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**Migration study of Passerine birds based on long-term
ringing data**

PhD thesis

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2013

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Introduction

Bird migration is the most spectacular and worldwide researched part in biology. Migration occurs to some degree in most bird species that live in seasonal environments.

In case of migration individuals make regular return movements, at about the same times each year, often to specific destinations, twice each year between regular breeding and wintering ranges, and have defined destiny in a strict direction.

Migration is in strongly seasonal environments that food supplies vary most markedly through the year, fluctuating between abundance and scarcity in each 12-month period. Generally, birds time their migrations so as to be present during the periods of abundance and absent during the periods of scarcity.

Specific migration strategy is the leapfrog migration. In case of this strategy, populations of a species breeding at different latitudes reverse their sequence in winter, with those breeding furthest north wintering furthest south. In this situation the higher latitude breeding populations over-fly lower latitude breeding populations to winter beyond them, thus reversing their latitudinal sequence of distribution between summer and winter. So the migration route of northern breeders is the longest. This is the cause of that the northern breeding populations start their autumn migration first and occur earlier at southern stopover sites.

Some species have loop migration, these birds taking mainly different routes on their outward and return journey. For instance in case of loop migration more northern originated birds could cross the study site in spring than in autumn. This pattern could be connected to the larger speed of spring migration compared to autumn migration. Birds could reach this larger speed not only by migrating/flying faster, also by changing the direction of flight. For instance in spring more northern breeders could cross the Carpathians, than in autumn, when presumably they avoid this barrier, because in that time they optimize to survival.

Migrating birds have to get over during their journey severely ecology barriers, such as high mountains, seas and deserts, to this they need to time the direction changes and fat accumulation very precisely.

Probably due to globally environmental changes – such as changes in temperature or vegetation period – breeding territory of several bird species shifted northward, they altered their breeding success, population dynamics, timing of moulting and migration.

The observed changes in timing of migration are not similar nor in spring, neither in autumn: they strongly depend on the length of migration route, nesting strategy or even the rate of sexual dimorphism (e.g. the larger is the differences in body size, the earlier migrate the males compared to females).

Understanding these processes and defining the influential factors is very important, because the population number of many migrating species decreased in recent decades. The reasons of these decreases could be environmental and human effects. In Europe the decrease were more pronounced in long-distance migrants than in short-distance migrants.

According to previous studies the migration behaviour of long distant migrant species is under strong genetic control. They cannot adapt to environmental changes so fast like short – or middle range migrants. However in the last decades more studies detected significant changes within few years (10-20 years) in migration phenology of long distant migrants, these allow us to conclude that these species can also adapt to altered migration conditions.

These changes can modify the timing of leaving the wintering grounds and the condition of birds at departure, which later could cause further shifts during migration route.

In spring similar trends could be observed in case of different species: most migrating passerine species arrive earlier due to the more optimal temperature of the first period of spring.

In autumn there are studies reported about forward and backward shifts as well. The migration shifted earlier, if the breeding ended earlier, or shifted later if the advanced environmental circumstances support the faster preparing to migration. Trends in changes show larger variation in different populations of the same species than in spring. However the optimal strategy could alter not only among species, also among populations and age and sex groups of the same species.

Results of Middle-East European studies often differ from West European experiments caused by on the one hand the differently effective local and global weather parameters, such as North Atlantic Oscillation, otherwise different reactions of European populations and within populations the different behaviour of age and sex groups during adapting to global changes

Only a few studies reported about long-term changes in biometrical traits. For example they explain the observed changes in body mass and wing length of passerines caused by climate change with Bergmann's rule and Allen's rule. However the changes in these traits could indicate changes in migration behaviour, or shifts in distributional area of long-distance migrant species.

Aims of the study

In the current study, we would like to answer, what are the differences in spring and autumn migration phenology of the studied species? We would like to revealing alterations in biometrical traits and interpret their effects.

We would like to answer the following questions:

1. What are the migration strategies of the species?
2. Is there any relationship between timing of migration and biometrical traits (e.g. wing length)?
3. Are there any differences in biometrics of spring and autumn migrants?
4. What changes did happen in timing of spring and autumn migration in the last two decades?
5. What changes did happen in biometrical traits (wing length, body mass, extra deposited fat) of species in spring and autumn migration in the last two decades?
6. Are there any differences in migration phenology and changes in biometrical traits between age and sex groups?

We hypothesize that the global environmental processes effecting parameters, which describe the migration of the studied species. We also hypothesize that revealing alterations in the timing of migration and biometrics at a Central European stopover site may contribute to a more coherent understanding of the population level migratory behaviour of different species, and may help shed light on possible effects of global processes like climate change.

