

1 **Change in migration phenology and biometrics of two sister *Sylvia***  
2 **species in Hungary**

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7 **Concise title:** Change of migration phenology of *Sylvia spp.*

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21 **ABSTRACT**

22 The distribution area and the timing of migration of many bird species have changed recently,  
23 presumably due to climatic factors. In our study we estimated the effect of climate change on  
24 migration phenology and biometrics of two sister *Sylvia* species: the medium distance migrant  
25 Blackcap (*Sylvia atricapilla*) and the long distance migrant garden warbler (*Sylvia borin*). We  
26 used the data of 52 440 Blackcaps and 6 943 Garden Warblers caught and ringed at the Ócsa  
27 Bird Ringing Station (47°15'N, 19°15'E) in Hungary between 1984 and 2008. The age and in  
28 case of blackcaps the sex groups were handled separately. The timing of the spring migration  
29 of garden warblers shifted earlier, whereas it did not change in blackcaps during the study  
30 period. We presume- in accordance with other observations concerning blackcaps in West-  
31 Europe- that it probably has changed earlier than the 80's. The timing of autumn migration  
32 shifted about two weeks later in all age and sex groups of blackcaps. We found significant  
33 correlation in the timing of autumn migration of sex groups, the sign of the differences  
34 between the timing of males and females changed. Juvenile garden warblers shifted their  
35 autumn migration 13 days later, but adults did not. Mean body mass decreased while mean  
36 wing length increased suggesting a change in the composition of the trans-migrant population.  
37 We hypothesise that due to climate change the breeding range of these species expanded  
38 northwards, producing an increased ratio of long-winged northern individuals in the trans-  
39 migrant populations.

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41 **KEY WORDS:** garden warbler, blackcap, climate change, migration phenology, biometrics

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44 **Zusammenfassung**

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46 **Veränderungen in Zugphänologie und Biometrie zweier Grasmückenarten in Ungarn**

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48 Bei vielen Vogelarten haben sich jüngerer Zeit Verbreitung und Zugphänologie verändert,  
49 vermutlich als Folge des Klimawandels. In dieser Studie untersuchten wir die Wirkung von  
50 klimatischen Veränderungen auf die Phänologie und Biometrie der Zuges zweier  
51 Grasmückenarten, nämlich des Mittelstreckenziehers Mönchsgrasmücke (*Sylvia atricapilla*)  
52 und des Langstreckenziehers Gartengrasmücke (*Sylvia borin*). Wir untersuchten 52.440  
53 Mönchsgrasmücken und 6.943 Gartengrasmücken, die von der Beringungsstation Ócsa  
54 (47°15'N, 19°15'E) zwischen 1984 und 2008 gefangen und beringt wurden. Altersgruppen  
55 und bei Mönchsgrasmücken zusätzlich Geschlechtsgruppen wurden unabhängig behandelt.  
56 Der Zeitraum des Frühlingszuges der Gartengrasmücke verschob sich nach vorne, während er  
57 sich bei der Mönchsgrasmücke im Verlauf der Studie nicht änderte. Wir nehmen an,  
58 unterstützt durch andere Beobachtungen von Mönchsgrasmücken in Westeuropa, dass bei  
59 ihnen diese zeitliche Verschiebung schon vor den 1980er Jahren erfolgte. Der Zeitpunkt des  
60 Herbstzuges verschob sich bei der Mönchsgrasmücke in allen Alters- und  
61 Geschlechtsgruppen um etwa zwei Wochen nach hinten. Wir fanden signifikante  
62 Veränderungen im Zeitpunkt des Herbstzuges, wobei die Vorzeichen der Veränderung bei  
63 Männchen und Weibchen verschieden waren. Junge Gartengrasmücken verschoben ihren  
64 Herbstzug um 13 Tage nach hinten, Altvögel hingegen nicht. Ihre mittlere Körpermasse  
65 verringerte sich, während sich die mittlere Flügellänge erhöhte, was auf eine Änderung in der  
66 Zusammensetzung der durchziehenden Population hindeutet. Wir nehmen an, dass sich die  
67 Brutgebiete dieser Arten auf Grund des Klimawandels nach Norden verschoben haben,  
68 wodurch mehr nördliche, langflügelige Individuen auftreten.

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## 71 **INTRODUCTION**

72 One of the most intriguing questions is to what extent living organisms are able to adapt to  
73 rapid environmental changes (Berteaux et al. 2004). Global and regional warming play an  
74 important role in distribution shifts in many taxa including birds (Root et al. 2003; Gordo  
75 2007). In birds specifically, climate change may alter the geographic distribution of species  
76 (Huntley et al. 2007), influence the timing and phenology of migration (Lehikoinen et al.  
77 2004, Tøttrup et al. 2006; Zalakevicius et al. 2006), moult (e.g. Pulido and Coppack 2004)  
78 and breeding (e.g. Crick and Sparks 1999; Charmantier et al. 2008). The rate and direction of  
79 changes may differ among species and between populations of the same species (Bearhop et  
80 al. 2005; Catry et al. 2006). Even age and sex groups may react differently (Catry et al. 2007).

