

## Research Article

# Forest patch structures and bird species composition of a lowland riverine coastal forest in Kenya

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### Abstract

The Lower Tana River forests in coastal Kenya represent lowland evergreen riverine tropical forest types that are rare in Kenya and probably in Africa. We assessed the bird species composition and forest conditions of 14 forest patches within the Lower Tana River valley each February and October between 1999 and 2004. Vegetation structures showed variations of different strengths in individual forest patches, but only canopy height differed significantly across sites. Overall, canopy cover was correlated directly with canopy height but inversely with bare ground. A total of 155 bird species of 43 families comprising 9 forest specialists (FF), 27 forest generalists (F), 42 forest visitors (f) and 77 species associated with savannah/woodland ecosystems were recorded from the 14 forest patches. The overall bird species composition did not differ significantly across these forest patches, but similarities in species composition of different strengths were evident across the sites.

**Keywords:** Lower Tana River forests, avian diversity, avian species richness, vegetation structure, Kenya

### Résumé

Sur la côte du Kenya, dans la partie inférieure de la rivière Tana poussent des forêts en contre-bas de type conifère riveraine tropicale qui sont rares au Kenya et probablement dans toute l'Afrique. Nous avons évalué la composition des espèces d'oiseaux et les conditions des forêts de 14 secteurs dans la vallée de la partie inférieure de la rivière Tana chaque février et octobre entre 1999 et 2004. Les structures de la végétation ont montré des variations de forces dans les secteurs de forêts individuelles mais seulement la hauteur de la canopée a varié considérablement au travers des secteurs. Globalement, la couverture de la canopée est mise en corrélation avec la hauteur de la canopée mais inversée de la surface de terre nue. Un total de 155 espèces de 43 familles comprenant 9 spécialistes de forêt (FF), 27 généralistes de forêt (F), 42 visiteurs de forêt (f), et 77 espèces associées avec les écosystèmes de la savanne/région boisée ont été noté dans les 14 sites de forêts. Au global la composition des espèces d'oiseaux n'a pas varié considérablement à travers ces sites de forêts mais des ressemblances dans la composition des espèces de forces différentes étaient visibles à travers les sites.

**Mots clés:** Basse-Tana River forêts, la richesse des espèces d'oiseaux, la diversité des espèces d'oiseaux, la structure de la végétation, Kenya

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## Introduction

The conservation of forests is a major challenge in developing countries because of high dependence on forest resources for livelihood [1]. Given the rapid population growth and ensuing increased demands for forest resources, this trend is likely to continue in tropical regions [2, 3]. Birds have often been used as “bio-indicators” of forest conditions [4, 5]. Many forest-dependent birds have been shown to be detrimentally affected by forest loss and degradation, and cases of species extinction have been reported when forest fragments are either too small or too degraded to support viable populations [6, 7, 8]. Although certain degraded forests have been shown to sustain subsets of primary forest avifauna, tropical birds are generally less resilient to habitat disturbance due to their high habitat specificity compared to their temperate counterparts [9, 10]. Due to this characteristic, there is need for considerable efforts to conserve the remaining natural and intact tropical forests to reduce threats to forest-dependent species.

A number of studies have examined how forest loss and fragmentation affect birds in Africa [2, 4, 11, 12, 13, 14, 15, 16, 17]. The Lower Tana River forests in coastal Kenya are unique in many ways. They represent lowland evergreen riverine tropical forest types which are rare in Kenya and probably in Africa, and whose importance for biodiversity has long been recognized [18, 19]. Over the years, these forests have experienced considerable demographic pressures. Generally, their use has been unsustainable, with burning, pole cutting, and felling of large trees for building canoes being of particular concern [18]. In addition, the forests are surrounded by agricultural and grazing lands—a trend toward forest conversion that has proceeded at an alarming rate in recent years [19]. Given the current human growth trends in Kenya’s Lower Tana River area, the demand for forest products will increase tremendously in the future [18].

Although the Lower Tana River forests are listed among the key forests for bird conservation in Africa and as an Important Bird Area (IBA) in Kenya [20], their avifauna is poorly known. Apart from general surveys in the 1970s [21], there is little ornithological information. As a step toward a better understanding of the avifauna of the Lower Tana River forests, we carried out focused ornithological surveys of the forest patches located within the Tana River Primate National Reserve. Although the forest patches within the Reserve are legally protected, they continue to experience human pressures like other patches located outside the Reserve.

In this paper we focused on assessment of forest structures and bird species composition, and based our analyses on 14 forest patches within the Reserve with the view of assessing their conservation values for birds.

## Methods

### *Study area*

The Tana River National Primate Reserve (1°55'S, 40°5'E) covers an area of about 171 km<sup>2</sup> within the Lower Tana River forest system [18]. The Reserve (Fig. 1) was gazetted in 1976 to protect the riverine forests and two highly endangered primates; the Tana River red colobus *Colobus badius rufomitratu*s and Tana River mangabey *Cercocebus galeritus galeritus* [18, 22]. Annual precipitation is about 250mm/year, and this increases downstream to about 1000mm/year over the Tana River Delta [23]. The forests within the Reserve occur in patches in the riparian zone extending for about 16 km along the meandering course of the Tana River. Of the 71 forest patches within the Lower Tana River forest system, 23 covering about 1527 ha fall within the Reserve [19]. We focused on 14 of these patches in our surveys (Table 1). Although these patches show fairly continuous stands, their separation distances are evident from ground observations. Most patches have separation distances of

approximately 100 m consisting of regenerating vegetation following clearance by surrounding communities.

The Reserve's flora is quite diverse and comprises a complex mix of pan-African species of western and central African rainforest species and eastern and coastal forest endemic species, with at least 10 rare woody plant species [24]. Characteristic trees across the patches include *Ficus* spp., *Phoenix reclinata*, *Acacia robusta*, *Diospyros mespiliformis* [25]. These species form a mosaic of habitats comprising grasslands, bushlands, and deciduous woodlands along the banks of the Tana River.

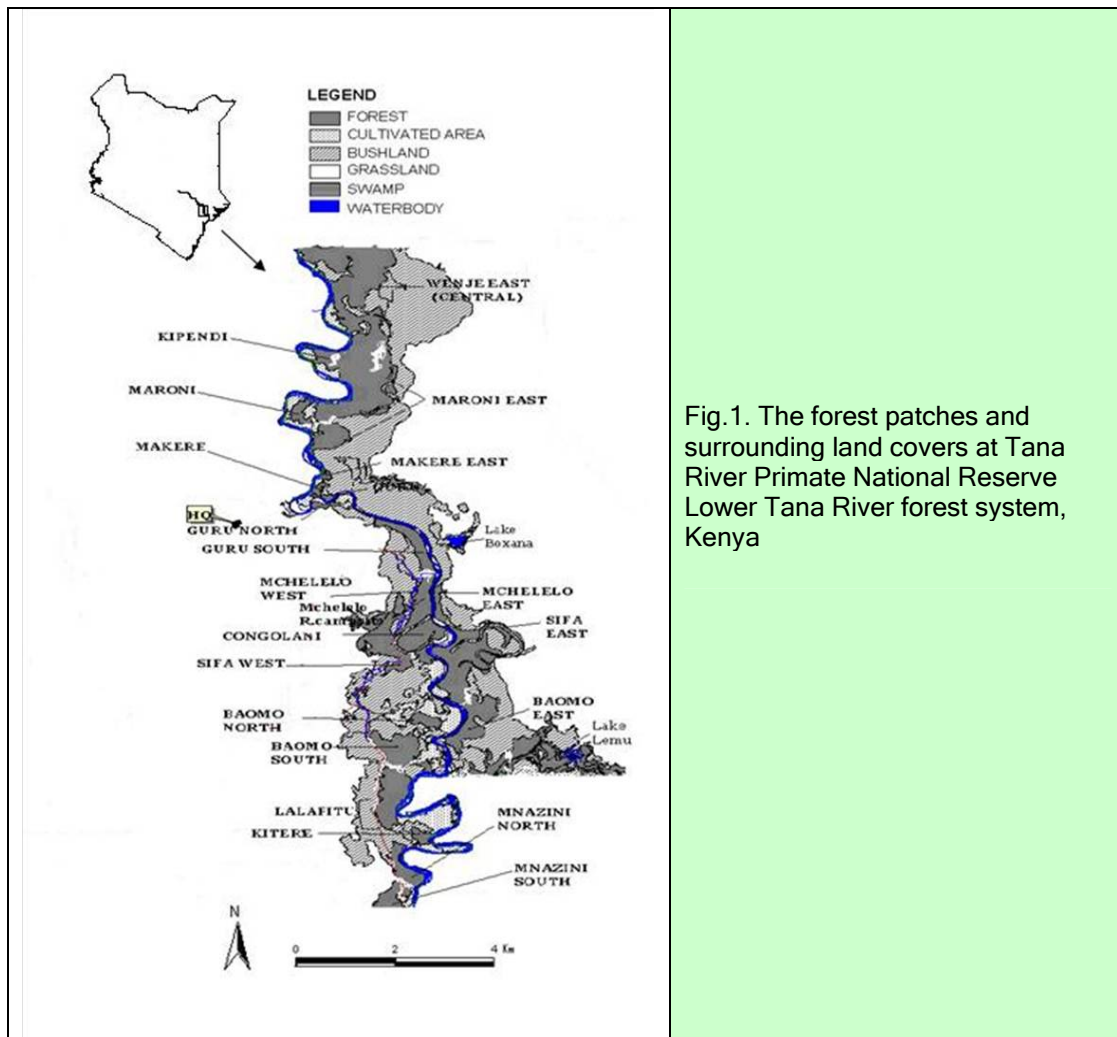


Fig. 1. The forest patches and surrounding land covers at Tana River Primate National Reserve Lower Tana River forest system, Kenya

