

Article

Do Habitat Measures Affect European Turtle Dove Abundance Trends? A Case Study from Hunting Grounds in Spain

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Abstract

The European turtle dove (*Streptopelia turtur*) has undergone a marked decline across Europe, with habitat degradation considered an important driver. We examined whether different habitat-management strategies were associated with temporal changes in its relative abundance during the years 2021–2025 in Spain, coinciding with the hunting moratorium period. We analyzed 185 surveys from 47 hunting grounds in southern and eastern Spain, conducted through walked transects and point counts. Management practices included water and food provision, agricultural measures and forest management. The relative turtle dove abundance increased over the study period, with significantly higher values in 2024 and 2025 than in 2021. Agricultural measures, primarily game crops, were positively associated with turtle dove abundance (mean effect = 1.76, 95% CI: 1.18–2.62), showing a marked abundance increase after three years of implementation. By contrast, water provision and forest management showed no clear effects and food provision was negatively associated with turtle dove abundance (mean effect = 0.57, 95% CI: 0.39–0.84), although the latter association should be interpreted cautiously because food provision was widespread among the study sites. Our findings highlight the potential value of agricultural habitat interventions for conserving and restoring turtle dove populations, supporting their inclusion in adaptive, landscape-scale conservation strategies targeting this formerly declining migratory gamebird.

Keywords: columbids; game crops; habitat; hunting; management



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1. Introduction

The European turtle dove (*Streptopelia turtur*, hereafter referred to as TD) is a widely distributed migratory columbid occurring in Europe, North Africa and Asia, which has experienced a marked population decline in Europe over recent decades due to a combination of factors, including habitat loss in breeding and wintering areas, as well as additional pressures from illegal killing and, in some areas, unsustainable levels of hunting [1]. Owing to this conservation concern, an adaptive harvest management plan (AHM) was approved to recover its populations, which involved the enforcement of a hunting moratorium in

countries belonging to the western flyway from 2021 to 2025, and the promotion of habitat improvements which may benefit the TD at large scale [2,3].

The TD is associated with the ecotone between farmland and forest, which provide wild and cultivated seeds [4,5] and specific nesting requirements (e.g., thorny scrub or high-canopy forest edges) [6], showing a dependence on stopover resources during migration [7]. As the species is particularly sensitive to habitat degradation and hunting pressure, management interventions should focus on maintaining or increasing landscape heterogeneity in order to provide suitable foraging resources and nesting substrates, and also ensuring water availability in contexts of water scarcity [8,9]. Although research has addressed the effect of habitat factors on the TD abundance in countries belonging to the western flyway, including single-factor habitat association analysis [10–14] and management practices such as food provision before the moratorium was implemented [15,16], few studies have evaluated the effects of habitat management interventions on the species. In the United Kingdom (UK), where the TD has suffered a sharp population decline [17], the provision of seed-rich habitats helped to slow the TD decline [18,19] and influenced post-fledglings spatial behaviour [20], while seed supplementation in plots visited by other granivorous birds of conservation concern showed low disease transmission risk [21]. Thus, together with adaptive hunting which has recently been associated with positive population responses at the flyway scale [3], habitat management is increasingly recognized as a key component of TD conservation. However, evidence assessing whether different habitat-management strategies are associated with different population trajectories under the same management framework remains scarce, particularly in Mediterranean hunting grounds where these measures are widely implemented. A synchronous quantitative comparison of the combined effects of multiple interventions within a unified management framework could help to develop tailored measures to be incorporated in current policies.

In countries along the western flyway where the TD is a quarry species (France, Portugal, Italy and Spain), a substantial proportion of hunting grounds conduct habitat measures which may favour the species, i.e., water and food provision (through ponds, water troughs, feeders and feeding plots) and habitat interventions, including agricultural and forest measures [22]. However, in Spain, the only studies which have evaluated the effects of management are those comparing the TD abundance in areas where food is provided, a management measure which may help to increase recruitment but also could lead to overharvesting scenarios when hunting is not planned properly [15,16].

In Spain, there are already habitat prescriptions to benefit the TD [23], and regional administrations are promoting habitat measures within [24] and outside hunting grounds, but the role of habitat management in the current recovery of the species remains unknown. In this study, we evaluated whether hunting grounds implementing different habitat-management strategies showed different temporal trajectories in TD relative abundance during the hunting moratorium (2021–2025), using the moratorium as a natural experimental window to effectively eliminate hunting disturbance and independently evaluate the net effect of habitat management. By comparing hunting grounds under the same hunting regulations but differing in habitat management, we aimed to identify which interventions may help to recover TD populations.

