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Etude de la bioécologie de la tourterelle des bois *Striptopelia turtur* dans la Haute Moulouya (Maroc)

Résumé de thèse

Le présent travail constitue une contribution á l'étude de la Bioécologie de la tourterelle des bois dans la plaine de la Haute Moulouya au Maroc. Ainsi, la biologie de reproduction, l'écologie alimentaire, la niche écologique, la parade nuptiale et l'hivernage de la tourterelle des bois au Nord de l'Afrique sont les points abordés dans cette étude. Le suivi est réalisé dans les vergers du pommier et les habitats riverains dans la zone de Midelt. Les tourterelles des bois sont surveillées, depuis leur arrivée aux habitats de reproduction, entre les mois de mars et avril jusqu'à leur départ vers les sites d'hivernage durant le mois d'octobre de l'année d'étude. Les résultats obtenus ont montré que la tourterelle des bois niche essentiellement dans les zones á haute altitude, particulièrement dans les vergers du pommier. Après, leur arrivée dans la région de Midelt, vers la fin du mois de mars, les tourterelles débutent la construction des nids préférentiellement, sur les pieds de deux variétés du pommier "*Starking delicious* et *Golden delecious"*, vers la fin du mois d'avril. Egalement, la ponte des œufs a lieu la fin du mois d'avril et l'éclosion et l'envol des poussins commencent le mois de mai.

Sur un total de 467 nids surveillés, on a obtenu un taux de nids actifs de 73.87%, un taux d'éclosion de 71.16% et un taux de survie des poussins qui dépasse les 70%. En comparaison avec les zones de basse altitude, les dates d'arrivée et la phénologie de reproduction sont tardives dans la Haute Moulouya, tandis que les dates de départ y sont plus avancées. Cependant, les pratiques agricoles, notamment, l'usage des filets anti grêle et d'exclusion limitent et s'opposent à la nidification des tourterelles dans les vergers étudiés. Pour faire face à la perte des habitats de reproduction et de nourrissage sur les zones de reproduction, la tourterelle des bois fréquente divers habitats, y compris les céréales, les luzernes et les rivières pour l'alimentation.

Globalement, au nord de l'Afrique, les premières arrivées des tourterelles ont lieu durant la dernière semaine du mois de mars et le départ a lieu vers la mi-octobre. Par rapport au Maroc, la tourterelle des bois arrive beaucoup plutôt en Algérie et en Tunisie. Durant la période allant du mois d'octobre au mois de février, on a révélé l'hivernage des individus de la tourterelle des bois dans six sites en Afrique du nord (3 au Maroc, 2 en Algérie et 1 en Tunisie). Ceci, nous a permis de souligner un changement au niveau du statut migratoire de la tourterelle des bois dans la région.

Mots-clés : Tourterelle des bois, Maroc, Haute Moulouya, Bioécologie, Alimentation, Hivernage, Migration, Reproduction.

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Que ce travail témoigne de tout mon respect à mes parents

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A ma sœur et mon frère,

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RESUME

Le présent travail constitue une contribution á l'étude de la Bioécologie de la tourterelle des bois dans la plaine de la Haute Moulouya au Maroc. Ainsi, la biologie de reproduction, l'écologie alimentaire, la niche écologique, la parade nuptiale et l'hivernage de la tourterelle des bois au Nord de l'Afrique sont les points abordés dans cette étude. Le suivi est réalisé dans les vergers du pommier et les habitats riverains dans la zone de Midelt. Les tourterelles des bois sont surveillées, depuis leur arrivée aux habitats de reproduction, entre les mois de mars et avril jusqu'à leur départ vers les sites d'hivernage durant le mois d'octobre de l'année d'étude. Les résultats obtenus ont montré que la tourterelle des bois niche essentiellement dans les zones á haute altitude, particulièrement dans les vergers du pommier. Après, leur arrivée dans la région de Midelt, vers la fin du mois de mars, les tourterelles débutent la construction des nids préférentiellement, sur les pieds de deux variétés du pommier "*Starking delicious* et *Golden delecious"*, vers la fin du mois d'avril. Egalement, la ponte des œufs a lieu la fin du mois d'avril et l'éclosion et l'envol des poussins commencent le mois de mai.

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Mots-clés : Tourterelle des bois, Maroc, Haute Moulouya, Bioécologie, Alimentation, Hivernage, Migration, Reproduction.

ABSTRACT

This thesis provides a comprehensive study on the Turtle dove, *Streptopelia turtur*, at a large scale in Morocco and North-West Africa, including Algeria and Tunisia. It presents recent data on biology, ecology, ethology and migration of declining Turtle doves.

Given the critical situation of Turtle doves and the lack of data on the North African population, we have set as objective to present a deep analysis of the situation this game in high altitudes of Moulouya plain in Morocco (North Africa). In summary, this work focused on: i) reproductive biology in high altitudes, ii) food ecology and nest-niche, iii) courtship display during the breeding season, iiii) breeding chronology, migration dates and wintering in North Africa. In order to achieve these goals, we have carried out this study between March and October from 2015 to 2019, on the upper Moulouya plain, while for migration and wintering research, the observations were extended to Algeria and Tunisia for a better and accurate situation awareness of turtle dove in Northwest Africa.

During five years of observations, we found that Turtle Dove nests in high altitude areas, mainly in apple orchards. After arriving at the Midelt sites in late March, Doves began nesting and laying on *Starking Delecious* and *Goulden Delecious* trees in late April. Hatching and fledging began around May. On the other hand, among the 467 monitored nests, success rates were 73.87% during nesting, 71.16% during incubation, and 70% for chicks. The failure factors were mainly predation and nest desertion. Moreover, the arrival dates and breeding phenology were late in the upper Moulouya compared with low breeding sites, while départure dates were earlier at upper lands. However, agricultural practices, including the use of hail and exclusion nets limit the nesting attempts in covered orchards.

In northern Africa, first doves arrived at breeding sites during the last week of March and leave to sub-Saharan Africa in mid-October. Furthermore, compared to Morocco, Turtle doves arrived much earlier in Algeria and Tunisia. On the other hand, unusually, the present study revealed the wintering of many Turtle dove' individuals in six Northwest African sites (three in Morocco, two in Algeria and one in Tunisia), between October and February. This new data presents a potential change in the migratory status of Turtle Dove in Northwest Africa.

Keywords: Breeding habitats, food, migration, wintering, Turtle dove, Moulouya plain, Morocco.

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INTRODUCTION

La tourterelle des bois *Streptopelia turtur* est une espèce migratrice de longue distance (Brown et Aebischer, 2003 ; Eraud *et al.,* 2013 ; Lormee *et al.,* 2016). Elle traverse des milliers de kilomètres entre les aires de reproduction en Europe et les sites d'hivernage en Afrique subsaharienne (Eraud *et al.,* 2009). Malgré cette large distribution, la population de la tourterelle des bois est en déclin rapide et continu, particulièrement au niveau du pourtour méditerranéen (Dunn et Morris, 2012). Ainsi, la population Européenne n'a cessé de diminuer depuis les années 1970 (Eaton *et al.,* 2011) et les tendances actuelles sont regressives. Par conséquence, l'espèce étant l'un des oiseaux les plus en déclin en Europe.

Les déclins de la population de la tourterelle des bois sont généralement attribués à une combinaison de la réduction et la modification des habitats de reproduction (Browne et Aebischer, 2004 ; Browne *et al.,* 2004 ; Bakaloudis *et al.,* 2009), la réduction dans la disponibilité des ressources trophiques (Browne and Aebischer, 2003 ; Rocha et Quillfeldt, 2015) et le changement des conditions environmentales sur les aires d'hivernage (Eraud *et al.,* 2009). Cependant, avec les changements climatiques et l'application de nouvelles pratiques agricoles, la mise à jour des données sur l'état et l'évolution de la population de la tourterelle des bois semble être une nécessité urgente avant d'arriver au point irréversible.

Au Maroc, la tourterelle des bois est un oiseau migrateur nicheur, distribué sur une grande surface du territoire national (Hanane, 2017 ; El Hassani *et al.,* 2018). Elle s'étale depuis le Bas et le Moyen Draâ, dans les provinces de Goulmime et Assa au sud, jusqu'aux nord du pays, et de l'atlantique à l'ouest jusqu'au derniers Oasis dans le Sud-Est saharien dans la région de Figuig (Thévenot *et al.,* 2003). Cependant, les études sur ce gibier sont limitées en termes d'espace et en terme de sujet. En effet, au Maroc, les études sont concentrées sur les habitats de basse altitude (Hanane, 2017) et les vergers d'olive et d'orange (Hanane and Baâmal, 2011 ; El Hassani *et al.,* 2018). Ainsi, ces études sont limitées à la biologie de reproduction dans les habitats agricoles (Hanane, 2017). Tandis que, la reproduction sur les hautes altitudes, l'écologie trophique et l'éthologie sont encore inexplorés. En plus, avec la dégradation des populations Européennes et pour éviter une potentielle situation critique, il est nécessaire de connaître la situation et les facteurs entourant la tourterelle au Maroc, notamment que ce gibier est un migrateur nicheur, qui fait l'escale au Maroc durant le printemps et l'automne.

Dans ce contexte et dans l'objectif d'éclaircir la situation de la tourterelle des bois au Maroc, au Nord-Ouest de l'Afrique, nous avons mené la présente étude, principalement dans la haute Moulouya, avec extrapolation de l'aspect concernant la migration vers le nord-ouest de l'Afrique pour une meilleure interprétation de ce gibier.

Pour ce faire, nous avons abordé : i) une étude intégrale de la biologie chez la tourterelle des bois dans les hautes altitudes, en tenant compte de l'effet de l'altitude, des pratiques agricoles et d'autres facteurs sur le succès reproductif, ii) l'écologie de la tourterelle des bois, principalement le régime trophique, les habitats de nourrissage et la niche écologique dans les zone de hautes altitudes. iii) la parade nuptiale de la tourterelle, durant la saison de reproduction pour décortiquer les expressions de ce gibier et leur utilité en phase de formation des couples,

vi) enfin l'analyse détaillée des dates de migration et la recherche des potentiels sites d'hivernage dans l'Afrique du nord.

Le présent manuscrit est structuré en trois grandes parties :

Partie I : Généralités sur la tourterelle des bois

Nous avons abordé dans un premier temps, la zoologie de la tourterelle des bois, en insistant sur la classification et la morphologie de l'espèce. A partir de la zoologie il est possible de différencier et de comparer la tourterelle des bois aux autres espèces d'oiseaux. Ainsi, durant le suivi de developement des poussins, la morphologie permettra de comparer les poussins et les adultes. Dans un deuxième temps, nous avons étudié la reproduction et le statut juridique de l'espèce, particulièrement au Maroc, dans l'objectif de reveler des lacunes, le suivi de l'espèce sur le terrain et noter les aspects les plus suceptible d'influencer de la biologie dans les hautes altitudes. En troisième lieu, l'écologie de la tourterelle des bois est abordée, avec plus d'attention au régime alimentaire et les sites de nidification, pour mieux situer et comparer les résultats du présent travail avec ceux des données bibliographiques. Aussi, les dates de migration et les sites d'hivernage sont présentés pour orienter l'aspect de recherche sur l'hivernage des tourterelles au Nord de l'Afrique. En Quatrième lieu, le déclin des tourterelles est abordé pour évaluer l'effet de différents facteurs dans la zone d'étude sur la taille de la population. Enfin, cette première partie est réalisé pour mieux approfondir nos connaissances sur la tourterelle des bois dans l'objectif d'orienter les prochains sujets de recherche et adopter les méthodologies adéquates pour chaque objectif.

Partie II : Études expérimentales

Cette partie d'étude inclue les différents travaux réalisés sur le terrain. Elle est rédigée sous forme d'articles et divisée en cinq axes :

- Biologie de reproduction de la tourterelle des bois regroupe trois parties sous forme d'articles sur la biologie de reproduction dans les hautes altitudes ; la comparaison de la chronologie de reproduction entre la haute altitude et les basses altitudes et enfin l'effet des pratiques agricoles sur la reproduction.
- Ecologie de la tourterelle des bois redigée sous forme de trois articles portant les habitats et le régime alimentaire ; les sites de reproduction et le partage de la niche ; la construction des nids par des plantes aromatiques et médicinales pour faire face aux ectoparasites.
- Ethologie de la tourterelle des bois est redigée sous forme de deux articles qui portent sur la parade nuptiale et le comportement alimentaire durant la saison de reproduction.
- Migration de la tourterelle des bois : sous forme de deux articles. Le premier concernant les dates de migration, les sites d'hivernage et les facteurs prédicteurs au Nord-ouest de l'Afrique. Et le deuxième concernant la population nicheuse et hivernante une détaillée de la tourterelle des bois entre l'Europe et l'Afrique.
- Synthèse sur la conservation et les recommandations pour mieux protéger cet oiseau.

Partie III : Discussion, conclusion et perspectives

Cette partie discute d'une manière générale et synthétique les résultats de l'ensemble des travaux effectués avec une conclusion mettant en apparent les principaux resultats obtenus et des perspectives permettant de compléter le présent travail et susceptible d'éclaircir la situation de la tourterelle des bois à l'échelle nationale et internationale.

GENERALITES

1. Position taxonimique de la tourterelle des bois

Les oiseaux forment une classe d'animaux vertébrés bien définie et homogène. Ils sont encore appelés "dinosaures aviens" (Aves) et caractérisés par la bipédie, la disposition des ailes, les phanères particuliers "plumes" et le bec sans dents. Ainsi, les oiseaux sont le seul groupe représentant actuellement, les dinosaures théropodes, tandis que tous les autres groupes de dinosaures qualifiés de « non avians » sont éteints.

La tourterelle des bois fait partie de l'ordre des colombiformes qui réunit trois familles (Voous, 1960 ; Cramp, 1985) : les Columbidés, les Ptéroclidés (Gangas) et les Raphidés "famille éteinte de nos jours" (Biscaichipy, 1989). La tourterelle des bois appartient à la famille des Columbidés représentée au Maroc par six espèces, dont trois espèces de pigeons du genre Columba : le pigeon ramier (*Columba palumbus*), le pigeon colombin (*Columba oenas*), le pigeon biset (*Columba Livia*) et trois espèces de tourterelles (figure 1), du genre Streptopelia (Bergier *et al.*, 1999): la tourterelle des bois (*Streptopelia turtur*), la tourterelle turque : (*Streptopelia decaocto*), et la tourterelle maillée (*Spilopelia senegalensis*).



Figure 1: Les tourterelles) les plus observées au Maroc. (A : tourterelle turque, B : des bois, et C: tourterelle maillée

La tourterelle des bois *Streptopelia turtur* est un oiseau migrateur (Browne et Aebischer, 2005) dont les zones de nidification et les aires d'hivernage sont bien séparés géographiquement, à l'exception de quelques secteurs occupés par des oiseaux quasi-sédentaires de races africaines (Dubois, 2002). Basée sur des critères discrets de coloration du plumage et de longueur d'aile, quatre sous-espèces ou races de tourterelle des bois sont reconnues (Veiga, 1998)

- *Streptopelia turtur hoggara* répandue sur les montagnes du Sahara central, depuis l'Ahaggar (Algérie) au nord jusqu'à l'Aïr (Niger) au sud ;
- *Streptopelia turtur rufescens* fréquente en Egypte et au nord du Soudan ;
- *Streptopelia turtur turtur* colonise les Canaries, la majeure partie de l'Europe et l'Asie jusqu'à la rivière Irtysch, en passant par la Turquie, la Mer Caspienne et la Sibérie occidentale, jusqu'à les steppes arbustives du Kazakhstan ;
- *Streptopelia turtur arenicola* occupe le nord-ouest de l'Afrique jusqu'à la Libye, ainsi qu'une zone comprise entre la côte orientale de la Mer Caspienne et l'Altaï occidental, le Sinkiang, l'Iran et les îles Baléares.

2. Description morphologique de la tourterelle des bois

La tourterelle des bois est un oiseau de taille moyenne à petite (environ 30 cm d'envergure), petite tête, corps trapu, queue relativement longue (figure 2), plumage dur et épais, hyporachis atrophié ou absent, mais partie inférieure des plumes très duveteuse (Biscaichipy, 1989). La mue, contrairement à la plupart des autres oiseaux, est presque sans exception, complètement indépendante de la période de reproduction. Le bec grêle, avec une cire à la base, comprimé dans la partie médiane, un grand jabot en forme de deux poches latérales (Dubois, 2002).



Figure 2 : Deux partenaires de la tourterelle des bois (male et femelle)

Les tourterelles des bois possèdent des capacités d'adaptation flexibles face aux conditions créées par l'homme. L'espèce est facilement observée sur les bords des chemins et au détour des bosquets. C'est un très bel oiseau à la silhouette fine et élancée, se reconnaissant par son dos brun tacheté de noir et par de fines stries noires et blanches sur le côté.

3. Biologie de la tourterelle des bois

3.1.Biologie de reproduction

La Tourterelle des bois *Streptopelia turtur* est un oiseau migrateur distribué sur une grande surface du globe. Dès son arrivée sur les sites de reproduction, elle commence la construction des nids sur les arbres fruitiers (les oliviers, les palmeraies, les orangeraies, etc.) et les arbres forestiers (conifères, arbustes épineux, vegetation riverains, etc.), vers la fin du mois de mars et le début d'avril (Browne and Aebischer, 2004, 2005 ; Hanane and Maghnouj, 2005 ; Kafi *et al.*, 2015 ; EL Hassani *et al.*, 2018). L'emplacement des nids varie entre 1.3 à 4.5 m de hauteur et dépend de l'arbre support et les facteurs de dérangement. Après la nidification, la tourterelle pond une à deux œufs par nids (figure 3). L'incubation des œufs dure en moyen deux semaines et la couvaison des oisillons dure 13 á 17 jours avant l'envol (Hanane, 2017a).

Ensuite, les juvéniles sortent de leurs nids, mais les soins des parents durent encore quatre à sept jours hors du nid. Certains oiseaux de la première année font leurs premières migrations en phase sub-adult, pour compléter la croissance sur les aires d'hivernage.



Figure 3 : Nids de la tourterelle des bois sur les pommiers, A) les Œufs, B) les poussins

3.2.Statut juridique

3.2.1. A l'echelle internationale

Récemment, la tourterelle des bois est listée par l'UICN (International Union for Conservation of Nature) comme espèce vulnérable, vu sa situation critique sur les zones de reproduction et d'hivernage (Dunn *et al.,* 2018 ; Marx *et al.,* 2020). Cependant, le statut de l'espèce varie d'un pays à l'autre. Depuis 2015, l'espèce est listée vulnérable en Europe (Moreno-Zarate *et al.,* 2020). Le même statut est attribué en France, en Allemagne et en Hollande. En Royaume-Uni, la tourterelle des bois est considérée, comme l'espèce d'oiseau en déclin le plus rapide et au bord de l'extinction (Dunn *et al.,* 2020). Par contre, dans d'autre pays comme l'Espagne, le Portugal, l'Italie, et la Grèce, la tourterelle des bois est un gibier de chasse, sans aucun statut de conservation (Moreno-Zarate *et al.,* 2020 ; Chiatante *et al.,* 2020). L'écart dans les statuts de conservation de la même espèce risque de causer sa dégradation mondiale, notamment, si les populations en bon statut arrivent à un état critique, avant la reprise des populations déjà en déclin.

3.2.2. A l'echelle nationale

Par la situation géographique entre l'atlantique à l'ouest, la méditerranée au nord et le Sahara de l'est, la diversité climatique allant de l'humide sur les hautes montagnes au désertique sur les frontières avec l'Algérie et la Mauritanie, le Maroc offre les conditions favorables pour la tourterelle des bois, comme oiseau migrateur et nicheur. En effet l'espèce est repérée sur 80% du territoire du Royaume (Hanane, 2017a). Cependant, l'oiseau est classé sur la liste des espèces avec un statut défavorable, durant ces dernières années. Le principal facteur détériorant le statut de l'espèce est la chasse, en particulier les périodes de la battue. Celles-ci, s'étalent du 26 juin au 31 août de chaque année, en coïncident avec les périodes optimales de l'activité reproductrice de l'espèce inclue la ponte, l'éclosion et l'envol des poussins (Dubois, 2002).

Pour une gestion raisonnable et rationnelle de ce gibier, il est devenu impératif de retarder l'ouverture de sa chasse jusqu'à l'envol des derniers poussins. Ceci permettra une meilleure réussite des pontes durant leurs phases maximales et contribuera à la pérennisation de l'espèce.

4. Ecologie de la tourterelle des bois

4.1.Aire de répartition géographique

4.1.1. Aire d'hivernage

La tourterelle des bois hiverne en Afrique subsaharienne, depuis la Guinée et le Sénégal à l'ouest, jusqu'au Soudan et l'Éthiopie à l'est, et se disperse dans les forêts tropicales (Jarry et Baillon, 1991a). Les sites d'hivernage sont généralement, à proximité des points d'eau qui sont, de plus en plus, rares avec la sécheresse installée en Afrique Subsaharienne, depuis 30 ans (Eraud *et al.,* 2009b ; Vickery *et al.,* 2014). Ceci explique aussi, pourquoi on retrouve des regroupements exceptionnels des oiseaux sur des sites très restreints. En outre, les sites exacts d'hivernage sont très mal connus et nécessite la mise en place d'études scientifiques basées sur les nouvelles technologies pour bien décrire à grande échelle les zones d'hivernage et les routes de migration de ce gibier en déclin (Eraud et al., 2013 ; Hanane, 2017a).

4.1.2. Aire de reproduction

Les habitats de reproduction chez la tourterelle des bois sont répondus depuis les zones semi-désertiques de l'Afrique du nord et les zones méditerranéennes jusqu'au nord de l'Europe et l'Asie (Marx et al., 2020). Les sites de nidification sont mentionnés dans de nombreux pays : Grande-Bretagne, Portugal, Espagne, Grèce, Turquie en Europe, au Maroc, Algérie, Tunisie en Afrique du nord (Browne and Aebischer, 2003 ; Bakaloudis *et al.,* 2009b ; Dias *et al.,* 2013a ; Yahiaoui *et al.,* 2014 ; Absi *et al.,* 2015a ; Hanane, 2017a). D'une manière générale, Les types de milieux recherchés par la tourterelle des bois, en période de reproduction, sont des habitats forestiers, les terrains agricoles, particulièrement les plantations fruitières d'olive et d'oranges (Hanane, 2017a).

Au Maroc, la tourterelle des bois, particulièrement *Streptopelia turtur arenicola* est une espèce nicheuse estivante dans la majorité du territoire national. La distribution de ce gibier commence dès la région de Guelmim au sud, jusqu'à la mer méditerranéenne au nord, et de l'atlantique à l'ouest, jusqu'aux frontières avec l'Algérie à l'Est. La tourterelle niche dans de nombreux habitats agricoles, comme les vergers d'olivier et d'oranges et des écosystèmes forestiers, comme les thuriféraies et les conifères (Hanane, 2014a ; El Hassani et al., 2018). En outre, sur les habitats de nidification au Maroc, la tourterelle des bois partage les sites d'alimentation avec d'autres espèces de passereaux, dont les pigeons biset et ramier (Hanane, 2015 ; Hanane and Yassin, 2017). En générale, les habitats de l'espèce sont très proches des céréales et les sources d'eaux pour mieux réussir la reproduction et la survie des poussins.

4.2.Alimentation de la tourterelle des bois

4.2.1. Zone d'hivernage

Après les longues journées de migration post-nuptiale, depuis l'Europe, la tourterelle des bois profite des sites d'escale pour un approvisionnement maximal, permettant de continuer le trajet vers les sites de l'Afrique subsaharien (Eraud *et al.,* 2013). Sur les sites de gagnage, la

tourterelle des bois bénéfice des saisons pluvieuses pour retrouver les ressources alimentaires et les points d'eau indispensables à ses fonctions physiologiques (Murton 1968 ; Tellería *et al.,* 2020). Durant cette période d'hiver, entre novembre et février, les tourterelles se regroupent autour des points d'eau, l'élément essentiel pour faire face aux températures diurnes élevées en Afrique (Dubois, 2002). Ainsi, l'abondance des graminées et des plantes herbacées en pleine fructification permet aux tourterelles de faire face aux conditions difficiles de l'Afrique subsaharienne. Sur les sites d'hivernage, l'alimentation de la tourterelle des bois est constituée généralement de graminées diversifiées, comme *Pancium laetum*, *Tribulus terrestris* et *Echinocloa colona* (Dubois, 2002). Pour se nourrir, les tourterelles se déplacent tôt le matin et tard le soir, durant les périodes les plus chaudes, afin de limiter au maximum les pertes d'eau métabolique des graines qui ne suffit pas à couvrir les besoins hydriques de l'espèce (Jarry et Baillon, 1991a). Une alimentation satisfaisante sur les sites d'hivernage est indispensable à la tourterelle pour faire face aux conditions de migration vers les sites de reproduction en Afrique du nord et l'Europe.

4.2.2. Zone de reproduction

Sur les sites de reproduction, la tourterelle des bois s'alimente dans les éspaces dégagés de végétation ligneuse, dans les paysages semi-ouverts composés de parcelles cultivées et dans les zones boisées d'arbres fruitiers (Browne et Aebischer, 2003 ; Rocha et Quillfeldt, 2015 ; Gutierrez-Galan *et al.,* 2019a). Elle se nourrit en couple ou se rassemblent en groupe, souvent avec d'autres espèces d'oiseaux. Ainsi, elle est souvent associée aux espèces de pigeons, notamment, le pigeon ramier (*Columba palumbus*) et le pigeon colombin (*Columba oenas*), fréquemment sur les champs, les bordures des chemins et les zones humides riches en eau (Murton, 1968).

L'alimentation de la tourterelle des bois est formée principalement de graines, de fruits, et occasionnellement, des proies animales de vers, de mollusques et d'insectes (Murton, 1968 ; Dunn *et al.,* 2018). La tourterelle dont le regime alimentaire à tendance granivore se nourrit des graines de céréales et autre cultures, qu'elle prélève exclusivement au sol, au cours de la journée. En outre, elle absorbe de petits graviers et de graines de sable, qui lui servent à broyer les éléments durs. Cependant au Nord de l'Afrique, le régime alimentaire et les habitats du fourrage sont males connus. Ceci, nécessite un effort pour découvrir et délimiter les habitats de nourrissage susceptible de réussir la saison de reproduction de ce gibier en déclin.

5. Dates et routes de migration

5.1.Dates du départ et d'arrivée

La tourterelle des bois est la seule espèce migratrice de longue distance des columbidés, elle fait des trajets migratoires des milliers de kilomètres, entre l'Europe et l'Afrique subsaharienne (Browne *et al.,* 2005 ; Eraud *et al.,* 2009, 2013 ; Lormee *et al.,* 2016). En plus des sites de reproduction et d'hivernage, la connaissance des dates de migration est importante pour les efforts de conservation de ce gibier en déclin. En effet, le suivi de la tourterelle des bois depuis les années 1960 et plus particulièrement, avec l'usage des émetteurs satellites a fourni des données intéressantes sur le comportement migrateur de l'espèce (Eraud *et al.,* 2009, 2013 ; Lormee *et al.,* 2016). Les vagues de migration prénuptiale commencent vers la fin de février,

depuis les sites d'hivernage au sud de Sahara. Les groupements de migrateurs gagnent les sites d'escale au sud du Maroc et en Algérie pour l'approvisionnement et le repos, au début du mois de mars (Lormee *et al.,* 2016). Ensuite, les migrateurs arrivent aux premiers sites de nidification au sud de la région maghrébine vers la première semaine du mois de mars.

Les premières tourterelles arrivent en Europe, vers la fin d'avril et le début du mois de mai pour la reproduction. Par contre, la migration post-nuptiale commence au début de septembre dans la zone nordique de l'Europe et fini vers le début d'octobre, dans la zone nord-africaine. Les tourterelles font de petites escales au Maroc et en Algérie pour gagner les sites d'hivernage vers la fin du mois d'octobre (Lormee *et al.,* 2016).

5.2.Routes de Migration

Les tourterelles des bois nichent dans l'Europe et dans l'Afrique du nord, passent l'hiver dans les pays d'Afrique du Sahel. Pour passer des sites de nidification aux habitats d'hivernage, la tourterelle prend trois routes migratoires (Eraud *et al.,* 2013 ; Marx *et al.,* 2016a ; Lormee *et al.,* 2016 ; Marx *et al.,* 2020) :

- La route occidentale (figure 4), via Gibraltar est certainement la plus connue, passant par le Maroc-Algérie et la Mauritanie, pour gagner les sites d'hivernage. C'est l'itinéraire emprunté par la plupart des oiseaux nicheurs en Grande-Bretagne, en Hollande, en France, en Espagne et les autres aires de l'Europe occidentale ;
- La route orientale, rassemble les tourterelles et les oiseaux nicheurs en Est de l'Europe (la Baltique, la Biélorussie, l'Ukraine, la Roumanie et la Bulgarie). Cette route passe par le Bosphore en Turquie et le Moyen-Orient pour atteindre l'Afrique ;
- La troisième route, connue sous le nom de route migratoire d'Europe centrale, ou voie de migration Adriatique. Elle est souvent oubliée et passe par le sud de l'Italie, la Sicile et Malte vers l'Afrique via la Tunisie. Cette route est parallèle à celle de l'Est en Sibérie et en Europe du Nord, mais se dirige plus tard, vers l'ouest de la Pologne et de la Hongrie sur les Balkans et sur la mer Adriatique.

Les tourterelles passent par ces trois voies migratrices pour minimiser les distances parcourues sur la mer méditerranéenne entre l'Europe et l'Afrique et sur la mer de Marmara séparant la partie Asiatique et Européenne de la Turquie.

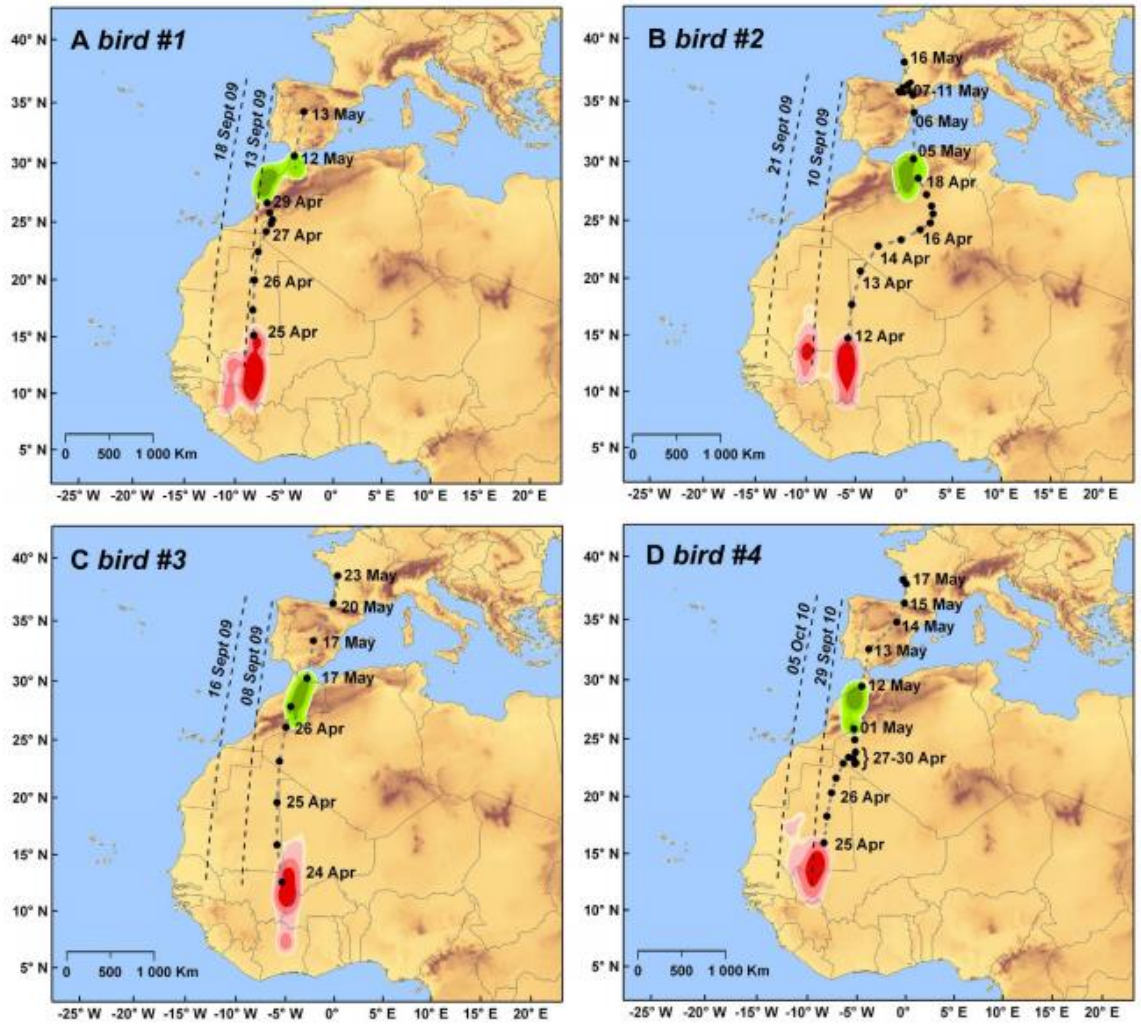


Figure 4 : Repérages des routes de migration occidentales, des aires d'escale (Vert) et d'hivernage (Rouge) des tourterelles des bois (A, B, C, D) avec dates clés (Eraud *et al.*, 2013)

5.3.Sites d'escales

Avant de traverser le Sahara, durant le printemps et l'automne, les tourterelles des bois, de provenance Africaine et Européenne, font des arrêts de repos et d'approvisionnement dans les sites d'escale, pour augmenter leurs réserves de graisse, facilitant la traversée des longues zones désertiques. Après le passage du désert du Sahara, sur le chemin du retour vers les aires de reproduction en Afrique du nord et en Europe, les tourterelles s'arretent sur deux sites d'escale au Nord de la Mauritanie, au centre du Maroc et de l'Algérie (Eraud *et al.*, 2013 ; Marx *et al.*, 2016a ; Lormee *et al.*, 2016 ; Marx *et al.*, 2020). En outre, durant la migration postnuptiale, les tourterelles effectuent des escales au Sud de l'Espagne et au centre du Maroc, pour augmenter les réserves avant de traverser le désert vers les sites d'hivernage (Hanane, 2017a). Les tourterelles migratrices passent en moyenne 56.67% de la période de migration sur les sites d'escale, pour un meilleur approvisionnement en graisses, en réserves et en eau permettant de parcourrir de longues distances, allant de 1500 à 3000 km, séparant les aires de nidification et les zones d'hivernage (Eraud *et al.*, 2013 ; Marx *et al.*, 2016a ; Lormee *et al.*, 2016 : Marx *et al.*, 2020).

6. Declin des populations de la tourterelle des bois

Le suivi des effectifs de la tourterelle des bois sur l'atlantique depuis les années soixante a révélé que l'espèce a perdu plus de 70% de sa population en Grand Bretagne et 30% en Espagne (Buruaga *et al.*, 2013 ; Lormée, 2020). Sur le reste des aires de distribution, les effectifs des individus restent mal connus et l'état des populations demeure moins étudié. En outre, la connaissance des nombres ou au moins des couples reproducteurs semble très important voire necessaire pour orienter les efforts de conservation, notamment dans les pays où l'espèce a perdu plus de 50% de sa population.

6.1.Facteurs aggravant le déclin

6.1.1. Menaces naturelles

6.1.1.1.Conditions climatiques

Sur les zones d'hivernage, les conditions climatiques, en particulier, la sécheresse peut conduire à la mortalité intense des hivernants (Jarry et Baillon, 1991a ; Eraud *et al.*, 2009b). L'installation de longues périodes de sécheresse durant les années soixante-dix, dans les régions du sahel, principales zones d'hivernage, a touché énormément la tourterelle des bois par l'insuffisance de nutriments, indispensables pour faire face aux longs trajets migratoires (Eraud *et al.*, 2009b). En effet, les longues périodes de sécheresse réduisent la production des céréales et les plantes herbacées qui forment les principales ressources pour la tourterelle et les oiseaux hivernants dans la zone du Sahel.

Dans les habitats de reproduction, les fortes périodes de pluies et les chutes de température, conduisent à la mortalité des jeunes et la perte des pontes (Dunn et Morris, 2012b ; Hanane, 2017a). Ceux-ci, influencent directement le succèss reproductif de la tourterelle des bois. En parallèle, les averses et les forts coups de vent (tempête et orage) provoquent systématiquement la destruction des nichées et des pontes. Par conséquence, les tendances de la population globale seront influencées sur les dimensions spatiales et temporelles.

6.1.1.2.Prédation

La prédation en générale, cause la perte des parents et les pontes de la tourterelle des bois. Au nord de l'Afrique et dans l'Europe, la prédation est considérée, comme facteur limitant du succèss reproductif de l'espèce, particulièrement, durant les phases de pontes. Parmi les prédateurs les plus rencontrés dans les habitats de reproduction de la tourterelle, on trouve les couleuvres et les reptiles qui se nourrissent de poussins et d'œufs de la tourterelle. D'autres cas de prédation par les rapaces et certains mammifères sont aussi enregistrés au nord de l'Afrique (Hanane et Maghnouj, 2005). Sur les aires d'hivernage, les cas de prédation ne sont pas mentionnés chez la tourterelle des bois et ceci nécessite une étude approfondie pour bien clarifier cet aspect.

6.1.1.3.Compétition avec d'autres espèces

Depuis longtemps, le déclin de la tourterelle des bois dans certaines régions a été attribué à l'invasion de la tourterelle turque "*Streptopelia decaocto*" et la tourterelle maillée (*Spilopelia senegalensis*) (Brahmia *et al.*, 2015b ; Hanane, 2017a ; Hanane et Yassin, 2017). Ces deux espèces sont des columbidés sédentaires qui ont connu une très forte expansion au cours du

dernier siècle, vu leur important pouvoir d'adaptation aux activités de l'homme. Contrairement à la tourterelle des bois limitée aux zones rurales, les tourterelles turque et maillée colonisent aussi bien les milieux ruraux que les zones urbaines. Par conséquent, la compétition territoriale entre les tourterelles migratrices et leurs cousines sédentaires conduit à l'extension de la tourterelle turque et la tourterelle maillée sur les habitats de la tourterelle des bois (Nasrine *et al.,* 2020).

6.1.2. Menaces de nature anthropique

6.1.2.1.Activités agricoles

L'intensification de l'agriculture a conduit à la destruction et la réduction des habitats naturels utilisés par les oiseaux (Wolff *et al.,* 2001 ; Allen *et al.,* 2020). Pour la tourterelle des bois, les activités agricoles ont accéléré la perte des habitats de reproduction, des supports de nidification et des sites de nourrissage (Browne *et al.,* 2004 ; Dias *et al.,* 2013b). En plus, l'entretien des parcelles via le taillage des arbres et les traitements phytosanitaires produit un dérangement nuisible pour les nicheurs, une destruction des nids et leurs supports, ainsi que la mortalité des pontes (Hanane, 2017a). Ceux-ci influencent directement la nidification et le succèss reproductif par la réduction des sites valables pour l'espèce et la perte des pontes durant la saison de reproduction. En outre, la réduction des surfaces céréalicultures sur les zones de nidification et les aires d'hivernage réduit les capacités physiologiques et la survie des migrateurs, pour faire faces aux longues distances entre l'Europe et l'Afrique subsaharienne.

6.1.2.2.Effet de chasse

Il est clair que l'exercice de la chasse sportive occasionne des pertes directes des adultes et des jeunes chez les oiseaux (Hakim *et al.,* 2020). Chaque année des milliers de tourterelle des bois sont tuées. En Europe, plus de quatre millions de tourterelles ont été chassée seulement en 2001 (Dubois, 2002). Cependant, la tourterelle des bois a subi une pression par la chasse qui diffère selon les régions géographiques. En Espagne, la période de chasse s'etend du 15 Août au 10 Septembre et cause un prélèvement de 1 million d'oiseaux (Rocha et Quillfeldt, 2015). En Italie, la chasse s'ouvre entre le troisième dimanche de Septembre et 31 Janvier de chaque année, et le nombre des oiseaux tués est de lordre de 500 000 individus annuellement. Dans la plupart des pays anglo-saxons nordiques, la tourterelle continue d'être protégée car elle n'est pas considérée, comme un gibier et ses cycles de présence se situent en dehors des périodes d'ouverture de la chasse (Dubois, 2002).

En Afrique du nord, quelques dates concernant les périodes d'ouverture sont connues. Au Maroc, la chasse est ouverte entre le début du mois de juillet et la fin du mois d'août de chaque année, avec un prélèvement estimé à 15 000 oiseaux par an (figure 5). Pour certains auteurs, la chasse en Afrique du nord aurait des effets néfastes sur les populations migratoires de tourterelles des bois passant de l'Europe en Afrique pour l'hivernage (Dubois 2002).



Figure 5 : Photo montrant un exemple de groupe des tourterelles des bois chassées au Maroc.

METHODOLOGIE

BIOLOGIE DE LA TOURTERELLE DES BOIS

1. Dates de migration, phénologie de la reproduction et le succèss de la reproduction des tourterelles des bois dans les hautes altitudes

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Synthèse de l'étude

La date de migration et la chronologie de reproduction constituent les principaux facteurs de réussite chez les oiseaux migrateurs. En effet, les oiseaux migrateurs, particulièrement les Afro-paléarctiques parcourent des milliers de kilomètres, depuis les aires d'hivernage pour se reproduire sur les zones de nidification.

La tourterelle des bois (*Streptopelia turtur*) est un oiseau migrateur parcourant de longues distances, entre l'Afrique et l'Europe, passant par le Maroc. La population de cette espèce a diminué par 91% au Royaume-Uni et de 69% à travers l'Europe, depuis 1980. Le décalage de migration est susceptible d'influencer les décisions et les périodes de reproduction de l'espèce et par conséquence les tendances de sa population. D'où l'importance de la présente étude, qui a comme objectif de suivre la tourterelle des bois dans les habitats de hautes altitudes, depuis son arrivée jusqu'à son retour, pour comprendre les dates de migration, la chronologie de reproduction et le succès des pontes.

Dans cette partie d'étude, nous avons mené un suivi de la tourterelle des bois sur les vergers de pommiers (n=20), sous le piémont de Jbel Ayachi (1400-1600 m) à Midelt (2015-2018). Les résultats obtenus nous ont permis de montrer que la tourterelle arrive aux vergers de Midelt vers la fin du mois de mars, tandis que le départ se fait vers la fin du mois de septembre, durant la période d'observation 2015-2018. La nidification et la ponte commencent principalement vers la fin du mois d'avril. Les premières éclosions sont enregistrées á la mi-mai et les poussins font l'envol au début du mois de juin. En outre, la chronologie de la reproduction, y compris la nidification et l'envol des poussins semble être influencée par l'altitude, les précipitations et plus particulièrement, contrôlée par la température. Pour le succès de la reproduction, parmi les 467 nids surveillés, nous avons pu montrer que 73.87% ont réussi pendant la période de nidification et 71.16% des œufs ont réussi durant l'incubation. Le taux de survie des poussins est plus élevé. Les principaux facteurs d'échec du succès reproductif sont la prédation et l'abandon des nids. Finalement, cette étude montre que la tourterelle se reproduit dans les habitats de haute altitude, avec des périodes de reproduction tardives et plus courtes, pour éviter les conditions climatiques vigoureuses et leurs impacts sur le succèss reproductif.

