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# Exploratory analyses of migration timing and morphometrics of the European Robin *(Erithacus rubecula)*

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**Abstract** Ornithological studies often rely on long-term bird ringing data sets as sources of information. However, basic descriptive statistics of raw data are rarely provided. In order to fill this gap, here we present the sixth item of a series of exploratory analyses of migration timing and body size measurements of the most frequent passerine species at a ringing station located in Central Hungary (1984–2017). First, we give a concise description of foreign ring recoveries of the European Robin in relation to Hungary. We then shift focus to data of 40,128 ringed and 11,231 recaptured individuals with 24,056 recaptures (several years recaptures in 313 individuals) derived from the ringing station, where birds have been trapped, handled and ringed with standardized methodology since 1984. Timing is described through annual and daily capture and recapture frequencies and their descriptive statistics. We show annual mean arrival dates within the study period and present the cumulative distributions of first captures with stopover durations. We present the distributions of wing, third primary, tail length and body mass, and the annual means of these variables. Furthermore, we show the distributions of individual fat and muscle scores, and the distributions of body mass within each fat score category. We distinguish the spring and autumn migratory periods and age groups (i.e. juveniles and adults). Our aim is to provide a comprehensive overview of the analysed variables. However, we do not aim to interpret the obtained results, merely to draw attention to interesting patterns that may be worth exploring in detail. Data used here are available upon request for further analyses.

Keywords: Ócsa Bird Ringing Station, wing, third primary, tail length, body mass, fat, muscle, bird banding, capture-recapture, long term data, meta-analyses, Robin Redbreast

**Összefoglalás** Madártani tanulmányokban gyakran elemeznek hosszútávú madárgyűrűzési adatsorokat, de az alapvető leíró statisztikák és exploratív elemzések általában nem hozzáférhetőek. E hiányt pótolandó, cikksorozatot indítottunk, melyben egy közép-magyarországi gyűrűző állomáson leggyakrabban előforduló énekesmadár fajok vonulás időzítésének és testméreteinek exploratív elemzéseit közöljük (1984–2017). A sorozat hatodik tagjaként szolgáló jelen cikkben először áttekintjük a vörösbegy magyar gyűrűs külföldi és külföldi gyűrűs magyarországi megkerüléseit, majd rátérünk a faj egy magyarországi, 1984 óta standard módszerekkel dolgozó gyűrűzőállomásról származó 40 128 gyűrűzött és 11 231 visszafogott egyedétől (összesen 24 056 visszafogási esemény, 313 esetben több évből) származó adatainak elemzésére. Az időzítés és a fogásszám jellemzésére a napi és évi fogás és visszafogás gyakoriságokat használtuk. Ábrázoltuk az évenkénti átlagos érkezési időket és azok változását. Az éven belüli időzítést az első megfogások kumulatív eloszlásával ábrázoljuk feltüntetve a tartózkodási időket is. Közöljük a szárnyhossz, a harmadik evező hossz, a farokhossz és testtömeg leíró statisztikáit. Ábrázoljuk ezen változók éves átlagait, a zsír- és izomkategóriák gyakorisági eloszlását, valamint a testtömegek eloszlását zsírkategóriák szerinti bontásban. Az elemzésben elkülönítjük a vonulási (tavasz, ősz) időszakokat és a korcsoportokat (fiatal, öreg). Célunk a vizsgált változók átfogó bemutatása és a bennük található mintázatok feltárása volt az eredmények interpretálása nélkül. Kérésre a cikkhez felhasznált adatsort rendelkezésre bocsátjuk.

Kulcsszavak: Ócsai Madárvárta, szárnyhossz, harmadik evező hossza, farokhossz, testtömeg, zsír, izom, madárgyűrűzés, hosszútávú adatsor, meta-analízis

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## Introduction

Bird ringing or banding is one of the principal and oldest methods in use to study various aspects of avian populations (Robinson *et al.* 2009). Overwhelming amount of data has been collected by professional research entities and within citizen science projects Cooper *et al.* 2014) in over a century of bird ringing, and has been used excessively in a diverse array of disciplines. However, compared to the amount of data available throughout the world, concise descriptive information on measured parameters suitable for meta- or comparative analyses is sporadically available (Gienapp *et al.* 2007, Harnos *et al.* 2015). Though purely descriptive studies are often hard to publish within the framework of current hypothesis-focused science, we feel that such studies may well play an outstanding role in generating new hypotheses. Therefore, it is essential that descriptive studies apply the most appropriate statistical methodologies (Harnos *et al.* 2015, 2016, 2017). The bulk of currently available data is often collected at permanent, long-term ringing stations where large amount of individuals of various species are trapped simultaneously (Csörgő *et al.* 2016). These projects generally apply standardized methodologies in trapping, handling and data collection, thus information derived from these sites is suitable for location-wise comparisons (Schaub & Jenni 2000, Marra *et al.* 2004, Schaub *et al.* 2008, Tøttrup *et al.* 2010).

The civil interest towards nature can be well matched with serious, scientific work. Many scientific research is based on the important work of volunteers, ”civilians” in data collection (citizen science, Miller-Rushing *et al.* 2008, Cooper *et al.* 2014).

Here we present exploratory and descriptive statistics on the migration timing and morphometrics of the European Robin *(Erithacus rubecula)* between 1984–2017 from a

Central European ringing station (Ócsa Bird Ringing Station, Hungary, see Csörgő *et al.* 2016 in English and Csörgő & Harnos 2018 in Hungarian for details).

The Robin is a small-sized omnivorous passerine of the Muscicapidae family (Collar 2018). The plumage of the nominate race is lined with grey, olive-brown upperparts and whitish belly, the chest, throat and face are red-brown to orange. Juveniles are markedly different, having spotted brown and white cryptic colouration, with gradually appearing patches of orange (Svensson 1992, Cramp 1988, Demongin 2016). The species shows little sexual dimorphism in plumage colour and body size (Pettersson & Lindholm 1983, Cuadrado 1991, Madsen 1997, Pérez-Tris *et al.* 2000, Rosińska 2007, Rosińska & Adamska 2007, Jovani *et al.* 2012, McCollin *et al.* 2015).

The Robin is polytypical with 9 described subspecies, namely *Erithacus rubecula rubecula*, *E. r. melophilus*, *E. r. witherbyi*, *E. r. tataricus*, *E. r. valens*, *E. r. caucasicus*, *E. r. hyrcanus*, *E. r. superbus* and *E. r. marionae* (Gill & Donsker 2017). The subspecies are quite similar in their appearance, with minor variations in plumage colouration and biometrics (Cramp 1988, Svensson 1992, Demongin 2016). The breeding distribution ranges across much of the boreal, temperate and Mediterranean zones of the Western Palaearctic and in Mediterranean North Africa (Cramp 1988). The nominate subspecies occupies the majority of the breeding range. Migration strategies of subspecies may be markedly different (see below) (Cramp 1988, Adriaensen & Dhondt 1990, Fennessy & Harper 2002).

Its habitat varies from deciduous and coniferous forest. It requires light or medium cover moist habitats, farmland hedges, gardens and parks but avoid the densest woodland (Cramp 1988, Mead 1997).

The Robin is classified as Least Concern in the IUCN Red List, the European population trends is increasing (BirdLife International 2017). Many individuals are poached for food in the Mediterranean Basin in winter (Collar 2018). Severe, hard winters may drive population fluctuations among residents in Britain (Marchant *et al.* 1990, Mead 1997). In Italy, large part of the recoveries are related to human activities, predominantly hunting (Spina & Volponi 2009). The wintering range of the bird is compressing in the western Mediterranean Basin (Fandos & Tellería 2017).

Their mating system is typically monogamous, however some studies found low frequency bigamy (Cramp 1988). The species is single-brooded in northern regions of its range, elsewhere it is double or rarely triple brooded (Cramp 1988). The Robin is territorial in the breeding area and also during wintering (Cramp 1988, Cuadrado 1997, Tobias 1997, Tobias & Seddon 2000). Breeding occurs from February to early July in general, from the end of April to late July in Central Europe, from mid-May in the northern and from mid-April in the southern part of Russia (Cramp 1988, Collar 2018).

Robins are nocturnal migrants and typically travel in short bursts and rest for several days between migration flights (Cramp 1988, Collar 2018).

