Article

The Migration of the Eurasian Woodcock (*Scolopax rusticola* L.) in the Carpathian Basin at the Turn of the 19–20th Centuries

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Simple Summary: There are few data sets in bird migration research that go back more than a century. The Carpathian Basin is one of the exceptions, where spring return data for migratory birds were intensively collected and published between 1894 and 1926. One of the most numerous records was that of the Eurasian Woodcock, which provided an opportunity to study the timing of migration of the species and the influence of different environmental and geographical factors on migration. In years with snowier and colder weather, birds returned later than in years with milder weather. The migration occurred earlier in lowlands than in mountain and hill areas. Food availability played a key role in explaining the differences between years and geographical regions. We also showed a two week difference in arrival time between southwestern and northeastern regions. It is likely that climate change is now causing the species to migrate much earlier, but the extent of this cannot be accurately determined without comparison with recent data.

Abstract: In the present study, 7344 spring observations of a short-distance migratory species, the Eurasian Woodcock, from the Carpathian Basin between 1894 and 1926 were used to investigate the timing of the species' migration and how different environmental factors influenced it. We used a generalized additive model (GAM) to explore migratory patterns by using environmental and geographical variables. In years when the weather was colder and snowier, the birds migrated weeks later than in years with milder weather. This may be due to the availability of earthworms, which are the most important food for the species. In areas at lower altitudes, migration occurred earlier than in mountainous areas, which may also be due to the different weather. Furthermore, a two week difference was observed between the south-western and north-eastern parts of the Carpathian Basin. This difference is still present nowadays, but the timing of migration has shifted earlier than in the past, probably due to climate change. It would also be important to compare the historical data with recent data to gain a better understanding of the effects of climate change on the migration of the Eurasian Woodcock.

Keywords: historical ornithological data; short-distance migration; weather

1. Introduction

The Eurasian Woodcock (*Scolopax rusticola* L.) is a monotypic species [1,2] classified within the highly diverse order of Charadriiformes in the family Scolopacidae, genus *Scolopax* [3–8]. Its global distribution is in the Palaearctic faunal range [9], with breeding ranges from Norway, the British Isles, western France to northern Spain, and from the Azores, Canary Islands and Madeira eastwards to East Asia. Between 2013 and 2017, in addition to its general eastward and northward expansion, it has also been found nesting in Iceland, and continued its expansion in the northern parts of Finland, starting in the early

1980s [10,11]. In recent decades, the European population (comprising 13.8–17.4 million mature individuals) has been stable but has become patchy in the western and southern fringes [10]. The predominant breeding population of the species is found in Russia, where a slight decline has been observed [10,12]. Hungary is not a typical nesting area for this species, but a small number of nesting records are known from year to year, with an estimated population of only 10–60 lekking males [13–15].

The Eurasian Woodcock is a broad-fronted partial migrant [16] and its migration is characterised by a leapfrog migration strategy [17,18]. This means that the migration route to the wintering grounds is longest in the northernmost breeding populations [19–21]. The migration of this species is significantly influenced by winter weather, especially frost. In its wide breeding range, it is typically migratory, but resident populations are also known (mainly in northwestern Europe). Its main spring migratory directions in Europe and western Siberia are northeasterly [1,2,9]. Individuals from western populations spend the winter in the British Isles, western Europe, the Mediterranean and the western Sahel [9].

Birds migrating through Hungary arrive from Russia, Ukraine, the Baltic states and Poland and head for wintering grounds in Italy and France [16,22,23]. The Royal Hungarian Ornithological Centre started collecting ringing data on Eurasian Woodcock as early as 1913, and as a result we now have more than 600 registered ringing records, including data from Belarusian, Czech, French, English, Italian, Russian, Slovak, and Spanish birds [16,24]. The results of recent satellite tracking studies on the prenuptial migration of the species show that the birds are migrating to Ukraine, European Russia and central Siberia by an average of 2678 km (maximum 5002 km) [25]. The known literature data on the number of migrating birds (1.4–6.8 million) show a significant variation, although there is an overlap between the data sources estimating the population [26], so the estimates are subject to uncertainty.

Several species are known to have changed their migration strategy due to the climate change over the last decades, especially those that are short-distance migrants [27–34]. However, little is known about the environmental driving factors that influenced the migration of birds in the period before significant climate change [35]. In some cases, however, century-long datasets are available for a whole country or a small region. In Great Britain, data back to 1736 [31], in Central Europe to 1828 [36], in Sweden to 1873 [29], in Dutchess County (US) to 1885 [37], in the Northern Great Plain (US) to 1910 [38] and in Estonia to 1923 [39] have been used to investigate the question. Most studies showed variation in return times, but there may be regional and temporal variation. For example, Kolářová et al. [36] found that birds were arriving earlier during the cooler early part of the nineteenth century than in the recent warm period.