New Data on Migration Time, Breeding Phenology, and Breeding Success of European Turtle Doves in Their Highest Breeding Habitats in North Africa

Abstract

The migration dates, breeding phenology, and reproductive success of the European Turtle doves were studied in the highest breeding habits at Midelt (1400 to 1600 m, Morocco. Data were recorded from March to October between 2015 and 2018, using Common Bird Census methodology. Results showed that, at high altitude breeding sites (n=20) Turtle doves arrived on 28.25 ± 2.05 March, while départure dates were on 28.00 ± 1.47 September. On the other hand, nesting activity began on 26.5 ± 0.64 April and laying dates were only two days after the nest construction date on 28.00 ± 0.7 April. First fledged chicks were 17.50 ± 2.72 May, and chicks started flying 3.50 ± 2.33 June. In addition, breeding chronology, including nesting and chick's flight were influenced by altitude, rainfall and more particularly controlled by temperature. For breeding success, Among the 467 monitored nests, 73.87% were survived during nesting période and 71.16% of eggs have survived. Chicks survive rate was higher with 79.56%. Failure factors during breeding success were diverse. Predation caused loss of 18.89% of eggs during incubation périodes and 10.54% of chicks during nestling phase. Few portions, including 4.41% of eggs and 4.39% of chicks were deserted by their Dove parents. Finally, our study highlight that the Turtle Dove breed in high altitude habitats with late and shorter breeding périodes, which might allow this bird to avoid the vigorous climate conditions at mountains and their effect on reproductive success.

Key words: Breeding phenology, migration dates, high altitude habitats, breeding success, Turtle Dove.

1.1.Introduction

Current advances in the study of avian migration have underscored the important linkages between wintering, stopover, and breeding zones [1–4], and the need to consider this interconnectivity in conservation measures [5]. It is becoming increasingly clear that the timing of spring migration, breeding chronology, and feeding quality can greatly influence reproductive success and population trends [6–8], especially for long distance migratory species [9]. Birds are hypothesized to adopt their migration dates and breeding chronology in agreement with environmental factors dominating in wintering and breeding grounds [10].

With development of technologies, especially satellite telemetry, the examination of individuals and their migration and or breeding strategies face different climatic and geographical conditions has greatly advanced with more abilities from wintering to breeding grounds [11,12]. However, the field monitoring of the strategies adopted by these populations need an exhaustive presence in field [13,14]. Additionally, many ecological and biological aspects must be monitored for a long période before conclusions. This is particularly important in the case of rapidly declining species, where threatening factors are still unclear in both breeding and wintering zones [15,16].

European Turtle Doves (*Streptopelia turtur*) is a trans-Saharan long distance migrant bird that winter in Africa subsahara and breed in North Africa and Europe [17,18]. Based on breeding and wintering areas, this game has undergone long-term declines, especially in Western Europe [19,20]. Over the past decades, the intensification of agriculture and habitat loss are classified

as principal causes that leading to the declining of Turtle doves [17,21,22]. These factors cause a failure of breeding success and reduction of migration capacities. Although the breeding ecology and migration dates of Turtle doves has been examined in detail [23,24], there has been no comparable examination of the detailed breeding chronology and reproductive success in high altitude habitats [17]. In all previous studies, research concerning breeding ecology was limited to an altitude ranging from 100 to 600 m in both Europe and North Africa [17,18,25–32]. Therefore, understanding the migration and breeding phenology at high altitude habitat well open a new windows in conservation measures, in particular with recent evidences indicating that Turtle doves breed and feed in mountainous zones [17,28].

In this paper, we present a four years analysis of breeding phenology and migration dates of Turtle doves in its highest breeding habitats. We examine the evidence that elevation in altitudinal parameter have coincided with late migration dates and breeding chronology in Doves. This change if it occurs how it will influence breeding success in this threatened game.

1.2.Methods

1.2.1. Study area

The present study was carried out in Midelt province, Ait Ayach valley (32°41'N, 4°44'W), (Morocco). The monitored sites were located at the Northern foot of Jbel Ayachi Mountains, in the Molouya high plateau, 1400 to 1600 m altitude above sea level. Midelt was dominated with forests that cover 17095 ha, including Xerophytes with 4 772 ha, Holm oak 3375 ha, red juniper 2280 ha etc, while irrigated perimeter covers more than 1000 ha [33]. The orchards were dominated by fruit trees, including apples, plums and peach trees.

In term of climate, temperature in Midelt ranges from 8 to 21.2° C with an annual average of 16.9 ° C, and precipitation vary largely between 65 mm and 481 mm from one year to another (data were extracted from 1957 to 2010 from Midelt Weather station). All these characteristics, including vegetation cover and climatic parameters would play a major role in the bio-ecology of the Turtle dove.

1.2.2. Data collection

Twenty apple orchards (7.47 ha in total) at Ait Ayach (Midelt) were selected and monitored during four years, from 2015 to 2018. For each season, the survey of Dove's arrival dates started in early March and continued until the building of the first nest. Equally, départure dates were recorded at the leaving of last birds from the whole breeding area. After the installation of Doves in the designated sites (after the arrival of breeding pairs), the nest initiation (first nest recorded after the arrival date), laying date (first egg after the nest initiation), hatching (first fledged chick) and chicks' nest leaving (first chick to leave its nest) were surveyed with three visits per month (each visit with three days in field), based on Turtle dove breeding biology reported in North Africa [25,26,34,35], (i) first visit was conducted at the beginning of every month, (ii) second visit from 10th to 20th days, (iii) third visit from 20th to 30th days). Common Bird Census (CBC) methodology [36] was used and research took place from 06.00 to 18.00 hours. In every single visit, recorded nests were monitored from the construction to the nest leaving or predation. Beside breeding chronology, reproductive success was evaluated by calculation of: hatching eggs (hatched eggs/ laid eggs), fledging and flying chicks (chicks leaving their nests/fledged chicks). Moreover, failure factors were cited (basing on carcasses and other aspects, such as the status of nest and feathers in or outside the nest) in along with breeding stages, in order to compare between breeding phases.

1.2.3. Data Analysis

The normality of data was checked for all variables with Kolmogorov–Smirnov test. Arrival and départure dates were defined and means were calculated (all arrival or départure dates during four years). Results were given as mean ± SD. Climatic conditions (temperature and rainfall) were accessed from Midelt weather station from 2015 to 2018. We analysed separately the relationship between breeding chronology, including nesting, laying, hatching, nest leaving and habitat characteristics, counting altitude, temperature, and rainfall by Simple Regression (linear model) and all variables with P-Value greater than 0.5 were eliminated. In parallel, Analysis of Variance with Lack-of-Fit test was conducted to evaluate the Best-fit for models by considering chronology (nesting, laying, hatching, and nest leaving dates) as dependent variables and habitats parameters (altitude, temperature, rainfall) as factors. Statistical analysis were performed using the STATGRAPHICS Centurion software (version XVI.I), And Graphs were created by GraphPad Prism Mac 6.0h software.

1.3.Results

1.3.1. Migration and Breeding chronology

During four years, first arrival dates in spring were on 28.25± 2.05 March, while last Doves were observed 28.00 ± 1.47 September. On the other hand, Turtle doves arrived solitary, particularly during first weeks of April. After these périodes, Doves were observed in groups, especially in pairs.

The breeding chronology of Turtle Doves, including nest initiation, laying, fledging and chick's flying dates at Midelt is summarized in Figure 5. Nesting (initiation of nest construction) began during the last week of April at Midelt (26.5 ± 0.64 April), and nesting période date from 26 April to 6 August. Similarly, laying dates were earlier, first eggs were found 28.00 ± 0.7 April, only two days after the nest construction date. The last laying date was on 12 August. On the other hand, first fledged chicks were 17.50 ± 2.72 May, and chicks started flying 3.50 ± 2.33 June.

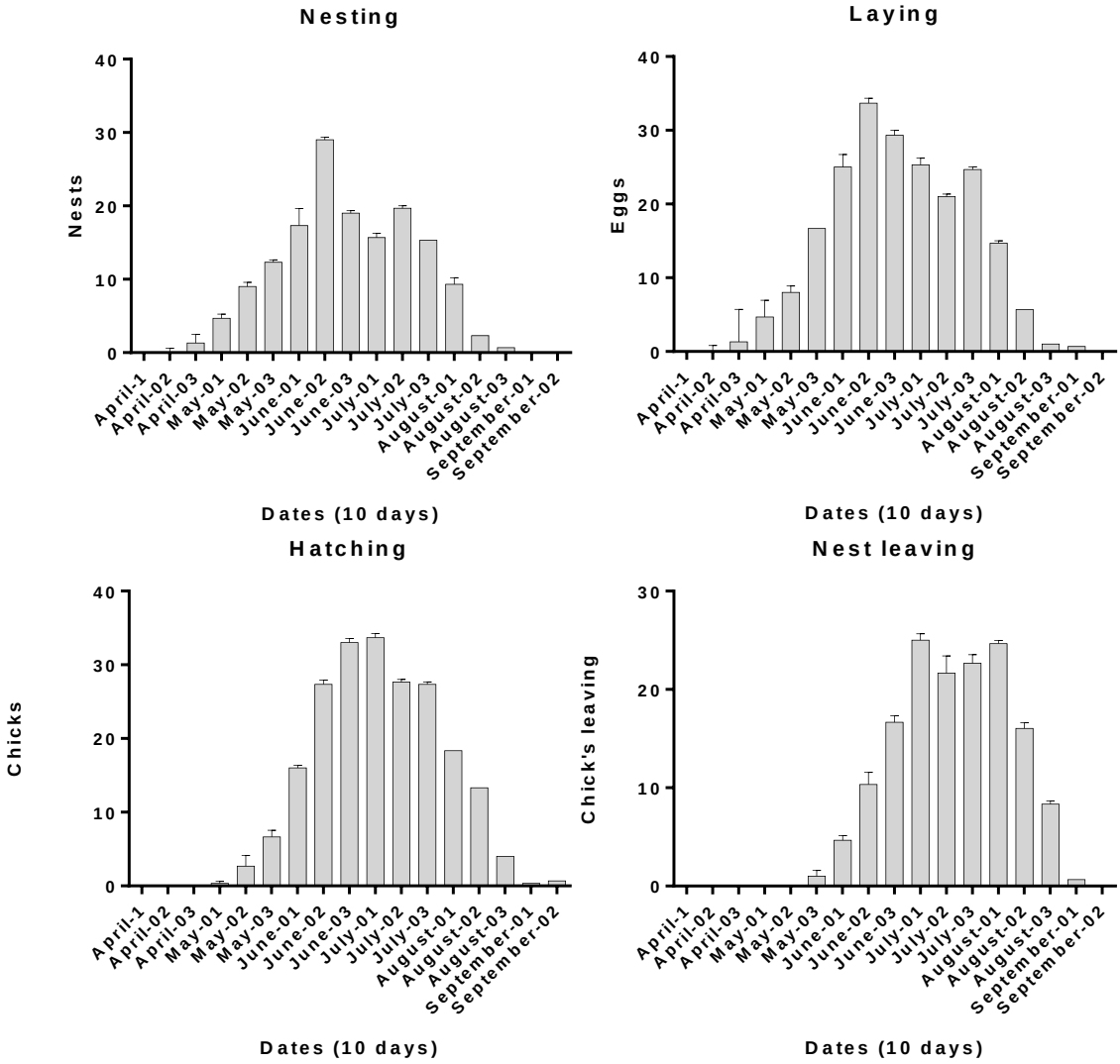


Figure 6: Breeding chronology of Turtle Dove at Midelt between 2015 and 2018

1.3.2. Breeding success

Among the 467 monitored nests at Midelt (table 1), only 73.87% were survived. During incubation stage, hatching success rate was 71.16%. In addition, during rearing période, chicks survive rate was higher with 79.56% of chicks. On the other hand, failure factors of breeding success were diverse. Predation presented the most risk menacing Turtle dove's breeding success, causing loss of 18.89% of eggs during incubation périodes and 10.54% of chicks during nestling phase. Additionally, 5.03% of eggs were unhatched and 5.49% of chicks were died inside their nests. Few portions, including 4.41% of eggs and 4.39% of chicks were deserted by their Dove parents.

Table 1: Breeding success of Turtle doves from 2015 to 2017 at Midelt, Morocco

	Parameters	Number	%
Nests	Total	467	100
	Succeed	345	73.87
	Predated	98	20.98
	Abandoned	24	5.14
Eggs	Total	635	100
	Succeed	455	71.16
	Predated	120	18.89
	Abandoned	28	4.41
	Destruction	0	0
	Unhatched	32	5.03
Chicks	Total	455	100
	Succeed	362	79.56
	Predated	48	10.54
	Died	25	5.49
	Abandoned	20	4.39

1.4.Discussion

Previous research has noted that Turtle doves breed in warm and lowlands, preferring farmlands and forests [26,35,37–41]. However, no previous effort has been made to investigate the breeding attempt in high altitude habitats, particularly in North Africa [24].

Our findings clearly indicate that the European Turtle dove breed in Midelt as a mountainous zone with an altitude ranging between 1400 and 1600 m. This species arrived on 28.25± 2.05 March and started its breeding season by nesting activity on 26.5 ± 0.64 April. The laying période took place two days after nest initiation on 28.00 ± 0.7 April. These breeding chronology is in agreement with results cited by [28], while previous studies have noted a variation of breeding chronology in Turtle doves. At Tadla (514 m altitude and 150 km to Midelt), first Doves arrived early on 19 ± 0.6 March [42,43], at Haouz (452 m altitude and 300 km to Midelt) 15 to 16 March [36], and in Moroccan North Atlantic (100 m above Sea level and 450 km to Midelt) 24 ± 0.16 March [45]. In all these preceding studies, particularly those cited in low breeding sites (between 100 m and 514 m above sea level), nesting and laying dates ranged between 19 to 23 March and 10 to 20 April respectively. Therefore, despite the limitation of this study to one high altitude site, the cited literature confirms that the arrival and breeding chronology dates are later in high altitude breeding lands. At this point, the latitudinal influence on arrival and breeding dates was excluded, because Tadla where Dove's chronology was earlier is in the same latitudinal level with Midelt, while the northern Atlantic is in the North of Midelt. The suggested raison behind this late breeding chronology at Midelt is the environmental factors that accompanying the elevation of the altitude (Figure 6). In fact, high temperatures and low rainfall promote an early nesting and check nest leaving (Table 2). Such results were mentioned in many other migratory birds [46–48]. In the barn swallow (Hirundo rustica), the arrival dates vary from 12 April at 110 altitudes to 24 April at 760 m [49]. Furthermore, temperature was warm at lowlands and predict the arrival dates of swallows. On the other hand, départure dates were on 28.00 ± 1.47 September, before the installation of cold temperatures in Dove's breeding site.

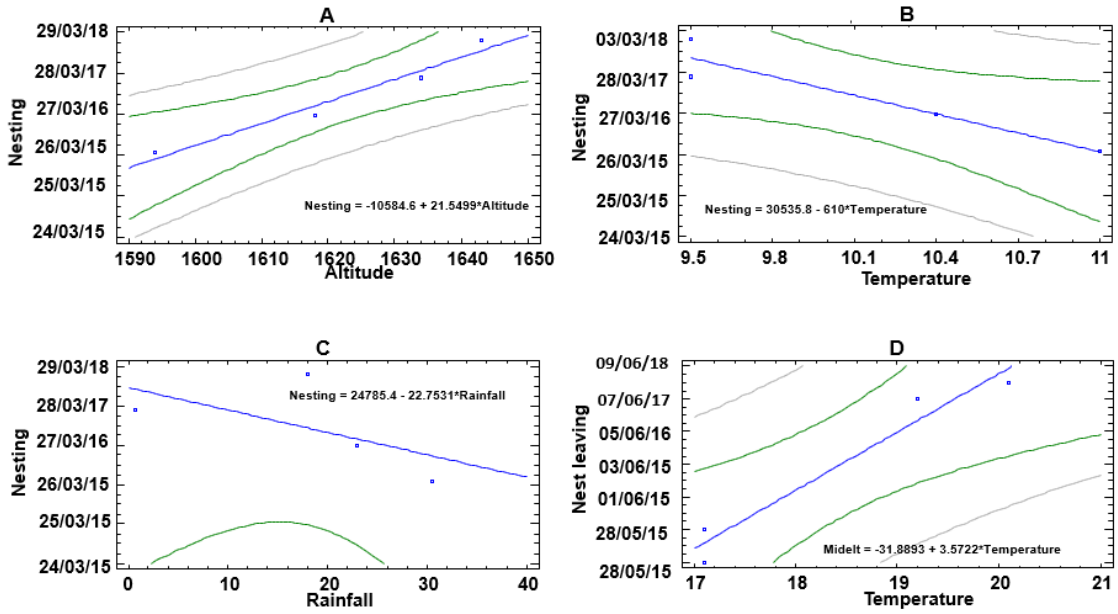


Figure 7: Relationship between the environmental factors and Turtle dove's chronology at Midelt during 2015 to 2018: A) Between nesting dates and altitude, B) Between Nesting dates and temperature, C) Between nesting dates and rainfall, D) between nest's lea leaving dates and temperatures. (The lack of fit test is designed to determine whether the selected model is adequate to describe the observed data).

Table 2: Models of the relationship between breeding chronology of Turtle doves (dates) and habitat conditions (altitude, temperature, and rainfall) during 2015 to 2018 (The lack of fit test is designed to determine whether the selected model is adequate to describe breeding activities).

Model	Sum of Squares	Df	Mean Square	F	P-Value
Nesting x Altitude	643077	1	643077	47.51	0.0204
Nesting x Temperature	602802	1	602802	17.90	0.0516
Nesting x Rainfall	248772	1	248772	1.18	0.3907
Nest Leaving x Temperature	88.1441	1	88.1441	38.27	0.0251

Across tree breeding seasons, breeding success was different from nesting to chicks rearing (Table 1). In total, 71.16% of eggs were hatched, and 79.56% of chicks were flown. Moreover, 57% of chicks (flied chicks/laid eggs) were flied at Midelt which is comparable to previous results cited in other North African breeding habitats [25,28,34]. In Algeria, the nesting success varies between 56% and 60.32% [26,27,35], and in Morocco success rate varies between 54,1 % and 55.5% [34,42,50]. Failure factors were different. The predation caused loss of a significant clutch part (20.98 of nest were predated, counting 18.89% of eggs and 10.54% of chicks) as well as desertion of nest (5.14% of nest were deserted, counting 28 eggs (4.41%) and 20 chicks (4.39%)). Furthermore, 32 eggs were unhatched and 25 died chicks were loss

(chicks were found died every cold morning). Similar results were cited in Orange orchards. In fact, [24,34,42] have reported that the human disturbance in orange orchards at Tadla, (150 km to Midelt) counting fruit harvesting, tree pruning and the overuse of pesticides in coincidence with Turtle Dove breeding périodes is the main factor causing nest desertion.

1.5.Conclusion

In summary, this study provides a deep analysis of Turtle Doves arrival dates, breeding chronology and reproductive success in its North African highest breeding zone. Results reveal the late arrival and breeding seasons in high altitude habitats compared to lowlands. However, breeding success was similar between low and high altitude zones. All these strategies, including late arrival and breeding chronology prevent Turtle Doves against low temperatures in high habitats (protection off eggs and chicks) and human disturbance in managed agricultural farms.

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2. Comparaison des dates de migrations, de reproduction et du succèss reproductif des tourterelles des bois entre les hautes et les basses altitudes

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Synthèse d'étude

La bioécologie des oiseaux semble être influencée par de nombreux facteurs, dont l'altitude qui réduit la fitness et la productivité des espèces vulnérables. En effet, les études ont montré que les conditions climatiques et géographiques des hautes altitudes influencent la chronologie et le succès des espèces en situation critique (Mansouri et al 2020).

La biologie de l'espèce a fait l'objet de plusieurs études, notamment en basse altitude. Par contre, l'espèce n'a pas été mentionnée ou étudiée dans les zones montagnardes. Ce qui limite les connaissances sur le statut de l'espèce et la taille de sa population et par conséquence les mesures de conservation dans ces habitats. Dans la présente partie d'étude, nous avons cherché à comprendre la chronologie de la tourterelle des bois entre la région de Beni Mellal qui se situe á une altitude de 600 m, comme zone de basse altitude et celle de Midelt (1400-1600 m), comme zone de haute altitude. L'étude est réalisée durant la période, allant du mois de mars jusqu'au mois de septembre de chaque année d'étude de la période allant de 2015 á 2018), et ceci, sur vingt vergers de pommiers à Midelt et une parcelle divisée en 20 petits vergers d'orangeraies à Beni Mellal. Dans cette étude, nous avons pu montrer que les dates d'arrivée sont précoces dans la zone de Beni Mellal, tandis que les dates de départ sont antérieures dans la zone de Midelt. Egalement, la phénologie de reproduction se montre précoce au niveau des zones de basse altitude. En revanche, sur un total de 893 nids (467 à Midelt et 426 à Beni Mellal), le succès de reproduction moyen est similaire entre les deux sites. Les principaux facteurs menaçant la tourterelle des bois sont les prédateurs, les conditions du milieu à Midelt et l'abandon des nids à Beni Mellal. En réponse aux conditions de chaque habitat, à Midelt, la période de reproduction est courte et s'est déplacée vers les périodes chaudes de l'été, pour assurer un meilleur succès reproductif et éviter les basses températures. Les résultats obtenus dans cette partie d'étude, nous ont permis de montrer que la saison de reproduction de la tourterelle est plus tardive et plus courte dans les hautes altitudes par rapport aux basses altitudes, ce qui permettrait à cet oiseau d'éviter les conditions climatiques vigoureuses des montagnes et leur effet sur le succès de la reproduction.

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

Abstract

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 départure 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 période was shorter and shifted to hot périodes 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.

2.1.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 périodes 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-Palearctic migrant bird that travels thousands of kilomêtres between breeding and wintering grounds. As the case of many long-distance migratory species, the shifting of départure and arrival times is susceptible to influence turtledove's breeding decisions and périodes. On the other hand, this game species declined by 91%withintheUK 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 région, 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 périodes and breeding chronology is urgently needed to understand certain migratory and breeding features in North African high-altitude zones, which are a 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 périodes which is consistent with breeding chronology. The aim of this study is to present data to assess varying chronologies in the turtledove 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.

2.2.Materials and Methods

2.2.1. 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 to1650m 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 600m 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 3). Effectively, Midelt located in Ayachi mountains was colder than Beni Mellal but with lesser rainfall ($n=48$, $t=-.952$, $df=22$, $p= 0.351$).

Table 3 : Main climatic characteristics in prospected sites, average temperatures, and rainfall, calculated from monthly means of the four study years.

Climatic parameters (2008-2017)		Midelt	Beni Mellal
	Altitude (m)	1400-1600	400-600
Temperatures (°C)	Average	16.05±2.00	18.63±1.81
	Minimal	5.8 (January)	10 (January)
	Maximal	26.8 (July)	34.00 (July)
Rainfall (mm)	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

2.2.2. Data Collection

1.2.1.1 Sample Design

Twenty apple orchards, with 7.47hain total, at Midelt and twenty orange groves, with 6.48ha, 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, départure 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.

2.2.3. Statistics.

Statistical analyses were done in STATGRAPHICS 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), départure dates (last day for doves at breeding grounds), and breeding périodes (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

(100xsuccesseggs/all laid eggs), and survived chicks (100xsurvivedchicks/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 consideredasapercentageofsuccessinside20plotsateach 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 période 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 périodes 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.

2.3.Results

2.3.1. Arrival and Départure 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, départure dates were different between the two sites. Last doves were observed for13.25±2.36days 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)).

2.3.2. 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 7 and Table 4. Nesting activities (first nest per season) beganin 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 on17.50±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 périodes (from arrival to départure 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 (600m).

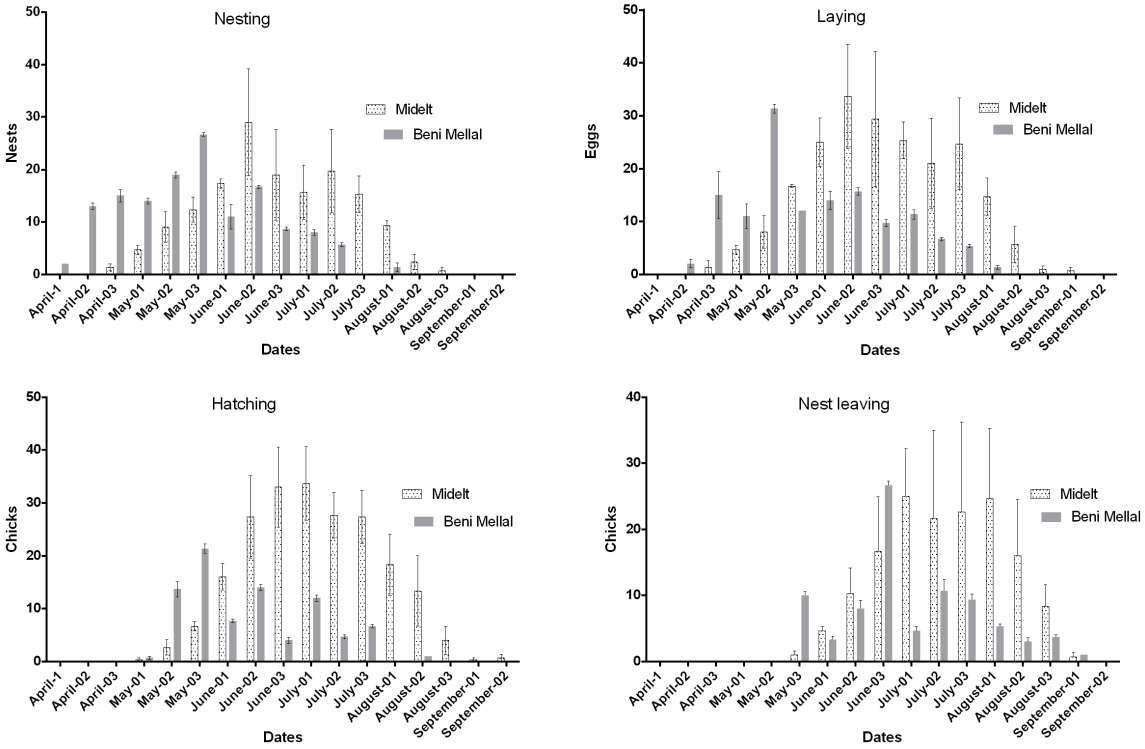


Figure 8 : Breeding chronology of Turtle Dove at Beni Mellal and Midelt between 2015 and 2018

2.3.3. Breeding Success.

Among the 893 monitored nests (467 at Midelt and 426 at Beni Mellal) (Table3), 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 période, 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 turtledove breeding success, while at Beni Mellal, nest desertion dominated all failed clutches.

Table 4: Turtle Dove's breeding success at Midelt (20 apple orchards) and Beni Mellal (n=20 orange groves).

Habitats		Midelt (2015-2017)		Beni Mellal (2015-2017)	
	Parameters	Number	%	Number	%
Nests	Total	467	100	426	100
	Succeed	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
	Succeed	455	71.16	344	64.66
	Predated	120	18.89	60	11.27
	Abandoned	28	4.41	116	21.80
	Destruction	0	0	11	2.25
	Unhatched	32	5.03	1	0.18
Chicks	Total	455	100	344	100
	Succeed	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

2.4.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 600m altitude (Table 3), while at Midelt (1400–1650m) 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 (30km 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 départure dates have started first at Midelt (28.00±1.47September) as a response to the installation of cold temperature, reflected by the snow on the top of the High Atlas Mountains (Figure 8), while at Beni Mellal, départures were late (11.75±2.46 October).

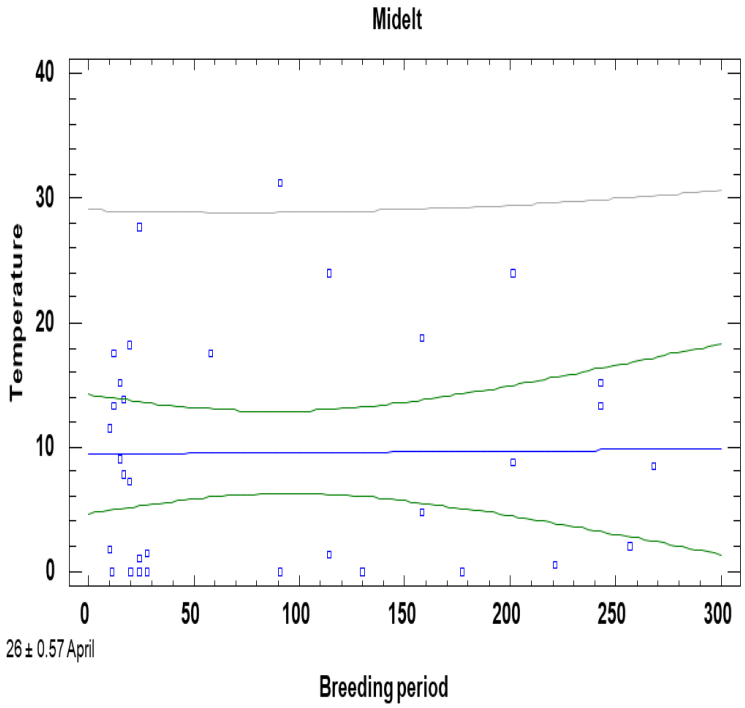


Figure 9 : GLMM model predicting the cold temperature avoidance of Turtle doves at Midelt (breeding périodes far from lowest temperatures).

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 7). 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 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 période 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 (1400–1650m) breeding seasons were shifted to a période between 26±0.57 April and 29.66±1.66 September in order to avoid vigorous conditions (low temperatures) in spring and autumn (Figure 8). Across four breeding seasons at both Midelt and Beni Mellal, average breeding success was different between highlands and low habitats (Table 4). 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 1600m), 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 a results reported in [30, 47]. These authors have declared the impact of human disturbance in orange orchards at Tadla (30km to Beni Mellal), including fruit harvesting, tree pruning, and the overuse of pesticides in coincidence with turtle dove breeding périodes.

2.5.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 low lands. 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.

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3. Biologie de reprodution de la tourterelle des bois dans la plaine de Midelt (Maroc)

(Published in J Anim Behav Biometeorol 2020)

Synthèse de l'étude

Dans cette partie d'étude, nous nous sommes interessé à l'analyse de la reproduction de la tourterelle des bois dans les habitats agricoles des hautes altitudes, pour évaluer l'effet des pratiques agricoles sur les stratégies de reproduction de l'espèce. Ainsi, différentes plantations sont suivies, y compris 10 vergers de pommiers pour l'effet du filet (5 vergers couverts de filets de grêle et 5 vergers non-couverts), 9 vergers de pommiers non-couverts pour l'effet de taillage (4 vergers taillés et 5 vergers non-taillés) et d'autres supports pour l'effet de type des arbres. Des résultats de cette étude, il ressort que les vergers de pommiers hébergent 85% des nids de la tourterelle des bois, dont 60% des nids sont enregistrés sur *Golden Delicious*. La tourterelle connait un taux élevé d'échec dans la région de Midelt, plus particulièrement dans les vergers de pommiers. Ceci, est dû principalement aux attaques de prédateurs. De plus, les pratiques agricoles dans les vergers de pommiers semblent influencer considérablement, le succès de nidification de cette espèce. Nous avons remarqué que la tourterelle des bois ne construit pas ses nids dans les vergers couverts de filets. Nous avons remarqué le taillage des arbres favorise la nidification des tourterelles sur les pommiers.

The turtle dove (*Streptopelia turtur*) in Midelt plain, Morocco: nesting preferences and breeding success versus the impact of predation and agricultural practices

Abstract

Breeding success plays a crucial role in the dynamics of bird populations and yet is the least-studied avian life-stage. Habitat quality during breeding phase may have important implications for survival and conservation, particularly for declining populations in landscapes that have undergone wide-scale human modification. The European Turtle dove is a widespread but fast declining species both in breeding and wintering zones. Reduced food availability is thought to influence breeding success of this game species, but it is not known how agriculture practices could influence breeding Doves, in its high altitude breeding zones. Here, we monitored Turtle dove nests in apple orchards from early Marsh to the end of October 2015. Nest-tree support, breeding success, and predation were determined and analysed depending on agricultural practices. Compared to prune, cherry and other plantation, apple orchards had the highest overall Turtle doves' nests (85%). However, 60% of recorded nests were located on Golden delicious, where are noted the highest nesting success rates (respectively 77.6% and 57.9% for eggs and chicks). However, Turtle dove showed high rate of nesting failure in the Midelt région, more especially in apple orchards, and this is mainly due to predation attacks, which caused a loss of 77.8% of broods, both among eggs and chicks. In addition, several farming practices in apple orchards influenced significantly nesting success of this species. In fact, this game bird does not breed in the orchards covered by hail-nets. Similarly, tree pruning disturb doves nesting on apples.

Key-words: Apple orchards, breeding success, farming activities, European turtle doves.

3.1.Introduction

Numbers of both farmland and migratory birds have been decreasing since the 1970s (Heath et al 2000; Burfield and Van Bommel 2004; Eaton et al 2011), and knowing the cause of these regressions is essential in determining approaches to aid population recovery. This is the case of European Turtle dove (*Streptopelia turtur*), which is a migratory and breeding species in North Africa (Thévenot et al 2000; Dakki and Sehhar 2004), Europe and Russia (Browne and Aebischer 2004; Lormee et al 2016). North African and Western European populations this threatened species overwintering in sub-Saharan Africa and Sahelian savannah (Eraud et al 2009; Lormee et al 2016), and migratory flyways include southern France, Spain and Morocco (Browne and Aebischer 2004; Eraud et al 2009). Conservation of this species is therefore of international concern.

In bird species, population declines can typically be attributed to a combination of reductions in breeding habitat and food availability (Wiehn and Korpimäki 1997; Dombrowski and Golawski 2002; Gutiérrez-Galán and Alonso 2016), which have effects on survival and breeding productivity. In the case of the Turtle doves, an analysis of CBC data between 1965 and 1995 concluded that breeding site availability on farmland was controlling Doves distribution (Browne et al 2004; Dunn and Morris 2012; Hanane 2016). Cereal production in Africa, strongly influences overwinter survival of Turtle doves, suggesting that conditions on wintering lands are also vital for this species (Eraud et al 2009; Mansouri et al 2019). Although, the effects of climate change, droughts and food supply in both breeding and wintering zones (Browne and Aebischer 2001), hunting (Jarry 1999; Rocha and Hidalgo 2002; Boutin and Lutz 2007) and competition with the collared dove (*Streptopelia decaocto*) remain poorly

acknowledged or require advance evaluations (Rocha and Hidalgo 2002; Browne and Aebischer 2003; Hanane 2017). Farmland diversity has decreased around world (Pain and Pienkowski 1997; Dombrowski and Golawski 2002; Zwarts et al 2009), leading to hedgerow and woodland removal and total loss of nesting sites (Pain and Pienkowski 1997; Jarry 1999). The overuse of pesticides, suppression of woodland within farmland and the reduced range of cereal cultivation have been suggested as human-related factors putting pressure on bird populations (Best and Stauffer 1980). Habitat degradation may have also taken place, with a reduction in breeding sites quality, such as tall, suppression of wild plants for nesting or farmlands with mono-culture (Best and Stauffer 1980; Hanane and Baâmal 2011; Gutiérrez-Galán and Alonso 2016), resulting in longer distances travelled between nesting and feeding sites (Dunn and Morris 2012).

In such context, detailed knowledge of the species' habitat requirements across its home ranges is directly necessary to comprehend the role of certain habitat features in favouring higher Turtle dove breeding rate, and to develop targeted and effective management measures (Pain and Pienkowski 1997; Hanane 2017). However, few studies have addressed these questions in North Africa (Hanane et al 2011; Hanane 2014), and these works were mainly focused on the breeding aspects at low altitude habitats (300-700 m). This study aimed to investigate the breeding ecology of Turtle doves in its high altitude farmlands. In addition, this paper is particularly focused on the impact of particular agricultural practices on the Turtle dove nesting preferences and the predation rate in high altitude habitats.

3.2.Material and methods

3.2.1. Study Area and Sites

The present study was carried out in Ait Ayach valley (32°41'N, 4°44'W), Midelt province (Morocco), which located at the Northern foot of Jbel Ayyachi, in the Central High Atlas chain. The prospected habitats (orchards) were at altitudes of 1450-1650 m, belonged to the upper Moulouya plain. This plain was dominated by farmlands, including apple plantations, and a semi-arid climate, with dry and relatively cold winter. The annual average temperature being about 29°C. Precipitations were low (annual average of 89 mm), with about 21 cm of snow (2015-2017). The Ansgmir River and Hassan II reservoir constitute the major sources of water in this semi-arid area. They permitted to create an irrigated perimeter of 4.200 ha, occupied by both cereals and fruit trees, which would play a major role in the bio-ecology of the Turtle dove (Table 5). These agro-ecosystems were characterized by agricultural activities relatively diversified (pruning, irrigation, grass mowing, installation of protection nets, use of chemical pesticides, etc.), and with high potential impact on nesting strategy and behaviour of the Turtle dove (Table 6).

Table 5: Principal agricultural plantations in Midelt Province

Plantation	Species	Surfaces (Ha)
Cereals	Durum wheat	2330
	Soft wheat	217
	Barley	172
	Maize	200
Farming	Alfalfa	548
	Bean	10
Fruit Trees	Apple tree	1 503
	Peach tree	13
	pear tree	54

Table 6: Major agricultural practices in apple orchards in Midelt région.

Practices	Période	Frequency	Methods
Tree trimming	Dec.-Feb.	Once a year	Use of secateurs and saws
Irrigation	Whole year	1-2 times/month (depending on whether)	Traditional systems
Treatments	Mar.-Sept.	1-3 times/month (depending on the degree of infestation)	70% with tractor and boom sprayer 30% with mobile trolley sprayers
Mowing grass	Mar.-Oct.	3-4 times/year	6% traditional (sickles) and 94% with back engines (brush cutters)
Netting	Apr.-Sept.	Permanent	Covering of some orchards with hail nets, that are installed for long periods

3.2.2. Methods

The study was conducted between early April and the end of October 2015, taking into account the breeding season of turtle dove in North African zones (Hanane 2014). Data was collected in three distinct apple orchards: representing differences in farming activities: (i) hail-net-covered orchards, (ii) Tree-pruned orchards, (iii) non-covered and non-pruned apple orchards. Censuses were performed from the early mornings to the end of the day, including days of unsuitable weather conditions (wind, rain).

Preferences toward nesting support was studied in nine non-covered and non-pruned apple orchards, and their surrounding hedges, formed by poplar and wild rose trees (Figure 9). In addition, other farmlands were prospected (Table 7), including two plum orchards (240 trees), two cherry orchards (218 trees), two islets of tamaris (800 trees), two islets of cypress (140 trees) and one patch of walnut (50 trees).

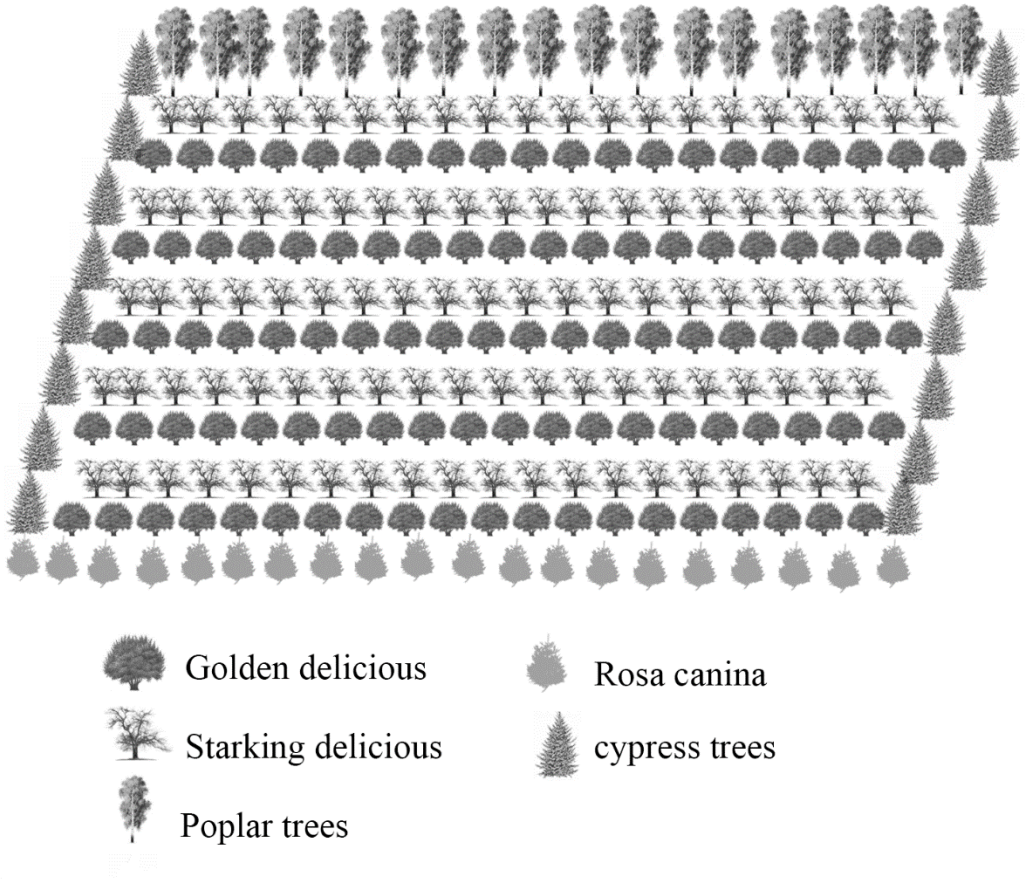


Figure 10 : Distribution model of trees in the prospected apple orchard (10 rows x 20 lines).

To investigate the effect of hail-nets on breeding preferences of Turtle doves, ten unpruned apple orchards (five covered with hail-net (1200 trees) and five uncovered (1200 trees)) were monitored. In parallel, the pruning impact on nesting was studied in nine additional non-covered apple orchards (3300 trees), where nests were recorded on cut and uncut trees of the two apple varieties, cultivated in the study site. Nests were investigated by a qualified observers with line prospection (the observer search nests line by line in apple orchards). The location of each nest tree was marked on a map of the study plot, and monitored (visited once per day). Moreover, other nesting parameters (Figure 10), including nest dimensions, incubated eggs and chicks, predation rate, agricultural practices and their interaction with nesting parameters, were monitored and measured.

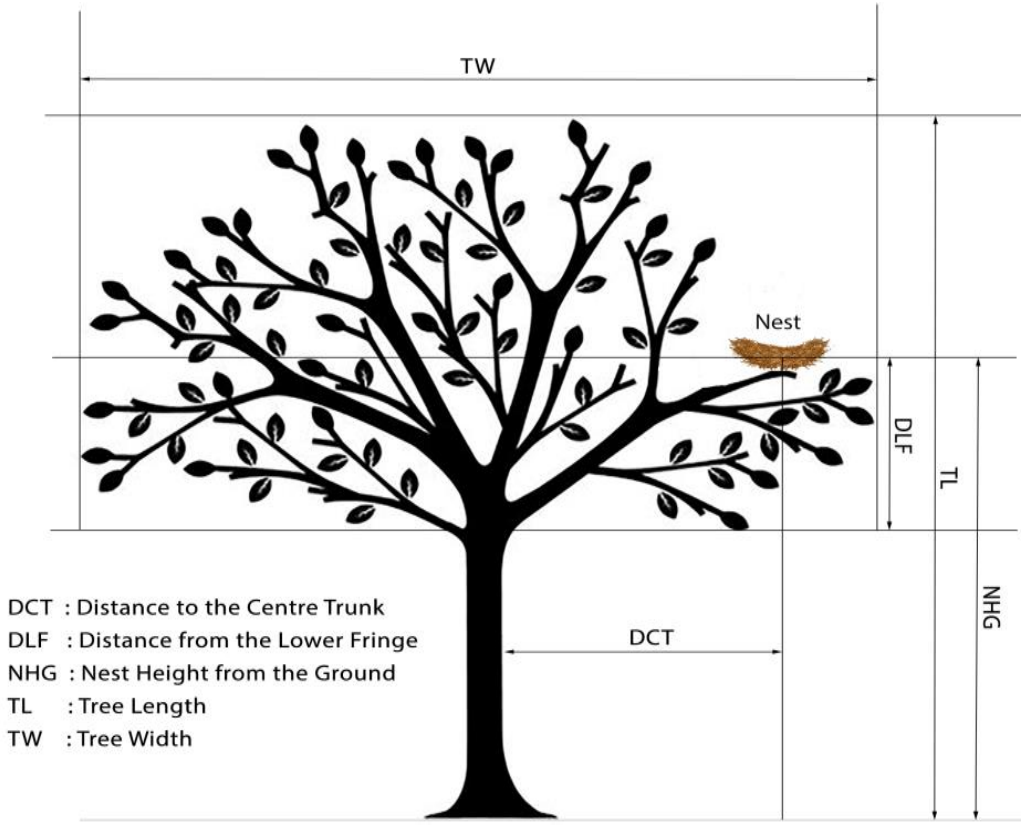


Figure 11 : Parameters of nest location on the apple trees.