As linking hunting opportunities with habitat management is one of the objectives of the AHM [2], and habitat measures are mandatory for hunting grounds aiming to harvest TD in Spain, our findings could help hunters, game managers and landowners to improve current management decisions, while also supporting policy-makers in maximizing the effectiveness of ongoing conservation efforts.

2. Materials and Methods

2.1. Study Area and Selection of Hunting Grounds

Two complementary data sets from hunting grounds were used in this study: TD abundance monitored during the 2021–2025 period, based on repeated surveys covering at least 3 years per site, and information on habitat management implemented during the same period. Hunting grounds were selected from the network of grounds participating in the voluntary project “Observatorio Cinegético”, (the Hunters’ watch, www.observatoriocinegetico.org accessed on 4 May 2026), as well as from sites where the co-authors conducted TD monitoring and collected habitat management data, within other ongoing research projects.

The Observatorio Cinegético is a voluntary project created in 2020 by Fundación Artemisan, in which hunters and game managers are invited to conduct yearly TD surveys according to a standardized method, using a free mobile application (CensData, 1-4.11.4 <https://play.google.com/store/apps/details?id=com.censodata.com&hl=es>, accessed on 4 May 2026). After registration, information and support were provided to ensure correct use of the app, with the information gathered by each ground being stored confidentially in a server.

One of the regions of Spain in which the TD is a gamebird of high socio-economic importance is Extremadura, and the regional administration (Junta de Extremadura), created a public “hunting ground inventory” in 2021, as part of the development of an adaptive management plan (DOE 2021), in preparation to a possible moratorium lifting. In these grounds, TD monitoring was mandatory to be part of the inventory [25].

From a total number of 181 different hunting grounds taking part in the Observatorio Cinegético for the study period at national level, only 41 fulfilled the information requirements, mainly because TD surveys were not conducted on a yearly basis.

In addition, data was available from six monitored grounds by the co-authors, hence the total number of grounds used for the analysis was 47. With the exception of a hunting ground where no hunting was allowed, in all grounds the TD had been hunted before the moratorium. The majority of sites were social hunting grounds (managed by a local association of hunters, $n = 30$), whereas the remaining 17 were privately managed (and one was within a national park, where hunting was not allowed). The hunting ground size area ranged from 2.95 to 299.91 km².

The grounds were located in southern and eastern Spain, including the regions of Extremadura ($n = 28$), Andalucía ($n = 15$), Comunidad Valenciana ($n = 2$), Castilla-La Mancha ($n = 1$) and the island of Mallorca ($n = 1$) (Figure 1). In these regions there is a wide range of favourable habitats for the TD [6], including “dehesa”, a savanna-like landscape of evergreen holm oak (*Quercus ilex*), cork oak (*Quercus suber*) and grasslands [26], mixed habitats of shrublands and arable crops, olive groves and other orchards and forest [27].

2.2. Habitat Management

Following Sánchez-García et al. [22], four types of habitat measures were considered in this study (Appendix A):

- Water provision (coded as WATER): This included artificial water sources such as troughs and ponds of different size targeting small and big game species, together with those targeting livestock which could be visited by the TD, providing water from early spring to late summer. Also, when natural water sources were actively managed and conserved (such as removing debris and sediment in streams and repairing natural ponds), the ground was also considered to provide water.
- Food provision/supplementation (FOOD): Actions providing seed grains targeting small game species (wheat, barley, sunflower seeds, etc.), through feeders, hoppers,

and plots and tracks where grain was spread, including small, fenced areas to reduce access of livestock and wild ungulates. Food provision had to be conducted from early spring to late autumn. Grounds providing food only targeting big game (using mainly corn and feed) were not considered.

- Agricultural measures (CROP): Interventions in which land was sown or managed for game and wildlife, including crops for game, field margins, stubbles and fallow/uncultivated land where harvesting and grazing was not conducted until September and no herbicides and pesticides were used.
- Forest measures (FOREST): In this category, we included different cutting regimes and wood removal in forest and shrublands, conducted not only to ensure forest multifunctionality, but also for fire prevention. In the studied sites, forest management was not conducted yearly, but instead every 10–12 years. Existing research in similar Iberian landscapes show that forest management is conducted every 10–20 years, depending on the type of vegetation, resources and fire risk [28,29].

