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Understorey bird abundance and diversity before and after a forest fire in Mangala Forest Reserve on the eastern slopes of the Uluguru Mountains, Tanzania

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Summary

In July 2010 an assessment of abundance and diversity of understorey birds was undertaken in Mangala Forest using mist netting. However, in October 2010 a non-intentional fire burned the entire forest and this event provided a good opportunity to assess the extent to which birds were affected. Assessment, using mist netting, was carried out one week, three months and eight months after the fire, and comparisons made with data obtained before the forest was burned. In total, 28 species were recorded. Of these, the number recorded before the fire, one week post-fire, three months post-fire and eight months post-fire was 22, 3, 3 and 11 species respectively. The understorey bird species diversity before the forest was burned was substantially higher than diversities found afterwards. The results confirm that forest burning can have a severe negative impact on bird abundance and species richness and should be halted. Because fires start from the surrounding farmland, there is a need to construct and maintain fire breaks around entire forests.

Introduction

Fire is one of the major disturbance agents in forest ecosystems (Kreisel & Stein 1999). It is among the major threats facing most of the forest reserves and national parks in Tanzania. In the Eastern Arc Mountains, it is among the main causes of loss and fragmentation of the forests (Newmark 1998) and has been identified as the primary threat facing their long term survival. Fires can start outside the forest in preparation of land for agriculture (Svensen & Hansen 1995, Werema, 2014) but can also be started by forest user groups such as loggers, charcoal burners and hunters (Burgess *et al*. 2005). In the Uluguru Mountains, fires are particularly frequent in the foothill woodlands (Svendsen & Hansen 1995, Werema 2014). They result in tremendous destruction of the vegetation each year (Lulandala 1998), particularly the understorey layer and canopy cover.

In the Eastern Arc Mountains, the effects of forest fires on avifauna, especially on forest interior bird species, have received little attention. In the Ulugurus the author has reported the negative affects of fire on understorey forest birds in the lower altitude Kimboza Forest Reserve (Werema 2014), but is aware of no other direct comparisons of forest bird abundance and diversity before and after fire.

The original objective of a study in Mangala Forest, which began in July 2010, was to compare the diversity of understorey birds between cold and hot seasons. However, in October 2010, a fire that spread from surrounding agricultural land completely burned the entire forest reserve. This provided a good opportunity to

assess the extent to which birds were affected. This paper presents and discusses the findings from a mist netting study of understorey birds from before and up to eight months after the forest was burned. The main focus was on understorey birds, which are good indicators of disturbance in tropical forests (Newmark 1991).

Materials and methods

Location

Mangala Forest Reserve is located in the eastern part of the Uluguru Mountains, Tanzania (06°58′ S, 37°45.5′ E, Fig. 1). The Ulugurus form one of the component blocks of the Eastern Arc Mountains and rank second among these in their number of endemic vertebrate and plant species (Burgess *et al*. 2002, Rovero *et al*. 2014). Mangala Forest Reserve was gazetted in 1914 with 35 ha, but due to encroachment its current size is 28.5 ha. The forest covers Mangala Hill between 420 m and 640 m above sea level. The reserve is owned by local government and is currently under Participatory Forest Management in which adjacent communities (villages) are involved. The southern and western parts are very steep compared to the northern and eastern slopes (Fig. 1). At the top of the hill on the northern side the greater part is bracken *Pteridium aquilinum* and a few trees, especially *Julbernardia globiflora* and *Brachystegia spiciformis*. The closed forest is found on the western and eastern sides, where the dominant trees are *Tabernaemontana pachysiphon*, *Bombax rhodognaphalon*, *Khaya anthotheca*, *Newtonia buchananii*, *Terminalia brownii*, *Albizia gummifera* and *Sorindeia madagascariensis*. The coolest months are from May to September.

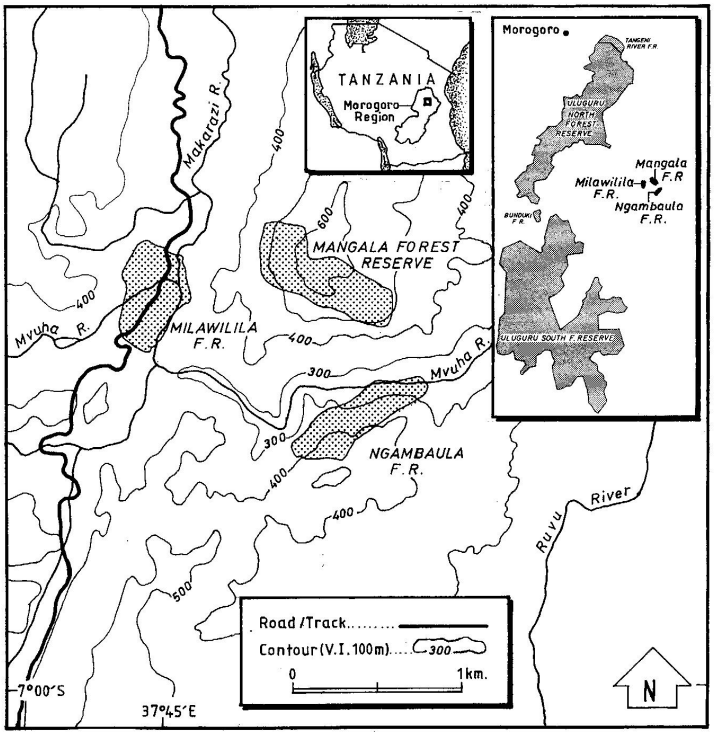

Figure 1. Location of Mangala Forest Reserve in the eastern foothills of Uluguru Mountains, Tanzania.

