The Effect of Climate-Driven Temporal Changes on the Migration Phenology of Short- and Long-Distance Migratory Bird Species at Gedser Fuglestation

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24 – 6 – 2026

Gedser, Denmark

Research Report

The effect of climate-driven temporal changes on the migration phenology of short- and long-distance migratory bird species.

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Source pictures front page

Natural History Museum Denmark. (n.d.). European Robin, *Erithacus rubecula.* The Danish Bird Migration Atlas. Retrieved February 22, 2026, from https://dk.birdmigrationatlas.dk/uk/species/european-robin

Natural History Museum Denmark. (n.d.). Willow Warbler, *Phylloscopus trochilus.* The Danish Bird Migration Atlas. Retrieved February 22, 2026, from https://dk.birdmigrationatlas.dk/uk/species/willow-warbler.

Preface

This research report has been written as part of a research internship that was conducted as part of the Applied Biology program at HAS Green Academy in ‘s-Hertogenbosch, The Netherlands. The research was conducted at Gedser Fuglestation in Gedser, Denmark, under the supervision of Tina Elley.

This study focused on the effects of temporal changes on the phenology of migratory patterns in both short- and long-distance migratory bird species. The results of this research contribute to our understanding of the effect of global warming on bird migration and can support future research in this field.

Summary

Climate change has been associated with shifts in migration phenology in many bird species. The aim of this study was to investigate the influence of climatic changes in Gedser, Denmark, from 2007 until 2025 on the timing of spring and autumn migration of two short-distance migratory species and two long-distance migratory species. The short-distance migratory species were the European Robin (Erithacus rubecula) and Goldcrest (Regulus regulus), the long-distance migratory species were Lesser Whitethroat (Curruca curruca) and Willow Warbler (Phylloscopus trochilus). Meteorological data was sourced from the Danish Meteorological Institute (DMI) and migration data was sourced from Gedser Fuglestation's database. This data was analyzed to find potential trends in average annual spring and autumn temperatures, average arrival dates during the spring and autumn ringing seasons, correlative relationships between temperature and arrival date and differences in response to temporal shifts between the short- and long-distance migratory species. Average autumn temperatures showed a significant positive trend, while average spring temperatures showed a non-significant positive trend. All research species showed trends towards earlier spring arrival dates, although none were found to be significant. Three species showed non-significant trends towards later autumn arrival dates, with only the Lesser Whitethroat showing a non-significant trend towards earlier autumn arrival. Significant negative correlative relationships between temperature and arrival date were found in the Goldcrest, Lesser Whitethroat and Willow Warbler. The European Robin showed a nearly significant negative trend, indicating that increasing temperatures might lead to earlier spring migration. No significant relationships were found between autumn temperatures and arrival dates. No significant difference was found in the response to temporal changes between the short- and long-distance migratory species. These findings suggest that increasing spring temperatures might cause earlier migration timing in birds, despite the absence of significant long-term trends in average spring arrival dates. In contrast, autumn migration timing was found to be less consistent between species, with limited evidence of a consistent response to temporal changes. Future studies incorporating extended research period durations and data collected across multiple geographical locations could prove to be valuable to our understanding of the influence of climate change on avian migration phenology.

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1. Introduction

Phenology refers to the study of recurring life-history events such as the migration of birds, blooming of flowers and spawning of fish and the timing of such events (Macphie & Phillimore, 2024). Phenological studies also examine how different biotic and abiotic factors can influence the timing of these events (Bergant et al., 2006). One example of an abiotic factor that can influence the timing of phenological events is climate change. Long-term shifts in climatic patterns as a result of climate change can strongly influence phenological events such as emergence, peak activity, and reproduction (Donahue & Wolkovich, 2021). These changes in phenology can, in turn, influence an individual organism's fitness (Davis et al., 2008). Intra- and interspecific interactions and behaviors such as predator-prey relationships or interspecific mutualisms can be altered as a result of climate driven phenological shifts. These behavioral alterations can disrupt the stability of the ecosystems in which they occur (Cesario et al., 2009; Rudolf & Yang, 2009). For example, the decline in individual fitness of great tits (*Parus major)* as a result of a phenological shift driven mismatch between the timing of nestling development and the peak of caterpillar abundance, a key food source for great tit hatchlings (Jenouvrier et al., 2013). Another example is the increase in competition between different plant species as their habitats start to overlap as a result of non-uniform phenological shifts among plants and pollinators caused by changes in climatic patterns (Inouye, 2019).

While not all animal species migrate, migration is a key phenological phenomenon in the species that do and among these migratory species there exists a wide range in migration strategies and distances. The migration of animals is a critical part of phenology and plays a crucial role in ecological relationships and the biological cycle of species (Anderwald et al., 2025). Like other organisms, migratory birds can be greatly influenced by phenological shifts in their migration patterns caused by climate change. The timing of migration can, for example, influence an individual's reproductive success rate or their chance of securing their own territory (Crick & Sparks, 2006). Climate driven changes in migration and breeding timing can decrease population sizes and densities by altering interspecific relationships and increasing competition between migratory- and resident bird species. In some cases, this increase in competition can even lead to fatal interactions. For example, pied flycatchers have occasionally been observed being killed by blue tits while trying to take over their nests (Ahola et al., 2007).

Migration in birds can be triggered by a multitude of factors. Photoperiod, temperature, food availability, local weather conditions and sex hormones all influence the phenology of migration. Of these factors, photoperiod and temperature seem to have the biggest impact on the timing of migration (Gao et al., 2024). While photoperiod remains a consistent annual migration cue for birds, the temperatures at the point of arrival are susceptible to change as a result of climate change. This, in turn, can lead to asynchronization between the arrival of migratory birds and the climate-driven seasonal events they rely on for breeding, such as spring green-up and peak food source abundance (Andreas et al., 2022; Andrew et al, 2017; Jenouvrier et al., 2013).

Although temperature is a commonly used migration cue for many different species, the reliance on it can be dependent on migration distance and is therefore not universal among short- and long-distance migratory bird species (Brzęk et al., 2021). Short-distance migratory species are defined as species whose migratory routes do not cross the Saharan Desert, whereas long-distance migratory species are defined as species whose migratory routes do cross the Saharan Desert (Karwinkel et al., 2025). Long-distance migratory species generally rely more on factors not influenced by climate change, such as photoperiod, as a cue for their migration (Ay et al., 2017). Photoperiod and, in some cases, daylight intensity regulate endogenous circannual rhythms in birds by stimulating the release of Gonadotropin releasing hormone, which stimulates the release of sex hormones, which cause migratory restlessness (Gwinner, 2003). On the other hand, short-distance migratory bird species rely more heavily on environmental factors in a closer proximity such as local temperature and weather conditions (Johnson et al., 2023). Global trends in phenological response to rising temperatures generally point towards the suggestion that short-distance migratory species respond more strongly to rising temperatures at the arrival points of their migration, with these species arriving 1,2 days earlier per degree Celsius (Butchart et al, 2017).

This study has examined the effect of changes in temperature on the mean spring and autumn arrival dates of short- and long-distance migratory birds and whether the relationship between temperature and migratory timing differs between these two groups at Gedser Fuglestation. Migratory distance classifications of the species in this study were based on the migration routes described in The Danish Bird Migration Atlas (Bjerrum et al., 2006). During this study, data from 2007 until 2025 from the station's database has been used. Data on the arrival date of individual birds has been collected through the capture of birds with the use of mist nets. The meteorological data for this study was sourced from the Danish Meteorological Institute (DMI, 2026). The mean seasonal temperature per year was calculated, along with the mean day of arrival per season, per year of each species. This data was used to find potential trends throughout the research period and the correlative relationships between mean temperature and mean day of arrival. It was hypothesized that an increase in mean annual temperature would lead to an earlier mean spring day of arrival and a later mean autumn day of arrival in all species, but that the correlative relationship between mean temperature and mean day of arrival was stronger in short-distance migratory species.

2. Materials and methods

2.1 Research area

The research for this study was conducted at Gedser Fuglestation. Gedser Fuglestation is located at the southernmost point of Denmark, on the island of Falster. The garden surrounding the station, in which the research was conducted, covers a total area of approximately 20,000 m^2, and for large parts, is covered in shrubs and trees. The ringing station, where captured birds were ringed and recorded, is located within the garden (Figure 1).

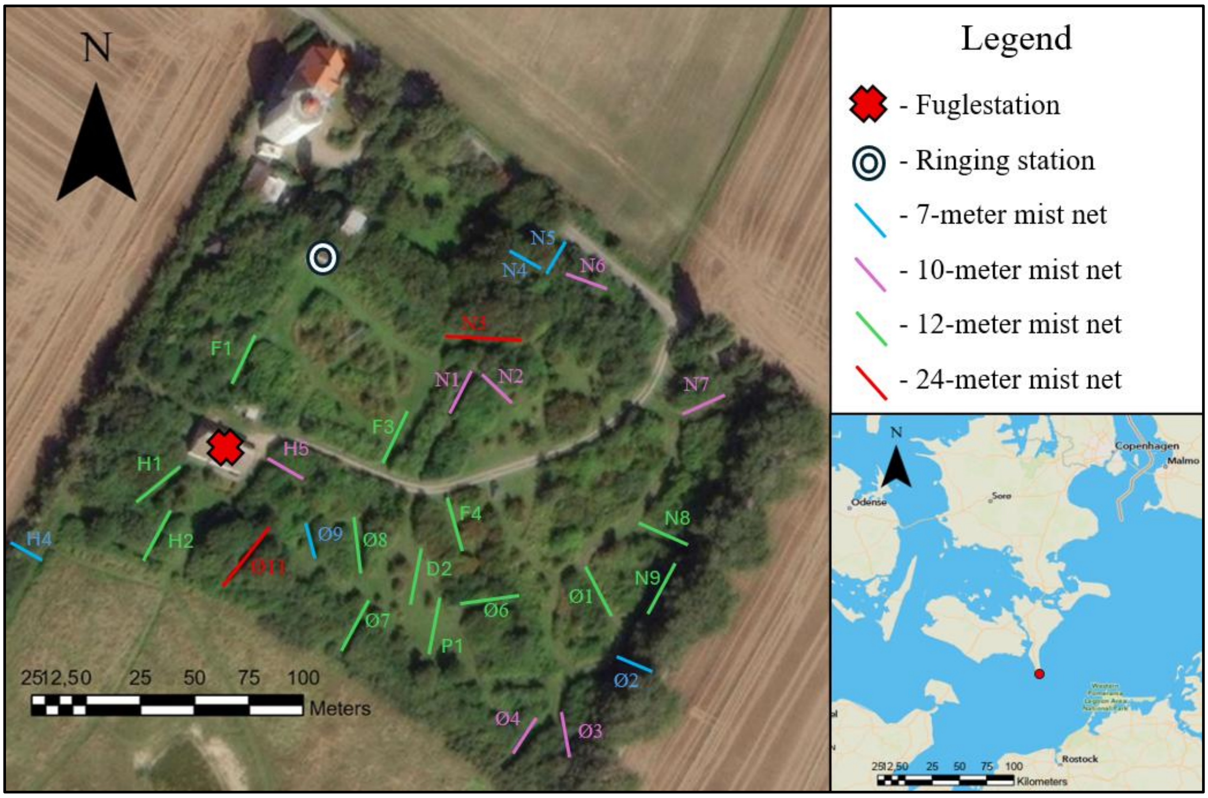

Figure 1: The locations of the Gedser Fuglestation, ringing station and all mist nets within the research area. Colored lines are used to indicate the locations of the mist nets. The location of the research area is shown compared to part of Denmark. (The length of the mist nets shown on the map are not scaled accurately, length is indicated only through color.)

