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Response of a globally endangered canopy insectivore to habitat degradation in an East African tropical rainforest: The role of differential forest protection levels

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This study examined the interplay between anthropogenic habitat degradation, forest protection level and density of Turner's Eremomela (TE) (*Eremomela turneri*), a globally endangered bird in Kenya's Kakamega forest. Sampling was conducted from May-June 2012 in two contiguous and one isolated forest blocks. Logging intensity, canopy height and cover, plant species richness and other key anthropogenic disturbance were used to characterize habitat quality. Density, encounter rates and TE spatial occurrence were determined using distance sampling. Combined TE density was 0.43 SE 0.09 ha^{-1}(N = 7, p = 0.03) and was higher in the most protected north block. Estimated overall population in closed canopy forest was 4,282 (CI = 3,417 to 5,147). High canopy cover boosted TE density (R^2 = 0.786, N = 7). Logging intensity was the key driver of forest disturbance (R = 0.742; p = 0.052) leading to reduced canopy cover (R = -0.658, p = 0.050) and reduced plant species richness (R = 0.771, p = 0.042). However, TE presence in the Kisere fragment suggests resilience to some level of isolation or forest disturbance provided sizeable near-primary forest is maintained. An effective medium term conservation strategy should include stricter forest protection and reforesting logged areas to reduce the impact of logging.

Key words: Eremomela turneri, human impact, habitat quality, forest protection.

INTRODUCTION

Species with narrow restricted ranges are among the most affected by perturbations in their highly specialized habitats. Turner's Eremomela *Eremomela turneri* (van Someren, 1920) (TE) is a forest canopy specialist bird that is endemic to the Guineo-Congolean rainforest system, which reaches its eastern limit in western Kenya forests of Kakamega and Nandi (Bennun et al., 2006). This globally-endangered species (IUCN, 2013) mainly inhabits the forest interior where it forages on arthropods in small locally itinerant groups of 3 to 10 individuals, mainly on large mature trees with closed or slightly open canopies (Kosgey, 1998 Unpublished MSc Thesis, Moi University, Kenya). Often, the groups form part of larger feeding parties involving other canopy Sylviids (Zimmerman et al., 1999). The Nandi forest system (South and North Nandi) are the main strongholds of the species (BirdLife International, 2013) but the spatially proximal Kakamega forest also holds

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substantial populations that are largely disconnected owing to years of anthropogenically-driven fragmentation and degradation (Schaab et al., 2010; Schleuning et al., 2011). The Kakamega and Nandi forests have similarities in habitat, floristic and edaphic character, though with slightly different altitudes (Bennun and Njoroge, 1999), as they both form part of the old Guineo-Congolean forest system which once extended to central Africa (Kokwaro, 1988). Analysis of photographic and remote sensing records and data over the past century suggests that the three forests were a contiguous unit as recent as one century ago (Doute et al., 1981; Tsingali et al., 2009; Schaab *et al.,* 2010). The species' westerly race *E. turneri kalinderi* still occurs only in forests of eastern Democratic Republic of Congo and western Uganda (BirdLife International, 2013).

Kakamega forest suffered several decades of massive unregulated logging until the late 1970s. Since the early 1980s, conversion to agriculture and settlement by the increasing adjacent human population has led to further forest loss and continued fragmentation and habitat degradation (Kokwaro, 1988; Akotsi et al., 2005; Farwig et al., 2008; Munyekenye et al., 2008; Schleuning et al., 2011). Moreover, different levels of official protection related to overlapping institutional management mandates have contributed to corresponding variations in habitat quality and suitability for various forest species, especially the forest specialists such as TE (Bennun et al., 2006). Our study aimed to evaluate the effects of tree removal, canopy structure change and other key aspects of anthropogenic impacts on the density and encounter rates of TE in zones of different protection levels of the forest. Being a forest specialist and upper canopy species, TE is vulnerable to habitat modification associated with loss of high canopy trees due to anthropogenic disturbance (Kosgey, 1998; Bennun et al., 1999; Otieno et al., 2011). To evaluate effects of protection on the species' response to habitat change, the study was carried out in three forest blocks with varying levels of formal protection. Protection level is used here to refer to the relative degree to which the forest blocks are actively managed to control access to the forest, minimize encroachment for agriculture, settlement, conversion or other anthropogenic activities such as infrastructure (Lakanavichian, 2006). It also refers to the degree of control of harvesting and use of forest products such as illegal logging, through patrols and law enforcement (Geist and Lambin, 2002; Lakanavichian, 2006). As we expected, the levels of forest protection influenced levels of forest disturbance and habitat quality, which in turn determined the species' density and distribution across the forest.

MATERIALS AND METHODS

Study area

Kakamega forest, Kenya's only true tropical rainforest is located in western Kenya between 0°07′–0°27′ N, 34°46′–34°57′ E with an altitude ranging from 1520 – 1680 m above sea level (Bennun and Njoroge, 1999; Fashing and Gathua, 2004) (Figure 1). Mean annual rainfall is 2000 mm and is bi-modally distributed with peaks of long and short rains in April-May and September-October, respectively (Fashing and Gathua, 2004; Mulwa et al., 2012). The absolute average temperature is 20°C with mean daily minimum and maximum of 12 and 26°C, respectively (De Meyer, 2001). The soils are well drained but deeply weathered and of low fertility. Soils of the northern part of the forest are alkaline alfisols, while those of the southern end are predominantly acidic ultisols (BIOTA, 2005).

