

Research Article

Migratory Dates, Breeding Phenology, and Reproductive Success of European Turtle Doves between Lowlands and Highest Breeding Habitats in North Africa

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The migratory time, breeding chronology, and reproductive success of the European turtle doves (*Streptopelia turtur*) were studied in Midelt as a high-altitude breeding habitat and Beni Mellal as a low-altitude breeding site from 2015 to 2018 in Morocco. Migration dates, breeding phenology, and breeding success were recorded from March to October for each season. As a result, during four years, arrival dates were earlier at the low breeding site, while departure dates were earlier at the high breeding site. Similarly, breeding phenology from nest building to fledging was early at low-altitude site. On the other hand, with four breeding seasons and 893 nests (467 at Midelt and 426 at Beni Mellal), average breeding success was 57% of chicks at Midelt compared to 60.15% at Beni Mellal. Moreover, at Midelt, 18.89% of eggs and 10.54% of chicks were predated, while at Beni Mellal 21.80% of eggs and 4.65% of chicks were deserted due to human disturbance. As a response, at Midelt breeding period was shorter and shifted to hot periods to ensure better reproductive success. Finally, our results highlight that the turtle dove breeding season is later and shorter at breeding highlands, which might allow this bird to avoid the vigorous climate conditions at mountains and their effect on reproductive success.

1. Introduction

Altitudinal and latitudinal variation can be important drivers of dynamics, demography, and phenology of wildlife populations [1]. Understanding the effects of altitudinal variation on populations is urgently required to update effective conservation and habitat management that promotes flexibility to altitude and climate change. Altitudinal variation may disturb synchrony between arrival on breeding grounds for migratory species or beginning of

breeding activities and the availability of food resources needed for successful breeding [2–5]. These phenological divergences, if they take place, could lead to reduced breeding success and population declines [1, 5, 6]. In some cases, migratory populations may adapt to chronological shifts in food resources by tracking thermal niches in space [7] or time [8].

Although many research studies have studied the effect of altitudinal variation on the timing of arrival and breeding dates in migratory species [9, 10], such as shifted breeding

periods of migratory bird species in the Sierra Nevada mountains of California [11], the cost of breeding dates on subsequent aspects of reproduction and phenology cycle remains poorly understood, particularly in long migrant and endangered species [12]. This cause-effect is crucial because changes in arrival dates and breeding phenology are likely to influence reproductive strategies, success, and eventually population trends [12, 13].

The European turtle dove (*Streptopelia turtur*) is a long-distance Afro-Palaearctic migrant bird that travels thousands of kilometres between breeding and wintering grounds. As the case of many long-distance migratory species, the shifting of departure and arrival times is susceptible to influence turtle dove's breeding decisions and periods. On the other hand, this game species declined by 91% within the UK and 69% across Europe since 1980 [14, 15], leading to this bird being one of the most strongly declining species in Europe [16]. For these reasons, any shifting in migratory or breeding chronology according to altitudinal elevation could accelerate the declining rate and lead to the extinction of this game bird [17]. Studies on the breeding ecology of turtle doves are very advanced in the Mediterranean basin [18–20]. However, data on the effect of altitude and mountainous climate on its breeding phenology and reproductive success are still limited or even absent. In [21], the tendency of doves to breed in lowlands was noted, favouring warm, dry conditions and avoiding the higher grounds and rainfall of the West and North [22]. Nevertheless, climate change and degradation of natural habitats, especially in arid zones, such as North Africa, push this species to establish in new habitats and farmlands [23, 24]. In the Magharibian region, including Morocco, with the extension of arid lands, most agricultural fields, which seem to be favourable for turtle doves, are linked to high-altitude mountains because of their richness in water [25]. Despite their fertility, water wealth, and foraging habitats, these zones are characterized by specific environmental conditions that can affect dove chronology and breeding success.

In such a context, precise knowledge of the migration periods and breeding chronology is urgently needed to understand certain migratory and breeding features in North African high-altitude zones, which are breeding lands and migrating routes [26, 27]. In addition, the comparison of turtle dove chronology between lowlands and highlands is unknown, and its awareness is useful in conservation management such as adoption of hunting periods which is consistent with breeding chronology.

