Modelling European turtle dove (*Streptopelia turtur* L. 1758) distribution in the south eastern Iberian Peninsula

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Abstract
*Modelling European turtle dove (*Streptopelia turtur *L. 1758) distribution in the south eastern Iberian Peninsula.* The European turtle dove population and breeding range has declined sharply in Spain. This study reanalyses data from the Atlas of Breeding Birds in Alicante (SE Spain), aiming to identify the main variables related to its occurrence and abundance. We used hierarchical partitioning analysis to identify important environmental variables associated with natural vegetation, farming, hydrological web, anthropic presence, climate, and topography. Analysis combining the most explicative variables of each group identified the mixture of pines and scrubland in the semiarid areas and the length of unpaved roads as the most important variables with a positive effect on occurrence, while herbaceous crops and scrublands in dry ombrotype climate areas had the most important negative effect. Abundance was related only to the availability of water points. We discuss the implications of these findings for habitat management in conservation of this species.

Key words: Agriculture intensification, Habitat change, Hierarchical partitioning analysis, Pinewood, Population decline, Mediterranean

Resumen
*Elaboración de modelos de la distribución de la tórtola europea (*Streptopelia turtur *L. 1758) en el sureste de la península ibérica*. La población y el área de reproducción de la tórtola europea han disminuido considerablemente en España. En el presente estudio realizamos un nuevo análisis de los datos obtenidos para la elaboración del Atlas de Aves Reproductoras de Alicante (SE de España) con el objetivo de identificar las principales variables relacionadas con la presencia y la abundancia de esta especie. Utilizamos el análisis de partición jerárquica para identificar estas variables ambientales (vegetación natural, agricultura, red hidrológica, presencia antrópica, clima y topografía). El análisis que combinó las variables más explicativas de cada grupo permitió determinar que la mezcla de pinos y matorrales en zonas semiáridas y a lo largo de las carreteras sin asfaltar es la variable que tuvo el mayor efecto positivo en la presencia de la tórtola, mientras que la mezcla de cultivos herbáceos y matorrales en el ombrotipo seco es la que tuvo el mayor efecto negativo. La abundancia solo se relacionó con la disponibilidad de puntos de agua. Se discuten las implicaciones de estos resultados con respecto a la gestión del hábitat para la conservación de esta especie.

Palabras clave: Intensificación de la agricultura, Cambio de hábitat, Análisis de partición jerárquica, Pinar, Disminución de la población, Mediterráneo

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Introduction

The European turtle dove (*Streptopelia turtur)* is a migratory species that winters in the sub–Saharan region but breeds from North Africa to the Urals (Cramp, 1985). As its populations have declined substantially in recent years, particularly in Western Europe (Jiguet, 2016; Harris et al., 2018), it has been classified as threatened (Bird Life International, 2016). Its population trend in Spain has been monitored since 1996 when assessment of populations of common birds began (SEO/BirdLife, 2010). A declining trend has been observed (Saenz de Buruaga et al., 2012), leading the species to be listed as vulnerable in the Red Data Book of Birds of Spain (Madroño et al., 2004).

The main causes of the decline in turtle dove populations are loss of nesting habitat and reduced food availability (Browne et al., 2005). Another cause is unsustainable hunting during the spring migration and the late breeding season (Boutin and Lutz, 2007).

The habitat of European turtle dove is mainly associated with open forests and agricultural environments (Gibbs et al., 2010). These two habitat types have substantially changed in the last decades due to forest closures, land abandonment and intensification of agricultural land (Hanane, 2017). In the Mediterranean region, the European turtle dove prefers a mixture of wooded areas and scrubland close to grassland or farmland (Balmori, 2003). In eastern Spain, orange crops show a widely cover area and breeds in such orchards (Gil–Delgado, 1981). Furthermore, the population of this dove decreases as altitude and tree cover increases (Saenz de Buruaga et al., 2012). In Spain, higher European turtle dove densities have been found in thermo–meso–mediterranean environments, especially in pine forests and on wooded farmlands (Carrascal and Palomino, 2008).

