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Research Article

Changes in Autumn Migration Phenology and Morphological Traits of Common Chiffchaffs *Phylloscopus collybita* (Vieillot, 1817) (Passeriformes: Phylloscopidae) in Pannonian Basin

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Abstract: Climate change can influence many aspects of avian phenology and especially migratory shifts receive much research interest in this context. In this long-term study, the timing of autumn migration and several morphological variables of the common chiffchaffs *Phylloscopus collybita* were studied between 2000 and 2020. We found a signficant increasing trend in the number of common chiffchaffs passing through the study site. Protogyny is characteristic of the common chiffchaff in Pannonian Basin: females leave the breeding and stopover areas on av. 2-5 days earlier than males. For adult males, a significant forward shift was observed in the timing of migration. We found that the average wing length showed a small but significant decreasing trend in the migrating juvenile population from 2000 to 2020. On a seasonal basis, an increasing trend in average wing length was observed in all age and sex groups from August to November. It can be interpreted in two ways: (1) with an increase in the proportion of males and (2) with an increase in the proportion of common chiffchaffs arriving from territories to the north of the Pannonian Basin as the autumn migration progresses. The dissimilarity in changes in the phenology and morphological traits of the different age and sex groups during the study period emphasize that environmental change may cause intra-specific selection pressures.

Key words: timing of migration, short-distance migrant, passerine biometrics, age, sex, West Hungary

Introduction

Numerous studies have shown that major changes have occurred in the abundance, distribution, morphology and phenology of many bird species in the last few decades (Hüppop & Hüppop 2003, Visser & Both 2005). As a result of climate change, the geographical distribution of several species may also be changing due to the different environmental conditions; these changes can be detected in both breeding and wintering areas (Pearce-Higgins & Green 2014, Pearce-Higgins et al. 2015). Changes in population numbers, individual sizes and body masses have been observed (Baillie & Peach 1992, Csörgő et al. 2009). The migration timing of several bird species has also shifted during the past few decades (Sanz 2002, Root et al. 2003, Lehikoinen et al. 2004,), which may also be due to climatic changes (Visser & Both 2005, Crick & Sparks 2006, Rubolini et al. 2007). The extent of phenology changes is influenced by the migration strategy, distance to the wintering area, sex, age, etc. (Catry et al. 2006, 2007). The migration timing and biometric features may vary from one geographical area

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to another for the same species, as different subspecies or populations may change their migration patterns differently due to, for example, changing local or global weather factors (Cotton 2003, Hubalek 2004, Rainio et al. 2006).

The shift of the autumn migration is less evident than that of the spring migration; however, several studies have reported changes for several species during the last few decades (Hanla et al. 1986, Gatter 1992). There are examples of both advancement and delay: it seems that passage is delayed in short-distance migrants (Thorup et al. 2007), while in long-distance migrants the timing can change in either way (Jenni & Kéry 2003, Thorup et al. 2007, Miholcsa et al. 2009). An earlier central-Hungarian study between 1984 and 2006 indicated that warmer weather caused a delay in male common chifchaff autumn departure dates from the breeding area, although it did not influence females (Csörgő & Harnos 2011).

Common chiffchaffs in Europe are classified in two subspecies. The two subspecies differ in their migration directions as *P. c. collybita* predominantly migrates SSW in the autumn and *P. c. abietinus* from Feno-Scandinavia migrates predominantly in SSE direction to S Europe and the Horn of Africa. However, *P. c. collybita*, to which the majority of the common chiffchaffs breeding and migrating through Hungary belong, primarily migrate in SSE direction. A migration peak can be observed at the end of September and early October in Hungary when the local breeding populations, together with passing migrants, fly southsoutheast to their wintering grounds in southern Europe and north Africa (MME 2021). Female common chiffchaffs migrate earlier and further than males during the autumn migration (Mills 2005, Csörgő & Harnos 2011). Chiffchaffs are agewise and sexually dimorphic with respect to wing length (adults and males are larger), and there is little overlap between the ages and sexes (Catry et al. 2005, Harnos & Csörgő 2011).

The aim of our study was to record annual changes in the numbers of common chiffchaffs captured at a stopover site in western Hungary, detect changes in the timing of autumn migration and stopover duration as well as changes in morphological variables. We hypothesised that, most possible as a consequence of climate change, birds shifted their autumn migration to later. This could affect migration timing of the males and females differently: the two sexes may use different migration strategies. Furthermore, we hypothesised that the composition of populations passing through the stopover area has also changed. We used wing length, body mass and fat reserves to examine how these variables have changed during the last twenty years: these biometric changes may represent changes in the composition of the population, possible shortening of the migration distance, thus indirectly showing the possible effects of climate change.

