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Recent changes in migration dynamics, body mass, and wing morphology of the Eurasian Blue Tit (*Cyanistes caeruleus*) and Great Tit (*Parus major*) during the post-fledging season in Hungary

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Temporal trends in the timing of autumn migration, changes in body mass, wing and 3rd primary lengths were analysed based on 23,141 Eurasian Blue Tits (*Cyanistes caeruleus*) and 20,757 Great Tits (*Parus major*) captured in three Hungarian ringing stations in the post-fledging period, between 2004 to 2024. The results showed that the timing of the autumn migration of tits in Hungary was stable in the long term for both age and sex groups. Usually, migration of the Eurasian Blue Tit starts in early September followed by some lower peaks in the number of migrating birds in the course of this month and early October, and a very clear maximum after the 20th of October. The Great Tit migration began at the beginning of September, followed by two peaks in the first and second half of October. In both species the average body mass and wing length decreased during the dispersion season (August) between 2004 and 2024. We hypothesized that the warming climate of the Carpathian Basin has increased the fitness of individuals with smaller body sizes in the Hungarian nesting populations of both species. The results of the migration period (September–October) showed a more complex picture, which did not allow a clear interpretation of the mass and size changes according to Bergmann's rule. The decrease in average wing length and the increase in the average length of the 3rd primaries, *i.e.* change in the wing morphology to a rounder shape might suggest an increased number of shorter- and rounder-winged individuals, and possibly, a shortening of migration distances in both species.

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1. Introduction

Changes in migration phenology and morphology traits in response to climate change have been recorded across a wide range of bird species (Hüppop & Hüppop 2003, Visser & Both 2005, Gyurácz *et al.* 2016, Zimova *et al.* 2021, Ożarowska & Meissner 2024). The recent climate changes have induced phenological changes in the timing of bird migration (Hüppop & Winkel 2006, Thorup *et al.* 2007, Remisiewicz & Underhill 2022), caused northwards geographical range shifts of some species (Brommer *et al.* 2012), and resulted in decreased migration distances (Ambrosini *et al.* 2016). There is evidence that birds have changed the timing of their spring migration (Bitterlin & Van Buskirk 2014, Dorian *et al.* 2020), but shifts in autumn migration phenology appear to be less consistent (Jenni & Kéry, 2003, Chambers *et al.* 2014). Changes in migration phenology usually have greater variability across populations of a given species in the autumn than in the spring season (Tøttrup *et al.* 2006).

In migratory birds, there is evidence linking the wing length and body mass to the timing of migration. Within species, individuals with lower body mass relative to wingspan and longer, more pointed wings have been shown to migrate faster or arrive earlier at their breeding and wintering sites (Yong & Moore 1994, Norberg 1995, Bowlin & Wikelski 2008). The interactions between biometrics and migration dynamics suggest that temporal changes due to climate change may impose selection pressures on wing length and body mass to increase flight efficiency (Kovács *et al.* 2012, Ożarowska *et al.* 2016, Zimova *et al.* 2021). The long-term changes in body mass and wing length of passerines are usually linked to climate change through Bergmann's and Allen's rules (Bergmann 1847, Allen 1877, Salewski *et al.* 2010).

The wing length of some passerines has decreased in the last 120 years. Although there have been significant changes in morphology over time, there has been no consistent trend for decreasing body size (Salewski *et al.* 2014). Furness and Robinson (2018) demonstrated that Eurasian Blue Tits (*Cyanistes caeruleus*) and Great Tits (*Parus major*) have undergone a slow but steady decrease in body mass and wing length over the past 60 years in Britain and Ireland: this has been linked to increasing winter temperatures and predator abundance. The individual size and body mass changes may be different even in sister species (Baillie & Peach 1992, Csörgő *et al.* 2009a), and it should be noted that even age and gender groups may adapt differently (Catry *et al.* 2006, 2007, Gyurácz *et al.* 2017).

