Ornis Hungarica 2023. 31(1): 133–146.
DOI: 10.2478/orhu-2023-0009

Variations in the spring migration of Eurasian Woodcock (*Scolopax rusticola* L.) in Hungary

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Received: February 16, 2023 – Revised: April 27, 2023 – Accepted: April 28, 2023

Bende, A., Faragó, S. & László, R. 2023. Variations in the spring migration of Eurasian Woodcock (*Scolopax rusticola* L.) in Hungary. – Ornis Hungarica 31(1): 133–146. DOI: 10.2478/orhu-2023-0009

Abstract We investigated the spatial and temporal patterns of migration of Eurasian Woodcock (n=23,539 specimens) collected in Hungary during spring sampling (2010–2019) in the framework of the Woodcock Bag Monitoring. There were differences in the temporal course of the spring migration of the species between the western and eastern regions of Hungary. In the western Hungarian counties, migration started earlier in all cases, while in Borsod-Abaúj-Zemplén county the main migration period – i.e. the period between the 25% and 75% cumulative sampling thresholds – started on average one week later than in Somogy county. We investigated the influence of weather factors on the spatial and temporal pattern of migration, in addition to geographical causes, based on the distribution of Péczely's macrosynoptic situations recorded the week before and after the migration peak. In years free of weather extremes, the migration period was characterised by neutral (80.0%) macrosynoptic situations, with unfavourable (9.5%) and favourable (10.5%) conditions occurring less frequently. In the years with weather anomalies (2013, 2016, 2018), unfavourable macrosynoptic situations (81.3%) determined the spring migration characteristics. Weather anomalies (macrosynoptic conditions with gale-force winds and heavy snowfall) affected the timing of spring migration, but regional differences were observed in all years regardless of weather conditions, suggesting that spring migration of Woodcock is phase-delayed in the southern Transdanubian and north-eastern regions of Hungary.

Keywords: woodcock migration, migration pattern, migration-weather correlation, macrosynoptic situations

Összefoglalás Az Erdei Szalonka Teríték Monitoring keretében tavaszi mintavétel során (2010–2019-es évek) Magyarországon gyűjtött erdei szalonkák (n=23539 pld.) vonulásának tér- és időbeli mintázatát vizsgáltuk. Eltérés mutatkozott a faj tavaszi vonulásának időbeli lefolyásában Magyarország nyugati és keleti régiója között. A nyugat-magyarországi vármegyékben a vonulás minden esetben korábban kezdődött, Somogy vármegyéhez képest Borsod-Abaúj-Zemplén vármegyében a fő vonulási időszak – vagyis a 25% és 75%-os kumulált mintavételi küszöbérték közé eső időszak – átlagosan egy hetes késéssel vette kezdetét. Megvizsgáltuk, hogy a földrajzi okok mellett az időjárási tényezők milyen hatást gyakorolnak a vonulás tér- és időmintázatára, amihez a vonulás tetőzést megelőző és az azt követő héten regisztrált Péczely-féle makroszinoptikus helyzetek megoszlását vettük alapul. Az időjárási szélsőségektől mentes években a vonulási időszakot a semleges (80,0%) makroszinoptikus helyzetek jellemezték, a kedvezőtlen (9,5%) és a kedvező (10,5%) állapotok ritkábban fordulnak elő. Az időjárási anomáliával terhelt években (2013, 2016, 2018) a kedvezőtlen makroszinoptikus helyzetek (81,3%) határozták meg a tavaszi vonulás karakterisztikáját. Az időjárási anomáliák (viharos széllel, jelentős havazással járó makroszinoptikus állapotok) a tavaszi szalonkavonulás időbeli lefolyására gyakoroltak hatást, azonban a regionális különbségek az időjárási viszonyoktól függetlenül minden évben jelentkeztek, tehát az erdei szalonka tavaszi vonulása Magyarország dunántúli és északkeleti régiójában fáziskéséssel zajlik le.

Kulcsszavak: szalonkavonulás, vonulás mintázat, vonulás-időjárás kapcsolata, makroszinoptikus helyzetek

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Introduction

The Eurasian Woodcock breeds only occasionally in Hungary (Bende & László 2020, Hadarics 2021), so in our region, it is only seen in larger numbers during its autumn and spring migration. Hungary is located between the main nesting and wintering areas of the Woodcock, and thus, based on ringing data (Schally 2019, Bende 2021) and telemetry studies (Aradis 2015, Arizaga *et al*. 2015, Le Rest *et al*. 2018), birds migrating through our region come from several countries (France, Italy, Greece) and arrive along different routes. Based on the data of foreign ringed specimens marked in Hungary or found in our country, Woodcocks arrive in spring mainly from France and to a lesser extent from Italy (Bende 2021), so the weather conditions here are decisive for the start of migration. Regarding bird species' migration strategy, weather conditions play a key role (Alerstam 2011), especially when extreme conditions with stormy winds, heavy frost and intense precipitation events dominate (Liechti 2006, Shamoun-Baranes *et al*. 2017). As discussed above, weather conditions can have a significant impact on the starting of migration and its progression through feeding opportunities and resting periods (Jenni & Schaub 2003, Newton 2006), as well as, on the survival of specimens (Klaassen *et al*. 2014).