In the case of the Eurasian Woodcock, the question arises: how does the species adapt to changing environmental conditions? In Helgoland [40], Sweden [29] and Estonia [39], birds have also returned earlier today than in the past. Hungary has a long tradition of ornithological research [41]. At the turn of the 19th and 20th centuries, outstanding ornithological work was carried out in the country, which at that time covered the entire Carpathian Basin. One of the best examples is the spring bird migration monitoring initiated by Ottó Herman in 1894. Between 1894 and 1926, data on migratory birds in the Carpathian Basin were collected in an organised way during the spring period and published in the form of annual reports. Each year, thousands of returning records of more than 150 migratory bird species were published. Given that a large proportion of the data was provided by foresters, more observations of Eurasian Woodcock were published than of most species.

In the present study, we sought to answer the question of when the species migrated in the late 19th and early 20th centuries in different environmental and geographical areas of the Carpathian Basin, and what environmental and geographical variables influenced its migration. We assumed that in warmer springs and at lower altitudes the birds were likely to return earlier, as well as that migration was earlier in the more westerly areas than in the eastern part of the region.

2. Materials and Methods

The dataset analysed spanned the years 1894 to 1926, and was collected manually from published annual reports of the Hungarian Ornithological Centre [42–70]. Given that the coordinators of this monitoring programme asked for data according to a standard protocol (paper questionnaire), the published data were reliable. For this reason, data from other sporadic data releases were not used in this study. The reported data (location of observation, its geographical coordinates and altitude, date of observation, any comments on nesting or overwintering) were recorded in Microsoft Excel. The settlements were then classified into larger geographical regions. The Carpathian Basin was divided into categories of different scales for data processing, so the data came from 11 large regions and 1971 municipalities (Table 1).

Table 1. Distribution of data by large geographical regions and number of municipalities within these regions.

Large Region	Number of Data Points	Number of Municipalities within Large Region
Burgenland	188	55
S-Transdanubia	438	151
Transylvania	2040	534
N-Transdanubia	871	223
N-Hungary	257	77
Felvidék (Slovakia)	1811	431
Croatia	156	69
Transcarpathia	544	130
Hungarian Great Plain	172	60
Parcium	638	188
Vojvodina	229	53

The dataset encapsulates a total of 7344 observations including flushed birds in the forest and roding individuals, each representing daily records across 18 variables (Table 2), including the year, month, and day of observation (day of arrival), the cumulative number of days from January to the end of the observation month, the onset of migration in days relative to January (adjusting and accounting for leap years), and the altitude above sea level. Furthermore, the dataset encompasses geographical and meteorological variables such as settlement names, geographic coordinates (latitude and longitude), region/county designations, geographical units, daily mean, maximum, and minimum temperatures (°C), and daily precipitation totals (mm). Given the long tradition of hunting the species in the region at that time [71,72], it is possible that some of the birds observed were shot, but no information is available on the proportion of these numbers. The meteorological data were collected in HungaroMet Nonpofit Zrt- Meteorological Databank [73]. These variables offer a comprehensive overview of the environmental conditions, facilitating a detailed analysis of their potential impacts on migratory behaviours of birds over a longer span of time.

Determining the beginning and end of migration is a difficult task for most species that overwinter and nest locally. At the beginning of migration, there may still be overwintering birds in the area, while breeding birds may be a source of bias in later periods. Most of the observers had been in the field regularly due to their work (as most of the data were from foresters). As a result, some of the data were annotated, if the species overwintered in the area (see the cited sources of the data). This has ensured that overwintering and migratory birds have been reliably separated. The amount of data on wintering birds (*n* = 22) and observations during the winter period (*n* = 43) was otherwise very low, as this was a comparatively rare phenomenon compared to the present day [2,74–77]. The number of observations increased markedly on 10 February, whereas before that date there were only sporadic data. The annual reports also published migration intervals when migratory birds were observed in the area by one observer. These were used to determine the period

that could be considered the migration period of the species. We also considered published migration data from wintering sites. For example, in Italy, data from the last decades suggest that the number of wintering birds are already declining in early February [78], so it is likely that the species is already present in high numbers in the Carpathian Basin at this time, and winterers are already leaving the area. Since these birds wintered much less frequently in the Carpathian Basin in the past, the above observation is even more valid for the data from a century ago. As individuals nesting in Hungary may already have complete broods in early March [15,79], the migration period overlaps almost entirely with the nesting period of the local population. However, observers have noted observations of nesting birds, so it can be stated with high confidence that the data we used refer to migrating individuals. Accordingly, the data before 10 February and after 30 April were removed from the database, leaving a total of 7344 data points.

