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Urban landscape selection by Eurasian collared dove (*Streptopelia decaocto*) in eastern Spain

Selección del paisaje urbano de la tórtola turca (*Streptopelia decaocto*) en el este de España

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ABSTRACT

The Eurasian collared dove (*Streptopelia decaocto*) is an invasive species, and its distribution is continuously on the increase. Today its expansion has spread to the American continent. In this study we describe the effects of the urban environment on the Eurasian collared dove in eastern Spain. The abundance and presence of this dove were analyzed in 46 localities using counting points. Overall, 220-point counts were surveyed between autumn 2015 and late-winter 2016. A hierarchical partitioning analysis was used to identify explanatory variables of different types such as resources, climate and urban structure, and human presence, which may influence the presence and abundance of this species. In the case of presence, the number of town inhabitants, parks, mean minimum temperature, exotic vegetation and schools had a positive association, while pedestrian number and restaurants had a negative association. Abundance was positively related to native vegetation, exotic vegetation, and water, while urban area was negatively associated with it. Exotic vegetation was the only variable that has a positive relation to presence and abundance. These results can help to predict the use of urban habitats in potential localities for its invasion.

Keywords. Distribution expansion, habitat selection, parks, urbanization

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RESUMEN

La tórtola turca (*Streptopelia decaocto*) es una especie invasora y su ámbito de distribución aumenta continuamente. Hoy en día, su expansión incluye el continente americano. En este estudio se describen los efectos que el ambiente urbano tiene sobre la tórtola turca en el este de España. Se muestrearon 46 localidades mediante puntos de conteo. La abundancia de la tórtola turca fue evaluada en 220 puntos de conteo entre otoño de 2015 y finales de invierno 2016. Se utilizó el análisis de partición jerárquica para identificar variables explicativas como recursos, clima y estructura urbana, y presencia humana, que pueden influir en su presencia y abundancia. En el caso de la presencia de la especie, el número de habitantes de la ciudad, parques, temperatura media, vegetación exótica y colegios tuvieron una asociación positiva, mientras que el número de peatones y los restaurantes estuvieron negativamente asociados. La abundancia estuvo positivamente relacionada con la vegetación nativa, vegetación exótica y el agua, mientras que la zona urbana estuvo negativamente asociada. Estos resultados pueden predecir el uso de hábitats urbanos en localidades potenciales para su invasión.

Palabras clave. Expansión de distribución, parques, selección de hábitat, urbanización

INTRODUCTION

The extent of urban areas is increasing worldwide and most of the human population now lives in towns and cities (Johnson and Munshi-South 2017). Urbanization has a strong impact on natural habitats and resources (Murgui and Hedblom 2017), and such impact can have effects on not only species distribution and abundance, but also on the composition of biological communities (Lancaster and Rees 1979, Dowd 1992). For instance, the introduction of tree brown snake (*Boiga irregularis*) was responsible for forest bird extinction on Guam Island (Savidge 1987); and the release of pig, black rat and other species on islands have had a negative effect on endemic species (Blackburn *et al.* 2009, Donald *et al.* 2010).

Urban populations are expected to rapidly grow in the future (United Nations Organization c2012), and this trend suggests that their activities will substantially transform natural habitats to meet a growing population's demands with a higher levels of resources consumption (Hutton and Leader-Williams 2003). Therefore, the emergence of new small urban areas, near big towns and cities, would be an ideal environment to facilitate the expansion of the Eurasian collared dove (*Streptopelia decaocto*). This species came from South-Western Asia (Baptista *et al.* 1997) and has expanded through Europe due to anthropic corridors that facilitate invasions according to processes that have been known for more than 40 years (Udvardy 1969, Blackburn *et al.* 2009). Climate and biogeographic changes have also been proved to play a role in the expansion of this species (Ziska and Dukes 2014). For example, at the beginning of the twentieth century in Europe, increased rainfall weakened the North Balkan barrier and opened the way for the Eurasian collared-dove to expand from Turkey (Bernis *et al.* 1985) and its spread since the 1930s (Hengeveld and Van den Bosch 1991).

