Ostrich: Journal of African Ornithology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tost20

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Available online: 16 Mar 2011

To cite this article: Jasson RM John & Jonathan DL Kabigumila (2011): The use of bird species richness and abundance indices to assess the conservation value of exotic Eucalyptus plantations, Ostrich: Journal of African Ornithology, 82:1, 27-37

To link to this article: http://dx.doi.org/10.2989/00306525.2011.556799

OSTRICH 2011, 82(1): 27–37
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OSTRICH
ISSN 0030–6525 EISSN 1727–947X
doi: 10.2989/00306525.2011.556799

The use of bird species richness and abundance indices to assess the conservation value of exotic *Eucalyptus* plantations

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The East Usambaras are within the Eastern Afromontane hotspot, which is known for its exceptionally rich biodiversity. The original forest of the East Usambaras has been reduced by human activities, including establishment of *Eucalyptus* plantations, but little is known about the value of these plantations for biodiversity. Therefore, from July 2003 to June 2004, we studied avifauna in natural forests and plantations using the timed species count (TSC) method, based on which we provide an assessment of the conservation value of *Eucalyptus* plantations to the local avifauna. From 240 TSCs, 100 species in 79 genera, 32 families and seven orders were recorded. A total of 63 forest species were recorded in forest and 41 forest species in the *Eucalyptus* plantations with four forest species exclusively in the plantations. The two habitats shared a greater percent of non-forest bird species (85%) than forest bird species (64%). There was some degree of seasonal variation in species richness and relative abundance between habitats. The study shows that 'responsibly managed' plantations could benefit some local avifauna. We recommend proper management of the *Eucalyptus* plantations, including the retention of some undergrowth and of surviving isolated forest trees, in order to provide hospitable habitats for birds.

Introduction

Natural forest in the Eastern Arc Mountains is being rapidly fragmented by human habitation, food-crop farming and planting of exotic trees (Carlson 1986, Newmark 2002). Approximately three-quarters of the natural forest in these mountains is open forest, in which the canopy is broken and non-continuous. Much of this open forest, particularly at higher elevations, used to be closed-canopy forest but has been modified by human activities in the past 50 years (Newmark 2002). The natural forest is still under human pressure even to date (Burgess et al. 2007) and about 11 km^2 of the natural forest in the Usambara Mountains alone have been converted to exotic tree plantations (Newmark 2002).

The Usambara Mountains provide a good case study. They are perhaps among the richest of all the Eastern Arc forests (Rodgers and Homewood 1982, Hamilton 1989), and have been ranked fourth of all the continental African forests in their importance for bird conservation (Collar and Stuart 1988). Secondly, more than half of its original forest cover has been removed for agriculture (Hamilton and Bensted-Smith 1989), but more importantly it has the largest proportion of tea plantations in the whole of Eastern Arc Mountains. The expansion of tea plantations and protection of natural forests from harvesting resulted in the establishment of *Eucalyptus* plantations as a source of fuel used in the ovens to dry tea leaves. Being a fast-growing tree and resistant to diseases compared with most indigenous trees, it has been preferred over other trees, to the extent that some natural forest patches under the management of tea estates were converted into *Eucalyptus* plantations (John 2005).

The Amani Plateau (900–1 100 m asl) is composed of a mosaic of habitats from traditional agricultural fields, disturbed forests (mainly due to invasion of exotics), pure stands of exotic plantations such as *Cedrela odorata* and *Maesopsis eminii*, tea estates, *Eucalyptus* plantations, and large continuous natural forest (Borghesio et al. 2008). Of these habitats, the tea estate is the poorest in terms of forest birds. While the effect of fragmentation on local birds has been studied in the area (Newmark 1991, 2002, 2006), it is only recently that other habitats, including the traditional agricultural fields, have received biological attention (Borghesio et al. 2008).

There has been extensive research in recent years on plantations and avifauna in tropical forests (Mitra and Sheldon 1993, Fuller 1995, Díaz et al. 1998, Petit et al. 1999), although few have compared the value of indigenous and exotic plantations (Farwing et al. 2008), with even fewer having worked on exotic *Eucalyptus* plantations (Marsden et al. 2001, John and Kabigumila 2007). Studies in exotic *Eucalyptus* plantations have shown that they are of insignificant value for tropical birds in Brazil (Marsden et al. 2001), unlike other plantations of native trees (Farwing et al. 2008), and are not preferred for nesting birds in Tanzania (John and Kabigumila 2007). This is in stark contrast to studies conducted in native *Eucalyptus* plantations in Australia (Keast 1990), where they provide good habitat and nesting sites for birds. In Australia, Keast (1990) found that *Eucalyptus* forest avifauna was dominant on the continental mainland, accounting for between one-third and half of the total land and freshwater species. It is on this basis that this

study was carried out to establish whether the *Eucalyptus* plantations, although exotic in the Eastern Arc Mountains, support a large portion of the local avifauna.

Materials and methods

Study area

The East Usambara Mountains are situated in north-eastern Tanzania within 40 km of the coastal town of Tanga, between 4°48′–5°13′ S and 38°32′–38°48′ E. The mountains cover an area of about 130 000 ha and form one of the smallest ranges of the Eastern Afromontane hotspot in Tanzania (Newmark 2002). About 76% of this area is protected in the Amani Nature Reserve and 13 other forest reserves (Johansson and Sandy 1996).

