Occupancy Pattern Of A Forest Dependent Bird Among Coastal Forest Fragments In Northeast Tanzania

Robert B. Modest

Abstract: The loss of biological resources in the coastal forests of eastern Tanzania is alarming. This is due to human related activities such as vegetation clearing for agriculture and intensive livestock grazing. By their nature, these activities affect forest dependent birds through destroying habitat and or blocking migratory corridors, and thus interrupting site occupancy pattern. The aim of this study therefore, was to determine whether habitat degradation along the Tanzania's north eastern coast affects site occupancy patterns of forest dependent birds among forest fragments and the associated savannahs. Lowland Tiny Greenbul, a forest dependent bird was used as a model. The data was collected along transects set inside the forest fragments and along the neighboring matrices. The collected data was then used to build site occupancy probability models using the software Presence. The results revealed that ideal undisturbed habitat positively influenced both the relative abundance and site occupancy probability of the model bird — indicating the significance of maintaining habitat in their natural state for the welfare of forest dependent species and the broader biodiversity. This study emphasizes minimizing human pressures in the forests and the matrices for the persistence of the species.

Key Words: Birds, Forest Clearing, Biodiversity, Savannahs, Migratory Corridors.

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1 INTRODUCTION

The Tanzania's coastal forests which are part of the coastal forests of eastern Africa world's biodiversity hotspot are globally renowned for their high level of biodiversity and endemism in both flora and fauna [1], [2], [3], [4]. The biodiversity in these forests however have traditionally faced severe anthropogenic pressures emanating from activities such as pole collection, clearing for agriculture and tree felling for timber [2], [5], Fig 1. These activities which are deleterious in nature have been reported to pose enormous negative effects on avian biodiversity elsewhere, such as reducing species richness and abundance [6], [7], as well as interrupting species site occupancy pattern [4], [8]. For fragmented habitat such as those along Tanzania's coastal forests on the other hand [2], the possibility of these activities driving contiguous species populations into "island sub-populations" is high [9]. Determining occupancy pattern of wildlife in habitat that have suffered fragmentation such as those in the coastal forests of eastern Tanzania is thus essential for understanding changes in their status over time. The findings can provide useful information in decision making and on setting priorities for species management [10]. Therefore, this study was designed to investigate the site occupancy pattern of a forest dependent bird species among fragmented coastal forests in north eastern Tanzania. The study covered the landscape stretching between Pangani and Wami Rivers along the Tanzania's north east coast. Along this landscape are scattered and fragmented coastal forests — mostly deteriorated, but with some remnants of healthy and vibrant patches [2].

There are four vegetation complexes in the area; "1) A heterogeneous forest-savannah-grassland mosaic, 2) the coastal forests, 3) a shoreline with salt flats, coastal fringe forests, herbaceous dune vegetation and mangrove forests, and 4) a maritime ecosystem". Some common tree species include Adansonia digitata, Afzelia quanzensis, Pteleopsis myrtifolia, and Synaptolepis kirkii [1]. Generally, the vegetation along the landscape show different levels of degradation following persistence human interference — with loss of forest cover in protected areas being lower than those in unprotected segments [11]. Moreover, the human induced pressure intensifies in a south-north orientation, whereby the northern part is heavily degraded due to intensive livestock grazing, human settlements, tree cutting, and cultivation of semi-annual and annual crops. As these activities can be detrimental to some groups of birds, investigating occupancy pattern of forest dependent species is essential to understand the effects of human induced pressures on their populations. The aim of this study thus, was to find out whether site occupancy patterns of forest dependent birds differs among habitat depicting different degree of degradation along the aforementioned landscape. The study used the Lowland Tiny Greenbul (Phyllastrephus debilis) as a model. This bird is a forest specialist species which is mainly restricted to well-developed forested habitat, and preferring forest interior [12]. The species range covers the moist lowland forests in eastern Africa, but also may occur in dense bushes around forest edges, and its main diet comprises butterflies, bees, wasps, locusts and ants [13]. As it is well established that this model bird prefer ideal intact habitat, information on how the species is affected by severity of habitat degradation however, is not available. The hypothesis tested stated that, levels of habitat degradation among coastal forests along the north eastern Tanzania's coast would have no influence on site occupancy pattern of the model bird under investigation.

