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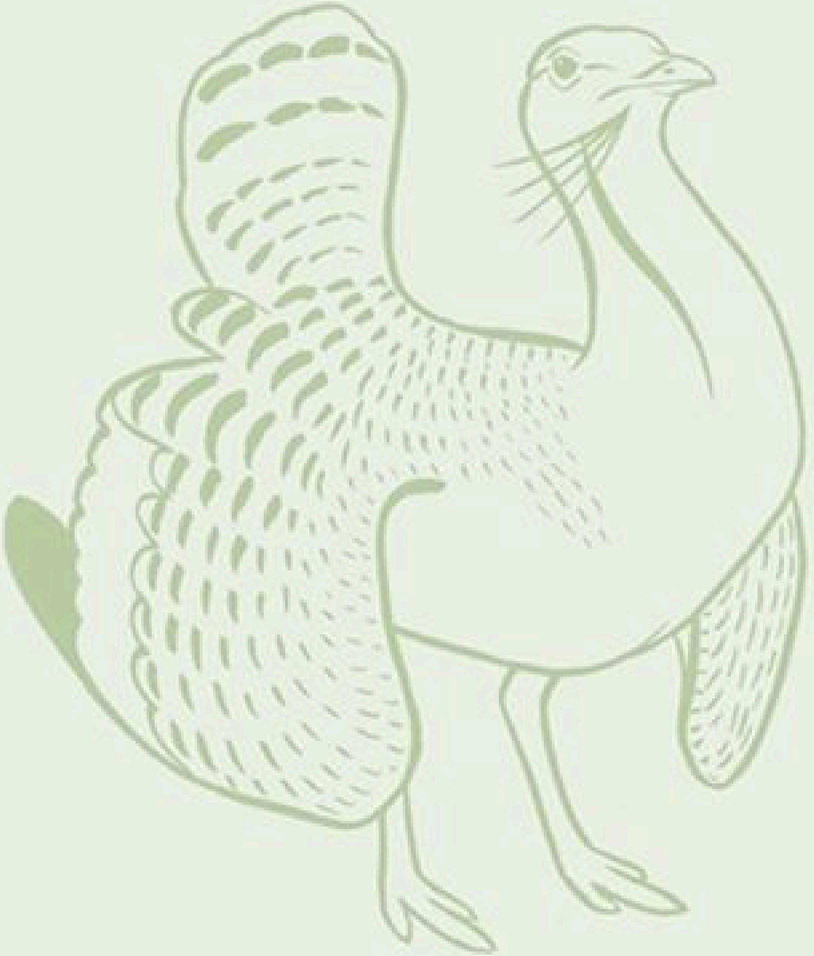

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Preserving an obscure bird: achievements and future challenges of Corncrake (*Crex crex* Linnaeus, 1758) conservation in Hungary

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István Szentirmai, Sándor András Boldogh, Károly Nagy, Béla Habarics & Tibor Szép 2016. Preserving an obscure bird: achievements and future challenges of Corncrake (*Crex crex* Linnaeus, 1758) conservation in Hungary. – Ornis Hungarica 24(2): 1–17.

Abstract The Corncrake is a strictly protected species in Hungary and a qualifying species of many Natura 2000 sites. Despite its Least concern global conservation status, it receives much attention and was elected as “Bird of the Year” by MME BirdLife Hungary in 2016. In this paper, we estimate its population trends and analyse the suitability of the protected area system and agri-environment schemes for the species. We compiled information on major threatening factors and conservation measures applied for the species. We reviewed international publications on the ecology and conservation management of the species to extract information for practical conservation. We estimated that 500–2000 pairs of Corncrakes breed in Hungary. Although their breeding sites are well covered by protected areas, Natura 2000 sites (42%) and High Nature Value Areas (67%), their population has declined by 55% over the last 20 years. We found that most of the major threatening factors are addressed by conservation management, and appropriate measures are applied in most cases. Recent research findings and recommendations by the BirdLife International Corncrake Conservation Team suggest that mowing of grasslands around nesting places should be delayed until 1–15 August either in the entire field or at least on 2 hectares around nests. Prescriptions of agri-environment schemes should also be adjusted to the above requirements and more farmers should be encouraged to enrol in Corncrake conservation programmes. We strongly suggest that more emphasis should be devoted to combat important threats for the most important breeding sites such as aridification and flooding.

Keywords: population trend, agri-environment scheme, conservation measures, delayed mowing, refuge stripe

Összefoglalás A haris fokozottan védett faj, és jelölőfaja számos Natura 2000 területnek Magyarországon. Annak ellenére, hogy globálisan nem veszélyeztetett, hazánkban mégis jelentős figyelmet kap, és a Magyar Madártani és Természetvédelmi Egyesület programjában is elnyerte a 2016-os „év madara” címet. Jelen tanulmányban megbecsültük jelenlegi állománynagyságát, és elemeztük annak változásait, valamint vizsgáltuk, hogy mennyire megfelelő a védett és Natura 2000 területek, valamint a Magas Természeti Értékű Területek (MTÉT) elhelyezkedése a haris számára. Összegyűjtöttük a faj számára legjelentősebb veszélyeztető tényezőket, és az érdekében alkalmazott természetvédelmi intézkedéseket. Felkutattuk a nemzetközi szakirodalmat, és kigyűjtöttük azokat az ökológiai és természetvédelmi biológiai információkat, melyek segíthetik a faj gyakorlati védelmét. Eredményeink szerint hazánkban 500–2000 pár haris költ évente. Bár a védett, Natura 2000 (42%) és MTÉT (67%) területek nagy arányban fedik le a haris költőhelyeit, állománya mégis 55%-kal csökkent az elmúlt 20 év során. A természetvédelmi intézkedések reagálnak a faj legfőbb veszélyeztető tényezőire, és az alkalmazott kezelések többsége is megfelelő. A legfrissebb kutatások és a BirdLife International Harisvédelmi Csoportjának ajánlása szerint a fészkek körüli kaszálást augusztus 1–15-ig szükséges elhalasztani, vagy az egész gyepterületen, vagy legalább 2 hektáron. Az agrár-környezetgazdálkodási programok előírásait is a fentiekhez kell igazítani, és kívánatos volna minél több gazdát ösztönözni a programokban való részvételre. Kiemelten szükséges, hogy a természetvédelem olyan veszélyeztető tényezőkkel is foglalkozzon, mint például a legfontosabb élőhelyeket érintő szárazodás és az elöntések általi károkozás.

Kulcsszavak: populációs trend, agrár-környezetgazdálkodás, természetvédelmi intézkedés, késői kaszálás, búvósáv

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Introduction

The Corncrake *(Crex crex)* deserves special attention from ornithologists and conservationists for several reasons. It was elected as "*Bird of The Year*" in 2016 in the programme of the MME BirdLife Hungary, as it received more votes than the Quail *(Coturnix coturnix)* or the Eurasian Stone-curlew *(Burhinus oedicnemus)*. In addition, Corncrake has a controversial conservation status, being a strictly protected species in Hungary (Ministry of Environment Decree No. 13/2001) and a Least Concern species in the Red List of IUCN (BirdLife International 2015). Furthermore, a decade has passed since the last comprehensive summary on the conservation biology of the Corncrake was published (Koffijberg & Schäffer 2006), and a considerable amount of experience in practical conservation has been accumulated by now (see for example the special issue of Vogelwelt 136).

On the one hand, Corncrake is a priority species in Hungarian nature conservation, being strictly protected by law and a qualifying species of several Special Protection Areas (SPA) of the Natura 2000 network. On the other hand, IUCN has recently downgraded the Corncrake to the Least Concern category on its Red List, mainly due to emerging information on large (1.515–2.740 million pairs) and stable Eastern European and Russian populations (BirdLife International 2015). Although this assessment was mainly based on expert opinion, a recent study, using species distribution modelling supported its outcome (Fourcade *et al.* 2013). These results may undermine the importance of conservation actions in Western and Central Europe from a global perspective. In spite of the IUCN assessment, some authors argue that our European populations still deserve attention and conservation efforts. Koffijberg *et al.* (2016) points out that Western and Southern European populations are still declining. In addition, agricultural intensification in the western part and land abandonment in the eastern part of the species' range is still ongoing and both processes may cause further habitat loss in the future. Authors also point to the uncertainties of population estimates from large populations (e.g. Russia), which make trends and future prospects difficult to assess. Another aspect of global Corncrake protection is the relationships and connections between distinct populations. A recent study found very low genetic structure and high genetic diversity across European populations, indicating that there may be intensive gene flow between populations (Fourcade *et al.* 2016). The authors argue that dispersion from eastern populations may be an important means of maintaining the declining populations in the West. Therefore, we believe that the Hungarian Corncrake population is worth the efforts of nature conservation and that its management should be further developed.

Current knowledge on the biology and threatening factors of Corncrake were summarised by researchers by the early 2000s (Green *et al.* 1997, Schäffer & Koffijberg 2004), and a European conservation action plan was released in 2006 (Koffijberg & Schäffer 2006). Although these documents provided a solid basis for practical conservation, several studies have been published on the species and a large amount of experience has been gathered in conservation management since the time of their publication (see papers in the special issue of Vogelwelt 136).

Opportunities for Corncrake conservation have changed considerably in Hungary over the last decade. The Natura 2000 network of the European Union was designated and incorporated into national legislation, including several SPAs declared for the protection of the species (Government Decree No. 275/2004). Within the framework of agri-environment schemes, High Nature Value Areas (HNVA) were also established and some programmes targeted the Corncrake as well (Rural Development Programme 2015–2020). From 2003 onwards, the number and total area of HNVA have been gradually increasing and their prescriptions improving.

In this paper, we attempt to evaluate the conservation status and future prospects of Corncrakes after two decades of extensive conservation efforts in Hungary by (i) estimating population trends, (ii) analysing the suitability of the protected area system and agri-environment schemes for the species and (iii) compiling information on major threatening factors. We collected and evaluated conservation measures applied for the species by conservation managers. We reviewed international research papers published on the ecology and conservation management of the species over the last 10 years to extract information that can help improving our practices in Hungary.

Materials and methods

Population trends

The Corncrake was a common bird in Hungary previously (Chernel 1899), but it became rare by the 1970s and 1980s (Szép 1991, Horváth 1998). Based on data from the Common Bird Monitoring (MMM) of Hungary during 1999–2012 (Szép *et al.* 2012), the Corncrake is a rare breeding species in Hungary with a mean frequency of 2.6% (*SE: 0.6*). Between 167 and 1020 Corncrakes were recorded annually during 2007–2015, thus the size of the breeding population may currently be estimated at 500-2000 breeding pairs (MME BirdLife Hungary 2016). The majority of the population breeds in the northern and north-eastern part of the country, where the four most important regions are (i) Aggtelek National Park and its surroundings, (ii) small river valleys in the Zemplén Mountains, (iii) the floodplain of Tisza and Bodrog Rivers and (iv) Szatmár-Bereg (Wettstein 1999, Boldogh & Szentgyörgyi 2003, Wettstein & Szép 2003, Boldogh *et al.* 2009) *(Figure 1)*.

For proper monitoring of population trends, specific schemes such as the Monitoring of Rare and Colonial Birds (RTM) (Szép & Waliczky 1993) can provide data from populations that breed in specific regions. During the field surveys, international guidelines and methods

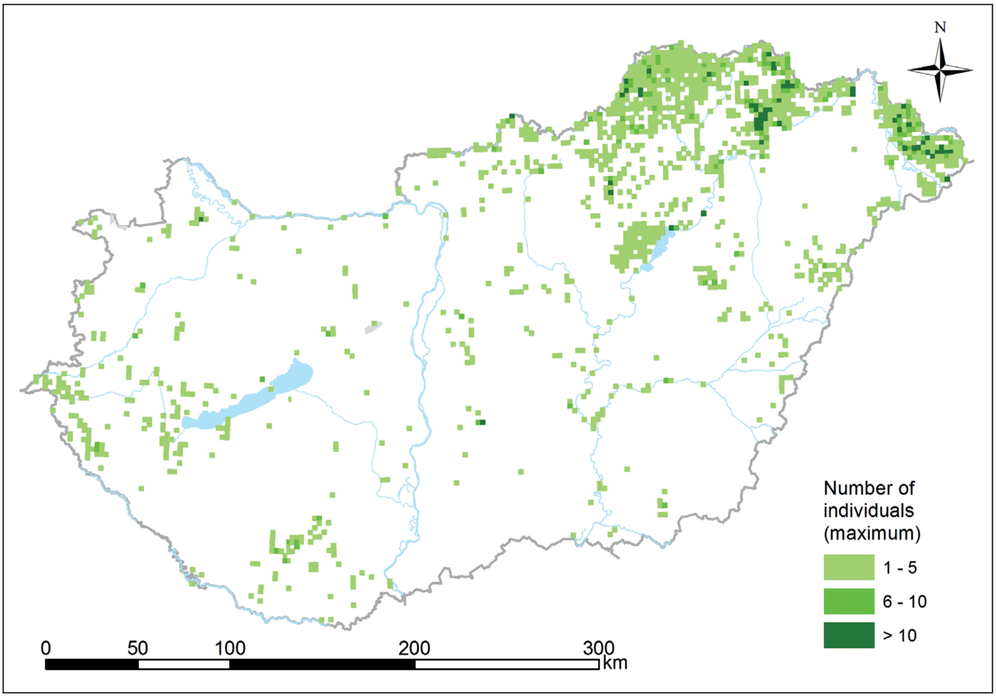

Figure 1. Distribution of Corncrakes in Hungary in 1997–2016
1. ábra A haris elterjedése Magyarországon 1997–2016

were followed (Schäffer & Mammen 2003). The study areas are described elsewhere (see Boldogh *et al.* 2016a for details). To estimate long term population trends, we used data from Szatmár-Bereg and Aggtelek, two of the most important breeding sites in Hungary, between 1997 and 2016.

Annual population trends were calculated using TRIM software (Pannekoek & van Strien 2001), which allows for missing counts in the time series and produces unbiased yearly indices and standard errors using Poisson regression (log-linear models; McCullagh & Nelder, 1989). TRIM is used frequently in the case of national common bird monitoring schemes in Europe (Gregory *et al.* 2008). In the two studied populations, we used annual counts within the 2.5×2.5 km UTM squares for trend analysis. In the case of the population of "*Szatmár-Bereg*", 141 idividual 2.5×2.5 km UTM squares were surveyed, of which 12 did not have any positive observation of Corncrake. For the population of "*Aggtelek*", 167 UTM were surveyed, of which 21 did not have any positive observation.

For the trend modelling, we used the basic "Time Effect" model of the TRIM (expecting effects for each site and year) (Pannekoek & van Strien 2001). Wald-test implemented in the TRIM was used to test similarity in the annual changes of the population indices of the two studied populations. Missing counts of particular sites were estimated ('imputed') from changes in all other sites (Pannekoek & van Strien 2001). The TRIM produced imputed yearly indices with its 95% confidence intervals. The first year of the survey (breeding season: 1997) was the base year with a value of 100% and all other indices were calculated relative to this reference point. In addition, serial correlation was taken into account. The estimated slopes of the population trend (mean annual change based on multiplicative slope of imputed data with 95% confidence intervals, TRIM) reflect average percentage change per year. The overall slope estimate in TRIM software is converted into discrete categories (trend classification, van Strien *et al.* 2001). The category depends on the overall slope as well as on its 95% confidence interval. When the trend was not significant and the confidence intervals were sufficiently small, the species was classified as a stable population.

Conservation status

We used the database of MME BirdLife Hungary to investigate the coverage of Corncrake breeding sites by nationally protected areas and Natura 2000 sites. Since the distribution data of Corncrake is stored on a 2.5×2.5 km grid basis, we overlapped squares occupied by Corncrakes with the area of protected areas and Natura 2000 sites and then calculated the percentage of area where they intersect. Then we calculated the percentage of the breeding populations that is recorded from UTM squares overlapping with protected or Natura 2000 areas. We used ArcMap 10.2.1 GIS software for all spatial analyses. We studied agri-environment schemes and analysed whether they have relevant prescriptions for Corncrakes. Then we calculated the overlap between areas involved in agri-environment schemes with relevant prescriptions and the distribution area of the Corncrake the same way as described above for protected areas.

Questionnaire survey

To collect data on threatening factors to Corncrake and conservation measures that are applied for the species, we conducted a questionnaire survey among the experts of national park directorates. Corncrake experts were asked to list the most important current threats by regional breeding sites. They were asked to provide information on the importance and extent of each threat within each breeding site. Importance was categorised as high, medium and low, depending on the supposed severity on the performance of the population. Extent was defined as the percentage of area affected by the threat within the breeding site. In addition, experts were also asked to list those conservation measures that are applied to secure the persistence of Corncrake populations for each breeding site and indicate the percentage of the breeding population to which the measure is applied.

Altogether, we received data from 10 national park directorates, from 34 breeding sites. These breeding sites represented the Hungarian Corncrake population well enough, because only some minor populations were missed out due to the lack of regular monitoring and conservation management. From questionnaires, we calculated the number and percentage of breeding sites for each threatening factor, where it was found to be of either high, medium or low importance. Similarly, we calculated the number and percentage of breeding sites for each conservation measure, where it was applied, and the mean of the percentage of populations per breeding site to which it was applied. Note that more than one threatening factor may be in effect and more than one conservation measure can be applied within a single breeding site.

Results

Population trends

The trend analysis showed that the size of the two studied breeding populations was similar and varied in a similar range during the studied period of 1997–2016 ("Aggtelek": 15–260 pairs, "Szatmár-Bereg": 53–286 pairs, TRIM). The population indices of the two breeding populations showed large annual fluctuation, but varied significantly differently (*Wald-test*: 342.33, *df*=19, *P*<0.001, TRIM) *(Figure 2)*. The breeding population of "Szatmár-Bereg" showed a steep population decline (mean annual change: -9.9% (minimum: -11.3%, maximum: -8.5%, *P*<0.01, TRIM), whereas the population of "Aggtelek" had a large annual fluctuation with a stable trend over the studied period (mean annual change: -0.7%, minimum: -1.7%, maximum: 0.3%, *P*<0.01, TRIM). The "Szatmár-Bereg" population declined by 86% (81%–90%) during the studied 20 years, whereas this value was not significant for the population of "Aggtelek" (mean: -12%, minimum: -27%, maximum 5%).

The overall population trend of the Corncrake, based on these two populations, showed significant moderate decline (mean annual change: -4.1% (minimum: -4.9%, maximum: -3.4%, *P*<0.01, TRIM). The population in these two regions declined by 55% (48%–61%) during the studied 20 years.

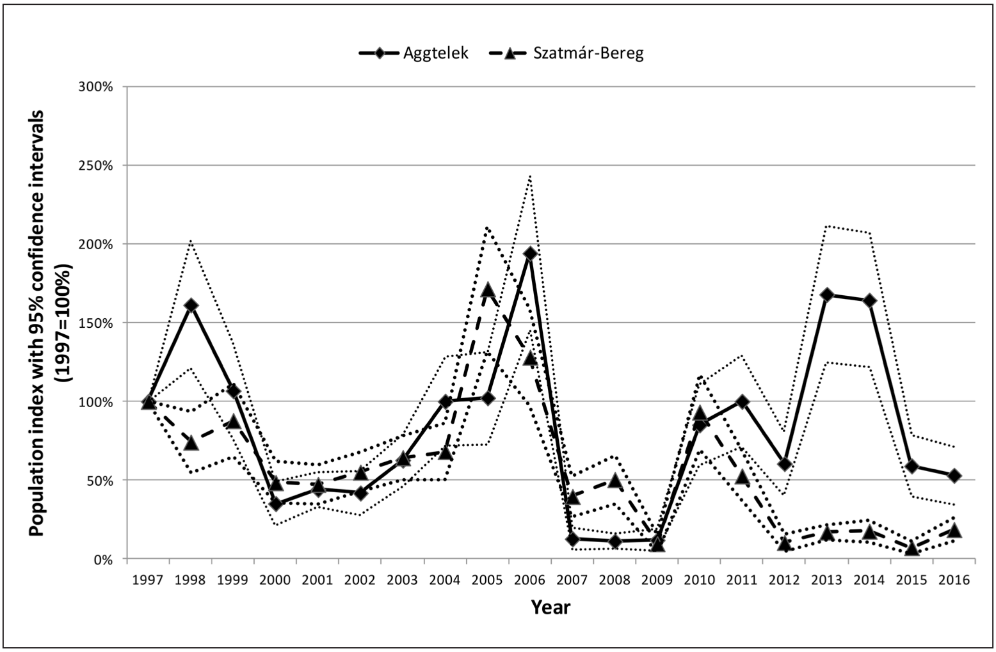

Figure 2. Population indices of the two studied breeding populations (Aggtelek, Szatmár-Bereg) during 1997–2016. Annual population index with 95% confidence intervals, estimated with TRIM, are given for both populations

2. ábra A két vizsgált fészkelő populáció (Aggtelek, Szatmár-Bereg) populációs indexe azok 95%-os konfidencia intervallumaival, TRIM által becsülve 1997–2016 között

Conservation status

Forty-one percent of the breeding area of Corncrakes was covered by Natura 2000 sites, including both Special Protection Areas (SPA) and Special Areas of Conservation (SAC). UTM quadrats overlapping with Natura 2000 sites harboured 20% of the breeding population. Eighteen percent of the breeding area was covered by nationally protected areas, including national parks, landscape protection areas and protected areas, and 13% of the population bred within UTM quadrats overlapping with protected areas. UTM quadrats overlapping with protected areas or Natura 2000 sites together covered 42% of the distribution area and harboured 22% of the breeding population.

There are three agri-environment packages in the 2016–2020 programme with relevant prescriptions to Corncrakes (Rural Development Programme 2015–2020). The "Horizontal Grassland Package" is available for farmers of any grassland in the country. Although the Corncrake is not a target species of this package, the following optional measures are beneficial to the species: "bird-friendly mowing" and leaving 5–10% or 10–15% unmown as a refuge area during each cut. The "Lowland Bird Conservation Package" and the "Upland Bird Conservation Package" are available within certain HNVA, and Corncrake is a target species of these packages. According to the prescriptions of the "Lowland Bird Conservation Package", 50% of grasslands have to be mown or grazed after 1 July, "bird-friendly mowing" has to be applied, 10–15% unmown area should be left during each cut, and at least 1 ha protective zone should be left unmown around the nests of protected birds in the case if they are discovered either by the farmer or national park directorate staff. The "Upland Bird Conservation Package" contains the same Corncrake-related prescriptions, except that 50% of grasslands have to be mown or grazed after 31 July.

Forty percent of Corncrake breeding areas overlapped with HNVA with relevant packages for the species. While 23% of the breeding area was within eligible areas for the "Upland Bird Conservation Package", only 18% was eligible for "Lowland Bird Conservation Package". Consequently, 67% of the total population bred within areas where any relevant agri-environment package is available, 47% within areas eligible for the "Upland Bird Conservation Package" and 20% within eligible areas for "Lowland Bird Conservation Package".

Current threats

Nine major threatening factors to Corncrakes were identified by the experts of national park directorates *(Table 1)*. By far the most common threat was mechanised mowing during the breeding season, occurring in 83% of breeding sites. Less widespread threats were grazing during the breeding season (13%), encroachment of grassland by bushes and aridification of grassland habitats (10%), which lead to inadequate cover for Corncrakes. The rest of the threats were restricted to only a few breeding sites, although they can be important there.

Mowing and grazing during the breeding season were also experienced as threats of high importance in the majority of breeding sites, whereas low importance is attributed to encroachment and medium importance to aridification in most breeding sites *(Table 2)*. In addition, these four threats acted over a high proportion (19–50%) of the area within breeding sites.

It is also important to note that some of the less widespread threats may be of high importance if they affect large numbers of Corncrakes. Flooding, for example, is a serious problem in the Bodrogzug, the most important breeding site in Hungary. Similarly, man-made fires during the spring happen more and more frequently in the northern part of the breeding range, where a significant part of the population breeds.

Applied conservation measures

Based on the information provided by national park directorates, there were three main groups of conservation measures that are currently applied for Corncrakes. The most important one was the restriction of mowing during the breeding season, which has several variants *(Table 2)*. This measure varied both in the area of the restriction and the date until when mowing was delayed. In most breeding sites (49%), the restriction was often applied to the entire field in which calling males were detected, whereas the second most widespread measure was when restriction was applied often to more than 2 ha around the calling place (43%). In most breeding sites (74%), mowing was often delayed until 15 August, or until 1 August, which was applied much less frequently (23%). In the most important breeding sites of Aggtelek, Bodrogzug and Szatmár-Bereg, mowing was delayed until 1 or 15 August in at least 2 hectares. In most breeding sites, several different measures were applied depending on protection status and ownership of grasslands. Very often it was impossible to apply a measure to every one of the known nesting places.

Table 1. Major threatening factors to Corncrakes in Hungary based on expert opinion of national park managers. Values of impact indicate the number of breeding sites from where the respective threat was reported as of high, medium or low importance. Values of extent indicate the mean percentage of area within breeding sites where the respective threat was detected

1. táblázat A harist veszélyeztető legfőbb tényezők a nemzeti park igazgatóságok szakembereinek véleménye alapján. A megadott értékek azoknak a költőterületeknek a számát mutatják, ahonnan az adott tényezőket jelentős, közepes vagy alacsony jelentőségűként jelezték, valamint annak a területnek az arányát, ahol a tényező kifejti a hatását

Threat	**Impact/extent number of sites/percentage of area**			
	high	***medium***	***low***	***sum/mean***
mowing	18/34	6/42	6/6	30/30
grazing	6/30	3/13	4/8	13/19
encroachment	2/35	1/40	9/16	12/21
aridification	3/63	6/51	1/5	10/50
grassland conversion	0	1/10	2/2	3/5
spring burning	0	3/6	1/1	4/5
flooding	1/100	3/30	0	4/48
nest predation	1/100	0	2/18	3/45
intensification	0	0	1/15	1/15

Restricted grazing was applied in the territory of Kiskunság National Park, where grazing was the most typical management of grasslands. Since grazing is usually carried out on large areas at the same time, restrictions were also applied to entire fields or grazing districts. Grazing was most often delayed until 15 July, but sometimes also until 1 or 15 August.

