A Kenyan endemic bird species Turdoides hindei at home in invasive thickets

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Abstract

Thickets along rivers in Eastern Kenya are important habitats for many endangered species. These habitats also provide fundamental ecosystem services for humans. Intense anthropogenic activities during the past decades have caused a severe reduction of this vegetation and resulted in fragmentation of the remaining thicket patches. We assessed the occurrence of the Kenyan endemic bird species Hinde’s Babbler (Turdoides hindei) in a highly fragmented environment and performed detailed land use mapping along the Nzeeu River in East Kenya. We measured the time the birds spent in thicket patches, which differed in their habitat setting: pristine versus surrogate vegetation, different habitat size and different edge-size-ratio. Further, we identified areas of potential conflicts between human activities and our target species. Four T. hindei family groups were observed, mostly in invasive Lantana camara patches. Habitat size and edge-size-ratio of the respective thicket patches revealed a significant impact on the duration of stay of T. hindei with disproportional longer stays in small habitat patches and in patches with larger edge-size-ratio than in rather large patches or thickets with small edge-size-ratio. The 75%– and 95%-kernels showed no overlap between family groups and only marginal overlap with the 75%–kernels of human disturbances. Our data show that the invasive L. camara thickets (even small patches with high edge-size ratio) are a suitable surrogate habitat for the Kenyan endemic for T. hindei. The birds avoid open land likely because of higher predation pressure outside of thickets. Limited overlap between zones of human activity and the occurrence of T. hindei may be a response either to lacking thickets in these areas, and/or an adaptation to elevated hunting pressure in these zones. Therefore, the transformation of thickets into open agricultural land has a negative impact on the persistence of T. hindei. For the preservation of the remaining T. hindei family groups in our study area we suggest to establish an interconnected network of thicket patches, as the high mobility of the species allows persistence in such patchy environments.

Zusammenfassung

Gebüschtstrukturen entlang von Flussläufen in Ostkenia bilden wichtige Lebensräume für viele gefährdete Tierarten. Diese Ökosysteme stellen außerdem wichtige Ökosystemdienstleistungen für die Menschen bereit, die sich entlang der

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Introduction

Ecosystems along East African rivers serve as important habitats for many endangered animal and plant species (McClanahan & Young, 1996) and in parallel provide important ecosystem services for people settling along these rivers and their livestock, such as a high ground water level, fertile soils, shade, wood and various (medicinal) plants (Enanga, Shivoga, Maina-Gichaba, & Creed, 2011). Wood is frequently used for timber, charcoal and the burning of bricks (Government of Kenya, 1981; Wyant & Ellis, 1990). This creates a conflict between human needs and nature conservation.

Today, most of the vegetation along these rivers is highly degraded as it was transformed into agricultural land to feed the growing human population or has been replaced by the invasive shrub species Lantana camara (Enanga et al., 2011). In consequence, the remaining vegetation exists in small and isolated remnant patches. The increasing level of fragmentation together with the decrease in habitat quality may negatively affect the local flora and fauna (Boschbier, Goedhart, Poppen, & Vog, 2010; Richard & Armstrong, 2010). This situation may finally lead to the decrease in the density of local populations and may reduce individual fitness leading to local extinction (Boscolo & Metzger, 2011).

The globally vulnerable Kenyan endemic bird species Turdoides hindei, Hinde’s Babbler, occurs in small and geographically isolated population clusters across the Central and Eastern Kenyan high- and lowlands, preferably in thickets along rivers (Shaw & Musina, 2003). The agricultural intensification caused a strong decrease of these vegetation structures and subsequently has led to a population decline of this bird species during the past decades (Shaw & Musina, 2003; Shaw, Musina, & Gichuki, 2003; Shaw, Njoroge, Otiño, & Mlamba, 2013a,b). Especially the populations at the south-eastern distribution margin are thought to suffer under high demographic pressure (Government of Kenya, 2014a,b) and the effects of climatic changes in our study area (Jaetzold, Hornetz, Shisanya, & Schmidt, 2007).

We assessed T. hindei in a highly fragmented environment along the Nzeeu River south of Kitui, East Kenya, where we performed a detailed land use mapping. We measured the time our study species spent in various environments, such as thickets varying in size and quality and further recorded human activities in the area. Based on this data we define zones of potential conflict between human activity and the bird species. In detail we raise the following three questions:

(i) Does T. hindei show any habitat preferences in our study area?
(ii) Does habitat performance (size, design, quality) influence the habitat suitability for T. hindei?
(iii) Are overlaps between species’ occurrence and human activities potential zones of conflict?