In the present study, we analysed the temporal trends in the timing of the autumn migration, and changes in body mass, wing and 3rd primary lengths of the Eurasian Blue Tit and Great Tit in the post-fledging period in the Carpathian Basin over the past two decades, from 2004 to 2024. The Palearctic Eurasian Blue Tit and European Great Tit are both cavity-nesting and partial-migrant species. Both species breed and migrate sympatrically in Hungary (Csörgő *et al.* 2009b). The European population of the Great Tit and Eurasian Blue Tit, including the Hungarian breeding populations, appear to have increased moderately in recent decades. In Hungary, the overwintering Great Tit population has increased, but changes in the number of overwintering Eurasian Blue Tit were unclear between 1999 and 2018 (Gyurácz 2022, Szép *et al.* 2022, PECBMS 2025). However, even within a country, population trends of tits can vary significantly across regions, as regional environmental factors affecting bird survival may differ (Perdeck *et al.* 2000). The migration strategies of these two partial migrant species did not differ significantly (Lukács 2022). The apparent survival of first-year birds was lower than that for adults, but the time of migration and sex had no apparent effect on survival probabilities for both tit species. Capture probability in the juvenile groups was not significantly higher than in the adult groups for both species (Gyurácz *et al.* 2022a). Yet so far there has been no study investigating changes over the last decades in migratory tits' daily captures or body condition at migratory stopover sites in the Carpathian Basin.

The aim of our study was to detect changes in the timing of autumn migration as well as in body mass and wing morphology (wing length and 3rd primary length) in the two species of tits during the last twenty years. We hypothesized that due to global warming, birds shifted their autumn

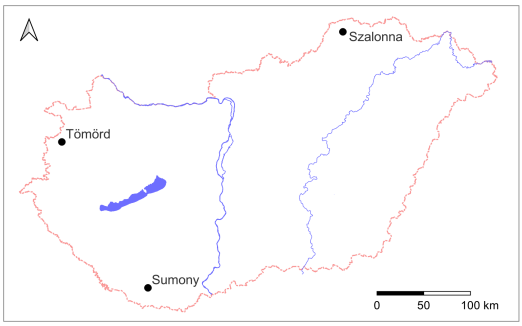

Fig. 1. Geographical locations of the three study sites.

migration to later. This could affect migration timing of the age and sex groups differently: the two ages and sexes may use different migration strategies, *i.e.*, females are more dispersive than males, the juveniles migrated significantly earlier than the adults in autumn (Smith & Nilsson 1987, Lukács *et al.* 2015). Furthermore, given that climate change has been shown to influence avian body mass, morphology, and migratory strategies (Salewski *et al.* 2010, Mainwaring & Street 2021), we hypothesized that the proportions of juveniles and adults, as well as females and males, vary within bird populations passing through Hungary. Biometric changes may represent changes in the age and sex composition of the tits, thus indirectly or directly showing the possible effects of climate change.

2. Materials and methods

2.1. Study sites

Our study was carried out at three bird ringing stations (Fig. 1) of BirdLife Hungary Actio Hungarica in west Hungary (Tömörd: 47°22' N, 16°41' E), south Hungary (Sumony: 45°58' N, 17°56' E) and northeast Hungary (Szalonna: 48°27' N, 20°42' E). The habitat at the study sites differed:

1. Tömörd: forest, an ecotone community with the Turkey Oak (*Quercus cerris*) as the characteristic plant; a bushy area, its characteristic plant was the Blackthorn (*Prunus spinosa*); grassland with scrubs with two small patches of the Dwarf Elder (*Sambucus ebulus*); and marsh with the characteristic plant was the Reedmace (*Typha latifolia*).
2. Sumony: reed-bed of the Common Reed (*Phragmites australis*), places with the Reedmace, and a bushy area, with willows (*Salix* spp.) as the characteristic plants.
3. Szalonna: gallery forest with Sessile Oak (*Quercus petraea*) and White Willow (*Salix alba*) along the Bodva brook. There were dense bushes at the edge of the forest and the lower levels of the habitat were covered with rich and dense vegetation.