2.2 Research species

For this study, four species of migratory birds were selected, two short-distance migratory species and two long-distance migratory species. The two short-distance migratory species chosen for this study were the European Robin (*Erithacus rubecula*) and the Goldcrest (*Regulus regulus*), the long-distance migratory species were the Lesser Whitethroat (*Curruca curruca*) and the Willow Warbler (*Phylloscopus trochilus*). These species were selected because they are the most commonly captured short- and long-distance migratory species at Gedser Fuglestation.

2.3 Mist nets

Mist nets were used to capture the target bird species. These nets are made up of five horizontal shelfs, with each shelf containing a pocket that stretches the entire length of the net. Each net is strung between two vertical poles (Figure 2). The nets vary in length and can be 7, 10, 12 or 24 meters long. In total, 27 nets were used at set locations around the garden (Figure 1). According to the station's ringing protocols, the daily minimum collective length of all used nets must be 60 meters for collected data to be considered valid (Appendix I). If this minimum could not be met, the collected data from that day was excluded from the station's database.

Following the station's standardized protocol, the nets were set up 30 minutes before sunrise, after which the researchers went out in rounds to check for captured birds every 30 minutes for a total of five hours. Captured birds were taken to the ringing station at the end of each round (Appendix I).

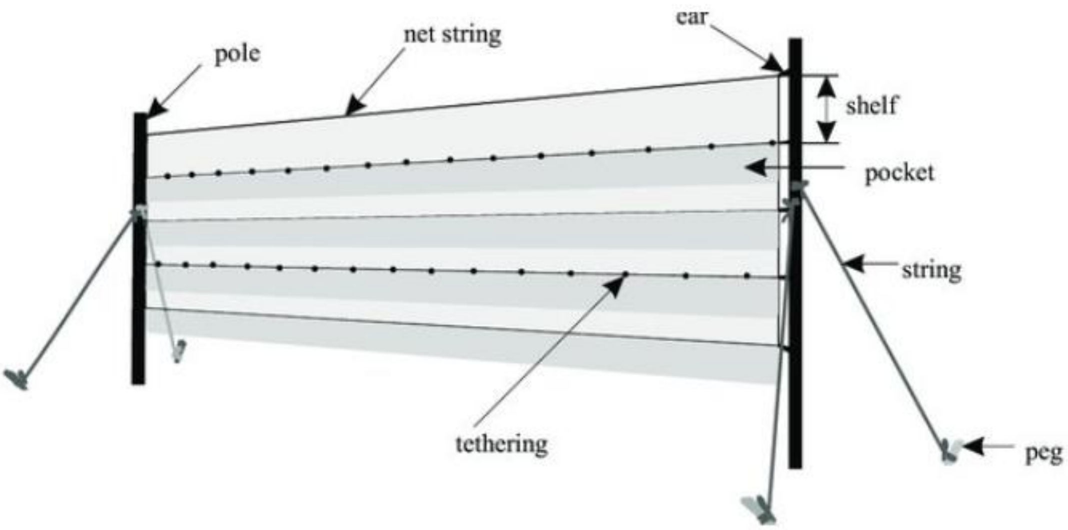

Figure 2: Schematic representation of a mist net used to capture birds during this study (Busse, 2000).

2.4 Ringing and data collection

The capture and ringing of birds at Gedser Fuglestation is performed during two ringing seasons per year, the Spring ringing season (March 1st to June 15th) and the autumn ringing season (July 20th to November 15th). Any bird captured during these seasons was taken to the ringing laboratory where steel ring with a unique number was placed around each bird's right leg. Following the station's standardized monitoring protocol, species, ring number and date of capture were all noted on the station's data collection sheets before the birds were released (Appendix II). For this study, only the first capture during each ringing season, per year of each individual bird were taken into account to prevent re-captures of the same bird within the same season from skewing the data.

2.5 Data analysis

2.5.1 Temperature

In order to determine whether the mean temperature per year, per ringing season has changed over time, the mean daily air temperature (°C) from march 1st until June 15th of each year from 2007 until 2025 was sourced from the Danish Meteorological Institute (DMI, 2026). To determine potential trends in temperature and the statistical significance of these trends linear regression analysis was utilized, with year being the explanatory variable and mean temperature and the response variable. The coefficient of determination (R^2) was used to quantify the proportion of variance in mean temperature per ringing season, per year. The statistical significance of any potential trend was determined using a significance level of $p < 0,05$. All statistical analyses utilized during this study were performed using Rstudio version 2026.01+403.

2.5.2 Day of arrival

In order to determine the average day of arrival per ringing season of each year from 2007 to 2025 for each species, data was sourced from Gedser Fuglestation's ringing database. To determine potential trends in the mean day of arrival and the statistical significance of these trends linear regression analysis were utilized, with year being the explanatory variable and mean day of arrival and the response variable. The coefficient of determination (R^2) was used to quantify the proportion of variance in mean day of arrival per ringing season, per year. Statistical significance of any potential trend was determined using a significance level of $p < 0,05$.

2.5.3 Correlation

To determine whether changes in mean temperature influence the mean day of arrival of migratory bird species at Gedser Fuglestation, the correlative relationship between these two variables was examined using linear regression. The coefficient of determination (R^2) was used to quantify the strength of the relationship between temperature and the mean day of arrival per ringing season, per year. Statistical significance of any correlative relationship trend was determined using a significance level of $p < 0,05$.

3. Results

3.1 Temperature

During the period from 2007 to 2025 a non-significant positive trend (ß = 0,03 degrees Celsius per year^{-1}, R^2 = 0,06, p = 0,332) was found in the average temperature in Gedser during the spring season (Figure 3). During this same period, a significant positive trend (ß = 0,10 degrees Celsius per year^{-1}, R^2 = 0,62, p < 0,001) was found in the average temperature in Gedser during the autumn season (Figure 4).

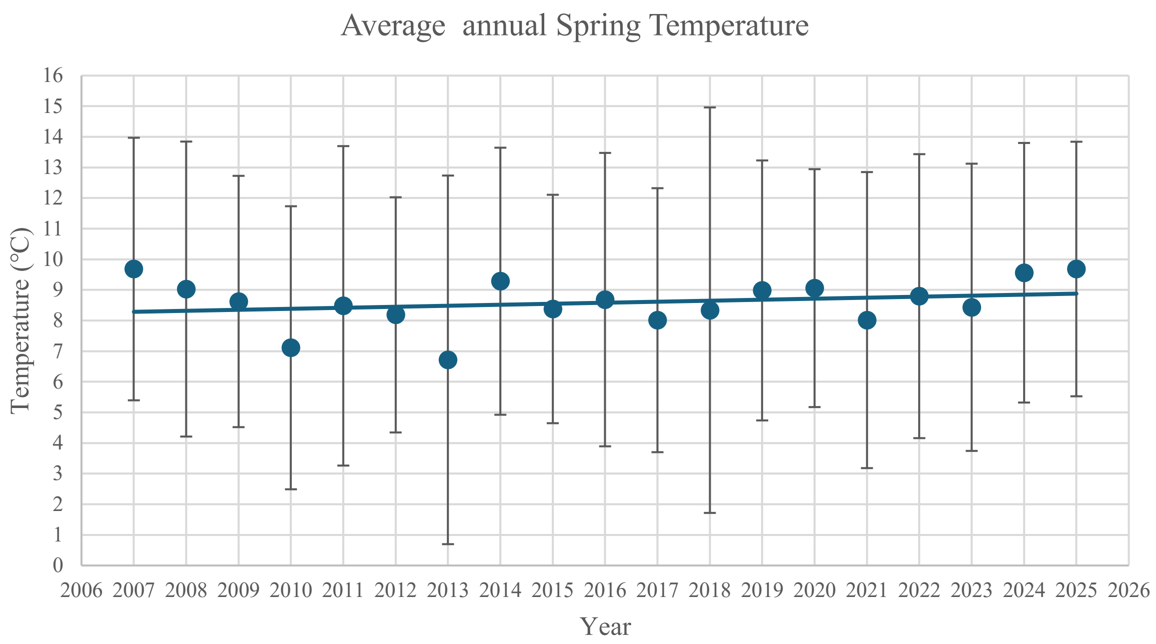

Figure 3: The average temperature during the spring ringing season per year from 2007 until 2025.

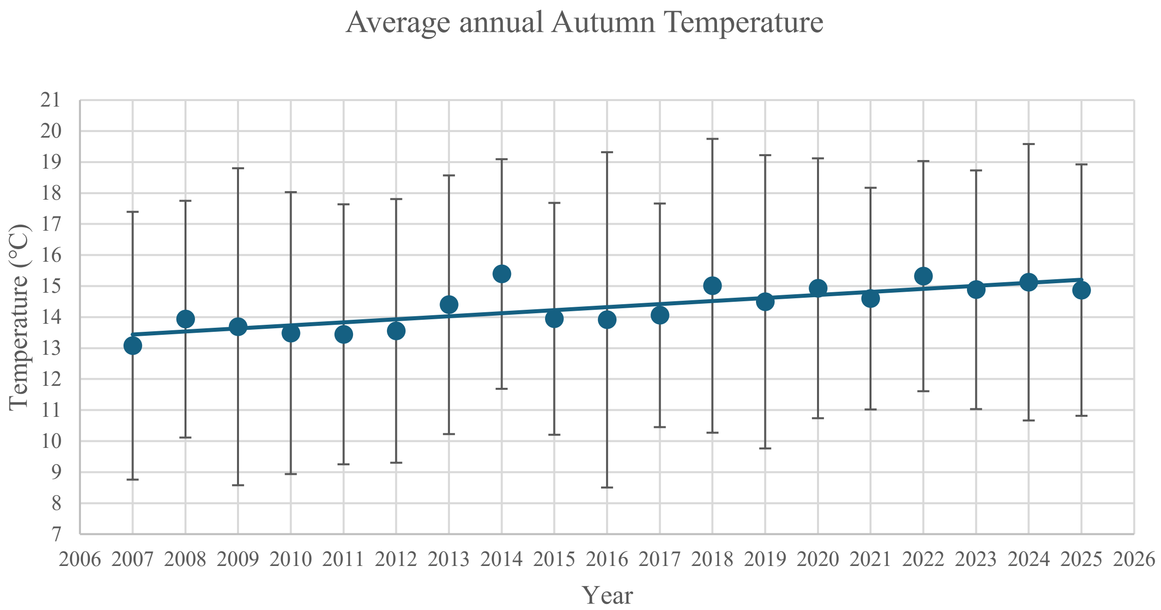

Figure 4: The average temperature during the autumn ringing season per year from 2007 until 2025.