81 In case of European birds, climate change may cause northward shifts in the breeding  
82 areas (Huntley et al. 2007). These changes depend on the migration strategy of the species  
83 concerned. The migration of long distance migrants is predominantly under genetic control  
84 (Gwinner and Wiltschko 1978) allowing a slower adaptation to rapid changes compared to  
85 residents, short-range or facultative migrants (Both and Visser 2001). Spring migration  
86 shifted earlier, in particular in species with more generalized diet, shorter migration distance,  
87 more broods per year, and less extensive prenuptial moult (Végvári et al. 2009).

88 The prediction is obvious for spring migration due to the advantages of early breeding  
89 (Crick and Sparks 1999; Dunn 2004). The timing of spring migration shifted earlier at most of  
90 the examined species. In case of good weather conditions earlier arrival is beneficial, since  
91 earlier birds can occupy better territories and can raise their reproductive success (Forstmeier  
92 2002).

93 In autumn, the causes of the shifts are more complicated as birds generally optimize for  
94 survival and could use different strategies to adapt to the changing environment. Departures  
95 may occur earlier under a warming climate if nesting is completed earlier, or even later if the

96 extended season encourages additional nesting attempts (Jenni and Kéry 2003). Advanced  
97 spring migration and delayed autumn migration of several passerine species have been  
98 detected at our study site (Miholcsa et al. 2009).

99 Blackcaps have a large Palearctic distribution area. The southern populations are  
100 resident, the northern and eastern populations of European blackcaps are long-range migrants  
101 while the Central European populations are partial or medium-distance migrants (Cramp and  
102 Brooks 1992). Blackcaps breeding in Hungary are medium-distance migrants, their main  
103 wintering range covers the Eastern Mediterranean Basin, but birds may overwinter in any part  
104 of the Mediterranean region. Cross migrant blackcaps at our study site originate from northern  
105 populations, thus are long-distance migrants (Csörgő and Gyurácz 2009 a). In Western  
106 Europe the spring arrival of blackcaps shifted earlier according to the studies of Lungberg and  
107 Endholm (1982) and Tøttrup et al. (2006), similar shift have been observed in Central Eurasia  
108 by Askayev et al. (2009), while the timing of autumn migration is delayed (Nowakowski  
109 1999).

110 Garden warbler has the most northern distribution area in the Palearctic region amongst  
111 the Sylvidae warblers (Cramp and Brooks 1992). According to ring recovery data, birds from  
112 our study area migrate through the Apennine Peninsula towards Africa (Csörgő and Gyurácz  
113 2009 b). Their wintering grounds cover the Sahel region south from the Sahara (Cramp and  
114 Brooks 1992; Grattarola 1999). In Northern and Western Europe and Central Eurasia the  
115 timing of spring migration of the garden warblers shifted earlier (Hüppopp and Hüppopp 2003;  
116 Jonzén et al. 2006; Sparks et al. 2007, Askayev et al. 2009), the timing of autumn migration  
117 did not change in Denmark (Tøttrup et al. 2006) and in Switzerland (Jenni & Kéry 2003).

118 In our study we analyzed the changes in timing of migration of two *Sylvia* warbler  
119 species at an Eastern European stopover site. We hypothesize that birds shift their migration  
120 earlier in spring and later in autumn. We suppose it can be a possible effect of recent climate  
121 change. We propose that the changes depend on age and moulting strategy in autumn.

122 Furthermore, we analyzed the change in differences in migration peaks of the two sex groups  
123 of blackcaps as we hypothesize that the two sex groups may use different migration strategy.  
124 Additionally, we used wing length and body mass in order to examine how these biometric  
125 parameters have changed during the last 25 years. In our view the biometric changes could be  
126 explained by the changes in the composition of populations passing through the area, thus  
127 indirectly showing the possible effects of climate change.

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## 129 **2. MATERIALS AND METHODS**

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### 131 **1.1. Location and data**

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133 Data were collected in Central Hungary (47°15'N, 19°15'E) at the Ócsa Bird Ringing  
134 Station. The station is situated within the Ócsa Landscape Protection Area, a coherent part of  
135 the Danube-Ipoly National Park. The site is at the edge of a postglacial peatbog. The  
136 surrounding is highly variable comprising all habitat types from reedbeds to closed forests.  
137 The study area has a typical continental climate with cold winters and warm summers. Our  
138 bird ringing database contains data of 25 years (1984–2008). Mist-netting and ringing were  
139 conducted at the same locations, using the methodology of Szentendrey et al. (1979)  
140 throughout the whole study period. We used the records of 13 049 adult and 39 391 juvenile  
141 blackcaps (*Sylvia atricapilla*) trapped and ringed between February-November and 1 968  
142 adult and 4 975 juvenile garden warblers (*Sylvia borin*) ringed between April-October within  
143 the study period. Only data from first captures were used. We distinguished two age groups  
144 by features published by Svensson (1992). 1st calendar year birds are referred to as juveniles,  
145 older birds as adults. In blackcaps we could determine the sex of birds by cap colorization  
146 (Svensson 1992). All birds were measured by a few experts who follow the same  
147 methodology (Szentendrey et al. 1979) to eliminate inter-observer bias. The right wing length

148 (to the nearest millimetre using the ruler) and the body mass (to nearest 0.1 g using a digital  
149 balance) were measured for each individuals. Visual fat scores were estimated following the  
150 scale of Kaiser (1993), ranging from zero (no visible fat) to eight (whole belly covered with  
151 fat). We used the data of birds whose fat scores fall into the linear range of the Kaiser scale in  
152 biometric analysis.

