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Seasonal variation in understorey bird species diversity and abundance in the Uluguru Nature Reserve, Tanzania

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Abstract

The Uluguru Mountains form a component block of the Eastern Arc Mountains of Tanzania and Kenya and are known for a high degree of endemic vertebrate and plant taxa. Among the Eastern Arc Mountains, the Uluguru Mountains rank second in the number of endemic species. Although the forests in these mountains have received considerable ornithological attention, studies on how forest bird communities in the available low elevation forests are affected by seasons remain patchy and sporadic. Such studies are important because in the Uluguru Mountains, forest destruction in the lower slopes has been severe to an extent that there is very little substantial forest survives below 900 m above sea level. Using mist netting, seasonal variation in understorey bird communities in the remaining low elevation forests in the Uluguru Nature Reserve was assessed between 2005 and 2011. Species diversity and relative abundance of the birds were higher during the cold season in comparison with the hot season possibly due to seasonal elevational movements of some species. Elevational migrants made a large proportion of the avifauna in the study area. The results suggest that low altitude forests are important cold season refugia of elevational migrants and these forests need continual protection.

Key words: Eastern Arc mountains, elevational migrants, mist nets, nature reserve, species diversity, understorey birds

Résumé

Les monts Uluguru font partie de la chaîne de montagne appelée Arc oriental, à l'est de la Tanzanie et du Kenya et ils sont connus pour le fort taux d'endémisme de taxons de vertébrés mais aussi de plantes. Pour tout l'Arc oriental, les monts Uluguru se classent deuxièmes pour le nombre d'espèces endémiques. Bien que les forêts de ces montagnes aient suscité une attention considérable de la part des ornithologues, les études sur la façon dont les communautés d'oiseaux forestiers vivant dans les parties disponibles des forêts de basse altitude sont affectées par les saisons restent incomplètes et sporadiques. De telles études sont importantes parce que, dans les monts Uluguru, la destruction des forêts a été tellement sévère sur les pentes de basse altitude qu'il ne reste que très peu de forêt véritable en dessous de 900 m d'altitude. Entre 2005 et 2011, nous avons évalué, au moyen de filets japonais, les variations saisonnières des communautés aviaires dans les dernières forêts de basse altitude de la Réserve Naturelle d'Uluguru. La diversité des espèces d'oiseaux et leur abondance relative étaient plus élevées pendant la saison fraîche que pendant la saison chaude, probablement à cause de la migration altitudinale saisonnière de certaines espèces. Les espèces qui migrent en altitude constituent une grande proportion de l'avifaune dans la région étudiée. Les résultats montrent que les forêts de basse altitude sont des refuges importants en saison fraîche pour ces migrants d'altitude et qu'elles ont besoin d'une protection continue.

Introduction

The Uluguru Mountains form a component block of the Eastern Arc Mountains of Tanzania and Kenya and are known for a high degree of endemic vertebrate and plant taxa (Burgess, Doggart & Lovett, 2002; Burgess *et al.*, 2007; Rovero *et al.*, 2014). Among the Eastern Arc Mountains, the Uluguru Mountains rank second in the number of endemic species (Rovero *et al.*, 2014). For example, these mountains have three endemic species of birds: the Uluguru Bush-Shrike *Malaconotus alius*, Loveridge's Sunbird *Nectarinia loveridgei* and Uluguru Mountain Greenbul *Andropadus neumanni.* The high biodiversity and

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concentration of endemic, rare and threatened species in the Uluguru Mountain forests make them one of the highest priorities for conservation.

Unfortunately, on the Uluguru Mountains, forest destruction in the lower slopes has been severe to the extent that today, very little, if any, substantial forest survives between 400 and 900 m above sea level (a.s.l.) (Stuart & Jensen, 1985). Below Uluguru nature reserve boundaries (between 1000 and 1500 m), the forest has been extensively cleared and very few forest remnants remain on the lower slopes of these mountains. Most of the forest is found above 1000 m a.s.l. in the northern section of the nature reserve (formerly Uluguru North Forest Reserve) and above 1500–2000 m a.s.l. in the southern section (formerly Uluguru South Forest Reserve) (Burgess, Doggart & Lovett, 2002).