A previous study about land use of European turtle dove throughout mainland Spain found that localities dominated by complex cultivation presented the most favourable trend for this species, while the extensions of several forest types were related to more negative trends (Moreno–Zarate et al., 2020). According to Moreno–Zarate et al. (2020), most of the province of Alicante is located in the area with medium–high favourability in the transition area between meso–mediterranean and thermo–mediterranean zones, and it is currently undergoing major landscape changes driven by increased urbanisation, abandonment of traditional crops, and intensification and irrigation of new crops (Serra et al., 2008; López–Iborra et al., 2011). Therefore, knowing the relationship between occurrence of this dove and habitat characteristics may help understand the causes of the decline of this species in south–east Spain and provide insights into possible management measures that can benefit its conservation. A detailed atlas of breeding birds in Alicante, with birds and habitat data available on the 1 km² scale (López–Iborra et al., 2015), provides the opportunity to identify the main habitat variables that affect the distribution of the European turtle dove. The aim of this paper was to evaluate the relative importance of natural vegetation (forests, shrubland),

crops of several types, and human pressure on the probability of the dove´s occurrence and abundance. These analyses also check for the potential effect of the physical environment (climate, topography, hydrological web) interacting with vegetation anthropogenic structures. However, it is more difficult to analyse the impact of modifications caused by humans. If natural or cultivated vegetation is more important than physical variables in determining the presence or abundance of the European turtle dove, there is greater potential to improve its conservation through habitat management.

Material and methods

Study area

The study area is located in the province of Alicante (SE Spain). This province covers about 5,800 km². It includes mountainous areas in the north and west, and wetlands and plains in the south–eastern and southern sectors. The study area has a semi–arid Mediterranean climate (Rivas–Martinez, 1987). Average annual precipitation varies from 300 to 600 mm, and rainfall is highest in autumn and winter (Rivas–Martinez, 1987). Landscapes are characterised by the dominance of scrub with various levels of development, and by mixtures of scrub and forest areas where Aleppo pines (*Pinus halepensis*) predominate, interspersed with agricultural fields (Rigual, 1972).

Presence and abundance of European turtle dove

The occurrence data came from the surveys conducted for the Atlas of Breeding Birds in the province of Alicante (López–Iborra et al., 2015). The census was conducted in a stratified random sample of 132 2 × 2 km squares defined according to UTM grid and covered approximately 10 % of this province. In each cell of 1 km², a transect of 1 km was walked twice during the breeding season between 2001 and 2004. The species was detected in 147 cells of 1 km² (see López–Iborra et al., 2015 for details).

Predictive variables

Of the available 113 variables (López–Iborra et al., 2015), we selected those of higher biological significance. The number of variables used thus decreased to 25 (table 1). These variables were classified into six groups (López–Iborra et al., 2015): i) size of the natural vegetation area (forest, scrubs, and a mixture of both habitats); ii) agricultural areas; iii) hydrological web (artificial and natural water bodies); iv) topographic variables; v) climate variables; and vi) variables related to human disturbance, such as urbanized surfaces and parks (table 1).

As topography and water availability defined the development of vegetation cover, the forest variables, scrub, and mixtures of the two, were subdivided into ombrotypes (semi–arid, dry, and subhumid), bioclimatic belts (thermo–mediterranean, meso–mediterranean,

Table 1. Environmental variables used as predictors in HP analyses. A more detailed list is found in López–Iborra et al. (2015). The total forest area was the sum of three developmental stages of pine (young, medium, mature), pines associated with other tree crops and new, repopulated pines. Three variables were obtained from the total extent of woody crops: the first was the sum of almond trees (almonds, mixture of almond trees and vineyards, mixture of almond trees and other crops); the second was the total olive area (olive trees, mixture of olive trees and other crops); and the third was the total vineyard areas (vineyard, mixture of vineyards and other crops), citrus crops area, cherry, pomegranate and fig trees. The total area of herbaceous crops consisted of intensive labour on dry land, which may also be associated with tree crops and vineyards, herbaceous crops on irrigated fields, forced crops, and other crops (López–Iborra et al., 2015).

Tabla 1. Variables ambientales utilizadas como predictores en los análisis de partición jerárquica. Para obtener una lista más detallada de las variables, véase López–Iborra et al. (2015). La superficie forestal total se obtuvo de la suma de las fases de desarrollo de los pinos (joven, intermedio y maduro), los pinos asociados a otros cultivos arbóreos y los nuevos pinos de repoblación. De la extensión total de cultivos leñosos se obtuvieron tres variables: la primera fue la suma de almendros (almendros, mezcla de almendros y viñedos, y mezcla de almendros y otros cultivos), la segunda fue la superficie total de olivos (olivos y mezcla de olivos y otros cultivos) y la tercera fue la superficie total de viñedos (viñedos y mezcla de viñedos y otros cultivos) y la superficie de cítricos, cerezos, granados e higueras. La superficie total de cultivos herbáceos comprendió las tierras de secano con labor intensiva, que también pueden estar asociadas a cultivos arbóreos y viñedos, cultivos herbáceos en campos de regadío, cultivos forzados y otros cultivos (López–Iborra et al., 2015).

