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Analysis of Moroccan breeding and wintering population of the vulnerable European Turtle dove *Streptopelia turtur*: Breeding habitats, wintering sites and governing factors ☆

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ABSTRACT

The estimation of population size, the identification of breeding habitats, wintering zones, and governing factors are key matters for the understanding of population trends, as well as for the adoption of relevant conservation approaches, particularly within threatened species. From 2015 to 2019, a large-scale survey of the vulnerable Turtle doves (*Streptopelia turtur*) was established in Morocco. We monitored the breeding population, wintering attempts, and factors surrounding Doves in different Moroccan habitats. Results obtained from this study showed that 2846 breeding pairs were revealed in both farmlands and woodlands. In parallel, an important population of Doves was identified as wintering birds in Morocco instead of regular wintering grounds in Sub-Saharan Africa, and this is valuable information about this long-distance migrant bird. Moreover, the logistic binomial model showed that the occurrence probability of breeding and wintering Turtle doves in Morocco is significantly governed by climate conditions (temperature and rainfall), the abundance of food resources, and vegetation cover. Therefore, the availability of such requirements is suggested to control the wintering Doves in Morocco instead of Sub-Saharan quarters. In order to clarify this point, there is an urgent need to set up an integrated program of long-term ecological monitoring in North Africa and South Europe, as well as to set in new technologies to understand this issue.

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Introduction

The European Turtle dove (*Streptopelia turtur*) is a Palearctic-African migrant species that has undergone an accelerated and severe decline across its breeding and wintering ranges [1–3] with a loss of 70% of the population between 1980 and 2010. Recently, this game bird has been classified as 'Vulnerable' throughout wintering and breeding grounds, and 'Near Threatened' within the European countries following recent assessments [4,5]. The various factors responsible for the Doves' decline include degradation and loss of breeding habitats [3,8], reduction of food availability in breeding and in wintering grounds due to agricultural intensification [2,7], hunting [11], and environmental conditions change throughout the migration flyways [2,12].

Turtle doves breed in Europe and Northwest Africa, while wintering sites were located in sub-Saharan Africa [9–11]. In Northwest Africa and Europe, two different subspecies are identified: *S. t. arenicola* and *S. t. turtur* respectively [6,15]. Most researches have focused on the European subspecies and, comparatively, little is known about the status of the Northwest African subspecies [6]. Despite being a common migrant and breeding bird, the Turtle doves population is not yet estimated (except for a limited attempt made by [16] in a small area in Morocco) [6]. In Morocco, the Turtle dove is reported as a breeder in a variety of habitats, counting farmlands (olive trees, orange trees, and apple orchards) [9,17,18], forests (*Tetraclinis* and Argan), and other woodlands [17,19]. In parallel, the Turtle dove is a major game species, highly valued by national and international hunters in Morocco [6]. Most studies on Turtle doves in Morocco have focused on breeding biology [9,20–25], breeding habitat use [9,19], while other biology and ecology aspects were unexplored. However, with the recorded decline within the European population, the analysis of the national population is urgently needed at least to clarify the current situation of Turtle doves in Morocco.

The goals of this study are twofold. First, we summarized the breeding and wintering Turtle doves population in Morocco during five seasons. Second, we identified the most important factors predicting breeding and wintering attempts of Doves in this North African territory. The present study will help estimate the national population and situate it in the global context. Consequently, the present work will be a reference to evaluate the population trends of Turtle dove, mainly in Northwest Africa.

Methods

Study area

We monitored breeding and wintering Turtle doves over the majority of Moroccan Dove's described breeding habitats and migratory routes [4,7,11,13,18]. The study area extended from the Atlantic coasts in the West to the Moroccan-Algerian Saharan borders in the East, and from the Mediterranean Sea in the North to the Southern borders with Mauritania in the South (Fig. 1). From the South to the North, the vegetation cover was variable composed of a mixture of Acacia forest (Saharan habitats), coniferous and Argan forest (central Morocco), holm and Atlas cedar forest (in the Middle Atlas and North). In the Eastern Sahara, vegetation was dominated by palm oases. Along with these ranges, many wetlands and urban zones were visited in big cities and small towns. All breeding and wintering sites corresponded to woodlands (forests and riparian vegetation), arable farmland landscapes with predominantly cereal crops, and Saharan oases predominated with palms.