Uluguru Mountain forests, including Uluguru Nature Reserve, have received considerable attention ornithologically and most likely the majority of the forest species which occur in these mountains have been found (Stuart & Jensen, 1985). All ornithological records both published and unpublished in the Uluguru Mountain forests are found in a review by Stuart & Jensen (1985) and recent studies by Svendsen & Hansen (1995) and Doggart *et al.* (2004a,b). Some of the species in these mountains have been found to undertake seasonal elevational movements between montane and lowland forests (Stuart & Jensen, 1985; Burgess & Mlingwa, 2000; Werema, 2014a,b). Despite these ornithological records, systematic studies concentrating at different elevations during the cold and hot seasons are either few or nonexistent. Our understanding of how understorey birds are affected by seasons remains patchy and sporadic and relatively little attention has been given to species that undertake seasonal elevational movements. Elevational migrants are affected by habitat fragmentation and may not be able to cross open areas along elevational gradients that they use when migrating (Loiselle & Blake, 1991, 1992; Blake & Loiselle, 2000). Therefore, an understanding of migratory systems of different species is important on conservation grounds.

This study attempts to assess the influence of seasons in the determination of the distribution and abundance of forest birds in the Uluguru Nature Reserve. The main emphasis is on assessment of whether or not seasons affect the abundance and diversity of understorey forest birds some of which have been found to make seasonal elevational movements in these mountains (Stuart & Jensen, 1985; Burgess & Mlingwa, 2000). The study localities are the only ones with 'available' and substantial 'low elevation' forest in the Uluguru Nature Reserve. Due to seasonal elevational movements of some species, I predicted that the study localites are cold season refugia for elevational migrants.

Study area

The study was conducted in the Uluguru Nature Reserve which is located in the Uluguru Mountains that form part of the Eastern Arc Mountains of Tanzania (Fig. 1). The study sites were located at 900, 1000 and 1200 m a.s.l. These sites are well suited for assessment of the influence of seasons on abundance and diversity of understorey birds because they are the only ones with substantial lower elevation forests in the Uluguru Mountains. For example, the 1000 m locality was in the vicinity of the forest edge (See Fig. 1). Below these sites, there is cultivation, and any existing forest occurs in small fragments (Burgess, Doggart & Lovett, 2002).

Data collection

Mist netting was used to capture understorey birds. At 900 m and 1200 m sites, mist nets were set during the cold season between May and August 2005 and during the hot season between October 2005 and February 2006 (Table 1). Ten mist nets (3 × 12 m, 4 × 9 m, and 3 × 6 m each 2.5 m high, mesh size 30 mm, four shelves) were used. At 1000 m site, fifteen mist nets (12 m, 16 mm mesh, 4 shelves) were set in July 2010 and January 2011 during the cold and hot seasons, respectively (Table 1). For comparative purposes, net locations and sampling effort were maintained during each season at each site. This made up a mist netting effort of 6480 metre-net-hours during each season (Table 1). During each mist netting session, the nets were erected for 36 daylight hours and were open from dawn (06:00) to dusk (18:00) for three consecutive days at each site. Nets were checked every 30 min, but more frequently during the morning and evening hours when birds were most active. All birds mist-netted were ringed and then released at the site of capture.

Data analysis

The avifauna in the study area were divided into two major groups: forest-dependent species (hereafter forest