Variable	Description
Natural vegetation (area in ha, except for diversity indices)	
Scrub	Area covered by any kind of scrub
ScrubPine	Area covered by a mixture of pines and scrub
Forest	Area covered by forest
DivForest	Shannon diversity index for forest types
DivScrub	Shannon diversity index for scrub types
DivScruPines	Shannon diversity index for the scrub–pine mixture
Farming (area in ha, except diversity indices)	
DivWoodCrop	Shannon diversity index for woody crops
DivHerbCrop	Shannon diversity index for herbaceous crops
WoodCrop	Area covered by woody crops
HerbCrop	Area covered by herbaceous crops
Hydrological web	
River	Length (m) of rivers
RavGullies	Summation of length of ravines and gullies
NWB	Summation of water bodies number (pounds and pools)
TotalChan	Length (m) of channels and ditches
Anthropic	
Unproductive	Area covered by unproductive vegetation
IsolHouses	Area (m^2) covered by isolated houses
HousDevel	Area (m^2) covered by housing developments
Urban	Area (m^2) occupied by cities
PavRoad	Length (km) of paved roads
UnPavRoad	Length (km) of unpaved roads
Climate	
OmbrIndex	OmbrothermicIndex
ThermIndex	ThermicityIndex
Topograpphy	
DistCoast	Distance to the coast (km)
AltMean	Average altitude (m)
Slope	Average slope

and supra–mediterranean) and aspect (north, south). Thus 12 types of scrub and 10 mixtures of scrub–pine were obtained and used to calculate the Shannon–Wiener diversity index (Margalef, 1973) in each surveyed cell. The Shannon–Wiener diversity index values calculated for forests, herbaceous cultures and woody crops were obtained from the forest covers and crop types taken from digital land use maps.

Collinearity between the predictive variables was assessed using Pearson's correlation coefficient and collinearity was considered high when $r > 0.7$ (Mason and Perreault, 1991). For instance, pond and pool water bodies correlated highly and were summed to create a new variable: number of water bodies (NWB). The sub–humid thermo–mediterranean scrub on the southern and northern slopes showed a high correlation ($r = 0.89$), and scrubland were taken as a group. The pine–scrub and scrub mixture showed no collinearity. Hence, both variables were used in our analysis. Regarding anthropic variables, as the numbers of isolated houses and their surfaces also correlated ($r = 0.74$) we used the latter (table 1).

Statistical analysis

A hierarchical partitioning (HP) analysis was run to assess the variables that best explained the presence and abundance of European turtle dove. HP is used in ecological studies to identify the environmental variables that are most likely related to the occurrence or abundance of species to control for collinearity with other variables (López–Iborra et al., 2011). HP computes all the possible hierarchical models in a set of independent predictors, and its explicative capacity is divided into the individual effect I of each variable and its joint effect J through other variables (MacNally, 2002). A negative J can be possible for variables that act as suppressors of other variables (Chevan and Sutherland, 1991).

HP was applied separately to dove presence and abundance data. Only the data from the second visit to transects (1 May–15 June) were used because earlier presences could correspond to migrating birds. During this period, the European turtle dove was detected in 126 squares of 1 km². Abundance was analysed only for the presence squares and the number of doves detected in the 1 km transect. Given the limitation in the number of variables that HP can handle (Olea et al., 2010), this analysis was applied in a first step using the variables in each group shown in table 1. Some of the variables of natural vegetation cover (scrub, scrub–pine and forest) and farming (TreeCrop, HerbCrop) are available as more detailed variables according to the degree of pine development, the main crop type or as a result of crossing scrub or scrub–pine cover with the slope orientation, thermotype or ombrotypes (see López–Iborra et al., 2015 for details; table 1s in supplementary material).

To test if it was possible to identify the subtypes of these habitats that are relevant for European turtle dove presence or abundance, HP analyses were also performed for each group with these more detailed variables.

Finally, an HP analysis was performed for each response variable (occurrence or abundance) by combining the variables that were significant in the analysis of each group. As the HP analyses may give rise to some errors when there are more than nine variables (Olea et al., 2010), each analysis was performed with a maximum of eight independent variables, plus a spatial term (see below). For occurrence analyses with more than eight candidate variables for the final analysis, predictors were decreasingly ranked according to their percentage of explained deviance and the eight variables that explained a higher percentage of deviance were used in the final analysis.