- *Robert B. Modest, Department of Wildlife management, Sokoine University of Agriculture, Tanzania, Email: robertbmodest@yahoo.com*

***Fig.1:** Depiction of the prevailing situation in the study area*

2 METHODOLOGY

2.1 Study Area

The study was carried out within the East Africa Coastal Forests world's biodiversity hotspot in North Eastern Tanzania. The geographic coordinates are 6°16'42.94″ to 6°16'57.65″S, and 38°32'08.35″ to 38°51'17.37″E [2], [4] Fig. 2. The area receives a high peak of rainfall from March to May, and there is a shorter spell of rainfall from October to December [1]. Further description of the study site is provided in [4].

***Fig. 2:** Map of the study area. Dark grey-shaded areas indicate study forests. Dashed lines show transects in the matrices.*

2.2 Data Collection

Data collection commenced between October 2010 and June 2013. The data was collected from four coastal forests namely Zaraninge (42.7 km^2, plateau only), Kwamsisi (4.06 km^2), Gendagenda (10.97 km^2), and Msubugwe (22.32 km^2), Fig. 2. The data was collected monthly, whereby an observer recorded number of individuals of the study species along transects established within the abovementioned forests. To ensure that the species habitat is covered adequately, transects were located in the interior habitat as well as within 10 m from forest edges [14]. In order to minimize the chances of double counting the birds, transects were placed at inter-distances of ≥ 150 m from each other. In Zaraninge which is the biggest of the study forests there were nine transects, whereas the other forests had a fewer number of transects as follows; Msubugwe (six), Gendagenda (five), and Kwamsisi (four). Moreover, a single transect was placed in the matrices separating Zaraninge and Kwamsisi, Kwamsisi and Gendagenda, and Gendagenda and Msubugwe forests respectively. The transect length within the forests ranged from 100 m to 500 m, while those in the matrices were 4000 m each. Data gathering was done into two blocks of time — from 07.00 hours to 10.30 hours for the morning session, and from 03.30 hours to 6.30 hours for the evening session. Moreover, data collection involved quantification of levels of habitat disturbance along each transect in order to describe the characteristic of each study site — termed as site-specific covariates [15], [16]. For the case of forest fragments, coding of levels of habitat disturbance based on counting number of freshly cut tree stumps along transects (which were then summed-up at the end of the study). The coding followed the scale as follows: No stump, = non disturbed forest; 1 to 10 stumps = lightly disturbed forest; 11 to 20 stumps = disturbed forest; and more than 20 stumps = highly disturbed forest. To ensure that the stumps were only counted once during the course of the study, the wall paint was used to mark every new stump during site re-visit. On the other hand, coding levels of habitat disturbance in the savannah matrices based on noting number of livestock and/or human trails along transects as follows: No trail = undisturbed Savannah; 1 to 4 trails = lightly disturbed savannah; and 5 or more trails = highly disturbed savannah. For the case of this study; to distinguish human trails from trails created by wildlife "a human trail was defined as the one with some signs of tree cutting and leading to a water source, to a nearby village, or to pitsaw camps". Moreover, to distinguish livestock trails from those created by wildlife, each trail was scanned for presence of cattle dungs. In addition to these criteria, the researcher's experience of the study area, and a review of previous publications such as that by Burgess & Clarke [17], as well as Hassan et al. [18] were useful in the characterization of the sites. The site characterization described above resulted into seven site-specific covariates as shown under Table 1. These covariates are the ones that were used in modeling the bird's site occupancy probability along with the abundance, and seasonality data.

***Table 1:** Study sites characterization into site-specific covariates based on their levels of disturbance.*

Study site	**Site-specific covariate name**	**Abbreviation for site-specific covariate**
Zaraninge	Non Disturbed Forest	NDF
Kwamsisi	Disturbed Forest	DF
Gendagenda	Lightly Disturbed Forest	LDF
Msubugwe	Highly Disturbed Forest	HDF
Zaraninge/Kwamsisi matrix	Undisturbed Savannah	UNS
Kwamsisi/Gendagenda matrix	Lightly Disturbed Savannah	LDS
Gendagenda/Msubugwe matrix	Highly Disturbed Savannah	HDS