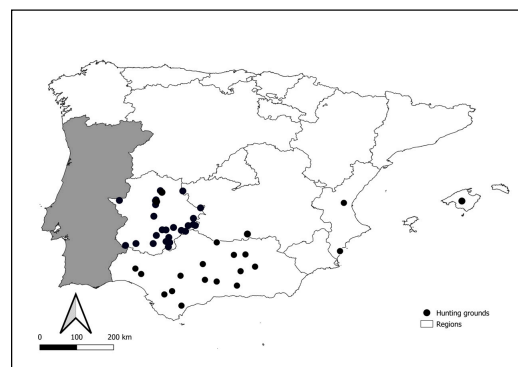


Figure 1. Location of the hunting grounds included in this study across southern and eastern Spain (showing Portugal in grey colour).

For each hunting ground, we recorded whether the four main habitat management measures were implemented annually during the study period (2021–2025). Information on management intensity (e.g., number of water troughs, ponds and feeders, and the area used for game crops or forest clearings) was also collected to characterize management practices across hunting grounds.

Information was first obtained through a structured questionnaire (based on Sánchez-García et al. [22]), face-to-face meetings and phone interviews with the managers. Monitoring of the measures was conducted by the co-authors during field visits afterwards, and Extremadura the measures were checked in collaboration with wildlife wardens from Extremadura (*Agentes del Medio Natural*), as 14 grounds belonged to the hunting ground inventory aiming to create a network of grounds interested in the conservation and sustainable hunting of the TD.

The habitat measures were then positively categorized as “conducted” when they had been implemented on a yearly basis, with the exception of forest management, for which different approach was followed; grounds with forest measures conducted in the period 2021–2023 were categorized positively (Appendix B).

2.3. Turtle Dove Surveys

Turtle dove surveys were conducted to detect breeding birds in the hunting grounds. Two monitoring methods were used to survey the TD abundance: walked transects conducted by trained volunteers and point counts conducted by researchers. In total, 35 grounds were monitored through walked transects and 12 through point counts. It

was not possible to use the same method in all sites because pilot trials conducted in 2020 showed that volunteers had difficulties in conducting point counts properly [25].

Volunteers using the Observatorio Cinegético were asked to choose an area with a representative and favourable habitat for the TD within the hunting ground [6], where it was possible to conduct a transect on foot during the early morning (3 h after dawn), and in the absence of wind, rain and other unsuitable weather conditions. Volunteers were asked to conduct at least one valid transect per year, though they were invited to conduct several when possible.

Based on previous information from south-western Spain, mainly Extremadura [30], surveys were conducted at the time period when “cooing” turtle dove activity is at its highest during the breeding period (increasing detection [31]), and before juveniles were recruited into the population, which normally occurs from early July onwards; hence, surveys were conducted from May to early July (Supplementary Materials Videos S1 and S2). Volunteers were instructed to conduct transects covering 4–6 km long from early May to early July, recording every TD seen or heard along a walked transect, and if possible conducting transects at the same locations during the project duration. Geographic coordinates from the observation point for every bird detected (heard or seen) were registered, as well as the track coordinates. Once each survey was finished, both the track and the bird observations were transferred to a geographic information system (GIS) layer within the Observatorio Cinegético system. Each transect was checked and validated, discarding those transects that did not follow the requirements (including counts from vehicles), or showing an overwhelming number of birds (higher than 30 birds observed/km), suggesting that the survey had been conducted close to a feeding or watering point.

In the grounds where monitoring was conducted using point counts, TDs were monitored at points separated 500–600 m from each other along transects in May–June, recording all TD heard or seen per point during a 5 min period [31].

In transects, a kilometric abundance index (KAI) was calculated per hunting ground, and if more than one valid transect was conducted per year, mean KAI values were calculated. With regard to point counts, each survey per hunting ground was conducted once a year, and the number of points varied among sites, ranging from 7 to 17 points, calculating the mean number of TD detected per point count for each survey.

2.4. Data Analysis

To assess the effect of habitat management on TD relative abundance, we fitted generalized linear mixed models (GLMMs) within the region, included as a random effect to account for data hierarchy. The GLMM fixed-effects model included the following fixed explanatory variables: (i) “monitoring method”, the method used to estimate abundance (transect or point count) to account for potential differences in abundance estimates between methods; (ii) “year”, capturing annual variation in TD abundance; (iii) and the four management-related variables, CROP, FOREST, FOOD and WATER, each of them classified as “conducted” or “not-conducted” within each hunting ground. A GLMM with a Gamma distribution and a log-link function was fitted, using TD abundance as the response variable. All statistical analyses were performed using R v4.3 software [32], namely the package ‘glmmTMB’ [33].