Table 2. Variables used with their definitions and measurement levels. "Beginning of migration in days compared to January with leap years" is the dependent variable.

Variable	Description
Month	Categorical variable capturing seasonal effects. This variable was excluded from the analyses since the variables "days" and "years" adequately capture migratory patterns.
Number of days from beginning of migration compared to January with leap years from January to the end of the month	Numeric variable that captures intra-monthly timing effects.
Beginning of migration in days compared to January with leap years compared to January	Numeric variable that is related to timing within the year. This is our most important variable of interest (beside year). This variable shows in days how many days have passed since 1st January of each year considering leap years.
Geographic latitude and geography length	These variables were excluded from the analyses since the variables "days" and "years" adequately capture migratory patterns.
Altitude above sea level	Numeric variable that could influence the dependent variables due to geographical effects.
Region, county, geographical unit	Categorical variables that might capture regional differences affecting the dependent variables.
Daily mean temperature, daily maximum temperature, daily minimum temperature, daily precipitation total, type of daily precipitation total (the last variable is categorical)	These climate-related numeric variables may impact the dependent variables.

We used R software Version 4.4.1 [80] with R-studio [81] and employed a generalized additive model (GAM) using the mgcv R package [82]. GAMs [82–86] represent a robust approach to statistical modelling in the case of complex, non-linear relationships between predictors and a dependent variable, i.e., migratory patterns. Unlike linear models that assume a non-linear relationship between predictors and the dependent variable, GAMs allow for the modelling of non-linear relationships without needing to specify the form of the non-linearity a priori [87]. This is achieved through the use of so-called smooth functions. We modelled migratory patterns using the independent variables (predictors) of daily minimum temperature, daily maximum temperature, altitude above sea level, year, and daily precipitation total, to examine their potential influence in driving bird migration in our time-series data.

First, the geographical data, including settlement names and coordinates, were catalogued to understand the spatial distribution of observations, aiding in the examination of regional variations in migratory patterns. Altitude above sea level data were analysed to explore the influence of sea elevation on migration.

For the objectives outlined predicting the increase in "year" and simultaneously explaining the change in the values of the variable "beginning of migration in days compared

to January with leap years", we first tested our dataset on some assumptions such as the assumptions of linearity, homoscedasticity, and kernel density estimate (KDE) to evaluate the normality of residuals, and multicollinearity.

GAM allows for capturing the dynamics of climate-related variations over time. Estimated degrees of freedom (edf) reflects the complexity of the relationship between the predictor(s) and the dependent variable, with an edf close to 1 suggesting a nearly linear relationship, while higher values indicate a more complex, non-linear relationship.

"Deviance explained" and "adjusted R-squared" are measures of overall model fit, that is, the proportion of variance in the dependent variable accounted for by the model. The generalized cross-validation (GCV) score in GAM and scale estimate provide information about the model's predictive performance (measures of model fit) and the spread of residuals, respectively. Lower values indicate a better fit. "Ref.df." refers to the reference degrees of freedom, while the F-value is a measure of the variance explained by the predictor, with the highest F-value suggesting the strongest predictor.

Next, we evaluated the multicollinearity assumption by calculating the variance inflation factor (VIF) for each independent variable (predictor). High levels of correlation (VIF > 10) between independent variables can undermine the statistical significance of regression models. Moreover, we tested underlying assumptions of statistical tests such as heteroscedasticity, the distribution of residuals, and the Durbin–Watson statistic assessing autocorrelation among the residuals.

Our hypothesis is that the selected climate-related variables significantly explain the variation in both "year" and the "beginning of migration in days compared to January with leap years." This approach will enable the simultaneous examination of the impact of climate-related factors on both the progression of years and the timing of migration onset in days (considering leap years) simultaneously. When reporting the GAM results, we present the them from the models with a Gaussian family and identity link function. The sample size (*n*) refers to the valid cases without missing values.

We also generated an effects plot to visualize the temporal dynamics of each predictor. The smooth curve represents the estimated effect of a predictor on the dependent variable while holding other predictors constant. Furthermore, we assumed differences in migration timing between different geographical regions. Of the 11 geographical regions, at least one observation record was taken, but only those years with at least 30 observations between 1894 and 1926 were considered for the analysis.