This species is one of the most successful invasive birds for its ability to travel long distances, and also due to its multi-brooding behavior (Bernis *et al.* 1985). It is believed to have arrived in the Iberian Peninsula from France (Bernis *et al.* 1985). In Spain, the first individuals were observed in Asturias in 1960, and rapidly spread along the Cantabrian coast by crossing the central part of the Spain and eventually colonizing the Mediterranean coast (Rocha-Camarero and de Trucios 2002). It has recently colonized North America (Hengeveld 1993, Fujisaki *et al.* 2010), and it has been postulated that this species expansion will continue in this continent, including Central and South America (Romagosa and Labisky 2000, Fujisaki *et al.* 2010).

The link between the Eurasian collared-dove and urban areas has been known for centuries (Hengeveld 1993, Romagosa and Labisky 2000). However, studies about its preferences in urban landscapes are scarce. In Great Britain, the Eurasian collared-dove is linked to populated zones, especially parks with trees of the genus *Pinus*, which provide food resources (Coombs *et al.* 1981). This species avoids areas where intensive agriculture takes place (Hudson 1972) but, in Spain, it inhabits other environments, such as the dehesas. Spanish dehesas are wooded open savannas where the main tree species are the holm oak evergreen tree (*Quercus ilex*) and cork oak tree (*Quercus suber*). This habitat is used by domestic herds (Rocha-Camarero and de Trucios 2002, Gaspar *et al.* 2009, Oviedo *et al.* 2013).

Analyzing the characteristics of the urban landscape used by this species would be useful to determine which factors influence the presence and abundance of the Eurasian collared dove in colonized towns and cities of Europe. Given the prediction that this species will keep expanding, this study aims to determine the most important factors that could favor Eurasian collared-dove expansion in its non-native environment. At the same time, we discuss the Eurasian collared-dove's microhabitat preferences in anthropic areas that, to our knowledge, have been poorly studied.

MATERIAL AND METHODS

The study was carried out in 46 localities within the geographical framework of the Valencia Region in eastern Spain (37º51' - 40º47' North and 02º09' West - 04º12' East; Table 1; Fig. 1), which occupies the central sector of eastern Iberian Peninsula and covers an area of 23,255 km² (Murgui 2001, Aguilella *et al.* 2010).

The abundance and presence of the dove were determined using point counts in urban and periurban areas of the 46 pre-selected localities. Then, for five minutes after a one-minute settlement period, Eurasian collared-doves were counted once in 220-point counts without regarding distance. This number of point counts was randomly distributed in the set of localities according to their area and human population (Table 1). The distance between count points was at least 200 m. Counting periods started at sunrise and lasted for 3 h. Birds were recorded by both sight and sound (Hutto *et al.* 1986, Kasprzykowski and Goławski 2009). These point counts were carried out from autumn 2015 to late winter 2016 (before the 2016 breeding season) by one observer per point count. Point counts were carried out by four independent observers who followed the same census protocol (Table 1).

Table 1. Demographic (INE c2016), geographic (SigPac c2016), and climate (WCD c2016) information of the 46 selected localities of Eastern Spain to study the presence and abundance of the Eurasian collared-dove. Observers were: Alan Bermúdez (AB), José Antonio Gil-Delgado (JGD), Edgar Bernat (EB), Iván Rodríguez (I).

Locality	Total Point Counts (observer)	Altitude (m)	Area (Km²)	Number of inhabitants	Mean minimum annual temperature (°C)	Average annual precipitation (mm)	Survey zone
1. Devesa*	2 (AB)	0	0.21	0	7	427	Periurban
2. El Saler	2 (AB)	3	8.2	1699	7	427	Urban
3. Muntanyeta dels Sants	3 (AB; JGD)	27	0.1	0	7	427	Periurban
4. Vinarós	7 (JGD)	7	95.5	28190	5.7	515	Urban/Periurban
5. Morella *	4 (JGD)	984	413.5	2575	0	570	Urban
6. Villores*	2 (JGD)	661	5.3	37	0.5	516	Urban
7. Forcall*	3 (JGD)	699	39.2	476	1.2	497	Urban
8. Sant Mateu	5 (JGD)	322	64.6	1995	3.9	518	Urban/Periurban
9. L'Eliana	6 (JGD)	93	8.8	17436	6.1	433	Urban/Periurban
10. Pobla de Vallbona	7 (JGD)	102	33.1	22994	6	424	Urban/Periurban
11. Liria	7 (JGD)	164	228	22745	5.5	424	Urban/Periurban
12. Onil	5 (EB)	697	48.4	7548	2.3	480	Urban/Periurban