3.2 Average day of arrival short-distance migratory species

3.2.1 European Robin

During the period from 2007 to 2025 a non-significant negative trend (ß = -0,17 days per year^{-1}, R^2 = 0,03, p = 0,474) was found in the average day of arrival of the European Robin during the spring season (Figure 5). During this same period, a non-significant positive trend (ß = 0,08 days per yer^{-1}, R^2 = 0,06, p = 0,321) was found in the average day of arrival of the European Robin during the autumn season (Figure 6).

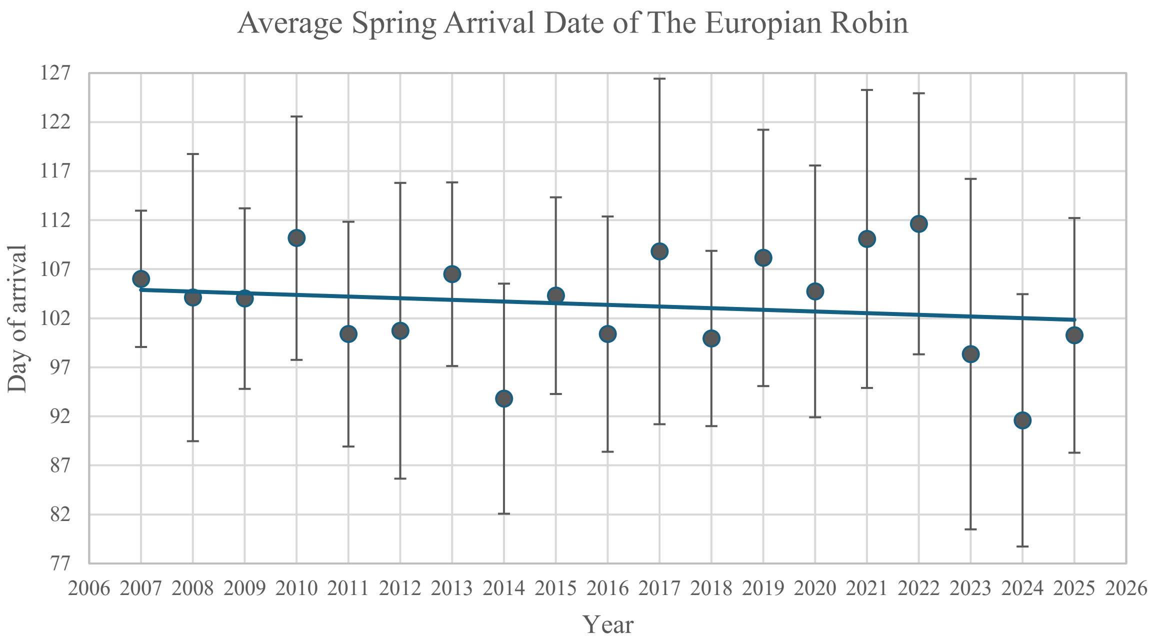

Figure 5: The average day of arrival of the European Robin during the spring season from 2007 to 2025.

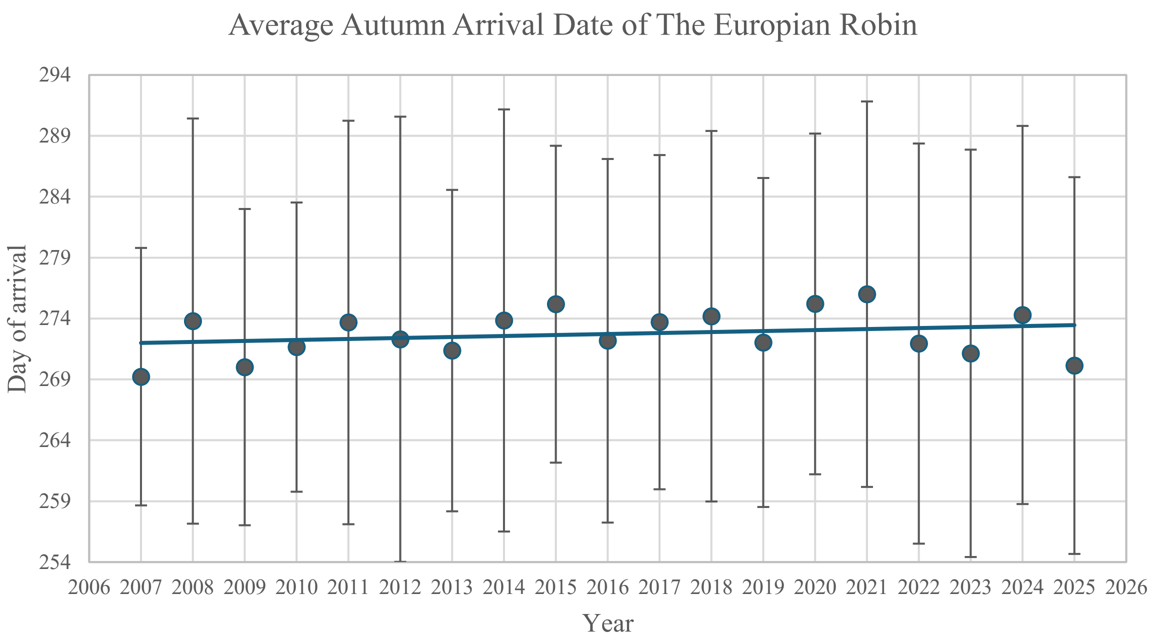

Figure 6: The average day of arrival of the European Robin during the autumn season from 2007 to 2025.

3.2.2 Goldcrest

During the period from 2007 to 2025 a non-significant negative trend (ß = -0,48 days per year^{-1}, R^2 = 0,17, p = 0,080) was found in the average day of arrival of the Goldcrest during the spring season (Figure 7). During this same period, a non-significant positive trend (ß = 0,49 days per yer^{-1}, R^2 = 0,08, p = 0,234) was found in the average day of arrival of the Goldcrest during the autumn season (Figure 8).

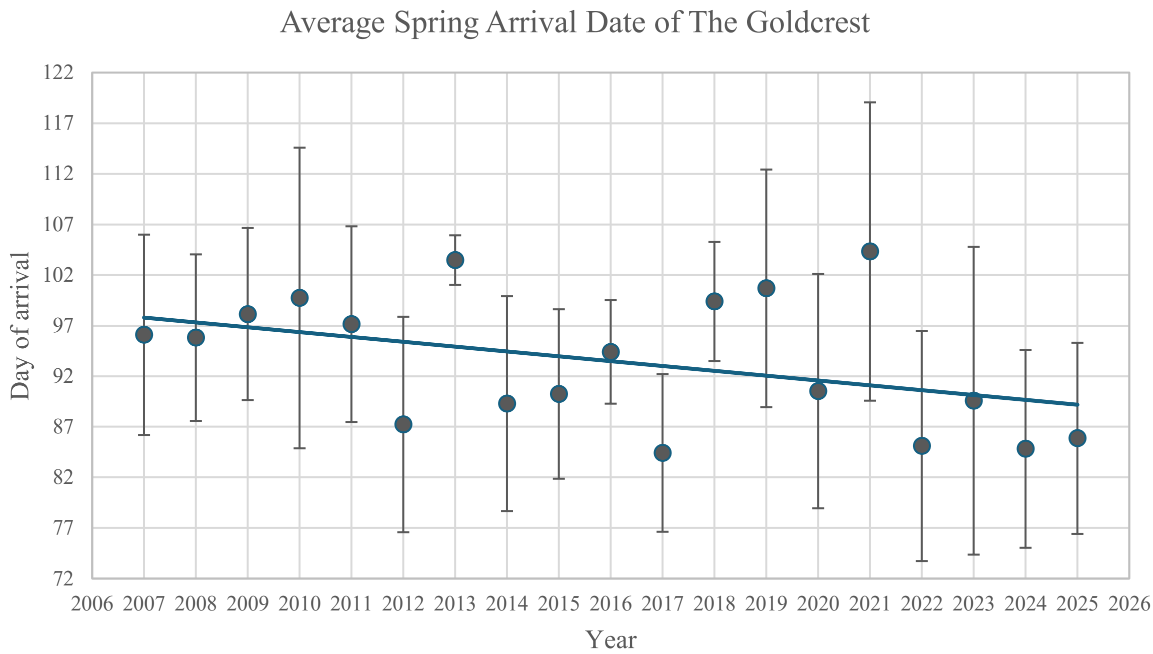

Figure 7: The average day of arrival of the Goldcrest during the spring season from 2007 to 2025.

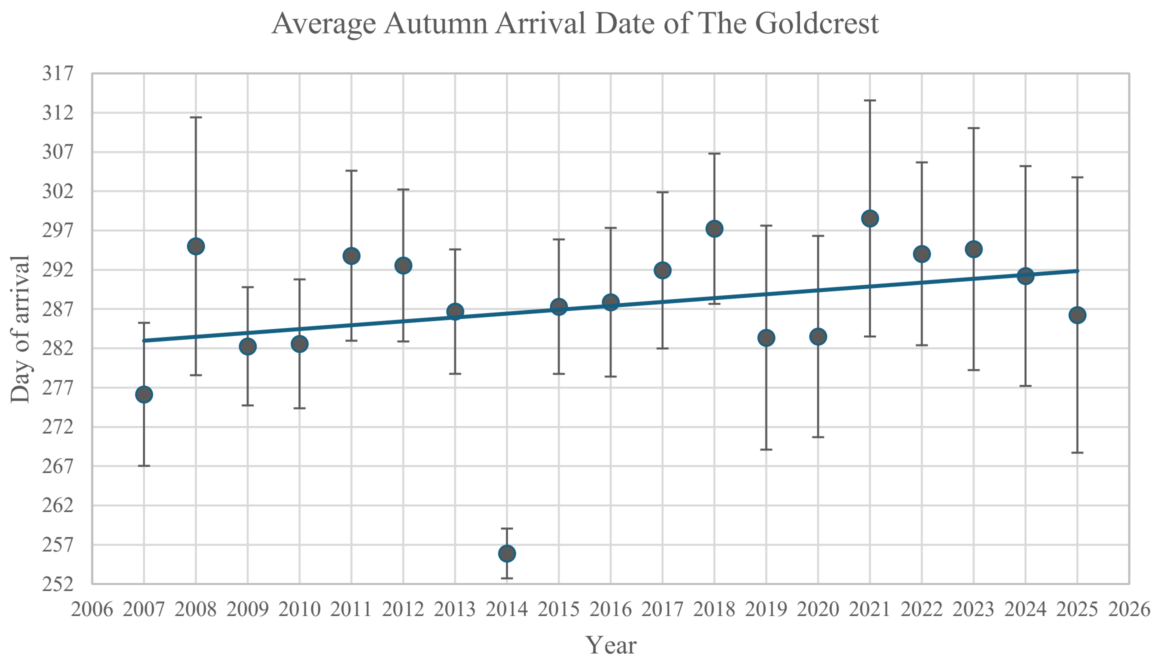

Figure 8: The average day of arrival of the Goldcrest during the autumn season from 2007 to 2025.