Several theories have been put forward concerning the factors that trigger the spring migration, the most in Hungary well-known of which is the theory developed by Schenk (1924), claiming that *"the migration starts with the first north-western cyclone in spring"*, i.e. the mass spring migration is induced by depression over the British Isles and high air pressure over southern Europe (Hegyfoki 1907, Schenk 1924, Pátkai 1951). The North Atlantic Oscillation (NAO) is one of the climatic variables, along with temperature, precipitation, and wind conditions, that have been most often investigated as a predictor of spring migration phenology (Haest *et al.* 2018). Larger-scale Hungarian studies on the migration characteristics of the species, in the framework of the Hungarian Woodcock Bag Monitoring between 1990 and 1999, were only carried out after almost seventy years (Faragó *et al*. 2000). During these examinations, however, no data were available that would have allowed a nationwide examination of the spatial and temporal characteristics of the migration, so the opinion of Schenk (1924), i.e. the spring migration of Woodcock in Hungary is phase-delayed, could neither be disproved nor confirmed. The year 2009 marked a turning point in Woodcock research, when the spring Woodcock hunting in Hungary was threatened by the enforcement of the European Union Birds Directive (79/409 EEC). As a condition for the deviation from the Directive, Hungarian Hunters' National Association launched the Hungarian Woodcock Bag Monitoring in 2009, which was joined in 2010 by the Institute of Wildlife Management and Vertebrate Zoology of the University of West Hungary with a biometric testing module. Owing to the new national monitoring, an exceptional opportunity was offered to examine the migration of Woodcock with time series based on a large sample (n=23,539), provided by more than 5,000 participants, following a standard protocol for a decade. This amount of data offered the opportunity to gain a picture of the spatial and temporal patterns of migration on a longer time scale and on a national scale, and the role of the major atmospheric phenomena that determine the weather of the Carpathian Basin in influencing migration.

Material and Method

From the spring of 2010, the Woodcock Bag Monitoring, under the coordination of the Hungarian Hunters' National Association, has set a target of up to 5,600 Woodcocks to be bagged annually. In addition to recording body sizes, the place where the birds were bagged (county, municipality, game manager), the exact time of sampling (month, day, hour, minute) and the sex of the birds were recorded. During the monitoring, more than 500 authorised hunters – with more than 800 sampling points – participated in data collection each year, which data were sent directly to the Institute of Wildlife Biology and Management of the University of West Hungary during the first five years (2010–2014). In the second phase of monitoring (2015–2019), the basic data sent by the hunters were forwarded to our institute by the staff of Szent István University. In order to evaluate the migration dynamics in a uniform way, the data sets of the sampling period from 1 March to 10 April (41 days) were analysed. In order to ensure uninterrupted observational data collection, during the first phase of monitoring (2010–2014), no sampling opportunity was available to data providers on Saturday mornings, and therefore data from the Saturday evening were excluded from the analysis.

In our studies, we based our results on the proven correlation that the temporal variation in the number of Woodcocks bagged is proportional to the variation in the number of birds migrating during the spring migration, thus, the collected samples faithfully reflect the spatial and temporal pattern of the spring migration of the Woodcock population in Hungary (Faragó *et al*. 2012a, 2012b, 2014, 2015a, 2015b, 2016, Schally 2020, Bende 2021). To characterise the temporal course of migration, we defined the main migration period in each year as the period between 25% and 75% cumulative sampling values. This allows us to determine the length of the period when migration is the most intense and 50% of the birds migrate through Hungary. The dates associated with the main migration period defined in this way allowed comparisons to be made between years, even at a finer spatial, regional or county level. Counties with a small number of annual items ($n < 30$) were not used for regional comparisons.

Statistical tests were conducted using a two-sample t-test to analyse the temporal differences between the eastern and western regions of the country during the main period of migration. Linear correlation analysis ($r_{25\%,}$ $r_{75\%}$) was also conducted to examine the correlation between the annual changes in the differences between the south-western and north-eastern regions of the country. For our statistical analyses, we chose Somogy county from the south-western region of Hungary, which has a large number of items, and Borsod-Abaúj-Zemplén county from the north-eastern region of Hungary, which also has a significant number of items. The regional time differences in the migration from Hungary by year were tested using a one-sample t-test, where we assumed that the empirical frequency average corresponds to 8 days for the average of the probability variable characterising the difference.

To examine the relationship between spring migration and weather, we used Péczely's classification system of large-scale weather situations, the data sets of the catalogue of macrosynoptic types (Károssy 2016). Four main centres of action play a role in the formation of low- and high-pressure atmospheric formations moving in the cellular structure of the temperate zone (Károssy 2016):

1. Icelandic low-pressure minimum,
2. Azores high-pressure maximum,
3. Persian Gulf low-pressure minimum,
4. Siberian high-pressure formation.