We used the Kruskal–Wallis test to examine whether there was an overall effect on the timing of the first observed individuals in different years. Only years in which at least 100 observations were made were considered. This covers 19 years between 1897 and 1915.

3. Results

The median arrival date for the entire dataset for the first individuals of the species was on 19 March. The number of sightings started to increase in the last third of February, peaking in mid-March and declining by the end of April (Figure 1).
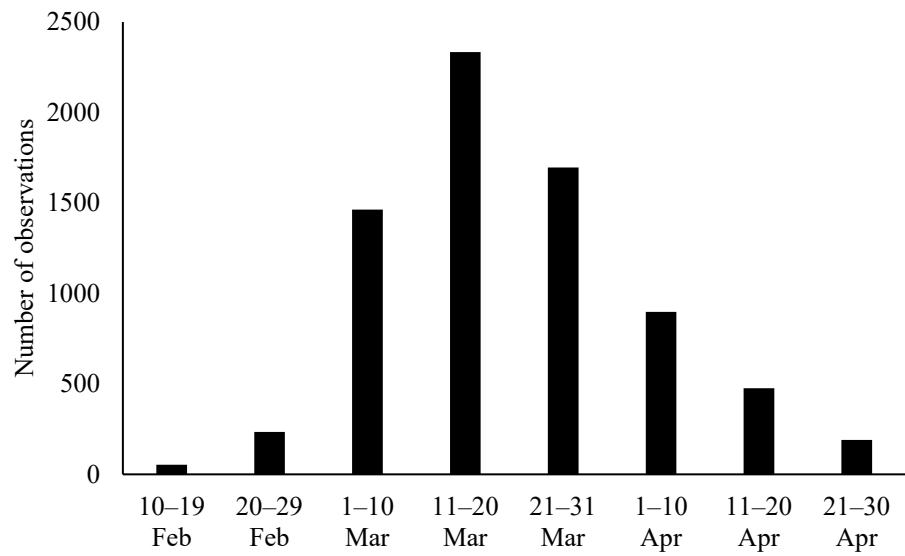
Figure 1. Number of observations by 10-day intervals.

The annual median date of the first observed individuals differed significantly between years (H = 1279, *p* < 0.001), with the earliest of these years being 1897 (8 March) and the latest of these years being 1907 (2 April) (Figure 2).
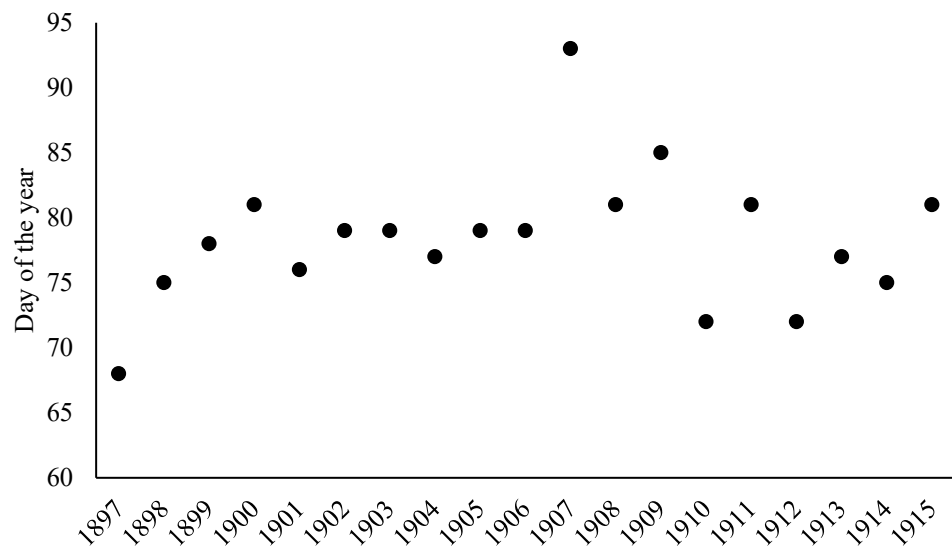

Figure 2. Annual median dates of the first observed individuals during the spring migration.

