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Breeding Season Habitat Selection of the Eurasian Collared Dove in a Dry Mediterranean Landscape

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Simple Summary: This study examines how the Eurasian Collared Dove, a bird species that recently spread to the Iberian Peninsula from South Asia, chooses its habitats in a semi-arid Mediterranean landscape in Alicante, Spain. By analyzing data from the *Atlas of Breeding Birds in the Province of Alicante*, researchers identified key environmental factors influencing the dove's presence and abundance. The study found that Eurasian Collared Doves are more likely to be found near human-made areas like isolated buildings and suburbs, water sources such as ponds, large cultivated areas, and warmer regions. Conversely, they tend to avoid natural habitats like pine forests and scrublands. Abundance of the species is positively linked to anthropic features like larger suburban areas and urban-related land uses. These insights can help predict the dove's future spread in similar climates in South America, North America, and Australia, as well as its ongoing growth in the Mediterranean and Europe. This information is valuable for understanding how species adapt to new environments and can aid in managing their populations.

Abstract: Birds select habitats to optimize resources and maximize fitness, with some species recently colonizing new areas, like the Eurasian Collared Dove (ECD) in the Iberian Peninsula. The ECD spread across Europe in the early 20th century from South Asia. This study reanalyzes data from the *Atlas of Breeding Birds in the Province of Alicante* (SE Spain) to identify macrohabitat-level environmental variables related to its occurrence and abundance in this semi-arid Mediterranean landscape during the breeding season. We performed Hierarchical Partitioning analyses to identify important environmental variables for the species associated with natural vegetation, farming, topography, hydrographical web, urbanization, and climate. Results show that ECD has a higher occurrence probability near anthropic areas (isolated buildings, suburban areas), water points (medium-sized ponds), larger crop surfaces (total cultivated area), and warmer localities (thermicity index). The species avoids natural habitats like pine forests and scrublands. Abundance is positively linked to anthropic features like larger suburban areas and urban-related land uses. These findings can help predict its expansion in regions with a Mediterranean climate in South America, North America, or Australia, and its continuous natural expansion and population increase within the Mediterranean basin and Europe.

Keywords: colonization; dove; expansion; luxury effect; pine forest; scrubland; suburban areas

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1. Introduction

Habitat selection is the primary mechanism for mobile animals to cope with changing conditions, such as spatial and temporal variability in resource availability [1–3]. Birds appear to choose habitats to which they are well adapted while avoiding others [4–6]. Among the bird species that inhabit the Iberian Peninsula, some have been present for less than a century due to recent colonizations or invasions, while others that are native have drastically reduced their populations [7,8]. Among the former, the most well-known case of natural colonization and expansion is that of the Eurasian Collared Dove (*Streptopelia decaocto*), which was first found in Northern Spain in the 1960s [7].

Even though the first record of the Eurasian Collared Dove in Europe was registered in Crete in the second half of the 16th century (but probably present earlier according to subfossil records in Bulgaria [9,10]), this species, originally restricted to Asia, began its natural expansion and colonization of Europe in the Balkans in the 1930s, subsequently spreading to most of Europe, the Middle East, and North Africa [11]. The species was also introduced in North and Central America [11], and has already been cited in some American countries south of the Rio Grande [12–15]. In its native areas in South Asia, it occupies diverse environments where it often avoids cities [16,17]. However, in invaded and newly colonized areas, the species is associated with heavily anthropized forested environments, such as parks and gardens in suburban areas, though it also occupies, to a lesser extent, the center of urban areas [18–23]. The first colonizers are usually found in urban areas and from where they spread to rural ones [11]. In some regions of Spain, the species extends its distribution further than cities to woodlands dominated by holm oaks (*Quercus ilex*) and cork oaks (*Q. suber*) mixed with pastures and crops: dehesas [24,25]. Studies on the colonization of the Eurasian Collared Dove in Europe have been conducted in temperate regions [19,26]. In contrast, research in North America, where the species arrived in the late twentieth century and is categorized as invasive, has been focused on arid environments [12,27]. Therefore, the use of semi-arid environments by this species is still unexplored.

Whilst the processes of colonization and selection of breeding habitats are frequently well researched on island systems, particularly for birds [28–30], similar processes on mainlands are relatively less well known. Habitat selection in colonizing birds is a complex process influenced by various environmental, biological, and social factors [6,31]. Understanding these factors is crucial not only for management efforts but also for predicting their expansion into non-colonized territories, especially across large terrain extensions like continents, and evaluating how bird populations might respond to changing environments (e.g., drought in Mediterranean regions).

The aim of this article is to identify macrohabitat-level environmental variables that the Eurasian Collared Dove selects during the breeding season in a dry region of eastern Spain. Thus, we evaluate the relevance of natural vegetation, farming, topography, hydrographical web, urbanization, and climate on the probability of the dove's occurrence and its abundance. This case study holds significant relevance for the management of the Eurasian Collared Dove, a species currently expanding in the mainland Mediterranean region.

