9	0	700–2 530
FS	Evergreen Forest Warbler *Bradypterus lopezi**	0	1	0	0	0	2	0	3	250–300, 900–2 690
FE	Grey-backed Camaroptera *Camaroptera brachyura*	0	2	0	1	0	0	0	3	300–1 500
FS	Forest Batis *Batis mixta*[NE]	1	0	0	0	0	3	1	3	300–>2 350
FE	Black-throated Wattle eye *Platysteira peltata*	0	0	0	0	0	1	0	1	600–1 200
FS	White-tailed Crested Flycatcher *Elminia albonotata**	0	0	0	0	1	0	1	0	300, 1 200–2 570
FE	Paradise Flycatcher *Terpsiphone viridis*	1	1	2	0	0	0	3	1	300–>2 200
FS	Crested Flycatcher *Trochocercus cyanomelas*	5	0	1	0	0	0	6	0	300–1 700
FS	Loveridge's Sunbird *Nectarinia loveridge**[E]	0	0	0	0	2	0	2	0	600–2 580
FE	Olive Sunbird *Nectarinia olivacea**	8	15	1	11	11	26	20	52	300–2 100
FE	Dark-backed Weaver *Ploceus bicolor*	1	0	0	0	0	0	1	0	300–1 570
FS	Red-faced Crimsonwing *Cryptospiza reichenovii**	0	0	1	0	4	7	5	7	600–2 520
FE	Peter's Twinspot *Hypargos niveoguttatus*	8	4	0	0	0	0	8	4	300–1 200
FE	Green-backed Twinspot *Mandingoa nitidula*	0	0	2	0	3	0	5	0	300, 1 200–1 500
FE	Lesser Seed-cracker *Pyrenestes minor*	0	0	0	1	0	0	0	1	300–900
Total number of individuals per season		111	89	78	48	68	92	257	229	
Total number of species per season		23	17	16	15	14	16			
Species diversity per season		2.459	2.268	2.104	2.218	1.705	2.070			

cerviniventris and Pale-breasted Illadopsis *Illadopsis rufipennis*, were only found in lower-altitude forests and not at the higher altitudes.

Vegetation structure

Milawilila (at 350 m) forest had the highest density and mean plant species diversity (Table 2). As a result of continual forest clearance, particularly poles for house construction by villagers, the mean plant species diversity and density of trees were low at Kisewe (550 m). For shrubs, the highest density was recorded at Kisewe (Table 2).

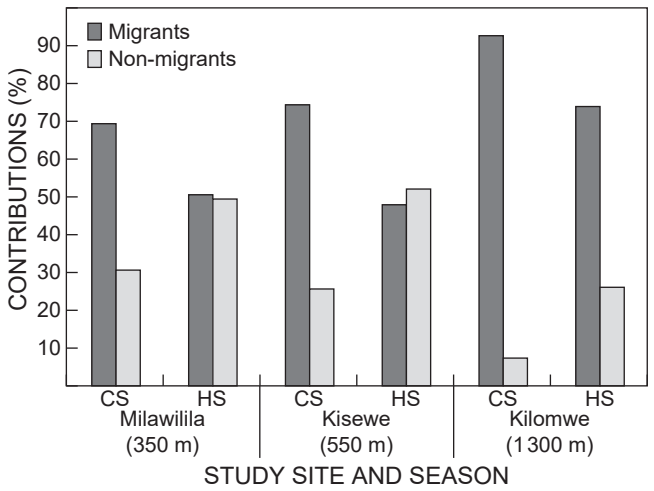


Figure 3: Percentage contributions of altitudinal migrants and non-altitudinal migrants in the community at each site during each season. CS = hot season, HS = hot season