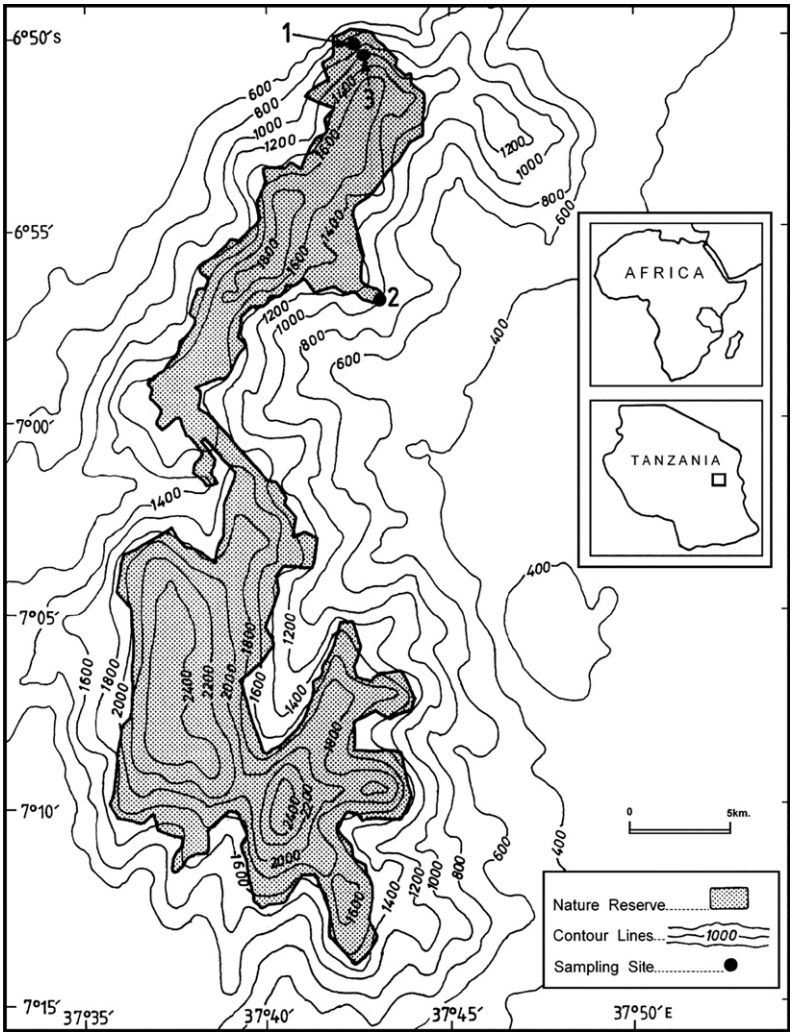


Fig 1 Map of the Uluguru Nature Reserve showing sampling sites (1 = at 900 m, 2 = 1000 m and 3 = at 1200 m)

Table 1 Dates of sampling and sampling effort for each site during the cold and hot seasons

	Season and sampling effort			
	Cold season		Hot season	
Site	Mist netting dates	Mist netting effort (metre-net-hours)	Mist netting dates	Mist netting effort (metre-net-hours)
900 m	15–17 May 2005, 30 July–1 August 2005	6480	16–18 November 2005, 5–7 February 2006	6480
1000 m	27–29 July 2010	6480	12–15 January 2011	6480
1200 m	21–23 May 2005, 3–5 August 2005	6480	19–22 November 2005, 8–11 February 2006	6480

species) and nonforest species. Forest species are normally encountered in forested areas, and their survival depends on the presence of forest. Nonforest species are usually found in disturbed forest and open areas such as farmland. Forest species were further classified into two groups: elevational and nonelevational migrants (Stuart & Jensen, 1985; Stuart *et al.*, 1993; Burgess & Mlingwa, 2000; Werema, 2014a,b). Because the objective of the study was on understory forest birds, I have excluded nonforest species from analysis. These were Malachite Kingfisher *Alcedo cristata* and Zanzibar Sombre Greenbul *Andropadus importunus.* To avoid misinterpretation, I consider all species captured as understorey birds.

Assuming equal number of captures between seasons, Yates corrected chi-square tests were used to test whether there were significant differences in captures of individuals (Zar, 1999). Same season recaptures were not included in counts and analysis. Shannon–Wiener diversity indices during the cold and hot seasons were computed using a software package: PAST (Hammer, Harper & Ryan, 2001). The diversities for the cold and hot seasons were compared using *t*-tests after Hutcheson (1970) using a software package: PAST (Hammer, Harper & Ryan, 2001).

Community composition of understorey birds among the study locations were assessed using hierarchical agglomerative cluster analyses with average linkage sorting and Sørensen dissimilarity index, comparing all captures identified to species level. The index is bound 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 the software package, the Community Analysis Package (CAP) version 4.1.3 (Seaby & Henderson, 2007).

Throughout this article, the species nomenclature follows Stuart & Jensen (1985).

Results

Community composition and species elevational ranges

In total, 688 individual birds of 39 species were mist-netted (Table 2). Of the total number of individuals mist-netted, 221 (26 species), 252 (24 species) and 215 (25 species) were captured at 900, 1000 and 1200 m, respectively (See Table 2). In Table 2, I present the records of the forest birds in the surveyed localities within the Uluguru Nature Reserve and their elevational distribution ranges. For those species that are elevational migrants, in Table 2, the maximum elevational span in which any one species was recorded is indicated. For almost all species, the elevational distribution ranges matched with those of the earlier records in the Uluguru Mountains, with exception of the African Pitta *Pitta angolensis*.