Habitat reconstruction or improvement was conducted only in three breeding sites. In Aggtelek National Park, formerly important habitats were reconstructed by removing bushes and degraded reed beds from 40 hectares. In parallel, 4 km of fire lines were constructed to protect managed areas and maintain an appropriate vegetation structure for arriving Corncrakes in spring. In the Lower-Tisza Valley, an extra water supply was provided to grasslands, and arable fields were converted to grasslands to increase the area of potential habitats. In Őrség National Park, large old fields and sown grasslands were improved via the creation of permanent refuge strips, increasing the variety of vegetation by variable mowing times and creating shrub edges within Corncrake habitats.

Table 2. Conservation measures applied to secure breeding success of Corncrakes in Hungary. The number of breeding sites where it is in use and the mean percentage of nesting sites affected by it within each site is shown for each measure

2. táblázat A haris sikeres költése érdekében alkalmazott természetvédelmi intézkedések Magyarországon. A táblázatban azoknak a költőhelyeknek a számát, illetve a költőhelyeken belül annak a területnek az arányát adjuk meg, ahol az adott intézkedést alkalmazzák

Conservation measures	**Earliest date of mowing or grazing**	**Number of sites/percentage of area**
Restricted mowing		
entire field	15 Aug	13/49
entire field	1 Aug	2/38
entire field	15 July	4/33
> 2 ha	next year	1/30
> 2 ha	15 Aug	11/61
> 2 ha	1 Aug	3/82
2 ha	15 Aug	4/85
2 ha	1 Aug	3/22
2 ha	15 July	1/10
1 ha	15 Aug	6/33
1 ha	1 Aug	2/40
1 ha	20 July	1/100
Restricted grazing		
entire field	15 Aug	1/50
entire field	1 Aug	1/70
entire field	15 July	2/20

New insights from scientific literature

Several works have been published on Corncrake ecology and conservation biology in the last 10 years. Here, we review those studies that have important implications for the practical conservation of the species.

Monitoring

The methodology of surveying Corncrakes is well established among experts (see papers published in the special issue of Vogelwelt 136), but minor differences may cause considerable discrepancies in population estimates. Budka and Kokociński (2015) compared three census methods by using them in parallel within 1×1 km study plots: (i) territory mapping, when the location of each calling male is recorded by GPS, (ii) point-based censusing, when the distance and direction to calling males from five points (corners and centroid) was estimated in each study plot, and (iii) middle-point counting, when calling males were counted from the same five points within four distance categories (0–50 m, 50–200 m, 200–500 m, 500–1000 m). Not surprisingly, territory mapping turned out to be the most accurate census technique. The middle-point counting method consistently underestimated population size, while the point-based census method overestimated population size when a small number of males were present within a study plot, but underestimated it when males were numerous.

Individual discrimination by male song was proposed as a potential way of population surveys (Kenyeres *et al*. 2000, Mikkelsen *et al.* 2013). Although it seemed to be an attractive and cost-effective method, a recent study, based on the recordings of 120 males, pointed out that it has severe limitations (Budka *et al.* 2015). The results of discrimination analyses, the statistical method used to assign song recordings to distinct individuals, are only reliable if the number of males is known prior to the analysis. This is, however, usually not the case when monitoring populations. It was shown that the method tends to underestimate populations if they consist of numerous individuals.

Habitat requirements

Understanding habitat requirements has always been a key issue in Corncrake conservation. Although the fundamentals of Corncrake's ecology were laid down long time ago (reviewed by Schäffer & Koffijberg 2004, Koffijberg & Schäffer 2006), several interesting findings have emerged in the last decade. A study in Scotland documented that Corncrakes were attracted in highest numbers by so-called cover areas that were specifically managed to provide vegetation tall enough throughout the breeding season (Corbett & Hudson 2010). Fewer Corncrakes could be found in silage and hay fields and none in long-term set-asides without any management. These results are straightforward with regard to cover areas and managed fields based on previous studies (see references in Koffijberg & Schäffer 2006), but are somewhat surprising in the case of set-asides. The authors of the study proposed that the sward of abandoned grasslands becomes too dense to allow the movements of Corncrakes and are therefore avoided by them (see also Tyler 1996, Green *et al.* 1997). In line with this latter argument, Grishchenko and Prins (2016) found in Russia that calling males were present in the highest density in old fields abandoned 5–15 years ago, whereas their density steeply declined after this period.

Several studies showed a shift in habitat preference of calling males between their first and second breeding attempt within the same season (Brambilla & Pedrini 2011, Budka & Osiejuk 2013). Males in the Italian Alps were more numerous at lower elevation sites (< 1000 m) during the first half of the breeding season, and at higher elevation sites (> 1000 m) during the second half (Brambilla & Pedrini 2011). The shift is most likely explained by changes in habitat suitability, i.e., earlier-mown lower sites become unsuitable, whereas a slower-growing vegetation in higher meadows reach the required height by the middle of the breeding season (see also Delov & Iankov 1997). Males in Eastern Poland preferred abandoned meadows at the beginning of the breeding season, and the proximity of bushes increased the chance of site occupancy (Budka & Osiejuk 2013). In the second part of the breeding season, however, extensively mown meadows were the most common habitat in the territory of male Corncrakes. This phenomenon is also attributed to the fact that vegetation of mown meadows provides enough cover by the second part of the season.

The broader landscape also matters for Corncrakes as shown by a recent study in Transylvania, Romania (Dorresteijn *et al.* 2015). Here, breeding Corncrakes preferentially occupied areas where landscape heterogeneity was high at the 100 ha scale. A simulation model indicated that a loss of only 35% of this landscape diversity may result in a 66% decrease in the availability of suitable habitats. An observation in the Italian Alps also supported the predictions of this model, because the Corncrake population declined in parallel with the introduction of agricultural subsidies that promoted mowing in all fields within the same period. This, therefore, reduced the diversity of vegetation structure available in the area (Brambilla & Pedrini 2013).

Dispersion

It is well known that male Corncrakes may travel large distances within a breeding season, which has important implications for conservation (summarised by Koffijberg *et al.* 2016). However, it is still unclear how frequent these dispersal events are and what factors drive males to leave their territory. The main reason for the lack of data on dispersal is the difficulty of catching and ringing Corncrakes in large enough quantities for traditional mark-recapture/recover studies. Although radio tracking offered an attractive alternative (e.g., Hoffmann 1997), there are some uncertainties in localising individuals beyond larger distances, since the area to be searched increases steeply with dispersal distance. Two alternative methods have recently been used to follow the movements of Corncrakes: satellite tracking and individual identification based on call discrimination.

Eight male Corncrakes were attached with satellite transmitters along the Czech-German border in 2012–2014. Satellite tracking allowed them to be followed throughout the breeding season and even during migration (Peške *et al.* 2015). All but one of these males remained in the same field until the autumn migration. One male left the breeding area after the field in which it was calling had been mowed, and after several stopovers it ended up in Hungary, 580 km away from its origin.

Song recognition may be a promising way of tracking the movement of individual males both within and between populations, as it requires much less resources than radio tracking, ringing or satellite tracking (Peake *et al.* 1998, Kenyeres *et al.* 2000, Peake & McGregor 2001). Detailed analyses of recordings, however, revealed that there is a relatively high likelihood of chance similarities between the songs of distinct males, especially in large populations (Mikkelsen *et al.* 2013, Budka *et al.* 2015). Therefore, results of song analyses should be used with caution to study dispersal behaviour in Corncrakes.

Another important aspect of dispersal is to understand its driving factors. Much evidence revealed that males were more likely to leave their breeding sites if mowing happened near their calling places (Van den Bergh 1991, Hoffmann 1997, Mikkelsen *et al.* 2013, Peške *et al.* 2015). Consequently, disturbance and habitat loss might be two of the main reasons for long-distance dispersal in this species.

Conservation management

In spite of the long history of Corncrake conservation, there is a shortage of well-documented management programmes, especially on the effectiveness of different conservation measures. One of the main reasons for the scarcity of evidence is the obscure life of this species, which makes the estimation of its breeding success almost impossible (Schäffer & Koffijberg 2004). Fortunately, the International Corncrake Conference in Pilsen, 2015, provided an excellent opportunity to share experiences from practical conservation programmes (BirdLife International Corncrake Conservation Team 2016).

One of the most thoroughly documented conservation programmes was conducted in Scotland, and resulted in the tripling of the Corncrake population in 30 years (Beaumont & England 2016). The basis of the programme was the establishment of so-called cover areas within protected areas, which provided vegetation tall enough throughout the breeding season. These were fields of 0.1–4 ha near hay or silage that were mown or grazed once a year after 1 August. Some of these cover areas were created artificially by fertilising the soil and then sowing or planting one or a combination of the following plants: cow parsley *(Anthriscus sylvestris),* stinging nettle *(Urtica dioica)* and yellow iris *(Iris pseudochorus)*. The protected areas where these measures were applied supported 10–15% of Corncrake population in the UK. Outside the protected areas, agri-environment schemes were introduced. Farmers enrolled into these programmes were subsidised to mow their meadows after 1 August or 15 August or 1 September and to create special cover areas. Since 1998, the majority of the UK Corncrake population has been covered by these agri-environment schemes.

After the collapse of the Corncrake population in Switzerland by 1970, a conservation programme was started by SVS/BirdLife Switzerland in 1996. The programme was based on the determination of exact calling places of males and then delayed mowing after 15 August on 1 ha around the calling place (Inderwildi 2016). After launching the programme, the breeding population increased considerably and 48% of all calling males were recorded from grasslands with conservation measures.

Refuge stripes have become an important instrument in the management of Corncrake habitats and have proven to be efficient in reducing mortality during mowing operations (Tyler *et al.* 1998). A recent study in Germany added further details to this measure by the radio tracking of adult and juvenile Corncrakes (Arbeiter *et al.* 2015). The results of this study suggested that refuge stripes should be at least 10 m wide, since the majority of Corncrakes (25–66%) stayed in the unmown area until its width went below this threshold. Refuge areas could provide not only temporal cover but also suitable habitat until the fledging of young birds, provided their width was between 10–30 metres.

Conclusions and recommendations for future conservation efforts

Based on the analyses of 2.5×2.5 km UTM grid distribution data, we found that 22% of the Hungarian Corncrake population breeds within either nationally protected areas or NATURA 2000 sites, where legal means are available to secure their breeding success. Even more, 67% breeds in HNVA, where relevant management prescriptions are applied to grasslands. These results should be interpreted by caution, because they do not take into account the exact location of breeding sites, so the number of pairs nesting in protected, NATURA 2000 or HNVA could be higher or lower. Our calculations are a rather rough estimation of the overlap between these areas and the distribution of Corncrakes.

In spite of the relatively good coverage of the population by areas with a good potential for Corncrake conservation, the Corncrake population seems to be steeply declining. One potential explanation for this contradiction might be that the decline is due the decline of subpopulations outside of protected areas. This is, however, unlikely, since the decline was detected exactly in the protected area of Szatmár-Bereg. Other reasons for the decline may be that either the conservation measures are not always applied, or the measures applied are not adequate. The first scenario may happen in HNVA, where farmers can participate in the agri-environment scheme on a voluntary basis, and therefore only a smaller portion of the eligible areas may be really managed for Corncrakes. In addition, prescriptions in the "Lowland Bird Conservation Package" are not entirely suitable for the species, since mowing is only delayed until 1 July. We know, however, that mowing before 1 August may still cause breeding failure, especially in the second broods (Green *et al.* 1997, Green 2010). It should also be considered that the Hungarian population is not independent from other populations, and influxes from eastern breeding areas may cause large fluctuations in Hungary (Fourcade *et al*. 2016, Koffijberg *et al*. 2016).

Conservation measures applied by national park managers both within and outside protected areas seem to address major threatening factors. In most breeding sites, including the most important ones in North-Eastern Hungary, mowing is delayed until 1 or 15 August on at least 2 hectares around calling places of males. This is in line with the most recent recommendations of the BirdLife International Corncrake Conservation Team (2016). In other cases, mowing or grazing is only delayed until 15 July and only 1 ha is left unmown around calling places of males, which both are insufficient to secure successful breeding (Green *et al.* 1997). Any conservation measure is, however, applied to only to 48% of all nesting pairs on average within breeding sites, which may further reduce their overall effectiveness *(Table 2)*. To enhance positive effects of conservation measures, two main steps could be recommended. First, more efforts should be allocated to surveys to discover most of the calling males and thereby determine nesting places, so that a larger fraction of the population can be subjected to measures. Second, mowing or grazing on occupied grasslands should be delayed until 15 August by when both the first and second broods reach independence (Green *et al.* 1997, BirdLife International Corncrake Conservation Team 2016). If the entire field cannot be left unmown, at least 2 ha around the calling sites should be left unmown or excluded from grazing.

Well-documented conservation programmes can also help us to refine our conservation measures and make them more efficient. From the results of the Scottish conservation programme and landscape-scale studies (Dorrestijn *et al.* 2015, Beaumont & England 2016), we conclude that a network of high-quality cover areas should be maintained at least in core breeding areas. These grasslands should be managed primarily for Corncrakes, independent of the current presence or absence of breeding pairs. They should be mown no more than once a year and not earlier than 15 August. Cover areas may promote landscape-scale habitat heterogeneity and thereby keep the area attractive for Corncrakes (Brambilla & Pedrini 2013, Dorrestijn *et al.* 2015). Furthermore, they may provide an opportunity to produce a second clutch by some individuals in the population, which is an important condition for a stable population (Green *et al.* 1997, Green 2010).

Besides high-quality habitats, agri-environment measures can also be important means of Corncrake-friendly grassland management outside protected areas (Boldogh *et al.* 2016b). Among the currently applied measures, inside-outward mowing, refuge stripes and delayed mowing until 1–15 August are well established by previous studies (see Koffijberg & Schäffer 2006, BirdLife International Corncrake Conservation Team 2016). Thanks to a recent study, we also learned that refuge stripes should be at least 10–30 metres wide to provide suitable cover and habitat for young Corncrakes until fledging (Arbeiter *et al.* 2015). It would be also important to involve more farmers in agri-environment programmes at least in the most important breeding areas, and thereby increase the proportion of breeding pairs affected by conservation measures. The spatial extension of High Nature Value Areas with Corncrake-friendly prescriptions would also be desirable.

There are important threats, such as aridification or flooding, which are much more difficult to tackle. Unfortunately, these problems affect the most important breeding populations in North-East Hungary, and could not yet be addressed by conservation managers. The severe decline in the “Szatmár-Bereg” population could also be attributed to warmer weather during the breeding season (Bartholy *et al.* 2014), which could have reduced the number and size of the suitable breeding habitats for Corncrakes (Wettstein *et al.* 2001). Although water supply to drying Corncrake habitats was provided in the Kiskunság National Park, more reconstruction projects would be necessary to halt the deterioration of important habitats.

Monitoring the effect of conservation measures is also necessary to be able to develop them further. For monitoring populations, territory mapping is recommended, which provides the most accurate estimates from the available methods (Budka & Kokociński 2015). However, surveys should be extended to larger areas, because Corncrakes may shift between habitats over the breeding season (Brambilla & Pedrini 2011, Budka & Osiejuk 2013).

As grasslands are habitats for a number of other plant and animal species of conservation relevance, the influence of Corncrake-friendly management on other species should be considered as well. A previous study revealed that both butterfly and bird species richness was higher in those grasslands that were occupied by Corncrakes than in control sites without Corncrakes (Wettstein & Szép 2003). The density of Corn Bunting *(Emberiza calandra)* and Tree Pipit *(Anthus trivialis)* was also higher in Corncrake habitats. Other species, e.g. Skylark *(Alauda arvensis)* and Yellow Wagtail *(Motacilla flava)*, however, prefer shorter swards than Corncrake. A recent study also found that the highest plant diversity of mesic hay meadows can be achieved by mowing them twice a year (Szépligeti *et al*. 2016), which is unsuitable for Corncrakes. Therefore, conservation management of grasslands should choose its targets for each field and treat them accordingly.

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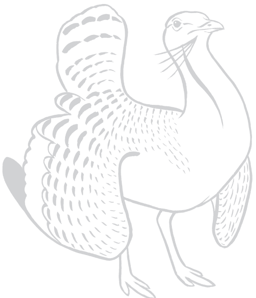

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Where can flood refugees go? Re-distribution of Corncrakes *(Crex crex)* due to floods and its consequences on grassland conservation in North-Eastern Hungary

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Abstract The Corncrake is a threatened umbrella species for wet meadows, which mostly depends on managed grasslands. Therefore, effective conservation requires bird-friendly land management schemes and subsidies. Although the most important populations in Hungary usually breed in protected areas, some of these are regularly flooded, which forces Corncrakes to find breeding sites elsewhere. Such movements from protected/subsidised areas to suboptimal sites have risks for Corncrake populations and their conservation. Here, we describe a large-scale dynamic system of interlinked populations based on data from 4194 Corncrake territories found at four different sites (Aggtelek, Bodrogzug, Szatmár-Bereg and Zemplén regions) across eight years between 1997 and 2006 in NE Hungary (c. 1500 km^2). The results showed that the total population fluctuated between 407 and 631 pairs and that the populations were more-or-less stable in the first four years (1997–2000). However, extended floods caused the disappearance of the species from the Bodrogzug region in 2005–2006, while in the other sites, the number of territories increased five-fold (Zemplén), three-fold (Aggtelek) and two-fold (Szatmár-Bereg). The correlation between the number of territories and maximum water level of river Tisza in April-May was negative in the Bodrogzug site and positive in the three other sites, indicating that interlinkages of the populations were associated with water levels. Our data thus support the hypothesis that many of the birds driven out by inundation of floodplain meadows moved to other sites in NE Hungary in flood years. These results suggest that even large, centrally located populations of Corncrake can be greatly exposed to risks of flooding and that it is highly important to maintain suitable alternative breeding sites for the species. The High Natural Value Areas programme may allow administrative and funding support to provide or extend protection and/or subsidies to maintain this large-scale dynamic system. To this end, the area managed in bird-friendly ways and subsidised under agri-environmental schemes was extended by 35,000 hectares in NE Hungary in 2009.

Keywords: Corncrake, High Nature Value Areas, grassland protection, agri-environment schemes, landscape scale

Összefoglalás A haris a nedves gyepek kitüntetett ernyőfaja. A faj napjainkban leginkább mezőgazdasági hasznosítású gyepterületekhez kötődik, ezért hatékony védelme madárbarát gazdálkodási gyakorlatot és agrár-támogatásokat igényel. Habár a legjelentősebb hazai állományok védett területeken költenek, ezen területeket rendszeresen érik áradások, melyek más költőhelyek keresésére kényszeríthetik a harisokat. A védett/támogatott területekről szuboptimális költőhelyekre történő mozgások kockázatosak lehetnek a haris-állományokra, és kihívást jelentenek a védelem számára. Dolgozatunkban négy állomány nagy térbeli léptékű, dinamikus kapcsoltsági rendszerét ismertetjük négy északkelet-magyarországi helyszínen (Aggtelek, Bodrogzug, Szatmár-Bereg, Zemplén) nyolc éven át (1997–2006) gyűjtött 4194 haris-territórium adata alapján. Az összesített állomány 407 és 631 pár között változott, és az első négy vizsgálati évben (1997–2000) viszonylag stabil volt az egyes helyszíneken. A második négyéves periódus végére (2005–2006) azonban a bodrogzugi állomány szinte eltűnt a hosszú árvizek hatására, míg a többi helyszínen a territóriumok száma megduplázódott (Szatmár-Bereg), illetve a háromszorosára (Aggtelek) vagy ötszörösére nőtt (Zemplén). A territóriumok száma és a Tisza április-májusi maximum vízállása közötti korreláció negatív volt a Bodrogzug esetén, és pozitív a többi helyszín esetén, mely arra utalt, hogy az állományok közötti kapcsolatok összefüggésben voltak a vízállással. Adataink ezért alátámasztják azt az elképzelést, miszerint a nyílt ártéri rétek elárasztása révén költőhelyükről elüldözött madarak más északkelet-magyarországi helyszínekre kényszerülnek az árvizes években. Ezek az eredmények azt mutatják, hogy még nagy, középponti helyzetben levő haris-állományok (pl. Bodrogzug) számára is kockázatokat jelenthet az árvíz, és ezért megfelelő alternatív költőhelyeket kell fenntartani a fajnak. A Magas Természeti Értékű Területek program adminisztratív és anyagi segítséget nyújthat a védelem és a támogatások biztosítására és kiterjesztésére e nagy térbeli léptéken működő dinamikus rendszer fenntartása érdekében. E célból történt meg a madárbarát művelési gyakorlat és az agrár-környezetvédelmi támogatási rendszerek áttervezése és bővítése újabb, összesen 35 000 hektár területre Északkelet-Magyarországon 2009-ben.

Kulcsszavak: haris, Magas Természeti Értékű Területek, füves élőhelyek védelme, agrár-környezetgazdálkodási rendszer, tájlépték

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Introduction

Grasslands cover approximately 40% of the terrestrial area of the world, and about 20% of Europe (Suttie *et al.* 2005). Grasslands are important habitats for wildlife, but at the same time, they are also significant for agricultural production (Hopkins & Holz 2006). The area of grasslands in Europe has decreased during the past decades, whereas the management of the remaining areas has intensified (European Environment Agency 2007, Pe'er *et al.* 2014). The decline in biodiversity in grasslands due to agricultural intensification is well-known all over Europe (Chamberlain *et al.* 2000, Donald *et al.* 2001, Benton *et al.* 2002, Donald *et al.* 2006, Henle *et al.* 2008, Kleijn *et al.* 2009, Pe'er *et al.* 2014).

The Corncrake is known to depend on managed grasslands (Green *et al.* 1997, Schäffer & Koffijberg 2004), but the increased intensity of grassland management has a negative impact on this species (Green & Rayment 1996, Berg & Gustavson 2007). Consequently, the population size of this formerly abundant bird has decreased in major parts of its Eurasian breeding range (Green *et al.* 1997, Keišs 2005, Keišs *et al.* 2007). The northern and western European populations in particular are scattered and are now endangered (Green 1995, Crockford *et al.* 1996, Schäffer & Koffijberg 2004). In contrast, populations in Central and Eastern Europe (CEE) were reported to increase (Koffijberg *et al.* 2016), which may be related to the disappearance of the collective farming systems and general temporary extensification of agriculture due to the collapse of the socialist economy (e.g. Elts 1997, Keišs 1997, Schäffer & Green 2001, Keišs 2005, Koffijberg & Schäffer, 2006¸ Koffijberg *et al.* 2016). In addition, comprehensive conservation schemes have been established in several countries (Stowe & Green 1997, O'Brien *et al.* 2006, Schoppers & Koffijberg 2006, Beaumont & England 2016). Otherwise, abandonment of management of grasslands, which has been occurring in many CEE areas, enhances vegetation succession and eventually drives out Corncrakes as the vegetation becomes too dense (Schäffer & Koffijberg 2004, Koffijberg *et al.* 2016).

Today, agricultural subsidies increasingly result in the expansion of arable lands and in a simultaneous reduction and even more intensive use of grasslands, especially in the new CEE member states of the EU (e.g. Pe'er *et al.* 2014), which is unfavourable for Corncrakes (Keišs 2005, Koffijberg & Schäffer 2006, Bíró *et al.* 2013). However, there are different kinds of subsidies within agri-environment measures, and some, such as the High Nature Value Area programmes, were introduced to maintain Corncrake-friendly management regimes in grasslands (European Commission 2005, Sztahura & Rezneki 2015). However, finding measures that are both beneficial for the Corncrake and other grassland birds and profitable to farmers in agricultural areas is complicated and difficult (Kleijn *et al.* 2004, Berg & Gustavson 2007, Beaumont & England 2016). The administrative systems of subsidies are rigid and limited to defined areas and periods, however, the habitat use of Corncrakes is not. The long-distance movements of Corncrakes within a breeding season have been known for a long time (Bürger *et al.* 1998, Koffijberg & van Dijk 2001, Schäffer & Koffijberg 2004, Koffijberg *et al.* 2016), and this knowledge can be used for the designation of subsidised areas. These movements can also be triggered by floods, which have particular importance in the Carpathian Basin. If Corncrakes move from protected and/or subsidised areas threatened by floods to unfavourable breeding sites, such movements will have an important implication for Corncrake conservation. The Corncrake is an umbrella species as its protection covers other species of wet meadows (e.g. Wettstein & Szép 2003, Boldogh *et al.* 2016). In Hungary, three agri-environmental packages have measures that are relevant to Corncrakes within the Rural Development Programme (2015–2020) (Boldogh *et al.* 2016). These include the "bird-friendly mowing", the "delayed mowing" and the "keeping unmown area" measures, which can be beneficial to the Corncrake, and obviously for other protected species (Green *et al.* 1997, Stowe & Green 1997, Beaumont & England 2016).

The main aims of this study were to (i) identify interlinkages among major Corncrake breeding sites in north-east Hungary, (ii) improve our interpretation of monitoring data on a national and regional scale, and (iii) to draw attention to the vulnerability of the most important breeding sites of Corncrakes in Hungary. Our general aim was to provide input for nature conservation authorities for the adequate designation of High Nature Value Grassland Areas and other protected sites.

Material and Methods

We surveyed populations of Corncrakes between 1997–2000 and 2003–2006 at four sites in NE Hungary (total 1475.3 km^2) *(Figure 1),* following international guidelines and methods (Sheppard & Green 1994, Schäffer & Mammen 2003). Previous results suggested that the most important breeding sites of the species were in this part of the country (Szép 1991, Boldogh 1999, Boldogh & Szentgyörgyi 2003).

Censuses of singing Corncrakes in the potential breeding habitats were conducted at night (23:00–03:30) throughout the breeding season (15 May–30 June). Data from surveys conducted before 15th May were excluded from the analyses to avoid overlap with the migration of birds. Most of the surveys were completed by mid-June, thus, the subsequent increase in the number of displaced males did not influence our results. We aimed to survey all suitable breeding sites regardless of their management regime or protection status and strived for similar sampling effort in all sites and years. In a single survey, c. 70–80% of the singing males can be recorded, hence 2–3 visits per site are recommended (Schäffer & Mammen 2003). Accordingly, we surveyed 75% of the study area at least twice and 15% of the area at least three (or more, up to six) times. Generally, at least five days passed between subsequent surveys. If a singing male was found less than 200 m apart at the same site during a subsequent survey, it was treated as the same individual. We inferred one territory when the same individual was heard at the same site subsequently on at least two (but often more, up to six) survey occasions. The location of calling males was determined by GPS or recorded on 1:25 000 and 1:10 000 topographic maps.