(*Continued*)

Table 1. Demographic (INE c2016), geographic (SigPac c2016), and climate (WCD c2016) information of the 46 selected localities of Eastern Spain to study the presence and abundance of the Eurasian collared-dove. Observers were: Alan Bermúdez (AB), José Antonio Gil-Delgado (JGD), Edgar Bernat (EB), Iván Rodríguez (I)..

Locality	Total Point Counts (observer)	Altitude (m)	Area (Km^2)	Number of inhabitants	Mean minimum annual temperature (°C)	Average annual precipitation (mm)	Survey zone
13. Benilloba	3 (EB)	520	9.5	786	3.4	508	Periurban
14. Banyeres	5 (EB)	816	50.3	7155	1.6	519	Urban/Periurban
15. Alcoi	8 (EB)	562	129.9	59567	3.2	493	Urban/Periurban
16. Cocentaina	6 (EB)	430	52.9	11406	3.9	480	Urban/Periurban
17. Chiva*	6 (AB; JGD)	270	178.7	15004	4.5	429	Urban
18. Utiel	6 (AB; JGD)	720	236.9	11915	1.1	438	Urban/Periurban
19. Requena	7 (AB; JGD)	692	814.2	20621	1.7	437	Urban/Periurban
20. Titaguas*	3 (AB; JGD)	720	63.2	473	0.6	446	Urban
21. Chelva	4 (AB; JGD)	475	190.6	1446	3	401	Urban
22. Losa del Obispo	3 (AB; JGD)	520	12.2	502	3.6	409	Urban/Periurban
23. Burjassot	8 (AB)	59	3.4	37546	6.7	442	Urban/Periurban
24. Torrent	9 (AB)	49	69.3	80107	6.5	440	Urban/Periurban
25. Valencia	16 (AB)	15	136.4	786189	6.8	445	Urban
26. Viver	4 (I)	559	49.9	1558	2.8	450	Urban/Periurban
27. Pina de Montalgrao*	2 (I)	1039	31.6	129	0	522	Urban/Periurban
28. Barracas*	2 (I)	981	42.2	181	0.1	507	Urban/Periurban
29. Azuébar*	2 (I)	298	23.4	325	4.8	453	Urban/Periurban
30. Chóvar*	2 (I)	415	18.3	327	3.8	483	Urban/Periurban
31. Aín*	2 (I)	498	12.3	131	3.5	480	Urban/Periurban
32. Altura	4 (I)	391	129.5	3647	4	446	Urban/Periurban
33. Segorbe	5 (I)	368	106.1	9073	4.2	441	Urban/Periurban
34. Port Sagunt	5 (AB; JGD)	0	3.61	40842	6.4	441	Urban
35. Sagunt	3 (AB; JGD)	49	132.4	64944	6.4	441	Urban
36. Canet de Berenguer	5 (AB; JGD)	10	38	6426	6.7	441	Urban/Periurban
37. Canals	6 (JGD)	160	21.8	13628	5.4	426	Urban/Periurban
38. Navarres	4 (JGD)	275	47	3104	4.6	433	Urban/Periurban
39. Sumacárcer*	4 (JGD)	45	20.1	1168	5.9	408	Urban/Periurban
40. Xàtiva	7 (JGD)	115	76.6	29095	5.8	431	Urban/Periurban
41. Quesa	3 (JGD)	200	73.2	690	5	412	Urban/Periurban
42. Vallada*	4 (JGD)	300	61.5	3121	4.5	421	Urban/Periurban
43. Faura	4 (AB; JGD)	27	1.2	3477	6.5	433	Urban/Periurban
44. Benavites	3 (AB; JGD)	36	4.3	626	6.5	435	Urban/Periurban
45. Benicarló	7 (AB; JGD)	21	47.9	26403	5.7	508	Urban/Periurban
46. Peñíscola	5 (AB; JGD)	46	79	7444	5.9	499	Urban/Periurban