These centres of action determine the weather patterns on the continent in the short or even longer term. Our work is based on Péczely's classification system (1957, 1961) for Hungary, which classifies the weather of the Carpathian Basin into 13 types based on the air pressure values converted to sea level. When examining the relationship between bird migration and weather, particular importance is given to the formation of tropospheric atmospheric formations with a cellular structure, both vertically and horizontally, i.e. cyclonic and anticyclonic types, which Péczely considered to be separated at 1015 hPa threshold value. The frequency of wind directions and the orographic characteristics of the Carpathian Basin were also decisive factors in the classification (Péczely 1957, 1961).

The macrosynoptic conditions recorded in the week before and after the maximum of the spring migration of Woodcock were as follows:

I. North-guided meridional positions
- mCc: Backside flow system of a cyclone,
- AB: Anticyclone over the British Isles,

II. South-guided meridional positions
- mCw: Frontal flow system of a cyclone,
- Ae: Anticyclone to the east of Hungary,
- CMw: Frontal flow system of a Mediterranean cyclone,

III. Zonal west-guided positions
- zC: Zonal cyclonic flow,
- Aw: Anticyclone to the west of Hungary or incoming anticyclone from the west,
- As: Anticyclone to the south of Hungary

IV. Zonal east-guided positions
- An: Anticyclone to the north of Hungary,
- AF: Anticyclone over the Fenno-Scandinavia region,

V. Central anticyclone
- A: Anticyclone over the Carpathian Basin,
- C: Cyclone centre over the Carpathian Basin.

We classified these large-scale atmospheric formations into three groups (favourable, neutral, unfavourable) based on their impact on migration and compared their frequency with the bagging dynamics of the sample (n=23,539) collected during the study period (2010–2019). The classification criteria were based on the findings on atmospheric physical conditions affecting bird migration from Liechti (2006), Alerstam (2011), Ćiković and Radović (2013), Shamoun-Baranes *et al.* (2017) and Le Rest *et al.* (2018). Macrosynoptic conditions free of strong frosts, with favourable wind direction and no stormy winds and low atmospheric humidity were considered favourable, conditions free of extremes but not meeting the favourable criterion were considered neutral, and conditions with extreme, stormy, heavily foggy, strong frosts or intense precipitation events were considered unfavourable (Alerstam 1976). The goodness of fit test (χ^2) was used to check whether the macrosonoptical conditions of the years assumed to be average correspond to the average for the period 1958–2010. We also tested whether the macrosynoptic states recorded during the migration period of years considered extreme for bird migration were statistically verifiably different from the Péczely states of the average years, i.e. they could be considered extreme. In this case too, the goodness of fit test (χ^2) was applied. This is consistent with the method used by Gyurácz *et al.* (2010).

This classification is also in line with the finding of Le Rest *et al*. (2018) that only weather extremes had a significant effect on the migration of Woodcock and its interruption. Statistical analysis of the data was performed using Microsoft Excel 2016 and Statistica 13. For geospatial processing, chromatic maps were created using the geospatial software ArcGIS 10.3.

Results

The migration dynamics by regions

In the ten years examined, the main migration period in Borsod-Abaúj-Zemplén County started min. 3 days and max. 10 days later than in Somogy County. The county differences in the start and end sampling days of the main migration period in each year are well correlated ($r_{25\%}$ = 0.7867, $r_{75\%}$ = 0.6568), i.e. the time delay in the sampling days of the main period occurs in each year of the spring migration of the Woodcock *(Figures 1, 2)*.

The time difference between the beginning (day corresponding to a 25% cumulative sampling rate) and the end (day corresponding to a 75% cumulative sampling rate) of the main period between Somogy and Borsod-Abaúj Zemplén Counties was observed in each year. The difference observed was not significantly different over the period examined ($t = 2.1$, $df = 17$, $P = 0.404$). There was no statistically verifiable difference in the length of the main migration period between the counties examined in each year ($t = 2.1$, $df = 17$, $P = 0.277$).

In the south and west Hungarian counties, migration started earlier each year, with Baranya county typically reaching the 25% cumulative sampling rate first. In 2011, being the average year presented as an example, this date fell on 21 March. Compared to this start date, we examined the time delay in the other counties. In the counties of the southern and western Transdanubian region (Baranya, Zala, Somogy, Tolna Counties) and in north-western Hungary (Győr-Moson-Sopron County) the main migration period started at a similar time to the start date. In Vas county and in the Danube-Mountains region (Veszprém, Fejér and Komárom-Esztergom Counties), a two-day phase-delay was observed compared to the start date of the main period. In the North Hungarian Mountains region, and in some years in Komárom-Esztergom and Fejér Counties, a phase-delay of up to 5 days was recorded compared to the baseline date, which confirms the time delay – at a cumulative value of 50% and 75% too – of the Woodcock migration between the western and north-eastern regions of Hungary in all years studied *(Figures 3, 4)*.