3.3 Average day of arrival long-distance migratory species

3.3.1 Lesser Whitethroat

During the period from 2007 to 2025 a non-significant negative trend (ß = -0,10 days per $year^{-1}$, R^2 = 0,02, p = 0,597) was found in the average day of arrival of the Lesser Whitethroat during the spring season (Figure 9). During this same period, a non-significant negative trend (ß = -0,17 days per yer^{-1}, R^2 = 0,11, p = 0,166) was found in the average day of arrival of the Lesser Whitethroat during the autumn season (Figure 10).

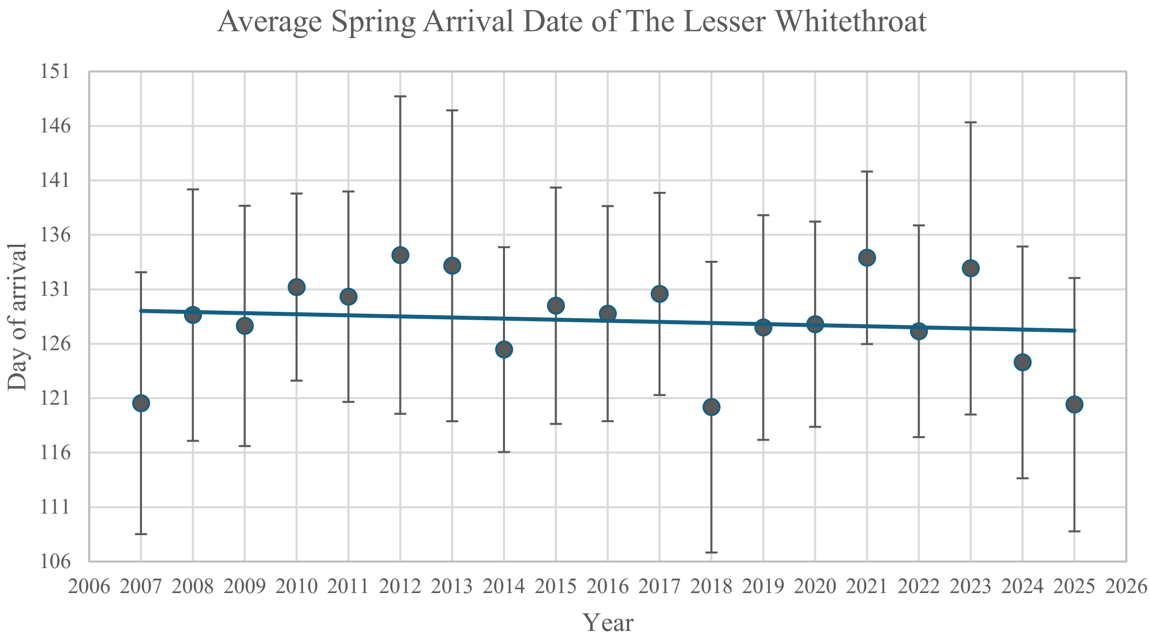

Figure 9: The average day of arrival of the Lesser Whitethroat during the spring season from 2007 to 2025.

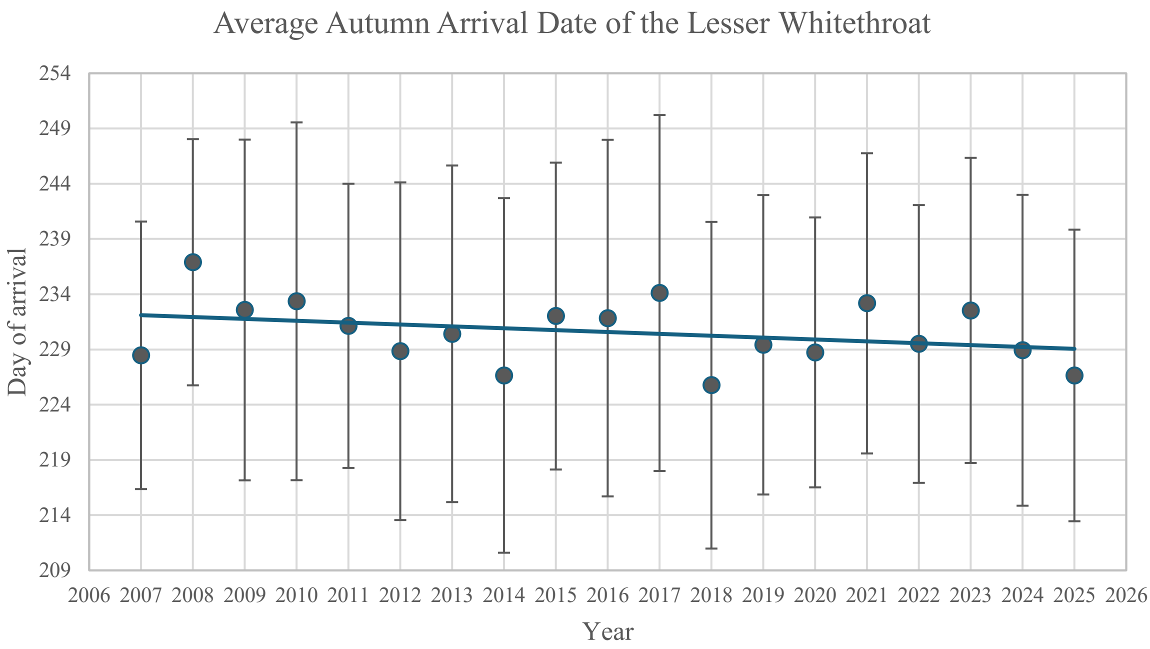

Figure 10: The average day of arrival of the Lesser Whitethroat during the autumn season from 2007 to 2025.

3.3.2 Willow Warbler

During the period from 2007 to 2025 a non-significant negative trend (ß = -0,01 days per year^{-1}, R^2 < 0,01, p = 0,947) was found in the average day of arrival of the Willow Warbler during the spring season (Figure 11). During this same period, a non-significant positive trend (ß = 0,07 days per yer^{-1}, R^2 = 0,02, p = 0,579) was found in the average day of arrival of the Willow Warbler during the autumn season (Figure 12).

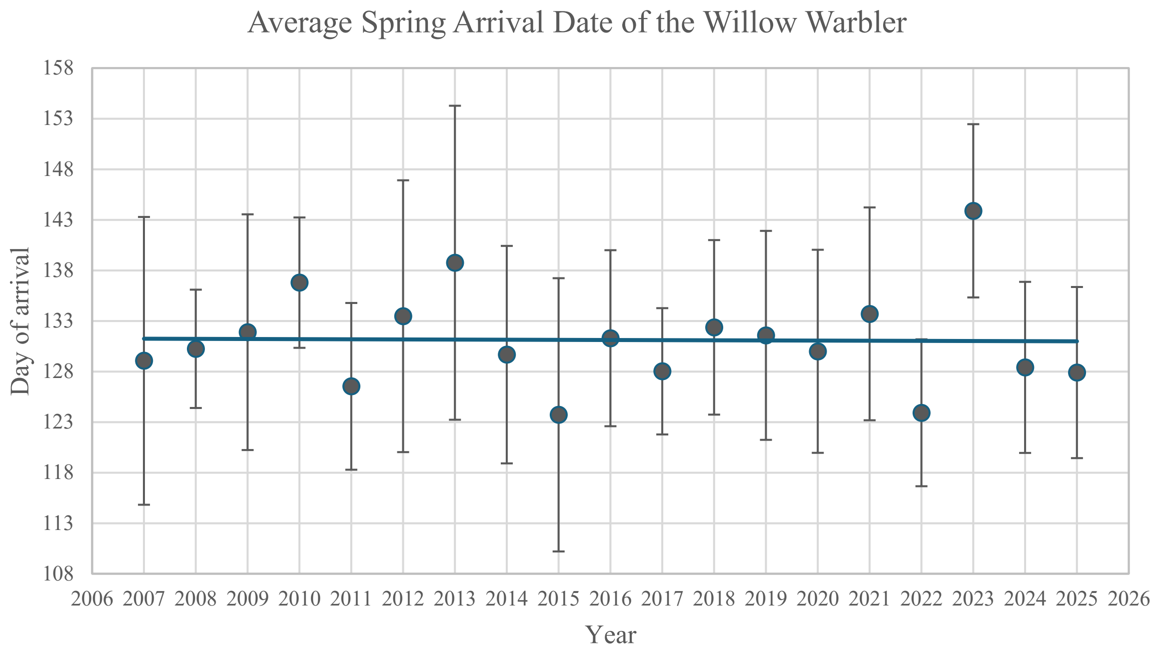

Figure 11: The average day of arrival of the Willow Warbler during the spring season from 2007 to 2025.

