A journey fraught with dangers

THE MIGRATION ROUTE OF A DISAPPEARING SPECIES

Final Report

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Sovon

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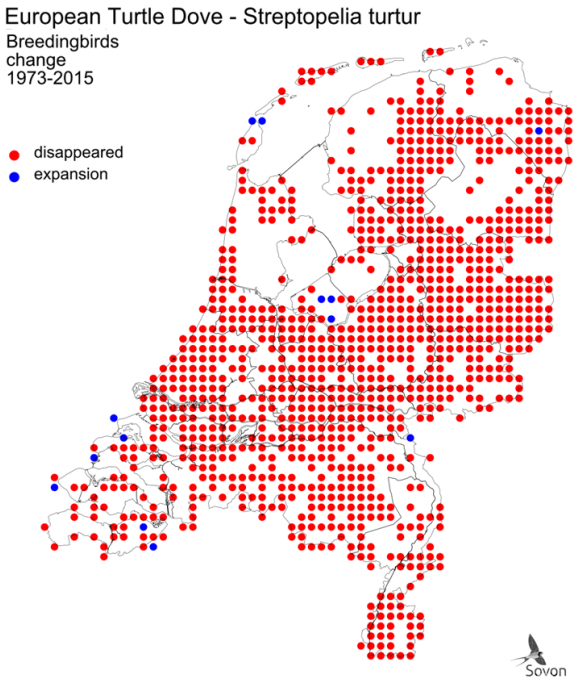
European Turtle Dove - Satellite Report

Background

Turtle doves are disappearing from our landscape. Since the 1970s, their population has plummeted by more than 85% in West Europe: the Netherlands has seen a 97% population decline. Once common in the Dutch countryside, European turtle doves have disappeared from most of the country, leaving just a few remaining strongholds in provinces such as Drenthe, Flevoland, Limburg and Zeeland.

Relatively little is known about the smallest dove in the Netherlands. Combined with their massive population decline, this has led to the compilation of an International Species Action Plan by the European Commission (completed May 2018). The decline of this migratory dove is a complex and international problem; habitat loss in both wintering and breeding areas, unsustainable (legal) hunting, illegal trapping and killing, and disease are all contributing factors to their decline.



Source: Sovon

The Action Plan identifies so-called 'Actions' that range states need to undertake in order to stabilise the population and, ultimately, reverse the decline. Among the objectives is the call to "Undertake studies to determine migration routes and key stopover/bottleneck areas in Western Europe, Eastern Europe and Central Asia" (Objective 7.1.1).

Migration studies of European turtle doves have taken place in several European countries over the last decade, including Germany, England, France and Spain. Since research began, turtle doves breeding in west Germany, England and France have been found to follow the so-called 'Western Flyway': through France and Spain, crossing the strait of Gibraltar into Morocco and then crossing the Sahara to their Sahel wintering grounds. With the ongoing advancements in telemetry technology, and increasing numbers of migratory studies being initiated, more is being discovered regarding the migratory behaviour of the European turtle dove.

Introduction

In 2020, the Netherlands joined the international effort to protect the European turtle dove on migration, with a group of organisations coming together and initiating the first Dutch migratory study for the species. This research has used the lightest telemetry technology on the market to follow the migration route of 2 European turtle doves breeding in Zeeland, the Netherlands. The aims of this study were two-fold:

1) To learn more about the migration route and timing of Dutch breeding turtle doves – their route, where they overwinter, key stopover areas, "bottlenecks" or vulnerable areas they encounter.
2) To raise public awareness – tagged individuals were to be used as a communication tool to reach the public and other researchers through blogs, radio, tv, articles, and with an online 'near real time' map.

Following the completion of this research, the results will be disseminated to the international European turtle dove research community and other interested organisations. The raw data will also be made public via Move Bank (www.movebank.org), whereby it can be used for further research purposes.

Method

Research into ETD ecology has been carried out in Zeeland, one of the populations remaining strongholds, since 2018. Zeeland had an estimated 136 territories in 2019 (Klootwijk, 2019) concentrated along the coast of Walcheren, west Zeeuws Vlaanderen and in Zuid-Beveland. A habitat use study in Zuid-Beveland (2018-2020) revealed that ETD territories required small-scale agricultural landscapes containing scrub, trees, water and grassland, and that their foraging behaviour was heavily influenced by farming activity.

On 13th June 2020, two European turtle doves were captured on Walcheren, using a bownet trap baited with seed. The doves were sexed in situ as a male and female based on plumage - later confirmed by DNA analysis of feathers. The doves, named 'Jos' and 'Jozien' and weighing 155 g and 144 g, were ringed and standard measurements (weight, wing, bill length and tarsus-toe) were recorded. They were then equipped with 2 g solar powered PTTs (Microwave Telemetry Inc. USA), attached using a full body harness of 2 mm Teflon ribbon - a non-(feather)-damaging material used in turtle dove research in Germany and Spain. The combined weight of the PTT, harness and metal identification ring weighed 2.7% and 3.0% of each bird's body mass respectively – below the 3% 'best practice' upper limit generally accepted in tracking studies. This research was approved under Article 10a from the 'Wet op de Dierproeven' (door Rijksuniversiteit Groningen). The doves were then released and data collection began immediately. Location fixes were taken via the ARGOS satellite system and processed by Collecte Localisation Satellites (CLS), creating a versatile csv file that could then be mapped in QGIS.

The PTTs used in this study transmit data continuously, rather than operating with the standard ON/OFF duty cycle. This enabled location fixes to be taken at irregular intervals, but much more frequently; recording only being limited by the solar rechargeable battery.

Satellite tags vary considerably in their location fix accuracy. To test this, the two project tags were both placed in a known location from 16/5/2020 7:28 (UTC) to 19/5/2020 18:21 (UTC). More than 200 fixes were taken during this time, with the average location fix accuracy of all points being 1.5 km. Theoretically, accuracy class 3 has the highest location accuracy, with class B being the least accurate, but it was evident from the results that this was not always the case (Table below). Of the collected data, 75% of location fixes were found to be within a 10 km radius. The range in individual location fix accuracy varied from 99 metres, to 46 km. Consequently, all location fixes have been used in this analysis, regardless of accuracy class, with the exception of 5 particularly aberrant locations.

Accuracy Class	Number of Location Fixes	Average Distance from actual tag location (km)
3	20	3.2
2	14	0.4
1	21	1.9
0	42	3.0
A	48	5.4
B	67	1.5
	TOTAL: 212 fixes	**AVERAGE DIST**: 1.5 km

Table: Accuracy test for 2 PTTs - 16/5/2020 7:28 (UTC) to 19/5/2020 18:21 (UTC

For the purposes of this project about ETD migration ecology, four annual phases were identified: breeding, wintering, autumn migration, and spring migration. Breeding phase was taken as Jos' first and last location fixes over his Dutch breeding area. The wintering phase was taken as the period between the day after Jos left his final stopover location (which was on the border of the Sahel), and the last date he was recorded on his wintering grounds before heading north in the spring. Stopovers, used for resting and refuelling during migration, were identified where Jos spent more than ca. 24 hours in a single area – indicated by 2 consecutive locations in the same area, recorded >24 hours apart.

While limitations in tag accuracy prevent the identification of a particular field or copse of trees, as the focus of Jos' stopover, wintering or breeding area, these locations possess multiple points which create a visual 'hotspot' of activity. Hotspots don't possess clear perimeters, but do provide insight into the landscape and area(s) where Jos spent most of his time.

Photo: Capture attempt in June 2020 (Jennifer Vreugdenhil)

Results: Overview

Turtle doves 'Jos' and 'Jozien' were captured together at a feeding station in Walcheren, Zeeland on June 13th, 2020. Of the two doves, only Jos could be followed on migration. His results are investigated in the following section in more detail. Contact with Jozien was unfortunately lost after 20 days.

Name	Jos	Jozien
Ring number	2518158	2518157
Sex	Male	Female
Weight upon Capture (g)	155.3	143.7
Wing length (mm)	182.0	176.0
Date tagged	13/06/2020	13/06/2020
Date of last position	30/08/2021	03/07/2020
Last location	Walcheren, Netherlands	Walcheren, Netherlands
Number of days followed	443	20
Total coordinates collected	2118	76

Table: An overview of the tagged doves and their data collection

Turtle Dove Jos: Results

Jos' location between 13/6/2020 and 30/08/2021 was plotted in QGIS. His migration route to the African Sahel and back to the Netherlands in the spring was a round trip of more than 9400 km.

Based on the distance travelled between Jos' location fixes in autumn, it was clear that he was migrating nocturnally: he began active migration bouts during the early evening and flew until early/mid-morning. Insufficient data was collected during spring migration to confirm whether this was also the case on his return journey. Jos appeared to travel very little during the day, probably staying in one area, although tag accuracy limitations prevent this from being confirmed.

Other tracking studies have also confirmed ETDs to be predominantly nocturnal migrants. English ETD 'Titan' appeared to be migrating at night (Requena 2019), and studies by Schumm et al (2021) and Lormée et al (2016) recorded more than three quarters of active migration locations at night. This was the case on both autumn and spring migrations.

The furthest Jos flew in a single night (18:11 to 11:13) was ca. 715 km (42 km/hr), when he crossed the Atlas Mountains to the edge of the Sahara. By comparison, English ETD Titan's longest flight reached 700 km, and his maximum speed recorded at 60 km/hr (Requena 2019). The average speed of French breeding ETDs was calculated as 52.6 km/hr during active migration (Lormée et al 2016), while an ETD who bred in Germany was found to have mean flight speeds of 45.7 km/hr during autumn and 50.7 km/hr during spring (Schumm et al 2021). ETDs appear to have similar active migration speeds on both post- and pre-breeding migrations (Schumm et al 2021).