The aim of this study is to present data to assess varying chronologies in the turtle dove migration time and breeding parameters between lowlands and high grounds. We are investigating for any difference in turtle dove arrival dates between lowlands and highlands and its eventual influences on breeding chronology and success.

2. Methods

2.1. Study Sites. Data were collected at two different farmland sites in Morocco, from early March to late September, between 2015 and 2018. Chosen sites were different in their

geographical location and environmental conditions. Ait Ayach valley (32°41' N, 4°44' W), as a high-altitude site (1400 to 1650 m above mean sea level), is located in the Midelt province. On the other side, the lowland site was located in Beni Mellal (32° 20' 22'' N, 6° 21' 39'' W), with 400 to 600 m altitude above mean sea level. Both sites were dominated by olives, oranges, and apples but differed in terms of climate conditions (temperature and precipitation data were accessed from one to two weather stations nearest each observation site from 2015 to 2018) (Table 1). Effectively, Midelt located in Ayachi mountains was colder than Beni Mellal but with lesser rainfall ($n=48$, $t=-.952$, $df=22$, $p=0.351$).

2.2. Data Collection

2.2.1. Sample Design. Twenty apple orchards, with 7.47 ha in total, at Midelt and twenty orange groves, with 6.48 ha, at Beni Mellal were selected and monitored from early March to late September between 2015 and 2018. The survey of turtle dove's arrival at both sites started in early March and continued until the building of the first nest during each breeding season. At both sites, three sorties were performed per week, and the arrival date is noted once turtle dove is observed each year. Equally, departure dates were noted after the leaving of last birds (the day of the observation of the last dove for each site).

After the installation of doves in the selected sites, the breeding surveys were elapsed, the nesting time (first nest recorded after arrival dates), laying dates (first egg after nest constructions), hatching (first hatched egg for each season), and chicks' nest leaving (first chick to fly) were monitored at the rate of three visits (three days continuously along the week per visit) per month for each site, based on *S. turtur* breeding chronology reported in Europe [28, 29] and North Africa [30, 31]: (i) first visit at the beginning of every month, (ii) second visit between 10th and 20th days, and (iii) third visit between 20th and 30th days. Besides breeding chronology, breeding success, hatched egg's rate (100 x hatched eggs/all laid eggs), and flying chick's rate (100 x chicks leaving their nests/fledged chicks) were calculated in percentage. In addition, failure factors were recorded (based on carcasses and other aspects, such as the status of nest and feathers in or outside the nest) along with breeding phases, in order to compare between stations.

2.3. Statistics. Statistical analyses were done in STAT-GRAPHICS Centurion software, version XVI.I. Before running the statistical analysis, we checked for normality and homogeneity of variance for all variables with the Kolmogorov–Smirnov test. To assess differences in arrival (first day for doves after prenuptial migration), departure dates (last day for doves at breeding grounds), and breeding periods (number of days between first arrivals and last individuals in breeding habitats), the independent *T*-test was used, considering the two sites as unrelated ecosystems.

Breeding success, including nest success (100 x success nests/all built nests), hatched eggs (100 x success eggs/all laid

TABLE 1: Main climatic characteristics in prospected sites, average temperatures, and rainfall, calculated from monthly means of the four study years.

Climatic parameters	Midelt	Beni Mellal	
	Altitude (m)	1500	<600
Temperatures (°C)	March-September	20.08 ± 0.69	22.21 ± 0.64
	Annual average	16.05 ± 2.00	18.63 ± 1.81
	Minimal	5.80 (January)	10 (January)
	Maximal	26.80 (July)	34.00 (July)
Rainfall (mm)	March-September	15.55 ± 3.55	25.00 ± 2.19
	Average	15.17 ± 2.24	35.37 ± 6.52
	Minimal	5 (January)	3.5 (July)
	Maximal	29.8 (May)	60.5 (March)
	Annual	181.8	356

Minimal temperatures: the lowest temperature during the coldest month. Maximal temperature: the highest temperature during the hottest month. Average rainfall: the average rainfall of the whole year. Minimal rainfall: the lowest rainfall during the rainless month. Maximal rainfall: the highest rainfall during the rainiest month. Annual temperature: the average of annual temperatures. Annual rainfall: the whole rainfall of the year. All these parameters were calculated for four years.

eggs), and survived chicks (100 x survived chicks/all hatched chicks) were compared using the Wilcoxon sign test. Before running the Wilcoxon test, breeding success parameters (nest success, hatched eggs, and survived chicks) were considered as a percentage of success inside 20 plots at each site (20 apple orchards in Midelt and 20 orange groves in Beni Mellal).