2.3 Data analysis

The bird survey data was used to obtain the relative abundance of the species in each site — regarded as total number of individuals per site [19]. On the other hand, the same bird survey data was coded into presence/absence for modelling the site occupancy probabilities using the software Presence [15]. In order to meet the closure assumptions required for modelling using the software Presence, the presence/absence data was sorted into seasons and only the data collected during the middle of each seasons was analysed [15], [20]. The study area experiences four seasons, for this matter, analysis focused on data collected during November to December (middle of the short rainy season), April to May (middle of the long rainy season), February to early March (middle of the short dry season), and July to August (middle of the long dry season). These survey seasons were treated as survey specific covariates during modelling [20]. Then, using the site specific covariates defined under Table 1, and the survey specific covariates defined as p(survey), nine a priori models were established. For each season three models were evaluated: 1) a constant model which treated both occupancy and detection probabilities as being constant; 2) models where occupancy was a function of site-specific covariates while detection probability was a function of survey-specific covariates; and 3) models where both occupancy and detection probabilities were functions of site-specific covariates, Table 3. While the site-specific covariates used are those defined under Table 1 above, the survey-specific covariates were obtained based on the seasons covered during bird survey, see for example Mackenzie et al. [20] for details. On defining the nine a priori models in Table 3, only those covariates that were believed could potentially explain occupancy probability (ψ) and detection probability (p) of the study species were evaluated [20, 21]. The software Presence ver. 6.1 was used to build the site occupancy probability (ψ), and detection probability (p), following the single-season single-species approach through the application of the likelihood theory [15], [20]. Model selection to evaluate support of the data, and to assess the strength of each site and survey specific covariates on influencing the species based on Akaike Information Criterion. Following this selection procedure, models with delta Akaike of ≤ 2 were considered to have support in the data and were treated further on averaging. Averaging of a competing set of candidate models was achieved using the following formula:

$$\hat{\theta}_A = \sum_{j=1}^{m} w_j \hat{\theta}_j$$

Where w_j = Akaike weight for model j, θ_j = overall detectability or occupancy for model j, θ_A = overall detectability or occupancy for the averaged model [22].

3 Results and Discussion

3.1 Results

A total of 751 individual birds were recorded. Table 2 presents the relative abundance of the species in each study site.

Table 2: *Relative abundance of the species per site: The relative abundance is regarded as the actual number of individuals recorded per site.*

Site	Size (km^2)	Relative Abundance
Zaraninge (Plateau only)	42.7	415
Msubugwe	22.32	148
Gendagenda	10.97	97
Kwamsisi	4.06	64
Zaraninge/Kwamsisi matrix	-	22
Kwamsisi/Gendagenda matrix	-	5
Gendagenda/Msubugwe matrix	-	0

Table 3 presents the a priori models used in modelling site specific and survey specific covariates against the survey data. Based on prior knowledge and literature review, nine models were used to determine the influence of the covariates on the study species.

Table 3*: The a priori models used on determining occupancy (ψ), and detection probabilities (p) of the study species.* ***Nor. par*** *= number of parameters. See Table 1 for description on abbreviations of the model covariates.*

Model	No.par.	Description
ψ (.),p(.)	2	Both occupancy and detection probability are constant.
ψ (NDF),p(Survey)	4	Occupancy influenced by non-disturbed forest, detection probability influenced by survey season.
ψ (LDF),p(Survey)	4	Occupancy influenced by lightly disturbed forest, detection probability influenced by survey season.
ψ (DF),p(Survey)	4	Occupancy influenced by disturbed forest, detection probability influenced by survey season.
ψ (HDF),p(Survey)	4	Occupancy influenced by heavily disturbed forest, detection probability influenced by survey season.
ψ (NDF),p(NDF)	5	Both occupancy and detection influenced by non-disturbed forest.
ψ (LDF),p(LDF)	5	Both occupancy and detection influenced by lightly disturbed forest.
ψ (DF),p(DF)	5	Both occupancy and detection influenced by disturbed forest.
ψ (HDF),p(HDF)	5	Both occupancy and detection influenced by heavily disturbed forest.