Of the species mist-netted, Loveridge's Sunbird *Nectarinia loveridgei* is endemic (E) to the Uluguru Mountains (Stuart & Jensen, 1985; Burgess *et al.*, 2007). Six species, the Green Barbet *Buccanodon olivaceum*, Shelley's Greenbul *Andropadus masukuensis*, Stripe-cheeked Greenbul *Andropadus milanjensis*, Sharpe's Akalat *Sheppardia sharpei*, Forest Batis *Batis mixta* and Fülleborn's Black Boubou *Laniarius fuelleborni* are near-endemic (NE) to the Uluguru Mountains (Burgess *et al.*, 2007).

Seasonal differences in abundance and diversity

Of the total individuals mist-netted, 378 and 310 were captured during the cold and hot seasons, respectively (Table 1). Overall, during the cold season, the number of captures of birds was significantly higher than the hot season ($\chi^2 = 6.52$, df = 1, $P < 0.025$). The Shannon–Wiener diversities were higher during the cold season than the hot season at each site, respectively; at 900 m: 2.308 and 2.114, 1000 m: 2.338 and 1.678 and at 1200 m: 2.280 and 1.662. The cold season was significantly diverse at 1000 m (*t*-test: $t = 4.434$, df = 208.52, $P < 0.001$) and at 1200 m: 2.280 and 1.662 (*t*-test: $t = 3.719$, df = 212.83, $P < 0.001$), but not at 900 (*t*-test: $t = 1.345$, df = 211.95, $P = 0.18$). Statistical clustering of the study locations during each season by species composition of all species separated the localities by seasons has shown that the cold season had a cluster of its own (Fig. 2).

Of the total 688 individuals captured, 531 individuals (over 77% of all captures of 15 species) were of species known to make seasonal elevational movements in the Uluguru Mountains (Stuart & Jensen, 1985; Burgess & Mlingwa, 2000; Werema, 2007, 2014a,b). Of the 531 individuals, 308 and 223 were mist-netted during the cold and hot seasons, respectively, and the difference was significant ($\chi^2 = 13.29$, df = 1, $P < 0.001$). The Shannon–Wiener diversities of elevational migrants at each site were significantly higher during the cold season than the hot season at each site [(900 m: 1.822 and 0.935 (*t*-test: $t = 5.922$, df = 103.88, $P < 0.0001$), 1000 m: 1.863 and 1.226 (*t*-test: $t = 4.369$, df = 177.52,

Table 2 Number of individuals mist-netted for different species at each altitude and season