For breeding phenology, an ANOVA test was conducted to assess the variation of each explanatory variable (nesting time, laying date, hatching date, and chick survival) on the breeding sites. Moreover, in order to examine how the breeding period reacts to the temperature at Midelt site, generalised linear models (GLMs) were fitted considering a Gaussian distribution (McCullagh and Nelder, 1989). The explanatory variables are both quantitative (temperatures in °C between March and September during four years and breeding periods in days during four seasons). Results were given as sample size and mean ± SD, and graphs were created by GraphPad Prism Mac 6.0h software.

3. Results

3.1. Arrival and Departure Dates. During four years, high- and low-altitude breeding zones differed significantly. First arrival dates in spring were earlier with an average of 8.00 ± 1.77 days at Beni Mellal (20 ± 0.40 March) compared to Midelt (28.25 ± 2.05 March) ($n = 8$, $t = 13.73$, $df = 3$, $p = 0.001$). Similarly, departure dates were different between the two sites. Last doves were observed for 13.25 ± 2.36 days late at Beni Mellal (11.75 ± 2.46 October) compared with Midelt (28.00 ± 1.47 September) ($n = 8$, $t = 19.022$, $df = 3$, $p < 0.01$). On the other hand, first arrival dates in spring were advanced with an average of 2.5 ± 0.75 days per year in our sample ($n = 8$, (4 years) * 2 (sites)).

3.2. Breeding Chronology. The comparison of breeding chronology in turtle doves during four breeding seasons including nesting, laying, fledging, and chick's flying dates between Midelt and Beni Mellal is summarized in Figure 1 and Table 2. Nesting activities (first nest per season) began in average on 4.75 ± 1.54 April at Beni Mellal, while at Midelt, first nests were recorded late in the last week of April (26.5 ± 0.64 April). Similarly, laying dates (first egg per season) were earlier by an average of 15.5 ± 3.22 days in low-altitude breeding habitats. In fact, the first eggs were found on 12.5 ± 2.53 April at Beni Mellal and 28.00 ± 0.7 April at Midelt. For chicks, hatching and flying dates were also earlier in the low-altitude breeding zone. For Beni Mellal, first hatched chicks were on 11.5 ± 2.62 May in average, while at Midelt, first chicks occurred late on 17.50 ± 2.72 May. Chicks started flying (nest leaving) first at Beni Mellal on 27.50 ± 2.53 May and 3.50 ± 2.33 June at Midelt. Breeding periods (from arrival to departure dates) were likely longer in low-altitude habitat. At Midelt, breeding season (from the arrival to the last individuals in breeding habitats) took in average 184.00 ± 2.04 days compared with 205.5 ± 2.40 days at Beni Mellal ($n = 8$, $t = 85.699$, $df = 3$, $p < 0.004$). All these findings showed an early breeding chronology at Beni Mellal at a low-altitude breeding habitat (600 m).

3.3. Breeding Success. Among the 893 monitored nests (467 at Midelt and 426 at Beni Mellal) (Table 3), only 73.87% were succeeded at Midelt compared to 80.98% at Beni Mellal ($n = 20$, $z = -4.83$, $p < 0.001$). During the incubation phase, fledging success was higher at Midelt compared with Beni Mellal ($n = 20$, $z = -5.04$, $p < 0.001$). However, during the rearing period, the success rate was higher at Beni Mellal ($n = 20$, $z = -5.65$, $p < 0.001$). Failure factors were also variable between these habitats. At Midelt, predation presented the most threat menacing turtle dove breeding success, while at Beni Mellal, nest desertion dominated all failed clutches.

