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Understorey Bird Communities 8 and 18 Years after River Diversion in Kihansi Gorge, Udzungwa Mountains in the Eastern Arc Mountains, Tanzania

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Abstract

On the most south-western slopes of the Udzungwa Mountains in Tanzania lies Kihansi River. The river was diverted underground in 2000 to run electric turbines for electricity generation. Using mist netting, pre-diversion (in 1998 and 1999) and short term post-diversion (in 2001) effects of the river diversion on understorey birds were undertaken before and year after river diversion, respectively. Intermediate and long-term effects of river diversion on understorey birds at the same transects are non-existent. In September 2008 and August and September 2018, using mist nets, birds were surveyed at the same transects to assess whether or not there have been changes in avian community structure, abundance and diversity eight and 18 years after the river was diverted. Results suggest that there have been no significant changes in pre- diversion and eight and 18 years post-diversion birds' species abundances and diversities. This suggests that the diversion of the river has had no intermediate term effects on avifauna in the gorge.

Keywords: Avian community composition, Kihansi River, Mist netting, River diversion, Species diversity, Understorey forest birds

Introduction

On the most western part of the Udzungwa Mountains within the Eastern Arc Mountains, Tanzania lies the Kihansi gorge. Here there is a steep terrain with a fast flowing river–the Kihansi River and a riverine forest that is surrounded by dry woodland (Cordeiro et al. 2006). The physical structure of Kihansi River and its associated waterfalls (found along Kihansi Gorge) made it suitable for construction of a hydropower plant for electricity generation (Rija et al. 2011). For the highly needed electricity, the government of Tanzania undertook initiatives to construct a hydropower plant in the Kihansi Gorge. Between 1994 and 1999 a dam was constructed upstream of the spray wetlands and in the year 2000 Kihansi River was diverted underground to run electric turbines for electricity generation. The diversion of the river reduced the natural flow of water from between 10-32 m^3/s to about 1.5–2 m^3/s (Cordeiro et al. 2006) leading to a loss of approximately 90% of the water that previously maintained the different habitats found in the gorge (Zilihona et al. 2004).

Prior to, and after, the construction of the hydropower plant, studies in the Kihansi Gorge area were conducted which showed the presence of different species of flora and fauna. Among these species are rare plant and animal species including the critically endangered plant *Coffea kihansiensis* (Rija et al. 2011), a toad *Nectophrynoides asperginis* (Poynton et al. 1998, Channing et al. 2006) and a recently described butterfly *Charaxes mtuiae* (Collins et al. 2017). These studies have also shown that reduction of the river flow has impacted microclimatic conditions and ecological systems of the gorge. Specifically, the reduction in river flow along the gorge and spray caused a major part of the

gorge habitat to desiccate (Kjarick 2006) including the drying up of the spray-dependent habitat (Doggart and Milledge 2001) which threatened the survival of the toad *N. asperginis.* The diversion has also affected some plant taxa in the gorge wetlands (Quinn et al. 2005), insects (Zilihona et al. 2004) and birds (Cordeiro et al. 2006).

The short term effects of river diver diversion on birds have been addressed by Cordeiro et al. (2006) through their pre-diversion baseline studies (conducted in 1998 and 1999) and post-diversion surveys (in 2001). Through these studies, Cordeiro et al. (2006) established a sampling regime in the hot and cold seasons to accommodate the aspect of seasonality in birds abundance and diversity (Burgess and Mlingwa 2000, Werema 2016a, Werema et al. 2016 a, b). A year after the river was diverted, Cordeiro et al. (2006) found that one of their sampled sites, the Upper Kihansi transect, suffered a significant decrease in number of individuals of birds. Overtime, the impact of river diversion could have already impacted understorey birds in the gorge as it has been the case of the toad *N. asperginis* and the plant *C. kihangensis* (see Rija et al. 2011). Because hydropower schemes that involve river diversions have the potential to change ecosystems (Cordeiro et al. 2006), intermediate and long term ecosystem changes due to diversion of the Kihansi River are currently not well understood. Additionally, while short term responses of flora and fauna to changes in the gorge ecosystem have been addressed (e.g., Zilihona et al. 2004, Quinn et al. 2005, Cordeiro et al. 2006, Kjarick 2006), long term responses of flora and fauna to changes in the gorge ecosystem are non-existent. It is probable that there have been changes in forest cover and microclimate in the gorge which may have already impacted the understorey birds, only that we are not aware. The study was therefore of great interest in order to assess intermediate term effects of river diversion on the avifauna. The results reported here were undertaken 10 and 20 years after the pre-river diversion avifauna study by Cordeiro et al. (2004, 2006) in 1998 (i.e., eight and 18 years after the river diversion). The post river diversion surveys were conducted such that they could be compared with the pre- and post-diversion effects baseline data by Cordeiro et al. (2006).