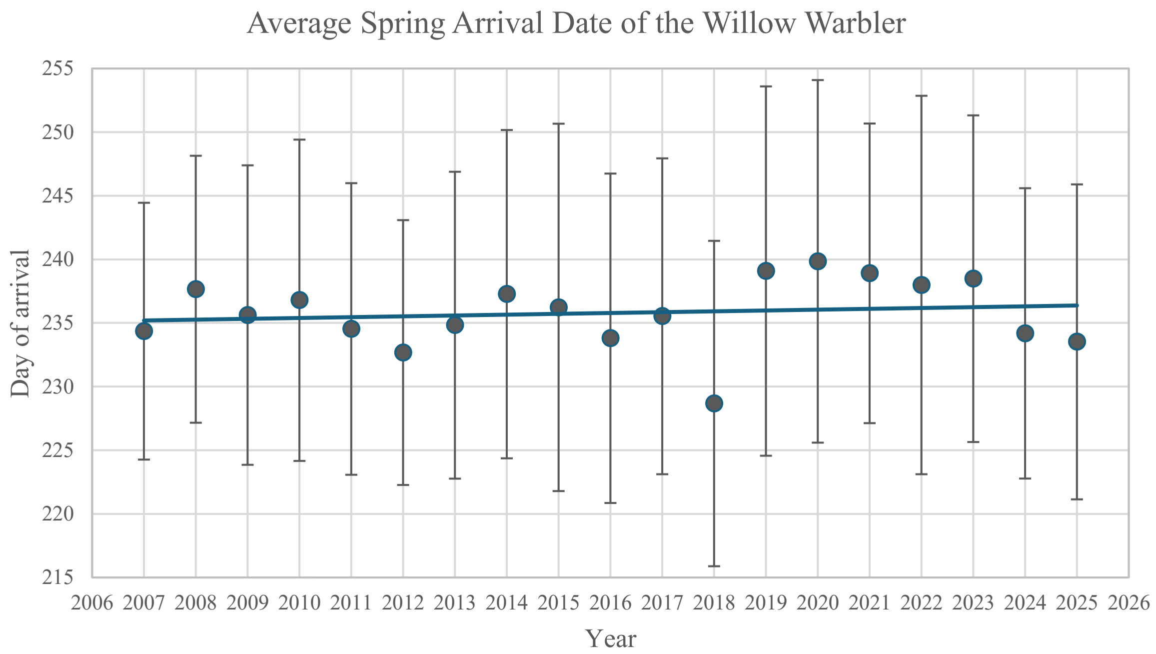

Figure 12: The average day of arrival of the Willow Warbler during the autumn season from 2007 to 2025.

3.4 Correlation temperature and day of arrival

3.4.1 Short-distance migratory species

3.4.1.1 European Robin

During the period from 2007 until 2025 a non-significant negative relationship (ß = -3,09, R^2 = 0,20, p = 0,056) was found between the average annual temperature and the average day of arrival of the European Robin during the spring season (Figure 13). During this same period, a non-significant positive relationship (ß = 0,86, R^2 = 0,10, p = 0,185) was found between the average annual temperature and the average day of arrival of the European Robin during the autumn season (Figure 14).

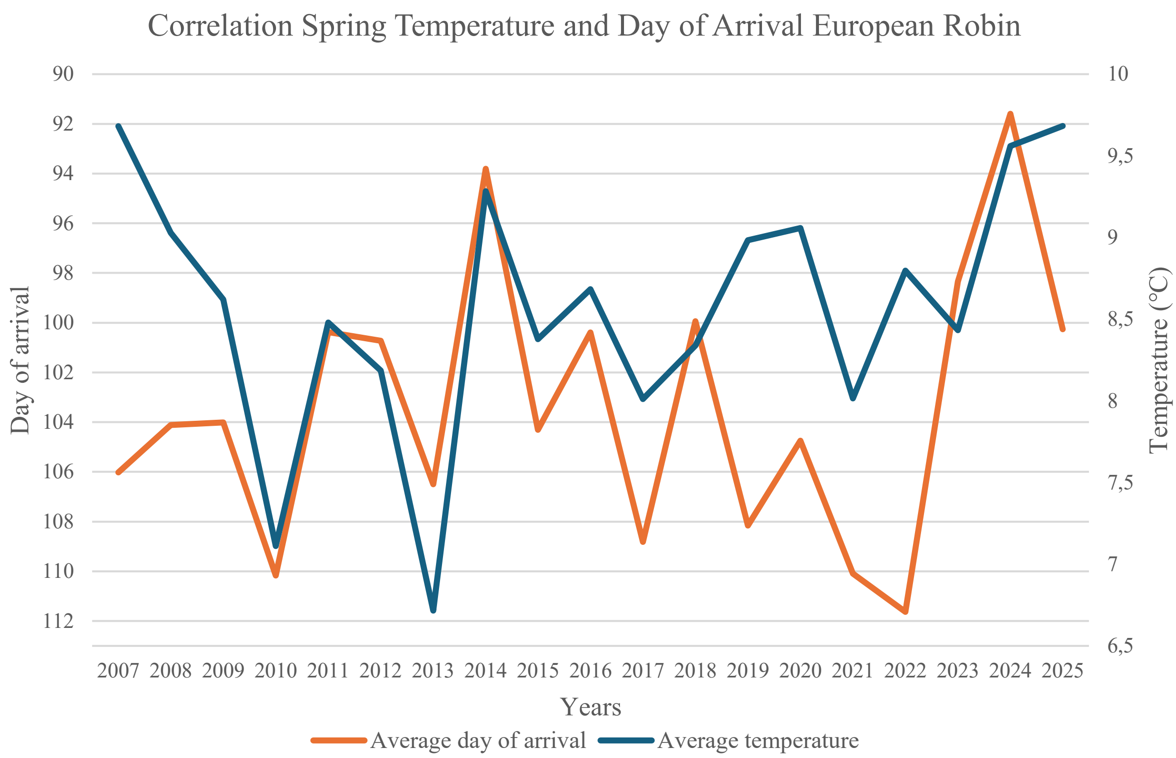

Figure 13: Average annual temperature and average annual day of arrival of the European Robin during the spring season.

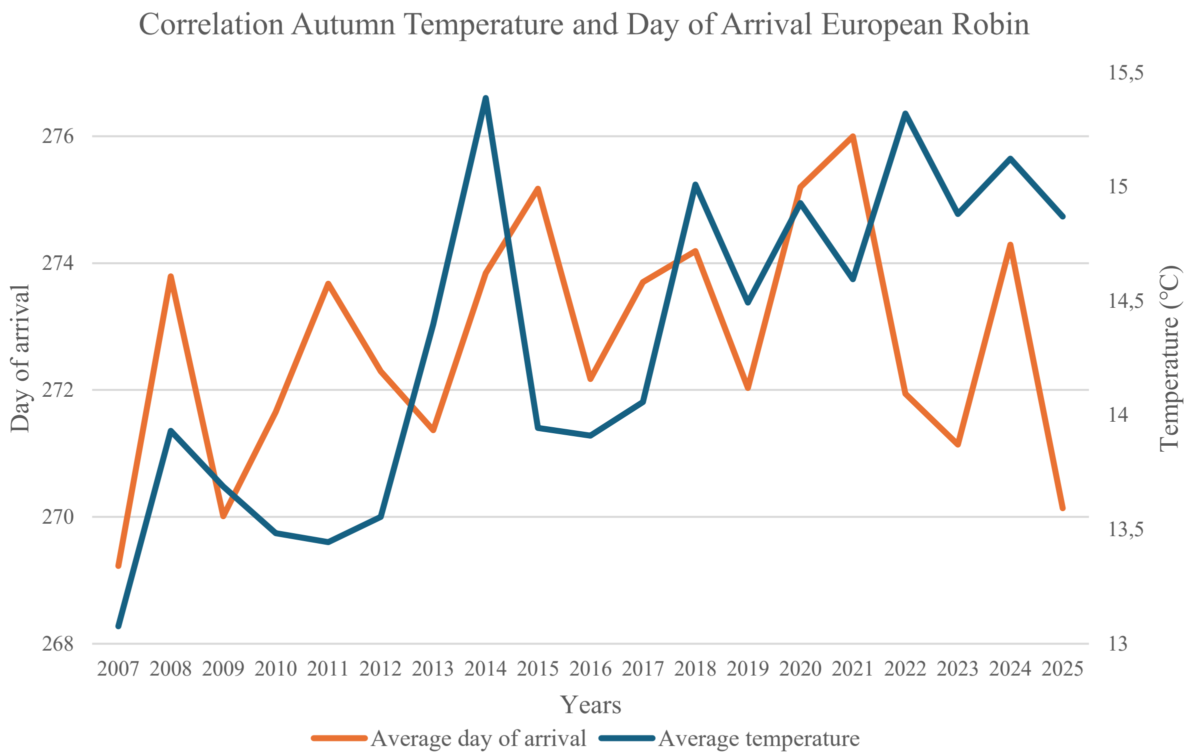

Figure 14: Average annual temperature and average annual day of arrival of the European Robin during the autumn season.

3.4.1.1 Goldcrest

During the period from 2007 until 2025 a significant negative relationship (ß = -3,86, R^2 = 0,22, p = 0,045) was found between the average annual temperature and the average day of arrival of the Goldcrest during the spring season (Figure 15). During this same period, a non-significant negative relationship (ß = -0,72, R^2 < 0,01, p = 0,832) was found between the average annual temperature and the average day of arrival of the Goldcrest during the autumn season (Figure 16).

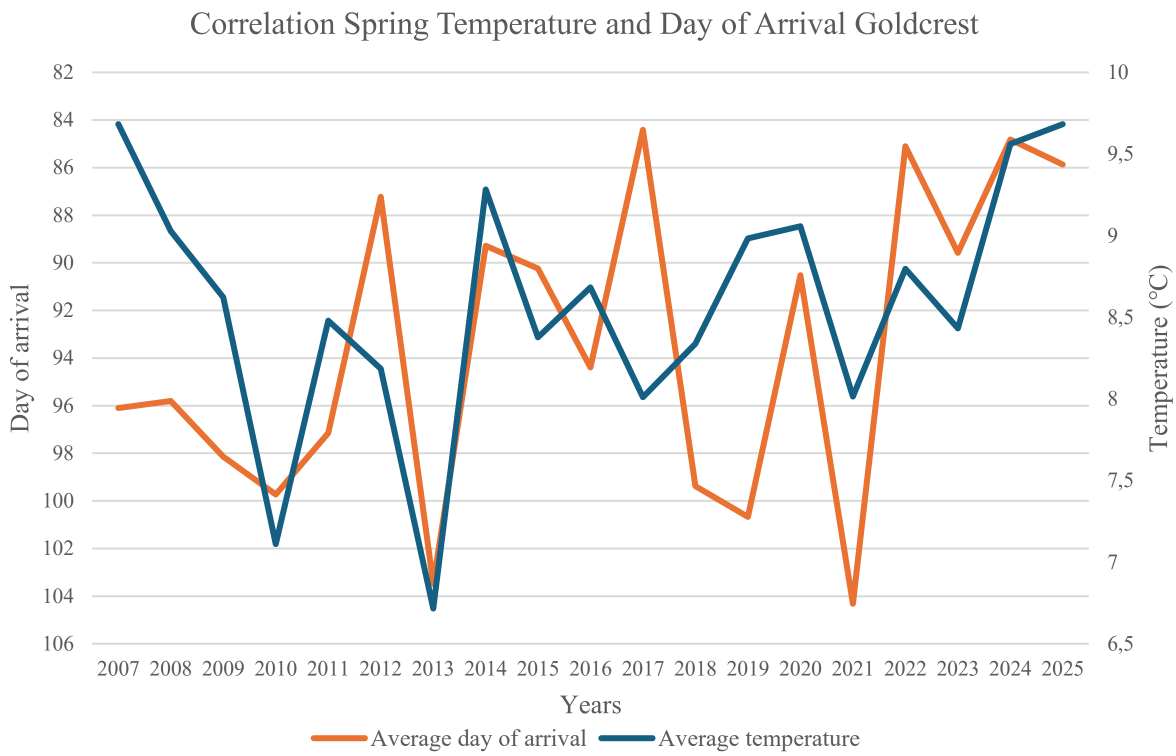

Figure 15: Average annual temperature and average annual day of arrival of the Goldcrest during the spring season.