Data collection

This study was conducted in Morocco between 2015 and 2019 including breeding seasons (from March to September) and wintering phases (between October and February) of Turtle doves. The selection of these dates was based on Turtle doves' breeding dates in Europe [22,23], Northwest Africa, mainly Morocco and Algeria [6,7,24], and wintering periods in sub-Saharan quarters of Africa [2,9,10]. During these surveys, we documented the breeding activities (courtship, breeding pairs, nests, and breeding sites) from early March to September of each study year. Three visits per Month were adopted and nests were recorded via the line-transect method based on three lines of orchards (following the lines of cultivated trees inside the orchards) [7]. Furthermore, a walk-transect of about 5 km long, was selected in the riparian rivers' vegetation (two parallel transects of each river side vegetation) [25]. The transect method is a suitable method to collect birds and the ecological variables, mainly landscape features (vegetation, water bodies, and human impacts), in a cost-effective manner. In dense forests, nesting activities were investigated using Common Bird Census (CBC) methodology (based on the observation of Doves or their acoustic calls [11,26]. Nests were monitored from the construction period to the chick's flight or clutch failures. Additionally, after the leaving of the last Doves (the day on which the last Doves were observed between September and October), the research of wintering birds starts, with three visits per month from October to February: (i) first visit at the beginning of every month, (ii) second visit between 10th and 20th days, (iii) third visit between 20th and 30th days). The line-transect method was adopted with a walking range of 7 km in farmlands, 10 km in forests, and 15 km in Saharan lands, based on the surfaces covered by each landscape (the longest transects in the Saharan lands were adopted due to their huge surfaces in the South of Morocco). During every single transect, which took around four hours walk, from 06.00 a.m to 6.00 p.m, the numbers of Doves seen and/or heard singing were recorded.