3.2.3. Statistical analysis

Descriptive statistics were used to analyse data. Statistical tests were done in R software, version R2.12.2 (R Core Development Team, 2009) and graphs were created by GraphPad Prism 6.01. After assessing normality of variances, all data were non-parametric. Therefore, comparison of breeding success, including eggs hatching and chick fledging rates, between two apple varieties in all orchards, was tested with chi-square test. Additionally, the correlations between egg's abundance, chick's hatching and predation rates were analysed with Spearman's Correlation. On the other hand, the density of nests (number of nests per 100 trees) was calculated in each nesting support to precise Dove preferences toward tree-support for breeding.

3.3.Results

3.3.1. Impact of agricultural activities on nesting activities

3.3.1.1.Nest-support utilization

Turtle doves started singing and flight displays (courtship) almost as soon as they arrived on the monitored sites in mid-April and birds were observed in all studied orchards. Nest construction began few weekends after their installation in breeding orchards. At the end of breeding season, 84.69% of nests were recorded on apples, 9.18% on wild rose, 5.10% on Tamaris, and 1.02% on poplar. Plum, cherry, cypress and walnut trees, remain inhabited by turtle doves. This confirms firstly that the Turtle dove do not use some trees as a nesting supports. To precise Doves preferences toward support trees, the density of nests in each orchards (number of nests per 100 trees) was calculated (Table 7). The highest values were

recorded in wild rose (15.3) and apple trees (4.6), while lowest values were recorded in the Tamaris (0.6) and poplars (0.5). Despite wild rose supporting a high density nests, apple trees play a major role as nesting supports for the species due to their abundance in the study area.

Table 7: Size of study samples and nest densities in four different nesting trees turtle doves.

Shaft Type	Apple tree	Tamaris	Briar tree	Poplar tree	Total
Number of trees	1800	800	60	200	3260
Number of nests (%)	84.69	5.10	9.18	1.02	100
Density (nests/tree)	0.046	0.006	0.150	0.005	0,207

3.3.1.2.Effect of hail nets

In ten monitored apple orchards, nesting activities were limited to uncovered trees. Thirty nests were recorded in uncovered 1200 apple trees. Hail-nets covered-apples were inhabited by Turtle doves (Figure 11). Hail-nets might have formed a physical obstacle to Dove's nesting activity. Therefore, the overuse of hail-net could threat nesting and breeding success of Doves and other bird populations.



Figure 12 : Hail Nets installed on apples (Midelt orchards).

3.3.1.3.Effect of tree pruning

A total of 83 nests were recorded throughout the study habitats (nine non-covered apple orchards). However, the majority of nests (97.6%) were noted in unpruned apple trees. Only 2.4% of nest were located on pruned trees (Figure 12). Despite the similarity in number of pruned and unpruned apples, nesting activity of the turtle dove were favourable in pruned trees. Concerning the breeding success (Table 8), pruned trees appeared to be favourable for the turtle doves, with a success of 77.6% for eggs and 57.9% for chicks in golden variety. Pruning trees may reduce nesting quality of trimmed trees. In addition, pruning activity might provide small twigs locally used for nest construction.

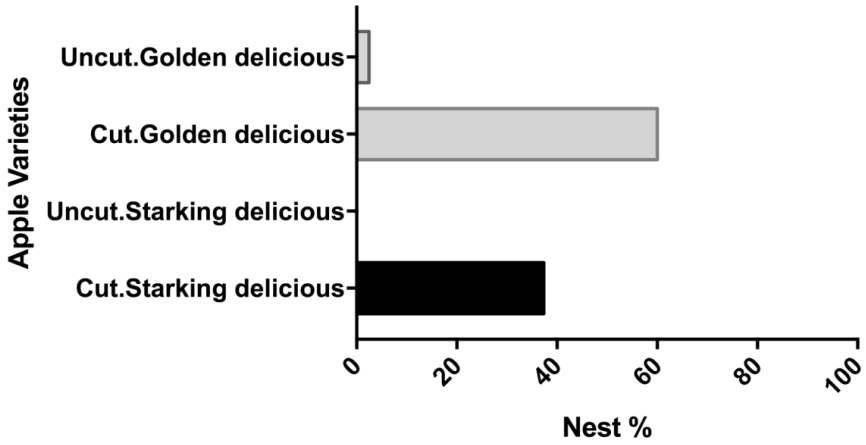


Figure 13 : Effect of turtle doves cutting trees on the nesting at the apple.

Table 8: Success of nests on two varieties of apple trees.

Tree variety*	C. SD		C. GD		UC. SD		UC. GD	
	Number	%	Number	%	Number	%	Number	%
Number of eggs	61		98		0		4	
Successful eggs	20	32.78	76	77.55	0	0	4	100
Chicks hatched	20		76		0		4	
Successful chicks	8	40	44	57.89	0	0	0	0
Number of eggs	61		98		0		4	

*SD : starking delicious, GD : golden delicious, C : cutted, UC : uncutted.Impact of agricultural activities on the breeding success

3.3.1.4.Influence of nesting supports on egg hatching

Breeding success was monitored in different nesting trees throughout nine non-covered and non-pruned apple orchards and their surrounding hedges (Table 9), and revealed high variation of hatching rates depending on tree species. Hatching rate was 100% on both wild roses and poplar trees, followed by 80% on tamaris trees. Trees of these three species ensure better egg's protection from predators, due to significant height of poplar trees, thorny structure of wild rose, beside bushy branches and foliage of tamaris. On the other hand, hatching rate in apples was medium (about 58%), eggs were predated in their nests.

Table 9: Hatching success in the different trees.

Nesting parameters \ Trees =>	Apple		Tamaris		Wild rose		Poplar	
	Number	%	Number	%	Number	%	Number	%
Number of eggs	166		10		18		2	
Number of predated eggs	54	32.53	2	20	0	0	0	0
Number of eggs lost by fallen fruit	6	3.61	0	0	0	0	0	0
Number of abandoned eggs	2	1.20	0	0	0	0	0	0
Number of unhatched eggs	8	4.81	0	0	0	0	0	0
Number of successful eggs	96	57.83	8	80	18	100	2	100

3.3.1.5.Effect of apple's variety on breeding success

Turtle doves breeding success on two varieties of apples (Golden and Starking delicious) was studied in nine uncovered apple orchards. As result, 60.2% of nests were built on the golden variety (Figure 13), against 39.8% on the Starking delicious. Similarly, breeding success reached 77.6% for eggs and 57.9% for chicks on golden variety, counter 22.4% for eggs and 42.1% for chicks on Starking delicious (Test for eggs success: Chi^2=7.93, df=2, P=0.019; and for Chicks: Chi2=9.946, df=2, P=0.0069). Golden delicious seemed to provide better protection to spawning birds.

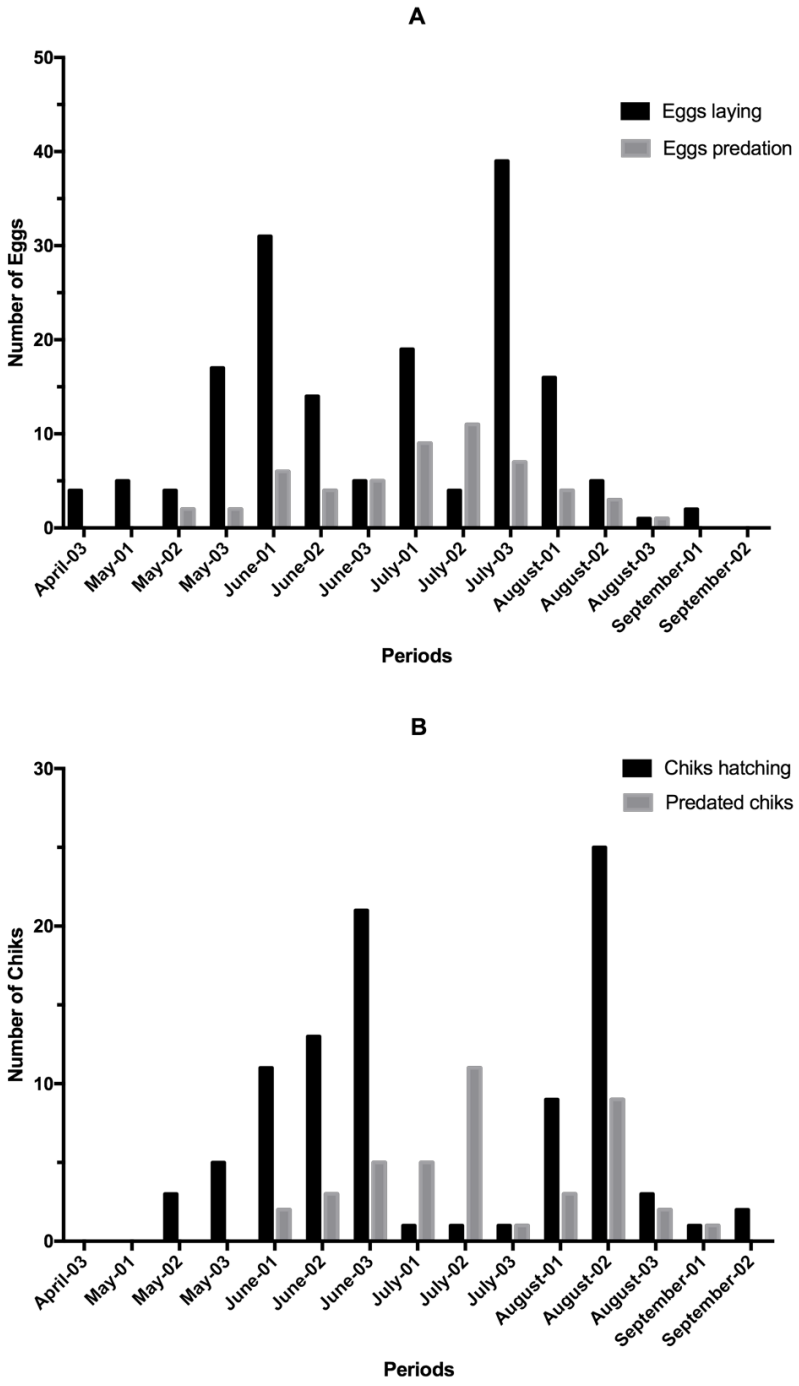


Figure 14 : Phenology of turtle doves nest predation. (A): Predation of eggs; (B): Predation of chicks

3.3.2. Effect of Predation

Predation of eggs was observed throughout study orchards. Almost, during all the laying période, with highest attacks during July (Figure 14). First eggs were attacked during the second week-end of May. Moreover, the highest predation rates were observed during June and July. In parallel, first attacks on chicks were recorded in the primer decade of June (3th June) and continued until early September, with two picks, respectively during the second decade of June and the second decade of August. The frequency of egg predation seems to be slightly proportional to the abundance of eggs (R = 0.635, P=0.011), while this correlation is not clear for predation of chicks (R = 0.43, P=0.101).

3.4.Discussion

Despite that olive and orange trees are the most important nest-trees used for breeding by Turtle doves (Hanane 2012; Hanane and Baâmal 2012; Hanane 2014; Hanane 2017), this study provides first evidence on breeding doves inside apple orchards, and therefore these habitats might play a similar role in high altitude zones, especially, with their placement next to extent of cereals and water availability (Mansouri et al 2019). In the study site, the majority of nests (84.69%) were recorded in apple orchards compared to five other tree species. The choice of apple trees indicated a high quality of these varieties as nesting support and their availability in the study area, which is in agreement with previous study in Britain that showed this species requires a good quality habitat features with suitable nesting and feeding areas in close proximity (Browne et al 2004; Dunn and Morris 2012; Gutiérrez-Galán and Alonso 2016). Apple trees, organized in dense orchards, provide for Turtle doves both safety (relatively dense trees and foliage forming a good camouflage) and favourable nesting structures (i.g. forks made with horizontal or sub-horizontal branches) and abundant twigs to build their nests. Moreover, these orchards, as well as other fruit trees, are generally associated or close to cereal and irrigated lands, as food sources (Mansouri et al 2019).

Turtle doves have placed their nests on Golden delicious and Starking delicious with a preferences toward golden delicious (60.2% of nests). Despite this supporting role played by apples, farming technics and practices cause a serious problem to this threatened species. Covered orchards (with hail nets) and pruning technics limited nesting activity, which is in agreement with results reported by (Blanke and Weidenfeld 1997; Tasin et al 2008), and support that the Turtle doves suffer from agricultural practices in Mediterranean farmlands (Rocha and Hidalgo 2002; Hanane and Baâmal 2011; Hanane 2012). In this work, hail nets form a physical obstacle against birds, and lead Doves to avoid these covered orchards (Blanke and Weidenfeld 1997; Tasin et al 2008). Similarly, the pruned apple trees were unsuitable for turtle dove's nesting. The pruned twigs lead to a destruction of suitable horizontal forks, which facilitate nesting. On the contrary trimmed twigs may serve as small twigs locally used for nest construction, as other species, like Pied Flycatchers (Ficedula hypoleuca) which profit from local twigs and plants to build their nest (Briggs and Deeming 2016).

The Breeding success of Turtle doves was also differed within different nest-tree supports. Wild rose and poplar were the safest support for nesting with 100% of success for eggs. Nesting success on apple trees was medium, with 58% of hatching. The protection of nests on Wild rose and poplar, is due to the significant height of poplar trees, thorny structure of wild rose and bushy branches and foliage. These elements camouflage nests from predators. On the contrary, despite the availability of apples, 42% of nest had been lost, the majority of them

(77% of egg) were predated (Figure 6). However, in term of the breeding success, obtained result are similar to those cited in agro-ecosystems, such as olives, oranges (55.5%) and forests, as woodland and coniferous trees (53%) (Marraha 1992; Hanane and Baâmal 2011). But, in term of failure factors, our results indicate that the predation of eggs was the major threat to nesting success (Figure 12, 13, 14), which is differed from the reduction of nesting sites reported in Britain and Spain (Browne 2004; Rocha and Quillfeldt 2015; Gutiérrez-Galán and Alonso 2016), and nest desertion cited in olives and oranges in Morocco (Hanane and Baâmal 2011; Hanane 2016). The habitat features and characteristics could interfere in this case (Chamberlain and Fuller 2000; Baker et al 2012). The abundance of cats and reptiles, especially snakes (Figure 14), in the study sites could be the most relevant in the predation factor. In addition, predation attacks were observed almost during all the incubation and nestling périodes, with highest frequencies during June, July and August.

The results of this work show that, in the studied apple orchards, Turtle doves face different threats from those cited in other agricultural habitats in North Africa (Marraha 1992; Hanane 2017) and southern Europe (Browne et al 2004; Rocha and Quillfeldt 2015; Gutiérrez-Galán and Alonso 2016). This game species looks, however, to be well-adapted to apple orchard conditions (Mansouri et al 2020). Indeed, although they are highly frequented, the nesting success (47%) confirm the importance and the suitability of such habitats for breeding Turtle doves.

3.5.Conclusion

In conclusion, the findings obtained from this study indicate that Turtle doves breed in apple orchards located in high altitude zones and have an adequate potential to support this threatened species. However, further, more depth studies on the effects of predators on the survival of Turtle Dove nests are needed. Investigation on how this species behaves in more natural and artificial Mediterranean habitats are also required to determine whether Turtle doves change their behaviour depending on habitat type.

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ECOLOGIE DE LA TOURTERELLE DES BOIS

1. Habitats de nourissage et le régime trophique de la tourterelle des bois

(Published in **S**audi Journal of Biological Sciences 2019)

Synthèse de l'étude

Globalement, au niveau des sites de reproduction dans les zones d'étude, la tourterelle des bois a perdu les habitats de nidification et les sites de nourrissage. Ainsi, les données sur le régime trophique de ce gibier sont fragmentaires et rares. Cette partie d'étude porte sur le regime alimentaire de la tourterelle des bois dans la région de la haute Moulouya. Ceci, permettra de comprendre les différents types de cultures et d'habitats naturels fréquentés par ce gibier, pour tamponner la dégradation et la perte des habitats de nourrissage. Pour ce faire, nous avons mené une prospection de terrain dans différents sites à savoir, dix parcelles de céréales d'une surface 3.45 ha, dix parcelles de luzernes étendues sur 1.39 ha, dix vergers de pommiers étendues 3.66 ha et dix stations au niveau de la rivière Insgmir étendues sur 2.63 ha entre le mois d'avril et septembre de l'année 2016. Ainsi, afin de déterminer, d'une manière precise la nature du régime alimentaire de l'espèce, nous avons recolté les jabots (n=68) auprès des chasseurs de la région, entre le mois d'août et le mois de septembre de l'année 2016, ensuite le contenu des jabots est analysé dans le laboratoire.

Les résultats obtenus nous ont permis de souligner que la tourterelle des bois fréquente une variabilité d'habitats d'alimentation en fonction du temps. La culture céréalière semble être fréquentée durant le mois de mai (première phase de reproduction). Ensuite, entre le mois d'août et le mois de juillet, les tourterelles fréquentent fortement les habitats riverains. En outre, la tourterelle des bois se nourrit en couple et en groupe, associée à d'autres espèces. Le régime alimentaire de cette espèce est trés diversifié, avec une tendance granivore. Tous ces aspects, y compris la variabilité des habitats d'alimentation et la diversité du régime alimentaire, semblent être une stratégie adaptative suivie par la tourterelle des bois pour faire face la dégradation et la modification de ses habitats naturels d'alimentation.

Diversity of feeding habitats and diet composition in the turtle doves *Streptopelia turtur* to buffer loss and modification of natural habitats during breeding season

Abstract

The approach of the birds to use physical and alimentary resources in degraded and modified natural habitats is an important aspect of their adaptation. This study was undertaken during 2016-2017 at forty habitats in the Moulouya plain, Morocco to examine behavioral diet, habitat use and foraging ecology of turtle dove, *Streptopelia turtur*. We monitored turtle doves in four major plots namely cereal plots, lucerne farms, apple orchards, and stations in the Ansgmir River covering 40 habitats. Digestive tract contents were also identified and evaluated for 68 Turtle Doves shot by hunters during two consecutive years. The results showed that the turtle doves use a variability of feeding habitats. The cereal cultivation seemed to be more preferable habitat for feeding especially in the month of May, the first breeding phase of the year. But, during the months of August and July, the riverbanks were the preferred habitat for turtle doves. The diet of this species is polyphagous and diverse with a granivorous tendency. Diet analysis showed that soft wheat and barley seeds constituted 44.53% and 38.74% respectively followed by barley seeds with 38.74% and sand stones (9.16%) of the seeds eaten by Turtle Doves. However, moderate proportion of elements (7.32%) remained undefined. All these aspects, including the variability of feeding habitats and the wide diet seem to be an adaptive strategy followed by turtle dove to counter the degradation and the modification of its natural feeding habitats.

Keywords: Feeding habitats, Diet behavior, Polyphagous Turtle doves

Introduction

Turtle dove, *Streptopelia turtur* a migratory species coming from the Western Palearctic low altitude régions (Eraud et al., 2009, Lormee et al., 2016), is one of the Europe's fastest declining breeding bird species (Hayhow et al., 2017). It breeds in the northern part, especially North Africa, Europe and Asia (Browne et al., 2005, Bakaloudis et al., 2009). This bird is highly appreciated by the hunters (Alés, 1996), in Morocco more than 150,000 individuals are killed each hunting season. In the Médoc région of France, thousands of these birds are hunted every year during the breeding season (Dubois, 2002, Eraud et al., 2011).

Population decline of the Turtle Dove has been directly linked to the modification and reduction of its breeding habitat over the last few decades. This columbidae chooses its habitat in different ecosystems, including orchards, cultivated lands, forest edges, coppice trees, and hedgerow sceneries, where it finds most of its food (Kleemann and Quillfeldt, 2014, Kafi et al., 2015). These habitats play a very important role in the survival of the species. In fact, crops offer an important food resources, while the landscape fixed elements, such as trees, provide a capital support for nesting (Rocha and Quillfeldt, 2015, Hanane, 2016, Roshnath and Sinu, 2017). In wintering grounds, seeds are the main nutrients for turtle doves (Guy, 1991). But, low cereal productivity, due to drought and reduced cereal-growing surfaces, is one of the elements threatening the survival of this migratory specie, as well as its ability to adapt with difficult migratory trajectories (Eraud et al., 2013, Lormee et al., 2016). In particular, this species has a strictly granivorous diet and is mainly based on cultivated crops and their seeds (Guy, 1991, Roux et al., 2006). In addition to the hunting and predation, recent studies show

that reduced food availability, destruction and modification of feeding habitats (Browne and Aebischer, 2003, Rocha and Quillfeldt, 2015), are among the main factors threatening the turtle dove population (Alés, 1996, Browne et al., 2005, Bakaloudis et al., 2009). This reveals how important is to study the trophic diet of the turtle dove (Lormée, 2001, Wells-Berlin et al., 2015).

In breeding zones, data on the turtle dove's diet is fragmentary and limited. Knowledge of the seeds that are ingested by Turtle Doves during the breeding période is necessary in order to carry out specific management actions which can increase the abundance of important dietary components (Boutin et al., 2007). Most of the investigations are focused mainly on breeding habitats, population size, and agricultural activity's effects on breeding (Eraud et al., 2009, Eraud et al., 2011, Lormee et al., 2016). This work aimed to understand the Turtle dove's nutritive behavior and to identify the main seeds consumed by Turtle Doves in different habitats of the Middle Atlas région (Morocco). Knowledge of the main seeds included in the diet will help managers in planning grazing schemes that might increase the abundance of important seeding species in the breeding habitats. We are looking into how this game uses different cultivated fields and natural habitats to deal with degradation and loss of its original feeding habitats, during breeding season.

1.7.Material and methods

1.2.1. Study sites

The present study was carried out in the Ait Ayach valley, in the province of Midelt (32°41′ North and 4°44′ West), at the junction of the Middle Atlas and the High Atlas, Morocco (Fig. 15). This mountainous région is dominated by agricultural activities including apple plantations. Also, these agro-ecosystems are characterized by a variety of agricultural practices that likely influence the turtle dove's nesting strategy and feeding behavior (Ousaaid et al., 2017). In the study zone, four habitats are distinguished, counting apple orchards, cereals (common wheat and barley), riverbanks, and lucerne cultivation.

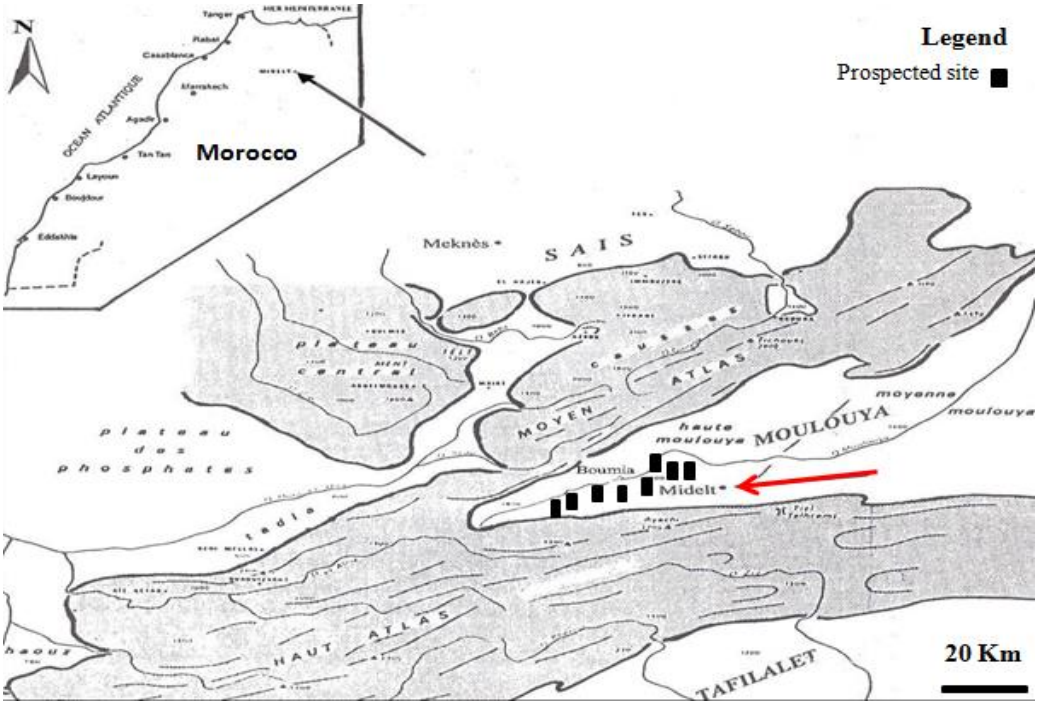


Figure 15 : Geographical localization of prospected habitats in Midelt province, Morocco.

1.2.2. Ethical note

This study was performed under the proper legislation of the Moroccan law and was approved by the Ethical Committee of both Moroccan Research Group for bird protection (Birdlife Morocco) and laboratory of Functional Ecology and Environment, Biology département, Faculty of science and Technology-Fez. Also, during study, all nest and birds were recorded with minimum disturbance. Digestive tract contents were identified and evaluated for 68 Turtle Doves shot by hunters during two consecutive years.

1.2.3. Methodology

After a preliminary survey and identification of the habitats visited by turtle dove in 2015, we conducted this work during the breeding season, from April 2016- September 2017. About 40 habitats in small plots (depending on the nature of agricultural fields) were monitored three times per month (separated by ten days). Ten cereal plots (3.45 ha), ten lucerne plots (1.39 ha), ten apple orchards (3.66 ha) and ten stations in the Insgmir river (2.63 ha) were monitored. In another part, the river banks were studied along a 5.7 km transect, from Tattehante in the east to Bonhas in the Ouest. The observed turtle dove individuals, in each habitat, were counted (from 06:00 to 18:00 h) to analyze and follow the feeding behavior of this game.

1.2.4. Diet composition

To determine the turtle dove's trophic diet; a batch of 68 birds were analyzed. These individuals were collected in the studied région from the local hunters, between August and September 2016 and 2017. After determining the individual's sex via dissection, 38 males and 30 females were identified. The turtle dove's diet was determined by the analysis of the digestive tract contents. Seeds and debris consumed were compared with plant references collected from the studied zones.

1.2.5. Statistical analyses

Descriptive statistics were used to analyse data. Statistical tests were carried out by the SPSS software (version 18.00, IBM 2009) and STATGRAPHICS (Centurion XVI, 2010). After assessing normality and homoscedasticity of variances, parametric data, such as the comparison of seasonal feeding habitats, daily consultation of habitats and female-male diet were analysed using ANOVA one-way test and multiple range test (MRT). To describe variability of consulting habitats during breeding season (qualitative data), Dêtrended correspondence analysis (DCA) (For seasonal feeding gradient) and Factor analysis (potentially correlated habitats and périodes) were conducted. Results reported as significant assume a false discovery rate of 0.05. Graphs are created by GraphPad Prism Mac 6.0 h software.

1.8.Result

1.3.1. Feeding habitats

The feeding habitat available and used by Turtle Doves are presented in Fig. 16. The graph showed that for feeding, the turtle doves use a variety of habitats. Cereal cultivation appeared to be the most favorable feeding agrosystems for this species ($F = 9.32$, $DF = 3$, $P < 0.001$). In fact, the turtle birds were highly concentrated in these plots (Table 10). Beside the cereal plots,

riverbanks present a great interest for turtle doves feeding. This is very remarkable during the hot summer phase. On the contrary, lucerne plots and apple orchards were less preferred by the turtle dove during breeding season (Table 10).

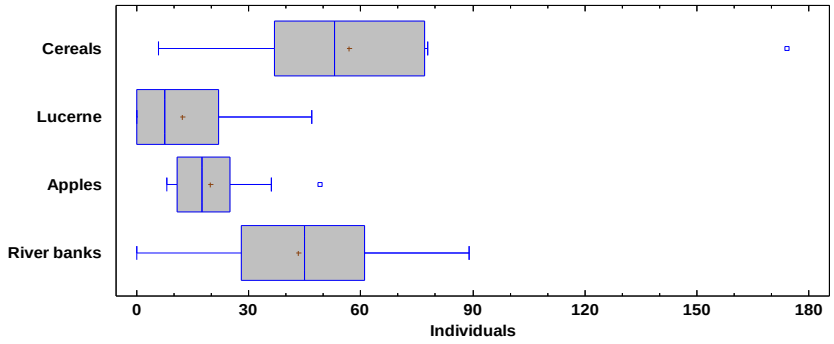


Figure 16 : Feeding habitats (Box and Whisker Plot) used by turtle doves during breeding season (2016-2017).

Table 10: Multiple comparison, determining which habitat is significantly important for turtle dove feeding.

Contrast	Sig.	Difference	+/- Limits
Cereals – Lucernes	*	44.7143	19.2936
Cereals – Apples	*	37.2857	19.2936
Cereals - River banks		13.5	19.2936
Lucernes – Apples		-7.42857	19.2936
Lucernes - River banks	*	-31.2143	19.2936
Apples - River banks	*	-23.7857	19.2936

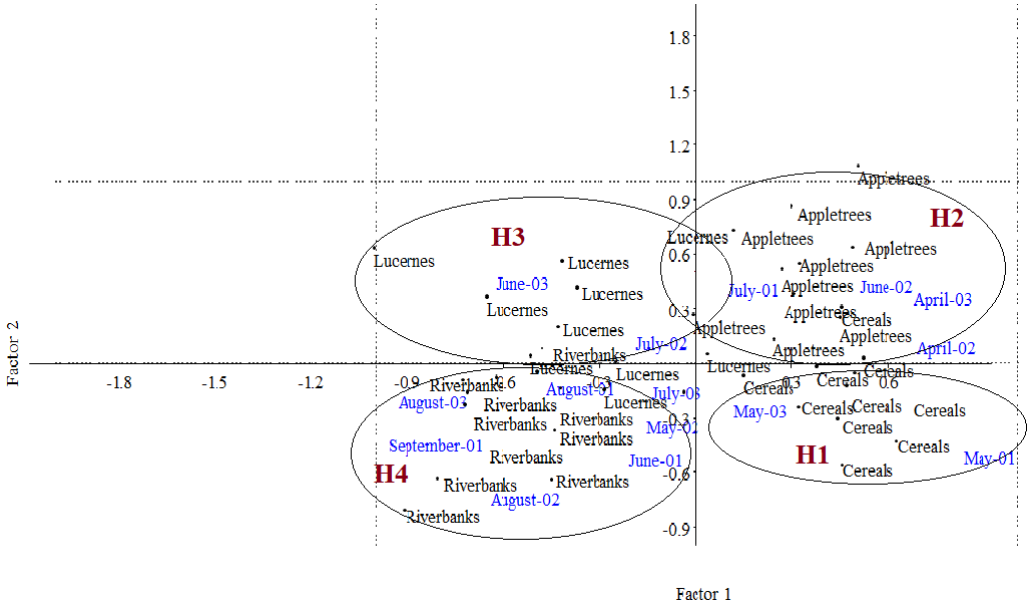


Figure 17 : Dêtrended Correspondence Analysis (DCA) (F1 (38.01 %)*F2 (29.36 %)) of feeding habitats visited by the turtle doves during breeding season (2016-2017).

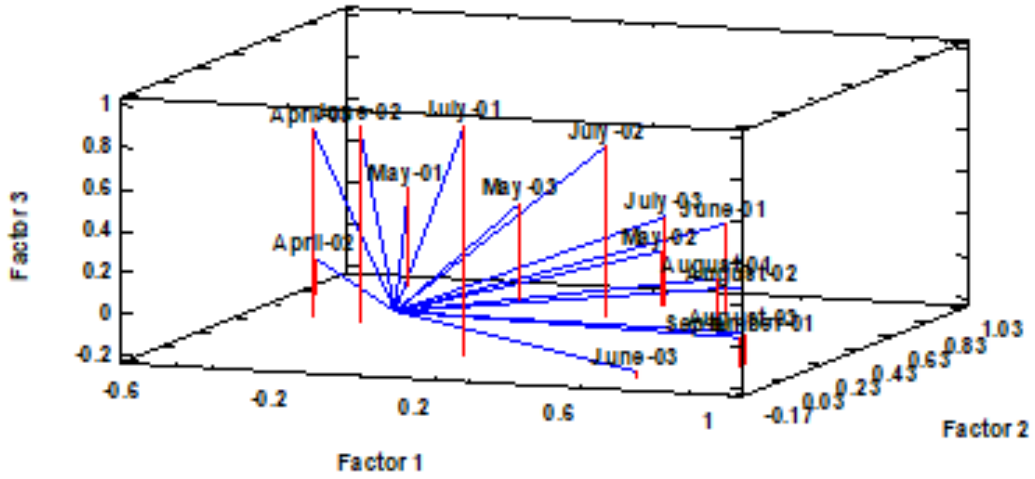


Figure 18 : Factor Analysis (FA) of feeding habitats used by turtle dove during breeding season (3D Loading plot, (F1 (38.01 %)*F2 (29.36 %)*F3 (9.18%)).

Graphical representation (F1 * F2 and F1 * F2 * F3) of the results, using Dêtrended Correspondence Analysis (DCA) and Factor Analysis (FA), enabled us to identify four feeding habitats, variable depending on time (Fig. 17, Fig. 18). During the month of April, turtle dove was observed more in the apple orchards (H2). Cereal plots (H1) were preferred massively by the turtle doves in May. But, during June the birds were located proportionally among the lucerne cultivation (H3), the apple orchards and the river banks. Between July and September, the turtle dove individuals were concentrated mainly on the Insgmir River banks (H4) before migration.

1.3.2. Feeding behavior

Turtle dove's feeding behavior was monitored in different feeding habitats during five months' période (from April to September). The observations were undertaken thrice a day; in the morning between 6:00–11:00 h, at Midday between 11:00–15:00 h and in the afternoon between 15:00–19:00 h. The results obtained are presented in Fig. 19.

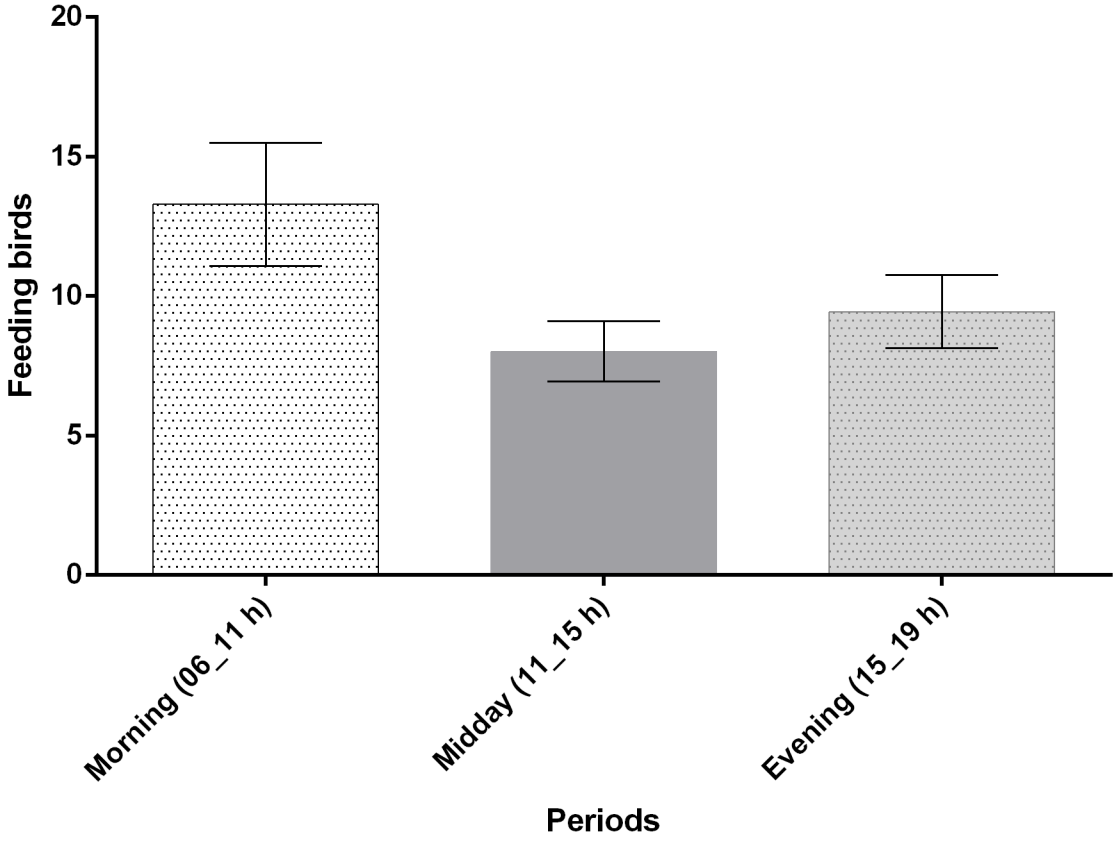


Figure 19 : Daily consultation of feeding habitats by the turtle doves during breeding season (2016-2017).

Table 11: Multiple comparison, determining which période is suitable for turtle dove feeding.

Périodes	Sig.	Difference	+/- Limits
Morning – Midday	*	5.27119	4.44456
Morning – Evening		3.84746	4.44456
Midday – Evening		-1.42373	4.44456

* denotes a statistically significant difference.

The graphical presentation showed that the turtle doves visited feeding habitats throughout the day. However, the number of birds that visited these habitats was greater in the morning and afternoon (DF = 1; F = 7.15; P = 0.009). A fewer individuals fed during midday (Table 11). During the observations (n = 23 * 40 (habitats)), we also noticed that the turtle doves were feeding in groups, particularly in couple. In reality, an average of 19.59 ± 2.77 couples were observed every time in the field, compared with 9.09 ± 1.32 of solitary individuals. This difference was statistically significant (DF = 1, F = 12.253, P = 0.001).

1.3.3. Diet composition

Results obtained in the turtle's diet showed a wide diversification in the consumed elements (Fig. 20). Indeed, the digestive tract contents were very rich in seeds of different plant species and inert elements. Soft wheat dominates the trophic diet with 44.53%, followed by barley

seeds with 38.74% and sand stones (9.16%). A small part of the content was occupied by the gastropod shells (0.24%) and grit stones (0.02%). However, a moderate proportion of elements (7.32%) remained undefined, because of their deteriorated forms and colors. The comparison between males and females of turtle doves revealed a qualitative difference; which was the presence of the gastropod shells only in females and the grit stones in males without any significant variance in weight (Table 12). For other elements, no significant difference was revealed between the two sexes.

These results showed a much diversified trophic diet in the turtle doves. However, most of consumed seeds were from cultivated plants, including soft wheat and barley. In addition, the presence of sand stones and gravel can be explained by their role in the physical digestion of food.

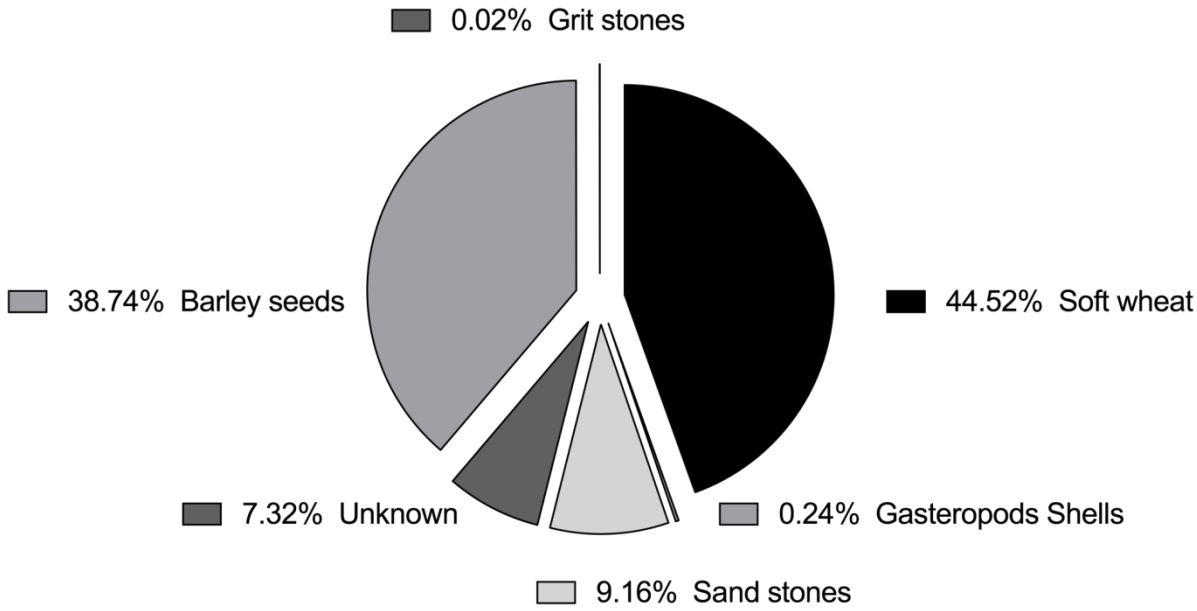


Figure 20 : Composition of turtle dove's diet.

Table 12: Comparison of digestive tract contents between males and females in turtle doves.

Digestive tract contents	Males (g)	Females (g)	F	P
Soft wheat	1,72±0,69	2,45±0,02	0,062	0,804
Barley seeds	1,54±0,57	2,07±0,80	0,153	0,698
Sand stones	0,22±0,16	0,68±0,05	0,665	0,421
Gastropods Shells	0,00±0,00	0,026±0,00	0,008	0,930
Grit stones	0,0018±0,00	0,00±0,00	0,879	0,356

1.9.Discussion

In this study, we have shown that the turtle dove is visiting a variety of feeding habitats, including cereal plots, to fulfill its nutritional needs (Fig. 17). This is in consistent with the results reported by Dubois, 2002, Browne and Aebischer, 2003. In fact, the richness of cereal plots in edible seeds represents the main factor that attract the turtle doves to consult these

habitats, as already mentioned by Lormée, 2001, Roux et al., 2006, Kafi et al., 2015. However, the consultation of lucerne cultivations, riverbanks and apple orchards may be due to the reduction in surfaces occupied by cereals, or under the pressure of human activities that are modifying the natural habitats (Eraud et al., 2009, Hanane, 2014, Yuan et al., 2014). In reality, during recent years, cereal surfaces are in decline (Eyshi Rezaei et al., 2015, Marshall et al., 2015) because of the agricultural policies adopted in several countries and climate changes (Carpintero and Naredo, 2006, Marshall et al., 2015). Therefore, river banks present a supplementary habitat rich in food and close to the water (Hanane, 2017, Kafi et al., 2015, Rocha and Quillfeldt, 2015), and these two elements (water and food) are fundamental for the any animal's life (Dubois, 2002, Mekonnen and Hoekstra, 2012, Paray et al., 2018).