Materials and Methods

Study area

The study was carried out at the Tömörd Bird Ringing Station in western Hungary (47°21'N 16°40'E), located 15 kilometres from Szombathely. The study site had a typical continental climate with cold winters and hot summers. There were four natural habitat types around the station: (1) Scrubland: bushes and herbs make up compact, dense vegetation, which was dissected by small grass patches. Its characteristic plant was the blackthorn (*Prunus spinosa*). (2) Forest edge: broadleaf trees and bushes formed a compact, dense edge, forming an ecotone community with the Turkey oak (*Quercus cerris*) as the characteristic plant. There was plenty of felling and normal forestry management in the forest. (3) Unmanaged grassland with shrubs: this habitat type represented a transition between the wet habitats of the swamp and the steppe communities that used to cover the agricultural land around the marsh. There were a few bushes in the grassland, with two small patches of the dwarf elder (*Sambucus ebulus*). (4) Marsh: a small (6 ha), permanent and isolated wetland. The characteristic plant was the broadleaf cattail (*Typha latifolia*).

Data collection and analysis

The birds were captured and ringed, or recaptured, from 2000 to 2020 during the post-fledging period (dispersal and migration) between the last weekend of July and early November. We used 28 numbered Ecotone mist-nets (12 metres long and 2.5 metres high, with 5 shelves and a mesh size of 16 mm) for trapping. The nets were placed evenly in the four habitat types. Throughout the study period, the number of nets and their location did not change. Birds were captured from dawn to dusk, except on rainy and stormy days. All birds were ringed and aged according to Svensson (1992). First-year birds that hatched in the year of ringing were classified as juveniles, while all older birds were classified as adults. Based on the results of previous studies (Catry et al. 2005, Csörgő & Harnos 2011), birds with a wing length of 58 mm and longer were considered males (Fig. 1).

The flattened maximum wing length was measured to the nearest millimetre using a graded

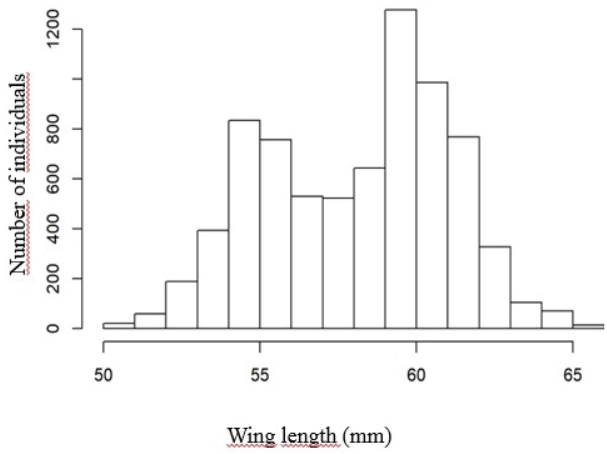

Fig. 1. Histogram of the wing length of common chiffchaffs captured between 2000 and 2020 (n = 8788).

wing ruler. Birds were weighed on a digital balance to the nearest 0.1 g. The fat score was estimated visually according to the SE European Bird Migration Network protocol (Busse & Meissner 2015), ranging from 0 (no fat) to 8 (bulging fat). By fitting a multivariate linear model, we defined the birds' fat reserves as the amount above the body mass of a bird with a fat score of zero. An individual has zero fat reserve, if its weight is equal to the average weight of the birds with 0 fat scores with the same size. Fat reserve is negative, if its weight is less than that. Based on the species-specific catch curves, the autumn migration period was considered to start on 30 August (Gyurácz & Bánhidi 2008, Gyurácz et al. 2017). Temperature data were obtained from Szombathely Meteorological Station located within 20 km of the study area (NCDC 2020).

