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Discriminating between nesting and non-nesting habitat in a vulnerable bird species: implications for behavioural ecology

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ABSTRACT

Nowadays, partitioning amongst nesting and non-nesting habitats is not much studied. Here, I investigate whether or not the turtle dove (*Streptopelia turtur*) nesting habitats overlap with those used for other purposes in a North African agroforestry system. A total of 33 nest points and 33 turtle dove presence points were considered. The study, conducted in May to June 2017, attempted to determine the factors that may play a role in discriminating between the nesting habitats and non-nesting habitats. I used a linear discriminant analysis (LDA) to test the relevance of proximity of food resources, forest edge and human presence variables in the distribution of the species. The results show substantial segregation in the habitats selected for nesting and those selected for other uses [average distance was 1129.69 ± 169.40 m (n = 66) with a maximum of 1518.6 m and a minimum of 617.72 m], with selection depending primarily on the proximity to forest edge and feeding areas. I discuss these findings and their implications on behavioural ecology and future researches of this vulnerable species. I suggest guidelines for future studies that will seek to better understand the behavioural dynamics of turtle doves in the Mediterranean agroforestry systems. This can only be done when disturbance covariates, such as: (i) forest logging, (ii) cereal harvesting and (iii) hunting and predation pressures, were imperatively taken into account.

KEYWORDS

Turtle dove, *Streptopelia turtur*, habitat occupancy, agroforestry system, Morocco

INTRODUCTION

Wildlife management in a mosaic of natural (forest) and artificial (arable lands) habitats requires a deepen knowledge of the actual needs of species for one and other of these environments. Habitat selection is the innate or learned behavioural response that allows a bird to choose amongst the various environmental components, habitats or structures in a location that will influence survival or adaptation (Block & Brennan 1993; Brito et al. 2018). In birds, there is a substantial difference between characteristics of nesting sites and those of foraging areas both in terms of space and habitats. Knowing these differences proves to be important for conservation and species management. In some farmland birds, these needs are shared between, on the one hand, nesting sites requiring the presence of trees and, on the other hand, foraging (e.g. cereal crops) and watering sites. Spatial distribution of doves and pigeons (Aves, Columbiformes) throughout a habitat depends on these needs (i.e. dependent on trees for nesting and cereal crops for feeding and drinking) (Browne & Aebischer 2003; Hanane 2017). In this study, the European turtle dove (*Streptopelia turtur*) was chosen as a model system for three reasons: first, there is no previous study focusing on assessing the spatial uses of habitats to satisfy its vital needs. Second, in its European breeding areas, the species has experienced a rapid and serious decline (~78% in 1980–2013; PECBMS 2015; Dunn et al. 2016) and has been classified as 'Vulnerable' throughout Europe ('Near Threatened' within the EU27 countries) following a recent assessment (BirdLife International 2015). Third, the species is known to use the farmland during its breeding period both in Europe (Dias et al. 2013) and in North Africa (Yahiaoui et al. 2014; Hanane & Yassin 2017; Hanane 2018; Hanane et al. 2018). In these environments, combining natural and artificial habitats, Hanane (2018) had evidenced the dependency of turtle doves on forest edges for nesting. This choice is probably an adaptive response to (i) nest predation pressure (Yanes & Oñate 1996; Yanes et al. 1996; Penloup et al. 1997; Mezquida

& Marone 2002; Barrientos et al. 2009), (ii) human disturbances (Rodgers 1996; Hanane & Baâmal 2011; Hanane 2012, 2014b) and (iii) proximity of cultivated seeds (Dunn et al. 2015; Gutiérrez-Galán & Alonso 2016; Gutiérrez-Galán et al. 2018). In relation with this last point, Browne and Aebischer (2003) and Hanane (2017) had highlighted the necessity of the presence of nesting supports adjacent to crops of cereal (e.g. wheat and barley) in this game species. This has been proven to greatly improve the survival of their nests (Kafi et al. 2015).