There was also a significant difference between years for the earliest observation date in a given year, but no trend-like advance was statistically detectable over the observation period (Z = 0.386, *p* = 0.699) (Figure 3).
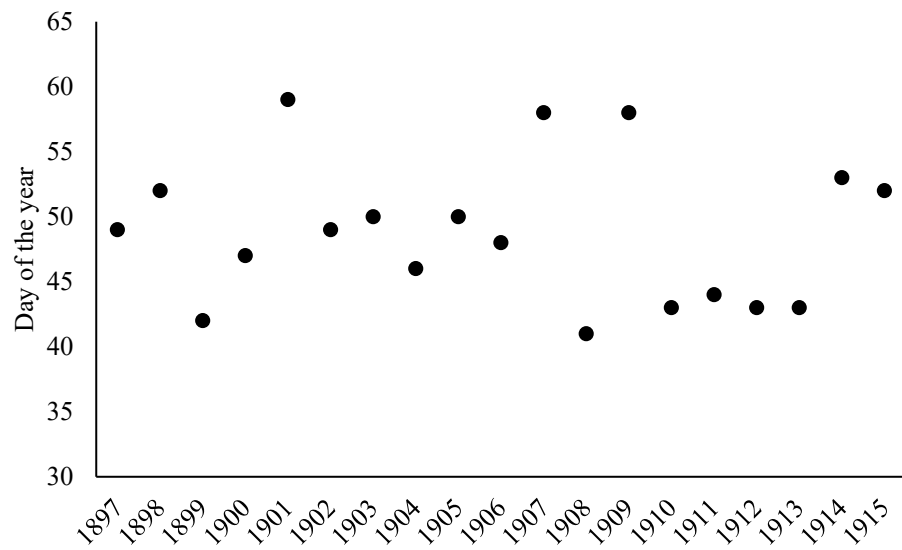
Figure 3. Earliest observations by years between 1897 and 1915.

Comparing data from the larger geographic regions, there was a significant difference in the timing of first arrivals (H = 1424, *p* < 0.001), with the earliest (10 March) median date of first sightings in South Transdanubia and the latest (24 March) in Felvidék (Slovakia) and Transcarpathia (Figure 4).
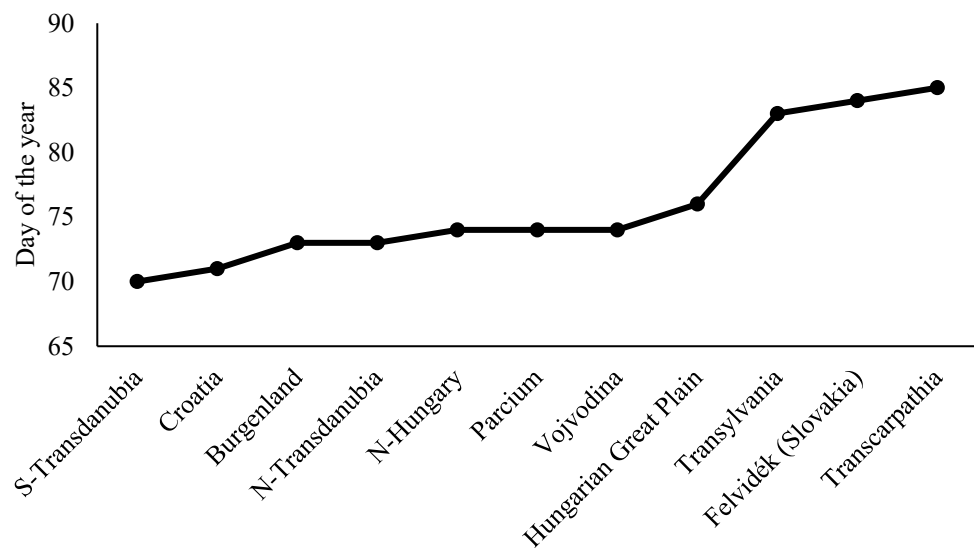

Figure 4. Median dates of the spring migration of Eurasian Woodcock by large region in the Carpathian Basin between 1897 and 1915. The order of the regions is by its geographical location from the west–southwest to the east–northeast direction.

The predictors did not show multicollinearity after removing the variable "daily mean temperature". The VIF statistics yielded the following results: altitude above sea level (1.10), maximum temperature (1.87), minimum temperature (1.86), precipitation (1.01), and year (1.06). The scatter plot of residuals versus predicted values revealed heteroscedasticity. The histogram of residuals, supplemented with a KDE, was used to evaluate the normality of residuals. The plot indicated that the residuals were not perfectly normally distributed.