We used the records of 9,035 (746 adults, 5,881 juveniles and 2,408 indeterminates) common chiffchaffs captured and ringed (Appendix 1). The total annual capture in the first year (2000) was set as 100 % and the capture index of change in numbers was calculated according to the formula of Greenwood et al. (1993). The capture index of change means: more captures of chiffchaffs over the study period is equal to more chiffchaffs passaging through the area and/or population increase of local breeders. A simple linear regression was used to determine trends in the capture index rates. The timing of the migration was determined by the peak of the migration, obtained by fitting a curve to the daily catches of each year using Kernel-smoothing (Bowman & Azzalini 1997). Changes in the timing of migration intensity for a given proportion of the annual captures (10, 25, 50, 75 and 90 %) were determined by quantile regression (Cade & Noon 2003). The simple linear regression was used to model the relationship between mean and maximum monthly temperature, and timing of autumn migration. True stopover time (time spent of recaptured birds at the study area) was estimated based on the daily capture history of each year. Pooling the data was not rational because most of the birds stayed only 1-2 days at the study area. Standard Cormack-Jolly-Seber (CJS) models (Lebreton et al. 1992) was used for the estimation of survival (Φ) and seniority (γ; based on the reversed capture history) parameters (Schaub et al. 2001). Goodness of Fit tests, implemented in UCARE program, was used for the validation of the CJS model for each year and for both (normal and reversed) capture histories. Stopover duration was calculated as $-\ln(1/\Phi) - \ln(1/\gamma)$. Standard deviation was determined by bootstrapping (N=100, half of the data was selected randomly). These analyses were performed using MARK and RMARK software (White & Burnham 1999). The minimum stopover length was defined as the period from the date of first capture to the date of last recapture (Ellegren 1991). Fat reserve was defined as the difference between actual body mass and body mass belonging to 0 fat score estimated from the linear model (Kovács et al. 2012). Annual changes in mean stopover duration, wing length, body mass and fat reserve were also examined using linear regression. Kernel-smooting and all analyses were performed using the R 3.6.0. version (R Core Team 2015).

Results

Changes in timing of migration

A strong increasing trend in the population index of change was observed for common chiffchaff in the post-breeding dispersal and migration seasons between 2000 and 2020 ($r = 0.52$, $t = 2.67$, $p = 0.015$, Fig. 2). The rate of adult females to males was 1 : 1.86.

The overall autumn migration peak of the common chiffchaffs showed a significant shift by two days ($p < 0.001$) over the study period from 4th October 2000 to 2nd October 2020. That of the adult males shifted by three days ($p = 0.007$) from 7th October 2000 to 4th October 2020. Fig. 3 shows the Kernel maximum in two years with similar annual captures from the earlier (2000) and later (2017) study periods. Analysing the migration timing of females seperately (shift in peak), the advance was not significant ($p > 0.05$) but showed a trend towards earlier passage by two days. The migration peak for juveniles did not change during the study period. It was on average the 1st day of October.

Between 2000 and 2020, the quantile regression for all birds showed the beginning of the migration period shifted forward by five days, while the median passage date changed by two days. For late arrivals, the change was one day (Table 1, Fig. 4). For adult males, quantile regression detected a forward shift of three days at the median passage date (50 % quantile, 2000: 7 Oct, 2020: 4 Oct). For juveniles and adult females, quantile regression did not detect a significant shift ($p = 0.05$). There were no significant relationships between timing of autumn migration and mean and maximum monthly temperatures among all captures, ages and sex groups (mean temperature: $F_{15,36.3} = 1.31$, $p_{reg} = 0.25$; max. temperature: $F_{15,36.3} = 0.85$, $p_{reg} = 0.61$).

Fig. 5 shows the minimum stopover length of the recaptured birds ($n = 1488$, 16.47%). The stopover duration was lowest in 2002 (mean = 6.47 days, SD =1.05) and highest in 2010 (mean = 21.31 days, SD = 3.95); however, no significant shift was found in the mean stopover duration for any recaptured birds from 2000 to 2020 ($p = 0.05$). The goodness-of-fit test suggested that the standard CJS model fitted well to the capture-recapture data in all years ($p > 0.05$). Time-dependent models (*Delta AICc* > 60.00, *AICc Weight* = 0) were included in the analysis in stopover duration at the stopover site (Φ) and seniority (γ) but they always ranked lower than time-independent models (*AICc Weight* = 1) in all years.

Changes in morphological traits

The average wing length of all birds and juveniles showed a signficant decrease of 0.05 mm/year from 2000 to 2020. The average wing length of all birds and juvenile females showed significant increasing trends of 0.03 and 0.01 mm/day respectively from the beginning to the end of autumn migration season, while in juvenile males it did not. The average wing lengths of adult males and females did not change sigfnicantly between 2000 and 2020 and from the beginning to the end of autumn migration season (Table 2, Fig. 6). There was no significant change in mean body mass in any of the groups between 2000 and 2020. The average body mass of all groups increased significantly (0.01 g/day) from