In Morocco, the turtle dove is a common migratory breeding bird (Thévenot et al. 2003; Hanane & Baâmal 2011). It is widely distributed in forests (Hanane 2003; Vernon et al. 2005; Cherkaoui et al. 2007; Hanane & Yassin 2017; Hanane 2018) and in farmland (e.g. fruit orchards in irrigated areas). In a socio-economic point of view, the turtle dove is a major game species in Morocco, highly valued by national and international hunters (HCEFLCD 2013).

Most studies on turtle doves have focused on breeding biology (Rocha & Hidalgo 2002; Browne et al. 2004, 2005; Hanane & Baâmal 2011; Kafi et al. 2015; Hanane 2016a, 2016b), breeding habitat use (Browne & Aebisher 2004; Browne et al. 2004; Browne et al. 2005; Bakaloudis et al. 2009; Dunn & Morris 2012; Sáenz de Buruaga et al. 2012; Dias et al. 2013; Yahiaoui et al. 2014; Dunn et al. 2016 ; Hanane 2018), foraging habitat use (Browne & Aebisher 2003; Dunn et al. 2015; Rocha & Quillfeldt 2015; Gutiérrez-Galán & Alonso 2016) and migration (Eraud et al. 2013; Lormée et al. 2016; Marx et al. 2016). Although this species is fairly well studied, there is, however, no study that has focused on studying factors conditioning the spatial distribution of this vulnerable species in its breeding areas. Yet this topic is of great importance for managers of agroforestry habitat-associated species of conservation concern (Hanane 2017). The knowledge and also quantification of such factors will undoubtedly allow defining future conservation actions as well as the adoption of an appropriate management of this species.

The main objective of the study was, therefore, to identify the most important factors driving the spatial distribution of nesting sites of turtle doves and those used as foraging habitats (cereals and water) in a North African agroforestry landscape.

1. MATERIALS AND METHODS

1.1. Study area

Observations were made in a Moroccan natural Thuya forest (32.8 km^2) located within Oued Mellah watershed at the vicinity of Ben Ahmed city (Hanane & Yassin 2017; Hanane 2018; Hanane et al. 2018). The study area receives 320 mm of mean annual rain, most of which falls during the winter rainy season (November–January). Temperature varies widely, being more temperate during the winter but with peaks in summer reaching, at times, 42°C. The altitude ranges from 450 to 649 m. In addition to the Thuya forest, the landscape is also composed of cereal crops (600 ha), vegetated ravines (250 ha) and olive plantations (200 ha). In the study area, the tree layer consists mainly of Thuya in association with wild olive (*Olea europaea oleaster*) and Tizra tree (*Rhus pentaphylla*), whilst cereal crops are dominated by wheat (*Triticum turgidum* and *Triticum aestivum*) and barley (*Hordeum vulgare*). Vegetated ravines are dominated by the common rush (*Juncus effusus*), Oleander (*Nerium oleander*), and Chilean myrtle (*Luma apiculata*) (Hanane & Yassin 2017; Hanane 2018; Hanane et al. 2018). In this landscape, olive orchards are distributed in very small patches (1.52 ± 0.05 ha) throughout the area (Hanane 2018). Very small and single-family houses, mostly distant from each other (2.10 ± 0.85 km), are found in the vicinity of crops and forests. In the study area, there is no human habitation within the forest area (HCEFLCD 2006; Hanane & Yassin 2017; Hanane 2018; Hanane et al. 2018).

1.2. Data collection

Monitoring took place in 2017, from mid-May to mid-June, during the peak of breeding season [most pairs of the turtle doves are nesting during this period (Hanane 2018)]. To achieve the objective advocated by the study, two criteria are taken into account: (i) the location of active nest (i.e. nests with eggs, nestlings or incubating adults) to the extent that 'nests' constitute the core of the territory and (ii) location of birds (both adults and juveniles) performing different activities (e.g. singing, foraging, roosting, preening, drinking, walking and flying) because of the needs of the species throughout its overall habitat. The locations of both nests and birds were georeferenced using a portable GPS (Magellan eXplorist XL) and then reported using Quantum GIS v1.7.3 (QGIS).

