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ORIGINAL ARTICLE

Distribution of the European turtle dove (*Streptopelia turtur*) at the edge of the South-Western Palaearctic: transboundary differences and conservation prospects

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Abstract
The European turtle dove (*Streptopelia turtur*) is classified as vulnerable by the IUCN. In this context, it is important to explore the factors affecting its abundance and the ways in which it can be effectively managed for conservation. This study compares the distribution of this dove in Spain and Morocco. These countries, which are separated by the Strait of Gibraltar, are each occupied by a different subspecies (i.e. *Streptopelia turtur turtur* in Spain and *S. t. arenicola* in Morocco) that may be adapted to different environmental conditions. Such differentiation could result in differences in the species' abundance between the two countries. The occurrence of this dove was assessed by means of road counts, and the resulting records were used to explore the niche overlap between the two subspecies. The niches of both populations overlapped, suggesting the selection of similar environmental conditions in the two countries. However, the species occurred more frequently in Morocco than in Spain. To study the potential role of local effects on the observed differences in abundance, 494 sampling points were surveyed in four different sectors of Spain and Morocco. These additional counts indicated that, after controlling for the effect of local habitat structure and climate, the European turtle dove is more frequent in Morocco than in Spain. Differences between the two countries, in relation to hunting pressure, agricultural intensification and the abandonment of marginal cultures and woodlands, could account for the observed transboundary differences in the abundance of European turtle dove and help to explain its severe decline in Spain.

Keywords Range edge · Habitat selection · Niche overlap · Peripheral population

Introduction

The European turtle dove (*Streptopelia turtur*) is a migratory species that breeds in farmlands and open woodlands of the Western Palaearctic. This species has experienced a drastic decline in recent decades, as a result of habitat degradation in its breeding and wintering grounds, over-hunting and displacement by expanding populations of other dove species (Fisher et al. 2018). As a consequence, the European turtle dove is categorised as vulnerable on the IUCN Red List of Threatened Species and is increasingly managed for protection in many European countries (BirdLife International 2017; Fisher et al. 2018).

The factors shaping the abundance of the European turtle dove at the south-western edge of the Palaearctic (Morocco and Spain) are still poorly known (Balmori 2004; Hanane 2017) despite a sharp reduction in numbers having been reported in Spain (Escandell 2019; Moreno-Zarate et al. 2020).

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Such a decrease could be related to the location of these populations at the edge of the species range (Western Palaearctic), which may make them particularly sensitive to some changes due to the proximity to their limits of environmental tolerance (Sexton et al. 2009). A similar decline may also have occurred in Morocco, since this country is at the very edge of the Palaearctic. However, the available evidence does not support this possibility. Previous studies report very high densities of this species in Morocco (Hanane 2017), and a recent study that used population numbers from several species as an index of agricultural intensification showed that the European turtle dove was far more abundant in Morocco than in Spain (Tellería et al. 2019).

One possible explanation for the observed transboundary differences in European turtle dove abundance is that Spain is occupied by the nominal subspecies *Streptopelia turtur turtur* (Linnaeus 1758), while Morocco is occupied by *S. t. arenicola* (Hartert 1894). This taxonomic difference, accepted in current reviews (Clements et al. 2015), could result in different responses to environmental conditions on either side of the Strait of Gibraltar. More explicitly, North African doves could be better adapted to local conditions than their Spanish counterparts, which are at the range edge of the nominal subspecies (but see Pironon et al. 2017). Thus, in the current context of global change affecting the Mediterranean region, the Spanish populations could be more vulnerable to changes (e.g. increasing temperatures and decreasing precipitation) in this climate change hotspot (Giorgi 2006; Cuttelod et al. 2008).

To explore the factors affecting the European turtle dove on both sides of the Strait of Gibraltar, we compared the niche of this species in Spain and Morocco. We hypothesised that if the two populations differ in their niches, such variation in habitat preferences between subspecies could explain the observed differences in numbers between the two countries. On the contrary, if they show niche overlap, differences in abundance would more likely be the result of other factors that vary on either side of the Strait of Gibraltar (e.g. habitat quality, anthropogenic pressure).