Methods

In October 2010, a non-intentional fire spread from the farms surrounding Mangala Forest Reserve and burned all 28.5 ha of the reserve area. The understorey birds had already been surveyed in July 2010, prior to the fire. Fifteen mist nets, each 12 m long and 2.6 m high, with 4 shelves and a 16 mm mesh size, were set, from the edge towards the middle of the forest, for three consecutive days. After the fire mist nets were set in the same locations with the same sampling effort maintained. Three sessions were conducted, one week post-fire (in October 2010), three months post-fire (in January 2011) and eight months post-fire (in July 2011). In each session, one day was used to clear lines and set the nets. The following three days (36 daylight hours) were used to run the nets (6480 metre-net hours each visit). They were checked every hour but more frequently during the morning and evening, and were closed during the night. The general habitat characteristics, including the understorey and overstorey cover, were noted each visit.

Data analysis

Because mist nets were used to sample birds it implies that only species that forage in the understorey were surveyed. Understorey birds were divided into three groups: forest-dependent species (FF species), forest generalists (F species) and forest visitors (f species) (Stuart & Jensen 1985, Newmark 1991, Bennun *et al*. 1996). FF species (forest specialists) are 'true' forest birds of the interior undisturbed forest and F species are those which can occur in undisturbed forest but are most often found in forest strips, gaps and edges. Forest visitors (f species) are birds that can be recorded in forest but are not dependent on it. To assess the impact of the fire, the bird species diversity and abundance before the burn event was compared with data obtained one week, three months and eight months afterwards. For each session, species diversities were computed using the Shannon-Wiener diversity index. Comparisons of Shannon-Wiener diversities were performed using a t-test described by Hutcheson (1970).

Abundance data were assessed to determine whether they were normally distributed (Shapiro & Wilk 1965). A Kruskal-Wallis test was used because the data were not normally distributed. All statistical tests and comparisons were computed using a software package: PAST (Hammer *et al*. 2001). Throughout this paper bird nomenclature follows Stuart & Jensen (1985).

Results

Habitat characteristics

Before the fire the forest had closed understorey and overstorey layers. After the fire, all seedlings and saplings in the shrub layer were killed, creating an open forest floor with dead saplings in the understorey layer. The leaf litter was completely burned. Shrub mortality was apparent in the entire forest. The canopy formed from large and tall trees 20–30 m high was incompletely burned. Three months post-fire, the understorey began to recover after the short rains in December 2010. This recovery continued such that 8 months post-fire there were more seedlings and saplings. The overstorey recovered quickly after the short rains.

Bird abundance and diversity

In total, 108 individuals of 28 species were netted (Table 1). Half these captures (50%) were made in the pre-fire session, followed by 31.5% eight months post-fire.

Only 6% and 13% respectively were contributed by the sessions one week and three months post-fire (Table 1). There was a highly significant difference in the number of individuals mist netted among sampling sessions (KW = 25.27, df = 3, p < 0.001). Numbers of species mist netted pre-fire, one week post-fire, three months post-fire and eight months post-fire were 22, 3, 3 and 11 respectively (Table 1). Species diversity was significantly higher before the fire than in any post-fire sampling session (Tables 1 & 2). None of the FF species was caught one week or three-months post-fire (Table 3) and less than half were caught eight months post-fire.

Table 1. Birds mist netted at Mangala Forest. FD = forest dependency: *FF* = Forest-dependent species, *F* = Forest generalists and *f* = forest visitors.