Migration strategies may be markedly different among subspecies, within subspecies' breeding populations and between individuals of the same population (Cramp 1988, Adriaensen & Dhondt 1990, Fennessy & Harper 2002). Korner-Nievergelt *et al.* (2014) divided Europe into four regions: (1) Scandinavia, the Baltic countries, Belarus and North East Russia, where the Robin is a breeding or migratory bird, but it does not overwinter; (2) the central part of Europe including the British Isles, and the band from the Low Countries to Romania, Moldavia and Ukraine, which is both a breeding and a wintering area; (3) southern Europe; and (4) edge of northern Africa. The last two parts are also breeding areas and important wintering sites for the birds originating from northern and central Europe.

Sedentary individuals typically occur in urban breeding habitats and on temperate islands, while other populations may range from obligate short/medium range migrants to various degree of partial migration. In general, populations east of line connecting Norway and Central Europe are obligatory migrants, moving southward to the Mediterranean Basin, Black Sea hinterland, South Caspian, Mesopotamia and Gulf region. Birds west of line from Germany to Balkans are partially migratory or largely resident (Collar 2018). The migration strategy is probably genetically determined (Biebach 1983).

Robins from Fennoscaninavia and the Baltic countries migrate mainly through Denmark during autumn and continue south-west towards Western Europe and North-West Africa (Bønløkke *et al.* 2006, Fransson & Hall-Karlsson 2008, Valkama *et al.* 2014). Main migratory pathway of the Finnish birds follows both coasts of the Baltic Sea, crosses Central Europe in a rather wide belt ending as far as Morocco and Algeria. Adult birds are slightly ahead than the young (Valkama *et al.* 2014). Danish birds have been recovered in a rather narrow zone through the Netherlands, Belgium, western Germany, France, Spain and Portugal (Bønløkke *et al.* 2006). The recovery pattern suggest that nearly all Robins migrating through the south coast of the Baltic see are moving west-southwest and are originated from Scandinavia and western Russia (Ehnbom *et al.* 1993, Remisiewicz *et al.* 1997, Fransson & Hall-Karlsson 2008, Valkama *et al.* 2014). Minor proportion of the Fennoscandian birds migrate to the south-southest (Remisiewicz *et al.* 1997, Valkama *et al.* 2014). Based on orientation tests using Busse's method (Busse 1995) in Poland, over 30% of tested birds use the eastern way. Probably due to the lack of ringing activity, recaptures are missing from this area (Busse *et al.* 2001, Ściborska & Busse 2004, Rosińska & Adamska 2007). Robins were studied with the same method for directional preferences during autumn migration in southern Poland. More than 60% of the tested birds showed reversed (northern) headings, probably because the Carpathian mountains are potential barriers for this species (Adamska & Filar 2005). Most German breeders are migratory, and most of the birds passing through Germany originate from North, North-East and lot of northern birds winter in Germany (Bairlein *et al.* 2014). In central Europe including the Czech Republic, Slovakia and Hungary and Croatia the Robin is a common breeder and there are a lot of migrants coming from Fennoscandinavia, Poland and the western part of Russia (Klvaňa 2008, Gyurácz & Csörgő 2009, Budinski 2013). Birds from Bohemia prefer the south-western direction, most recoveries were made in Switzerland, France and the Iberian Peninsula. The majority of the birds from Moravia and Slovakia head more to the south (Appenine Peninsula) and to south-east (Balkan Peninsula) (Klvaňa 2008). Birds passing through Croatia were recaptured in Italy and Tunisia (Budinski 2013). Italy is a crossroad for this species. They come from Fennosscandinavia, the Baltic areas, Central and Eastern Europe. The majority of the autumn recoveries are in the Alpine area, in Emilia Romanque, Tuscany and Sardinia. Robins ringed in Italy are concentrated in the south-western Mediterranean and some in North Africa (Spina & Volponi 2009). Robins prefer the south-south-eastern direction (34%) in northern Italy towards the Apennine Peninsula based on orientation studies (Adamska & Rosińska 2006).

The dynamics of the migration depends on the place of origin and the target area. Most birds leave Sweden in September, adults and juveniles in the same time. Their mean position is in September is South Denmark, and they reach their wintering quarters in West and South-West Europe in November (Bønløkke *et al.* 2006, Fransson & Hall-Karlsson 2008). Autumn migration in Finland starts in September-October, the median is at the end of September, beginning of October. Adults' median date is in September in the latitude of South Sweden and the Baltic states, in October in South-West Germany, in November in South France. Adult birds are slightly ahead than the young. Juveniles are only in Denmark in October (Valkama *et al.* 2014). Local Belgian populations start their migration in the second half of August, the trans-migrant northern birds pass through the country from mid-September until mid-November, in high numbers in the first half of October (Adriaensen 1987). Autumn passage on the Polish Baltic coast lasts from mid-August to early November peaking late September and October. Passage in south appears to occur slightly later than in north, and also slight tendency for adults to pass later than juveniles. Adult females arrive later than adult males (Polakowski & Jankowiak 2012). In Germany autumn migration lasts from late August to mid-November, peak in late September, early October (Bairlein *et al.* 2014). The passage between September and November with a peak in October is observed in the Italian Alps. On the Apennine Peninsula, the earliest foreign birds can be detected in late August, the most intensive period is in October and the migration ends in November (Schubert *et al.* 1986, Bottoni *et al.* 1991, Spina & Volponi 2009). In Iberia the autumn migration period lasts from September to November with a main peak in October, and the birds reach North Africa from late September (Cramp 1988, Remisiewicz 2001). Birds migrating to the Balkan Peninsula travel later than those migrating to other parts of the wintering range (Remisiewicz 2002). Birds migrating later in the season stay for winter in the more northern regions (Remisiewicz 2001).

The species shows a typical leap-frog migration strategy. 48% of the Scandinavian birds winter in North Africa, and only 18% appears in Central Europe. However the proportion of Central European individuals in North Africa is only 31%, 34% of the birds are resident (Korner-Nievergelt *et al.* 2014). Birds breeding on the Apennine Peninsula winter in Marocco and Algeria (Adamska & Rosińska 2006, Spina & Volponi 2009).

The species has a week population level migratory connectivity. The wintering sites of Finnish, Swedish, Danish birds can be found from Great-Britain, South Finland, South Sweden through south-western Europe and North-Africa to the Balkan Peninsula (Remisiewicz *et al.* 1997, Bønløkke *et al.* 2006, Fransson & Hall-Karlsson 2008, Klvaňa 2008, Spina & Volponi 2009, Gyurácz & Csörgő 2009, Bairlein *et al.* 2014, Valkama *et al.* 2014). Like in the northern European populations the main wintering grounds of Robins ringed in Poland, Germany and Czech Republic are the Iberian Peninsula, southern and western France, the Baleari Islands, Algeria and Morocco, northern Italy, Sardinia, Corsica and also the Balkans (Remisiewicz *et al.* 1997, Klvaňa 2008, Bairlein *et al.* 2014).

Although, the migratory connectivity is very week, exceptions may exist on specific parts of the migratory route. Robins ringed at Ottenby Bird Observatory were recovered east of Robins ringed at Fasterbo, indicating parallel migrations to wintering area (Fransson & Hall-Karlsson 2008). From biometric measurements it has turned out, that Robins from the two sites (Falsterbo, Ottenby) use different migration strategies, Falsterbo Robins are "short-stage migrants", travelling over land, while the Ottenby Robins are "long-stage migrants" (Pettersson & Hasselquist 1985, Karlsson *et al.* 1988, Sandberg *et al.* 1988, Åkesson *et al.* 1992).

The resident males' survival was higher (50%) than the survival of migrants (17%) in Belgium. Resident and migratory birds were habitat separated (migratory males in woodland, resident males in gardens and parks, all females were migratory, Adriaensen & Dhondt 1990).

The Iberian Peninsula is an important wintering site for the Robins arriving from a very large area (Campos *et al.* 2011b). Biometry of birds arriving from north and local individuals is different (Domínguez *et al.* 2007). Sexes show strong latitudinal segregation (there are more females in south, Catry *et al.* 2004). The males are dominant over the females (Campos *et al.* 2011a). Maintenance of winter territories has not only feeding, but even more anti-predation benefits (Cuadrado 1997).