2.2. Data collection and analysis

Bird ringing took place during the post-breeding dispersion period and autumn migration from the end of July to early November between 2004 and 2024. This study is based on data on birds captured between August 1 and October 30. In order to catch the birds, 12 m long and 2.5 m high mist nets with a small mesh (16 × 16 mm) were used at the three study stations. The total length of the mist nets was 348 m in Tömörd, 600 m in Sumony, and 480 m in Szalonna. Net controls were performed from dawn to dusk every hour, and additionally once in the evening darkness. There was no capturing when it was very hot or during prolonged periods of heavy rainfall. All birds were ringed, sexed, and aged according to Svensson (1992). There are two age-groups, *i.e.*, juveniles (1y) and adults (1+); we included only data on the first capture in the season. All juveniles were checked if the individual was fully grown. The birds were weighed to the nearest 0.1 g (using a digital balance). The flattened maximum wing length and 3rd primary length were measured to the nearest millimetre using a graded wing ruler (Busse & Meissner 2015). Based on previous studies, we assumed that systematic annual changes in mean body mass were not influenced by daily variation in temperature, and wing-related measurements were not significantly confounded by the ringer effect (Gosler 2002, Macleod *et al.* 2005, Salewski 2010).

We used the records of 23,141 Eurasian Blue Tits (2,932 adults 13%, 19,821 juveniles 85% and 388 age not-identified 2%) and 20,757 Great Tits (2,707 adults 13%, 17,678 juveniles 85% and 372

Table 1. Biometrics in the post-fledging period (mean, standard deviation and sample size).

Species	Biometric trait	Age/Sex	Mean	SD	*n*
Eurasian Blue Tit	Body mass	adult male	11.37	0.67	813
		adult female	10.76	0.48	1383
		juvenile male	11.35	0.71	5471
		juvenile female	10.69	0.41	7599
	Wing length	adult male	68.27	1.66	818
		adult female	65.75	1.62	1372
		juvenile male	67.24	1.82	5571
		juvenile female	64.79	1.74	7618
	3rd primary length	adult male	52.24	1.42	801
		adult female	50.23	1.45	1365
		juvenile male	51.48	1.87	5479
		juvenile female	49.61	1.89	7572
Great Tit	Body mass	adult male	18.37	0.65	1407
		adult female	17.24	0.99	856
		juvenile male	18.26	0.93	5716
		juvenile female	17.08	0.85	7083
	Wing length	adult male	77.33	2.36	1343
		adult female	74.50	1.59	807
		juvenile male	76.38	0.71	5739
		juvenile female	73.59	1.77	7095
	3rd primary length	adult male	58.33	2.01	1299
		adult female	56.18	1.26	778
		juvenile male	58.06	0.01	5598
		juvenile female	55.82	1.25	6928

age not-identified 2%). The number of nets and study periods were standard in all three study sites, so the annual captures did not need to be standardised per unit area of net and per period. Data on birds captured in August (dispersal period) and September–October (autumn migration period) were analysed separately. Although the autumn migration of Eurasian Blue Tits started at the end of August, only a few individuals were migrating during this month (Gyurácz 2022). The timing of peak migration (when the largest number of birds were captured in that season) was determined by fitting a migration curve to the daily capture rates (%), smoothed by a 2-day moving average in Microsoft Excel (Microsoft Corporation 2023). Estimated trends in the timing of migration intensity for a given proportion of the annual captures (10, 25, 50, 75, and 90%) were determined by a general linear model (GLM) using the "lm" function of R base package. This method allowed the estimation of separate trends for birds arriving at the beginning and at the end of migration, as well as the main, most intense part (between 25 and 75% which includes the median). The negative slopes of linear graphs indicate a shift toward earlier migration, and positive slopes toward later migration (Cade & Noon 2003). To determine which independent variables (year of capture, age, and gender) influenced body mass, wing length and 3rd primary length, we also applied a multivariate GLM (Yosef & Wineman 2010). The year of capture was treated as a continuous variable, the

age and gender were the categories. We did not observe significant differences in the dependence of biometric parameters on year, age or gender at the different ringing stations, thus data from the different locations were aggregated. All analyses were performed using R 5.2.3 *(*Hlavac 2022).

3. Results

3.1. Timing of migration

On average, early September start of the Eurasian Blue Tit migration is followed by lower peaks in the number of migrating birds until early October, and a very clear maximum after the 20th of October. The Great Tit migration begins at the beginning of September, followed by two peaks in the first and second halves of October (Fig. 2). No significant changes were detected in the arrival dates of the age and sex groups of Eurasian Blue Tit and Great Tit in any of the five quantiles in Hungary (GLM, $p > 0.05$, Fig. 3a,b) during the 21 years of the study period.