2. Materials and Methods

2.1. Study Area

The study area is located in the province of Alicante (SE Spain), close to the Mediterranean Sea with an area of approximately 5800 km^2 (Figure 1). This province is characterized by mountains in the north and west (up to 1500 m above sea level), whereas the southern sectors are dominated by wetlands and flat land with crops. Scrublands and forest–scrub mixtures dominate those environments with less human impact, where Aleppo pine (*Pinus halepensis*) is the most abundant tree. These areas are often interspersed with agricultural fields and crops [32]. The study area has a semi-arid Mediterranean climate, with average annual rainfall in the range of 300–600 mm, and precipitation mostly occurring in autumn and winter [33].

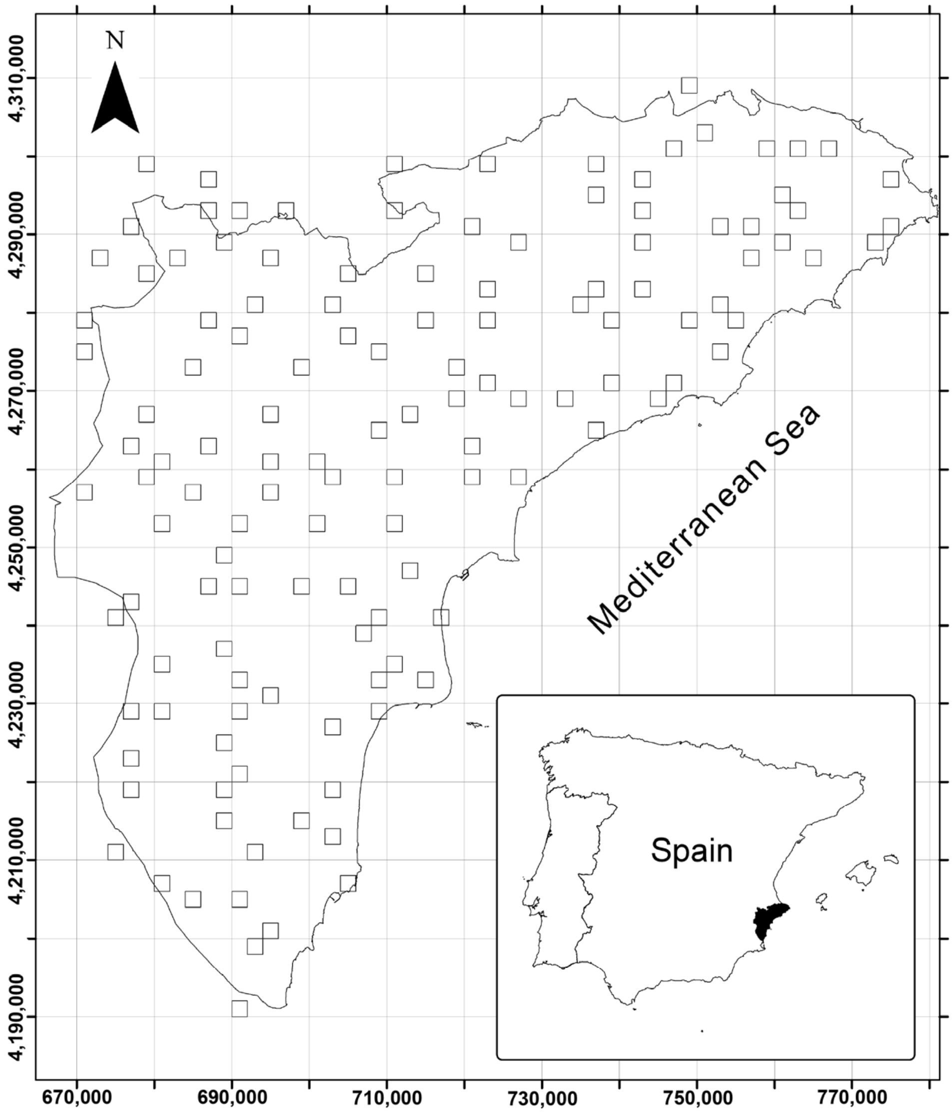

Figure 1. Map of Alicante province and its location in SE Spain. The 10 × 10-km UTM grid is shown (thin line) along with the 2 × 2 squares that were randomly selected for the fieldwork of the *Atlas of Breeding Birds in the Province of Alicante* [34,35].

2.2. Presence and Abundance of Eurasian Collared Dove

The occurrence data of the Eurasian Collared Dove (hereafter ECD) was obtained from surveys conducted for the *Atlas of Breeding Birds in the Province of Alicante* [34]. Two cells of 2 × 2 km were randomly selected within each 10 × 10 km UTM (Datum ED50) grid cell, thus granting a spread of sampling though the environmental gradients existing in the study area and approximately covering the 10% of this province (Figure 1). Each random 2 × 2 km cell was divided into four 1 × 1 km cells, totaling 528 sampling units. In each cell of 1 km^2, a transect of 1 km was walked twice during one breeding season between 2001 and 2004. The methodology has been described in detail in the atlas by López-Iborra et al. [34]. We extracted 112 environmental variables for each one of the 528 km^2 from López-Iborra et al. [34] (available in Supplementary Table S1). For analytical purposes, these variables were classified into two main divisions, each containing six groups of variables. The first division (groups i–vi) refers to land cover and use, while the second division (groups vii–xii) refers to topography, hydrographic network, urbanization, and climate. Complete descriptions of the group variables and their sources can be found in Supplementary Tables S1 and S2 but also in López-Iborra et al.'s atlas [34].