The main objective was to assess whether the river diversion for the Kihansi hydropower project has had any effects on an understorey bird community in Kihansi Gorge. Specifically, the pre-diversion baseline data were compared with the findings of understorey bird species richness and diversity eight years, and 18 years, after river diversion.

Materials and methods

Study area

The Kihansi gorge (8^{o} 35′ S, 35^{o} 50′ E) is located on the eastern escarpment of the south-western part of the Udzungwa Mountains, Tanzania (Figure 1). Kihansi gorge is about 6 km long rising from an elevation of 300 m to 1100 m. The gorge is bordered by a riverine forest varying in width from the river. This forest is about 90 ha of closed canopy (Cordeiro et al. 2006). It is surrounded by formerly cultivated land on the lower southern and upper northern sides and open miombo woodland on the eastern and western slopes. In the upper part of the gorge the forest has been narrowed down by farming practices leaving strips of riverine which join the boundary of the Udzungwa Scarp Forest reserve. The gorge receives an average annual rainfall of roughly 1800 mm; the mean daily minimum and maximum temperatures of are about 13 °C and 25 °C, respectively (Cordeiro et al. 2006). For detailed description of the study area, see Cordeiro et al. (2004, 2006).

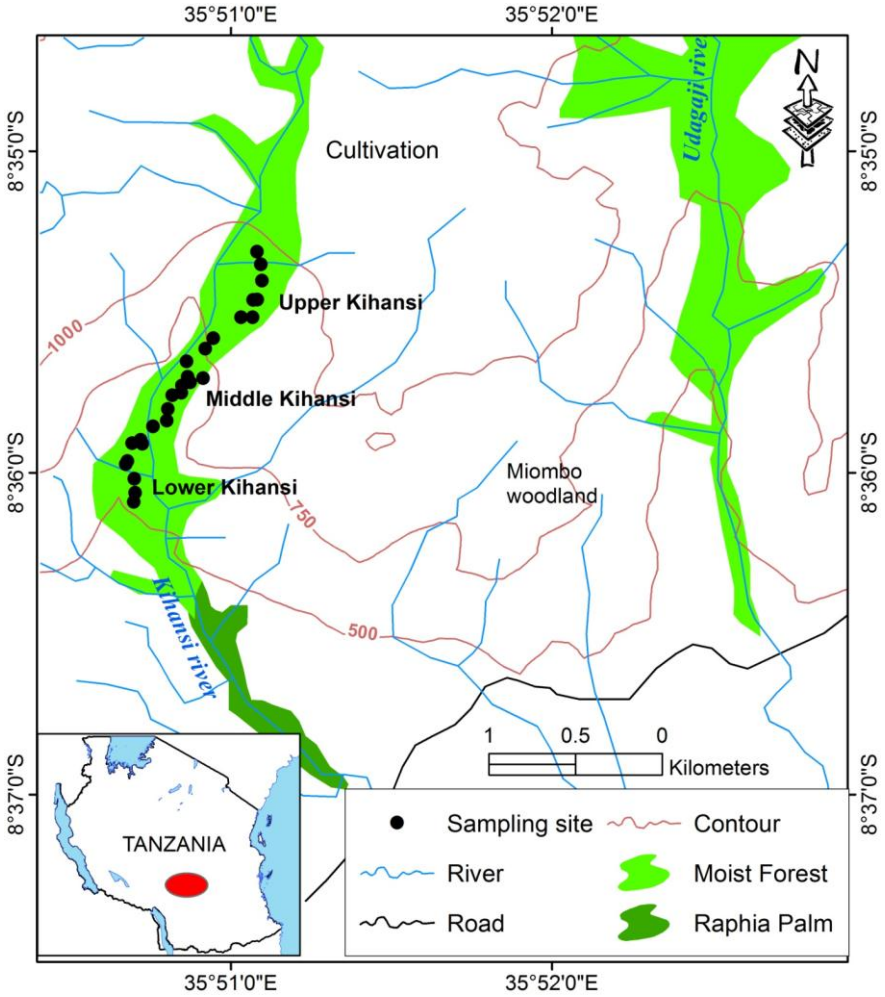

Figure 1: A map showing locations of mist net transects in Kihansi Gorge (modified from Cordeiro et al. 2006).

Methods

Mist netting

Mist netting was conducted as per recommended ecological monitoring protocols for Kihansi by Cordeiro et al. (2006) who conducted a pre-river diversion mist netting during the cold season in June 1998. To obtain data on capture rates and species composition of the understorey avifauna, mist-nets were erected from the ground level in the transects (sites) that were previously established by Cordeiro et al. (2006). Mist netting surveys were conducted in June 1998 (pre-diversion), July 2001 (one year post-diversion), September 2008 (eight years post-diversion and August- September 2018 (8 years post-diversion). The transects were Upper Kihansi gorge located between 800 – 870 m asl, Middle Kihansi gorge found between 600 – 750 m asl and Lower Kihansi gorge located between 480 – 560 m asl. For each of the above transects, mist netting was conducted in September 2008 and in late August – early September 2018. Each mist net was 3 m high and mesh size was 36 mm and