Strong site attachment and site fidelity were proved experimentally in Italian studies. Adult Robins have a stronger site attachment and homing success than juveniles. Adult birds were better homers than sub-adults, but no significant differences were observed between males and females. Subadults become site-attached during autumn and early winter at their first season on the wintering ground (Benvenuti & Ioalè 1980, 1983, Ioalè & Benvenuti 1983).

First signs of return passage are in early February with increasing numbers along coasts of Algeria and Morocco (Cramp 1988). The spring migration could start in early January, but mostly in midd-February, first the breeding population of Apennine Peninsula arrives in this time (Spina & Volponi 2009). The passage through this area begins in mid-March and ends at the beginning of May peaking between the last week of March and the third week of April. Spring migration lasts from March to April in northern Spain (Arizaga *et al.* 2010). The obligatory migrant individuals originated from the British Isles arrive back at the end of March. This population migrates along the coast of the Atlantic Ocean, in the case of the other populations the general bearing is north-east (Fennessy & Harper 2002).

The first individuals arrive to their breeding site in Central Europe in early March and the migration peaks mainly in April (Hubálek 2005, Klvaňa 2008, Gyurácz & Csörgő 2009, Bairlein *et al.* 2014). The Robins arrive to the northern breeding areas from the end of March to the end of May, the yearly peaks are between mid-April and mid-May (Sokolov *et al.* 1998, Biaduń *et al.* 2011, Valkama *et al.* 2014). The Belgian and the Danish birds depart from mid-March to early May with a peak in the first half of April (Adriaensen 1987, Bønløkke *et al.* 2006). Robins depart in March from the wintering quarters and reach the North Sea in April, the average is in mid-April in Germany (Hüppop & Hüppop 2003). The first Robins arrive in Sweden in mid-March, the mean arrival time in South Sweden is in the second half of April (Stervander *et al.* 2005) and the birds reach their breeding sites in May (Fransson & Hall-Karlsson 2008). Finnish birds have similar phenology (Valkama *et al.* 2014). Birds do not reach the Urals until early May (Cramp 1988).

The average stopover time in spring was shorter than that in autumn in the central pre-Alps of Italy (Bottoni *et al.* 1991). In spring, European Robins selected optimal wind condition to start a new flight, while in autumn they departed under moderately unfavourable winds on the Courish Spit (Eastern Baltic; Bulyuk & Tsvey 2006). The wind condition may effect the timing, accordingly the stopover duration may vary in a broader interval, between 1 and 19 days (Bulyuk & Tsvey 2013). In spring, Robins presumably use the same routes as in autumn with no detected indication of loop migration (Cramp 1988, Remisiewicz *et al.* 1997, Bønløkke *et al.* 2006, Fransson & Hall-Karlsson 2008, Bairlein *et al.* 2014).

The migration timing of Robins did not change markedly in the last decades in autumn in Poland (Nowakowski *et al.* 2005). The mean spring passage time has become earlier in North Europe (Sokolov *et al.* 1998, Hüppop & Hüppop 2003, 2011, Stervander *et al.* 2005, Tøttrup *et al.* 2006, Valkama *et al.* 2014). The NAO index had no significant effect on arrival time, however the mean temperature had (Hüppop & Hüppop 2003), the decline of the mean temperature in February shifted later the spring arrival (Biaduń *et al.* 2011).

The migratory distance of north-eastern birds decreased during the past decades due to the north-eastwards shift in the wintering grounds, while the proportion of residents increased (Remisiewicz 2001, 2002, Tøttrup *et al.* 2006, Tellería 2015). This distance is more or less independent of the yearly weather. Partial and short distance migrants only slightly shifted their wintering grounds, but their migration distance changes with the winter temperature (Ambrosini *et al.* 2016).

In Hungary all of the breeding and trans-migrant individuals belong to the nominate subspecies (Gyurácz & Csörgő 2009). The Hungarian breeding population is estimated to 306,000–409,000 pairs showing a moderate increase recently (Szép *et al.* 2012). The species is protected in Hungary (BirdLife Hungary 2018). Robin is one of the most common migrants from March to mid-April in spring and from September until mid-November in autumn (Antli & Németh 1998, Hadarics & Zalai 2008, Gyurácz & Csörgő 2009, Gyimóthy *et al.* 2011b). The autumn migration has one wave, the breeding population depart until the middle of September and use south-western and south-eastern ways to the wintering areas (BirdLife Hungary 2018). Autumn passage migrants in Hungary originate mainly from Slovakia, Poland, Ukraine, southern Scandinavia, Baltic States and north-western Russia. Compared to the high number of ringed birds from north of Hungary, there were only a few northern recoveries *(Figure 1)*. For example, there were 691,134 captures (more than 20,000 per year) with 2438 recaptures within Sweden up to 2003, 373,258 captures (6-8000 per year) with 1147 foreign recoveries in Finland. The species uses a south-western fly-way west to the Carpathian basin (Fransson & Hall-Karlsson 2008, Valkama *et al.* 2014). More than 60% of the birds showed northern headings that we called "reversed directions" in Poland, meaning that the Carpathians are potential barriers for this species (Adamska & Filar 2005). On the other hand, birds originating from eastern breeding sites use eastern routes. Recoveries are mainly from Italy, but Hungarian ringed birds have also been recaptured in Spain, France and Algeria (Gyurácz & Csörgő 2009, BirdLife Hungary 2018). Probably they also winter in Morocco (Hornok *et al.* 2012). The majority of the Hungarian breeding birds leave the Carpathian Basin and use south-western (and winters in the Apennine Peninsula and on the surrounding islands) and south-eastern ways to the wintering area by mid-September (BirdLife Hungary 2018). Autumn passage migration peaks in late September to early October in Hungary (Gyurácz *et al.* 2008, Gyimóthy *et al.* 2011b). The stopover duration is 4–9 days on average (Gyimóthy *et al.* 2011b). The habitat quality influences the the dynamics and the age distribution on different ringing stations of Hungary (Gyimóthy *et al.* 2011b). Northern individuals arrive at the end of autumn migration according to studies of wing-length, body mass and fat reserves (Gyimóthy *et al.* 2011a). The spring migration in Hungary lasts from the beginning of March to the end of April, and the passage is faster than in autumn. The peak of the migration is between late March and early April (Gyurácz & Csörgő 2009, BirdLife Hungary 2018).

The Robin is an abundant passage migrant and may sporadically breed and overwinter at the Ócsa Bird Ringing Station, the source of data analysed in this paper.

Our aim is to provide a comprehensive overview of migration timing, body size measurements and inter-annual changes in these variables. Hopefully, these patterns will help formulate research questions and provide information for further higher level analyses. However, we do not aim to interpret the obtained results, merely draw attention to interesting patterns, that may be worth exploring in detail.

## Materials and methods

### Bird ringing data

The Ócsa Bird Ringing Station is situated in Central Hungary (N47.2970, E19.2104) in the Duna-Ipoly National Park in the immediate vicinity of Ócsa town. The study site is characterized by a post-glacial peat bog with a mosaic of habitats including open water surfaces, reedbeds, bushy vegetation and forests. It is situated in a humid continental transitional climate zone (for further details see Csörgő *et al.* 2016, ocsabirdringing.org). Birds were trapped with standard mistnets placed at standard locations throughout the study period. Trapping effort is seasonal and changed over the years (see Csörgő *et al.* 2016 for details).

The day of the year of first capture in spring and in autumn were considered as arrival (migration) timing of individual birds. Stopover duration was calculated as the difference of within season last and first captures excluding within day recaptures. Biometric measurements were taken following strictly standardized methods (Szentendrey *et al.* 1979, EURING 2015). Only data of the first captures were used in the analysis. We distinguished first calendar year birds (juveniles) from adults upon plumage characteristics (Cramp 1988, Svensson 1992, Demongin 2016), and we present all results according to these groups. We present data for spring and autumn migratory seasons separately; birds caught after the 70th and before the 110th day of the year were considered to be spring migrants and birds caught after the 230th and before the 310th day of the year were considered to be autumn migrants. A total of 40,128 were captured and ringed between March and November; 14,162 in spring and 3,330 adults and 19,378 juveniles in autumn (the rest of the birds was not aged) in the study period of 1984–2017. This total value constitutes cca. 17.8% of the 224,393 European Robins ringed in Hungary in this period.

