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To what extent is migration contributing to the decline of Common Swifts (*Apus apus*)?

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ABSTRACT

Common Swifts (*Apus apus*) have declined by over 50% since 1995, and as the species has been Red-listed as a result, it is important to uncover what the main causes of their decline are. To investigate whether or not their migration is contributing to their decline, I used a variety of weather data to see how conditions on their migration are likely to be affected by climate change, as this could potentially make their routes more perilous. Although there was no clear conclusion due to a lack of data, it appears that climate change will negatively affect local conditions of various locations along Swifts' migration routes.

INTRODUCTION

Common Swifts (*Apus apus*, henceforth referred to as Swifts) are a migratory species which spend the winter in sub-Saharan Africa and breed further north in various locations, commonly in northern Europe. Swifts have experienced a large decrease in numbers, declining by more than 50% since 1995 (Hewson *et al*., 2012). However, the cause of their decline is currently uncertain, although there are certain factors which are thought to possibly contribute to this. One suggested factor is climate change, which is likely to alter the conditions along the Swifts' migration route which could have a negative impact. By looking at weather data it is possible to investigate how much of an impact climate change may have in future. Swifts are relatively dependent on the weather conditions, as different conditions can influence the behaviour of the airborne insects and spiders ('aerial plankton') which Swifts feed on, and most insects need warmth to fly so cold weather could cause a shortage of food (Taylor, 1963). On the other hand, Swifts have adapted to exploit the best food sources. For example, they are known to choose the largest insects available (RSPB, no date) and generally fly higher than Hirundine species in the UK. They are also able to adapt to changes in weather conditions, as they fly lower in the evening when insects descend in swarms as the air cools down (Elkins, 2004), but when the air is unstable, they may increase their altitude as there is a higher insect density at higher altitudes (Johnson, 1957). Additionally, as food availability for Swifts can fluctuate in different areas if the weather changes, Swift nestlings have adapted to be able to survive for several days without food (Lack, 1956c).

Although Swifts are able (to some extent) to adapt to changes in weather conditions which affect insects by feeding in different areas (Elkins, 2004), a major change in weather conditions along their migration routes could have a negative impact on them if the insects are no longer able to survive. In addition, the Swifts themselves may not be able to survive in certain weather conditions, so I researched the changes in climate which may occur.

METHODS

Using geolocators, the migration routes of several common Swifts have been tracked (BTO, 2010-2016; Åkesson *et al*., 2012). I was able to use maps and case studies from some of these projects along with weather data to support my hypothesis.

In order to investigate the impact of climate change on the migration routes of Swifts, I used data from the Goddard Institute of Space Studies (GISS, 2022) to look at the temperature changes of the countries along the migration routes. Firstly, I looked at stopover sites in Liberia, Central African Republic, Morocco, South Congo and Spain to see whether there has been a high increase in temperature in specific areas important to Swifts during their migration. I then looked at global trends to compare the change in temperatures of countries along the migration routes with that of other countries across the world.

To see these global trends, I used maps from GISS which showed the global changes in temperature between 1950 and 2021 for different seasons; I looked specifically at trends for the seasons when Swifts would be migrating (autumn, running between September and November, and spring, running between March and May). By looking at the colours on the map showing the extent of the change in temperature over time, it is possible to see whether the migration routes are likely to be affected to a large or small extent by climate change and therefore how dangerous the routes are likely to become in future.

Also using information from GISS, I was able to look at graphs from weather stations across the world which showed the increase in average temperatures for specific locations over a chosen period of time. To determine which locations to investigate, I used a map from the BTO's study of the migration route taken by the Swift known as A320 to see where the important stopover sites were for this bird. Although this data has the limitation of only showing the route taken by one specific Swift, when compared to other maps of Swift migration routes from other sources (Åkesson *et al*., 2012; Jacobsen *et al*., 2017), it seemed to follow a similar route to others and had the advantage of clearly showing stopover sites which many other maps did not. I chose to use data between 1950 and 2021 as this corresponded with the times I used when looking at global trends, and is likely to be more reliable than data from before 1900. I obtained the data for weather stations in: Monrovia Roberts in Liberia, Berberati in Central African Republic, Bassatine in Morocco, Dolisie in South Congo, and Avila in Spain. These are all located as close as possible to important stopover sites for the Swift A320. It is important to note, however, that there was no available data for the wintering grounds of the Swift in Democratic Republic of the Congo, so Berberati was the closest weather station to this area, and was also very close to a stopover site where A320 spent around four days.

In addition to data from these sources, I carried out a literature search, using a variety of books and journals from the Chris Mead Library to research the migration timings and feeding behaviour of Swifts, to see if these are likely to be affected by climate change. I also accessed scientific papers from journals by using Google Scholar and using keywords such as 'swift', 'migration', 'climate change' and 'Sahara'.

RESULTS

According to the maps showing the average rise in temperature for different countries across the world, the general global trend was an increase in temperature, with a few exceptions. The maps used show that since 1950, the migration route typically taken by Swifts in autumn has experienced a particularly high temperature rise where the Swifts cross the Sahara (an increase of 2–4 ˚C), compared to the rest of Africa and Europe (1–2 ˚C; Figure 1). Similarly, the temperature rise in spring was also particularly high in the west of the Sahara where the Swifts usually migrate through; however, the area which experienced a change of 2–4 ˚C was larger than in autumn, encompassing more of the Sahara and extending further north towards Spain.

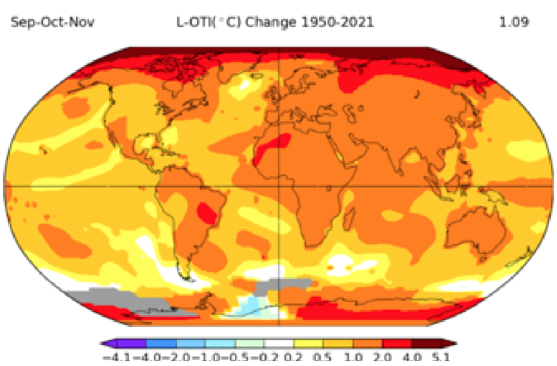
The graphs of temperature change from the chosen weather stations along the migration route also all showed a clear trend of increasing annual mean temperatures (Figure 2). Most of these graphs had an average increase of approximately 2 ˚C, although Bassatine in Morocco showed the largest difference in mean annual temperature from the lowest recorded during this time period to the highest recorded (approximately 4 ˚C). However, the general rise in temperature for Bassatine was around 2 ˚C (similar to the other locations), and the lowest recorded temperature of approximately 14.2 ˚C in 1972 appears to be an anomalous result, as it is significantly lower than that of any other year.

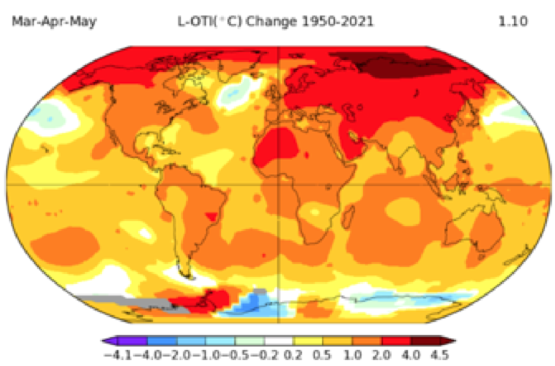
The literary search of how the conditions of the Sahara Desert may change due to climate change was relatively inconclusive as it is unknown precisely what changes will occur. As the climate changes, it is predicted that the storms will become more frequent and intense due to increased evaporation as a result of rising temperatures, but areas which are not close to storm tracks are likely to experience a decrease in precipitation levels and an increase in risk of drought (NASA, no date). Assuming that in this case 'storms' refer to tropical storms, it is most likely that the migration routes for Swifts will become drier, as tropical storms do not generally occur anywhere along the migration routes (Figure 3).

Therefore, if many areas of Africa become drier, especially North and sub-Saharan Africa, the distance necessary for birds to safely cross the Sahara is likely to increase. The Sahel (a region in sub-Saharan Africa which is important to many migratory species) is already experiencing much drier conditions, so it will probably continue to do so as climate change becomes worse, as this change is most likely due to a combination of a decrease in plant cover due to human activity and the increase in surface temperature of the Atlantic Ocean due to climate change (Cox, 2010).

However, there is some controversy on exactly how conditions will change in the Sahara. Lui *et al.* (2001) predicted that the Sahara could actually become smaller and move further North and West, which could be justified by the prediction that monsoon rainfall could increase in future (Pausata *et al.*, 2020).

Figure 1. Temperature changes since 1950 in autumn (left) and spring (right). Gray areas indicate a lack of data. Maps adapted from the Goddard Institute of Space Studies (2022).