at each site the nets were operated for 3 consecutive days. The nets were opened one hour before sunrise (usually at 06:00) and closed half an hour before sunset (usually at 18:00), to allow time to remove any late catches. Under certain circumstances it rained while running mist nets. Under such situations mist nets were closed in which case nets were operated for equivalent effort during the fourth day. Mist-nets were checked every 30 minutes but more frequently during the morning and evening hours. Mist-nets were closed at night to avoid entangling bats and to prevent net destruction by nocturnal ground-dwelling mammals. There were slight variations in mist netting efforts at the study sites 8 and 18 years post-diversion in comparison to those of Cordeiro et al. (2006) (Table 1) but there was no significant difference in mist netting efforts among sites sampled (Friedman's test: $\chi^2 = 1.7$, df = 3, p = 0.637).

Table 1: Pre-diversion and post-diversion mist netting efforts at various sites at Kihansi Gorge

Sampling sites	Sampling period and sampling effort in metre-net-hours			
	Pre-diversion (1998)	One year post-diversion (2001)	Eight years post-diversion (2008)	18 years post-diversion (2018)
Upper Kihansi	3456	3456	3498	3492
Middle Kihansi	3456	3456	3444	3413
Lower Kihansi	3456	3456	3414	3049

Net trails/transects were cleared of saplings and other forest enriching vegetation. However, in certain instances, small tree branches had to be cleared out of the way and saplings had to be tied down away from the nets but released after sampling.

In September 2008, the birds captured in mist nets were banded with rings from East African Natural History Society. However, due to lack of rings in August – September 2018 birds captured were not ringed but for each individual mist netted a temporary marking was done on the tail feathers by using a blue marker pen for easy identification of recaptures.