Models were assumed to have support in the data if their delta Akaike were ≤ 2. Based on this criterion, seven models were supported for the long dry season, whereby, non-disturbed forest (NDF) and season effects p(Survey) were the most influential with the Akaike weight of 0.19. For the short dry season, only the constant model was supported. Three models were supported during the long rainy season, and a constant model had the highest weight. For the short rainy season, on the other hand, four models were supported, whereby, non-disturbed forest (NDF), and p(survey) covariates were the most influential accounting for the highest Akaike weight of 0.31 (Table 4). The overall averaged site occupancy probabilities ($\overline{\Psi}$), for the modelled seasons were; Long dry season (0.38), Short dry season (0.35), Short rainy season (0.60), and Long rainy season (0.53).

Table 4: *Model selection inference for the Tiny Greenbul occupancy (ψ) and detection probability (p) based on presence/absence survey of the coastal forests in north east Tanzania. The best model in each season is shown at the top of the lists. ΔAIC = difference between maximum and minimum Akaike values of competing models; W = Akaike weight.*

Model / Season	ΔAIC	w
Long dry season		
ψ(NDF),p(Survey)	0	0.19
ψ(NDF),p(NDF)	0.18	0.17
ψ(DF),p(Survey)	0.99	0.12
ψ(LDF),p(Survey)	0.99	0.12
ψ(HDF),p(Survey)	0.99	0.12
ψ(LDF),p(LDF)	1.78	0.08
ψ(HDF),p(HDF)	1.78	0.08
Short dry season		
ψ(.),p(.)	0	0.42
Short rainy season		
ψ(.),p(.)	0	0.31
ψ(NDF),p(survey)	1.03	0.18
ψ(NDF),p(NDF)	1.58	0.14
Long rainy season		
ψ(NDF),p(survey)	0	0.31
ψ(NDF),p(NDF)	1.13	0.17
ψ(HDF),p(HDF)	1.13	0.17
ψ(LDF),p(Survey)	1.35	0.16

3.2 Discussion

The higher relative abundance of the Lowland Tiny Greenbul was recorded in Zaraninge, a forest which was categorized as non-disturbed. However, this forest is not 100% undisturbed as it had suffered severe tree cutting in previous years. The forest was put under a non-disturbed category because during data collection there was no freshly cut trees (c.f. plateau segment of the forest). Additionally, all logs and stumps from the previous logging shocks had decomposed, thus, the forest looked almost natural. Zaraninge forest used to be a forest reserve, under which people could easily accesses its resources owing to low protection status. But, currently the plateau section of this forest is under Saadani National Park, and thus, is managed under strict rules with no extractive use allowed — therefore, the recovery of this segment of the forest can be attributed to this fact. Surprisingly, Msubugwe which was categorized as a highly degraded forest ranked the second in terms of relative abundance of the species. This brings in an ambiguity. As a matter of fact, the relative abundance of the model bird (a forest specialist) in Msubugwe forest was supposed to be even lower than that recorded in Gendagenda (though smaller in size) — taking into account that Gendagenda is a less disturbed forest compared to the former. The fact that Msubugwe is surrounded by highly degraded savannahs, the higher relative abundance of the bird (a forest specialist) could be a result of individual congestion in this forest. Msubugwe forest, in addition to tree cutting pressure in its core habitat [12], [18], faces severe pressure from grazing livestock in the surrounding matrices (personal observation). The pressure in the matrices probably is restraining individuals inside the forest, and the forest is certainly acting like "a remote island" for the species [23]. Hence, the higher relative abundance of the Lowland Tiny Greenbul (a forest specialist that prefer natural habitat) in Msubugwe forest might not imply association with quality habitat; rather individuals are unable to move outside due to the high level of habitat disturbance in the surrounding matrices c.f. [24]. The more important observation is that, about three quarter of individual birds were recorded in the south eastern side of Msubugwe. The south eastern part of this forest is relatively less disturbed compared to the western part. Therefore, it seems that the birds are avoiding the sections of the forest that are hit hard by tree cutting and vegetation clearing (see Fig. 3 for impression of the habitat degradation in the study area). Maclean et al. [25] also found a similar phenomenon on water dependent birds in one of the wetland in Uganda. This study by [25] reported higher concentration of water dependent birds in a number of small patchy swamps, and they attributed this to lack of alternative habitats as the area was facing high anthropogenic pressure and habitat fragmentation. Newmark et al. [26] also observed a similar phenomenon in West Usambara Mountain north east Tanzania, where they reported three forest specialist bird species failing to cross a cleared forest gap of just less than 15 meters. Therefore, the Uganda's wetland, and the West Usambara Mountain scenarios might also apply to the Msubugwe case. Thus, it can generally be proclaim that, Msubugwe forest perhaps is currently in a stated of inhospitable 'remote island' for the Lowland Tiny Greenbul, and that individuals are unable to disperse as the forest is surrounded by highly degraded matrices intolerable by the species [23],[27].