### Bird surveys

In each of the 14 forest patches, we conducted bird surveys by a combination of mist netting and timed species counts [26]. Ten mist nets (3 x 12 m, 36 mm mesh) were placed haphazardly in the understorey along cleared narrow trails. The nets were placed at intervals of about 30 meters. These surveys were conducted every February and October from 1999 to 2004, coinciding with the dry and wet seasons in the area. Four days of mist netting were conducted in each patch with nets operated between 06:30h and 11:00h (an average of 10 mist-netting hours per patch). Recaptures from mist-netting sessions were excluded from the analyses. Following [27], timed species counts (TSCs) were conducted simultaneously with mist netting, and attempts were made to cover more than 50% of each

patch. Every time a bird species was detected, we recorded time, together with an indication of whether the detection was by sight or sound, and if it was within a distance of 25 m and above 3 m from the ground. The distance was chosen since few birds could be detected beyond 30 m because of the density of vegetation. Detected species were scored according to when first recorded (four if in the first 10 minutes, three if in the next 10 minutes, and so on). A total of 12 counting sessions, each lasting 40 minutes (an average of 7-8 hours), was done in each patch.

#### *Forests patch structures surveys*

We conducted vegetation surveys to determine structural characteristics of each patch. This involved estimation of habitat complexity following Braun-Blanquet scales of visual estimation of cover [28]. We walked in haphazardly selected directions through the forests and marked 40 points at intervals of 10 m. At each point, canopy height was estimated to the nearest 1 m of the vegetation height range, 4-20 m. Canopy cover was estimated to the nearest 5/10% for the same height range. Shrub density was estimated using a square checkered board of 40×40 cm divided into 8×8 cm black and white squares. Researchers counted the number of squares visible at a vegetation height range of 1-2 m within a fixed radius of 5 m north and south of the observer standing at each of the 40 points. This was a modification of the half-sight measurement technique [see 11]. Two plots measuring 1×1 m were also established at each point and the percentage of herb, litter cover, and open areas was estimated visually. Other vegetation variables such as plant species present were also recorded.

Table 1. Bird species richness and the forest structural features in 14 patches in the Tana River Primate National Reserve, Kenya.

Forest patches	Species Richness	Patch structure characteristics ((Mean ± SD)					
		Canopy Height (m)	% Canopy Cover	% Shrub Density	% Litter Cover	% Herb Cover	% Open Area
Wenje East/Central	79	10 ± 7.3	50 ± 27.6	20 ± 6.6	70 ± 21.4	05 ± 10.8	20 ± 19.0
Kipendi	79	05 ± 3.9	60 ± 20.2	20 ± 6.4	65 ± 26.3	15 ± 18.8	15 ± 18.4
Maroni	58	10 ± 21.3	40 ± 27.4	20 ± 3.4	45 ± 37.2	05 ± 11.8	40 ± 35.4
Maroni East	54	20 ± 16.1	50 ± 26.3	20 ± 4.7	55 ± 29.6	15 ± 17.7	30 ± 31.0
Makere	46	20 ± 5.7	60 ± 14.6	25 ± 4.4	75 ± 19.2	10 ± 14.8	10 ± 13.5
Makere East	81	10 ± 6.5	50 ± 22.8	20 ± 7.9	65 ± 22.8	15 ± 17.9	15 ± 19.0
Guru North	46	20 ± 14.1	70 ± 21.4	20 ± 7.9	75 ± 25.1	10 ± 17.7	10 ± 19.7
Guru South	53	10 ± 6.8	60 ± 17.9	20 ± 5.6	80 ± 19.2	05 ± 7.9	15 ± 16.1
Mchelelo Complex <sup>1</sup>	45	20 ± 11.2	50 ± 32.3	15 ± 9.4	75 ± 23.1	20 ± 21.8	05 ± 11.4
Mchelelo East	71	10 ± 8.9	30 ± 31.1	15 ± 7.9	65 ± 22.9	10 ± 17.9	20 ± 21.2
Sifa East	81	20 ± 12.4	60 ± 26.1	20 ± 5.5	65 ± 22.1	15 ± 20.6	20 ± 20.3
Baomo South	47	30 ± 21.3	70 ± 22.1	15 ± 7.5	70 ± 25.5	15 ± 17.8	10 ± 18.0
Manzini North	33	20 ± 8.9	60 ± 24.1	15 ± 7.3	60 ± 25.1	25 ± 20.4	15 ± 23.2
Mnazini South	38	20 ± 7.8	40 ± 22.8	20 ± 5.5	75 ± 23.4	05 ± 3.6	20 ± 22.5

#### *Statistical analyses*

All statistical analyses were done using STATISTICA 7.0 [29]. Vegetation measures over the 40 points were averaged for each forest patch and percentages arcsine-transformed for normality before analysis [30]. A two-way analysis of variance followed by Student Newman-Keuls multiple range tests were used to assess structural differences among the 14 forest patches. Standard stepwise multiple regression analyses were used to assess the relationships between the vegetation variables across sites and how they were correlated. The number of bird species recorded from each patch through

mist-netting and timed species counts was compiled and forest bird categories defined following Bennun *et al.* [31]: “FF species” (forest specialists) are true forest birds, characteristic of the interior of the undisturbed forest; “F species” (forest generalists) may occur in undisturbed forest but are also regularly found in forest strips, edges and gaps; “f species” (forest visitors) are birds which are often recorded in forests but are not dependent upon it; “s species” are birds associated with savannah/woodlands areas and are not dependent on forests. We tested for statistical differences in overall species richness and of individual forest bird categories across the 14 patches using ANOVA [32]. The patches (most separated by approximate distances of about 100m) were treated as independent sampling units. Similarities in species composition between each pair of forests were assessed using Jaccard’s similarity index of range 0 (dissimilar) to 1 (identical) [23]:  $S_j = \alpha/\alpha+\beta+\delta$ ; where  $\alpha$  = joint occurrence species in patch A and B;  $\beta$  = number of species in patch B but not in A;  $\delta$  = number of species in patch A but not in B. Patches with  $S_j > 0.6$  indicated higher level of similarity and vice versa. The numbers of individual understory species ringed per forest were compiled and analysis of variance used to compare ringing totals across patches. The scores of individual canopy/mid-level species detected from the TSCs were averaged over all counts per patch to give simple relative abundance indices that were ranked for each patch. We adopted a two-step procedure to determine how bird species richness was influenced by patch structure variables. First, we evaluated the relationship between overall species richness and patch characteristics using multiple stepwise regression models (forward selection procedure). Second, we investigated the effects of patch characteristics on the presence/absence of individual forest specialist birds (FF) pooled for each patch across the 14 patches.