Study sites

Our study was conducted from July 2003 to June 2004 on the Amani plateau. All the study sites were within an altitude of 900–1 100 m asl. Twelve sites were selected: six sites were located in natural forest and six in *Eucalyptus* plantations (Table 1). In selecting the study sites we avoided the smallest forest fragments of less than 10 ha. *Eucalyptus* plantations with trees younger than nine years of age were not selected. We followed Newmark (1997) for the criteria regarding disturbances to the forest. Each forest site was assigned to a 'disturbance' category, based on the extent of invasion by *Maesopsis eminii*. Forests in the East Usambaras were thus categorised as 'undisturbed', 'moderately disturbed' or 'disturbed' (Table 1). Forest sites or patches of approximately equivalent area to that of *Eucalyptus* sites were selected. *Eucalyptus* plantations in this study were not harvested until the completion of our study. Breeding (September–February) and non-breeding season were treated equally as per sampling effort.

One of the main important characteristics of the *Eucalyptus* sites was the understorey vegetation, which was lacking in some sites due to management practices and wherever available it was dominated by *Lantana camara*, an invasive shrub in the area. The herbaceous layer was less than 2 m tall. Due to the small sample size of the two habitats we did not test the significance of either understorey vegetation cover or the presence of remnant indigenous trees in *Eucalyptus*. However, we present the relationship between the study site area and species richness.

Bird surveys

Timed species counts (TSCs) were carried out over a fixed period of 1 h, divided into shorter periods of 10 min each (Pomeroy 1992, Bennun and Howell 2002). The TSCs were separated by an interval of 10 min or 100 m. A species seen or heard in the first 10 min received a 'score' or 'weight' of 6, while a species first recorded in the second 10-minute period scored 5 and so on. In making the counts, we intentionally visited as many parts of the area as we could in the time, concentrating on places where bird activity was greater, such as fruiting and flowering plants. All positive identifications within 25 m were counted, both by sight and sound. The survey consisted of 20 TSCs from each site regardless of its size as each site was visited at least once a month. For standardisation purposes, surveys were conducted between 8:30 and 12:00, i.e. after the early morning peak of bird activity decreases as described by Bennun and Howell (2002). We used the works of Moreau (1935, 1936), Stuart (1983) and that of Mlingwa et al. (2001) to categorise birds into forest and non-forest species and names follow the African Bird Club Checklist (African Bird Club and Dowsett 2007–2010).

Data analysis

The analysis aimed to compute similarity, species richness and relative abundance of forest and non-forest birds in natural forest and *Eucalyptus* plantations. Species were categorised as forest species if they fulfilled one of two

Table 1: Description of study sites (disturbance levels adapted from Newmark 1997)

Site	Habitat	Size (ha)	Description
Turaco	Forest	45	Undisturbed (primary forest)
Mbomole 1	Forest	42	Moderately disturbed and close to human settlement
Mbomole 2	Forest	12	Moderately disturbed forest, enclosed by tea plantations but within a 1 km proximity to large forest block
Mlesa	Forest	64	Large continuous forest block (c. 200 ha) but only 64 ha were surveyed in this study; other parts were inaccessible due to rugged terrain. The surveyed area was moderately disturbed separated longitudinally from the entire forest block by a ridge and was close to human settlement
Bulwa	Forest	20	The most isolated forest patch, but lightly disturbed by timber harvesting and firewood collection. It was enclosed by tea plantations with the nearest forest about 4 km away
Germany	Forest	67	Disturbed forest, surrounded by tea plantations and disturbed by harvesting for firewood, timber and poles
Mgambo	*Eucalyptus*	40	20% of the floor was occupied by herbaceous layer
Derema	*Eucalyptus*	42	Very few indigenous trees but with open understorey
Monga 3	*Eucalyptus*	48	Little vegetation on the plantation floor (1% undergrowth)
Ndola	*Eucalyptus*	50	Middle stratum and understorey completely opened
Monga 1	*Eucalyptus*	60	80% of its understorey was occupied by *Lantana camara*, an invasive herb, with a few old indigenous trees
Monga 2	*Eucalyptus*	16	50% of the understorey was covered by herbs

criteria: 1) they live in the forest interior, or 2) they live on the forest edge, but appear to be dependent on forest habitat to complete their annual cycle (Moreau 1935, 1936, Stuart 1983, Mlingwa et al. 2001).

Coefficient of similarity

A coefficient of similarity for forest and non-forest species for forest and *Eucalyptus* sites was calculated by using Sorenson's index of similarity (C_s) for comparing two sites (Magurran 1988):

$$C_s = \frac{2j}{a+b}$$

where j = the number of species common to forest and *Eucalyptus,* a = the number of species in forests, and b = the number of species in *Eucalyptus*.

Species richness

Observed species richness (OSR) as determined by a survey may not necessarily equate to total species richness (TSR) of the community (Colwell and Coddington 1994, Gotelli and Graves 1996). Even in thorough surveys, one can never be certain that all species are found (Pomeroy and Dranzoa 1997), which renders direct comparison of species richness impossible (Lande 1996). Various methods for estimation of species richness from TSC data exist, which include Jackknife 1, Chao 1 and Chao 2 (Bolwig et al. 2006, Romdal 1998). Romdal (1998) recommends Chao 1 for large samples from TSCs. We therefore employed the Chao 1 (S_1*) estimator, a non-parametric method, to obtain the TSR from the TSC mean scores (MS). The Chao 1 is given by the formula (Colwell and Coddington 1994):

$$S_1^* = S_{obs} + \left(\frac{a^2}{2b}\right)$$

where S_{obs} = the observed number of species in the sample, a = the number of species only observed once (singletons), and b = the number of species observed only twice (doubletons).

Comparison of TSR between the forest and *Eucalyptus* plantations was examined using the Mann-Whitney *U*-test. We used TSC indices (mean scores) to categorise species into 'common' and 'rare': common = MS ≥ 0.5 and rare = MS < 0.5.