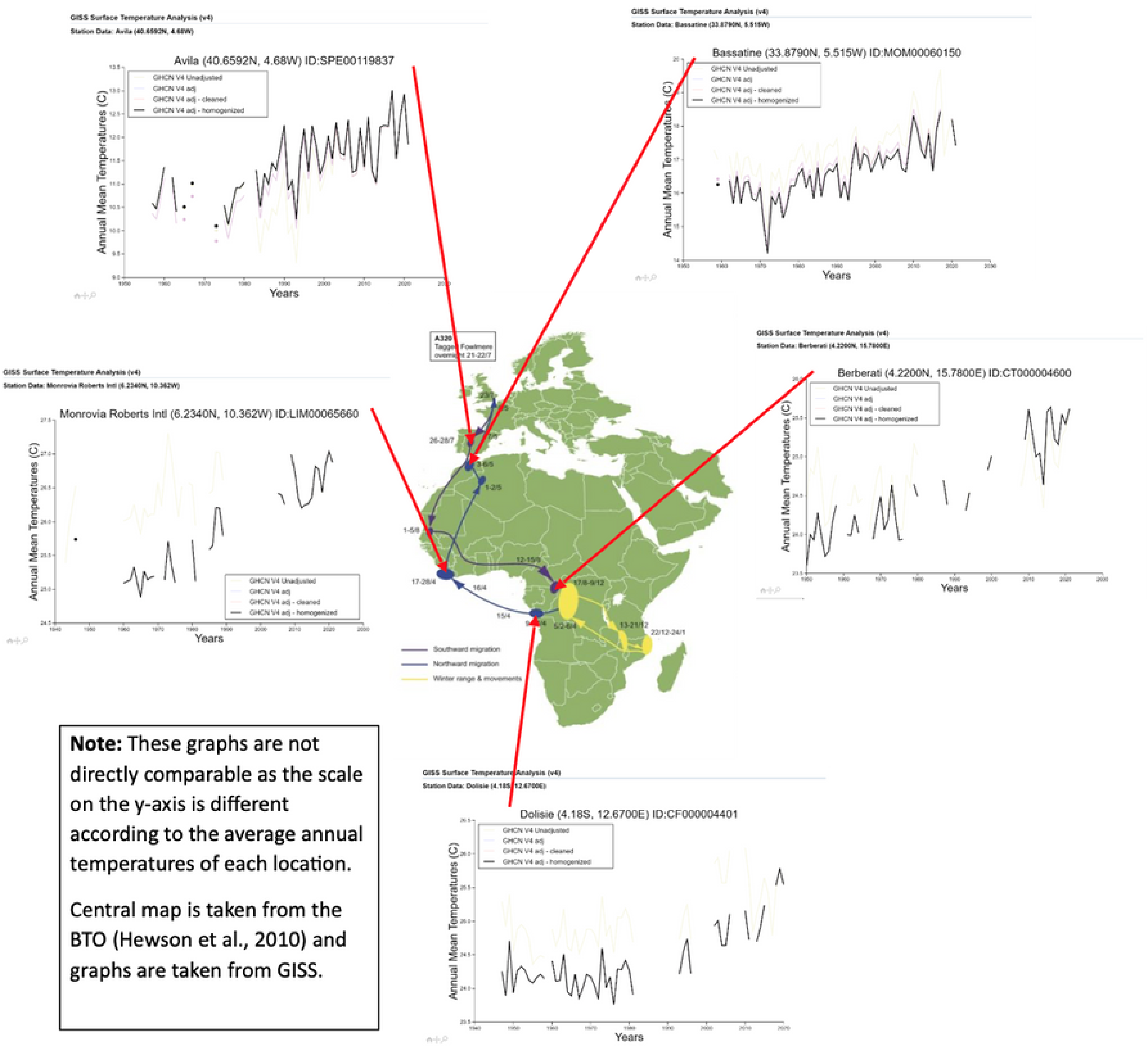


Figure 2. Temperature changes in key migration stopover locations.

CONCLUSION

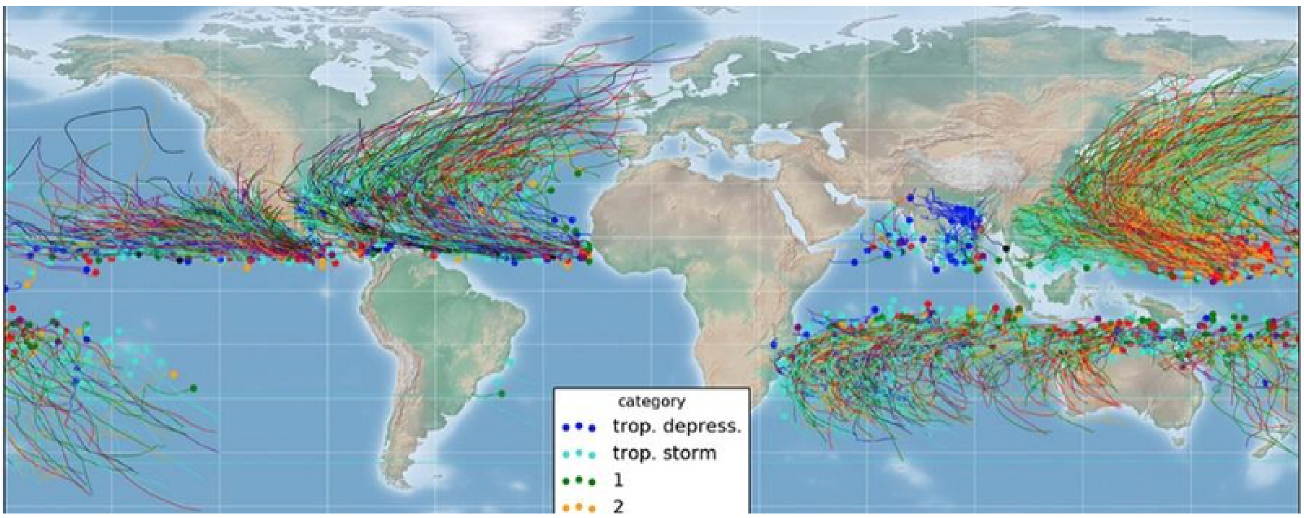
The inconclusive nature of current scientific research about the change in conditions of the Sahara due to climate change makes it impossible to predict exactly how migratory birds such as Swifts will be affected, so if this were to be achieved it would be necessary to have more evidence and data. However, it is unlikely that either change to conditions will have a positive impact on Swifts as they migrate. If the conditions become drier, Swifts could suffer from a shortage of food as there are usually more insects during the wet season and very few during the dry season, hence rainfall is especially important at some of the stopover sites such as those in West Africa. Furthermore, if sources of water in the Sahara were to dry up, the Swifts may not easily be able to drink, as they drink by flying low over water and skimming the surface, or else by catching raindrops. It is thought that insects in tropical regions may potentially be more vulnerable to climate change than insects in places such as the UK; this is because they don't usually experience high temperature variability and they may not be able to adapt to large temperature fluctuations (Bonebrake & Deutsch, 2012). This could then have an impact on Swifts, as they migrate to areas within the tropics. However, this is a tenuous link and more data would be needed to prove this theory.

On the other hand, if the amount of precipitation were to increase by a large amount (for example if there were more storms which reached Africa or if monsoon rainfall dramatically increased) it could potentially also be dangerous to Swifts. Large numbers of Swifts (and other species) were killed in a rainstorm off the coast of Tunisia in April 1982 (Perrins *et al.*, 1985) and 30 Swifts died due to the rain and wind in England in July 1930 during their autumn migration (Watson, 1930).

Apart from the Sahara, there are also other locations where a change in weather conditions could have a negative impact on Swifts. For example, poor weather conditions in the past have occasionally meant that Swifts are unable to return to their wintering grounds in Africa from north European breeding grounds as they have not been able to accumulate enough fat for migration, such as in 1986 (Kolunen & Peiponen, 1991). This led to the starvation of several Swifts as there were insufficient numbers of insects whilst the weather conditions were poor. As migratory species, they have not adapted to the winter conditions of their breeding grounds so if they are unable to migrate due to poor weather one year, they will likely die. In contrast, in Oxford in 1976, there was an unusually hot summer which was dangerous to chicks in the nest and many chicks did not survive (Bromhall, 1980). This shows that, even though hot weather can lead to an abundance of prey, it can still cause nesting attempts to fail.