The forest covers a total of 12000 ha but only 9500 ha still comprise closed canopy forest, 3500 ha of which occurs in the northern and 6000 ha in the southern block, respectively (Schaab et al., 2010). The northern block was gazetted as a National Wildlife Reserve in 1986 (Munyekenye et al., 2008; Schaab et al., 2010) and is under the management of Kenya Wildlife Service, KWS, while the southern block which includes Isecheno Nature Reserve, Ikuywa and Yala River Nature Reserve, is managed by the Kenya Forest Service, KFS (Fashing and Gathua, 2004; Akotsi et al., 2005; Munyekenye et al., 2008). Ikuywa is predominantly a secondary forest zone with high disturbance levels (Table 2) and a high proportion of exotic coniferous plantations forming a matrix of patches within the larger southern block (Fashing and Gathua, 2004; Munyekenye et al., 2008; Schaab et al., 2010). The non-canopy and non-forested areas include grassy and bushed glades, plantations for commercially exploited wood as well as a scattered area of cash-crop and subsistence cultivation (Akotsi et al., 2005; Schaab et al., 2010). Kisere Forest Reserve, also managed by KWS and totaling 458 ha (Munyekenye et al., 2008), is a distinct fragment which is suspected to historically have been contiguous with Kakamega forest (Schaab et al., 2010).

The forest constitutes one of Kenya's 61 Important Bird Areas (IBAs), hosting at least 350 bird species (BirdLife International, 2013), many of which are range-restricted or endemic species characteristic of the wider Guineo-Congolean forest system (Kokwaro, 1988). Of the birds, two (TE and Chapin's Flycatcher *Muscicapa lendu*) are globally endangered while a further 15 are regionally threatened (BirdLife International, 2013; Mulwa et al., 2012). There are at least 850 plant species recorded in the forest, 150 of which are woody species, although there is no significant endemism (Bennun and Njoroge, 1999; Fischer et al., 2010).

As a result of massive exploitation through legal and illegal logging between the 1960s and through the early 1980s, a mixture of large secondary-growth trees now dominates the forest flora with minimal natural primary-growth stands. Even for this secondary forest, significant stands of closed canopy and contiguity exists only in the northern part of the forest, consisting of the Buyangu block, now protected as a National Wildlife Reserve. The southern sector, comprising of the Isecheno, Yala and Ikuywa as well as the detached units of the Kisere, Kaimosi and Malava blocks (Figure 1), are managed as Forest Reserves. Due to stricter protection controls by KWS over the past few years, there has been a considerably lower intensity of illegal logging and general anthropogenic disturbance in the northern sector than in the southern block under KFS in which regulated access for controlled use of some forest products such as fuel wood, grass thatch or cattle grazing was allowed for several years in keeping with the definition of Forest Reserves under conservation legislation (Schleuning et al., 2011). The small, isolated Kisere block continues to suffer the most severe anthropogenic impact as it is only partially protected as a reserve and therefore anthropogenic access is less strictly controlled (Schaab et al., 2010). Apart from logging pressure, the south and Kisere blocks also experience impacts from the local community in the form of cattle grazing, charcoal burning and harvesting of firewood, thatch grass and honey. Some of this is allowed in quota determined under concessional controls regulated the KFS. Demand on the KFS for agricultural land by the local community

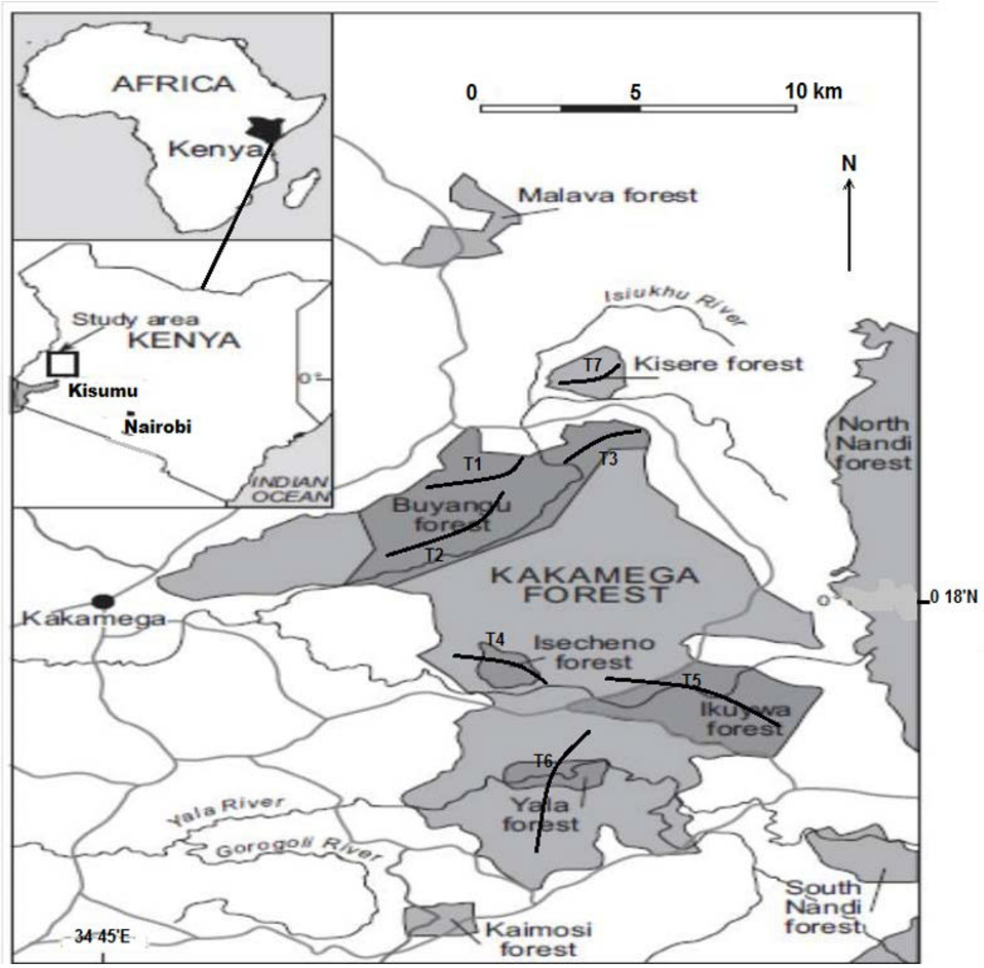

Figure 1. Map of Kakamega Forest showing the various blocks and survey transects. The transects are indicated in bold dark trace. Transect key: T1 = Buzambuli; T2 = Salazar; T3 = Primate/birding area; T4 = Isecheno Nature Reserve; T5 = Ikuywa forest area; T6 = Yala River Nature Reserve; T7 = Kisere forest (Adopted from Munyekenye *et al.,* 2008).

with a high population estimated to range between 220-600 persons per km^{-2} or 6 persons per ha^{-1} (Farwig et al., 2008) is an additional challenge that is already observable in the form of small-scale farming encroachment on some parts of the forest edge (Schaab et al., 2010).