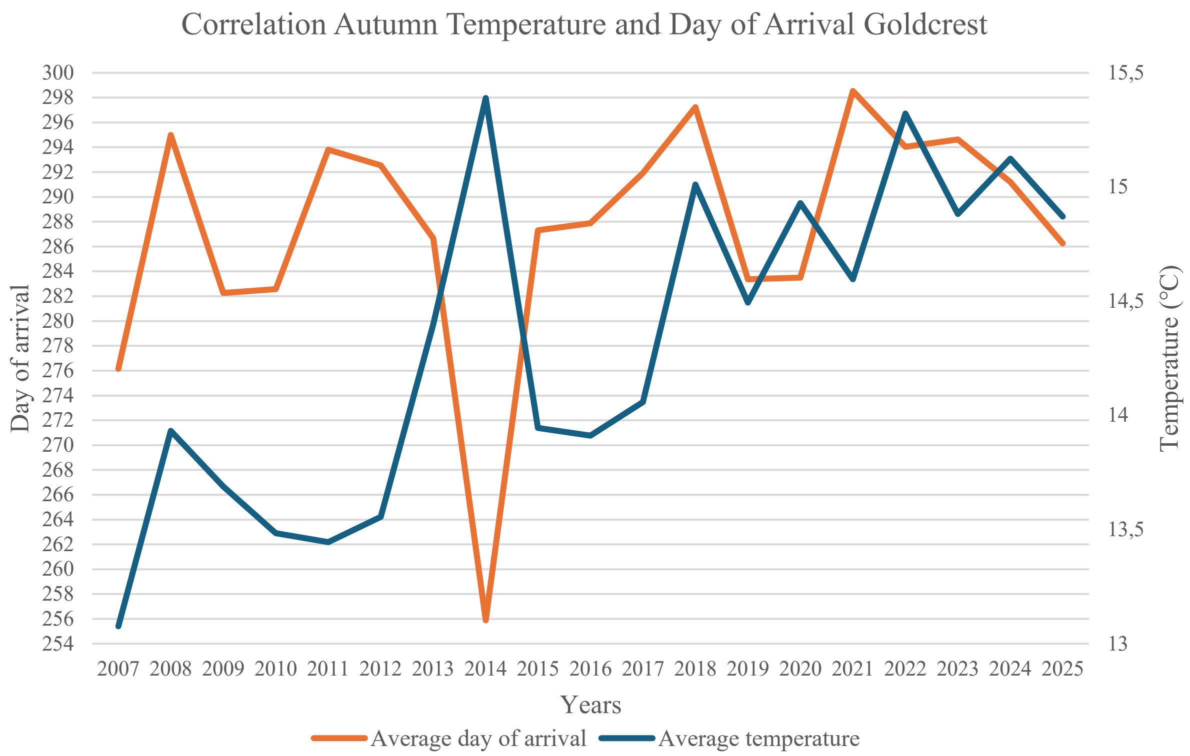

Figure 16: Average annual temperature and average annual day of arrival of the Goldcrest during the autumn season.

3.4.2 Long-distance migratory species

3.4.2.1 Lesser Whitethroat

During the period from 2007 until 2025 a significant negative relationship (ß = -3,88, R^2 = 0,49, p < 0,001) was found between the average annual temperature and the average day of arrival of the Lesser Whitethroat during the spring season (Figure 17). During this same period, a non-significant negative relationship (ß = -1,82, R^2 = 0,20, p = 0,057) was found between the average annual temperature and the average day of arrival of the Lesser Whitethroat during the autumn season (Figure 18).

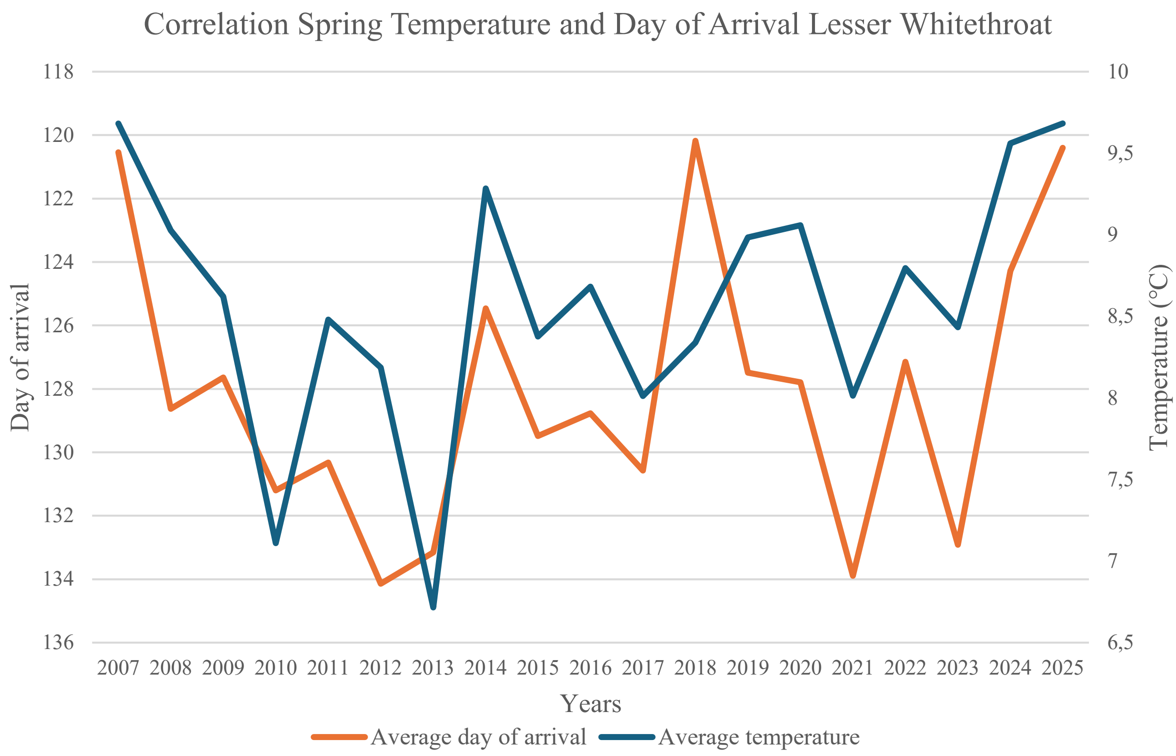

Figure 17: Average annual temperature and average annual day of arrival of the Lesser Whitethroat during the spring season.

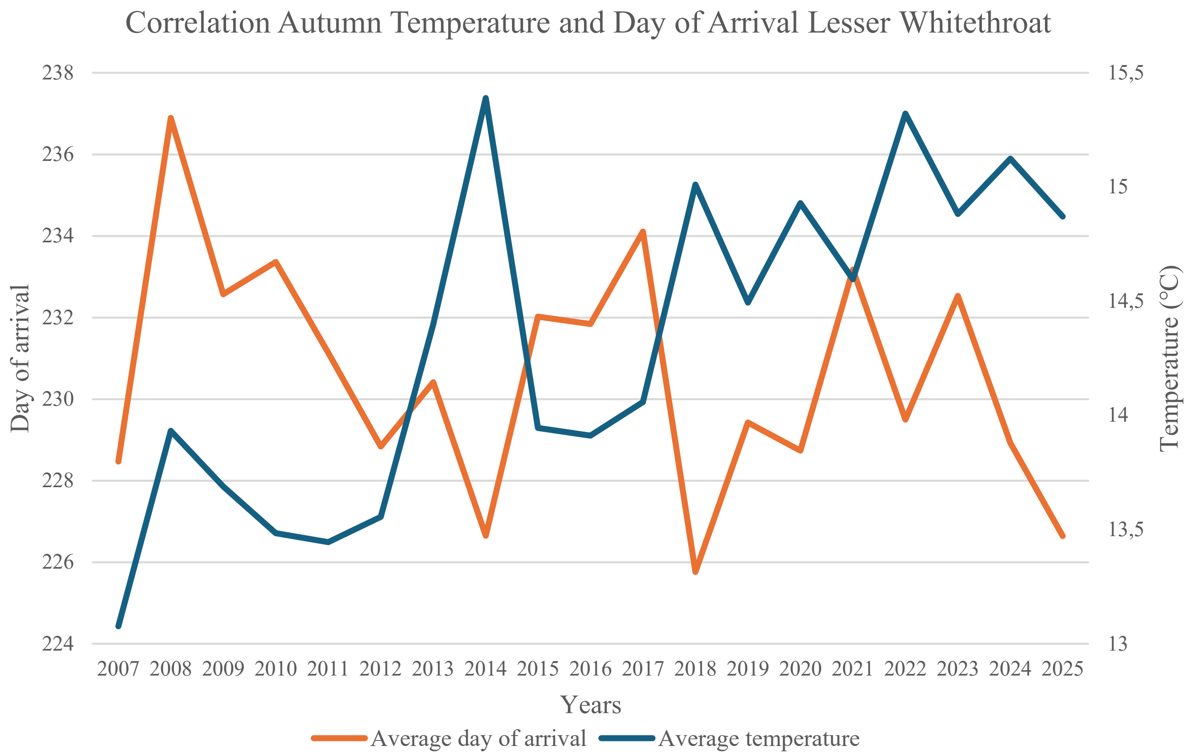

Figure 18: Average annual temperature and average annual day of arrival of the Lesser Whitethroat during the autumn season.

3.4.2.2 Willow Warbler

During the period from 2007 until 2025 a significant negative relationship (ß = -3,17, R^2 = 0,26, p = 0,026) was found between the average annual temperature and the average day of arrival of the Willow Warbler during the spring season (Figure 19). During this same period, a non-significant positive relationship (ß = 0,70, R^2 = 0,03, p = 0,460) was found between the average annual temperature and the average day of arrival of the Willow Warbler during the autumn season (Figure 20).