Generalized logistic linear models were used for occurrence HP (Jongman et al., 1995). For abundance HP, Poisson regressions were used and pseudo–R^2 as the goodness–of–fit measure (Jongman et al., 1995). A spatial term was included in all the analyses as the probability of occurrence or the abundance predicted by a cubic function of the geographic coordinates ($X+Y+X^2+Y^2+XY+X^3+Y^3+X^2Y+Y^2X$) to control for spatial autocorrelation (Legendre, 1993). The significance of the independent contribution of the environmental variables was obtained by a bootstrap test based on 999 randomisations (MacNally, 2002). Given that HP analysis does not provide information on the sign (positive or negative) of the effect of the independent variables, univariate regressions were carried out with each significant predictor and the spatial term to obtain the regression coefficient and its sign was used to describe the direction of the effect. The 'hier.part' package (Walsh and MacNally, 2015) in the R software (R Core Team, 2018) was used to perform the HP analyses.

Results

Occurrence models

According to the HP analysis of the occurrence data, the group of human pressure variables explained the highest percentage of deviance, followed closely by natural vegetation and farming variables (table 2).

Natural vegetation was the group with most significant variables. This group was disaggregated into seven subgroups that were analysed separately (table 1s in supplementary material). At least one significant variable was identified in all the groups. Variables with a significant positive effect were (variable group between parentheses): Pin_Mid (forest), ScPineS (mixture scrub and pine orientation), ScPineTme (mixture scrub and pine thermotype), ScPineSa (mixture scrub and pine ombrotype). Five significant variables had a negative effect, all relative to types of scrub defined by orientation, thermotype or ombrotype (table 1s in supplementary material). We also disaggregated farming variables into two groups: woody and herbaceous crops. The woody crops HP revealed a positive effect of almond, citrus and other fruiting trees and a negative effect of the cherry orchards. Herbaceous crops HP detected a negative effect of the two categories of this crop type that were not mixed with woody crops (table 1s in supplementary material).

Table 2. Results of the HP analysis of presence and abundance of European turtle dove performed with each group of variables: *I* and *J*, independent and joint effect of each variable in the model, respectively; %I, percentage of the independent contribution of each variable in the group; S, direction of the effect; Zs, Zscore, randomisation test of independent contribution of each variable; %DV, percentage of deviance accounted for by each variable in the group; %Dev, percentage of deviance accounted for a model including all the variables in each group. (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).

Tabla 2. Resultado de los análisis de partición jerárquica de la presencia y la abundancia de la tórtola europea realizado con cada grupo de variables: I y J, efecto independiente y conjunto de cada variable del modelo, respectivamente; %I, porcentaje de contribución independiente de cada variable del grupo; S, dirección del efecto; Zs, Zscore, test de aleatorización de la contribución independiente de cada variable; %DV, porcentaje de desviación explicada por cada variable del grupo; %Dev, porcentaje de desviación explicada por el modelo que incluye todas las variables de cada grupo. (*p < 0,05, **p < 0,01, ***p < 0,001).