The feeding activity of this game occurred essentially during the morning phase and before sunset (Fig. 19). This is consistent with the results reported by Dubois (2002). He showed that the increased diurnal temperatures, particularly in Midday, mean that the seed's metabolic water would become insufficient to cover the water requirements of this bird (van Leeuwen et al., 2016, Jungklang et al., 2017, Abdu et al., 2018, Park et al., 2018). This fact pushes turtle doves to look for seeds early in the morning and late in the evening (Table 2), in order to minimize the water losses due to the displacement during the day's hottest périodes (Dubois, 2002, Eyshi Rezaei et al., 2015). Turtle dove top feeding was observed during June and July (Fig. 21). These périodes are synchronized with optimum breeding phases of this bird in the Mediterranean zone (Fig. 22). This coincidence indicated that the turtle doves look for food in order to rear their chicks. Furthermore, turtle doves feed in groups, especially in couple, this is in agreement with results revealed by Dubois, 2002, Ward and Enders, 1985. Turtle dove feeds in couple or in a group, often with other bird species. In our case, turtle dove is associated with wood pigeon (Columba palumbus), the rock pigeon (Columba livia), the house sparrow (Passer domesticus) on cereal plots, blackbird (Turdus merula) on apple orchards and lucernes. This confirmed that this game shares the feeding habitats with other avian species. This group feeding behavior provides a possibility to obtain necessary information from other group members about the environment and the habitat's feeding quality (Lachmann et al., 2000, Serrano-Davies et al., 2017), then to decide whether to stay or leave their current foraging range (King and Cowlishaw, 2007).

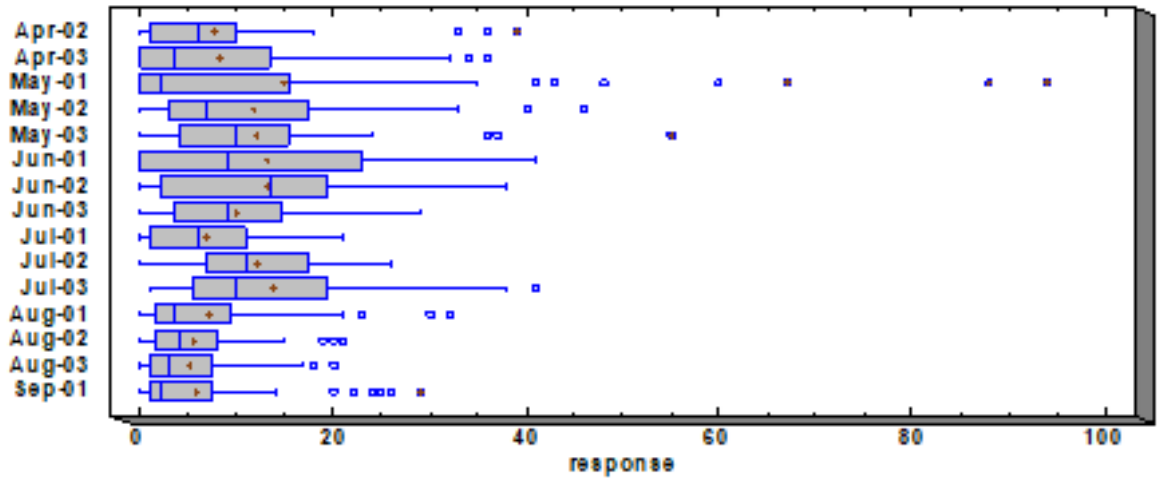


Figure 21 : Variation of turtle dove seasonal feeding behavior (Box-and-Whisker Plot).

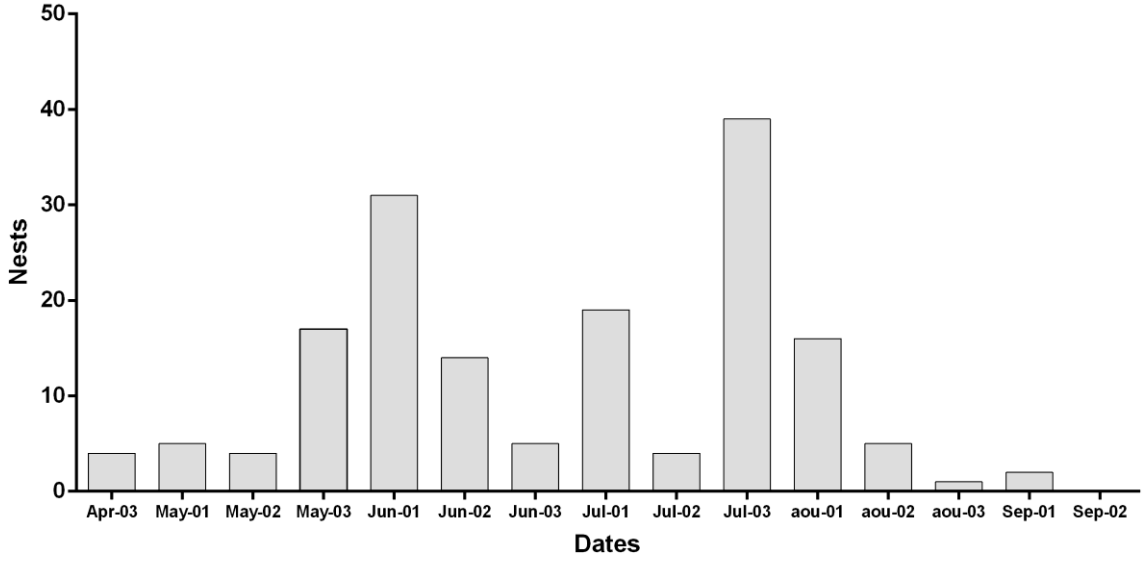


Figure 22 : Nesting phenology of turtle dove during breeding season (2016_2017).

As reported by many authors (Dubois, 2002, Roux et al., 2006, Gutiérrez-Galán and Alonso, 2016, Hanane, 2017), turtle dove is characterized by a wide trophic diet with affinity to cereal seeds. In our case, the digestive tract analysis showed that the turtle dove is characterized by a polyphagous trophic diet with a granivorous tendency (Fig. 20). However, according to Dubois (2002) this game occasionally consumes mollusks and inert materials. In the present study, besides gastropod shells, we found also sand and grit stones. These inert materials may play a role in physical digestion (Crompton and Nesheim, 2016, Vamanu, 2017).

1.10. Conclusion

Finally, our study suggested that the turtle dove is characterized by a diversity in several aspects of the diet. Feeding habitats are very diverse, depending on their nature (agricultural or natural) and time. This diversity in feeding habitats is reflected in the digestive tract contents. Indeed, different cultivated and wild seeds are revealed in the trophic diet of hunted birds. In addition, the individuals of this game search their food in groups, associated with other species, in the coldest périodes of the morning and evening to avoid all water losses. All these strategies would help turtle doves to deal with reduction of natural feeding habitats and unavailability of nutrients.

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2. Niche de nidification de la tourterelle des bois dans trois zones humides d'Afrique du Nord

(Submitted to International Journal of Ecology 2021)

Synthése d'étude

La presente étude porte sur la niche ecologique de la tourterelle des bois dans les zones humides nord Africaines. Pour ce faire, nous avons suivi, les habitats de nidification de la tourterelle des bois et les espèces cohabitantes dans trois zones humides, dans la haute Moulouya, y compris Oued Insguemir et Oued Tablkhirte, durant la période allant du mois de mars jusqu'au mois de septembre entre 2015 et 2017. Nous avons suivi les sites de nidification, les arbres support des nids sur l'ensemble de trois zones des cours d'eau, y compris l'amont, la zone intermediaire et l'aval. Egualement, l'emplacement des nids (la hauteur des nids et des arbres) et leurs dimensions (grand axe, petit axe et la profondeur du nid) sont etudiés pour analyser la cohabitation entre la tourterelle des bois et les espèces coexistentes.

Les resultats obtenus montrent que la tourterelle des bois partage les habitats de nidification avec differentes espèces cohabitantes dans les mêmes sites. En effet, sept espèces d'oiseaux, y compris des espèces migratrices et sédentaires, sont rencontrées communement avec la tourterelle des bois, en particulier dans la zone intermédiaire et dans la zone d'aval des rivières etudiés. Generalement, le manque de concurrence pour les ressources alimentaires avec les espèces voisines (toutes les espèces recensées ont des regimes alimentaires insectivores) a contribué à ce partage harmonieux des sites de reproduction et des arbres de nidification. En conclusion, la tourterelle des bois cohabite avec d'autres espèces d'oiseaux dans les habitats de nidification.

A new feature of nesting ecology in the vulnerable european turtle dove: nest-site and nesting-tree sharing with coexisting species at three north african wetlands

Abstract

Studies of niche partitioning in the European Turtle dove (*Streptopelia turtur*) have mainly addressed food habits and foraging activities, and limited to conspecific species counting Laughing dove and Wood pigeon. The recent degradation of natural and suitable habitats for Turtle doves, particularly in North Africa would push this species to refuge in wetlands with a variety of other bird species. The understanding of potential cohabitation between Doves and other species in these less disturbed ecosystems would help in the conservation measures of this declining game. The study, conducted from early March to September between 2015 and 2018, attempted to determine which species cohabit with Turtle doves in three Northwest African wetlands at Morocco, and how these species select nesting sites and trees. We used Dêtrended corresponding analysis (DCA) to test the relevance of nest-site and nesting-tree variables in the nest distribution of the breeding species. The results show significant niche sharing between Turtle doves and seven breeding species, especially at Intermediate zone and Downstream of rivers. The lack of competition for food resources with neighbouring species may helped in this harmony sharing of both nesting sites and nesting-trees. We further suggest guidelines for future researches that seek to understand the spatio-temporal dynamics of species coexisting with Turtle dove in the same habitats.

Keywords: Turtle dove, nest-site, nesting-tree, niche share, wetlands.

2.1.Introduction

The cohabitation of similar and different species that share resources in the same environment is of crucial interest in ecology1,2. To coexist, species should differ on at least one aspect of their ecological function and or behavioural aspects3,4. They should use space and/or time differently at their environment. For illustration, these species could use different food resources and/or their activity patterns could be separated in time5. Because, the coexistence of similar species and the use of same resources at same time risk to create a hostile environment and/or antagonism behaviours6,7.

For bird species, the nest-site selection is of vital importance, particularly migratory species. These birds travel for a long distance from wintering to breeding grounds, and any failure in nesting habitats would disturb whole life cycle. Consequently, the selection of nest location is considered the main adaptive response to a combination of: climatic conditions 8,9, nest predation pressure 10–12, and human disturbances 13,14. Its selection is therefore vital for individual fitness.

The present study analyses the patterns of nesting habitat selection of Turtle doves in tree North African wetlands, to examine how they use nesting sites and nest-support with different species that nest in the same wetlands. More specifically, we studied nest location of all species that nesting commonly with S. turtur in macro-habitat represented by river zones, including Upsteam, Intermediate zone and Downstream, and in micro-habitat reflected by nesting-trees. The choice of wetlands has two reasons. First, these natural habitats are less influenced by human activities in Northwest Africa15,16, and the monitoring of any ecological aspect will be less influenced by human pressure. Second, with acceleration of desertification and climate

change in North Africa 17–19, wetlands, especially rivers will be the latest and suitable refuge for resident and migratory species, including Turtle doves for breeding and foraging20, and thus their analyses will open our eyes to appreciate their role in conservation measures of this declining game. In fact, the study of Turtle doves cohabitation with existing species in wetlands, will evaluate their interactions as community concerning habitat use and its implication for conservation purposes.

2.2.Materials and Methods

Observations were made in Moulouya high plain, situated in the foot of Jbel Ayachi Mountain and junction with Middle Atlas chain. The high plain is located at an altitude of 1400-1600 m upon sea level and characterised by an arid climate, with cold winter. The area is dominated by farmlands (804.354 ha), forests (185.004 ha) and uncultivated lands (280.000 ha). Three study wetlands were selected and monitored from 2015 to 2017 (Figure 24). First, Insgmir River, take départ from junction of Middle Atlas Mountain chain and Central high Atlas Mountain (32°29'26.00"N, 5° 6'2.24"W) and finish by Hassan II dam (32°47'48.80"N, 4°50'29.21"W) in north of Midelt city. Second, Eastern Tablkhirt River, take départ from Northwest of Boumia city (32°42'36.92"N, 5° 8'13.46"W), cross Zaida city and finish by Hassan II dam (32°50'27.93"N, 4°49'48.37"W). Third, Ouestern Part of Tablkhirt River, it take source from Imzil rural village in West (32°41'49.83"N, 5°11'44.79"W) and finich in Northwest of Boumia city in East (32°42'36.92"N, 5° 8'13.46"W). Along these Rivers, we have noted a variety of plant species, including riparian vegetation and farm plants (Table 15), and these were distributed in each side of the river streams.

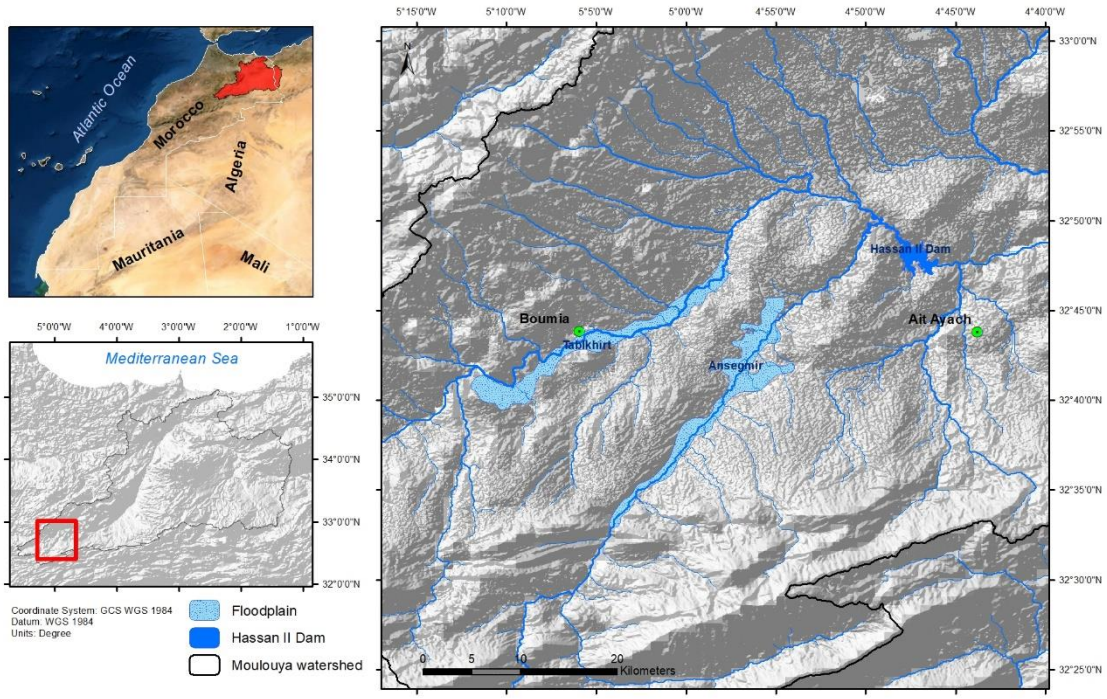


Figure 23: Study rivers of Ansmir and Tablkhirt (Blue) in Moulouya watershed (Reed) at Midelt province, Morocco.

Table 13: Abundance of vegetation genus identified in studied Rivers in Moulouya high plain at Midelt, Morocco.

Nature	Plants	Insgmir	Eastern Tablkhirt	Western Tablkhirt
Wild Riparian genus +++++	Poplar sp.	+++++	+++++	+++
	Salix sp.	+++++	++++	+++++
	Rosa sp.	+++	++++++	+++
	Phragmites sp.	+++	+++++	+++
	Crataegus sp.	++	++	++++
	Rubus sp.	+++	++	+
	Juncus sp.	++	++	++
	Tamarix sp.	++	++	__
	Pinus sp.	+	+	+
Cultivated genus	Malus sp.	+++++	+++++	+++++
	Prunus sp.	+++	+++	+++
	Cydonia sp.	+++	+++	+++
	Pyrus sp.	++	++	+
+++++ Very abundant	+++ Abundant	++ Less abundant	+ rare	__ Absent

2.2.1. Study area

Given that wetlands in Morocco are the only habitats in which avifauna and other species can live and act with a minimum human disturbance, and are one of the favorable habitats for Turtle doves during breeding and migration périodes 21,22, fieldwork was exclusively carried out in these habitats.

The study took place from early March to September, during the breeding season of Turtle doves, between 2015 and 2017. These périodes were chosen based on the breeding périodes of Turtle doves at North African zone, particularly in Moulouya high plain 14, 23,24. The study Rivers were initially divided to tree zones (figure 24); i) Upstream in the top of the river, from the mountain sources to the first farmlands in the plain, ii) Intermediate Zone, starts from first farmlands under mountain foot to the finish line of irrigated perimeters, iii) Downstream, located in the borders of irrigated lands to the nearest dam that built on the monitored river. Each zone was assigned an exclusive numerical identifier. In each year, we systematically searched nests in rivers with an inventive method consisting of side by side (right and left sides of the river stream) walked transects of 6 to 10 km per day, from 06.00 to 18.00 hours. To describe nest-niche of Turtle doves, in each single transect (two transects simultaneously at both sides of river), detected nests were assigned with unique serial number (for a good monitoring), identified (species), localised (with phone Geotracker software, and then reported in an Open Source GIS (Quantum GIS v1.7.3).), and characterized (two categories: nesting-three, breeding zone). In parallel, nest dimensions (three categories: big axis (big diameter or length), small axis (small diameter or width), depth (thickness or cup depth)), nest placement (two categories: nest height upon ground (NH), nesting-three height (NTH)), and distance between neighbouring nests (intra and interspecific) were measured with clinometer and long distances were extracted from Google Earth (Quantum GIS). Nests were monitored three time per week in each river, from nesting to loss of clutch or flight of survival chicks.

2.2.2. Sampling design

Given that wetlands in Morocco, particularly rivers are the only habitats in which avifauna and other species can live and act with minimum human disturbance (Dakki et al 2020), and are one of the favorable habitats for Turtle doves during breeding and migration périodes (Abubakar 2017, Salim and Ali Abed 2017, Mansouri et al 2019), fieldwork was exclusively carried out in these habitats.

The study took place during the breeding season, from early March to September, between 2015 and 2017. These périodes were chosen based on the breeding périodes of Turtle doves at North African zone, particularly in Moulouya high plain (Hassani et al 2018, Mansouri et al 2019, 2020). The study Rivers (Figure 1) were initially divided to tree zones; i) Upstream in the top of the river, from mountain sources to the first farmlands in the plain, ii) Intermediate Zone, starts from the first farmlands under mountain foot to the finish line of irrigated perimeters, iii) Downstream, located in the borders of irrigated lands to the nearest dam that built on the monitored river. Each zone was assigned an exclusive numerical identifier. In each year, we systematically searched nests in rivers with an inventive method consisting of side by side (right and lift sides of river stream) walked transects of 6 to 10 km per day, from 06.00 to 18.00 hours. To describe nest-niche of Turtle doves, in each single transect (two transects simultaneously at both sides of river), detected nests were assigned with unique serial number (for a good monitoring), identified (nesting species), localised (with phone Geotracker software, and then reported in an Open Source GIS (Quantum GIS v1.7.3), and characterized (two categories: nesting-three and breeding zone). In parallel, nest dimensions (three categories: big axis (big diameter or length), small axis (small diameter or width), depth (thickness or cup depth)), nest placement (two categories: nest height upon ground (NH), nesting-three height (NTH)), and distance between neighbouring nests (intra and interspecific) were measured with clinometer and long distances were extracted from Google Earth (Quantum GIS). Nests were monitored three to two time per week in each river, from nesting to loss of clutch or survival of chicks.

2.2.3. Statistical analyses

Before performing statistical tests, we checked for normality and homogeneity of variance for all the variables. For Turtle doves nesting features, including nest height upon ground (NH), nesting-three height (NTH), and nest dimensions (big axis, small axis, depth), they were calculated as mean ± SD. We also checked for possible correlations among variables of Turtle dove nests by using Pearson's rank correlation (r) index. In order to analyse the ecological niche of Dove we used Dêtrended Corresponding Analysis (DCA) and Principle Component Analysis (PCA), which are a powerful method for analysing multi-ecological variables. The distribution (three zones) of breeding species (n=8), nests (n=453), used nesting-trees (n=10) were analysed with DCA, since this analysis allowed as to reduce dimensionality of the set variables (n=21) to a smaller and representative variable, particularly distribution of breeding species along Rivers (Macro-habitat) and used nesting-threes (combined with nest placement form a micro-habitat). On the other hand, nesting features, including nest dimensions (n=3) of four species that sharing the same habitat and nesting-tree (Turtle dove, Black bird, European serin and Woodchat shrike), nest placement (n=2) were analysed with PCA in order to investigate factors that characterising each species nest ('representative' variables were reduces (n = 5) and eigenvalues were >1.0). We interpreted the ecological meaning of the principal

components, which explain the greatest amount of combined variation within the nest structure data, by examining the component loadings of each variable (McGarigal et al. 2000). Finally, we compared distances of neighbouring nest of Turtle dove and species that breed on the same habitats and use the same nesting-trees (Black bird, Bonelli's warbler, and woodchat shrike) with One-way ANOVA tests. All statistical analyses were performed with STATGRAPHICS software (Centurion XVI, 2010) and results were considered significant at $P < 0.05$.

2.3.Results

2.3.1. Habitat and nest-tree sharing

In studied wetlands, Turtle dove shared breeding sites with a variety of bird species (Figure 25). Seven species, counting Western Bonelli's warbler (*Phylloscopus bonelli*), common Black bird (*Tordus merula*), European serin (*Serinus serinus*), White stork (*Ciconia ciconia*), common Nightingale (*Luscinia megarhynchos*), Woodchat shrike (*Lanius senator*) and House sparrow (*Passer domesticus*) were found in the same nesting sites with Turtle doves. However, the distribution of these species differed between river zones and nesting support. At Upstream, four species, counting Bonelli's warbler, black bird, European serin, woodchat shrike were inventoried as breeders on Plum sp., Tamarix sp. and Reed sp. trees, while turtle dove was absent at this zone. At Intermediate zone, eight birds were listed as breeders on different supports. The group counting Turtle dove, black bird and woodchat shrike preferred Wild rose, Blackberry and Hawthorn for nesting, while the group with bonelli's warbler, common nightingale, European serin, and house sparrow preferred Salix sp. as nesting-trees. The white stork built its nest alone on Poplar. At Downstream, only four species were inventoried as breeders with turtle doves. Though, Doves shared Quince sp. as nesting support only with bonelli's warbler, while black bird, common nightingale and woodchat shrike shared Whit willow as nesting-tree.

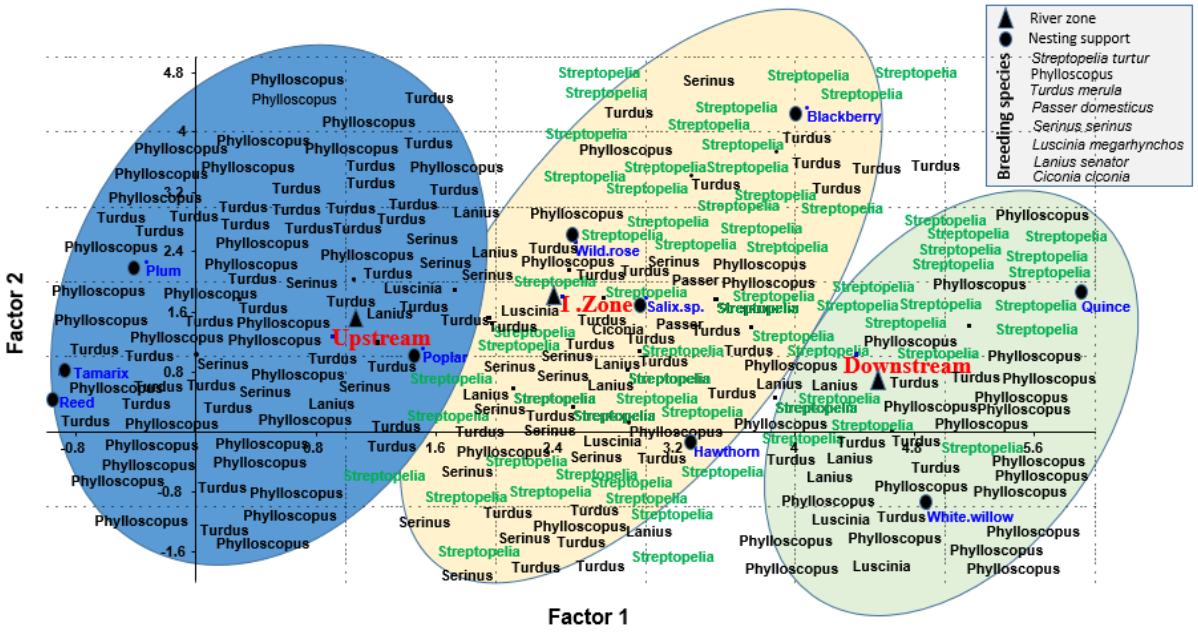


Figure 24 : Distribution of Turtle dove nesting-site and nesting-tree along river at Moulouya high plain (analyzed with Dêtrended Corresponding analysis) (F1=71.69% X F2= 11.94).

2.3.2. Nest emplacement and dimension

Turtle dove built its nests (n= 98) on an average height of 3.74±1.83 m upon ground. Those nests were categorized by a big axis with 14.10±0.41 cm, a small axis with 11.43±0.28 cm, and a depth with 4.79±0.26 cm in average. In parallel, through whole nest dimensions, only small axis was correlated to the big axis (Spearman Rank Correlations; n=20, r=0.51, p=0.0253) and depth (Spearman Rank Correlations; n=20, r=0.73, p=0.0013). On the other hand, the European turtle dove and common black bird are the biggest bird, while European serin and Western bonelli's warbler are the smallest birds among studied species. In comparison with neighboring species (sharing same habitats) (Figure 26), dove's nests were characterized with their length (big axis) and width (small axis) (G1). Black bird and Western bonelli's warbler built a nests characterized with higher depth (thickness) to protect their clutches (G2). The group encircling the European serin (G3), counts nests described with highest support and height upon the ground.

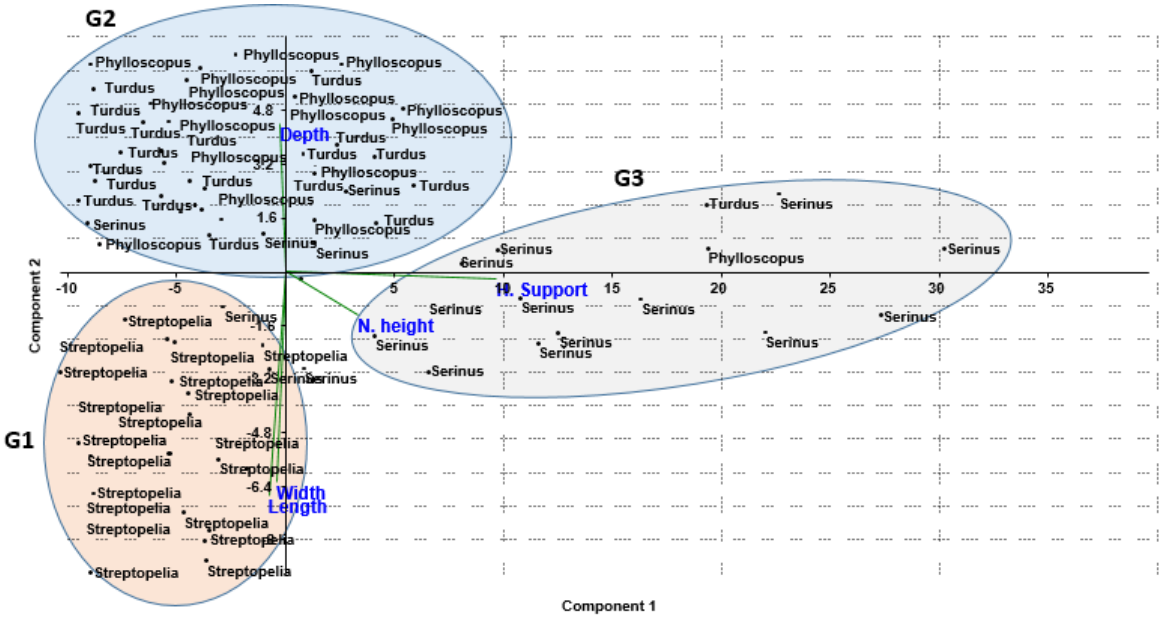


Figure 25 : Turtle dove nest situation among coexisting species that share the same nesting-site and nesting-tree at Moulouya high plain analysed with Principal Component Analysis (PCA)

2.4.Discussion

From 1960 to 2020, the majority of studies concerning Turtle doves have investigated this game separately from other species that could existing in the same habitats, and this will miss a precious information that would help in conservation of this declining migratory bird. In best case, turtle doves were studied comparatively with conspecific competitors (Columbidis), such as laughing dove, collared dove, stock dove and wood pigeon, mainly in geographical distribution25–29, in feeding competition 27,30, in breeding biology 31–33 and in parasite infestation34,35. On the contrary, this study have situated Turtle doves among interspecific breeding species in wild nesting sites.

As expected, this study showed a clear evidence of interspecific interaction between threatened Turtle dove and other bird species during breeding périodes. Obtained results unveil a sharing of breeding habitats and nesting sites in studied wetlands. Turtle doves nested in river wetlands

with seven other species, including resident birds, such as black bird, house sparrow, European serin and Western bonelli's warbler, and migratory birds, such as white stork, common nightingale, and woodchat shrike. This confirm for first time an interspecific cohabitation behaviour in Turtle doves which was neglected in previous studies29,36. In macro-habitat (rivers), except Upstream, Turtle doves nested in Downstream and Intermediate zone at three different rivers regularly with seven species from 2015 to 2017. In microhabitat, at intermediate zone Doves have nested commonly with black bird on Wild rose and Blackberry nesting-threes, and on Hawthorn nesting-threes with western bonelli's warbler, blackbird and common nightingale. At Downstream, turtle doves nested separately on Quince threes, while western bonelli's warbler, blackbird and common nightingale nested on White willow threes. This kind of interactions have been documented, particularly between some dove species during the breeding season (for instance between the Turtle dove and the Collared dove in Spain 26,37 and between the White-winged dove Zenaida asiatica and the Morning dove in USA 38, and between Doves and pigeons (for instance between Turtle doves and wood pigeon 36. In North African ecosystems, migratory Turtle doves and resident Wood pigeons, and Laughing dove segregated nesting-threes support and breeding habitats, in order to reduce potential competition for food sources and nesting support 36, which is in contradiction with our results. In this study, Turtle doves shared the same habitat and same nesting-tree with at least three species, including migratory and resident birds (seven Dove nests with seven B. bird nests, nine nests with B. warbler, and two nest with W. shrike on the same nesting-tree). Moreover, in many cases, distance between Dove nests and neighbouring species nests on the same tree-support was very close in the same breeding périodes of all these species (between Dove and bonelli's warbler on Wild rose threes d= 22.88±4.77 cm, and between Doves and black bird on black berry trees d=38±6.37 cm) (table 16).

Table 14: Comparison of distances separating Dove nests and nests of neighbouring species that using the same nest-tree, and same nesting-three species (Turtle dove and Black bird, Bonelli's warbler, Woodchat shrike), tested using one way ANOVA test.

	Species			Statistic test	
	S.turtur-T.merula	*S.turtur-P.bonelli*	*S.turtur-L.senator*	F	P
Nests on the same three-support	7	9	2	-	-
Nests on the same three species	19	25	6	-	-
Distances between nests of the same three-support	22.88±4.77 cm	22.88±4.77 cm	172.5±115.39 cm	11.413	0.000
Distances between nests on the same three species	31.22±5.61 m	37.33±7.47 m	67.87±32.00 m	1.041	0.369

The raison behind sharing (present study) or segregation (previous study) of breeding habitats between migratory Turtle doves and coexisting birds is suggested to be intraspecific competition. In fact, migratory Turtle doves, resident Laughing doves and Wood pigeons are a strict granivorus 14,39–44 and a severe conspecific competitor at both wild and agricol ecosystems 32,36,42,45, and therefore the segregation of breeding habitats and nesting-threes will allow them to avoid a concurrence for breeding sites and feeding resources. While, the sharing of breeding habitats and nesting-three by Doves with interspecific birds, such as Black bird and Bonelli's warbler known for their insectivorous diet 46,47 would not affect both breeding or feeding sources available for both sides of these taxa. Furthermore, Turtle doves are currently documented to diversify feeding habitats far from nesting sites14,23, and thus the sharing of nesting sites would not influence the availability of feeding resources close to or far from nesting habitats.

Concerning nest dimensions, among studied species, Turtle doves were characterized by the largest nests (length and width), followed by Black bird with a deepness nests, while European serin and Bonelli'a warbler nests were the smallest nests. In addition, European serin nests were built on the highest height upon the ground and nesting-threes. These findings suggest that Turtle dove and Black bird known by a medium body size48,49 are building a medium nests, while European serin and Bonelli's warbler built small nests in correlation to their body sizes. Such results were demonstrated largely in bird communities48,50 and support that each species build a safe and comfortable nest in correlation to species body size, and in order to ensure better clutch protection.

2.5.Conclusion

Generally, these data reinforce the lack of information on nest-niche selection of the threatened European turtle dove in Mediterranean zone. This work shows that for breeding, Turtle doves share nesting habitats with different species, including migratory and resident birds. Further, more detailed investigations are needed to allow deeper insights into the coexistence of the Turtle doves with a concurrent and predatory species. Our future challenge is to understand the spatial and temporal dynamics of doves in harmony with competitor and favourable species and to determine the factors that may cause a trend in the size of populations.

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3. Comparaison des caractéristiques de nidification et du succès reproductif de la tourterelle des bois entre les vergers et les habitats riverains

(Published in International Journal of Zoology 2021)

Synthèse de l'étude

La tourterelle des bois (*Streptopelia turtur*) se reproduit dans les écosystèmes agricoles et les habitats forestiers. Cette partie d'étude porte sur la comparaison des caractéristiques de nidification et le succès de reproduction de la tourterelle, entre les vergers de pommiers et la végétation riveraine dans la province de Midelt (Maroc). Ainsi, nous nous sommes intéressés à l'emplacement des nids (hauteur des arbres et nids), les dimensions (diamètres et profondeur) et le succès reproductif (taux de réussite durant les phases de reproduction).

Les résultats obtenus nous ont permis de souligner que les l'emplacement des nids, sur les supports de nidification, est similaire entre les vergers et les sites riverains. Cependant, les dimensions des nids, principalement, le grand et le petit diamètre, se montrent de grande taille dans les vergers de pommier. Les corrélations sont variables entre les paramètres de l'emplacement et les dimensions des nids. En outre, durant les quatre saisons de reproduction et les 566 nids suivis (467 dans les vergers et 99 dans les sites riverains), le succès de reproduction moyen est de 57% des poussins dans les pommiers, contre 53% dans les habitats riverains. De plus, dans les vergers de pommiers, les pontes ont échoué à cause de la prédation (18.89% des œufs et 10.54% des poussins) et les basses températures (5.03% des œufs non éclos et 5.49% des poussins morts), tandis que, dans la végétation riveraine, la prédation et la désertion des nids ont engendré une perte de 33.16% et 21.33% des pontes respectivement.

Comparison of Nesting Features and Breeding Success of Turtle Dove *Streptopelia turtur* between Orchards and Riparian Habitats

Abstract

The European Turtle dove (*Streptopelia turtur*) breeds in both farmlands and woodlands. In this context, it is important to explore the difference in breeding ecology of this threatened game in natural and artificial ecosystems. This study compares nesting features and breeding success of Doves between apple orchards and riparian vegetation in Midelt Province, Morocco. As a result, during four years (2015-2018), nest placement, including nesting-tree height and nest height was similar between orchards and riparian sites. While nest dimensions, mainly big and small diameters were larger in orchards. Correlations were variables among nest placement parameters and dimensions. On the other hand, with four breeding seasons and 566 nests (467 in orchards and 99 in riparian sites), the average breeding success was 57% of chicks in apples compared to 53% in rivers. Moreover, in apple orchards, clutches were failed due to, mainly predation (18.89% of eggs and 10.54% of chicks) and cold temperatures (5.03% of unhatched eggs and 5.49% of dead chicks), while in riparian vegetation, predation and desertion were responsible for the loss of 33.16% and 21.33% of clutches.

Key words: Apple orchards, nest placement, rivers, reproductive success.

3.1.Introduction

The European Turtle dove *Streptopelia turtur* is one of a number of birds that have declined dramatically and rapidly in Europe (-78% in Britain between 1980 and 2013, as well as -70% in Spain between 1980-2017) [1]. Consequently, it has been classified as 'Near Threatened' within the European countries and 'Vulnerable' throughout Africa and Europe, following recent evaluation [2]. Potential factors responsible for the species' decline include breeding habitat degradation [3], reduction of food availability due to agricultural intensification [4,5], hunting, and variation in ecological conditions throughout the migration flyway [5–7].

In North Africa, mainly western countries, Turtle doves are common summer migrants and breeders [8–10]. Morocco hosts an important Turtle dove breeding population [11], largely dispersed in forest ecosystems [12,13] that are representing 12.7% of the national surface [14], and farmlands representing 1.5% [11] of the total land area. In agricultural lands, they are more frequent in farm landscapes with irrigated perimeters [10, 15–19], including olive, orange and apple orchards being particularly favoured [15, 18–20]. Similarly, in Algeria, the Turtle dove is a migratory breeding species, distributed over a wide area of the northern territory of the country to the palm oases and groves in the south (Yahiaoui et al 2014, ABSI et al 2015, Saâd et al 2020). On the contrary, in Tunisia, the Turtle dove is less studied without any information about breeding and foraging ranges (Boukhriss et al 2009).

Most studies on both European and Northwest African Turtle doves have focused on farmland habitats, involving breeding biology [3,19–22] breeding habitat use [3, 4, 21–24], foraging habitat use [4, 18, 25–27] and migration [28–30]. While in forests, studies were limited to habitat use [23, 31–35] and feeding resources [27, 33]. Moreover, studies comparing wild habitats and farmland are inexistent in both Europe and Africa, and this explains the urgent need to analyse the situation of Turtle doves in both woodlands and agricultural habitats.

The goals of this study are twofold. First, we compared nesting features, including nest placement and dimension between apple orchards as farmlands and riparian vegetation as wild habitats at Midelt province, Morocco. Second, we compared breeding success and we identified

the most important failure factors menacing Turtle doves' clutches in both orchards and riparian habitats.

3.2.Materials and Methods

3.2.1. Study area

This study was carried out in the Midelt Province, located in the Daraa-Tafilalet region between the Middle Atlas in the Northeast and High Atlas Mountains in the North (Figure 1). The Midelt area is characterized by a cold arid climate with a mountainous tendency and the rainfall regime is marked by extremely variable and irregular low rainfall, stormy precipitation brings eroded products upstream [36, 37].

Two zones were selected, Ait Ayach Valley under Ayachi Mountain and Moulouya between Imzil in the Northwest and Zaida in the East. Twenty apple orchards were selected as farmlands (Ait Ayach and Moulouya) and Eighteen line-transects were selected at Ansegmir and Tabelkhirt rivers. Moreover, apple orchards and riparian habitats were selected jointly to avoid any potential difference in climate conditions or geographic location that could influence analysed parameters, and this will allow a better comparison between the two sites.

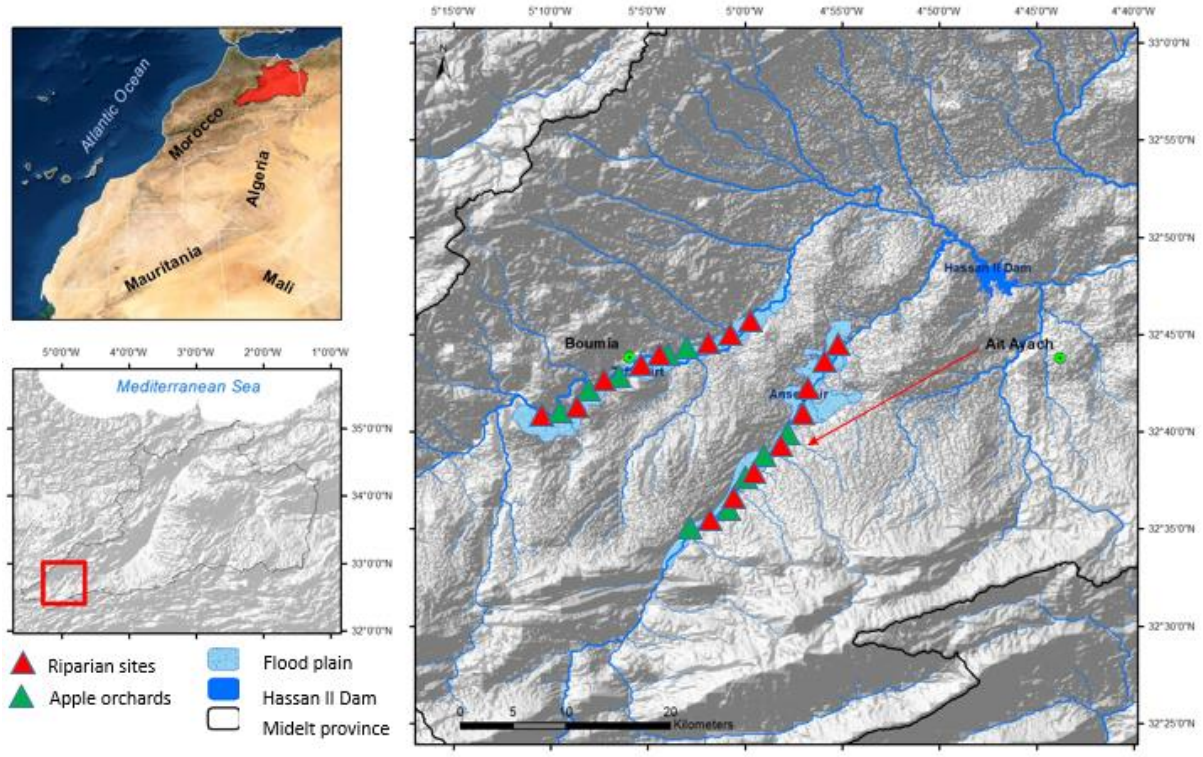


Figure 26: Breeding habitats of Turtle doves (orchards and Riparian sites) in Midelt province (Morocco).

3.2.2. Data collection

We searched for nests systematically from early March to late August between 2015 and 2018, using parental behavioural cues and Common Bird Census (CBC) methodology (Calladine 1999). In our case, this methodology was adopted inside apple orchards and nests or breeding pairs were researched line by line based on the tree-lines of the apple orchards (Mansouri 2020 jaab). While in the riparian vegetation, line-transect was used (Mansouri 2019) and nests were researched side-by-side of the river stream in Ansegmir and Tablkhirt Rivers. Nests were researched from 06.00 to 18.00 hours. All nests were found during nesting periods (nest

building). To determine the laid eggs, hatched nestlings and survived chicks, each nest was visited weekly until it failed or chicks fledged. Moreover, breeding success, including 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 (Mansouri 2020zoology). In parallel, 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 each breeding phase, in order to compare between the two habitats. Moreover, after chicks leaving, each nest was analysed in term of placement, including nesting-tree, nest height (NH) and nesting-tree height (NTH), as well as in term of dimensions, counting nest big diameter (NBD), nest small diameter (NSD) and nest depth (ND). Furthermore, the location of each nesting tree was referenced using a mobile GPS and then reported in an Open Source GIS (Quantum GIS v1.7.3). Finally, distances between dove' nests and the nearest human activity (buildings and infrastructures), the nearest water source, and the nearest road were measured with QGIS, in order to explain any potential difference in studied parameters.

3.2.3. Statistics

Statistical analyses were done in STATGRAPHICS 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 nest placement and dimension between orchards and riparian sites the independent *T*-test was used, considering the two sites as unrelated ecosystems. Similarly, breeding success, including nesting, laying and fledging survival were analysed with *T*-test. In addition, correlations among nest placement and nest dimension parameters were tested with Pearson correlation coefficient. Results were given as sample size and mean ± SD.

3.3.Results

3.3.1. Nest placement and dimension

A total of 566 Turtle Dove nests were found (467 in orchards and 99 in riparian vegetation) from 2015 to 2018. Of these, 467 were located only on apple trees (orchards), while in riparian habitats, nests were located in diverse supports. In fact, 55 nests were found on Wild rose (*Roza canina*), 37 nests on hawthorn (*Crataegus azarolus*), three on *Tamarix sp*., one nest on *Salix.sp*., one on Poplar, and one black berry (*Rubus fruticosus*).