## 153 **1.2. Statistical analysis**

154

155 Bird migration phenology has been traditionally described by measures of central  
156 tendency (mean, median and mode) and spread (first and last observations, or 5% and 95%  
157 percentiles). We defined arrival times as the day of the year when the birds were caught at the  
158 first time and characterized the annual timing of migration by the location of the peak of the  
159 kernel smoothed arrival distribution curves (Fig. 1). Kernel smoothing was used to reduce the  
160 effects of missing observations (Silverman 1986; Knudsen et al. 2007).

161 Peaks of smoothed curves were identified separately for each species by season and age  
162 group and in blackcaps also by sex. To detect a shift in the timing of annual peaks during the  
163 study period, we applied linear regression analysis. The estimated shift in timing was  
164 calculated from the regression equations as the number of years times the estimated per year  
165 change (regression coefficient). Shift was regarded as significant if the corresponding linear  
166 regression was significant.

167 Quantile regression (Cade and Noon 2003) was used to estimate trends in 10%, 25%,  
168 50%, 75% and 90% percentiles of the distribution of arrival times from 1984 to 2008. As  
169 different quantiles may represent different population segments which may have different  
170 responses to the changing environment, quantile regression can provide an insight to different  
171 trends of migration timing of early and late arrivals. Shift in timing and significance was  
172 determined same as for linear regression.

173 We analysed the relationship between migration peaks of the two species and of the two  
174 age groups of blackcap by Spearman's rank correlation (Hollander and Wolfe 1973).  
175 Furthermore we tested the changes in differences between migration peaks of male and  
176 female blackcaps by linear regression.

177 Concerning changes in body condition, we first applied a linear model to estimate body  
178 mass from fat score and wing length. We used wing length to control for body size. Extra  
179 deposited fat was defined as the difference between actual (observed) body mass and body  
180 mass belonging to 0 fat score estimated from the linear model. Changes in average extra  
181 deposited fat from 1984 to 2008 were estimated by linear regression weighted by sample size.

182 The changes in average wing length were determined by linear regression. Additionally  
183 in case of garden warblers we used quantile regression to explore changes in the annual  
184 distribution of this parameter. To see the differences between an early (1984–1990) and a late  
185 (2002–2008) period smoothed density plots were applied.

186 All statistical analyses were made by the R 2.9.2 program (R Development Core Team  
187 2007).

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### 190 **3. RESULTS**

191

#### 192 **3.1. Changes in timing of migration**

193

194 No significant shift was found in spring migration peak of blackcaps ( $p = 0.5$  and  
195  $p = 0.08$  for males and females, respectively). Peak of spring migration of garden warblers  
196 shifted 9 days earlier ( $p = 0.016$ ). Quantile regression detected a shift of 8 days at the  
197 beginning of the migration period (10% and 25% quantiles) while the median passage date  
198 (50% quantile) changed by 6.5 days. For late arrivals (75 and 90% quantiles) the changes

199 were not significant (Table 1 and Fig. 2a). In the timing of autumn migration of blackcaps the  
200 largest delay was detected in adult males (17 days,  $p = 0.02$ ), whereas the smallest occurred in  
201 juvenile males (11.5 days,  $p = 0.02$ ). Females of both age groups shifted their peak time 14  
202 days later on average (adults:  $p = 0.035$ ; juveniles:  $p = 0.025$ ). We found similar results by  
203 quantile regression for all groups (Table 2). In autumn the time of peak migration of garden  
204 warblers did not change significantly in adults ( $p = 0.1$ ), whereas it shifted 14 days later ( $p =$   
205  $0.05$ ) in juveniles. Juvenile garden warblers migrated later than adults in the whole study  
206 period. Therefore the difference of median passage dates between the two age groups  
207 increased from 2 to 14 days from 1984 to 2008. In juveniles about the same delay was found  
208 for all quantiles in autumn (Table 1).

209       There was no significant correlation in the peak of migration of the two species neither  
210 in spring, nor in autumn. Migration peaks of male and female blackcaps correlated  
211 significantly in autumn (adults:  $r = 0.55$   $p = 0.028$ , juveniles:  $r = 0.81$   $p < 0.0001$ ). In autumn  
212 the differences between migration peak of adult male and female blackcaps increased  
213 significantly between 1984-2008: estimated differences between males and females were -5  
214 days for 1984 and 7.6 days for 2008 ( $p = 0.006$ ).