Habitat stratification

The study was carried out from May to June 2012. Field sampling was conducted in closed canopy forest within three forest blocks: the northern sector of the forest (National Wildlife Reserve), the southern sector of the main body of the forest, (Forest Reserve); and Kisere Forest Reserve (Figure 1). Three transects each were established in the northern and southern blocks, and one in Kisere block making a total of 7. The transects were selected in a stratified fashion to reflect the degree of protection and relative disturbance levels: lowest disturbance and highest active protection level with no utilization in the northern block; moderate disturbance with regulated access in the southern block; high disturbance with moderate to low protection level in Kisere block (Table 2). The stratification was aimed at obtaining representative samples as well as facilitating spatial comparison of results (Nomani et al., 2012). In selecting and laying the transects, the main challenge was logistical especially as much of the closed-canopy TE habitat both in the north and the south was characterized by thick under-storey, thus precluding straight transects.

Bird survey

The 7 transects for survey of TE covered a total of 14 km. The surveys were conducted between 07.00 and 10:00 h along randomly selected 2-km transects in each forest block using distance sampling protocol (Buckland et al., 2001). Randomness was achieved by ensuring that transects originated from points where different existing small tracks/trails met or formed multiple arms or forks. At such points, only the right-facing track was selected. Further, it was ensured that transects were located at a separation distance of not less than 200 m from the adjacent ones, to avoid double counting (Nomani et al., 2012). Such a mix of systematic and random transect layout has been found to improve precision in density estimates using distance (Nomani et al., 2012).

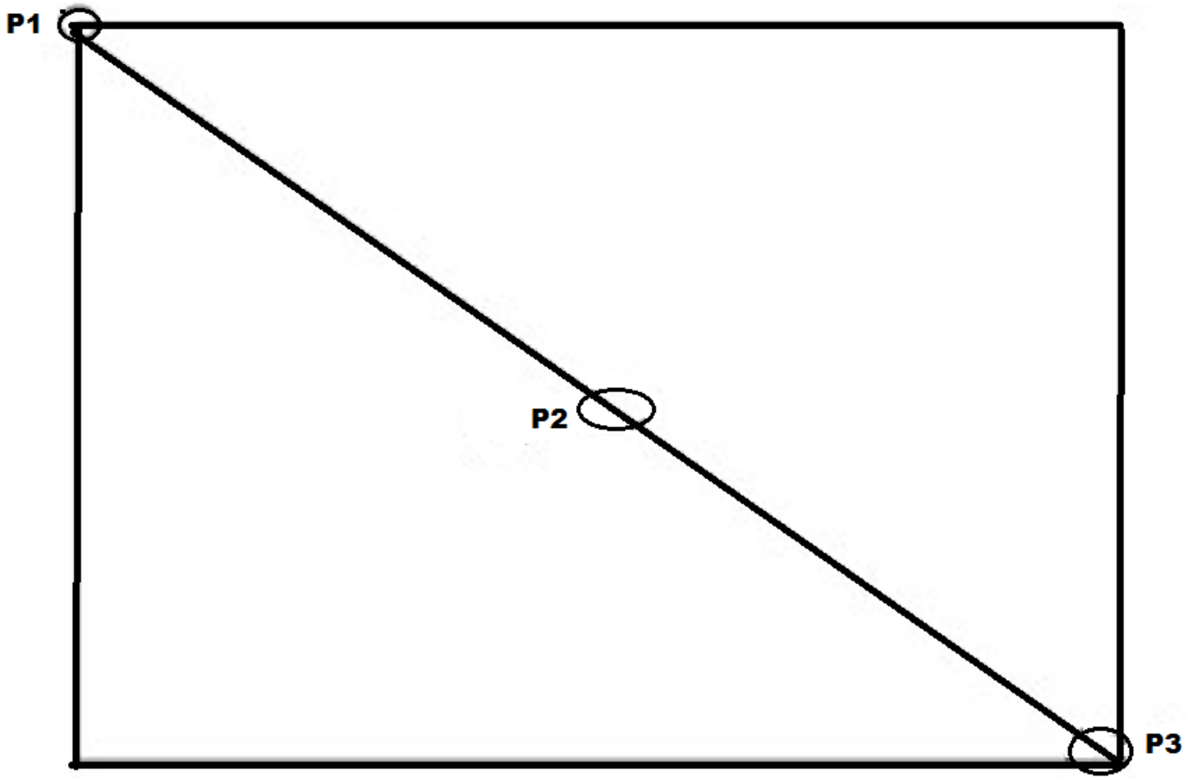

Figure 2. Sampling points for measuring percent forest canopy cover on quadrats. The three points P1, P2 and P3 represent the replicate points along a diagonal running through the centre of each 10x 10 m quadrats along belt transects used for surveying birds and assessing vegetation. Readings from all points in each quadrat were averaged to one value of percent cover.

Surveys commenced from different ends of each transect each time as recommended by Bibby et al. (998). Transects passed through the under-storey some of which had to be slightly cleared. The bird transects had a fixed width of 50 m (25 m on either side) and birds were counted by moving slowly and recording all encounters of TE (Bennun and Howell, 2002; Bibby et al., 1998). Transect method was used in favour of point counts because of the rarity of TE that would otherwise have yielded many zero counts in point counts. Fixing transect widths had two main advantages. First, it helped to maximize detection probability of the species in the closed nature of the forest habitat where this parameter declines rapidly with increased perpendicular sighting distance (Bibby et al., 1998). Secondly, it helped to improve accurate identification of TE that is not only small in size but also tends to move constantly while feeding high in the canopy in mixed flocks with other similar warblers.