3. Results

A total of 185 valid surveys were used for analysis; 142 transects (including replicas) were conducted, covering in total 1868 km (median single transect length of 8.24 km for the whole study) detecting 7592 TDs, and 43 point-count surveys (mean 12 ± 5 standard deviation points per survey) detecting 623 TDs.

3.1. Management Traits

Out of 47 hunting grounds, 98% ($n = 46$) provided water and 87% food ($n = 41$), while a lower proportion of grounds conducted agricultural (23%, $n = 11$) and forest measures (21%, $n = 10$). One ground did not implement any of the measures, 41 provided water and food simultaneously (87%) and eight grounds conducted all measures (17%). The ground implementing no measures was a social ground with an area of 30,72 km² within a landscape of high habitat diversity, and the eight grounds implementing all measures were mainly private grounds ($n = 6$), averaging 38 km² and with a high interest in TD conservation and hunting.

Four grounds declared to have agricultural measures, but they were interventions of very small size (patches of 500–1000 m²), i.e., game crops and uncultivated land also used as feeding plots. In grounds implementing agricultural measures, there were game crops, mainly using a mix of cereals and legumes, with one ground also implementing field margins. When looking at the forest measures, in all cases there were combinations of forest clearance and firewalls, the latter conducted inside and along the boundaries of the grounds to reduce fire risk. The hunting ground managers declared that food, water provision and agricultural measures targeted TDs together with other game species, whereas none of the grounds had forest measures targeting TDs (though the majority of managers knew that it could favour the TD).

Considering all grounds, water trough density had a median value of 0.15 troughs/km² (interquartile range: 0.01–0.5; range: 0–5.21), and 0.04 ponds/km² (IQ range: 0–0.11; range: 0–0.91). With regard to feeders, their median density was 0.23 feeders/km² (IQ range: 0.11–0.57; range: 0–5.33). Among hunting grounds with agricultural management, the median managed area was 2.84 ha/km² (IQ range: 1.57–5.19; range: 0.57–15.61), whereas for forest measures, the median managed area was 1.55 ha/km² (IQ range: 1.08–2.31; range: 0.50–3.29) (Figure 2, Appendix B). It is important to note that the number of water troughs, feeders and the mean area devoted to agricultural measures did not change significantly during the study period, as in Spain the management actions are normally planned in periods of 5 years, as the duration of a hunting management plan (in Spanish “Plan de Ordenamiento Cinegético”) spans from 4 to 5 years.

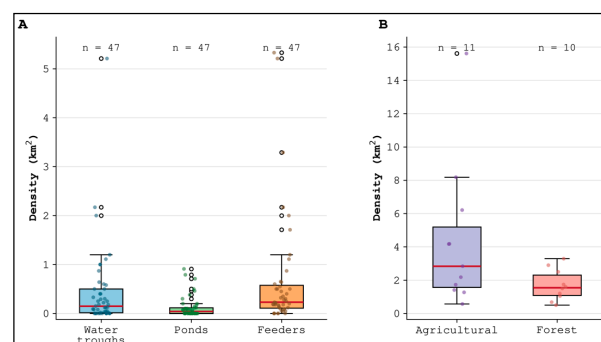


Figure 2. Distribution of the habitat management densities across the studied hunting grounds. (A) Densities of water troughs, ponds and feeders ($n = 47$); and (B) densities of agricultural and forest management, considering only grounds categorized as “conducted” ($n = 11$ and $n = 10$, respectively). Boxes represent the interquartile range, horizontal red lines indicate medians, and whiskers extend to the most extreme values within 1.5 times the interquartile range. Coloured points represent individual observations, while open circles indicate values beyond the whiskers.

3.2. Habitat Effects on Relative Abundance Trends

The generalized linear mixed model (GLMM), grouped by hunting ground ($n = 47$) and based on 185 surveys (averaging all valid transects) collected over a five-year period, revealed significant variation in TD abundance associated with monitoring method, year,

and management variables (agricultural and forest measures, food and water provision). The results of the GLMM analysis are presented in Table 1.

Table 1. Estimated coefficients from the generalized linear mixed model (GLMM). “Variable” denotes the explanatory variable or the intercept; “Estimate” refers to the model-derived coefficient; “S.E.” represents the corresponding standard error; and “*p*-value” indicates the level of statistical significance. The reference levels were Point count for monitoring method, 2021 for year, and non-managed for CROP (agricultural) and FOREST measures, FOOD and WATER provision. Overall model fit: AIC = 767; conditional pseudo-R² = 0.379, representing the variance explained by the fixed and random effects combined.