Species	Study sites based on seasons						Earlier records in the Ulugurus
	900 – CS	900 – HS	1000 – CS	1000 – HS	1200 – CS	1200 – HS	
Accipiter tachiro African Goshawk	0	1	0	0	0	0	650–1600
Accipiter minullus Little Sparrowhawk	0	0	1	0	0	0	300–1200
Sarothrura elegans Buff-spotted Flufftail	0	0	1	0	0	0	900
Aplopelia larvata Lemon Dove[a]	4	1	4	2	1	0	300–2220
Turtur tympanistria Tambourine Dove	1	5	2	6	1	5	300–2100
Cercococcyx montanus Barred Long-tailed Cuckoo[a]	0	0	0	0	0	1	300, > 1500
Buccanodon olivaceum Green Barbet[NE]	0	0	0	0	2	3	300–2060
Pogoniulus bilineatus Yellow-rumped Tinkerbird	0	2	0	0	0	1	300–2145
Pogoniulus leucomystax Moustached Green Tinkerbird	0	0	0	0	1	0	1200–2500
Ispidina picta Pygmy Kingfisher	2	1	0	1	0	0	200–1200
Pitta angolensis African Pitta	0	1	0	0	0	0	–
Andropadus masukuensis Shelley's Greenbul[aNE]	4	1	7	0	1	0	300–2300
Andropadus milanjensis Stripe-cheeked Greenbul[aNE]	7	0	18	6	5	1	250–2145
Andropadus virens Little Greenbul[a]	23	19	59	41	30	54	200–1800
Phyllastrephus cabanisi Cabanis Greenbul	0	0	4	1	1	0	1200–2200
Phyllastrephus cerviniventris Grey-olive Greenbul	2	4	0	0	0	2	700–1500
Phyllastrephus flavostriatus Yellow-streaked Greenbul	0	0	1	1	0	0	300–1500
Alethe fuelleborni White-Chested Alethe[a]	15	1	5	3	9	1	250–2145
Cossypha natalensis Red-capped Robin-Chat	9	14	0	7	3	7	300–1800
Pogonocichla stellata White-starred Forest Robin[a]	8	1	11	0	2	2	300–2600
Sheppardia sharpei Sharpe's Akalat[aNE]	0	0	4	0	0	0	700–2140
Turdus olivaceus Olive Thrush	1	0	0	0	0	0	300–2550
Zoothera gurneyi Orange Ground Thrush[a]	1	0	3	0	0	0	700–2530
Bradypterus mariae Evergreen Forest Warbler[a]	1	0	0	0	3	0	250–2660
Camaroptera brachyura Green-backed Camaroptera	2	4	1	0	1	3	300–1500
Batis mixta Forest Batis[NE]	0	0	6	0	0	0	300–2340
Platysteira peltata Black-throated Wattle-eye	0	2	0	0	0	0	600–1200
Trochocercus albiventris White-tailed crested flycatcher[a]	3	0	6	0	2	0	300, 1200–2570
Terpsiphone viridis Paradise Flycatcher	1	0	0	0	0	0	300 - > 2200
Trochocercus cyanomelas Crested Flycatcher	4	10	2	0	0	2	300–1700
Laniarius fuelleborni Fülleborn's Black Boubou[aNE]	0	0	3	0	1	0	900–2570
Dicrurus ludwigii Square-tailed Drongo	0	0	1	0	0	0	300–1540
Anthreptes collaris Collared Sunbird	0	1	1	0	2	0	300–1800
Nectarinia loveridgei Loveridge's Sunbird[aE]	0	0	0	0	2	1	600[b], 1300–2580
Nectarinia olivacea Olive Sunbird[a]	29	31	8	18	15	31	300–2100
Ploceus bicolor Dark-backed Weaver	0	0	11	0	0	0	300–1570
Cryptospiza reichenovii Red-faced Crimsonwing[a]	1	0	3	4	10	4	600–2520
Hypergos niveogutatus Peter's Twinspot	0	3	0	0	1	0	300–1200
Mandingoa nitidula Green-backed Twinspot	1	0	0	0	4	0	300, 1200–1500
Number of individuals	119	102	162	90	97	118	
Number of species	20	18	23	11	21	15	

[a]Species known to be elevational migrants in the Uluguru Mountains (Stuart, 1983; Stuart *et al.*, 1993; Burgess & Mlingwa, 2000; Werema, 2007, 2014a,b).

[b]Recorded by Werema (2007). CS = cold season and HS = hot season, E and NE = endemic and near-endemic species. Earlier records in the Uluguru Mountains are based on Stuart & Jensen (1985), Svendsen & Hansen (1995), and Doggart *et al.* (2004b). Taxonomy follows Stuart & Jensen (1985).

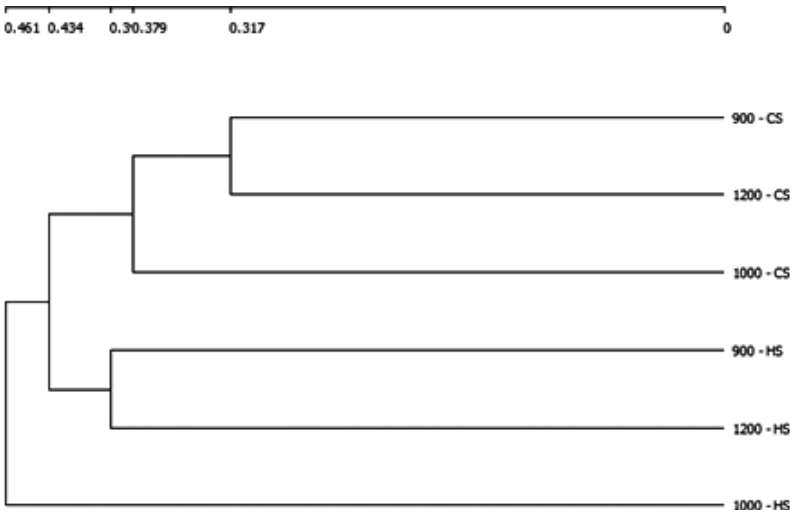


Fig 2 Dendrogram based on a matrix of occurrence of the avifauna in the study area by localities and seasons, using Sørensen dissimilarity index (CS = cold season and HS = hot season)

$P < 0.0001$) and at 1200 m: 1.681 and 1.014 (*t*-test: $t = 4.638$, df = 164.41, $P < 0.0001$)]. Statistical clustering of the study locations during each season by species composition of elevational migrants separated the localities by seasons: the cold season formed a cluster well separated from the rest (Fig. 3).