2.3. Predictive Variables

The studied groups of variables in the first division (land cover and use) were as follows (Table 1): (i) detailed land cover and use (forest, scrubland, mixes of both, and agriculture); (ii) summary variables of habitats and soil use (combination of variables from group (i); (iii) subclasses of pinewood; (iv) subclasses of scrubs; (v) subclasses of scrub–pinewood mixtures; and (vi) diversity of land cover and use categories. The groups in the second division were as follows (Table 1): (vii) topographic variables; (viii) natural hydrographic network (rivers); (ix) artificial hydrographic network and water bodies; (x) urbanization pressure; (xi) transportation network (roads, highways, railroads); and (xii) bioclimatic variables. Note that this grouping was carried out just to ease the statistical proceeding and these groups were not considered as whole predictor variables in our models (see Section 2.4).

Table 1. The two main divisions and the 12 groups of explanatory variables used to model the occurrence of the Eurasian Collared Dove in Alicante province (SE Spain). For a complete list and description of the variables included in each group, see Supplementary Tables S1 and S2 and also refer to López-Iborra et al. [34].

Division	Group	Description
I. Land cover and use	(i) Detailed land cover and use	Area (ha) covered in each square kilometer by different types of vegetation and crops, including water bodies and unproductive surfaces due to construction and infrastructure.
	(ii) Summary variables of habitats and soil use	Area (ha) covered in each square kilometer by the aggregation of diverse vegetation types and crops.
	(iii) Subclasses of pinewood (iv) Subclasses of scrubs (v) Subclasses of scrub–pinewood mixtures	Based on the primary variables of land use (i), various derived variables have been generated as subclasses of the Pines–TreeC (iii), scrub (iv) and Scrub–Pines (v) to consider types of these environments that appear too general in the original source. To achieve this, the area covered by these types of vegetation was cross-referenced with ombrotypes, thermotypes, and the orientation of sunny and shady slopes.
	(vi) Diversity of land cover and use categories	Diversity index of land cover and use categories (i) included under summary variables (ii) or scrubs and pines.
II. Topography, hydrographic network, urbanization, and climate	(vii) Topographic variables	Altitude and topographical relief.
	(viii) Natural hydrographic network (rivers)	Length of natural elements of the hydrographic network.
	(ix) Artificial hydrographic network and water bodies	Extent and quantity of artificial water conduits or reservoirs, excluding dams.
	(x) Urbanization	Occupation of the territory by buildings and other urban elements, such as parks.
	(xi) Transportation networks	Length of communication paths of various types.
	(xii) Bioclimatic variables	Descriptors of climate conditions

2.4. Statistical Analyses

To identify the individual variables that better explained the occurrence and abundance of ECD in the province of Alicante, we conducted Hierarchical Partitioning analyses (HP) using the "hier.part" package [36] in R software 4.1.0 [37]. HP does not aim to identify the best regression model as such but rather uses all models in a regression hierarchy to distinguish those variables that have high independent correlations with the dependent variable. HP computes all possible hierarchical models that can be developed with a set of independent predictive variables. For instance, if U, V, and W are variables, HP computes single-order (U, V, W), second-order (UV, UW, VW), and higher-order (UVW) models. It then tests whether the addition of a given variable improves the goodness of fit [35]. Such variables are likely to be most influential in controlling variation in the dependent variable and its explicative capacity is divided into the individual effect I of each variable and its joint effect J through other variables [5,22,35,38–40]. Moreover, model outputs also provide the percentage (I%) of the total group I counted in each variable. For presence/absence models, we considered presence in a sampling unit when the dove was detected at least in one visit. For abundance models, the abundance index was the total number of individuals detected in the two visits carried out in each sampling unit. Abundance models were performed only with the sampling units where presence of the species was found.

To take into account of spatial autocorrelation, a spatial term was calculated by fitting a GLM model for the response variable (binomial for presence/absence or Poisson for abundance) using the cubic function as a predictor (‘$x + y + x^2 + xy + y^2 + x^3 + x^2y + xy^2 + y^3$) of the UTM coordinates of the center of each km^2 [41–43]. Finally, 113 variables were studied, including the spatial term.

The HP analyses can produce minor rounding errors when there are more than nine variables [44], so each analysis was performed with a maximum of eight independent variables, plus a spatial term [36]. As some groups (i–xii) of variables in the original López-Iborra et al. [34] dataset had more than 8 elements (see Supplementary Table S1), we divided large groups into smaller subgroups to avoid statistical problems (see Supplementary Tables S1 and S2). Division one (land cover and use), which included 6 groups (i–vi), was divided into 12 subgroups (Supplementary Table S1), while division two (topography, hydrographic network, urbanization, and climate) included 6 groups (vii–xii) (Supplementary Table S2).