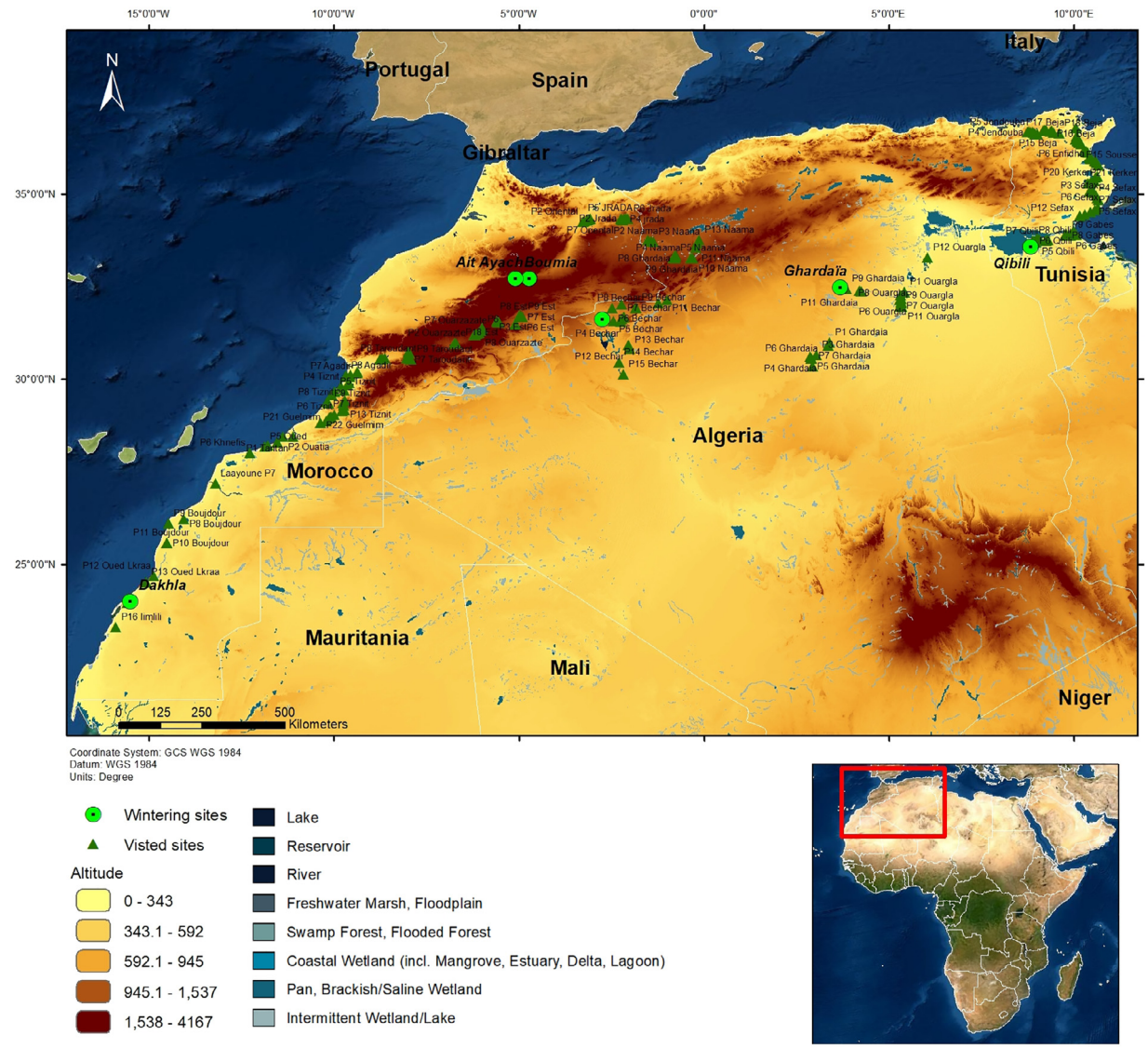

Fig. 1. Visited habitats (breeding and wintering sites) used by migrant Turtle doves in Morocco from 2015 to 2019.

We documented the altitude above sea level and the location of the sites where birds (wintering) or nests (breeding) were observed. Similarly, the breeding features or the wintering habitat including (4 categories: farmland (orchards, cereals, etc.), forest, oases, and wetland (rivers, lakes, dams, etc.)), the topography (3 categories: mountain, dune, plain), the vegetation type (3 categories: arboreal, bushes and herbaceous), the site urbanization rate (urban, rural and natural), the climate factors (temperature and rainfall). Also, the distance (by meters) from the observed birds to the nearest water source, cereals, and human infrastructure were noticed. Climate factors (rainfall and temperature) were accessed from the nearest weather stations to each breeding or wintering site from 2015 to 2019. All these features are suggested to predict the real reasons behind the selection of these habitats for wintering and breeding. In parallel to fieldwork, data of wintering Doves between 2006 and 2007 were included for further clarifications of the wintering behavior (long-term periods) of this game bird in the Moroccan territory.

Data analysis

Geographical locations of wintering and breeding Turtle doves were localized using Geotracker software. Moreover, breeding pairs and wintering birds were defined and results were given as the number of observations. In order to compare wintering behavior (within a group or solitary), Wilcoxon Test was used and results were given as mean ± SD.

Table 1
Summary of monitored and analysed variables (response and explanatory) to predict breeding and wintering of Turtle doves in Morocco.

Response variable Qualitative	Explanatory variables Quantitative	Qualitative
Occurrence of breeding pairs	Altitude (Alt), Distance to nearest cereals (NC), Distance to nearest water body (NW) Distance to nearest human building (NB), Temperature (Tmp), Rainfall (Rn).	Topography (Tpg) Vegetation (Vgt) Urbanization (Urb) Habitat (Hbt)
Occurrence of wintering Individuals	Altitude (Alt), Distance to nearest cereals (NC), Distance to nearest water body (NW), Distance to nearest human building (NB) Temperature (Tmp) Rainfall (Rn)	Topography (Tpg) Vegetation (Vgt) Urbanization (Urb) Habitat (Hbt)

Table 2
Breeding population of Turtle doves in studied habitats (farmlands and woodlands) in Morocco between 2015 and 2019.

Region	Habitat type	Habitat surface m^2	Nesting-Support	Breeding pairs	Nests	Survived nestling
Midelt	Farmlands	4450	Apples	934	467	362
Beni Mellal		4500	Oranges	852	426	319
Fez		287,428.3	Olives	862	431	138
Midelt	Woodlands	1,310,680	Wild rose, Hawthorn and Poplar	198	99	99

We assessed the relevance of altitude, habitat type, topography, vegetation type, urbanization rate, temperature, rainfall, distance to the nearest water source, nearest, cereals and nearest human building as predictors of wintering and breeding occurrence of Turtle dove per transect (dependent variables: with 0 (no Turtle dove observed) and 1 (observed Turtle dove)) using two models with a binomial error structure and log them using link function. In these models, the effect of possible multi-collinearity between explanatory variables was checked using the variance inflation factor (VIF): values not exceeding the threshold of 5 indicate no multi-collinearity-associated biases [27]. In our models, the highest VIF value was 1.29, meaning that the estimated effects were not affected by a possible multi-collinearity problem. Prior to statistical analyses, the investigated variables were log(x) or log(x + 1)-transformed to ensure normality (Shapiro–Wilk test, $P > 0.05$ for all transformed variables). Models were constructed based on the corrected Akaike's Information Criterion (AICc) values allowing us to rank and select the model of best fit [28]. We calculated the weight of each model to determine the explanatory variables strength (predictors) on response variables (dependent) (Table 1). Variables' significance and trend in the most parsimonious model were shown as Wald and parameter estimate values. All statistical tests and analyses were carried out using Statistica 12 software.