Of the total number of individuals mist-netted, 157 (23%) were of nonelevational migrants. Of these, 70 and 87 individuals were captured during the cold and hot seasons, respectively, and there was no difference in abundance between the seasons ($\chi^2 = 1.63$, df = 1, $P > 0.1$).

Discussion

Community composition and species elevational ranges

A total of 39 forest bird species were mist-netted. All of these species have been found in the Uluguru Mountains (Stuart & Jensen, 1985; Svendsen & Hansen, 1995;

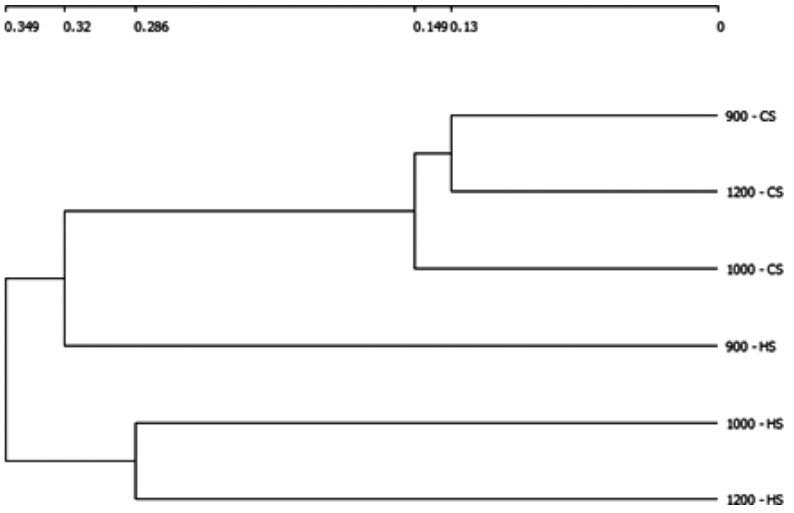


Fig 3 Dendrogram based on a matrix of occurrence of the elevational migrants in the study area by localities and seasons, using Sørensen dissimilarity index (CS = cold season and HS = hot season)

Doggart *et al.*, 2004a,b) except the African Pitta. The African Pitta is a well-known intra-African migrant (Keith, Urban & Fry, 1992) and has not been recorded in the Uluguru Mountains probably due to lack of field work throughout the whole year. All elevational ranges for the rest of the species matched the earlier ornithological records in the Uluguru Mountains (Stuart & Jensen, 1985; Svendsen & Hansen, 1995; Doggart *et al.*, 2004a,b). Of the endemic (E) and near-endemic (NE) birds found in the Uluguru Mountains forests (Burgess *et al.*, 2007), only Loveridge's Sunbird (E), Green Barbet (NE), Shelley's Greenbul (NE), Stripe-cheeked Greenbul (NE), Sharpe's Akalat, Forest Batis (NE) and Fülleborn's Black Boubou (NE) were mist-netted. The absence of the other endemic and near-endemic species could have been due to lack of field work at the higher elevation sites during the study. Earlier records showed the lowest elevation of Loveridge's Sunbird to be 1300 m a.s.l. (Stuart & Jensen, 1985; Svendsen & Hansen, 1995; Tøttrup, Larsen & Burgess, 2004). In the Uluguru Mountains, Werema (2007) observed some individuals of this sunbird at 600 m a.s.l. along a riverine forest during the cold season, but none was detected during the hot season. It is possible that some individuals of this sunbird are probably moving to low elevations during the cold season and back to high elevations during the hot season (Werema, 2007).