Prior to any HP analysis and to avoid multicollinearity, we carried out a preliminary GLM (binomial family with logit link for presence/absence data and Poisson family with log link for abundance data) for each of the 18 groups/subgroups (12 from division 1 and 6 from division 2) of environmental variables from the two main divisions (Supplementary Tables S1 and S2). We obtained the variance inflation factor (VIF) through the “vif” function of the R package “car” [45] from GLMs (see below). When VIF was >5 for any variable, indicating high multicollinearity [46], we deleted from the group the variable with the highest VIF, or the second highest if the first was considered of key biological relevance based on other studies of the species. This process was repeated to check if the reduced group of variables still showed multicollinearity. Given that HP analysis does not provide information on the sign (positive or negative) of the effect of the independent variables, univariate regressions (GLMs) 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. GLMs were performed with the function “glm” of the package “stats” [37].

To test the relative importance of variables within each group/subgroup of the two divisions (Supplementary Tables S1 and S2), an HP analysis was performed on them after removing multicollinear variables. HP analyses for the presence of ECD were carried out using binomial regression and log-likelihood as the goodness-of-fit measure. Abundance HP analyses were performed with Poisson regressions and RMSPE as the goodness of fit [47]. The significance of the independent contribution of the environmental variables was evaluated by a randomization test based on 999 randomizations [40]. For each group/subgroup, the percentage of deviance (%D) of the whole group and the percentage of the independent effect of each variable in the group (I%) were obtained. To select the most relevant variables, we considered those with a significant contribution (Z.Score > 1.64) and additionally with a percentage of the independent effect in the group (I%) higher than 10% ([36]; Supplementary Table S3).

Once all the most relevant variables from each group/subgroup of the two main divisions were selected (Supplementary Table S3), we repeated the entire process (GLM, VIF, and HP) with combinations of these most relevant variables from the two divisions separately (land cover and use (groups i–vi)/topography, hydrographic network, urbanization, and climate (groups vii–xii)). The most relevant variables were then recombined in a final analysis for each division (Division I and Division II), and finally, those most relevant variables from both divisions were combined in a single group analysis again following the same aforementioned procedures. Variables, acronyms, and description can be found in Supplementary Table S1.

3. Results

3.1. Presence of the Eurasian Collared Dove

ECDs were detected in 120 out of 528 km^2 cells. Of the 12 subgroups in the first division (land cover and use), the highest %D (19.3) is found in the analysis of the detailed land cover and use, corresponding to group i, subgroup 4 (Supplementary Table S3). Among the six subgroups in the second division, the highest %Ds correspond to urbanization (%D = 24.1), corresponding to group x, and to the artificial hydrographic network and water bodies (%D = 23.7), corresponding to group ix (Supplementary Table S3). The variables that show positive relationships with the presence of ECD are associated with anthropogenic variables and anthropic environments, including most crops while natural environments such as forests, scrublands, and rivers show negative relationships (Supplementary Table S3).

The second step of the analysis showed that the highest %D includes the anthropogenic variables (%D = 18.0 for the first division; %D = 30.5 for the second division) (Tables 2A and 3A). The variable linking unproductive land in urban areas (%I = 25.33) stands out in the first division (Table 2C), and the variable associated with the number of isolated buildings (NIsolBuild %I = 20.83) stands out in the second (Table 3C). The dry scrubland area (SCSeMmeU) and the total surface of cultivated area (TotCultAr) were also relevant in the first division, the former one with a negative effect on the occurrence of the ECD (Table 2C). In the second division, suburban area, number of medium ponds, and the termicity index were also positively related to the species (Table 3C).

Table 2. Variables of the first division identified by the Hierarchical Partitioning (HP) analyses as key for the occurrence of the Eurasian Collared Dove in SE Spain. Analyses combined different groups of variables (A, B) while those selected variables were included into the final analysis for the first division (C). The percentage of deviance (%Dev) of the whole group is shown. The explanatory power of each variable is segregated into the independent effect (I) and the effects caused jointly with other variables (J). Model outputs also provide the percentage (I%) of the total group I counted in each variable. Significant variables are marked with an * (Sig.), while the +/− shows if the variable increases (+) or reduces (−) the probability of finding the species. Note that selected variables, marked in bold, are significant (* $p < 0.05$; *** $p < 0.001$) and >%10. Multicollinear variables (VIF > 5) have already been deleted.