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### 217       **3.2. Changes in biometrics**

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219       The extra deposited fat decreased significantly from 1984 to 2008 in each age and sex  
220 group of both species in autumn (Table 3), however it did not change in spring. The average  
221 wing length of adult blackcaps and garden warblers showed a significant increase in both  
222 seasons (0.04 mm/year,  $p = 0.05$  for blackcap males in both season and 0.03 mm/year,  $p =$   
223  $0.05$  for blackcap females in both season, 0.05 mm/year,  $p = 0.01$  for garden warblers in  
224 spring and 0.06 mm/year,  $p = 0.005$  for garden warblers in autumn). Although median wing

225 length of adult garden warblers did not change significantly, wing length distribution shifted  
226 toward larger wing lengths (Table 4, Fig. 3, 4). We have not observed remarkable size  
227 differences between sexes.

#### 228 **4. DISCUSSION**

229

230

231 The distribution area and the timing of migration of many bird species has changed  
232 recently, presumably due to climatic factors (Gordo 2007). In our study we pointed out some  
233 possible consequences of climate change on the migrating populations of blackcaps and  
234 garden warblers caught at the Ócsa Bird Ringing Station in Hungary.

235 The timing of spring migration of many long and medium distance migrants shifted  
236 earlier (e.g. Gordo and Sanz 2005, Sparks and Tryjanowski 2007). The reason of this  
237 changing trend could be the optimization to reproduction. In spring birds benefit from the  
238 early arrival and could increase their reproductive success in case of favourable spring  
239 weather conditions (Forstmeier 2002; Dunn 2004). In spite of the possibility of prosperous  
240 consequences of advanced spring migration neither sex groups of blackcaps altered their  
241 spring arrival timing significantly during our study period. The reason may be that this  
242 species migrates very early in spring and earlier arrival could be non-adaptive as local  
243 weather is highly unfavourable preceding the observed arrival dates. In Hungary the first  
244 blackcaps arrive in late February, however a handful of recent observations of overwintering  
245 birds suggest that a minor fraction of the population may have become sedentary (Csörgő and  
246 Gyurác. 2009 a). Nevertheless in early spring (late February, early March) the weather in  
247 Hungary can be very cold sub-zero temperatures and snow is often characteristic of this  
248 period. If these unfavourable circumstances occur permanently, the survival rate of birds is  
249 very low. We presume - similarly to the observations in Western Europe - that the spring

250 migration of blackcaps has already shifted earlier before our study period in the previous  
251 decades. According to the observations in Northern and Western Europe e. g. in Sweden the  
252 timing of spring migration of blackcaps shifted on average 5 days earlier between 1965–1979  
253 compared to the 1941–1950 period (Lundberg and Endholm 1982). A Danish study pointed  
254 out that the median of arrival dates of blackcaps showed greater shift than those of its related  
255 species between 1976 and 1997 (Trottrup et al 2006). In Central Eurasia a study reported on 6  
256 days earlier shift in first arrival date of blackcaps between 1957-2008 (Askeyev et al. 2009).  
257 The first garden warblers arrive to Hungary in the second half of April, the peak of migration  
258 is in the middle of May (Csörgő and Gyurácz 2009 b). We found that the spring migration of  
259 garden warblers shifted 6.5 days earlier in Ócsa. Similarly to our results, Jonzén et. al. (2006)  
260 showed a 7 days average shift of spring migration of garden warblers in Sweden (Falsterbo,  
261 Ottenby) between 1980–2004. In Germany (Helgoland) the mostly Scandinavian originated  
262 cross migrant garden warblers shifted their spring migration on average 7.4 days earlier  
263 between 1960 and 2000 (Hüpopf and Hüpopf 2003). In England (Sussex) the first arrival  
264 date of garden warblers occurred on average 16.8 days earlier during 42 years long study  
265 period (Sparks et al. 2007), however, it only shifted 4 days earlier during 51 years in Central  
266 Eurasia (Kazan) (Askeyev et al. 2009) and did not change significantly in Lithuania (Vilnius)  
267 between 1971–2004 (Zalakevicius et al. 2006).

268         Contrary to the observations in Central Eurasia (Askeyev et al. 2007, Askeyev et al.  
269 2009), there was no significant correlation in the peak of migration of the two sister species  
270 neither in spring, nor in autumn at our study site. However, the lack of correlation in our data  
271 is not surprising as blackcaps in Central Eurasian are long-distance migrants, while they are  
272 medium distance migrants in Eastern Europe. Blackcaps in Central Eurasia arrive on average  
273 at the same time with garden warblers (Askeyev et al. 2009), while there is a marked  
274 difference in arrival dates in Europe.

275           After the dispersion period of early August the autumn migration of blackcaps starts in  
276 late August and the peak of migration is in the first half of September at our study site  
277 (Csörgő and Gyurácz. 2009 a). The autumn passage of blackcaps takes two months, thus the  
278 detected approximately two weeks shift is remarkable in all sex and age groups.