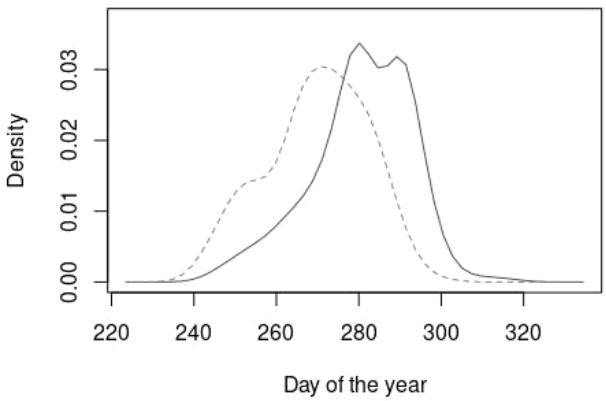

Fig. 3. Smoothed line of daily captures of common chiffchaffs caught in two years with similar number of annual captures: 2000 (solid line, total capture 300) and 2017 (dashed line, total capture 286). Day 220 = 8 August.

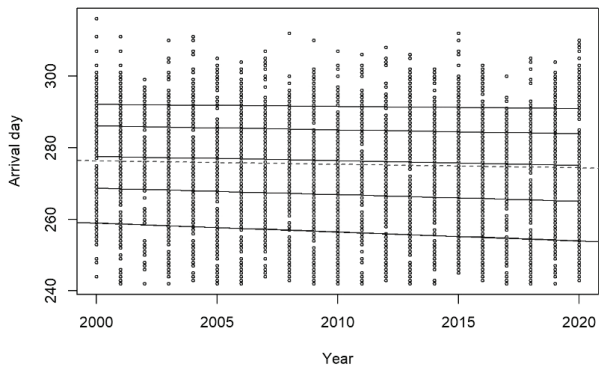

Fig. 4. Scatter plot of first capture day of the year vs. year. Lines were fitted by quantile regression (10, 25, 50, 75, 90% solid line, linear regression broken line) to the arrival times of autumn migration of all common chiffchaffs.

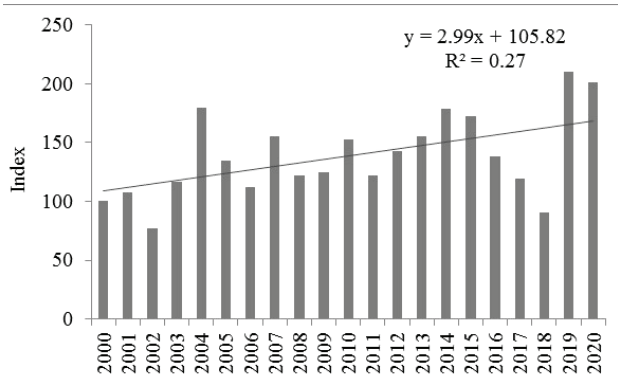

Fig. 2. Capture indices at the study site calculated for 2000–2020.

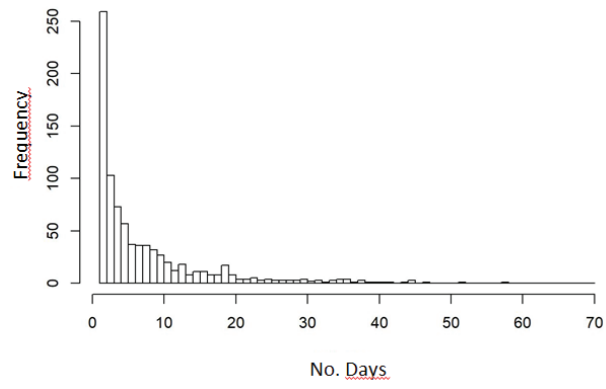

Fig. 5. Minimum length of stopover of recaptured common chiffchaffs (n = 1488) at Tömörd, western Hungary.

Table 1. Changes in timing of autumn migration of all common chiffchaffs: results of linear regression for the 10%, 25%, 50%, 90% quantile regression.

Quantiles	2000	2020	Coefficient	SE	*t* value	*p* value
10%	16 Sept	11 Sept	−0.25	0.06	−4.46	0.0001
25%	26 Sept	22 Sept	−0.18	0.04	−4.65	0.0001
50%	4 Oct	2 Oct	−0.12	0.03	−4.19	0.0001
75%	13 Oct	10 Oct	−0.11	0.03	−3.24	0.0001
90%	18 Oct	17 Oct	−0.06	0.02	−2.30	0.02

Table 2. Results of the linear model test with mean wing length of captured common chiffchaffs at Tömörd, western Hungary, as the dependent variable, and year or first capture day of the year as independent variables.