The t tests conducted on nest placement characteristics of Turtle dove *Streptopelia turtur* demonstrated that nest height (NH), nesting-tree height (NTH) were similar between Orchards and Riparian breeding habitats (Table 1). On the contrary, nest dimensions (Except depth) were significantly different between studied habitats. Nest big diameter (NBD) and Nest small diameter (NSD) were larger in orchards compared to rivers. While nest depth was similar between two sites.

Table 15 : Comparisons of nest placement parameters and nest dimensions of Turtle doves between Orchard and Riparian habitats tested using t-tests.

	Habitat		Test	
	Orchards	Rivers	T	P
NTH	4.52±0.94	4.56±1.17	0.114	0.910
NH	2.44±0.51	2.17±1.07	-1.016	0.316
NBD	16.23±1.72	14.10±1.84	-3.774	0.001
NSD	12.58±2.05	11.43±1.25	-2.134	0.039
ND	4.79±1.24	4.20±1.152	1.535	0.133

Correlation was variable among nest placement parameters and nest dimensions in studied habitats (Table 2). At riparian sites, only nest small diameter (NSD) and nest big diameter (NBD), as well as nest small diameter and nest depth (ND) were significantly correlated. While at Orchard habitats, only nest small diameter (NSD) and nest height (NH), as well as nest height (NH) and nesting-tree height (NTH) were significantly correlated. On the contrary, the other parameters were uncorrelated at both studied habitats. **(NBD: nest big diameter, ND: nest depth, NH: nest height, NTH: nesting tree height, NSD: nest small diameter, P: p-value).**

Table 16: Pearson correlation coefficients among nest placement characteristics and dimensions of Turtle dove in orchard and riparian habitats.

	Riparian habitat						Orchard habitats				
	NBD	ND	NH	NSD	NTH		NBD	ND	NH	NSD	NTH
NBD	-	0.021	-0.08	0.73	0.34	NBD	-	0.01	0.25	0.35	0.21
P	-	0.92	0.70	0.001	0.13		-	0.96	0.27	0.11	0.35
ND	0.02	-	0.03	0.513	0.02	ND	0.01	-	0.44	0.36	0.09
P	0.92	-	0.86	0.025	0.91		0.96	-	0.05	0.10	0.68
NH	-0.08	0.03	-	-0.07	0.37	NH	0.25	0.44	-	0.52	0.57
P	0.70	0.86	-	0.74	0.10		0.27	0.05	-	0.022	0.011
NSD	0.73	0.51	-0.07	-	0.24	NSD	0.35	0.36	0.52	-	0.24
P	0.001	0.025	0.74	-	0.27		0.11	0.10	0.022	-	0.28
NTH	0.34	0.02	0.37	0.24	-	NTH	0.21	0.09	0.57	0.24	-
P	0.13	0.91	0.10	0.27	-		0.35	0.68	0.011	0.28	-

3.3.2. Breeding success

Among the 566 monitored nests (467 in Orchard habitats and 99 in Riparian sites) (Table 3), only 73.87% were succeeded at orchards compared to 53.35 % at rivers. During the incubation phase, fledging success was higher in orchards compared with river sites. However, during the rearing period, the success rates were similar between the two sites. Failure factors were also variable between these habitats. In orchard habitats, predation, nest abandonment, and non-hatching presented the most threats menacing Turtle dove breeding success, while in riparian sites, predation, nest desertion and nest destruction dominated all failed clutches.

Table 17: Turtle dove's breeding success at Orchards (n = 20 apple orchards) and Riparian vegetation (n = 18 Riparian sites) tested with simple t-test.

		Orchards		Riparian		Test	
Phase	Parameter	Number	%		%	T	P
Nests	Total	467	100	99	100.00		
	Succeeded	345	73.87	53	53.35	1.1748E+16	0.001
	Predated	98	20.98	27	27.27		
	Deserted	24	5.14	18	18.18		
	Destructed	0	0	1	1.01		
Eggs	Total	635	100	184	100.00		
	Succeeded	455	71.16	125	67.93	8.5267E+14	0.001
	Predated	120	18.89	36	19.56		
	Deserted	28	4.41	22	14.13		
	Destructed	0	0	1	0.54		
	Unhatched	32	5.03	0	0.00		
Chicks	Total	455	100	125	100.00		
	Succeeded	362	79.56	99	79.20	1.2796E+14	0.001
	Predated	48	10.54	17	13.60		
	Died	25	5.49	0	0.00		
	Deserted	20	4.39	9	7.20		

3.4.Discussion

In the Mediterranean area, Farmlands, mainly olive, orange and apple trees are the most important nesting-trees used by Turtle doves for breeding [10, 11, 19]. However, Riparian vegetation was recently found to host Turtle dove nests in Italy [38]. These compiled results are similar to our findings that highlighting the breeding of Doves in both farmlands and woodlands. The abundance of nesting-trees (apples in orchards and Wild rose, Salix, Tamarix in Rivers) and availability of water (irrigated orchards and river streams) explains the high incidence of nesting Turtle doves in these habitats [18, 37]. Moreover, Doves are cited to select breeding sites in habitats that are characterized by large extent cereals, waters and nesting trees [11], and this is in agreement with our results. Nevertheless, the higher nesting rates highlighted in orchards compared to riparian sites did not indicate a particular attraction, but reflects, particularly their abundance in the study area [18, 19, 37].

Generally, Turtle dove nests are placed increasingly higher upon the ground [19, 39], which is similar to our results. The use of taller nesting-trees in both orchards and riparian vegetation or higher nest placement, is targeting the protection of nestling from ground threats. In reality, nest-height in Turtle doves is reported to promote greater breeding success via protection of clutches from terrestrial predators and human disturbance, mainly in farmlands [19]. Therefore, Turtle doves select taller nesting-trees to elevate nest-placement[31]. On the other hand, nest morphology was variable between the two sites. Nests were larger (big and small diameter) in orchards. Similar results were reported by [40] in olives at northwest Algeria where Doves nests were morphologically variable depending to habitat type. Also, [41] have reported a variability in nest morphology depending on nesting materials and this is suggested to be the main factor controlling the difference observed in nest morphology between studied sites in our case.

The average breeding success was different between farmlands and riparian habitats (Table 2), through four breeding seasons. In summary, 73.87% of nests, 71.16% of eggs and 79.56% of chicks survived in orchards. While, in riparian sites, only 53.35% of nests, 67.93% of eggs and 79.20% of chicks succeeded. In total, 57% of chicks (flown chicks/laid eggs) survived in apple orchards compared to 53.80% in riparian sites. The significant difference recorded between the two sites is controlled, mainly by human disturbance, roads and the availability of feeding resources. In fact, in riparian sites, human impact was higher due to the intensification of agriculture near rivers and roads used by tractors and other engines. While, in apples, the breeding periods of Turtle doves between April and August were out of human presence that coincides with August September. Similar results were recorded by Mansouri et al (2020a, b) in orange groves and apples, where breeding success was higher in apples that are less influenced by human activities. Further, the Turtle dove was mentioned as human sensitive species, particularly being the man factor threatening this game. In the same sense, in our study, failure factors were different between orchards and riparian sites. In apple orchards, a significant clutch portion was failed due to predation, mainly reptiles (18.89% of eggs and 10.45% of chicks) and lower temperatures during the morning (5.03% unhatched eggs and 5.45% dead chicks) (the relationship between dead chicks and lower temperatures of the morning are planned for next work with the aim to investigate micro-climate effect on breeding performances of Turtle doves and to confirm statistically these relations), while in riparian sites, clutches were mainly failed due to predation and desertion that caused the loss of 33.69%

of eggs and 20% of chicks successively. This comparison not only analyses breeding success between orchards (farmlands) and riparian sites (natural woodlands), but it also distinguishes failure factors between the two sites, and this confirms our suggestion supporting the control of differences in breeding success of turtle doves from one habitat to another by local factors characterizing each one instead of the habitat type.

3.5.Conclusion

In summary, our study demonstrates that nesting features and breeding success of migrant Turtle doves differed between farmlands and woodlands. Nest dimensions, mainly nest diameters were larger in apple orchards, while nest placements were similar between apples and riparian vegetation. Equally breeding success rates were different. Nesting, hatching and fledging rates were higher in apple orchards compared to riparian habitats. In addition, clutches were failed due to predation and rough morning temperatures in orchards, while predation and desertion were the main factors of clutch fails in riparian habitats. Additional studies of micro-factors influencing breeding performances of Turtle doves in both farmlands and woodlands are required to further explore the difference between natural and artificial habitats used by this globally vulnerable game. Similarly, the use of novel technologies, including telemetry and geolocators will improve our understanding of the habitat use in both farmlands and wild habitats, particularly with the capacity of these tools to monitor all activity details inside and outside nesting sites.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper

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ETHOLOGIE DE LA TOURTERELLE DES BOIS

1. Parade nuptiale de la tourterelle des bois

(Published in Journal of Animal Behaviour and Biometeorology 2020)

Synthése d'étude

Le comportement sexuel, durant la parade nuptiale, présente la première étape, pour réussir la reproduction chez les oiseaux. Durant les expressions de parade, l'un des partenaires émet des signaux pour convaincre l'autre. Chez la tourterelle des bois *Streptopelia turtur*, les études concernant la parade nuptiale sont absentes, malgré son importance pour la reproduction de ce gibier en déclin. Pour convertir le manque d'information, nous avons défini deux types d'expressions comportementales dans la parade nuptiale chez la tourterelle des bois : le comportement visuel sous forme de vols «en arc» et le comportement vocal, sous forme de «roux», afin d'analyser, sous les conditions naturelles, leurs expressions durant la saison de reproduction et contribution attractive envers les femelles. Le suivi est effectué dans différents types d'habitats naturels et agricoles, y compris la colline Ayad (32 ° 36'15 "N 5 ° 1'8" W), la colline Boygra (32 ° 36'38 "N 5 ° 0'51" W) et le point Oalabbo de topographie en forme de bol (32 ° 37'4 "N 5 ° 0'24" W), pendant la saison de reproduction entre le mois de mars et le mois septembre de l'année 2016. Les expréssions vocales et visuelles sont dénombrées durant toute la journée, depuis 06h00 du matin jusqu'à 18h00, dans les differents habitats. Les résultats obtenus indiquent que les tourterelles mâles combinent entre les comportements acoustiques et visuels pour attirer leurs partenaires, avec des expressions intenses, entre le mois de mai et le mois de juillet. Durant la journée, les appels vocaux et les vols sont concentrés entre 8h00-10h00 (matin) et 16h00-18h00 (soir). De plus, la durée des séquences acoustiques est plus importante que les expressions de vol. Aussi, les expressions vocales sont plus attractives pour les femelles. Nous avons bien remarqué que les tourterelles chantent sur les arbres (support vertical) plus que sur le sol, avec des fréquences et amplitudes complexes (cris sonores), pour orienter leurs cris vers les femelles. Cependant, la présence de concurrents intra-spécifiques augmente le taux de chant et de vol, afin d'assurer l'attraction des partenaires.

Field investigation of Turtle doves' courtship: vocal calls versus arc-flight

Abstract

During the breeding season, many avian species produce a complex expression to attract the mates. In turtle doves *Streptopelia turtur*, male signals visually and acoustically during courtship. The only previous study on turtle doves' song was limited to quantifying acoustic expressions and their role in detection of turtle doves. In the present study, we defined two types of languages in turtle dove's courtship display: "arc-shaped" flights and vocal "roux", with aim to investigate, under natural conditions, their attractive role towards females. Similarly, the influence of intraspecific competitors and position of singing were analysed during two breeding seasons (2016-2017). Summarizing, results chow that male turtle doves combined acoustic and arc-flight displays to attract mates, with intense expressions between May and July. Throughout day, vocal calls and flights are concentrated between 8h00-10h00 (morning) and 16h00-18h00 (evening). Moreover, the duration of acoustic display is more important than flying expressions. On other hand, turtle doves sing on trees (vertical support) more than ground, with a complex frequencies and amplitudes (sound calls) to spread out their calls toward females. However, the presence of competitors in the same field increase rate of singing and flying, in order to ensure mates attraction.

Keywords: *Streptopelia turtur*, courtship display, flight, song.

1.1.Introduction

During the breeding season, many avian species produce a relatively complex behavioural expressions to attract mates (Brumm 2002; Zollinger and Brumm 2015). Both sexes adopt a variety of communications, the most important are the acoustic and visual languages (Staler et al1988; Zann 1996; Livezey 2016). In songbirds, males direct their vocalisations toward females during courtship display (Sossinka and Bohner, 1980). However, in other species like *Streptopelia risoria* and Menura novaehollandiae, the males combine between songs and dances to better distribute their information (Fusani et al 1997; Dalziell et al 213). Despite, what is more effective (song or visual), female recipients are widely known by their sensitivity to male signals and respond with varying behaviours between acceptance and refuse (Neunuebel et al 2015; Pennycuick 2015; Finton et al 2017). In general, studies of audiovisual communications in birds are focused on controlled experiments in laboratories (Caryl 1981; Krieg and Getty 2016; Ullrich et al 2016), while captivity results can be very different from natural expressions (Solonen 2013).

In turtle dove *Streptopelia turtur*, studies of breeding biology are very advanced (Hanane and Baâmal 2011; Kafi et al 2015). Though, these researches concentrate on arrival dates (Herbert and Wilson 2013), spawning phenology, breeding success and population size. Works on turtle dove's sexual behaviour are very limited or even absent. In fact, two studies were conducted on two close species, *Streptopelia risoria* and *Streptopelia decaoto*, showed that, during courtship display, the male performs visual expressions (arch flights) accompanied with specific calls (Roux), in order to convince the female (Fusani et al 1997; Catchpole and Slater 2008). This aspects are crucial before any breeding success.

In this study, we pointed out two categories of behavioural expressions in the turtle dove's courtship display: "arc-shaped" flights and vocal "roux", in the object to analyse, under wild conditions, their attractive contribution towards females. We theorised that vocal expressions were very attractive more than arc flights. Similarly, we supposed that the sequence durations

were variable according to the nature of the courtship display (acoustic or visual). The clarification of this fundamental features will offer an essential keys of breeding success in turtle doves.

1.2.Materials and Methods

1.2.1. Study sites

Ait Ayach valley (32°41'6" N 4°44'42" O), is situated in the West of the Moulouya plain, Midelt province, Morocco. The habitat is located in an altitude of 1500 m, with an average annual rain of 182.06 mm and medium temperature of 15.72 ℃ (2015-2016). On other hand, the prospected zone is cultivated mainly by apple orchards (1600 ha) which are suitable for Turtle dove breeding (more than 220 nests during 2015). Cereal surfaces cover 4500 ha and provide an important food resources for this bird.

1.2.2. Sample design

The monitoring of courtship display in Turtle dove was carried out in different kinds of wild and agricultural habitats including apple orchards, riparian vegetation and cereal plots, during two breeding seasons (March to September 2016-2017). Basing on early field prospections during 2015, three viewpoints were fixed: Ayad hill (32 ° 36'15 "N 5 ° 1'8" W), Boygra hill (32 ° 36'38 "N 5 ° 0'51" W) and Oalabbo in bowl topography (32 ° 37'4 "N 5 ° 0'24 "W). The chosen sites were topographically high for better visibility (better and easy pairs' counting), and camouflaged (apple trees and other riparian vegetation) to avoid any disturbance. Voice calls and arc flights were audio recorded and videotaped during the whole day from 06h00 to 18h00, with microphone, canon camera (LEGRIA HF R506, advanced zoom X57) and binoculars (in case of good visibility conditions). However, males singing inside trees and in camouflaged localities were audio recorded only. In case of the competition (presence of more than male singing and flying in the same locality), recording were performed focusing on the first individual to display. Sequences' duration and the positions of their emission were noted for later analysis. In parallel with audio-visual behaviour, the observed pairs (in mating or just the two partners in meeting after each expression) were noted to analyse the relationship between the behavioural expressions and the pair's formation (witch of the expressions is more effective?). Moreover, distance between competitors was estimated basing on the distance between apple trees inside orchards (in Midelt apple orchards, tree lines are separated by 3.5 m as optimum distance) and Total Station (Topcon SANS PRISME (MODEL: NTS-102B, NTS-315B), Prismless range 500 m - Measurement time less than 1 sec).

1.2.3. Sound analysis

Recorded sound sequences (in HD format with camera and MP3 format with microphone devise 200 kHz maximum range) during Turtle doves' acoustic courtship were converted to wave format (in audio.online-convert.com web site). During the analysis, sequences (wave formats) were calibred to 25 second périodes (basing on the sequences' maximum duration recorded in field (23s)), as in the case of house mice female calls (Finton et al 2017). Oscillograms and spectrograms were generated with SoundRuler software (SoundRuler 0.9.6.0; Macros Gridi-Papp, GNU GPL). Sequences were divided on syllables and sections basing on Oscillograms and using section length button. The section duration were measured (in millisecond) and compared between first segments (beginning of calls) and last segments (end of calls).

1.2.4. Data analysis

Statistical tests were executed in SPSS software (version 24.00, IBM 2009). Parametric data (checked with normality test), such as the comparison of vocal and flight sequences during day and season and acoustic syllables, was analysed using one-sample t-test. Non-parametric data (non-conform to the requirements for parametric tests) including sequence duration and time interval between two successive sequences was compared by Wilcoxon and Mann-Whitney Sign Tests. In the case of sequences' duration, recorded displays were partitioned in tree périodes; (i) beginning of breeding season (from arrival date to the end of April), (ii) optimum breeding phase (corresponding to courtship peaks in May and July), (iii) end of breeding season (August). Because of their non-conformity with parametric tests (checked with normality), sound and flight sequences (during three périodes) were analysed with Kruskal-Wallis test. Results reported as significant assume a false discovery rate of 0.05. Graphs were created by GraphPad Prism Mac 6.0h software. The overall mate-attractiveness of acoustic and visual courtship was modelled by means of Generalised Linear Mixed Model (GLMM). In these analyses, arc flight were log(x + 1) transformed to ensure normality.

1.3.Results

1.3.1. Seasonal and daily courtship display

The expression of the two courtship languages differed qualitatively and quantitatively. Songs were more important than flying, during turtle dove's breeding season (Figure 1). In fact, songs were displayed from the second decade of April until the first week of August. In contrary, flights were limited to the période between the second week of May and the first week of July. In addition, during day, vocal expressions (72.88 ± 13.14 sequences on average per day) were very intense in comparison with arc flight sequences (12.13 ± 2.50 sequences in average per day) ($n = 51$, $t = 4.539$, $P < 0.001$). However, turtle dove's courtship activities (flying and singing) were concentrated essentially between May and June, with a second recovery of songs at the beginning of July, as reflected by the peaks during these périodes (Fig. 27). In parallel, the formation of turtle dove's pairs follows the courtship peaks. In fact, first pair's peak was recorded in coincidence with the parade peaks (songs and flight) between May and June. The second peak was distinct after the recovery peak of vocal expressions in July.

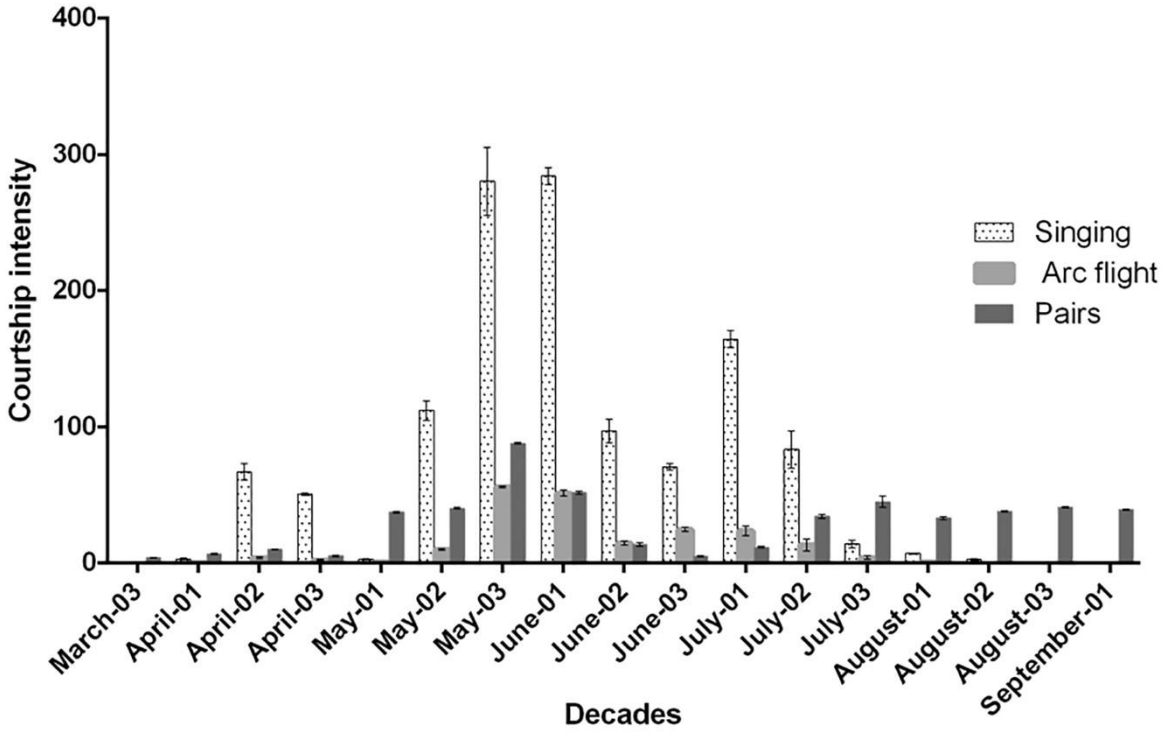


Figure 27 : Courtship display (sound and flight) in Turtle doves during the breeding season (2016-2017).

Concerning the daily courtship, intensity was variable (Figure 28). The expression of the two sequences (flights and songs) was more intense early between 08h00 and 10h00 during the morning and late between 16h00 and 18h00 during the evening (Table 17). However, acoustic activity is also more important than visual expressions. Indeed, t-test conducted on sequence duration of singing and flying demonstrated that the difference between these two expressions is widely significant ($n = 18$, $t = 4.824$, $P < 0.001$).

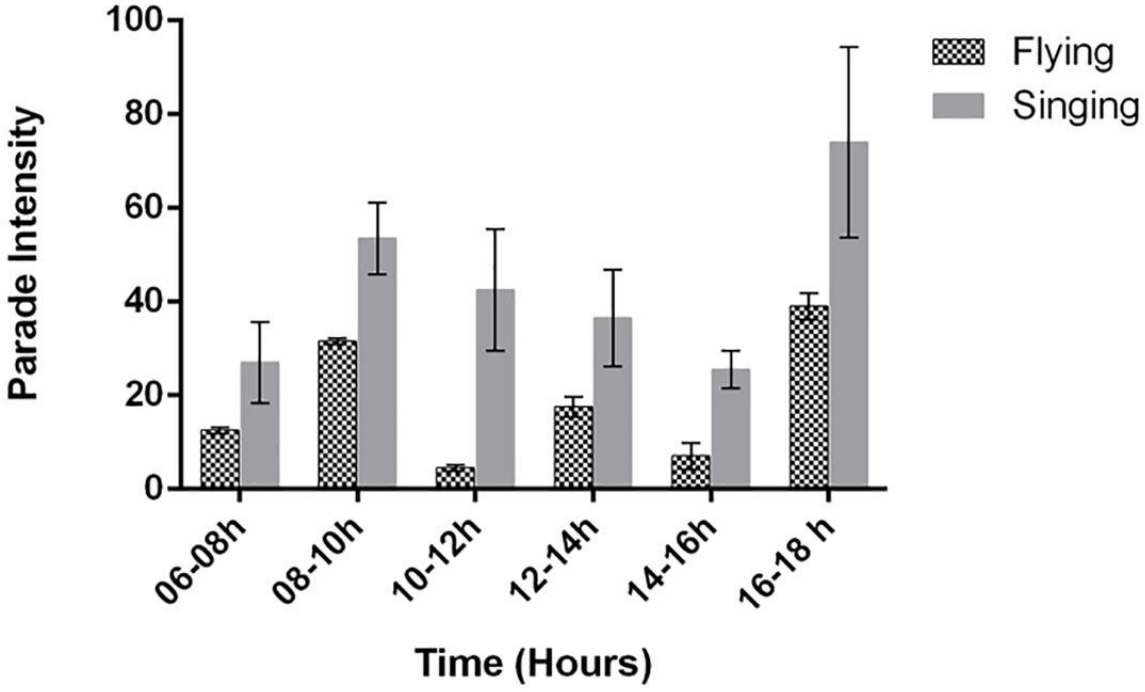


Figure 28 : Daily (08h00 to 18h00) courtship intensity in Turtle doves, during breeding season (2016-2017).

Table 18: Daily (08h00 to 18h00) courtship intensity in Turtle doves, during breeding season (2016-2017).

Contrast	Sig.	Difference	+/- Limits
06-08H - 08-10H	-	-1.71429	5.30462
06-08H - 10-12H	-	-1.92857	5.30462
06-08H - 12-14H	-	-1	5.30462
06-08H - 14-16H	-	1	5.30462
06-08H - 16-18	*	-5.57143	5.30462
08-10H - 10-12H	-	-0.214286	5.30462
08-10H - 12-14H	-	0.714286	5.30462
08-10H - 14-16H	-	2.71429	5.30462
08-10H - 16-18	-	-3.85714	5.30462
10-12H - 12-14H	-	0.928571	5.30462
10-12H - 14-16H	-	2.92857	5.30462
10-12H - 16-18	-	-3.64286	5.30462
12-14H - 14-16H	-	2	5.30462
12-14H - 16-18	-	-4.57143	5.30462
14-16H - 16-18	*	-6.57143	5.30462

* denotes a statistically significant difference.

1.3.2. Sequences' duration

Sequence length varied according to the nature of behavioural expression (Table 18). Seasonal acoustic activity, represented by the "roux" calls, take more time compared with visual expressions, reflected by the arc-shaped flights ($P < 0.001$). In contrary, the time intervals

between two successive expressions were more important between flights in comparison with acoustic sequences (P <0.001). This indicates the high intensity of the songs in turtle doves, during breeding season.

Concerning périodes, the optimum breeding phase (May and July) was characterised by a sequences with long duration in vocalisation, while flight sequences were comparable in all périodes (Kruskal-Wallis test for: (i) vocalisation: H = 37.648, P< 0.001; (ii) flight: H = 0.996, P = 0.60).

Table 19 : Duration (time in seconds) differences between flying and singing in turtle dove's courtship, during breeding season.

Courtship categories		Singing (s)	Flying (s)	Z	P-value
Average duration for each sequence	whole Season (N = 60)	8.10 ± 3.69	5.65 ± 2.70	-6.548	<0.0001
	Beginning of season (N = 20)	5.00 ± 0.35	5.80 ± 0.68	-0.774	0.438
	Optimum breeding périodes (N = 20)	9.10 ± 0.67	7.00 ± 0.80	-2.183	0.029
	End of breeding périodes (N = 20)	2.55 ± 0.43	5.75 ± 0.59	-3.995	<0.0001
Average time interval between two successive sequences		1930.38±1613.52	24955.83±4361.49	-4.961	<0.0001

1.3.3. Structure of acoustic sequences

Oscillogram of turtle dove's voice call (Figure 29) chowed a complexity in vocalisation sequences. In fact, every sequence is divided on 6.35±0.67 segment (n=12 audio recordings). Similarly, each segment is partitioned on three syllables. This small sections were different between the beginning (7.81 ± 0.27 ms) and the end (9.58 ± 0.31 ms) of segments (n =12, t = 31.657, P < 0.001).

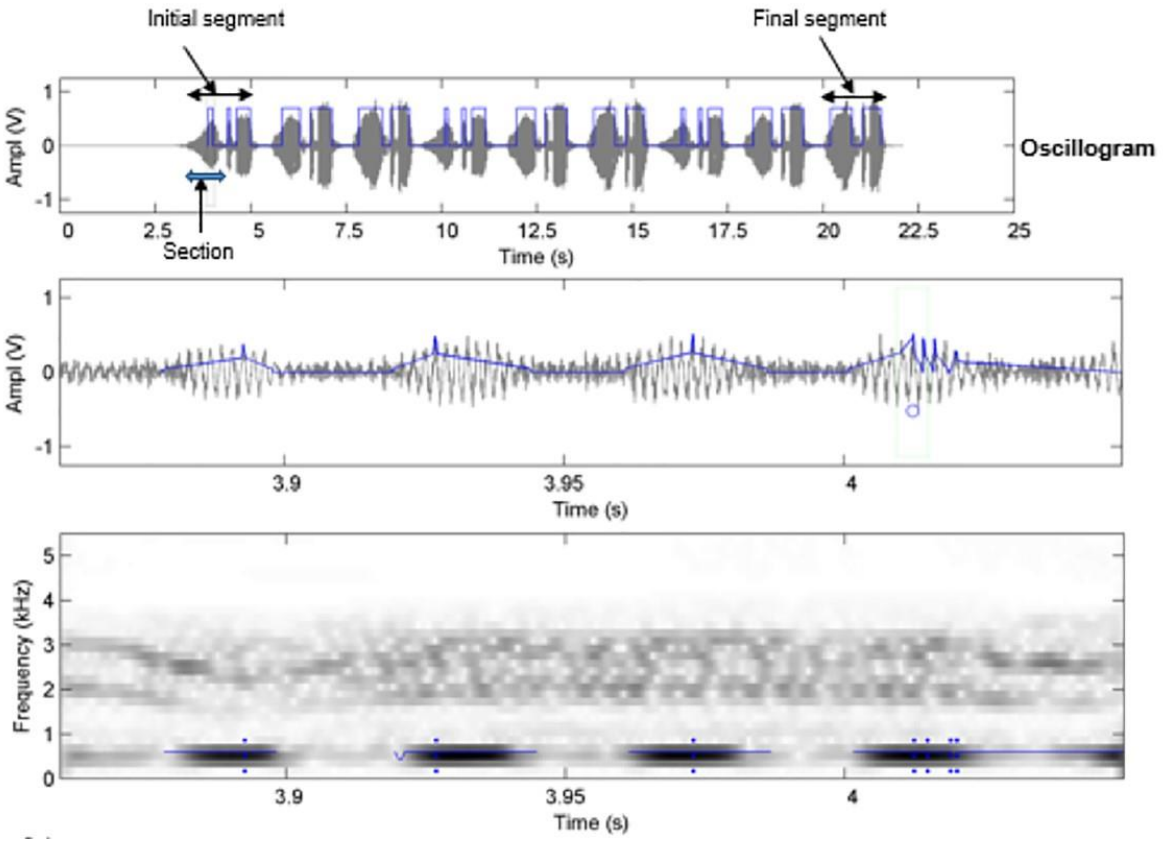


Figure 29 : Oscillogram (top) and spectrograms (bottom) of sample broadband vocalizations illustrating the complexity (multiple syllables (sections)) of courtship call's structure in Turtle dove.

The field survey of acoustic courtship showed two main situations for expression; the position on the trees and ground singing. However, statistical calculation confirmed that the turtle dove prefers trees more than ground to express their acoustic display (Table 19). In fact, during six months of monitoring, the acoustic activities, expressed on trees, exceed largely the ground songs ($P < 0.05$). Furthermore, no difference was recorded concerning the sequence durations between two positions ($P > 0.05$).

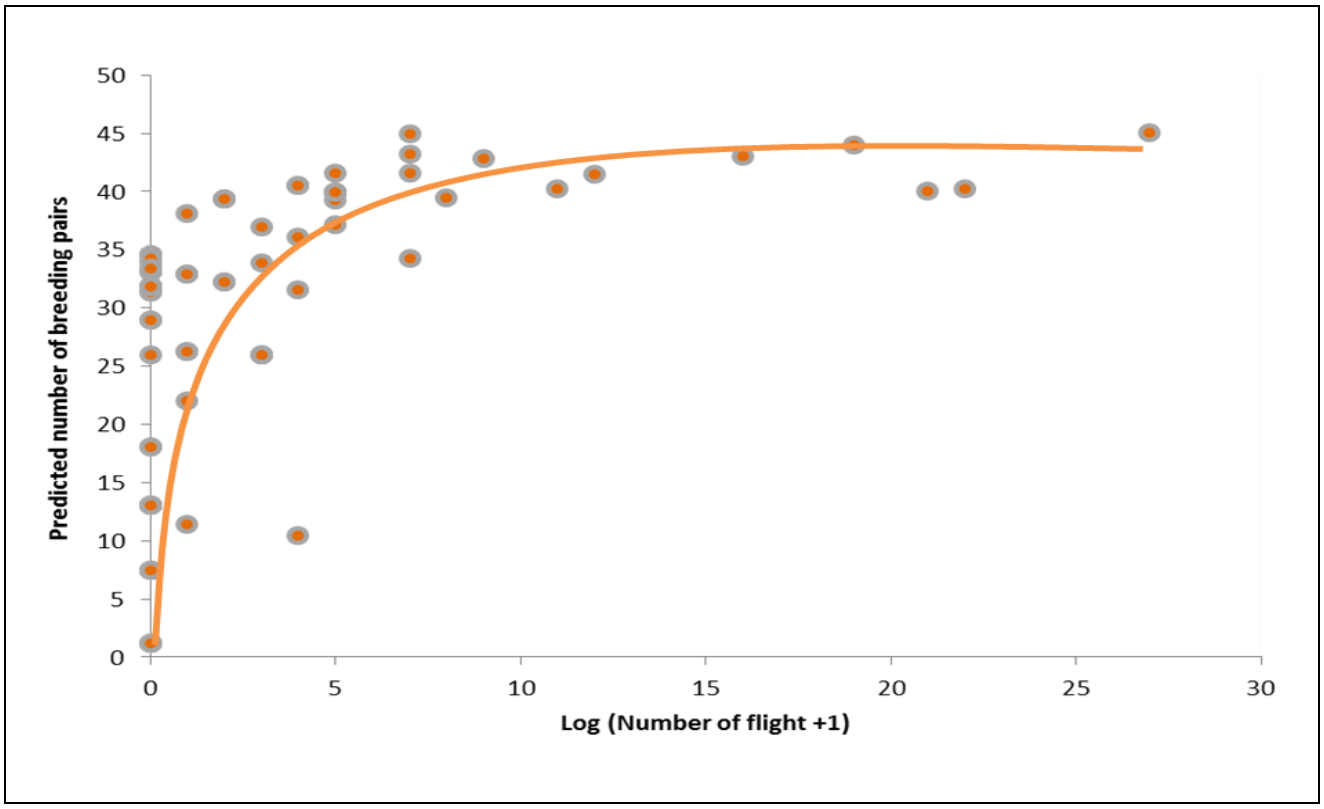
Table 20: Differences between singing on tree and singing on the ground (N =10 days spread-out equally between April and July) in apple orchards and riparian vegetation, Morocco, 2016.

Singing position	On the tree	On ground	Test	P-value
Total sequences	415	89	-	-
Average sequences per day	75.45±9.56	16.18±3.33	F =10.36	0.005
Average duration for one sequence (s)	7.77±0.48	8.35±0.74	U =-0.004	0.99

1.4.Discussion

Through this field-based study we investigated the use of visual and acoustic signals in Turtle dove's courtship display. North African Turtle dove, especially the males, uses both acoustic and visual expressions (Figure 26, 27) to attract females. Our results agree with previous experimental studies on other bird species, including passerines (Larsen and Dabelsteen 1990;

Gate et al 2005; Patricelli 2007; Stanger-Hall et al 2018) and support that these birds use both visual and acoustic languages during sexual behaviour. Moreover, some avian species combine between this two signal modules to improve and/or maximize the information exchange, as has been shown in zebra finch and other birds (Wang et al 2008; Ullrich et al 2016; Kaplan 2017). But the present work shows a paradoxical results. In field, acoustic courtship dominated the theatre (Figure 28), while the statistical analyses, using Generalised linear Mixed Model (GLMM), indicated a relative link between visual behaviour (flight) and formation of breeding pairs (Figure 30).



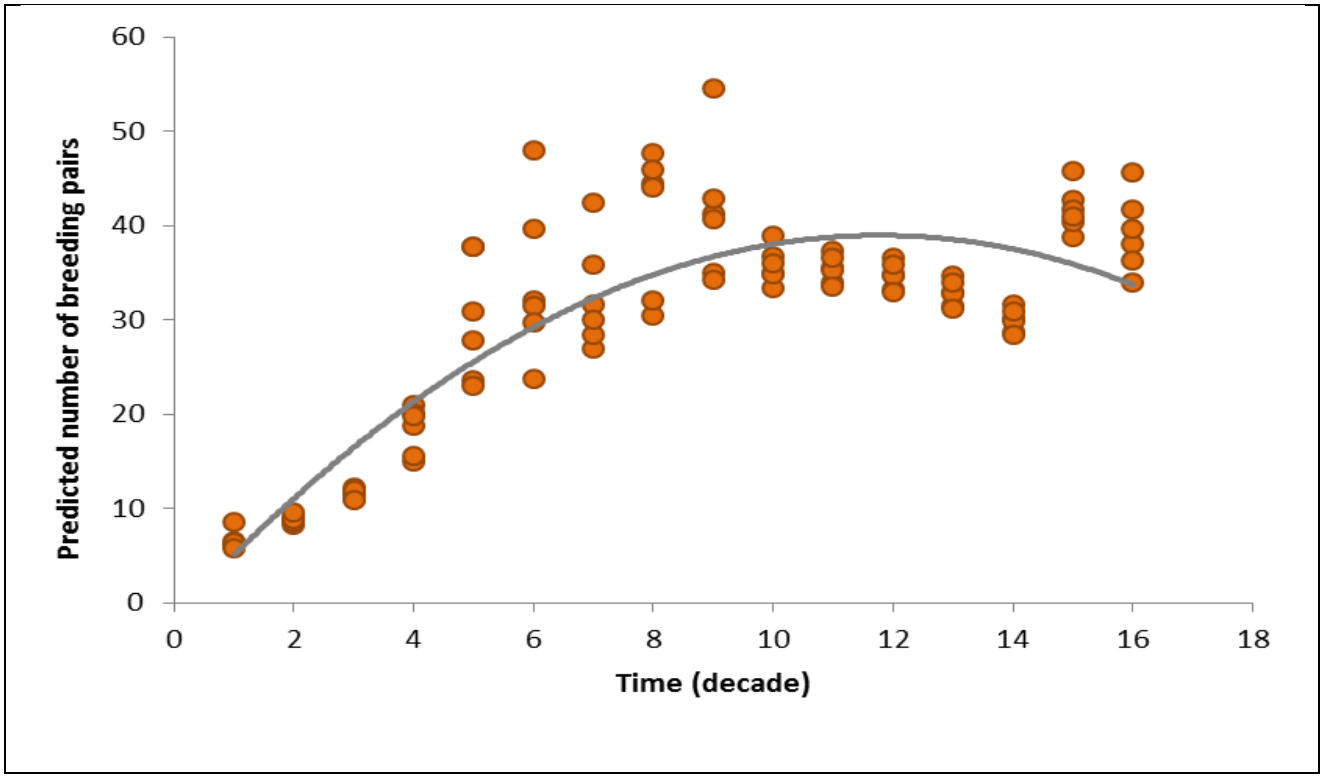


Figure 30 : GLMM model predicting the Mate-attractiveness (pair formation) of visual expressions (Flight above) and time (decades below) during Turtle dove's courtship.

This finding can be explained by two elements. First, our approach was observational and, therefore, the acoustic dominance was very easy to be distinguished in field, since sound easy-dissemination (Hick et al 2016; Potvin et al 2018), even if its effectiveness would be useless as in Cervus elaphus (Reby and McComb 2003), in which a negative correlation between reproductive success and acoustic courtship was reported. Second, the visual signal (flights) was revealed recently to be a good physical indicator of the presence and body performance of the partner (Zhang et al 2018), which could make it more attractive with its quality note by the intensity. This is in contradictory with results obtained by (Kroodsma and Miller 1982; Cramp 1985; Bhatt et al 2000) who have reported that the acoustic expressions are very important in bird's courtship display, in particular, loud songs can spread out over a long distance, stimulate the fitness and mark the territory (Gil and Gahr 2002; Kaplan et al 2009; Ohms et al 2012). However, the main question in this topic is which expression is more effective in mate attraction. In reality, with contradiction found between field and laboratory analyses, our results suggested a synergetic effectiveness combining sound and flight, as found in warbler and zebra finches that combine between plumage or flights, as a visual behaviour and acoustic songs in a fitness components (Avey et al 2005). This combination could offer an audio signature, while the visual behaviour could provide the image of the partner and its performances. On other side, recipient females are basing on these two channels and their amplitude to make a virtual conception (image) of potential partners, in particular their physical quality and motivation state (Collins et al 1994; Boukhriss and Selmi 2009; Perez et al 2015; Zollinger and Brumm 2015). Similar results were recorded in domesticated Australian zebra finch and other lyrebirds (Ullrich et al 2016; Dalziell et al 2013; Mulder and Hall 2013), which integrate courtship song

and dance in order to attract effectively the mate. The mesmerising effect of sound and movement is not limited to birds, it's a common strategy adopted by other animals, including spiders and compared with humans dancing to music (Ejima and Griffith 2008; Mulder and Hall 2013).

Seasonal parade was variable, courtship intensity was very high, essentially between May, June and July. These périodes (May, June and July) correspond exactly to the turtle dove's optimum nesting phases, as reported in North African areas (Calladine et al 1999; Nemeth et al 2012; Hanane 2016, 2017; Rieger and Marler 2018). Likewise, during day, sequence intensities varied from on période to another. Expression peaks were recorded between 08h00 and 10h00 during morning and between 16h00 and 18h00 during evening (Figure 2). The choice of these phases to display courtship may be due to the fresh weather conditions during the morning and evening. As this is already cited in the turtle dove dietary behaviour and singing rate (Browne and Aebischer 2004; Nemeth et al 2012; Linhart and Fuchs 2015). This columbidae sings and researches its food out of the day hot périodes (midday) to avoid or limit the water loss due to perspiration. In fact, the parade activity requires a very important physical effort, particularly in the presence of intraspecific competitors that require more effort, in order to ensure field dominance (Dubois 2002; Kaplan et al 2009; Hick et al 2015). Consequently, we examined the courtship in the presence of competitors (Figure 31). As a results, turtle doves, in the presence of other intraspecific competitors (male turtle doves displaying in the same habitat and période), increases rate of songs (with competitors: 6.34±0.20 song sequences, compared with 3.5±0.21 repetitions in the absence of competitors, one simple t-test, N = 32, t = -9.482, P< 0.001) and flights (with competitors: 2.09±0.25 flight repetitions against 0.81±0.13 repetitions in the absence of competitors, t-test, N =32, t = -4.381, P< 0.001) before engaging mate or leaving the territory (in case of fail engaging).

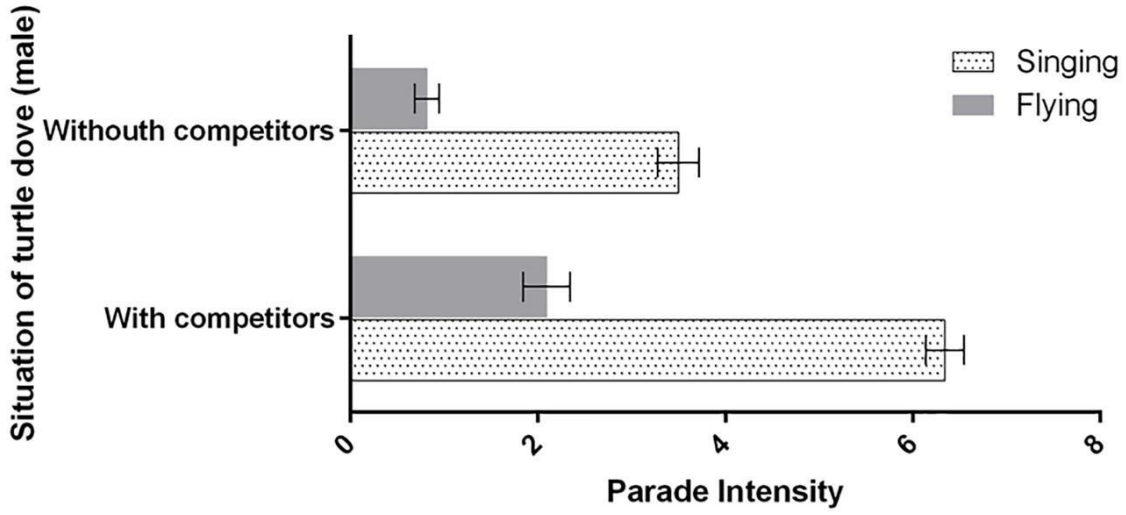


Figure 31 : Variation of courtship display in Turtle dove depending on the presence or absence of competitors in the same habitat.