Two observers working in pairs, one observing with a pair of binoculars and listening and the other recording, moved at a slow steady pace looking out for and listening to TE calls. When detected, records were also made of flock size and the perpendicular distance of each sighting from the transect centre, using a range finder (Fewster et al., 2009; Buckland et al., 2001). For a cluster of birds, the perpendicular distance was estimated to the centre of the cluster. Biases related to pseudo-replication were reduced by ignoring birds flying from behind and by the 200 m distance maintained between adjacent transects (Bibby et al., 1998). Using a range finder was helpful in improving distance estimates from detected birds to transect centre. Further, bird surveys were conducted twice along each transect on alternate weeks and on days separate from/prior to habitat sampling to reduce undue disturbance of birds.

Vegetation assessment and anthropogenic impact

Vegetation structure was assessed along the same transects used for birds, to determine the relationship with the assemblages of TE. Ten quadrats of 10 x 10 m were established on alternate sides of transects at 190 m intervals and within these, estimates of canopy height and canopy cover from three different points along a diagonal line down the quadrat, were scored. Canopy cover (defined here as canopy closure) was determined using a convex spherical densitometer (Korhonnen et al., 2006). Measurement was done while standing at three points in each quadrat: one corner, quadrat centre and the opposite quadrat corner along a diagonal line (Figure 2) The densiometer was set horizontally at elbow level about one foot from observer such that its levelling bubble was at the centre and to further improve its horizontal positioning especially in sloppy terrain, a camera tripod stand was used to steady the instrument. Standing at a point under that canopy for each measurement, an observer assumed four equally-spaced dots in each square of the grid and counted the number of dots equivalent to the quarter-square canopy openings. This was then multiplied by 1.04 to obtain and record the percent overhead space not occupied by canopy (Jennings et al., 1999; Korhonnen et al., 2006). By subtracting this from 100, percent canopy cover was derived for that particular point. This was repeated for each of the

Table 1. Results of the detection function Chi-square goodness of fit test results for model selection in estimating density of Turner's Eremomela.

Forest block	Cut points	Observed values	Expected values	χ^2	df	P<0.05
Block 1	0.00	11	11.1	<0.01	1	0.07
Block 2	7.50	13	9.32	1.45		
Block 3	15.0	3	6.57	1.94		
Total	-	-	-	3.39	1	

The results are defined by Half Normal Cosine fit on the basis of the lowest AIC value to estimate Turner's Eremomela density. The differences between observed and expected abundances were insignificant.

other two points in the quadrat end finally a mean value calculated for each quadrat (Jennings et al., 1999; Sutherland, 2006). Measurement was made consistently by one observer. The mean percent canopy cover were then scored as open (0 to 33%), medium (34 to 66%) or closed (more than 66%).

Canopy heights were measured using a Nikon Forestry Pro range finder. Again three measurements were made at three different points in each quadrat by the observer standing successive directly underneath each of the tallest canopy points and looking directly above the top of the crown and determining the height directly after correcting the observer's own eye-level height by adding it to the recording.

All plant species were identified in each quadrats. Plants were identified with expertise from a member of the Kakamega Environmental Education Programme with 15 years' experience in botanical field work specifically in the study forest (who is also a co-author here). Use was also made of plant field guides and references such as Blundell (1999), Dharani (2002) and Fischer et al. (2010). Any plants not readily identified in the field was collected, pressed and sent for further specialized identification at the East African Herbarium at the National Museums of Kenya.

While walking slowly and occasionally stopping along stretches of 200 m on transects, observations and assessment of evidence of human activities were made and recorded. Various forms of activities including fuel wood collection, cattle grazing, charcoal burning, logging, vegetation clearing or harvesting, game snaring, roads and track or farming encroachment, were recorded. Logging intensity was assessed in each of the quadrats by counting all stumps of cut trees of diameter sizes of 10 cm and above using a tape measure (Fewster et al., 2009). Logging is generally regarded as the most profound cause of habitat destruction in Kakamega forest (Bennun and Njoroge, 1999; Schaab et al., 2010; Schleuning et al., 2011). Human activities, observed along the transects were assessed by scoring the frequency of occurrence of each form at every 200 m stretch for each transect and block to determine overall disturbance indices. The 200 m stretch assessment of activities was considered more appropriate than entire-length transect assessments to clearly discern the most key forms of anthropogenic disturbance of the forest habitat from overall disturbance scores (Miller et al., 1998).

Statistical analyses

To improve distribution of count data towards normal distribution, counts of TE, plant species and stems cut, were transformed using logarithms (Zar, 1999) and analyses proceeded after attaining reasonable normality tested by using normal distribution plots. Proportion or ratio data such as percent canopy cover score and overall habitat disturbance scores were transformed by arc-sine square root to minimize departure of variance from the mean (Zar, 1999). Densities of TE were determined per hectare for each forest block using the Conventional Distance method from DISTANCE v 6 software (Buckland et al., 2001). The half normal detection function model with Cosine adjustment that had the lowest Akaike Information Criterion (AIC) value was selected in density estimation (Buckland et al., 2001). Based on the relatively small total number of detections of TE and also on the Chi-squared goodness of fit test results, it was found suitable to fit the species' detection functions curves from the three separate forest blocks into one single global pool (Buckland *et al*., 2001). This was because the of the small difference between the total Half Normal Cosine AIC values (165.08) of the three component detection functions and the combined value (168.76) which was only 2.2%, suggesting no confounding effect of perpendicular sighting distance (Bibby et al., 1998; Buckland et al., 2001). The model also provided the closest approximation of expected TE abundance estimation from the observed ones (Table 1). Apart from density, encounter rates were also determined for TE to establish relative likelihood of sighting the species across transects and blocks surveyed. Encounter rates for each transect were calculated for each block and transect from the relationship: $ER = n/L$, where ER = encounter rate; n = total number of TE individuals encountered in each block or transect in the entire survey and L = total transect length covered for the block/transect.