Materials and methods

Study species

Turdoides hindei occurs in cool and moist highland regions such as the foothills of Mount Kenya (Meru, Kirinyaga)
and east of the Aberdares Range (Nyeri region), but also at medium elevations (Thika, Oldonyo Sabuk) and at the dryer and warmer lower elevations in eastern Kenya (Machakos and southwards, Kitui and eastwards) (Plumb, 1979; Shaw & Musina, 2003; Shaw et al., 2003). Most of the species’ populations can be found along rivers where the individuals hide in dense thickets (Dowsett & Forbes-Watson, 1993). The bird species is a co-operative breeder and thus lives in family groups differing in size (Njoroge, Bennun, & Lens, 1998). Like other representatives of the genus Turdoides, also T. hindei shows territorial behaviour (Gaston, 1978a,b; Zahavi & Zahavi, 1990; Monadjem, Owen-Smith, & Kemp, 1995; Njoroge et al., 1998; Shaw et al., 2003).

Most of the habitats suitable for T. hindei are today highly fragmented due to clearance of the vegetation and deforestation along most rivers. As a result of severe disturbances of these habitats, most remaining patches are now dominated by the invasive shrub species L. camara, providing a surrogate habitat for T. hindei (Njoroge et al., 1998; Njoroge & Bennun, 2000; Shaw et al., 2013). The strong habitat destruction and consequences of climatic change caused a severe decline of this bird species, especially at its eastern distribution margin (Shaw et al., 2003, 2013a,b). This negative population trend in combination with the species’ restricted distribution in the central and eastern provinces of Kenya has led to its classification as globally vulnerable according to the IUCN Red List (BirdLife International, 2012).

Study area

All data were recorded between the 18th September and 21st November 2013 along the Nzeeu River located southeast of Kitui (1°23’S; 38°00’E). The bimodal precipitation regime provides two rainy seasons in our study area (Jaetzold et al., 2007); the period of our study covered the end of the dry season and the beginning of the second rainy season. Periodical pericpitation and limited soil fertility restrict the agricultural productivity (Jaetzold et al., 2007). 97.1% of the human population in our study area depend on subsistence crop farming (Government of Kenya, 2014a). The demographic pressure in Kenya is very high and the human population in our study area has almost doubled between 1999 and 2009 (Government of Kenya, 2014a). In consequence, fallow periods for fields are neglected. This further decreases soil fertility, which in turn leads to an increased demand for ‘new’ agricultural land. In addition, the vegetation along the river is frequently exploited for timber, charcoal and brick production. The region is further affected by climate change with increasing rainfall variability and rising temperatures (Jaetzold et al., 2007). These factors lower the reliability of agricultural production and food security and lead to a severe destruction of pristine habitats.

Land use mapping

Land use was mapped along a 2 km section of the Nzeeu River, in accordance with the spatial distribution of the four T. hindei family groups observed. We mapped a 200 m zone on both sites of the river. Mapping was performed with a Samsung Galaxy Tab 2 10.1 tablet with a built-in GPS device, and the software QGIS (QGIS for Android vers. 1.9.90-Alpha). We mapped the Nzeeu River and streets as lines. Thickets, agricultural fields and open land were mapped as polygons. We further divided the thickets into pristine and the invasive L. camara. Point data were taken for trees and various types of human disturbance, such as houses, brickworks, charcoal production areas and graveyards.

Assessing Turdoides hindei

We monitored four family groups of T. hindei from 7 am until 5 pm. The presence of family groups was detected via contact calls. During foraging in a new habitat patch, individuals increase the number and volume of these contact calls (own observation) facilitating the tracking of individuals. GPS coordinates of individuals were determined every 10 min. with a GPS device (Garmin Etrex H, Kansas, USA). To prevent potential disturbances of the animals and subsequent displacement, bird observations were conducted with at least 10 m distance to the respective group; exact GPS coordinates were taken after the group moved to a new location. To ensure comparability among the family groups, a similar number of observation points (ca. 250 per group) were taken for each group. Furthermore, all observations randomly covered the entire day which we divided afterwards into the following time slots: morning (earlier than 10 am), forenoon (10 am to 12.29 pm), noon (12.30 pm to 2.59 pm), and afternoon (after 2.59 pm). Each time period consisted of an equal time interval (2.5 h) and for each time interval a similar number of observations were collected.