Discussion

Seasonal differences in understorey bird abundance

Seasonality of forest species occurrence seemed to influence species richness and distribution patterns. The higher abundance at Milawilila (350 m) and Kisewe (550 m) during the cold season in comparison with the hot season is certainly due to seasonal altitudinal migration of some species. This was shown by the higher proportion of altitudinal migrants in the bird communities during the cold season compared with the hot season. These findings agree with other studies from the Uluguru Mountains (Stuart and Jensen 1985; Werema 2014, 2015, 2016a) and other Eastern Arc Mountains (Stuart 1983; Burgess and Mlingwa 2000; Cordeiro et al. 2006) that have also found several montane bird species at lower altitudes during the cold season. The altitudinal migrants breed at higher altitudes during the hot season months (September–February), and some of the individuals in a population migrate to lower-altitude forests during the cold season (Stuart and Jensen 1985; Stuart et al. 1993; Burgess and Mlingwa 2000; Werema 2007; Werema et al. 2016). These results indicate seasonally dynamic bird communities, due to local altitudinal migrations and individual dispersal.

At Kilomwe (1 300 m), the higher captures of birds and the higher abundance of altitudinal migrants than non-altitudinal migrants during the hot season could be due to some individuals that migrated from the lower-altitude sites and perhaps other non-forested areas in the farmland. This is possible because the forest is found at a relatively higher altitude than the other two forests. Nevertheless, the percentage captures of altitudinal migrant species were higher than those of non-migrant species during the cold

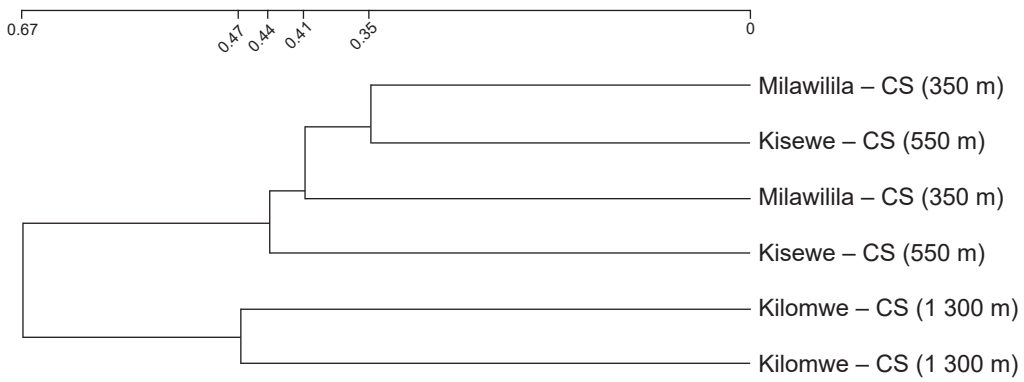


Figure 4: Dendrogram based on agglomerative average-linkage cluster analysis using Sørensen's dissimilarity index showing the similarity of bird communities between seasons

Table 2: Selected vegetation parameters of the forest fragments. Mean plant species diversity was expressed as mean Shannon-Wiener index, Values in parentheses are the SD

Forest site and altitude	Density of trees (trees 100 m^{-2})	Density of shrubs (shrubs 10 m^{-2})	Mean plant species richness	Mean plant species diversity
Milawilila (350 m)	10.5	8	9.2 (1.8)	2.088 (0.068)
Kisewe (550 m)	8.6	10.9	3.1 (0.7)	0.573 (0.242)
Kilomwe (1 300 m)	9.5	6.1	6.7 (3.3)	1.619 (0.490)

season, suggesting that the former migrated downslope to Kilomwe forest from relatively higher altitudes in the Uluguru Mountain forests. Kilomwe would be a good site for seasonal altitudinal migrants owing to its location with reference to the Uluguru Mountain forests (see Figure 1). An alternative explanation is that due to partial migrations in some species, there were some individuals that did not move from Kilomwe forest but stayed instead, hence leading to the higher percentage contribution of captures of altitudinal-migrating species during the cold season.

Of the altitudinal migrants at all three sites, there were higher abundances of Olive Sunbird during the hot season compared with the cold season. Given that the Olive Sunbird has been found to make seasonal altitudinal movements (Werema 2016b), the results presented here are contrary to the patterns that have been observed for this species. This suggests that individuals of the Olive Sunbird perhaps moved from the surrounding farmland matrix and used the forest habitats during the hot season. The Olive Sunbird has been documented to have the ability to cross forest gaps (Korfanta et al. 2012) and to move between forest and *Eucalyptus* plantations (John and Kabigumila 2011) in the East Usambara Mountains. Elsewhere, the Olive Sunbird is known to be prone to be 'here today, gone tomorrow' (Fry et al. 2000).