Plants species richness for each transect was evaluated as the total cumulative number of species recorded in all quadrats along transect while mean number of stems cut was derived from all stems cut of all size classes averaged by the number of quadrats in a transect and number of transects in a block. Percent canopy cover scores were coded on a scale of 1 to 3 such that open (0-33%) scored 1; moderately open (34-66%) scored 2; closed (>66%) scored 3. From this, the mean canopy cover score was derived for each transects and ultimately, for each forest block. Mean canopy height was also obtained from combined canopy heights in all quadrats divided by the number of quadrats in each transect, or divided by number of transects for each block.

Overall human habitat disturbance indices for each forest block were determined as mean scores obtained from frequencies of encounter rates of each form of activity within all 200 m stretches along transects. Thus overall disturbance index was calculated as follows:

$D_I = [\Sigma(a_{fi}*10)/A_f)]\ Tt*100$, where D_I= overall habitat disturbance index; a_{fi} = the sum of encounter rates of the *ith* activity in a 200-m stretch of a transect; $A_f =$ the sum of all encounters of all forms of activity in all transects; T_t = the sum of all transects in a forest block and *10* = the number of 200-m stretches in each transect (Otieno et al., 2012).

Analysis of covariance (ANCOVA) was performed to test any co-linearity amongst vegetation variables and bird density estimates. We treated the vegetation variables as fixed variables and bird densities as random effects (Zar, 1999). We used linear regression to evaluate the relationships between the remaining key parameters with TE density (dependent variable) across all transects. A Chi goodness of fit test was employed to test for any associations of TE to either the northern (National Wildlife Reserve) or the southern (Forest Reserve) forest blocks. For this, a priori assumption was

Table 2. Estimated encounter rates of Turner's Eremomela across the forest with corresponding habitat disturbance levels in each block.

Block	Transect location	Disturbance index	TE ER
North	Buzambuli Trail	0.50	2.50
	Primate/birding trail	1.30	3.50
	Salazar Village	0.30	2.50
South	Isecheno (Nature Reserve)	1.50	3.25
	Ikuywa	1.40	0.75
	Yala River Nature Reserve	0.30	4.75
Kisere	Kisere	1.90	3.00

Forest disturbance expressed as overall indices of intensity determined from combined observed evidence of all individual human impacts. TE ER = Turner's Eremomela encounter rate km^{-1}. For forest blocks, North = the National Wildlife Reserve; South = the southern block comprising the Forest Reserve; Kisere = the detached forest fragment.

Table 3. Estimated densities of Turner's Eremomela in each forest block surveyed.

Fragment	Density (ha^{-1})	DCV	EST	EST LL	EST UL	AIC	ESW (m)	Dp (%)
North	0.53	0.33	1,855	1,252	2,458	61.7	15.0	93.5
South	0.39	0.32	2,340	1,584	3,096	76.6	20.0	95.4
Kisere	0.33	0.47	151	79	230	26.9	22.5	91.8
Overall	0.43	0.20	4,282	3,417	5,147	168.8	17.7	94.3

Results are based on AIC with minimum value; DCV = density coefficient of variation; EST = population estimate; LL = lower limit; UL = upper limit; AIC = Akaike Information Criterion (with cosine adjustment function and distances scaled using right-truncation); ESW – Effective strip width; Dp = mean detection probability. For forest blocks, North = the National Wildlife Reserve; South = the southern block comprising the Forest Reserve; Kisere = the detached forest fragment.

that the latter is comparatively more disturbed.

RESULTS

We detected 81 individuals of TE in 27 encounters across all transects and forest blocks. The combined density of the species was 0.43 ha^{-1} (SE0.09) with a projected population estimate of 4,282 (CI = 3,417 – 5,147, p = 0.03) for closed canopy forest (Table 3).

Density estimates were highest in the northern block, and lowest in the Kisere fragment (Table 3). The same applied for encounter rates of the species in all surveys with 2.92 birds km^{-1} (n = 6) in the northern block and 2.90 birdskm^{-1} (n = 6) in the southern block (Table 2). In Kisere, the encounter rate was 3.00 birds km^{-1} (n = 2) though the notably higher rate might arise from the single transect run in the block. The species was sighted at the shortest overall perpendicular distance in the north due its more near-natural state because of stricter protection as compared to the more disturbed south and open Kisere (Figure 3).

However, the estimated population for the species was highest in the southern block of the forest at 2,340 (CI = 1,584 - 3,096) due to its larger size relative to north block which recorded 1, 855 (CI = 1,584 –2,458) and Kisere with 151 (CI = 79–230), N = 7, p = 0.02).

Analysis of variance showed no statistically significant difference in abundance of TE among forest blocks but Kisere block recorded the highest plant species richness despite the greatest logging pressure (Table 4) which has contributed to massive disturbance and comparatively lower overall canopy cover (Figure 4).

Tree logging was the most significant form of anthropogenic forest disturbance and although the presence of foot paths and tracks was the most frequent form of anthropogenic feature across all blocks (Table 5) tree logging had the most prominent impact on forest disturbance and negative influence on TE density and occupancy. The other forms of human activity showed no direct significant relationship to TE density or encounter rates.