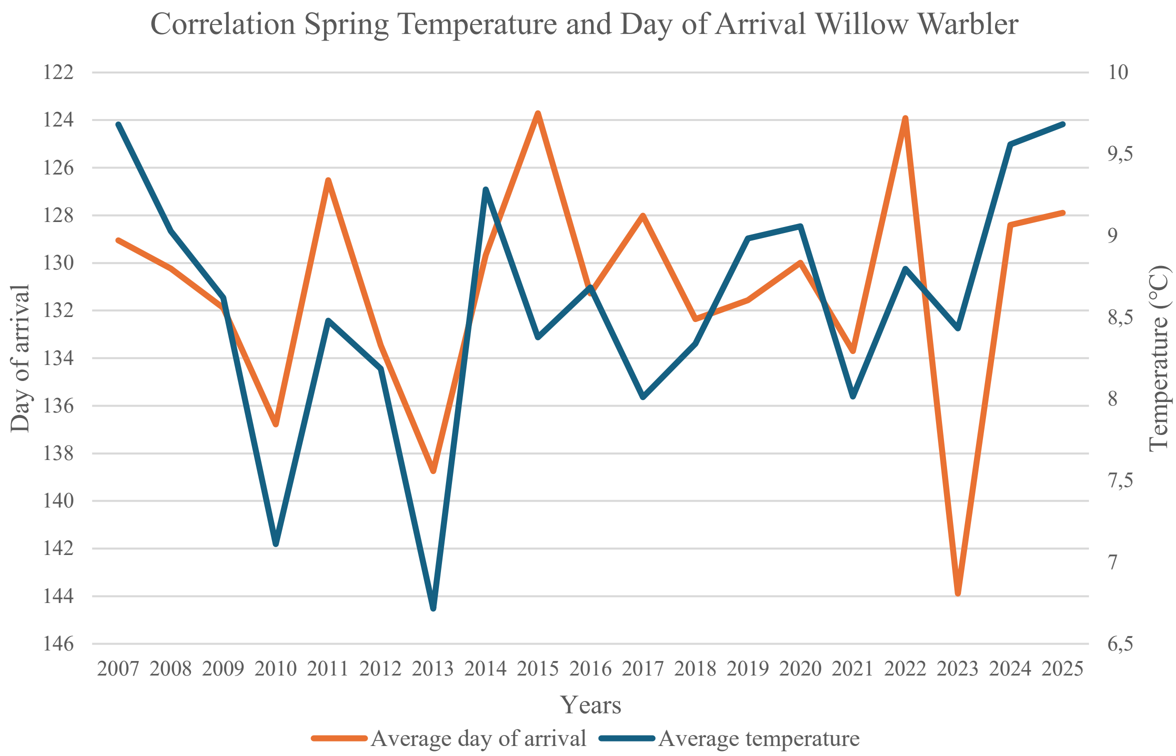

Figure 19: Average annual temperature and average annual day of arrival of the Willow Warbler during the spring season.

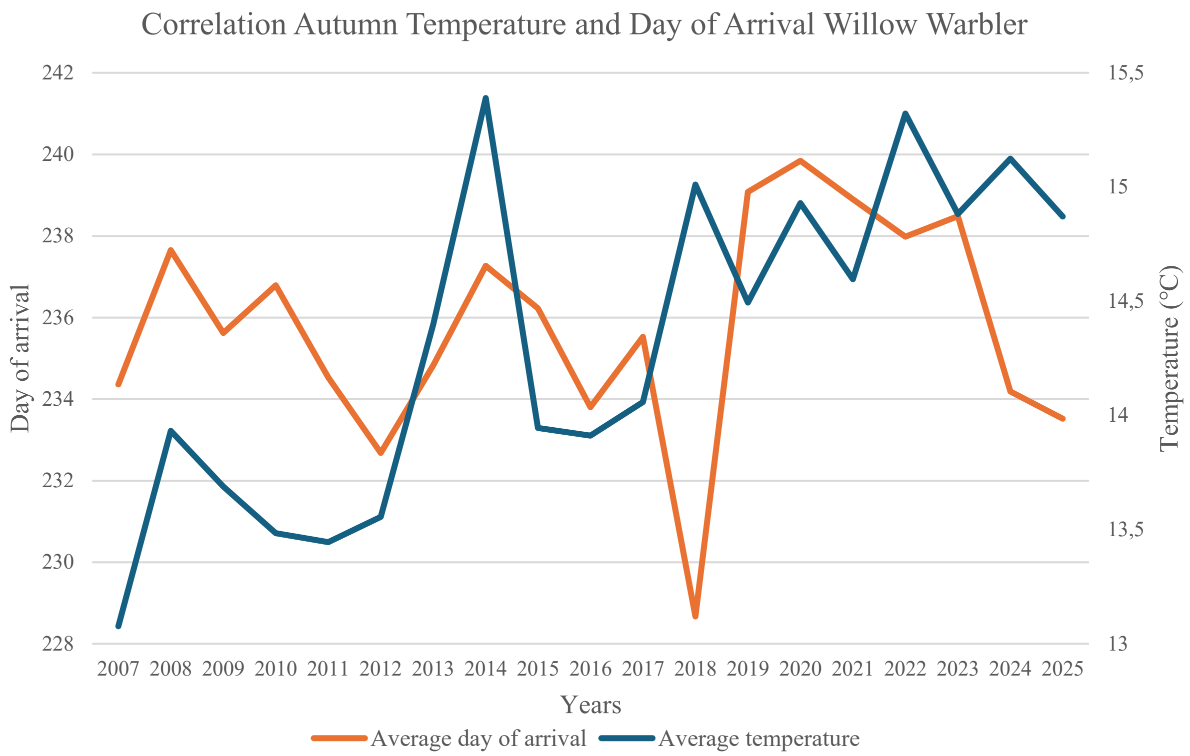

Figure 20: Average annual temperature and average annual day of arrival of the Willow Warbler during the autumn season.

3.5 Difference in temperature-arrival date relationship between short- and long-distance migratory species

During the period from 2007 until 2025 a non-significant difference was found in the relationship between average spring temperature and average day of arrival between short-distance migratory species and long-distance migratory species (ß = 0,05, p = 0,978). During this same period a non-significant difference was also found in the relationship between average autumn temperature and average day of arrival between short-distance migratory species and long-distance migratory species (ß = 0,63, p = 0,809).

4. Discussion & Conclusion

4.1 Discussion

This study has examined the effect of changes in temperature on the timing of migratory patterns in migratory bird species during the period from 2007 until 2025. Specifically, the aim of this study was to determine the extent to which changes in seasonal temperatures influence the average spring- and autumn arrival dates of two short- and two long-distance migratory species and whether the response to temporal changes differed between these two migratory groups.

During this study, a significant increase in mean annual autumn temperature was found over the period 2007 until 2025. This increase in temperature is consistent with previously conducted research, indicating a positive temporal trend across Europe in recent decades as a result of climate change (Copernicus Climate Change Service, 2018; Guzik et al., 2021). In contrast, a non-significant increase in mean annual spring temperature was found over the same research period. The insignificance of this trend does not necessarily indicate an absence of rising temperatures during the spring seasons. Mean spring temperatures in Northern Europe can be strongly influenced by intraseasonal climatic variability caused by atmospheric circulation patterns, such as the North Atlantic Oscillation. This variability can cause intraseasonal fluctuations in temperature which can mask underlying long-term climatic trends when they occur in consecutive years and are observed over relatively short periods of time. (Helema & Holopainen, 2012). It is possible that the non-significant increase in mean spring temperatures found during this study could have been caused by these climatic fluctuations and that research conducted over a longer period could find a significant increase in temperature (Cahill et al., 2017).

During this study, every research species showed a non-significant change in mean spring arrival date from 2007 until 2025. Despite the absence of any significant trends in mean spring arrival date, all species did show a negative trend in spring arrival date during this period. The consistency of these trends might indicate a gradual shift towards earlier spring migration, as similar phenological shifts have been documented before in numerous other migratory species (Ay et al., 2017; Butchart et al., 2017; Crick & Sparks, 2006). These findings might suggest that the significance in these phenological trends could become more apparent as research is conducted over a longer period of time. In contrast to the arrival date trends during the spring season, arrival date trends during the autumn season showed less consistency across the research species. The European Robin, Goldcrest and Willow Warbler all showed non-significant positive trends in arrival date during the autumn season. In Contrast to these species, the Lesser Whitethroat showed a non-significant negative trend during the same period. Given both the inconsistency and the insignificance of the trends found among the different species, these results offer limited evidence for long-term shifts in autumn migration timing. Given this lack of evidence, it is difficult to draw any meaningful conclusions based on these trends as they might reflect naturally occurring phenological variability, rather than a consistent phenological response to changes in climatic trends.

Across all research species, a consistent negative relationship between spring temperature and day of arrival was found. Statistically significant negative correlative relationships between mean spring temperature and mean arrival date were found in the goldcrest, Lesser Whitethroat and Willow Warbler. Although the relationship between temperature and arrival date in the European Robin was found not to be significant ($p = 0,056$), it did come very close to the significance threshold ($p = 0,050$). These findings are consistent with the hypothesized expectations that temperature is an important migration cue for migratory bird species and that rising spring temperatures might lead to earlier spring migration (Ay et al., 2017; Both & Marvelde, 2007; Butchart et al., 2017; Crick & Sparks, 2006). Similarly to the migration timing trends, the correlative relationship between mean temperature and mean arrival date was less consistent during the autumn season compared to the spring season. Non-significant positive correlative relationships between mean autumn temperature and mean autumn arrival date were found in the European Robin and the Willow Warbler. Meanwhile, non-significant negative correlative relationships between mean autumn temperature and mean autumn arrival date were found in the Goldcrest and Lesser Whitethroat. Previously conducted research has shown that the timing of autumn migration is influenced by numerous ecological factors such as food availability, local weather conditions and breeding success, making it more susceptible to year-to-year variability than spring migration timing (Crick & Sparks, 2006; Newton, 2010). The inconsistency and lack of significance of the correlative relationships between temperature and autumn arrival date make it difficult to draw any meaningful conclusion regarding climatically driving phenological shifts as any evidence for these conclusions is limited.

The Goldcrest autumn arrival date data does contain a notable outlier, namely that the average day of arrival in 2014 was 20 days earlier than the second earliest found arrival date in this species. One possible explanation for this could be that the mean temperature during the spring of 2014 was notably higher than those of years around this year. Intraseasonal temporal fluctuations during the spring season have been documented to cause large year-to-year variability in migration timing in Goldcrests during the autumn migration (Maciag & Remisiewicz, 2025).