	Presence					
(A) Groups i	**I**	**J**	**I%**	**Z.Score**	**Sig.**	**+/−**
%D 18.0						
SpatialTerm	**17.29**	**9.55**	**28.23**	**22.87**	***	
CitrusT	4.54	3.70	7.40	6.36	***	+
ForcedCrops	3.36	1.57	5.48	2.97	***	+
IntCropTC	4.14	−1.05	6.75	4.89	***	+
Unproductive	**13.46**	**7.99**	**21.96**	**16.65**	***	**+**
Scrub	**8.80**	**3.27**	**14.35**	**11.17**	***	**−**
Scrub-Pines	5.32	1.51	8.69	6.39	***	−
MatPines	4.37	1.88	7.13	4.28	***	−
(B) Groups ii + iii + iv + v + vi	**I**	**J**	**I%**	**Z.Score**	**Sig.**	**+/−**
%D 20.6						
SpatialTerm	**23.65**	**3.19**	**39.99**	**36.68**	***	
TotCultAr	**7.97**	**7.63**	**13.47**	**9.95**	***	**+**
TotTreeCropAr	4.01	4.71	6.78	4.74	***	+
PintmatU	4.55	3.73	7.70	6.40	***	−
SCSeMmeS	3.67	9.03	6.21	3.75	***	−
SCSeMmeU	**6.98**	**10.21**	**11.80**	**9.46**	***	**−**
SPSeMmeS	3.48	7.21	5.88	3.74	***	−
SPSeMmeU	2.39	5.56	4.04	2.05	*	−
ShrubDiv	2.43	4.20	4.11	2.48	***	−

Table 2. *Cont.*

	Presence					
(C) Combined A + B	**I**	**J**	**I%**	**Z.Score**	**Sig.**	**+/−**
%D 23.7						
SpatialTerm	**21.19**	**5.65**	**31.15**	**29.11**	***	
Unproductive	**17.23**	**4.21**	**25.33**	**23.79**	***	**+**
Scrub	4.48	7.58	6.59	5.00	***	−
TotCultAr	**16.09**	**−0.50**	**23.65**	**21.92**	***	**+**
SCSeMmeU	**9.03**	**8.16**	**13.27**	**11.47**	***	**−**

Table 3. Variables of the second division identified by the Hierarchical Partitioning (HP) analyses as key for the occurrence of the Eurasian Collared Dove in SE Spain. Analyses combined different groups of variables (A,B), while those selected variables were included into the final analysis for the second division (C). The percentage of deviance (%Dev) of the whole group is shown. The explanatory power of each variable is segregated into the independent effect (I) and the effects caused jointly with other variables (J). Model outputs also provide the percentage (I%) of the total group I counted in each variable. Significant variables are marked with an * (Sig.), while the +/− shows if the variable increases (+) or reduces (−) the probability of finding the species. Note that selected variables, marked in bold, are significant (*** $p < 0.001$) and >%10. Multicollinear variables (VIF > 5) have already been deleted.

	Presence					
(A) Groups viii + ix + x	**I**	**J**	**I%**	**Z.Score**	**Sig.**	**+/−**
%D 30.5						
SpatialTerm	**13.08**	**13.77**	**14.99**	**16.85**	***	
AUrbaniz	**11.00**	**10.32**	**12.60**	**12.54**	***	**+**
NIsolBuild	**17.72**	**17.74**	**20.30**	**24.79**	***	**+**
AIsolBuild	8.70	16.99	9.96	9.66	***	+
Gullie	3.65	9.46	4.19	4.52	***	−
SSmallPonds	7.16	18.24	8.21	8.79	***	+
NLargePonds	**9.03**	**6.92**	**10.35**	**10.95**	***	**+**
NMedPonds	**11.83**	**14.80**	**13.56**	**14.83**	***	**+**
NPools	5.11	12.52	5.85	6.31	***	+
(B) Groups vii + xi + xii	**I**	**J**	**I%**	**Z.Score**	**Sig.**	**+/−**
%D 21.74						
SpatialTerm	**9.52**	**17.32**	**15.29**	**12.93**	***	
Slope	**11.38**	**17.54**	**18.26**	**14.82**	***	**−**
Road	**15.11**	**12.74**	**24.35**	**20.46**	***	**+**
Path	**8.80**	**10.55**	**14.12**	**11.23**	***	**+**
TermicIn	**13.33**	**24.38**	**21.40**	**17.78**	***	**+**
CoastDist	4.15	9.50	6.66	5.46	***	−
(C) Combined A + B	**I**	**J**	**I%**	**Z.Score**	**Sig.**	**+/−**
%D 31.0						
SpatialTerm	8.35	18.49	9.39	11.82	***	
ArUrbaniz	**10.68**	**10.63**	**12.00**	**13.00**	***	**+**
NIsolBuild	**18.53**	**16.93**	**20.83**	**22.76**	***	**+**
NLargePonds	5.53	10.42	6.21	6.51	***	+
NMedPonds	**12.31**	**14.32**	**13.84**	**15.79**	***	**+**
Slope	8.26	20.66	9.28	11.03	***	−
Road	8.57	19.28	9.64	11.02	***	+
Path	6.16	13.19	6.92	7.56	***	+
ThermicIndex	**10.55**	**27.15**	**11.86**	**15.30**	***	**+**

The combined analysis showed that during the breeding season in Alicante, the ECD is preferably present in suburban areas (ArUrbaniz I% = 12.01; Table 4; Figure 2). Additionally, it selects regions with a high number of isolated buildings (NIsolBuild I% = 20.67), medium-sized water ponds (NMedPonds I% = 14.55), and cultivated areas (TotCultAr I% = 10.54), particularly in the warmer areas of the province (Thermicity Index I% = 14.43) (Table 4; Figure 2).