Groups	Factors	Coeff.	SE	t value	p value
All birds	Year	−0.05	0.01	−4.01	0.0001
	Day of year	0.03	0.00	9.48	0.0001
Juvenile	Year	−0.05	0.01	−4.49	0.0001
	Day of year	0.04	0.00	7.87	0.0001
Juvenile male	Year	−0.02	0.01	−2.89	0.001
	Day of year	0.00	0.00	0.90	0.370
Juvenile female	Year	−0.02	0.01	−2.96	0.001
	Day of year	0.01	0.00	2.59	0.02
Adult	Year	−0.01	0.05	−0.25	0.808
	Day of year	0.02	0.01	2.56	0.01
Adult male	Year	−0.01	0.03	−0.22	0.827
	Day of year	0.01	0.01	0.71	0.483
Adult female	Year	0.06	0.05	1.06	0.300
	Day of year	0.01	0.01	0.76	0.449

Table 3. Results of the linear model test with mean body mass of captured common chiffchaffs at Tömörd, western Hungary, as the dependent variable, and year or day of year (first captures) as independent variables.

Groups	Factors	Coeff.	SE	*t* value	*p* value
All birds	Year	0.00	0.00	−0.10	0.919
	Day of year	0.01	0.00	5.99	0.0001
Juvenile	Year	0.00	0.00	−0.32	0.749
	Day of year	0.01	0.00	5.12	0.001
Juvenile male	Year	0.00	0.00	0.79	0.439
	Day of year	0.01	0.00	3.35	0.001
Juvenile female	Year	0.00	0.00	1.00	0.328
	Day of year	0.01	0.00	8.47	0.0001
Adult	Year	0.01	0.01	0.81	0.431
	Day of year	0.02	0.00	5.43	0.0001
Adult male	Year	0.01	0.01	1.11	0.281
	Day of year	0.01	0.00	2.91	0.001
Adult female	Year	0.02	0.02	1.29	0.213
	Day of year	0.01	0.00	3.65	0.0001

the beginning to the end of autumn migration season (Table 3, Fig. 6). There was no significant change in average extra deposited fat in any of the groups between 2000 and 2020. The average extra deposited fat of each age and sex group increased significantly (0.01 g/day) from the beginning to the end of autumn migration season (Table 4, Fig. 6).

Discussion

Timing of migration

The numbers of individuals of many European bird species are currently undergoing rapid declines but there are also examples of increasing and expanding populations (BirdLife 2021). According to the

Hungarian common bird monitoring scheme, significant increasing population trends are more common among breeding species using predominantly forests or other wooded and bushy habitats in Hungary (Szép et al. 2012); these data resemble those reported from all of Europe (BirdLife 2021). In our study, we pointed out a signficant increasing trend in the number of common chiffchaffs passing through the studied west Hungarian stopover site. Because only small numbers of common chiffchaffs from areas to the north of the Carpathian Basin pass through Hungary (Gyurácz & Csörgő 2009), the increasing migrant individuals might be related to the extension of the forests of Hungary and its northern neighbouring countries. The forested area of Hungary increased by 7.1% between 2000 and 2017 (CSO 2019), mainly due to false acacia and poplar afforestation in areas previously used for farming. The proportion of forests has also increased in Slovakia and Ukraine (Forest Europe 2020). In addition, the increase in