Data analysis

Birds in the study area were divided into species that can be adequately surveyed by mist netting and those which cannot (see Newmark 1991). Species that can be adequately surveyed by mist nets are those that forage in the understorey layer of the canopy. Therefore analysis is limited to species that forage in the understorey. Species that forage in the overstorey layer of the canopy but were captured in mist nets presumably by chance (i.e., African cuckoo hawk *Aviceda cuculoides*, scaly-throated honeyguide *Indicator variegatus* and square-tailed drongo *Dicrurus ludwigii*) were excluded from analysis. Therefore, to avoid misinterpretation, all other captures of birds are referred to as understorey.

Species diversity during each sampling period was calculated using the Shannon–Wiener index of diversity using the software package PAST (Hammer et al. 2001). Also using the software package PAST, a special t-test was used to determine whether there were significant differences in species diversity (i) among sites, (ii) between pre-diversion sampling period and eight and 18 years post-diversion, and (iii) between one year post-diversion sampling period and eight and 18 years post-diversion (see Hutcheson 1970, Magurran 1988). The pre-diversion and one year post-diversion data were obtained by re-analysing Cordeiro et al. (2006) cold season data.

A cluster analysis was used to assess pre- and post-diversion avian community

composition similarity among transects and sampling periods. This was done 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 and Henderson 2007).

Results

Post-diversion overall species richness and diversity

From post-diversion data based on six survey sessions in all the three transects, a total of 142 individuals belonging to 20 different species were captured in the mist nets (Table 2). About 40% of these (69 individuals, 15 species) were caught at the Upper Kihansi transect, 22.5% (32 individuals, 6 species) at the Middle Kihansi transect and 29.5% (42 individuals, 8 species) at Lower Kihansi transect. Four species were frequently captured such that they accounted for over 77% of all captures. These were little greenbul *Eurillas virens* (38% of total captures), olive sunbird *Cyanomitra olivacea* (19%), red-capped robin-chat *Cossypha natalensis* (11.3%) and African pygmy kingfisher *Ispidna picta* (9.2%).

The overall species diversity at the Upper Kihansi transect was H = 2.030, those of the Middle and Lower Kihansi transects were H =1.491 and H = 1.715, respectively. The diversity at the Upper Kihansi transect was significantly higher than that of the Middle Kihansi transect ($t = 2.6475$, $df = 96.251$, $p < 0.01$) but not significantly higher than that of the Lower Kihansi transect ($t = 1.5676$, $df = 109.99$, $p > 0.05$). There was no significant difference in overall diversity between the Middle and Lower Kihansi transects ($t = 1.2811$, $df = 70.917$, $p > 0.05$).

Comparison of community structure and species diversity of understorey birds between before and after river diversion

The highest diversity was recorded at the Upper Kihansi transect during the 8 years post-diversion mist netting period (Table 3). There was no significant difference in diversity of understorey birds between the pre-diversion and post-diversion monitoring sessions at the Middle and Lower Kihansi sites (Table 4). Also, there was no significant difference in diversity between the pre-diversion and 18 years post-diversion mist netting sessions at the Upper Kihansi transect (Table 4). The 8 years post-diversion mist netting periods had significantly higher diversity than the pre-diversion, one post-diversion and 18 years post-diversion mist netting periods at the Upper Kihansi transect (Table 4).

One would have expected similarities in community structure at each transect. A dendrogram depicted that communities of birds among sites and sampling sessions were not similar (Figure 2). For example, 8 years post-diversion community structure at the Upper Kihansi transect was well separated from those of pre-diversion, one year and 18 years post-diversion at the same transect (Figure 2). In a similar manner, at the Middle Kihansi the pre-diversion and one year post-diversion understorey communities were separated from the rest of the sampled periods and transects.

Table 2: Number of individuals mist netted at the Kihansi gorge transects. For pre-diversion and one year post-diversion data see Cordeiro et al. (2006). Nomenclature follows Gill and Donsker (2018).