The analysis of the acoustic expressions showed a complexity in turtle dove vocalisation (Figure 29). The calls were formed with small segments (syllables) that were variable between individuals. Further, segments were divided on three syllables with variable duration and frequency between the first and the last one. This variation and complexity in sound calls (three

syllables) could be governed by difference in physical fitness of male turtle doves. In fact, many animal species, such as red deer stags where the roars were complex (common and harsh roars) and influenced by the male fitness and body size (Hick et al 2016). On other hand, sexual competition with other intraspecific birds could interfere in this complexity. Therefore, In order to propagate a convincing calls (for females), males produce a specific call segments with different amplitude and frequency that indicating their good physical quality and sexual motivation (Fant 1960; Reby and Mccomb 2003; Hanane and Maghnouj 2005; Hick, Doucet and Mennill 2016).

Turtle dove sings in two positions: on trees and on the ground. However, calls emitted on the tree were more important than those produced on the ground, in terms of quantity. In the opposite, the average duration was comparable between this two positions. Dominance of calls on trees as a vertical support will facilitate the signal propagation (Fitch and Reby 2001). Particularly, these columbidae use a multi-dimensional calls in order to spread out the signals and to dominate competitors (Goodwin 1970; Fusani et al 1997; Mathevon et al 1997). Indeed, during the courtship displays, distances between competitors (males emitting the sequences at the same time) were very short (in order of 65.06 ± 8.19 m during whole season), in particular between May and July (31.18 ± 3.56 m, corresponding to the optimum breeding phase). As a result, songs on trees can spread out more and can help competitors to attract the female's attention and supress competitor's sound.

1.5.Conclusion

In summary, this paper provides a qualitative (seasonal and daily) and quantitative (time and sequences) analysis of courtship display in turtle doves during breeding season, under wild condition. We revealed a synergetic effectiveness of acoustic and visual signals with a field dominance of sound sequences compared to visual arc-shaped flights in the attraction of mates. In addition, expressions increased in the presence of competitors on the same habitats. Similarly, turtle doves sing on the tree position with use of multidimensional calls (diverse syllables with variable amplitudes and frequencies), to ensure a long propagation of sound (calls) and competitor's dominance. Despite its limitation to the quantification of acoustic and visual courtship, this initial research has decrypted a basic information (signalling language) on sexual behaviour of turtle doves, under wild conditions and opened the window for future researches to reduce the lack of data on breeding behaviour of this threatened bird.

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2. Nids de la tourterelle des bois

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Synthèse d'étude

Vu l'intérêt que représente le comportement de nidification dans la réussite des pontes chez les oiseaux, nous avons essayé dans cette partie d'étude de determiner la composition et la morphologie des nids de la tourterelle des bois et leurs effets sur les ectoparasites menaçant les poussins.

Pour mener cette étude, nous avons analysé la composition (plantes utilisées) de 84 nids de la tourterelle des bois, durant deux saisons de reproduction dans deux années 2015 et 2016. L'étude est menée au niveau des vergers de pommiers, dans la région d'Okhaja Ait Ayach, province de Midelt. Les résultats obtenus montrent que la tourterelle des bois construit ses nids, essentiellement dans les zones périphériques des vergers, en adoptant l'orientation Est, pour protéger les nids contre le vent de l'ouest et bénéficier des rayons solaires provenant de l'Est. En plus, les nids sont caractérisés par des dimensions corrélées à la taille de l'espèce. Nous avons constaté que les nids de la tourterelle des bois sont construits par des brindilles à base des tiges et des brindilles d'origines racinaires et tiges des plantes. Parmi les composantes des nids de la tourterelle des bois, nous avons noté la présence des brindilles issues, des plantes aromatiques et médicinales, comme l'*Artemisia herba alba* (identifiée dans 23 nids), l'*Ononis spinosa* (17 nids) et l'*Eruca sativa* (9 nids). Parallèlement, nous avons suivi 75 poussins de la tourterelle, durant trois phases, après l'éclosion, post-élevage et avant l'envol. Les résultats obtenus montrent que la charge ectoparasitaire des oisillons est très faible durant toutes les phases de dévelopement, seulement deux ectoparasites sont identifiés sous les plumes des oisillions; *Columbicola columbae* et *Dermanyssus gallinae*. Ceci, peut-être dû aux rôles préventifs des plantes aromatiques et médicinales inclus dans les nids, notamment celles connues par leurs effets toxiques, contre les insectes parasitaires et les microorganismes pathogènes.

Nest building, dimension, and selection of aromatic and medicinal twigs to repel ectoparasites in the European Turtle dove

Abstract

Studies incorporating the nesting behaviour and ecology of parasite disease in the European turtle dove during breeding periods are rare. In this research, we examined nest features and nesting materials in Turtle doves, with the aim to characterize nest dimensions, building and incorporated vegetation, mainly aromatic and medicinal plants. In parallel, we estimated the ectoparasite load on chicks, in order to verify an eventual relation between odorant plants and pathogen loads. The study was carried in apple orchards at Okhaja Ait Ayach, Midelt province Morocco, during 2015 and 2016. The obtained results demonstrate that the Turtle dove constructs a medium nest, compared to its body size, using several plant species, including medicinal and aromatic species known for their toxicity against pathogens. The inhibition capacity of nesting materials is reflected in parasite loads, since only 8% of chicks were infested with *Columbicola columbae* and *Dermanyssus gallinae*. The use of repellent materials in nests is a success behavioural strategy for this declining game to protect nestlings against pathogens.

Keywords: Aromatic plants, nest, ectoparasite, turtle doves.

2.1.Introduction

For long distance migrant birds, nest site availability and nest construction are the main factors ensuring good breeding success (Newton, 1994). Since, nests constitute a support for eggs and nestlings, as well as a protection for clutches (Mainwaring et al., 2014). Research on the nest construction, mainly used nesting materials, is a central topic to understand the species behavioural ecology and breeding success, particularly in birds of conservation concern (Crossman et al., 2011; Hansell, 2000a). A bird nest is a special construction forming a receptacle in which clutch (eggs and young) develop. The nest may be an evolutionary compromise between avian behaviour and adverse environmental conditions (low temperatures and rain), keeping the eggs and nestling warm during incubation and other physical factors (Kern, 1984; Kern and Van Riper, 1984; Sciurine and Kern, 1980), and such costs as the energy expended in nest building, predation risk during nest building and nest predation due to nest conspicuousness (Slagsvold, 1984, 1989a). In addition, the size of a nest is also related to the birds' body size, nest type and clutch size (Slagsvold, 1982, 1989(a, b). Nest-building behaviour is often related with courtship and pair formation in birds, because males can use nest sites and nesting material to attract a mate. The degree to which this behaviour is used in courtship varies from mere manipulation of a piece of nest material, or display of a potential nest site, to the building of an entire nest by the male (Collias and Collias, 1984). The actual nest-building behaviour is used in displays by polygamous and monogamous bird species (Collias and Collias, 1984). However, in many species, nest-building behaviour is often related to the protection of clutch from parasites and pathogens. The use of the same nest sites by several breeding cohorts, within one or several breeding seasons, increases the risk of incurring a pathogen loads (Clark and Mason, 1985; Sansano-Maestre et al., 2009; Schulz et al., 2005). Indeed, microorganisms and parasites can lie dormant in faeces and nest materials for a long period, as they can support rough conditions, including temperatures and rain (Clark and Mason, 1985), this can increase their loads in the nest and the risk of infection to birds or their

nestlings (Rätti et al., 1993; Robinson et al., 2010). As a response, many bird species incorporate odorant vegetation and other active materials into their nests to counteract the selective pressure of pathogens (Clark, 1991; Fauth et al., 1991; Suárez-Rodríguez et al., 2013; Wimberger, 1984). Chemical components contained in fresh vegetation or other materials found in nests may act as toxicants, repellents or natural fumigants in controlling pathogens (Banbura et al., 1995; Scott-Baumann and Morgan, 2015). Therefore, the understanding of nesting materials and their effects on parasite loads is crucial at least for threatened species.

The European Turtle dove *Streptopelia turtur* is a trans-Saharan migrant, the populations of which have undergone sustained and rapid declines in range and abundance, mainly in Europe (Lormée et al., 2019). In countries such as the UK, 93% of population have declined between 1970 and 2010 (Moreno-Zarate et al., 2020) and the species is listed as a rare bird. This declines has been, essentially attributed to the reduction in breeding productivity (Browne and Aebischer, 2004; Dunn and Morris, 2012), combined with a scracity of food resources (Browne and Aebischer 2004; Mansouri et al 2019). Concerning the infection on Turtle doves, the data are relatively rare to assess its eventual effect. (Lopez, 1995) found an infection rate of 50% in Spanish Doves, and (Lennon et al., 2013) found a high incidence of trichomonad parasite infection (86%) in UK Turtle doves, while (Stockdale et al., 2015) found a 100% infection rate by *T. gallinae* in adult and nestling Turtle doves in Germany. However, these studies are limited to Europe and one genus of parasites, while the defence mechanisms used by breeding Doves against these pathogens are still unexplored.

In this context, the present study aims to characterize Turtle dove nests, including their materials of construction, and to determine the relationship between nest materials and ectoparasite load in nestlings, with the hypothesis that the parasites of chicks are sensitive to potential repellent effect of nesting materials, particularly aromatic and medicinal plants. In parallel, nesting behaviour, including nest placement and building are targeted, in order to characterize nests of the vulnerable Dove.

2.2.Methods and Materials

2.2.1. Study area

The present work was carried out in High Moulouya valley, at Ait Ayach zone (Midelt province, Morocco), more especially in Oukhaja orchards (32°41'N, 4°44'W). The selected site is located in relatively high altitudes (1400-1600 m), in a plain dominated by apple and cereal farmlands, which offer the necessary nesting supports (trees) and food resources for breeding Turtle doves and nestlings (Mansouri et al., 2019). Moreover, the climate is semi-arid, with cold winter; for the study period (2015-2017), the annual averages of temperature and precipitations were respectively 29 °C and 89 mm.

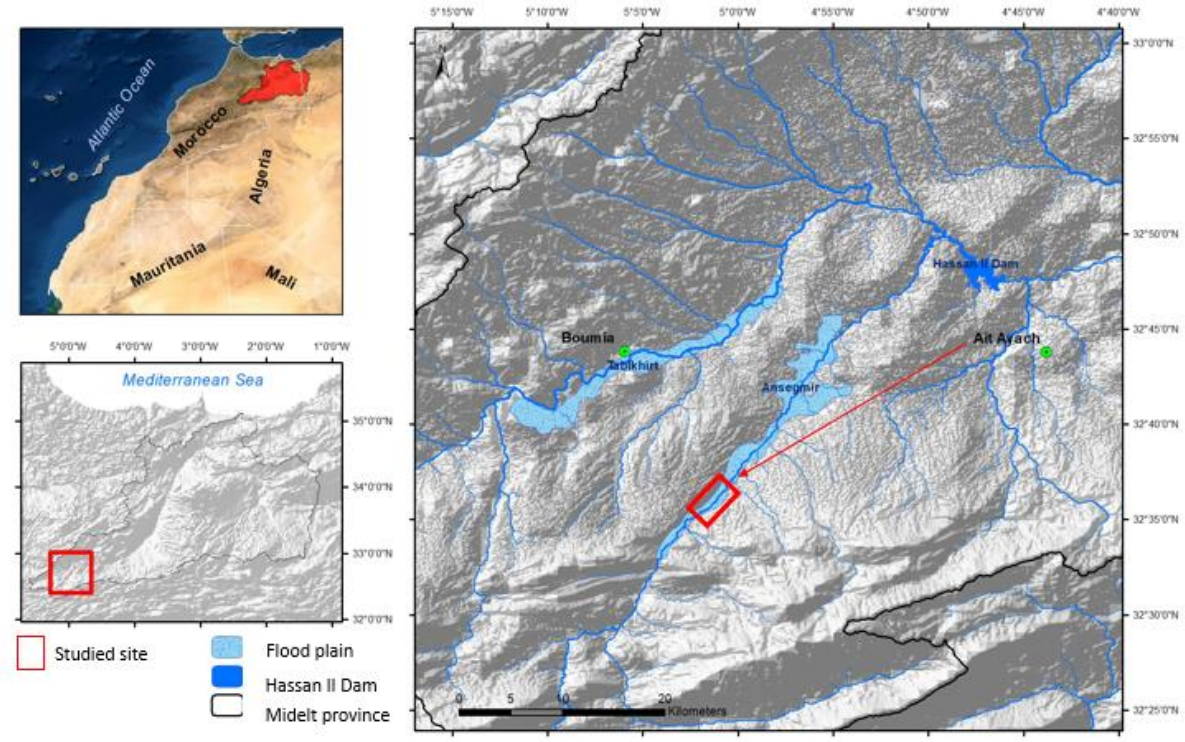


Figure 32 : Breeding sites used by migrant Turtle doves in Midelt province (Morocco) from 2015 to 2017.

2.2.2. Methods

The study was conducted in 2015 and 2016, between early April and the end of September, taking into account the breeding season of the species as defined in this area by Mansouri et al., 2020(a,b). Data were collected in apple orchards, from 84 nests identified during the 2015 season. Nest dimensions (big diameter, small diameter and cup depth) were measured with a clinometer. Similarly, the placement of nests (in relation to the centre and periphery of the orchards) and their orientation were recorded at the first visit, when the Doves are out of their nests. During the 2016 season, we monitored only the studied nests in 2015 that are occupied also in 2016 by breeding Doves.

For parasite load, Turtle dove chicks were monitored tree times: i) first day after hatching, ii) second visit during post-rearing (7 to 9 days after hatching), and ii) before chicks' emancipation (14 to 16 days after hatching), and every chick examined was ringed with numbered leg ring, weighed 0.1g. At each monitoring campaign, we determined the ectoparasite load, by inspecting the chick' body between feathers and anus, after the parents leave the nest for food search (Fowler and Cohen, 1983). In order to analyse the potential repellent effect of nesting vegetation twigs, the parasite load is limited to ectopathogens, which were preserved separately in 80% ethanol tubes and brought to the laboratory of entomology at Faculty of Sciences and Technologies of Fez. All parasites of each tube are examined using a stereo zoom microscope and identified to the species level.

The nests monitored at the end of 2016 breeding season were collected and brought to the laboratory, where the twigs were identified, in terms of nature (plant roots, stems or both) and taxonomies (species and family). In addition, the plant species surrounding the nesting sites were collected and identified to check if the Turtle doves make a choice of nesting plants or use any available and abundant materials.

2.2.3. Statistics

Statistical analyses were done in STATGRAPHICS Centurion software, version XVI.I. Before running the statistical analysis, we checked for normality and homogeneity of variance for nest morphology variables with the Kolmogorov-Smirnov test. We also checked for possible correlations among variables of Dove nests by using Pearson's rank correlation (r) index. Infestation rate among chicks was calculated as number of infested chicks/all examined chicks and transformed to percentage. Finally, results were given as sample size and mean ± SD.

2.2.4. Ethical Note

The study with Turtle Dove chicks conforms to the Moroccan guidelines for the use of animals in research, as well as to the legal requirements of the National Office of Sanitary Safety of Food Products (NOSFP). During the study, stress was minimized and all chicks were cared for and treated appropriately in accordance with the Moroccan laws for animal experiments. Birds used for the recording showed normal behaviour and did not appear to suffer from their occasional removal from the nests. After the study, chicks leaved their nests successfully.

2.3.Results

2.3.1. Nest characterization

After two years of monitoring (2015-2016), 84 nests were identified and monitored. Turtle Dove nests were characterized by big axis with 16.51±0.25 cm, small axis with 13.00±0.26 cm, and depth with 4.59±0.15 cm in average. In parallel, all nest' dimensions were uncorrelated (Spearman Rank Correlations Coefficients were inferior to 0.4 and all P values were superior to 0.5).

2.3.2. Nest building location

Turtle Doves built their nest mainly in the periphery of the apple orchards (n=64 nests) compared to the centre (n=20 nests). On the other hand, the majority of nests (n=38 nests) were oriented to the East, 10 nests to the North, 8 nests to the West, and 7 nests to the Southeast, while the minority of nests were oriented between South (n=5), Northwest (n=4) and Southeast (n=3). In addition, both parents built their nest cooperatively.

2.3.3. Nesting materials and Parasite load

In a total of 84 sampled nests, 16 nests were destroyed by farming practices inside apples) during 2015, therefore only 64 nests were analysed. As results, Turtle Doves used a variety of materials to build their nests. Indeed, 47.06% of nesting twigs were from plant stems and 42.94% were a mixture twigs, including plant stems and roots. However, in term of plant species, we recorded twelve herbaceous species among nesting materials used by Turtle Doves (Table 1), belonging to six families (Rosacea, Asteraceae, Fabaceae, Poaceae, Brassicaceae and Polygonaceae). The most frequent were *Cladanthus scariosus* (recorded in 43 nest), *Artemisia herba alba* (23 nests) and *Ononis spinosa* (17 nests). In addition, many plant species were less incorporated in nesting materials, such as *Rumex crispus* (3 nests) and *Rosa canina* (3 nests).

Table 21: Plant species identified in nesting materials of European Turtle doves

Common name	Scientific name	Family	Number on nests incorporating plant species
Undefined	*Cladanthus scariosus*	Rosacea	43
White wormwood	*Artemisia herba alba*	Asteraceae	23
Spiny restharrow	*Ononis spinosa*	Fabaceae	17
Alfalfa or lucerne	*Medicago sativa*	Fabaceae	15
Foxtail barley	*Hordeum jubatum*	Poaceae	12
Hare barley	*Hordeum murinum*	Poaceae	12
Common barley	*Hordeum vulgare*	Poaceae	9
Rocket salad	*Eruca sativa*	Brassicaceae	9
Wall rocket	*Diplotaxis muralis*	Brassicaceae	8
Bridal broom	*Retama monosperma*	Fabaceae	6
Dog rose	*Rosa canina*	Rosacea	3
Curled dock	*Rumex crispus*	Polygonaceae	3

Concerning ectoparasite loads, only 6 chicks were found infested, particularly during post-rearing phase (Table 14). However the parasite load was eliminated at the age of 16 days by parent (adults pic up on the chicks' body to eliminate pathogens and dead skins). Further, two kind of ectoparasites were identified Columbicola columbae on five chicks and Dermanyssus gallinae on one chicks (Figure 23). On the other hand, infestation rate was limited to 8% and breeding success was very high with 97.33% of survived chicks. In addition, two Turtle Dove chicks were died due to nest desertion resulting from human disturbance (they were not infested by parasites).

Table 22: Parasite load during the growth période of Turtle Dove chicks and success rate.

Parameters	Hatching	Post-rearing	Before fight
Nestling age	First day	7-9 days	14-16 days
Ectoparasite load	0	6	0
Success rate	75 (100%)	75 (100%)	73 (97.33%)

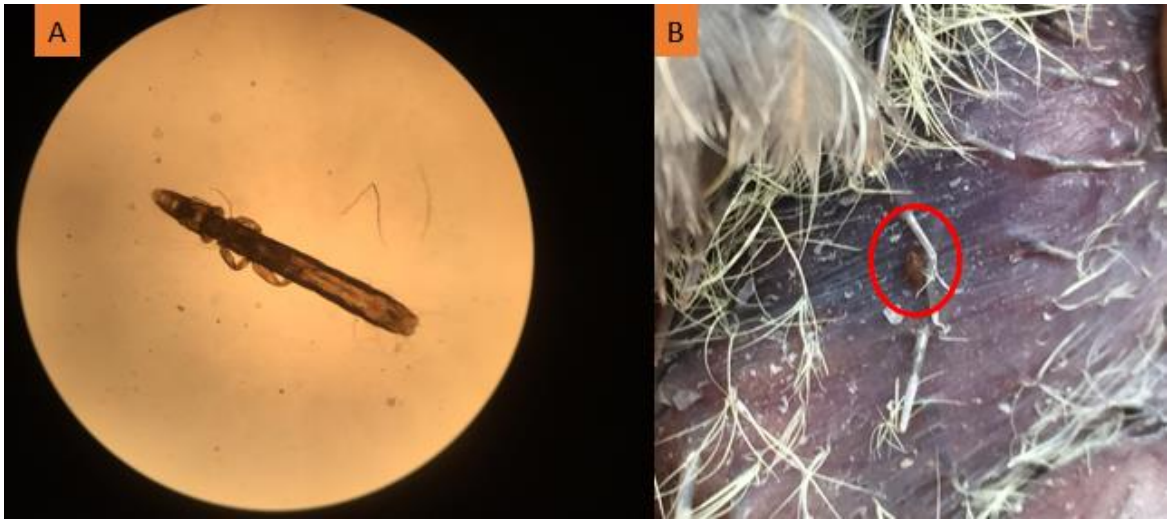


Figure 33 : Identified parasites, (A) *Columbicola columbae* and (B) *Dermanyssus gallinae*, on the body of Turtle Dove chicks

2.4.Discussion

Nest construction is a well-known behaviour in several bird species, but we have rather little information about the species-specific nests (Walsh et al., 2010). Similarly, despite being a widespread and threatened species, little is known about nesting features of Turtle Doves, mainly in North Africa.

Our field research, based on a sample of 84 nests, indicates that Turtle doves built a medium-size nest, suggesting an appropriate relation between nest morphology and Dove's size (Biddle et al., 2016; Hanane, 2010). This conclusion is now verified in many species that construct nests with high variety of shapes (scrapes, cups, domes, burrows, etc.) and a wide range of sizes, in correlation with their body size (Collias and Collias, 1984; Hansell, 2000b), the predation risk and, occasionally, with environmental conditions that could affect nestling, knowing that the nests are the principle support to the clutches (Biddle et al., 2016, 2016; Mainwaring et al., 2014; Walsh et al., 2010). This nesting behaviour allows bird species to reduce building costs. Furthermore, in the Midelt apple orchards, Turtle doves orient their nests, mainly to the eastern direction, probably in a way to protect them against the frequent Western winds, but also to ensure better exposition to the sun. This behavioural strategy was demonstrated in Tree Pipit Anthus trivialis which orients its nests to the East in order to avoid western wind and to benefit from solar radiation during the morning to warm up nestling.

In the nests of Midelt, thirteen plant species, belonging to six families, were identified. This diversity of materials could be attributed to two factors: the diversity in vegetation surrounding the breeding sites and/or a potential role in protecting the nestlings against pathogens. Concerning the first suggestion, many other plant species (Rosmarinus Officinalis, Stipa Tenacissima, Leontodon Hispidus, Biscutella Didyma and 23 other species) were abundant in/and around apple orchards, without being incorporated to the nests. This indicates a behavioural pattern in selecting nest materials, while our study supports the hypothesis of selecting plants that likely could protect nestlings. Despite the absence of statistical evidence, a large literature attributes a powerful repulsive impact on pathogens to some species that were incorporated in 89.28% of nests and the low rate of infestation (8%) in chicks: Cladanthus scariosus, Artemisia herba-alba, Rosa canina and Retama monosperma (El Hamdani et al.,

2018; Jafarirad et al., 2016; Mighri et al., 2010; Mohamed et al., 2010; Ousaaid et al., 2020; Rovná et al., 2020; Segal et al., 1987; Spadaro et al., 2014; Wenzig et al., 2008).Moreover, (Lennon et al., 2013; Stockdale et al., 2015) found a 100% infection rate by T. gallinae in adult and nestling Turtle Doves, with clinical signs (Lennon et al., 2013; Stockdale et al., 2015), while in this study, where repellent twigs were incorporated, infestation rate was at only 8%, by two ectoparasites Columbicola columbae and Dermanyssus gallinae. Indeed, the identified plant materials contain volatile secondary compounds, such as hydrocarbons (mainly monoterpenes and isoprene), which could have biocidal effects on parasites and pathogens (Clark, 1991; Dubiec et al., 2013). Thus, this strategy would help the Midelt Turtle doves to reduce parasite loads and to ensure a better breeding success; this avoids any future decline as that recorded in Europe

2.5.Conclusion

In the high altitude apple orchards of the Midelt region, the nests of Turtle dove are of medium-size, in comparison to their body size, and have preferably an eastern orientation. They use diverse nesting materials, mainly plant twigs and stems. Far from being a simple physical support for eggs and chicks, Dove nests contain plants that are well-known as repellent and/or toxic to ectoparasites, ensuring thus a maximum protection to nestlings against ectopathogens. The species seems to operate a choice of such 'medicinal' plants, among several other species that exist around the nesting sites. Further, more deep studies are needed to verify if such plants impact also the endoparasites and if this impact increases the survival of Turtle Dove nestlings. Investigation on how this species behaves in more natural and artificial Mediterranean habitats are also required to determine the cost of pathogens on Turtle dove population.

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3. Comportement alimentaire de la tourterelle des bois durant la saison de reproduction

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Synthèse d'étude

Pendant la saison de reproduction, de nombreux oiseaux sont confrontés à des fluctuations spatiales et saisonnières de la disponibilité des ressources alimentaires, nécessaires pour le développement des oisillons. La réduction de la nourriture est souvent identifiée comme facteur déterminant des tendances de la population et le succès de la reproduction chez de nombreux oiseaux, comme la vulnérable tourterelle des bois *Streptopelia turtur*. Dans la présente étude nous nous sommes intéressés aux comportements de recherche alimentaire durant la saison de reproduction. Pour ce faire, nous avons surveillé l'intensité d'alimentation, dans différents habitats naturels et agricoles, depuis le mois de mars jusqu'à le mois de septembre de l'année 2016/2017 à Midelt. Parallèlement, la chronologie de la reproduction, y compris la nidification, la ponte et l'envol des poussins, ont été surveillée dans les mêmes habitats pour évaluer la corrélation entre les acitivités de reproduction et les taux de recherche de nourriture. Les résultats obtenus nous ont permis de montrer que les tourterelles se nourrissent activement au niveau des sites de reproduction, depuis l'arrivée jusqu'aux dates de départ. La recherche de nourriture se montre très intense pendant les phases de reproduction, principalement pendant les périodes de ponte et de croissance des poussins. Nous avons pu, les tourterelles se nourrissent activement, pendant la fin de la saison de reproduction avant les départs de migration ce qui leur permet d'accumuler les réserves á utiliser pendant les trajets de migration. En outre, pendant la journée, elles se nourrissent fortement le matin et le soir afin d'éviter les périodes les plus chaudes, comme stratégie pour économiser l'eau métabolique.

Foraging efforts and behaviour of the European Turtle doves (*Streptopelia turtur*) during the breeding season

Abstract

During breeding season, many avian species face spatial and seasonal variation in the availability of food resources required to rear chicks. Reduction of food abundance is often identified as the most important factor determining population trends and breeding success in bird species, such as the vulnerable European Turtle dove *Streptopelia turtur*. During breeding periods, the increase of food requirements in chicks should therefore result in increased foraging effort to maintain the amount of food required for optimal chick development. To investigate the feeding effort of turtle doves during breeding season, we monitored foraging and drinking rates, in different wild habitats and farmlands, from March to September 2016-2017 in Midelt, Morocco. Similarly, breeding chronology, including nesting, laying and chicks' fledging were monitored in the same habitats to evaluate the correlation between breeding efforts and foraging rates. We found that Turtle doves feed actively from the arrival to departure dates. Foraging activities were intense during breeding phases, mainly laying and chicks' growth periods. Equally, Doves feed intensively during the end of breeding season before migration departures. In addition, Doves feed actively during the morning and evening in order to avoid the hottest periods as a strategy to save metabolic water.

Key words: Breeding season, Foraging rates, Turtle Dove, Morocco.

3.1.Introduction

Many factors influence the structure of avian species, including habitat quality, competition, and species-requirements (Thornton et al 2011, Sol et al 2012, Ehrlen and Morris 2015). One of the most critical factors in the regulation of all animal populations is food resource availability (Sol et al 2011, Ferger et al 2014). Bird species have access to food resources derived from human activities and wild resources during breeding and non-breeding seasons (TREMBLAY et al 2005, Dias et al 2013, Mansouri et al 2019). Availability of food resources permit a breeding success and survival of these species (Salleh Hudin et al 2017). In fact, food resources are used by adults and their nestling during breeding periods. However, reduced food provisioning of both adults and nestlings may influence survival rates and breeding success in bird species (White 2008).

The European Turtle dove (*Streptopelia turtur*) is a long-distance Afro-Palearctic migrant bird that travels thousands of kilometers between breeding zones in North Africa and Europe, and wintering grounds in sub-Saharan Africa (Lormee et al 2016). The population of Turtle doves has declined by 70 % in its European ranges. As in most other avian species, European Turtle doves face considerable temporal and spatial variation in food availability (Dunn & Morris 2012). During the breeding season, Turtle doves preferred nesting sites close to feeding habitats where food resources are abundant (Gutiérrez-Galán and Alonso 2016). Food resources influence many traits of this threatened game related to reproduction, such as breeding success, nestling growth, to wintering ecology and migration capacities (Eraud et al 2009, Dunn et al 2018). Despite this axial role of feeding resources, few studies have interested foraging features in Turtle doves. Diet composition (Rocha & Quillfeldt 2015), foraging habitats (Gutierrez-Galan et al 2019, Mansouri et al 2019), and the impact of resource availability on survival (Eraud et al 2009) are the only analysed issues. However, with consideration of reduction in food abundance as one of the main factors behind the negative trends in Turtle dove population

at both breeding and wintering quarters (Gutierrez-Galan et al 2019), the study of feeding ecology will be the main key to evaluate recent feeding strategies of this game bird to encounter loss and degradation of foraging habitats.

In this study, our objective was to examine the feeding behaviour and strategies of Turtle doves during breeding season. We aimed to analyse, in field, the evolution of feeding rates in correlation to breeding activities, including nesting, laying and hatching. However, many studies reported that with the growth of chicks, avian species accelerate foraging rates in order to satisfy the food requirements of nestling (TREMBLAY et al 2005). Therefore, we have based our study during the breeding season in Midelt province where Doves were reported as a breeder (Mansouri et al 2020), with the aim to easily quantify the feeding rates in correlation with breeding chronology.

3.2.Material and Methods

3.2.1. Study area

The present study was carried out in the Ait Ayach valley, Midelt province Morocco. The study zone was located at the high plain of Moulouya, at the junction of the Middle Atlas and the High Atlas chain (figure 1). The Midelt is located at 1300 to 1600 m above sea level. A steppe climate is present in Midelt. The annual average temperature in Midelt is 14.7 ° C and the average rainfall per year is 263 mm. This mountainous region is dominated by agricultural activities, including apples, cereals, Lucerne and other cultivated plantation (Mansouri et al., 2019, 2020). The study sites were selected at Okhaja rural centre. Four habitats are distinguished, counting apple orchards, cereals (common wheat and barley), riverbanks, and lucerne cultivation.

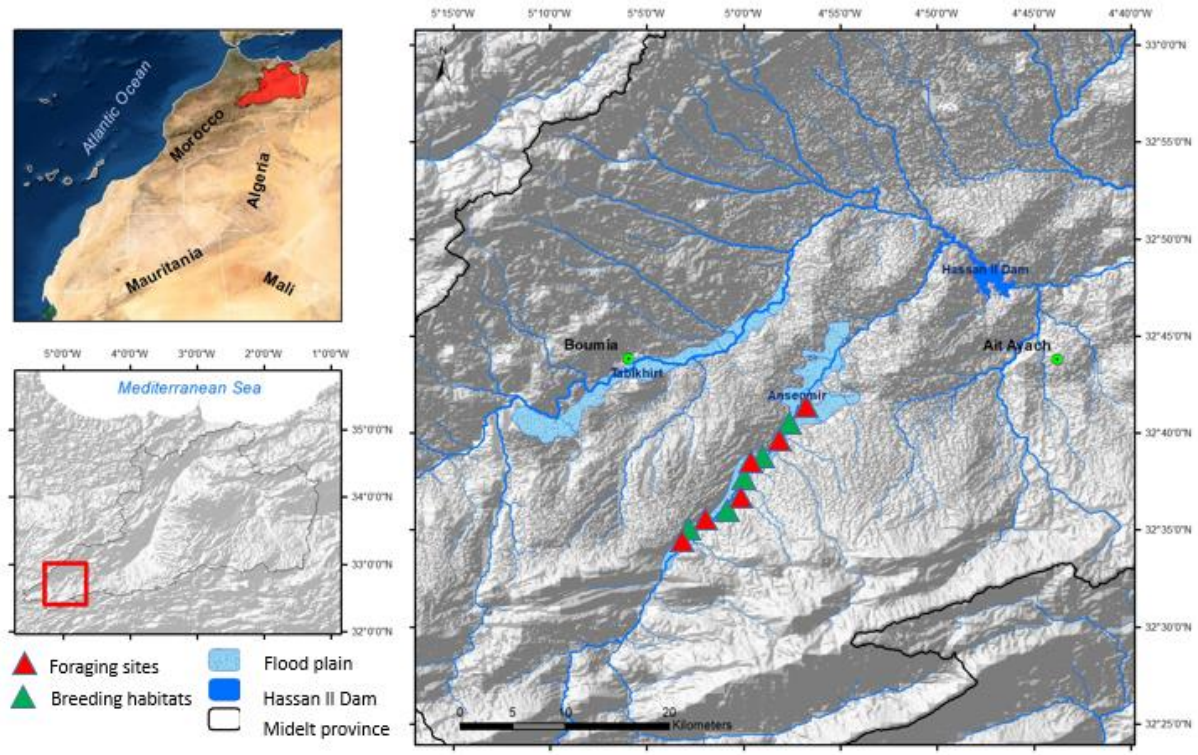


Figure 34 : : Foraging and breeding habitats of Turtle doves at Oukhaja, in Midelt Province (Morocco) during breeding season 2016-2017

3.2.2. Sample design

The monitoring of the feeding activities of Turtle dove was carried out in different kinds of wild and agricultural habitats, during one breeding season, from March to September 2016-2017. The selected sites, including ten cereal plots (3.45 ha), ten lucerne plots (1.39 ha), ten apple orchards (3.66 ha) and ten stations in the Ansguemir river (2.63 ha), were topographically high for better visibility (better and easy feeding birds counting), and camouflaged (apple trees and other riparian vegetation) to avoid any disturbance. Feeding rates were recorded as the number of feeding Doves observed at each site every two hours from 06:00 to 18:00. The observations were done by binoculars (in case of good visibility conditions). In parallel, drinking rates were recorded in the nearest water point, in Ansguemir River, to the feeding site. Turtle dove's displacement from foraging site to water point was considered as drinking attempt. On the other hand, breeding activities, including nesting (construction of nests), laying (number of eggs) and hatching (fledged chicks) were monitored in the surrounding apple orchards. Temperatures were extracted from the Midelt weather biometeorology station during the 2016-2017 season.

3.2.3. Data analysis

Statistical analyses were done in STATGRAPHICS Centurion software, version XVI.I. Before running the statistical tests, we checked for normality and homogeneity of variance for all variables with the Kolmogorov–Smirnov test. The relation between foraging and drinking rates was tested with Pearson's correlation coefficient, considering seasonal and diurnal rates as variables. We analysed separately the relationship between breeding activities, including nesting (nest construction), laying (eggs), hatching (fledged chicks) and foraging rates by Simple Regression (linear model) and the lack of fit test to determine whether the selected model is adequate to describe the observed data (foraging), considering feeding activities as dependent variables and breeding parameters as factors. Similarly, the relationship between drinking activities (dependent variable) and diurnal temperatures (factor) was analysed by Simple Regression and the lack of fit test. ANOVA one way test was conducted to compare seasonal and diurnal feeding and drinking rates. All variables with P-Value greater than 0.5 were eliminated. Results were given as mean ± SD and Graphs were created by GraphPad Prism Mac 6.0h software.

3.3.Results

We recorded 1220 unique feeder visits over 153 days (Feeding= 964 and drinking= 256). During breeding season, breeding Turtle doves feed actively. Generally, individuals feeding rates increased throughout the season with two maximum feeding rates from May to July and August (figure 2).On the other hand, feeding activities and drinking rates were distributed throughout day. While, daily activities were intense between 06h00 and 10h00 during morning and between 16h00 and 18h00 evening. Moreover, foraging rates were uncorrelated with drinking activities during day (n= 12, Correlation Coefficient = 0.802561, P=0.7811), while seasonally these two activities were correlated (n= 14, Correlation Coefficient = 0.541861, P=0.0453). In term of comparison, feeding rates were dominant during breeding season (n=14 (decades), F = 8.26198, P-value <0.05) and daily (n= 12 (hours), F = 18.4221, P-value < 0.05) in comparison with drinking water.

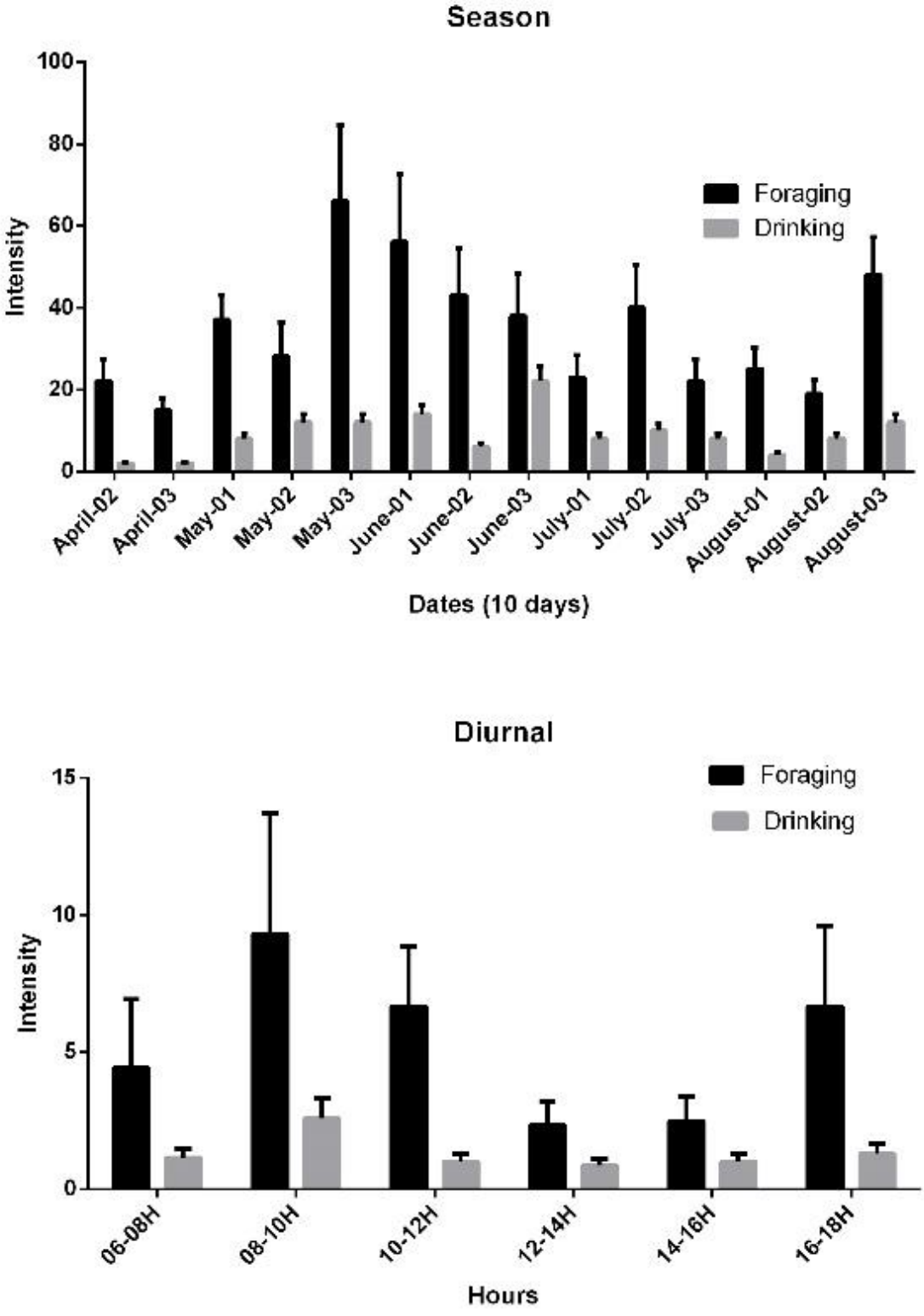


Figure 35 : Seasonal and diurnal feeding activities of Turtle doves in Midelt during breeding season 2016-2017

3.3.1. Foraging rates and breeding chronology

Feeding activities started after the arrival of migrant Turtle doves to study sites (figure 3). Feeder visits to foraging sites were observed since their first days in the breeding area during April. On the contrary, breeding chronology, mainly nesting activities started lately during the first week of May. In term of comparison, foraging rates were intense in coincidence with the intensity of breeding activities, mainly the hatching of chicks between the last week of May and the first week of August. Another reprise of foraging intensity was observed during the last week of August before autumnal migration.

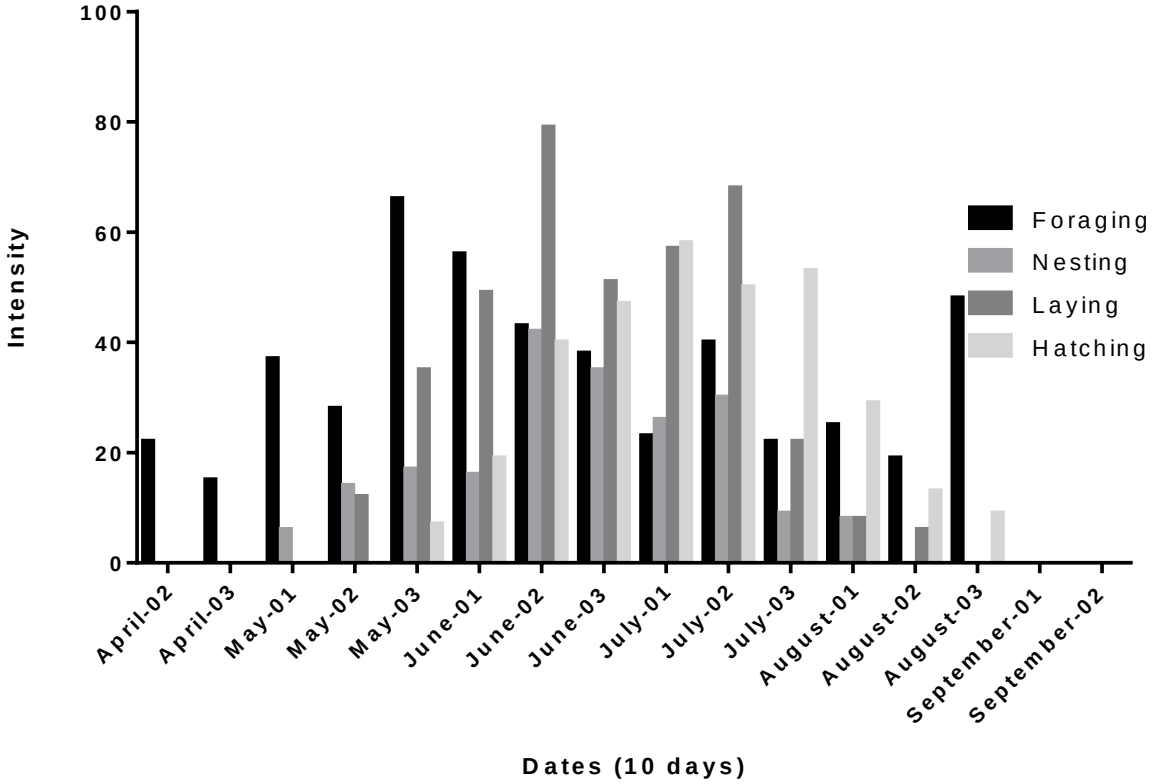


Figure 36 : Feeding rates and breeding chronology of Turtle doves in Midelt during breeding season 2016-2017

Foraging rates were controlled by breeding activities of Turtle doves (figure 4). In fact, feeding rates were correlated mainly to breeding chronology, largely laying of eggs and hatching of chicks. While nesting activities were less correlated with foraging degrees. On the other hand, no relation was recorded between feeding activities and the breeding phase during the day.