To localise the turtle dove nests in this agroforestry landscape, I followed the sampling design used in 2016 and 2017 by Hanane and Yassin (2017) and Hanane (2018). In parallel, the presence of turtle dove was surveyed using the point count method (Bibby et al. 2000). Fifty survey points were randomly distributed in the study area with a minimum distance of at least 150 m between two points. Points were selected by drawing random points using the QGIS (Quantum GIS Development Team 2017) random selection tool. I recorded, during a period of 10 min, all turtle doves heard and seen at a fixed radius of 50 m (Sweeney et al. 2010; Anjos et al. 2011; Hanane et al. 2018). All surveys were conducted during early morning and only under favourable meteorological conditions.

1.3. Habitat variables selection

Amongst the 50 plots, I selected only those where the turtle dove was detected (n = 33). Because I have chosen to have a balanced design, I took into account the 33 nest points localised in 2017 (see Hanane 2018). Within each sample plot (centred at nest for nest plots and at survey point for survey plots), six variables were measured: altitude (m) directly collected at nest using the GPS and measured at each 50-m radius plot by considering three points mean elevation; the distance (m) from nest tree or survey point to the nearest standing water;

distance (m) from nest tree or survey point to the closest cereal field; distance (m) from nest tree or survey point to the closest human settlement; distance (m) from nest tree or survey point to the closest track; and distance (m) from nest tree or survey point to the closest Thuya forest edge. This latter distance is either positive (indicating distances outside the forest) or negative (indicating distances within the forest). These variables were used because they influence the presence of both nests (Hanane 2018) and birds (Browne & Aebischer 2003; Dunn & Morris 2012). QGIS 2.18.14 was used to measure the distances.

1.4. Statistical analysis

Before performing statistical analyses, I checked for normality and homogeneity of variance for all the variables. Variables that did not conform to the requirements for parametric tests were square root transformed before all analyses (Zar 1984; Underwood 1996; Quinn & Keough 2002). I also checked for possible correlations amongst variables by using Pearson's rank correlation (r) index. For the six variables, r did not reach the threshold of 0.7 (Table S1). I thus performed a linear discriminant analysis (LDA) on the six studied variables to calculate the discriminant function between territory habitat and nesting habitat. All the assumptions of discriminant function analysis were met (Tabachnick & Fidell 2001; Niemc et al. 2018), including the homogeneity of covariances (Box's M test; $P > 0.05$) and the homogeneity of variance (Levene's test; $P > 0.05$). The overall correct classification rate was also evaluated. All statistical analyses were performed in R-3.0.2 software (R Development Core Team 2013). I used the package 'MASS' to perform the LDA. A two sample t-test was used to determine whether nest placement varied between territory habitat and nesting habitat. Means are quoted ± standard errors. The results were considered significant at $P < 0.05$. To account for the two sample multiple t-tests, I used the Bonferroni correction (Rice 1989) and considered differences to be significant when $P < 0.0083$.

2. RESULTS

The t-tests conducted on plot spatial positioning of territory habitat and nesting habitat, distance from nest tree or survey point to the closest standing water (min–max: 8.65–1,527.25 m), Thuya forest edge (from −538.35 to 861.82 m) and track (16.82–634.54m), were significantly different, whilst those on elevation (349–619 m), closest distance from nest tree or survey point to cereal field (113.21–1,374.79 m) and closest distance from nest tree or survey point to human settlement (312.55–1172.95 m) were not (Table 1). The maximum observation distance of a turtle dove from the nest tree, the most far away, was 1,518.6 m. The average of this distance was 1,129.69 m (SE = 169.40).