### Statistical methods

To describe daily and yearly capture frequencies and the cumulative distribution of the date of first captures with recaptures, we used the functions of the `ringR` package (Harnos *et al.* 2015). Descriptive tables (mean, median, standard deviation (SD), minimum (min), maximum (max) values and sample size (N)) on the timing of migration, stopover duration, the length of wing, third primary and tail, and body mass were created by the `data.table` package (Dowle *et al.* 2013). The annual mean values of timing, body mass, wing-, third primary and tail lengths are plotted against time (year) on scatterplots. Loess smooth lines were fitted to highlight trends (Cleveland *et al.* 1992). The distribution of the same variables were represented with histograms and overlaid smoothed histograms. Boxplots were used to show the body mass distributions by fat score categories. Fat and muscle score frequencies are shown using barplots. We distinguished seasons and age groups throughout the analyses. For more details on the analysis, please visit ocsabirdringing.org. All analyses were carried out in R 3.4.0 (R Core Team 2017).

## Results

A total of 153 foreign recaptures were recorded between 1951 and 2017 in relation to Hungary *(Figure 1)*. Annual capture and recapture frequencies at the study site are shown in *Figure 2*. Within-year capture and recapture frequencies, together with cumulative distribution of individual first and last captures are depicted in *Figure 3*, while their respective descriptive statistics are presented in *Table 1–2*. Changes in annual mean arrival dates throughout the study period and the distribution of within-year migration timing

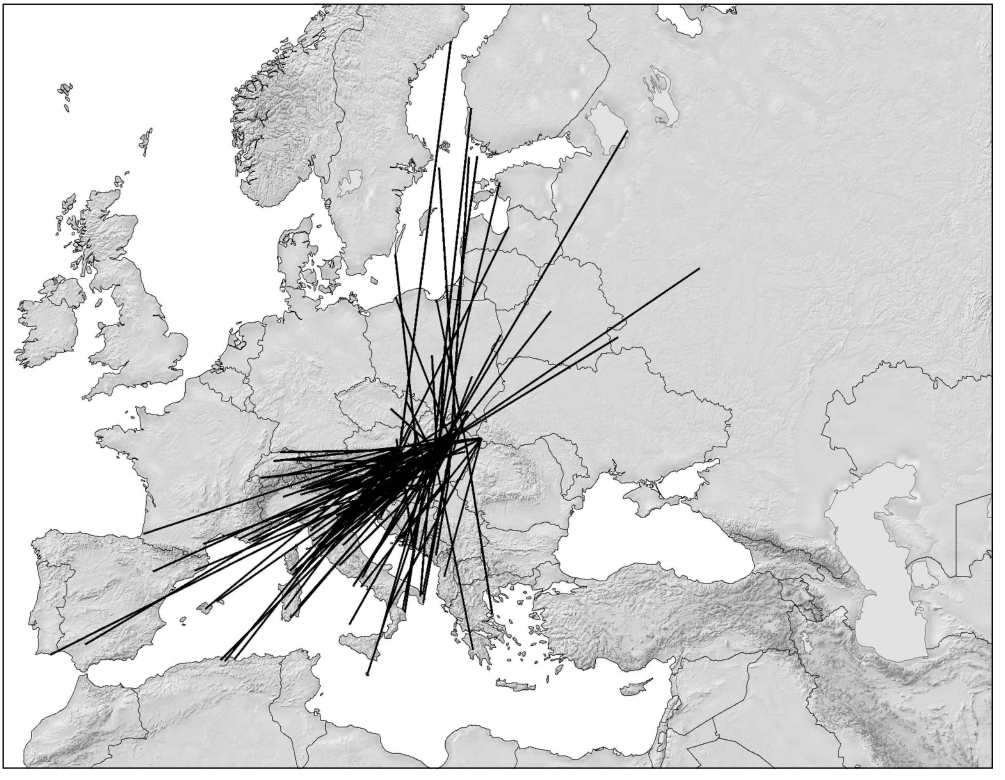

*Figure 1.* Foreign ring recoveries of European Robins. The data of birds ringed in Hungary and recovered abroad and the birds ringed abroad and recovered in Hungary are depicted

*1. ábra* Magyarországon jelölt és külföldön megkerült, illetve külföldön jelölt és Magyarországon megfogott vörösbegyek

according to season and age are presented in *Figure 4*. The trend of annual mean wing lengths and the distribution of wing length measurements according to season and age are shown in *Figure 5*, while their respective descriptive statistics are presented in *Table 3*.

Third primary length *(Figure 6, Table 4)*, tail length *(Figure 7, Table 5)* and body mass *(Figure 8, Table 6)* are presented in a similar fashion. Body mass in relation to season and age and fat scores are visualized with boxplots in *Figure 9*. Finally, the distribution of fat and muscle scores grouped by season and age can be found in *Figure 9 b,d,f* and *Figure 10*.

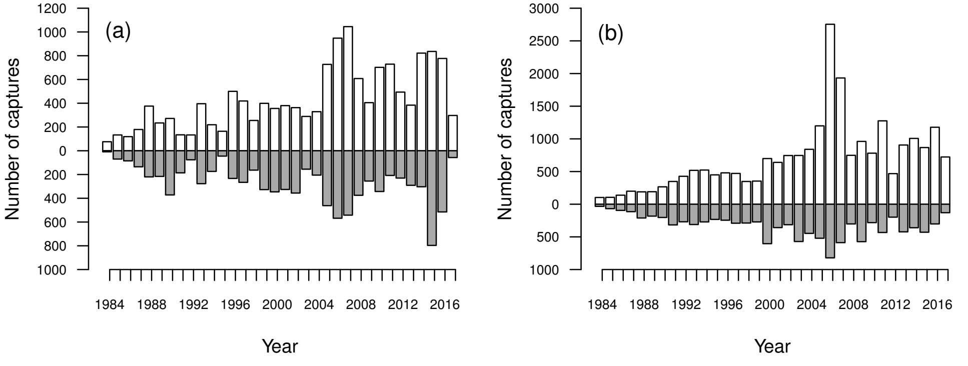


*Figure 2.* Annual capture (white bars) and recapture (grey bars) frequencies in spring (a), and in autumn (b)

*2. ábra* Éves fogás (fehér oszlopok) és visszafogás (szürke oszlopok) gyakoriságok tavasszal (a) és ősszel (b)

*Table 1.* Descriptive statistics of migration timing (day of the year)
*1. táblázat* A vonulás időzítés (év napja) leíró statisztikái

| Season | Age | Mean | Median | SD | Min | Max | N |
|---|---|---|---|---|---|---|---|
| spring | adult | 89.0 | 89 | 8.5 | 70 | 110 | 14162 |
| autumn | adult | 277.6 | 278 | 12.5 | 231 | 310 | 3330 |
| autumn | juvenile | 272.5 | 273 | 16.3 | 230 | 310 | 19378 |

*Table 2.* Descriptive statistics of stopover duration (day)
*2. táblázat* A tartózkodási idő (nap) leíró statisztikái

| Season | Age | Mean | Median | SD | Min | Max | N |
|---|---|---|---|---|---|---|---|
| spring | adult | 5.6 | 4 | 5.1 | 1 | 35 | 3582 |
| autumn | adult | 4.9 | 3 | 5.0 | 1 | 40 | 537 |
| autumn | juvenile | 5.9 | 4 | 5.7 | 1 | 75 | 3800 |

*Table 3.* Descriptive statistics of wing length (mm)
*3. táblázat* A szárnyhossz (mm) leíró statisztikái

| Season | Age | Mean | Median | SD | Min | Max | N |
|---|---|---|---|---|---|---|---|
| spring | adult | 72.5 | 72 | 2.1 | 65 | 80 | 13493 |
| autumn | adult | 72.8 | 73 | 2.1 | 66 | 79 | 3214 |
| autumn | juvenile | 72.3 | 72 | 2.0 | 65 | 79 | 18744 |