For ETDs following the Western flyway, the Sahara poses the greatest ecological barrier en route, and their migration strategy here has been a subject of interest in recent tracking studies. ETDs are known to build up their fat reserves in their wintering grounds before embarking on spring migration (Morel and Roux 1973), which was thought to enable the doves to fly non-stop to southern Europe (Zwarts et al 2009; Eraud et al 2013). This was shown not to be the case when geologger tagged doves took 2.5 to 4 days to cross the Sahara; indicating that individuals were probably stopping somewhere during the crossing. A trip across the Algerian desert noted that ETDs would take shelter from the sun and wind in abandoned vehicles along the route (Haas 1974, from Zwarts et al 2009), and PTT research on French breeding ETDs showed an individual taking a 12-hour diurnal stop in the Sahara during spring (Lormée et al 2016).

Jos further supports the theory that ETDs take their time crossing the Sahara: he took nearly 35.75 hours to cross the Sahara in autumn (ca. 1121 km). Examination of the location fixes suggest he stopped to rest approximately half way – most likely during the day as observed previously in literature. This subsequently results in average speeds of 37.1 km/hr to 41.4 km/hr during his Sahara crossing.

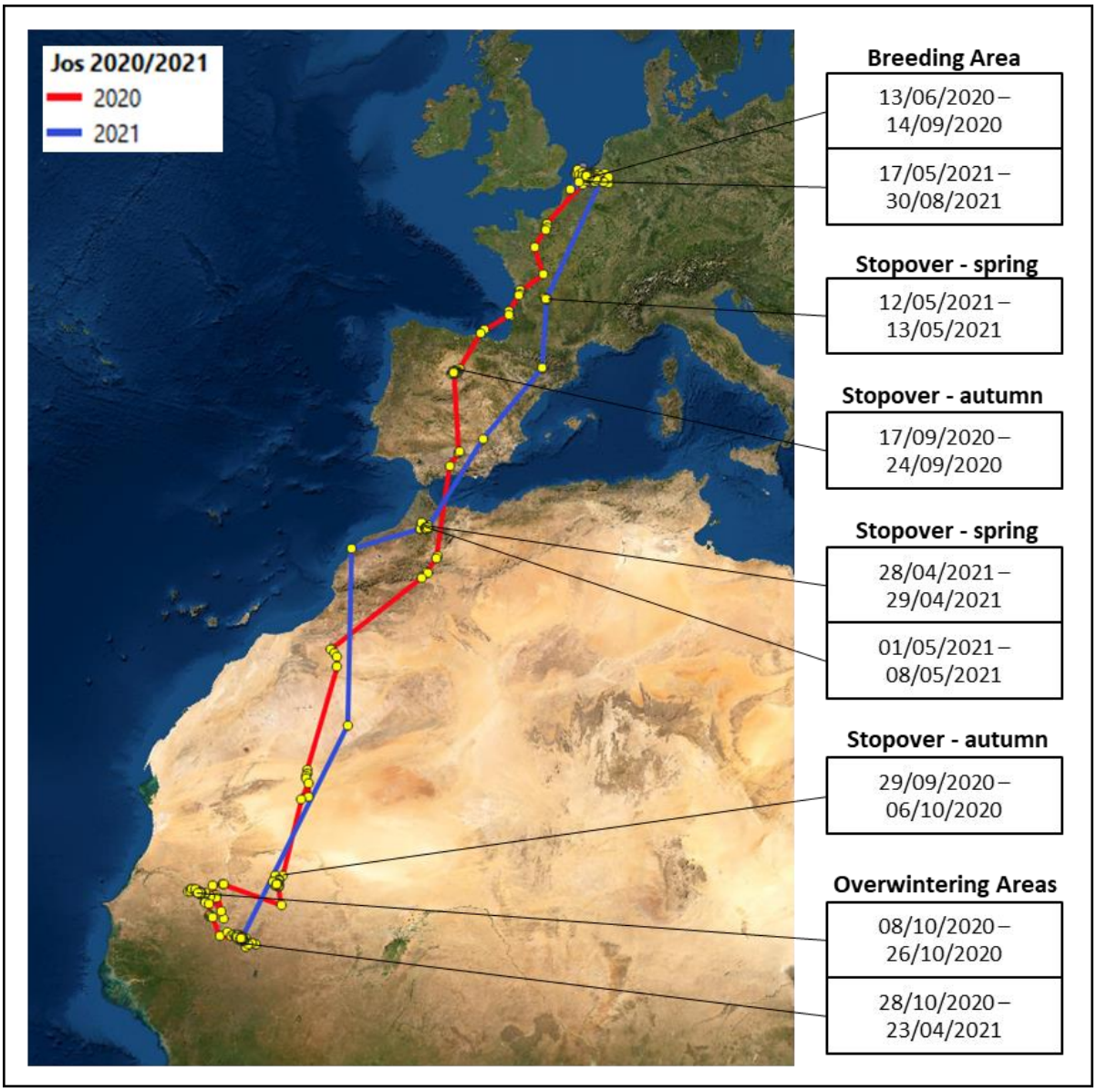


Image: Jos' locations and migration route between June 2020 and August 2021

Autumn 2020

Jos left Walcheren, Netherlands, on the 14th September 2020. He flew over Belgium and entered France on the night of the 14th September. Stopping during the day in Normandy and close to Bordeaux, Jos entered north Spain around midnight of the 16th. He arrived at his first staging site near Valladolid by late morning on the 17th, where he stayed for 7 days.

On the night of the 24th September, Jos continued through southern Spain, spending the 25th in an area 70 km north of Granada. He then flew over the (west) Mediterranean Sea and into Morocco, spending the 26th in the middle Atlas Mountains. He then flew down through Morocco and stopped for the 27th on the northern edge of the Sahara – at the border where Morocco meets Mauritania and Algeria. Jos crossed the Sahara in 36 hours – from 8.30pm on the 27th to 8.30am on the 29th September. It's unclear from his coordinates whether he took a break in the middle of the Sahara.

On the morning of the 29th, Jos arrived at his second staging site, Ayoun el Atrous, Mauritania, right on the edge of the Sahara. He stayed here for 8 days before moving on to his wintering areas in Senegal and Mali.

His journey from the Netherlands to Senegal took him a total of 22 days, including his two stopovers in central Spain and southern Mauritania.

Winter 2020/2021

Jos' overwintering period ran from the 7th October 2020 to the 23rd April 2021 – 199 days. He moved very little during the winter months – 98 % of his days were spent at wintering locations. He stayed in 3 different locations: first in the Senegal River Valley close to Kaédi, Mauritania, where he stayed from the 8th – 26th October 2020 (19 days). He then moved ca. 300 km southeast (upriver) and stayed at a further two locations east of Kayes in southwest Mali.

Spring 2021

Jos left his final wintering area in Mali on the evening of April 23rd 2021, but data recording was more irregular on Jos' return journey making it difficult to identify his precise movements on his migration north.

On the morning of the 26th, Jos was recorded in the middle of the Sahara, and on the 28th of April he stopped in Meknes, Morocco, for at least 24 hours. Jos then stayed in a farming area close to Fes, Morocco, in the middle Atlas Mountains for a period of at least 8 days (1st – 8th May). This was the only clear stopover identified in Jos' return journey.

On the 11th and 12th of May Jos flew over south Spain and up into France. He stayed at least 24 hours in 'Parc naturel regional Périgord-Limousin', Dordogne. His next coordinates, on the morning of the 17th May, showed him to be already back in the Netherlands, over Breda. By evening he had flown west and was over his breeding area in Walcheren.

His journey from the Sahel in Mali back to his breeding grounds in the Netherlands took him 23 days, including 3 stopovers in Morocco and France.

Turtle Dove Jos: Discussion

Stopover Areas

From the data collected by his transmitter, Jos seemed to be flying at night and resting in one place during the day. Therefore, stopover locations have been taken as areas where he stayed in one location for more than ca. 24 hours (i.e. where he did *not* fly during the night). Five stopover sites were identified.

When he was heading south to the Sahel, Jos spent 8 days in an area just south of Valladolid, Spain, and 8 days near Ayoun-El-Atrous, Mauritania. During his return journey to the Netherlands, he stopped for at least 8 days in an area close to Fes, Morocco. Fewer coordinates were recorded during his return journey, but the data suggests he also stopped briefly (1 to 3 days) in Meknes, Morocco and in Parc naturel regional Périgord-Limousin, France.

Valladolid, Spain

On the journey south, Jos stopped just south of Spanish city Valladolid. He stayed here for 8 days - from the 17th – 24th September. With the city to the north, and the forested area just south of his registered positions, Jos appeared to prefer the outskirts of the pine forest. The area has a mosaic of different land uses including farmland, villages and forest. Interestingly, although there are vineyards in the area, they do not seem to be present around Jos' staging site.

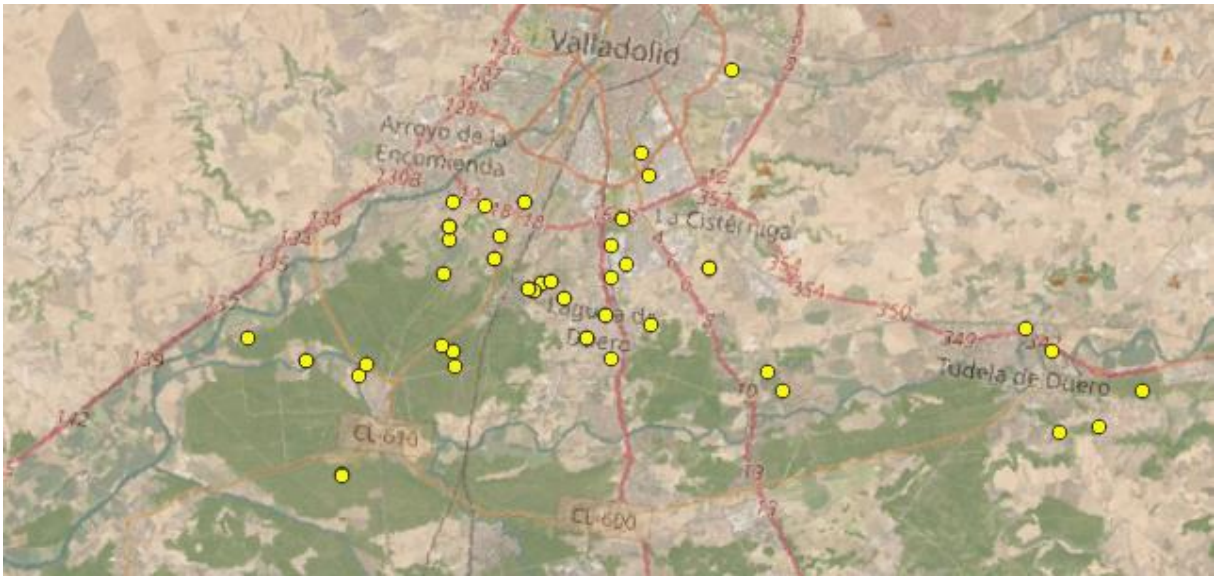


Image: The centroid of Jos' coordinates is in the area between the city Valladolid and a pine forest.