3.2. Changes in biometric traits

The means and standard deviations of biometric traits are shown in Table 1. The body mass, wing length and 3rd primary length were significantly associated with year of capture, age and gender of birds for both species. Adult and male birds have significantly larger body mass, wing length and 3rd primary length than juveniles and females in both species and in both post-fledging periods. The body mass (-0.008 gram/year), wing length (-0.019 mm/year), and 3rd primary length (-0.029 mm/year) of all Eurasian Blue Tits captured in August decreased significantly from 2004 to 2024. The body mass (-0.006 gram/year), wing length (-0.009 mm/year), and 3rd primary length (-0.022 mm/year) of all Great Tits captured in August also showed a decreasing trend from 2004 to 2024 (Table 2). The body mass (0.004 gram/year) and 3rd primary length (0.024 mm/

Table 2. Results of the multiple general linear model test with body mass, wing length and 3rd primary length of birds captured in August as dependent variables: year of capture, age and gender of birds are independent variables.

Species	D. variables	I. variables	Coeff.	SE	t	P value
Eurasian Blue Tit	Body mass	Year	−0.01	0.01	−3.35	0.001
		Age	−0.04	0.05	−0.84	0.401
		Sex	0.63	0.04	17.46	0.001
	Wing length	Year	−0.02	0.01	−3.13	0.002
		Age	−1.26	0.16	−7.81	0.001
		Sex	2.69	0.09	27.55	0.001
	3rd primary length	Year	−0.03	0.01	−5.34	0.001
		Age	−0.74	0.14	−5.01	0.001
		Sex	1.83	0.09	20.61	0.001
Great Tit	Body mass	Year	−0.01	0.01	−1.74	0.082
		Age	−0.24	0.08	−2.99	0.002
		Sex	1.07	0.06	17.59	0.001
	Wing length	Year	−0.01	0.01	−1.22	0.222
		Age	−0.99	0.26	−3.84	0.001
		Sex	2.68	0.13	21.22	0.001
	3rd primary length	Year	−0.02	0.01	−3.45	0.001
		Age	−0.43	0.23	−1.86	0.063
		Sex	2.09	0.11	18.86	0.001

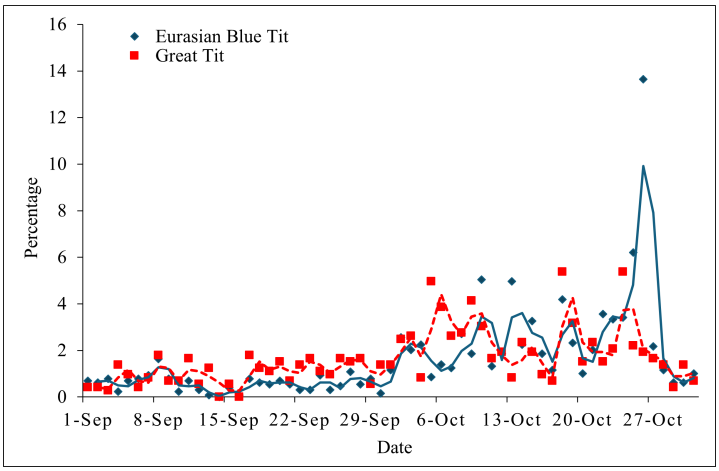

Fig. 2. Smoothed line of daily capture rate of Eurasian Blue Tits (total capture 1290) and Great Tits (total capture 726) caught in 2024.

year) of all Eurasian Blue Tits captured in September-October showed a significant increase from 2004 to 2024, while their wing length (-0.012 mm/year) decreased. The body mass (-0.005 gram/year) and wing length (-0.023 mm/year) of all Great Tits captured in September-October decreased significantly from 2004 to 2024, while their 3rd primary length (0.018 mm/year) increased between 2004 and 2024 (Table 3).

Table 3. Results of the multiple general linear model test with body mass, wing length and 3rd primary length of birds captured in September–October as dependent variables: year of capture, age and gender of birds are independent variables.