Seasonal changes in abundance and diversity

The results have shown that during the cold season, the relative abundances and diversities of birds were higher than during the hot season. Similarly, when known elevational migrants were analysed separately, the species diversities during the cold season were significantly higher than those of the hot season. Analogous results were shown by the cluster analyses which showed differences in avifauna assemblages based on seasons. The higher relative abundances and diversities at each site during the cold season than the hot season can be attributed to the cold season downwards movements of some individuals of seasonal elevational migrants from the higher elevation forests. Although the seasonal differences in relative abundances and capture rates of birds can be partially explained in other ways such as seasonal changes in detectability and chance (Burgess & Mlingwa, 2000), the results suggest that seasonal elevational migration of birds in the study area is the most likely explanation for the higher diversity and abundance during the cold season compared to the hot season. These results concur with the findings of Cordeiro *et al.* (2006) who, while mist netting at Kihansi Gorge (at 760 m above sea level), in the Udzungwa Mountains, found that captures of birds were higher during the cold season than during the hot season, largely due to movements of some individuals to the lower elevation forests. Also, consistent with the results of the present study is a body of literature indicating higher abundance of elevational migrating birds recorded at lowland forests during the cold season than during the hot season in the Uluguru Mountains (Stuart & Jensen, 1985; Burgess & Mlingwa, 2000; Werema, 2007, 2014a,b), across the Eastern Arc Mountains of Tanzania (Stuart, 1983; Stuart *et al.*, 1993; Burgess & Mlingwa, 2000) and further south in Malawi (Dowsett-Lemaire, 1989).

Of the species known to make seasonal elevational movements, the results showed that some individuals of species such as Lemon Dove *Aplopelia larvata*, Little Greenbul *Andropadus virens* and White-chested Alethe *Alethe fuelleborni* did not leave the study site during the hot season when most individuals were expected to be in the higher elevation montane forest. This phenomenon has been termed 'partial migration' whereby some individuals of a species are elevational migrants while others are residents (Rabenold & Rabenold, 1985; Loiselle & Blake, 1991; Burgess & Mlingwa, 2000).

Of the elevational migrants in this study, at 1200 m, the Little Greenbul had higher captures during the hot season than the cold season. For this species, of the total 54 individuals captured (See Table 2), only four individuals were mist-netted between 16 and 18 November 2005 while 50 individuals were mist-netted between 5 and 7 February 2006, with the sampling efforts and net locations maintained. This suggests that some individuals either were still moving from lower to higher elevations in February or that between November and February, they moved from the lower altitudes and had used the study site as their hot season habitat. Another species, the Olive Sunbird *Nectarinia olivacea* had higher abundance during the hot season than the cold season possibly due to movements of some individuals from the lower elevation sites, including the cultivated areas. This sunbird was commonly observed in cultivated areas in the vicinity of the forests (Pers. Observ.). It is therefore possible that during the hot season, some individuals tend to use the forest habitats more than they use the cultivated areas.

Conclusion and conservation implications

Although these results may not constitute definitive proof of elevational migration for some species, they are nevertheless sufficient to construct a hypothesis of elevational migration in the species documented so far. Changes in species detectability, for instance, may not provide an explanation for the overall patterns of the results as some species known to be elevational migrants seem to have completely left the study site during the hot season. Because the study was conducted within the boundaries of the Uluguru Nature Reserve, the results have conservation implications: protection of the entire elevational gradient of the forest in the Uluguru Mountains and elsewhere in the Eastern Arc Mountains. For example, due to forest loss and fragmentation at the lower elevations, it is possible that as the migrant species move to lower elevation forests during the cold season, they are inhibited from moving further downhill to the lowest elevation forests due to the lack of continuous forest. Consequently, some individuals may stay at the forest edge during the entire cold season waiting for the hot season to come so that they can move up to higher elevations to breed. In areas with continuous elevation gradients where forest extends down to low elevations, some individual elevational migrants have been found to move between different elevations. For example, at 650 m above sea level, during the cold season, Werema (2014b) found recaptures of Little Greenbul *Andropadus virens* which were originally ringed during the hot season, at relatively higher elevations (1200 and 1500 m).

The results suggest that elevational migration is an important component of the dynamics of bird communities in the Uluguru Mountains. They further demonstrate the importance of the study sites as cold season refuges for those species that make seasonal elevational movements, some of which are near-endemic to the Uluguru Mountains. Because known elevational migrants made up a large proportion of the avifauna in the study sites, there is a need to better understand elevational migratory movements which are of critical importance on applied conservation grounds. Further studies are needed to have a better understanding of the ecology of seasonal elevational migrating birds in the Uluguru Mountains. With more fieldwork, it may turn out that there are many more species which make seasonal elevational movements than is currently known. In particular, further studies should concentrate on the impact of forest disturbance and fragmentation on seasonal elevational movements in the forest fragments found at the lower elevation slopes of the Uluguru Mountains, and the entire Eastern Arc Mountains.

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