Table 4. Variables of the combined analysis identified by the Hierarchical Partitioning (HP) analyses as key for the occurrence and abundance of the Eurasian Collared Dove in SE Spain. The percentage of deviance (%Dev) of the whole group is shown. The explanatory power of each variable is segregated into the independent effect (I) and the effects caused jointly with other variables (J). Model outputs also provide the percentage (I%) of the total group I counted in each variable. Significant variables are marked with an * (Sig.), while the +/− shows if the variable increases (+) or reduces (−) the probability of finding the species. Note that selected variables, marked in bold, are significant (*** $p < 0.001$) and >%10. Multicollinear variables (VIF > 5) have already been deleted.

	Presence							Abundance					
	I	J	I%	Z.Score	Sig.	+/−		I	J	I%	Z.Score	Sig.	+/−
%D 31.7							%D 25.6						
SpatialTerm	**10.74**	**16.11**	**11.95**	**15.23**	***			**−4.93**	**−4.24**	**48.90**	**9.79**	***	
Unproductive	7.28	41.16	8.11	9.68	***	+		**−2.80**	**−3.62**	**27.73**	**5.66**	***	**+**
SCSeMmeU	6.95	10.23	7.74	8.45	***	−							
TotCultAr	**9.47**	**6.12**	**10.54**	**13.73**	***	**+**							
ArUrbaniz	**10.79**	**10.52**	**12.01**	**13.16**	***	**+**		**−2.36**	**−3.48**	**23.37**	**3.53**	***	**+**
NIsolBuild	**18.57**	**16.88**	**20.67**	**24.72**	***	**+**							
NMedPonds	**13.07**	**13.55**	**14.55**	**17.60**	***	**+**							
ThermicIndex	**12.97**	**24.74**	**14.43**	**17.38**	***	**+**							

3.2. Abundance of the Eurasian Collared Dove

Only two variables were selected for being significant (Supplementary Tables S2 and S3). The combined analysis indicates that the ECD is more abundant in extensive suburban areas (ArUrbaniz I% = 23.37, positive effect) and in unproductive zones of urban areas (unproductive I% = 27.73, positive effect) (Table 4; Figure 2).