Data analysis and statistics

The 95% Minimum Convex Polygon (MCP) was calculated for each T. hindei group based on GPS observations. The 95%-MCP was selected as this estimator is assumed to be suitable for comparative analyses (Kernohan, Gitzen, & Millsapgh, 2001). Furthermore, 75%- and 95%-kernels were calculated for each group with the fixed kernel method (Worton, 1989) using the R package adehabitatHR (Calenge, 2006) in R vers. 3.0.2 (R Core Team, 2013). The ad-hoc method was used to estimate the smoothing parameter h for the kernel of each group. For calculating the habitat preferences of T. hindei we exported the kernels to QGIS 2.0.1 and performed an overlay analysis with the mapped land use data. We calculated the Jacobs Index (Jacobs, 1974) to express habitat preferences, here classified into two parameters: “thicket” and “open space” (consisting of agricultural land and fallow land). The Jacobs Index compares the proportion of available habitat with the proportion of habitat used and ranges from −1 (absolute avoidance) over 0 (no interaction) to 1 (absolute preference) for the respective habitat.
Table 1. Activity ranges of *Turdoides hindei* for the four family groups. The table shows smoothing parameters calculated with the ad-hoc method for each family, 95% Minimum Convex Polygon (MCP), 95% kernel, 75% kernel, and 75% kernel for individual birds.

<table>
<thead>
<tr>
<th>Group</th>
<th>Smoothing parameter h (ad-hoc method)</th>
<th>95% MCP [ha]</th>
<th>95% kernel [ha]</th>
<th>75% kernel [ha]</th>
<th>75% kernel (individual birds) [ha]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>26.26</td>
<td>5.04</td>
<td>7.13</td>
<td>3.48</td>
<td>1.16</td>
</tr>
<tr>
<td>4</td>
<td>28.60</td>
<td>4.79</td>
<td>7.5</td>
<td>4.07</td>
<td>1.02</td>
</tr>
<tr>
<td>6</td>
<td>48.70</td>
<td>13.43</td>
<td>23.91</td>
<td>12.88</td>
<td>2.15</td>
</tr>
<tr>
<td>7</td>
<td>63.18</td>
<td>9.38</td>
<td>27.09</td>
<td>9.25</td>
<td>1.32</td>
</tr>
</tbody>
</table>

stepwise model selection by AIC implemented in the MASS package (Venables & Ripley, 2002) until a minimal adequate model was obtained. Parameter estimates, t-statistics and p-values for all models were assessed from the summary tables.

Results

Land use

In total we conducted land use mapping for an area of 79.2 ha. The major proportion of this study area consists of open space, fallow land and agricultural fields (59%). Most of the agricultural plots were interspersed by fruit trees like mango, citrus and papaya. 41% of the mapped area was covered with thickets, of which 91% were the invasive *L. camara* and only 9% could be identified as remaining pristine gallery forest without *L. camara*. We found 167 points of human activities: 39 locations for brick production, 5 sites for charcoal production, 29 houses, 88 wells, 4 small reservoir dams, 1 bigger water tank, and 1 sandpit.

Population structure and activity

The four observed family groups differed in number of individuals, with three, four, six and seven individuals. Neither the MCP (Fig. 1) nor the 95% kernels (red line, Fig. 1) or 75%-kernels (blue line, Fig. 1) overlapped with neighbouring groups. The space visited by one individual obtained for 75%-kernels (in parenthesis for 95% kernels) ranged from 1.02 ha (1.87 ha) per bird for the group of four birds to 2.15 ha (3.99 ha) per bird for the group consisting of six individuals (Table 1). Mean movement distances decreased over time of day, with highest values during morning (132.62 m per hour) compared to afternoon (71.12 m; $t_{112} = -2.86, p < 0.01$), noon (62.96 m; $t_{112} = -3.15, p < 0.01$) and afternoon (53.62 m; $t_{112} = -3.76, p < 0.001$), with no differences between the other temporal cohorts (Fig. 2).

Habitat use and patch quality

The main proportion of observations of *T. hindei* over all four family groups was restricted to thickets (72.3%), and type (thicket or open space). Based on that approach, we calculated the proportion of localisations of the bird species in thickets compared to all observations. We further calculated the proportions within the 75%- and the 95%-kernels. To analyse the preferences of *T. hindei* concerning the availability of single large trees within the habitat we additionally performed an overlay analysis with the mapped land use data, bird observations and locations of trees.

To quantify the overlap between *T. hindei* and human activities we calculated 75%-kernels for human disturbance based on factors mentioned above. As smoothing parameter $h$ we used the mean smoothing parameter of all bird groups ($h = 41.69$). The calculated kernels were exported from R into QGIS and intersected with the 75%-kernel of the bird groups. With an intersect analysis of the 75%-kernel of the birds’ activity ranges and the calculated kernels of the 75% human disturbances new polygons representing the overlap were produced in QGIS.