The first site, the Aggtelek National Park and its surroundings (Aggtelek NP in *Figure 1*), is 1160 km^2. Dominant natural and semi natural habitats in the area are deciduous forests (e.g. *Quercetum petraeae-cerris*, *Querco petraeae-Carpinetum*) and different grasslands (55% and 13%, respectively). Arable lands cover 30%. The most important breeding habitats are wet meadows (e.g. *Caricetum acutiformis-ripariae*, *Cirsio cani-Festucetum*

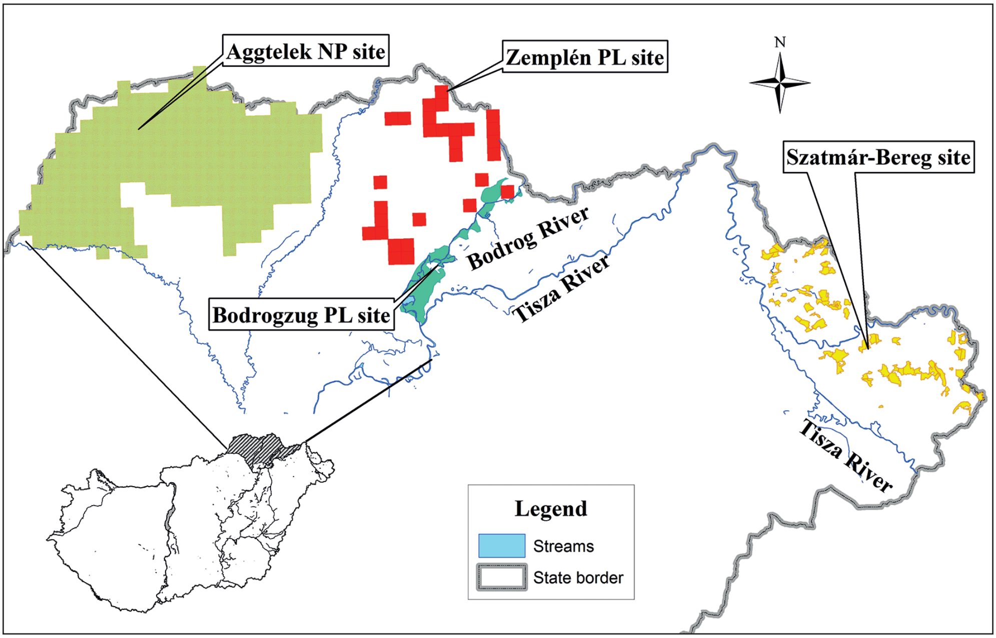

Figure 1. The distribution of the study sites in NE Hungary
1. ábra A vizsgálati helyszínek Északkelet-Magyarországon

pratensis) and abandoned pastures (Boldogh & Szentgyörgyi 2003) in the small river valleys (e.g. Szuha, Bódva valley). Most meadows are abandoned and overgrown with high vegetation, and less than 20% of the grasslands are managed. Flooding of the breeding habitats is infrequent and is restricted to small areas (Marosi & Somogyi 1990). Parts of the site are protected as Aggtelek NP (200 km^2) (Homepage of the Hungarian State Nature Conservancy 2016).

The second site covers 125 km^2 in the Zemplén Mountains (Zemplén PL in *Figure 1*) and involves wet meadows mainly along small streams (e.g. Bózsva, Bényei). A large portion of the site is covered by wet meadows (e.g. *Agrostio-Deschampsietum caespitosae*, *Angelico-Cirsietum olerace*) and arable lands (60% and 15%, respectively). The majority of the meadows are unmanaged (not grazed or mowed). Floods are very rare here. Parts of the site are included in the Zemplén Landscape Protection Area (Homepage of the Hungarian State Nature Conservancy 2016).

The third site, the Bodrogzug and Bodrogmente, consists of 90.5 km^2 in the flood-plain of rivers Bodrog and Tisza (Bodrogzug PL in *Figure 1*). Riparian meadows (e.g. *Alopecuretum pratensis*, *Agrostetum albae*) and marshes are the dominant habitat types (70% and 15%, respectively). The intensity of management is moderate as less than 30% of the grasslands are managed, mainly used for mowing and grazing (80% and 20%, respectively). The threat of flooding is high (Marosi & Somogyi 1990). In years with high water level, 20–100% of the site is flooded mainly from April to June. This site is of great conservation interest because of breeding and migrating birds, therefore, it is protected and included in the Ramsar Convention of Wetlands (Tardy 2007) (Homepage of the Hungarian State Nature Conservancy 2016).

The fourth site, the Szatmár-Bereg lowland, is in the easternmost part of Hungary between rivers Tisza and Szamos, and consists of 99.8 km^2 (Szatmár-Bereg in *Figure 1*). Different grasslands (e.g. *Agrostetum albae*, *Alopecuri-Festucetum pseudovinae*) cover the whole territory (Wettstein *et al.* 2001, Wettstein & Szép 2003). Many are abandoned due to the decreasing number of livestock. A considerable part of the site is a floodplain of river Tisza and its tributaries. Parts of the site are protected as the Szatmár-Bereg Landscape Protection Area (Homepage of the Hungarian State Nature Conservancy 2016).

We studied the observed fluctuations of Corncrake populations at the four sites between 1997 and 2006, with the exception of 2001 and 2002, when surveys were not carried out at the Zemplén PL and Bodrogzug PL. We analysed the changes in the number of territories at the four sites in eight years and as a function of water level, using generalised least squares regression (function 'gls' in R package 'nlme'). This allows the specification of an autocorrelation structure, which, in our case, involved temporal (between-year) autocorrelation in the number of territories within sites (grouping factor). We characterised water levels by the maximum water level reading of river Tisza, measured at the checkpoint of Tokaj, during the settlement and breeding period of Corncrakes (April-May). We used the ArcMap 9.2 GIS software for determining the High Nature Value Programme status of the breeding sites and visualizing the results of the evaluation. All statistical analyses were performed in the R statistical environment (version 3.2.2, R Core Team 2015).

Results

In total, 4194 (100%) territories with singing Corncrakes were recorded at the study sites during 8 years. One thousand two hundred and fifty-seven (30%) Corncrake territories were at the Aggtelek NP site, 777 (18.5%) at the Zemplén PL site, 1281 (30.5%) at Bodrogzug PL site and 879 (21%) in the Szatmár-Bereg site *(Table 1)*. The total number of territories on the four sites fluctuated between 407 and 631 territories between 1997 and 2000, and between 427 and 580 territories between 2003 and 2006 *(Table 1)*, and did not differ between the two time periods (mean±S.D., period 1: 544.5±96.35, period 2: 504.0±68.86; t_6=0.684, p=0.520).

The number of territories was relatively stable between 1997 and 2000 in the Bodrogzug, Szatmár-Bereg and Zemplén sites and decreased in the Aggtelek site *(Figure 2)*. In contrast with the last four years (2003–2006), Corncrakes have almost completely disappeared from the Bodrogzug site, while the number of territories increased five-fold in the Zemplén PL site, three-fold in Aggtelek NP, and two-fold in the Szatmár-Bereg site *(Figure 2)*. The generalised least squares regression showed a significant interaction between site and maximum water level of river Tisza in April-May ($F_{3,24}=4.846$, $p=0.009$), indicating that the relationship between Tisza water level and number of territories differed among the sites. This was because the relationship was negative for the Bodrogzug site and generally positive for the three other sites *(Figure 3)*.

The number of territories in the Bodrogzug PL site strongly depended on maximum water level of river Tisza in April-May. If the water level of river Tisza at Tokaj exceeds 550 mm (c. 95 m above sea level), more than 80% of the Bodrogzug area is inundated, whereas the entire Bodrogzug area is inundated if water level on river Tisza exceeds 600 mm *(Figure 4)* (Vass 2014, Szabó *et al.* 2016). In flood years, the water levels were much higher than these values. For example, the maximum water level at Tokaj was 847 cm in 2001. When

Table 1. The number of territories estimated based on the presence of singing Corncrakes in the four study sites in NE Hungary in 1997–2006 (surveys were incomplete in 2001 and 2002). For details of different sites, please see *Materials and methods*

1. táblázat A haris territóriumok száma a harsogó hímek száma alapján az egyes mintaterületeken Északkelet-Magyarországon 1997–2006 között (2001-ben és 2002-ben a felmérések nem minden mintaterületen történtek meg). Az egyes területek leírása az *Anyag és módszerek* részben szerepel

Year	Aggtelek NP	Bodrogzug PL	Szatmár-Bereg	Zemplén PL
1997	134	232	125	88
1998	216	238	96	81
1999	143	215	133	70
2000	47	199	81	80
2003	84	228	78	37
2004	140	158	70	101
2005	233	10	162	135
2006	260	1	134	185

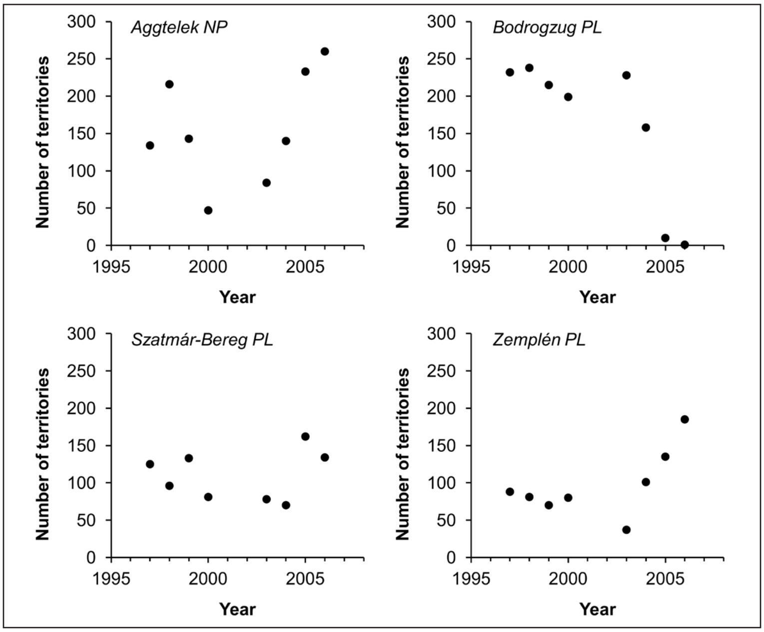

Figure 2. Number of Corncrake territories at the four study sites in the eight study years
2. ábra A haris-territóriumok száma a négy vizsgálati területen a nyolc felmért évben

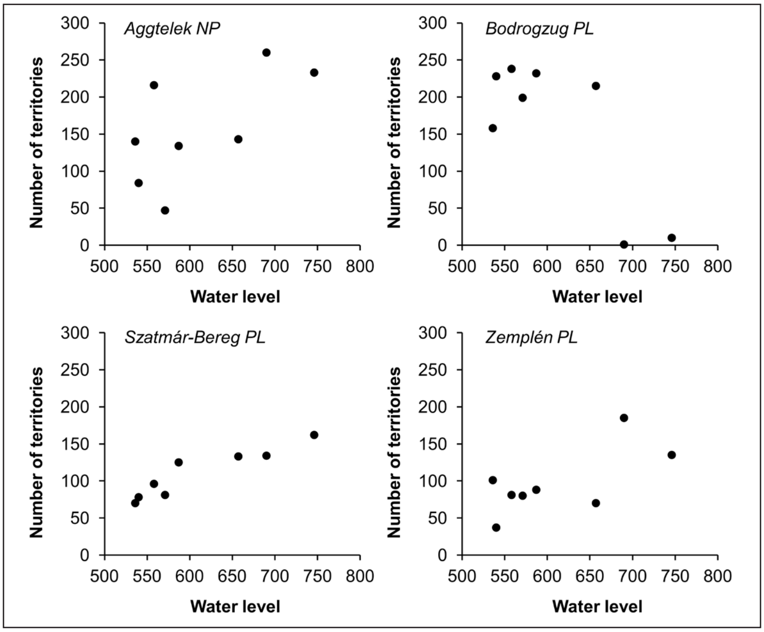

Figure 3. Number of Corncrake territories as a function of maximum water level of river Tisza at Tokaj in April-May (in cm) of each year
3. ábra A haris-territóriumok száma a Tokajnál április-májusban mért maximális vízállás (cm) függvényében

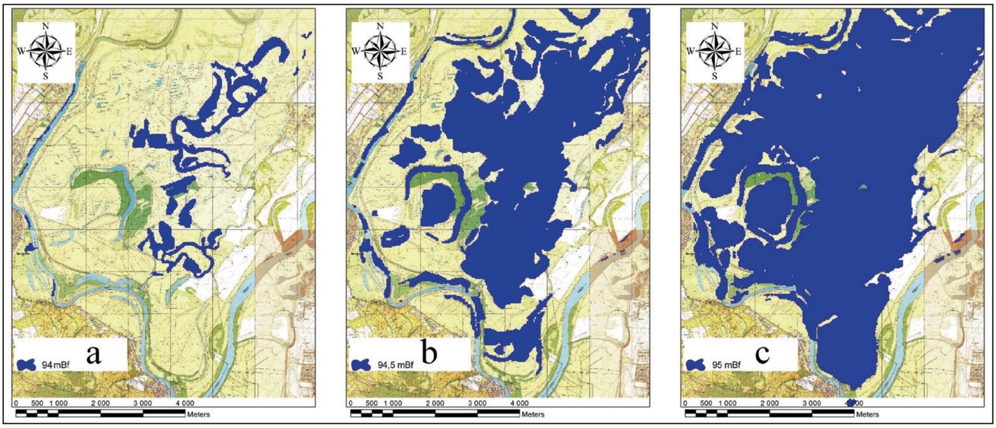

Figure 4. Area (in blue) inundated in the Bodrogzug PL site when the water level of river Tisza at Tokaj is at 94.0 m (a), 94.5 m (b) and 95 m (c) above sea level. Source (a-c): G. Molnár after the ÉKÖVIZIG (Miskolc) database

4. ábra. A Tisza által elöntött terület (kékkel) a Bodrogzugi TK területén, amikor a Tisza vízszintje eléri a 94 m-es (a), a 94,5 m-es (b) és a 95 m-es (c) tengerszint feletti szintet. Forrás (a-c): Molnár G. az ÉKÖVIZIG (Miskolc) adatai alapján

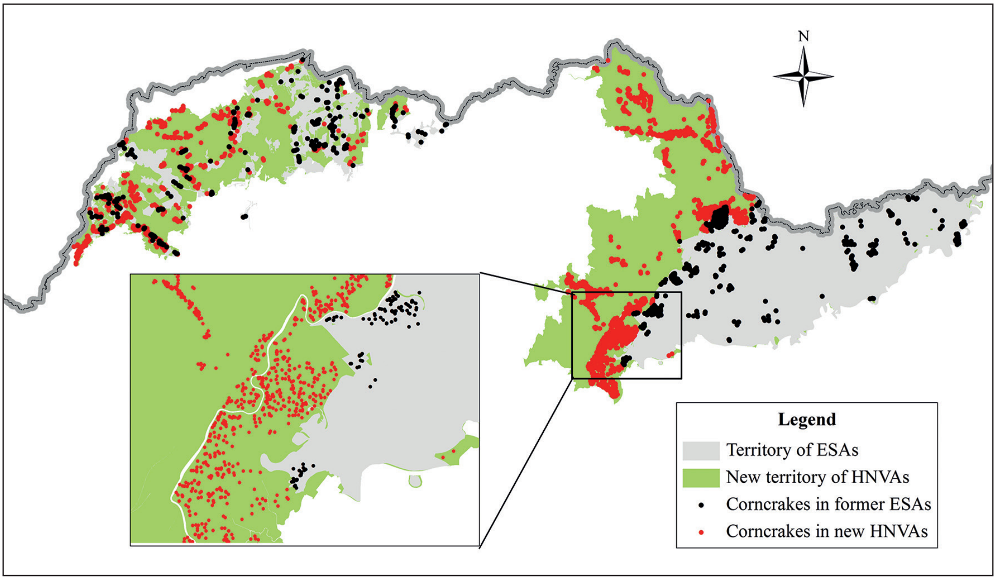

Figure 5. Distribution of Corncrake territories based on singing males observed during 1997–2006 in the previously designated subsidised territories (ESAs) and the enlargement of areas included under the High Nature Value Areas programme with consideration to the large-scale redistribution patterns of Corncrakes in NE Hungary

5. ábra A haris-territóriumok eloszlása az éneklő hímek alapján 1997 és 2006 között a korábbi agrártámogatási rendszer (ESA) területén, és a támogatási rendszerbe a Magas Természeti Érzékenységű Területek programon át újonnan, a haris újraeloszlási mintázatának figyelembevételével bevont területeken Északkelet-Magyarországon the maximum April-May water level was above 660 m in 2005 and 2006, Corncrakes almost disappeared from the site *(Figure 2)*. In addition, in 2006, a long and intense flood in April (maximum level: 892 cm) was followed by a "green" flood in late May and early June. These years also showed large increases of the nesting population in the Aggtelek, Szatmár-Bereg and Zemplén sites, and the increase was greatest at the Zemplén site *(Figure 2)*, which is closest to the Bodrogzug site *(Figure 1)*.

Finally, none of the most abundant breeding sites was covered by any agri-environment subsidy schemes (e.g. ESA) until 2009 *(Figure 5)*. However, the extension of HNVAs efficiently covered Corncrake breeding sites at three of the sites studied *(Figure 5)*.

Discussion

The studied areas in NE Hungary hold the most important local Corncrake populations in the country (Boldogh *et al.* 2009, 2016), which are also remarkable even in an international context (Koffijberg *et al.* 2016). The sizes of the local populations fluctuate considerably, which was also reported for other populations of the breeding range (e.g. Keišs 2003, Sukhanova & Mischenko 2003, Schäffer & Koffijberg 2004, Schoppers & Koffijberg 2006, Koffijberg *et al.* 2016). However, our study is the first to report both concerted changes (period between 1997–2000) and negative correlations (period between 2003–2006) in the sizes of the local populations. In time period 2, population declines in the Bodrogzug PL site were in concert with population increases in the other local populations. Our results suggest that the different inter-population relationships between time period 1 (when only small floods occurred) and time period 2 (when extended floods occurred) may be explained by the flood characteristics of river Tisza. The negative correlation between local population size at Bodrogzug PL site and maximum water level of Tisza River indicates that the higher the flood level, the less area is available for birds to nest in this site. The contrasting patterns between Bodrogzug PL site (population decline) and the other three local populations (population increases) suggest that many of the birds that had been driven out from the floodplain meadows at Bodrogzug PL site appeared in the other parts of the studied area in the years with inundation (time period 2). Unfortunately, there are no bird ringing results to confirm the movement of individuals between sites.

Factors triggering long-distance movements and distribution of Corncrakes within one breeding season are poorly revealed (Koffijberg *et al.* 2016), although searching for suitable breeding sites for a second brood and/or after disturbance by mowing might initiate such movements (Green *et al.* 1997, Schäffer & Koffijberg 2004). Our study provides a good example of the direct effect of flood on Corncrake distribution in Hungary, a phenomenon that has been suggested to operate on a much larger scale in some other parts of Europe (Mischenko & Sukhanova 1999, Koffijberg & van Dijk 2001). Due to the large mobility of Corncrakes within and between breeding seasons (e.g. van den Bergh 1991, Bürger *et al.* 1998, Koffijberg *et al.* 2016), floods may have an impact on geographically distant Corncrake populations, especially when they affect large numbers of Corncrakes, e.g. in the core breeding areas in Russia. For instance, Koffijberg and van Dijk (2001) assumed in their study that the influx of Corncrakes in the Netherlands in 1998 was due to immigration from Belorussian and Russian populations, where the high water tables and floods hindered breeding in the floodplains. Similar effects of distant floods could also not be excluded in Hungary (Boldogh *et al.* 2009). Our results confirm that local populations need to be monitored simultaneously (all sites in all years), and they also suggest that the data from monitoring of the local populations have to be evaluated with consideration to their interrelationships.

Our study also shows that floods can have contrasting effects on Corncrake populations. On one hand, floods often have important positive effects on maintaining suitable vegetation at the breeding sites (Schäffer & Koffijberg 2004), and can delay the start of mowing that may threaten nests in floodplain meadows. On the other hand, a delayed retreat of floodwaters may be disadvantageous for Corncrakes, because this species prefers and tolerates much drier habitats than other Rallidae (Schäffer 1999). Our results show that this can happen in different years at the most important breeding site in Hungary (Bodrogzug PL site, time period 2). Long periods of flooding at this site are partly a result of human activities *(Figure 3)*. Due to the impact of a hydroelectric dam at Tiszalök, the retreat of floods is 2-2.5 times slower in this section of the river than in upper or lower reaches. Our data show that the dense, concentrated local populations of Corncrakes, as well as the populations of other grassland birds, are highly vulnerable to floods and other threats in this part of the floodplain. In fact, in years of flooding, the birds can not find breeding places here at all, or they have to move elsewhere, presumably leaving behind their nests.

This pattern of redistribution should be considered in designing Corncrake conservation measures in the region. Our data suggests that in order to reduce the negative impact of floods and improve protection of Corncrakes, it is highly important to maintain suitable alternative breeding places outside floodplains. Because the intensity and the methods of land use are key issues in the conservation of Corncrake populations (Green & Rayment 1996, Schäffer & Green 2001, Schäffer & Koffijberg 2004), the extension of favourable grassland management (e.g. Schäffer & Weisser 1996, Green *et al.* 1997) to the unprotected and unsupported areas is justified by our results. According to recent studies (e.g. O'Brien *et al.* 2006, Beaumont & England 2016), the conservation management schemes have clear benefits to Corncrakes. The implementation of allowance guidelines and measures (c.f. Sztahura & Rezneki 2015) that enable Corncrake-friendly management on HNVAs (e.g. supervising by national park directorates, delayed mowing, obligatory use of game-repellent chains when mowing, adequate mowing directions, leaving unmown areas) would likely lead to a more favourable conservation status of Corncrakes (Faragó & Szentirmai 2014, Boldogh *et al.* 2016). Our results also implicitly suggest that an extension of the areas managed in bird-friendly ways and subsidised under the HNVA programme was necessary in NE Hungary for the effective protection of Corncrakes. Previously, less than 25% of known Corncrakes were in ESAs in different years (Boldogh *et al.* 2009), whereas this number increased to about 70% after the redesign and enlargement of this area by 35 000 ha in the HNVA programme *(Figure 4)*. We believe that the extension will be a significant step forward in Corncrake conservation in NE Hungary.

Our results also suggest that further direct human impacts (e.g. building of a new dam on river Bodrog) and climate change may have serious negative impacts on Corncrakes in the studied region and in Hungary. Climate change projections suggest a complete restructuring of the annual distribution of precipitation, as well as an increase in heavy precipitation events and severely increased peak river discharges and floods (Christensen & Christensen 2004, Bartholy *et al.* 2007, Kyselý & Beranová 2008, Bartholy *et al.* 2009, Rakonczai 2011). Therefore, the breeding possibilities of Corncrakes may become more limited in riparian meadows in the future. Hence, the importance of suitable breeding habitats outside flood-affected areas will probably grow in the near future and these habitats thus deserve an adequate conservation strategy. This is also because there is a risk that many of these grasslands will be converted to arable lands or will be abandoned and exposed to succession and invasive plants, which will generate conditions that are suitable neither for diverse wildlife nor for Corncrakes.

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Nest site selection of the Great Bustard *(Otis t. tarda)* in Körös-Maros National Park, Eastern Hungary

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Abstract In the present study we aimed to identify factors influencing the spatial distribution of Great Bustard *(Otis t. tarda)* nests found between 1998 and 2015 in Dévaványa-Ecseg area in Körös-Maros National Park.

During the study period covering 17 years, we obtained information on 536 nests, which shows that Great Bustards used the following grassland crop types for breeding: wheat (43.07%), grassland (23.3%), fallow land (14.45%) and alfalfa (7.67%). These nests were found during the following activities: chemical weed control (33.63%), hay-cutting (25.37%), disking (8.55%) and harvesting (7.08%) and other 18 types of activities.

To identify the effects of disturbance and environmental factors on the spatial distribution of nests, such as distances to lek sites, roads, settlements and altitude, we formulated generalized linear models. As a result, we found that nest sites were significantly closer to lek sites and farther from human settlements than expected by random sampling.

Our results may contribute to the understanding of Great Bustard nest distributions, which can be helpful in nest detection prior to the initiation of disturbing agricultural activities, which is a key issue in the conservation of this bird. This study opens the way to analyse the effects of other environmental factors such as anthropogenic linear objects.

Keywords: R, QGIS, agricultural activities, Great Bustard conservation, nest site selection

Összefoglalás Aktuális kutatásunkban a Körös-Maros Nemzeti Park Dévaványai-Ecsegi puszták részterületén 1998 és 2015 között előkerült túzok (*Otis t. tarda* L.) fészkek elhelyezkedését befolyásoló külső tényezőket és a fészkek előkerüléseinek részleteit vizsgáltuk.

A vizsgált 17 évben 536 fészekről van információnk, ami az eddigi tanulmányokhoz hasonlóan azt mutatja, hogy a búza (43,07%), a gyep (23,3%), az ugar (14,45%) és a lucerna (7,67%) az elsődlegesen túzok fészkeket rejtő kultúrák. Ehhez kapcsolódóan pedig a fészkek vegyszerezés (33,63%), kaszálás (25,37%), tárcsázás (8,55%), aratás (7,08%) és további 18 tevékenység közben kerültek elő.

A statisztikai modellekkel a dürgőhelyek, utak, települések és szintvonalak esetleges hatását figyeltük, melyekből fészekcsészék helyzete és a dürgőhelyek kapcsolata között, valamint a fészekcsészék és a települések távolsága között szignifikáns összefüggést kaptunk. Előbbi pozitív, utóbbi negatív irányban tért el. Ezek alapján megállapítható, hogy ez a két külső tényező biztosan hatással van a túzokok fészkelőhely választásában.