An alternative explanation for the differences in abundance between the two countries, as indicated by previous road counts (Tellería et al. 2019), could be merely methodological. An uneven suitability of sampling areas at local scales (e.g. if more road counts in Spain were carried out in unsuitable sites) would result in differences in the number of doves. To control for this potential issue, in the present study, we carried out point sampling of doves to test for differences in dove abundance between the two countries, after controlling for the effect of climate and local habitat structure. Thus, if the European turtle dove has a similar niche in both countries and is more abundant at sampling points of Morocco, it would suggest the influence of other drivers on the Spanish population of the species. It is possible that differences in the abundance of this species between the two countries at this edge of the Palaearctic result from a mixture of natural and anthropogenic factors that are useful to understand from a conservation perspective (Dallimer and Strange 2015).

Methods

Study area

The study area is broadly characterised by a Mediterranean climate and vegetation. However, these conditions (particularly those related to the effect of summer drought) differ between the moister areas of Northern Spain and the drier expanses of Southern Morocco. To exclude those areas where the environmental conditions in peninsular Spain are outside the range of conditions in Morocco and vice versa, we first constructed a multivariate environmental similarity surface (MESS) map (Phillips et al. 2009) using mean temperature and precipitation of the warmest quarter and tree cover (see Tellería et al. 2019). The resulting MESS map was used to define our study area within two environmentally similar sectors on both sides of the Strait of Gibraltar (Fig. 1).

Niche overlap

Records of the occurrences of the European turtle dove were gathered via road counts in spring 2016 and 2017 (Fig. 1a, see Tellería et al. 2019 for details) and expanded upon in the spring of 2019. These data (geo-referenced sites where the species was detected) were used to explore niche overlap between Spanish and Moroccan populations. To do so, we used the multivariate approach described in Broennimann et al. (2012, 2016) and Di Cola et al. (2017), which accounts for differences in environmental availability and species occurrence between the two study areas. To do this, we extracted the environmental values associated with both turtle dove occurrences detected in road counts and for 2000 randomly selected background points across the study areas of Morocco and Spain (Table 1), using 'raster' package within R (Hijmans 2020). For each point, we obtained a set of variables provided by high-resolution (30 arc sec) climate data in Chelsa V1.2 (Karger et al. 2017a, b) as surrogates of environmental conditions. Since Mediterranean drought strongly constrains primary productivity, especially during the hottest summer months (Nahal 1981), we used temperatures (Bio1, Bio5, Bio 9, Bio 10) and precipitation (Bio 12, Bio14, Bio 17; Table 1). Because migratory birds could take advantage of the surplus of resources resulting from seasonal changes in precipitation (Wisz et al. 2007), we incorporated precipitation seasonality (Bio15) and net primary productivity during the breeding and post-breeding periods (June and August, respectively). We also included elevation (in m a.s.l.) and woodland cover from GlobCover 2.2 (ESA 2008), since the European turtle dove

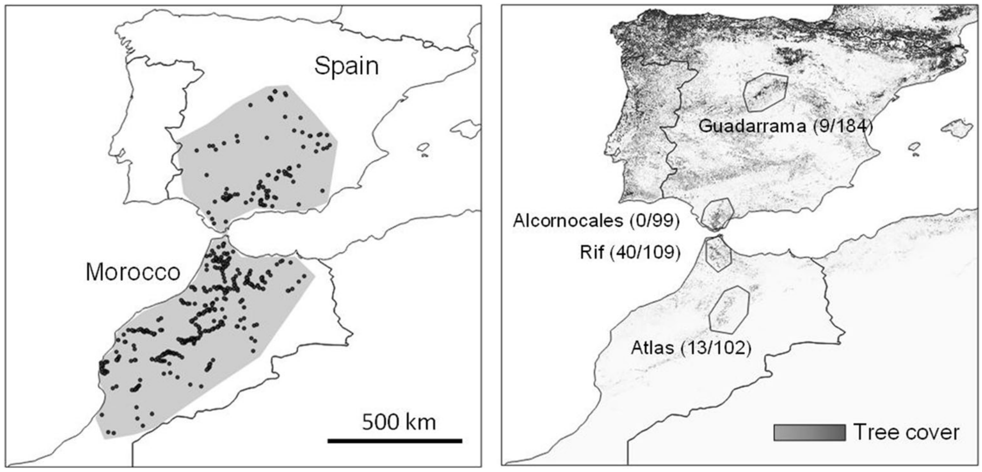

Fig. 1 (**a**) Locations of European turtle dove occurrences (black dots), obtained through road counts within the study area (in grey). (**b**) Distribution of the four study sectors where point sampling was carried out to detect doves. Scores in parentheses show the number of positive occurrences of doves vs. the total number of sampling points per area. Shading represents gradient of tree cover (i.e. higher cover is shaded darker) within the region

mainly selects agricultural landscapes interspersed with tree-covered patches (Dias et al. 2013).