		Estimate	S.E.	<i>p</i> -Value
(Intercept)		−0.377	0.475	0.430
Monitoring method	Transect	1.173	0.169	<0.001 ***
Year	2022	0.076	0.193	0.693
	2023	0.213	0.188	0.258
	2024	0.450	0.189	0.017 *
	2025	0.519	0.190	0.006 **
CROP	Managed	0.564	0.205	0.006 **
FOREST	Managed	−0.168	0.205	0.413
FOOD	Managed	−0.558	0.197	0.005 **
WATER	Managed	0.507	0.466	0.277

Note * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Estimates significant at the 95% confidence level indicated that the transect method showed higher abundance estimates (mean = 3.23, 95% CI [2.32–4.5]) than the point counts, hence the abundance estimated using transects was 3.23 times that estimated using point counts. With regard to year effects, during the first two years (2022–2023), no significant abundance differences were observed when compared to the reference year (2021). In 2024, there was a significant difference ($p = 0.017$) when compared to the 2021 abundance (mean = 1.57, 95% CI [1.08–2.27]), becoming strongly significant ($p = 0.006$) in 2025 (mean = 1.68, 95% CI [1.16–2.44]).

When considering the management variables, no clear effect of water provision on TD abundance was found ($p = 0.277$), whereas a significant negative effect ($p = 0.005$) was found for food provision (mean = 0.57, 95% CI [0.39–0.84]) and agricultural management showed a significant positive effect ($p = 0.006$, mean = 1.76, 95% CI [1.18–2.62]) (Figure 3). It should be noted that 98% of the hunting grounds in this study provided water and 87% food, hence the between-group variation for this variable was very limited, and the statistical power of the significance test was therefore constrained.

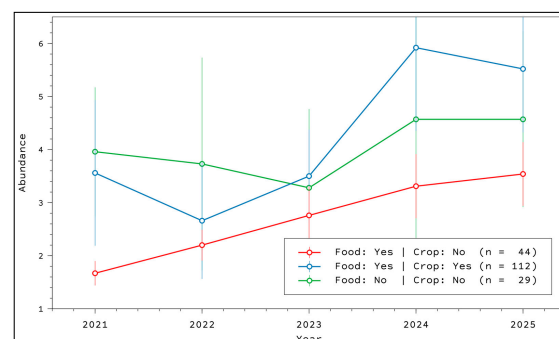


Figure 3. Annual variation in mean turtle dove abundance from 2021 to 2025 in hunting grounds grouped according to the implementation of food provision and agricultural habitat management. Points represent annual mean abundance, error bars indicate ± 1 standard error (SE), and lines connect annual estimates within each management group. Sample sizes for each group are shown in the legend.

4. Discussion

Overall, TD relative abundance increased throughout the study period across the monitored hunting grounds. However, recovery trajectories differed according to habitat management, with hunting grounds implementing agricultural measures showing a significantly higher increase in relative abundance, whereas those providing food showed a negative association. Because all hunting grounds were subject to the hunting moratorium, these findings suggest that habitat management could explain differences in population recovery among sites.

As expected, the majority of the grounds provided food and water, while lower percentages conducted agricultural and forest measures, and out of 47 grounds, only eight conducted all measures considered. This is not surprising, because conducting agricultural and forest measures can be more expensive than water and food provision, especially in grounds with limited economic resources (regardless of being a social or private hunting ground). These findings are partially in agreement with previous studies evaluating the proportion of habitat management measures conducted in hunting grounds, though in our study the proportion of grounds conducting land interventions (21–23%) was lower when compared to a large sample of grounds within the TD-inhabiting western flyway including Spain (47–50%, see Sánchez-García et al. [22]).

Our results suggest that the hunting moratorium may have increased the TD abundance during the study period, though agricultural measures could have contributed to a rapid recovery. Interestingly, Dunn et al. [18], who evaluated the effect of seed-rich plots for the TD in Britain (in which the species is not hunted), showed a slower temporal decline in the abundance of breeding TD males on sites with these intervention plots. In this study we found a similar result when conducting agricultural measures, though in the UK there was a different context, and different seed species were sown in the plots. This finding points towards the idea that the provision of seed-rich habitats (in our case, mixes of cereals and legumes) is key when aiming to support TD populations, which is in agreement to previous studies confirming the importance of cultivated seeds [4,5]. Although we did not measure the occurrence of wild seeds within or in the boundaries of the agricultural measures, we are led to believe that the implementation of agricultural measures may have increased habitat heterogeneity and the extent of farmland–forest ecotones [6], not discarding that the measures favoured the occurrence of wild seeds, as no pesticides were used and the labour was limited to ploughing and sowing in later winter/spring, leaving the plots “untouched” until autumn, well after the TD started their migration. Further research is needed in this topic.