| | Presence | | | | | | Abundance | | | | | |
	I	*J*	%I	Zs	S	%DV	*I*	*J*	%I	Zs	S	%DV
Natural vegetation												
Scrub	3.77	2.95	14.62	4.68***	–	1.30	0.00	0.00	0.47	–0.69		
ScrubPines	4.29	3.25	16.67	5.53***	+	1.48	0.01	0.00	5.53	–0.15		
Forest	3.58	–0.44	13.88	4.3***	+	1.23	0.00	0.00	2.07	–0.53		
DivForest	0.03	–0.03	0.13	–0.65		0.01	0.01	0.00	6.58	–0.02		
DivScrub	1.69	1.56	6.54	1.8*	–	0.58	0.00	0.00	1.07	–0.62		
DivScrubPines	2.37	1.90	9.20	2.56**	+	0.82	0.01	0.00	9.07	0.2		
SpatialTerm	10.03	1.05	38.94	14.97***		3.46	0.08	0.01	75.20	6.29***		
%Dev	8.88											
Farming												
DivWoodCrop	0.74	–0.31	3.25	0.3		0.26	0.00	0.00	1.32	–0.64		
DivHerbCrop	0.99	0.97	4.33	0.67		0.34	0.00	0.00	1.72	–0.57		
WoodCrop	4.74	2.07	20.73	6.24***	+	1.63	0.00	0.00	2.39	–0.51		
HerbCrop	8.00	2.29	34.99	10.32***	–	2.76	0.01	0.01	12.62	0.38		
SpatialTerm	8.39	2.69	36.70	10.33***		2.89	0.08	0.01	81.94	5.91***		
%Dev	7.88											
Hydrological web												
River	2.05	–0.13	11.91	1.94*	+	0.71	0.00	0.00	0.48	–0.65		0.09
RavGullies	0.72	–0.06	4.20	0.3		0.25	0.01	0.00	7.66	0.42		1.46
NWB	0.66	0.08	3.85	0.21		0.23	0.04	0.00	28.26	3.22*	+	5.40
TotalChan	2.17	–0.12	12.64	2.24*	–	0.75	0.02	0.00	9.56	0.61		1.83
SpatialTerm	11.57	–0.49	67.40	15.3***		3.99	0.09	0.00	54.04	7.56***		10.32
%Dev	5.92						19.09					
Human pressure												
Unproductive	0.58	0.90	2.19	0.1		0.20	0.00	0.00	3.24	–0.36		
IsolHouses	0.15	–0.08	0.57	–0.55		0.05	0.01	0.00	9.86	0.29		
HousDevel	2.06	1.78	7.72	1.7*	–	0.71	0.00	0.00	0.34	–0.63		
Urban	0.09	0.14	0.35	–0.62		0.03	0.01	0.00	4.71	–0.21		
PavRoad	2.53	0.72	9.50	2.71**	–	0.87	0.00	0.00	2.05	–0.47		
UnPavRoad	12.25	0.03	45.97	18***	+	4.22	0.00	0.00	2.92	–0.41		
SpatialTerm	8.98	2.10	33.70	10.61***		3.10	0.09	0.00	76.89	8.19***		
%Dev	9.19											

Table 2. (Cont.)

	Presence						Abundance					
	I	J	%I	Zs	S	%DV	I	J	%I	Zs	S	%DV
Climate												
OmbrIndex	0.63	0.75	4.82	0.23		0.22	0.01	0.00	9.87	0.2		1.28
ThermIndex	2.56	1.16	19.44	2.95**	+	0.88	0.03	0.02	27.86	2.01*	+	3.60
SpatialTerm	9.97	1.11	75.74	14.57***		3.44	0.07	0.02	62.27	5.09***		8.04
%Dev	4.54						12.92					
Topography												
DistCoast	0.71	0.79	5.32	0.26		0.24	0.01	0.01	5.48	–0.2		0.67
AltMean	2.41	1.05	18.10	2.56**	–	0.83	0.03	0.02	30.25	2.08*	–	3.71
Slope	0.36	–0.35	2.69	–0.21		0.12	0.00	0.00	3.12	–0.46		0.38
SpatialTerm	9.84	1.25	73.89	11.97***		3.39	0.06	0.02	61.14	5.74***		7.50
% Dev	4.59						12.26					

In the final model, which included the best variables from all the groups, the predictor with the highest independent contribution was scrub–pine mixture in the semi–arid (ScPineSa), with a positive effect. Furthermore, the cover of forests, woody crops and length of unpaved roads also had a positive effect, while herbaceous crops and dry scrublands had a negative influence (table 3).

Abundance models

Three variables were found to have a significant effect on abundance. NWB and the thermicity index had a significant positive effect, while altitude had a negative effect (table 2). When these three variables were analysed jointly in the final model, only NWB had a significant positive effect (table 3).

Discussion

We evaluated the habitat variables that could explain the occurrence and abundance of the European turtle dove in the province of Alicante. The groups of variables that explained a higher proportion of deviance in the occurrence analysis were natural vegetation, farming, and human pressure, while the most important groups in analyses of abundance were hydrological web, climate and topography.

When considering the natural vegetation variables, the models for presence found that European turtle dove was associated with pine woods in an intermediate development stage. The mixture of scrubs and pines had a positive significant effect only on southern slopes and for a thermo–mediterranean and semiarid climate. This agreed with the results found by Saenz de Buruaga et al. (2012) in the Basque Country (north-

ern Spain), where this dove has been associated with patches of trees and scrublands. In countries such as the UK and Greece, this species prefers forest covered by medium–sized trees and abundant shrub vegetation (Browne et al., 2005; Bakaloudis et al., 2009). These results agree with studies proposing that its presence is limited by the availability of the resources that the habitat can provide for nesting (Browne et al., 2004). Our analyses also agree with other studies that identified a preference for a landscape covered by medium–aged pines (Bakaloudis et al. 2009; Hanane and Yassin, 2017).