With this background and the species occurrence dataset, we created a grid defined by axis 1 and axis 2 from a principal component analysis (PCA) in which each cell represents a unique combination of environmental conditions available to doves. The method then applies Gaussian kernel density functions to estimate the occupancy of each cell by the two populations and uses Schoener's D metric to calculate the overlap between them (Schoener 1970; it ranges from 0 to 1, representing completely different niches to identical niches, respectively). Since background environments can differ between areas, we tested niche equivalency and similarity (Di Cola et al. 2017). The equivalency test evaluates whether the observed overlap (D) between the Spanish and Moroccan populations is higher than that observed when the occurrences in the two areas are randomly reallocated within them. If the observed value of D falls within the density of 95% of the simulated values, the null hypothesis of niche equivalency (i.e. that the overlap results from a random distribution of occurrences) cannot be rejected. The niche similarity test examines whether the observed overlap (D) differs from the overlap between the observed niche in one area and the niches produced by randomly selected occurrences from the other area and vice versa (Broennimann et al. 2012, 2016). If the observed overlap is larger than the simulated values, the species occupies environments in both areas that are more similar to each other than would be expected by chance. For both the equivalency and similarity tests, the expected distributions were based on 100 random iterations.

Table 1 Results of the principal components analysis in which the environmental variables considered in the study of niche overlap were included (Fig. 2)

	Axis 1	Axis 2
Elevation	− 0.535	0.002
Annual Mean Temperature (Bio 1)	0.884	0.186
Max Temperature of Warmest Month (Bio 5)	0.757	− 0.589
Mean Temperature of Driest Quarter (Bio 9)	0.813	− 0.539
Mean Temperature of Warmest Quarter (Bio 10)	0.845	− 0.506
Annual Precipitation (Bio 12)	− 0.507	0.249
Precipitation of Driest Month (Bio 14)	− 0.729	− 0.605
Precipitation Seasonality (Bio 15)	0.604	0.696
Precipitation of Driest Quarter (Bio 17)	− 0.768	− 0.576
Productivity in June	− 0.268	0.033
Productivity in August	0.021	− 0.093
Woodland cover	− 0.351	0.055
Eigenvalue	4.956	2.185
Explained variance (%)	41.30	18.21

Results show the factor loadings and signs for each variable within the axes, as well as the eigenvalue and variance explained by each axis

Species occurrence

European turtle doves were counted via point sampling, in 494 circular points distributed across four different areas, both inland (Guadarrama and Atlas) and coastal (Alcornocales and Rif; sector herein) of Spain and Morocco (country). Sampling points were separated from each other within the study sectors (Fig. 1b) and carried out between the last week of April and June of 2019 (see ESM 1). The sectors were selected as part of a large-scale study that aims to understand the features affecting the distribution of woodland birds on both sides of the Strait of Gibraltar. Sampling points were distributed across tracks and small roads within each area, including a wide diversity of habitats ranging from open areas (e.g. cereal fields, grasslands) to dense forests (e.g. pine, cedar or oak woodlands). The location of the sampling points was randomly distributed across different elevations and landscapes within each of the four sectors (see Supplementary Material). At each sampling point, the abundance of doves was recorded during a 10-min period within a 100-m-wide radius (Johnson 2008). All doves heard and seen were recorded. Since many doves migrate north over the study area during this period (Gargallo et al. 2011), we also noted the behaviour of observed individuals to determine if they showed breeding activity (e.g. territorial songs; Dunn and Morris 2012). In addition, each sampling point was geo-referenced with GPS devices for further exploration of the effect of spatial distribution on the results. The percentage cover of grasses, shrubs (of less than 0.5 m height and between 0.5 and 2 m in height) and trees (> 2 m height) was also recorded visually in 25-m-radius circles within the sampling points, as well as the number of shrub and tree species. These latter data were used to carry out a PCA in order to obtain a latent variable that described habitat structure. The factor scores for each sampling point within this component (habitat herein) were used as a composite index of habitat structure (increasing shrub and tree cover vs. grass cover; Table 2). A similar PCA was carried out with the same list of variables used in the niche overlap analysis, but recorded for each of the sampling points (Table 1), and the component with the greatest explanatory value obtained (environment herein) was used as a composite index of drought intensity (Table 2).