Analysis of covariance showed a strong co-linear link between percent tree canopy cover and canopy height, and hence the latter was removed from the Spearman's rank correlation of the multiple variables. Subsequently, canopy cover was selected as the better predictor of TE density and was used in linear regression of the two variables and TE had a strong positive correlation to percent canopy cover (R = 0.886, p < 0.01). Furthermore,

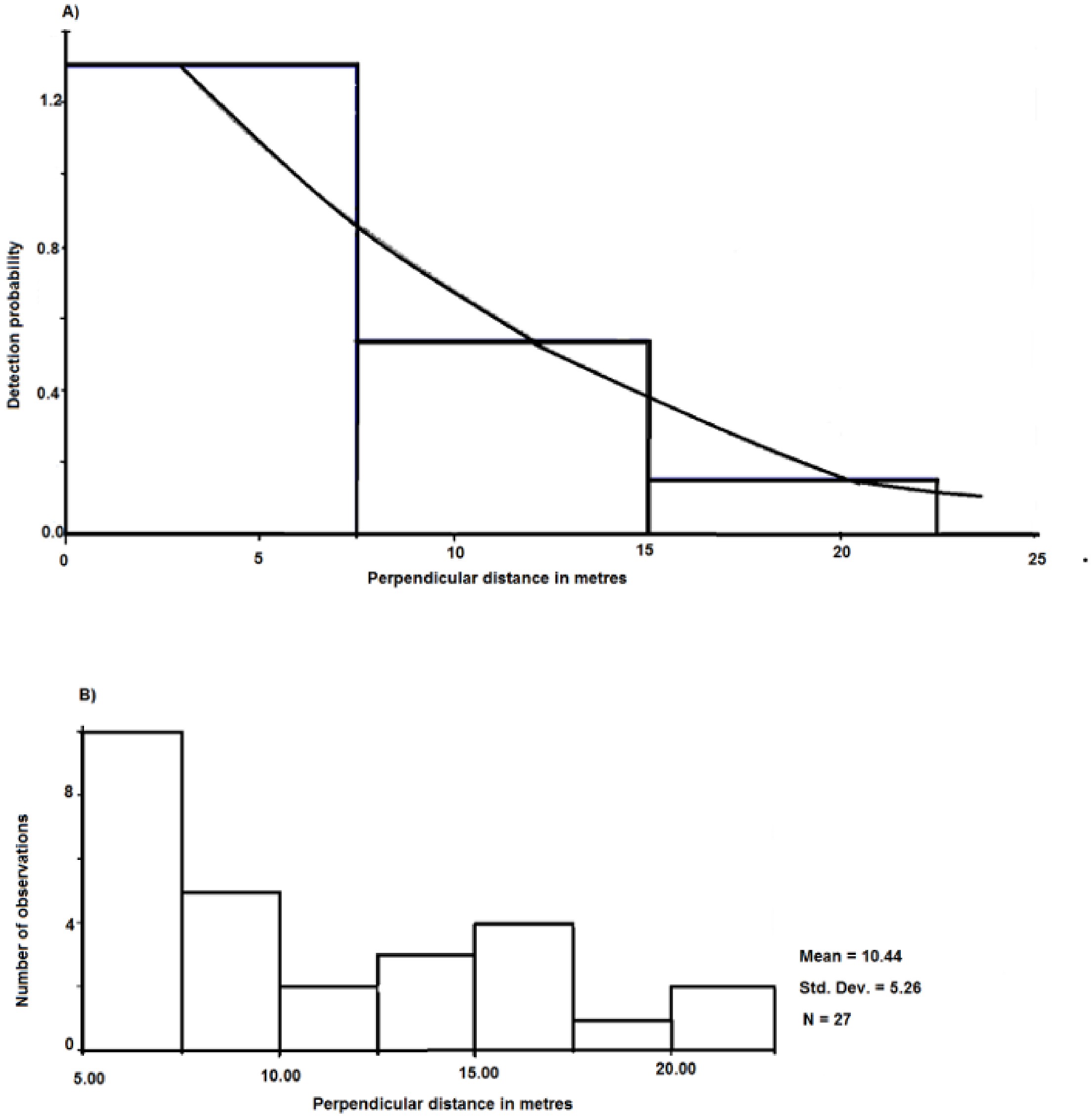

Figure 3. Detection probability and observations of Turner's Eremomela from density estimation using distance. (A) The curve of the detection probability represents the species' detection function g(x); (B) Histogram of observations of Turner's Eremomela across all transects. Both the detection curve and histogram arise from a global analysis of the density calculation.

Table 4. Plant species and means of other vegetation parameters across the forest blocks and transects surveyed.

Forest block	Transect name	Spp BT	Spp BB	SCut BT	SCut BB	CanC BT	CanCBB	CanH BT	CanH BB
North	Buzambuli	15.70	15.10	0.10	0.23	2.20	2.20	20.60	20.90
	Primate	14.30		0.40		2.20		21.30	
	Salazar	15.20		0.20		2.30		21.0	
South	Ikuywa	8.50	12.90	0.60	0.30	1.90	2.43	19.70	23.00
	Isecheno	14.40		0.30		2.50		23.30	
	Yala	15.70		0.00		2.90		26.0	
Kisere	Kisere	16.80	16.80	2.6	2.60	2.16	2.06	21.70	21.70

For forest blocks, North = the National Wildlife Reserve; South = the southern block comprising the Forest Reserve; Kisere = the detached forest fragment. Spp = Species; SCut = mean number of stems cut, representing logging intensity; CanC = mean percent canopy cover; CanH = mean canopy height; BT = by transect; BB = by forest block.