4. Discussion

Migration time, breeding chronology, and reproductive success of European turtle doves differed between lowlands and high-altitude breeding sites. In fact, turtle doves arrived early in low and warm habitats, presented in our case by Beni Mellal with 600 m altitude (Table 2), while at Midelt (1400–1650 m) prenuptial arrival dates were significantly late. Similar results were noted in the barn swallow (*Hirundo rustica*), in which the arrival time was earlier in low-altitude zones [32]. On the other hand, results recorded at Beni Mellal are comparable to those cited in North African lowland habitats. At Tadla (30 km to Beni Mellal), the first arrived turtle doves were noted on 19 ± 0.6 March [33], at Haouz on 15 to 16 March [34], and in Moroccan North Atlantic on 24 ± 0.16 March [35]. Therefore, despite the limitation of the present study to two sites, the cited literature confirms that the arrival dates are early in lowlands and do not change depending on the years as mentioned by Browne et al. [36]. On the contrary, the departure dates have started first at Midelt (28.00 ± 1.47 September) as a response

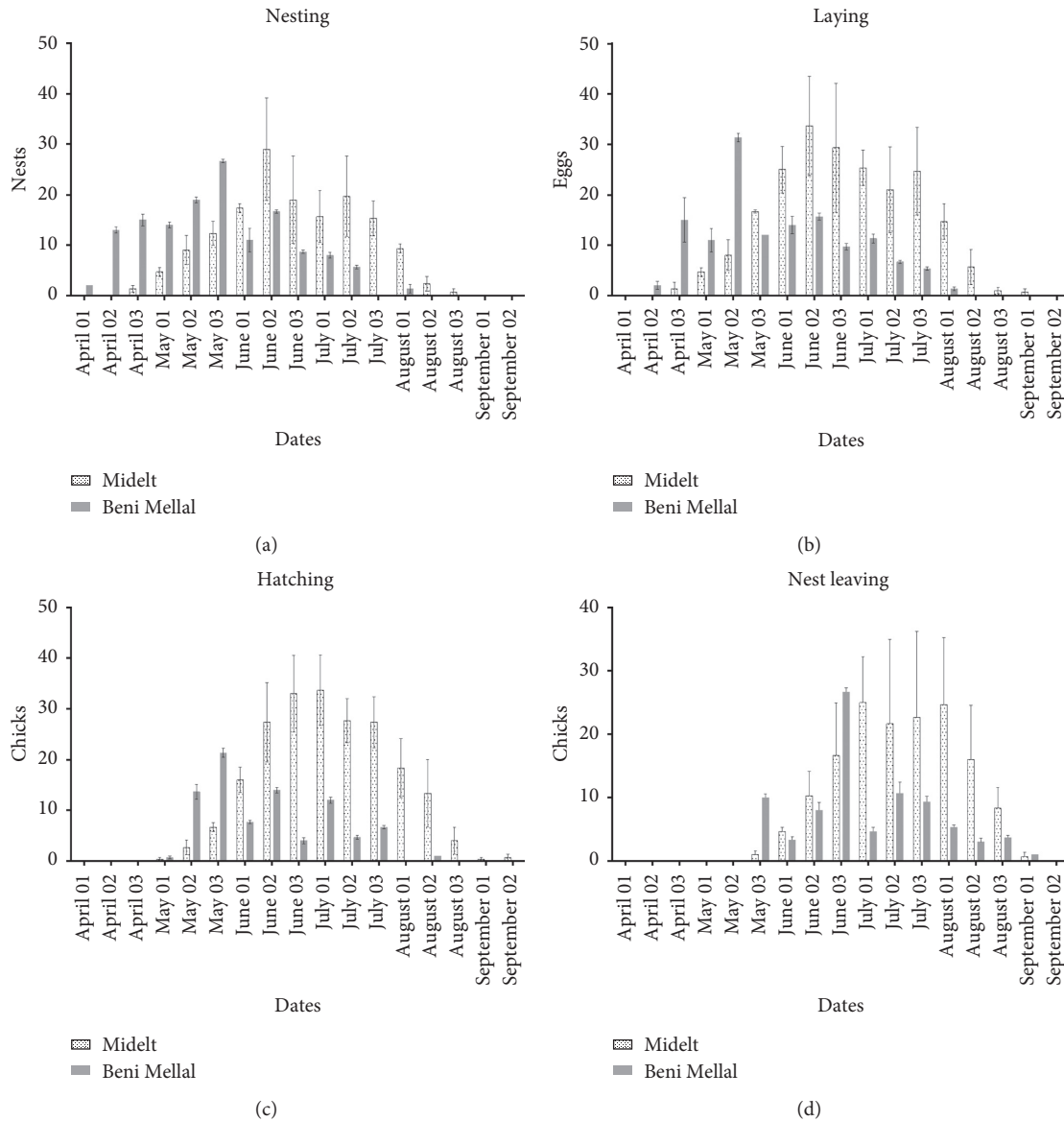


FIGURE 1: Breeding chronology of turtle dove at Beni Mellal and Midelt between 2015 and 2018.

TABLE 2: Summary of the ANOVA test examining the difference in nesting, laying, and hatching dates between Midelt ($n=20$) and Beni Mellal sites ($n=20$) during four breeding seasons of *S. turtur*.

Variable	Sum of squares	df	F	p value
<i>Within sites</i>				
Nesting	199.799	3	0.77	0.5186
Laying	477.421	3	1.08	0.3713
Hatching	166.638	3	0.32	0.8107
<i>Between sites</i>				
Nesting	34.6574	1	0.40	0.5301
Laying	249.75	1	1.73	0.1985
Hatching	163.045	1	1.00	0.3242

to the installation of cold temperature, reflected by the snow on the top of the High Atlas Mountains, while at Beni Mellal, departures were late (11.75 ± 2.46 October).