Because the number of European turtle doves detected at each sampling point ranged from one to four individuals, and we did not want fit models with Poisson distribution of errors, we reduced these data to presence vs. absence. To test for differences between Morocco and Spain on dove probability of occurrence, we used generalised least square mixed models in which country was included as a fixed effect after accounting for the effect of habitat, environment and sector. We used the function gls in the R package "nlme" (Pinheiro et al. 2020). We fitted six different models, one without considering the spatial correlation between sampling points (no structure) and five models with different spatial correlation structures (exponential, Gaussian, spherical, linear and rational quadratic; Dormann et al. 2007) with restricted maximum likelihood (REML) and then used AICc to select the best correlation structure. All analyses were performed in R version 3.5.3 (R Development Core Team 2019).

Results

Road counts

We detected 409 sites in which European turtle doves ($n = 820$ individuals) occurred along 6710 km of road counts in Morocco and 108 sites ($n = 148$ individuals) along 6288 km in Spain (Fig. 1a). We compared the observed frequencies (i.e. the number of sites where the species was detected) between the two countries by means of a chi-square test. We calculated the expected number of sites with doves per country by multiplying the total number of recorded sites by the ratio of kilometres sampled in each country. The results showed that European turtle dove was present in more sites in Morocco than in Spain (χ^2: 106.99, df = 1, $P < 0.001$).

Niche overlap

The two axes obtained in the PCA explained 59.6% of the variance in environmental conditions (Table 1). Axis 1

Table 2 Results of the two different principal component analyses in which regional and local environmental variables have been ordered in gradients to study the European turtle dove distribution

PCA for regional environment gradient		PCA for local habitat structure	
Variables	Axis	Variables	Axis
Elevation	0.835	Grass cover	− 0.379
Annual Mean Temperature (Bio 1)	− 0.957	Shrub cover < 0.5 m	0.503
Max Temperature of Warmest Month (Bio 5)	− 0.784	Shrub cover 0.5–2 m	0.435
Mean Temperature of Driest Quarter (Bio 9)	0.368	Tree cover > 2 m	0.261
Mean Temperature of Warmest Quarter (Bio10)	− 0.927	Shrub species	0.460
Annual Precipitation (Bio 12)	0.367	Tree species	0.368
Precipitation of Driest Month (Bio 14)	0.866		
Precipitation Seasonality (Bio 15)	− 0.866		
Precipitation of Driest Quarter (Bio 17)	0.871		
Productivity in June	0.288		
Productivity in August	− 0.172		
Woodland cover	0.249		
Eigenvalue	6.348		2.53
Explained variance (%)	52.90		42.15

Results show the factor loadings and signs for each variable within the axis, as well as the eigenvalue and the variance explained by each axis defined a gradient of increasing drought (elevated temperatures vs. reduced precipitation) in lowlands, while axis 2 defined a gradient from warm areas to sectors that were highly seasonal in precipitation (Table 1). In this environmental scenario, the niche of the Spanish and Moroccan doves overlapped significantly (Schoener's D index = 0.41), with some Spanish turtle doves occurring in more tree-covered, rainy areas and some Moroccan turtle doves occurring in warmer sectors (Fig. 2). The equivalency test indicated that the niches of the two study populations were similar ($P = 0.009$), and the similarity tests showed that niches in the two areas overlapped more than would be expected by chance (Spain vs. Morocco $P = 0.019$, Morocco vs. Spain $P = 0.079$). Thus, these results suggest that the niches of the two populations were highly overlapping.