*Table 4.* Descriptive statistics of third primary length (mm)
*4. táblázat* A harmadik evező hosszának (mm) leíró statisztikái

| Season | Age | Mean | Median | SD | Min | Max | N |
|---|---|---|---|---|---|---|---|
| spring | adult | 54.3 | 54 | 1.8 | 46 | 62 | 12633 |
| autumn | adult | 54.2 | 54 | 1.8 | 48 | 60 | 3100 |
| autumn | juvenile | 54.1 | 54 | 1.8 | 48 | 62 | 17795 |

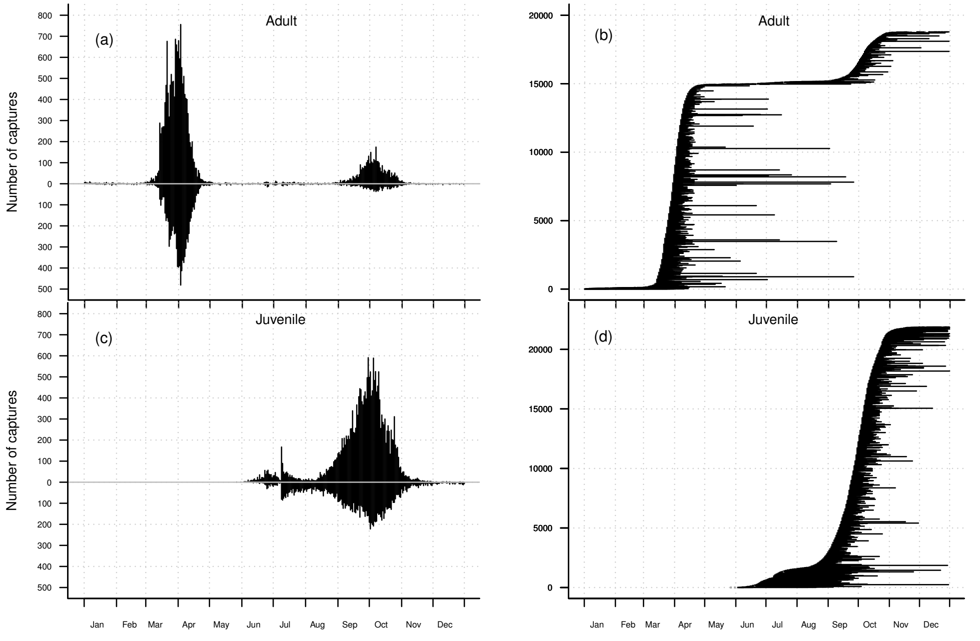


*Figure 3.* Within-year capture (black bars) and recapture (grey bars) frequencies (a, c) and cumulative distributions of individual first capture dates (b, d) according to age groups (horizontal lines: stopover durations)

*3. ábra* Éven belüli fogás (fekete oszlopok) és visszafogás (szürke oszlopok) gyakoriságok (a, c) és az egyedek első megfogási idejének kumulatív eloszlása (b, d) korcsoportonként (vízszintes vonalak: tartózkodási idők)

*Table 5.* Descriptive statistics of tail length (mm)
*5. táblázat* A farokhossz (mm) leíró statisztikái

| Season | Age | Mean | Median | SD | Min | Max | N |
|---|---|---|---|---|---|---|---|
| spring | adult | 60.2 | 60 | 2.5 | 51 | 68 | 13356 |
| autumn | adult | 60.3 | 60 | 2.6 | 52 | 69 | 3169 |
| autumn | juvenile | 60.0 | 60 | 2.6 | 51 | 69 | 18469 |

*Table 6.* Descriptive statistics of body mass (g)
*6. táblázat* A testtömeg (g) leíró statisztikái

| Season | Age | Mean | Median | SD | Min | Max | N |
|---|---|---|---|---|---|---|---|
| spring | adult | 15.9 | 15.9 | 1.2 | 11.7 | 22.7 | 13947 |
| autumn | adult | 16.3 | 16.2 | 1.4 | 11.9 | 22.3 | 3297 |
| autumn | juvenile | 16.1 | 15.9 | 1.3 | 11.6 | 23.7 | 19155 |

## Migration timing

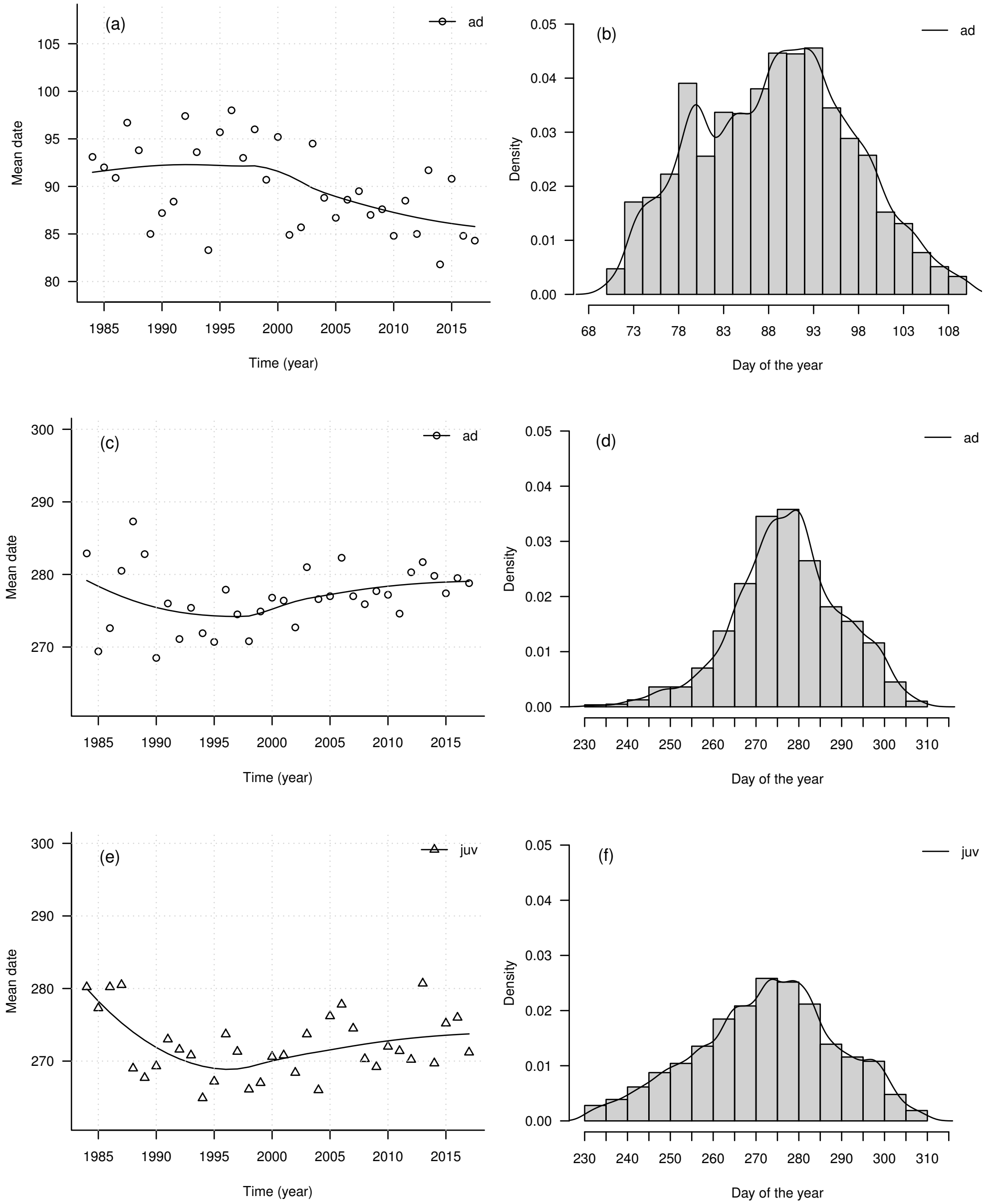


*Figure 4.* Annual mean migration timing (day of the year) throughout the study period and histograms/smoothed histograms of timing in spring (a–b) and in autumn (c–f)

*4. ábra* Az éves átlagos vonulás időzítés (év napja) a vizsgálati időszakban és az időzítés hisztogramja/simított hisztogramja tavasszal (a–b) és ősszel (c–f)