Species	D. variables	I. variables	Coeff.	SE	t	P value
Eurasian Blue Tit	Body mass	Year	0.01	0.01	5.76	0.001
		Age	−0.04	0.01	−2.51	0.05
		Sex	0.61	0.01	53.24	0.001
	Wing length	Year	−0.01	0.01	−5.33	0.001
		Age	−0.98	0.04	−26.74	0.001
		Sex	2.38	0.03	80.38	0.001
	3rd primary length	Year	0.02	0.01	11.98	0.001
		Age	−0.64	0.04	−17.25	0.001
		Sex	1.79	0.03	60.16	0.001
Great Tit	Body mass	Year	−0.01	0.01	−3.95	0.001
		Age	−0.09	0.02	−4.17	0.001
		Sex	1.16	0.02	71.39	0.001
	Wing length	Year	−0.02	0.01	−9.31	0.001
		Age	−0.94	0.04	−21.97	0.001
		Sex	2.76	0.03	90.85	0.001
	3rd primary length	Year	0.02	0.01	7.17	0.001
		Age	−0.37	0.04	−8.48	0.001
		Sex	2.18	0.03	70.52	0.001

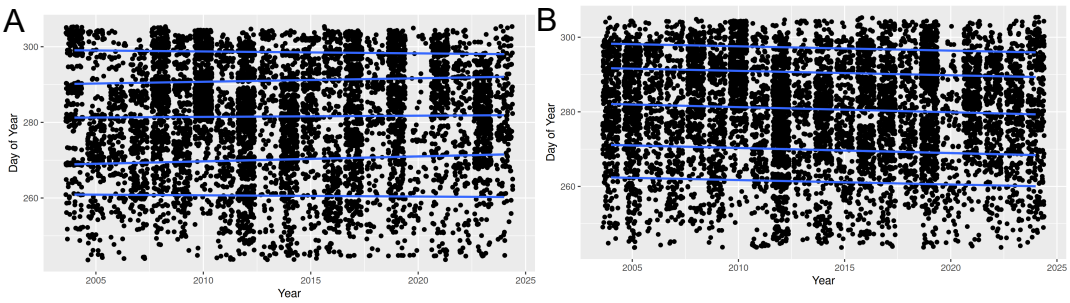

Fig. 3. Scatter plot of capture time (day of the year) of juvenile female a) Eurasian Blue Tits and b) Great Tits versus year in Hungary. Data were fitted with quantile regression lines (10, 25, 50, 75, 90%).

4. Discussion

4.1. Timing of migration

The autumn migration dynamics of Eurasian Blue Tits and Great Tits vary depending on age, sex, year, and stopover site. The dominance of juveniles and females is very characteristic among migrants (Smith & Nilsson 1987, Gyurácz & Bánhidi 2008). In some years, the irruptive autumn migration is also striking in specific locations (Gyurácz *et al.* 2011). The starting and median date of migration has also shown significant differences from year to year (Nowakowski 2003, Nilsson *et al.* 2008, Lukács *et al.* 2015). However, despite their partial migration showing great variability in space and time, our results showed that the timing of the autumn migration of tits in Hungary appeared to be stable in the long term for both age and sex groups.

On average, partial and short-distance migrants are able to react earlier to rapid changes of the environment than trans-Saharan migrants, as exogenic factors have more influence on their migration pattern than endogenous (Berthold 1996, Pulido 2007). Several studies have reported changes in the migration strategy of various bird species as possible consequences of climate change (Lehikoinen *et al.* 2004, Rubolini *et al.* 2007, Kovács *et al.* 2012), but the most important factors determining the number of migratory individuals of the Eurasian Blue Tit and Great Tit in a given year are the size of the beech crop and the size of the breeding population: there are more migrants at lower beech crop levels and higher population densities (Nowakowski & Vähätalo 2003, Nilsson *et al.* 2006, Newton 2006).