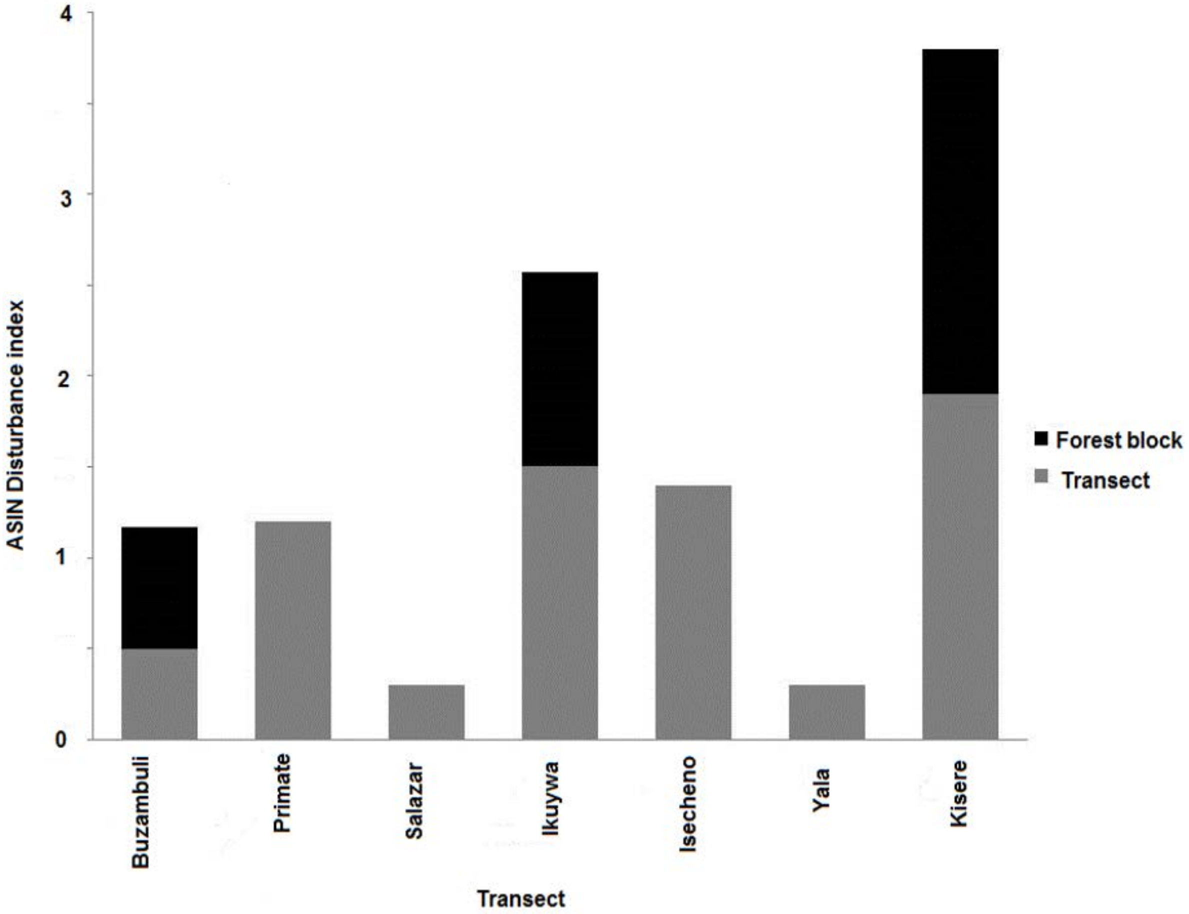

Figure 4. Variation in levels of disturbance across transects and forest blocks. The disturbance refer to indices of anthropogenic impacts on as derived from indices determined from amalgamation of all component human activities recorded. The forest blocks are north (National Reserve); south (Forest Reserve); and Kisere Nature reserve. ASIN = Arcsine transformation of disturbance score.

Table 5. Percent frequency proportion of major human activities. Percent frequencies are derived from encounter frequencies of all activities within 200-m stretches along all transects surveyed.

Forest block	Presence of paths/roads	Fuel-wood collection	Cattle grazing	Logging or vegetation clearing	Game hunting or snaring	Total
North (Wildlife Reserve)	13.4	2.7	0	0	0.7	
South (Forest Reserve)	16.5	13.8	0	1.7	1.4	
Kisere Forest Reserve	18.9	11.8	2.4	11.8	0	
Total	48.8	28.3	2.4	13.5	2.1	100

linear regression yielded the predictive equation: $Y = 0.126 X + 1.614$ between TE density and percent canopy cover, where Y = TE density and X = arc-sine of percent canopy cover ($R^2 = 0.786$, N = 7) (Figure 5).

This strong effect of percent canopy cover on TE density is presumably due to logging intensity which negatively impacted canopy cover (R = -0.658, p = 0.051) and significantly contributed to overall disturbance of TE habitat (R = 0.742; p = 0.050). TE density was also positively correlated to overall plant species richness (R = 0.771, p = 0.042) and negatively to overall disturbance (R = -0.520, p = 0.049) but despite the differences in disturbance levels (Figure 3) and TE densities (Table 3) between the north and the south blocks, there was evidently no significant differences in spatial occurrence of the species across the total whole of the surveys area