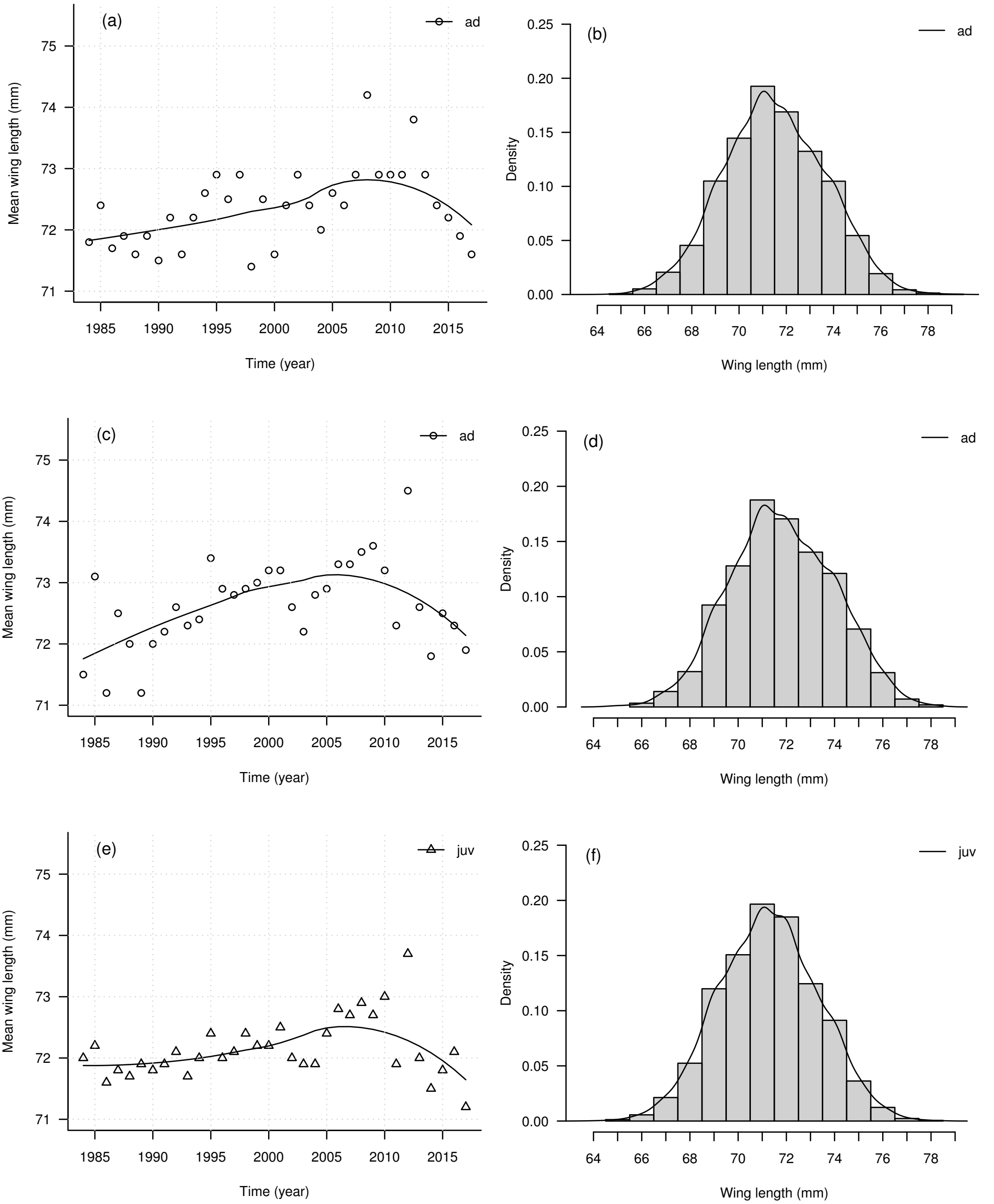


*Figure 5.* Annual mean wing length (mm) throughout the study period and histograms/smoothed histograms of wing length in spring (a–b) and in autumn (c–f)

*5. ábra* Az éves átlagos szárnyhossz (mm) a vizsgálati időszakban és a szárnyhossz hisztogramja/simított hisztogramja tavasszal (a–b) és ősszel (c–f)

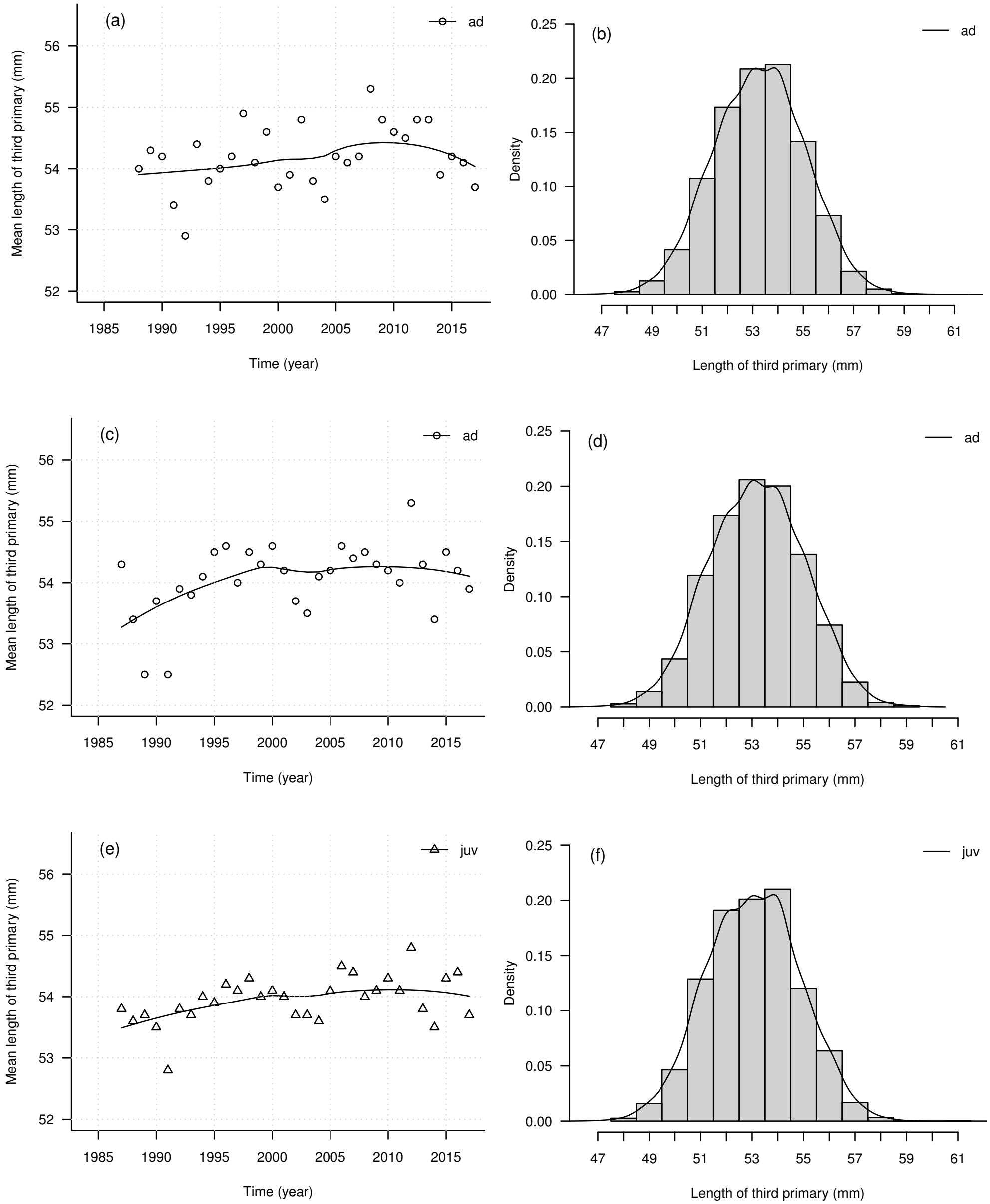


*Figure 6.* Annual mean third primary length (mm) throughout the study period and histograms/smoothed histograms of third primary length in spring (a–b) and in autumn (c–f)