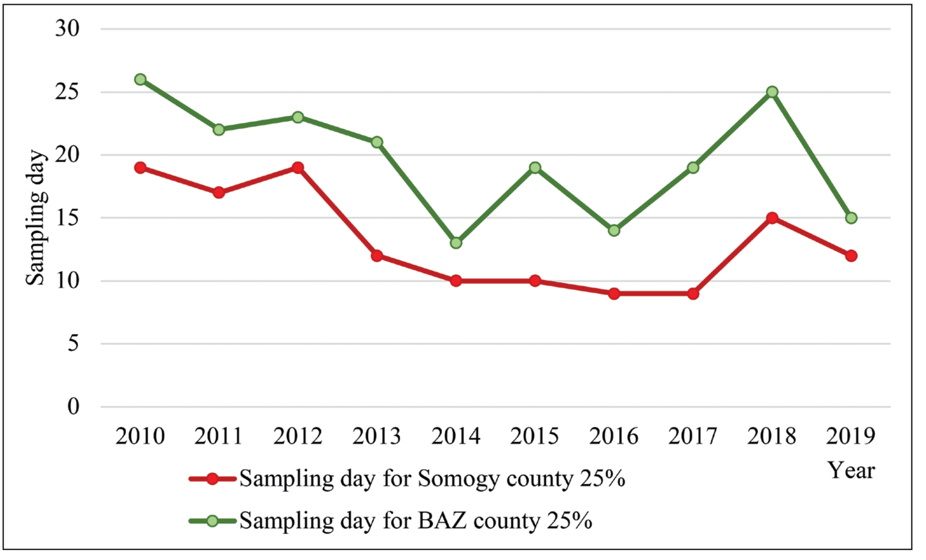

Figure 1. Sampling days indicating the beginning of the main migration period (25%) of Woodcock (*Scolopax rusticola* L.) in Somogy and Borsod-Abaúj-Zemplén (BAZ) counties in the years 2010–2019

1. ábra Az erdei szalonka (*Scolopax rusticola* L.) fő vonulási időszakának kezdetét (25%) mutató mintavételi nap a 2010 és 2019 közötti években Somogy és Borsod-Abaúj-Zemplén vármegyében

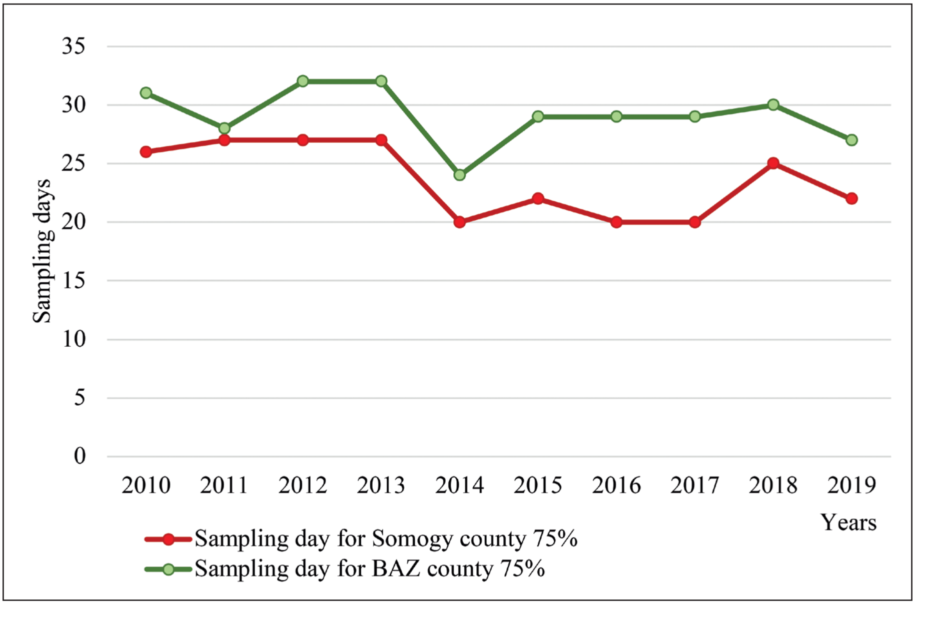

Figure 2. Sampling days indicating the beginning of the main migration period (75%) of Woodcock (*Scolopax rusticola* L.) in Somogy and Borsod-Abaúj-Zemplén (BAZ) counties in the years 2010–2019

2. ábra. Az erdei szalonka (*Scolopax rusticola* L.) fő vonulási időszakának kezdetét (75%) mutató mintavételi nap a 2010 és 2019 közötti években Somogy és Borsod-Abaúj-Zemplén vármegyében