Eredményeinkkel közelebb kerülhetünk a fészkek elhelyezkedésének megértéséhez, ami segíti a fészkek felderítését, még a zavarást okozó mezőgazdasági vagy egyéb munkák megkezdése előtt, ami a faj védelmének egyik záloga. Jövőbeli kutatási irányokként a környezeti tényezők hatásának további tanulmányozása és az egyéb ember által létesített vonalas építmények vizsgálata javasolt.

Kulcsszavak: R, QGIS, mezőgazdaság, túzok védelem, előfordulási gyakoriság

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Introduction

The Great Bustard *(Otis tarda)* is a bird of key conservation concern distributed in the Eurasian steppe zone, which is also considered as an endangered flagship species, and as an umbrella species in its primary habitats (IUCN 2016). Majority of the Central-European population of this bird is located in Hungary (Sterbetz 1984, Alonso & Palacín 2010, Alonso 2014), where the primary role of Great Bustard conservation is represented by Körös-Maros National Park, as 40% of the national population is harboured in this region (I1). Therefore, the only Great Bustard Conservation Station in Hungary has been established here in 1978 (Czifrák 2014), followed by the operation of the largest Great Bustard conservation sample area in Central-Europe since covering 400 hectares (Széll 2005).

Research of this Great Bustard population has been initiated by Sterbetz and Faragó (Sterbetz 1975, 1976a, 1976b, 1984, 1986, Faragó 1983a, 1984, 1989, 1990a, 1990b, 1992a) during the 1980s and 1990s, showing the preference of Great Bustards for agricultural areas providing hypotheses to understand these processes (Sterbetz 1976a, 1980, Faragó 1983b, 1985a, 1985b, 1988).

Great Bustards breed in this region between late April to early August (Németh *et al.* 2009). During this period, a major and a supplementary nesting period can be distinguished (Faragó 2004). Nest site choice of the Great Bustard is primarily driven by a number of environmental factors (Alonso *et al.* 1998, 2004) such as distance to the nearest lek site (Osborn *et al.* 2001). Further, females show site fidelity to nest sites (Alonso *et al.* 2000), while another investigation showed that individually marked birds use all available potential nest sites independent of distance to the lek (Magaña *et al*. 2010).

Based on historical data, Great Bustards breed in native steppes (Stegman 1955). However, following the appearance of human agriculture, croplands rich in insects and providing optimal microclimatic conditions attracted Great Bustards for nesting (Bél 1737). Among natural and seminatural habitats, Great Bustards prefer to breed in alkali grasslands *(Achilleo-Festucetum pseudovinae)*, loess grasslands *(Salvio-Festucetum rupicolae)*, and Foxtail-grasslands *(Agrostio-Alopecuretum pratensis)* (Sterbetz 1976a). However, these habitats are often suboptimal due to to extremely wet or to extremely dry soil conditions. Thus, relatively high wheat and alfalfa plantations are more preferable during summer heat waves. Among available crops, females choose between fields based on the developmental state of crops during late April and early May (Fodor 1974a, 1974b, Faragó 1983c). Furthermore, Magaña *et al*. (2010) concluded that the most optimal nest sites of Great Bustards are characterised by vegetation cover high enough to provide a clear view on the surrounding areas or the nesting female which at the same time hide the bird, decreasing the probability of predation (Martín 2008). Besides, a number of previous studies have shown that habitat heterogeneity contributes to increased predation pressures driven by edge effects, whereas nest predation decreases with edge distance in homogenous habitats (Koivula *et al.* 1993, Chalfoun *et al.* 2002). Based on these conditions, wheat fields provide the most optimal nesting conditions combining visibility and decreased predation pressures. Further, microclimatic studies have indicated that alkali wet grasslands exhibit the largest amounts of variance in climatic parameters, due to large temperature and humidity extremities. Again, microclimatic conditions measured in wheat and alfalfa fields are significantly more stable (Faragó 1983c).

Our study aims to analyse the spatial distribution of Great Bustard nests in relation to various environmental and disturbance parameters, in order to inform conservation management in Dévaványa-Ecseg area.

To do so, in our investigation we applied spatial statistics for the identification of (1) potential nest sites which would inform conservation on the location of areas where nests would easier be found without disturbing incubating females, which might contribute to increased nest survival and (2) social (distance to lek site), environmental (altitude) as well as disturbance (distance to roads and settlements) parameters predicting the location of nest sites.

Materials and Methods

Our study is based on the database of Great Bustard nest records collected since 1998 in Dévaványa-Ecseg area of Körös-Maros National Park. This database were collected by members of the Ranger Service of Körös-Maros National Park Directorate, who collected these data from field workers such as hunters, agricultural tractor drivers, and other field workers, who called them to inform on Great Bustard's nest. Until 2004, only the year and coordinates of the nests were recorded. From 2005 onwards, these data are supplemented by area ID, settlement name, date, habitat and agricultural activity type. Additionally, since 2015, the size of the agricultural field, distance to field boundary, number of eggs, applied buffer zone, nest reoccupation event (yes or no), defecation event, located in outside or inside of the national park or SPA area.

To analyse relationships between the distribution of Great Bustards, we used the official spatial layers lek sites, public roads, settlements and altitude, provided by Körös-Maros National Park Directorate.

During the first step, we generated 5, 25, 50 and 95% occurrence probabilities of Great Bustard's nests, applying kernel density estimations fitted on nest coordinates. Kernel density estimation provides a contour plot of the two-dimensional histograms, which has been successfully applied in calculating animal breeding ranges.

During the second step, to compare the distances of random and actual nests from lek sites, settlements, roads and altitude, we formulated autologistic generalized linear models (GLM).

All statistical analyses were conducted in the R statistical programming environment (R Development Core Team 2016). Random point generation and spatial distance calculations were done using the „spatstat" specific package (Baddeley 2010). Breeding ranges were calculated and transformed into shape file format using the „maptools" (Lewin-Koh 2011) and „adehabitat" (Calenge 2006) packages. The resulting spatial datasets were visualised using the QGIS software (Quantum GIS Development Team 2016).

Kernel density estimates were used only to assess potential breeding areas and formed no part of the model formulation process. During the second step, to compare the distances of random and actual nests from lek sites, settlements, roads and altitude, we formulated autologistic generalized linear models (GLM). During the second step, to compare the distances of random and actual nests from lek sites, settlements, roads and altitude, we formulated autologistic generalized linear effects models, applying the „glm" function and entering the point type (random or real) as dependent variable, considering binomial family and logit-link (GLM).

Results

Between 1998 and 2015, we found a total of 536 nests in the study area *(Figure 1)*.

The majority of nests were found between 2011 and 2012, the number of which amounted to: mean n=33.1, sd=±10.45. Nests were discovered in municipality areas of 16 settlements: most of these were found in the district of Dévaványa, followed by those of Szeghalom, Ecsegfalva and Körösladány *(Figure 2)*.

Nest locations found between 1998 and 2015 are indicated in *Map 1*, which includes 509 nest locations.

Map 2 shows the 5, 25, 50 and 95% occurrence probabilites of Great Bustard nests. The application of 50% occurrence probabilities is especially useful in conservation practice as it is expected to increase the nest location probabilities of approximately 50% of nests during future nest searches, which allows the effective establishment of nest protection buffer zones, providing undisturbed habitats for rearing the chicks and thus contributing to the increased survival of the birds.

As a result of kernel density calculations, 5% breeding ranges size amounted to 1071 hectares, 25% range convered 7941 hectares, 50% range covered 23 326 hectares, while the 95%-os range covered 110 169 hectares.

Annual distribution of nest detections shows that major nest regions have shifted since the 1990s: whereas the area east of the settlement provided in several nests 17 years ago, most

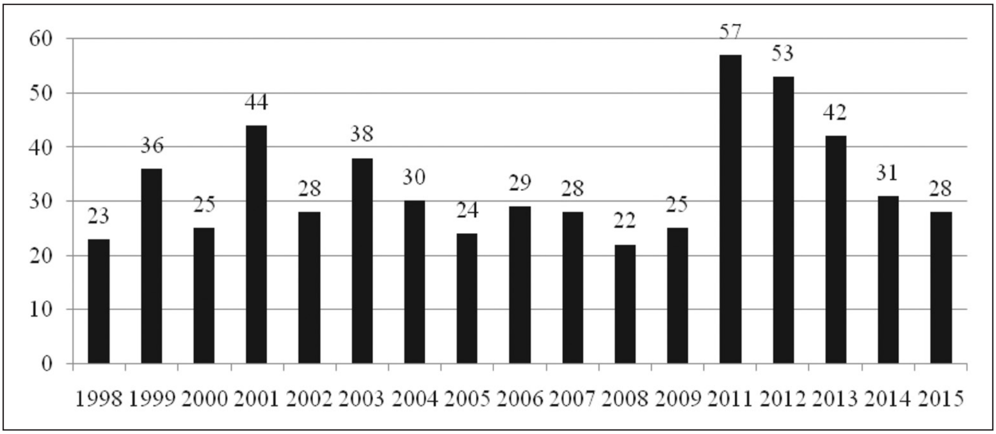


Figure 1. Annual numbers of the Great Bustard nest between 1998 and 2015
1. ábra 1998 és 2015 között előkerült túzokfészkek (db) évenkénti bontásban

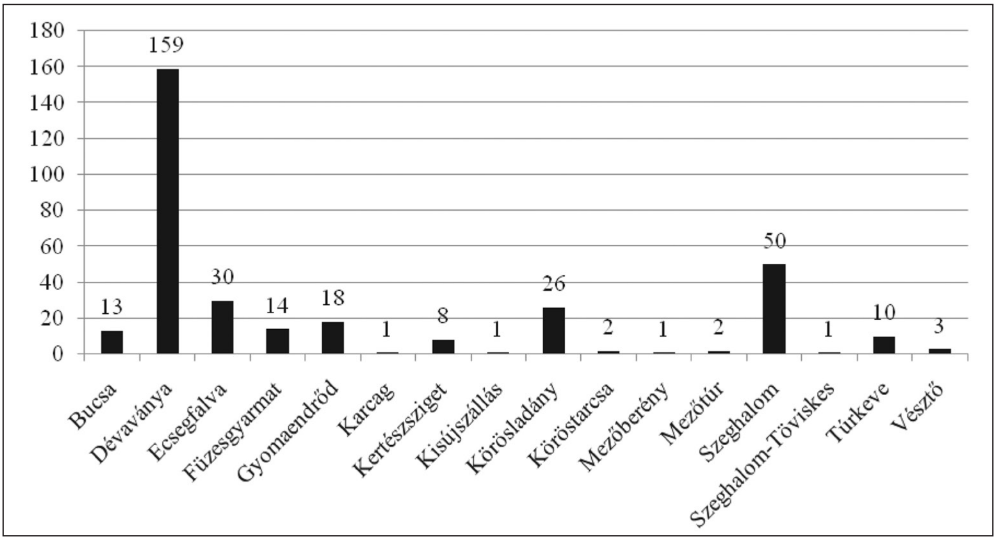
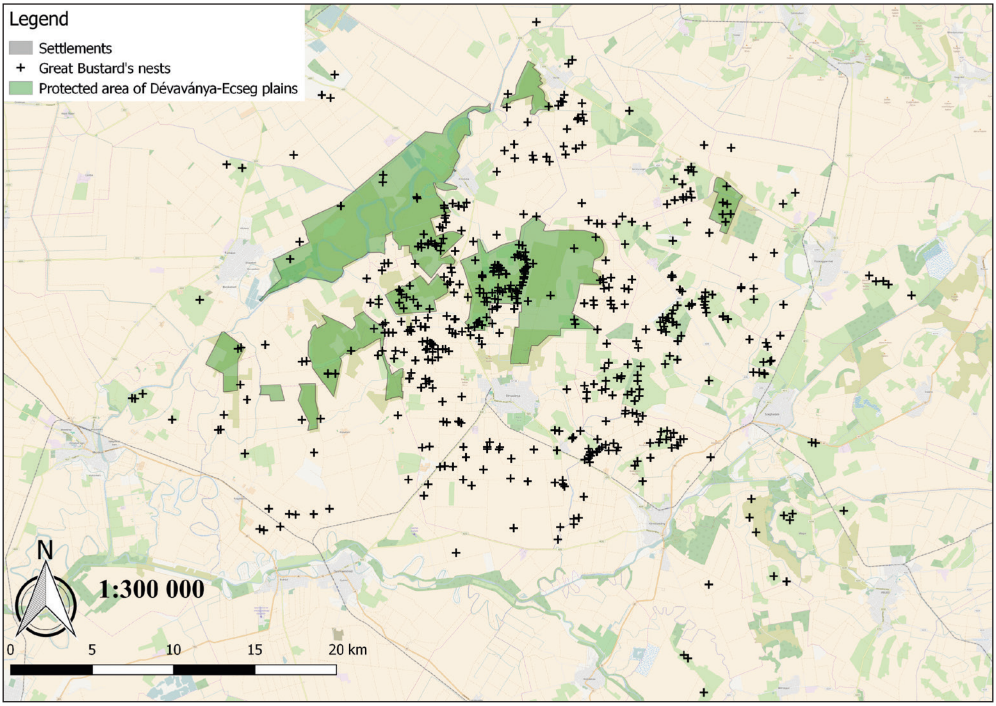


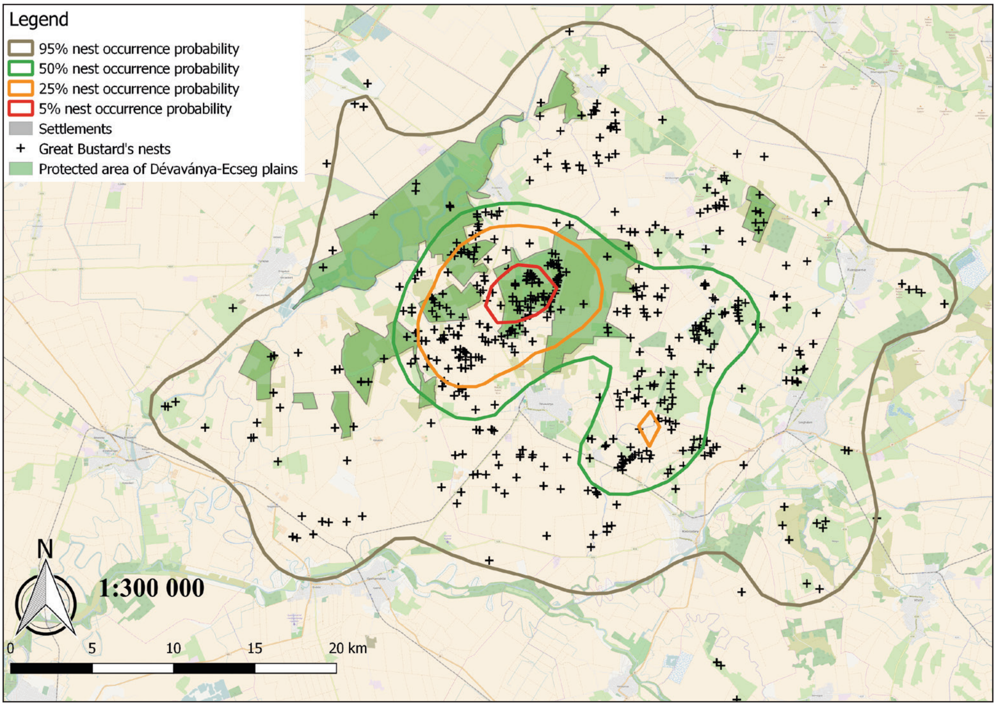
Figure 2. Settlements where Great Bustard nests were found during the last 17 years (nests/settlement)

2. ábra Települések, melyekről túzok fészkek kerültek elő a 17 év alatt (db/település)



Map 1. Spatial distribution of Great Bustard nests in Dévaványa-Ecseg Plains area

1. térkép A túzok fészkek előfordulása a Dévaványai-Ecsegi pusztákon



Map 2. 5, 25, 50 and 95% occurrence probabilities of Great Bustard nest
2. térkép A túzok fészkek előfordulási gyakoriságának 5%-os, 25%-os, 50%-os és 95%-os körzetei

of the eggs were found north-west of the town since the beginning of the 2000s. Based on nest frequencies, most of nests have been found in the central region of the study area and north of it. The 25% breeding range of nests includes an isolated patch, where caution is thus needed on female movements, when carrying out agricultural activities.

However, the intersection of annual 50% breeding ranges show a different pattern, exhibiting an area closer to Dévaványa and a clearly separated patch.

Considering the detection dates of nests, the earliest clutch was on 6 April 2014, while the latest clutch was discovered on 7 August 2006.

We possess information on 339 since 2004. During this period, we found 61 nests in April, 152 nests in May, 85 nests in June 40 nests in July and a single nest in August *(Figure 3)*.

Since 2004, nests have been found in the following habitat types, as ordered by decreasing importance: wheat (43.07%), native grassland (23.3%), follow land (14.45%) and alfalfa (7.67%), with a cumulative frequency of 88.49% *(Table 1)*. These 339 nests were found during 22 agricultural activities and other antropogenic disturbance processes. Majority of nests were discovered during chemical weed control (33.63%), followed by hay-cutting (25.37%) disking (8.55%) and harvesting (7.08%). During these operations, 74.63% of nests were discovered *(Table 2)*.

In 2015, 28 nests were found in total, 11 of which were located in the vicinity of Dévaványa, 6 near Szeghalom and 4 in Ecsegfalva *(Map 3)*.

Table 1. The Great Bustard nest's distribution by habitat types between 2004 and 2015
1. táblázat A fészkek élőhelyenkénti eloszlása 2004 és 2015 között

Habitat type	**Barley**	**Pea**	**Wheat**	**Canary grass**	**Alfalfa with grass**	**Cereal**	**Lawn**	**Lawn (farm place)**	**Ploughland overgrown with grass**	**Alfalfa**	**Sunflower**	**Rape**	**Stubble field**	**Triticale**	**Fallow land**	**Sowing grassland**	**Oat**	**All**
Quantity (piece)	6	1	146	8	3	2	79	1	1	26	6	5	1	1	49	1	3	339
Percentage (%)	1.77	0.29	43.07	2.36	0.88	0.59	23.30	0.29	0.29	7.67	1.77	1.47	0.29	0.29	14.45	0.29	0.88	100.00

Table 2. Reasons for finding Great Bustard nests between 2004 and 2015
2. táblázat A fészkek megkerülésének okai 2004 és 2015 között

Activities	**Harvesting**	**Direct nest searching**	**Mushroom picking**	**Ring rolling**	**Chamomile picking**	**Hay - cutting**	**Survaying before hay - cut**	**Observation**	**Combinatoring**	**Warren hunting**	**Transporting**	**Transporting, soil sampling**	**Cultivatoring**	**Grazing**	**Area pulling**	**Chemical fertilizer spreading**	**Smoothing**	**Stem-crushing**	**Disking**	**Area measurement**	**Dung spreading**	**Fallow landing**	**Hunting**	**Chamical spraying**	**Sowing**	**All**
Quantity (pieces/ activity)	24	1	1	1	2	86	1	4	2	1	18	1	6	8	1	13	2	12	29	1	1	2	4	114	4	339
Percentage (%)	7.08	0.29	0.29	0.29	0.59	25.37	0.29	1.18	0.59	0.29	5.31	0.29	1.77	2.36	0.29	3.83	0.59	3.54	8.55	0.29	0.29	0.59	1.18	33.63	1.18	100.00

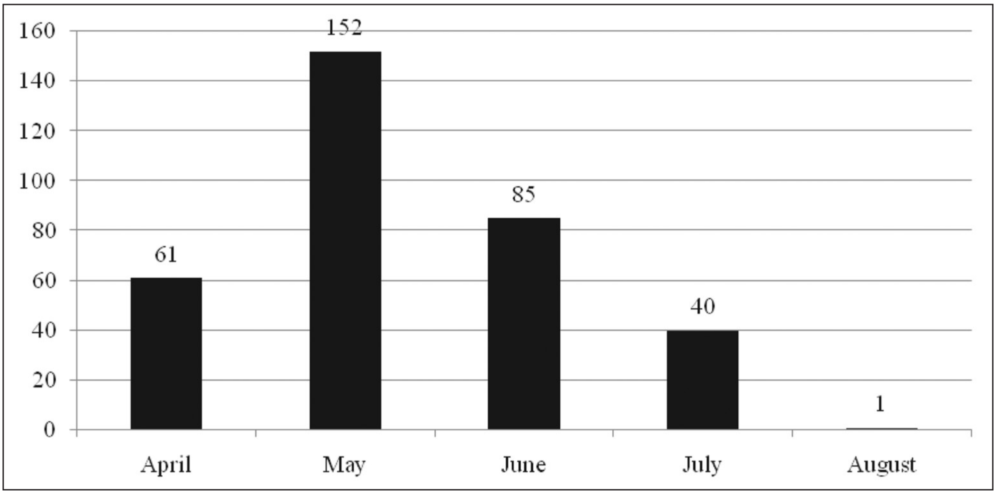
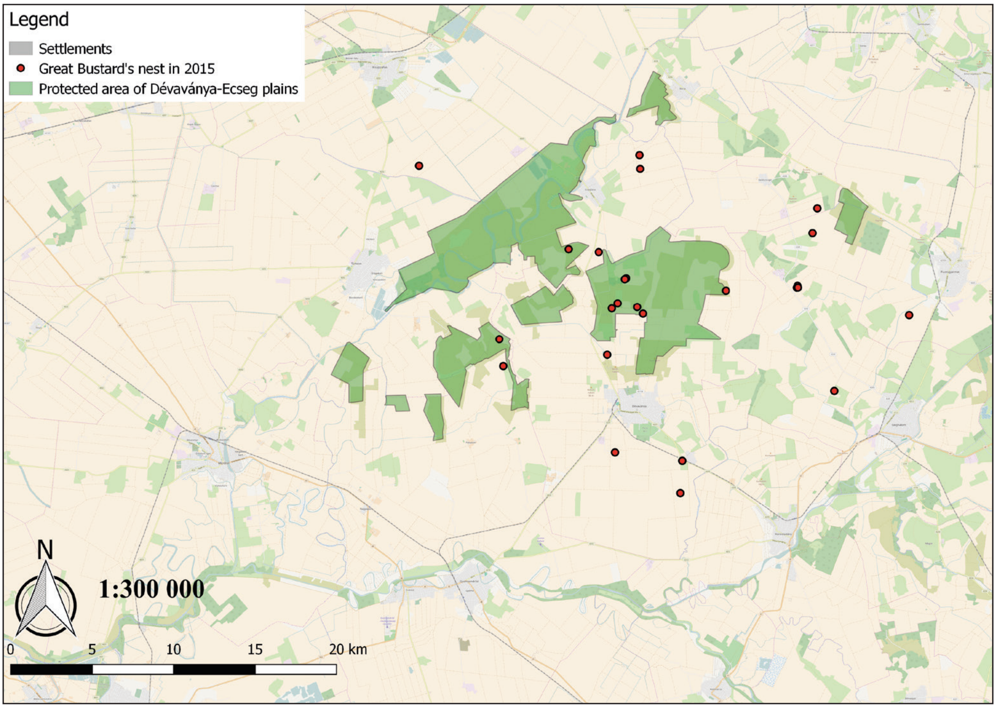


Figure 3. Monthly distribution of the Great Bustard nests' locations between 2004 and 2015
3. ábra A túzok fészkek előkerülése (db) havi bontásban 2004 és 2015 között

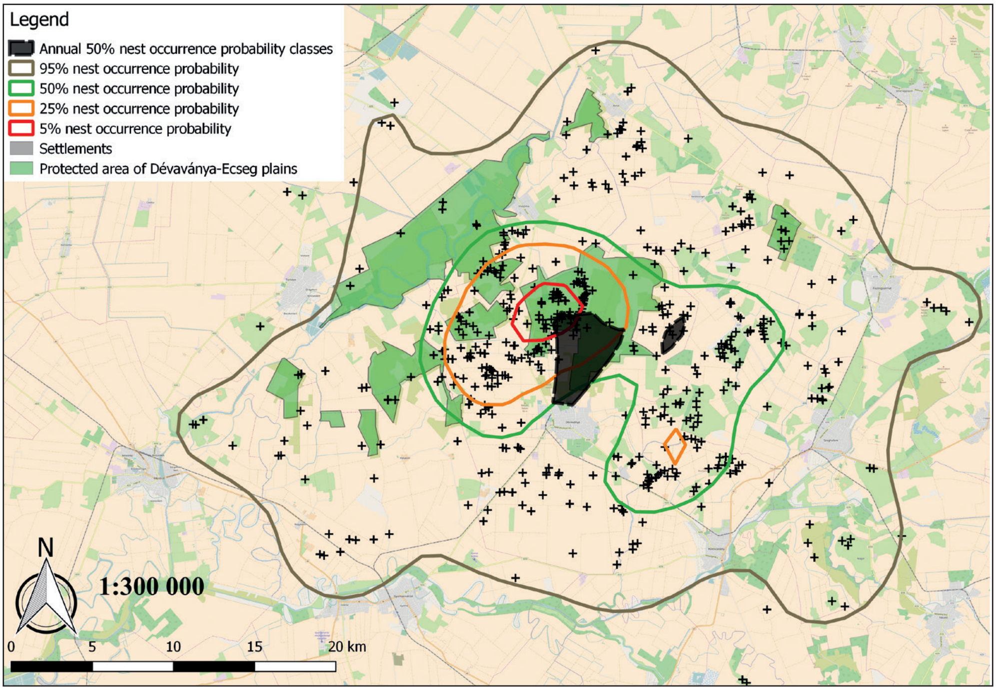


Map 3. Spatial distribution of Great Bustard nest in 2015
3. térkép A túzok fészkek területi eloszlása 2015-ben

In 2015, majority of nests were found in native grasslands (28.6%), followed by fallow land (17.8%), wheat (14.3%) sunflower (14.3%). Agricultural operations inducing disturbance are ranked in descending order of frequency as following: hay-cutting (39.3%), chemical pest control (17.9%) and cultivation (10.7%). Among these nests, 35.7% were found in fields of 5–20 hectares, 28.6% were located in a range of 50–100 hectares and 17.9% of nests were discovered in fields with size of less than 5 hectares. 14 (50%) of discovered nests were located within less than 100 metres from field boundaries, 13 (46.4%) were found in a range of 100–300 metres from field boundaries and a single nest was discovered (3.6%) farther than 300 metres from field boundaries. All nests included one or two eggs, 9 out of which (32%) included a single egg, while the remaining 19 nests contained two eggs (68%). Thus, average nest site amounted to 1.68 in 2015. Out of all discovered nests, 4 (14.3%) were not reoccupied by females, while 24 were reoccupied (85.7%).