Migration is probably contributing to some extent to the decline of Swifts as there has been a large decline in their population and there are relatively few other causes of mortality for Swifts. Although some falcons are predators to Swifts, they have very few natural predators compared to many other species, so it is unlikely that this is the main cause of their decline. Similarly, there have been cases where humans have been known to use Swifts as a source of food in Malawi and one Swift was shot in 1968 with a bow and arrow in the Democratic Republic of Congo (Chantler & Driessens, 2000); sometimes Swifts also fly low over roads in the evenings and are hit by cars, but humans directly killing Swifts is probably also not the main cause of decline as there are not frequent occurrences of these events. That does not mean that humans are not responsible for the decline of Swifts, though, as a very likely

Figure 3. Prevalence of storms across the globe. Adapted from Giffard-Roisin et al. *(2020).*



cause of decline is that humans are destroying the nesting habitats of Swifts (OpenLearn, 2010). Humans are also the main cause of climate change which, as discussed in this paper, is likely to have a negative impact on the conditions along the migration routes of Swifts. Additionally, climate change could potentially have some impact on the timings of the migration of Swifts, although a study of the Swifts nesting in Oxford between 1949–1957 (Lack, 1958) showed that for each of the six years where the mean date of the Swifts' return to their nesting site was studied, there was only a difference of nine days, suggesting a lack of influence by the weather. When Lack studied weather maps for these years, they also showed that the Swifts returned in varying weather conditions. However, there was an exception in 1951, where a cold northerly airstream through France and Britain corresponded to a large gap between the arrival times of different Swifts back to the colony, as the first Swifts arrived before the cold weather and the last Swifts arrived afterwards, showing that the timing of their return was influenced by the weather. Cold weather has often been shown to have an impact on the migration of Swifts as it affects the number of airborne insects, although this is unlikely to increase with an increasing global temperature.

It is impossible to draw a conclusion as to what extent migration is contributing to the decline of Swifts without having more data on the locations of Swifts' deaths and the causes of mortality, as they may be dying on migration, but without data to show this we cannot prove it. If there were to be more data on this, it would be possible to compare weather data for these locations at the time of the Swift's death to see if there is a relationship between them. Future studies could also focus on collecting more data on the decline of some of the insects which are a source of food for Swifts to see if this is causing the decline. Without this data, there is not yet enough evidence to show that Swifts are declining due to migration, but it is highly likely to be a contributing factor if not the main cause.

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Stopover sites in Africa for Tree Pipit (*Anthus trivialus*): an analysis of habitat and food availability.

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ABSTRACT

A lot is known about the chosen habitat and food preferences of Tree Pipits (*Anthus trivialus*) in the UK, but there's very little data available on their preferences for stopover sites en-route to and from their wintering grounds in Africa. By carrying out literary reviews, looking into ringing data and researching habitat and weather data, stopover sites can be identified, along with the habitat the areas are composed of. It showed that if available, Tree Pipits will use sites of a similar habitat (therefore containing similar food types) to those in the UK, with them having an obvious preference for open woodlands, especially coniferous trees. However, they will use other open areas, and more research is needed into the species' migratory habits to identify legitimate preferences in stopover sites.

INTRODUCTION

Tree Pipits (*Anthus trivialus*) are a migratory species to the UK, arriving around April and leaving late August to early September (The Sound Approach, 2019). Most information about their preferred habitat and food sources is known from their breeding range: Central and Northern Europe – from as far South as Spain and as far North as Norway (BirdLife International, 2022) – but very little is known about their habitat or chosen stopover sites on migration to and from Africa. In the UK, they prefer partially open habitats with perches to sing from (Simms, 1992). These are most frequently managed habitats, with a mixture of open space and perches, such as early successional woodlands and recently cleared plantations. A survey by Sussex Ornithological Society plotting 444 territories found 47% of Tree Pipits in young conifer plantations, 42% on commons and heaths, 5% in deciduous woodland ecotones, and the rest on a mixture of pastures, wooded lanes, and recently coppiced Chestnut. In Britain, new, open coniferous plantations with old trees left standing held the highest population density per km², with 67 pairs per km². However, the habitat in Europe with the greatest number of pairs (126 per km²) was traditionally managed farmland in Switzerland (Simms, 1992). This could suggest that managed or dynamic landscapes are more attractive to Tree Pipits, as they keep a balance of open and vegetated components, so in theory migratory stopover points could have a similar habitat.

Tree Pipits live off a diet of mainly invertebrates. Of 60 stomachs dissected in the USSR, 75% contained weevils, 41.7% bugs, 36.8% leaf-beetles, 33.3% caterpillars, 18.3% click beetles, 8.3% rove beetles, and only 8.3% containing plant seeds. They do, however, move to a more vegetarian diet in autumn and winter, feeding on berries and other plant matter (such as seeds of Pine, Aspen and other trees, alongside those from forbs such as Deadnettle, *Lamium sp* and Cow-Wheat,

Figure 1. Distribution of Tree Pipits in Europe and North Africa. Yellow is the breeding range, green the range on migration. Adapted from Birdlife International (2022).

Melampyrum sp.; Simms, 1992). Therefore, in theory, autumn stopover sites would contain these species, while spring ones could be theorised to have healthy populations of the invertebrate species mentioned.

Tree Pipits are a declining species in the UK, with long-term surveys showing them as rapidly declining, partially due to a loss of suitable habitat (dynamic woodlands – many have been left to turn into closed-canopy, or felled and never re-stocked). It is also hypothesised that there could be problems relating to habitat on their migration routes which could be causing declines, so by surveying the habitat type of favoured stopover points, subsequent studies could be done into how that habitat has changed overtime, and any potential effects (Massimino *et al.*, 2019).

Additionally, any prominent or important sites for migrating Tree Pipit will be picked up on through the research, and by looking at their management, habitat type, and flora and fauna, over time this could be converted into a baseline for managing other sites with potential to become important stopovers for birds. If migration-related impacts do influence declines, this could be a valuable tool in conserving the species.

METHODS

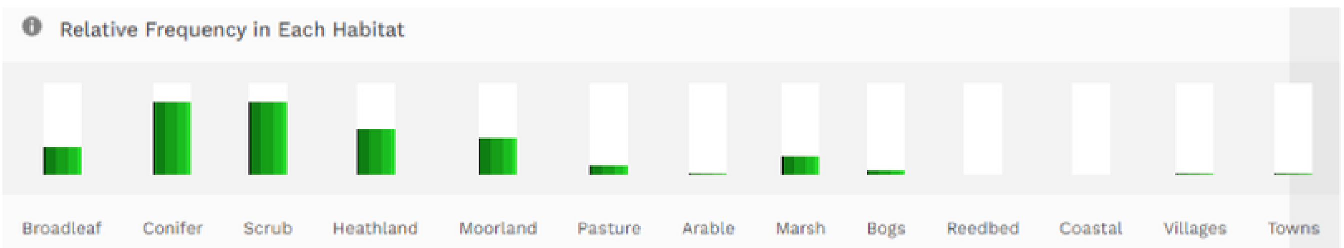
Background Research

Prior to any research on the bird's migration patterns and stopover points, I did some background research on the species to gauge its preferred breeding habitat and food sources and to act as a baseline of what to look for in stopover sites. This was done online, via the RSPB and BTO's collective data and research published on their websites, which are two of the top results when searching for 'Tree Pipit UK'.

Literary Review

To find out in-depth detail about the Tree Pipit is dietary and habitat preferences, I used the Chris Mead library at the BTO, by looking up all the books in the 'Pipits... Wagtails' section 598.861, then looking up 'Tree Pipit' in each and following it to corresponding pages, noting down useful information. This was where I got most of the information on habitat preferences in the UK and abroad, and read the study where Pipit stomachs were dissected (Simms, 1992). I also discovered the subspecies *Anthus trivialis haringtoni,* which I have largely excluded from

Figure 2. The Tree Pipit's preferred breeding habitat in the UK. Adapted from Robinson (2005).



subsequent research as they migrate to and from different areas, have different stopover sites, and there's less available data as they're not present in the UK. I was also given a book by a colleague on Cuckoo's, which briefly mentioned Tree Pipit decline in relation to suitable habitat (McCarthy, 2009).

To find out more on their migratory habits, I looked in the 'Migration' section of the Chris Mead Library (591.72) and again looked up 'Tree Pipit' down the index and followed it to corresponding pages. This gave me more in-depth information about where the Tree Pipits migrated to (direction, more specific times of year, and some potential stopover points, e.g., sightings of them at times of year where they would be migrating). It was also suggested I look in *The Migration Atlas: movements of the birds of Britain and Ireland* (2002) and look up Tree Pipit. This gave me some information on habitat types and areas the species has been known to use on migration, collected via ringing data.

I also searched for 'Tree Pipit Migration' online, which directed me to the scientific paper Zduniak's (2014) paper studying migratory Tree and Red-Breasted Pipits.

<u>Ringing Data</u>

BTO ringing data was used to get an in-depth idea of when the birds were travelling through different areas, and to look for clusters of sightings that could suggest stopover sites. On the BTO page on Tree Pipits, there were links to pages on ringing recoveries outside of the UK (Summary of Ringing Totals | BTO - British Trust for Ornithology) and EuroBirdPortal, which via a combination of ringing data and sightings, produces a general map of Tree Pipit movements over the last year (EuroBirdPortal, 2022).