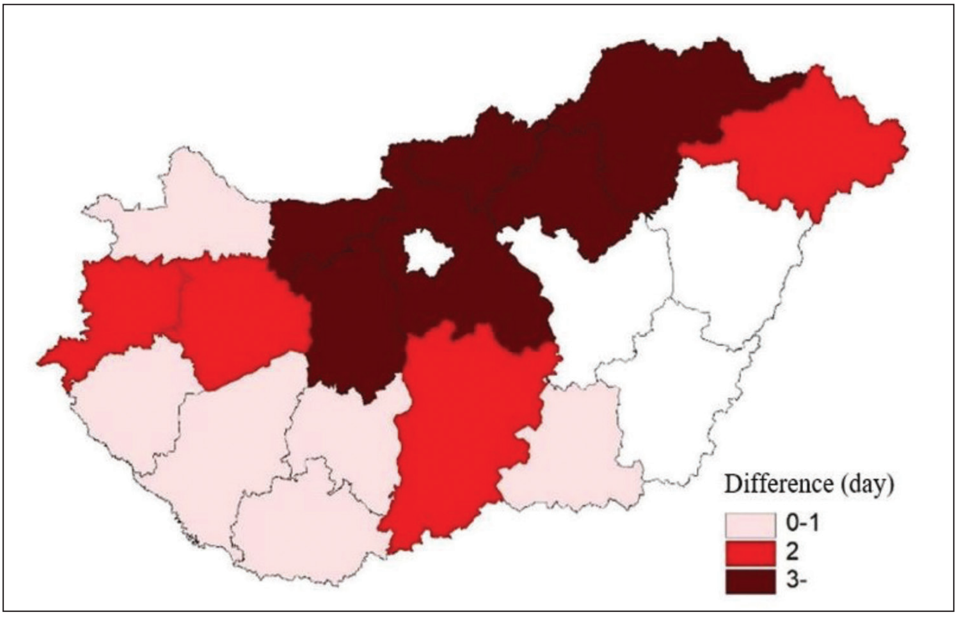

Figure 3. Temporal variation in the spring migration of Woodcock (*Scolopax rusticola* L.) between counties in 2011 based on dates associated with 50% cumulative sampling values

3. ábra Az erdei szalonka (*Scolopax rusticola* L.) tavaszi vonulásának időbeli eltérése az egyes megyék között 2011-ben az 50%-os kumulált mintavételi értékekhez tartozó időpontok alapján

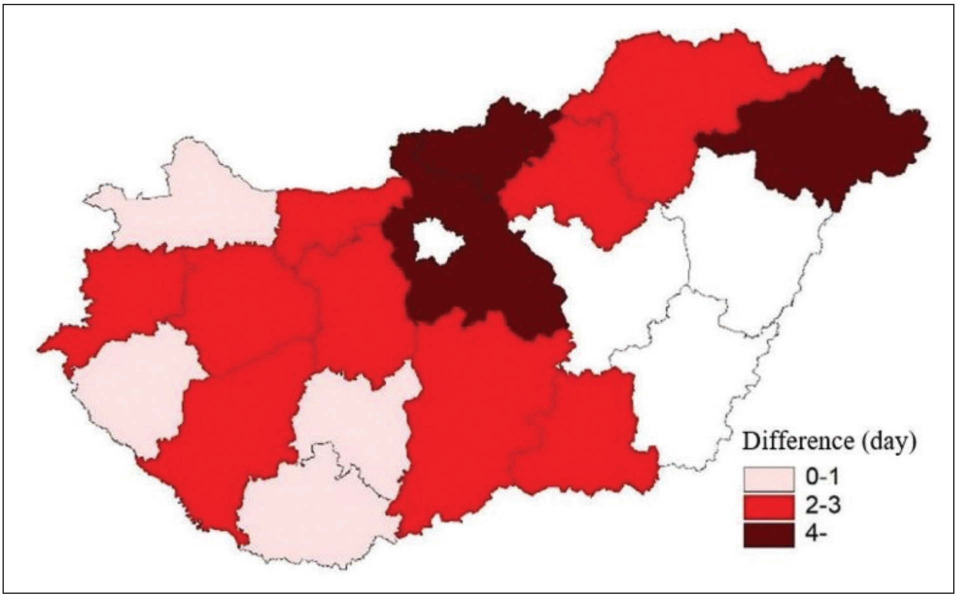

Figure 4. Temporal variation in the spring migration of Woodcock (*Scolopax rusticola* L.) between counties in 2011 based on dates corresponding to 75% cumulative sampling values

4. ábra Az erdei szalonka (*Scolopax rusticola* L.) tavaszi vonulásának időbeli eltérése az egyes megyék között 2011-ben a 75%-os kumulált mintavételi értékekhez tartozó időpontok alapján