3.4.Discussion

Loss of foraging sites was mentioned as one of the main factors affecting population trends of Turtle dove *Streptopelia turtur*, in both breeding and wintering grounds (Dunn et al 2018, Moreno-Zarate et al 2020). In this study, we have monitored the foraging behaviour of the vulnerable Doves during the breeding season from the arrival to departure dates.

Research of foraging resources started immediately after the arrival of the first migrant Turtle doves to breeding habitats during the second week of April. Feeding rates were intense during

the morning between 06h00 and 10h00, and evening between 16h00 and 18h00. This is in agreement with the results reported in Turtle doves by Dubois, (2002) and Mansouri et al (2019). These authors mentioned intense foraging rates in Turtle doves during the morning and evening. As a possible explanation, this feeding behaviour during the coldest periods of the morning and evening permits to avoid the summer hottest temperatures of the midday. Because, the research for foraging resources in hot temperatures accelerate the loss of physiologic waters (Savory 1980, Bonter et al 2013), and this is confirmed by the close correlation recorded between drinking rates of Doves and the evolution of summer temperatures (figure 5). On the other hand, foraging activities were distributed from the arrival to migration departures in autumn, which is in agreement with results mentioned by Mansouri et al 2019 in the same zone, and supporting the actively feeding rates from the arrival to departure of this threatened species
Figure 5: Correlation between drinking rates of Turtle doves and diurnal temperatures in breeding zone.

During the breeding season, foraging rates were correlated to the breeding activities, mainly laying and hatching. The intensity of feeding rates increased with the increasing number of laid eggs and hatched chicks between the last week of May and the first week of August. These increasing foraging rates, particularly during hatching periods are supposed to be induced by the food supply required by new nestling as recorded in many avian species (Gill and Hatch 2002, Robb et al 2008). For example, during the breeding season, the food supply required by chicks of carrion crows, Corvus corone corone, increased significantly with their growth (CANESTRARI et al 2007). In fact, all avian nestlings require more food supply in accordance with their growth (Maziarz & Wesołowski 2010, Brommer et al 2011), and this forces their parents to increase foraging rates to satisfy the requirements of chicks (Boland et al 1997, Caffrey 1999, Roehe et al 2016). This explains the coincidence between high-intensity rates of foraging activities and the occurrence of laid eggs and hatched chicks of Turtle doves during breeding seasons. In addition, another intense feeding rates were recorded after the breeding phase (nesting, laying and fledging), in the last week of August. The high foraging rates observed in the last periods before migration departures, in autumn, are possibly due to the attempts of Turtle doves to accumulate the satisfying reserves that are enough to cross the harsh Saharan desert to wintering grounds. At this point, many long-distance migrant birds were documented to accumulate fuel reserves in breeding quarters before starting their migration journeys (Schaub et al 2008, Goymann et al 2010, Eikenaar 2017), and these reserves are used as fuel to accomplish their flaying efforts during the long migration routes (Sissel Sjoberg et al 2015, Howard et al 2018).

3.5.Conclusion

In summary, our study demonstrates that feeding rates of migrant Turtle doves started from the first day in the breeding zone. Diurnally, Turtle doves feed actively during the coldest periods of the morning and evening. Moreover, foraging activities were intense during the rearing of nestlings in order to satisfy the food requirements of Dove's chicks. While drinking rates were intense during the hottest temperatures of the summer. In addition, feeding activities were recovered just before migration departures to accumulate sufficient reserves for long migration journeys. Additional studies of feeding behaviour and ecology of Turtle doves are required to further explore the relationship between feeding sorties realised by parents and the growth of

nestling. Similarly, the relationship between feeding efforts and success rates well be an important feature to understand foraging strategies of Doves.

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MIGRATION ET HIVERNAGE DE LA TOURTERELLE DES BOIS

1. Nouveaux sites d'hivernage de la tourterelle des bois

(Submitted to Saudi journal of biological sciences 2021)

Synthèse de l'étude

Les populations des oiseaux migrateurs trans-sahariens ont subi un déclin sévère et continu au cours des dernières décennies (Sanderson et al 2006). Des études récentes montrent que les tendances démographiques des oiseaux migrateurs, hivernant en Afrique subsaharienne, diminuent, d'une manière plus significative que celles des résidents ou des migrateurs de courte distance (Sanderson et al 2006), proposant un impact de facteurs opérant en dehors des aires de reproduction.

Dans la présente étude, nous avons choisi la tourterelle des bois (*Streptopelia turtur*) comme oiseau migrateur trans-saharien de longue distance, pour comprendre la situation de l'espèce en Afrique du nord. Dans ce contexte, notre objectif est d'identifier l'évolution du temps de migration et de découvrir les sites potentiels d'hivernage au nord-ouest de l'Afrique. Ces habitats peuvent servir, comme alternatifs aux sites d'hivernage éloignés dans l'Afrique subsaharienne. Nous avons mené notre étude à grande échelle au nord-ouest de l'Afrique, y compris le Maroc, l'Algérie et la Tunisie. Les dates de migration et les individus hivernants sont enregistrés entre l'année 2015 et 2017. Les resultats obtenues montrent que les tourterelles arrivent au nord de l'Afrique durant la dernière semaine du mois de mars et quittent la région vers l'Afrique subsaharienne á la mi-octobre. Par rapport au Maroc, les tourterelles arrivent beaucoup plus tôt en Algérie et en Tunisie. Inhabituellement, la présente étude révèle l'hivernage des individus de la tourterelle des bois dans six sites en Afrique du nord-ouest (trois au Maroc, deux en Algérie et un site en Tunisie), entre le mois d'octobre et le mois de février. De plus, le modèle binomial logistique a montré que la probabilité d'occurrence des hivernants diminue considérablement avec l'augmentation de la température et les précipitations. Cependant, l'espèce hiverne le plus souvent près des zones humides pour s'approcher des plans d'eau. La probabilité d'occurrence de couples reproducteurs des tourterelles augmente avec l'altitude, le rapprochement des zones humides et les forêts. Ces résultats sont cruciaux dans l'évolution de la migration de ce gibier menacé, et pour l'adoption de mesures de conservation appropriées, car les conditions environnementales sur ces aires d'hivernage pourraient jouer un rôle central dans les tendances de la population et ces nouveaux sites d'hivernage pourraient aider á la conservation de cette espèce, en déclin dans l'Europe occidentale.

New data on migration time, breeding phenology and breeding success of European Turtle doves in its highest breeding habitats in North Africa

Abstract

The identification of migration dates and wintering zones are key matters for the understanding of the Afro-Palearctic migration evolution as well as for the adoption of pertinent conservation measures. From 2015 to 2019, a large-scale survey of Turtle doves, a vulnerable species, was established in Northwest Africa, including Morocco, Algeria and Tunisia. We monitored migration and breeding dates, and wintering individuals using Line-Transect method. Data revealed that Turtle doves arrived in last week of March (20.73±7.18 March) and leaved North African région in 13.53±4.50 October. Compared to Morocco, Turtle doves arrived significantly earlier in Algeria and Tunisia. Unusually, Turtle doves were discovered wintering in six Northwest African sites (three in Morocco, two in Algeria and one site in Tunisia), from October to February, where individuals feed in group and avoid solitary behaviour. Moreover, the logistic binomial model showed that the occurrence probability of wintering Turtle doves decreased significantly with increasing temperature and rainfall. However, the species wintered most often close to wetlands since its wintering probability decreased with increasing distance separating recording area to nearest water body. Furthermore, the occurrence probability of breeding Turtle doves increased with increasing altitude. Also Turtle doves' breeding pairs more likely occurred in wetlands and forest, and in areas with herbaceous vegetation layer avoiding farmlands. These findings are a crucial issue in migration evolution of this threatened game, for adoption of appropriate conservation measures, because environmental conditions on these wintering areas might play a pivotal role in population trends and this new wintering sites could help in recovery of this declining species in Western Europe.

Keywords: Turtle doves, migration dates, wintering sites, Northwest Africa.

1.1.Introduction

Population of trans-Saharan migrant birds have suffered a severe and continuous decline during recent decades (Sanderson et al 2006). Unlike to resident birds, understanding the causal processes demonstrates difficult because this may operate at various key stages in the life cycle of migrant bird species and across wide geographic ranges (Newton 2004). In regards to the breeding stage, it has been revealed that the intensification of agriculture could contribute to the decline of several Afro-Palearctic species, especially those breeding or feeding in agrosystems (Kirby et al 2008). However, recent studies show evidence that population trends of long-distance migrant birds wintering in Africa sub-Sahara were declining more significantly than those of residents or short distance migrants (Sanderson et al 2006), proposing an impact of factors operating outside the breeding grounds.

It is well reported that the environmental conditions on the wintering areas are affecting the population trends of trans-Saharan migrant birds (Moller et al 2008; Schaub et al 2005). Equally, the variation in survival rates has been reported to be significantly correlated with rainfall regimes (Moller 1989) and food resources (Schaub et al 2005). Besides this direct impact on dynamic of populations, environmental conditions undergone by birds on their wintering zones may also have a negative consequences on breeding success (Norris & Taylor 2006), and these are suspected to be more vigorous with climate changes and modification of natural habitats (Norris 2005)

Although many trans-Saharan migrant birds are held to overfly the Saharan desert by combining migrating journeys and stopover périodes (Bairlein and Schaub 2009; Schmaljohann et al 2007), some of them they undertake a nonstop flight from a breeding zones to wintering grounds (Schmaljohann et al 2007), and a minority of these species have been detected to winter in South Europe and North Africa (Webster et al 2002; Woodrey and Inzunza 2005). Therefore, understanding characteristics and conditions as well as predominant environmental factors influencing migratory species on wintering, stopover sites before and during crossing may play a key role in the success of migration flights and wintering périodes. Consequently, the identification of most important migration routes, stopover sites and wintering habitats are therefore fundamental matters for understanding recent population trends, predicting the costs of changes in habitat use, climate conditions and developing cost/effective conservation measures (Bairlein and Schaub 2009; Kirby et al 2008; Webster et al 2002; Woodrey and Inzunza 2005).

In the present study, we have chosen the European Turtle Doves (*Streptopelia turtur*) as a trans-Saharan long distance migrant bird. This game has declined over the Western Europe (birdlife international 2012). This declining in its population has been dramatic in some areas such as the United Kingdom, where breeding Doves have declined by 70% since mid-nineties (Risly et al 2010). Intensification of agricultural activities on the breeding zones is reported to be the main factor behind this trend, through modification and loss of the breeding habitats and a severe decrease in food availability (Browne et al 2005; Browne and Aebischer 2003). On the other hand, latest studies suggest that the quality of habitats, food resources and environmental conditions on the sub-sahelian wintering grounds may have also a critical impact on Dove population and trend (Eraud et al 2009). This evidently illustrates the relevance of demographic processes other than those operating on the breeding zones and consequently, the urgent need to gain a deep understanding into the migration ecology of the species, especially those in dramatic decline before the irreversible point.
In this context, our aim was to identify the evolution of migration time, including arrival and départure dates of the species and to discover any potential wintering sites in Northwest Africa that could serve as alternative of distant wintering ground in deep Africa. More reasons are behind the select of this area: (i) Turtle doves use this area for breeding and stopover before getting the Europe, (ii) Turtle doves have a well status in this area and their conservation may help to establish and recover the declining populations in Europe, especially the shift in hunting périodes, that will protect breeders to cross from Europe to Africa (iii) Northwest Africa is warm than Europe, also some Southern parts are similar in their climate to the Africa sub-sahara where Turtle doves spend wintering périodes.

1.2.Methods

1.2.1 Study area

We monitored wintering Doves over the majority of the Northwest African Turtle dove's described breeding and migratory routes (Cabodevilla et al 2018; Hanane 2017; Lormée et al 2019). The winter study area extended from the Atlantic coasts in Western Morocco to the Algerian Sahara Desert oases, and from the Mediterranean Sea in the North of Tunisia to the Western borders with Algeria in the South (Fig. 32). From South to North, the vegetation zones were a mixed of Accacia forest, coniferous forest, Argan, and holm forest. In the Sahara, human

habitation was fulfilled with farmlands inside oases. Along these ranges, many wetlands and urban agglomerations were visited in cities and small towns. All wintering sites (except Bechar in Algeria) corresponded to arable farmland landscapes with predominantly cereal crops, and Saharan Oases predominated with palms. Additionally, wintering habitats used by Doves were close to rivers and encompassed irrigated agricultural landscapes including cereal crops such as Triticum sp. and Hordeum vulgare.

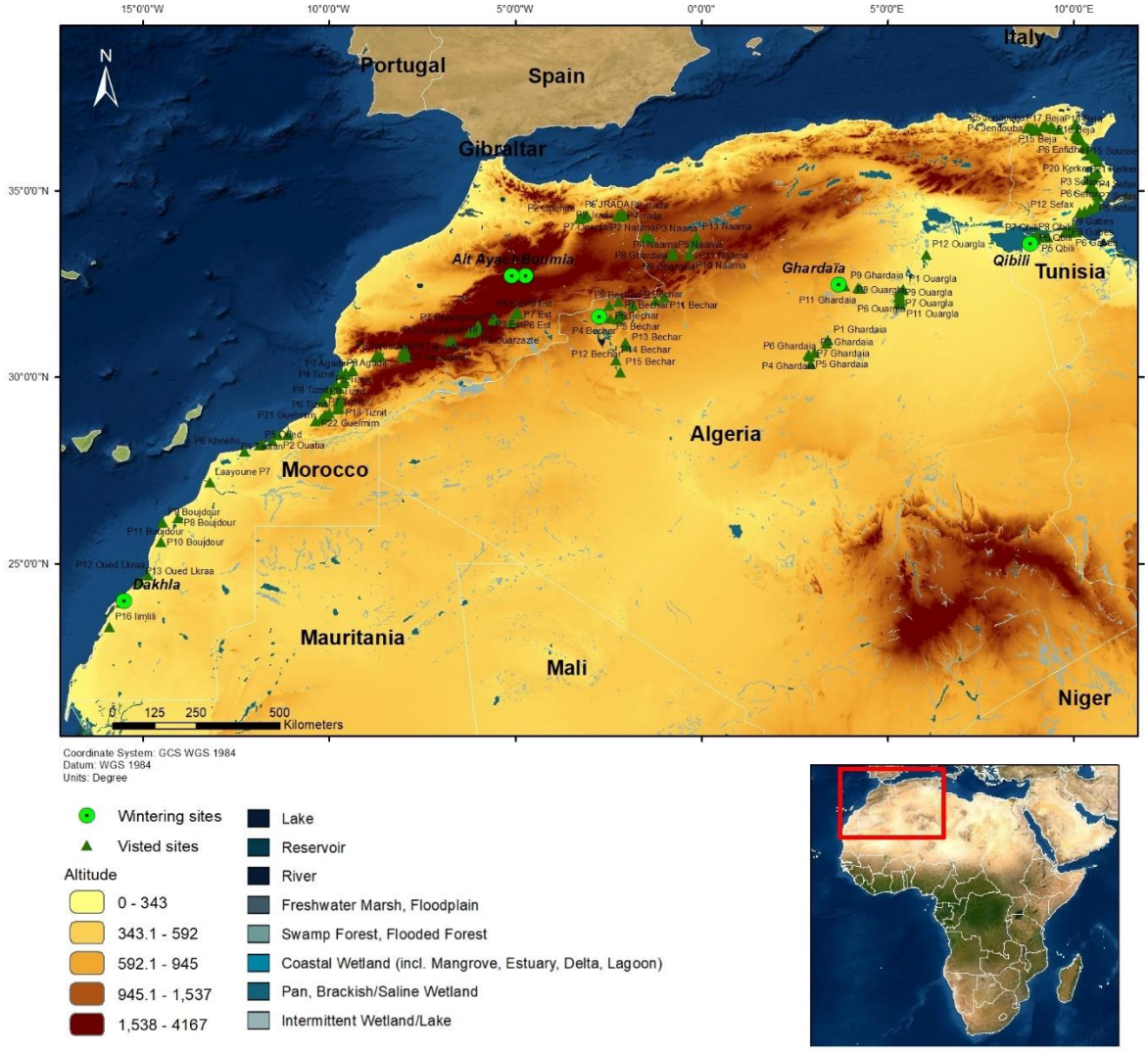


Figure 37 : Prospected areas in Northwest Africa.

1.2.2 Data collection

Field work was carried out from 2015 to 2019, in Northwest Africa, including breeding seasons (March–October) and wintering périodes (October–February) of Turtle doves. These phases were chosen basing on Turtle doves breeding seasons in Europe (Bakaloudis et al 2009; Browne et al 2005; Browne and Aebischer, 2003; Calderon 2016; Eraud et al 2009; Marx et al 2016) and Northwest Africa (Absi et al 2015; Boukhemza-Zemmouri et al 2008; Cherkaoui et al 2007; Hanane 2012; Kafi et al 2015; Mansouri et al 2020); and wintering time in sub-sahelian grounds (Eraud et al 2009). The breeding surveys were elapsed from March to October of each

study year at the rate of three visits (each visit with three sorties per 10 days) per Month in Morocco, Algeria and Tunisia. One transect, about 5 km long, was selected at potent breeding and feeding sites to maximize the potential number of encounters with Doves built on the results cited in previous works (Calladine et al 1999; Gutierrez-Galan et al 2019; Kafi et al 2015; Mansouri et al 2019). During these surveys we recorded the arrival dates (the day on which the first individual of the species is recorded each spring in the area), how individuals arrived (two categories: in group or solitary) and the départure dates (the day on which the last doves were observed between September and October). Furthermore, after the assessment of départure dates during the end of breeding périodes, the research of wintering Turtle doves started in coordination between three countries Morocco, Algeria and Tunisia, with tree 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). Line-transect method was adopted with a walked ranges of 10 km in forests, 7 km in agricultural fields and 15 km in Saharan dunes, from 06.00 to 18.00 hours, based on surfaces covered by each landscape in North Africa. During every single transect, which took around four hours to walk, the numbers of Doves seen and/or heard singing were recorded. The rivers and urban zones were heavily investigated using Common Bird Census (CBC) methodology Calladine et al (1999), because of their complexity (mixture of vegetation, urban areas and agricultural lands). Immediately after the observation of wintering or breeding birds, the sites were mentioned and localised. Additionally, we recorded the Altitude of the area where individuals were observed, the characteristics of the habitat counting the type (4 categories: farmland, forest, oases and wetland), the topography (3 categories: mountain, dune, plain), the vegetation type (3 categories: arboreal, bushes and herbaceous), the urbanisation degree of site (urban, rural and natural), the climate factors (temperature and rainfall). Also, distance (m) from observed individuals to nearest water plan, cereals and human building were noticed. Climatic precipitation and temperature data were accessed from one to two weather stations nearest each observation site from 2015 to 2019. All these elements are susceptible to explain the real reasons behind the choice of these habitats for wintering and breeding.

1.2.3 Data Analysis

Geographical positions of wintering Doves were localised using Geotracker software. Arrival and départure dates were defined and means were calculated. Results were given as mean ± SD. In order to compare mean arrival and départure dates among three countries, Kruskal-Wallis test was used. Equally, wintering behaviour (in group or solitary) was compared by Wilcoxon Tests.

We assessed the relevance of altitude, habitat type, topography, vegetation type, urbanisation degree, temperature, rainfall, distance to nearest water source, nearest cereals and nearest human building as predictors of wintering and breeding occurrence of Turtle dove (responses variables: with 0 (no Turtle dove observed) and 1 (observed Turtle dove)) by mean of two models with a binomial error structure and log it 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 (Kramer-Schadt et al 2013). 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 (Burnham 2002) We calculated the Weight of each model to determine the strength of explanatory variables on response variables (Table 20). Significance and trend of variables in the most parsimonious model were shown as Wald and parameter estimate values (Table 21). All statistical tests and analyses were carried out using Statistica 12 software (StatSoft 2013).

1.3.Results

1.3.1 Chronological phenology of wintering Turtle doves in Northwest Africa

First Turtle doves arrived in late March (20.73±7.18 March) at Northwest African territories. These individuals arrived solitary during first périodes of March, while during April, Doves arrived in groups, principally couples. From West to the East, arrival dates differed between countries. Doves arrived earlier (12 days) in Algeria on 17.20±3.96 March and Tunisia on 16.00±4.30 March, compared to Morocco on 29.00±3.93 March (F=15.58, DF=2, P=0.0005).

Last Doves were observed 13.53±4.50 October. This date marked the final phase of Doves in the Magharibian zones. This limit constitutes a basis to consider non migrant Turtle doves as a wintering birds. Moreover, Turtle doves leaved first at Moroccan territories on 8.40±3.04 October compared with Algeria and Tunisia (F=6.56, DF=2, P=0.01). After autumnal départures, many Doves were found wintering in Northwest Africa. During five years (2015-2019), 72 birds (48 in Morocco, 15 in Algeria and 9 in Tunisia) were identified as wintering individuals between mid-October and February. Moreover, wintering Turtle doves were meted monthly, during five wintering seasons (Fig. 33). On the other hand, in most of 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), and feeding actively.

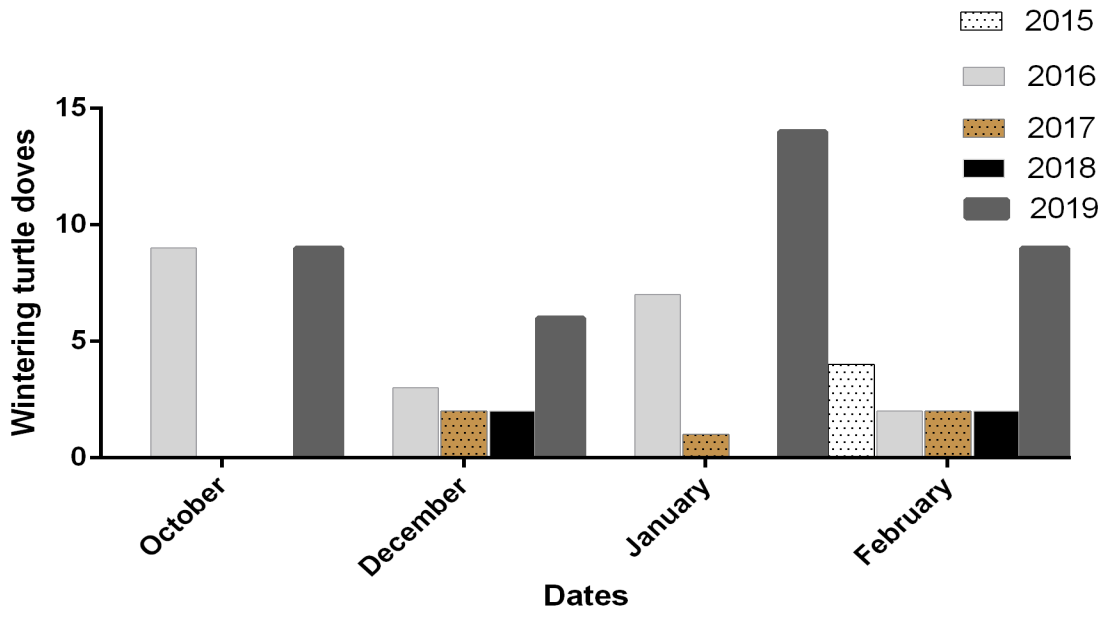


Figure 38: Monthly variation in wintering Turtle doves during five wintering seasons (2015 to 2019) in Northwest Africa.

1.3.2 Factors affecting the occurrence of breeding and wintering Turtle Doves

The occurrence of breeding Doves significantly increased with increasing altitude. Turtle doves' breeding pairs occupied less likely farmland in the study zones. However, they were more likely occurred in wetlands and forest, and in areas with herbaceous vegetation layer (Table 20).

Table 23: Summary of most parsimonious models for measures of both responses variables (Occurrence of breeding pairs and wintering individuals) in North African surveyed site (Morocco, Algeria and Tunisia). (Alt: Altitude, Tpg: Topography, Hbt: Habitat, Vgt: Vegetation).

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

On the other hand, the occurrence probability of wintering Turtle doves in Northwest Africa significantly decreased with increasing distance separating recording area to nearest water body. In fact, they wintered most often close to wetlands. Moreover, individuals wintered less

likely when temperature was greater from October to February. Likewise, the wintering probability of Turtle doves decreased significantly with increasing rainfall (Table 21).

Table 24: Significance of retained variables on the occurrence of breeding and wintering Turtle Doves in North Africa 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	0.00
	Habitat type	Farmland	-6.70	0.50	181.51	0.00
	Habitat type	Wetland	8.42	0.53	249.95	0.00
	Habitat type	Forest	7.29	0.55	176.90	0.00
	Vegetation	Hebaceous	11.53	0.81	202.76	0.00
	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	0.00
	Temperature		-15,89	3.63	19.13	0.00
	Rainfall		-1.48	0.45	11.02	0.00

1.4.Discussion

Surveying the European Turtle Doves throughout their annual cycle (Breeding and wintering phases) in this large scale study, allowed us to document breeding phase, migration dates and possible overwintering locations of individuals in wide Northwest African zones. The present study shows that the Turtle doves arrived in late March (20.73±7.18 March) at North African territories. These périodes agree with Dove's prenuptial migration reported previously in the North African breeding and stopover zones (Eraud et al (2009, 2013; Lormee et al 2016; Marx et al 2016). In Morocco Doves return to breeding sites at third week of March (19 ± 0.6 March at Tadla, and 15 to 16 March at Haouz) (Hanane 2009; Hanane & Maghnouj 2005), in Algeria the arrivals were at the end of March and early April in North Ghardaïa (Boukhemza-Zemmouri et al 2008; Chedad et al 2020; Kafi et al 2015). Furthermore, arrival dates were earlier in Algeria (17.20±3.96 March) and Tunisia (16.00±4.30 March) compared to Morocco (29.00±3.93 March), which is in contradiction with results reported by (Hanane & Baamal 2011). These authors have reported an early arrival in Morocco, which is completely different from results recorded in our study. On the other hand, this temporal shift observed in arrival dates from Morocco to Tunisia is supposed to be due to migration routes, départure dates or/and spend time in stopover sites during migration journeys. In fact, (Eraud et al 2013; Lormee et al 2016; Marx et al 2016) have reported a variable départure dates from the wintering quarters ranging from 12 to 25 April, and this is susceptible to influence arrival time by thirteen days. In addition, with use of Geolocators, Lormee et al (2016) have stated that during migration journeys, Turtle doves took different migration routes, including coastal routes in Morocco and Eastern routes in Algeria, and these distances are widely different, which is suggested to interfere in arrival dates. Besides, these Doves spend quite an important part of the migration time in Saharan stopover sites in South Morocco. These shifting départures and refuelling time

at stopovers differ between migratory groups or waves and therefore the arrival dates are suggested to be variable at breeding zones.

A valuable result highlighted by our study is that Turtle Doves use several wintering sites in Northwest Africa. This highlights the wintering birds, particularly without crossing the ecological barrier of the Sahara Desert. Despite the wide range of studies that interested to migratory and wintering aspects of Turtle doves (Boukhemza-Zemmouri et al 2008; Browne and Aebischer 2003; Calderon 2016; Eraud et al 2009, 2013; Lormee et al 2016; Marx et al 2016), only one study have reported three wintering Doves in Northwest Africa (Chedad et al. 2020). Additionally, with use of Geolocators and satellite telemetry, (Eraud et al 2013; Lormee et al 2016) have localized wintering areas in Western Mali, the Mauritanian/Malian borders and the Inner Delta Niger, and some Doves extended their wintering ranges over North-West of Burkina Faso and the Ivory-Coast. Contrary to these previous studies, our data reveal that Doves used Northwest African grounds as wintering sites. The observation of these birds from the mid-October to February between 2015 and 2020 in several sites was an important evidence that these birds were adapted with these habitats and confirm the separate observation made by Chedad et al (2020) in Algeria.

Table 25: Characteristics of Turtle doves wintering sites in Northwest Africa.

	Morocco			Algeria		Tunisia
	Ait Ayach	Dakhla	Boumia	Ghardaïa	Bechar	Qibili
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)	(32°28'60N, 3°40'60E)	(31°37'37.71"N, 2°44'41.90"W)	(33°34'47N,8°50'26W)
Topography	Valley, Cavities and riverbanks	Agricultural Oases + Dunes	Height Plain, riverbanks	Saharan Oasis + Dunes	Saharan Oases + Dunes	Oases + Dunes
Altitude (m)	1300	50	1500	489	700	28
Mean temperature	11.98±1.53	18.88±1.38	11.98±1.53	17.63±1.73	19.58±2.56	15.38±4.14
Trees	Orchards (85%): Apples, Pruns, Olives	Tamarixsp., Palm (55%)	Orchards (2%): Apples, Amends, Prunes,	Orchards (99%): Palm, Olives	Tamarixsp., (99%)	Orchards (75%): Palm, Olives
Seeds	Cereals (15%): Triticumsp, Hordeum vulgare, Zea mays,	Cereals (45%): Zea mays, Triticumsp,	Cereals (98%): Triticum turgidum,Triticumaestivum, Hordeu	Cereals (1%): Hordeumvulgare	Cereals (1%): Triticumsp,	Cereals (25%): Triticumsp, Zea mays

	mvulgare, Zea mays, Cider arietinum, Pisumsativum, Lens culinaris

Breeding populations of Turtle doves in Western Europe and North Africa are thought to spend winter périodes in sub-Saharan territories of West Africa where food resources (seeds and split grains) are abundant, water is offered and resting conditions are ensured (woody cover) (Jarry and Baillon, 1991; Zwarts et al 2010). Surprisingly, the observed individuals spent winter in Northwest Africa, particularly in régions where, plausibly, ecological characteristics met the requirements of the species. Besides, the analysis of North African wintering sites (six localities) revealed the important elements making these habitats favourable for Doves (table 22). They wintered most often close to wetlands where the warm temperature, food resources, water and physical support (tamaris and palm groves) was abundant (Table 3), as the case of Boumia and Ait Ayach sites in Morocco, and Ghardaya in Algeria where wintering grounds where close to cereals and rivers (Ansgmir river at Ait Ayach, Moulouya river at Boumia and Mzab river at Ghardaya). In the contrary, this bird avoids arid zones where water sources were less abundant or distant from cereals (Table 20). All cited factors are suggested to be the main reasons behind the installation of this Trans-Saharan bird in North African zones instead of crossing the Sahara. In fact, Turtle doves are known to be associated with agricultural lands in both wintering and breeding habitats ((Browne and Aebischer 2003; Gutierrez-Galan et al 2019; Mansouri et al 2019) Thus, the availability of different seeds after agricultural seasons during summer in Northwest Africa could offer an opportunity for these birds or in less for low performance individuals (three individuals where sub adults) to face wintering périodes in the case of incapacity of migration. On the other hand, this new migration status (short migration from Europe to North Africa) could be in its initial phase and Turtle doves may be able to develop and convert from long distance migrant bird to an opportunist or even resident species. This change in migration behaviour is not the first in its kind for migratory birds. In austral migration system (between North and South American continents), during last century many bird species have changed their migratory behaviour, and instead of wintering in the south temperate portion of the continent they have limited their migratory ranges to the nearest and rich habitats (food and water) in the North America (Chesser 1994; Jahn et al 2004). Despite the far distance between Turtle Dove as an Afro-Palearctic migrant bird and austral migrant birds in America, the reason pushing these species could be the same. In American austral birds, especially migrant shorebirds, the lack of sufficient food resources to accumulate fat reserves (fuel for birds during migration) prevents these birds to complete their journeys to wintering habitats (Dingle 2008). This explanation could be applied on Turtle doves, particularly this game suffers from a lack of food resources in both breeding and wintering zones (Dunn et al 2018). This negative effect reduce survival of Turtle doves, including

breeding success and migration capacities (Eraud et al 2009). Therefore, as a direct and possible response, Turtle doves may limit their journeys to the first fertile and warm habitats encountered in their routes, such results were found in white stork, Ciconia ciconia, which recently was reported to overwinter in Europe instead of Africa (Belabed et al 2019; Hanane 2017; Jagiello et al 2020). The wintering storks were grouped around rubbish dump of Montpellier in France for feeding (Archaux et al 2004; Blanco 1996).

1.5.Conclusion

Finally, because we found wintering Doves in North Africa, we prompt that After Breeding seasons, all Turtle dove populations coming from Europe and North Africa don't cross Sahara to habitual wintering grounds. Indeed, there is an urgent need to set up an integrated programme of long-term ecological monitoring in South European and North African farmlands, and to apply new technologies to understand this issue and adopt an integral conservation programmes that take in consideration wintering, stopover and breeding zones for this declining bird before irreversible point.

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SYNTHÈSE ET RECOMMANDATIONS

Tourterelle des bois entre l'Europe et l'Afrique

(Submitted to International journal of ecology 2021

Synthèse d'étude

Actuellement, un déclin global des oiseaux migrateurs est enregistré au sud et au nord du Paléarctique. La tourterelle des bois *Streptopelia turtur* est le bon exemple des oiseaux du Paléarctique qui a subi un déclin rapide et sévére dans ses aires de répartition africaine et européenne, elle est inscrite comme espèce vulnérable sur la liste rouge de l'Union internationale pour la conservation de la nature (l'UICN) en 2015. Dans cette étude, nous avons synthétisé une littérature scientifique, récemment disponible sur la tourterelle des bois en Afrique, comme voie d'hivernage, de reproduction et de migration, et en Europe, comme lieu de reproduction. De plus, nous avons discuté les connaissances existantes, en soulignant les lacunes dans les données disponibles et nous avons ainsi, proposé des recommandations des lignes directrices de recherche hautement prioritaires, et nous avons essayé de diriger et de collaborer plus efficacement les efforts de recherche pour encourager les stratégies de gestion intégrales et durables. En outre, nous avons pu souligner les urgences pour que les enquêtes futures se concentrent sur six domaines stratégiques, notamment la démographie, les performances de reproduction, les caractéristiques de migration, les activités de chasse, la génétique et les maladies parasitaires. La mise en place d'un programme intégré de surveillance écologique à long terme en Afrique et en Europe, ainsi que l'intégration de nouvelles technologies dans les programmes de surveillance, semble un besoin crucial. Ces programmes devraient être normalisés et intégrant les citoyens locaux, les agriculteurs et les chasseurs dans tous les pays le long de la trajectoire de migration des tourterelles pour produire des données comparables et synthétiques. La collaboration scientifique entre les instituts de recherche, entre l'Europe et l'Afrique à l'échelle internationale, et entre les pays du même continent à l'échelle régionale, devrait être coordonnée, afin de faciliter le partage des données, d'unifier les efforts de conservation et d'offrir une réponse rapide, entre les aires sources et le zones de destination.

Turtle dove *Streptopelia turtur* between Europe and Africa: A review of recent knowledge and urgencies for future research before getting the irreversible point

Abstract

Currently, an overall decline in Palearctic migrant birds has been recorded from South to the North of the Palearctic. The European Turtle-dove *Streptopelia turtur* is the brilliant example of the Palearctic birds that has undergone a rapid and grave decline across its African and European ranges, and it was listed as a vulnerable species on the IUCN Red List in 2015. In this review, we synthesise the scientific literature recently available on the Turtle dove in Africa as a wintering, breeding and migration routes, and Europe as a breeding quarters. Moreover, we discuss existing knowledge, highlight lacks in available data and recommend high-priority research guidelines, and attempting to direct and collaborate research efforts more effectively to encourage an integral and sustainable management strategies. Urgencies for future investigations are focused in six strategic fields, including demography, breeding performances, migration features, hunting activities, genetics and parasites diseases. Setting up an integrated programme of long-term ecological monitoring in both Africa and Europe, as well as integrating new technologies into monitoring programmes, is a crucial need. These programmes should be standardised and integrating local citizens, farmers and hunters in all countries along the migration trajectory of Turtle doves to produce a comparable data. Scientific collaboration among research institutions between Europe and Africa as an international scale, and between countries of the same continent as a régional scale, should be coordinated in order to facilitate data share, to unify conservation efforts and to offer a quick response between source and destiny quarters.

Key words: Africa, Europe, Turtle doves, conservation measures, collaboration.

1.1.Introduction

Populations of migratory bird species that winter in the Southern tropic grounds and breed in Northern temperate régions have suffered continued and often grave declines over the past half century (Baillie and Peach 1992, Beresford et al. 2018). An analysis of survey records from the bird species in Europe database (BirdLife International 2004a, Tucker and Heath 1994), for three decades between 1970 and 2000, has highlighted this severe decline (Fay et al. 2020, Haest et al. 2020, Sanderson et al. 2006), Over the last 30 years, 40% of 119 Afro-Palearctic migrant bird species (long-distance migrants that winter in sub-Saharan Africa and breed in Europe) showed significant decline in population trends. Furthermore, data of population trends between 1980 and 2009 from the Pan-European Common Bird Monitoring Scheme (PECBMS) indicate that of the 38 Afro-Palearctic migrants monitored by this scheme, 71% have declined mainly in abundance features (Husby et al. 2020, Vickery et al. 2014, Briedis et al. 2020). Moreover, this trend data from the PECBMS indicates that Afro-Palearctic migrants are experiencing greater rates of population decline estimated at 23%, compared to resident and short-distance migrants that lost only 7% of their population sizes in Europe (Briedis et al. 2020).

A variety of factors, including habitat degradation, nesting-sites loss, and unsustainable hunting activities on breeding grounds in Europe and North Africa, and the loss of staging areas in migratory flyways are likely to be inducing the declines (Newton 2006, Sanderson et al. 2006, Ockendon et al. 2014, Vickery et al. 2014). There is also proofs that reduced over-winter

survival in sub-Saharan Africa wintering quarters may be a contributing factor (Aloni et al. 2019).

The European Turtle-dove *Streptopeliat urtur* is an example of an Afro-Palearctic migrant that has undergone rapid and severe decline, mainly across its European ranges (Moreno-Zarate et al. 2020). It has been classified as a vulnerable species throughout Europe (Moreno-Zarate et al. 2020). Potential factors responsible for the species' decline, include modification of nesting habitats (Mansouri et al. 2020a), reduction in food resources in breeding zones (Browne and Aebischer 2003, Gutierrez-Galan et al. 2019) and in wintering grounds (Eraud et al. 2009), change in ecological conditions throughout the migration flyways (Browne and Aebischer 2001, Eraud et al. 2009) and unsustainable hunting (Boutin 2001).

Two different subspecies are classified: *S. t. turtur* in Europe and *S. t. arenicola* in Northwest Africa (Hanane 2017). Both subspecies have a granivorous diet (Mansouri et al. 2019) and are true migrants (Browne and Aebischer 2001). Studies on Turtle doves has focused principally on the European continents compared to the Africa where the species is a wintering (sub-Sahara), migrant and breeders (North Africa). Most literatures on both African and European Turtle doves have focused on breeding features (Browne and Aebischer 2004, Browne et al. 2005, Boukhemza-Zemmouri et al. 2008, Eraud et al. 2009, Hanane and Baamal 2011, Hanane 2012, 2014, 2015, 2016a, b, Kafi et al. 2015, Brahmia et al. 2015, Mansouri et al. 2020a, b), habitat use (Browne and Aebischer 2004, Browne et al. 2004, 2005, Bakaloudis et al. 2009, Dunn and Morris 2012, Dias et al. 2013, Buruaga et al. 2013, Yahiaoui et al. 2014, Dunn et al. 2017, Gruychev and Gradimir 2020, Moreno-Zarate et al. 2020, Tellería et al. 2020), foraging habitats (Browne and Aebischer 2003, Rocha and Quillfeldt 2015, Dunn et al. 2015, Gutiérrez-Galán and Alonso 2016, Gutierrez-Galan et al. 2019, Mansouri et al. 2019), and migration routes (Eraud et al. 2013, Marx et al. 2016, 2020, Lormee et al. 2016).

The objectives of this review paper are threefold. First, we summarise existing knowledge on the history, status, and bio-ecology of the Turtle dove in Europe and Africa. Second, we identify the most critical research lacks that need to be addressed in the future, according to the need of each quarter. Third, we propose a framework for developing an integrated research and monitoring over the coming years. The suggestions will help to collaborate and orient scientific research to address Turtle dove conservation issues on both the régional and intercontinental scales, since the species is a long-distance migrant.

1.2.Current knowledge

1.2.1 Comparison of scientific research on the Turtle dove Between Africa and Europe

Despite the importance of Africa as a wintering and breeding zone for Turtle doves, only four countries were involved in scientific research, while in the Europe where the game is only a breeder, 10 countries were involved in researches (Table 23). In addition, 39 peer reviewed papers have cited the Turtle dove in Africa, compared with 44 papers in Europe. In parallel, 10 studies have cited this game in both Europe and Africa as a trans-border researches.

In Africa, studies have addressed four key topics of Turtle doves: Breeding biology (58.97%), ecology (25.64%), geography range (10.25%) and population demography (2.56%). On the other side, In Europe, ecology (56.81%), geography range (22.72%), biology (13.63%), genetic (2.27) and hunting (2.27) were the principal addressed topics. Ten papers have investigated migratory aspects, including flyways, stopover and wintering quarters between Europe and

Africa. The majority of these topics were studied in farmlands and agrosystems, counting orchards, groves and gardens, while the minority was investigated in wild and naturel habitats, including forests, rivers and wetlands.

Table 26: comparative synthesis of published papers on the Turtle-dove *Streptopelia turtur* between Africa and Europe.

Continent	Country	Principal Topic	References
Africa	Morocco	Breeding biology	(Hanane and Maghnouj 2005, Hanane and Baamal 2011, Hanane and Besnard 2014). (Cherkaoui et al. 2007, Hanane 2009, 2010, 2012, 2014, 2016a, b, Mansouri et al. 2020a, b).
		Ecology	(Hanane and Baamal 2011, Hanane 2018, Mansouri et al. 2019)
		Demography	(Hanane 2017)
		Distribution	(Thevenot et al. 2003, Hanane et al. 2019)
	Algeria	Breeding biology	(Boukhemza-Zemmouri et al. 2008, Belabed et al. 2012, Absi et al. 2015, Kafi et al. 2015, Brahmia et al. 2015, Nasrine et al. 2020)
		Distribution	(Yahiaoui et al. 2014, Chedad et al. 2020)
		Ecology	(Benamane et al. 2019, Bakour and Moulaï 2019)
	Senegal	Ecology	(Morel and Morel 1979, Morel 1985, 1986, Jarry and Baillon 1991)
	Guinée	Ecology	(Morel and Morel 1988)
Europe	Spain	Distribution	(Sáenz et al. 2012, Buruaga et al. 2013, Moreno-Zarate et al. 2020)
		Ecology	(Jiminez et al. 1992, Rocha and Hidalgo 2001, Camarero and de Trucios 2002, Rocha et al. 2006, Hidalgo de Trucios and author 2007, Rodríguez-Turienzo et al. 2010, Rocha and Quillfeldt 2015, Gutiérrez-Galán and Alonso 2016, Gutierrez-Galan et al. 2019)
		Biology	(Peiro 1990)
	Portugal	Distribution	(Dias et al. 2013)
		Ecology	(Dias and Fontoura 1996)
	France	Ecology	(Devort et al. 1988, Eraud et al. 2009)
		Biology	(Hermant and Frochot 1997, Bakaloudis et al. 2009)
	Italy	Distribution	(Marx et al. 2020, Chiatante et al. 2020)
	Greece	Distribution	(Bakaloudis et al. 2009)
	Germany	Distribution	(Kleemann and Quillfeldt 2014, Marx and Quillfeldt 2018)
		Genetic	(Calderon et al. 2016)
	Malta	Hunting	(Gruychev and Gradimir 2020, Caruana-Galizia et al 2016)

	Bulgaria	Biology	(Gruychev 2017)
		Distribution	(Gruychev and Gradimir 2020)
	Hungary	Migration	(Bankovics 2001)
	Britain	Biology	(Browne and Aebischer 2004, Dunn et al. 2017)
		Ecology	(Lofts et al. 1967, Murton 1968, Browne and Aebischer 2001, 2003, 2004, Browne et al. 2005, Dunn and Morris 2012, Stockdale et al. 2014, Dunn et al. 2015, 2018)
Africa and Europe		Migration	(Hahn 2020, Marcolli and Maggini 2019, Eraud et al. 2009, 2013, Marx et al. 2016, 2020, Lormee et al. 2016, Cabodevilla et al. 2018, Tellería et al. 2020)

1.2.2 Population size and declining

Evaluation of Turtle dove population size and trend are a crucial component of any status assessment and indicate the urgency of any conservation requirements (Assandri et al. 2019). Despite its wide geographic ranges in Europe, extending from Spain in South to the Urals in north (Cramp 1985), Turtle dove abundance has been found to decrease regularly. In England the population declined by 94% from 1995 to 2016 (Harris et al., 2018), in France numbers fell by 48% between 1989 and 2015 (Comolet-Tirman et al. 2015), and in Spain the population declined by 37% between 1996 and 2018 (Moreno-Zarate et al. 2020). The rest of European populations of Turtle doves have not been estimated yet. In Africa the population size remains unclear. On the contrary, population of Turtle doves in Africa are less studied; only one area, at Tadla Central Morocco, have been a subject of population estimation without any information on declining status (Hanane and Besnard 2014). This comparison shows a lack of cooperative investigations on demography and population trends of Turtle doves between Europe and Africa.