Results

Species richness

From 240 TSCs, 100 species in 79 genera, 32 families and seven orders were recorded in this study (Appendix 1). Sixty-seven percent of all the species recorded were forest birds including those believed to undergo intra-African migration (Stuart 1983, Mlingwa et al. 2001). With the exception of seven families (Coliidae, Alcedinidae, Phoeniculidae, Corvidae, Motacillidae, Laniidae and Fringillidae), the rest of the known families in the area included one or more forest species. The number of species observed in forest sites ranged from 40–51 with TSR ranging from 49–71 species, whilst species observed and estimated in *Eucalyptus* sites ranged from 32–47 and 42–69, respectively. Total species richness for forest and non-forest birds combined did not differ significantly between forest and *Eucalyptus* (U' = 26.000, $n_1 = n_2 = 6$, $P = 0.240$), whereas the difference was significant (U' = 36.000, $n_1 = n_2 = 6$, $P = 0.002$) for forest species. There was no clear trend between species richness expressed in both OSR and TSR and size of the study site (Figure 1). Some study sites, although relatively smaller, had considerably higher species richness as compared to larger sites.

Sixty-three forest species were recorded at forest sites and 41 forest species in *Eucalyptus* plantations. Only four forest bird species were recorded exclusively in the *Eucalyptus* plantations: African Harrier-hawk *Polyboroides typus*, Bar-tailed Trogon *Apaloderma vittatum*, Eastern Nicator *Nicator gularis* and Banded Green Sunbird *Anthreptes rubritorques*. The coefficients of similarity for the forest and non-forest species between *Eucalyptus* and forest were 0.638 and 0.848, respectively. There was no significant variation in species richness between breeding and non-breeding seasons at forest sites (U' = 24.000, $n_1 = n_2 = 6$, P = 0.378) or among *Eucalyptus* sites (U' = 28.000, $n_1 = n_2 = 6$, P = 0.127) (Figure 2). However, pooled data to compare the two habitat types showed significant variation in species richness between breeding (U' = 36.000, $n_1 = n_2 = 6$, P = 0.002) and non-breeding seasons (U' = 36.000, $n_1 = n_2 = 6$, $P = 0.002$).

Relative abundance

The MS and respective species ranks (SR) for each study site were plotted to show the pattern of relative species abundance (Figure 3). Natural forests had homogenous avian communities with few species above (over-represented) and below (under-represented) the trendline (smooth concave curve). At the Turaco site, an undisturbed forest, the plotted points (MS versus SR) fell along the expected trendline (Figure 3). The *Eucalyptus* sites showed a clear deviation from the trendline. Few

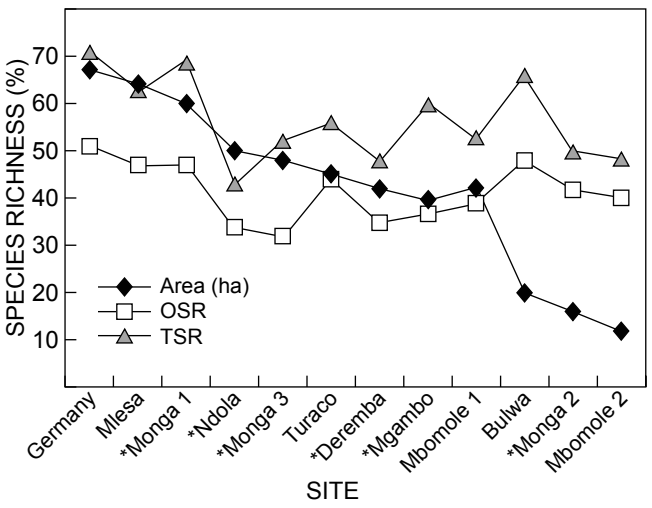

Figure 1: Relationship between the area of the study sites and species richness for both observed species richness (OSR) and total species richness (TSR) in the study sites. * = *Eucalyptus* plantation sites

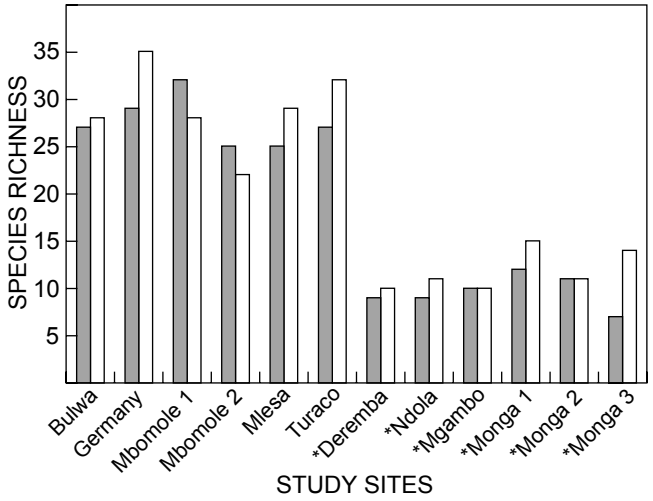

Figure 2: Seasonal differences in total species richness (TSR) between study sites. * = *Eucalyptus* plantation site, open bar = non-breeding season, solid bar = breeding season

species showed higher MS in *Eucalyptus* plantations, indicating some level of dominance by one or two species. For example, at Derema, the abundant species (MS = 4.40) was over three times as common as the second species (MS = 1.35). At Monga 1, the most abundant species (MS = 4.15) was about twice as common as the second species (MS = 1.90) (Figure 3) and this was dominated by sunbirds.