Valladolid province is situated on a plateau in the north of the Iberian Peninsula, at around 700 - 800 m asl. Tree species such as pine, oak, poplar and willow grow in the area. Due to the climate, agriculture is dominated by dryland farming. Crops grown in the area include wheat, barley and rye, legumes, sugar beets, alfalfa, and grapevines. Livestock are also important in the area.

Image: Jos stayed in an area containing several different land uses.

Photos: Jos' stopover area in Valladolid province (Google, Nicolás Pérez, Nac and Antonio Arranz)

Ayoun el Atrous, Mauritania

After crossing the Sahara, Jos arrived on the edge of the Sahel and immediately stopped - 60 km north of the village Ayoun el Atrous. He stayed here for a period of 8 days, from the 29th September to the 6th October 2020. It's debatable whether this place classifies as a stopover or wintering area, but the data suggests it to be more of a stopover location.

Firstly, the area is located on the Sahara-Sahel border – it is the very first edge of 'Sahel' that Jos would have flown across. In the 36 hours prior to arriving at Ayoun on the 29th September, Jos flew approximately 1110 km across the Sahara. Satellite imagery (below) of the region suggests this place was the first sign of greenery after kilometres of solid desert. If Jos was hungry and exhausted this would have been a logical stopping point.

Secondly, Jos stayed here just 8 days. In his wintering locations, he stayed for a period of several weeks before moving on. This suggests the area was not particularly suitable for a long-term stay, lacking in sufficient food, water or shelter.

Thirdly, there are references in literature to staging areas located immediately north and south of the Sahara, which enable turtle doves to refuel and rest before going further.

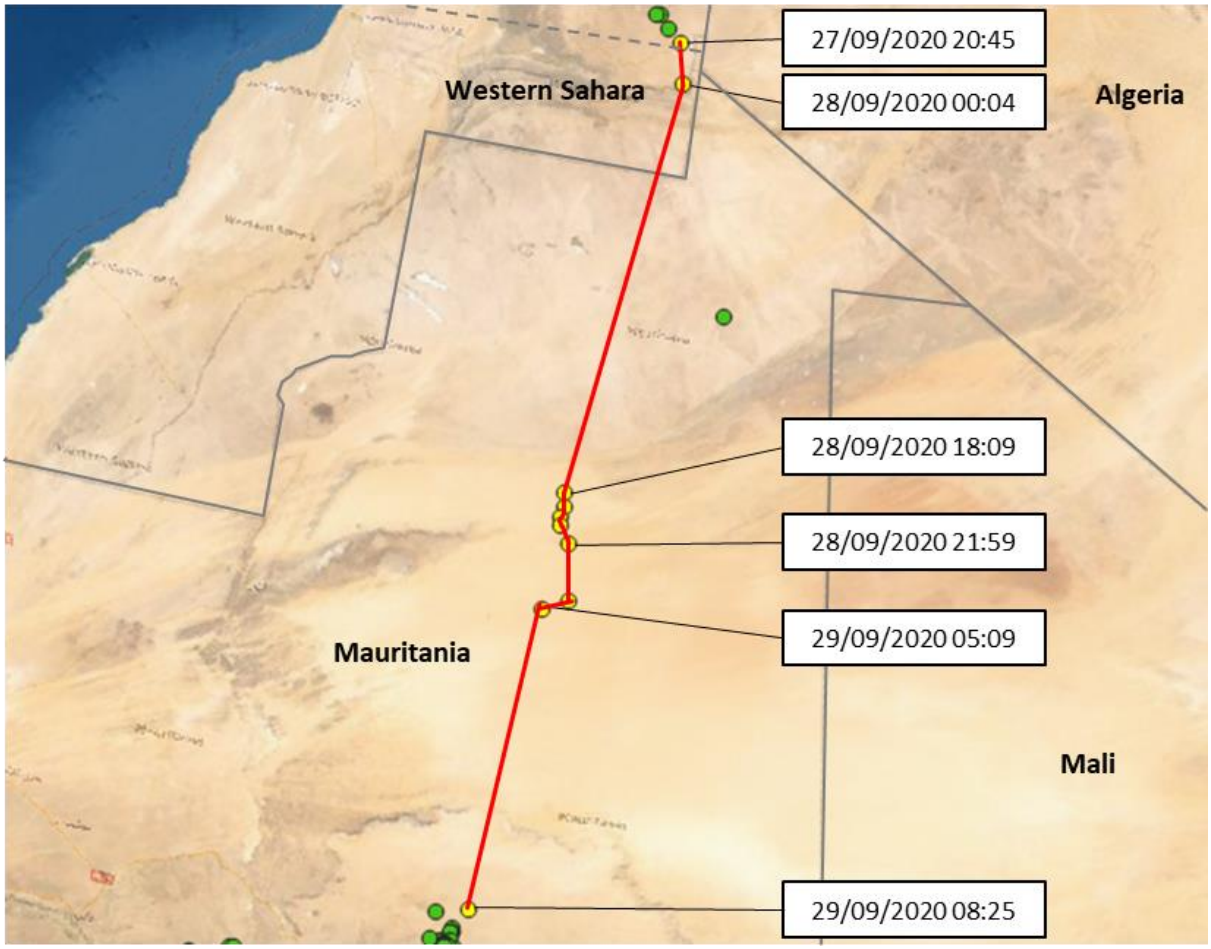
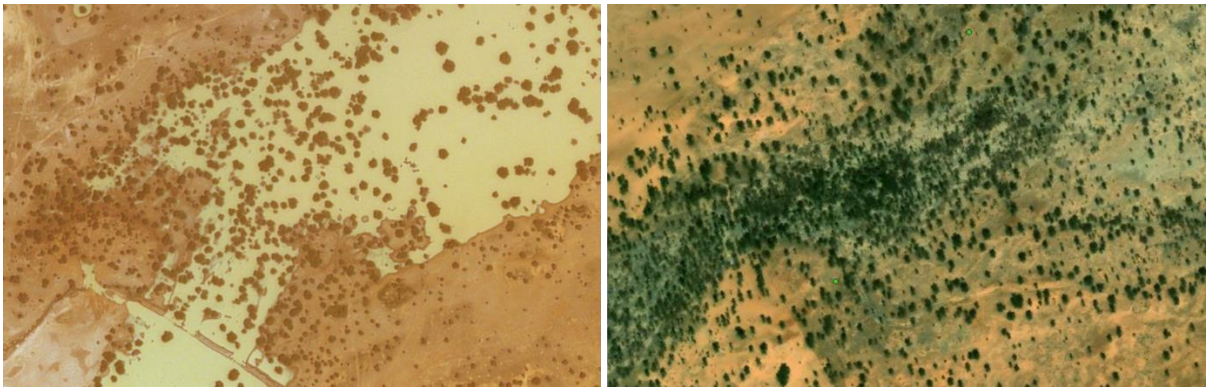


Image: Jos' positions 36 hours before arriving at his stopover site near Ayoun el Atrous, Mauritania.

This part of southern Mauritania, between Tamchekett and Ayoun, is right on the border between Sahel and Sahara. Rainfall here is temporally and spatially erratic, and nomadic livestock herding is the main livelihood of the area (US AID FEWS NET Project, 2005; Green Climate Fund, 2019). Rainfall here is usually between 150 and 200 mm per year, falling between June and October.

Jos' coordinates show him to be residing in an area much greener than the surrounding desert - with scrub, trees and, at least on occasion, water. The timing of Jos' stay here would have coincided with the end of the rainy period. Paths and vehicle tracks are also visible on satellite imagery, confirming the presence of livestock farming.



Satellite imagery: Jos stayed in an area containing several different land uses

Photos: The area around Tamchekett and Ayoun-El-Atrous, Mauritania (Med Hassene, July 2018; Ahmed Hacen, Aug 2021)

Fes, Morocco

Jos' return journey to the Netherlands provided far less datapoints than his journey south, but one clear stopover was identified 16 km west of Fes, Morocco. Jos stayed here for a minimum of 8 days, from the 1st to the 8th of May 2021. Jos' activity was particularly concentrated in an area at the foot of the middle Atlas Mountains, close to the villages of Douar El Adam and Douar Ghomra.