Further to this, I was emailed some unpublished research by BTO Senior Research Ecologist, Greg Conway, on the movements of migrating Tree Pipits carrying geolocator tags, which helped further reinforce the ringing data, showing a general migratory pattern on the route the population in Britain and Northern Europe take while migrating.

RESULTS

From my research, I found five confirmed or very likely stopover areas. First identified was western Portugal. Ringing data from the BTO shows that out of the 25 foreign ringing recoveries, nine were found in western Portugal, a higher concentration than anywhere else, also reflecting the size of the area, and the fact it's one of the last stopover opportunities before crossing the Sahara. (Robinson, 2021). Though no specific sites could be found, it is possible Tree Pipits could be using the Cork Oak forests in the area as stopover points, as these mimic the ideal breeding habitat of Tree Pipits in Britain (large standing trees to use as perches, surrounded by open areas to forage and nest in; Simms, 1992). While no information could be found about different invertebrate species, and how these may be similar to those found in ideal breeding habitats, the Cork Oak forests are known to contain large mammals like Wild Boar (*Sus scrofa*) (Portuguese Cork Association, 2015) which have been proven to increase numbers of certain invertebrates through their rotavating action (de Schaetzen *et al.*, 2018).

The second stopover site is a cluster of islands off the south-eastern coast of Greece (Paximadia, Dragonda and Gianissada). This is not a confirmed stopover site, but a study of prey items caught by Elenora's Falcons (*Falco eleonorae*) on the island of Paximadia found 9 were caught between August-September (Alerstam, 1990). Records from Euro Bird Portal (2022) shows this is the time of year birds will be flying through Greece on migration South into Africa, and that birds do not breed in this part of Greece, with very few records of them in Euro Bird Portal over the summer months. Paximadia and the surrounding islands however are very open habitats (from photos) and the flora mainly consists of grasses and other forbs, similar to the ground flora of heathlands and grassland in the UK Pipits breed on (Robinson, 2005).

However, it has also been said that migrating Tree Pipits will occupy areas of coastal scrub and can be found in dense ground vegetation where no bushes or trees are available. (Wernham, 2002) so in that respect, the Tree Pipits fit the trend, as that is the habitat they are using on the islands. It is also likely that the Pipits are stopping over as opposed to simply being hunted on migration, as they migrate at altitudes of 3,500–5,000m high (Jiguet, 2019).

The third stopover point is Les Landes Forest, France. Ringing data and personal communications with Hewson (2022) suggest this could be an important stopover site for Tree Pipits from eastern England. Two ringing recoveries in the Les Landes Forest area were found between August–October, the usual time birds will be migrating south (Robinson, 2021). Les Landes is an artificial plantation forest, planted on previous marshland in the latter half of the 19th century, and felled and replanted overtime, like the Conifer plantations in the Tree Pipit is breeding habitat in the UK. The dominant species in Les Landes is the Maritime Pine (*Pinus pinaster*) which is a Mediterranean species (Britannica 2022), with Scots Pine (*Pinus sylvestris*) and Norway Spruce (*Picea abies*) more common species for the UK.

Although no specific sites were found from research, Morocco almost certainly holds some important stopover sites for Tree Pipits. Two ringed birds have been recovered from the region (Robinson, 2021) with one also mentioned in The Migration Atlas (2002) which also said: "[this] suggests that North Africa may provide additional stopover sites for British Birds" – referring to the British population of Tree Pipits (Wernham, 2002). With the high concentration of sightings and recoveries of migrant birds in Portugal, it is also plausible that after crossing the area of the North Atlantic or Mediterranean Sea separating Africa from Spain and Portugal, and prior to crossing the Sahara, that the birds may need somewhere to stop and refuel. Jiguet (2019) states that some birds do stop-off while crossing the Sahara, 56% suddenly rest after two days of travelling, suggesting they need to stock up their energy reserves prior to flying. They may be in the air flying for up to 40 hours at a time (Jiguet, 2019).

Figure 3. Gianissada Island, Greece (Kounelis, 2009)

While no specific sites were found, Morocco is known to have species of Conifer tree making up woodlands, with parts of it classed as temperate coniferous forest biome. As it contains many of the same trees as the Tree Pipits breeding grounds (B.E., Sawe. 2017), it is likely to be a suitable stopover site for Tree Pipits.

The final stopover site identified was in Eilat, Israel, where studies (F.Jiguet, 2019) of Red-Breasted and Tree Pipits were carried out. Of 2327 birds initially ringed for the study, 1853 birds were recaptured in the spring migration, and 474 recaptured in the autumn migration, showing there were four times as many birds captured in spring than autumn, so possibly more using that route to migrate. This, combined with other research from EuroBirdPortal, and the BTOs ringing data previously mentioned, could suggest there's a loop migration, where birds go up through Israel on spring passage towards the UK, and down through Portugal and Morocco on autumn passage to Africa. Out of those ringed, 53.9% were juveniles, 43.3% adults, and 2.6% unidentified. It was also discovered that stopovers normally were no less than four or five days at a time for Tree Pipits. The site itself is comparatively open compared to the other sites which Tree Pipits have been shown to stopover at, consisting of reserves, reservoirs, gardens, and agricultural land, with desert either side of it. (Zduniak, P. and Yosef, R., 2014.)

CONCLUSION

Overall, the research showed there was a pattern to the species' stopover sites. Where possible, they do try to pick sites similar to those they use to breed in in the UK - Coniferous plantations and forests with lots of open space. The best example of this is Les Landes, a site where there have been multiple recoveries of ringed birds, and a site which was suggested likely to be an important stopover point for the birds (Hewson, 2022). It has a very similar management plan to many UK plantations, of planting, clear-felling and repeating, so creates large tracts of open space for the birds as is done in the UK. However, the dominant tree species was *Pinus pinaster*, while the dominant one in UK plantations will likely be different. Because of this, it is likely there will be different types of invertebrates for the birds to feed on. However, due to the site's relatively close proximity to the UK, it is likely there will be similarities in genuses, though more research needs to be done.

The Cork Oak forests in Portugal also mirror the "ideal" UK habitat for Tree Pipits. This is a cleared Coniferous woodland (Simms, 1992), but with a few trees left standing as perches. The largely open, empty field layer of a Cork Oak forest is a relatively good proxy for this, and the presence of Wild Boar as ecosystem engineers could be positively influencing the invertebrate life of the forests, also providing a food source for the birds. Due to a lack of time, not much research could be done on the forests of Morocco, but it is known they contain areas of temperate coniferous woodland, so it can be assumed this is where they stopover. However, more research must again be done.

On migration Tree Pipits will use areas of coastal scrub and grassland as stopover points (Wernham, 2002), and the stopover point in Eilat was again a very open area compared with the others. Since Eilat is just North of the Sahara, it is likely birds are less fussy about habitat type on spring migration, since they will be in a bad condition after crossing the Sahara, and will need somewhere with food and water to refuel quickly. Since the surroundings are mainly desert, there aren't many alternative sites either.

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What is the impact of migration routes on the survival of migrating Cuckoos (*Cuculus canorus*)?

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ABSTRACT
The Cuckoo (*Cuculus canorus*) migrates to Africa using two different routes. Using data collected by the BTO from tracking the migration of Cuckoos, there is a 12% lower survival rate on the western route than on the eastern route. There are many reasons why this could be; this change in survival could have been a result of climate change, but also of habitat loss and habitat change in the stopovers. Cuckoos remain for a few weeks and store up energy in order to cross the Sahara Desert into their wintering grounds in the Congo rainforest. This highlights the importance of stopovers on the migration journey. Looking at the data, it seems likely that less favourable conditions on the western route contribute to higher mortality rates than on the eastern route.

INTRODUCTION

The Cuckoo (*Cuculus canorus*) migrates from Africa to the UK in late March or April to breed. The adult Cuckoos spend several weeks here until they begin their migration back to the Congo Rainforest in July or August. About a month later, after remaining dependent on its foster parents for two weeks after fledging, the young Cuckoo, without the aid of any adult Cuckoos, start the journey back to where they will spend much of their life (Wyllie, 1981). On autumn migration, the Cuckoo has two distinct routes to reach the same wintering grounds, which enables us to assess the survival during migration independently of origin and destination (Hewson *et al.*, 2016). So, we can see that the factors that impact their survival are associated with their migration particularly in the stopover sites.

Between 1967–2007, the Cuckoo has declined by 59% (McCarthy, 2009). This issue of understanding why there is a decline in long-distance migrating birds and where mortality occurs during their annual cycle is becoming increasingly important because they are big indicators of climate change, habitat change and habitat loss. If there is a decrease in these birds' population then it is a sign that one of these factors has changed for the worse.

It was thought that the Cuckoo and other migrating birds found their way to Africa by something called the "3-compass method", which used a solar, stellar and geomagnetic field compass. However, it has been concluded that they possess an internal "GPS device" and with further research scientists found that they do this by pecton structures in the eye, which are the most primarily required sensory organ during the migration of migrating birds. (Gerrand, 2015).