I used an LDA to test which of the six variables maximises variation between nesting and non-nesting habitats in the turtle dove. This analysis showed the relevance of the distance from nest tree or survey point to the closest standing water and to closest distance to the track in discriminating

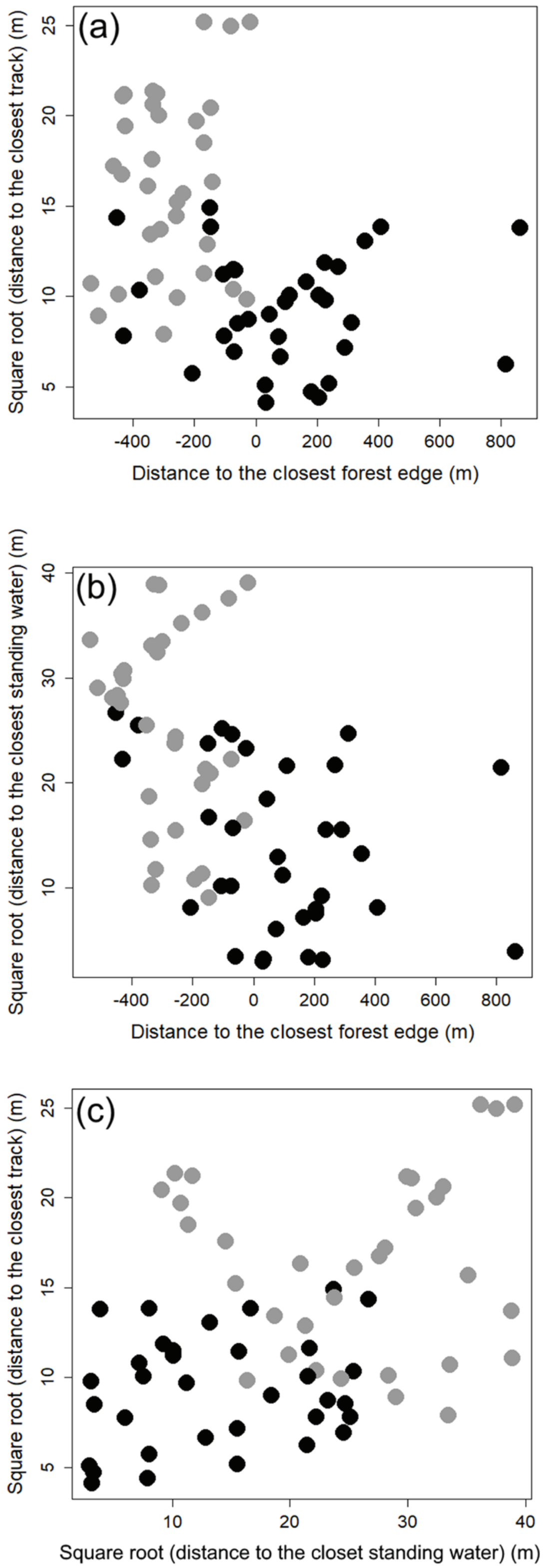

Figure 1. (a) Distribution of the 66 presence points (nests and birds) in relation to the distance to the closest track and forest edge. Grey circles represent the position of nests, and black circles represent turtle dove's positions. (b) Distribution of the 66 presence points in relation to the distance to the closest standing water and forest edge. (c) Distribution of the 66 presence points in relation to the distance to the closest standing water and track.

Table 1. Untransformed values of the environmental variables measured at habitats occupied by the Turtle-dove (TD) for different uses (n = 33) and at nesting habitats (n = 33) in an agroforestry landscape, Morocco, 2017. An asterisk (*) indicates that data differed significantly (two-sample t-tests, P < 0.008).