Table 2. Pair-wise Jaccard’s similarity indices of the bird species composition for the 14 patches in the Tana River Primate National Reserve, Kenya

	Forest patches												
	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN
KpW	0.32												
MrW	0.24	0.51											
MrE	0.34	0.4	0.36										
MkW	0.29	0.26	0.20	0.3									
MkE	0.74*	0.32	0.27	0.29	0.32								
GrN	0.26	0.22	0.19	0.28	0.55	0.3							
GrS	0.30	0.22	0.19	0.35	0.58	0.33	0.61*						
McC <sup>a</sup>	0.31	0.13	0.15	0.23	0.35	0.29	0.32	0.39					
McE	0.68*	0.32	0.29	0.34	0.37	0.67*	0.38	0.34	0.33				
SfE	0.65*	0.34	0.28	0.34	0.38	0.65*	0.36	0.38	0.30	0.74*			
BmS	0.35	0.29	0.32	0.43	0.32	0.32	0.29	0.3	0.25	0.32	0.35		
MzN	0.18	0.13	0.12	0.15	0.31	0.18	0.30	0.4	0.52	0.19	0.22	0.17	
MzS	0.28	0.13	0.17	0.25	0.28	0.27	0.33	0.41	0.6	0.31	0.31	0.28	0.55

WjE, Wenje East/Central; Kpd, Kipendi; Mrn, Maroni; MrE, Maroni East; Mkr, Makere; MkE, Makere East; GrN, Guru North; GrS, Guru South; McC, Mchelelo Complex; McE, Mchelelo East; SfE, Sifa East; BmS, Baomo South; MzN, Manzini North; MzS, Mzazini South. Highly similar patches ( $S_j > 0.6$ )

## Results

### *Bird species composition*

A total of 155 species of 43 families was recorded from the 14 patches. These comprised 9 species categorized as forest specialists (FF), 27 forest generalists (F), 42 forest visitors (f) and 77 species associated with savannah/woodland ecosystems (see Appendix 1). Makere East (81) and Sifa East (81) had the highest numbers of species. Mnazini North (33) had the fewest species (Table 1). The overall species composition did not differ significantly across the 14 patches ( $F = 4.01$ ,  $p = 0.06$ ). Wenje East/Central, Makere East and Sifa East had the highest numbers of forest-specialist birds, with FF of 7, 7 and 8, respectively. Similarities in species composition of different levels among the 14 patches were evident (Table 2). Makere East/Wenje ( $S_j = 0.74$ ), Sifa East/Mchelelo East ( $S_j = 0.74$ ) and Mchelelo East/Wenje East/Central ( $S_j = 0.68$ ) had higher levels of similarities in bird species composition. Among the species categories, only savannah/woodland species differed significantly across sites ( $F = 7.62$ ,  $p = 0.02$ ). Differences in other groups across the patches were not significant.

Forty under-storey species comprising 386 individuals were ringed in the 14 patches. Forest specialists (FF) and forest generalists (F) formed the bulk of individuals ringed (Appendix 2). Higher ringing records were from Mchelelo Complex (83) and Maroni East (38). Olive sunbird *Nectarinia olivacea* (forest specialist), red-capped robin-chat *Cossypha natalensis* (forest generalist) and Fischer's greenbul *Phyllastrephus fischeri* (forest specialist) formed the bulk of individual species captured across the patches with 70, 68, and 34 individuals respectively. Tropical boubou *Laniarius aethiopicus* (forest visitor) ranked highest in relative abundance in most patches (see Appendix 3).

### *Forest patch structures*

Canopy heights differed significantly across the sites ( $F$ -test = 8.56,  $p < 0.01$ ,  $df = 12$ ). Baomo South had the highest mean canopy height,  $30 \pm 21.3$  (mean  $\pm$  S.D.) of the 14 patches (Table 1). Other vegetation variables showed variations in individual patches, but these did not differ significantly across the patches. Overall, canopy cover was directly correlated with canopy height (Pearson  $r = 0.56$ ,  $p = 0.04$ ) but inversely correlated with bare ground (Pearson  $r = -0.57$ ,  $p = 0.03$ ). The percentage of bare ground was directly correlated with the percentage of shrub density (Pearson  $r = 0.64$ ,  $p = 0.01$ ) but inversely correlated with percentage of litter cover (Pearson  $r = -0.74$ ,  $p = 0.002$ ) across the patches.

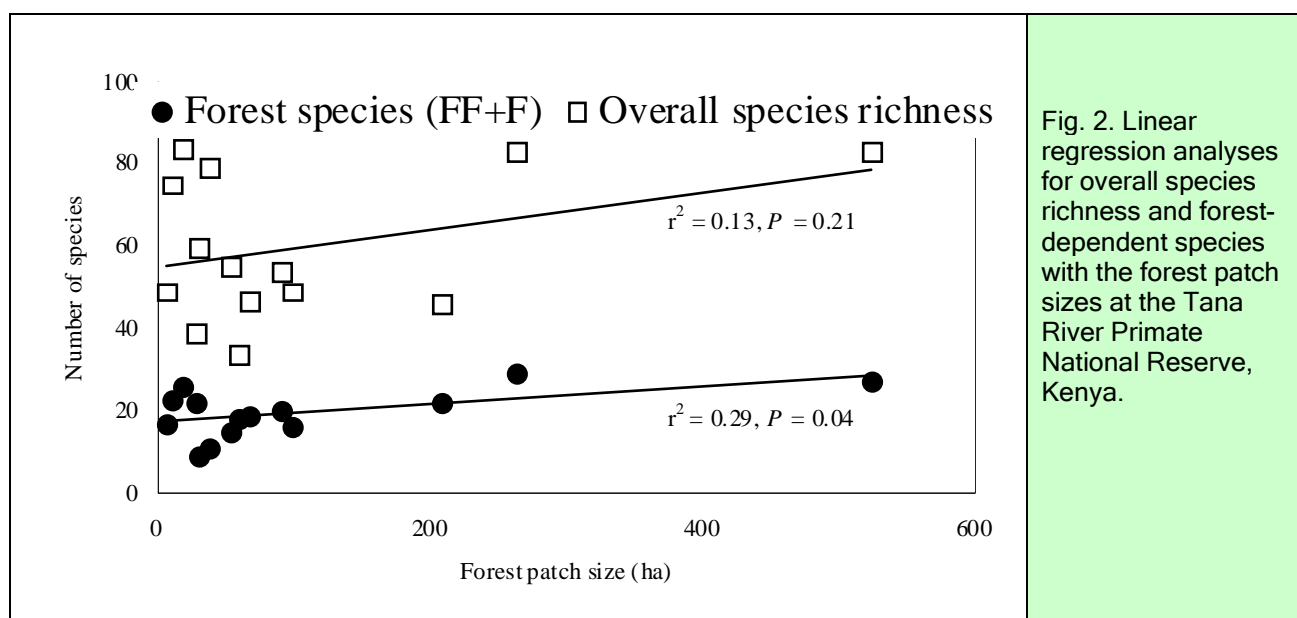
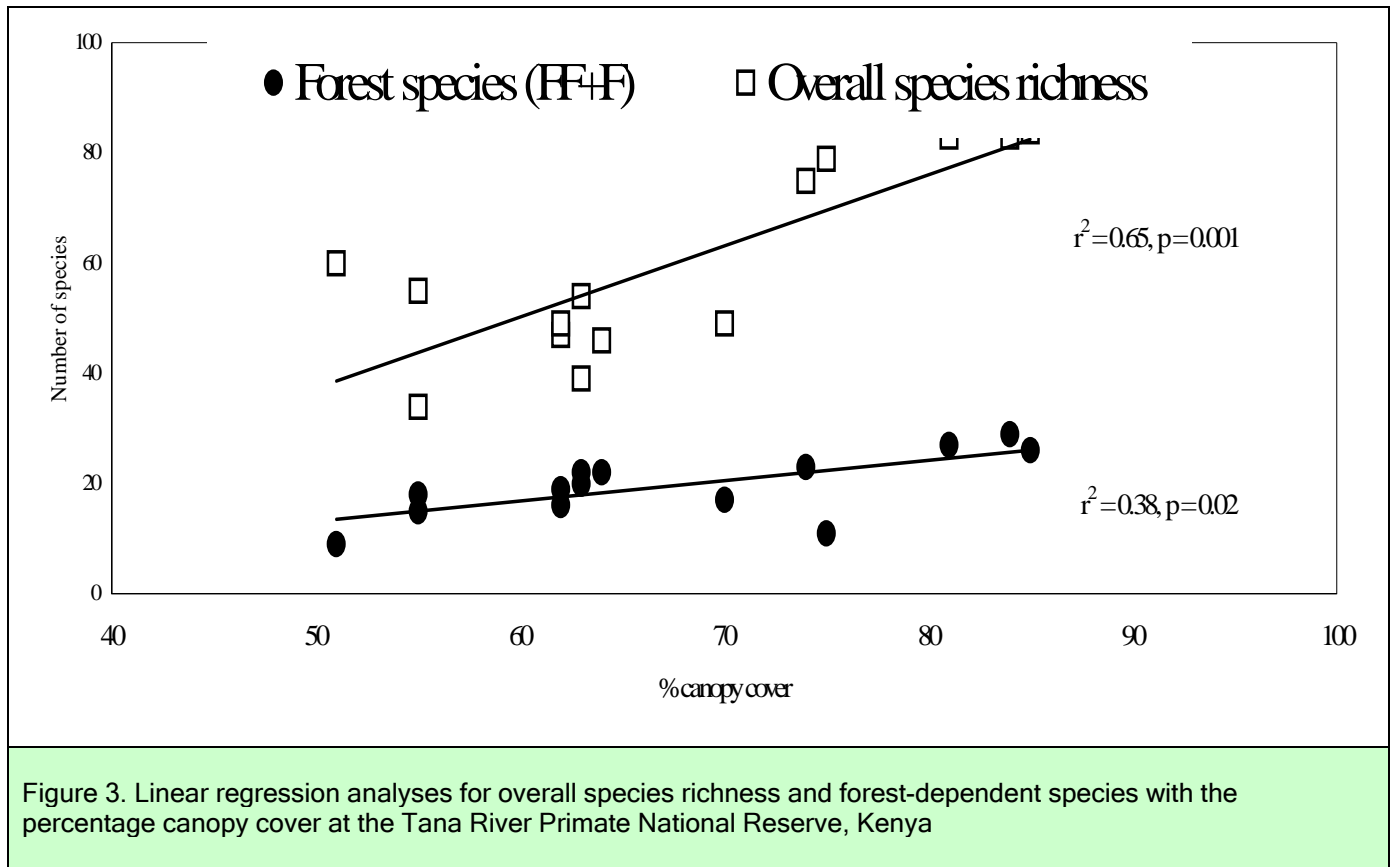