In this study, agricultural measures were initially declared in 15 grounds, but after checking the information collected in four of them, it was concluded that no proper agricultural measures were conducted, as they corresponded to management units in which game crops were sown at small scale in combination with water and food provision, strategically used in the past for TD monitoring and in some cases, to increase hunting opportunities before the moratorium [15]. The remaining grounds with true agricultural measures, had a median area of 2.84 ha per 100 ha, and a positive effect on TD abundance was found. Owing to the small number of grounds studied, it is not possible to advice for a minimum surface to implement in areas of similar characteristics, but our results are within the size of the intervention plots used by Dunn et al. [18], who spread 4–7 plots per study site, totalling 2 ha per 100 ha in the UK. To the best of our knowledge, current management recommendations in Spain advice a minimum intervention surface for margins with trees/shrubs, and a minimum abundance for food points [23], but not for crops for game, the main agricultural measure implemented in this study.

Given the importance of the farmland–forest ecotone for the TD [6], we expected to find a positive relationship between forest measures and TD abundance, but no effect was found. This may reflect the nature of the interventions, which primarily aimed at fire prevention

(e.g., firebreaks) and multi-purpose forest management, rather than improving habitat suitability for the TD. It has been demonstrated that firebreaks may cause detrimental effects in birds species when removing nesting scrub or create forest edge fragmentation [29,34]. As reported by hunting ground managers, these measures were not specifically designed to benefit the species, which may explain their lack of abundance effect.

Water and food provision were the most commonly implemented measures, yet no significant effect was detected for water, and a negative association was found for food provision. This result should be interpreted with caution, as both measures were implemented in a high proportion of the hunting grounds. With regard to food provision, which historically has been implemented in the studied areas, increasing the proportion of bagged juveniles and in some cases leading to overhunting scenarios [16], we speculate that the negative association could be related to the TD breeding requirements. When birds arrive to their breeding grounds, they search for habitats providing nesting and foraging resources, the latter mainly wild seeds, changing towards cultivated seeds when wild seeds deplete [35]. As surveys were conducted from May to early July, when wild seeds may be still available, it is likely that food provision could be more important later in the breeding season, especially for juveniles during the first weeks of life. Nevertheless, while supplementary food resources may be important under resource-limited conditions, our results suggest that land-based interventions are likely to play a more important role in supporting breeding habitats and sustaining populations when compared to food and water provision, though further studies at larger scales should confirm this hypothesis [6].

In the grounds where only water and food provision were conducted, TD relative abundance showed a gradual but steady increase throughout the study period. By contrast, grounds implementing agricultural measures showed a fluctuating pattern during the first two years (2022–2023), followed by a marked abundance increase from 2024 to 2025. This pattern suggests that TD population responses to habitat management may require several years to become evident, which is agreement with similar time-lagged effects found in other farmland game species, such as habitat restoration programmes targeting the red-legged partridge (*Alectoris rufa*), showing measurable population increases after three or more years [36,37]. As the TD is long-distance migratory species wintering in the Sahel [7,38] other factors operating outside breeding grounds, including survival during migration and the winter areas [39], are also likely to influence annual population trends.

Some limitations of our study should be discussed. Continued participation depended largely on the interest and motivation of hunters and managers, which may have introduced self-selection bias because if participants were more engaged in monitoring, management or conservation were also more likely to provide complete survey series. Consequently, the study sample cannot be assumed to be fully representative of the wider population of hunting grounds, and the estimated associations should be interpreted accordingly. However, the selected grounds encompassed diverse contexts, including private and social hunting grounds, a wide range of size areas, and sites with different levels of resources, so the diversity represented in the final sample supports the relevance of the results across a broad range of hunting-ground conditions.

The use of management measures by the species was not evaluated (as conducted in other studies through GPS loggers, see Joly [40] and Ren et al. [41], which hampers the full understanding of the measures' effectiveness. Moreover, in this study, it was not possible to conduct a BACI experiment because with the exception of two sites (monitored and supervised by the co-authors), the habitat management did not change and no data was available before the moratorium was enforced in 2020. In any case, this is the first study conducted in Spain to evaluate the TD trends in different habitat management contexts, using real-world case scenarios from hunting grounds managed for TDs during the moratorium period.