Variables	Habitat		t-value	P-value
	TD's plots	TD's nest-points		
Elevation	455.10 ± 17.72	453.27 ± 6.60	0.096	0.924
Distance to the closest standing water	289.38 ± 49.63	736.36 ± 78.19	-4.827	<0.008*
Distance to the closest cereal field	329.52 ± 94.85	304.27 ± 24.76	0.258	0.799
Distance to the closest human settlement	396.38 ± 78.67	450.27 ± 23.32	-0.657	0.518
Distance to the closest track	90.65 ± 8.78	289.85 ± 28.36	-6.710	<0.008*
Distance to the closest forest edge	87.52 ± 49.05	-282.11 ± 24.14	6.759	<0.008*

The 0.05 alpha level is adjusted to 0.008 using a Bonferroni correction

Table 2. Results of the discriminant function analysis between habitat occupancy for different uses (n = 33) and nesting site occupancy (n = 33) in the Turtle-dove in an agroforestry landscape, Morocco, 2017.

	Function 1
Eigenvalue	1.842
Percentage of eigenvalue associated with the function (%)	100
Canonical correlation	0.805
Wilks' Lambda	0.352
Chi–square statistic	51,183
Significance (degrees of freedom)	P < 0.001 (6)
Standardized canonical discriminant function coefficients	
Elevation	0.563
Distance to the closest standing water	-0.458
Distance to the nearest cereal field	0.330
Distance to the closest human settlement	-0.254
Distance to the closest track	-0.518
Distance to the closest forest edge	0.792

between the two types of occupancy (Fig. 1a; Tables 2 and 3). The prediction of the classification using the linear discriminant function is very good because 90.7% of the original observations were correctly classified. For nesting, turtle doves tend (i) to moving away from tracks and standing water (Fig. 1b, c) and to breaking into the Thuya forest without, however, exceeding 600 m away from the nearest forest edge. In contrast, no differences were recorded between the habitat occupancy for different uses and nesting site occupancy for elevation, closest distance to cereal crops and closest distance to human settlements.

3. DISCUSSION

The results of the discriminant analysis support the existence of a substantial separation in the turtle dove's nesting sites and foraging habitats. For nesting, turtle doves choose trees that were far away from tracks and standing water. For their foraging habitat, turtle doves tend to approach tracks and standing water. This spatial pattern is quite common and logical, because turtle doves need to move to feed and drink (Wiehn & Korpimaki 1997; Hanane 2017). This also explained the forest edge effect to the extent that, for these same needs, turtle doves must necessarily cross these edges. Turtle doves are known to use open lowland habitats for feeding (Brown & Aebischer 2005; Fisher et al. 2018). This was also asserted by Hensley et al. (1995) and Yahiaoui et al. (2014) who argued that turtle doves tend to be associated with woodland edges, probably because they depends on habitats outside woodland for food and their occurrence in woodland can be influenced by the proximity of food sources. The turtle dove also uses the Thuya forest edge for perching. The configuration of the landscape

Table 3. Significant predictor variables obtained from discriminant analyses between habitat occupancy for different uses (n = 33) and nesting site occupancy (n = 33) in the Turtle-dove in an agroforestry landscape, Morocco, 2017.

	Wilks.lambda	F-value	P-value
Elevation	1.000	0.012	0.912
Distance to the closest standing water	0.720	20.183	0.000
Distance to the nearest cereal field	0.977	1.233	0.272
Distance to the closest human settlement	0.950	2.732	0.104
Distance to the closest track	0.603	34.166	0.000
Distance to the closest forest edge	0.608	33.513	0.000