Fig. 2. Linear regression analyses for overall species richness and forest-dependent species sizes with the forest patch sizes at the Tana River Primate National Reserve, Kenya.

### Forest patch structural features and bird species composition

There was an overall positive relationship between overall bird species richness, forest-dependent bird species with the overall forest patch sizes (Fig. 2). In particular, patch sizes significantly influenced the numbers of forest-dependent birds ( $p < 0.04$ ). Other bird categories showed associations of different strengths but these were not significant. Individual patch structural features showed that canopy cover played a major role in the species richness and the numbers of forest-dependent species (Fig. 3). Other structural variables showed no significant associations with either species richness or richness of individual forest bird categories.



The assessment of the presence/absence of individual forest specialists (FF) based on the vegetation variables of canopy cover, shrub density, and open areas showed that the presence of Fischer's greenbul *Phyllastrephus fischeri*, black-headed apalis *Apalis melanocephala*, and olive sunbird *Nectarinia olivacea* was influenced significantly by a combination of these vegetation variables (Table 3).

### Discussion

Our results show that overall species composition did not differ significantly across the 14 patches surveyed, and similarities of different levels among the patches were common. This could suggest that most forest patches still have suitable habitats that ensure availability of food, nesting sites, and protective cover for the species but are still vulnerable to persistent encroachment evident around them. In the long term this could jeopardize the ability to sustain particular bird species, especially forest-dependent bird categories. In addition, results from this study suggest that individual species

responded differentially to changes in the forest conditions brought about by increasing changes and encroachment. Generally, the proportion of forest-dependent species and individuals was lower than in many Kenyan forests [33]. This is not surprising, given that these forest patches are surrounded by non-forest habitats indicating forest disturbance. The observed differing distribution with some species occurring in only some patches and not in others could suggest the sensitivity of those species to particular structural changes. This observation may be linked to the requirements of individual bird species.

Table 3. Logistic regression models for multiple forest structure variables of canopy cover, shrub density, and open areas with the nine forest-dependent species (FF) across the 14 forests fragments of the Tana River Primate National Reserve. Dependent variable (species) = logit of probability of occurrence along a gradient of habitat variables.

Species	Regression Constant $B_0$	Forest structure variables			Wald $\chi^2$	P
		Canopy cover	Shrub density	Open area		
African crowned eagle	-127.60	0.10	2.34	0.48	2.18	0.535
<b>Fischer's greenbul</b>	-197.44	6.78	-11.37	6.33	15.13	0.002
East coast akalat	-1.88	0.05	0.11	-0.03	0.19	0.980
Red-tailed ant thrush	-7.03	3.54	-0.88	0.46	3.43	0.330
<b>Black-headed apalis</b>	-5.99	0.96	-2.85	1.25	7.65	0.054
Little yellow flycatcher	0.90	-0.22	0.66	-0.28	3.06	0.383
Blue-mantled crested flycatcher	6.47	0.01	-0.17	-0.10	2.14	0.544
<b>Olive sunbird</b>	-14.92	0.34	-0.79	0.72	7.72	0.049
Green-backed twinspot	-20.40	0.09	0.81	-0.15	3.82	0.282

Species with significant relationships are in boldface. Appendix 1 gives the scientific names for the species.

The vegetation measures suggested that all forests patches were experiencing different levels of human disturbance. Vegetation parameters measured from the various patches indicate much variability, especially in canopy height and cover. Generally, it can be shown that a few forest patches are in better condition than others. Baomo South, Guru North, Sifa East, Makere, Mnazini North, and Mchelelo Complex had characteristics of fairly good habitats judging from their high values of canopy height and percentage canopy cover. These also had a high abundance of forest-dependent species as would be expected. Some patches, such as Kipendi and Maroni, hosted fewer forest-dependent species, but this may not necessarily mean that they have lost their potential conservation importance. As observed elsewhere [33, 34], vegetation data are usually “noisy”, and the occurrence of some species in forests of apparently different habitat conditions may complicate the search for general patterns. However, the relative abundance at which forest-dependent species occurred in the various patches could provide a means to assess the habitat quality of each patch.

Generally loss and fragmentation of natural habitat rank among the most severe threats to biodiversity worldwide, with tropical forests being degraded and destroyed more rapidly due to human activities [35, 36, 37]. For forest-dependent organisms, such habitat changes represent significant threats to ecosystem sustainability, and have direct implications on the quality of habitats on which the forests depend [38, 39]. Ground observations during our study showed that human influences (encroachment, mid-forest farming, fires, and tree cutting) were dominant especially around two patches (Wenje East/Central and Baomo South) that had high densities of human settlements. However, all patches surveyed supported a moderately rich avifauna that is characteristic of coastal forests [18]. But these



bird assemblages could be threatened by deforestation and degradation unless urgent conservation measures are undertaken.

The continued forest loss and degradation in the Lower Tana River of coastal Kenya presents a conservation challenge. These forest patches are individually too small to support viable populations of bird species, and there are presumably considerable bird movements between them. The continued reduction in patch sizes will affect the ecological requirements for forest-dependent birds, and create habitats for generalists, and possibly predator species in and around the patches. Some of the bird species recorded during the study, including the southern banded snake eagle *Circaetus fasciolatus*, Fischer's turaco *Tauraco fischeri*, and the East Coast akalat *Sheppardia gunningi*, are listed as globally threatened [20], and could face severe impacts on their long-term survival if conservation action for the forest patches is not fast-tracked accordingly. It was evident that these species are still found in some forest patches in the area. Reduced breeding success of forest-dependent birds is likely as suitable habitats diminish. It is therefore important that a large set of more-or-less interconnected patches be maintained within the Lower Tana River Forests and within the Reserve in particular.