The impact of weather on the spatial and temporal patterns of spring migration

Based on the frequency of Péczely's macrosynoptic situations in years with no extreme weather conditions, we found that the most typical states were the anticyclone over the British Isles (AB, 20.0%) and anticyclone to the west of Hungary or incoming anticyclone from the west (Aw, 15.2%). In the first case, an anticyclone develops in the North Sea region, transporting Arctic air into the Carpathian Basin with a northerly flow, while in the second case, the Azores anticyclone moves towards Central Europe, extending long in a west-east direction. In addition to the above, the backside flow system of a meridional cyclone (mCc, 11.4%), with the position of the anticyclone centre over west Europe or the Atlantic Ocean, and the Anticyclone of an east flow with an azonal-oriented anticyclone (An, 13.3%) over Poland were also dominant. Also typical was the macrosynoptic state of anticyclone to the east of Hungary (Ae, 8.6%), which only develops adverse conditions when the south-east flow intensifies to a storm or is accompanied by strong cooling. However, this macrosynoptic condition is generally characterised by variable directional and weak air movement, so it does not significantly affect the migration.

Among the centric anticyclones, the central Péczely-state (A, 7.6%) over the Carpathian Basin is the same as the Ae state. As in the two situations above, the synoptic state of the cyclonic centre over the Carpathian Basin (C, 3.8%) has no significant effect on the

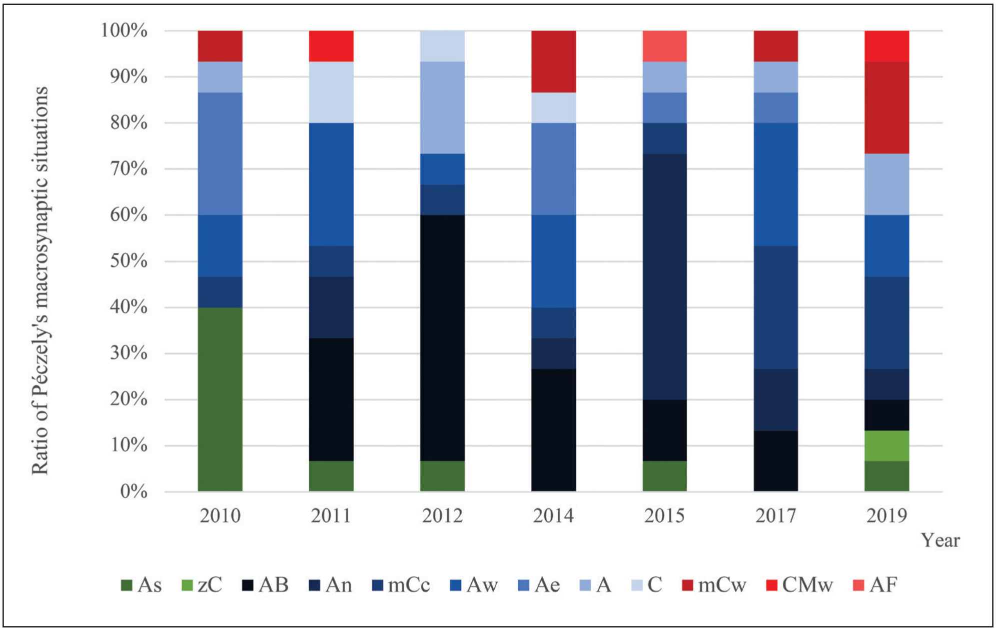

Figure 5. Proportion of Péczely's macrosynoptic situations during the most intensive phase of the spring migration of Woodcock (*Scolopax rusticola* L.) in years with normal migration (favourable – green, neutral – blue, unfavourable – red)

5. ábra A Péczely-féle makroszinoptikus állapotok aránya az erdei szalonka (*Scolopax rusticola* L.) tavaszi vonulásának legintenzívebb szakaszában a normál vonulással jellemezhető években (kedvező – zöld, semleges – kék, kedvezőtlen – piros) migration if the winds with variable direction are not stormy and there is no significant cooling.

These conditions are not considered particularly favourable, because the air currents that develop are typically from the north, but their absence of extremes (wind, temperature, precipitation) does not significantly affect the spring migration of Woodcock. The above conditions, which can be considered neutral, accounted for 80.0% of all macrosynoptic situations in years with average migration.

Zonal, west-guided flow systems create favourable conditions during the spring migration. The anticyclone south of Hungary (As, 9.5%) and the smallest zonal cyclonic flow (Zc, 1.0%) typically bring mild oceanic air waves to the Carpathian Basin. The proportion of truly favourable macrosynoptic situations with optimal atmospheric conditions was only 10.5% in the years with the average circulation.

Among the considerable snowfall, persistent frost, and stormy winds producing south-guided meridional positions of macrosynoptic situations with unfavourable atmospheric conditions for migration, the frontal flow system of a cyclone (mCw, 6.7%) and the frontal flow system of a Mediterranean cyclone (CMw, 1.9%) were the most common, with a smaller proportion of anticyclones (AF, 1.0%) over the equally unfavourable Fenno-Scandinavian region. In years with an average migration rate, the proportion of Péczely's situations with unfavourable conditions was only 9.5% *(Figure 5)*.