The pooled data for forest species are presented in Table 2 to show the mean scores and species ranks. On average, the Olive Sunbird *Cyanomitra olivacea* was the most abundant species with MS of 3.44 in forest and 3.03 in the *Eucalyptus* plantations. Among the 26 'common' (MS ≥ 0.5) species in forests, the Square-tailed Drongo *Dicrurus ludwigii* was the commonest species with a mean score of 3.76 followed by Green Barbet *Stactolaema olivacea* (3.49) and Silvery-cheeked Hornbill *Bycanistes brevis* (3.28). *Eucalyptus* plantations had only 12 species with MS ≥ 0.5 (Table 2). Nine of these species belonged to the 26 'common' bird species in the forest sites. Comparison of MS for these 12 species between *Eucalyptus* plantations and forest showed no significant difference (U' = 75.000, n_1 = 12, n_2 = 9, P = 0.885), indicating that they are almost equally abundant in both habitat types. With the exception of Fisher's Turaco, all threatened and range-restricted species recorded in this study had lower MS in the two habitat types (Table 2), and thus were classified in the rarest category, i.e. MS < 0.5.

The comparison of MS for all birds in both breeding and non-breeding seasons within habitat types (i.e. *Eucalyptus* sites and forest sites) did not show any significant variation (U' = 452.000, n_1 = 27, n_2 = 32, P = 0.767). In contrast, a comparison of MS for bird species only observed in both *Eucalyptus* and forest sites in the breeding season (Table 3) showed a significant difference (U' = 303.500, $n_1 = n_2$ = 21, P = 0.038), indicating that forest sites were more preferred than *Eucalyptus* during the breeding season.

Discussion

Species richness

In total, we recorded 100 bird species in our study sites. This is a relatively low number compared to 340 species representing 61 families recorded from the East Usambaras (Pohjonen and Cordeiro 2001). However, our study was confined to the Amani Plateau and surveyed only two habitat types among many others in the area. In the East Usambaras, some bird species are rare and restricted; for example, the endangered Usambara Hyliota *Hyliota usambarae* is found below 900 m (Borghesio et al. 2008), while others are characteristic of coastal forest (Mlingwa et al. 2001). Furthermore, it was easier to prove presence than confirm absence especially in forest. For example, we did not detect ground-foragers such as Northern Olive Thrush *Turdus pelios*, but this species was frequently mist-netted in our study sites by other researchers during the same period (Newmark 2006). Moreover, our study is comparable to that of Borghesio et al. (2008) at Amani Plateau, who found 124 bird species in smallholder agriculture and forest sites.

The main finding of our study is that forest sites had higher richness of forest-dependent species than *Eucalyptus* sites, although total species richness was not significantly different between the two habitats. We also found that many species were more abundant in forest sites than *Eucalyptus* plantation but a few species, especially sunbirds, showed higher abundance in *Eucalyptus* plantations. Another interesting observation was that some threatened and range restricted species were found in both habitat types.

The non-forest species at Amani use different habitat types, including the *Eucalyptus* plantations and forest, while forest-dependent species may occasionally use *Eucalyptus* plantations, which explains why there was a significant difference for forest species but not for total species richness. Stuart (1983) describes this situation of forest birds living in or using non-forest habitats as a spill-over effect. The difference between OSR and TSR in this study is in agreement with the general scenario that in tropical forest habitats with high diversity it is difficult to enumerate all the species in a given study. The diversity of rich communities such as those of the Eastern Arc mountains is rarely thoroughly explored and some of the rare species may not be seen (Romdal 1998). Some forest sites such as Germany, Bulwa and Mlesa emerged the most species-rich sites, and this may have resulted from other factors such as degree of isolation (Newmark 1991, 2006, Bolwig et al. 2006) and disturbance levels rather than their respective sizes. This also applied to *Eucalyptus* plantations. While this is in contrast to the generally accepted patterns that richness increases with increasing habitat area for any type of habitat (Wiens 1989, Rosenzweig 1995, Diaz et al. 1998) it is in support of other studies that hypothesised that local species richness can, in some cases, increase as the forest habitat becomes degraded (Wiens 1989, Danielsen 1997) as all of the three sites were either moderately or heavily disturbed (Newmark 1997).

For *Eucalyptus* plantations, the variation in OSR and TSR, in additional to the degree of isolation, could be explained by the presence of undergrowth and remnant indigenous