Results

Breeding Turtle doves

After five years monitoring (2015–2019), 2846 breeding pairs were recorded in three breeding regions (Table 2). At Midelt, 1132 breeding pairs were recorded in apple orchards (934 pairs) and woodlands (198 pairs). At Beni Mellal, all the 852 recorded pairs were in orange groves. Moreover, 862 pairs were observed in olive orchards at Fez. In parallel, 1522 nests were documented between 2015 and 2019; the majority of which were in farmlands, 467 nests in apple trees, 426 in orange trees, and 431 in olive trees. While the minority (198 nests) were in woodlands. On the other hand, 918 successful chicks left their nests during the surveyed breeding seasons. The majority of which were in farmlands (362 in apple trees, 319 in orange trees, and 138 in olive trees), while only 99 successful chicks were observed in woodlands.

After the autumnal departures, many Turtle dove individuals were found wintering in the Moroccan territory. During five years (2015–2019), 48 birds (12 in Boumia, 22 in Ait Ayach, and 14 in Dakhla) were observed in different Habitats as wintering individuals between mid-October and February. Additionally, 27 wintering Doves were recorded between 2006 and 2007 (22 in Missour region, 3 in Taroudant, 2 in Agadir). Moreover, wintering Turtle doves were observed monthly, during seven wintering seasons (2006–2007and 2015–2019). On the other hand, in most of the visits, Doves were found in groups (3.71 ± 1.12 individuals) in comparison with solitary birds (0.57 ± 0.20) (Wilcoxon Test: $Z=-3.25$, $P = 0.001$).

Wintering doves were observed in Ait Ayach and Boumia located in high altitudes and Dakhla with the lowest altitude above sea level (Table 3). All wintering sites were rich in cereals and other seeds that might resolve the feeding requirements of wintering birds. Similarly, wintering sites were rich in vegetation cover, including cultivated plantations, such as orchards and woodlands such as *Tamarix* and *Eucalyptus sp*.

Table 3
Characteristics of Turtle doves' wintering sites documented in Morocco from 2015 to 2019.

	Wintering sites		
	Ait Ayach	Dakhla	Boumia
Localization of wintering habitat	(32°41′N,4°44′W)	(23°59′35.10″N,15°30′29.19″W)	(32.7304°N,5.0989°W)
Topography	Valley, Cavities and riverbanks	Agricultural Oases + Dunes	Height Plain, riverbanks
Altitude (m)	1300	50	1500
Mean temperature	11.98 ± 1.53	18.88 ± 1.38	11.98 ± 1.53
Vegetation	Orchards (85%): Apples, Pruns, Olives	Tamarix *sp*., Eucalyptus sp., Palm (55%)	Orchards (2%): Apples, Amends, Prunes,
Seeds	Cereals (15%): *Triticumsp, Hordeumvulgare, Zea mays,*	Cereals (45%): *Zea mays, Triticumsp,*	Cereals (98%): *Triticumturgidum,Triticumaestivum, Hordeumvulgare, Zea mays, Cider arietinum, Pisumsativum, Lens culinaris*

Table 4
Summary of most appropriate models for measures of both dependent variables (Occurrence of breeding pairs and wintering individuals) in Moroccan surveyed sites. (Alt: Altitude, Tpg: Topography, Hbt: Habitat, Vgt: Vegetation, Urb: Urbanization, NC: distance to nearest cereals, NW: distance to nearest water body, NB: distance to nearest human building, Tmp: temperature, Rn: Rainfall).