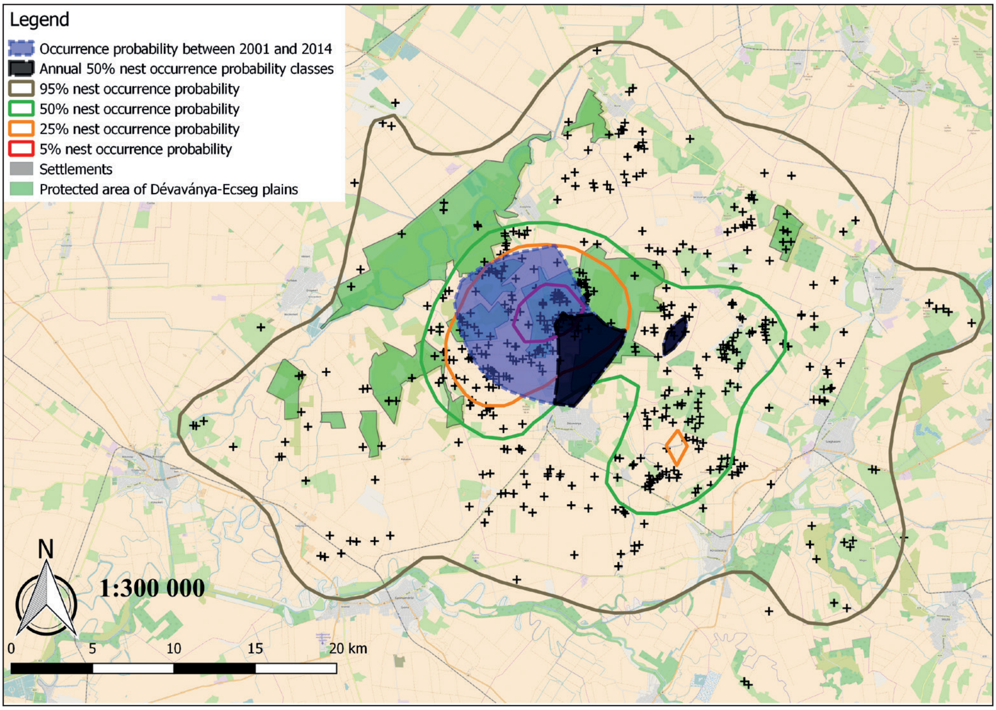
In four cases, protective buffer zones were not established (14.3%), while the size of the buffer zone was 10–50m^2 in a single case (3.57%), ranging between 50–200 m^2 in four cases (14.3%), between 200–700 m^2 in 12 cases, (42.9%), while this size exceeded 700 m^2 in seven cases (25%). Defecation into nest was observed in a single case (3.6%), while in the other 27 (96.4%) cases no such behaviour was detected.

Actual nest positions were significantly closer to lek sites than those of random locations (Kruskal-Wallis test $\chi2$=8.6039; df=1, p=0.0033). Results of the autologistic model



Map 4. Spatial distribution of the Great Bustard nests with occurence probabilities and annual 50% probability classes

4. térkép A fészkek elhelyezkedése az előfordulási gyakoriságokkal és az évenkénti 50%-os gyakoriságok metszetével



Map 5. Spatial distribution of Great Bustard nests with breeding probability, annual 50% occurence probability cut between 1998 and 2015 and 50% occurence probability cut between 2001 and 2014, which recommended as Great Bustard nesting test area

5. térkép Az 1998 és 2015 között előkerült fészkek elhelyezkedése a fészkelési gyakoriságokkal, az évenkénti 50%-os gyakoriságok metszetével és 2001 és 2014 között a fészkek előfordulási gyakoriságának 50%-os metszetével, ami ajánlott túzokfészkelési vizsgálati terület is egyben

show that real nests were located significantly farther from settlements than random nests (p=0.0007). Contrary to our expectations, road distance and altitude exerted no effects on nest positions (p=0.5639 and p=0.8608, respectively).

Map 4. shows the intersection of annual 50% breeding range layers, which covers 1729 hectares.

Between 2001 and 2014, non-protected agricultural areas north and northeast of Dévaványa shows also a prefered territory by females. The intersection of these areas amounts to 6787 hectares *(Map 5)*.

Discussion

As compared to the past 30 years, agricultural habitats used for nesting include fallow lands in a large number of cases, besides wheat, grassland and alfalfa (Faragó 1985a, Morgado & Moreira 2000). Fallow lands are usually established in arable lands severely affected by rainy periods, resulting in temporary wetlands, especially in former oxbows and marshes of the region which makes agricultural operations impossible. Additionally, fields are increasingly set aside as a result of agricultural environmental schemes, the Great Bustard-friendly specific programme of which is also available in the study region (I2).

Agricultural operations causing disturbance represent the seasonal management of agricultural activities: majority of nests have been found in wheat fileds, during chemical wheat control which is a characteristic activity during the breeding period.

Considering the annual distribution of nest detections, the importance of distrubance types might vary substantially.

Based on literature resources, the clutch size of Great Bustards range between 1 and 3 (Fodor 1974b, Faragó 1983b, 1992b, Morgado & Moreira 2000). However, the average number of eggs was less than 2.0, which indicates the intensified conservation of Great Bustards, considering the low mean breeding success of females (Morales *et al.* 2002). In contrast, the frequency of nest desertion was rather low in our study, contrasting with an earlier study in Hungary (Demeter *et al.* 1994). However, we possess no data on breeding success, which would allow to test the effects of predation pressure in wild populations (Morales *et al.* 2002, Faragó *et al.* 2014). Nest location data from 2015 indicate that majority of nests were found close to field boundaries, which is probably a result of traffic disturbance and do not necessarily reflect real nest distribution patterns (Lane *et al.* 2001) However, if this pattern is a real element of Great Bustard nesting behaviour, then it might be beneficial for females by easier reaching various habitats from field edges, allowing an increased availability of wider diet spectra for females and the young, which might induce positive effects in population dynamics.

In contrast to our prior expectations, nest positions were not related to roads and altitude, while leks but not nests were found closer to lek sites (Burnside *et al.* 2013, Lóránt & Vadász 2014). Similar results were found by Osborne *et al*. (2001), which were not confirmed by further investigations carried out in Spain, elsewhere (Magaña *et al.* 2010). Therefore, this nest localisation study calls for future investigations carried out on satellite or radio-tagged birds.

The missing effects of roads on nest distributions might have been driven by sampling bias, as the real number of nests in various distances from roads are not sufficiently known.

However, if roads do not really affect nest positions, nest surveys need to include fields connected to public and dirt roads. Considering nest locations and frequencies found in 17 years, the focal nesting area of Great Bustards is situated north of Dévaványa.

The results of kernel density estimates show that nests have been detected during agricultural operations in areas necessarily far from settlements, but close to lek sites.

As most of the nests were found within the municipality area of Dévaványa, mostly in wheat, grassland, fallow land and alfalfa habitats, these habitat classes need to be primarily searched for Great Bustard nests. Additionally, the results of spatial statistics show that majority of nests might be found within a five kilometres range of lek sites and farther than four kilmoteres from settlements (Moreira *et al.* 2004). As females do not seem to avoid neither public nor dirt roads, fields adjoining linear objects are also recommended to be surveyed. These works are suggested to be started in April and to be continued in May, in order to obtain reliable data on Great Bustard movements prior to agricultural operations.

One of the key objectives of our study was to outline areas where the probability of finding Great Bustard nests is significantly higher than predicted by random search which thus allows the detection and protection of nests before agricultural disturbance.

To do so, further studies are required within possible hotspots. For nest surveys, we recommend to apply 50% breeding ranges, which by definition omit large areas with probable nest occurrence. Additionally, 50% breeding ranges indicate areas where no nests were detected during the past 17 years, which are close to settlements and predicted to be avoided by Great Bustards *(Map 4)*. This contradiction is a result of computing breeding ranges based on nest location only and not controlling for environmental and disturbance models in the same sets.

Based on our results, the isolated habitat patch needs to be surveyed which is indicated by both 25 and 50% breeding range intersections, located in non-protected agricultural areas north and northeast of Dévaványa. However, the intersection of these areas amounts to 6787 hectares, which is still too large for nest surveys.

Our study calls on further investigations on the effects of the spatial distribution of predation pressure and on spatial aggregation patterns of females during breeding (Fodor *et al.* 1971, Demeter 1995).

Such an integrated study would allow the formulation of complex models which would result in more precise maps of habitat use, resulting in more reliable approaches for nest surveys, which facilitates Great Bustard conservation.

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DE GRUYTER OPEN

A high level of nest predation observed in a large Sand Martin *(Riparia riparia)* colony

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Tibor Szép, Jenifer Für & Edit Molnár 2016. A high level of nest predation observed in a large Sand Martin *(Riparia riparia)* colony. – Ornis Hungarica 24(2): 46–53.

Abstract During the 2016 field season, we investigated the influence of intense nest digging predation at a Sand Martin colony that is situated in natural habitat along the Tisza river. Over this season, foxes dug a large number of holes which either partly or fully destroyed 39% of burrows in a large colony, comprising over 1,500 pairs. This high level of predation caused death and/or injury to between 7% and 44% of breeding individuals and lowered the reproductive success of the colony as on average 20% (between 5% and 43%) less nestlings were fledged. The level of digging showed a negative exponential growth with burrow density. Our observations show that the burrows were most at threat between 0 m and 0.4 m from the top and between 0 m and 1.4 m from the bottom of the wall. These observations show that it is critically important to decrease the number of foxes and other potential nest predators, whose numbers have increased well above 'natural' levels over the last decade, in regions where Sand Martins are nesting as this species is in drastic decline.

Keywords: predation, *Riparia riparia*, colony, Tisza

Összefoglalás Munkánkban megvizsgáltuk a partifecske természetes élőhelyén, a Tisza mentén lévő jelentős nagyságú telepen 2016-ban tapasztalt nagymértékű kiásásos fészekragadozás jellemzőit és hatását. A rókák által kiásott nagyszámú üreg az 1500 páros nagyságot meghaladó nagy telepen a fészkelő üregek 39%-nak részleges/teljes pusztulását eredményezte. E jelentős ragadozás egyrészt a költő egyedek 7–44%-nak pusztulását/sérülését okozta, másrészt a kirepült fiókák számának átlagosan 20%-al való csökkenését (5–43%) eredményezte. A rókák által kiásott üregek száma növekedett, de egyre lassuló ütemben a partfalon lévő partifecske üregek sűrűségével. A kiásásos ragadozás által legfenyegetettebb üregek a partfal felső 0,4 m sávjában, illetve a függőleges partfal aljától számított 0–1,4 m sávjában helyezkedtek el. A korábbi évtizedekhez képest jelentősen megnövekedett számú róka és más fészekragadozó számának csökkentése a partifecske telepek körzetében nagyon fontos e faj drasztikus csökkenést mutató hazai állományának védelme számára.

Kulcsszavak: ragadozás, *Riparia riparia*, telep, Tisza

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Introduction

Populations of Sand Martin *(Riparia riparia)* breeding along the Tisza river in Hungary have experienced sharp declines over recent decades (mean annual population growth rates: -2.7% over the period between 1986 and 2014, T. Szép unpublished data), a pattern that is also seen in the case of other Hungarian long distance migratory bird species (Szép *et al.* 2012). A variety of processes are thought to underlie the declines of Afro-Palaearctic migrant species in distant areas (Vickery *et al.* 2014). Sand Martin, for example, breeds in large colonies in eastern Hungary

(Szép 1991) and an increasing subsection of this population has formed a massive breeding colony exceeding 1,000 pairs over the last decade (T. Szép, unpublished data). In 2016, however, our field teams encountered large numbers of holes dug by predators within the largest colony, a river area where ca. 55% of the entire population of the river was breeding.

In the case of Sand Martin, a number of detailed studies are available that have addressed degree of aerial predation (Szép & Barta 1992, Probst *et al.* 2011), with emphasis on Hobby *(Falco subbuteo)*, the most important aerial predator (Mead & Pepler 1975). In terms of ground-based predators (Mead & Pepler 1975), Fox *(Vulpes vulpes)* and Badger *(Meles meles)* are the main candidates responsible for 'digging predation' of Sand Martin burrows; indeed, Persson (1987) recorded high levels of nest predation by badger in Sweden with 25% of nests destroyed.

In this report, we discuss the number of Sand Martin burrows that were destroyed either partly or fully by this kind of nest predation in the Tisza river colony during 2016, how the level of this predation depend on the density of the burrows in the walls, which kind of burrows and which where the most threatened, and what could be the influence of predation on breeding individuals and their reproductive success.

Material and methods

The Sand Martin is an aerial insectivorous bird, which usually digs new burrows after its arrival back to breeding areas in the spring in perpendicular walls of soil formed naturally (e.g. rivers) or artificially by humans (e.g. sand pits) (Cramp 1988). Each burrow comprises a 30–70 cm long tunnel with a nest chamber at the end.

In this study, we investigated the largest Sand Martin colony along the river Tisza at Szabolcs (48.188° N, 21.488°) during the breeding season (between middle April – beginning of August), 2016. This colony was situated along a 540 m long river bank, formed naturally by the flood of the river during the preceding winter. We followed the formation of the colony by taking digital pictures (Panasonic FZ1000) from the front of the colony at 6 m long sections along the river (90 sections in all, marked with numbered peg on the top of the bank), twice a week, and we counted Sand Martin burrows and measured the height of the perpendicular part of the river bank along the 6 m sections from these pictures using ImageJ software (Schneider *et al.* 2012). In this way, we used the daily counts of Sand Martin burrows in the studied sections to identify the number of destroyed burrows resulting from natural falls of river banks following heavy rain.

In terms of predators that operate on the ground, we identified Badger, Fox, Weasel *(Mustela nivalis)*, Stoat *(Mustela ermine)*, Brown Rat *(Rattus norvegicus)* and Domestic Cat *(Felis silvestris catus)* (Mead & Pepler 1975, Persson 1987) as potential Sand Martin predators. Indeed, in the context of our integrated monitoring of the Tisza river colony (Szép *et al.* 2003), we also encountered additional predators including Beech Marten *(Martes foina)* and Wildcat *(Felis silvestris)* (Szép T. unpublished). However, at this colony, on the basis of footprints and smells, it is clear that foxes carried out predominant digging into nesting holes, although we were unable to estimate the number of predators.

We were able to identify and count the number of holes dug by nest predators in our studied sections in the river bank front using pictures because the size and shape of holes and burrow entrances affected by predation are very different from normal Sand Martin burrows. Indeed, nest predators also dig into chambers from the top of the bank, an angle which was invisible from our pictures. We surveyed these holes along the top of the colony surveying 6 m long sections on 11th of July 2016 (subsequent to fledging of the first Sand Martin clutches). As a pilot experiment to protect burrows, we covered the top of one 6 m long section of the colony with a 1 m wide metal net before the colonization of this section in April and found that no Sand Martin burrows were dug by predators from the top in this section.

We then randomly selected eight subcolonies along the Szabolcs colony situated in 1–6 m wide parts of the banks (1 m: 1 piece, 2 m: 5 pieces, 6 m: 2 pieces), where every burrows were numbered (551 burrows) and investigated weekly with a digital endoscope (Olympus IPLEX LX videoscope) to follow breeding history of the first and additional/second clutches in the burrows (i.e. start of egg laying, clutch size, hatching, number of nestlings before fledging at the age of 15–18 days, evidence of nest predation). We measured the distance of these burrows from the top and bottom of the perpendicular part of river bank from pictures. In the case of these intensively studied sections, we directly investigated the holes dug by predators in the front and top of the subcolonies.

We used parametric and non-parametric statistical tests depending on the distribution of the data using SPSS 18.0 (Norris *et al.* 2012). We modeled the of digging predation and burrow density with negative exponential growth models (Bates & Watts 1988), using the nls () function of the R statistical software (R Core Team 2015).

Results

Sand Martin burrows and holes dug by predators in the colony

Across the studied colony, 2,776 burrows were made by Sand Martins in 2016. The birds started digging on the 23rd of April and the first 10% of burrows were complete by the 1st of May, the first 50% by the 16th of May, and the first 90% by the 3rd of June *(Figure 1)*. Burrows were dug into 50 separate 6 m long sections (mean number of burrow/section=55.32, SD=49.044, median=30, minimum=2, maximum=206, n=50). The density of Sand Martin burrows varied between 0.81–17.04 burrows/m^2 (mean=5.591, SD=4.267, median=4.3, n=45).

Following days with heavy rain and partial predator digging activities, 1,603 burrows had collapsed by falling down the river banks by August; by the beginning of July (the end of the first clutch fledging period), 991 burrows had disappeared (36% of all burrows).

We identified 280 holes that were dug by predators in front of the colony during the breeding season. This digging started on the 25th of April, with the most intense periods between 1st–16th of May, 20th–30th of May and 6th of June – 11th of July *(Figure 1)*. This kind of nest predation occurred at 35 pieces of 6 m long sections from the 45 sections where incubation/

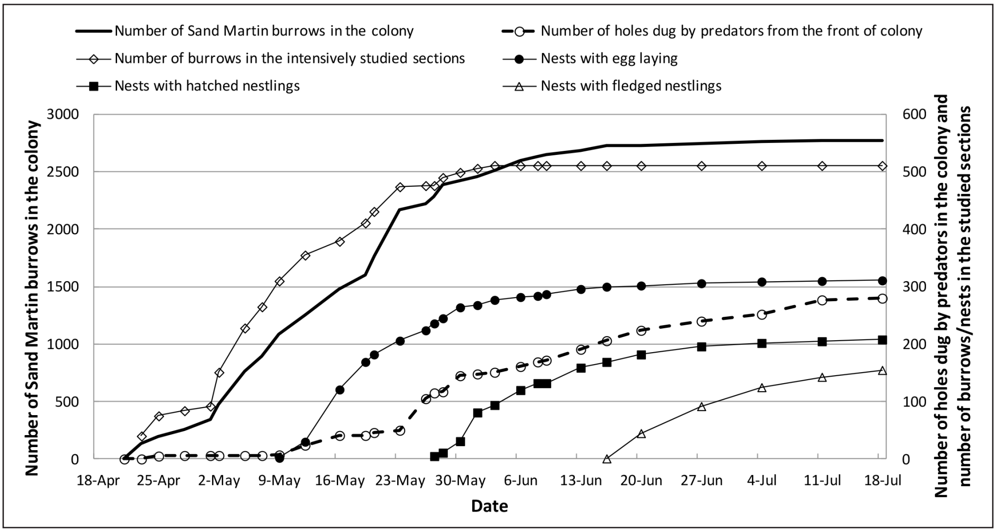

Figure 1. Number of Sand Martin burrows in the colony and number of holes dug from the front of the colony by nest predators during the 2016 breeding season. The number of burrows, nests with eggs, nests with hatched nestlings, and nests with fledged nestlings in the eight intensively studied subcolonies are shown

1. ábra Partifecske fészkelő üregek és a ragadozók által a partfal oldaláról kiásott üregek száma a 2016-os költési időszakban a szabolcsi telepen. Az intenzíven vizsgált 8 telepészlet esetében a fészkelő üregek száma, a tojásos, kikelt fiókás és kirepült fiókás fészkek száma megadva a teljes költési időszakra

nestling rearing digging were possible (5 sections there were only burrow digging) and our analysis demonstrates a significant positive correlation between the number of holes dug at the front of the colony and the density of the burrows in the section (r=0.698, n=45, $P<0.001$, Spearman rank correlation).

We identified 128 holes dug from the top of the colony by predators during the breeding season up until the end of the fledging of the first clutches. This kind of predation occurred in 23 distinct 6 m long sections, and there was a significant positive correlation between the holes dug from the top and the density of burrows in the section (r=0.671, n=45, $P<0.001$, Spearman rank correlation).

Considering both kind of nest predation (dug from front and top direction), the number of dug holes increased with the density of burrows *(Figure 2).* The fitted negative exponential model: (the standard errors and the p-values of the estimated parameters are: SE=3.49 (p=0.1088), SE=3.09 ($p < 0.0001$), SE=0.09 (p=0.0394), respectively. The estimated maximum number of holes is about 21/section.

Breeding and predation in intensively studied subcolonies

The number of burrows in the eight subcolonies we studied comprised 18.4% of the entire colony. In these subcolonies, digging started on the 23rd of April, and the first 10% of all burrows were completed by the 25th of April, the first 50% by the 9th of May, and the first 90%

by the 20th of June *(Figure 1)*. The arrival of birds to these subcolonies was about one week earlier than the rest of the colony.

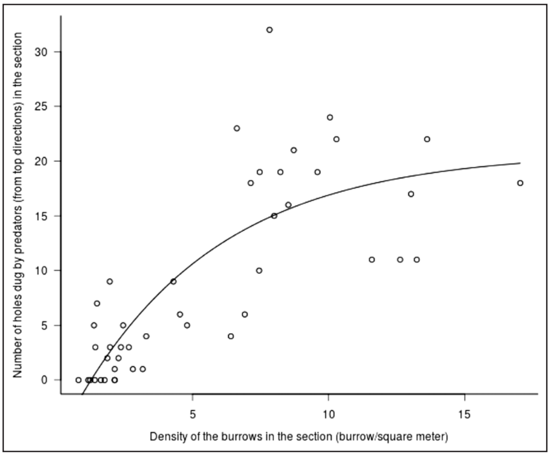

Figure 2. Number of holes dug by predators (from front and top of the colony) in the 6 m long sections of the colony as well as the density of burrows (burrow/m²) in these sections and the fitted negative exponential growth model

2. ábra A 6 m hosszú lakott szakaszokon a ragadozók által kiásott üregek száma (a partfal oldaláról és tetejéről) és a partifecske üregek sűrűsége (üreg/m²) és az illesztett negatív exponenciális növekedési görbe

We investigated all burrows in these eight subcolonies with an endoscope and determine that eggs were laid in 311 burrows, 60.9% of the total (95% CI: 56.6%–65.1%) 511 burrows. The level of burrow occupancy was similar to previously reported, at 60% (Szép 1990), while the level of burrow disappearance by river bank collapse (34.6%, 177 burrows) was similar as in the colony during the rearing of the first clutches.

Egg laying started on the 9th of May (median: 19th of May) and by the 25th of May eggs had been laid in 90% of nests (n=208) *(Figure 1)*. Of these, 66.9% hatched, starting on the 27th of May (median: 4th of June), and by the 24th of June hatching has commenced in 90% of all nests (n = 208). Nestlings reached 15–18 days old in 50.5% (n=157) of nests that contained eggs; fledging started on the 16th of June (median: 24th of June), and by the 11th of July young in 90% of nests had fledged.

In the eight subcolonies, 26 holes were dug by predators from the front of the colony. These 26 holes destroyed partly/fully 76 Sand Martin burrows (mean value: 2.923 burrows/dug holes from front; 95% CI: 2.228–4.247). In these cases, predation started on the 30th of May, and 50% of the partly/fully destroyed burrows were dug until the 13th of June while by the 5th of July 90% had been dug by predators. This kind of predation occurred mainly during the pairing, incubation and hatching periods. Breeding adults were potentially influenced (killed/injured and/or breeding were abandoned) in 43.4% of these nests, incubating adults and eggs were killed/destroyed in 7.9% and nestlings were killed 21.1% of the nests. There were successful breeding only in 10.5% of these nests (in 17.1% of these nests the influence was not identifiable).

In two subcolonies, we were able to examine the number of holes dug in total by predators from the top of the colony (15 holes) as well as the number of Sand Martin burrows destroyed either partly or fully by this predation (31 burrows) and found that the mean value was 2.067 burrows/dug holes from top (95% CI: 1.516–3.247). Across the eight subcolonies, 38 nests in total were dug from the top of the colony. This predation started on 9th of May, and by the 20th of June 50% of the partly/fully destroyed burrows had been dug, while by the 10th of July 90% had been dug by the predators. This kind of predation occurred mainly during the periods of nestling rearing; nestlings were killed in 42.1% of nests, breeding adults were potentially influenced (killed/injured and/or breeding were abandoned) in 15.8% of these nests, and in none of these nests the nestlings were able to reach fledging age (0%) during the first clutch period (in 26.3% of nests predation occurred during the period of additional/second clutches and the influence was not identifiable in a further 15.8% of nests).

Distance of burrows from the top and bottom of the perpendicular part of the river bank was significantly different among burrows predated from front or top of the colony and burrows that lacked nest predation (i.e. distance from the top of the bank: F=119.329, df=2, 105.425, P<0.001; distance from the bottom of the bank: F=24.072, df=2, 92.829, P<0.001, Welch robust test of equality of means) *(Table 1)*. Burrows predated from the top of the wall were mainly situated in the top 0.4 m wide layer (90%) *(Table 1)*, while those predated from the front of the colony were situated in the lower layer but across a wider range from the bottom of the wall with 90% between 0–1.4 m *(Table 1)*.

Of the 551 burrows we investigated, 140 (25.4%) contained nestlings, and the mean number of nestlings before the fledging (at 15–18 days old) was 1.02 nestlings/burrow (SD=1.741, n=551). The number of burrows dug partly/fully by predators was 114, 20.7% of all studied burrows, and in these there was a significantly lower number of fledged nestlings (mean=0.605, SD=1.520, n = 114) than in burrows that did not experience this kind of predations (mean=1.124, SD=1.780, n=437) (mean difference=-0.518, SD=0.166, 95% CI: -0.193–0.843, t=3.124, df=201.561, P=0.002, Welch test).