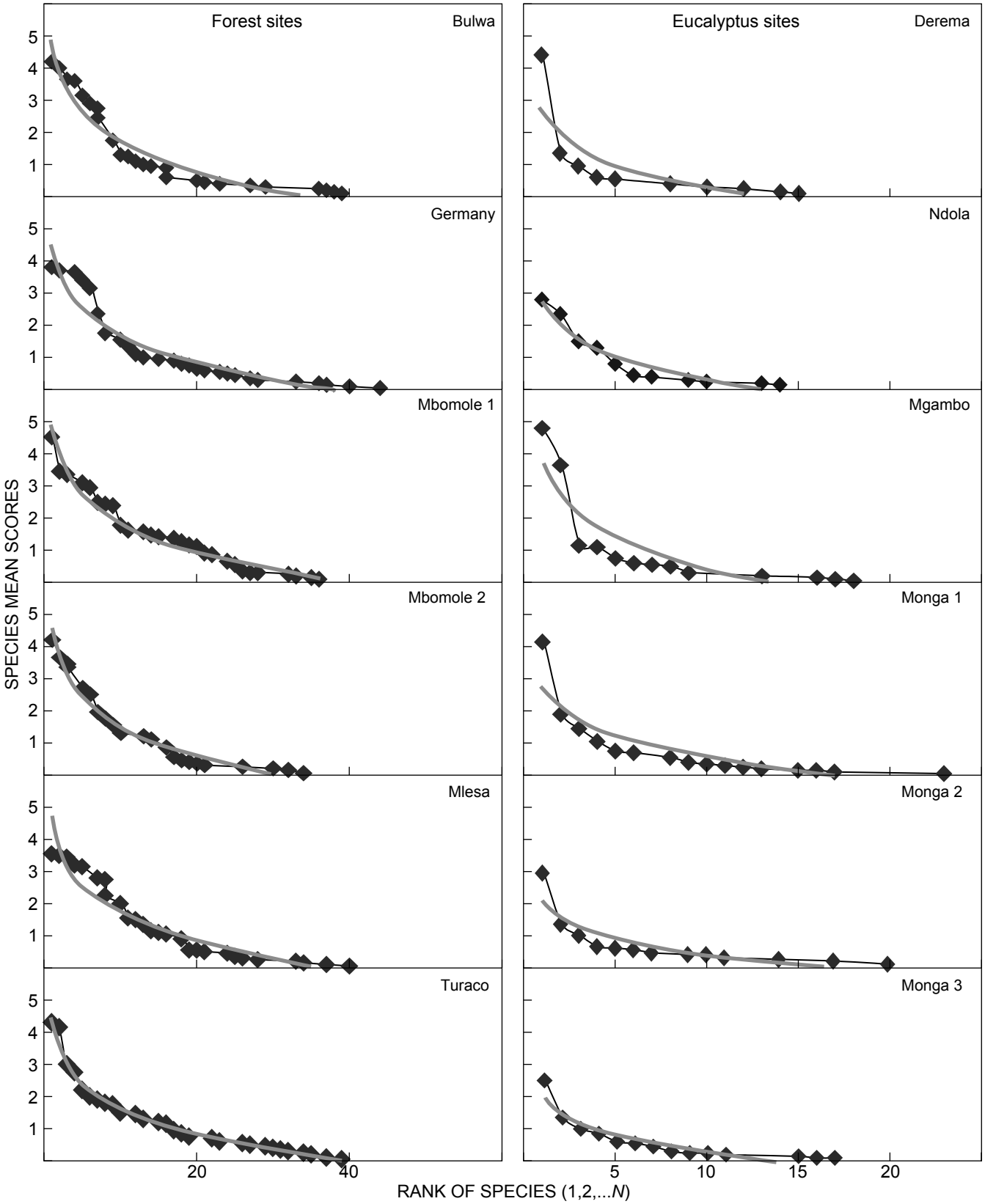

Figure 3: Species rank abundance plots for 12 study sites (forest on left, *Eucalyptus* plantation on right). The trendline (smooth concave curves) represents the expected trend pattern in species rich habitats (Romdal 1998); from the most common (with high mean scores) species to rare (lower mean scores) species. The plotted data curves lie along the expected trendline for most of forest sites unlike for the *Eucalyptus* sites. Turaco (an undisturbed site) represents a good example

Table 2: Species relative abundance expressed as averaged (pooled) mean scores (MS) and species ranks (SR) of each species in both natural forest and plantation sites. IUCN red-listed and restricted-range species are indicated by an asterisk (*). Threat status follows BirdLife International (2009) and IUCN (2009) and definition of restricted-range species given by Stattersfield et al. (1998). NT = Near-threatened, VU =Vulnerable, EN = Endangered, CR = Critically Endangered