*6. ábra* Az éves átlagos harmadik evező hossz (mm) a vizsgálati időszakban és a harmadik evező hosszának hisztogramja/simított hisztogramja tavasszal (a–b) és ősszel (c–f)

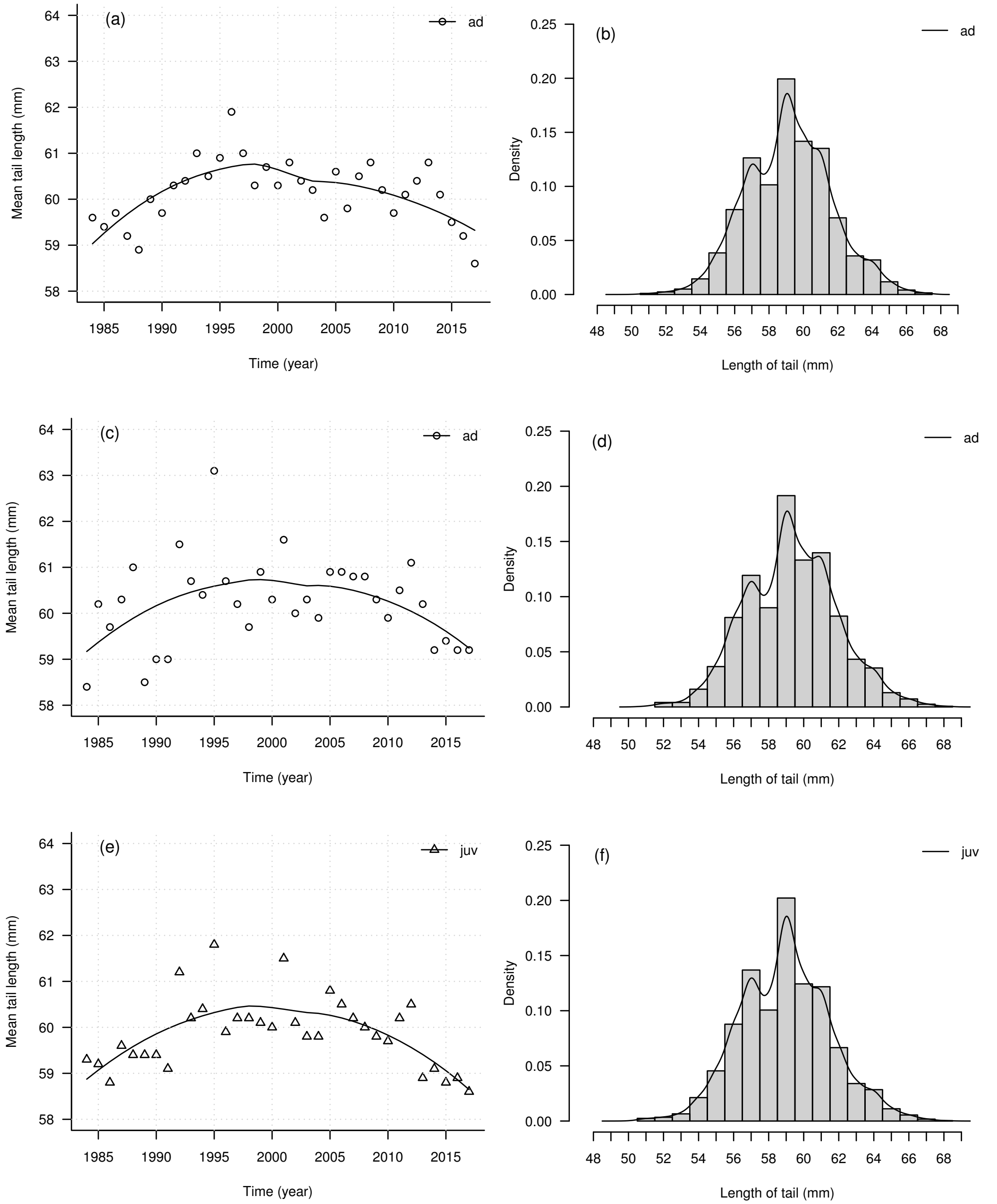


*Figure 7.* Annual mean tail length (mm) throughout the study period and histograms/smoothed histograms of third primary length in spring (a–b) and in autumn (c–f)

*7. ábra* Az éves átlagos farokhossz (mm) a vizsgálati időszakban és a farokhossz hisztogramja/simított hisztogramja tavasszal (a–b) és ősszel (c–f)

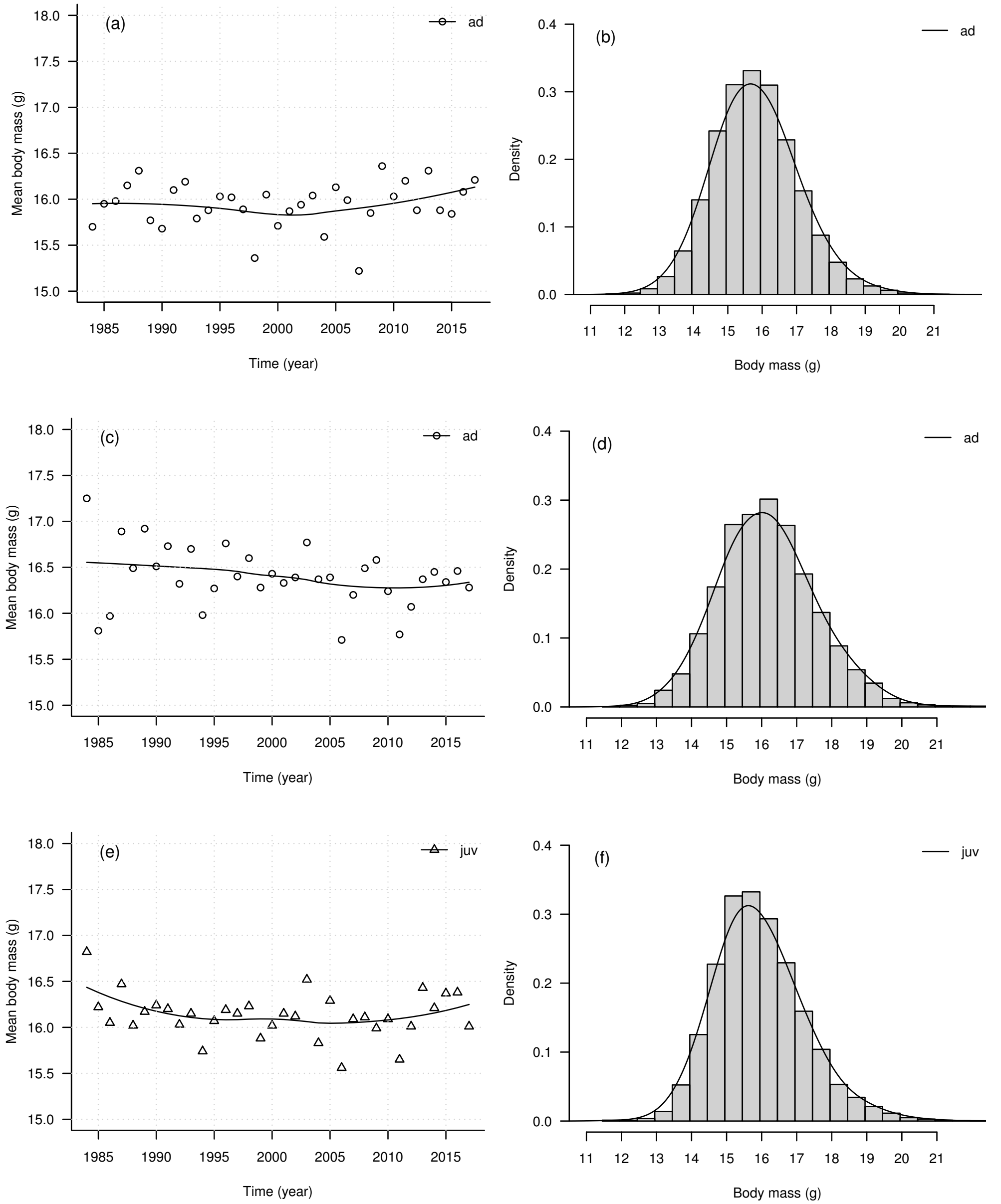


*Figure 8.* Annual mean body mass (g) throughout the study period and histograms/smoothed histograms of body mass in spring (a–b) and in autumn (c–f)