Species occurrence

Point sampling also showed that European turtle doves were more frequently detected in Morocco than in Spain (Fig. 1). The species was recorded in 53 out of 211 sampling points in Morocco and in 9 out of 283 sampling points in Spain. In most cases (94.59%), the records referred to singing individuals, and so we assumed that they were breeding birds. The iterative procedure of the GLS mixed models did not converge in one of the models (i.e. that based on the linear spatial correlation structure), and other model (spherical) did not show any significant effect of the study variables. The remainder of the models suggested that, after controlling for the effect of environment, habitat and sector, the probability of occurrence of the European turtle dove was higher in Morocco than in Spain (Table 3).

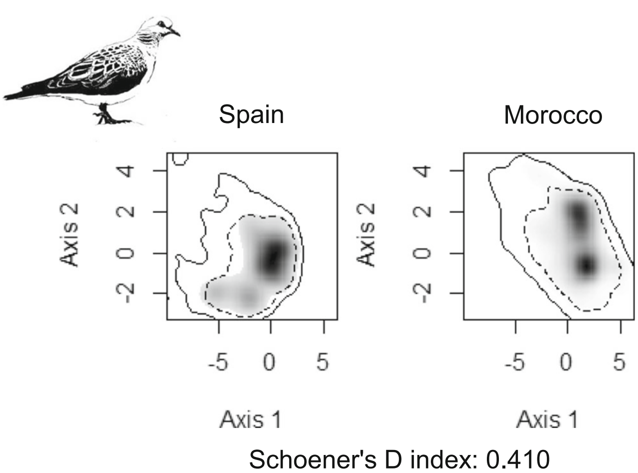

Fig. 2 Representation of the environmental spaces described by the first two components of the PCA. Spaces are occupied by Spanish and Moroccan breeding populations of European turtle dove (grey shading shows the density of occurrences of the species by cell), and the Schoener's D index reports the niche overlap between the two populations. The solid and dashed contour lines illustrate, respectively, 100% and 50% of the available (background) environment

Discussion

Population differentiation and niche differences

The European turtle dove has been reported as a panmictic species across Europe that is not genetically structured across flyways (Calderón et al. 2016). However, two different subspecies have been recognised, on either side of the Strait of Gibraltar (Clements et al. 2015), a pattern that is common to other bird species (García et al. 2008; Perktas et al. 2011; Hórreo et al. 2014; Doña et al. 2015; Potti et al. 2016; but see Ceresa et al. 2015 and Olsson et al. 2016). In this context, the reduction of gene flow between Spanish and Moroccan birds, followed by the adaptation of populations to local conditions on either side of the Strait, would potentially lead to differentiation. As a result, different morphs within a single species may be specialised in the use of different resources (Skúlason and Smith 1995). Such evolutionary processes could also lead to dissimilar numerical thresholds in populations under similar environmental conditions, which could explain differences in occurrence probability among populations.

This situation could apply to the case of the European turtle dove. The Moroccan population is a subspecies that is geographically isolated by the Mediterranean Sea from the nominal form, which could imply a better adaptation to local conditions in North Africa. Isolation could allow peripheral populations to adapt to environmental conditions at the edge of the species' range (Holt and Gomulkiewicz 1997; García-Ramos and Kirkpatrick 1997; but see Pironon et al. 2017). According to this view, the Moroccan population of the European turtle dove could be better adapted to environmental conditions in the South-Western Palaearctic compared with the nominal form on the European side of the Strait of Gibraltar. This differential adaptation may explain the observed differences in the occurrence of the species between the two sides of the Strait.

However, the results in this paper do not support any significant difference in the use of the environment by the two subspecies. Even though individuals of the two populations thrive under dissimilar environmental conditions (e.g. drier conditions in Morocco than in Spain), the two populations overlap in their niches more than would be expected by chance (Fig. 2). It should be noted that this significant overlap does not exclude the potential effect of some small biological variations causing differences in occurrence between populations. For example, it is possible that Moroccan doves could be better adapted to drought than their Spanish counterparts. However, our results on niche overlap do not provide any clear evidence to support this idea. In this sense, it would be interesting to explore whether genomic data or mitochondrial DNA sequences support a clear differentiation between the Moroccan and Spanish populations (e.g. Calderón et al. 2016), regardless of the current taxonomic context.