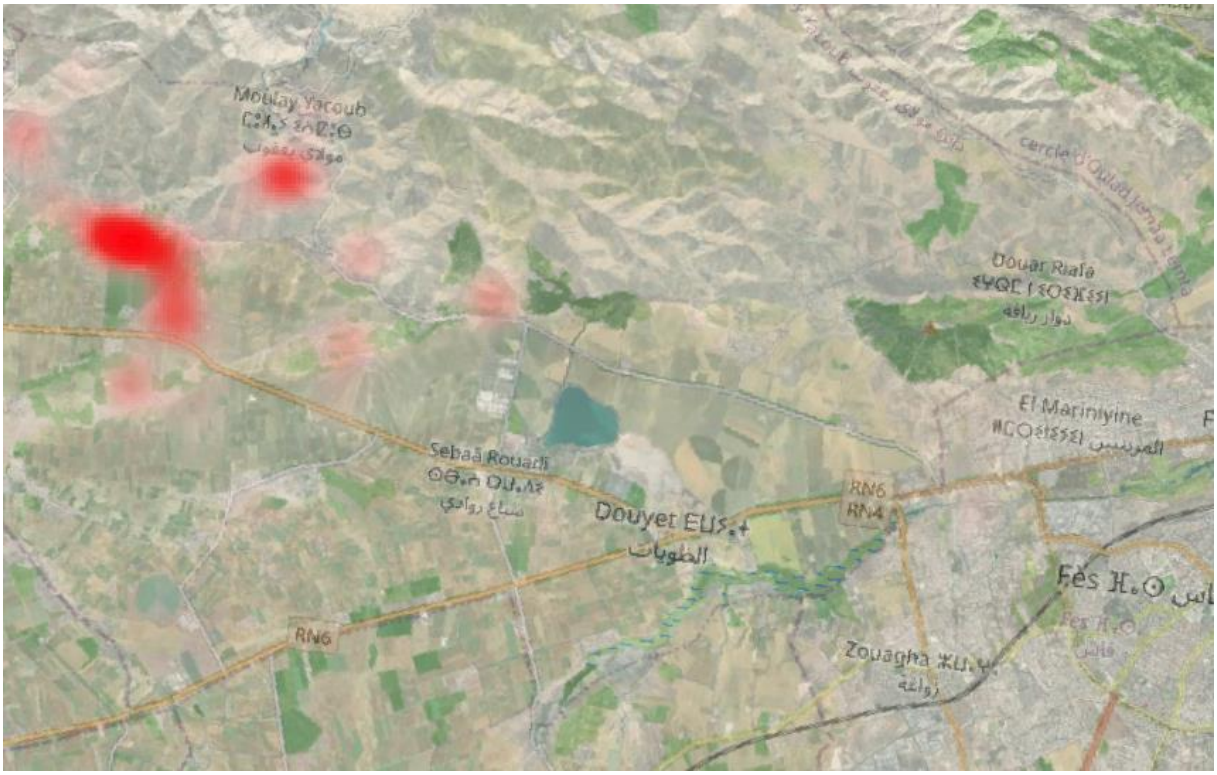


Image: Jos' coordinates were most concentrated around the foot of the middle Atlas Mountains, west of Fes.

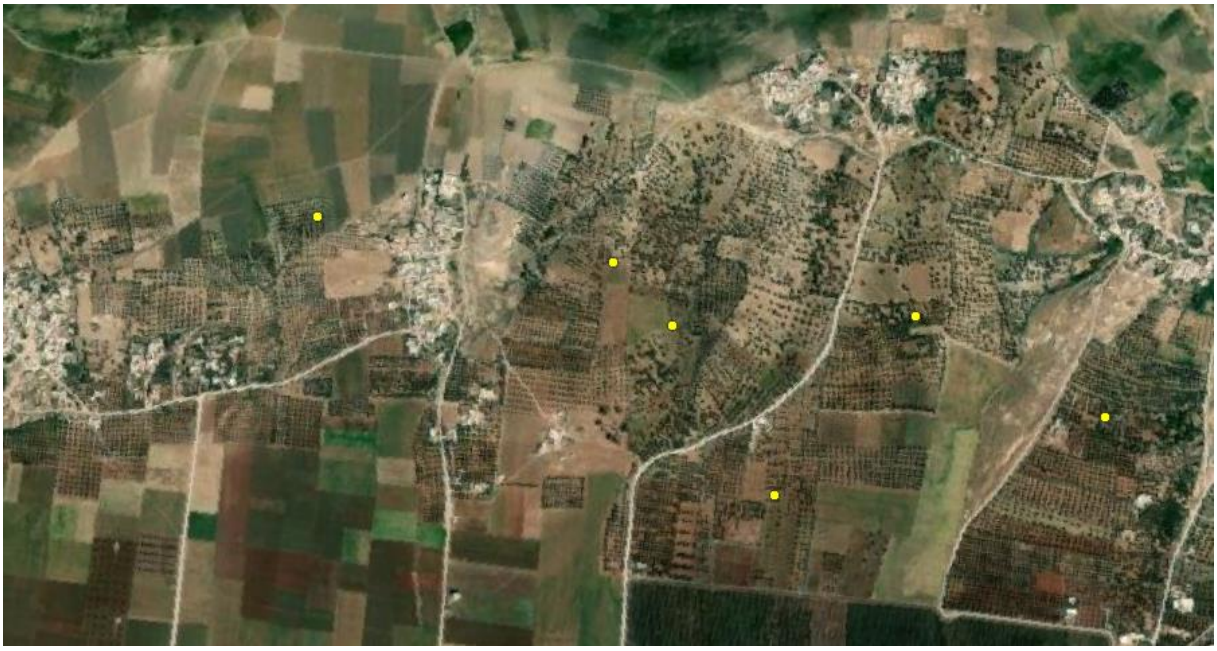


Image: Jos stayed close to tree plantations during his stopover near Fes.

This region has a hot-summer Mediterranean climate, with hot, dry summers and cold, wet winters. The area west of Fes is important for both livestock and arable farming, primarily producing crops such as cereals, beans, olives and grapes. Satellite imagery suggests he had a preference for tree plantations (most likely to be olive), rather than the comparatively featureless open fields of the surrounding area.

Images: Jos' stopover area and surroundings (Bety Bety, Apr 2018; Bernard Blanc, Mar 2017; Mostafa Bourbakri, May 2007)

Short Stopover Area: Meknes, Morocco

Jos stopped close to Meknes for at least 24 hours before he flew 33 km east to his stopover west of Fes. His location fixes near Meknes were concentrated around the foot of the Middle Atlas Mountains. Satellite imagery of the area shows a landscape of arable fields and, what is most likely, olive groves, scattered with small towns and villages, and bordered to the north by the Bab Rmila Natural Park which is forested. Land use around Meknes and Fes is similar – the area is important for both livestock and arable farming, primarily producing crops such as cereals, beans, olives and grapes.

Given the limited number of location fixes collected here, it's not possible to speculate which landscape features were of particular interest to him.

Photo (clockwise from top left): Bab Rmila Natural Park taken from the surrounding farmland, Fatah Naji, September 2019; Middle Atlas Mountains near Moulay Idriss Zerhoun, Danielle Takeshita, February 2018; Middle Atlas Mountains near Moussaoua, Abdelfattah Elmenssoufi, April 2019

Short Stopover Area: Dordogne, France

Jos' final stopover location in Parc Naturel Régional Périgord-Limousin, Dordogne, France, also corresponded with an agricultural landscape, with meadows, forests (mainly chestnut and oak) and a steady water supply in the form of pools and lakes. He stayed here at least 23 hours. Agriculture in the area includes livestock, viticulture, fruit (strawberries, apples, plums), nuts, cereals (wheat, barley), rapeseed, sunflowers and maize (CED 2022). As with Jos' other short stopover, insufficient location fixes were collected to determine which landscape features might have been of particular interest to him.

Photo (clockwise from top left): All taken near Saint-Jory de Chalais (Google Images October 2010, Google Images July 2021, Arnaud Dethor, October 2015)

Stopover Areas: Comparison

The five identified stopover sites have several things in common. What stands out most is that they are all in areas with a range of different habitats in rural farming areas, where trees and/or scrub are plentiful but don't form dense forest, and water is available.

The two stopover areas in Valladolid, Spain, and Fes, Morocco, corresponded to arable farming landscapes largely growing cereal crops. When southbound, Jos stopped near Valladolid at the end of autumn harvest – cereal stubble is likely still present. When northbound, Jos' arrival near Meknes and Fes towards the end of April/early May will have coincided with ripening (and first harvest) of cereal crops such as barley. It's likely there would be ripe seed available for doves at this time of the year in Morocco. It is also possible that weed seeds provide an important food source at this time of year. Eraud et al (2013) hypothesized that spring stopovers in Morocco, in areas growing cereal crops, might be used by turtle doves to restore their body condition in lieu of their pre-breeding moult. The presence of arable cereal farming is also indicative of a reliable water source. The Douro River flows past Valladolid, and farmland in Fes is irrigated by way of an aquifer.

Jos' stopover area near Ayoun el Atrous, in south Mauritania, is on the dry Saharan/Sahelian border. The main economic activity of the area is nomadic livestock farming, where pastoral farmers follow the rain (and grass). Photos and satellite imagery of the area support this; a myriad of paths and vehicle tracks come together around a dry water basin/pool surrounded by scrub and trees (evidence, even if only temporary, of water). Rain falls here from June to October, with August receiving the most rain. Jos was here at the end of September, when there's a good chance the pools still contained water. The Single Species Action Plan notes that the first stops of turtle doves arriving in the Sahel may be in pastoral rather than agricultural farming zones.

In Spain and Morocco, photos of the areas indicate a sparse vegetation structure, with a lot of bare ground - at least between the trees of Valladolid's pine forest and the olive groves in Fes. Ayoun el Atrous, with its arid climate, also has a very open, sparse vegetation with a lot of bare sandy ground.

Wintering Locations

Jos' wintering period, from the date he left his post-Saharan stopover to the date he began moving north again, lasted a total of 199 days. Of these, he spent 197 days in just three overwintering areas, two of which were just 5 km apart.