***Localities with no presence of the Eurasian collared-dove**

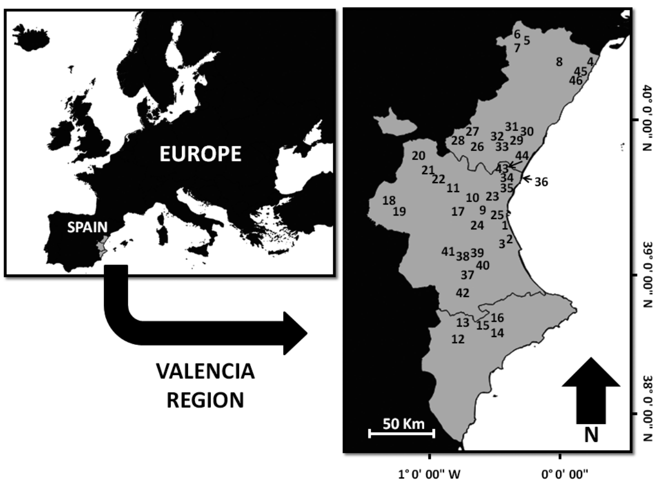

Figure 1. Sampled localities to study the urban landscape selection of the Eurasian collared dove in eastern Spain. Numbers correspond to the localities identity found in Table 1.

The geographical coordinates and altitude of each point count were obtained from SigPac (SigPac c2016), while mean minimum temperature and rainfall were obtained from World Climate Data (WCD c2016). The area and human population of each locality were obtained from the Spanish National Statistics Office (INE c2016).

Two types of areas in towns and cities were sampled based on type of buildings, traffic and pedestrian traffic. Urban areas were characterized by the presence of commercial and residential buildings with more than five floors, public green areas and continuous traffic (vehicles and pedestrians), while periurban areas were composed of detached and semidetached residential houses with private gardens, less traffic where vehicles and pedestrians are more occasional (Supplementary Material Photography 1).

Eighteen explanatory variables were estimated within a 50-meter radius from the point counts to detect those factors with a positive or negative association with the presence and abundance of the Eurasian collared-dove. Explanatory variables were grouped into three categories: resources, climate and urban structure, and human presence (Table 2).

Statistical analysis

Hierarchical partitioning (HP) analysis (Walsh and Mac Nally c2015) was used to assess the variables that best explained the presence and abundance of Eurasian collared doves. HP is used in ecological analysis to find environmental key factors for the presence or abundance of species (López-Iborra *et al.* 2011; Bernat-Ponce *et al.* 2018). HP fits all the possible regression models for a group of predictor variables, and estimates the independent effect (I) of each predictor on the response variable and percentage (I %) of the total I of the variable group (Chevan and Sutherland 1991, Mac Nally 2000, Quinn and Keough 2002). This work applied logistic regression and log-likelihood as goodness-of-fit measures for presence HP. For abundance data HP, Poisson regressions were used and R^2 as the goodness-of-fit measure (Jongman *et al.* 1995). In both cases, the significance of effects was determined with 999 randomizations (Mac Nally 2002). For a significant contribution of the variable, the observed I had to be over the 95 percentile with Z-scores ≥ 1.64 (Hallstan *et al.* 2010). HP analyses were carried out using the "hier part" package (Walsh and Mac Nally c2015) in RStudio 3.5.1 (RStudio Team c2018).