1.2.3 Breeding success

(Hanane and Maghnouj 2005, Hanane 2016a, Mansouri et al. 2020b)In Europe, Breeding performance of Turtle doves is widely investigated from seventies of last century, especially in Britain where Doves are in rapid decline (Browne and Aebischer 2004, Browne et al. 2005, Marx et al. 2020). While in Africa, until recently, little was known about the breeding parameters of Turtle-doves in African grounds. In last decade, this situation was inversed, more than 15 papers have investigated breeding success of Doves (Hanane 2017, Mansouri et al. 2020b). In term of comparison, reproductive success varies between continents. In Europe, breeding success vary from 38% to 41.3% in Britain (Browne and Aebischer 2004, Browne et al. 2005), between 36% and 58% in Spain (PEIRÓ 1990), while data of other European populations are inexistent. In Africa, the breeding success is higher and similar between countries, particularly in North Africa. In Morocco, average breeding success is between 41% to 60.15% (Hanane and Maghnouj 2005, Hanane 2016b, Mansouri et al. 2020b), in Algeria the rate vary between 56% a 59% (Absi et al. 2015, Kafi et al. 2015), while data from other African breeding quarters is inexistent.

1.2.4 Main failure factors

In both continent, failures of clutches in Turtle doves were attributed to different factors. In Europe, including Britain and Spain where Turtle doves were heavily investigated, before the intensification of agriculture, failure factors were mainly predation and nest desertion (Lofts et al. 1967, Peiro 1990), but recently, an analysis of CBC data between 1965 and 1995 concluded that breeding and feeding habitats loss was limiting Turtle Dove distribution, abundance and survival in the majority of European grounds (Browne and Aebischer 2004, Browne et al. 2004, Busch et al. 2020, Howard et al. 2020), (Aebischer 2002). In Spain, beside the effect of agriculture, the hunting activity during summer causes a loss of 800.000 to 900.000 birds annually which is the highest hunting quotas in the world.

In Africa, mainly in Morocco as in Algeria, more than half of nest failures were attributed to nest desertion (Hanane and Maghnouj 2005, Boukhemza-Zemmouri et al. 2008, Hanane and Baamal 2011). These high proportions of desertion are perhaps driven by human disturbance associated with agricultural practices, such as tree pruning, fruit picking, pesticide application and ploughing between the lines of fruit trees (Hanane and Baamal 2011, Hanane 2016a, b). Recently, a deep analysis of breeding success of Turtle doves in North Africa between 2015 and 2019 revealed that the predation and nest desertion are becoming a major threats to Turtle dove nests in North Africa and causing loss of 21% and 10.54% of clutches respectively (Mansouri et al. 2020a, b). From this comparison we conclude that in both African and European grounds, Turtle doves suffer from agricultural and predation with different degrees depending on the nature of breeding habitats.

1.2.5 Other threatening factors

Recently, with use of new technologies to monitor Turtle doves from breeding habitats, in North Europe, to African sub-Saharan wintering grounds in South, researchers have revealed a news factors that influencing the survival of this valuable game (Eraud et al. 2013, Lormee et al. 2016). In African wintering quarters (Mali, Niger, Mauritania and Senegal), the environmental condition, principally the lack of rainfall causes a reduction of cereal production which influences negatively wintering survival and migration capabilities of Turtle doves, since this game relies on cereal seeds as a main food sources to face hard wintering conditions (MOREL 1985, Jarry and Baillon 1991, Eraud et al. 2009) and as a fuel to travel thousands of kilomêtres between wintering quarters and breeding zones (Eraud et al. 2013, Arlt et al. 2015). In their way back to breeding grounds Turtle Doves need to refuel after crossing the Sahara desert (Eraud et al. 2009, 2013). Four stopover sites were found in their migration routes, including one site in Spain, two sites in Morocco, and two staging sites in Both Algeria and Mauritania (Eraud et al. 2013). However, with desertification in South (Morocco, Mauritania and Algeria) (Huang et al. 2020) and reduction of cereals in North (Spain) (Fajardo et al. 2020), the stopover grounds risk to unsatisfied migratory Doves in term of water and nutrients, which are the crucial elements for their migration efforts during the longue journeys.

Currently, a detailed analysis of nest-niche in Turtle doves have mentioned a critical results. The wide expansion of Laughing dove *Streptopelia senegalensis* distribution throughout Morocco has raised a negative effects on native species, particularly Turtle doves S. turtur (Hanane 2015). As results, Turtle doves select breeding habitats far from this invasive species, in order to avoid any potential competition. Nonetheless, with its great adaptive and competitive behaviour, the continuous expansion of Laughing dove risk to dominate breeding

and feeding resources available for Turtle dove, and causing the asphyxia of our threatened game, especially if we know that the invasive species are considered to be among the top five drivers altering global biodiversity (Sala et al. 2000, Duncan et al. 2003, Gurevitch and Padilla 2004, Didham et al. 2005). Such result was demonstrated in the Eurasian collared-dove *Streptopelia decaocto*, which have dominated breeding habitats in both North America and Europe instead of native birds (Eraud et al. 2007, Bonter et al. 2010). Consequently, with reduction and degradation of Turtle dove's habitats and colonisation of the rest of sites by invasive species declining rhythms are probably to be the highest.

1.3.Priorities in future research directions

1.3.1. Demographic research

With absence of information on population size in North African, determining spatiotemporal variation of Turtle doves is of vital importance to improve our understanding of the population dynamics in this axial area in migration, in staging, and in breeding (Hanane and Besnard 2014). Launching and a long-term and sustainable data collection procedure through a monitoring network, involving researchers and local population of farmers, hunters and non-governmental organisations, from both Europe and Africa, has to be the "key urgency" for future research and conservation programmes. This network should focus on abundance estimation in agrosystems and wooded landscapes. The advantages in setting up a monitoring network is to determine how Turtle-doves size vary seasonally and annually in wide ranges with different views from farmers, hunters, researchers to decision makers.

In Europe, the updating of previous results would be of great importance in term of knowledge and in term of the orientation of conservation measures. For example, the verification of hunting programs and laws in Spain that housing 2.4 million turtle dove every breeding season (Moreno-Zarate et al. 2020), will be urgent before getting the irreversible point as the case of Britain where Turtle doves become a rare bird (Lormee et al. 2016).

Finally, the collaboration between European and African efforts is needed, at least in exchanging of data and information annually, since the Turtle doves take départ from Sub-Sahara and stage in North Africa before getting Europe. Additionally, if Turtle dove is under different status of conservation between Europe and Africa, conservation efforts will be a loss of time and efforts.

1.3.2. Migration routes and wintering areas

In Europe, Turtle dove S. turtur migration aspects were heavily studied from 1960 to 2020 (Eraud et al. 2013, Marx et al. 2016, 2020, Lormee et al. 2016, Cabodevilla et al. 2018), (Karine et al. 2019). Migration routes (Spain-Morocco via the strait of Gibraltar, Italy-Tunisia via the Sardinian route, and Eurasian-African route via Turkey and Lebanon), Stopover sites (in Spain, Morocco, Algeria, and North Mauritania) and Wintering grounds (Malian-Mauritanian borders, Senegalian-Gambian Borders, Northern Ghana and Niger) were defined with maximum precision thanks to Geolocators and satellite telemetry (Eraud et al. 2013, Zuban et al. 2020). However, recently, many species using the same migration routes with European Turtle dove have changed their migration behaviour (Bókony et al. 2019, Howard et al. 2020). In this case, we mention the example of white stork, Ciconia ciconia, which was reported to overwinter at higher latitudes, closer to breeding grounds in Europe instead of Africa (Rotics et al. 2017). Since the climatic change and reduction of food availability in wintering grounds are the principal factors behind white stork new migration behaviour (Tortosa et al. 2002,

Berthold et al. 2002, Nevoux et al. 2008, Tobółka et al. 2015), the update of data concerning wintering and stopover sites of Doves is urgently needed, particularly for European population that lost 80 % of its size (Moreno-Zarate et al. 2020) and which is under the pressure of climatic change and reduction of food resources at both breeding and wintering quarters (Moreno-Zarate et al. 2020).

In North Africa, the data on migratory aspects of the local Turtle doves, *Streptopelia turtur* arenicola, are limited to the arrival and départure dates only (Mansouri et al. 2020b). Many interrogations remain unanswered, counting: (i) the main migratory routes of North African Doves, ii) the main staging sites, iii) and the principal wintering grounds. However, the important question is that do North African Doves use the same migratory routes and wintering grounds as the European sub-species? If so, the understanding of the stopover and wintering areas use would be a great key to clarify why European population is in extreme decline, while North African one is remain less influenced. Similarly, the conservation measures will be more effective if we take in consideration the entire migration trajectory of Doves from Europe to Africa thanks to the use of new technologies (Bairlein and Schaub 2009, Eraud et al. 2013, Kristensen et al. 2015, Lormee et al. 2016).

1.3.3. Breeding features

Breeding performance is an axial pillar in the continuity of Turtle doves. Breeding habitats provide the basic needs for breeding pairs and clutches (eggs and nestlings), including protection from human disturbance (Hanane 2012, Mansouri et al. 2020b), rough weather conditions (Sadoti 2008) and predators (Hatchwell et al. 1999) and offering necessary food sources (Wiehn and Korpimäki 1997). Therefore, identifying the environmental and ecological factors associated with breeding site selection, in both wild and artificial habitats, at diverse spatial scales: macro-habitat, including nesting sites and landscape features, as well as micro-habitat, counting nesting-tree, nest placement, and nesting plasticity, is therefore essential for determining high-priority protected areas. Such information is needed in Europe and Africa, in assessing the effects of predation and human disturbance on the productivity and abundance of Turtle-dove populations.

In both Europe and Africa, the predation and nest desertion has been noticed as the major factors that threatening the breeding performance of Turtle doves (Hanane and Maghnouj 2005, Moreno-Zarate et al. 2020, Mansouri et al. 2020b). For these reasons, it is urgently needed to identify the causes, mainly agricultural activities, leading to nest predation and desertion, in order to reduce their impact on breeding success. It would therefore be important to investigate, for instance, which agricultural practices are highly influencing breeding performances of Doves, and how these activities are impacting the critical stages of breeding season. On the other hand, the research for favourable breeding habitats far from the farmlands will be as a new gate to build an effective conservation measures (Boutin 2001), particularly if these new sites would offer the necessary requirement for Turtle dove recovery in countries such as Britain where the species is becoming rare (Deborah et al. 2020).

1.3.4. Hunting

Hunting, especially unsustainable activity may threaten biodiversity of bird species (Leopold 1986, Caro et al. 2014). In Turtle doves, this activity is less studied (Hanane 2017). The only case that have studied this activity was in Spain, but limited to the age ratio of killed Doves (Rocha and Quillfeldt 2015). In Britain and Northern Europe, Turtle doves are note a hunted

game, but in Italy, Greece and Turkey, despite the being listed as a valuable game, the data on killed birds and their impact on the trend of the species is inexistent. The same, in African ranges, Turtle doves are killed every summer in Morocco, Algeria and Tunisia silently without any official data. Therefore, the collection of data concerning number of killed Doves, particularly in countries located in migration routes (Spain Morocco, Malta and Turkey), is essential in conservation efforts. Furthermore, the examining of the hunting activity impact on demography of Turtle doves, in both wintering and breeding quarters, is thus essential to quantifying the detailed effect of hunting on spatio-temporal trends, on population size, and to ensure effective management.

1.3.5. Genetic and Disease Research

Two subspecies of Turtle-dove are interesting; S. t. arenicola which breeds in Northwest Africa and S. t. turtur which nests in Europe and occur in Northwest Africa as a migratory bird (Hanane 2017). However, under the influence of both global changes and anthropogenic landscape modification, it is possible that the distributions of the two local subspecies are shifting. No comparative genetic research has been conducted on the Northwest African Doves, while the European subspecies was analysed at wide range, from Spain in the West to the Turkey in the East (Calderon et al. 2016). This study suggests that the variations in the genetic structure of the European Turtle doves are coincident with recent changes in the availability of suitable habitat. Thus, the use of genetic analysis will give an historical view of the entire population of Turtle doves and will assess the ecological factors, including population connectivity and migration, between Europe and Africa in order to jointly adopt an effective conservation effort on the most game changer régions.

In term of disease, domesticated and wild bird species are among the taxa that are highly affected by various maladies (Grimaldi et al. 2015). Similarly, Turtle doves are infected mainly by Trichomonas tenax, Tetratrichomonas canistomae, Trichomonas gallinae, which cause the mortality of adults and chicks, without any quantification of their impact on breeding success or population size (Lennon et al. 2013, Stockdale et al. 2014, Martínez-Herrero et al. 2017). For these reasons, studying the sources and the impact of parasitic diseases on breeding performances is of great importance, in all countries frequented by Turtle-doves. Comparing the prevalence levels of different parasitic diseases between the European and Northwest African subspecies would constitute another level of understanding differences in population dynamics.

1.4.Recommendation for an effective conservation measures

Synchronising research efforts among countries and continents frequented by Turtle doves is recommended to optimise conservation approaches. In Europe, programmes of scientific monitoring of migratory birds are well-established (e.g. http://www.ebcc.info/pecbm.html, French ACT programme, Spanish SACRE programme). Despite the importance of Africa as a wintering grounds (Sub-Sahara) and as a stopover zone (North Africa) for the populations of migratory birds that get the European continent, no similar network exists. In the future, setting up a solid scientific monitoring scheme linking between Europe and Africa and standardising methodological approaches, would benefit not just the Turtle-dove but also other migrant species as well as resident birds. Such network, would offer a comprehensive data on abundance, used habitats, predators, food supplies, climatic influences, and menacing factors, which will help implement an effective management strategy regarding Sub-Sahara as a

wintering lands, North Africa as a migratory routes and/or breeding sites and Europe as a Northern Breeding quarters. Moreover, this kind of integral network would help in the attenuation of contagious diseases that use birds as a vectors because of their capacity for long-range movement, mainly zoonotic pathogens and viruses (Brinkerhoff et al. 2009, Folly et al. 2020), which were isolated from Turtle doves and other migratory species (Lennon et al. 2013, Stockdale et al. 2014, Martínez-Herrero et al. 2017).

1.5.Conclusion

This review paper provides a comparative synthesis of the current state of knowledge on the Turtle-dove, the threatened columbidae species in both European and African continents. It highlights the main achievement scientific research, as well as priority areas for future research to assist in the conservation of Turtle doves. As climate change and landscape modification evolution, scientific vigilance is required to maintain not only Turtle doves but also biodiversity. Indeed, there is a serious need to set up an integral programme of long-term bio-ecological and ethological monitoring in both African and European farmlands, wetlands and forests, with benefit of new technologies to address all frequented area.

This approach will enable researchers, local citizens and policymakers: i) to assess the central ecosystems for the maintenance of Turtle dove and other threatened species, ii) to identify population trends of species and set up the adequate conservation status, and iii) to quantify the impact of human activities on habitat features, breeding performance and population size of species of conservation concern. This approach necessitates the existence, on an intercontinental scale, of networks for monitoring Afro-Euro-Palearctic migrant bird populations. Finally, the role of scientific investigation in providing an evidence base for conservation measures is of paramount importance. Scientific partnership among researchers, both at régional, such as Northwest Africa, and at international scales, such as between Europe and Africa, is to be encouraged and supported in order to share knowledge, skills and techniques.

1.6.References

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DISCUSSION GÉNÉRALE

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1. Biologie de reproduction

1.1.Nidification dans les vergers de pommiers

La nidification de la tourterelle des bois a été largement discutée. Ainsi, dans notre étude, nous avons montré que pour la nidification les tourterelles des bois (*Streptopelia turtur arnicola*) choisissent les habitats de hautes altitudes, au niveau de la haute Moulouya. Ceci est paradoxal avec les études insistantes sur la reproduction de la tourterelle dans les zones á basses altitudes (Browne *et al.*, 2004 ; Hanane, 2017). Au niveau de Midelt, la tourterelle des bois construit ses nids essentiellement, sur les pommiers qui assurent le support des pontes. L'usage des pieds de pommiers, comme arbres fruitiers, confirme l'importance des écosystèmes agricoles, en particulier arboricole pour ce colombidé, durant la nidification (Kafi *et al.,* 2015). Dans le même sens, la colonisation des vergers de pommiers dans la haute Moulouya est supposée d'être due à leur abondance dans la région et leur emplacement près des surfaces céréalières et les fluents d'Oued Moulouya, importants pour l'alimentation des adultes et des poussins. Ceci est confirmé par le taux du succèss reproductif de l'espèce dans les vergers de pommiers qui dépasse les 57.83% de pontes. Ces resultats sont semblables a ceux rapportés dans les habitats de basses altitudes par de nombreux auteurs au Maroc (Hanane, 2012 ; 2016) et en Algérie (Boukhemza-Zemmouri *et al.,* 2008 ; Kafi *et al.,* 2015), et témoigne de l'importance des vergers de pommiers dans la réussite de la reproduction de l'espèce dans les hautes altitudes.

La tourterelle des bois construit ses nids à des niveaux bien determinés de l'arbre á une hauteur moyenne de 281.4±10.9 cm, éloignés du centre de l'arbre et de la frange inférieure, par une distance moyenne de 197.0±9.63 cm et 123.7±8.18 cm respectivement. Concernant les grandeurs, les nids sont caractérisés par un grand axe d'une moyenne de 16.5±0.25 cm et un petit axe de 13.01±0.26 cm. L'épaisseur moyenne du nid étant de 4.6±0.15 cm. Nos résultats, portant sur l'emplacement et les dimensions des nids, diffèrent de ceux signalés par Hanane (2009) sur les oliviers de Tadla au niveau du Maroc Central et par Boukhriss *et al.,* (2009) sur les oasis Tunisiens, notamment la hauteur des nids ; élément important pour la réussite des pontes. En effet, ces travaux soulignent que ce gibier construit ses nids à une hauteur d'environ 250 cm au niveau des oliviers de Tadla et à 258 cm au niveau des oliviers des oasis Tunisiens, en comparaison avec nos résultats (281.42±10.9 cm) au niveau des pommiers dans la présente étude. Ce choix de la position des nids à une hauteur importante au niveau des pommiers, vise probablement la protection de la progéniture contre les prédateurs. Ces derniers constituent une menace très importante pour les pontes de la tourterelle des bois.

1.2.Chronologie de la reproduction

Après la migration prénuptiale, les premières tourterelles des bois arrivent aux sites de reproduction dans la région de Midelt, vers la fin du mois de mars. Les premieres arrivées s'effectuent individuellement, par couples, puis par groupes. Après l'installation au niveau des vergers du pommier, la tourterelle des bois commence la construction de son nid vers la fin du mois d'avril et la nidification continue, jusqu'à la première semaine du mois d'août. Ensuite,

la ponte des œufs débute vers la fin du mois d'avril et continue jusqu'a début du mois d'août. L'éclosion et l'envol des poussins commencent la mi-mai et le début du mois de juin respectivement. Nos résultats diffèrent de ceux des habitats de basses altitudes ; dans la région de Tadla (514 m d'altitude), les premières tourterelles arrivent tôt vers le 19 mars (Veen *et al.,* 2010, Mansouri *et al.,* 2019), dans la région de l'Haouz (452 m d'altitude), les individus arrivent entre 15 et 16 du mois de mars (Browne *et al.,* 2005), et dans les côtes Atlantiques au nord du Royaume (100 m d'altitude), les tourterelles arrivent 24 mars (Belabed *et al.,* 2012). Aussi, les dates de nidification et de ponte varient respectivement entre 23 mars et 10 avril, dans ces habitats de basses altitudes (100 à 600 m). Par conséquent, malgré la limitation de cette étude à un site de haute altitude, la littérature citée, confirme que les dates d'arrivée et de chronologie de reproduction sont plus tardives dans les zones de reproduction de haute altitude à Midelt. Ce retard peut être dû aux effets des conditions de l'habitat, notamment l'altitude et le climat froid de la région de Midelt. De tels résultats sont mentionnés chez de nombreux autres oiseaux migrateurs (Olsen and Olsen, 1989 ; Brahmia *et al.,* 2015). Par exemple, chez l'hirondelle rustique (*Hirundo rustica*), les dates d'arrivée varient du 12 avril dans les zones á basse altitude (110 m) au 24 avril dans les zone à 760 m d'altitude (Bradley et al., 1997). De plus, les basses températures conduisentt à la mortalité des œufs et les poussins chez les oiseaux. Donc, il semble que la tourterelle des bois évite ces conditions vigoureuses, sous la montagne de Jbel Ayachi par le retard de la saison de reproduction.

1.2.1 Facteurs influençant la reproduction

La reproduction de la tourterelle des bois au niveau de la haute Moulouya est influencée par les conditions de l'habitat et les activités agricoles. Les facteurs environnementaux, notamment les fortes précipitations, les chutes de températures et les hautes altitudes retardent la chronologie des pontes chez la tourterelle des bois dans la région d'étude. Ceci est en accord avec des études récentes sur les populations aviaires, au niveau des hautes altitudes (Dunn and Morris, 2012). En effet, les hautes altitudes sont caractérisées par des fortes précipitations et des chutes de températures qui obligent les oiseaux migrateurs à reporter leur chronologie de reproduction vers les périodes les plus chaudes de l'année, afin d'assurer l'optimum du succèss reproductif.

Les activités agricoles, au niveau des vergers de pommiers, influencent les stratégies de nidification chez la tourterelle des bois. Durant la saison de reproduction, les nids sont construits uniquement dans les vergers non-couverts de filets de grêle et sur les arbres taillés de Starking délicious. Le choix des vergers non-couverts de filets peut être dû aux barrieres physiques que forment ces filets pour l'accès aux vergers. En effet, les filets de grêle et d'exclusion limitent l'accès de la faune de grande taille et des insectes respectivement (Olimpi *et al.,* 2020). Concernant le taillage des arbres, la préférence des pieds taillés de pommiers, comme support des nids, est due aux brindilles résultantes de taillage des arbres. Le taillage des pommiers élimine les brindilles qui forment un obstacle pour la nidification et offre ces dernières, comme matériaux pour la construction des nids.

Parallèlement, les nids de la tourterelle des bois sont menacés par les prédateurs et l'abandon. La prédation cause la perte de 18.89% des œufs et 10.54% des poussins, tandis que la désertion

des nids cause la perte de 4.41% des œufs et 4.39% des poussins respectivement. Dans les vergers d'olivier et d'orangeraie, (Hanane and Baamal, 2011) ont mentionné que la désertion des nids est le principal facteur causant la perte des nids (45 à 63.3% des nids). Ceci contredit nos résultats supportant la perte des nids à cause des prédateurs. La différence des facteurs d'échec entre la présente étude et celles de certains auteurs (Hanane and Baamal, 2011 ; Hanane, 2017) est supposée être le type d'habitat et les pratiques agricoles y associées. Les vergers d'olivier et d'orangeraie sont caractérisés par le taillage des arbres et les traitements phytosanitaires en coïncidence avec la construction des nids de la tourterelle des bois (Hanane et Baamal, 2011) ce qui conduit au dérangement des couples reproducteurs et la désertion des nids. Par contre, à Midelt l'abondance des prédateurs, notamment les reptiles et les mammifères entrainent des pertes énormes au niveau des pontes et par conséquence, ils provoquent le desert des nids.

2. Ecologie de la tourterelle des bois

2.1 Habitats de nourrissage et régime alimentaire

La présente étude montre que la tourterelle des bois fréquente une variété d'habitats dans la haute Moulouya pour répondre á ses besoins alimentaires. En effet, les tourterelles sont rencontrées dans les parcelles de céréales, de luzernes, dans les vergers de pommier et les habitats riverains avec alternance, durant la saison de reproduction. Avec la dégradation et la modification des habitats naturels, communément utilisés par les tourterelles, la diversité des habitats de nourrissage, y compris les parcelles agricoles et les habitats sauvages et plus particulièrement, l'alternance de consultation de ces sites réduisent l'impact de la réduction des sites naturels. L'ensemble de ces stratégies est déjà mentionné chez d'autres espèces migratrices (Kirby *et al.,* 2008) qui diversifient les habitats d'alimentation pour faire face à la réduction des ressources et les sites de nourrissage (Abbas *et al.,* 2019). En outre, la variété des habitats de nourrissage est reflétée dans le régime alimentaire de la tourterelle des bois dans la zone de Midelt. L'analyse des jabots des tourterelles a révélé un régime diversifié avec une tendance granivore, ce qui est en accord avec la littérature, relative au comportement trophique de ce gibier (Gutiérrez-Galán and Alonso 2016, Gutierrez-Galan *et al.,* 2019), Cependant, les graines de sables consommées sont utilisées afin de broyer physiquement les graines de céréales. En plus, la consultation des habitats de nourrissage durant toute la journee (matin et soir) aide la tourterelle à conserver les réserves en eau de l'espèce, particulièrement durant les périodes les plus chaudes de la journée.

2.2 Habitats de nidification

Dans les zones de reproduction, seulement trois études ont concerné la niche écologique de la tourterelle des bois; la ségrégation des sites de nidification avec *Streptopelia senegalensis*, (Hanane, 2015 ; Hanane and Yassin, 2017) et *Columba palumbus* (Hanane, 2017), et la ségrégation des sites de nourrissage avec *Columba palumbus* (Murton, 1968). L'ensemble de ces travaux soulignent la ségrégation des habitats de la tourterelle des bois loin des autres espèces dans les sites de reproduction. Par contre, dans notre étude, au niveau des zones humides de la haute Moulouya, les tourterelles partagent les habitats de nidification avec sept

autres espèces, y compris les oiseaux sédentaires (Merle noir et Pouillot de bonelli) et migrateurs (pie grièche á tête rousse, rossignole philomèle et cigogne blanche). Ainsi, dans les zones intermédiaires et les avales des rivières, la tourterelle partage les arbres de nidification avec le Merle noire, la pie grièche a tête rousse et le pouillot de bonelli. Par conséquence, nos résultats confirment le comportement social de la tourterelle des bois par la cohabitation avec d'autres espèces d'oiseaux.

Les comportements du partage révelé dans la présente étude et de la ségrégation mentionée dans la littérature, des habitats de nidification entre la tourterelle des bois et d'autres espèces aviaires peuvent être contribués, principalement à la compétition intra et interspécifique. En effet, la ségrégation des sites de nidification entre la tourterelle des bois et les compétiteurs interspécifiques, y compris la tourterelle maillée et le pigeon ramier est contrôlée par la concurrence sévère entre ces colombidés characterisés par des niches écologiques et trophiques très proches (Hanane *et al.,* 2019). Donc, pour éviter la compétition entre ces concurrents qui utilisent les mêmes ressources, la ségrégation des sites de nidification permetterat d'assurer les besoins de chaque espèce, loin des ces concurents, sans perdre de l'énergie sur le comportement de compétition et d'antagonisme (Murton, 1968). Par contre, le partage des habitats de nidification entre la tourterelle connue par son régime granivore d'un côté et le merle noir, le pouillot de bonelli et la pie grièche á tête rousse connues pour leurs régimes alimentaires insectivores et leurs modes de vie différents d'un autre côté (Schnack, 1991), ne présente aucun risque de compétition ni pour les ressources alimentaires, ni pour les sites de nidification.

3. Ethologie de la tourterelle des bois

3.1 Parade nuptiale

Le suivi de la parade nuptiale chez la tourterelle des bois dans la haute Moulouya, durant la saison de reproduction a permis de définir, d'une manière qualitative et quantitative, le comportement sexuel de l'espèce. En effet, la parade nuptiale chez la tourterelle est caractérisée par deux expressions importantes, le langage acoustique reflété par les "roux" et le langage visuel exprimé par les "vols en arc". Cependant, les expressions acoustiques dominent la scène. Qualitativement, les appels vocaux sont plus importants que les vols durant la saison de reproduction et pendant la journée. Quantitativement, les séquences vocales durent plus que les séquences de vol. Ces résultats montrent que la tourterelle des bois combine le language acoustique et visuel, afin d'assurer la communication avec ses partenaires et ceci comme a été souligné chez d'autre espèces d'oiseaux (Ligon *et al.,* 2018). L'usage mutuel des deux langages a été mentionné aussi chez les espèces monogames des oiseaux chanteurs pour mieux diffuser les signaux et assurer l'attraction des femelles (Ota *et al.,* 2015). Cependant, durant la présente étude, les vols en arc sont plus efficaces dans l'attraction des femelles et la formation des couples. Il a été souligné que l'efficacité des vols, comme expressions corporels est due à leur capacité de montrer la qualité physique de l'émetteur (Penteriani *et al.,* 2007). En effet, ce comportement du vol permet à la femelle d'apprécier les capacités physiques et corporelles des mâles et par conséquence de prendre la décision de s'engager ou pas (Partan *et al.,* 2005). En outre, en présence des males compétiteurs dans le même site, l'émetteur augmente le nombre et la durée des expressions vocales et visuelles pour dominer le théâtre, comme ceci a été déjà

montré chez d'autres espèces d'oiseaux (Montgomerie et Thornhill, 1989 ; Carleial Rômulo *et al.,* 2020).

Les roux de la tourterelle des bois sont formés de plusieurs motifs (six), dont chacun est divisé en trois syllabes (initiation, intermédiaire et finition). Ceci confirme la complexité et la diversité des séquences vocales (Multimodal) dans l'objectif de saturer les canaux de signal chez la femelle. Des résultats communs étaient signalés chez le pinson zèbre (Spencer *et al.,* 2003) ou les mâles orientent leurs signaux vocaux complexes pour convaincre la femelle, notamment que la complexité des séquences vocales indique la qualité sexuelle des émetteurs et facilite le choix chez les femelles (Cooney Christopher *et al.,* 2018).

4. Migration et hivernage de la tourterelle au Nord-Ouest de l'Afrique

4.1 Dates de départ et d'arrivée

Dans l'objectif de déterminer le statut à grande échelle de la tourterelle des bois, nous avons mené un suivi des dates de migration au niveau de trois pays d'Afrique du Nord : le Maroc, l'Algérie et la Tunisie, comme habitats d'escale et de reproduction. Les résultats obtenus montrent que les tourterelles arrivent au niveau des sites de reproduction en Afrique du Nord, vers la fin du mois de mars. Cependant, l'espèce s'installe premièrement en Algérie et en Tunisie durant la premiere quinzaine de mars, par contre au Maroc, la date d'arrivée est enregistrée vers la fin du mois de mars. D'une manière générale, nos résultats sont similaires á ceux obtenus par certains auteurs dans les sites d'escale et de nidification au Nord de l'Afrique (Eraud *et al.,* 2009, 2013; Lormee *et al.,* 2016; Marx *et al.,* 2016). Au Maroc les tourterelles arrivent aux sites de nidification entre 15 et 20 mars (Hanane, 2009; Hanane & Maghnouj, 2005). En Algérie, certains auteurs ont souligné que les dates d'arrivée varient entre le mois de mars et le mois d'avril (Boukhemza-Zemmouri *et al.,* 2008; Chedad *et al.,* 2020; Kafi *et al.,* 2015). Cependant, Hanane et Baamal (2011) ont rapporté une arrivée précoce des tourterelles au Maroc par rapport à l'Algérie et la Tunisie, ce qui n'est pas en accord avec les résultats obtenus dans la présente étude, dont les individus sont observés en premier lieu, dans les sites Algériens et Tunisiens. La difference de 12 jours entre le Maroc et les autres pays est supposée être due à la différence des dates de départ des différentes vagues de migration dès les sites d'hivernage en Afrique subsaharienne et les périodes de repos dans les sites d'escales. Ceci, a été montré par l'usage des émetteurs satellitaires chez la tourterelle des bois (Eraud *et al.,* 2013 ; Marx *et al.,* 2016 ; Lormee *et al.,* 2016).

4.2 Habitats d'hivernage

Après l'accent mis sur l'hivernage des tourterelles des bois dans les zones d'Afrique subsaharienne, y compris le Mali, le Niger et le Sénégal (Jarry et Baillon, 1991 ; Eraud *et al.,* 2009, 2013), la présente étude a mis en évidence des résultats précieux concernant les sites d'hivernage au Nord-Ouest de l'Afrique. Durant notre étude, réalisée á grande échelle en Afrique du Nord, 72 individus hivernants ont été rencontrés sur six sites (trois au Maroc, deux en Algérie, et un en Tunisie). Ceci change le statut de la zone d'Afrique du Nord vers une zone d'escale, de reproduction et d'hivernage pour la tourterelle des bois. Ce nouveau statut de

migration peut être gouverné, principalement par la réduction des ressources alimentaires nécessaires pour confronter la difficulté et la distance de migration entre l'Europe et l'Afrique subsaharienne, alors que les conditions sont favorables dans les habitats du Nord de l'Afrique. En effet, dans le système de migration Austral reliant l'Amérique latine et l'Amérique du Nord, à cause de la réduction des ressources alimentaires, les oiseaux migrateurs, notamment les limicoles limitent leurs migrations aux premiers sites favorables dans l'Amérique du Nord, sans passage aux sites d'hivernages habituels (Chesser, 1994). Ainsi, récemment, les tourterelles des bois souffrent de la perte et la dégradation des habitats d'alimentation dans les aires de reproduction et d'hivernage. Ceci peut limiter les capacités migratoires des oiseaux, notamment les sub-adults, moins performants et par conséquence, ces individus choisisent de ne pas confronter les trajets passant par le Sahara. Concernant les conditions favorables, pour certaines espèces d'oiseaux, comme la cigogne blanche, à cause de la richesse des décharges Européennes en nutriments et l'augmentation des températures, des populations importantes hivernent dans ces sites qui répondent à leurs besoins écologiques en terme de nutrition et en terme de qualité écologique (Tortosa *et al.*, 2002 ; Rotics *et al.*, 2017). Dans le même sens, l'analyse des facteurs prédicteurs d'hivernage montre que les tourterelles hivernent dans des sites proches des zones humides, riches en eau, en nutriments et caractérisés par des climats tempérés et par de faibles précipitations entre octobre et février. Ces éléments répondent aux besoins de l'espèce, comme le font les sites au sud du Sahara (Lormee *et al.*, 2016). Donc l'hivernage de la tourterelle se fait dans des sites, dont leur qualité répond aux exigences de l'espèce et ceci peut être une alternative de bon choix aux sites sub-hariens.

CONCLUSION GENERALE ET PERSPECTIVES

CONCLUSION GENERALE

Par la présente étude nous avons pu apporter des élèments de réponse á de nombreuses questions qui se posent sur la biologie de reproduction, l'écologie, l'éthologie et la migration des vulnérables tourterelles des bois au Nord-Ouest de l'Afrique et plus particulièrement, dans les zones de hautes altitudes.

Le suivi de la tourterelle des bois dans la Haute Moulouya a montré que l'espèce colonise les sites de hautes altitudes. Dès leur arrivée aux sites, durant la troisième semaine du mois de mars, les tourterelles commencent la parade nuptiale par l'émission des appels vocaux et des vols en arc pour former les couples reproducteurs. La tourterelle combine les deux expressions, avec la dominance du langage acoustique dans les sites de reproduction, malgré l'efficacité des vols dans la rencontre des deux partenaires. Une fois les couples sont formés, la construction des nids et les pontes commencent globalement, vers la fin du mois de mars (entre le 26 et le 28 mars), alors que l'éclosion et l'envol des poussins commencent vers le 17 mai et le 3 juin respectivement.

Les vergers du pommier dans la zone de Midelt, par la présence d'eau (Oued Ansgmir) et leur entourage céréaliculture, offrent un habitat favorable pour la nidification et l'alimentation de la tourterelle des bois et pour sa progéniture. En effet, les nids sont rencontrés sur les deux variétés du pommier "*Starking delicious* et *Golden delicious"*, dominantes dans la zone d'étude et les tourterelles rejoignent les parcelles de céréales, de luzernes et les habitats riverains pour l'alimentation. Cependant, les pratiques agricoles, notamment l'usage des filets de grêle et d'exclusion constituent des contraintes pour l'espèce, elles limitent et s'opposent à la nidification dans les vergers couverts. En outre, l'attaque des pontes par des prédateurs dont, certains reptiles et notamment, les serpents et les faucons reste l'un des facteurs les plus menaçant pour la population de la tourterelle des bois. Ainsi, de cette étude, il ressort que les chutes de températures et les fortes précipitations qui régnent dans ces zones altitudinales, retardent la chronologie de reproduction de la tourterelle des bois dans les vergers de la Haute Moulouya pour réussir sa progéniture.

L'examen du régime alimentaire des individus étudiés montre que ces derniers se nourrissent sur des graines de cérèales (blé et orge), des escargots et des insectes. Cette diversification alimentaire permet á la tourterelle des bois de persister aux modifications et aux pertes des habitats de nourrissage. Au niveau des habitats la Haute Moulouya, la tourterelle des bois manifeste un comportement de partage de sites de nidification avec d'autres espèces, y compris les oiseaux migrateurs (exemple : la pie grièche á tête rousse) et sédentaires (exemple : le merle noir). En plus, dans notre étude, nous avons pu souliner que les supports de nidification sont partagés avec le merle noir "*Turdus merula"* et le pouillot de bonneli "*Phylloscopus bonelli"*. Ceci démontre un comportement social particulier chez la tourterelle dans la zone de Moulouya. En outre, des effectifs importants de la tourterelle des bois hivernent dans des sites de Boumia (Moyen Atlas), Ait Ayach (Haute Moulouya) et Dakhla (Sud du Maroc) et trois autres habitats au sud d'Algérie et le Sud-Ouest de la Tunisie. L'identification des sites

d’hivernage de la tourterelle des bois est d’un grand interêt dans la compréhension du comportement de migration et dans l’élaboration des stratégies de conservation de l’espèce.

De cette étude, il ressort qu’au lieu de pénétrer le Sahara vers les sites habituels d’hivernage, les tourterelles hivernent dans les premiers habitats favorables, en termes de nutrition et de conditions environnementales, au Nord-Ouest de l’Afrique.

PERSPECTIVES

Malgré l'importance de la présente étude dans les efforts du suivi et la conservation de la tourterelle des bois, différents aspects y compris la démographie, l'impact de la chasse, l'effet des changements climatiques, les trajets de migration et les facteurs menaçant l'éspèce nécessitent un suivi et une révision attentifs pour preserver ce gibier en déclin. Ainsi, l'application des nouvelles technologies, telles que les géolocalisateurs et les suivis par les Capteurs de géolocalisation (SGL), serait d'un grand intérêt dans la détérmination des profils migratoirs de l'éspèce, ainsi que pour l'identification des sites d'éscales et d'hivernage de l'espèce.

Cette étude bioécologique semble d'une grande importance dans la compréhension des nouveaux paramètres biologiques relatifs à la tourterelle des bois. Cependant, plusieurs autres aspects necessitent une recherche plus approfondie :

- Développer d'avantage le phénomène parasitaire des poussins et des adultes de la tourterelle des bois,
- Approfondir des études sur le comportement reproductif de l'éspèce, en utuilisant de nouveaux outils technologiques de précision,
- Etablir une carte de répartition géographique de la tourterelle des bois qui sera d'un grand intérêt dans la compréhension de l'écologie de cette éspèce.

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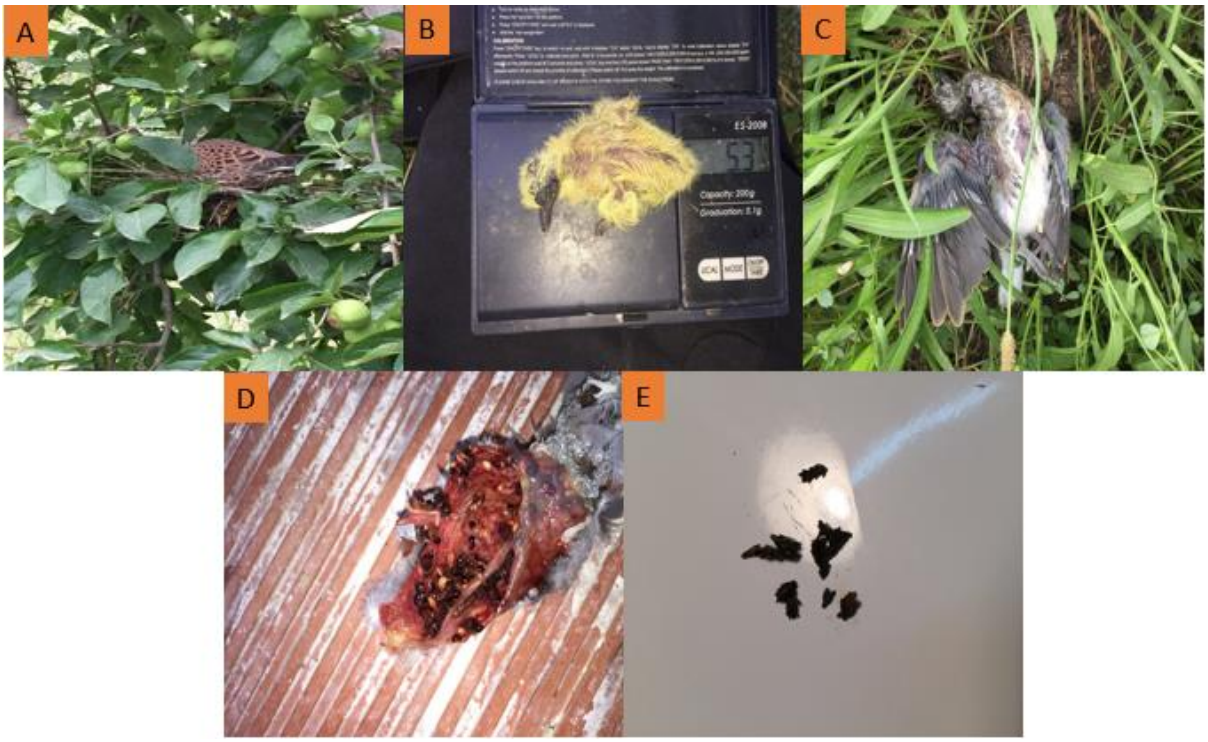
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ANNEXES



Annexe: A) La tourterelle des bois en couvaison; B) Poids du poussin après l'éclosion; C) Mortalité des poussins de la tourterelle des bois; D) Jabot de la tourterelle des bois; E) Contenu des jabots de la tourterelle des bois.