The Durbin–Watson statistic was 0.0024, which pointed towards a strong positive autocorrelation among the residuals, indicating that the assumption of independence of errors was violated. The assessment of these assumptions revealed several concerns regarding the underlying assumptions. Furthermore, the distribution of residuals indicated

deviations from the expected normal distribution. Given these violations of statistical assumptions, we employed GAM to fit to the data, with the climate-related independent variables and migratory patterns as the dependent variables ("Beginning of migration in days compared to January with leap years"). Results from the GAM model can be seen in Table 3.

Table 3. A summary of the GAM model fitted on the data with the independent variables listed as smoothers. R-sq. (adj.) = 0.445; deviance explained = 44.8%; GCV = 107.33; Scale est. = 106.73; *n* (observations in the model) = 6667, N (total number of observations in the dataset: 7344; Family: Gaussian, and Link function: identity.

| | Parametric Coefficients | | | |
	Estimate	SE	t-Value	*p*-Value
Intercept	80.4108	0.1265	635.5	$p < 0.001$
	Approximate significance of smooth terms			
Smooth term	Edf	Ref. df.	F-value	*p*-value
s(Altitude_above_sea_level)	7.660	8.490	179.16	$p < 0.001$
s(Daily_maximum_temperature)	4.576	5.674	56.08	$p < 0.001$
s(Daily_minimum_temperature)	7.435	8.326	23.33	$p < 0.001$
s(Daily_precipitation_total)	8.145	8.769	10.47	$p < 0.001$
s(Year)	8.759	8.977	124.51	$p < 0.001$

The highest F-value in the GAM model (after year), is the altitude above sea level, showcasing the strongest predictor of the dependent variable. The spline terms for the variables "altitude above sea level", "maximum temperature", "minimum temperature", "precipitation", and "year" capture the non-linear relationships between these predictors and the migration days (Figure 5). What follows next is the interpretation of each predictor.
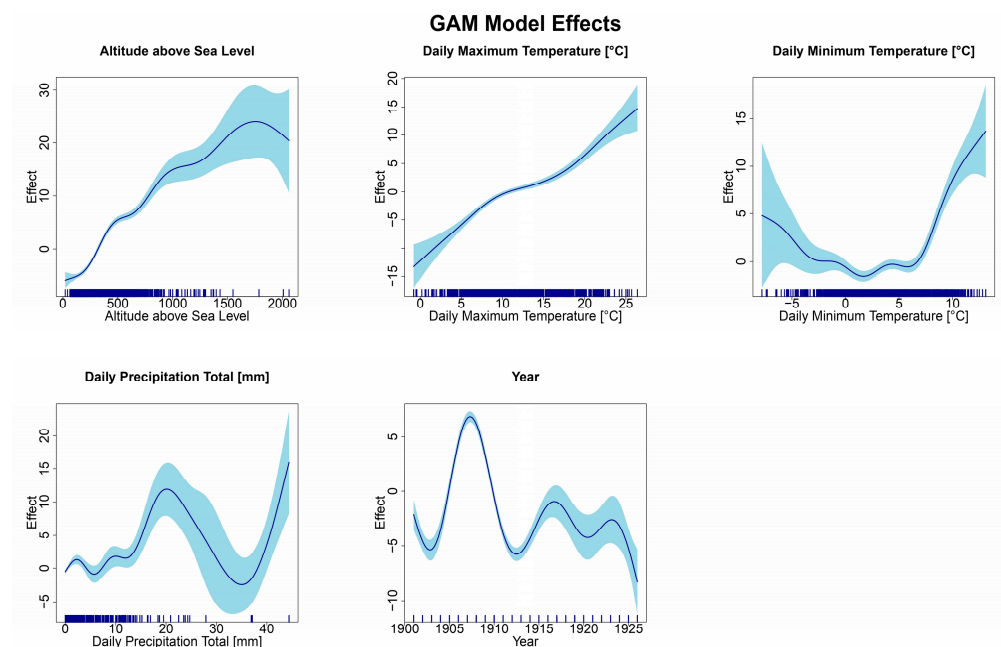

Figure 5. Effects plot of the predictors based on the GAM model in Table 3. The shaded area around the smooth curve represents the 95% CI.

The relationship between altitude and migration days is non-linear: as altitude increases, there is an initial increase in migration days, suggesting that in certain altitude ranges, migration is delayed. However, after a certain point, the relationship levels off (or even decreases), indicating that beyond a specific altitude, changes in altitude have little to

no additional impact on migration days. For example, at lower altitudes, an increase might delay migration, but at higher altitudes, this effect might diminish or reverse.