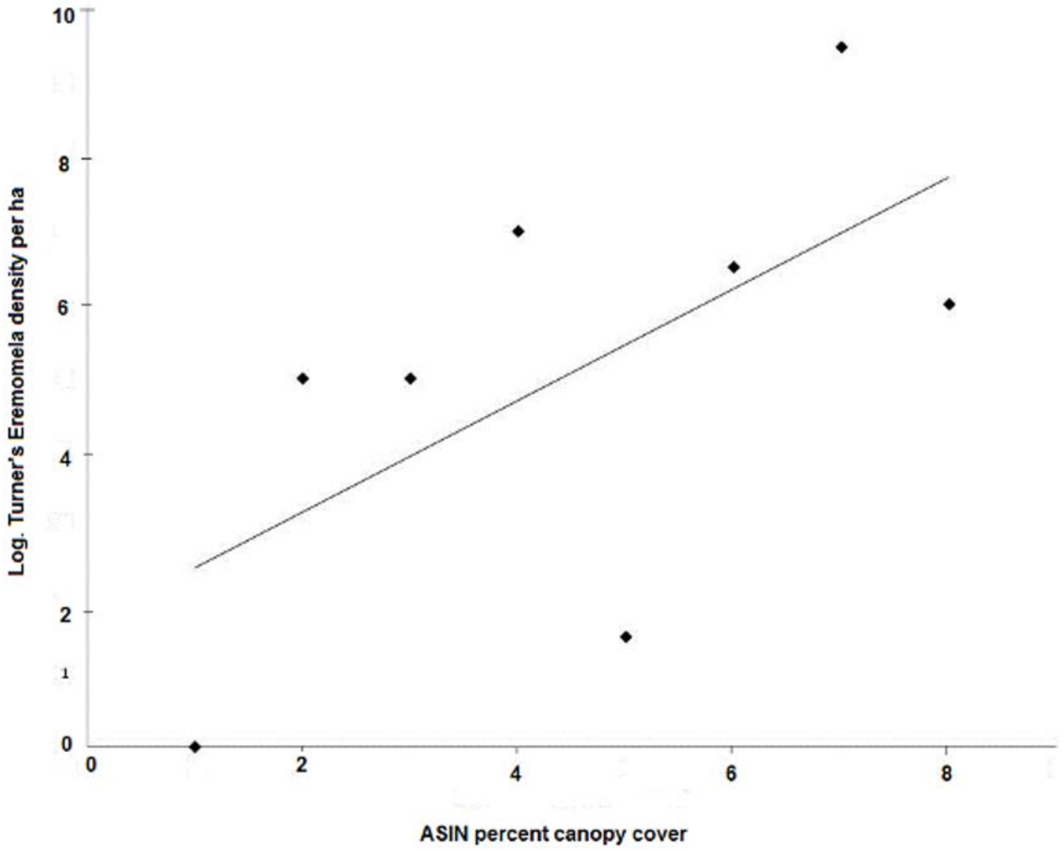

Figure 5. Regression plot of relation between tree canopy cover and Turner's Eremomela density. Canopy cover is derived from percent tree cover characterized as either open, moderate or closed which was subsequently arcsine transformed. ASIN = Arcsine.

in general ($\chi^2 = 34.5$, $p = 0.05$, df = 2).

DISCUSSION

As a forest-specialist (Tews et al., 2004; Bennun et al., 1996), TE is sensitive to habitat perturbations, arising from persistent human impacts (Brooks et al., 1999; Woltmann, 2003; Kirika et al., 2008). Accordingly, our results show a negative effect of overall forest disturbance on the species' density. Lowest measures of forest disturbance especially logging were observed in the northern block characterized by a greater degree of protection from wildlife authorities as compared to the southern block or the Kisere fragment. The significant negative role of tree removal on TE is further underscored by the direct relationship between the species 'density and canopy tree canopy cover. Apart from changing the canopy structure and contributing to habitat loss, logging accelerates habitat fragmentation (Githiru and Lens, 2004) which, in turn hampers effective dispersal (Laurence at al., 2004). Thus TE was observed in lowest densities in the Kisere Forest Reserve, a fragment characterized by high disturbance and open canopy resulting from severe deforestation (Bruhl et al., 2003; Diaz, 2006).

It is worth noting that forest contiguity and closed canopy are not in themselves sufficient to guarantee high habitat quality standards desirable for specialist canopy-feeding birds such as TE if the vegetation characters no longer reflect near-natural conditions (Fernandez-Juricic, 2004). Thus, even a contiguous, canopy-closed forest but consisting of predominantly exotic or non-native trees incapable of habouring preferred arthropod prey, would still not provide suitable habitat conditions for TE (Farwig et al., 2008). To underscore this point, a closer examination of individual transects surveyed in the present study shows that Ikuywa transect, despite its location in with median levels of overall disturbance, recorded the lowest encounter rates of TE and also lowest plant species richness (Table 4). This is mainly because Ikuywa consists of considerable stands secondary forest and non-native plantation trees (Farwig et al., 2008) which present a generally lower native habitat complexity for the species, than more naturally vegetated areas.

The estimated TE population of 4,282±865 with a density of 0.43 ha^{-1} (SE 0.09) is low as compared to South Nandi forest where density was estimated to be 1.11 ha^{-1}

(SE 0.38) with a population of 14,418 (CI = 8,839 – 19,997). This owes to the fact that the current projection is restricted to the area still covered by closed-canopy forest whereas the South Nandi estimate was attributed to the entire forest cover. We feel that the estimates for Kakamega are realistic in view of the ongoing encroachment pressure from the rapidly increasing human population who depend heavily on natural products from the forest (Schleuning et al., 2011).

Consequences of human-induced habitat degradation for sensitive species may be manifested at different intensities along various spatially explicit units, which are otherwise characterized by closely comparable habitat attributes (Newmark, 2005). This often arises from variations in intensity of the anthropogenic impacts, or in temporal longevity scales over which such impacts have operated (Lindenmeyer and Fischer, 2006). For this reason, the lower density of TE in Kakamega forest as compared to South Nandi forest can be attributed to the longer period over which forest exploitation and degradation has occurred in the former, compounded with a higher density of population of adjacent communities with the consequence of greater destruction severity, a more rapid reduction in overall forest size and loss of the species' habitat (Schaab et al., 2010; Schleuning et al., 2011).

Despite higher levels of deforestation in Kakamega forest relative to Nandi, TE appears resilient in a number of ways. First, it has persisted in Kakamega during decades of massive forest habitat loss and modification (Schleuning et al., 2011). Second, the species maintained a population in the small Kisere fragment despite its insularized, heavily-logged condition. Third, the species was encountered on most transects of closed canopy forest blocks indicating that it is widely dispersed rather than clumped in a few key spots, even though densities were not the same in all sites. Fourth, although the widely-held assumption that all satellite forest fragments of Kakamega once formed one contiguous block (Doute et al., 1981; Kokwaro, 1988) is now being contested (Schaab et al., 2010), recent mapping research (Tsingalia and Kassily, 2009), appear to strengthen the argument for a historical connection with a consequent possibility of genetic mixing between sub populations of TE amongst the separated fragments (Bennun and Njoroge, 1999).

Conclusion and recommendations

Despite TE's non-clumped occurrence across the three forest blocks studied in Kakamega forest, especially the fairly well protected northern block, the species remains vulnerable to increasing anthropogenic pressure from an increasing adjacent human population. The strong positive correlation between the species' density and mature canopy cover underscores an urgent need to curb logging pressure throughout Kakamega forest and more effectively control other human-induced impacts that degrade its habitat. Apart from controlling tree removal through stricter protection of all forest blocks, rehabilitation of logged areas can offer a good chance of conserving the species by re-connecting fragmented habitats and facilitating movement thus minimizing insularization of sub-populations or groups.

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