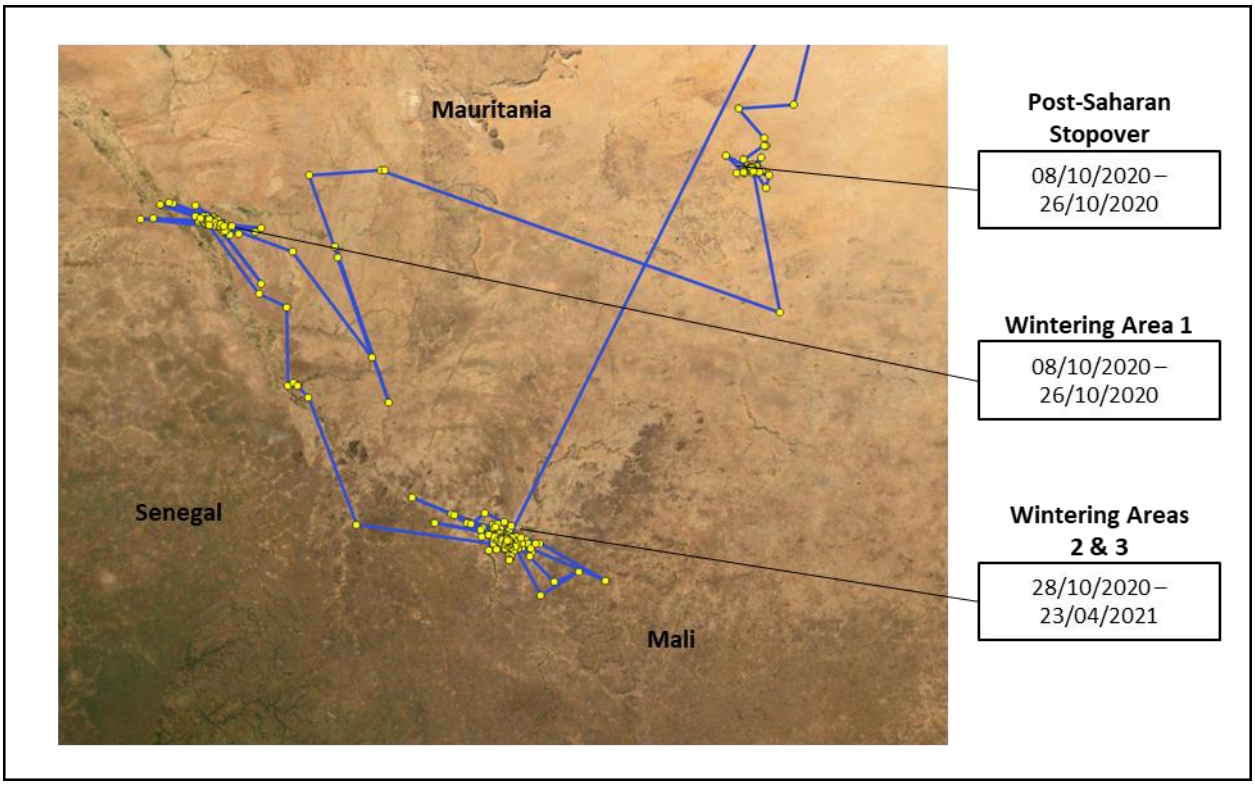


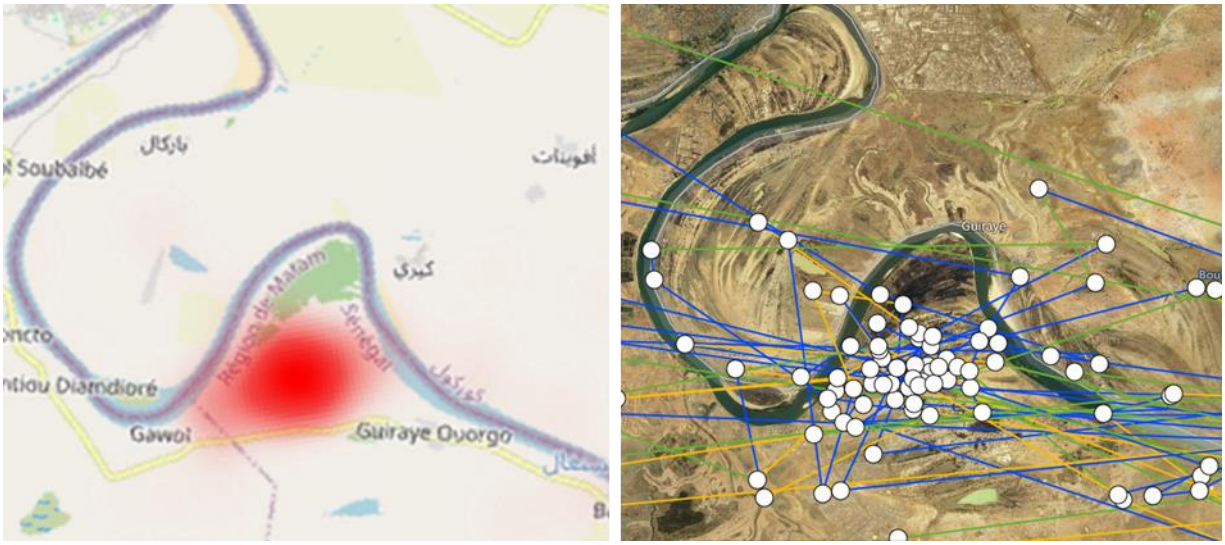
Image: Jos' winter movement (2020/2021).

After stopping for a week near Ayoun-El-Atrous, Mauritania, on the south Sahara/Sahel border, Jos headed west towards the Senegal River Valley. East Senegal, along the river, is one of the European turtle dove wintering locations mentioned in the International Species Action Plan (2018), where it is noted that 'sufficiently large stands of *Acacia nilotica* and *Acacia sayel* remain intact'.

On the 8th October 2020 Jos arrived at his first wintering area, in northeast Senegal. This area is along the Senegal River, and is 6 km south of the city Kaédi, on the Senegal/Mauritanian border. After 19 days, Jos travelled about 300 km southeast (upriver) on the 27th of October. He followed the Kolinbiné tributary east of the city Kayes, and stopped at his second wintering area just north of the village Kouroukoula. He stayed in the area for 102 days, until the 6th February 2021, when he moved just 5 km further upstream and stopped close to the village of Kanamakounou. He resided here for 76 days, until he began his journey north on April 23rd.

Area 1: Senegal River Valley, Matam Region, Senegal (8-26th October)

Just 6 km south of Kaédi, Mauritania, a 10 km stretch of the Senegal River valley became Jos' first wintering area. He stayed here for a relatively short period. His activity was centred between Gawol and Guiraye, in north Matam, Senegal – just south of a forest reserve and within 1.5 km of the Senegal River.



Images: Most of Jos' positions were just south of the 'Forêt Classée de Gawol Guiraye'.

Typical trees of the Senegal Valley are acacias, including A*cacia nilotica*, which grow profusely along the river banks. Agriculture (arable and livestock) are the main economic activities in the region, including crops such as rice, sorghum and maize. Overwintering turtle doves in Senegal have been recorded resting in a variety of tree species including *Acacia nilotica* (Single Species Action Plan, 2018), and the species uses rice fields for foraging, where it eats grass seeds before harvest and spilt grains following the harvest (Zwarts et al, 2009).

Satellite imagery of the area shows a sparse vegetation with many trees/shrubs, and the geometric pattern of agricultural field boundaries is visible to the south. The Senegal River provides a stable source of water, and photos taken near Gawol show the banks to be gently sloping in certain areas – ideal for drinking turtle doves.

Images: The area has a sparse vegetation and shows evidence of farming activity.

Images: Gawol, Senegal (Tiago Sy)

Area 2: West of Kayes, Kouroukoula, Mali (28 October 2020 – 6 February 2021)

On the 27th October, Jos travelled 290 km up the Senegal River to Kayes, Mali, and ca. 10 km up the Kolinbiné tributary. From the 28th of October Jos lived in an area of riparian forest just north of the village Kouroukoula. He stayed in this second wintering area for 102 days.

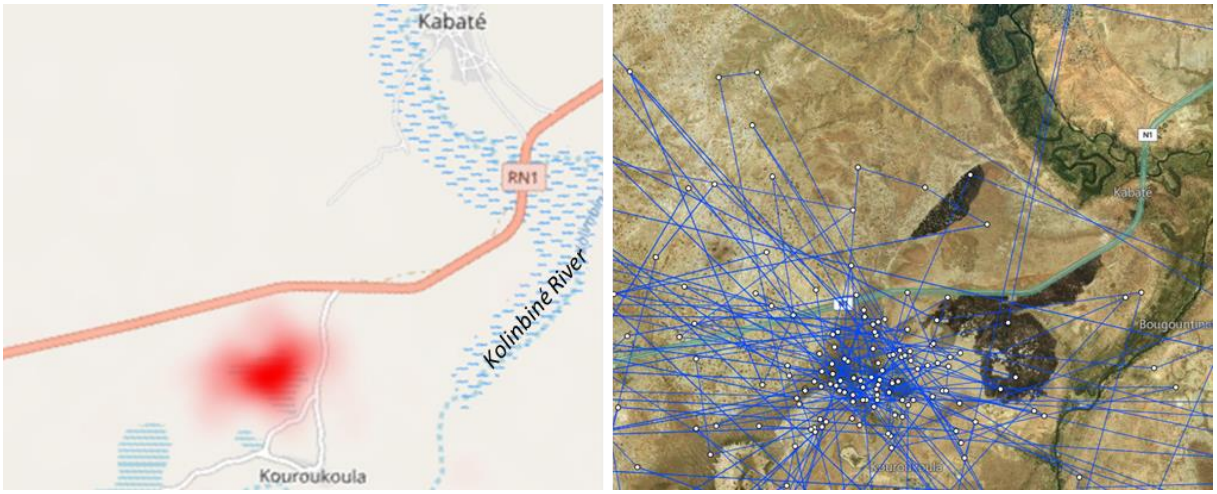


Image: Jos stayed in this second wintering area for 102 days – from the end of October 2020 to early February 2021..