Estimated influence of nest predators on the colony

The estimated mean number of burrows dug by predators was 1,083 (minimum=818, maximum=1,605) based of the mean number of burrows influenced by holes dug from the front and top of the colony (95% CI). In the colony, 39% (minimum=29.5%, maximum=57.8%) of the 2,776 burrows suffered because of digging predation, and the number of fledged

Table 1. Distance from the top and bottom of the wall of predated (dug from the front of the colony and from the top of the colony) and unpredated burrows in the eight intensively studied Sand Martin subcolonies at Szabolcs in 2016

1. táblázat A kiásásos ragadozás által érintett és nem érintett partifecske üregek távolsága a partfal tetejétől és aljától az intenzíven vizsgált 8 teleprészleten, a Szabolcs térségében lévő telepen 2016-ban (Átlag, medián, szórás és mintaszám megadva a nem kiásott, a partfal oldaláról és a partfal tetejéről kiásott üregek esetében)

	Distance from the top of the bank (m)			**Distance from the bottom of the bank (m)**		
	No predation	*Predation from the front*	*Predation from the top*	*No predation*	*Predation from the front*	*Predation from the top*
Mean	0.695	0.813	0.337	1.040	0.832	1.195
Median	0.800	0.800	0.400	1.000	0.800	1.200
SD	0.294	0.274	0.132	0.317	0.399	0.177
n	437	76	38	437	76	38

nestlings was lower at an average of 561 individuals (minimum=158, maximum=1,354), taking into account mean differences between predated and not predated burrows. Thus, the estimated number of lost nestlings is around 20% (minimum=5%, maximum=43%) of the potential total number of fledged nestlings in the colony (ca. 3,100 nestlings) estimated to be present if nest predation had not occurred.

Our results show that this kind of predation causes death or serious injury to breeding birds in 15–43% of burrows dug by predators. The estimated number of adult individuals affected by predation of this kind was between 245 and 1,380 birds, 7–44% of the total number of individuals out of an estimated 1,691 (minimum=1,571, maximum=1,807) total breeding pairs in the colony.

Discussion

Nest predation by foxes digging into Sand Martin burrows reached a very high level in 2016, affecting 39% of burrows in a colony with 1,500 breeding pairs of birds. This high level of predation caused death or injury to 7–44% of the breeding individuals and led to a lower level of reproduction in the colony as an average of 20% (5–43%) less nestlings fledged.

The threat of digging predation from the top of colony is higher because it affects nests containing nestlings; no fledging was possible from nests predated in this way. However, in the case of burrows dug from the front of the colony, we did find found nests containing fledged nestlings as this kind of predation mostly threatens breeding adults during the pairing and incubation periods.

The level of digging predation increased with density of the burrows, but when higher than a specific density level (ca. 8 burrows/m^2) the number of holes dug by predators did not increase in accordance with the dilution effect (Foster & Treherne 1981). However in the case of large density of burrows, one hole dug by predators could harm more burrows, which needs to be considered as well when potential of dilution effect expected to reduce predation threat.

Distance of burrows from both the top and bottom of the perpendicular part of the wall is an important factor determining threat from digging predation. Our results show that the positions most at threat are the 0–0.4 m layer from the top of the wall, because of the predation from the top of the colony and – the 0–1.4 m layer from the bottom of the wall, because of the predation from the front of the colony. Breeding walls with the minimum 2 m perpendicular height could provide more safe position for burrows against digging predation, however the chance of falling the breeding wall after heavy rains increase with the height of the wall, depending on the type of soil (Szép T. pers. obs.), which need to consider when breeding habitats prepared artificially for Sand Martin colonies.

Reducing the threat of nest predation is very important in the case of this species which population shows drastic decline. To decrease the numbers of Foxes and other potential nest predators (e.g. Beech Marten, Badger) which numbers increased above the former “natural” level during the last decade in the area of Sand Martin colonies, especially around large colonies is very important. The use and development of mechanical protection for Sand Martin burrows against digging (e.g. covering the top and front part of the colony with metal net with proper mesh size) and developing chemical protection with natural compounds (e.g. capsaicin) (Baylis *et al.* 2012) for deterring predators are necessary as well for the protection of large colonies.

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Cranial morphology of European passerine bird families (Aves, Passeriformes)

Péter Ujhelyi

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Péter Ujhelyi 2016. Cranial morphology of European passerine bird families (Aves, Passeriformes). – Ornis Hungarica 24(2): 54–77.

Abstract The subject of this study focuses on the cranial morphology of 24 native European passerine bird families. In addition to the discussion of taxonomical questions regarding to the examination of beak, orbit, cranium and mandible, the author aims to provide guidance to the determination of raptors' prey remains. Most of the studied bird families are well-distinguishable using the knowledge on the mentioned osteological traits except some less-specialised families.

Keywords: taxonomy, determination, cranial morphology, songbirds

Összefoglalás A dolgozat az Európában honos 24 énekesmadár-család koponyamorfológiai jellemzésével foglalkozik. A csőr, a szemgödör, az agykoponya és az állkapocs vizsgálatával a szerző egyes taxonómiai kérdések megvitatása mellett a ragadozómadarak zsákmánymaradványainak meghatározásához kíván segítséget nyújtani. A vizsgált madárcsaládok többsége a felsorolt csonttani bélyegek ismeretében jól elkülöníthető, csupán néhány kevéssé specializált család meghatározása jelenthet gondot.

Kulcsszavak: Aves**,** Passeriformes, koponyamorfológia, határozás, taxonómia

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Introduction

Studying of avian osteo-morphology has a tradition dated back to the middle of the 19th century. Initially, the skeletal system was examined particularly in systematic perspectives: the structure of the palate (Huxley 1867, Hofer 1945, Witmer & Martin 1987, Zusi 1993), the sternum and humerus (Fürbringer 1888), the cranium, sternum, shoulder, pelvis and hindlimb (Suschkin 1905), number of the vertebra (Boas 1929, Zweers *et al.* 1987), and the morphology of carpometacarpus (Steiner 1922, Lambrecht 1933, Hinchliffe 1985) was considered in distinguishing the larger bird orders. In the past century, mainly palaeontologist used comparative osteo-morphological methods and studied less vulnerable skeletal compartments from excavations. Although, the examination of postcranial parts of the skeleton is dominant in paleontological researches, in some cases, the determination of cranial remains may also be necessary (Jánossy 1992). Whereas, fossils can confidently be classified among recent species, only with deep knowledge on bones (Lambrecht 1933), thus classical morphological researches – simultaneously with the emergence of molecular taxonomy – should be preserve their roles in systematics (Judin 1978). Several detailed osteological collections of different bird groups, which could also facilitate paleontological studies, have been made to date: Podicipediformes (Bochenski 1994), Ardeidae (Boev

1988), Anseriformes (Bacher 1964, Woelfle 1967), Galliformes (Ebersdobler 1968, Kraft 1972), Charadriiformes (Barbosa 1991), Columbidae (Fick 1974), Falconiformes (Otto 1981, Schmidt-Burger 1982, Solti 1980, 1981a, 1981b, 1994), Strigiformes (Winde 1970, Langer 1980), Picidae (Kessler 2016).

Despite passerines constitute most probably the prey of owls (März 1987), finches (Finckenstein 1937, Moreno 1985, Ujhelyi 1992) and corvids (Tomek & Bochenski 2000) are the most intensively studied groups within this order. The only detailed studies including more bird families are Jánossy's (1983) guide for humerus and the works of Moreno (1985, 1986, 1987), and Cuisin (1989) about the Spanish and French fauna. Numerous parts of the skeleton are also presented in Kessler (2015).

I assembled the craniomorphological characterization of 24 native European passerine families in this study. Besides the premaxilla and the cranium, I paid special attention to the morphology of mandible, because bone remains can be identified significantly easier with the knowledge on the structure of the *pars caudalis mandibulae*. Other authors did not attribute sufficient importance to it, however the complete *pars caudalis mandibulae* can often be found among food remains. Furthermore, my work contains the anatomy of the *vomer* since previous researches entirely omitted this. This study is based on the comparative osteological collection of the Hungarian Natural History Museum. Some specimens of a few groups were studied in the Paleontological Institute of the Russian Academy of Science (Moscow) and in the Museum of Natural History, Vienna (Naturhistorisches Museum, Vienna). I asked G. Csorba from the zoological collection of the Berlin's Museum of Natural History (Museum für Naturkunde, Berlin) to carry out some comparative examinations, particularly for this study. I would like to emphasize with the list of genera of each family that I mainly considered the European members of these families in the compilation of cranial morphology for this study. The original illustrations completed this text were also made in the above-mentioned collections. The delimitation of each bird families follows Voous (1977), however their order differs, because here I present sequentially the osteologically more related groups. Although, the linear listing could never perfectly reflect the complex system of songbirds, but it is remarkable that the osteological characteristics could be comparable with the biochemistry based systematics of Sibley and Ahlquist (1990) in many instances. Newertheless, the nomenclature of this study can partially be followed using the work of Baumel *et al.* (1979), I explain the terms on explanatory figures.

Corvidae

(*Perisoreus* Bonaparte, 1831; *Garrulus* Brisson, 1760; *Cyanopica* Bonaparte, 1850; *Pica* Brisson, 1760; *Corvus* Linnaeus, 1758; *Nucifraga* Brisson, 1760; *Pyrrhocorax* Tunstall, 1771)

Corvids are large songbirds which can already be distinguished by body size from other members of their order. Their upper beak is robust, the length of the *pars praenarialis* is often larger than the diameter of the nostril. The nostril is completely open in most of the species, but for example in *Pyrrhocorax pyrrhocorax* it is splitted by a horizontal bone plate. In some specimens of *Corvus corax* a well-developed *septum nasi* is located in the nasal cavity, however this bone membrane is vestigial or absent in most of the species. In plan view the *brachium processi maxillopalatini* is visible through the nostril and the *foramen basale* forms its base. The *corpus processi maxillopalatini* is also well-developed and it is partialy hollow in some genera. The edges of the *vomer* are dorsally retracted on both sides, the *processus corniculatus vomeris* is well-developed. The *incisura interpalatina* is usually narrow and there is a bone crest on the ventral surface of the *lamella caudolateralis*. The *foramen orbitonasale* is a long gap in most of the cases but it can be devided by bone plates into more parts. The *septum interorbitale* is well-developed and thick. The *fenestra olfactoria* can be found in numerous genera *(Perisoreus, Garrulus, Pyrrhocorax, Pica, Cyanopica),* but this aperture is bony in *Nucifraga* and *Corvus* species. The *rostrum sphenoidale* is thickened in most of the species. The *processus orbitosphenoidalis lateralis* is particularly developed in *Nucifraga caryocatactes*. The *processus postorbitalis* and the *processus zygomaticus ossis squamosi* are moderately developed. The *symphysis mandibulae* is weak in the case of *Perisoreus infaustus* but in the species of other genera *(Nucifraga, Pyrrhocorax)* it is remarkably long. The *foramina postsymphysialia* are opened on the caudal edge of the *symphysis*, except for the *Nucifraga* genus, where these apertures are located on the ventral surface of the *symphysis*. Behind the *foramen laterale* the *impressio mandibularis* is moderately pronounced and the oval *fenestra mandibulae* is relatively small. On the ventral surface of the *pars caudalis mandibulae* between the peaks of the *processus externus* and the *processus internus* a V-shaped bone ridge streches.

Oriolidae

(*Oriolus* Linnaeus, 1766)

The upper beak is massive and the length of the bony palate approaches the half of the beak. The *pars praenarialis* is larger than the diameter of the nostril. The remnant of the *septum nasi* is located on the rostral end of the naval cavity. The wide *brachium processi maxillopalatini* and the *foramen basale* near its base are visible in plan view. At the end of its extension the lengtheneed *corpus* is hardly separated. The simply structured *vomer* is little pneumatized and the *processus corniculatus vomeris* is short. The *incisura interpalatina* ends at the base of the *processus spiniformis*. The remarkably spacious, single (not split) *foramen orbitonasale* opens close to the axis of the skull. The *fenestra olfactoria* is strongly lengthened in rostral direction, the *fenestra septi interorbitalis* is always located. The *processus postorbitalis* and the *processus zygomaticus ossis squamosi* is moderately developed, where extensions could not be found on the caudal bony wall near the eye socket. The *foramina venae occipitalis externae* opens far from each other and behind the *foramen magnum*. The slim mandible is slightly hooked in lateral view and there is no significant nook *(impressio mandibularis)* on the lateral surface of the mandible. The *foramen laterale* is also absent. The *symphysis* is well-developed, but the *fenestra mandibulae* is small. The bone ridge is vestigial on the ventral surface of the *pars caudalis mandibulae.* The *fossa caudalis mandibulae* is basically absent between the peak of the *processus externus* and the *processus internus*.

Laniidae

(*Lanius* Linnaeus, 1758)

The upper beak of *Lanius* species is relatively short and strength. The *septum nasi* is always located between the nostrils. The *foramen basale* opens at the base of the wide *brachium processi maxillopalatini* which is visible in plan view. The *corpus processi maxillopalatini* is barely separated from the *brachium* in their morphology. The structure of the pneumatized *vomer* is complex, the paired *processus corniculatus vomeris* is dorsally strongly curved. The *incisura interpalatina* is relatively wide, the *lamella caudolateralis* forms a long extension. In *Lanius* species the rostral part of the *pterygoideum* fusions to the *palatinum* differently to the majority of songbirds. The *foramen orbitonasale* is split: the *foramen orbitonasale laterale* is larger than the *f. o. mediale*. The *fenestra septi interorbitalis* is never completely bony. The *processus postorbitalis* is vestigial and the *processus zygomaticus ossis squamosi* is moderately developed. The *foramina venae occipitalis externae* open close to each other and these apertures are connected to the edge of the *foramen magnum* via the paired *sulcus occipitalis*. The *symphysis mandibulae* is moderately thick, the *impressio mandibularis* is varied by species. The *foramen laterale* is absent. The wide-based *tuberculum pseudotemporale* is moderately developed. A sharp bone ridges is located on the ventral surface of the *processus internus*. The *fossa caudalis mandibulae* is barely expressed.

Hirundinidae

(*Hirundo* Linnaeus, 1758; *Delichon* Horsfield et Moore, 1854; *Riparia* Forster, 1817; *Ptyonoprogne* Reichenbach, 1850)

The typically prolate beak of swallows and martins makes the members of this family to easily recognizable. The *brachium processi maxillopalatini* is not visible over the nostril, but it is located behind the *processus postnarialis*. The *foramen basale* exists. The *vomer* is flat, the contour of the *processus corniculatus* is angular. The basically wide *incisura interpalatina* ends at the peak of the *processus spiniformis*. The *pars interorbitalis* is narrow, the *septum interorbitale* is thin. The *foramen orbitonasale* is split: the *f. o. laterale* is smaller then the *f. o. mediale*. The *fenestra olfactoria* and the *fenestra septi interorbitalis* are spacious. The *processus postorbitalis* and the *processus zygomaticus ossis squamosi* weakly developed. A paired groove *(sulcus occipitalis)* extends between the *foramen magnum* and the *foramina venae occipitalis externae*. The *symphysis mandibulae* is weak, the *foramina postsymphysialia* open far from each other on its dorsal surface. The mandible branches are widely expanded. The *angulus mandibulae* is typical of the mandible with a peak in its middle. The *processus internus* is not visible in lateral view and bone ridge is never located on its ventral surface. The *fossa caudalis mandibulae* is deeply curved.

Comment: The swallows form a very special group of songbirds. Their anatomical specializations regarding to their lifestyle make it difficult to identify which families are closely related to them. Whereas the Corvidae-Oriolidae-Laniidae triplet is farther related to all other passerines than the swallows, thus I have listed them here right after the Laniidae.

It needs to be considered in the practice of the determination of families that the skull of the swallows remind to the skull of the swifts (Apodiformes: Apodidae), however these two groups differ in many morphological traits. The nook *(impressio supraorbitalis)* behind the *pars interorbitalis*, and the lateral position of the *foramina venae occipitalis externae* separate swifts from any other songbirds.

Bombycillidae

(*Bombycilla* Vieillot, 1808)

The upper beak with a significant widening at its base is relatively short. The bony palate is also shortened. The nostril is spacious and the *septum nasi* is always absent. The *corpus processi maxillopalatini* is short, wide and partially pneumatized. The *vomer* is flat and the contour of the *processus corniculatus* is angular. The wide *incisura interpalatina* is protractedly wedged forward. The orbital surface of the weakly pneumatized *ala mesethmoidei* is concave. The split-like *foramen orbitonasale* is single (not split). The *fenestra septi interorbitalis* is bony and absent in adults, whilst the *fenestra olfactoria* is remarkably spacious. The *processus postorbitalis* is almost melded into the cranium and the *processus zygomaticus ossis squamosi* is also vestigial. The *ala tympanica* hardly covers the *cavum tympani* in lateral view. The *foramina venae occipitalis externae* open at the end of one-one paired groove *(sulcus occipitalis)* behind the *foramen magnum*. The *symphysis mandibulae* is short, the mandible branches are widely expanded. The *impressio mandibularis* is always located and the *foramen laterale* opens in front of it. The ventral surface of the *pars caudalis mandibulae* is smooth, the *fossa caudalis mandibulae* is moderately notched. The axis of the lengthened *processus internus mandibulae* is approximately right angles to the mandible branch.

Sturnidae

(*Sturnus* Linnaeus, 1758; Pastor Temminck, 1815)

The upper beak is slim and pointed. The nostrils are spacious. The *septum nasi* is always absent. The *brachium processi maxillopalatini* is visible through the nostrils in plan view and the *foramen basale* is absent at the bottom of it. The strongly lengthened *corpus processi maxillopalatini* is partially pneumatized. A weak bone ridge is located at the midline of the *vomer*, the *processus corniculatus vomeris* is vestigial. The *incisura interpalatina* ends at the middle of the lengthened *collum vomeris*. The *foramen orbitonasale* is split: the larger *f. o. mediale* is in the interior eye cavity while the small *f. o. laterale* opens at the edge of the eye cavity. The *fenestra septi interorbitalis* can be found in both young and adult birds. The *processus postorbitalis* is barely appreciable, the *processus zygomaticus ossis squamosi* is also vestigial. A typical hump is located on the ventral surface of the *rostrum sphenoidale*. The *foramina venae occipitalis externae* open directly at the edge of the *foramen magnum*. In some species (*Sturnus* spp.), a sharp bone ridge *(crista nuchae)* extends at the edged of the *regio occipitalis*. A typical characteristic of the mandible is the mid-peaked *angulus mandibulae* in lateral view. The *foramen laterale* is absent near the *impressio mandibularis*. The *canalis mandibulae* opens just before the *fenestra mandibulae* at the lateral surface of the mandible. The two European starling genera *(Sturnus, Pastor)* significantly differ in the structure of the *pars caudalis mandibulae*: the *processus externus* is already well-developed in the young of the *Sturnus* species, however in *Pastor roseus* this has standard size. A more or less developed hump is located at the rostral edge of the *processus internus.*

Comment: The differences in the morphology of the *pars caudalis mandibulae* absolutely justify the split of *Sturnus* and *Pastor* genera.

Cinclidae

(*Cinclus* Borkhausen, 1797)

The upper beak is slim and sharp and at its ridge, a weak concavity can be found before the *processus dorsonarialis*. The *septum nasi* is absent in the spacious and lengthened naval cavity. The *brachium processi maxillopalatini* is invisible in plan view. A sharp bone ridge extends at the midline of the lengthened *vomer*, which continues in a long bone mandrel at the front of the *vomer*. The *lamella caudolateralis* is significantly shortened. The *pars interorbitalis* is relatively narrow. The *ala mesethmoidei* is strongly pneumatized and it is markedly protuberant on its orbital surface. The *foramen orbitonasale* is split, the *f. o. laterale* opens at the edge of the eye cavity and it is also visible in plan view. The *fenestra olfactoria* and the *fenestra septi interorbitalis* are both spacious. The *processus postorbitalis* is small and rounded, the *processus zygomaticus ossis squamosi* is vestigial. The *fenestra mandibulae* is a relatively small aperture on the rearer part of the mandible and the *canalis mandibulae* opens just before this at the lateral surface of the mandible. A sharp bone ridge is located on the ventral surface of the *pars caudalis mandibulae* which is split into two branches and extends to the rear extension of the mandible *(processus externus et processus internus)*.

Troglodytidae

(*Troglodytes* Vieillot, 1807)

The upper beak is slim, the diameter of the nostrils and the length of the *pars praenarialis* are equal. The *septum nasi* is absent in the naval cavity. The thin and hooked *brachium processi maxillopalatini* is invisible through the nostril in plan view. At the base of this extension, the *foramen basale* is absent and the *corpus processi maxillopalatini* is not pneumatized. The *vomer* is flat and the *processus corniculatus vomeris* is small. The *incisura interpalatina* is wide and the *processus spiniformis* is lengthened. The *foramen orbitonasale* is single (not split). The *fenestra olfactoria* and the *fenestra septi interorbitalis* are both spacious. The *processus zygomaticus ossis squamosi* is vestigial and a relatively sharp bone ridge extends behind it, between the small *processus postorbitalis* and the tympanic cavity *(cavum tympani)*. The mandible is slim and slightly curved in lateral view. The *impressio mandibularis* is absent on its lateral surface. The lateral surface of the *processus externus mandibulae* is convex.

Certhiidae
(*Certhia* Linnaeus, 1758)

The upper beak is thin and slim and strongly curved in lateral view. The *septum nasi* is absent in the naval cavity. The *foramen basale* is absent, the hooked *brachium processi maxillopalatini* is behind the *processus postnarialis* in plan view. The *corpus processi maxillopalatini* is pneumatized. A tiny bone ridge is visible at the midline of the *vomer*, the *processus corniculatus vomeris* is vestigial. The wide *incisura interpalatina* is wedged in front of the short *processus spiniformis*. The *foramen orbitonasale* is single (not split). The *septum interorbitale* is relatively well-developed, the *fenestra olfactoria* and the *fenestra septi interorbitalis* is smaller than on the skull of the Troglodytidae and Regulidae families. The *processus postorbitalis* and the *prosessus zygomaticus ossis squamosi* are both vestigial. The moderately sharp *crista nuchae* separates well the occiput area *(regio occipitalis)*. The mandible is strongly curved in lateral view. The *foramina postsymphysialia* open at the end of the *symphysis* in a ventral groove. The little deviated, slim *processus externus mandibulae* is typical for the *pars caudalis mandibulae* which lateral surface is slightly concave.

Tichodromadidae
(*Tichodroma* Illiger, 1811)

The upper beak is long and thin, the length of the *pars praenarialis* and the nostril are equal. The *septum nasi* is absent in the naval cavity. The *brachium processi maxillopalatini* is invisible through the nostril in plan view. The *lamella caudolateralis* is short and rounded. The *foramen orbitonasale* is split. The *septum interorbitalis* is strongly perforated, the *fenestra olfactoria* is larger than the *fenestra septi interorbitalis*.The mandible is thin and curved and the *symphysis mandibulae* is well-developed. The *fenestra mandibulae* is vestigial and almost completely bony.

Sittidae
(*Sitta* Linnaeus, 1758)

The upper beak is long and slim, the diameter of the spacious nostril is slightly smaller than the length of the *pars praenarialis*. The *septum nasi* is absent in the naval cavity. The *brachium processi maxillopalatini* is invisible through the nostril in plan view. The very wide *incisura interpalatina* extends in front of the *processus spiniformis*. The *foramen orbitonasale* is a single (not split) aperture. The *septum interorbitalis* is highly developed, the *fenestra septi interorbitalis* is completely bony and the *fenestra olfactoria* is also significantly narrowed. The *processus zygomaticus ossis squamosi* and the *processus postorbitalis* are both developed. The hardly curved mandible is powerful and chisel-like. The *foramina postsymphysialia* open close to each other at the caudal edge of the *symphysis*. The *foramen laterale* is located in front of the *impressio mandibularis*. The *processus coronoideus* forms a sharp bone ridge above the relatively narrow *fenestra mandibulae*. Typical characteristics of the lateral edge of the *pars caudalis mandibulae* are the twin bone peaks and the rounded *processus externus*.

Paridae (s. str.)

(*Parus* Linnaeus, 1758)

The upper beak is short and massive, the diameter of the oval nostril is much smaller than the length of the *regio praenasalis*. The remnant of the bony bracing membrane *(septum nasi)* is always located at the caudal part of the naval cavity. The *processus dorsonarialis* is remarkably wide, the upper beak and the forehead is sharply separated by the *sulcus frontonasalis rectus* behind it. The *brachium processi maxillopalatini* is invisible through the nostril in plan view. The *corpus processi maxillopalatini* is short and partially pneumatized. The shape of the lengthened *vomer* differs by species. The *incisura interpalatina* is more wedged in front of the vestigial *processus spiniformis* often forwards to the *collum vomeris*. The *lamella caudolateralis* is barely developed, however the *lamella caudomedialis* is significantly wide. The *foramen orbitonasale* is split. The *septum interorbitale* is robust, the *fenestra olfactoria* is relatively narrow and the *fenestra septi interorbitalis* is often completely bony. The *processus postorbitalis* is absent and the *processus zygomaticus ossis squamosi* is weakly developed. The mandible is relatively short and the *symphysis* is well-devleoped. The *foramina postsymphysialia* open close to each other in the groove on the dorsal surface of the symphysis. The *foramen laterale* is always located at the base of the sharply separated *impressio mandibularis*. The *fenestra mandibulae* is large and remarkably spacious in some species (e.g. *Parus caeruleus*). The ventral surface of the *pars caudalis mandibulae* is smooth and the *processus externus* is moderately developed and its contour is angular.

Remizidae

(*Remiz* Jarocki, 1819)

The upper beak is relatively short and triangular, the diameter of the nostril is much smaller than the length of the *pars praenarialis*. The *septum nasi* is well-developed in the naval cavity. The *processus dorsonarialis* is remarkably wide as in *Parus* species. The slightly curved *vomer* has multiple peaks and behind it, the *collum vomeris* significantly narrows. The *incisura interpalatina* is bony on a significant part, a slight notch can only be found on a short caudal part of the *palatinum*. The *processus spiniformis* is vestigial, but the *lamella caudolateralis* is spikwise lengthened. The *septum interorbitale* is relatively perforated: the *fenestra olfactoria* and the *fenestra septi interorbitalis* are both well-developed and behind the single (not split) *foramen orbitonasale,* an extra aperture breaks through the bone membrane. The *processus postorbitalis* is absent and the *processus zygomaticus ossis squamosi* is vestigial. The sharp edge of the *margo postorbitalis* merges into the cranium above the *processus zygomaticus*.The structure of the curved mandible is special and can be distinguished from any other songbirds: the lengthened *processus externus* is much longer than the *processus internus*. The latter extension contains a sharp bone peak at its rostral edge. The relatively narrow *fenestra mandibulae* is located on approximately equal distance between the caudal end of the *symphysis* and the peak of the *processus externus*. The position of the *foramina postsymphysialia* and the *foramen laterale* does not differ from the drescition in the Paridae family.