*8. ábra* Az éves átlagos testtömeg (g) a vizsgálati időszakban és a testtömeg hisztogramja/simított hisztogramja tavasszal (a–b) és ősszel (c–f)

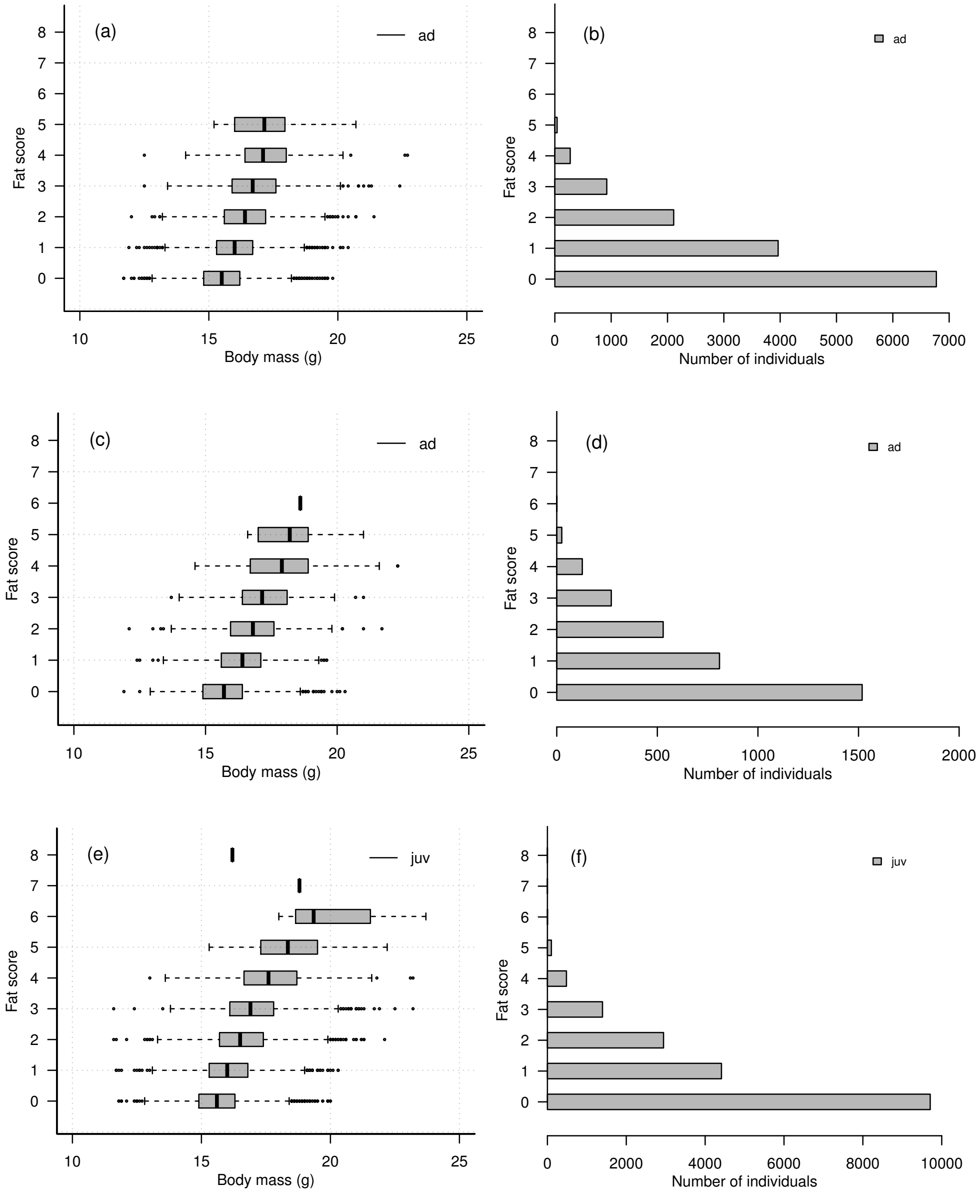


*Figure 9.* Boxplots of body mass according to fat score, and fat score frequencies in spring (a–b) and in autumn (c–f)

*9. ábra* A testtömeg boxplot-ja zsírkategóriánként és a zsírkategóriák gyakoriságai tavasszal (a–b) és ősszel (c–f)

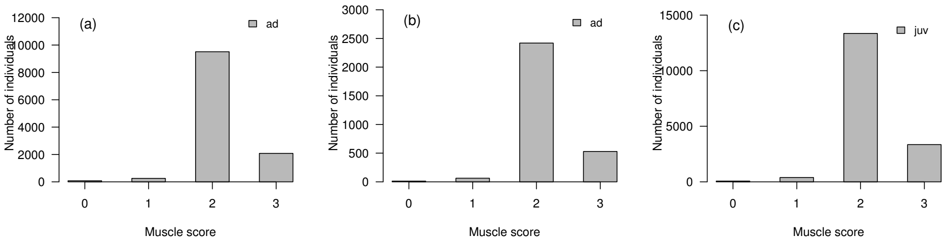


*Figure 10.* Muscle score frequencies in spring (a) and in autumn (b–c)
*10. ábra* Izom kategória gyakoriságok tavasszal (a) és ősszel (b–c)

## Discussion

The exploratory analyses of timing and morphometrics of the Robin revealed several patterns of interest. Apparently, there is considerable variation in inter-annual capture and recapture frequencies *(Figure 2 a,b)* with an growing trend *(Figure 2 a)* in both seasons probably due to the increased capture effort end extended working seasons after 2001 (Csörgő *et al.* 2016). Beyond this increase, the number of captured birds is highly variable, probably due to the variability in the number of trans-migrants in different years. The stopover durations are similar in all cases, only the juveniles stay 1 day longer than the adults in autumn *(Figure 3 b,d, Table 2).*

The birds appear in greater numbers in both seasons, but the amount of juveniles greatly exceeds the amount of the adults in autumn, and there are four times more adults in spring than in autumn, which can be a result of potential local loop migration. The existence of a few captures of all age groups during the breeding season corroborates that there is a small local breeding population at the study site *(Figure 3 a,b).*

The spring migration timing appears to be more or less constant before 2000 and slightly decreasing after *(Figure 4 a)*, the autumn timing hits a bottom in the middle of the 1990's, than it slightly increasing. Both trends after 2001 are probably due to the extended working seasons (Csörgő *et al.* 2016). Timing of the adults is a bit delayed compared to that of the juveniles in the autumn *(Figure 4 c,e)*. The distribution of arrival timing in spring has two peaks and the distributions are broadened at larger values in case of autumn timings. Both cases are probably the result of the previously mentioned changed working seasons *(Figure 4 b,d,f)*. There are apparent increasing trends over the years both in the wing length and in the third primary length of the birds, which can be the result of the extended working seasons, since usually larger birds arrive earlier in spring and leave later in autumn *(Figures 5–6 a,c,e).*

Tail length seems to peak around the late 1990's, although with a considerable inter-annual variation *(Figure 7 a,c,e)*. The mean body mass is more or less constant over the years *(Figure 8 a)*, however a slight decreasing trend can be observed during the autumn season in case of the adult birds *(Figure 8 c,d).*

The biometric variables except the slight bimodality of the tail length have unimodal distribution indicating that there is no considerable size difference between the sexes *(Figure 5–8 a,c,e)*.

The fat score distributions suggest that the birds can accumulate fat reserves, and it is more pronounced in spring than in autumn *(Figure 9)*. Muscle score distributions suggest that the birds also build their muscles in both seasons *(Figure 10)*.

Our results show that comprehensive exploratory analyses may reveal intriguing patterns, which may be investigated in more detail in the future. However, we emphasize that although the temporal extent of the data reported here is considerably large, all information presented here derives from a single location and thus has to be interpreted accordingly. Nonetheless, we hope that our results will help researchers conducting comparative or meta-analyses with baseline data and may also encourage others to report their data in a similar fashion. We also seek cooperation with interested parties and are willing to share all data reported here. Please contact the corresponding author for details.

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