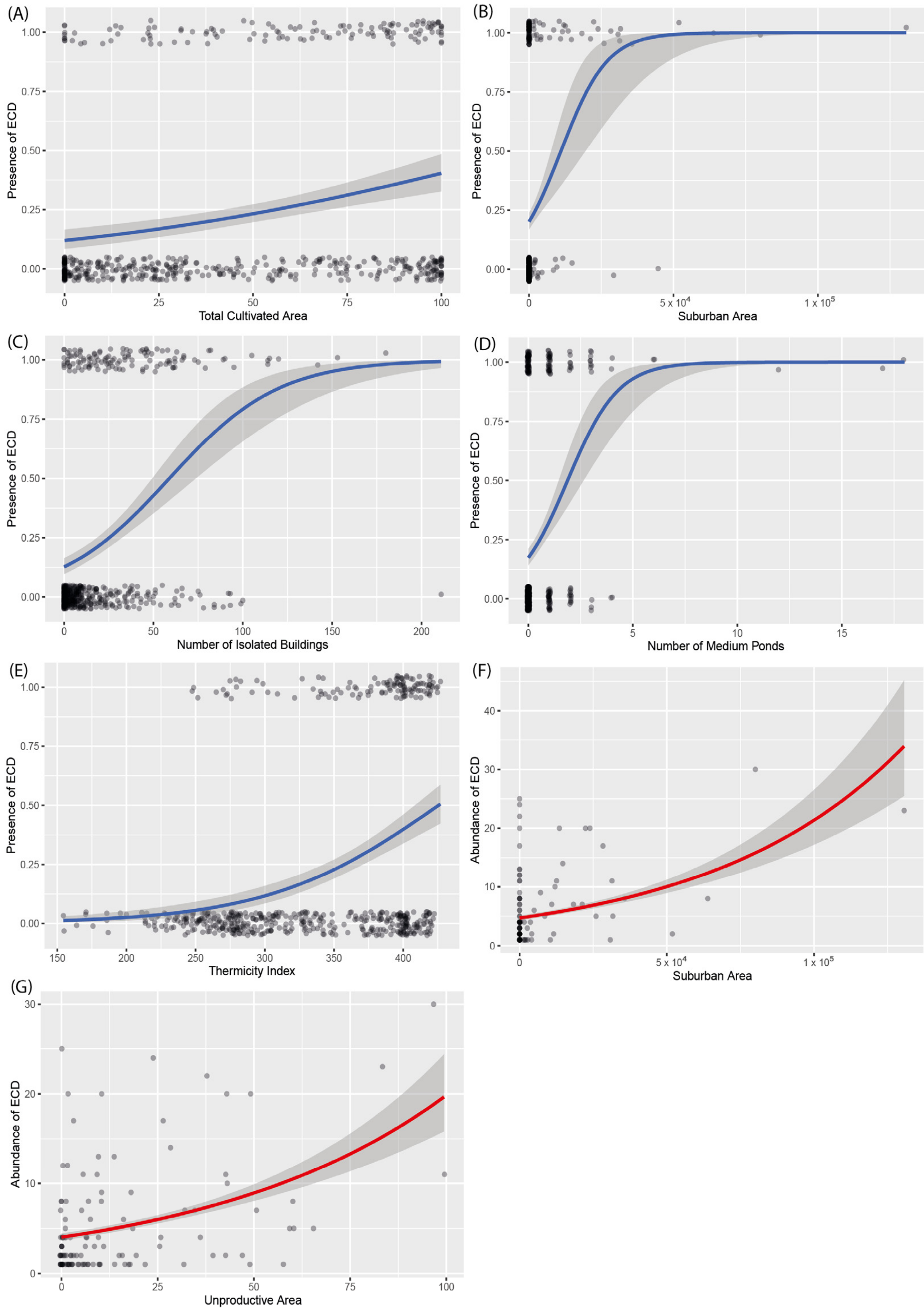

Figure 2. Relationships of the most relevant environmental variables, according to the HP analyses, showing a positive relationship for the presence (blue line: (**A**–**E**)) and abundance (red line: (**F**,**G**)) of the Eurasian Collared Dove in SE Spain.

4. Discussion

ECDs were detected in 23% of the studied cells, and 5 out of 112 variables, excluding the control variable, are key to determining its occurrence during the breeding season in a semi-arid landscape of southeastern Spain. We found that ECD selects anthropic areas (isolated buildings, number of medium-sized water ponds, suburban area, total cultivated area), while it is mostly absent in natural environments for breeding.

Natural areas in this semi-arid or dry study area were unsuitable for the presence of ECD during the breeding season. These areas represented by pine forests, scrubs, and mixed communities of pines and scrubs, were unoccupied. These natural vegetation communities in Alicante consist of species well adapted to a climate characterized by scarce rainfall and warm summers, defining the thermo-Mediterranean belt [33,34,48]. Thus, natural vegetation communities may inhibit the occurrence of ECD in dry environments. Therefore, the natural features of this Mediterranean native ecosystem, such as scrub environments that do not provide nesting places, limit its colonization and use during the breeding period. According to Gamez Carmona [49], in Spain, the ECD's presence in non-urban habitats is typically due to its proximity to urban areas. The species regularly uses these areas to access nearby seasonal resources, both natural (such as forest habitats) and cultivated (including orchards, cereal fields, and fallow lands), as well as for water sources like wetlands. In Extremadura (W Spain), the ECD inhabits the "dehesas" (human-modified open habitats with scattered holm oak trees that constitute pasturelands with cattle waterholes; [24]). In coastal habitats, however, their presence is largely restricted to urbanized spaces such as seafront promenades, beaches, and ports [49].

In Eastern Spain, the species shows a preference for anthropized areas, especially urbanized environments, aligning with findings from other studies [18–23,50]. The preference for suburban areas may be favored as these areas offer a refuge from predators present in natural surrounding environments like the Mediterranean forests [51,52] and provide specific conditions (e.g., microclimate, water, food resources, the luxury effect; [53,54]) typical of modified landscapes [55]. Moreover, isolated buildings are frequently present in gardened areas, in a cultivated matrix, or in open forest remnants with well-sized trees, often *Pinus halepensis* in Alicante, which are necessary for nesting and roosting [22,56]. Furthermore, the total cultivated area is also positively selected by the ECD for breeding in Alicante as these environments usually present isolated houses, like farmhouses, among the crops, which are providers of trophic resources [57]. These isolated buildings can be a key factor to explain the rapid expansion of the species in the Iberian Peninsula during the last decades as these infrastructures connect urban and suburban areas between them and might be working as dispersion corridors [58].

The number of ponds/water points of intermediate size increased the occurrence of ECD in Alicante. Our results show that water bodies artificially maintained by humans are frequently used by ECD during the breeding season (spring–summer). However, previous studies did not identify water ponds as a key requirement for ECD [19,20,24,59], except for Gámez Carmona [49] who found more 10 ind/km^2 in wetlands in Spain. Most previous studies were conducted in temperate climates across Europe, where natural water is continuously available and summer temperatures are lower than in Alicante [19,20], or where the climate has Atlantic influences [24]. Alicante, however, is a semi-arid region with high temperatures and scarce precipitation during summer [34], and pigeons and doves strongly depend on water [60,61]. Despite Alicante's extensive hydrographical network [34], rivers and streams often dry up in summer. As water is a limiting factor for the species [49,62,63], the availability of ponds is crucial for access to water resources [13]. Therefore, the absence of water ponds poses a significant environmental limitation for the species in this semi-arid region.