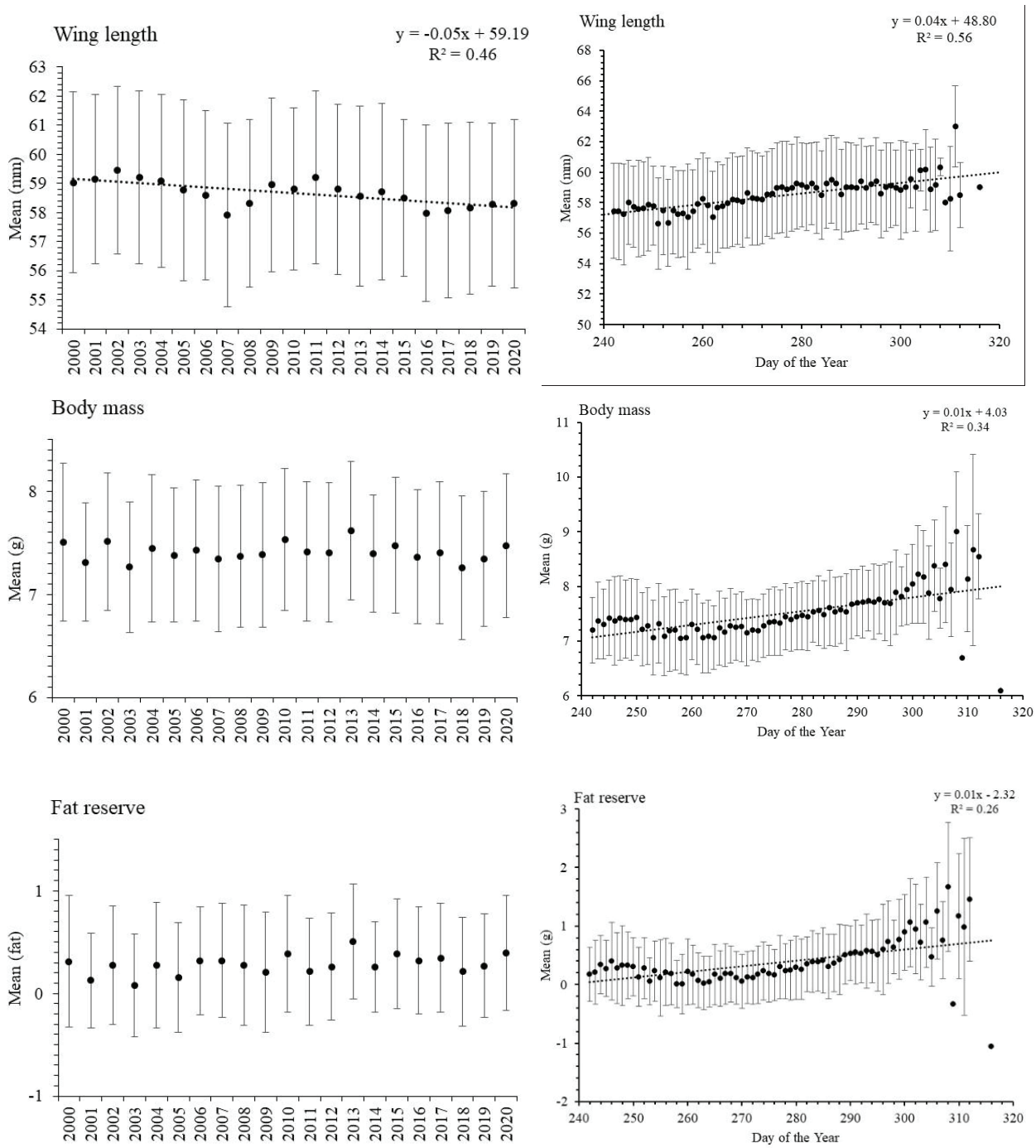

Fig. 6. Linear regression of mean population biometrics against year and day of capture for all common chiffchaffs captured between 2000 and 2020 between August and early November. Day 240 = 28 August.

Table 4. Results of the linear model test with mean fat reserve of captured common chiffchaffs at Tömörd, western Hungary, as dependent variable, and year or first capture day of the year as independent variables.

Groups	Factors	Coeff.	SE	t value	p value
All birds	Year	0.01	0.01	2.07	0.052
	Day of year	0.01	0.00	4.99	0.0001
Juvenile	Year	0.06	0.00	1.36	0.189
	Day of year	0.01	1.36	4.48	0.0001
Juvenile male	Year	0.01	0.00	1.33	0.200
	Day of year	0.01	0.00	3.70	0.0001
Juvenile female	Year	0.01	0.00	1.71	0.104
	Day of year	0.01	0.00	7.60	0.0001
Adult	Year	0.01	0.01	1.51	0.148
	Day of year	0.01	0.00	4.61	0.0001
Adult male	Year	0.01	0.01	1.46	0.161
	Day of year	0.01	0.00	2.96	0.001
Adult female	Year	0.01	0.01	0.89	0.391
	Day of year	0.01	0.00	3.82	0.0001