FD	Species	Pre-fire	One week post-fire	Three months post-fire	Eight Months post-fire
F	Lemon Dove *Aplopelia larvata*	1	0	0	0
FF	Tambourine Dove *Turtur tympanistria*	0	0	0	5
FF	Bar-tailed Trogon *Apaloderma vittatum*	1	0	0	3
f	Brown-hooded Kingfisher *Halcyon albiventris*	0	0	1	0
F	Pygmy Kingfisher *Ispidina picta*	1	0	0	0
FF	African Broadbill *Smithornis capensis*	1	0	0	1
FF	Pale-breasted Illadopsis *Illadopsis rufipennis*	1	0	0	0
FF	Shelley's Greenbul *Andropadus masukuensis*	1	0	0	0
FF	Stripe-cheeked Greenbul *Andropadus milanjensis*	4	0	0	1
F	Little Greenbul *Andropadus virens*	11	0	0	0
F	Grey-olive Greenbul *Phyllastrephus cerviniventris*	1	0	3	2
FF	Yellow-streaked Greenbul *Phyllastrephus flavostriatus*	4	0	0	0
FF	White-chested Alethe *Alethe fuelleborni*	7	0	0	5
f	Bearded Scrub Robin *Cercotrichas quadrivirgata*	0	0	0	1
f	White-browed Robin Chat *Cossypha heuglini*	1	0	0	0
FF	White-starred Robin *Pogonocichla stellata*	2	0	0	5
FF	Sharpe's Akalat *Sheppardia sharpei*	1	0	0	0
FF	Orange Ground Thrush *Zoothera gurneyi*	5	0	0	0
FF	Forest Batis *Batis mixta*	1	0	0	0
F	African Paradise Flycatcher *Terpsiphone viridis*	1	0	0	1
FF	Blue-mantled Crested Flycatcher *Trochocercus cyanomelas*	2	0	0	0
FF	Square-tailed Drongo *Dicrurus ludwigii*	1	0	0	0
F	Collared Sunbird *Anthreptes collaris*	0	1	0	0
F	Olive Sunbird *Nectarinia olivacea*	3	1	10	0
FF	Dark-backed Weaver *Ploceus bicolor*	1	0	0	0
F	Peters's Twinspot *Hypargos niveoguttatus*	3	0	0	1
F	Green-backed Twinspot *Mandingoa nitidula*	0	0	0	9
f	Bronze Mannikin *Lonchura cucullata*	0	4	0	0
	Total number of individuals	54	6	14	34
	Total number of species	22	3	3	11
	Species diversity (Shannon-Wiener index)	2.720	0.868	0.759	2.097

Table 2. Comparisons of species diversities between pre- and post-fire mist netting sessions.

Comparison	t-value	*df*	*p* value
Pre-fire vs one week post-fire	t = 5.349	8.27	< 0.001
Pre-fire vs three months post-fire	t = 7.567	26.97	< 0.001
Pre-fire vs eight months post-fire	t = 3.002	81.26	< 0.001

Table 3. Effect of fire on species richness in each forest dependency category.

Sampling session	*FF* species	*F* species	*f* species	Total
Pre-fire	14	7	1	22
One week post-fire	0	2	1	3
Three months post-fire	0	1	2	3
Eight months post-fire	6	4	1	11

Discussion

The results show that understorey bird species diversity was significantly higher before the forest was burned than in any of the post-fire periods. This can be attributed to the creation of an open understorey layer. This agrees with the findings of Slik & Van Balen (2006) in Borneo, Indonesia, and Lee *et al*. (2011) in South Korea, who concluded that decreased bird species diversities after fire were probably the result of the understorey layer becoming too open to support forest-dependent species. At Mangala, the open understorey layer apparently inhibited use by forest-dependent species one week and three months post-fire. Similar results have been reported by Barlow *et al*. (2002) in the Amazonian forests of Brazil, and also by Werema (2014) in the lower altitude Kimboza Forest Reserve, eastern Tanzania. Barlow *et al*. (2002) and Werema (2014) found that the number of captures per unit mist netting effort was significantly reduced in burnt compared to unburnt forest, and attributed this to changes in the composition and physiognomic structure of the vegetation community.

Contrary to the findings of this study, Adeney *et al.* (2006) found an increase in bird species richness after fire in Sumatran forests. They attributed this to the fact that birds of the open fields tended to replace interior forest specialists. At Mangala, this could explain the presence of Brown-hooded Kingfisher *Halcyon albiventris*, Eastern Bearded Scrub-Robin *Cercotrichas quadrivirgata* and Bronze Mannikin *Lonchura cuculata* in the forest eight months after the fire. While reducing suitability for forest-dependent understorey species fire disturbance can create new microhabitats for non-forest species. In general, however, the findings of this forest study are opposite to some of those from grasslands and woodlands where fire has led to an increase in bird species richness (Nkwabi *et al*. 2011, O'Reilly *et al.* 2006).

The increase in abundance and diversity of understorey birds eight months after the forest was burned compared to values one week and three months post-fire show that some of the species concerned are able to perform local movements and reuse the forest after only partial recovery from disturbance. Similar mobility is shown by forest species known to make seasonal altitudinal movements (Burgess & Mlingwa 2000). The presence of Bar-tailed Trogon *Apaloderma vittatum*, Stripe-cheeked Greenbul *Andropadus milanjensis*, White-chested Alethe *Alethe fuelleborni* and White-starred Forest Robin *Pogonocichla stellata* in Mangala Forest eight months post-fire could have represented short cold season visits since these species are known to make seasonal altitudinal movements (Burgess & Mlingwa 2000.). However, the pre-fire and eight months post-fire sampling sessions were conducted during the same month of the

year (i.e., July) in subsequent years and provide a comparison independent of any seasonal movements. They clearly show a decrease in bird abundance and diversity after the fire during the same cold season.

Conclusion and recommendation

Forest fires have negative impacts on the diversity of understorey forest birds. Conservation interventions are necessary and measures against forest fires are needed. There is a need to construct and maintain fire breaks around entire forests. This has been found to be effective against fires in some of the Eastern Arc Mountains forests. It is hoped that this study will spur others to follow effects on understorey forest avifauna for several years after a forest fire. Longer term studies are needed to determine the trajectory of the response of these bird communities to forest fires in East Africa.

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