Table 3 Results of generalised least square mixed models in which European turtle dove occurrences have been regressed against environment, habitat and country according to five spatial correlation structures

		Spatial correlation structure				
		No structure	Exponential	Spherical	Gaussian	Quadratic
Intercept (inland, Morocco)	$b \pm$ se	0.220 ± 0.026	0.254 ± 0.072	0.271 ± 0.177	0.259 ± 0.056	0.256 ± 0.073
	t (p)	8.206 (< 0.001)	− 3.523 (< 0.001)	1.527 (0.127)	4.580 (< 0.001)	3.523 (< 0.001)
Environment	$b \pm$ se	− 0.037 ± 0.020	− 0.007 ± 0.039	− 0.088 ± 0.038	− 0.040 ± 0.037	− 0.062 ± 0.039
	t (p)	− 1.869 (0.062)	− 1.798 (0.073)	− 2.288 (0.022)	− 1.108 (0.268)	− 1.611 (0.108)
Habitat	$b \pm$ se	0.003 ± 0.015	0.000 ± 0.016	0.003 ± 0.015	0.001 ± 0.015	0.001 ± 0.015
	t (p)	0.185 (0.852)	0.004 (0.997)	0.173 (0.862)	0.101 (0.919)	0.056 (0.995)
Sector (coastal)	$b \pm$ se	0.033 ± 0.042	− 0.038 ± 0.095	− 0.131 ± 0.209	− 0.001 ± 0.077	− 0.025 ± 0.094
	t (p)	0.795 (0.427)	− 0.398 (0.690)	− 0.623 (0.533)	− 0.015 (0.988)	− 0.267 (0.789)
Country (Spain)	$b \pm$ se	− 0.191 ± 0.031	− 0.217 ± 0.082	− 0.208 ± 0.200	− 0.229 ± 0.063	− 0.221 ± 0.082
	t (p)	− 6.226 (< 0.001)	− 2.632 (< 0.008)	− 1.040 (0.298)	− 3.596 (< 0.001)	− 2.766 (< 0.007)
AICc		284.67	170.50	182.89	166.29	166.33

The results show the coefficients of the multiple regression (b ± se) and associated *t* tests

Species occurrence

This study suggests that the European turtle dove is more common in Morocco than in Spain. These differences are supported by both extensive road counts over large areas (see Tellería et al. 2019) and by point sampling carried out in the four study sectors. Under the latter approach, the environmental gradient related to the dry Mediterranean region was positively related to the presence of the dove, a trend that is likely associated with the higher occurrence of the species in drier areas of Morocco. Our results also suggest that increasing habitat complexity had a negligible effect on the occurrence of European turtle dove. This result may reflect the difficulties of choosing sampling points to assess habitat preferences in a bird species that moves within tree-covered areas for nesting and open areas for feeding, tending to avoid the most covered sectors where grass layers tend to be scarce (Table 2; Dias et al. 2013; Sáenz de Buruaga et al. 2013; Hanane 2019). Thus, our findings suggest that the most peripheral population of this species in the south-western limit of the Palaearctic is more abundant than its Spanish counterpart. This pattern does not support the suggested decreasing abundance in the most peripheral populations, where individuals face the limits of their environmental tolerance (Sagarin et al. 2006; Sexton et al. 2009). Our result, which is similar to that reported in other peripheral populations of birds (Boakes et al. 2017), suggests that the differences in the two populations are instead related to other factors associated to each area.

Transboundary effects

The results in this paper indicate that the numerical differences detected between the Spanish and Moroccan populations of the European turtle dove are not related to differences in climate or habitat structure. The niche differences between the two populations are not sufficient to convincingly support the idea that the populations interact with the environment in different ways. Instead, the observed differences in abundance between the two populations could be related to other transboundary differences (Dallimer and Strange 2015; Arrondo et al. 2018), such as the fact that human-induced pressures on this species are particularly pronounced in Spain. In a previous study of the factors affecting raptor distribution in the two countries (Tellería et al. 2019), we found the opposite population trend to that observed here, with higher numbers of raptors in Spain than in Morocco. In that study, we speculated that the reported trends could be related to marked differences in illegal hunting pressure on protected raptors in Morocco, but were not due to any subtle pervasive effect of agricultural intensification (e.g. pesticide use). We supported this idea because, despite the relative scarcity of raptors, Morocco had a higher abundance of bird species (e.g. doves, shrikes, etc.) that are negatively affected by agricultural intensification in Europe (Donald et al. 2006).