Community composition and overall diversity

Despite the fact that the three fragments are small in size, isolated and embedded in a farmland matrix, they had a higher abundance of forest-dependent birds compared with non-forest-dependent birds. Most of the species captured were forest dependent (both FS and FE species) and some of them are of conservation concern (i.e. endemic and near-endemic to the Uluguru Mountains). This suggests that these forests, though fragmented and isolated, remain of considerable ornithological importance, and warrant urgent efforts to restore and reconnect their habitat. If conservation measures of these forests are not undertaken local extinctions are likely to occur (see Newmark 1991).

Altitudinal distributions of most of the species detected in this study conform to earlier records from the Uluguru Mountains (Stuart and Jensen 1985; Svendsen and Hansen 1995; Doggart et al. 2004). The results also suggest that the avifauna communities in the fragmented landscape studied fall into two groups: lowland and montane forest communities. Kilomwe forest, at a relatively higher altitude (i.e. 1 300 m), than the other sites, was found to have a distinct avifauna community in comparison with the other two sites. This could be attributed to the effect of altitude because this site had many species mainly found in montane forests, notably Moustached Green Tinkerbird, Uluguru Mountain Greenbul, Olive Mountain Greenbul, Olive Thrush, Olive-flanked Ground-robin *Dryocichloides anomalus* and Loveridge's Sunbird. The separation of the avifauna into lowland and montane groups concurs with the results of Romdal and Rahbek (2009) along a homogenous forest gradient in the Udzungwa Mountains, Tanzania. In their study these authors found lowland and montane bird communities having a boundary at 1 200 m asl. In contrast, in the Usambara Mountains, Stuart (1983) found three communities: the lowland community below 750 m, an intermediate community between 750 m and 1 350 m, and a montane community above 1 350 m.

Of the three sites, at Milawilila forest the overall diversity and abundance of understorey birds were higher than at the other sites regardless of its size. These results are in contrast to other studies that have indicated that the size of the forest is the main determinant of the number of species (Newmark 1991; Burgess and Mlingwa 1993; Dami et al. 2012). The three fragments that were studied were highly similar in size (12.8–25 ha) and thus it should not be surprising in this case that area is not an important predictor of the number of bird species. The higher diversity and abundance of birds at Milawilila forest could be attributed to high density of trees and high plant species diversity found in this forest (Tables 1 and 2). The findings of this study suggest that both high tree density and plant species diversity are important determinants of bird species richness in fragmented and isolated forests. This observation concurs with the results of other studies of bird communities in the tropics (Waiyaki 1995; Hughes et al. 2002; Waltert et al. 2005; Laube et al. 2008). For example, Waiyaki (1995) reported that forest structure of Kenyan coastal forests was more important than fragment area in determining the composition of understorey forest bird communities.

Conclusion

The results suggest that these forests, although they are isolated and small in size, are of high conservation value for birds. They seem to be important habitats for forest-dependent species, species of conservation concern and some of the montane species whose individuals move to the lower-altitude forests during the cold season. More thorough studies covering both the cold and hot seasons may detect additional seasonal altitudinal migrants in the Uluguru Mountains. It is possible that more altitudinally migrating species that have not been documented are using these forests during the cold season than is currently known.

There is a pressing need for an effective, long-term conservation programme in these forests. Informal discussions with the village government of Kisewe that manages Kilomwe forest showed a growing concern over the rate and extent of forest loss in this forest. They showed willingness to become involved with conservation of this forest as it is an important water catchment of Kisewe stream.

The remaining forests in the Uluguru Mountains harbour a number of understorey birds, mostly forest dependent. This means that if the forest is further cleared, local extinctions can and almost certainly will occur. Therefore efforts to conserve these species should be a priority in these areas.

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