Cuckoos are insectivorous birds. Their diet consists of hairy, warningly coloured and sometimes toxic caterpillars which very few other birds eat (Wyllie, 1981). The only competition for food would occur at stopover sites where there is competition for restricted food supplies that can reduce survival of the migration or breeding success (Newton, 2006).

The costs of migration may be route specific and are not necessarily related directly to migration distance. The BTO tracking data (2011–2022) showed that the Cuckoo's mortality is up to the completion of the Sahara crossing. However, the mortality rate was higher for the birds that flew the shortest distance before reaching the desert. This could suggest that the lack of rainfall provides more food sources thus not giving the Cuckoo as much fat stores. Which could be the biggest impact factor that is contributing to the fall in the population of Cuckoos.

Cuckoo tracking (Hewson *et al.*, 2016) showed that the Cuckoos from England are mainly taking the western route whereas the ones from Scotland and Wales are mainly migrating using the eastern route via Italy. So, for this paper, we can assume that their migration is contributing to the decline in population in certain areas because they are likely to be exposed to similar pressures during the rest of their annual cycle.

The main problem in understanding the decline in Cuckoos is that there isn't sufficient evidence of the conditions and data on their migration to determine the cause of the higher mortality rates in Cuckoos.

METHODS

I read books on the Cuckoo species and migrating behaviour and talked to Chris Hewson about his research. In Hewson and Atkinson's research (2011), they tagged multiple male Cuckoo's using satellite tracker to find out where these birds were migrating to. Satellite trackers are crucial in receiving this vital information about Cuckoo migration and they are thus important to being able to ensure survival of the Cuckoo population. There are many advantages of using satellite trackers: they emit the data live in contrast to geolocators (and you need to recapture the tag in order to receive the data) or a Motus tracker, which requires the bird to fly near the tower to transmit the data. Satellite trackers are also highly accurate and last a long time due to them being very robust and having a longer battery life.

However, some disadvantages that have hindered tracking studies, therefore resulting in a lack of data, would be that these tags weigh around 5g. This means they are too heavy for most birds; only male Cuckoos can be tagged as females are too small. The trackers haven't been developed any smaller as of yet because they are very expensive (costing around £3000 each), and therefore would cost a lot to develop.
Hewson and Atkinson (2011) have tagged Cuckoos from eight different locations across the UK. These being: Kinloch & Skye, Trossachs National Park, Tregaron, Dartmoor, New Forest, Ashdown Forest, Sherwood Forest, Thetford Forest and the Norfolk Broads.

I then looked at data collected of rainfall in Northern Spain and Northern Italy and compared these with the increases in insect populations in both places using the weather data and insect surveys. I also looked at the data that the trackers picked up as to which route the bird took and whether they survived the journey.

I also cross-referenced this information with the populations of the breeding grounds in the UK and where the specific bird was tagged.

RESULTS

The preparation for the migration is the most important part of the migration process to ensure the survival of the Cuckoo. An unusual increase in mortality during recent years is associated with the western route before the crossing of the Sahara Desert, meaning it is likely that the conditions at the stop-over sites in this area are responsible for these deaths. This could be due to several possible causes: a decrease in rainfall in Spain as well as severe droughts and associated wildfires occurring in recent years; large-scale habitat changes; or increased predation pressure (Hewson *et al.*, 2016).

In autumn migration strategies are thought to be more energy-selected compared to spring where they are time-selected. This could make them more vulnerable to the effects of environmental change at stop-overs because the autumn migration has evolved in relation to energy availability. However, there is a possibility that Cuckoos that take the western route undertake more pre-migratory fattening at their breeding location. The evidence for this is shown by the data that trackers collected; on average these birds left the breeding grounds eight days later than the eastern route Cuckoos and therefore spent less time in the stopover sites before crossing the Sahara. (Hewson *et al.*, 2016).

Food availability and rainfall

The regions where the western route Cuckoos tend to be tagged are seeing a particularly severe decline in large moths, the caterpillars of which are a major food source for the adult Cuckoos. The total abundance of larger moths caught in the RIS light-trap network in Britain decreased by 33% over 50 years (1968–2017). Losses were greater in the southern half of Britain (39% decrease) than in the northern half (22%) (Fox, 2021)

Therefore, the effects of poorer conditions on stop-overs the further south in Europe they go would have a bigger impact on the survival of the population.

In the places where the rainfall is above 800–900mm (Mata, 2008) they coincide with the average stopover areas therefore seem to be ideal stopover sites for the Cuckoo (Hewson *et al.*, 2016). This leads us to ask why these places are more advantageous than others. If we find the answer to the question, then we can determine the causes of the decreasing survival of the Cuckoo population. Furthermore, we can find the best ways of conserving these areas. This also leads us to ask the question: with an increase in climate change, will this affect these areas and potentially decrease the population more?

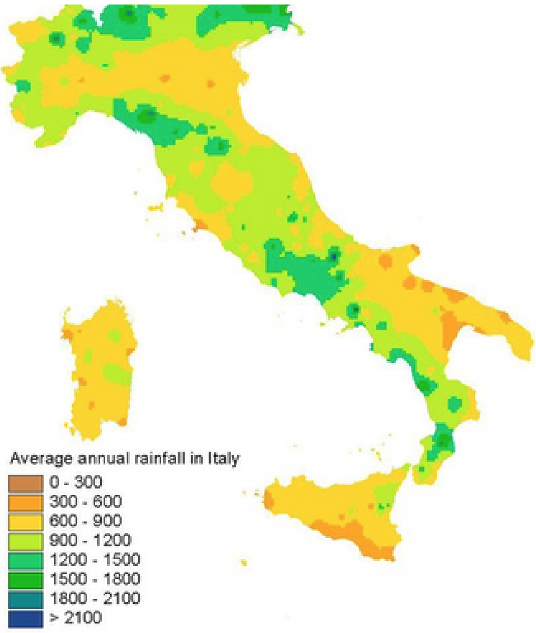


Figure 1. This graph correlates with the data Hewson found on where Cuckoo stopovers are located. The greener areas are where the Cuckoos prefer to stopover (Grimm, 2002).

Data shows (Figure 1 and 3) that Northern Italy has over four times as much rainfall as Northern Spain (Figure 2). Therefore, we can assume that, because there is more rainfall, there are also more caterpillars of moths and butterflies. Cuckoos taking this route are then likely to have more energy-stores and a higher proportion of them will be able to survive the desert crossing. This is an example of more favourable conditions contributing to lower mortality rates.

Research shows that Cuckoos taking the south-

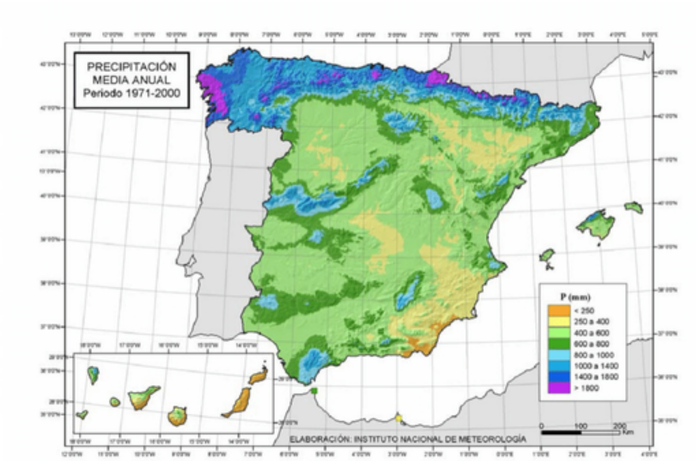
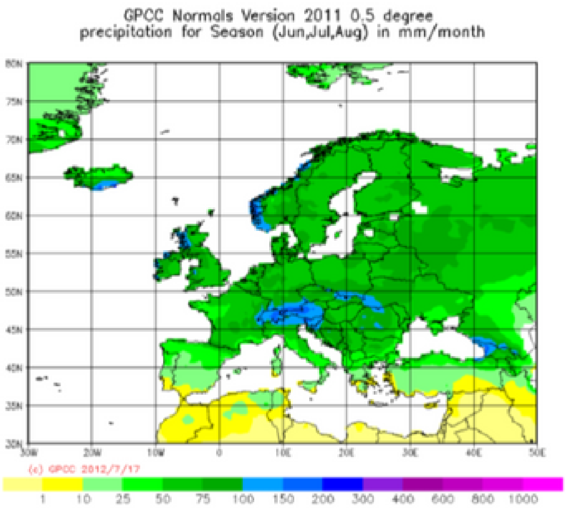


Figure 2. This graph correlates with the data found on where the Cuckoo stopover points are (Mata, 2008).

western route via Spain are 12% less likely to survive the migration journey over the Sahara crossing than those taking the south-eastern route via Italy or the Balkans (Hewson *et al.*, 2016). We can assume that these birds usually take the same route every year (apart from when they are disrupted by bad weather) from the same breeding grounds as they were hatched. As Cuckoos are site-loyal, the bird is likely to be tagged in a similar place in the UK to where they are born.