A separate HP was performed for each group of variables. Then an HP analysis was performed which included the variables that were significant in the analyses per group. Since all groups included less than nine variables, HP analysis were not affected by the errors produced when more variables were analyzed (Walsh and Mac Nally c2015). The abundance HP analysis only included those localities (n = 33 localities: 119-point counts) with the presence of Eurasian collared-dove. A spatial term was included in all the models as a cubic function of the coordinates to control the effect of spatial autocorrelation (Legendre 1993). The directionality of the effect of each variable was obtained from univariate logistic or Poisson regression for the presence or abundance models, respectively.

To detect multicollinearity, the variance inflation factor (VIF) in each variable group was calculated using the 'vif' function of the package 'car' (Fox and Weisberg 2019). Multicollinearity was considered high when VIF > 5 (Zuur *et al.* 2010). Altitude and mean minimum annual temperature correlated highly (VIF > 5) in the presence and abundance analyses and, consequently, altitude was not included in the HP analyses. Considering that mean minimum annual temperature was not the same at the same altitude at different latitudes, we believed that it had more biological sense to include temperature in the analyses.

RESULTS

The species was detected in 33 out of 46 of the studied localities and 54.1 % of point counts (n = 220). The number

Table 2. Variables used in habitat description, included in the hierarchical partitioning analysis. The code names used in Table 3 are in brackets.

Category	Variable
Resources	Presence/absence of parks (Parks)
	Presence/absence of fountain water (Water)
	Presence/absence of restaurants (Restaurants)
	Presence/absence of schools (Schools)
	Presence/absence of roundabouts (Roundabouts)
	Presence/absence of native vegetation (shrubs/trees) (NatVeg)
	Presence/absence of exotic vegetation (shrubs/trees) (ExVeg)
	Presence/absence of crops (Crops)
Climate and urban structure	Altitude above sea level (m) (Altitude)
	Urban/suburban area (Urban area)
	Town surface (km^2) (Surface)
	Mean minimum annual temperature (°C) (Temperature)
	Mean annual precipitation (mm) (Precipitation)
	Average number of floors of the eight closest buildings to the point count (Buildings)
Human presence	Average number of pedestrians entering the evaluation radius per minute (Pedestrians)
	Average number of vehicles entering the evaluation radius per minute (Traffic)
	Number of inhabitants in the town (Inhabitants)
	Number of cars parked in the evaluation radius (ParkedCars)

of Eurasian collared doves counted in points with presence ranged between 0 and 36.

The HP analysis showed that at least one variable in each group had a significant positive association with the presence of the Eurasian collared dove (Table 3). The presence HP analysis showed in the resources group that the positive and significant variables were parks, schools, and exotic vegetation. In the climate and urban structure group, only mean minimum annual temperature had a positive and significant relation. In the human factors group, town/city population was the only significant and positive variable. Of all the analyses, only restaurant presence (resources), and pedestrian traffic (human presence) had a negative and significant relation (Table 3). The combined HP analysis revealed that seven variables and the spatial term were significant. Apart from the spatial term, population in towns/cities and park presence explained approximately the 30 % of the deviance on the presence of Eurasian collared dove (Table 4). Exotic vegetation and restaurants had relatively small but significant contributions according to their results in final model.

The same analysis in relation to abundance identified three significant variables with positive associations with the Eurasian collared dove in the resources group (water, native vegetation, exotic vegetation) (Table 3). The urban area variable (climate and urban structure) was negative (Table 3) while the variables related with the human presence group had not effect on the abundance of Eurasian collared-dove. The final combined HP showed that exotic and native vegetation gave the highest independent contributions and together explained 35 % in deviance (Table 4).

DISCUSSION

In our study area Eurasian collared-doves inhabit urban and periurban landscapes, which agrees with previous studies in other countries (Coombs *et al.* 1981, Cramp 1985, Hengeveld 1993, Blair 1996, Romagosa and Labisky 2000). Further, it has a clear preference for green areas, such as parks and urban areas with native and exotic vegetation. This preference can be explained by the species nesting in trees and feeding especially on the ground

Table 3. Results of the hierarchical partitioning analysis performed for each group of variables with the presence and abundance data of Eurasian collared dove in eastern Spain. Individual contributions of variables to explain response variables are expressed as %I. Significant contributions (*p*<0.05) are indicated by *. The directions of the relation are shown only for the significant variables.