Species	Upper Kihansi **(800-870 m asl)**				Middle Kihansi **(600-750 m asl)**				Lower Kihansi **(480-560 m asl)**			
	1998	2001	2008	2018	1998	2001	2008	2018	1998	2001	2008	2018
Tambourine dove (*Turtur tympanistra*)				1								
African pygmy kingfisher (*Ispidina picta*)	1		1	2	1		1	3	1		4	2
Stripe-faced greenbul (*Arizelocichla striifacies*)	3		1		1							
Little greenbul (*Eurillas virens*)	16	4	13	17	8	1	4	8	4	1	5	7
Yellow-bellied greenbul (*Chlorocichla flaviventris)*			1									
Fischer's greenbul (*Phyllastrephus fischeri*)			2	1								2
Red-capped robin-chat (*Cossypha natalensis)*	1	1	2	1	1	2	4	1	1	1		8
White-chested alethe (*Alethe fuelleborni*)					1							
White-starred robin (*Pogonocichla stellata*)	1	1	2		1	2					1	
Green-backed camaroptera (*Camaroptera brachyura)*			1									
Blue-mantled crested flycatcher *(Trochocercus cyanomelas)*					1	1						1
Ashy flycatcher (*Muscicapa caerulescens*)	2					2						
Dark batis (*Batis crypta*)	3	5	2	2		1	1			1		
Sharpes akalat (*Sherpardia sharpei*)					1	1						
Black-throated wattle-eye (*Platyseira peltata*)			1									
Collared sunbird (*Hedydipna collaris*)			2					1				
Olive sunbird (*Cyanommitra olivacea*)	4	3	3	4	4	6	4	5	1	1	5	6
Red-faced crimsonwing (*Cryptospiza reichenovii)*					1	1						
Green twinspot (*Mandingoa nitidula*)	1	2	6	1							1	
Red-throated twinspot (*Hypargos niveoguttatus*)			2									
Total number of individuals	32	16	39	29	20	17	14	18	7	4	16	26

1998 = pre-diversion, 2001 = one year post- diversion, 2008 = 8 years post-diversion, and 2018 = 18 years post-diversion

Table 3: Pre-diversion, one, eight and 18 years post-diversion species diversity at the Kihansi gorge sampling sites

	Pre-diversion	1 year post-diversion	8 years post-diversion	18 years post-diversion
Upper Kihansi	1.657	1.630	2.355	1.420
Middle Kihansi	1.887	1.959	1.451	1.336
Lower Kihansi	1.154	1.386	1.420	1.574

Table 4: Species diversity indices among different sampling sessions at the Kihansi gorge

	Study sites								
	Upper Kihansi			Middle Kihansi			Lower Kihansi		
Comparison	t	df	p	t	df	p	t	df	p
Pre-diversion vs 8 years post-diversion	2.1162	66.726	< 0.05	1.2319	33.033	> 0.1	1.0160	10.682	> 0.1
Pre-diversion vs 18 years post-diversion	0.8021	59.382	> 0.5	1.4954	35.805	> 0.1	1.5938	9.466	> 0.1
8 years post-diversion vs 18 years post-diversion	2.8277	57.723	< 0.01	0.3482	31.819	> 0.1	0.9029	34.820	> 0.1
1 year post-diversion vs 8 years post-diversion	2.1732	45.975	< 0.05	1.9562	30.263	> 0.05	0.0982	6.276	> 0.1
1 year post-diversion vs 18 years post-diversion	1.792	43.980	> 0.05	2.2633	33.195	< 0.05	0.5664	5.493	> 0.1