Population trends are linked to the migration routes the Cuckoos take. For example, many of

Figure 2. Absolute long-term mean precipitation for 1951–2000 for summer. Adapted from the Global Precipitation Climatology Centre.



the Cuckoos taking the western route come from England, where the population has decreased over recent years (Hewson et al, 2016; Figure 4). Cuckoos taking the eastern route tend to come from North Scotland and

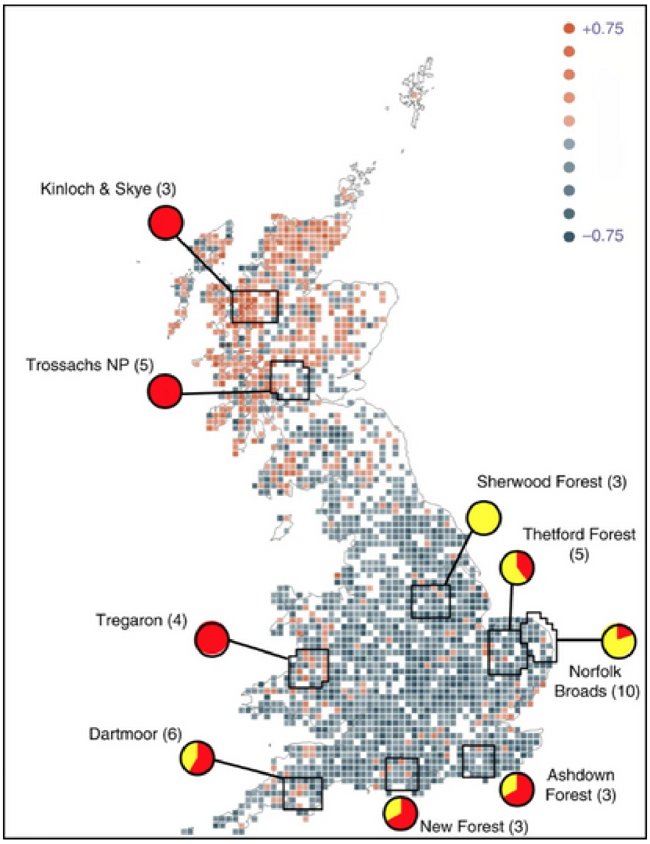


Figure 4. Tagging locations of Cuckoos, adapted from Hewson (2016).

Wales, where the population has increased or stayed the same.

During 2012, the tracking data shows that none of the tracked birds that took the western route survived. For example, Reacher (tagged in Norfolk) died near Granada (Southern Spain) on the autumn migration. In that same year rainfall in Spain (especially Southern Spain) was low compared to Northern Italy (Figure 3).

Rainfall could have been a factor in the Cuckoo deaths for a couple of reasons: food availability and harsh weather conditions.

In 2012, there is a strong possibility that the reason for the dip in survival of the Cuckoo on the western route is due to low food availability. Less rainfall means caterpillars are less accessible, and the Cuckoos don't get the required fat stores needed to complete the migration journey so they are less likely to survive the migration.

Harsh weather

Likewise, rainfall also affected the eastern route in 2015 as Italy suffered a drought. This caused a number of disturbances in the Cuckoo migration. For example, Cookie, who was tagged in Northern England, died near Milan because of the drought; it also caused both Roy and Viator to stop over in Croatia instead. However, Viator later died in the Sahara Desert, which could be because the fat stores he acquired in Croatia were not enough to sustain him across the desert. This gives evidence that if the conditions of a stopover site change or worsen, then this could have an impact on the survival of these birds. We also must consider if the worsening conditions are due to climate change. If so, then climate change more generally could mean a detrimental effect on the Cuckoo population in the long term.

Predation

Predation is another factor which determines the success of a stop-over site. Being a larger than average bird, Cuckoos do not have many predators other than birds of prey, such as the Peregrine (*Falco Peregrinus*). The Peregrine population has increased from 34 to 47 territorial pairs between 1998-2017 in northern Spain where the Cuckoo's stopover site is located (Zuberogoitia, 2019). From this we can draw the conclusion that the rise in Peregrine numbers could be contributing to the poorer conditions on the western route and lessened the survival rates of the Cuckoos taking that route. Cuckoo chicks and eggs are vulnerable to nest predators like Stoats and Weasels, too.

Looking at the tracking data that was collected, many of the Cuckoos seem to favour more mountainous areas which could be due to them wanting to avoid human contact. It seems unlikely that anthropogenic causes of death are having an impact at this stage in the journey, although hunting is more common in Africa. However, anthropogenic impacts could be separated into several categories: hunting and accidental deaths; being killed by man-made objects; dying due to pollution; and contact with urban environments (Figure 5). Of these, 36% were deliberately taken by man; 35% of the deaths were human-related; 10% domestic predator and 19% died in another way. This means that over 80% of those deaths were associated with human impacts. We need more research into these stopovers and how much impact humans have on them

.

The poor conditions that determine a good stopover site, as seen by the evidence, are either weather, especially rainfall; food availability and predation (either by birds of prey or human impacts). We need to conserve the location that Cuckoos inhabit, especially these important stop-over sites. To do this more data and research are needed into the exact causes of decline. At the moment, all we can do is speculate about them using the little data we have.

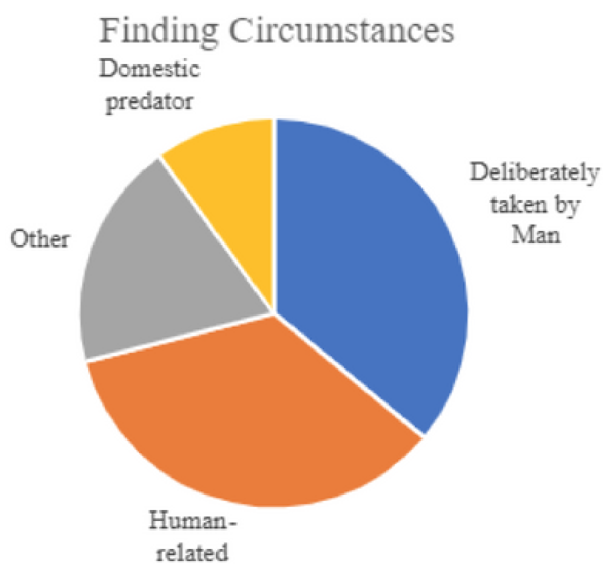


Figure 5. Conditions under which dead Cuckoos were found. Adapted from Wernham (2002).

CONCLUSION

At this stage, it is not clear what is affecting the decline of Cuckoos in England and as to whether the decrease is due to a problem in England or a problem on the migration route. The data point towards the decrease being due to the stopover sites not being satisfactory, and therefore it could be that the decline is due to most of the Cuckoos born in England taking that route. The data discussed in this paper would seem to support the hypothesis that the western route's poorer conditions are contributing to the higher mortality rates along the route.

However, we can only assume that this is the reason for the decline in the survival of the population of migrating Cuckoos. There is still a lack of data on the migration of Cuckoos. To increase our knowledge, we would need more data on the caterpillar population in stop-over sites as well as the human activity in those locations so we can better determine the cause of the decline, and analyse why the eastern route is more successful.

We then must think about whether conservation can have an impact. If we cannot change the route which Cuckoos take to migrate, then could we introduce food sources or protect these stopover sites from human interference, thus helping more Cuckoo taking that journey survive and therefore stopping the decrease in their population.

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What affects Lesser Black-backed Gulls (*Larus fuscus*) more: wind farms or climate change?

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ABSTRACT
Combating climate change has been a key driving force for the increased development of offshore wind farms in recent years. Wind turbines are an excellent source of renewable energy, especially offshore in the UK where strong winds create a reliable power source, but can be harmful to some species of birds, including the Lesser Black-backed Gull. This paper explores the extent of the damage, what can be done to minimise risk, and whether abandoning wind farms and allowing climate change to run its course would be less harmful to the species than allowing wind farms to continue being built on migration routes, potentially injuring or killing Lesser Black-backed Gulls.

INTRODUCTION

The Lesser Black-backed Gull (*Larus fuscus*), is a large white-headed gull species with a dark, grey to black mantle. They have a highly varied diet within the species (O'Connell, 1995), allowing flexibility to live in a variety of habitats, including urban. They are protected by the Wildlife and Countryside Act 1981 (as amended) (WCA 1981), making it an offence to kill or injure the species or destroy eggs or nests. Lesser Black-backed Gulls are fully protected where they are a notified feature of a Site of Special Scientific Interest (SSSI). They are also a qualifying species for several Special Protection Areas (SPAs), under the EU Birds Directive Annex I, a piece of legislation obliging member states to take special protection measures where species are rare or threatened (BirdLife Data Zone, 2022).