Comment: The Remizidae family is highly separated in the structure of the *pars caudalis mandibulae* from the Paridae and any other European passerine families.

Aegithalidae
(*Aegithalos* Hermann, 1804)

The typically shaped upper beak is short, the diameter of the spacious nostril sometimes exceeds the length of the *pars praenarialis*. Opposite to the Paridae and the Remizidae families, the *septum nasi* still could not be found in vestigial form too, the *processus dorsonarialis* is even narrower. The thin *brachium processi maxillopalatini* is invisible through the nostril in plan view. The two well-developed *processus corniculatus vomeris* at the beginning of the *vomer* contact to each other along the symmetry axis of the skull. The *incisura interpalatina* is wide and long, the *lamella caudolateralis* is short and rounded. The *foramen orbitonasale* is single (not split). The *septum interorbitale* is strongly perforated, the *fenestra olfactoria* and the *fenestra septi interorbitalis* are both well-developed. The *processus postorbitalis* is absent. The peak of the moderately developed *processus zygomaticus ossis squamosi* is widely rounded and the *margo postorbitalis* arches uninterruptedly to this peak. The *foramina postsymphysialia* open at the caudal edge of the moderately developed *symphysis*. The *fenestra mandibulae* is moderately spacious. The morphology of the *pars caudalis mandibulae* is mainly equal to *Parus* species, however the *processus externus* is slightly shifted outwards.

Paradoxornithidae
(*Panurus* Koch, 1816)

The upper beak is slim, the length of the *pars praenarialis* and the diameter of the nostril are equal. The *septum nasi* is always absent in the naval cavity and the *processus dorsonarialis* is relatively narrow. The *brachium processi maxillopalatini* is invisible in plan view and the *foramen basale* is absent at the base of this extension. The *corpus processi maxillopalatini* is lengthened and pneumatized. The *vomer* has multiple peaks. The wide *incisura interpalatina* extends in front of the short *processus spiniformis*. The *foramen orbitonasale* is single (not split). The *fenestra olfactoria* and the *fenestra septi interorbitalis* are both well-developed. The tiny *processus postorbitalis* is melted in full length to the dorsal edge of the *processus zygomaticus ossis squamosi* in a specific way, but a negligible gap can be found between these two extensions in some young specimens. The mandible is slightly curved and the *symphysis* is weakly developed. The *foramen laterale* is located in front of the *impressio mandibularis*. A weak bone ridge extends at the ventral surface of the *pars caudalis mandibulae* and the *processus externus* is vestigial and widely rounded.

Comment: The *Panurus biarmicus* can be separated from any other European songbirds based on the rounded shape of the *processus externus mandibulae*.

Regulidae
(*Regulus* Cuvier, 1800)

The upper beak is slim and sharp, the *processus postnarialis* is particularly thin. A specific trait of *Regulus* species is the vestigial *septum nasi* in the caudal part of the nasal cavity. The *brachium processi maxillopalatini* is visible through the nostril in plan view too, at its end the *corpus* is relatively wide, lengthened and not pneumatized. The midline of the *vomer* is little peaked and the *processus corniculatus vomeris* is well-developed. The wide *incisura interpalatina* is wedged to the peak of the lengthened *processus spiniformis*. The *foramen orbitonasale* is single (not split). The *fenestra olfactoria* and the *fenestra septi interorbitalis* are both remarkably spacious. The *processus postorbitalis* is vestigial and the *processus zygomaticus ossis squamosi* is moderately developed. The mandible is lengthened and thin and the *fenestra mandibulae* is relatively spacious. The *protuberantia caudolateralis* is ridge-like developed at the lateral surface of the *pars caudalis mandibulae,* a tiny aperture *(foramen pneumaticum)* can be found behind it. The peak of the *processus internus* is remarkably sharp.

Comment: Based on their measurement the *Regulus* species are recognizable and can easily be separated from the members of the Sylviidae family according to the existence of the *septum nasi* and the developmental level of the *protuberantia caudolateralis*.

Sylviidae
(*Sylvia* Scopoli, 1769; *Acrocephalus* J. A. et F. Naumann, 1811; *Lusciniola* Gray, 1841; *Locustella* Kaup, 1829; *Hippolais* Baldenstein, 1827; *Phylloscopus* Boie, 1826; *Cisticola* Kaup, 1829; *Cettia* Bonaparte, 1834)

The slightly curved upper beak is slim, aharp and the nostril is spacious. The *septum nasi* is always absent in the naval cavity. The *brachium processi maxillopalatini* is invisible through the nostirls in plan view and the spacious *foramen basale* is always located at its base. The structure of the *corpus processi maxillopalatini* and the *vomer* differ by genera. The *incisura interpalatina* is particularly wide in *Sylvia* species. In *Cettia* and *Sylvia* species, the *lamella caudolateralis* is rounded, but in the species of other genera, this bone plate is sword-like lengthened and sharp. The single (not split) *foramen orbitonasale* is usually spacious and little lengthened aperture. The *septum interorbitale* is strongly perforated, the *fenestra olfactoria* and the *fenestra septi interorbitalis* are equally spacious. The *processus postorbitalis* and the *processus zygomaticus ossis squamosi* are vestigial. The *foramina venae occipitalis externae* are a little far from each other and from the edge of the *foramen magnum*. The mandible is thin, lengthened, the *impressio mandibularis* is weakly expressed and the *fenestra mandibulae* is moderately spacious. The ventral surface of the *pars caudalis mandibulae* is smooth and the *fossa caudalis mandibulae* is barely notched.

Comment: This family contains osteo-morphologically little differentiated genera, thus the determination of species in practice is usually not feasible based on their cranial morphology.

However, the whole Sylviidae family can be well separated from the similar Muscicapidae family based on the structure of the *foramen orbitonasale*, the position of the *brachium processi maxillopalatini* and the *foramina venae occipitalis externae* and the notched *fossa caudalis mandibulae*.

Muscicapidae (s. l.)
(*Muscicapa* Brisson, 1760; *Ficedula* Brisson, 1760; *Cercotrichas* Boie, 1831; Saxicola Bechstein, 1803; *Phoenicurus* T. Forster, 1817; *Oenanthe* Vieillot, 1816; *Monticola* Boie, 1822; *Luscinia* T. Forster, 1817; *Turdus* Linnaeus, 1758; *Erithacus* Cuvier, 1800)

The upper beak is usually thin, lengthened, and in some genera (in the Muscicapinae subfamily), it is broadened at the base of the beak. The nostril is spacious and the lack of the *septum nasi* is typical in most of the genera. The *brachium processi maxillopalatini* is usually visible in plan view (through the nostrils) and the *foramen basale* opens at its base. The structure of the *vomer* is varied by genera and the *processus corniculatus vomeris* is usually vestigial. The *foramen orbitonasale* is split and the two apertures are sometimes located relatively far from each other. The *fenestra olfactoria* is flattened and the *fenestra septi interorbitalis* is a little more spacious. The *processus postorbitalis* and the *processus zygomaticus ossis squamosi* are both vestigial. The *foramina venae occipitalis externae* usually open close to each other at the end of the paired *sulcus occipitalis*. The mandible is slim, the *impressio mandibularis* is weakly expressed and the *fenestra mandibulae* is relatively narrow. The *tuberculum pseudotemporale* is relatively absent and the *processus coronoideus* is vestigial. The *fossa caudalis mandibulae* – opposite to the members of the Sylviidae family – is deeply notched.

Comment: Some genera within this family are distinguishable from other members based on some certain osteological traits. The concavity on the ridge of the upper beak is typical for the *Phoenicurus* and *Oenanthe* genera. The *foramen orbitonasale laterale* is remarkably shifted outwards in *Luscinia* species and it is also visible in plan view. The strongly protuberant *ala tympanica* is typical for *Turdus.* Furthermore, the *brachium processi maxillopalatini* and the position of the *foramina venae occipitalis externae* can be modified in these species. Among the European members of this family, the well-developed *septum nasi* can only be found in the nasal cavity of *Erithacus rubecula*.

Motacillidae
(*Motacilla* Linnaeus, 1758; *Anthus* Bechstein, 1805)

The upper beak is slim and sharp, the nostril is spacious and the *septum nasi* is always absent. A weak concavity can be found on the dorsal beak of *Anthus* species before the nostril. The *brachium processi maxillopalatini* is visible through the nostril in plan view and the *foramen basale* is absent at its base. The *incisura interpalatina* is wide, rostrally strongly lengthened and the *processus spiniformis* is particularly long and slim in *Motacilla* species. The *foramen orbitonasale* is usually single *(Motacilla* spp., *Anthus* *pratensis, A. spinoletta, A. cervinus)*, but in some *Anthus* species it is split *(A. trivialis, A. campestris)*. The *fenestra olfactoria* and the *fenestra septi interorbitalis* are both spacious. The *processus postorbitalis* is vestigial, the larger *processus zygomaticus ossis squamosi* is sharply peaked. The *foramina venae occipitalis externae* open just behind the edge of the *foramen magnum*. The mandible is slim, the *fenestra mandibulae* is moderately spacious. The *processus externus* is short and angular, a weak bone ridge extends at the ventral surface of the *processus internus*.

Prunellidae

(*Prunella* Vieillot, 1816)

The upper beak is slim and sharp, a weak concavity can be found on its dorsal part. The nostril is spacious and the *septum nasi* is absent. The *brachium processi maxillopalatini* is invisible in plan view, the *foramen basale* is absent at its base. The *lamella caudolateralis palatina* is short and typically rounded. The *foramen orbitonasale* is a single (not split) aperture. The *fenestra olfactoria* and the *fenestra septi interorbitalis* are both spacious. The *processus postorbitalis* is vestigial, but the *processus zygomaticus ossis squamosi* is well-developed and its peak is widely rounded. The peak of the *lamina basiparasphenoidalis* is shortened. The mandible is slim, the *fenestra mandibulae* is moderately spacious. A weak bone ridge is located at the ventral surface of the *pars caudalis mandibulae*.

Comment: The developmental level of the *processus zygomaticus ossis squamosi* and the shape of the *lamella caudolateralis palatina* help in separating *Prunella* species from any other small, insectivorous songbirds.

Passeridae

(*Passer* Brisson, 1760; *Petronia* Kaup, 1829; *Montifringilla* C. L. Brehm, 1828)

The upper beak is relatively short and conical, the nostril is moderately spacious. The *septum nasi* is always located in the naval cavity. The split on the palate *(fenestra palatina)* wedges forward to approximately the half of the bony palate. The contour of the short and partially pneumatized *corpus processi maxillopalatini* is angular. The paired *processus corniculatus vomeris* at the peak of the vomer is particularly wide and dorsally hooked. The relatively wide *incisura interpalatina* is wedged toward the *collum vomeris*. The *foramen orbitonasale* is single (not split). The membrane which separates the eye sockets *(septum interorbitale)* is significantly bony and the *fenestra septi interorbitalis* is absent. The *processus postorbitalis* and the *processus zygomaticus ossis squamosi* are both well-developed and on the latter an extra lateral extension can be found. The *foramina venae occipitalis externae* are far from each other. The mandible is relatively short, the *symphysis* is moderately developed and the *foramina postsymphysialia* opens at the base of the mandible branches. The *tuberculum pseudotemporale* and the *processus coronoideus* are both well-developed. The *foramen laterale* opens at the beginning of the deep *impressio mandibularis*. The ventral surface of the *pars caudalis mandibulae* is smooth and its lateral edge is peaked. The peak of the *processus externus mandibulae* points to the symmetry axis of the mandible and the *fossa caudalis* is deeply notched.

Comment: The developmental level of the *septum nasi* is typical for the whole Passeridae family among all European conical beaked passerine birds. Some similar bone membrane can exceptionally be found in some species of the Fringillidae, but never in the European members of the Emberizidae families.

Fringillidae (s. str.)
(*Fringilla* Linnaeus, 1758; *Serinus* Koch, 1816; *Chloris* Cuvier, 1800; *Carduelis* Brisson, 1760; *Acanthis* Borkhausen, 1797; *Carpodacus* Kaup, 1829; *Pinicola* Vieillot, 1807; *Pyrrhula* Brisson, 1760; *Loxia* Linnaeus, 1758; *Coccothraustes* Brisson, 1760)

The upper conical beak and the mandible are remarkably shortened and the nostril is relatively small. The *septum nasi* in well-development state can only be found in *C. coccothraustes* and it is vestigial in *Pinicola enucleator*, while it is absent in most of the species. The bony palate is particularly developed, the *fenestra palatina* is shifted backwards. The *corpus processi maxillopalatini* is lengthened, the *vomer* is partially pneumatized. The *incisura interpalatina* is completely bony in the Carduelinae subfamily, but it is narrow and forms a lengthened gap in *Fringilla* species (Fringillinae subfamily). A well-developed bone ridge usually extends at the ventral surface of the *lamella caudolateralis*. The *foramen orbitonasale* is a single (not split) aperture. The *septum interorbitale* which separates the eye sockets, is robust, the *fenestra septi interorbitalis* can only be found in *Fringilla* species but this aperture is bony in the member of the Carduelinae subfamily. The *fenestra olfactoria* is also reduced in proportion to specialization. The *processus postorbitalis* is usually small but the *processus zygomaticus ossis squamosi* is highly developed in specialized species. The *foramina venae occipitalis externae* open at the edge of the *foramen magnum*. The thickening of the *symphysis* and the existence of the *crista anterioventralis* at the ventral surface of the *pars caudalis mandibulae* are typical for the mandible. The *processus coronoideus* is markedly peaked and behind it, the well-developed *tuberculum pseudotemporale* is also visible in lateral view. The *foramen laterale* open at the beginning of the deep *impressio mandibularis*.

Comment: The existence of the *crista anterioventralis* is only typical in the Fringillidae family which distinguishes all members of this family from any other songbirds.

Emberizidae
(*Emberiza* Linnaeus, 1758; *Calcarius* Bechstein, 1803; *Plectrophenax* Stejneger, 1882)

The upper beak is thinner and slimmer than in the Passeridae and Fringillidae families and the contour line has a typical fracture at the midpoint in lateral view. The nostril is relatively spacious, the *processus postnarialis* is thin and the *septum nasi* is always absent in the naval cavity. The *corpus processi maxillopalatini* is lengthened and partially pneumatized.

The developed lateral extension of the twin peaked *processus corniculatus vomeris* is slim. The wide *incisura interpalatina* is rostrally lengthened towards the *collum vomeris*. The *pars interorbitalis* is markedly narrow. Differently to the seed-eater songbirds, the *septum interorbitale* which separates the eye sockets is strongly perforated. The *fenestra septi interorbitalis* is more spacious in *Emberiza* species than the *fenestra olfactoria*; in the *Calcarius* and the *Plectrophenax* this aperture is smaller or could be exceptionally bony. The *processus postorbitalis* is vestigial, however the *processus zygomaticus ossis squamosi* is wide and forms a rounded bone plate. The *ala tympanica* is some species *(Emberiza cia, E. citrinella)* is particularly developed. The *angulus mandibulae* is typically peaked and the curve of the mandible is refracted near the deep *impressio mandibularis* in lateral view. The *symphysis* is moderately thick and the *foramina postsymphysialia* are visible at the base of the mandible branches in bottom view. The *fenestra mandibulae* is spacious, the *processus coronoideus* and the *tuberculum pseudotemporale* are both well-developed. The ventral surface of the *pars caudalis mandibulae* is smooth and the *fossa caudalis mandibulae* is deeply notched.

Comment: The members of the Emberizidae family can easily be distinguished from the members of other bird families based on the refracted curve of the mandible.

Alaudidae

(*Galerida* Boie,1828; *Calandrella* Kaup, 1829; *Melanocorypha* Boie, 1828; *Eremophila* Boie, 1828; *Lullula* Kaup, 1829; *Alauda* Linnaeus, 1758)

The peak of the beak is relatively blunt, a lengthwise groove extends on the midline of the bony palate. A tiny aperture is located next to the rostral connection point of the *lamella craniolateralis* (this is absent in species of other families). The bone membrane *(septum nasi)* between the spaciour nostrils is vestigial but it can be found in all species. The *foramen basale* and the *brachium processi maxillopalatini* are both visible through the nostrils in plan view. The *corpus processi maxillopalatini* is lengthened and pneumatized. Particularly well-developed, paired *processus corniculatus vomeris* is located at the beginning of the relatively short *vomer*. The exceptionally wide *incisura interpalatina* is singnificantly lengthened to the front of the *processus spiniformis*. The *pars interorbitalis* is narrow. The *septum interorbitale* is robust and the *foramen septi interorbitalis* becomes completely bony by the age of the indicidual (usually at very young). The *fenestra olfactoria* can be found in every species. The single (not split) *foramen orbitonasale* opens close to the axis of the skull in the eye cavity. The *processus orbitosphenoidalis lateralis* is well-developed in some members of the family *(Eremophila, Melanocorypha, Calandrella)* but it is absent in others. The well-developed *processus postorbitalis* and the *processus zygomaticus ossis squamosi* are melted into a single extension on their peaked ends and a spacious aperture *(fenestra postorbitalis)* is located between the bases of the two extensions. The *rostrum sphenoidale* is remarkably thicker in comparison to the insectivorous passerine birds. The *foramina venae occipitalis externae* is located close next to the edge of the *foramen magnum*. The *symphysis mandibulae* is relatively short and a weak concavity can be found on its dorsal surface. The *foramen postsymphysiale* which opens at the symmetry axis is typical at the caudal edge of the *symphysis.* The mandible is slim in most of the members of this family, however the mandible of the specialized *Melanocorypha* species is robust. The *fenestra mandibulae* is moderately spacious and the short *processus coronoideus* forms a sharp bone ridge above it. The *processus internus mandibulae* is also visible in lateral view and its peak bends in dorsorostrally.

Comment: The fusion of the peak of the *processus postorbitalis* and the *processus zygomaticus ossis squamosi* which typical for the larks is absent in any other European songbird families. These two extension could be ended very close to each other in some woodpecker species (Piciformes: Picidae), but this analogous trait similar to larks can only be found among the members of Tetraonidae, Phasianidae (Galliformes) and Pteroclidae (Columbiformes) of the European avifauna.

Many characteristics of the upper beak, the position of the *foramen postsymphysiale* and the shape of the *processus internus* may be helpful in the determination of the larks in practice.

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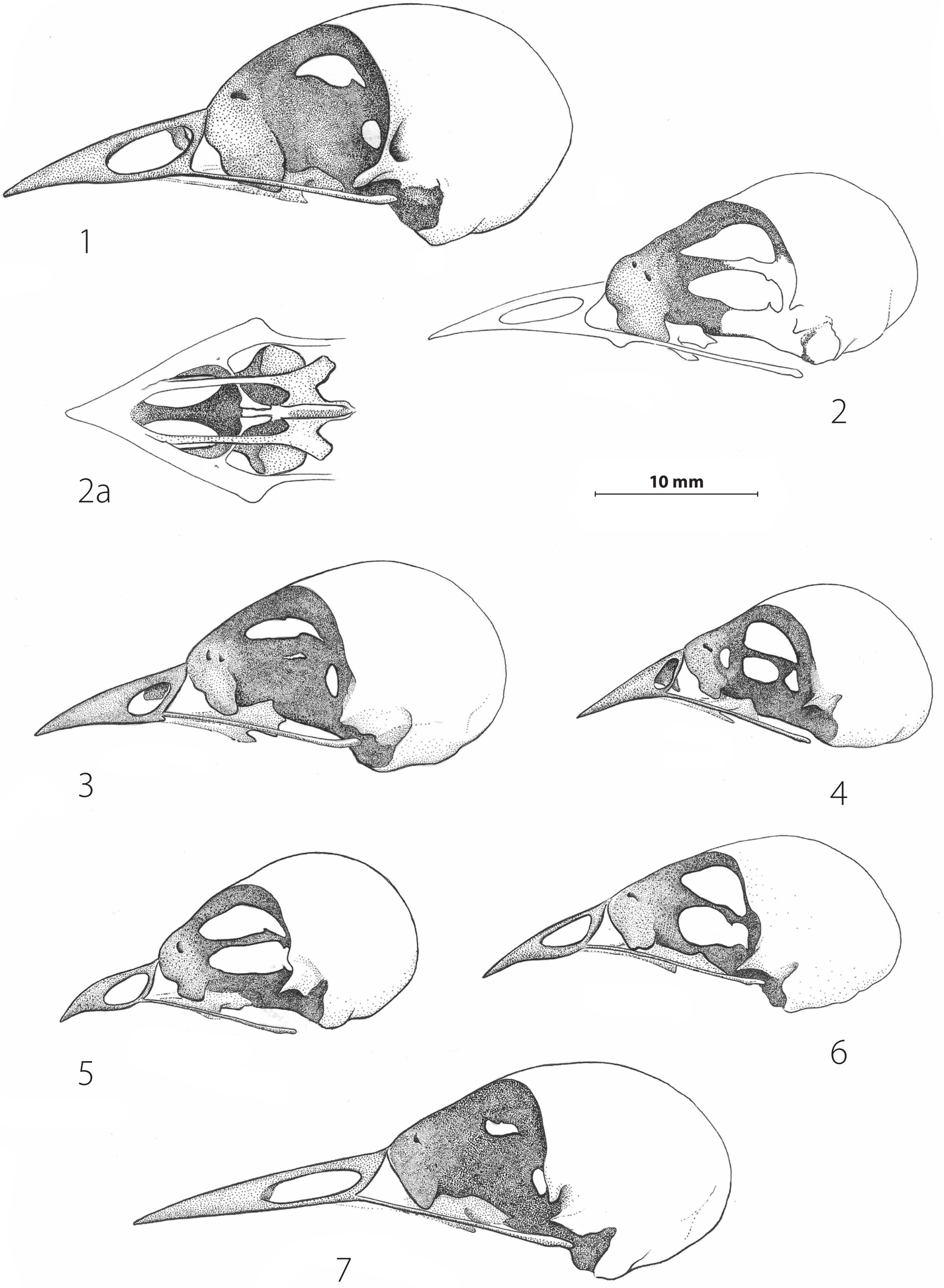


Plate 1. Skulls
1. táblakép Koponyák
1. Alauda, 2. Hirundo, 3. Parus, 4. Remiz, 5. Aegithalos, 6. Panurus, 7. Sitta

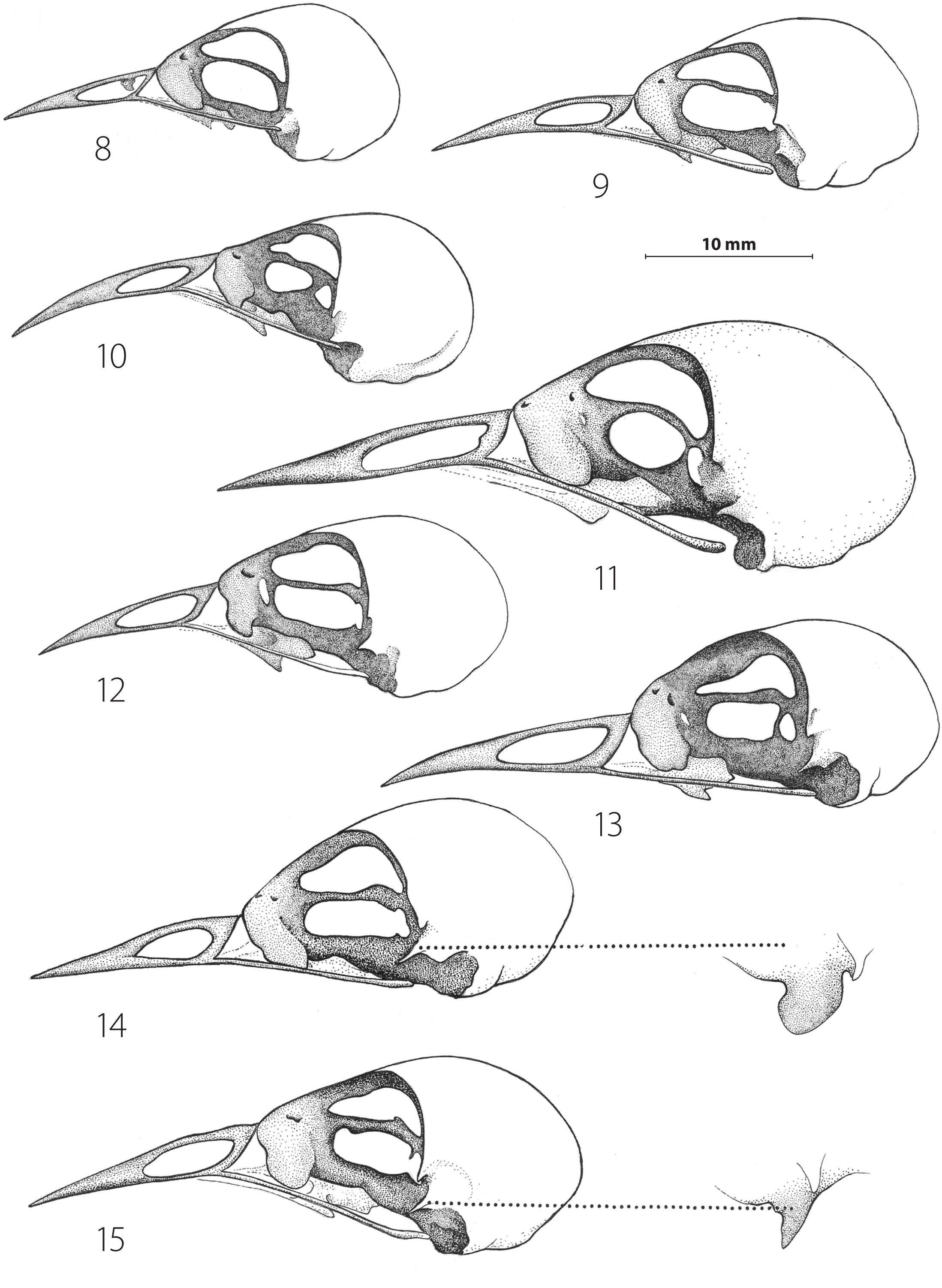
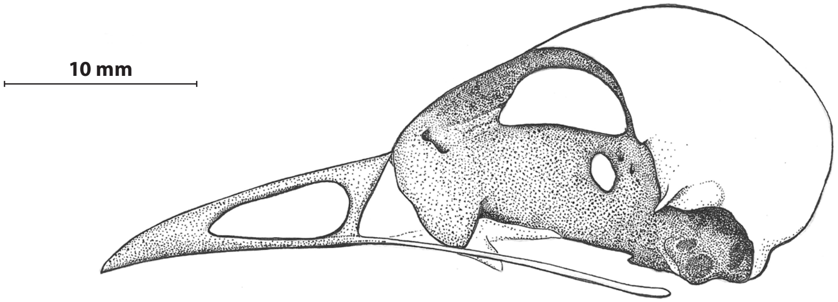