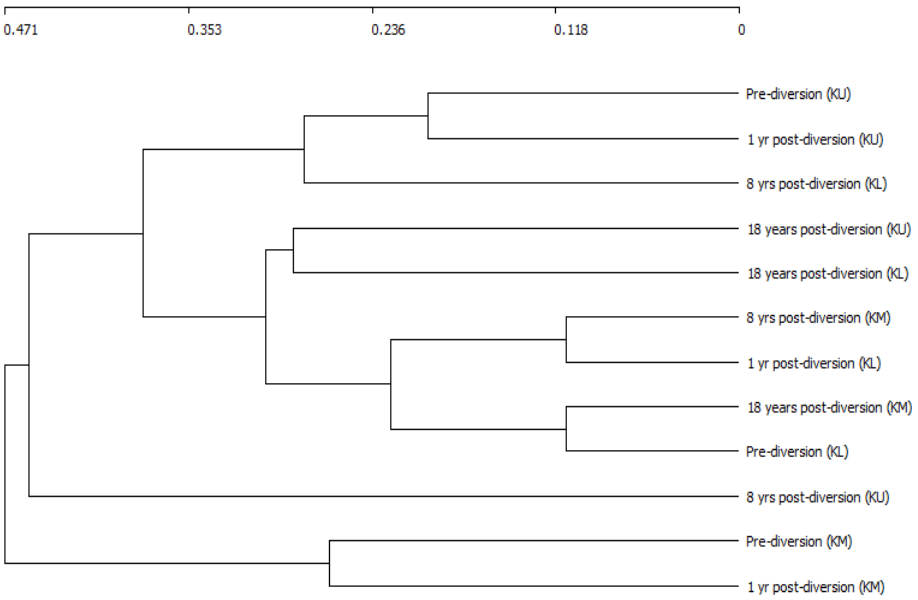

Figure 2: A dendrogram showing community structure of birds at different sites based on a matrix of occurrence of the avifauna in the study area by transects and sampling sessions, using Sørensen dissimilarity index (Transects: KU = Upper Kihansi, KM = Middle Kihansi and KL = Lower Kihansi).

Discussion

Generally, the post diversion capture rates of birds at each site were low. This is consistent with the pre-diversion findings of Cordeiro et al. (2004, 2006) who captured a few birds in the same study area (and transects). In their study, Cordeiro et al. (2004, 2006) attributed the low captures of birds to dry forest floor, small size of the forest, steepness of terrain, sparseness of the understorey vegetation and low density vegetation at the Kihansi Gorge.

The dominance of the little greenbul *E. virens* (37% of total captures), olive sunbird *C. olivacea* (18.5%) and red-capped robin chat *C. natalensis* (11%) is consistent with the findings of Cordeiro et al. (2004) at the same study sites. Similarly, re-analysis of Cordeiro et al. (2006) pre-diversion data at the Upper, Middle and Lower Kihansi transects indicates almost a similar trend whereby the little greenbul *E. virens*, olive sunbird *C. olivacea*, stripe-faced greenbul *A. striifacies*, red-capped robin-chat *C. natalensis* and African pygmy kingfisher *I. picta* dominated the captures by about 80% of all the captures (Table 2). Other species which were captured before the river was diverted, though in lower abundances, were still present in the study area eight to 18 years post-diversion (Table 2). The results suggest that the same species which dominated the study area before the river was diverted have continued to dominate it 10 and 20 years after the initial baseline surveys in 1998. This further implies that 10 and 20 years since the initial mist netting study in 1998 bird species communities are similar to that of pre-diversion species composition.

During the survey period, some species (e.g., white-chested alethe *Alethe fuelleborni*, Shelly's greenbul *Arizerocichla masukuensis*, Sharpe's akalat *Sherpadia sharpei* and ground orange thrush *Zoothera gurneyi*) mist netted by Cordeiro et al. (2006) during the pre-diversion sampling session were not detected

eight and 18 years post-diversion. The absence of these species could be due to detectability implying that they are present at the study area only that they were not caught in mist nets during the time of sampling. For example, white-chested Alethe *A. fuelleborni* has often been heard in the morning at the Upper Kihansi transect during post-diversion sampling. One and three individuals of Shelley's greenbul *A. masukuensis* were mist netted at the Upper Kihansi transect in February 2007 (Msuya and Werema 2007) and March 2009, respectively (Msuya 2009). One individual of ground orange thrush *Z. gurneyi* was mist netted at the Upper Kihansi transect on August 2007 (Msuya and Werema 2007). The same applies to other species which were detected in one mist netting session and not in another. For example, ashy flycatcher *Muscicapa caerulescens* was mist netted by Cordeiro et al. (2006) at the Upper Kihansi transect but not post-diversion sampling. This species has however been mist netted at the Lower Kihansi transect in March 2009 (Msuya 2009).