Response variable	Explanatory variables	K	AICc	Δ AICc	Relative likelihood	Weight
Occurrence of breeding pairs	Alt+NB+Tpg+Hbt+Vgt+Urb	7	107.09	0.00	1.00	0.12
	Alt+Tpg+Hbt+Vgt+Urb	6	107.21	0.12	0.94	0.11
	Alt+Rn+Tpg+Hbt+Vgt+Urb	7	107.63	0.55	0.76	0.09
	Alt+NB+Rn+Tpg+Hbt+Vgt+Urb	8	108.01	0.92	0.63	0.07
	Alt+NW+ Rn+Tpg+Hbt+Vgt+Urb	8	108.40	1.31	0.52	0.06
	Alt+NW+ Tpg+Hbt+Vgt+Urb	7	108.48	1.39	0.50	0.06
	Alt+NC+ NB+Tpg+Hbt+Vgt+Urb	8	108.62	1.53	0.47	0.05
	Alt+Tmp+Rn+Tpg+Hbt+Vgt+Urb	8	108.70	1.61	0.45	0.05
	Alt+NC+ NB+Rn+Tpg+Hbt+Vgt+Urb	9	108.76	1.67	0.43	0.05
	Alt+NC+ Rn+Tpg+Hbt+Vgt+Urb	8	108.79	1.71	0.43	0.05
	Alt+NB+Tmp+Tpg+Hbt+Vgt+Urb	8	108.85	1.76	0.41	0.05
	Alt+NW+ NB+Tpg+Hbt+Vgt+Urb	8	108.89	1.80	0.41	0.05
	Alt+Tmp+Tpg+Hbt+Vgt+Urb	7	108.89	1.80	0.41	0.05
	Alt+Tpg+Vgt+Urb	5	108.95	1.87	0.39	0.05
	Alt+NC+ NB+Tpg+Vgt+Urb	7	109.02	1.93	0.38	0.04
	Alt+NC+ Tpg+Hbt+Vgt+Urb	7	109.06	1.98	0.37	0.04
Occurrence of wintering Individuals	NW+ Tmp+Rn+Tpg+Hbt+Vgt	7	84.72	0.00	1.00	0.32
	NW+ NB+Tmp+Rn+Tpg+Hbt+Vgt	8	86.20	1.48	0.48	0.15
	Alt+NW+ Tmp+Rn+Tpg+Hbt+Vgt+Urb	9	86.37	1.65	0.44	0.14
	Alt+NW+ Tmp+Rn+Tpg+Hbt+Vgt	8	86.37	1.65	0.44	0.14
	NC+ NW+ Tmp+Rn+Tpg+Hbt+Vgt	8	86.57	1.85	0.40	0.13
	NW+ Tmp+Rn+Tpg+Hbt+Vgt+Urb	8	86.72	2.00	0.37	0.12

Predictors of the occurrence of breeding and wintering doves

Factors affecting the selection of breeding and wintering habitats by Turtle Doves in the study area are summarized in Table 4. The installation of breeding Doves in nesting sites increased significantly with increasing altitude elevation (small estimated value, Table 4). Turtle doves' breeding pairs occupied mostly high altitude habitats in Morocco. Similarly, they were more likely to occur in wetlands, forests, and areas with herbaceous plants, as well as less intensive farmlands (Table 4). On the other hand, the observation probability of wintering Turtle doves in Morocco diminished significantly with the increasing distance separating the recording site to the nearest water source. Doves wintered most often close to wetlands rich in water. Moreover, few individuals wintered when the diurnal temperature increased from October to February. Equally, the wintering probability of Turtle doves decreased significantly with increasing rainfall (Tables 4, and 5).

Discussion

This study aims to analyze the population of the European Turtle dove *Streptopelia turtur* at a large scale in Morocco. It is of a great concern for the upcoming relative investigations and conservation policies. Our principal target was to provide the first information on the breeding population size, wintering attempts, and governing factors. We collected new and appreciated data describing the selection of nesting and the wintering sites of the Turtle dove. Acquired data are the leading and only offered findings related to wintering Doves in Morocco and the entire Northwest African area, which is of great attention for the application of future deep monitoring of the less studied Moroccan Dove population.

Table 5
Significance of studied variables on the occurrence of breeding and wintering Doves in Morocco based on the top models (only significant relationships were shown).