279           Both species alter their foraging strategy before autumn migration, they switch from  
280 insects to fruits e.g. elderberry at our study site. The change of main food source may cause  
281 inexperienced juveniles to spend more time with food deposition than adults. Adult blackcaps  
282 – contrary to juveniles and garden warblers – have postnuptial moult, therefore they stay  
283 longer, like the inexperienced juveniles. Presumably this is the reason of the approximately  
284 two weeks shift in both age groups. Another observation on the timing of autumn migration of  
285 blackcaps was a 3 days delay in North Poland in the period between 1985–1998 (Nowakowski  
286 1999). Blackcaps favour late migration as a consequence of increasing temperature and  
287 improved food availability on the breeding grounds (Coppack et al. 2001).

288           In small bird species, energy-demanding life cycle stages, such as breeding, moult and  
289 migration are separated in time. Thus, there is a strong correlation between the timing of  
290 postjuvenile moult and migration of blackcaps (Pulido and Coppack 2004). The longer  
291 stopover time may be beneficial as it provides sufficient time to complete life cycle  
292 components such as moult and allows to prepare for migration (Pulido and Coppack 2004).

293           We found significant correlation between autumn migration peaks of the two sexes. We  
294 hypothesize that it may be due to similar responses of the sexes to annual changes of climatic  
295 parameters. Interestingly, the sign of the differences between the timing of autumn passage of  
296 adult males and females changed significantly. It means that in the early years of study period  
297 the males had earlier migration peaks compared to females and recently females leave earlier  
298 the study site and males staying longer. These results may imply that the two sex groups of  
299 blackcaps could use slightly different migration and refuelling strategies. Possibly, females  
300 place more importance on energy-maximization, in order to ensure successful reproduction

301 (Tryjanowski et al. 2004). On the other hand males are the territory defenders and that they  
302 generally arrive ahead of females to the breeding territories (Izhazi 1998, Gustin 1999). Catry  
303 et al. (2007) have presented convincing evidence on differential distance migration of sexes in  
304 chiffchaffs, with females moving further than males. In blackcaps was found a significantly  
305 larger proportion of females in samples of British birds that wintered in Africa (Catry et al.  
306 2006). If this sexual difference in sex-ratios on wintering grounds occurs, males can leave the  
307 breeding ground later, than females. In case weather is highly favourable on stopover site  
308 males can stay even longer and the differences between sexes increase.

309 In contrast to blackcaps, winter moulting adult garden warblers must fit this highly  
310 energy consuming life-cycle component into a relatively short winter, hindering delayed  
311 departure from the breeding grounds (Hedenström et al. 2007). They gain weight faster and  
312 hence migrate earlier than juveniles. In this species, the timing of autumn migration of adults  
313 did not change during the past 25 years, while juveniles shifted their timing 13 days later. The  
314 autumn migration commences in early August at our study site. The peak of autumn passage  
315 is in early September and the last individuals leave the ringing site at the beginning of  
316 October (Csörgő and Gyurácz 2009 b). Considering that the duration of autumn passage of  
317 garden warblers at our study site is two months, our results of a 13 day shift in the migration  
318 peak of juvenile garden warblers are non-negligible.

319 In contrast to our results the passage times of the last 5% of garden warblers in autumn  
320 shifted earlier in Denmark (Christiansø) (Tøttrup et al. 2006). The last passage date also  
321 shifted earlier in England (Oxfordshire) between 1971–2000 (Cotton 2003). However these  
322 studies cannot be compared with our results, as they have not handled the age groups  
323 separately during their analysis, while we have found large differences in the timing of adults  
324 and juveniles.

325 Both species deposit large amounts of fat before autumn migration. The average body  
326 mass of blackcaps is 18.7 grams in Sweden and 21 grams on Cyprus (Fransson et al. 2006).

327 Around 16% of body mass of garden warblers from South Sweden consist of deposited fat  
328 (Ellergen and Fransson 1992). In Greece the average body mass of juveniles is approximately  
329 20 grams (Fransson et al. 2008), while south from the Sahara it is around 17 grams (Ottosson  
330 2005).

331 As the published data shows that there could be large differences in mean body mass  
332 and in average deposited fat -depending on the distances between two stopover sites and the  
333 distance between their current stopover site and the wintering grounds- among migrating  
334 populations. On the other hand the pattern of refueling is strictly defined in a population.  
335 Therefore, the change in average deposited fat of species at a stopover site could indicate the  
336 changes in population composition of cross migrating birds. Remarkable decrease was found  
337 in extra deposited fat in all age and sex groups of blackcaps and in adult and juvenile garden  
338 warblers at the Ócsa stopover site (Table 3). This decrease could mean a drop with more than  
339 one fat score on average. As we have only analysed the first capture data of every individual,  
340 and as arriving migrants are predominantly caught shortly after arrival, our data represents the  
341 condition of newly arrived birds. Additionally the amount and availability of food for these  
342 species could not have changed in this rate at our study area between 1984-2008, thus, it  
343 signifies a change in the population composition of cross migrating birds.