	Presence				Abundance			
Variable	I	%I	Z.score	Direction	I	%I	Z.score	Direction
				Resources				
Parks	5.26	13.87	6.89***	+	0.02	5.22	0.68	
Restaurants	3.56	9.38	3.65***	-	0.02	6.71	0.94	
Water	0.24	0.62	-0.44		0.05	16.05	3.72***	+
Schools	4.44	11.71	5.25***	+	0.002	0.65	-0.53	
Roundabouts	0.14	0.36	-0.49		0.01	1.80	-0.19	
NatVeg	1.56	4.11	1.46		0.05	17.07	3.85***	+
ExVeg	3.42	9.01	3.62***	+	0.05	16.68	3.52***	+
Crops	0.57	1.52	0.06		0.01	1.95	-0.17	
SpatialTerm	18.73	49.42	26.08***		0.10	33.88	8.53	
%Dev	24.98				37.39			
				Climate and urban structure				
Surface	0.63	2.84	0.13		0.004	2.11	-0.32	
Temperature	5.03	22.51	5.77***	+	0.01	8.08	0.52	
Precipitation	0.6	2.7	0.16		0.01	2.87	-0.27	
Buildings	0.26	1.16	-0.33		0.01	6.24	0.26	
Urban area	0.95	4.25	0.57		0.04	21.06	2.72**	-
SpatialTerm	14.89	66.55	19.35***		0.11	59.64	9.07***	
%Dev	14.74				22.71			
				Human presence				
Pedestrians	4.16	13.02	4.85***	-	0.018	10.75	0.9	
ParkedCars	1.3	4.06	1.23		0.007	3.83	-0.13	
Traffic	0.63	1.97	0.16		0.012	6.93	0.22	
Inhabitants	8.45	26.41	10.22***	+	0.016	9.40	0.61	
SpatialTerm	17.44	54.54	26.51***		0.117	69.09	10.43***	
%Dev	21.07							

%Dev is the percentage of deviance accounted for in a logistic regression (presence) or Poisson (abundance) model including all the variables.

of green areas (Coombs *et al.* 1981). Urban parks are usually associated with tree presence. Furthermore, exotic vegetation revealed a positive association with both dove presence and abundance and it is often composed by trees which are suitable for nesting and roosting. This kind of vegetation is always linked to artificial habitats managed by humans, especially in private gardens that are part of the suburban environment.

The coastal zones of our study area have a climate with warm temperatures during summer and in winter these temperatures are mild (Rivas-Martínez 1987, Pérez-Cueva 1994).

Table 4. Results of the combined hierarchical partitioning analysis for the presence and abundance data of Eurasian collared dove in eastern Spain. Contributions of variables are expressed as %I. $p<0.05$ indicated by *. Signs are shown only for the significant variables. Variables with no values were not included in the combined analyses because were not significant in the previous HP analyses by groups.

	Presence				Abundance				
Variable	I	%I	Z.score	Direction		I	%I	Z.score	Direction
Inhabitants	6.98	14.72	9.19***	+	NatVeg	0.04	15.30	2.94**	+
Parks	6.63	13.98	8.09***	+	ExVeg	0.06	19.85	3.83***	+
Temperature	4.65	9.79	6.12***	+	Water	0.05	16.54	3.18***	+
Schools	5.45	11.48	6.72***	+	Urban area	0.04	13.60	2.61**	-
Pedestrians	5.84	12.30	6.73***	-	SpatialTerm	0.10	34.72	7.74***	
Restaurants	2.53	5.32	2.79**	-	%Dev	35.00			
ExVeg	2.86	6.02	3.34***	+					
SpatialTerm	12.52	26.38	15.99***						
%Dev	31.26								

%Dev is the percentage of deviance accounted for in a logistic regression (presence) or Poisson (abundance) model, including all the variables.