Turtle dove breeding chronology was variable between Midelt and Beni Mellal. On average, nesting, laying, and fledging dates were successively 20, 11, and 8 days earlier at Beni Mellal (Figure 2). These earliest breeding dates in lowlands are in consistent with those cited in [10, 37, 38] and support that the warm temperature at Beni Mellal promotes an early nesting and laying in migratory birds as mentioned previously in the swallow (*Hirundo rustica*) [37] and other migratory birds [39]. In the opposite, decrease in temperature in highlands can affect negatively egg's incubation and hatching [40]. On the other hand, the authors in [41, 42] have linked between early breeding and food abundance in the migratory population of collared flycatchers. The occurrence of larval peak in the forest induced precocious laying dates in collared flycatchers to ensure a better chick's feeding, which is in agreement with the result found at Midelt. The late cereal season coincided with the

TABLE 3: Turtle dove's breeding success at Midelt ($n=20$ apple orchards) and Beni Mellal ($n=20$ orange groves).

Habitats	Midelt			Beni Mellal	
	Parameters	Number	%	Number	%
Nests	Total	467	100	426	100
	Succeeded	345	73.87	344	80.98
	Predated	98	20.98	24	5.63
	Abandoned	24	5.14	57	13.38
Eggs	Total	635	100	532	100
	Succeeded	455	71.16	344	64.66
	Predated	120	18.89	60	11.27
	Abandoned	28	4.41	116	21.80
	Destructed	0	0	11	2.25
	Unhatched	32	5.03	1	0.18
Chicks	Total	455	100	344	100
	Succeeded	362	79.56	319	93.02
	Predated	48	10.54	8	2.32
	Died	25	5.49	1	0.02
	Abandoned	20	4.39	16	4.65

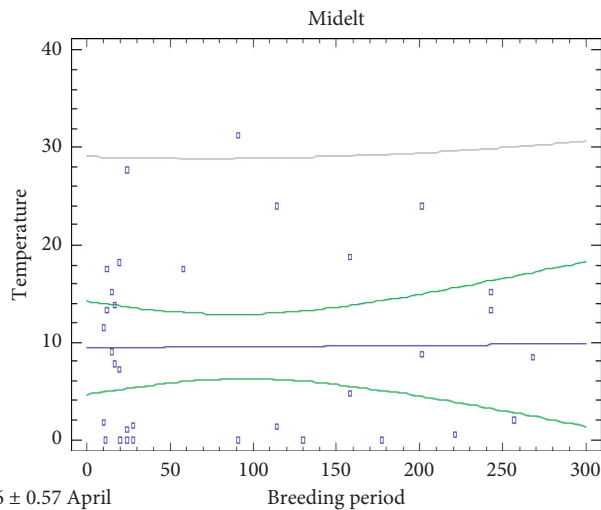


FIGURE 2: GLMM predicting the cold temperature avoidance of turtle doves at Midelt (breeding periods far from lowest temperatures).