Natural forest			*Eucalyptus* plantation		
Species	MS	SR	Species	MS	SR
Square-tailed Drongo	3.76	1	Olive Sunbird	3.00	1
Green Barbet	3.49	2	Collared Sunbird	2.33	2
Olive Sunbird	3.44	3	Eastern Bronze-naped Pigeon	1.50	3
Silvery-cheeked Hornbill	3.28	4	African Harrier-hawk	1.10	4
Little Greenbul	2.92	5	Tambourine Dove	0.93	5
Green-headed Oriole	2.73	6	Fischer's Turaco NT*	0.81	6
Tambourine Dove	1.99	7	Bar-tailed Trogon	0.60	7
Dark-backed Weaver	1.98	8	Purple-banded Sunbird	0.60	7
Shelley's Greenbul	1.88	9	Grey-backed Camaroptera	0.54	9
African Paradise-flycatcher	1.84	10	Green-headed Oriole	0.53	10
White-eared Barbet	1.59	11	Yellow White-eye	0.51	11
Fischer's Turaco NT*	1.29	12	Green Barbet	0.50	12
Eastern Bronze-naped Pigeon	1.18	13	Olive Pigeon	0.45	13
Moustached Green Tinkerbird	1.08	14	White-eared Barbet	0.43	14
Forest Batis	1.06	15	Peters's Twinspot	0.40	15
Trumpeter Hornbill	0.91	16	Black-headed Apalis	0.38	16
Collared Sunbird	0.90	17	Waller's Starling	0.38	16
Evergreen Forest Warbler	0.89	18	Black-bellied Starling	0.35	18
African Broadbill	0.86	19	Yellowbill	0.35	18
Cabanis's Greenbul	0.79	20	African Paradise-flycatcher	0.34	20
White-chested Alethe	0.69	21	Eastern Nicator	0.33	21
White-tailed Crested-flycatcher	0.64	22	Red-winged Starling	0.33	21
Tiny Greenbul	0.62	23	Amani Sunbird EN*	0.31	23
Yellow White-eye	0.60	24	African Goshwak	0.30	24
Black-fronted Bush-shrike	0.56	25	Trumpeter Hornbill	0.30	24
African Emerald Cuckoo	0.50	26	Moustached Green Tinkerbird	0.28	26
Yellow-streaked Greenbul	0.48	27	African Emerald Cuckoo	0.25	27
Black-backed Puffback	0.45	28	Long-billed Tailorbird CR*	0.25	27
African Goshawk	0.45	28	Silvery-cheeked Hornbill	0.24	29
Waller's Starling	0.45	28	Black-backed Puffback	0.23	30
Pale-breasted Illadopsis	0.40	31	Little Greebul	0.23	30
African Green-pigeon	0.40	31	Green Twinspot	0.23	30
Olive Pigeon	0.35	33	Southern Banded Snake-eagle NT	0.23	30
Red-headed Bluebill	0.35	33	Red-faced Crimsonwing	0.17	34
Lemon Dove	0.34	35	Black-throated Wattle-eye	0.15	35
Barred Long-tailed Cuckoo	0.33	36	Uluguru violet-backed Sunbird	0.15	35
Stripe-cheeked Greenbul	0.31	37	Evergreen Forest Warbler	0.13	37
African Crowned Eagle	0.30	38	African Green-pigeon	0.10	38
Black-and-white Shrike-flycatcher	0.30	38	Banded Green Sunbird VU*	0.10	38
Amani Sunbird EN*	0.30	38	Cardinal Woodpecker	0.05	40
Black-bellied Starling	0.30	38	Eastern Honeybird	0.05	40
Black-headed Oriole	0.30	38			
Green Twinspot	0.30	38			
Red-winged Starling	0.30	38			
Black-throated Wattle-eye	0.28	45			
Southern Banded Snake-eagle NT	0.28	45			
Long-billed Tailorbird CR*	0.25	47			
Peters's Twinspot	0.25	47			
Orange Ground Thrush	0.24	49			
African Golden Oriole	0.24	49			
Uluguru Violet-backed Sunbird	0.23	51			
Red-faced Crimsonwing	0.20	52			
Scaly-throated Honeyguide	0.20	52			
Sharpe's Akalat*	0.20	52			
Green-backed Camaroptera	0.17	55			
Usambara Nightjar	0.15	56			
Yellow-throated Woodland Warbler	0.15	57			
Eastern Honeybird	0.13	58			
Black-backed Apalis	0.10	59			
Yellowbill	0.10	60			
Cardinal Woodpecker	0.08	61			
Grey Cuckoo-shrike	0.05	62			
Mombasa Woodpecker	0.05	62			

Table 3: Timed species count indices for birds recorded in both natural forest and *Eucalyptus* plantation during the breeding season

Species	Natural forest	*Eucalyptus* plantation
Olive Sunbird	3.92	3.17
Green Barbet	3.92	0.19
Little Greenbul	3.52	0.08
Green-headed Oriole	3.44	0.42
Silvery-cheeked Hornbill	3.25	0.13
African Paradise-flycatcher	1.56	0.08
Moustached Green Tinkerbird	1.52	0.23
White-eared Barbet	1.46	0.31
Fischer's Turaco	1.42	0.38
Tambourine Dove	1.38	0.85
Trumpeter Hornbill	0.96	0.13
Eastern Bronze-naped Pigeon	0.50	0.13
Collared Sunbird	0.40	1.96
Grey-backed Camaroptera	0.23	0.10
Southern Banded Snake-eagle	0.19	0.15
African Goshawk	0.17	0.13
Red-winged Starling	0.13	0.13
Waller's Starling	0.10	0.25
Yellow White-eye	0.08	0.52
Eastern Honeybird	0.06	0.02
Yellowbill	0.04	0.08

tree species (Table 1). The presence of forest birds in these plantations may also be attributed to flowering resources, which offered foraging potential to sunbirds and other insectivores and frugivores in the plantations. Nevertheless, the presence of forest trees and undergrowth were probably not adequate for maintaining other forest species, resulting in lower species richness for forest species compared with forest sites. Our findings are in line with previous studies that show lower species richness in managed plantations (Cruz 1988, Diaz et al. 1998, Petit et al. 1999, Farwing et al. 2008). In Brazil, Marsden et al. (2001) recorded only eight species in 50 counts in managed *Eucalyptus*, which was far poorer than some of our sites, and their study suggested that the situation was caused by lack of understorey vegetation due to management practices.

The fact that some threatened species and/or species with very restricted geographical distributions, such as the critically endangered Long-billed Tailorbird and endangered Amani Sunbird (BirdLife International 2009), were also recorded in *Eucalyptus* plantations, although with lower abundances, indicates that the plantations can have potential value for some threatened species when properly managed. Borghesio et al. (2008) noted that the Long-billed Tailorbird was resistant to disturbance, as they recorded it in severely disturbed habitats usually with *Lantana camara* bushes and remnant trees covered with vines, a habitat that is usually removed in *Eucalyptus* plantations.

Since large proportions of some species undergo altitudinal movements leaving some residents on the Amani Plateau (Stuart 1983, Burgess and Mlingwa 2000, John and Kabigumila 2007), species richness does not vary significantly in either habitat between breeding and non-breeding seasons. However, the effect of these movements was reflected in species relative abundance where the frequency of encounter was lower for the breeding season. The difference for pooled data could be explained by the fact that many species avoid *Eucalyptus* plantations during breeding (John and Kabigumila 2007).