The temporal evolution of bird migration is largely influenced by temperature, air pressure, wind, precipitation, and cloud formation, both in irruptive and non-irruptive years (Gyurácz *et al.* 2003, Newton 2011). In terms of changes in the autumn migration, the effects of temperature are not as important as in the spring (Marra *et al.* 2005). European recoveries of Eurasian Blue Tits and Great Tits indicated the main axis of distant movements from northeast to southwest in Central and East Europe (Spina *et al.* 2022). Eurasian Blue Tits and Great Tits recovered in Hungary were ringed in Austria, Czechia, Lithuania, Poland, Russia, Slovakia, and Ukraine (Csörgő *et al.* 2009b). Cold fronts in the Baltic region or over Ukraine have a substantial effect on the autumn migration of these two tit species and other partial and short-distance migrants, for example the European Robin (*Erithacus rubecula*), Eurasian Blackcap (*Sylvia atricapilla*), Common Chiffchaff (*Phylloscopus collybita*), and Goldcrest (*Regulus regulus*) in September and October (Chernetsov 2012). During a cold front, a strong tailwind can be favourable, reducing the amount of energy required for flight and enabling birds to reach a higher migration speed and shorter migration time (Bloch & Bruderer 1982).

Concluding, it seems that the timing of autumn migration of Eurasian Blue Tits and Great Tits did not change significantly between 2004 and 2024, it may be the result of the similar macrosynoptic weather conditions of the years.

4.2. Changes in biometric traits

In Hungary, adult and male birds have significantly larger body mass, wing length, and 3rd primary length than juveniles and females in both species. These results provide strong support for the two hypotheses that explain the different migration behaviour of juveniles and adults, males and females, namely the body-size hypothesis and the dominance hypothesis. According to the first hypothesis, smaller juveniles and females are more likely to migrate than larger adults and males due to their reduced starvation tolerance. According to the second hypothesis, dominant individuals, usually the dominant adult males, force their less-dominant conspecifics to migrate (Smith & Nilsson 1987, Nyquist 2007). These hypotheses appear supported by correlative evidence the age and sex ratio in Hungary. The annual proportion of juvenile Eurasian Blue Tits and Great Tits was greater than 80%, and more than 50% were females during the autumn migration at the study sites (Gyurácz *et al.* 2011, Lukács *et al.* 2015).

In both species, we found that the average body mass and wing size showed a significant or non-significant decreasing trend in the birds captured in post-breeding dispersion season (August) from 2004 to 2024. Salewski *et al.* (2010) also showed that the average body mass of juvenile Eurasian Blue Tits and Great Tits decreased from 1995 to 2006 in Germany, and others described a decrease in body size of other bird species in recent decades (*e.g.* Ludwichowski 1997, Tornberg *et al.* 1999, Jakober & Stauber 2000). In many cases, the changes were explained by Bergmann's rule, which was applied to populations within species (Rensch 1938), assuming correlations between global warming and size changes of homeothermic animals (Yom-Tov 2001, Yom-Tov *et al.* 2006). Temperatures in Europe, both annual and seasonal means, have increased in recent decades (Jenkins *et al.* 2008). Based on this, we hypothesize that the warming climate of the Carpathian Basin has increased the fitness of individuals with smaller body mass and wing size in the Hungarian breeding populations of both species. Although Allen's rule (Allen 1877) suggests that wing length should increase with increasing temperature, we assume that other factors, such as migration, microhabitat selection, feeding ecology, and predator avoidance, have a more effective selection pressure on the wing and feather lengths (Leisler & Winkler 2003, Fiedler 2005, Yom-Tov *et al.* 2006, Salewski *et al.* 2010).

The results from the migration period (September-October) were more complex: the body mass and size changes did not fit Bergmann's rule (Bergmann 1847). The decrease in average wing length and the increase in the average length of the 3rd primaries, *i.e.*, the increase in the proportion of shorter and rounder winged individuals, suggested a shortening of migration distances in both species. In Germany, it was shown that Eurasian Blue Tits, but not Great Tits, decreased their migration distance between 1964 and 1996 in response to warmer winters (Smallegange *et al.* 2010). The average wing length also decreased in the Common Chiffchaff in Tömörd, which was also explained by the change in the composition of the population: more captured individuals were shorter-distance migrants (Gyurácz *et al.* 2022b). An increase in the average body mass of Blue Tits could also indicate a decrease in migration distance, because shorter passages and less energy use could result in birds arriving at stopover sites and potential wintering areas in better condition. A slight decrease in the migratory activity of Blue Tits and Great Tits was indicated by a significant increase in the recapture rate of juveniles between 1998 and 2021 (Gyurácz *et al.* 2022a). In a study in Poland, it was hypothesized that a higher berry crop resulted in the better condition of migrating Blackcaps (Ożarowska & Meissner 2024). However, it should be noted that morphological traits and their changes are not only affected by migration constraints but also by other environmental factors, *e.g.*, climate change, vegetation structure of habitat, competition, food resources, predation risk and weather (Kaňuščák *et al.* 2004, Tryjanowski *et al.* 2004, Ciach 2009).