Image: Satellite imagery of Jos' second wintering area

Based on satellite imagery, the habitat here is (visually) similar to that of Jos' first wintering area near Kaédi. Vegetation is sparse - trees and scrub are interspersed with open, bare ground. Although evidence of arable agriculture is not immediately obvious, the Kayes Region of Mali is a major peanut producing region. Other crops include rice, maize, millet and sorghum – all of which have increased in production since the 1960s. Unlike the permanent water supply of the Senegal River, water here is a pool - appearing disconnected from the Kolinbiné River at the time the image was taken. Judging by the surrounding vegetation, the pool varies in size and is likely subject to drying out. The Kolinbiné is known to flow through a number of shallow depressions, filling them with water during the rainy season. The rainy season runs from July to September, and would have been coming to an end when Jos arrived here.

Area 3: West of Kayes, Kanamakounou, Mali (7 Feb – 23 April 2021)

Jos' locations from the 7th of February, 2021, centre around a third wintering area, just on the other side of the Kolinbiné tributary. Areas 2 and 3 are just 5 km apart, but Jos' coordinates between November and April show two distinct wintering areas. His change of location could perhaps have been influenced by localised factors such as rainfall and water supply. Jos stayed at this third area for a period of 76 days, after which he began his journey north to his breeding grounds.

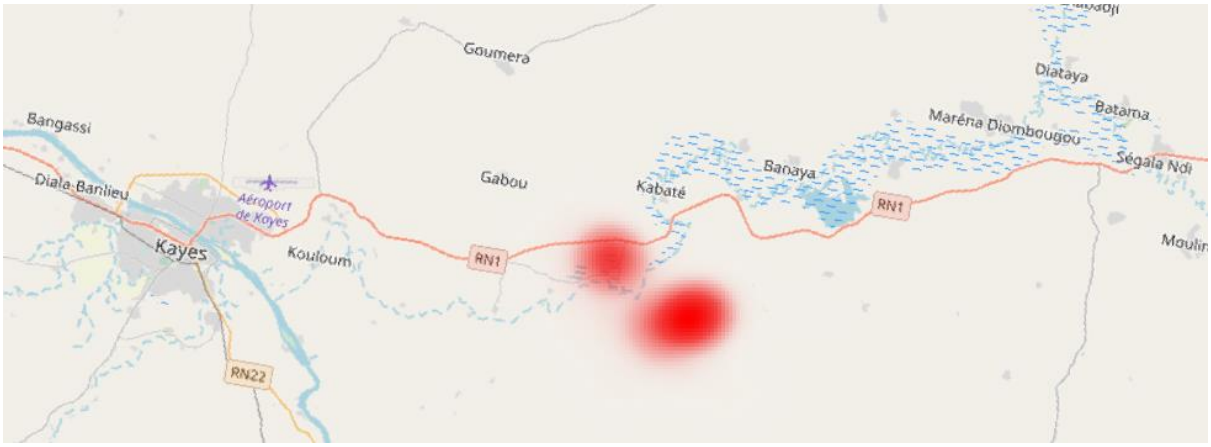


Image: Jos' wintering areas east of Kayes are just 5 km apart.

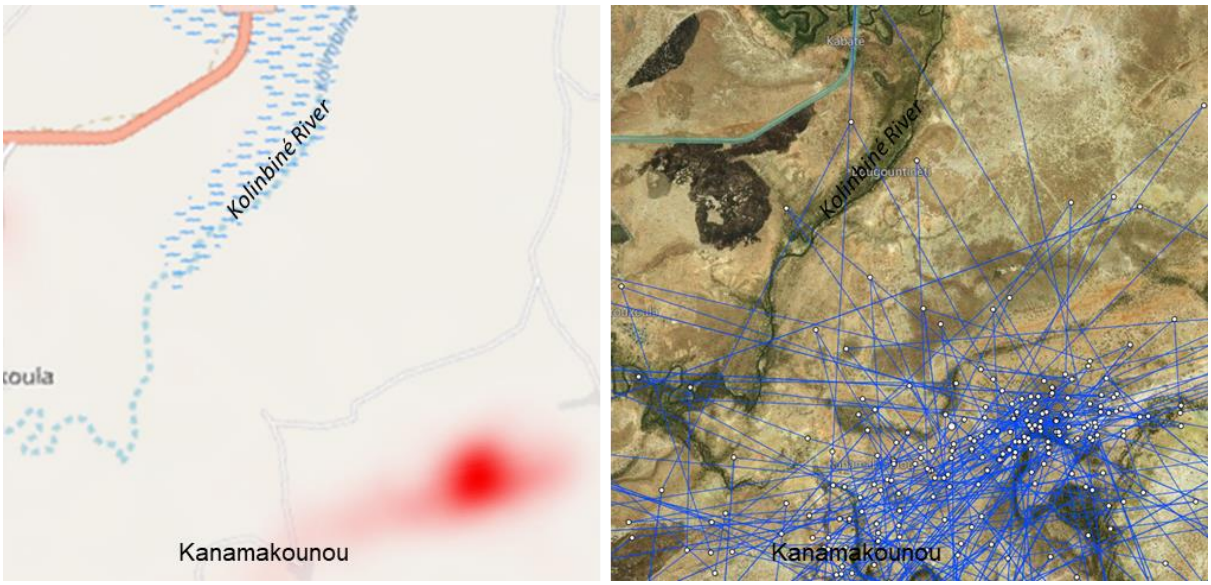


Image: Jos stayed in his third wintering area for 76 days – from early February to late April 2021.

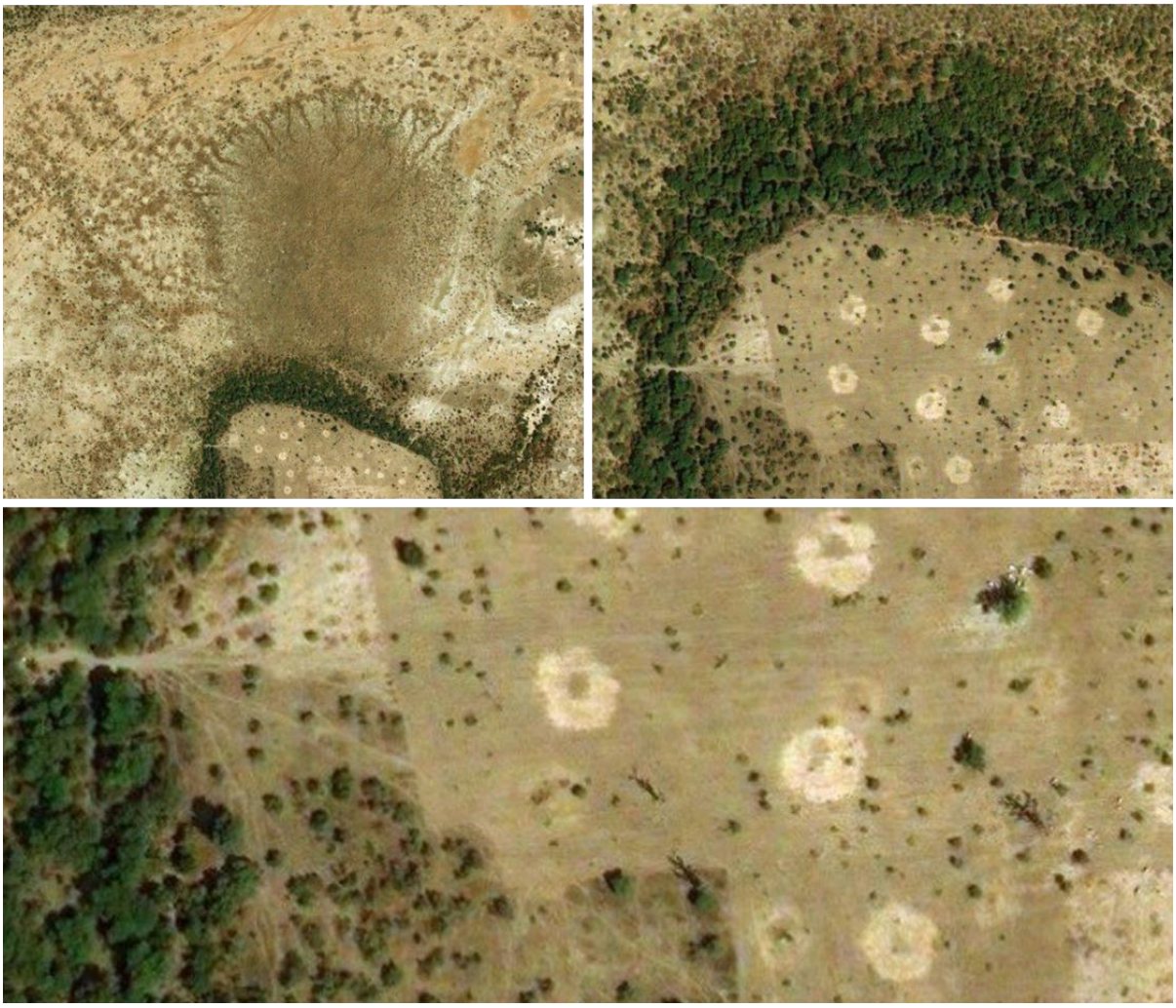


Image: Livestock tracks and regular shapes in the landscape indicate the presence of farming.

As with Jos' first two wintering locations, images of this third site indicate many habitat similarities. Once again, the area contains a sparsely wooded area, providing suitable shelter for turtle doves. The presence of field boundaries, paths and tracks, and 'bleached' circular forms indicate the presence of (at least) livestock farming. While it is unclear exactly what kind of farming takes place here, as previously mentioned, the Kayes region of Mali grows crops such as peanuts, rice, maize, millet and sorghum.

Adjacent to the trees, there's evidence of a temporary pool– dry in this satellite image, but clearly filled with water at certain times of the year. This might also be one of the shallow depressions known to be flooded by the River Kolinbiné during the rainy season.