the number of passing birds could be affected by climate change (Morrison et al. 2013): temperature and rainfall may affect the birds' survival and reproduction as well as other demographic trends (Rodriguez & Bustamante 2003) and climate change is a particularly important driver of bird population trends (Reif 2013). The results of our earlier studies showed the higher number of captured first-year common chiffchaffs in breeding and dispersal periods was associated with higher spring temperature and the amount of precipitation (Gyurácz et al. 2016, Kiss et al. 2016). The structure and material of a nest may depend on the humidity and rainfall: if built during dry weather, it is difficult to integrate the haulm into the nest, and optimum compactness is achieved by the use of wet material (Elkins 2004). The smallest annual catches between 2000-2002 and in 2018 may have been related to the fact that spring/summer were warmer and drier than usual in those years, even at the end of August, 32°C daily temperatures were common. September and October were also drier and warmer than usual, and at the end of October the daily temperature was often warmer than 20°C. The marsh dried out and marsh vegetation was degraded beacause of scarce rainfall in 2000 and 2001 (Gyurácz et al. 2011, Gyurácz & Bánhidi 2018). In addition to breeding success and the size of the breeding population, the abundance of common chiffchaffs during migration can also change due to change in breeding areas, migration routes and destinations, which can be used differently in different years. A good example for this is the migrating tits in Europe (del Hoyo et al. 2020).

In our study site, the ratio of migrant females and males (35 % : 65 %) was very similar to the central Hungarian stopover site Ócsa (33 % : 67 %) as calculated by Harnos & Csörgő (2011). During the breeding season, the capture rates of three species (Eurasian blackcap, barred warbler and common chiffchaff) were also male-biased in Hungary (Kiss et al. 2020). Female-biased mortality may be the most important explanation for male-biased adult sex ratios in birds (Liker & Székely 2005, Székely et al. 2014, Lovász et al. 2018) but other factors such as home range, territorial behavior, capture probability and stopover strategy might also play important roles (Amrhein et al. 2012).

For most species, there is no difference in the timing of migration between the sexes in autumn; for others, as we have shown in the present study, females migrate earlier than males (see also Mills 2005, Jakubas & Wojczulanis-Jacubas 2010, Csörgő & Harnos 2011, Bozó & Heim 2016). This strategy is characteristic of the common chiffchaffs in western and central Hungary, where the females can leave the breeding and stopover areas on average 2-5 days earlier than males. It has been shown that a close relative, the willow warbler *Phylloscopus trochilus*, has advanced fall departure in Sweden by nearly 10 days (Hedlund et al. 2015). Hedlund et al. (2015) found that male willow warblers show stronger shift in fall departure and females only marginally approach significance level. The goldcrest *Regulus regulus* is also considered a partial and short-distance migrant; migration of both sexes was somewhat different at our study site, with females migrating a little bit earlier than males (Gyurácz et al. 2003). These results indicate that females and males could use different migration strategies to determine the time of departure (Tryjanowski et

al. 2004). How much earlier females migrate is determined by the average temperature in September, with the difference in the migration timing of the two sexes being larger during warmer weather (Csörgő & Harnos 2011). The migration distances of sexes in common chiffchaffs are also clearly different, with females travelling further than males. Males try to overwinter as close to the breeding area as possible so that they can return as early as possible in the spring (Catry et al. 2007); however, the difference in the timing of the autumn migration may be caused by intraspecific competition (Weggler 2000) or by males looking for new nesting sites for the next year (Mills 2005).

In the central Hungarian study area (Ócsa) between 1984 and 2006, the autumn migration peaks of age and sex groups were at the end of September and early October and the majority of males and females passed at different times (Csörgő & Harnos 2011). Our results indicate that the migration peaks at our study site were in the first days of October for all common chiffchaffs. We observed a significant forward shift in the timing of migration between 2000 and 2020 for all birds and adult males; no significant changes were found for juveniles or adult females. Some similar studies in other species also found significant changes in the timing of autumn migration in Hungary (Miholcsa & Csörgő 2009, Csörgő et al. 2009, Kovács et al. 2009, 2012). Usually, the autumn passage of long-distance migrants has advanced in recent years and the migrants wintering north of the Sahara have delayed autumn passage. However, there are exceptions and there are also regional differences. The majority of common chiffchaffs are short-distance migrant but there are some inividuals wintering south of the Sahara. Their slightly earlier migration in recent years in west Europe and Hungary is presumably the result of selection pressure to cross the Sahel before its seasonal dry period. The trans-Saharan migrant juvenile garden warblers *Sylvia borin* shifted their autumn migration 13 days later but adults did not in Hungary between 1984 and 2008 (Kovács et al. 2012). In contrast, the autumn passage of garden warblers has advanced in the second half of the 20th century (Jenni & Kéry 2003).