In Alicante, the European turtle dove also selects sunny spaces to breed, as found in studies in other countries (Browne et al., 2005; Bakaloudis et al., 2009). In Morocco, this species of dove shows a preference for Thuya forest (*Tetraclinis articulata*), an environment that is characterised by high temperatures and less precipitation (Hanane and Yassin, 2017).

The length of unpaved roads is a positively selected variable that is related to the degree of human modification of the territory. This variable showed the highest independent contribution among the human pressure variables and presents the second contribution in the final analysis. The positive effect of this variable can be explained by the abundance of ruderal plant species that may be consumed by European turtle doves (Dunn and Morris, 2012; Gutiérrez–Galán and Alonso, 2016; Cramp, 1985; Browne and Aebischer, 2003) along edges of unpaved roads. This variable was included in the analysis as a measure of human impact and was expected to have a negative effect, but our analysis revealed that it had a positive effect. This can be explained if edges with ruderal species have disappeared from other places in cultivated areas owing to modern farming techniques, but remain mainly along unpaved roads.

Table 3. Results of the HP analysis for presence and abundance of European turtle dove performed with the selection of the most explicative variables from all groups. (For abbreviations, see tables 1 and 2).

Tabla 3. Resultado del análisis de partición jerárquica de la presencia y la abundancia de la tórtola europea realizado con la selección de las variables más explicativas de cada grupo. (Para las abreviaturas, véanse tablas 1 y 2)

	Presence							Abundance					
Variable	I	J	%I	Zs	S	%DV	Variable	I	J	%I	Zs	S	%DV
ScrubDry	8.49	5.27	14.73	11.15***	–	2.92	NWB	0.04	0.01	27.66	2.68**	+	4.48
UnPavRoad	9.85	2.43	17.10	12.85***	+	3.39	AltMean	0.02	0.03	16.17	1.32		2.62
ScPineSa	11.80	–1.06	20.49	15.87***	+	4.07	ThermIndex	0.02	0.03	12.71	0.85		2.06
HerbCrop	9.75	0.53	16.93	11.67***	–	3.36	SpatialTerm	0.06	0.02	43.46	4.8***		7.04
WoodCrop	3.74	3.07	6.49	4.39***	+	1.29	%Dev	16.19					
Forest	4.86	–1.73	8.44	6.08***	+	1.68							
AltMean	1.78	1.68	3.09	1.61		0.61							
River	1.12	0.79	1.95	0.84		0.39							
SpatialTerm	6.20	4.88	10.77	7.59***		2.14							
%Dev	19.85												

Length of rivers was significantly and positively related to the presence of the European turtle dove only when this variable was analysed with the hydrological web variables. It was not significant in the final analysis, where it was the least important variable. This positive effect therefore seems to be explained by the vegetation associated with rivers rather than by the presence of water itself (Saenz de Buruaga et al., 2012).

Apart from the aforementioned unpaved roads, the human pressure variables contain two other variables (HousDevel and PavRoad) but both have a significantly negative effect. However, this effect was weak and these variables were not selected for the final analysis. These results suggest that the species can tolerate the presence of scattered houses and paved roads to a certain extent provided that the surrounding vegetation is suitable. Mason and Macdonald (2000) found that its presence in the UK was associated with residential areas.

European turtle doves only use crops with trees (Gil–Delgado, 1981; Carrascal and Palomino, 2008; Hanane and Baamal, 2011). Thus, herbaceous crops have a negative impact on its probability of presence. Within woody crops, orchards of almonds and citrus and other fruiting trees groves have a positive effect on its presence. Cherry tree orchards, with a reduced distribution limited to some mountainous areas in this province, appear to have a negative effect. Dry and irrigated tree crops are known to be positively selected by the species throughout its distribution (Antón–Recasens, 2004; Gil–Delgado, 1981; Hanane and Baamal, 2011) because they offer both food and potential nesting places. Thus, it was surprising to find that the effect of olive groves was not detected. This might be explained by the fact that in our study area olive trees are mostly grown in small groves in the midst of other crops that cover a larger extension.