Methods

Data were collected in Duna-Ipoly National Park (47°15'N, 19°15'E) at the Ócsa Bird Ringing Station. The station is located within the Ócsa Landscape Protection Area. During the analysis the data of nine Passerine species (Blackcap – *Sylvia atricapilla*, Garden warbler - *Sylvia borin*, Sedge warbler - *Acrocephalus schoenobaenus*, Reed warbler - *A. scirpaceus*, marsh warbler - *A. palustris*, Wood warbler - *Phylloscopus sibilatrix*, Willow warbler - *Ph. trochilus*, Pied flycatcher - *Ficedula hypoleuca* and Spotted flycatcher - *Muscicapa striata*) were used. Studied species have different migration strategy and were ringed between 1984-2011.

The reasons of selecting these nine species is that they have enough records in our database from every years, which is indispensable for analysing changes in migration phenology of long-distance migrants. We involved mainly the long-distance migrant species, because these are the most sensitive for global changes. Therefore from conservational

point of view tracking changes is most important in case of these species. We choose four groups of related species, because it is interesting to observe the differences in migration phenology of closely related species. Individuals of these species groups breed different habitat and they have various nutrition strategy. These features contribute to detect the effects of global changes. Among the nine species only the Blackcaps have wintering grounds on the Mediterranean region, the others are typical long-distance migrants and spend the winter south from the Sahara. The breeding range of the Reed Warblers does not protrude north of the Carpathian basin and birds from northern populations do not migrate through the region.

Only data from first captures were used. Two age groups were distinguished by plumage. 1st calendar year birds (captured in the year of fledging) are referred to as juveniles, older birds as adults. In Blackcaps and Pied flycatchers we could determine the sex of birds by colorization. We defined arrival times as the day of the year when the birds were caught at the first time.

In case of *Acrocephalus* species to avoid bias, the timing of spring migration was calculated using data of birds captured before 1st June (in case of Sedge and Reed Warblers) or 25th June (in case of Marsh Warblers) and the timing of autumn migration in all three species was calculated using data of birds captured after the 10th July.

In case of *Sylvia* species the end of spring and the start point of autumn migration were determined by the following methodology. Peaks of smoothed curves were identified separately for each species by season and age group and in blackcaps also by sex. The minimum points of the curves were used as the end of spring and the start point of autumn migration. To detect a shift in the timing of annual peaks during the study period, we applied linear regression analysis.

In case of all species quantile regressions were used to estimate trends in 10%, 25%, 50%, 75% and 90% percentiles of the distribution of arrival times (day of the year). In quantile regression, separate regression lines are fitted for each of the specified quantiles of the distribution, thus allowing to estimate separate trends for birds arriving in different segments of the migration wave.

In the analysis we used three variables of biometrical traits: wing length, body mass and extra deposited fat. 50% quantile regression analyses were performed to investigate the relationship between wing length and day of arrival on the study area. Differences in wing length between spring and autumn migration period were evaluated by Welch t-tests.

The long-term changes in biometrical traits (wing length, body mass) were determined by linear regression.

Concerning changes in body condition, we first applied a linear model to estimate body mass from fat score and wing length. We used wing length to control for body size.

Extra deposited fat was defined as the difference between actual (observed) body mass and body mass belonging to 0 fat score estimated from the linear model. Changes in average extra deposited fat were estimated by linear regression weighted by sample size.

All statistical analyses were made by the R 2.13.1 program (R Development Core Team 2010).

Defining migration strategies based on wing length data

Results and Conclusions

According to the results of wing length data analysis within one migration period in spring the longer winged blackcaps arrived earlier, while in autumn shorter winged individuals cross the study site earlier in both sex groups.

Populations of the same species may have differing wing shapes and wing lengths according to the distances covered during migration. Birds with longer, pointed wings generate more power with less energy and fly faster compared to shorter winged birds. The species which have longer migration ways have to adapt to more environmental circumstances during their migration, therefore birds flying over longer distances often have more pointed wings than those migrating over shorter distance. The observed pattern at Blackcaps could be caused by the different migration strategy of the long-distance migrant northern breeders and the medium-distance migrant southern breeders: in spring the northern breeders cross the study site earlier and later in autumn.

In case of Garden warblers within a migration period both in spring and in autumn the longer winged individuals cross the study site earlier. This difference can be observed in juvenile and adult birds as well. There is almost the same pattern in Wood warblers and Spotted flycatchers, but juvenile Wood warblers and adult Spotted flycatchers did not show any significant relationship. This pattern can be observed in case of leap-frog migration strategy.