Their general population trend is decreasing, with a decline of 48% since the 1970s (Slater, 2022). Due to increased year-round availability of food, there has also been also an increase in the numbers of Lesser Black-backed Gulls found in the UK in the winter months (Wernham *et al.*, 2002), as well as an increase in numbers of gulls breeding in other areas (e.g. Scandinavia, Iceland, and Belgium) and wintering in the UK. Breeders from these places are beginning to come to the UK instead of migrating further south as they have done historically (Wernham *et al.*, 2002).

From the mid-twentieth century onwards, landfills became more widely used due to the Clean Air Act. Changes to landfill practice meant that there was a predictable year round supply of food. Due to this increased year-round food availability, there has also been also an increase in the numbers of Lesser Black-backed Gulls found in the UK in the winter months (Wernham *et al.*, 2002), as well as an increase in numbers of gulls breeding in other areas (e.g. Scandinavia, Iceland, and Belgium) and wintering in the UK. Breeders from these places are beginning to come to the UK instead of migrating further south as they have done historically (Wernham *et al.*, 2002).

Presenting a barrier to migrating birds and birds commuting between breeding sites and feeding areas disrupts migration and daily flight patterns. Birds often choose to fly around wind farms rather than through them, which can disrupt migration routes to varying extents depending on the size of the wind farm. Alternatively, wind turbines carry a risk of harming gulls as they fly into blades and get injured. Killing Lesser Black-backed Gulls has more of an impact as they are long lived birds that have few young each year and a high adult survival rate (90%) (O'Connell, 1995), so killing a small number of them will impact populations to a greater extent than killing a shorter-lived bird produces a greater number of young each year (O'Connell, 1995).

IMPACTS OF CLIMATE CHANGE

Migration primarily evolved as a response to seasonal changes in food resources (Berthold , 1998). As food abundance varies with climate, meteorological factors are expected to be involved in the control of bird migration (Berthold, 1998). Changes in temperature, precipitation, climate, and more extreme weather: all consequences of climate change that affect birds. As birds, especially migratory birds such as the Lesser Black-backed Gull, are highly sensitive to weather, they are more directly affected by climate change than more sedentary birds that do not rely on seasonal climate changes to tell them when to migrate (Berthold, 1998). These patterns allow the birds to estimate that there will be food supplies at their destination (Berthold, 1998), so any changes to seasonal climates may cause birds to migrate at the wrong time, arriving where there are limited food supplies. Limited resources could decrease survival rates and overwinter return rates (O'Connell, 1995).

Weather and climate changes due to global warming can impact migration patterns (Klaassen *et al.*, 2011).We are seeing a reduction in the extent of migratory activity (Berthold, 1998). Extensive changes in bird migration can be expected, especially if marked changes in global climate should occur (Berthold, 1998). The migration patterns and breeding season timings of Lesser Black-backed Gulls may have to change quickly to keep pace with climate change, making them less used to their environment and potentially changing their behaviour (Berthold, 1998).

However, it's possible that Lesser Black-backed Gulls may be less sensitive to the effects of climate change than some other seabird species. For instance, they are not wholly reliant on sand eels for foraging during the breeding season, and are therefore not vulnerable to the northward shift in sand eel distribution with rises in sea surface temperature, which has been described in other species such as the Shag (*Phalacrocorax aristotelis*; Howells *et al.*, 2017). It is important to consider the entire breeding and wintering range of a migratory species when studying the effects of climate change on a species. The diet of Lesser Black-backed Gulls varies greatly across the species, including human refuse, waste from fisheries, various marine and terrestrial sources, plant matter, and eggs or chicks from neighbouring nests (O'Connell, 1995; Ross-Smith *et al.*, 2014). While diet varies greatly within the species, there is evidence that Lesser Black-backed Gulls who eat more fish have longer lifespans and higher reproductive success rates. Adult individuals with a diet consisting of >60% fish have a breeding period of >10 years, long lifespans, and high breeding success rates compared to Lesser Black-backed Gulls who have little or no fish in their diet (Annett, 1999).

Decreases in productivity could also be caused by extreme weather as a result of climate change, especially as storms and flooding increase. Low-lying nests may be flooded and destroyed (MPA 2022), reducing reproductive success.

Overall, climate change will certainly have some effect on Lesser Black-backed Gulls. However, this effect might be less pronounced than in seabirds, as they are more adaptable to different resources and habitats as a species. It is very difficult to predict the exact consequences of climate change on the species, and the amount of research required to make accurate predictions falls outside of the scale of this paper. Lesser Black-backed Gulls are most likely to experience indirect consequences through food source, prey, and habitat changes. It is important to note that studying the UK in isolation for the impacts of climate change on the Lesser Black-backed Gulls can be effectively meaningless due to the widespread distribution of these birds, so the effects will be more far-reaching than those described here.

COLLISIONS WITH WIND TURBINES

Governments worldwide are investing in offshore wind farms in an attempt to increase global renewable energy production (Ross-Smith *et al.*, 2016). Pre-Brexit, this meant upholding the Offshore Renewable Energy Strategy, set by the EU, and other renewable energy targets set by lawmakers in the UK and EU. This has resulted in a very fast-paced and scaled-up development of wind farms, without time to adequately research its effects on wildlife.

Offshore wind farms are valued as a source of renewable energy as they are fairly reliable, are considered less of an eyesore than terrestrial wind farms, and do not take up land that could be used for other purposes. These factors combined mean that offshore wind farms were a key part of renewable energy strategies, especially in places such as the UK during the early 21st century, where other forms of renewable energy, such as solar panels, can be less reliable (Bett & Thornton, 2016).

Wind energy is a key part of meeting the UK's renewable energy targets (50GW of installed offshore wind capacity by 2030). 24% of energy produced in the UK in 2020 came from wind energy, with offshore wind accounting for 13% and 11% from onshore wind. Wind energy generation has grown by 715% from 2009 to 2020 (Office for National Statistics, 2022). The EU Offshore Renewable Energy Strategy aims to increase its offshore energy capacities from 12 to 300 GW by 2050 (IEA, 2022). This is a major increase, prompting a large number of developing wind farms to undergo construction around major Lesser Black-backed Gull migration routes and breeding ground flight paths, for example in the North Sea, English Channel, and the Bay of Biscay.

Wind farms are often proposed in upland, offshore or coastal areas as these areas are the most likely to have high average wind speeds. These locations can impact on the breeding, wintering, and migrating habitats of birds.In Lesser Black-backed Gulls, even small population losses could become significant because of their longer lifespan, so the species does not replace itself as quickly as some shorter-lived species with much higher reproductive rates. In addition, as many UK-breeding Lesser Black-backed Gulls winter in southwest Europe and northwest Africa, there are a number a large proportion of wind farms are built on their migration routes, potentially further increasing the collision risk. Wind farms comprise of the wind turbines themselves, interconnecting cables, transformer stations, meteorological masts and ancillary infrastructure including onshore access roads and visitor centres. The components of the individual turbines comprise a tapering mast, the nacelle or hub, foundations and rotor blades. The proportions of the turbine are determined by the rotor blade length and tower height. I will mainly be focusing on the actual collision risk with the blades, however it should be noted that there are still risks to wildlife involved (collision and otherwise) with all components of a wind farm, as well as benefits (for example, a reduction in commercial fishing around the wind turbine bases can provide safe havens for fish as well as easy food supply for birds and other predators (Ross-Smith, 2022).

Although most research on the impacts of wind farms on wildlife including birds is either inconclusive or suggests effects that are not significant for a given species (Klaassen *et al.*, 2011), this should not be used as a justification for poor or inaccurate assessments for new developments. Studies show that in recent years, wind farm development has led to an increased number of collisions with wind turbines (Klaassen *et al.*, 2011).

Lesser Black-backed Gull breeding distributions and foraging ranges suggest a high likelihood of probability of interactions with offshore wind farms during the breeding season (Klaassen *et al.*, 2011), when they are most likely to be in the UK. Ross-Smith *et al.* (2016) showed that Lesser Black-backed Gulls fly lower at sea than over land, and lower at night than during the day, and spent significant amounts of time within the risk area of the turbines. During the breeding season, Lesser Black-backed Gulls flew closer to turbines than outside the breeding season, meaning that vulnerability to collision is higher during breeding (Thaxter *et al.*, 2019). However, this may be because they aren't encountering as many turbines outside the breeding season. If there were large turbines near their wintering grounds, it is suspected that many birds would fly just as close as they would in the breeding season (Ross-Smith, 2022).