For abundance, the analyses of groups of variables revealed a potentially positive effect of the thermicity index and NWB, along with a negative effect of altitude. However, the combined analysis of these variables indicated that only NWB presented a significant contribution. Doves need proximity to water to avoid dehydration and weight loss (Bartholomew and Macmillen 1960; Macmillen 1962; Willoughby 1966; McKechnie et al., 2016), which may explain the positive effect of NWB, and thus the presence of water bodies should favour its populations.

Today, the European turtle dove shows a generalised population decline in the Western Palearctic (Dias et al., 2013; Hanane, 2017). The habitat effects revealed by this and other studies may be useful for developing measures to mitigate its decline. Our results point out that the vegetation types present are the main determinants of the probability of this turtle dove being found in a Mediterranean province whose climate is mostly semiarid. The species is most likely to be present in mosaics of Aleppo pines and scrub, mid–sized pines and orchards. Thus, the conservation of this kind of landscape would contribute to maintaining appropriate habitats for this species. The European turtle dove seems relatively tolerant to disturbances caused by scattered houses and paved roads, and even seems to benefit from the presence of unpaved roads. The most negative effect is caused by pure scrub cover areas and herbaceous crops. These results suggest that management may contri-

bute to significantly improve habitat quality for these turtle doves. Despite forest fires, forests are growing in Spain and Alicante. Forest expansion occurs in some places in this province at the expense of tree orchards on terraces. Thus, substituting orchard crops for pines may generate a suitable habitat for the dove at early or intermediate phases, when trees are half grown, but they would be unsuitable when the trees are mature. In lowlands, abandoned orchards are substituted by scrubland that this is unsuitable for the European turtle dove. This implies that their survival in such areas would depend on the length of survival of the abandoned crop.

Acknowledgements

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Supplementary material

Table 1s. Results of the HP analysis performed with several groups of subtypes of selected variables of Table 1. Forest group include the following variables: Pin_TreeCrop, pines associated with tree crops; Pin_Mid, medium–sized pines; Pin_Young, young pines; Pin_Mat, mature pines; Pin_Repl, pine repopulation. Types of scrub and types of scrub/pine mixture were defined according to aspect (north, south), ombrotype (Sa, semiarid; dry; Subh, subhumid) and bioclimatic belts (Tme, thermo–mediterranean; Mme, meso–mediterranean; Sme, supra–mediterranean). Woody crops include: Almond, total sum of almond trees, almond trees with other crops, and almond trees with vines; Citrus, orange and lemon trees; Pome_Figs, sum of area with pomegranate or fig trees; Olive, sum of area with olive trees and olive trees with other crops; Vineyard, sum of area with vineyards and vineyards with other crops; OtherFru, other fruiting trees not included in above categories; Cherry and Palm, area covered by orchards with these species. Herbaceous crops include: IntenLab, intensive labour, mainly cereal, in dry land; IntenLab_TC, intensive labour associated with tree crops; IntenLab_Viney, intensive labour associated with vineyards; HerbCrop, herbaceous crops on irrigated lands; HerbCrop_OC, herbaceous crops associated with other crop types; HerbCropFor, forced herbaceus crop; %DV, percentage of deviance accounted for by each variable inthe group; %Dev, percentage of deviance accounted for a model including all the variables in each group. (*p < 0.05, **p < 0.01, ***p < 0.001). (For other abbreviations, see tables 1 and 2).

*Tabla 1s. Resultados del análisis de partición jerárquica realizado con varios grupos de subtipos de variables seleccionadas de la tabla 1. El grupo forestal incluye las siguientes variables: Pin_TreeCrop, pinos asociados a cultivos arbóreos; Pin_Mid, pinos de tamaño medio; Pin_Young, pinos jóvenes; Pin_Mat, pinos maduros; Pin_Repl, pinos de repoblación. Los tipos de matorral y de mezcla de matorral y pino se definieron según su orientación (norte o sur), ombrotipo (Sa, semiárido; Dry, seco; Subh, subhúmedo) y piso bioclimático (Tme, termomediterráneo; Mme, mesomediterráneo; Sme, supramediterráneo). Los cultivos leñosos incluyen: Almond, suma total de almendros, almendros con otros cultivos y almendros con viñedos; Citrus, limoneros y naranjos; Pome_Figs, superficie total de granados e higueras; Olive, superficie total de olivos y olivos con otros cultivos; Vineyard, superficie total de viñedos y viñedos con otros cultivos; OtherFrut, árboles frutales no incluidos en las categorías anteriores; Cherry y Palms, cultivos de cerezo y palmeras. Los cultivos herbáceos incluyen: IntenLab, labor intensiva, principalmente cereal, en secano; IntenLab_TC, labor intensiva asociada a cultivos arbóreos; IntenLab_Viney, labor intensiva asociada a viñedos; HerbCrop, cultivos herbáceos de regadío; HerbCrop_OC, cultivos herbáceos asociados a otros tipos de cultivos; HerbCropFor, cultivos herbáceos forzados; %DV, porcentaje de desviación explicada por cada variable del grupo; %Dev, porcentaje de desviación explicada por el modelo que incluye todas las variables de cada grupo. (*p < 0,05, **p < 0,01, ***p < 0,001). (Para otras abreviaturas veáse tablas 1 y 2).*