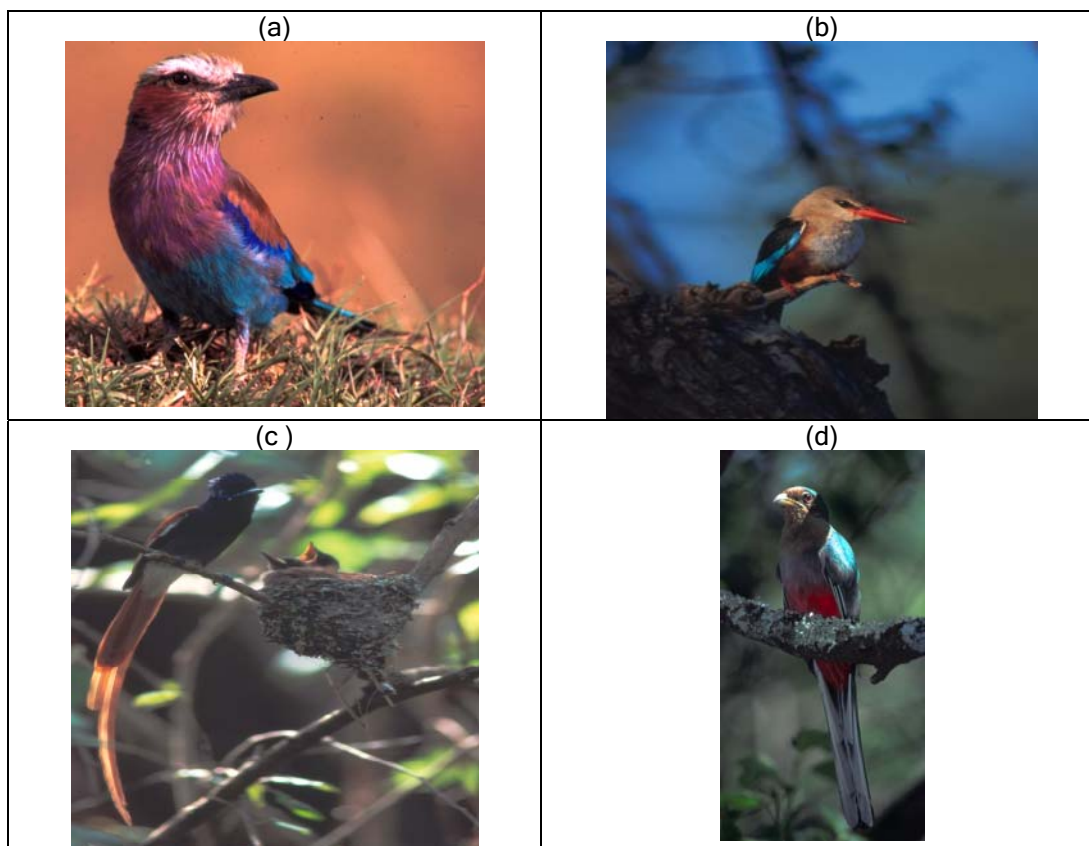


Fig. 4. Photos of some bird species recorded from the Tana River Primate National Reserve. (a) Lilac-breasted roller *Coracias caudate* (Photo by: Ornithology Section, National Museums of Kenya); (b) Grey-headed kingfisher *Halcyon leucocephala* (Photo by: Ornithology Section, National Museums of Kenya); (c) African paradise flycatcher *Terpsiphone viridis* (Photo by: Ornithology Section, National Museums of Kenya); (d) Narina's trogon *Apaloderma narina* (Photo by: Ornithology Section, National Museums of Kenya).

### Implications for conservation

This study provides baseline information, and supplements the required information necessary for conservation actions using birds as key taxa in the Lower Tana River Forests. Given that bird species vary greatly in their sensitivity to habitat disturbance, it would be more effective to use the numbers of sensitive species, especially forest specialists, rather than total species richness in the evaluation of conservation values of forest patches on the area. This is due to the fact that loss of sensitive species may be masked in the total species richness by invasion of species adapted to relatively disturbed patches. As observed in this study, these could include species associated with the savannah/woodland areas. Particular forest patches had higher forest-dependent species, indicating that some patches still have pristine patches that require adequate protection and conservation measures to avoid further degradation. For example, considerable changes in intact forest and other land covers occurred at the Tana River Primate National Reserve between 1994 and 2004. The total forest proportion decreased from 0.69 to 0.57 over the period with estimated linear annual rate of loss of forest of 22.3 ha (Owino, Unpublished data).

The patches within the Reserve are also a home to the Pokomo people, who farm the river banks. Generally the forest use and biodiversity within including birds is thought to be unsustainable despite the protection status as a reserve. The forest patches are exploited by the local people mainly for fuel wood, timber and traditional medicines. Some of the trees targeted for exploitation could be important to bird species. Unsustainable hunting of birds for subsistence has also been reported in the past, but these have not been adequately documented. However, with the increase in human population within the Reserve and the surrounding areas, there is likelihood that further risks of unsustainable use practices is eminent, and is a factor that can not be ignored.

The protection status of all Lower Tana River forest especially those patches within the Reserve need to be improved. Following the unsuccessful major World Bank GEF-funded project, which began in 1997 and was suspended, the urgency for conservation and protection of the Reserve has become very important. The GEF-funded project aimed at among and a other things the relocation programme of the local people living within the Tana River Primate Reserve to create a better opportunity for enhanced protection of the Reserve. Due to challenges and resistance from the local people to the GEF-Project, there is a need for concerted efforts focusing on habitat monitoring programmes within the Reserve. This should involve working closely with the local people living within the Reserve. Further, it is particularly important to document the effects on birds of selective logging of particular tree species within the Reserve. This would be important in developing guidelines for programs to restore the degraded areas with appropriate tree species that can enhance bird species richness and other fauna in the area.

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**Appendix 1.** Bird species recorded from the 14 forest patches of the Tana River Primate National Reserve. Taxonomy and species order follow the Ornithological Sub-Committee of the East Africa Natural History Society [40]. Species groups follow Bennun *et al.* [31].

Families and species	Group	Forest patches													
		WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS
<i>Accipitridae</i>															
Brown snake eagle <i>Circaetus cinereus</i>	s	1	1	1	1	0	1	0	0	0	1	1	1	0	0
Southern banded snake eagle <i>Circaetus fasciolatus</i>	F	1	0	0	0	1	1	0	1	1	0	1	0	1	1
African harrier hawk <i>Polyboroides typus</i>	f	0	1	0	0	1	1	0	0	0	0	0	1	0	0
Gabar goshawk <i>Micronisus gabar</i>	s	1	0	0	1	0	1	0	0	0	1	1	0	0	0
Eastern pale chanting goshawk <i>Melierax poliopterus</i>	s	0	0	0	0	0	0	1	0	1	1	0	0	1	1
African goshawk <i>Accipiter tachiro</i>	F	0	0	0	0	1	0	1	1	1	1	1	0	1	1
Shikra <i>Accipiter badius</i>	f	1	0	0	0	0	1	0	0	0	1	1	0	0	0
Little sparrowhawk <i>Accipiter minullus</i>	f	1	0	0	0	0	1	0	0	0	1	1	0	0	1
Lizard buzzard <i>Kaupifalco monogrammicus</i>	f	0	1	1	0	1	0	0	1	0	0	0	0	0	0
Palm-nut vulture <i>Gypohierax angolensis</i>	s	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ayres' hawk eagle <i>Hieraaetus ayresii</i>	F	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Long-crested eagle <i>Lophaetus occipitalis</i>	f	0	0	1	0	0	0	1	0	0	0	0	0	0	0
African crowned eagle <i>Stephanoaetus coronatus</i>	FF	0	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Falconidae</i>															
Pygmy falcon <i>Polihierax semitorquatus</i>	s	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Phasianidae</i>															
Crested francolin <i>Francolinus sephaena</i>	s	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Numididae</i>															
Crested guineafowl <i>Guttera pucherani</i>	F	0	1	0	0	1	0	1	1	0	0	1	1	0	0
Vulturine guineafowl <i>Acryllium vulturinum</i>	s	1	1	0	0	0	1	0	0	0	1	1	0	0	0
<i>Pteroclididae</i>															
Black-faced Sandgrouse <i>Pterocles decoratus</i>	s	0	1	1	1	0	0	0	0	0	0	0	0	0	0
<i>Columbidae</i>															
African green pigeon <i>Treron calva</i>	F	1	1	1	1	0	1	1	1	0	1	1	1	1	1
Tambourine dove <i>Turtur tympanistria</i>	F	1	0	0	0	0	1	0	0	0	1	1	1	0	1
Emerald-spotted wood dove <i>Turtur chalcospilos</i>	f	1	1	1	1	0	1	1	1	1	1	1	1	0	1
Red-eyed dove <i>Streptopelia semitorquata</i>	f	1	1	1	1	1	1	0	1	0	1	1	1	0	0
African mourning dove <i>Streptopelia decipiens</i>	s	1	0	0	0	0	1	0	0	0	1	1	0	0	0
Ring-necked dove <i>Streptopelia capicola</i>	f	1	1	0	0	0	1	0	0	1	1	1	0	0	0
Laughing dove <i>Streptopelia senegalensis</i>	s	1	1	0	0	0	1	0	0	0	1	1	0	0	0