344 A correlation was observed between length of migration route and wing length and  
345 wing morphology of migrating birds (Lockwood et al. 1998). The wing of northern breeders  
346 having longer migration route until the wintering ground is longer and more pointed than that  
347 of southern breeders with shorter migration route. This theory is supported by the data of  
348 blackcaps on the Iberian Peninsula, where the wing length of cross migrants is larger on  
349 average than that of residents (Perez-Tris 2001). According to the data of Western  
350 Mediterranean ringing stations there are differences in wing length and body mass among  
351 garden warbler populations (Grattarola 1999). Our study indicates that the wing length of  
352 blackcaps increased on average and the distribution of wing length shifted toward longer

353 winged birds regarding garden warblers (Table 4, Fig 3, Fig 4). We detected a large change in  
354 wing length (average shift of 0.8-1.3 mm), which cannot be explained by local adaptations.  
355 There are many studies, which have been reported morphological changes hypothesised as  
356 related to climatic variables (Kaňuščák et al. 2004, Tryjanowski et al. 2004). In accordance  
357 with our results long-term decrease in body weight and increase in wing length was found for  
358 ringed blackcaps in Britain between 1968 and 2003 (Yom-Tov et al. 2006).

359 We detected that the average body mass decreased and the average wing length  
360 increased in the migrating population during the study period. In our view this is explained by  
361 the change in the composition of individuals originating from different populations, by the  
362 increasing rate of northern originated birds among the trapped birds. Therefore a northward  
363 shift in the distribution or a larger reproductive success of these species in northern breeding  
364 territories, as the effect of climate change, is probable (Huntley et al. 2007). Our theory is  
365 supported by the positive correlation between warming weather conditions and the  
366 reproductive success in the populations of other northern breeder species (Møller 2002). The  
367 population sizes in northern breeding grounds of blackcaps and garden warblers have  
368 increased in the previous decades (Jiguet et al. 2010). According to our results there is a  
369 remarkable shift in the timing of migration in autumn and spring in case of two species.  
370 Garden warblers advanced their spring migration and the autumn migration of garden warbler  
371 juveniles and blackcaps was delayed.

372 In addition, our results may indirectly show the effects of climate change on extending  
373 breeding range northwards as on the predicted distribution map for blackcaps in the Climatic  
374 Atlas of European Breeding Birds, or effects on increasing reproductive success in northern  
375 breeding territories like in case of the prediction for garden warblers (Huntley et al. 2007).

376

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378

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382

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521 **Tables**

522 Table 1: Shift in timing of migration of garden warblers (*Sylvia borin*) estimated by quantile  
 523 regression. Estimated number of shifted days (d) from 1984 to 2008 and p-values (p) are  
 524 represented. Negative numbers represent earlier arrivals.

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quantiles	spring		autumn adult		autumn juvenile	
	d	p	d	p	d	p
<b>10%</b>	-8.0*	0.005	8	<0.001	16	<0.001
<b>25%</b>	-8.0	0.001	3	0.311	9	<0.001
<b>50%</b>	-6.5	0.096	1	0.142	13	<0.001
<b>75%</b>	-7.5	0.052	0	0.922	16	<0.001
<b>90%</b>	1.5	1.000	2	0.901	7	<0.001

527

528 \*e.g. -8.0 (upper left cell in the table) means that the shift of the 10% quantile of the distribution was 8 days  
 529 earlier on average in 2008 than in 1984.

530

531 Table 2: Shift in timing of migration of blackcaps (*Sylvia atricapilla*) estimated by quantile  
 532 regression. Number of days shifted (d) from 1984 to 2008 and p-values (p) are represented.

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quantiles	autumn adult				autumn juvenile			
	male		female		male		female	
	d	p	d	p	d	p	d	p
<b>10%</b>	17.0	<0.001	12.5	<0.001	10.5	<0.001	8.0	<0.001
<b>25%</b>	13.5	<0.001	12.5	<0.001	9.5	<0.001	7.5	<0.001
<b>50%</b>	12.5	<0.001	14.0	<0.001	11.5	<0.001	12.5	<0.001
<b>75%</b>	12.5	<0.001	12.5	<0.001	11.0	<0.001	15.5	<0.001
<b>90%</b>	9.0	<0.001	14.5	<0.001	10.0	<0.001	16.0	<0.001

542 Table 3: Change in annual average extra deposited fat in autumn in each group of garden  
 543 warblers (*Sylvia borin*) and blackcaps (*Sylvia atricapilla*) from 1984 to 2008 estimated by  
 544 linear regression. The changes in grams, slopes (grams/year) and p-values are represented.  
 545

	garden warbler		blackcap			
	autumn	autumn	autumn adult		autumn juvenile	
	adult	juvenile	male	female	male	female
<b>change (g)</b>	-1.5	-1.1	-0.7	-0.8	-1.0	-0.9
<b>slope</b>	-0.061*	-0.046	-0.029	-0.032	-0.042	-0.036
<b>p-value</b>	<0.001	0.026	0.006	<0.001	<0.001	<0.001

546  
 547 \*e.g. -0.061 in the table means that the decrease of extra deposited fat was 0.061 per year on average from 1984  
 548 to 2008.