According to the results of wing length data analysis within one migration period in spring the longer winged Sedge and Marsh warblers arrive earlier, while in juveniles shorter winged individuals cross the study site earlier during autumn migration. The same pattern could be observed in case of Willow warblers, but in this species the adult birds showed correlation between timing of migration and wing length.

In Reed warblers there was no relationship in spring, but in autumn longer winged individuals migrate later in both age groups.

The detected pattern could be explained by differential migration of sexes. However the sex groups cannot be distinguished based on plumage, but males have longer wings and

larger body mass than females in all *Acrocephalus* species and in Willow warblers. This hypothesis is strengthened by the fact that the differential migration of sexes in spring well documented: the selection pressure could be larger on males, because in case of good weather conditions earlier arrival is beneficial, since earlier birds can occupy better territories and can raise their reproductive success, but this pressure is not so pronounced in case of females. Therefore the males migrate earlier and the sex ratio in early spring at northern stopover and breeding sites could be biased toward males (protandry). This could explain by the differences in wing length data. Sexual differences also could cause the autumn pattern: males migrate later than females.

In case of pied flycatcher males long-winged individuals arrived earlier in spring, while there were no differences in case of females. In autumn adult birds did not show any changes, while in average long-winged juveniles arrived later to our study site.

There was no difference in average wing length of the crossing Blackcaps in spring and in autumn. Contrary the other species, which are long-distance migrants, Blackcaps, captured at our study site, are mainly middle-distance migrants in Central Europe, therefore there is no difference in migrating population of the two periods.

In Pied flycatchers the long-winged populations cross the study site in autumn. In case of the other species (the differences were not remarkably in Reed and Marsh warblers) the longer winged individuals migrate in spring. This pattern can be observed in case of loop migration.

Changes in migration phenology

Results and Conclusions

Timing of spring migration differed among species. Not only the timing, also the duration of migration has changed. The spread of spring migration interval decreased in Wood warblers and extended in Reed warblers. The migration peak – in almost every species and at every percentile – shifted 6-15 days earlier except Blackcaps and Marsh warblers.

In spring similar trends could be observed in case of different species: most migrating passerine species arrive earlier due to the more optimal temperature of the first period of spring. Advanced arrival can be beneficial as birds can commence breeding earlier, hence can optimize their reproduction and increase reproductive success. Earlier arrival is beneficial, since earlier birds can occupy better territories and can raise their reproductive success.

Blackcaps migrate very early in spring and earlier arrival could be non-adaptive as local weather is highly unfavourable preceding the observed arrival dates. In early spring (late February, early March) the weather in Hungary can be very cold sub-zero temperatures and snow is often characteristic of this period. If these unfavourable circumstances occur permanently, the survival rate of birds is very low. We presume - similarly to the observations in Western Europe - that the spring migration of blackcaps has already shifted earlier before our study period in the previous decades.

Marsh Warblers did not shift their spring arrival. In general, only Northern European populations migrate earlier in spring. However, the fact that Marsh Warblers did not alter their arrival may be attributed to their habitat. This species breeds only in herbaceous vegetation zone of wetlands in the Carpathian Basin, a habitat type becoming suitable for breeding only in May. Thus, the advantages of arriving earlier are not as pronounced compared to the early spring period.

The timing of autumn migration shifted later in most of the species. There could be a large difference in changes of timing between adults and juveniles: In case of Garden, Wood warblers and Spotted flycatchers the timing of migration shifted later in juveniles, but did not in adults. The shift was the smallest in Wood and the largest in Willow warbler juveniles. The migration period extended in case of Reed warblers and Marsh, Wood warbler and Spotted flycatcher juveniles.

In autumn the long-distance migrants could react to the climatic changes differently, which depend on the moulting strategy and the number of clutches. Although some studies of long-distance migrants found earlier departure in recent, warmer years, most report that migrants have not changed or even delayed their departure date. In small bird species, energy-demanding life cycle stages, such as breeding, moult and migration are separated in time. Only in winter moulting adult species must fit this highly energy consuming life-cycle component into a relatively short winter. After breeding adults can gain weight faster and hence migrate earlier than juveniles.

There is a strong correlation between the timing of moult and migration of. The longer stopover time may be beneficial as it provides sufficient time to complete life cycle components such as moult. Adult blackcaps have postnuptial moult, therefore they stay longer, like the inexperienced juveniles. There was no difference in timing of autumn migration between adult and juveniles Willow warblers. In the background could be that adult Willow Warblers - contrary to juveniles - have a second full moult after the breeding period, therefore they can stay so long at the study site as the inexperienced juveniles.