In the sampling periods of 2014 and 2019, the frequency of macrosynoptic conditions unfavourable for migration was higher. The migration period was characterised by a few days of non-extreme but unfavourable cyclonic activity (mCw, CMw, AF) – a cold front with repeatedly occurring stormy north-east winds – which did not have a marked impact on the length of the main period, as the adverse atmospheric conditions were only present for a short period of time and thus, did not significantly affect migration.

In contrast to the years of migration with no extreme weather conditions, 2013, 2016 and 2018 had a high proportion of extreme weather conditions that were unfavourable for migration, which had a significant impact on migration in these years *(Figure 6)*. The frontal flow system

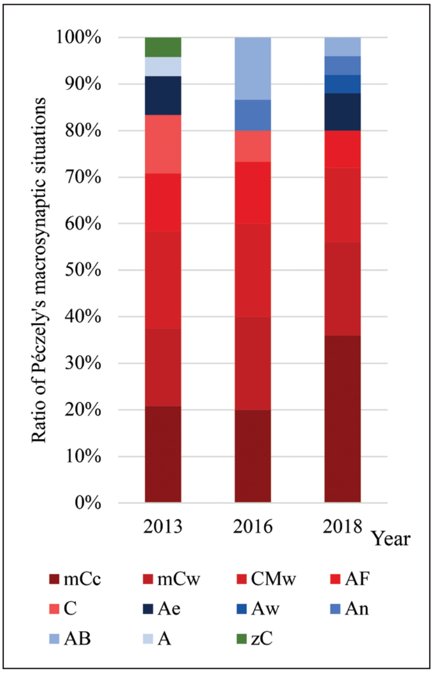

Figure 6. Ratio of Péczely's macrosynoptic situations during the most intense spring migration of Woodcock (*Scolopax rusticola* L.) in years with extreme weather conditions (favourable – green, neutral – blue, unfavourable – red)

6. ábra A Péczely-féle makroszinoptikus állapotok aránya az erdei szalonka (*Scolopax rusticola* L.) tavaszi vonulásának legintenzívebb szakaszában az időjárási szélsőségekkel jellemezhető években (kedvező – zöld, semleges – kék, kedvezőtlen – piros) of a Mediterranean cyclone (CMw, 18.8%) and the frontal flow system of a cyclone (mCw, 18.8%) macrosynoptic conditions resulted in heavy snowfall and stormy winds in our region. In addition to the above, the anticyclone (AF, 10.9%) over the Fenno-Scandinavian region had a significant impact in these two years, causing severe ground frosts. The influence of the cyclonic centre (C, 6.3%) over the Carpathian Basin was also important, which also produced strong cooling and stormy winds.

The high percentage of all these unfavourable macrosynoptic situations (81.3%) significantly affected the migration of Woodcock, especially during the most extreme spring of 2013. The overall proportion of macrosynoptic conditions creating neutral conditions was only 17.2% in these years, of which the anticyclone to the east of Hungary (Ae) condition was the most significant (6.3%). We compared the macrosynoptic positions of the average years with the average frequency of Péczely macrosynoptic positions between 1958 and 2010. Our results show that the distributions recorded in the years we considered as average were in line with the mean ($\chi^2 = 13.80$, df = 11, $P > 0.05$), while the distribution of Péczely states in the extreme years showed significant deviations ($\chi^2 = 45.26$, df = 11, $P > 0.05$).

There was no significant variation in the number of macrosynoptic states in the sampling periods studied, with an average of 7 states per period, but there was a significant variation in the distribution of states per year and their duration. In sampling periods with weather anomalies (2013, 2016, 2019) – when migration typically occurred under unfavourable macrosynoptic conditions (81.3%) – the average 8-day (SD = 1.62) main migration period recorded in normal years could be increased by up to 7 days (SD = 2.71), which means that in extreme weather conditions, birds may suspend migration in anticipation of improved atmospheric conditions, as they did in the spring of 2013, a year with extreme weather conditions, including stormy winds and heavy snowfall.

Discussion

In a mild spring, wintering grounds may start to be abandoned as early as mid-February, but the majority of Woodcocks do not leave their wintering grounds until 7–15 March. In the case of prolonged cold, winter-like weather, the start of migration may be postponed even later, up to mid-April (Clausager 1972, 1974, Bettmann 1975, Moritz & Nemetschek 1976). Based on spring sampling data from 2010-2019, the peak of migration of Woodcock in Hungary is typically between 16–24 March, which is consistent with previous data in the Hungarian literature (Schenk 1924, Pátkai 1951, Faragó 1985, Knefély 1987) suggesting that the mass arrival of Woodcock is in the last ten days of March.