549  
 550 Table 4: Changes (d) of wing length (mm) of adult garden warblers (*Sylvia borin*) from 1984  
 551 to 2008 in spring and in autumn estimated by quantile regression. The changes (mm), slopes  
 552 (mm/year) and p-values are represented.

quantiles	spring adult			autumn adult		
	slope	d	p-value	slope	d	p-value
<b>10%</b>	0.08	2.0	0.012	0.07	1.8	<0.001
<b>25%</b>	0.05	1.3	0.024	0.06	1.5	<0.001
<b>50%</b>	0.00	0.0	1.000	0.00	1.0	1.000
<b>75%</b>	0.00	0.0	1.000	0.06	1.5	<0.001
<b>90%</b>	0.06	1.5	0.037	0.06	1.5	<0.001

561

562 **Figures**

563

564 **Fig. 1** The daily number of mist-netted juvenile garden warblers (*Sylvia borin*) caught in 2008  
565 and the smoothed line fitted by kernel smoothing

566

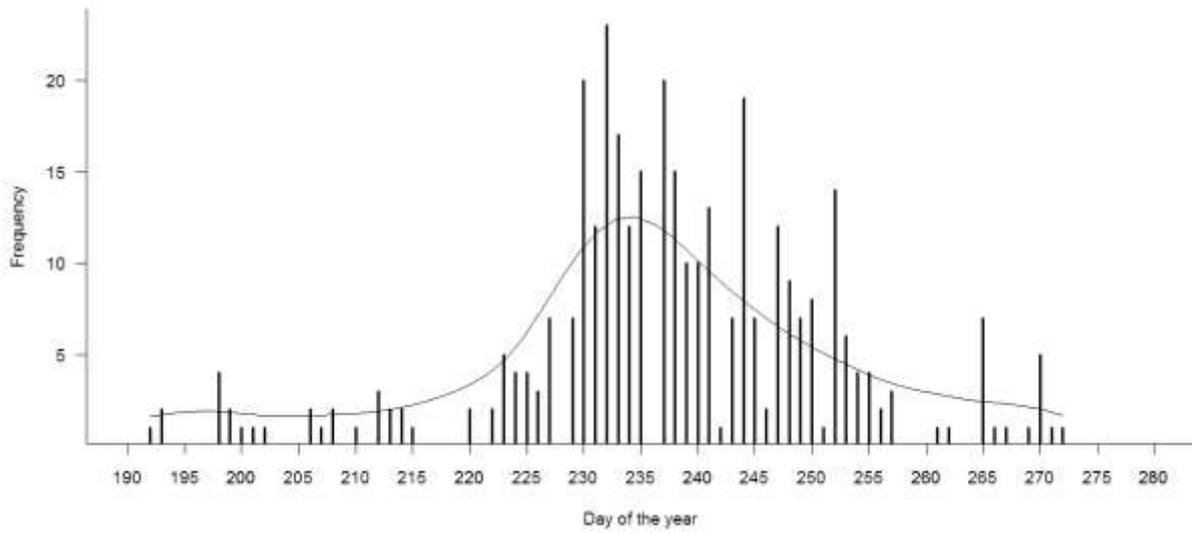
567 **Fig. 2** Scatter plot of capture times (day of the year) vs. year. Lines were fitted by quantile  
568 regression (10, 25, 50, 75, 90%; significant – solid lines, non-significant - broken lines) to the  
569 arrival times of spring migration of adult (a) and autumn migration of juvenile garden  
570 warblers (*Sylvia borin*) (b)

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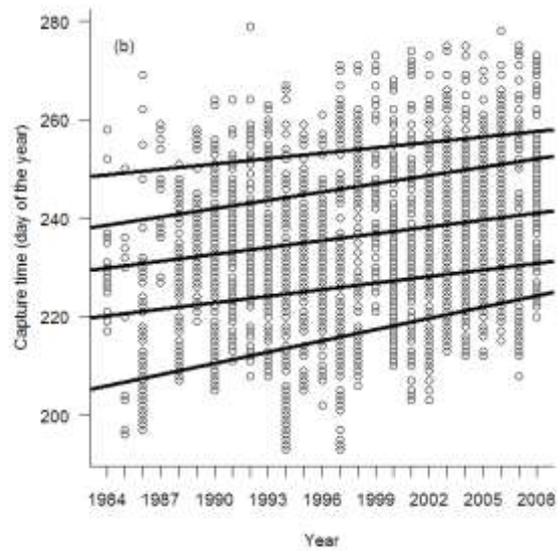
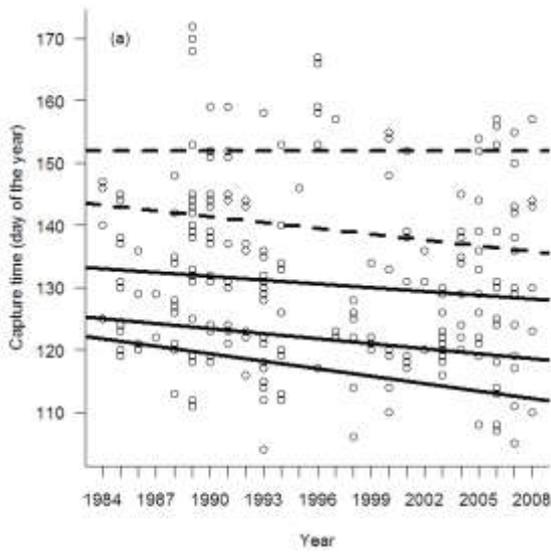
572 **Fig. 3** Wing length (mm) changes of adult garden warblers (*Sylvia borin*) captured in spring  
573 (a) and in autumn (b) and fitted lines (quantile regression 10, 25, 50, 75, 90%; significant –  
574 solid lines, non-significant – broken lines). Data points are jittered