The relationship between maximum temperature and migration days shows that migration days initially decrease as temperatures rise, suggesting earlier migration. However, as temperatures continue to increase, the migration days begin to rise again, indicating a threshold or optimal temperature range for migration. The curve's shape suggests that both very low and very high temperatures can delay migration, with an optimal range in between. There is a range of temperatures within which the effect on migration days is more pronounced (i.e., extreme temperatures might lead to significant delays), while moderate temperatures could have a smaller effect. There are clear inflection points where the curve shifts direction, indicating key temperature thresholds where the effect on the dependent variable changes.

Migration days decrease with increasing minimum temperatures up to a certain point. After this threshold, further increases in minimum temperature appear to stabilise migration days. This could indicate that colder minimum temperatures are associated with later migration, but beyond a certain temperature, further increases do not significantly impact migration timing. The minimum temperature spline models the effect of the lowest temperatures on migration days. This effect is not constant across all temperatures: the spline shows that at very low temperatures, migration is significantly delayed, while at higher minimum temperatures, the delay is less pronounced or even non-existent.

As precipitation increases, migration days initially increase, indicating that higher precipitation levels delay migration. However, at higher levels of precipitation, this relationship weakens, suggesting that extremely high precipitation might not have a strong additional delaying effect on migration days. There is a threshold effect where, beyond a certain point, additional precipitation does not significantly impact migration days. The spline shows that light to moderate precipitation delays migration, but beyond a certain point, additional precipitation has little additional effect, or it might even show a reversal where extremely high precipitation could prompt earlier migration. In sum, as daily precipitation increases, the effect on migration days initially decreases slightly but then increases substantially. This indicates that moderate precipitation might have a slight negative effect, but higher precipitation has a positive effect. Also, there seems to be a threshold after which the effect of precipitation becomes significantly positive. The effect of the year shows a cyclical pattern, with periods where the effect is positive and others where it is negative, suggesting the presence of cyclical patterns over the years. There is an initial decrease in migration days indicating that, over the years, migration might be occurring earlier. However, this trend does not continue indefinitely, as the relationship eventually stabilises, suggesting a period of change in migration patterns followed by a period of stabilisation.

4. Discussion

Our results show that the migration of the Eurasian Woodcock at the turn of the 19th and 20th centuries was influenced by weather, geography and altitude. In years when the weather was colder and snowier and in the mountainous areas the birds migrated later. We also found a two week difference between the south-western and north-eastern parts of the Carpathian Basin.

Migration from wintering areas in the past few decades may start as early as early February [78,88], and in mild or dry spring weather the first migrants may appear in Hungary as early as the beginning of February. However, the intensive migration starts only from mid- or late-February and March in the Mediterranean countries [78,89], which is why the first Eurasian Woodcock typically do not appear until early March in Hungary [16,90,91]. In case of prolonged cold winter weather, the onset of spring migration may be delayed even further [2,72,77,88,92–94]. The first birds typically return to northern Europe in March [95,96]. Our results suggest that the median date for the entire Carpathian Basin was 19 March, but that this differed significantly between years and between geographical regions. There was a three week difference between the earliest (8 March 1908) and latest (2 April 1901) start

dates, which is clearly due to the sometimes drastically different spring weather from year to year. This is in line with the results of the studies of Bende [72] and Bende et al. [88], based on 23,261 observations over a 10 year study period. Migration is influenced by a number of intrinsic factors (e.g., endogenous rhythms, changes in day length at wintering sites), especially in long-distance migrants [27,97–100]. A similar variance in return dates is only possible for short-distance migrants, as the genetic regulation of their migration is much lower, making the timing of migration much more flexible than for long-distance migrants. These species can respond more quickly to weather changes at wintering and stopover sites [101], consistent with several studies that have found a negative correlation between arrival time and temperature [102,103]. Based on field observations, it was found by Schenk [74] that the spring migration of this species is significantly influenced by weather conditions [74,88,90,91,104]. For instance, in Estonia, based on observation data from 1923 to 2008, the average temperature in March significantly affected the arrival of birds [38]. Comparing tracking and weather data, Le Rest et al. [105] found that higher air temperature and northward wind increased the probability of migration of the birds. In our study, we also proved this effect, as the statistical analyses clearly showed that the migration of the species is influenced by temperature and the amount and quality of precipitation. Low temperatures and snowy, wet spring weather during the study period did not favour spring migration of the species. Pátkai [106] showed in his studies in 1947 and 1948 that migration peaks when daily mean temperatures reach or exceed 16 °C and when warm Atlantic air masses reach the Urals. In most studies, wind direction and strength appear to be the primary factors influencing migration, with temperature being a secondary factor inducing rather than intensifying migration [39]. Precipitation events and high wind speeds inhibit migration, while cloud cover and humidity are considered to be side effects of the weather conditions that determine migration [107]. The results of Schenk [74,108] and Pátkai [106] have been confirmed by several studies [2,90–92,104,109]. It has also been shown in other nocturnal and broad-fronted migratory species that spring migration is most intense when cyclonic conditions prevail in the wintering area [110]. Our results are also consistent with the findings of Bulte et al. [111] and Kranstauber et al. [112] that migrants rarely experience wind conditions with optimal direction and speed throughout their migration, but that favourable conditions greatly facilitate their migration. Our results show that migration was clearly intense at higher temperatures. There is an indirect reason for this, as the most important food of the Eurasian Woodcock is earthworms [113], which are not available to the species when the ground is frozen and covered with snow. This is partly why adequate temperature and precipitation conditions have been crucial for the timing of migration, and also why unfavourable atmospheric conditions during higher amplitude weather extremes significantly inhibit migration, as confirmed by the results of Bende [72] and Bende et al. [88].