Wintering Areas: Comparison

The wintering habitat of European turtle doves is typically characterised by an abundant supply of food and water, and the presence of large trees and woodlots that can provide shelter. The absence of one or more of these factors ensures that turtle doves will stay only temporarily (Zwarts et al 2009).

All three of Jos' wintering locations encompassed a mix of grassland and shrubland, with some savannah and agricultural land. Area 1, in the Senegal Valley, was composed of a mosaic of different land uses including riparian forest, farmed land, bare sandy ground, and the Senegal River. Areas 2 and 3, on opposite sides of the Kolinbiné River, were also made up of sparsely wooded areas, scrub, sandy bare ground, farmed land and a (temporary) source of water. Given that turtle doves only winter in areas where water is available, it is likely that the pool shaped depressions visible in the satellite images of Areas 2 and 3 both contained water at the time of Jos' stay.

Research in France and England found that *Acacia sp*. roosting sites, water availability, and cultivated sorghum, millet and peanut fields, or natural scrubby grassland may be important for turtle doves (Eraud et al 2009, RSPB 2016). Jos' results appear to support this. Given the absence of typical arable landscapes around Jos' chosen wintering grounds, it's most likely that he was foraging on natural grassland on species such as *Panicum laetum*. Grassland in this region is closely related to the rainy season of June to October, after which the grass slowly disappears. It is likely that food becomes increasingly scarce for turtle doves as the winter progresses, and competition for resources higher.

All three areas were strongly in line with previous research regarding turtle dove overwintering areas, and catered to the basic needs of turtle doves, providing sources of food, water and shelter.

Jos and Jozien: What happened to them?

During the course of this project, both Jos and Jozien's transmitters stopped working. Contact was lost with Jozien after just 3 weeks of tracking, while Jos was followed for 14 ½ months before contact was lost. The exact cause and circumstances surrounding their disappearances are unknown, but there are a few conclusions that can be drawn. In both cases contact was lost with them in their Dutch breeding grounds, ruling out the possibility of hunting as a cause of death. If one of them had become injured or ill, there would most likely be a visible decline in battery power of their PTT; a dove spending increasing time sheltering in the scrub or undergrowth would limit the recharging of the solar powered battery. As we did not see a decline in battery power, this leaves the most likely cause of Jos and Jozien's disappearance as being either predation or else a technical issue, such as a broken antenna. Either of these scenarios would result in a sudden cease in data transmission.

Putting Jos' Data in Perspective

Although just two PTTs were deployed, this study still highlights some important points, and strengthens some of the conclusions drawn in earlier research.

As anticipated, Jos migrated along the Western flyway, following a similar path to ETDs tagged in France and the UK. This route crosses the Iberian Peninsula where migrating birds are joined by those breeding in Portugal and Spain (ISSAP, 2018). ETDs using this flyway are known to cross the Mediterranean Sea close to the Strait of Gibraltar (Eraud et al, 2013), which Jos did. German research however confirmed that ETDs were migrating in broader migratory fronts, and that larger leaps over the Mediterranean Sea occur (Schumm et al, 2021). This has also been demonstrated by Spanish breeding ETDs, where doves tagged in central Spain crossed into Morocco at the Strait of Gibraltar, whereas ETDs tagged in the east of Spain followed the coast south, continued over the Mediterranean and into northwest Algeria (Arroyo et al, 2019).

The Importance of Stopover Areas

Stopover areas were very important to Jos during both spring and autumn migration. His autumn migration from the Netherlands to Senegal took him 22 days – 16 of which were spent at stopover sites. That is 72 % of his time, enroute to the Sahel, spent resting, eating and rehydrating. His spring migration from Mali to the Netherlands took him 23 days, whereby more than 9 days were spent at stopover sites (36 % of his total journey). Similar importance appears to be placed on stopover sites by doves breeding in other Western European countries: the turtle dove tracked for a full migration cycle from Germany spent 51% (autumn) and 52% (spring) at staging areas (Schumm et al 2021), while the dove tagged in France spent 77% (autumn) and 62% (spring) of his time resting and refuelling (Lormée et al 2016). Assuming these are not isolated incidences, stopover areas clearly form a vital part of the migration strategy of European turtle doves. Protection of these locations could go a long way to supporting migrating the species, but research is still required to identify particularly large, specific staging areas.

Research in 2013 (Eraud et al 2013) and 2016 (Lormée et al 2016) found that stopover sites in Morocco were being used during spring migration, while sites in southern Spain and south of the Sahara were used during autumn. While this appears a fairly accurate generalisation, particularly for French and British breeding doves, individuals tracked for more than a year along the Western flyway actually used a variety of stopover locations, with doves originating from different countries appearing to adopt slightly different migration strategies.

Southbound turtle doves breeding in the UK and France seem to be using southern Spain for a stopover (Extremadura and Andalusia) and south of the Sahara for a second stopover (Requena 2019; Lormée et al 2016). German breeding doves seemed to take their first stopover further north, in Germany, France and north or east Spain, and didn't stop again until their wintering grounds (Schumm et al 2021). Jos, from the Netherlands, stopped in north Spain and after crossing the

Sahara. It's possible that doves breeding in more northern/eastern areas of the flyway are taking a post-breeding migration stopover earlier than doves flying from more Western latitudes.

Northbound doves breeding in the UK and France stopped in Morocco, with some individuals going on to make a second stop in the south of Spain (Requena 2019; Lormée et al 2016). The individual returning to Germany stopped briefly in south Mauritania, then again in Morocco (Schumm et al 2021), and turtle dove Jos stopped in Morocco and again in France on his way home to the Netherlands.

European Turtle Doves: Loop Migration and Nocturnal Migrants

Previous research (Eraud et al, 2013) suggested that ETDs might follow a loop migration – taking a more easterly route on their pre-breeding journey north. This was not the case with Jos whose return north through Africa indicated that he followed a similar route, except for a deviation after crossing the Sahara, when he actually headed west towards the coast of Morocco, before flying east again for a stopover in the Middle Atlas Mountains. After crossing the Mediterranean Sea his spring migration took a more easterly route: Jos flew northeast and crossed into France at the border, close to Andorra. The European turtle dove returning to its German breeding grounds suggested the reverse – a more easterly route in the spring as far as the Mediterranean, and then following a route through Europe similar to its outward-bound journey.

Enough coordinates were collected from Jos to verify that his long-distance flights during his journey south were made between evening and mid-morning. His daytime coordinates indicated that he was rather stationary. This is in agreement with other tracking studies from England, Germany and France, where PTTs utilising an on/off duty cycle indicated that most active migration occurred at night (Requena, 2019; Schumm et al, 2021; Lormée et al, 2016).

Overwintering Areas

Regarding the overwintering areas of European turtle doves, they are known to occupy a range of habitats including acacia scrub, open woodlands, savannah and agricultural land and forage on the seeds of both wild weeds and cultivated grains such as millet, sorghum and rice (Jarry & Baillon 1991; Zwarts et al, 2009; Browne and Aebischer, 2005). They are known to select areas where food, water and roosting opportunities are available – the absence of one or more of these factors ensures that turtle doves will stay only temporarily (Zwarts et al, 2009), and huge flocks have been recorded at such resources (Browne and Aebischer, 2005).

Three wintering areas were identified from Jos' data, all of which encompassed a mixture of grassland and shrubland, with some savannah and agricultural land (largely pastoral, but with arable land in the surrounding area). Wintering sites of the German breeding turtle dove were similarly characterized by a mosaic of agriculture, grassland, open water, trees and scrub. The two sites had a much higher percentage of tree cover (41.2%) compared to areas chosen by doves from other flyways (Schumm et al, 2021).

Over the last decade, ETDs tagged in Britain, France and Senegal (n=35) have been distributed across Senegal, Gambia, Mali and Mauritania during the winter months - largely over the floodplains of the Senegal and Niger Rivers. It was recorded that their African home ranges were often centred around forested roosting sites, often composed of Acacias. Doves were found to be flying several kilometres to find food and water on a daily basis, and were targeting farmland and grassland areas to forage (Requena, 2019). French breeding ETD 'Marcel' (Lormée et al, 2016) also overwintered in two areas which encompassed irrigated agricultural land growing cereal crops such as rice, sorghum and millet – the first along the Senegal River, in northeast Senegal, the second on the Niger River, close to Bamako, Mali).

A study of non-breeding European turtle doves in Senegal found habitat selection to be governed strongly by tree cover and partly driven by food availability. Tree cover of >15 % was notably favoured, and the diets of the study population showed an increase in millet and a decrease in sorghum over time – something which was also reflected in their foraging trips (Van Tuijl, 2018). Furthermore, a survival study of (French breeding) European turtle doves in relation to the conditions on their overwintering grounds, pointed to the sensitivity of the species to agricultural change (Eraud et al 2009)

Wintering Area Shift

Geologger research illustrated that individuals from the same breeding grounds do not necessarily use the same wintering areas - ETDs tagged in France were registered overwintering on the Mali/Mauritania border and on the Inner Niger Delta, Mali (Eraud et al, 2013). The results also suggested a clear eastward shift (of several hundred kilometres) during winter. It was hypothesized that the shifts might correspond to water and/or food availability (Eraud et al, 2013).

Subsequent PTT research, where ETDs were recorded on their wintering grounds, revealed that ETDs breeding in France, Germany and the Netherlands all experienced this same south-easterly shift between late October and early December. This resulted in translocations of 520 km, ca. 870 km and ca. 290 km respectively (Lormée et al, 2016; NABU, 2021).

The French breeding ETD experienced a south-easterly shift in early December (Lormée et al, 2016). Similarly, the German breeding ETD using the Western flyway also experienced a shift in a south-easterly direction in early November (Schumm et al, 2021). Jos also experienced this same shift – starting the winter in northeast Senegal, then flying southeast in late October to Kayes, Mali.