Fig. 3: *An area of a previously closed section of the forest that was converted into a pineapple field. Some native trees that were left behind after clearing can still be seen at the background, but due to change in habitat type, they eventually die.*

For the occupancy probability analyses, the covariate "non-disturbed forest" seemed to be more important for the species. This covariate appeared twice in the best models across the four seasons modeled. In addition, all other models that contained "non-disturbed forest" as a site-specific covariate always had higher Akaike weights (Table 4), and this agrees with the abundance data discussed above. These phenomena therefore, are an indication of the significance of natural habitat for the study species Fig. 4. The phenomena also calls for a need of maintaining the forests in their primary undisturbed condition for the welfare of the species — as such, the species is likely to disappear if habitat loss in the study system continues, cf. [28]. Species with specialized habitat requirements such as the Lowland Tiny Greenbul are sensitive to habitat disturbance cf. [29], thus, the association of the Lowland Tiny Greenbul with undisturbed habitat within the coastal forests of northeastern Tanzania rings an alarm regarding the persistence of the species in the area. This follows as it is reported that, habitat degradation within Vikindu forest in the southern neighborhood of Zaraninge caused local extinction of the Sokoke pipit [30], a bird species whose general habitat specialization is comparable to the Lowland Tiny Greenbul.

Fig. 4: *Lowland Tiny Greenbul Phyllastrephus debilis, a victim of habitat degradation in the coastal forests of north eastern Tanzania.*

Moreover, the occupancy probability of the model bird under the current study seemed to be influenced by seasonality. This is because the highest overall averaged occupancy probability was attained during the short rainy season, whereas, the lowest was during the short dry season. This tendency i.e. the discrepancy in the site occupancy probability across the seasons could be implicated to the breeding circle of the species which is documented to begin during October [13]. The bird activity and singing during this season probably increases and birds are presumably displaying for finding mates where it is easy to detect. On the other hand, the discrepancy could also be an indication that the Lowland Tiny Greenbul is probably not sedentary as previously reported, for example, by BirdLife International [30]. The species is perhaps able to undergo local migration by swapping habitat among forests and matrices though majority of individuals remain within forested habitat. The significance of these findings is that, results derived from a single season survey of the species in anyone locality within the coastal forests of east Africa cannot be generalized to explain the status of the species in the area. Thus, any future survey in the area intending in estimating the abundance of the species for example, should be designed as a repeated survey across seasons, or the data collected on a single season survey bases should not be extrapolated across other seasons.

4. CONCLUSION

In conclusion, both the abundance and modelling data suggest a susceptibility of the model bird to habitat degradation. This follows, as it was observed that, ideal non-disturbed habitats favourably influence the species relative abundance and site occupancy probability. Moreover, this study is concerned with the welfare of the model bird in Msubugwe, as the species is probably 'captured' in this highly degraded forest and individuals are unable to move out following degradation of matrices connecting this forest to other better sites. Thus, should habitat degradation continues, there is a possibility of driving the species to local extinction as there is similar cases already reported in other region of the coastal forests of Tanzania. On the other hand, this study have revealed that the model bird is possibly not sedentary as previously thought, as its site occupancy probability seemed to vary by seasons — as such, Lowland Tiny Greenbul is perhaps able to undergo local migration along the landscape via well-established savannahs. Since this study focused only on bird survey, a follow-up study using advanced technologies such as telemetry is recommend to establish the species dispersal pattern in the area. For proper management of the species within the coastal forests in eastern Tanzania, habitat restoration in the Msubugwe forest is recommended to enhance individual occupancy of all the niches available. Lastly, the on-going tree cutting within the forests and matrices should be stopped through applying strict control measures for the benefit of the study species and the general biodiversity.

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