Families and species	Group	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS
<i>Psittacidae</i>															
African orange-bellied parrot <i>Poicephalus rufiventris</i>	s	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Musophagidae</i>															
Fischer's turaco <i>Tauraco fischeri</i>	F	1	0	0	1	1	1	1	1	1	1	1	1		1
<i>Cuculidae</i>															
Thick-billed cuckoo <i>Pachycoccyx audeberti</i>	f	0	0	1	0	0	0	1	1	0	0	0	0	1	1
Klaas's cuckoo <i>Chrysococcyx klaas</i>	f	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Diederik cuckoo <i>Chrysococcyx caprius</i>	s	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Yellowbill <i>Ceuthmochares aereus</i>	F	0	1	1	0	0	1	0	0	0	0	0	0	0	0
White-browed coucal <i>Centropus superciliosus</i>	s	1	1	1	1	0	1	0	0	1	1	1	1	0	0
<i>Strigidae</i>															
Pel's fishing owl <i>Scotopelia peli</i>	F	0	0	0	0	1	0	1	1	1	1	1	0	1	1
African barred owl <i>Glaucidium capense</i>	F	1	0	0	0	1	0	0	0	1	1	0	0	0	0
African wood owl <i>Ciccaba woodfordii</i>	F	1	0	0	0	0	1	0	0	1	1	1	0	0	0
<i>Caprimulgidae</i>															
Slender-tailed nightjar <i>Caprimulgus clarus</i>	s	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Apodidae</i>															
Mottle-throated spinetail <i>Telacanthura ussheri</i>	F	1	0	0	0	0	1	0	0	0	1	1	0	0	0
African palm swift <i>Cypsiurus parvus</i>	s	0	1	1	0	1	0	1	0	0	0	1	1	0	0
<i>Coliidae</i>															
Speckled mousebird <i>Colius striatus</i>	s	0	1	1	1	0	1	0	0	0	0	0	0	0	0
White-headed mousebird <i>Colius leucocephalus</i>	s	0	1	1	0	0	0	0	0	0	1	1	0	0	0
Blue-naped mousebird <i>Urocolius macrourus</i>	s	1	0	0	0	0	1	0	0	0	1	1	0	0	0
<i>Trogonidae</i>															
Narina's trogon <i>Apaloderma narina</i>	F	1	0	0	0	1	1	1	1	1	0	1	1	1	1
<i>Alcedinidae</i>															
Grey-headed kingfisher <i>Halcyon leucocephala</i>	f	0	1	0	1	1	0	1	1	0	1	1	0	0	0
Brown-hooded kingfisher <i>Halcyon albiventris</i>	s	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Striped kingfisher <i>Halcyon chelicuti</i>	s	0	0	0	0	0	0	0	0	0	0	0	1	0	0
African pygmy kingfisher <i>Ispidina picta</i>	f	0	0	1	1	0	0	0	0	0	0	0	1	0	0
<i>Meropidae</i>															
Carmine bee-eater <i>Merops nubicus</i>	s	1	1	0	0	1	1	1	1	0	1	1	1	0	0
White-throated bee-eater <i>Merops albicollis</i>	f	1	0	0	1	1	1	1	1	0	1	1	0	0	0

Families and species	Group	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS
<i>Coraciidae</i>															
Lilac-breasted roller <i>Coracias caudata</i>	s	1	1	1	1	0	1	0	0	1	1	0	0	0	1
Broad-billed roller <i>Eurystomus glaucurus</i>	f	1	0	0	0	0	1	0	0	1	1	1	0	0	1
<i>Phoeniculidae</i>															
Green wood-hoopoe <i>Phoeniculus purpureus</i>	s	1	1	1	0	1	1	1	0	1	1	1	1	0	1
Common scimitarbill <i>Rhinopomastus cyanomelas</i>	s	1	1	0	0	1	0	0	1	1	0	1	0	1	0
<i>Bucerotidae</i>															
Red-billed hornbill <i>Tockus erythrorhynchus</i>	s	1	0	0	0	0	1	0	0	0	1	1	0	0	0
Von der decken's hornbill <i>Tockus deckeni</i>	s	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Crowned hornbill <i>Tockus alboterminatus</i>	f	1	1	1	1	1	1	1	1	0	1	1	1	0	0
African grey hornbill <i>Tockus nasutus</i>	s	1	1	0	0	0	1	0	0	0	1	1	0	0	0
Trumpeter hornbill <i>Bycanistes bucinator</i>	F	1	0	0	1	1	1	1	1	0	1	1	1	0	0
<i>Capitonidae</i>															
Red-fronted tinkerbird <i>Pogoniulus pusillus</i>	s	1	1	1	1	1	1	1	1	0	1	1	1	0	0
Black-collared barbet <i>Lybius torquatus</i>	f	0	0	0	0	0	1	1	1	1	1	1	0	0	0
Brown-breasted barbet <i>Lybius melanopterus</i>	f	1	0	0	0	0	1	0	0	0	1	1	0	0	0
Red-and-yellow barbet <i>Trachylaemus erythrocephalus</i>	s	1	0	0	0	0	0	0	0	0	0	0	0	0	0
d'Arnaud's barbet <i>Trachylaemus darnaudii</i>	s	1	1	0	0	0	1	0	0	0	1	1	0	0	0
<i>Indicatoridae</i>															
Scaly-throated honeyguide <i>Indicator variegatus</i>	f	1	0	1	0	1	1	0	1	1	0	0	0	1	0
Greater honeyguide <i>Indicator indicator</i>	f	0	0	0	0	1	0	1	1	0	1	1	0	0	0
Lesser honeyguide <i>Indicator minor</i>	f	1	0	0	0	0	1	1	1	0	1	1	0	0	1
<i>Picidae</i>															
Nubian woodpecker <i>Campethera nubica</i>	s	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Little spotted woodpecker <i>Campethera cailliautii</i>	f	0	0	0	0	0	0	1	1	1	0	0	0	1	1
Cardinal woodpecker <i>Denropicos fuscescens</i>	f	1	1	0	1	0	0	0	1	1	0	0	1	0	1
Bearded woodpecker <i>Thripias namaquus</i>	f	1	1	0	1	0	1	1	1	1	1	0	0	0	0
<i>Hirundinidae</i>															
Sand martin <i>Riparia riparia</i>	s	1	0	0	0	0	1	0	0	0	1	1	0	0	0
Wire-tailed swallow <i>Hirundo smithii</i>	s	0	0	0	0	1	0	1	1	1	0	0	0	1	0
Barn swallow <i>Hirundo rustica</i>	s	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Motacillidae</i>															
African pied wagtail <i>Motacilla aguimp</i>	s	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Families and species	Group	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS
<i>Pycnonotidae</i>															
Zanzibar sombre greenbul <i>Andropadus importunus</i>	s	0	1	1	0	0	1	0	0	0	0	1	0	1	0
Fischer's greenbul <i>Phyllastrephus fischeri</i>	FF	1	1	0	1	1	1	0	0	1	1	1	0	1	1
Northern brownbul <i>Phyllastrephus strepitans</i>	f	1	0	0	0	1	1	1	0	1	1	1	1	1	0
Terrestrial brownbul <i>Phyllastrephus terrestris</i>	F	1	1	0	1	1	1	1	1	1	1	1	0	1	1
Yellow-bellied greenbul <i>Chlorocichla flaviventris</i>	F	0	0	0	0	0	0	0	0	1	0	0	1	1	1
Common bulbul <i>Pycnonotus barbatus</i>	f	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Eastern nicator <i>Nicator gularis</i>	F	1	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Timaliidae</i>															
Scaly babbler <i>Turdoides squamulatus</i>	s	1	1	0	1	0	1	0	0	0	0	0	0	0	0
Scaly chatterer <i>Turdoides aylmeri</i>	s	1	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Turdidae</i>															
East coast akalat <i>Sheppardia gunningi</i>	FF	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-capped robin-chat <i>Cossypha natalensis</i>	F	1	1	1	1	0	1	0	1	1	1	1	1	1	1
White-browed robin-chat <i>Cossypha heuglini</i>	f	0	1	1	0	0	1	0	0	0	0	0	0	0	0
Red-tailed ant thrush <i>Neocossyphus rufus</i>	FF	1	0	0	1	1	1		1	1	1	1	1	1	1
Collared palm thrush <i>Cichladusa arquata</i>	s	1	0	0	0	0	1	0	0	0	0	0	0	0	0
White-browed scrub robin <i>Cercotrichas leucophrys</i>	s	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Eastern bearded scrub robin <i>Cercotrichas quadrivirgata</i>	f	1	0	0	1	1	1	1	1	1	1	1	0	0	1
Rufous bush chat <i>Cercotrichas galactotes</i>	s	0	1	0	0	0	0	0	0	0	0		0	0	0
<i>Muscicapidae</i>															
Ashy flycatcher <i>Muscicapa caerulescens</i>	F	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Southern black flycatcher <i>Melaenornis pammelaina</i>	s	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Pale flycatcher <i>Bradornis pallidus</i>	s	0	1	1	1	1	1	1	1	0	1	1	0	0	0
<i>Sylviidae</i>															
Siffling cisticola <i>Cisticola brachypterus</i>	s	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Tawny-flanked prinia <i>Prinia subflava</i>	f	1	1	1	1	0	1	0	0	0	1	1	0	0	0
Grey wren-warbler <i>Calamonastes simplex</i>	s	0	1	1	0	0	1	0	0	0	0	0	0	0	0
Grey-backed camaroptera <i>Camaroptera brachyura</i>	f	1	1	1	1	1	1	1	1	0	1	1	1	0	0
Yellow-breasted apalis <i>Apalis flavida</i>	f	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Black-headed apalis <i>Apalis melanocephala</i>	FF	1	0	0	1	1	1	1	1	1	1	1	0	1	1
Northern crombec <i>Sylvietta brachyura</i>	s	0	1	1	0	1	0	0	0	0	1	0	0	0	0
<i>Monarchidae</i>															
Little yellow flycatcher <i>Erythrocercus holochlorus</i>	FF	1	0	0	1	0	1	0	1	0	0	1	1	0	0
Blue-mantled crested flycatcher <i>Trochocercus cyanomelas</i>	FF	0	0	0	0	0	1	0	1	1	0	1	1	1	1
African paradise flycatcher <i>Terpsiphone viridis</i>	f	1	1	1	1	1	1	1	1	1	1	1	1	1	1