However, the mean minimum temperature decreases when altitude increases and both variables, altitude and-mean minimum annual temperature were highly negatively correlated. The expansion of the Eurasian collared-dove is associated with specific environmental gradients, such as temperature and precipitation (Bled *et al.* 2011). Our study showed that the presence of the Eurasian collared dove is restricted by the mean minimum annual temperature in the studied localities, and is less likely to establish in low temperatures (Altwegg *et al.* 2008). Meteorological varia-bles, such as precipitation, is a negative predictor for its presence in USA (Fujisaki *et al.* 2010, Bled *et al.* 2011, Scheidt and Hurlbert 2014). However, this variable was not important in our study, which was characterized by a Mediterranean climate, where precipitations are scarce and irregular, and temperatures are warmer (Pérez-Cueva 1994). Thus, in warmer and drier areas, precipitation has no effect and, thus, temperature could have a stronger influence on presence.

Birds respond differently to landscape characteristics (Villegas and Garitano-Zavala 2010). In urbanized areas, green areas are associated with parks and avenues (Fernández-Juricic 2000, González-Oreja *et al.* 2012, Aram *et al.* 2019), while in suburban areas there are not only parks, but also many private gardens. Therefore, the surface covered by vegetation increases in these suburban areas, where vegetation is a mixture of both native and exotic vegetation (Bernat-Ponce *et al.* 2018) which would explain the relevance of these areas for the species abundance. Further, the presence of trees provides the necessary places for Eurasian collared-doves to build nests (Coombs *et al.* 1981).

Cities and towns with a bigger human population increase the probability of finding Eurasian collared doves. A larger human population is associated with larger cities and towns, which also means more periurban areas and number of schools (Giménez García *et al.* 2018), which are variables that positively associated with the presence of doves, respectively. Schools are potential resources suppliers in urban areas because of the food scraps left by children in playgrounds. Moreover, big cities contain more parks, avenues and other types of green areas (Russo and Cirella 2018). However, the probability of finding Eurasian-collared doves in areas with heavier pedestrian traffic and restaurants is reduced. Areas with a heavier pedestrian traffic coincide with those areas where buildings, restaurants and commercial centers are more concentrated, which diminish available area, increase disturbances, and limit access to natural food and shelter resources. The negative link of restaurants with Eurasian collared-doves presence could be a consequence of increased pedestrian traffic.

The success of invasive species, especially in arid areas like the Mediterranean Region, is limited by lack of water

(Macmillen 1962, George 1975, Taylor *et al*. 2006). Thus, an additional water resource, especially during warm seasons, must supply their daily water requirements. Our results showed that water presence had a positive association with Eurasian collared-dove abundance. Usually most detached and semidetached houses in periurban areas have swimming pools, and these constructions constitute a new source of water. Water presence must be favorable during warm seasons because it facilitates access to water. Therefore, the positive selection of periurban areas in relation to the negative association with urban areas might be related to presence of water resources, the increase in green areas and the lesser impact of pedestrian traffic. Although Eurasian collared-doves also occupy urban areas, our results agree with previous studies (Hengeveld 1993, Romagosa and Labisky 2000) as suburban areas provide the necessary resources for species to avoid urban areas (Blair 1996, Chapman and Reich 2007). Furthermore, the resources offered by this environment, habitat and food resources would facilitate its use as new corridors for invasive species (Ziska and Dukes 2014).

In conclusion, our study indicates the key factors, such as parks and number of inhabitants, for the presence and, exotic vegetation and water availability, for the abundance of a species that is expanding in Europe and is invasive in America. Our results can be useful to predict which non colonized areas will be more plausibly colonized by the Eurasian collared dove. Furthermore, our results could be used to predict the parts of invaded areas that will harbor more individuals, which would be key for managing the Eurasian collared dove in its native and its non-native distribution area.

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AUTHOR'S CONTRIBUTION

AOBC and JAGD planed and designed the project; AOBC, JAGD and EBP participated in the field sampling; AOBC, EBP and GMLP conducted data analysis; AOBC wrote the manuscript. All authors discussed the manuscript.

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