Bioclimatically, the ECD was more likely to be found in areas within the province that have higher thermicity indices, typically at lower altitudes and closer to the coast. This pattern is consistent at the European, national, and regional levels, where colder winters appear to limit the species' occurrence being found mostly below 600 m above sea level [11,19,22,64–66]. In Europe, outposts at both high altitudes and high latitudes may be abandoned again after a few years due to factors such as harsh winters [11,20]. However, in a climate change scenario, the species could expand in both latitude and altitude in the coming decades. The variables that determine the occurrence of the ECD in Alicante align with the current distribution of the ECD in the rest of Spain [49], showing large inland areas of the Iberian Peninsula devoid of this species. Bermúdez-Cavero et al. [22] noted that this dove only struggles to settle in the inland towns of the Valencian Community in eastern Spain, largely due to low minimum temperatures compared to coastal towns. So, the dry Mediterranean climate is not a limiting factor for breeding, as it is abundant in the eastern Iberian Peninsula and has clearly expanded its range over the past 50 years [7,22,57,65,66], so much so that during the last decades, the species increased its distribution range by a 6% in Europe [11]. However, the causes behind colonization and changes in population sizes remain essentially unknown [11]. We consider that recent increased urbanization in Europe might be a key factor for these processes.

Regarding abundance, between 2000 and 2016, the European population of ECDs has increased by 80% [11]. According to our results and in line with previous studies, when present, this species is highly abundant in urban zones with large unproductive land and suburban areas, which is expected based on the results for occurrence [11,65,66]. These anthropized areas can provide trophic resources (herbaceous native and exotic plants) and nesting places, such as well-sized trees, as well as well-watered gardens that supply the required water amount for the species [22,23,63]. This situation could be linked to the "luxury effect" previously described for biodiversity, but in this case, it could be "mirrored" for the abundance of this species [54,67,68]. Suburban areas are usually linked to higher-income inhabitants. Income strongly influences how individuals and municipalities choose to manage their surrounding urban environment, with wealthier communities investing more in public green spaces and private gardens [68–70] which could create the perfect conditions for the ECD to breed. Furthermore, the unproductive areas in the present study are similar to urban vacant lots described in other studies [71,72]. This urban land is usually covered by spontaneous vegetation (including exotic species) and provides habitat for local birds, which could be linked to the high abundances of the ECD found in these habitats in the urban matrix [71,72].

The rapid expansion and high abundances of the species in urban, suburban, and cultivated environments might affect other species through competitive interactions. For example, in urban areas, the ECD might compete for trophic resources with the House Sparrow (*Passer domesticus*), a species that has experienced a completely inverse trend with sharp declines over the last decades in Europe [73–76]. However, other declining species of the same *genus*, such as the European Turtle Dove (*Streptopelia turtur*), which shows a generalized population decline in the Western Palearctic [77], should not be affected by ECD expansion due to their mostly different habitat use [38].

Our findings can be valuable in predicting its expansion and future distribution in areas where this species is invasive or potentially invasive, such as regions with a semi-arid Mediterranean climate in South America, North America, or Australia, but also its continuous natural expansion and population increase within the Mediterranean basin and Europe. Then, further studies might be focused on the potential impacts of the ECD on other species.

5. Conclusions

This study examines the environmental variables that influence the occurrence and abundance of the Eurasian Collared Dove (ECD) in Alicante (SE Spain) during the breeding season. ECDs prefer anthropogenic areas (such as isolated buildings, medium-sized water ponds, urban surfaces, and cultivated land) for breeding and are largely absent in natural environments like pine forests and scrublands. The species was more likely to be found in areas with higher thermicity indices, at lower altitudes, and closer to the coast. Suburban areas and unproductive urban land were key factors for higher ECD abundances in this semi-arid landscape, likely due to the greater availability of food, water, and nesting resources, as well as the absence of natural predators.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/birds5040050/s1, Table S1: Environmental variables (Division I) related to the surface area (ha) of habitats and land uses, obtained from the *Crop and Land Use Map of Spain* (2000–2010) at a scale of 1:50,000 from López-Iborra et al. [34]. Variables derived from shrubland and shrub–pine forest are named by combining the initial of these vegetation formations with identifying letters of ombrotype, thermotype, and orientation. For example, SCSaTmeS means semi-arid thermo-Mediterranean shrubland on a south-facing slope; Table S2: Environmental variables (Division II) related to topography, natural and artificial hydrographic network, urbanization, communication routes, and climate; Table S3: Variables identified by the initial Hierarchical Partitioning (HP) analyses for both divisions (Division I: i–vi and Division I: vii–xii) as key for the occurrence (left) and abundance (right) of the Eurasian Collared Dove in SE Spain (Alicante province). The percentage of deviance (%D) of the whole group is shown. The explanatory power of each variable is segregated into the independent effect (I) and the effects caused jointly with other variables (J). Model outputs also provide the percentage (I%) of the total group I counted in each variable. Significant variables are marked (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ (Sig.)), while the +/− shows if the variable increases (+) or reduces (−) the probability of finding the species or its abundance. Note that selected variables for further analyses, marked in bold, are significant (*) and >%10. Several variables were previously deleted due to VIF > 5 (see Material and Methods).

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