5. Conclusions

Based on the preliminary evidence from this study, in Mediterranean areas of similar landscapes aiming to recover and conserve TD populations, habitat management should prioritize the establishment of agricultural measures (in this study game crops), which likely favour the species through increased food resources and farmland–forest ecotone structure, both key factors for TD conservation.

Though our study was not designed to define minimum surface requirements, optimal spatial configurations or management intensity thresholds, the median surface of agricultural measures in grounds where this measure was implemented was 2.84 ha per 100 ha. These land interventions should be implemented in the medium-long term, at least 3–4 years, to allow for a positive population response. Future studies should conduct multi-scale integrated analysis, including using GPS-tagged birds to validate individual responses.

Overall, our findings support the incorporation of agricultural habitat management as a central component of adaptive conservation strategies for the TD in Mediterranean farmland landscapes. Linking future hunting opportunities to the implementation of effective habitat measures could provide a powerful incentive for conservation across extensive areas of privately managed and public land, reinforcing both the ecological and socio-economic objectives of the adaptive harvest management plan.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/d18090553/s1>. Video S1: European Turtle doves showing courtship behaviour. Video S2: European Turtle doves using a selective feeder in one of the hunting grounds (videos taken by C. Lázaro).

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Institutional Review Board Statement: This study was observational, hence no birds were handled and no ethical approval was required.

Data Availability Statement: Data is available upon request.

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Appendix A

Examples of habitat management measures implemented in the hunting grounds, from left to right, clockwise: water provision (pond), food provision (specific feeder for European turtle doves), forest management intervention, and agricultural measures (field margin and game crop).



Appendix B

Density of the types of measures conducted in the hunting grounds. For water and food provision it was calculated by the number of water troughs, ponds and feeders (including feeding plots) per km². The agricultural and forest measures were expressed as number of hectares in which these interventions were implemented per km². The values in bold in the agricultural measures column show the hunting grounds declaring this measure but categorized as “not conducted”.

Code	Region	Type	Water/km ²	Pond/km ²	Feeders/km ²	Agri/km ²	Forest/km ²
AND_1	Andalucía	Social	0.58	0.08	0.00	0.08	0.00
AND_2	Andalucía	Social	0.00	0.46	0.08	0.00	1.60
AND_3	Andalucía	Social	0.13	0.10	0.12	0.57	1.05
AND_4	Andalucía	Social	0.12	0.10	0.00	0.00	0.00
AND_5	Andalucía	Social	0.08	0.30	0.60	0.00	0.00
AND_6	Andalucía	Social	1.20	0.00	1.20	0.20	0.00
AND_7	Andalucía	Social	1.11	0.11	1.11	0.28	0.00
AND_8	Andalucía	Social	0.00	0.71	0.00	0.00	0.00
AND_9	Andalucía	Social	0.50	0.00	0.50	0.00	0.00
AND_10	Andalucía	Social	1.00	0.09	1.71	0.00	0.00
AND_11	Andalucía	Social	0.87	0.00	0.87	0.00	0.00
AND_12	Andalucía	Social	0.60	0.00	0.65	0.00	0.00
AND_13	Andalucía	Social	5.21	0.00	5.21	0.00	0.00
AND_14	Andalucía	Social	1.00	0.00	0.00	0.00	0.00
AND_15	Andalucía	Social	2.00	0.05	2.00	0.05	0.00
CM_1	Castilla-La Mancha	Private	0.00	0.12	0.32	1.73	1.74
CV_1	Com. Valenciana	Social	0.01	0.00	0.05	0.00	0.00
CV_2	Com. Valenciana	Social	0.33	0.50	0.50	0.00	0.00
EX_1	Extremadura	Social	0.02	0.00	0.00	0.00	0.00
EX_2	Extremadura	Social	0.22	0.00	0.35	0.00	0.00