During this study, a non-significant difference was found in the correlative relationship between temperature and migration phenology between short-distance migratory bird species and long-distance migratory species. This finding contradicts the initial hypothesis that short-distance migratory species would respond more strongly to changes in temperature than long-distance migratory species regarding their migration phenology. This hypothesis was based on previously conducted studies that found that short-distance migratory species rely strongly on temperature as a migration cue, whereas long-distance migratory species rely more on other cues such as photoperiod (Ay et al., 2017; Brzek et al., 2021; Jenni & Kéry, 2003). A possible explanation for the insignificance of this study's results could be the limited length of this study's research period. The potential significance of any trends found in phenological studies is strongly influenced by research period duration as previous research has found that shorter studies, 22 years or less, often fail to yield any significant results (Ellwood et al., 2017; Ergon et al., 2007). Extending the duration of this study's research period could therefore possibly have resulted in more significant results. Another explanation could be the limited geographical coverage of this study. Only meteorological and migration data sourced or collected in Gedser was used during this study. Gedser is an important geographical location that many migratory bird species pass through during their migration, it is however, only one part of larger migratory routes. Previous research has shown that the inclusion of data collected at multiple research location along migratory paths leads to higher significant trend detectability (Alves et al., 2025). Including meteorological and migration data collected at multiple locations along the migration paths of the research species could have resulted in more significant results and created a clearer view on how temperature effects migration.

4.2 Conclusion

From 2007 until 2025 a non-significant increase in mean annual spring temperature and a significant increase in mean annual autumn temperature were found. Although the increase in spring temperature was not significant, it did show a positive trend. During this same period no significant trends were found in the mean spring and autumn arrival date in any research species. Despite the lack of significance, all four research species did show a negative trend in mean spring arrival date, while trends in mean autumn arrival date were less consistent, with three species showing positive trends and only the Lesser Whitethroat showing a negative trend. Significant correlative relationships between mean spring temperature and arrival date were found in three species, with only the European Robin showing a nearly significant relationship, indicating that increases in temperature might be associated with earlier spring migration. In contrast, correlative relationships between temperature and arrival date were found to be less consistent during the autumn season as the European Robin and Willow Warbler showed non-significant positive relationships whereas the Goldcrest and Lesser Whitethroat showed non-significant negative relationships. This suggests that autumn migration timing is influenced by a larger variety of ecological factors. The hypothesis that the migration timing of short-distance migratory species is more strongly influenced by changes in temperature than long-distance migratory species was not supported, as there was no significance difference found in the response to temporal changes between the two migration distance groups. Overall, these finding suggest that spring temperature is an important migration cue in both short- and long-distance migratory species, as warmer spring temperatures are associated with earlier spring arrival dates. However, the influence of rising autumn temperatures remains unclear, as the response appears inconsistent amongst different species. Further long-term research will be important in order to gain a better understanding of how climate change influences bird migration.

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6. Appendices

Appendix I: Standardized ringing protocols

Ringing at Gedser Bird Observatory & Ringing Station

Standardized monitoring protocol

Welcome to Gedser Bird Observatory & Ringing Station. This protocol outlines some important information regarding our standardized bird ringing program in order to ensure high quality data collection. This protocol should be used as a guideline for foreign ringers as well as for the local staff. We request that all ringers, who intend to carry out standardized bird ringing at Gedser, are familiar with the contents of this protocol and follow the instructions outlined below when ringing.

Before setting up the nets

Always prepare the ringing equipment, eg. extra ring series, new sheets etc., the day before a ringing session.

You should always have a look at the weather forecast before setting up the nets! Keep an eye on the weather (precipitation) radar during ringing sessions and take appropriate action **before** weather conditions turn bad.

Link to radar: http://www.dmi.dk/vejr/maalinger/radar-nedboer/

Timing and fulfilling the standardized ringing program

The last net to be set up in the morning, should be active for catching no later than 30 minutes before sunrise, preferably between 60 minutes and 30 minutes before. The standardized ringing session begins between 30 and 60 minutes before sun rise (the time at which all nets were set) and lasts for five hours. The minimum requirements for the standardized monitoring program is 300 mistnet meter hours, which can, for instance, be obtained by running 5 mist nets of 12 meters for 5 hours (5x12x5). You can use more nets if you wish, but only if you can keep up doing rounds every 30–60 minutes.

After 5 hours of standardized ringing, please make a note in the ringing data for each ring series that the standard time has ended. This is important for data registration.

Link to almanac: http://www.torbenhermansen.dk/almanak/almanak.php

If for some reason (rain, storm, illness etc.) you have to furl the nets before the scheduled end of standard ringing, the ringing still can, potentially, be registered as a standard ringing session. If you have the nets open 30 minutes before sun rise and for at least 4 hours after, the data is still registered as a standard ringing session. Also, if you are forced to furl the nets in the middle of a ringing session, standard ringing can be continued if the maximum time that the nets are closed does not exceed one hour.

If the weather conditions are unsuitable for ringing early in the morning and you have to postpone opening the nets, you can still complete a standard ringing session if the nets are up no later than 2 hours after normal setup time and are open for at least 5 hours. Please write the reason for ending standard ringing prematurely in the notes field when entering the ringing data in Zuschlag's Bird Ringing Database.

Net rounds

The time interval between net rounds should be between 30 and 60 minutes, with 30 minutes being the normal interval and 60 minutes being the rare exception! The order in which the nets should be set up and checked is stated below:

H1 -> H2 -> H4 -> F1 -> H5 -> F3 -> F4 -> N1 -> N2 -> N3 -> N4 -> N5 -> N6 -> N7 -> N8 -> Ø1 -> N9 -> Ø2 -> Ø3 -> Ø4 -> Ø6 -> P2 -> D1 -> Ø7 -> Ø8 -> Ø9 -> Ø11

(A diagram of the net positions and net lengths is available in the lab ringing manual.)

The following nets are not part of the standardized ringing program:

E01 (field nets in front of the station), P2 with sparrowhawk nets from 1st September – 15 November.

D1 and P2 are included with the standardized nets when passerine nets are used before the 1st September. After this date the passerine nets should be replaced with sparrowhawk nets and are no longer included in the standardized design.

Ringing the birds

The birds can be either bagged and ringed in the lab or ringed directly by the nets. We recommend that all birds are taken back to the lab for further investigation and measurements, however if this is not an option due to the number of birds caught, you can ring directly by the nets using a fully equipped ringing waistcoat!

You are advised to use our recommended list of ring sizes, which can be found in the lab ringing manual. We ask you not to deviate from the list of recommended ring sizes. However, in rare cases, there may be good reasons to deviate from the recommended list of ring sizes. If you decide to use another ring size than what is recommended, please make a note in the note field in Zuschlag's Bird Ringing Database for the specific ringing record.

Ringing in the lab: Please keep track of which birds belong to which round or hour by hanging the bird bags on different hooks and assigning an appropriate label, i.e. "hour 6" for birds collected between 6am and 7am. The hour interval to be written in the notebook is the hour interval in which the bird was extracted from the mistnet.

Ringing by the nets: The hour interval to be written in the notebook, is the hour interval in which the bird was ringed/extracted.

Data registration, methods and biometrics

Sheets designed specifically for the standardized ringing program should be used for ringing as well as for recapture data. A copy of the sheet is shown in the lab ringing manual. Please keep one sheet for each ring size, however, all recaptures go in the same sheet.

If you decide to ring by the nets, please be sure that the notebook you are using has a number on the front. If it doesn't, please label it with the correct code (labels are found in the lab ringing manual).

Standard biometrics include: 1) Wing length 2) Fat score 3) Weight.

The standard wing length measurement is the maximum cord according to "Identification Guide to European Passerines" (page 19-21) by Lars Svensson. Information about fat score is found in the lab at the ringing table.

Special projects: We measure the wing formula of Sparrowhawks according to the method listed in the lab ringing manual.

<u>Data entry</u>

All ringing data (new ringing records and controls) is to be entered by the ringer in Zuschlag's Bird Ringing Database daily and totals entered into Dofbasen.dk. We will introduce you to these programs, when you arrive.

Even if no birds have been ringed during a standardized session (simply because there were no birds around), you should register the basic weather data, net time, net meters etc. in the ringing database.

If standardized bird ringing is not achievable, the basic weather data, net time, net meters etc. should also be entered in the ringing database. In that case you put a "0" in the "total net meters" field.

<u>Blogging</u>

We kindly ask that you post daily news on our blogspot, which is an integrated part of our website. Feel free to personalize your blogs. It would also be very much appreciated if the text is supported by one or more pictures. Our blog is visited by more than 100 people each day during the ringing seasons and the blogspot is an important window to the outside world, i.e. the public, various organisations and more.

<u>Park ranger duties</u>

When working as a ringer you are requested to help with essential gardening, which includes lawn mowing, regular pruning of bushes and trees, etc. Make sure to mow the grass under the nets regularly, so that the birds do not get wet and cold when dangling from the lower net shelf.

<u>Using the sound system</u>

The night before(from 2 am) and during standard ringing it is not permitted to manipulate passerine migration by using the sound system. The only exception to this rule is the tape lure of Tengmalm's Owl during October and November. However, when using the sound system you should always be aware that you are not causing any serious disturbance to birds, neighbours or public visitors. You should always consider animal ethics before turning on the sound system.

<u>General advice</u>

The garden is a public area allowing people to walk through the garden, have lunch and more, but people are not allowed to walk in-between the nets. If this happens, please guide them to the main path or the front yard.

Remember that the birds come first. This means that you should never open more nets than you can handle on your own! We want the bird ringing at Gedser to be carried out by responsible people who care more about the birds and the quality of the data than numbers or rare birds!

It is important that you are ready when the day starts. Have breakfast before you do the first round or set up the nets. You might suddenly find yourself busy with constant bird ringing for the next 5 hours or even more.

Remember, that you are not allowed to sleep while the nets are open. When catching nightjars and owls you should preferably do so with another person and take turns checking the nets. If you intend to carry out ringing during the hours of darkness on your own, you are not allowed to sleep between net rounds, because of the possibility of not waking up!

It is highly recommended that you always carry your cell phone with you. – You might want to call for assistance or inform other people about the spectacular bird you just extracted from a mist net. A telephone list is available in the lab ringing manual!

Remember that only the ringer decides if a bird is going to be shown to the public (this includes local people, birders and photographers). If there are too many birds in the nets or the bird has no fat or seems weak – then the bird should be released – take photos and let it go. Animal ethics always come first.

Appendix II: Ringing data collection sheet

Data collection sheet

Gedser Bird Observatory & Ringing Station

Coding: dd = day, mm = month, yyyy = year

Type of record: ☐ Ringing ☐ Recapture

Ring size:

Correctur stuff

RING no.	dd	mm	yyyy	hour	Licens nr	Species	Age	Sex	Wing	Weight	Fat	Comments	Input	Datacheck
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