Relative abundance

Most forest sites showed little dominance by a single species unlike the *Eucalyptus* plantations. The low numbers of species with MS $\geq$ 0.5 in our study may suggest that past extinction patterns, caused by periodic fragmentation of the forest habitat, have eliminated many vulnerable species, and that the remaining avian community is more resistant to disturbance (Fjeldså and Rabøl 1995). The poor visibility in the closed-canopy forest may also explain the relatively low indices of other species. The Square-tailed Drongo and hornbills were frequently recorded because they are conspicuous and vocal (Romdal 1998) or because of seasonal congregation, which make them score higher TSC indices. The same scenario has been described by other studies in tropical forests (Poulsen et al. 1997), while temperate forests (with fewer species) often contain species with 30–40% of individuals over- and under-represented (James and Rathbun 1981). Sunbirds were the most common throughout the study area, and this is because they move between both natural forests and *Eucalyptus* plantations for fruiting trees. This finding supports other studies in Australian *Eucalyptus* forests where it has been noted that at any time the abundance and diversity of nectar, manna, honeydew and lerp appeared to determine the abundance and diversity of honeyeater species (Keast 1990). In Bornean forests, Mitra and Sheldon (1993) observed flocks of birds including sunbirds flying into the plantations from surrounding areas during their morning surveys.

Almost all threatened and range-restricted bird species recorded in our study had MS $<$ 0.5, which means that they were in the 'rare' category according to our classification. This indicates that the method we used in this study grouping 'rare' and 'common' was consistent and that TSC can give a quick assessment provided that the surveyors have good knowledge on the songs and calls of the local forest avifauna (Pomeroy and Dranzoa 1997).

Most of the forest birds advertised their breeding territories by making calls and songs and this may explain the high TSC indices in the breeding season, with vocal species having high scores. Moreau (1936) studied the breeding birds of the East Usambaras and found a large proportion of birds singing more during the breeding season than the non-breeding season. Other studies (Lack 1933, Pomeroy 1992) have shown that breeding activities can greatly affect the numbers of birds detected in almost all habitats. Some species that had higher scores during the breeding season are known to undergo seasonal downward movements from the plateau during the non-breeding season (Stuart 1983, Burgess and Mlingwa 2000).

Finally, because of patchiness of the habitats at the Amani Plateau, where there is always a short distance between the habitats (e.g. from *Eucalyptus* to forest, or from forest to agricultural fields), and because of the subsistence agricultural fields on the plateau (Borghesio et al. 2008), which may act as connecting habitats to facilitate movements of

birds between our study sites. This may have resulted in the high similarities observed in our study. However, this needs to be formally tested in future as it may be significantly biased towards some species (Bolwig et al. 2006). While we acknowledge these limitations, we believe our results of species richness and abundance give a general picture of the conservation value of the *Eucalyptus* plantations at the Amani Plateau. However, in our previous study at Amani (John and Kabigumila 2007) we found that remnant indigenous trees and understorey vegetation were the main nest locations in *Eucalyptus* plantations. Thus the present data on species richness and relative abundance need to be interpreted with caution. The general result could be that many bird species respond to the overall suitability of the landscape matrix (Borghesio et al. 2008, Franklin and Lindenmayer 2009), rather than forest or plantations, because the plantations provide foraging grounds for some species even during the breeding season.

Amani Plateau was once covered by natural forest, and its avifauna community would have been dominated by forest species. This makes any further conversion or destruction of natural forest to be of great concern for conservation of the area. Natural forests in the Eastern Usambaras remain an important habitat for conservation of the local bird community, especially the forest species, as they provide suitable microhabitats that are lacking in *Eucalyptus* plantations. However, *Eucalyptus* has become one of the habitat mosaics of the East Usambaras and could provide additional habitats for local avifauna if properly managed and given its economic importance to the production of tea in this area; this is a cause for concern. Therefore, the viable option is to manage the landscape matrix of the region including plantations in a proper way that supports habitats for local avifauna. In view of the above facts, we recommend proper management of *Eucalyptus* plantations that retain some habitats (e.g. undergrowth and isolated indigenous trees) for local birds.

Acknowledgements — We are grateful to the University of Dar es Salaam–MarcArthur Project for funding this study. Thanks also go to WD Newmark, N Cordeiro and RBM Senzota for their technical support prior to and during this study. Fieldwork was made possible with assistance from Victor Mkongewa, Idrissa Mtunguja and Billy Munisi. Luca Borghesio and two anonymous referees commented on an earlier version of this manuscript. Finally, many thanks to the East Usambara Tea Company and Amani Nature Reserve management for their permission to undertake this study in the area.

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Received December 2009, accepted July 2010
Editor: A Monadjem

Appendix 1: Bird species recorded at study sites during the sampling period, their orders, families and grouping into forest and non-forest. * = forest birds

ACCIPITRIFORMES
Accipitridae
- Palm-nut Vulture *Gypohierax angolensis*
- Southern Banded Snake-eagle *Circaetus fasciolatus**
- African Goshawk *Accipiter tachiro**
- African Harrier-hawk *Polyboroides typus**
- Augur Buzzard *Buteo augur*
- Long-crested Eagle *Lophaetus occipitalis*
- African Crowned Eagle *Stephanoaetus coronatus**

Columbidae
- African Green-pigeon *Treron calva**
- Eastern Bronze-naped Pigeon *Columba delegorguei**
- Olive Pigeon *Columba arquatrix**
- Tambourine Dove *Turtur tympanistria**
- Red-eyed Dove *Streptopelia semitorquata*
- Lemon Dove *Aplopelia larvata**

CUCULIFORMES
Musophagidae
- Fischer's Turaco *Tauraco fischeri**

Cuculidae
- Barred Long-tailed Cuckoo *Cercococcyx montanus**
- Africa Emerald Cuckoo *Chrysococcyx cupreus**
- Yellowbill *Ceuthmochares aereus**
- White-browed Coucal *Centropus superciliosus*