In addition to weather, geographical conditions also have a significant impact on the spring migration. Our analysis of altitude suggests that migration of the species has occurred earlier in lower elevations. Although the Eurasian Woodcock is essentially associated with forested areas, it can inhabit flat, hilly and mountainous areas and may leave forests during its migration [16,72,114]. It is absent from the highest mountain areas due to habitat unsuitability (coniferous meadows, dwarf grasslands), so it is not surprising that it was observed earlier in areas at lower elevations. It has been previously noted that the arrival in mountainous areas depended on snowmelt, which could be delayed by periods of time up to weeks compared to lower areas [94,108,115,116]. Again, the background to this may be the availability of food: soil life is activated earlier in lower areas than in higher regions.

Whether we look at data from larger geographical regions, the earliest arrival dates were clearly associated with the south–southwestern regions of the Carpathian Basin, while the latest dates of arrival were observed in the north–northeastern regions. There was a two week difference in the first spring arrival dates between southern Transdanubia (10 March) and Felvidék (Slovakia) and Transcarpathia (24 March), based on data from the

turn of the 19th and 20th centuries. Schenk [108] hypothesised that Eurasian Woodcock would first arrive in the southwestern region of the Kingdom of Hungary and then continue to move north-eastwards, leaving the northern Carpathians. This hypothesis fits well with the suggestion of Szabolcs [117] that the spring migration takes place with a temporal shift in the whole area of Hungary. Within the present borders of Hungary, the migration does not take place all at once, but in several waves with a phase lag. The first birds arrive in southern Hungary at the beginning of March and then pass over Budapest around 10 March. They reach the eastern part of the Northern Central Highlands around 15–20 March. At the national level, the peak of migration is typically in the last week of March [22,118–135]. The above-detailed phase lag was statistically confirmed by Bende et al. [136] for the current area of Hungary. The two week difference in the southwest–northeast direction and the up to 3–10 day difference in the smaller spatial scales found by Bende et al. [136] are indicative of a permanent regional shift in the timing of spring migration.

The GAM findings suggest that daily maximum temperature was also a significant predictor of migratory patterns. It is important to note, however, that the rest of the climate-related independent variables were also significant in driving bird migration. For other migratory bird species within Europe, wind was the most important determinant [137]. For Eurasian Woodcock, temperature was more important due to food availability, but this factor could not be investigated due to the lack of historical weather data.

Based on a 140-year-long data series in Sweden, it was found that the species' spring migration shifted significantly earlier [29]. However, as the authors stated, the species has become a regular overwinterer in the south of the country, which significantly affected their results. In Helgoland, between 1960 and 2008, the spring arrival of the species advanced by 16 days [40]. The Estonian data showed an earlier arrival by a calendar month in a century-long timescale [40]. If we consider the Hungarian literature, birds are returning to Hungary earlier than they did a century ago [16]. It is also important to highlight that the earliest annual sightings often indicate that the first individuals were only sighted at the very end of February. Today, in contrast, overwintering populations are regular and increasing in the Carpathian Basin [16,25,138]. Therefore, it would be important to compare historical data with recent data in order to accurately assess the extent of change in migration timing.

Author Contributions: Conceptualization, L.B. and A.B.; methodology, L.B. and I.F.; software, I.F.; formal analysis, I.F.; writing—original draft preparation, L.B.; writing—review and editing, L.B., A.B. and I.F. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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