Families and species	Group	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS
<i>Platysteiridae</i>															
Pale batis <i>Batis soror</i>	F	1	0	0	0	0	1	1	0	0	0	1	0	0	0
Pygmy batis <i>Batis perkeo</i>	s	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Black-headed batis <i>Batis minor</i>	s	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Black-throated wattle-eye <i>Platysteira peltata</i>	F	0	1	1	1	0	0	0	0	0	0	1	0	0	1
<i>Prionopidae</i>															
White-crested helmet-shrike <i>Prionops plumatus</i>	s	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Retz's helmet-shrike <i>Prionops retzii</i>	f	1	0	0	1	0	0	0	0	0	0	1	1	0	0
Northern white-crowned shrike <i>Eurocephalus rueppelli</i>	s	0	1	1	1	0	0	0	0	0	0	0	0	0	0
<i>Laniidae</i>															
Red-backed shrike <i>Lanius collurio</i>	s	0	1	1	0	0	0	0	0	0	0	0	0	0	0
<i>Malaconotidae</i>															
Brubru <i>Nilaus afer</i>	s	0	0	0	0	0	0	0	1	1	0	0	0	1	1
Black-crowned tchagra <i>Tchagra senegala</i>	s	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Sulphur-breasted bush-shrike <i>Malaconotus sulfureopectus</i>	f	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Four-coloured bush-shrike <i>Malaconotus quadricolor</i>	F	0	0	0	0	0	0	0	0	1	0	0	0	1	1
Grey-headed bush-shrike <i>Malaconotus blanchoti</i>	s	0	1	1	0	0	0	0	1	0	0	0	0	0	0
Tropical boubou <i>Laniarius aethiopicus</i>	f	1	1	1	1	1	1	0	0	1	1	1	1	0	1
Black-backed puffback <i>Dryoscopus cubla</i>	F	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Campephagidae</i>															
Black cuckoo-shrike <i>Campephaga flava</i>	f	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Dicruridae</i>															
Common drongo <i>Dicrurus adsimilis</i>	s	1	1	1	1	1	1	1	1	0	1	1	1	0	0
Square-tailed drongo <i>Dicrurus ludwigii</i>	F	1	1	0	0	1	1	1	1	1	1	1	0	1	1
<i>Oriolidae</i>															
Eurasian golden oriole <i>Oriolus oriolus</i>	f	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Black-headed oriole <i>Oriolus larvatus</i>	f	1	1	1	1	0	0	1	1	1	1	1	1	1	1
<i>Sturidae</i>															
Black-bellied starling <i>Lamprotornis corruscus</i>	F	1	0	1	1	1	1	1	1	1	1	1	1	1	1
Rüppell's long-tailed starling <i>Lamprotornis purpuropterus</i>	s	1	1	1	0	0	0	0	0	0	1	1	1	0	0
Shelley's starling <i>Lamprotornis shelleyi</i>	s	0	1	0	0	0	0	0	1	0	0	0	0	0	0
Superb starling <i>Lamprotornis superbus</i>	s	1	0	0	0	0	1	0	0	0	1	1	0	0	0
Golden-breasted starling <i>Cosmopsarus regius</i>	s	0	1	1	0	1	0	0	0	0	0	0	0	0	0

Families and species	Group	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS
Fischer's starling <i>Spreo fischeri</i>	s	1	1	0	0	0	1	0	0	0	1	1	0	0	0
Magpie starling <i>Speculipastor bicolor</i>	s	0	1	1	1	0	0	0	0	0	0	0	1	0	0
Wattled starling <i>Creatophora cinerea</i>	s	0	1	1	0	0	0	0	0	0	0	0	0	0	0
<i>Nectariniidae</i>															
Eastern violet-backed sunbird <i>Anthreptes orientalis</i>	s	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Collared sunbird <i>Anthreptes collaris</i>	F	1	1	1	1	1	1	0	0	1	1	1	1	0	1
Olive sunbird <i>Nectarinia olivacea</i>	FF	1	0	0	0	1	1	1	1	1	1	1	1	1	1
Amethyst sunbird <i>Nectarinia amethystina</i>	f	0	1	0	1	0	0	0	0	0	0	0	0	1	0
Hunter's sunbird <i>Nectarinia hunteri</i>	s	0	1	0	0	1	0	1	1	0	0	0	0	0	0
Variable sunbird <i>Nectarinia venusta</i>	f	1	0	1	0	0	1	0	0	0	1	1	1	0	0
Violet-breasted sunbird <i>Nectarinia chalcomelas</i>	s	0	1	1	0	0	0	0	0	1	0	0	0	0	0
Black-bellied sunbird <i>Nectarinia nectarinioides</i>	s	0	1	1	1	0	0	1	0	0	0	0	1	0	0
<i>Passeridae</i>															
Grey-headed sparrow <i>Passer griseus</i>	s	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Ploceidae</i>															
White-headed buffalo-weaver <i>Dinemellia dinemelli</i>	s	1	1	1	0	0	1	0	0	0	1	1	0	0	0
Red-billed buffalo-weaver <i>Bubalornis niger</i>	s	1	1	1	1	0	1	0	0	0	1	1	1	0	0
Grosbeak weaver <i>Amblyospiza albifrons</i>	f	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Spectacled weaver <i>Ploceus ocularis</i>	f	0	0	0	1	1	1	1	1	0	0	0	0	0	0
African golden weaver <i>Ploceus subaureus</i>	s	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Golden palm weaver <i>Ploceus bojeri</i>	s	0	1	1	1	1	0	1	1	0	0	1	0	0	0
Lesser masked weaver <i>Ploceus intermedius</i>	s	0	1	1	1	0	0	0	0	0	0	0	1	0	0
Black-headed weaver <i>Ploceus cucullatus</i>	s	0	0	0	0	0	0	0	1	1	0	0	0	1	1
Dark-backed weaver <i>Ploceus bicolor</i>	F	1	1	1	1	1	1	1	1	0	1	1	1	0	0
Red-billed quelea <i>Quelea quelea</i>	s	0	1	0	1	0	0	0	0	0	0	0	1	0	0
<i>Estrildidae</i>															
Green-winged pytilia <i>Pytilia melba</i>	s	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Green-backed twinspot <i>Mandingoa nitidula</i>	FF	1	0	0	0	0	1	0	0	0	1	1	0	0	0
Red-billed firefinch <i>Lagonosticta senegala</i>	s	1	0	1	0	0	1	0	0	0	1	1	0	0	0
Black-and-white mannikin <i>Lonchura bicolor</i>	f	0	0	0	0	1	1	1	1	0	1	0	0	0	0
<i>Fringillidae</i>															
Yellow-fronted canary <i>Serinus mozambicus</i>	s	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Families and species	Group	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS
Summary	Total	79	79	58	54	46	81	46	53	45	71	81	47	33	38
	FF	7	1	0	4	4	7	2	5	5	5	8	4	5	5
	F	18	10	8	10	14	18	13	14	17	16	20	12	12	16
	f	25	18	15	20	15	24	18	20	13	23	23	15	8	12
	s	29	50	35	20	13	32	13	14	10	27	30	16	9	6

WjE, Wenje East/Central; Kpd, Kipendi; Mrn, Maroni; MrE, Maroni East; Mkr, Makere; MkE, Makere East; GrN, Guru North; GrS, Guru South; McC, Mchelelo Complex; McE, Mchelelo East; SfE, Sifa East; BmS, Baomo South; MzN, Manzini North; MzS, Mzazini South.