Variable	I	J	%I	Zs	S	%DV
Forest						
Pin_TreeCrop	0.26	−0.11	1.60	−0.65		0.09
Pin_Mid	3.98	−0.68	24.08	5.07***	+	1.37
Pin_Young	0.02	0.00	0.13	−0.67		0.01
Pin_Mat	0.30	−0.22	1.82	−0.28		0.10
Pin_Repl	0.10	0.02	0.59	−0.59		0.03
SpatialTerm	11.88	−0.79	71.78	14.94***		4.09
%Dev	5.70					
Scrub orientation						
ScrubS	3.05	1.53	17.00	3.67***	−	1.05
ScrubN	4.04	1.57	22.47	5.45***	−	1.39
SpatialTerm	10.87	0.21	60.53	14.76***		3.75
%Dev	6.19					

Table 1s. (Cont.)

Variable	I	J	%I	Zs	S	%DV
Scrub thermotype						
ScrubMme	6.62	0.74	28.02	9.16***	–	2.28
ScrubTme	0.08	−0.02	0.32	−0.6		0.03
ScrubSme	6.16	0.27	26.07	6.73***	–	2.12
SpatialTerm	10.77	0.31	45.59	14.33***		3.71
%Dev	8.14					
Scrub ombrotype						
ScrubSa	0.34	−0.34	1.38	−0.25		0.12
ScrubDry	13.56	0.20	54.66	17.5***	–	4.67
ScrubSubh	0.21	0.04	0.84	−0.41		0.07
SpatialTerm	10.70	0.38	43.13	15.61***		3.69
%Dev	8.55					
Mixture scrub and pine orientation						
ScPineS	5.63	1.81	34.22	7.04***	+	1.94
ScPineN	1.07	1.30	6.52	0.74		0.37
SpatialTerm	9.76	1.32	59.26	14.19***		3.36
%Dev	5.67					
Mixture Sscrub and pine thermotype						
ScPineSme	0.09	0.03	0.61	−0.71		0.03
ScPineMme	0.24	0.10	1.66	−0.41		0.08
ScPineTme	4.32	1.26	30.06	5.07***	+	1.49
SpatialTerm	9.71	1.37	67.67	12.92***		3.35
%Dev	4.95					
Mixture scrub and pine ombrotype						
ScPineSa	8.97	1.76	47.53	11.83***	+	3.09
ScPineDry	0.47	0.18	2.50	−0.06		0.16
SpatialTerm	9.43	1.65	49.97	12.3***		3.25
%Dev	6.51					
Woody crops						
Almond	4.09	0.19	17.00	5.2***	+	1.41
Cherry	2.20	−0.28	9.13	1.7**	–	0.76
Citrus	3.03	0.92	12.58	3.24***	+	1.04
Pome_Figs	0.04	−0.04	0.18	−0.7		0.01
Olive	1.50	1.00	6.23	1.37		0.52
OtherFrut	2.92	−0.88	12.10	3.31***	+	1.00
Palms	1.78	0.15	7.38	1.16		0.61
Vineyard	0.24	−0.01	1.00	−0.36		0.08
SpatialTerm	8.29	2.80	34.40	11.67***		2.86
%Dev	8.30					

Table 1s. (Cont.)

Variable	I	J	%I	Zs	S	%DV
HerbaceousCrops						
HerbCrop	5.05	0.36	26.25	6.68***	–	1.74
HerbCrop_OC	0.48	–0.23	2.51	–0.09		0.17
HerbCropFor	0.67	0.10	3.50	0.01		0.23
IntenLab_TC	0.04	–0.04	0.19	–0.66		0.01
IntenLab_Viney	0.02	0.01	0.09	–0.81		0.01
IntenLab	3.61	1.27	18.78	3.82***	–	1.25
SpatialTerm	9.37	1.71	48.68	12.9***		3.23
%Dev						