Not only delayed, but more extended autumn migration periods were observed in adult and juvenile Reed warblers at our study site. Reed warblers can have second clutches in the Carpathian Basin Earlier spring arrival suggests that the overall time allocated for

reproduction increases, hence the ratio of second clutches may also have increased in the past two decades. The increased number of second clutch fledglings amongst autumn migrants may yield a delayed and extended autumn migration pattern.

Changes in biometrics

Results and Conclusions

According to the results of the nine studied species average wing length increased, while average body mass decreased during the study period. Trends of changes were significant within our short-term study period. The extra deposited fat showed also decreasing tendency.

Wings of northern breeders having longer migration route are longer and more pointed, than that of southern breeders with shorter migration route. In the background of increased average wing length could be changes in cross migrating population: the ratio of northern originated birds could increase. Therefore a northward shift in the distribution or a larger reproductive success of these species in northern breeding territories, as the effect of climate change, is probable.

Furthermore the rainfalls of West-Sahel region influence the survival of severely migrating European bird species. The extent of the Sahara is increasing continuously, resulting in selection forces for longer-winged individuals. In this case, the ratio of longer winged individuals captured at our study site may increase, producing the observed pattern.

For migrating birds it is necessary to accumulate large amount of fat before migration. This accumulation is especially important to fly through the geographical barriers. The longer is the distance of non-stop flies during the migration route, the larger amount of accumulated fat is needed. In autumn the amount of deposited fat of northern breeders at our study site could be lesser than at the beginning of their migration, therefore the increased rate of these northern originated individuals in the captured population could decrease the average of observed body mass.

Species have altered their population level migratory behaviour, therefore shifts can be observed in their distribution. These processes can be followed by analysing changes in biometrical traits.

New scientific results

1. According to our results at some studied species (Sedge, Marsh and Willow warbler) longer winged individuals arrive earlier in spring and the shorter winged ones in autumn.
2. In contrary in case of the other species (Garden and Wood warblers, Spotted flycatcher) longer winged individuals migrate through the study site earlier both in spring and in autumn.
3. Except of the Blackcaps, the Reed and the Marsh warblers in the other species the wing lengths differed of migrants in spring and in autumn.
4. In most of the studied species (except: Blackcap, Marsh and Willow warbler) the timing of spring migration sifted earlier, while the timing of autumn migration shifted later. The timing of migration changed in juveniles of all species, but did not in adults.
5. In most species the average wing length increased and the average body mass decreased during the study period.
6. The average amount of extra deposited fat decreased during the study period.

Publications related to the dissertation

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Acknowledgement

I am grateful to my supervisor Dr. Reiczigel Jenő, for her endless support and patience throughout my work.

I would like to thank to my consultants Dr. Harnos Andrea and Dr. Csörgő Tibor for their help and professional support.

I would like to thank to Dr. Hornung Erzsébet for all her help and valuable advices.

I would like to thank to Dr. Végvári Zsolt and Dr. Kis János for revising my work and their advices to improve the final form of this dissertation.

I would like to thank to Privigyey Csaba and Prohászka Viola and all the volunteers of the Ócsa Bird Ringing Station for the collecting and recording the data during the last 29 years.

I would like to express my thanks to my colleagues Dr. Nagy Krisztina, Kiss Andrea, Varga Zsófia, Ágh Nóra, Fehérvári Péter, Vas Zoltán and Lang Zsolt for their help during my daily work.

Thanks to Dr. Horváth Márton and Dr. Kalmár Lajos for the opportunity to start my PhD studies. I thank Vili Nóra and Krisztián Szabó that I could always count on them during our work together.

I would like to express my thanks to all my colleagues at the Department of Biomathematics and Informatics and in the Institute of Biology for their personal and professional support. Special thanks to Szabó Gabriella for the continuous encouragement.

I would like to thank to the members of „Adaptation to climate change” Research group for all of supports.

I am grateful to Dr. Miklós Rusvai, the head of SZIE Postgraduate School of Veterinary Science for the opportunity to finish my PhD.

Thanks to my resident and cross migrating roommates (my husband Peti, my sister Zsófi, my brother Benedek, my friends Anikó, Reni, Andi and Alex) for the patience.

Last, but not least I would like to acknowledge my parents and grandparents family for their support, encouragement and patience.

Budapest, 2013. Februar 17.

Pásztor-Kovács Szilvia