The majority of the birds arriving in our region – based on the data of marked or foreign ringed Woodcocks found in our country – come from France (Schally 2019, Bende 2021) and first arrive in west Hungary. According to Schenk (1924), migrating Woodcock first reach the territory of the Kingdom of Hungary (before 1918) from the south-west (the Sava-Drava region), then continue in a north-east direction, leaving the northern ranges of the Carpathians, which fits well with the suggestion of Szabolcs (1971) that the spring migration takes place with a time delay in the whole territory of Hungary, starting in Baranya County and ending in the eastern region of the North Hungarian Mountains. The above findings – formulated in an empirical way – and the hypothesis of our own previous research (Faragó *et al*. 2012a, 2012b, 2014, 2015a, 2015b, 2016) were confirmed and clarified by the results of this study, thus clearly demonstrating that the migration of Woodcock in the western and north-eastern regions of Hungary is phase-delayed (Bende 2021). Satellite tagging research between wintering areas in Spain and nesting areas in Russia has shown that the species has an average daily migration distance of 174 km (100–256 km/day), so including stops (2–16 days), the spring migration – up to more than 5,000 km – lasts on average 40 days (24–62 days) (Arizaga *et al*. 2015). Sertić (2008) reported similar daily migration performance (maximum daily distance 200–300 km). The difference between the western and eastern regions of Hungary is min. 3 days; max. 10 days in years without weather extremes, which – taking into account rest periods – fits well with the migration performance determined by telemetry studies.

Our hypothesis – that the empirical frequency average corresponds to 8 days – about the mean of the probability variable characterising the difference between the western and eastern regions of the country was confirmed, i.e. there was no significant difference from the hypothesised frequency averages ($t = 1.7$, $df = 8$, $P = 0.5098$). The difference between the regions of the country is partly due to geographical reasons, as Woodcocks passing through our region have to travel more than 5,000 km by air in a straight line, but it can be assumed that there are other reasons for the differences besides geographical ones. Although the species necessarily leave forested areas during its migration and occurs in many habitats (Crespo *et al*. 2016), the availability of food plays an important role in the choice of resting sites and the length of time spent in forests (Duriez *et al*. 2005), and thus, feeding opportunities also influence migration.

In addition to the above, the spatial and temporal pattern of spring migration is most significantly influenced by weather factors. Our results show that during the peak migration period – in years without weather extremes – the macrosynoptic conditions were typically neutral for migration (80.0%) and only a minority of the macrosynoptic conditions were truly favourable (10.5%). Based on the results of previous domestic studies (Schenk 1924, 1931, Pátkai 1951) – and several foreign studies (Clarke 1912, Stadie 1938, Clausager 1972, Duchein 2019) – spring migration is most intense when the wintering area is cyclonic (Bruderer 1971, Beason 1978, Richardson 1990), which is confirmed by our results.

During the spring migration, the duration of stops is most affected by extreme weather conditions, which can lead to significant changes in the duration of the overall spring migration (Le Rest *et al*. 2018). Our results show that in years with extreme weather conditions, the 8-day main migration period can be up to a week longer than the average period in normal years. We hypothesise that this is because they may suspend their migration until atmospheric conditions are optimised. This is in accordance with the findings of studies that wind direction and strength are the primary influencing factors (Liechti 2006, Shamoun-Baranes *et al*. 2017). Intense precipitation events and strong (north, northeast) winds hinder migration, while the fog is more a side effect of the weather conditions that determine migration (Alerstam 1976). The results of 2013, 2016 and 2018 examined by us confirm the reduced migration intensity due to these extreme weather conditions.

Among the migration-favourable Péczely classes, migration-neutral conditions (65.3%) typically dominated in spring (1958–2010 average), while the proportion of situations with unfavourable atmospheric conditions was only 18.4% (Anagnostopoulou *et al*. 2019). Similar values were obtained for the frequency of Péczely values recorded in years considered as average, while a significant difference was observed in years with unfavourable migration and weather extremes.

The temporal repetition of the specific spatial components of synoptic systems is now a well-known process, and knowing their characteristics, it can be stated that the spring migration of Woodcock takes place under essentially neutral conditions. Our findings are in agreement with those of Bulte *et al*. (2014) and Kranstauber *et al*. (2015), who found that long-distance migratory species rarely experience wind conditions with optimal direction and speed throughout their journey, but usually exploited. As mentioned above, weather extremes have a significant impact on the temporal course and speed of passage through the region, but the regional differences we observed can be confirmed in all years regardless of weather conditions. The temporal differences between the eastern and western regions of Hungary in some years of the examined period (2010–2019) confirm previous findings that the spring migration of the species is phase-delayed between the south-western and western and north-eastern regions of the country.

Acknowledgement

The evaluation of the migration of the Woodcock was made possible by a monitoring programme coordinated by the Hungarian Hunters' National Association. We would like to thank the hunters who participated in the data reporting and helped us in our research in the framework of the Hungarian Woodcock Bag Monitoring. We would like to thank the reviewers of the paper and the editors of the journal for their valuable comments.

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