In areas of very high turbine density (for example in Galicia, Spain), vulnerability during migration is comparable to vulnerability in places with lower turbine densities during the

Table 1. This data shows an overall increase in the height of blades above sea level over time. While there was insufficient time to gather a full data set and make full comparisons, this source suggests why developers are increasing the height of their blades above sea level. (Farms et al., 2022)

Name	Year of Full Commissioning	Height of blades above sea level (m)	Model	Total Height (m)	Rotor diameter (m)	Tower height (m)
Gunfleet Sands	2010	26.5	SWT-3.6-107	133.5	107	80
Thanet	2010	Minimum 22	V90-3.0MW Offshore	Up to 160	164	105/140
London Array	2013	29.5	SWT-3.6-120	149.5	120	89.5
Borssele 3 and 4-Blauwind Offshore Wind Farm (small section of large green development)	2021	23/58	V164-9.5 MW	187/222		

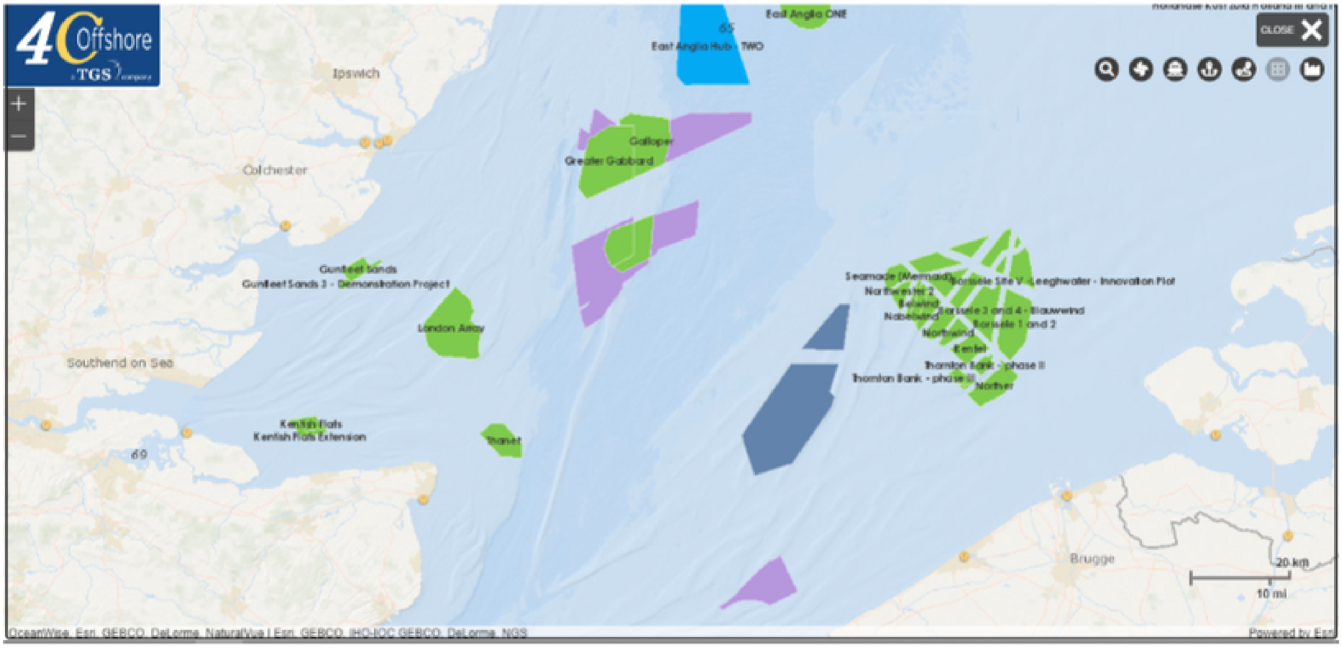

Figure 1. Section of the map studied, most relevant when compared with migration maps (Klaassen et al.*, 2011; Farms* et al.*, 2022).*

breeding season. While the Lesser Black-backed Gulls in this study were more variable in their migration strategy than other migratory species (O'Connell, 1995), the effects on their population and conservation status still need addressing as their migration strategy still involves crossing/close proximity to wind farms.. Limits placed on turbine density may be the best way to decrease fatalities during migration (Thaxter *et al.*, 2019). We can also consider switching off turbines during migration, using UV paint/deflectors on blades to assist in visibility of the blades to birds, or replacing older turbines with new, taller ones when they have to be renovated or replaced (Klaassen *et al.*,, 2011). Ross-Smith *et al.* (2016) stated that a risk window from 30–258 m carried the lowest risk of collision, compared to the highest risk at 22–250 m. This suggests that Lesser Black-backed Gulls are safer when blades are positioned at a minimum height of 30 m above sea level, as opposed to 22 m as in some designs. This has influenced legal requirements on minimum blade height for wind turbines near known colonies, or on common migration routes (Figure 1, Table 1; Ross-Smith, 2022).

Another factor to consider is wind farm placement. Winds are generally high (around 9–10 m/s) along all Lesser Black-backed Gull migration routes, allowing flexibility in terms of wind speeds and potential energy production offshore. It should be possible to build wind farms in areas that do not disrupt migration routes with more flexibility than on land. There are clearly other factors such as maritime traffic, the suitability of the seabed for construction, and fisheries. Similarly, it would be worth considering placing wind farms more northerly, considering other factors, as there are slightly more powerful winds further north (Global Wind Atlas, 2022).

With ongoing changes in migratory behaviour due to climate change, more data are needed to assess the extent of this change. Long-life GPS tags may be useful for mapping migratory patterns of species of concern to identify hotspots of vulnerability. Information relating to collision mortalities on offshore wind farms is also limited because of the difficulty of detecting collisions at sea (Klaassen *et al.*, 2011). More research around the number of collisions on offshore wind farms is urgently needed, for example via boat or aerial surveys.

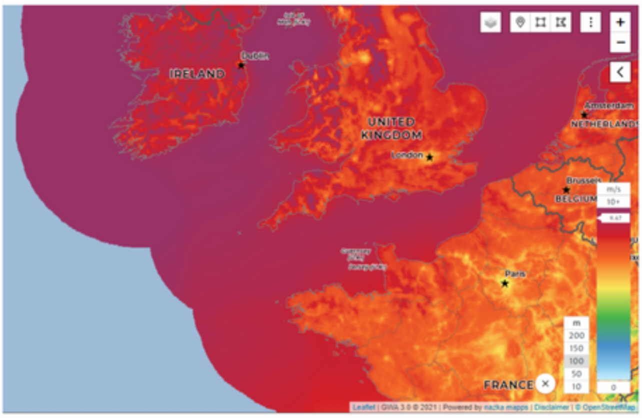

Figure 2. Wind speeds in the southern UK and Western Europe, with red being the fastest wind speeds.

The scale of direct habitat loss resulting from wind farm developments is likely to be small because of the small base size of each individual turbine, however the bases may interfere with seabed use, water flow near the coast, increasing erosion, or affect currents. Additionally, large numbers of turbines may have a greater impact on these factors because of the large numbers of bases involved-the overall seabed taken up by turbine bases is much larger. Research into this is ongoing as a lot of the consequences are uncertain.

CONCLUSION

While climate change may not affect Lesser Black-backed Gulls as much as other, more vulnerable species, the obvious far-reaching impacts of climate change and the potential of renewable energy developments to counteract this make offshore wind energy a worthwhile investment. We will not know the risks of climate change to the species until they actually happen – this especially concerns long-term risks. Short-term, there may be some benefit to the Lesser Black-backed Gull as a species as it is not as sensitive to weather changes as some other species due to its flexibility between habitats and diet (O'Connell, 1995). However, there may be problems with individual birds in the species. For example, if a key food source declines and the individuals can not easily switching over to another food source. Long-term, the effects are so far-reaching and impact so many species that it is impossible to talk about sufficiently in this paper due to time constraints.

Wind turbines can be less disruptive to wildlife than many other forms of renewable energy due to the relatively small base size and height. While there are collision risks with wind turbines, changes to their construction e.g. a minimum blade height above sea level of 30 m are likely to be able to effectively mitigate these risks (Ross-Smith *et al.*, 2016). We need more research on collision rates with offshore wind farms, for example via boat or aerial observation, since data on this is limited and hard to collect. This will allow us to further assess the extent of the actual risk to the Lesser Black-backed Gull, instead of making estimates. However, the current evidence available suggests that wind farms are less likely to be harmful to Lesser Black-backed Gulls than climate change. This is mainly due to the unpredictable far-reaching impacts of climate change on almost every aspect of wildlife. Under UK legislation, an Environmental Impact Assessment (EIA) is required if there are potentially significant environmental impacts as a result of the development and, in the majority of cases, impacts to conservation efforts can be minimised by careful siting. Ideally, information would be collated to identify areas with minimum impact on bird habitats from the beginning stages of planning. (Berthold, 2006).

Building more wind farms is likely to be beneficial to both Lesser Black-backed Gulls and the rest of the world by creating more renewable energy and therefore reducing impacts on Lesser Black-backed Gulls due to changes in climate. However, a minimum blade height of 30 m above sea level is likely the best way to keep building wind farms while minimising collision fatalities/injuries of the gulls with the turbines.

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