In conclusion, the Blue Tit and Great Tit appear to be well adapted tocurrent environmental changes, as indicated by shifts intheir migration timing and morphology. However, significant changes in body mass and wing morphology associated with changes in

environmental factors are not only caused by phenotypic plasticity, because morphological traits of birds also have genetic components (Jensen *et al.* 2003). Their flexible migration strategy has likely also contributed to the steady increase in their breeding population in Hungary and Europe in recent years. However, when interpreting the above findings, we recommend taking into account that this is a correlational study, and that numerous confounding factors — such as global climate change, the role of predators and parasites, habitat fragmentation, and anthropogenic disturbance — may also contribute to the emergence of the observed patterns.

Sinitiaisen (*Cyanistes caeruleus*) ja talitiaisen (*Parus major*) muuttodynamiikan, painon ja siipien morfologian viimeaikaisia muutoksia pesästälähtökauden jälkeen Unkarissa

Syysmuuton ajoituksen, painon sekä siipien ja kolmannen käsisulan pituuksien ajallista vaihtelua analysoitiin 23 141 sinitiaisella (*Cyanistes caeruleus*) ja 20 757 talitiaisella (*Parus major*). Linnut pyydystettiin kolmella unkarilaisella rengastusasemalla pesästälähtökauden jälkeen vuosina 2004–2024. Tulosten mukaan tiaisten syysmuuton ajoitus oli Unkarissa pitkällä aikavälillä vakaa sekä ikä- että sukupuoliryhmissä. Sinitiaisen muutto alkoi yleensä syyskuun alussa, minkä jälkeen muuttajien määrissä on pienempiä huippuja syyskuussa ja lokakuun alussa, kunnes saavutettiin selkeä maksimi lokakuun 20. päivän jälkeen. Talitiaisen muutto alkoi syyskuun alussa, minkä jälkeen seurasi kaksi huippua lokakuun alku- ja jälkipuoliskolla. Molemmilla lajeilla keskimääräinen paino ja siivenpituus pienenivät leviämisvaiheessa elokuussa vuosina 2004–2024. Oletimme, että ilmaston lämpeneminen Karpaattien altaassa olisi parantanut pienempikokoisten yksilöiden sopeutumiskykyä molempien tiaislajien pesimäpopulaatioissa Unkarissa. Muuttokauden (syys–lokakuu) tulokset olivat monimutkaisempia eivätkä mahdollistaneet painon ja koon muutosten selkeää tulkitsemista Bergmannin säännön mukaisesti. Siipien keskipituuden lyheneminen ja kolmansien käsisulkien keskipituuden kasvu, eli siipien muuttuminen pyöreämmiksi, saattavat viitata lyhyempi- ja pyöreämpisiipisten yksilöiden määrän kasvuun ja mahdollisesti muuttomatkojen lyhenemiseen molemmilla lajeilla.

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Conflict of interest. The authors report no conflicts of interest.

Author contributions. JGY: conceptualization, investigation, writing. AH: data curation, project administration. PM: metodology, software, formal analysis. ZL: data curation, project administration.

Ethics statement. The capture, ringing, and biometric measurements of bird species under legal nature conservation protection were conducted in accordance with the professional and ethical guidelines stipulated in Government Resolution No. PK-KTF/97-13/2017 (https://mme.hu/sites/default/files/pe_ktf_97_13_2017_vvt.pdf).

Data availability. The datasets supporting the findings of this study have been deposited in the Zenodo repository. doi: 10.5281/zenodo.21606687

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