The temporal evolution of bird migration is largely influenced by temperature, air pressure, wind, precipitation and cloud formation (Newton 2011). In terms of changes in the autumn migration, the effects of temperature are not as well generalised as in the spring (Marra et al. 2005). Cold fronts, which appear in the Baltic region or over Ukraine, have a substantial effect on the autumn migration, including stopover duration of common chiffchaffs and other short-distance migrants. The different annual stopover duration could also be an effect of different weather situations. One day after a cold front, large numbers of individuals are captured in Tömörd. During a cold front, a strong wind can be favourable when it is a tail wind, reducing the amount of energy required for flight and enabling birds to reach a higher migration speed and minimize migration time (Gyurácz et al. 2003). Based on the CJS model, the stopover duration was independent of the date of capture, which, together with the recapture rate, suggests the time-minimisation model for the autumn migration of the common chiffchaff. The stopover duration did not change significantly during the study period, suggesting that time minimization migration strategy is still adaptive to the common chiffchaffs.

Morphological traits and migration

Correlations have been observed between migration distance and wing length and wingspan of migrants (Lockwood et al. 1998, Vágási et al. 2016). Northern populations, with a longer migration route to the wintering area, have longer wings than southern populations of conspecifics (Seebohm 1901). We found that the average body mass and fat load did not change but the average wing length showed a small (but significant) decrease in the migrating juveniles from 2000 to 2020. The average wing length also decreased in adults but, presumably due to the relatively few annual captures, the change was not significant. In our view, the decrease in wing length cannot be explained by local adaptations but by the change in the composition of the population: more of the captured individuals are shorter-distance migrants. According to many studies, morphological changes in birds could be related to climatic factors (Kaňuščák et al. 2004, Tryjanowski et al. 2004). Temperatures in Europe, both annual and seasonal averages, have clearly increased over the last four decades (Jenkins et al. 2008); therefore, overwintering common chiffchaffs, especially males, have been observed more and more frequently in Hungary in recent years (Gyurácz & Csörgő 2009, MME 2021). However, it should be noted that wing length and its change are not only affected by migration constraints but also by other environmental factors, e.g., breeding habitat vegetation, feeding condition, predation risk, changes in climate and weather, etc. (Ciach 2009).

The increasing trend in average wing length of all age and sex groups from August to November can be interpreted in two ways. On the one hand,

it is due to an increase in the proportion of males. On the other hand, it can be explained with an increase of the proportion of common chiffchaffs arriving from territories to the north of the Pannonia region as the autumn migration progresses (MME 2021). The increasing trend in average body mass and fat reserve of juvenile and adult males and females from August to November indicates that sex classes could use similar refuelling and time-minimising stopover strategies during autumn migration (Alerstam & Lindström 1990). Such a strategy is common in passerines migrating in the spring but it could also benefit autumn migrants (Arizaga et al. 2008, Yosef & Wineman 2010, Bozó et al. 2020). Some individuals with zero or negative (having lower weight than predicted for those with 0 fat scores) fat reserves in early November may indicate a weakened condition or completed migration and possible overwintering in the study area (Gyurácz et al. 2017).

Conclusions

Based on the incresing tendency in annual capture of birds, we conclude that the common chiffchaff is adapting well to current climatic and other environmental changes. We have clearly shown that females migrate earlier than males in autumn, which indicates that the females and males could use different migration strategies in the departure. Of the morphological variables, wing length is the best indicator of the annual change in the proportion of birds with different migration strategies. We suggest the time-minimisation model for the autumn migration of the common chiffchaff and that this strategy is still adaptive to it. In the future, we plan to make further studies involving other species, also including more variables and factors, in order to understand better the effects of climate warming and land cover change on bird migration strategy.

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Appendix 1. Numbers of common chiffchaffs captured and ringed during the period of the present study.

Year	Adult		Juvenile		Indetermined	
	Capture	Recapture	Capture	Recapture	Capture	Recapture
2000	50	3	100	12	162	17
2001	26	8	212	18	96	9
2002	30	6	142	17	65	8
2003	34	6	227	38	105	15
2004	38	17	210	37	312	63
2005	20	18	228	74	165	20
2006	21	9	197	27	129	12
2007	29	3	97	16	356	38
2008	16	12	238	37	122	16
2009	18	7	305	28	63	8
2010	46	19	366	78	61	7
2011	11	6	268	42	99	19
2012	27	8	387	49	26	5
2013	26	16	271	76	183	21
2014	39	14	496	79	18	1
2015	65	20	418	45	51	2
2016	48	18	347	55	31	4
2017	53	16	272	44	44	6
2018	38	19	185	15	64	2
2019	74	18	434	55	140	8
2020	37	15	481	88	116	19
Total	746	258	5881	930	2408	300