Response variables	Explanatory variables	Level of effect	Estimate	SE	Wald test	*p*
Occurrence of breeding pairs	Intercept		15.45	2439.35	0.00	0.99
	Altitude		0.44	0.15	8.73	< 0.01
	Habitat type	Farmland	−6.70	0.50	181.51	< 0.01
	Habitat type	Wetland	8.42	0.53	249.95	< 0.01
	Habitat type	Forest	7.29	0.55	176.90	< 0.01
	Vegetation	Hebaceous	11.53	0.81	202.76	< 0.01
	Vegetation	arboreal	6.39			
Occurrence of wintering individuals	Intercept		48.51	579.30	0.01	0.93
	Nearest water		−1.41	0.48	8.63	< 0.01
	Temperature		−15,89	3.63	19.13	< 0.01
	Rainfall		−1.48	0.45	11.02	< 0.01

European Turtle doves select nesting locations mostly in agro-systems where nesting supports and foraging seeds are offered [4,11,13,29]. Similarly, in this study, nests were found in agrosystems, including olive trees (Fez), apple trees (Midelt), and orange orchards (Beni Mellal), as well as in woodlands, principally riparian plants (Midelt), where supporting trees and cultivated and/or natural seeds are abundant. Moreover, via Models constructed based on the corrected Akaike's Information Criterion (AICc), the installation of breeding Doves in nesting sites increased significantly with habitat rich in water, foraging sources, and woody cover, which were offered in wetlands, forests, and in areas with herbaceous vegetation. While breeding pairs avoid habitats where food and water resources are less abundant. In addition, Doves' nests were absent in intensified farmlands (habitats where agricultural activities were intense in coincidence with breeding periods of Doves). These results match with those cited by [9,30,31], which support that Turtle doves breed in farmlands characterized by minor human impact, mainly during Doves Breeding periods.

This study highlights the wintering of Turtle doves in Morocco, which is the first of its kind, since individuals were encountered from 2006 to 2019. This confirms that Turtle doves spent wintering periods between October and February in North Africa without crossing the Sahara desert to common wintering grounds located deep in Africa. In this context, our results differ completely from a wide range of studies that insisted on wintering of Turtle doves in sub-Saharan Africa, counting those that have used Geolocators and satellite telemetry [9,10]. However, our results confirm the isolated observations of wintering doves made by [32] in Algeria and by [14] in Morocco. On the other hand, wintering Doves were located in habitats characterized by warm temperatures and low rainfall. Wintering sites were close to water sources, rich in foraging seeds and dense vegetation cover, which is similar to regular wintering quarters of Africa [7,32]. Therefore, we suggest that the availability of suitable wintering conditions in Morocco is the main key leading Doves to spend wintering periods in this area. A similar strategy was recorded for White stork, this long-distance migrant bird has changed its wintering grounds from Africa to South Europe due to the availability of food resources (dumps) and warm climate conditions [33].

Finally, in contradiction to previous studies considering Morocco as a stopover and breeding zone for Turtle doves [10,34–36], our study discovers wintering Doves during 13 years, which is the first of its kind. Therefore, the Turtle dove phenological status in Morocco and other North African zones need to be investigated deeply at least to verify the resident probability of this highly appreciated game bird via new accurate technologies, including telemetry and isotopes.

Conclusion

In summary, this study estimates breeding pairs and wintering Turtle doves in different Moroccan regions. In addition, this investigation offers exhaustive data on the breeding and wintering parameters of the vulnerable Turtle dove. An important breeding population of Turtle doves was spotted in orchards and woodlands to ensure the protection and forage of nestlings. Equally, wintering Doves select habitats rich in foraging resources, water, and wood cover, and suitable climate. These data are important as a basis for future comparative investigations, mainly the bio-ecology and status of the Turtle doves in North Africa. Equally, our data could serve for future monitoring use and long-term management policies of the endangered Dove population in Morocco and entire Northwest Africa. The conclusions of our study would recommend that the maintenance of wetlands (surrounded by an arboreal cover, natural and cultivated seeds) and agrosystems near rivers, could ensure the increasing rates of breeding success and wintering probabilities by providing Doves with more suitable and safe habitats rich in seeds and water sources. This would require conservation strategies and cooperative efforts of different levels of Moroccan society, from experts, authorities, local eco-friendly NGOs, to the local farmers.

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Declaration of Competing Interest

The authors declare they have no competing interests.

CRediT authorship contribution statement

Ismail Mansouri: Visualization, Formal analysis, Writing – original draft, Writing – review & editing. **Wafae Squalli:** Visualization, Formal analysis, Writing – original draft, Writing – review & editing. **Abdelbari El Agy:** Data curation, Writing – review & editing. **Karima Es Salai:** Data curation, Writing – review & editing. **Kenza Bouayad:** Data curation, Writing – review & editing. **Badr Benhichou:** Data curation, Writing – review & editing. **Abderrahim El Hassani:** Data curation, Writing – review & editing. **Lahsen El Ghadraoui:** Data curation, Writing – review & editing. **Mohamed Dakki:** Data curation, Writing – review & editing.

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