575

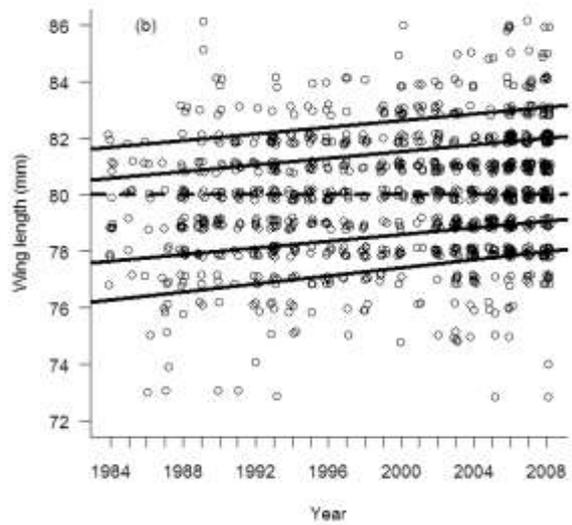
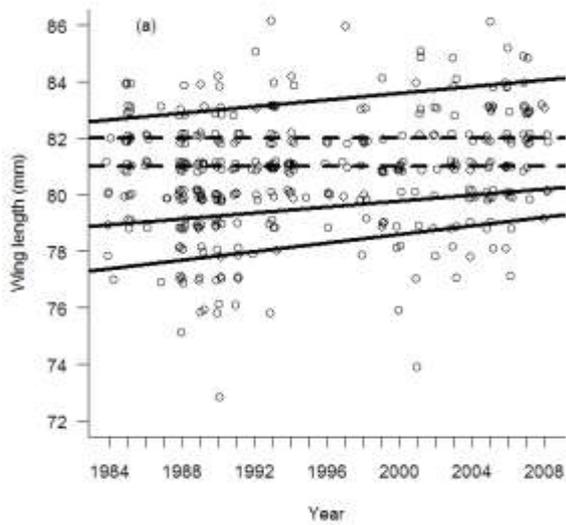
576 **Fig. 4** Smoothed density distributions of wing length (mm) of adult garden warblers (*Sylvia*  
577 *borin*) captured between 1984 and 1990 (solid lines) and between 2002 and 2008 (broken  
578 lines) in spring (a) and in autumn (b)



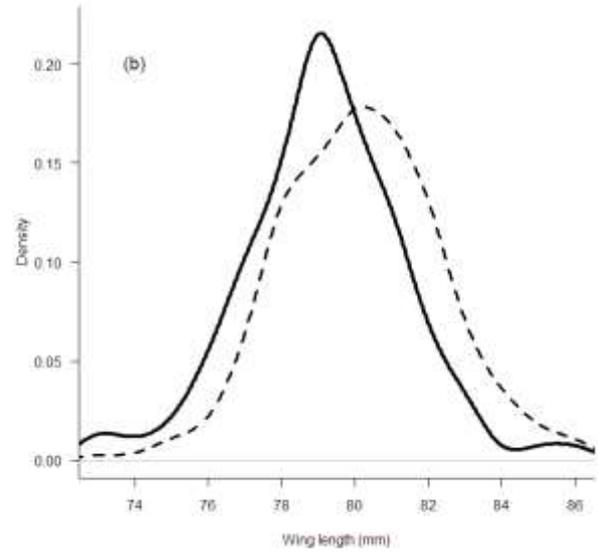
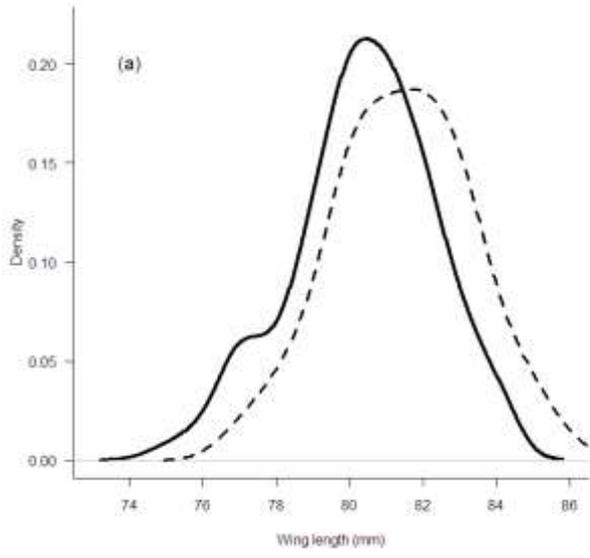
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