optimum breeding phase of turtle doves at apple orchards [43], and therefore, chicks are supposed to be well fed. However, compared with previous studies, our results particularly those found in lowlands are similar to those found in other Moroccan habitats. At Haouz (central Morocco), first eggs were found on an average of 9 to 10 April (2003-2004) [34] and at Tadla on 15 ± 1.52 April (2006-2008) [33], compared with average laying dates of 14.66 ± 1.85 April at Beni Mellal, while at Midelt laying dates were shifted to 27.33 ± 0.33 April. Similarly, the breeding period is comparable between low altitude in the present study and previous works conducted in North African ecosystems [24, 44-47]. At Tadla and Haouz, the breeding season was installed between 15 April and 15 August [34], compared with 5.33 ± 2.02 April to 9 ± 1.15 August at Beni Mellal (Present work). At Midelt (1400-1650 m) breeding

seasons were shifted to a period between 26 ± 0.57 April and 29.66 ± 1.66 September in order to avoid vigorous conditions (low temperatures) in spring and autumn (Figure 2).

Across four breeding seasons at both Midelt and Beni Mellal, average breeding success was different between highlands and low habitats (Table 3). In total, 57% of chicks (flown chicks/laid eggs) flew at Midelt (apple orchards) compared to 60.15% at Beni Mellal. Similarly, failure factors were different. At Midelt, besides predation, a significant clutch portion was failed due to vigorous climate conditions (32 unhatched eggs and 25 dead chicks). At Beni Mellal, inside orange groves, 21.80% of eggs and 4.65% of chicks were deserted, and 2.25% of eggs were destroyed. This comparison not only analyses breeding success between low-altitude (Beni Mellal with 600 m altitude) and high-altitude habitats (Midelt with 1400 to 1600 m), but it also distinguishes failure factors between the two sites. At Midelt, the apparent causes behind chick's mortality and unhatched eggs are supposed to be the cold conditions, in particular during the night and morning where temperatures are down at their extreme levels. Moreover, the authors in [48, 49] have approved that low temperatures influence survival and reproduction in birds, causing mortality of both eggs and nestlings [50], which is in consistent with results found in Midelt. At Beni Mellal, the desertion of nests was due to human management, which corresponds to results reported in [30, 47]. These authors have declared the impact of human disturbance in orange orchards at Tadla (30 km to Beni Mellal), including fruit harvesting, tree pruning, and the overuse of pesticides in coincidence with turtle dove breeding periods.

5. Conclusion

In summary, this study provides a deep analysis (field prospections and literature research studies) of turtle dove's arrival dates, breeding chronology, and reproductive success in lowlands and high-altitude grounds. Recorded results reveal the late arrival and breeding seasons in high-altitude habitats compared to lowlands. Similarly, nests were built at a high level in low-altitude territories. All these strategies, including late breeding and higher level of nesting, prevent turtle doves against low temperatures in high habitats (protection of eggs and chicks) and human disturbance in managed agricultural farms.

Data Availability

All necessary data are included within the article with clarity careful statement. The full data are available from corresponding author upon reasonable request for any future studies.

Ethical Approval

Our experimental procedures complied with the current laws and regulations on animal welfare and research in Morocco and had the approval of the Animal Research Ethics Committee of Sidi Mohamed Ben Abdellah

University and Birdlife Morocco. In addition, all procedures followed standard protocols.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

MI, DM, and EL designed fieldwork and analysed the data. MI and OD collected field data, and EL and DM supervised the study. MI and LE drafted the manuscript, and DM revised the manuscript. All authors read and approved the final manuscript.

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