The higher species diversity of birds at the Upper Kihansi transect eight years post-diversion could be due to chance. Of the three transects, species such as yellow-bellied greenbul *Phyllastrephus flaviventris*, Green-backed Camaroptera *Camaroptera brachyura*, black-throated wattle-eye *Platyseira peltata* and red-throated twinspot *Hypargos niveoguttatus* were only mist netted at the Upper Kihansi transect eight years post-diversion. These species have been recorded at this site by Cordeiro et al. (2004) although they were not mist netted during the pre-diversion sampling.

The higher species diversity eight years post-diversion than that of pre-diversion sampling at the Upper Kihansi transect is at odds with the results of Cordeiro et al. (2006) who found that the number of individuals of birds prior to river diversion was significantly higher than the post-diversion abundance (of 2001) at the Upper Kihansi transect. At this site, the changes in bird community composition were attributed to the decrease in numbers of the forest generalist *E. virens* a year after river diversion (Cordeiro et al. 2006). This is a possible reason given that *E. virens* is a seasonal elevational migrant which means that its abundance at any of the surveyed sites is dynamic (Werema 2015). For example, while only four individuals of this species were mist netted a year post-diversion in comparison to 16 individuals mist netted in 1998 prior to river diversion, 13 and 17 individuals were mist netted 8 and 18 years post-diversion, respectively (Table 2). The lack of significant difference in bird species diversity between pre-diversion and 18 years post-diversion sampling periods at the Upper Kihansi transect is also at odds with the results of Cordeiro et al. (2006) who found that the number of individuals of birds prior to river diversion was significantly higher than the number of captures mist netted a year post-diversion. Cordeiro et al. (2006) attributed this difference in changes in bird community composition to the decrease in numbers of the *E. virens* after river diversion. *E. virens* which was thought by Cordeiro et al. (2006) to have evacuated the area for more favourable locations is still there (with abundance almost similar to that captured before the river was diverted) only that it moves from one elevation to another depending on seasons: individuals moving to lower elevations during the cold season and vice versa (see Werema 2015).

Lack of significant differences in bird species diversity at Middle and Lower Kihansi 8 and 18 years post-diversion is consistent with those of Cordeiro et al. (2006) who found no changes in bird community both at Middle and Lower Kihansi transects a year after river diversion. This suggests that the diversion of the river has had no effect on the avian community at the Lower and Middle Kihansi transects and probably there have been no discernible post-diversion impacts at these sites.

The cluster analyses did not show any specific pattern, but a general view is that the

transects surveyed and sampling sessions had distinct community structures. However, some sampling sessions showed similarity in avifauna. For example, at the Upper Kihansi Gorge transect pre-diversion and one year post-diversion mist netting sessions formed a cluster of their own suggesting that there had been no significant changes in avian community structure for a short period of three years. The distinctiveness of the avifauna 8 years post-diversion at the Upper Kihansi Gorge (as evidenced by the relatively higher diversity at this site) was shown by a dendrogram whereby this sampling session was well separated from the other sites and sampling sessions.

Conclusion

The results suggest that there have been no significant changes in species diversities before and after the river was diverted. Thus the diversity of understorey birds has remained unchanged eight and 18 years after Kihansi River was diverted underground. Species which dominated the study area before the river was diverted continued to be abundant 10 and 20 years after the initial baseline surveys in 1998. Three species which have been documented to make seasonal elevational movements in the Eastern Arc Mountains, the little greenbul *E. virens* (Werema 2015), stripe-faced greenbul *A. striifacies* (Burgess and Mlingwa 2000) and olive sunbird *Cyanomitra olivacea* (Werema 2016b) continued to use the forests as refuges during the cold season. Thus the forest is also an important cold season habitat for these birds.

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