To test for potential differences in the movement distances varying with the time of day, we summed distances between consecutive locations per 1 h using the R package adehabitatLT (Calenge, 2006). Effects of the time of day (morning, forenoon, noon, afternoon) on movement distances were analysed using linear mixed effects models (Pinheiro & Bates, 2000) with a maximized log-likelihood implemented in the R package nlme (Pinheiro, Bates, DebRoy, Sarkar, & the R Development Core Team, 2013). To account for repeated measurements from bird groups the factor groupID was included as a random effect. Different variances per bird group were modelled using the varIdent variance structure. Contrasts between different times of day were investigated by re-ordering factor levels.

Furthermore, the effects of habitat patch size and edge-size-ratio and the type of thicket (*L. camara* vs. pristine) as well as two-way interactions between both parameters on the relative duration of stay per patch (duration of stay/patch size) were analysed using linear mixed effects models. The factors groupID ($n = 4$) and patchID ($n = 20$) nested within groupID were included as random effects to account for temporal (observation of the same bird group) and spatial (observation of the same thicket) autocorrelation. To achieve normal error distribution and to avoid heteroscedasticity movement distance was square root-transformed and the relative duration of stay as well as habitat patch size and edge-size-ratio were log-transformed ($x + 1$). Model simplification was done in a...
could further be specified to 97.9% in *L. camara* and 2.1% of the observations in pristine thickets. Only few observations were in open space (17.5%) and agricultural land (10.2%). Approximately 48% of the 75%-kernels and 35% of the 95%-kernels covered thickets (both, pristine or *L. camara*). Analysis on the relevance of the presence of single trees showed that the majority of *T. hindei* observations (65.9%) can be found in thicket patches including trees, 27.8% in open space with single trees and 14.8% in agricultural patches with single trees. Thus, *T. hindei* was more frequently observed in habitat patches with single trees than without ($\chi^2 = 8.24$, $p < 0.01$).

The scores of the Jacobs Index revealed that thickets provide high habitat suitability for *T. hindei*, while open space like agricultural and fallow land were mainly avoided (Table 2). According to linear mixed effects models, *T. hindei* stayed significantly longer in small habitat patches than in large habitat patches (Estimate $= -1.63$, $t_{227} = -8.43$, $p < 0.001$) (Fig. 3A) independent of the type of thicket (*L. camara* thicket vs. pristine; Estimate $= 0.22$, $t_{227} = 1.44$, $p = 0.15$). Furthermore, *T. hindei* stayed significantly longer in patches with increasing edge-size-ratio (Estimate $= 1.53$, $t_{227} = 9.99$, $p < 0.001$), with higher relative duration of stay per patch in *L. camara* compared to pristine thicket (Estimate $= 0.30$, $t_{227} = 2.00$, $p < 0.05$) (Fig. 3B). There was no interaction of habitat patch size and edge-size-ratio with thicket type, which was excluded from both models.

**Human disturbances**

The ranges of the 75% disturbance kernels based on the recorded disturbance points (see above) overlapped only marginally with the 75% kernel of *T. hindei* presence, with a mean overlap of 14% across all four family groups (Fig. 4). The group consisting of seven individuals showed the strongest overlap of its 75% kernel with the 75% disturbance kernel (9.4%) compared to the other family groups (six individuals 2.7%, three individuals 1.9%, and four individuals 0%).

**Discussion**

**Population structure**

The four family groups showed distinct, spatially restricted territories without any overlap. Accordingly, *T. hindei* can be classified as a sedentary, territorial bird species, which goes in line with previous studies on the population ecology of the species (Njoroge et al., 1998; Shaw et al., 2003). The four family groups differed strongly in the number of individual members (ranging from three to seven). However, the habitat area needed per individual was relatively similar, except for the group of six individuals inhabiting the most fragmented region for which the territory was almost double the size.
Table 2. Jacobs Index expressing the relevance of habitat structures, calculated for the two habitat types, thicket and open space, and each for the 75% and 95% kernel. Values range from −1 (absolute avoidance) to +1 (absolute preference).

<table>
<thead>
<tr>
<th>Group</th>
<th>Thickets</th>
<th>Open space</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>95% kernel</td>
<td>75% kernel</td>
</tr>
<tr>
<td>3</td>
<td>0.844</td>
<td>0.788</td>
</tr>
<tr>
<td>4</td>
<td>0.981</td>
<td>0.979</td>
</tr>
<tr>
<td>6</td>
<td>0.921</td>
<td>0.864</td>
</tr>
<tr>
<td>7</td>
<td>0.941</td>
<td>0.890</td>
</tr>
</tbody>
</table>

compared to the other groups. In this territory, only 44% of the 95% kernel covered thickets and the thicket patches in this territory were scattered. Previous studies already indicated a positive correlation between habitat fragmentation and the spatial extent of the territory of T. hindii (cf. Lens, 1992). Similar trends could also be found for other passerine bird species, like the Great Read Warbler Acrocephalus arundinaceus (Bosschieter et al., 2010), the Spotted Owl Strix occidentalis (Carey, Reid, & Horton, 1990), or three Passerine birds in forest fragments in Brazil (Hansbauer et al., 2008).