1 and 0 indicate presence and no records of species respectively.

**Appendix 2.** Bird species ringed from the 14 forest patches of the Tana River Primate National Reserve, Kenya.

Bird species by groups	Forest patches														Total
	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS	
<i>Forest specialists (FF)</i>															
Fischer's greenbul	1	0	0	6	0	0	0	0	12	5	1	0	7	2	34
East coast akalat	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Red-tailed ant thrush	0	0	0	2	0	1	0	2	8	1	1	4	1	3	23
Blue-mantled crested flycatcher	0	0	0	0	0	2	0	0	2	0	0	1	2	0	7
Olive Sunbird	10	4	1	4	0	7	5	4	13	5	5	3	5	4	70
Green-backed twispot	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
<i>Forest generalists (F)</i>															
Tambourine dove	0	1	0	1	0	1	0	0	0	0	0	0	0	0	3
African barred owl	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
Narina's trogon	1	0	0	0	0	0	0	0	0	3	0	0	1	0	5
Terrestrial brownbul	1	5	2	2	0	2	0	2	1	0	0	0	3	2	20
Yellow-bellied greenbul	0	2	0	2	0	0	0	0	0	0	0	0	0	0	4
Eastern nicator	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Red-capped robin-chat	2	4	3	7	0	0	0	0	31	6	4	2	6	3	68
Square-tailed drongo	0	2	0	0	0	0	0	0	2	0	0	0	0	1	5
Collared sunbird	0	1	0	0	2	0	0	0	0	0	0	0	0	0	3
Dark-backed weaver	1	1	0	1	0	4	0	0	0	2	0	0	0	0	9
<i>Forest visitors (f)</i>															
Emerald-spotted wood dove	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Grey-headed kingfisher	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
African pygmy kingfisher	0	2	2	2	3	1	4	2	5	2	0	0	2	0	25
Scaly-throated honeyguide	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Northern brownbul	1	0	0	0	3	0	0	0	1	0	0	0	0	0	5
White-browed robin-chat	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Eastern bearded scrub robin	1	0	0	0	0	0	0	3	2	0	0	1	3	0	10
Tawny-flanked prinia	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Grey-backed camaroptera	0	1	1	0	0	3	1	1	0	2	0	0	0	0	9
African paradise flycatcher	1	2	1	1	1	2	0	0	0	0	0	2	0	0	10
Retz's helmet-shrike	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
Tropical boubou	0	1	0	0	0	0	0	0	0	2	0	0	0	0	3
Spectacled weaver	0	0	0	1	0	2	0	0	0	0	0	0	0	0	3
<i>Savannah &amp; woodland species (s)</i>															
Brown-hooded kingfisher	0	0	0	4	0	0	0	0	5	3	0	0	0	2	14
Red-billed hornbill	0	0	0	0	0	5	0	0	0	0	0	0	0	0	5
Red-fronted tinkerbird	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Zanzibar sombre greenbul	0	0	0	0	0	2	0	0	0	1	0	0	0	1	4
Scaly babbler	2	0	0	2	0	3	0	0	0	0	0	0	0	0	7
Collared palm thrush	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Common drongo	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1

Bird species by groups	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS	Total
Red-billed buffalo-weaver	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3
African golden weaver	0	2	0	0	0	0	0	0	0	1	0	0	0	0	3
Golden palm weaver	0	0	6	0	0	0	0	0	0	0	0	0	0	0	6
Lesser masked weaver	0	0	9	0	0	0	0	0	0	0	0	0	0	0	9
Summary															
Total ringed	27	29	29	38	9	36	11	14	83	33	15	14	30	18	386
FF	12	4	1	12	0	10	5	6	35	11	10	8	15	9	138
F	7	16	5	13	2	7	0	2	35	11	5	2	10	6	121
f	3	7	5	6	7	9	6	6	8	6	0	4	5	0	72
s	5	2	18	7	0	10	0	0	5	5	0	0	0	3	55

WjE, Wenje East/Central; Kpd, Kipendi; Mrn, Maroni; MrE, Maroni East; Mkr, Makere; MkE, Makere East; GrN, Guru North; GrS, Guru South; McC, Mchelelo Complex; McE, Mchelelo East; SfE, Sifa East; BmS, Baomo South; MzN, Manzini North; MzS, Mnazini South

**Appendix 3.** Relative abundance and ranks (in parentheses) for the top 10 bird species identified from the timed species counts in the 14 forest patches of the Tana River Primate National Reserve. Only birds recorded above 3 m and within 25 m included.

Species	Forest patches													
	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS
African goshawk							0.7(09)	0.9(10)						
African green pigeon		1.2(09)											0.2(07)	0.3(05)
Tambourine dove	1.8(06)				1.0(08)	2.9(01)	0.9(07)			1.7(08)				
Emerald-spotted wood dove		3.6(01)	1.8(02)		1.3(06)									
Red-eyed dove		1.1(10)	1.6(05)	1.6(07)	1.6(05)		0.8(08)	1.6(05)				0.8(09)	0.2(06)	
Fischer's turaco	1.4(09)										2.8(04)	1.0(06)		
Narina's trogon													0.1(08)	
Grey-headed kingfisher									0.2(08)					0.4(03)
Brown-hooded kingfisher			1.3(08)	2.0(04)	1.7(04)	2.5(03)	1.7(02)	3.6(01)			2.1(09)		0.2(05)	0.2(09)
White-throated bee-eater									0.31(06)					
Lilac-breasted roller		1.8(03)	1.5(06)											
Green wood-hoopoe														0.4(04)
Von der decken's hornbill		1.3(07)												
Crowned hornbill												0.7(10)		0.2(08)
Trumpeter hornbill				1.08(10)				1.1(08)			2.3(07)			
Yellow-rumped tinkerbird					1.8(03)		1.2(04)	1.4(06)						
Red-fronted tinkerbird	2.3(05)				1.9(02)									
Brown-breasted barbet										1.4(10)				
Little spotted woodpecker														0.2(06)
Bearded woodpecker									0.2(07)					
Fischer's greenbul									0.1(10)	1.8(07)				
Terrestrial brownbul				1.2(09)										
Red-capped robin-chat						1.50(9)	1.0(06)			1.8(06)		1.2(05)		
Eastern bearded scrub robin						1.92(7)								

Species	WjE	Kpd	Mrn	MrE	Mkr	MkE	GrN	GrS	McC	McE	SfE	BmS	MzN	MzS
Grey-backed camaroptera	1.3(10)					1.58(8)						0.9(07)		
Black-headed apalis	1.6(08)								0.4(05)	1.5(09)	2.0(10)		0.5(02)	0.2(07)
African paradise flycatcher			1.4(07)	1.8(05)				1.0(09)	0.7(02)			1.3(04)		
Pale batis							1.1(05)							
Northern white-crowned shrike		1.5(05)	1.9(01)											
Tropical boubou	3.0(01)		1.7(04)	3.1(01)	2.0(01)	2.8(02)	2.5(01)	3.4(02)		2.5(02)	3.6(01)	3.1(01)		
Black-backed puffback	1.8(07)			2.3(02)	0.8(09)	2.2(05)	0.6(10)			2.4(03)	2.7(05)	0.8(08)		
Common drongo				1.3(08)								2.0(03)		
Square-tailed drongo	2.5(03)				1.3(07)			1.9(04)	0.4(04)	2.2(05)	3.3(02)		0.3(03)	
Black-headed oriole		1.7(04)	1.2(09)	1.8(06)									0.1(10)	
Black-bellied starling					0.8(10)			1.3(07)			2.2(08)			
Wattled starling		1.3(08)												
Collared sunbird				2.1(03)										0.1(10)
Olive sunbird	2.8(02)					2.4(04)	1.4(03)	2.1(03)	1.4(01)	3.2(01)	2.6(06)		1.4(01)	0.7(01)
Variable sunbird						1.4(10)								
Red-billed buffalo-weaver		1.4(06)												
Lesser masked weaver		2.1(02)	1.8(03)											
Black-headed weaver									0.2(09)				0.1(09)	
Dark-backed weaver	2.3(04)		1.1(10)			2.1(06)			0.6(03)	2.4(04)	3.2(03)	2.1(02)	0.2(04)	0.7(02)

WjE, Wenje East; Kpd, Kipendi; Mrn, Maroni; MrE, Maroni East; Mkr, Makere; MkE, Makere East; GrN, Guru North; GrS, Guru South & central; McC, Mchelelo Complex; McE, Mchelelo East; SfE, Sifa East; BmS, Baomo South; MzN, Manzini North; MzS, Mnazini South