CUPRIMULGIFORMES
Caprimulgidae
- Usambara Nightjar *Caprimulgus guttifer**

COLIIFORMES
Coliidae
- Speckled Mousebird *Colius striatus*

TROGONIFORMES
Trogonidae
- Bar-tailed Trogon *Apaloderma vittatum**

CORACIIFORMES
Alcedinidae
- Grey-headed Kingfisher *Halcyon leucocephala*
- Brown-hooded Kingfisher *Halcyon albiventris*

Phoeniculidae
- Common Scimitarbill *Rhinopomastus cyanomelas*

Bucerotidae
- Trumpeter Hornbill *Bycanistes bucinator**
- Silvery-cheeked Hornbill *Bycanistes brevis**

PICIFORMES
Capitonidae
- Moustached Green Tinkerbird *Pogoniulus leucomystax**
- Green Barbet *Stactolaema olivacea**
- White-eared Barbet *Stactolaema leucotis**

Indicatoridae
- Scaly-throated Honeguide *Indicator variegatus**
- Lesser Honeyguide *Indicator minor*
- Eastern Honeybird *Prodotiscus zambesiae**

Picidae
- Cardinal Woodpecker *Dendropicos fuscescens**
- Mombasa Woodpecker *Campethera mombassica**

PASSERIFORMES
Eurylaimidae
- African Broadbill *Smithornis capensis**

Motacillidae
- Grey Wagtail *Motacilla cinerea*

Pycnonotiidae
- Common Bulbul *Pycnonotus barbatus*
- Shelley's Greenbul *Andropadus masukuensis**
- Stripe-cheeked Greenbul *Andropadus milanjensis**
- Yellow-streaked Greenbul *Phyllastrephus flavostriatus**
- Tiny Greenbul *Phyllastrephus debilis**
- Cabanis's Greenbul *Phyllastrephus cabanisi**
- Little Greenbul *Andropardus virens**
- Eastern Nicator *Nicator gularis**

Timaliidae
- Pale-breasted Illadopsis *Illadopsis rufipennis**
- Arrow-marked Babbler *Turdoides jardineii*

Turdidae
- Sharpe's Akalat *Sheppadia sharpei**
- White-chested Alethe *Alethe fuelleborni**
- White-browed Robin-chat *Cossypha heuglini*
- Orange Ground-Thrush *Zoothera gurneyi**
- Common Stonechat *Saxicola torquata*

Muscicapidae
- Pale Batis *Batis soror*
- Forest Batis *Batis mixta**
- Black-and-white Shrike-flycatcher *Bias musicus**
- Black-throated Wattle-eye *Platysteira peltata**
- African Paradise-flycatcher *Terpsiphone viridis**
- White-tailed Crested-flycatcher *Trochocercus albonotatus**

Sylviidae
- Evergreen Forest Warbler *Bradypterus lopezi**
- Yellow-throated Woodland Warbler *Phylloscopus ruficapillus**
- Tawny-flanked Prinia *Prinia subflava*
- Grey-backed Camaroptera *Camaroptera brachyura**
- Long-billed Tailorbird *Orthotomus moreaui**
- Black-headed Apalis *Apalis melanocephala**

Zosteropidae
- Yellow White-eye *Zosterops senegalensis**

Laniidae
- Common Fiscal *Lanius collaris*
- Red-backed Shrike *Lanius collurio*

Malaconotidae
- Black-backed Puffback *Dryoscopus cubla**
- Tchagras *Tchagra* spp
- Black-fronted Bush-shrike *Malaconotus nigrifrons**
- Tropical Boubou *Laniarus aethiopicus*

Campephagidae
- Grey Cuckoo-shrike *Coracina caesia**

Dicruridae
- Fork-tailed Drongo *Dicrurus adsimilis*
- Square-tailed Drongo *Dicrurus ludwigii**

Oriolidae
- Green-headed Oriole *Oriolus chlorocephalus**
- African Golden Oriole *Oriolus auratus*
- Black-headed Oriole *Oriolus larvatus**

Corvidae
- White-naped Raven *Corvus albicollis*

Sturnidae
- Red-winged Starling *Onychognathus morio**
- Waller's Starling *Onychognathus walleri**
- Black-bellied Starling *Lamprotornis corruscus**

Nectariniidae
- Banded Green Sunbird *Anthreptes rubritorques**
- Olive Sunbird *Cyanomitra olivacea**
- Purple-banded Sunbird *Cinnyris bifasciata**
- Variable Sunbird *Cinnyris venusta*
- Collared Sunbird *Hedydipna collaris**
- Amani Sunbird *Anthreptes pallidigaster**
- Uluguru Violet-backed Sunbird *Anthreptes neglectus**

Ploceidae
- Spectacled Weaver *Ploceus ocularis*
- Baglafecht Weaver *Ploceus baglafetch*
- Dark-backed Weaver *Ploceus bicolor**
- Pin-tailed Whydah *Vidua macroura*

Estrildidae
- Peters's Twinspot *Hypargos niveoguttatus**
- Green Twinspot *Mandingoa nitidula**
- Red-faced Crimsonwing *Cryptospiza reichenovii**
- Red-headed Bluebill *Spermophaga ruficapilla**
- Common Waxbill *Estrilda astrild*
- Bronze Mannikin *Lonchura cucullata*

Fringillidae
- Yellow-fronted Canary *Serinus mozambicus*
- African Citril *Serinus citrinelloides*
- Cabanis's Bunting *Emberiza cabanisi*