**Pristine or surrogate habitat**

72.3% of all occurrences of T. hindii were restricted to thickets, with the major proportion found in L. camara (97.9%). These findings underline the high relevance of dense thickets in general, and suggest a high suitability of the invasive L. camara for the Kenyan endemic T. hindii. The importance of dense thickets is further underlined when comparing the occurrence of T. hindii in the 75% and 95% kernels, with a higher proportion of thicket in the core of each territory. The preference of T. hindii for thickets is further supported by the Jacobs Index, which also suggests that open space like agricultural land is avoided. This is in contrast with populations observed in other regions, i.e. close to Mt. Kenya or the Aberdares, where T. hindii can be observed on agricultural land such as coffee plantations (own observations).

**Patch design, availability of trees and human disturbance**

The importance of dense thickets for T. hindii shown by our data is congruent with other studies on the habitat preferences of T. hindii, which indicated that the population density and breeding success of T. hindii decrease after the clearance of thickets (Njoroge et al., 1998). However, our target species spent disproportionally more time in small thickets and in thickets with a high edge-size-ratio than in larger patches. This is in contrast to other studies indicating a higher risk of predation for bird species in small patches and along narrow corridors (Castellon & Sieving, 2006; Vergara & Hahn, 2009). Obviously, the degree of fragmentation of the remaining thicket patches has no significant impact on T. hindii, as long as the total cover of thickets remains the same. The presence of trees might also play a crucial role: 65.9% of T. hindii observations were made in patches characterized by large trees. The starting point to access adjoining thickets frequently was the top of a larger tree, crossing open land by flying to another tree, and subsequent hiding in the ground vegetation (own observations). Hence, large trees likely serve as observation points and stepping stones between patches.

The 75% kernels of human disturbance marginally overlapped with the 75% kernels of T. hindii presence which may have two non-exclusive reasons: (i) T. hindii is avoiding human presence because of bird hunting in this region; (ii) thickets, the main habitat for T. hindii are more common in areas with no or limited human activities. However, we are
not able to distinguish the roles of these two factors with our data set.

**Translating our data into conservation action**

Our data yielded four main findings: (i) the main habitat of *T. hindei* is dense thicket with the invasive *L. camara* serving as surrogate habitat; (ii) *T. hindei* can be seen more frequently in small thicket patches in our study area (possibly because the majority of the thicket fragments are small in this area); (iii) the existence of single trees plays a key role for the habitat suitability of thickets as these serve as vantage points and stepping stones; (iv) the occurrence of *T. hindei* does not overlap with hotspots of human activity.

In conclusion, a complete clearing would likely lead to a loss of local populations of this bird species. Yet, several small habitat patches already would help to maintain suitable habitats and support the persistence of *T. hindei* in the future. These remaining thicket patches should be interspersed with single trees, which are important linking elements for the birds. Thus, against the background of the single-large-or-several-small (SLOSS) debate, our example indicates that even fragmented thickets still provide an interconnected habitat mosaic with large trees as important linking components. Hence, the conservation strategy of several small protected areas provides the background for a management adapted to *T. hindei*. However, we have to note that these observations were made at a time of year in which there is normally little breeding activity. *Turdoides hindei* most probably prefers nesting in larger thicket patches to reduce the risk of nest predation by natural predators or anthropogenic disturbance. Thus, groups may prefer to remain in the proximity of larger thickets when they have recently fledged offspring. If so, the conservation of ‘several small’ thicket fragments might only apply outside of the breeding season. Further work during the breeding season is required to determine the value of retaining at least one large thicket patch per territory (as breeding habitat), in addition to several small thickets.

The creation of a protected area for this Kenyan endemic bird species is not very realistic in an environment characterised by food-insecurity and underdevelopment (Ramphal,
1993). The local people should be made aware of the importance of these habitats, also for ecosystem service provision. Such awareness could be raised by appropriate information through the officers in charge of agriculture or even through financial incentives for not clearing thickets and transforming them into agricultural land.

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References


Shaw, P., Musina, J., & Gichuki, P. (2003). Estimating change in the geographical range and population size of Hinde’s