Code	Region	Type	Water/km ²	Pond/km ²	Feeders/km ²	Agri/km ²	Forest/km ²
EX_3	Extremadura	Social	0.12	0.00	0.22	0.00	0.00
EX_4	Extremadura	Social	0.00	0.20	0.12	1.27	0.50
EX_5	Extremadura	Private	0.00	0.05	0.25	2.18	0.68
EX_6	Extremadura	Private	0.18	0.08	0.30	0.00	0.00
EX_7	Extremadura	Private	0.00	0.38	0.10	4.17	2.50
EX_8	Extremadura	Private	0.15	0.00	0.28	0.00	0.00
EX_9	Extremadura	Social	0.02	0.02	0.04	0.00	0.00
EX_10	Extremadura	Private	0.09	0.06	0.09	15.61	2.90
EX_11	Extremadura	Private	2.17	0.10	5.33	6.21	0.00
EX_12	Extremadura	Private	0.50	0.00	0.55	0.00	0.00
EX_13	Extremadura	Social	0.04	0.14	0.18	2.84	0.00
EX_14	Extremadura	Social	0.00	0.04	0.05	0.00	0.00
EX_15	Extremadura	Social	0.25	0.17	0.17	4.18	0.00
EX_16	Extremadura	Social	0.18	0.00	0.18	0.00	0.00
EX_17	Extremadura	Social	0.40	0.00	0.23	0.00	0.00
EX_18	Extremadura	Private	0.00	0.20	2.17	0.00	3.29
EX_19	Extremadura	Private	0.00	0.79	0.20	0.00	0.00
EX_20	Extremadura	Private	0.29	0.07	0.20	0.00	0.00
EX_21	Extremadura	Private	0.00	0.91	3.29	0.00	0.00
EX_22	Extremadura	Private	0.03	0.00	0.15	0.00	0.00
EX_23	Extremadura	Private	0.40	0.00	0.18	8.18	1.20
EX_24	Extremadura	Private	0.05	0.00	0.19	1.41	1.50
EX_25	Extremadura	Social	0.30	0.00	0.50	0.00	0.00
EX_26	Extremadura	Private	0.08	0.00	0.45	0.00	0.00
EX_27	Extremadura	Social	0.25	0.00	0.40	0.00	0.00
EX_28	Extremadura	Social	0.00	0.00	0.00	0.00	0.00
IB_1	Islas Baleares	Private	0.64	0.00	0.64	0.00	0.00

Appendix C

Number of surveys conducted in each hunting ground per year, indicating the method used.

Code	Method	2021	2022	2023	2024	2025	Sum
AND_1	Transects	1	1	1	1	1	5
AND_2	Transects	1	1	0	1	1	4
AND_3	Transects	1	1	1	1	0	4
AND_4	Transects	1	0	1	1	1	4
AND_5	Transects	1	1	1	1	1	5
AND_6	Transects	1	1	1	1	0	4
AND_7	Transects	1	1	1	1	1	5
AND_8	Transects	1	1	0	1	1	4
AND_9	Transects	1	1	1	0	1	4
AND_10	Transects	1	1	1	1	1	5
AND_11	Transects	1	0	1	1	1	4
AND_12	Transects	1	1	1	1	1	5
AND_13	Transects	1	1	0	1	1	4
AND_14	Transects	1	1	1	1	1	5
AND_15	Transects	1	1	1	0	1	4

Code	Method	2021	2022	2023	2024	2025	Sum
CM_1	Point counts	0	1	1	1	1	4
CV_1	Transects	1	1	1	1	0	4
CV_2	Transects	1	1	1	0	1	4
EX_1	Transects	1	0	1	1	1	4
EX_2	Point counts	1	1	1	1	0	4
EX_3	Point counts	1	0	1	1	1	4
EX_4	Point counts	0	1	1	1	1	4
EX_5	Point counts	1	1	1	1	1	5
EX_6	Point counts	1	1	1	0	1	4
EX_7	Point counts	1	1	1	1	0	4
EX_8	Point counts	1	1	1	0	1	4
EX_9	Transects	0	1	1	1	1	4
EX_10	Transects	1	0	1	1	1	4
EX_11	Transects	0	1	1	0	1	3
EX_12	Transects	1	1	1	1	1	5
EX_13	Transects	1	0	1	1	1	4
EX_14	Point counts	0	0	1	1	1	3
EX_15	Transects	0	1	1	1	1	4
EX_16	Transects	1	0	0	1	1	3
EX_17	Transects	0	0	1	1	1	3
EX_18	Transects	0	0	1	1	1	3
EX_19	Transects	0	0	1	1	1	3
EX_20	Transects	0	0	0	0	0	0
EX_21	Point counts	0	1	0	1	1	3
EX_22	Transects	1	1	1	0	1	4
EX_23	Transects	1	1	1	1	1	5
EX_24	Transects	0	0	1	1	1	3
EX_25	Transects	0	1	1	1	0	3
EX_26	Transects	0	0	1	1	1	3
EX_27	Transects	1	1	1	1	1	5
EX_28	Point counts	1	1	1	1	0	4
IB_1	Transects	1	1	1	1	1	5
		33	33	41	39	39	185

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