In the case of the European turtle dove, it is possible that hunting, agricultural intensification and abandonment of marginal crops could be affecting its abundance in both countries (Balmori 2004; Hanane 2019). The species continues to be actively hunted in many areas of Spain and Morocco (rough estimates suggest that around 150,000 and 900,000 doves are killed annually in Morocco and Spain, respectively; Mansouri et al. 2019, MAPA https://www.mapa.gob.es/). Thus, the observed differences in dove abundance may be related to higher hunting pressure in Spain, which some local studies have described as overhunting (Hidalgo de Trucios and

Rocha 2001). However, it is difficult to assess the effect of hunting on European turtle doves' breeding population sizes in the two countries, because of the poor quality of hunting statistics (Fisher et al. 2018) and because of uncertainties regarding the origin of hunted individuals (i.e. breeding birds or migratory individuals moving from northern areas along this western flyway; Marx et al. 2016).

In addition, it has been reported that agricultural intensification (e.g. landscape homogenisation, use of herbicides and insecticides, etc.) has driven major declines in European birds associated with agricultural areas (Donald et al. 2006; Emmerson et al. 2016; Traba and Morales 2019). This situation is very relevant to the European turtle dove in Spain, where Rocha and Hidalgo de Trucios (2002a) have reported sharp declines of the species in areas where traditional cereal fields have been substituted by intensive farming. Since agriculture in Spain is more intensified than in Morocco (https://data.worldbank.org/), transboundary differences in land use may account for differences in the abundance of some bird species (Tellería et al. 2019). More explicitly, because the European turtle dove relies on weed seeds (Gutiérrez-Galán and Alonso 2016; Gutiérrez-Galán et al. 2019; Mansouri et al. 2019) and food availability seems to affect population recruitment (Rocha and Quillfeldt 2015), it can be postulated that the low abundance in Spain could be related to reduced food availability for farmland birds due to the effects of intensive plough and herbicide use (Traba and Morales 2019). This trend in open fields, together with increasing shrub cover of woodlands within the agricultural matrix, could produce a critical loss of suitable conditions for the species in Spain, since the species avoids closed forests (Dias et al. 2013; Sáenz de Buruaga et al. 2013; Moreno-Zarate et al. 2020). Increasing forest density and undergrowth development related to rural abandonment is a widespread process in Europe (Navarro and Pereira 2015) that is uncommon in Morocco (Tellería et al. 2019).

Finally, competition with the collared dove (*S. decaocto*) has also been postulated as a determinant of the European turtle dove decline (Rocha and Hidalgo de Trucios 2002b). However, stronger evidence of direct competition between the two species is required (Fisher et al. 2018), as differences in nest site selection and poor dietary overlap do not support such an interaction (Dunn et al. 2018). In this context, it is interesting to note that we found a significantly higher abundance of the collared dove in Morocco than in Spain (Tellería et al. 2019). Therefore, at the geographical scale of this study, it does not appear to be a main determinant of cross-border differences in the abundance of European turtle dove. A similar observation can be made about the interactions of the European turtle dove with the laughing dove (*Streptopelia senegalensis*), which has long been a resident breeder in Morocco (Bergier et al. 1999; Hanane et al. 2011; Hanane 2015) and only occurs in Spain in a small number of localities (Gil-Velasco et al. 2019).

Conclusions

The results of this study show that the European turtle dove appears to be more common in Morocco than in Spain. This pattern may be related to a broad array of environmental and biological interactions, and determining the precise factor underlying the observed difference requires further research. However, since the European turtle dove is a game species related to agricultural habitats, the most parsimonious explanation is a transboundary difference in hunting and/or agricultural practices. Thus, any transboundary investigation on these topics within the context of broader approaches (e.g. Fisher et al. 2018) would be useful for preventing the decline (in Morocco) or rebuilding the population (in Spain) of the European turtle dove at the south-western edge of the Palearctic.

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