Lormée et al (2016) and Eraud et al (2013) hypothesize that this shift could be linked to food availability: ETDs could be foraging on millet and sorghum stubble in northern Senegal (Jarry & Baillon 1991; Zwarts et al, 2009; Browne and Aebischer, 2005) and move on once food resources are depleted. Their choice to move in a south easterly direction might reflect emerging food sources (such as spilt seed from the rice harvest) (FAO, 2022; Jarry and Baillon, 1991; Lormée et al, 2016).

Conclusions

The subtle differences in stopover location, and possibly migration strategy, make it difficult to target conservation effort to a particular hotspot and have a widespread impact. One particular area of interest however is north Morocco: where most turtle doves appear to have stopped during their spring migration. When Moroccan stopover locations were compared between tracking studies, it is clear that all doves were stopping just north of the High and Middle Atlas Mountains. The stopover locations form a 'belt' across the country, stretching from Safi on the coast, across to Beni Mellal at the foot of the High Atlas Mountains, and across to Meknes and Fes, at the foot of the Middle Atlas Mountains.

In the light of how broad the migratory front of Western flyway European turtle doves is, the appropriate regulation of legal and illegal hunting becomes all the more important. Given how much time turtle doves spend at staging areas, the timing of hunting seasons becomes crucial in all countries along the Western flyway. Hunting at stopover locations has the potential for devastating consequences – if not in terms of actual bag numbers, then in terms of disturbance to roost areas. The loss of resting places for migrating turtle doves can be expected to impact their survival, by forcing doves to migrate further before they are physically fit.

The year 2021 marked the first in a series of 'zero harvest' years for turtle doves in the countries of Portugal, Spain and France. With the development and recommendations of the Adaptive Harvest Management Mechanism (AHMM), it will be interesting to see the effect of this on Western Europe populations in both the short and long term. Hunting remains legal in Morocco and other African countries. Better hunting data and regulations are still required in many African countries before the impacts of hunting here can be determined.

The characterisation of stopover and wintering areas is Objective 7.6.1 in the ISSAP (2018). While turtle doves appear to stop in a range of different locations, all staging areas shared very similar landscapes. This was identified not only with Jos, but across other tracking studies of European turtle doves following the Western flyway (Schumm et al 2021; Requena 2019; Lormée et al 2016). With the exception of autumn stopovers sites south of the Sahara, turtle dove staging areas are characterised by a mosaic of different habitats and landscape features. They are all located in agricultural landscapes containing olive groves and/or cereal crops, and tree cover or scrub is always present. In addition, water is always available, whether through pools, lakes, farming or rivers. These characteristics make the doves' choices of stopover areas very logical – they all met their criteria for foraging possibilities, roosting opportunities and a reliable water source. Zwarts et al (2009) noted that the presence of water, food and shelter are all essential to turtle dove wintering areas, and that the absence of any one of these would result in the dove moving on to another area.

Van Tuijl noted in his thesis (2018) that turtle doves wintering in his study area were heavily reliant on anthropogenic adaptations in the landscape: they fed on crop seeds, drank from wells and roosted in (maintained) forest. Based on Jos' results, combined with those of other turtle dove tracking studies, it appears that this observation can be extended to virtually all stopover and wintering areas, and indicates the vulnerability of the European turtle dove to changes in the landscape brought about by humans.

Most notably, they appear to depend rather heavily on certain crops (cereals in particular). Whether they are foraging among ripe crops, fallen seed after harvest, storage facilities, or even weeds

associated with particular crops and farming methods, the impact is the same: if the crops, sowing time, harvest time, or farming methods in an area change, the turtle doves risk losing their food source.

In some cases, turtle doves stopped or wintered in areas with a permanent water supply (such as a river) and protected forest (such as a Natural Park), but in other instances, they stopped in areas where the water supply and tree/scrub cover were dependent on humans. Where the primary water source comes from irrigation, wells or pools, there is always a chance that changes in crops or farming methods will result in the loss of watering opportunities. Similarly, where olive groves provide shelter and roosting opportunities (for example, at Jos' spring staging area in Morocco), changes to the dominant crop type of the area could result in the long-term or permanent loss of this resource. In most of the identified African overwintering areas, stands of unprotected woodland (often *Acacia*) are used for roosting, and could be removed at any time due to farming expansion or grazing pressure in the area.

The future impact of climate change on crop distribution and water availability is also unknown. This impact may be particularly marked in areas with an already dry climate (such as Spain's Valladolid Province, situated on a plateau), or near Fes, Morocco (where groundwater is tapped in many areas to support farming).

In conclusion

Results of tracking studies to date haven't revealed specific bottlenecks or locations for wintering or staging European turtle doves, but rather illustrate that the species migrates over broad fronts, and that individuals breeding in different countries use slightly different staging locations. The most common stopover areas were in Morocco, north of the High and Middle Atlas Mountains, and in Spain (southern Spain for English and French breeding turtle doves, and north or eastern Spain for German breeding turtle doves and for Jos).

The characteristics of wintering areas were comparable between studies, as were those of most stopover areas. Turtle doves were present in places offering ample opportunities for food, water and roosting: in most instances, the landscape of their chosen areas reflected anthropological adaptations which would likely have increased the availability of one or more of these resources.

The absence, so far, of clear common wintering and stopover locations calls for a more landscape-wide approach to protecting and enhancing turtle dove habitat. This is something that will need to be addressed at local and national levels, and coordinated across the Western flyway in order for action to be most effective.

Further research is still required to better characterize stopover and wintering locations for European turtle doves, and to identify the areas and regions most commonly used along the Western flyway so as to target conservation measures more efficiently.

References

Arroyo, B., Moreno-Zarate, L., Fernández Tizón, M., Sardà-Palomera, F. and Bota, G. (2019) Parámetros poblacionales críticos para la tórtola europea: aplicaciones para su gestión. Instituto de Investigación en Recursos Cinegéticos (IREC)(CSIC-UCLM-JCCM), Ciudad Real.

Browne S, Aebischer N (2005) Studies of West Palearctic birds: Turtle Dove. British Birds 98 • February 2005 • 58-72.

Chambre Economique de la Dordogne – CED (2022) Baromètre Eco: Analyse de la conjecture en Dordogne. Online: https://dordogne.chambre-agriculture.fr/fileadmin/user_upload/Nouvelle-Aquitaine/099_Inst-Dordogne/Documents/Conjoncture_Economique/Barome__tre-Eco-Dordogne-2022.pdf

Eraud C, Boutin J-M, Riviére M, Brun J, Barbraud C and Lormée H (2009) Survival of Turtle-doves *Streptopelia turtur* in relation to western Africa environmental conditions. Ibis 151: 186-190.

Eraud C, Riviére M, Lormée H, Fox JW, Duchamp J-J and Boutin J-M (2013) Migration routes and staging areas of trans-Saharan turtle-doves appraised from light-level geolocators. PLoS ONE 8(3): e59396. DOI: 10.1371/journal.pone.0059396.

FAO (last accessed 2022) Crop Calendar. Online: http://www.fao.org/agriculture/seed/cropcalendar/searchbycountry.do

Fisher I, Ashpole J, Scallan D, Proud T and Carboneras C (compilers) (2018) International Single Species Action Plan for the conservation of the European Turtle-dove *Streptopelia turtur* (2018 to 2028). European Commission Technical Report 2018.

Green Climate Fund (2019) Strengthening the resilience of ecosystems and populations in four regional hubs in northern Mauritania. Online: https://www.greenclimate.fund/sites/default/files/document/22260-strengthening-resilience-ecosystems-and-populations-four-regional-hubs-northern-mauritania.pdf

International Single Species Action Plan - ISSAP (2018) – *see Fisher et al (2018)*

Jarry G, Baillon F (1991) Hivernage de la Tourterelle des Bois (*Streptopelia turtur*) au Sénégal : Etude d'une Population dans la Région de Nianing. Rapport interne CRBPO, Paris. Online: https://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_6/griseli1/010014331.pdf

Klootwijk M (2019) Zomertortels in Zeeland in 2019. Online: https://www.sovon.nl/nl/actueel/nieuws/zomertortels-zeeland-2019

Lormeé H, Boutin J-M, Pinaud D, Bidault H and Eraud C (2016) Turtle-dove *Streptopelia turtur* migration routes and wintering areas revealed using satellite telemetry. Bird Study 63:3, 425-429, DOI: 10.1080/00063657.2016.1185086

Morel GJ, Roux F (1973) Les migrateurs paléarctiques au Sénégal: notes complémentaires. Terre & Vie, Rev. Ecol. 27: 523–550.

Requena S (2019) A year in the life of… a Turtle Dove. Online: https://operationturtledove.org/2019/05/10/a-year-in-the-life-of-a-turtle-dove/

RSPB (2016) What we've learnt from Titan the satellite tagged turtle-dove. Online: http://www.rspb.org.uk/community/ourwork/b/biodiversity/archive/2016/08/30/what-we-ve-learnt-from-titan-the-satellite-tagged-turtle-dove.aspx

Schumm Y, Metzger B, Neuling E, Austad M, Galea N, Barbara N, Quillfeldt P (2021) Year-round spatial distribution and migration phenology of a rapidly declining trans-Saharan migrant—evidence of winter movements and breeding site fidelity in European turtle doves. Behavioral Ecology and Sociobiology (2021) 75:152. https://doi.org/10.1007/s00265-021-03082-5

US AID FEWS NET Project (2005) Mauritania Livelihood Profiles. Online: https://fews.net/sites/default/files/documents/reports/mr_profile_en.pdf

Coen van Tuijl (2018) MSc Thesis: Non-breeding habitat selection by a long-distance Afro-Palearctic migrant, the European Turtle Dove (*Streptopelia turtur*), changes with environmental conditions at wintering grounds. Wageningen University.

Zwarts L, Bijlsma RG, van der Kamp J and Wymenga E (2009) Living on the Edge: wetlands and birds in a changing Sahel. KNNV Publishing, Zeist.