in the study area, characterised by the adjacent presence of open habitats and tracks in close proximity to forest borders, would explain this behaviour. The presence of these forest edges would, therefore, contribute to ensure the presence of nesting sites and also provide areas of resting and perching. In other words, if some turtle doves are present at nests, others are, at the same time and not far from there, feeding, perching, resting or drinking. Although separate, these activities prove, nevertheless, complementary. Indeed, and for example, it has been demonstrated that in this species, the number of chicks fledged per nest was higher in close proximity to cereal crops, whilst it decreased gradually as the distance to the nearest cereal crop increased (Kafi et al. 2015). Closer proximity to feeding areas would also increase the food acquisition efficiency in adult doves whilst allowing them to spend more time caring for their broods (Pearse et al. 2004; Dunn et al. 2010; Hanane 2015; Hanane 2018; Evens et al. 2018). The maximum distance measured between the nest tree and the farthest turtle dove observed is relatively short (less than 1.6 km) and comes to support these explanations. Our results are also in accordance with the pattern evoqued by Reino et al. (2009) regarding the effect of forest edge on farmland birds. In short, the movements back and forth between the feeding and watering areas (outside forests), on the one hand, and the nesting sites (inside forests), on the other hand, would explain the joint effects of the forest edge and closeness of standing waters.

It is now admitted that, to nest, turtle doves select nest sites as far away as possible to anthropogenic disturbances (De Buruaga et al. 2012; Dias et al. 2013; Hanane 2015; Hanane 2018). This weak tolerance to humans prompts us to ask why distance to human settlement was not highlighted as a discriminant variable? The answer to this question is that this Columbidae species avoid the human presence for nesting and also for other activities such as the perching, feeding and drinking. This was previously noticed in European forests (Gillings and Fuller 1998; Hinsley and Bellamy 2000; Browne and Aebischer 2003; Browne et al. 2004; Bakaloudis et al. 2009; De Buruaga et al. 2012; Dias et al. 2013) and in the Mediterranean agricultural areas (Peiro 1990; Hanane & Baamal 2011; Hanane 2015).

In addition to avoiding human disturbance, the reconciliation of tracks could also be interpreted as an attractivity to open/cleared areas. In the United Kingdom, Brown and Aebischer (2003) had also evidenced the attractiveness of turtle doves for feeding at ‘man-made’ sites. The availability of feeding resources on and at the immediate vicinity of tracks (cereal seeds) would explain their use by the species. The use of tracks by the turtle doves is also favoured by the very low traffic of vehicles in this agroforestry landscape. Furthermore, during the data collection period, cereal crops were particularly under-used because of high density of cereals that not allowed birds having an idea on what is happening in their immediate surroundings. Brown and Aebischer (2003) have previously emphasised this under-use of cropped areas in the United Kingdom. The cereal crops conditions would, hence, explain why the distance from nest to the nearest cereal crops was not emerged as a discriminant variable in this period.

The results of the present study suggested, therefore, the existence of a segregation between turtle dove’s nesting and non-nesting habitat according to closest distance from each nest tree or survey point to standing water, to track and to forest edge. These results pointed out the importance of tracks, water and forest edges, respectively, as feeding, watering and resting/nesting areas. This spatial scheme in fact represents the spatial limit of the area in which, in a fairly faithful manner, a cycle of daily activities takes place. It goes without saying that the positioning (proximity or remoteness) of these landscape components would certainly dictate the selection of the nesting areas in this species. Hanane (2018) in studying the multiscale nest habitat selection in the same agroforestry system had also confirmed the positive effects of the proximity to forest edges and human presence avoidance on the probability of the turtle dove nest presence. This spatial discrimination model could nonetheless undergo some modifications especially after starting cereal harvestings. Indeed, cereal crops or stubbles would be more solicited than tracks allowing certainly interchanging these two variables (tracks before cereal harvesting and distance to cereal crops or stubbles after). Overall, our results provide new insights into the behavioural ecology of this vulnerable species. Understanding and quantifying the variability of this spatial pattern would be of great importance, whilst considering disturbance covariates such as (i) predation pressure, (ii) hunting activity, (iii) cereal harvesting and (iv) forest logging. These research perspectives would gain in quality if the experimental protocol would cover several other agroforestry systems throughout Morocco and also if the sample size, for both nests and birds, is sufficiently high.

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