Plate 2. Skulls
2. táblakép Koponyák
8. Regulus, 9. Troglodytes, 10. Certhia, 11. Cinclus, 12. Sylvia, 13. Muscicapa, 14. Prunella, 15. Motacilla



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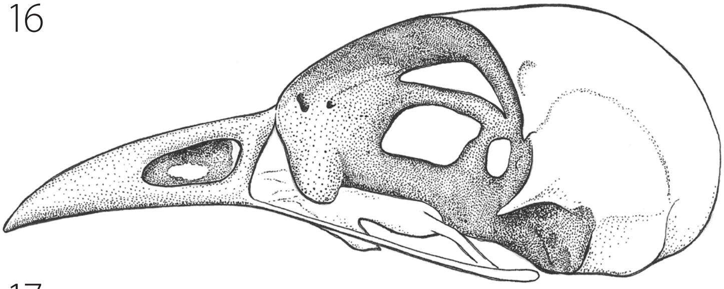

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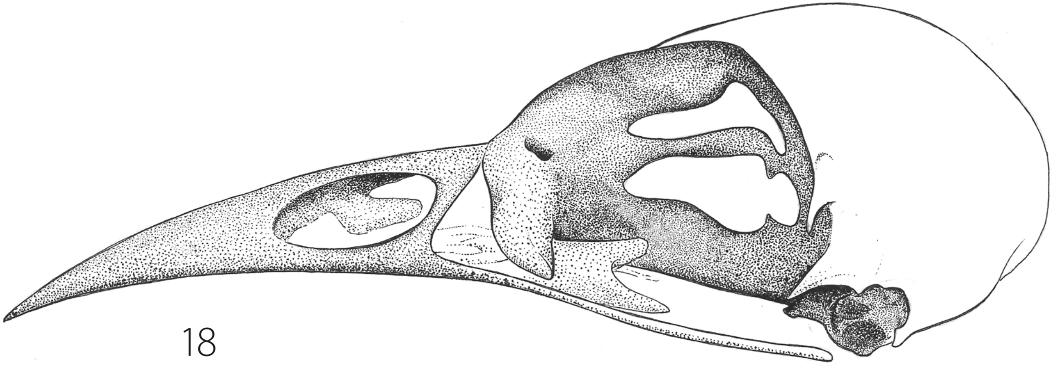

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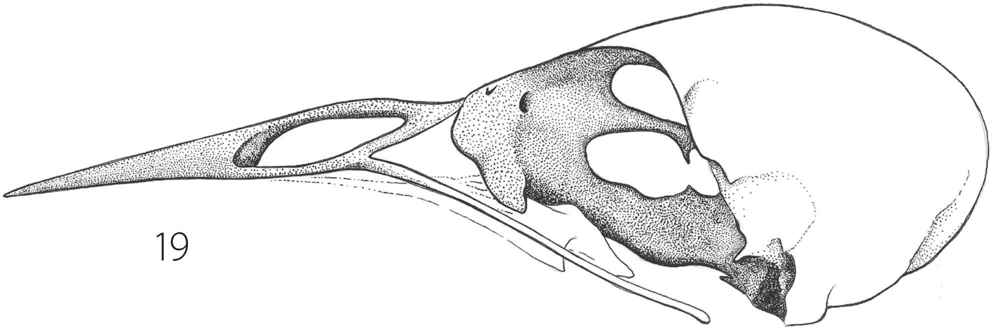

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Plate 3. Skulls
3. táblakép Koponyák
16. Bombycilla, 17. Lanius, 18. Oriolus, 19. Sturnus

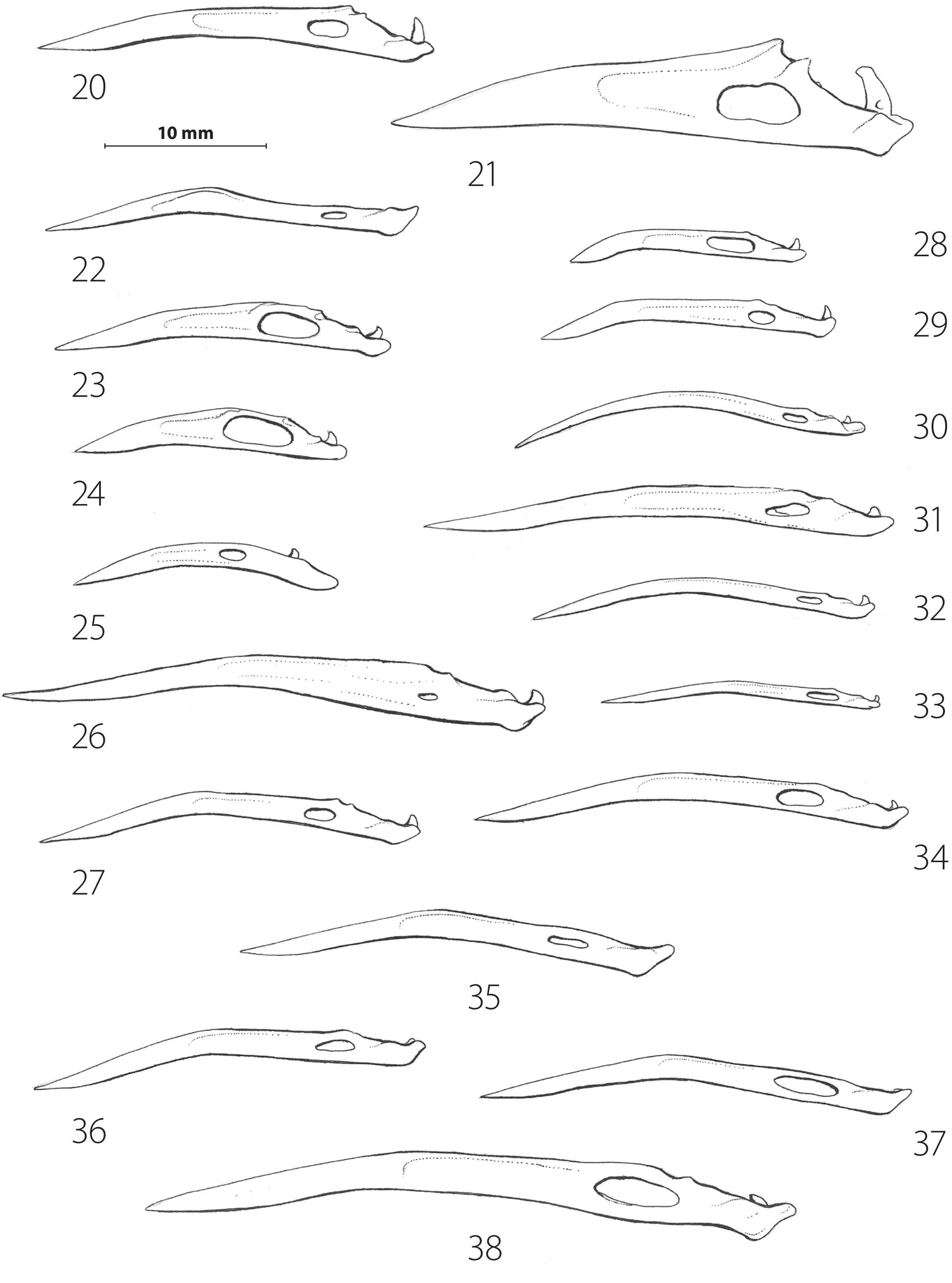

Plate 4. Lower jaws
4. táblakép Állkapcsok
20. Galerida, 21. Melanocorypha, 22. Hirundo, 23. Parus major, 24. P. caeruleus, 25. Remiz, 26. Cinclus, 27. Prunella, 28. Aegithalos, 29. Panurus, 30. Certhia, 31. Sitta, 32. Troglodytes, 33. Regulus, 34. Motacilla, 35. Muscicapa, 36. Sylvia, 37. Luscinia, 38. Turdus

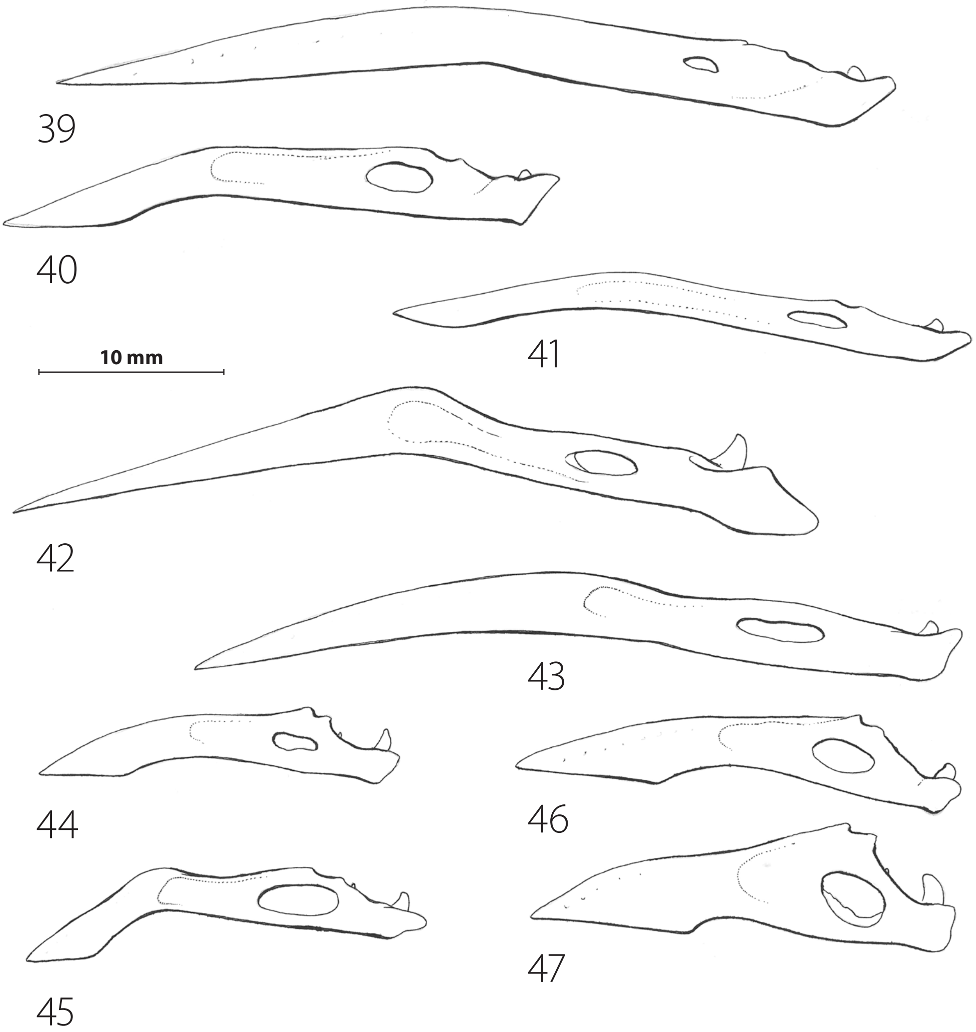

Plate 5. Lower jaws
5. táblakép Állkapcsok
39. Oriolus, 40. Lanius, 41. Bombycilla, 42. Sturnus, 43. Pastor, 44. Passer, 45. Emberiza, 46. Fringilla, 47. Chloris

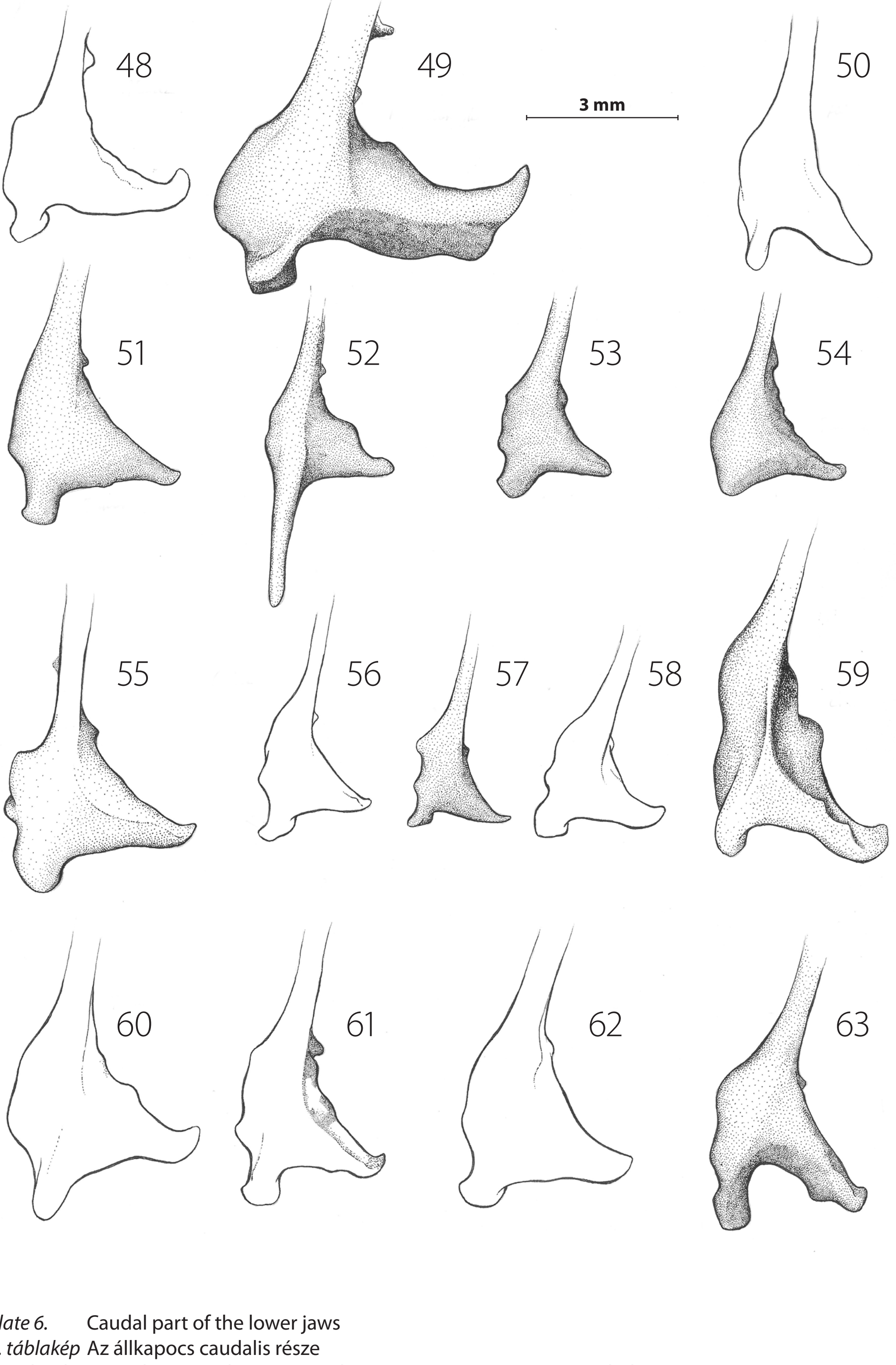

Plate 6. Caudal part of the lower jaws
6. táblakép Az állkapocs caudalis része
48. Alauda, 49. Melanocorypha, 50. Hirundo, 51. Parus, 52. Remiz, 53. Aegithalos, 54. Panurus, 55. Sitta, 56. Certhia, 57. Regulus, 58. Troglodytes, 59. Cinclus, 60. Prunella, 61. Motacilla, 62. Sylvia, 63. Muscicapa

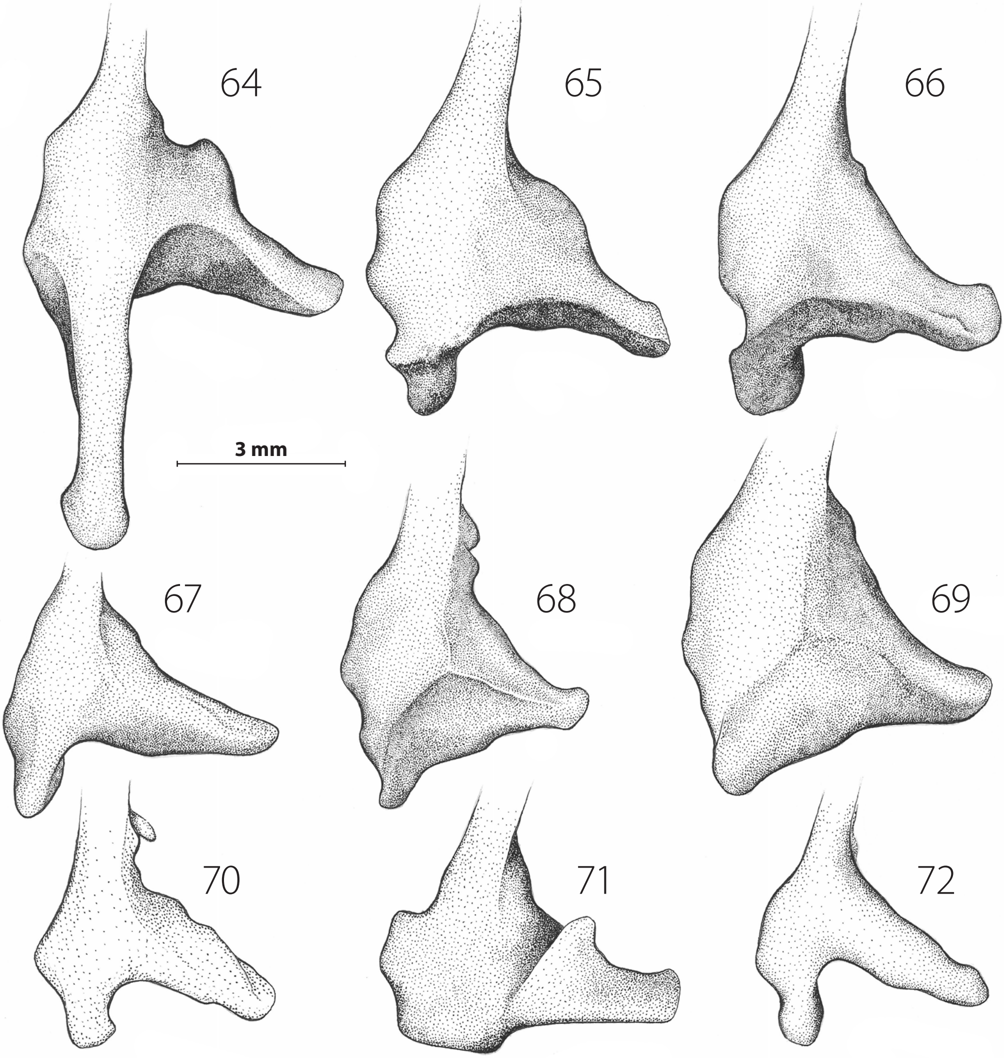

Plate 7. Caudal part of the lower jaws
7. táblakép Az állkapocs caudalis része
64. Sturnus, 65. Pastor, 66. Turdus, 67. Bombycilla, 68. Lanius, 69. Oriolus, 70. Passer, 71. Chloris, 72. Emberiza

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New species in the Hungarian avifauna in 2015

Tibor Hadarics

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Abstract This paper is a report on the appearance of the Naumann's Thrush *(Turdus naumanni)* in 2015 which can be considered as a new species of the Hungarian avifauna. The bird was seen and photographed in Népliget, Budapest on the 31st of December. With this observation, the number of bird species detected in Hungary has risen to 412.

Keywords: official bird checklist, Hungarian Checklist and Rarities Committee, Naumann's Thrush, *Turdus naumanni*

Összefoglalás 2015-ben egy faunára új madárfaj bukkant fel Magyarországon: a Naumann-rigó. A madarat 2015. december 31-én figyelték meg és fényképezték le a budapesti Népligetben. E faj előkerülésével a Magyarországon valaha bizonyítottan előfordult madárfajok száma 412-re emelkedett.

Kulcsszavak: Magyarország madarainak névjegyzéke, MME Nomenclator Bizottság, Naumann-rigó, *Turdus naumanni*

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In 2015, the Naumann's Thrush was accepted by the Hungarian Checklist and Rarities Committee as new to the Hungarian fauna. By this, number of bird species observed in Hungary to date, has risen to 412.

Turdus naumanni Temminck, 1820 – Naumann's Thrush
31st December 2015, Budapest, Népliget, 1 ad. exemplar (D. Laposa and others)

The Naumann's Thrush *(T. naumanni)* was formerly considered as conspecific with the Dusky Thrush *(T. eunomus)*. The taxonomic separation of the two species is based on their distinctly different plumages. The Dusky Thrush breeds in the northern parts of Central and Eastern Siberia, while the breeding area of Naumann's Thrush is located south of the Dusky Thrush's range with wide overlapping regions in the western *(naumanni)* and southwestern *(eunomus)* parts of their ranges (Clement 1999). Naumann's Thrush breeds in the southern parts of Central and Eastern Siberia, from the central Yenisey region east to the middle and upper Lena Basin. The southern boundary of the distribution is uncertain, perhaps discontinuous east of Lake Baikal, but embracing Angara basin in the west along with the southern part of Lake Baikal. Small numbers also breed north of the main range, near the Lena and Olenek deltas (Clement & Hathway 2000, del Hoyo *et al.* 2005). It winters mainly in China, ranging from extreme Southeast Russia and Korean Peninsula south to Eastern China (Yangtze basin) but some birds reach also Japanese islands and Taiwan (del Hoyo *et al.* 2005).

Preferred habitats of Naumann's Thrush are fringes of lowland tundra in thinning taiga and wooded steppe, dense riverine forests of willow and poplar, scrubby lowland areas with birch and alder. Less often it occurs in sparse larch or mixed larch and pine forest extending into open country or even in gardens (del Hoyo *et al.* 2005).

Of the two species, Dusky Thrush occurs in Europe more frequently than Neumann`s Thrush for several possible reasons. On one hand, as the distribution area of the Dusky Thrush is larger, it also has a larger population size, and the western part of its distribution is nearer to Europe than that of the Naumann`s Thrush with a smaller distribution range. On the other hand, as the Dusky Thrush has more northerly breeding area, it makes longer journeys during migration; long-distance migrants get to Europe more frequently due to reverse migration, compared to short-distance migrants (Gilroy & Lees 2003, Lees & Gilroy 2009, Pfeifer *et al.* 2007).

Based on historic data, it is often difficult to conclude whether the observed speciments represent occurrences of Naumann`s Thrush (sensu stricto) or Dusky Thrush, because were regarded to belong to one species; *Turdus naumanni eunomus.* Naumann`s Thrush has five records in Finland, Norway and Italy, seven in Poland, four in the Czech Republic, Germany and France, two in Great Britain and one in Belgium (Lewington *et al.* 1991, Slack 2009). Most of the data are from the late autumn and winter period (November–January), but there are occurrences also from October to spring. For example, there is an interesting observation from Bulgaria: six skeletal elements of Naumann's Thrush (sensu lato) were identified in food remains of an Eagle Owl in May 2003 in Southeastern Bulgaria (Milchev & Boev 2014).

Of the countries neighbouring Hungary, it was only recorded in Austria, with two records (Glutz von Blotzheim & Bauer 1988). Between 1853 and 1874 one male was acquired at the Vienna bird (food) market, most probably originating from the Wechsel mountains on the border between Styria and Lower Austria (this specimen is currently in the collection of Natural History Museum, Vienna). A second male was observed by R. Zach at Wolfsgraben (Lower Austria) on the 8th of April in 1984.

There is only one record from the Carpathian Basin from the nineteenth century. In the 1820s, Pál Jány, the first official animal preparator of the Chamber of Naturalia of Hungarian National Museum purchased an adult male at a market in Pest for the museum collection. The bird was found at the game market together with Fieldfares (or other thrushes) caught with limesticks but the exact date and location of the capture remained unknown. However, it should not have been caught too far from Pest, because birds were not typically brought to the market from hundreds of kilometres (Magyar 2006, 2016). Johann Friedrich Naumann was in Hungary in the autumn of 1835 and made a visit at the bird collection of the Hungarian National Museum (Schnell 1835) where, among others, viewed the Naumann`s Thrush specimen and painted it for his upcoming book. Although he did not mention it in the report of his Hungarian trip (Naumann 1837), he reported on it in a later article (Naumann 1851). In the appendix of his book, *J. A. Naumann's Naturgeschichte der Vögel Deutschlands* (Naumann 1845–1854), he refers to it as a specimen from the Carpathians, providing a description along with his painting on plate 358. Afterwards, based on this data the species was regularly mentioned in Hungarian checklists. In the checklists of Kornhuber

(1856), Madarász (1881) and Chernel (1888), it appeared without any further informations. Frivaldszky (1891) gave Hungary as the location of origin. The bird was displayed in an exhibition at the Second International Ornithological Congress, the catalogue of which also mentions Hungary as location of origin (Madarász 1891). In the two most important Hungarian ornithological books of the end of the nineteenth century (Chernel 1899, Madarász 1899–1903), as well as in István Chernel`s Brehm-translation (Chernel 1902), it appeared as having been collected in Hungary, without further specification. In the official checklists of the Ornithological Institute (Magyar Ornitológiai Központ 1898, Chernel 1918), the species appeared without date and location. In Schenk`s (1917) work, the location was given as the Carpathians *(specimen unicum in montibus Carpathicis captum)*. Up to this date, the exact location of origin was of little importance, as whether it had been caught around Pest, in the Northern Uplands or the Upperlands, it was surely within the boundaries of the former Hungary. The Trianon Treaty (1920) changed the boundaries of Hungary, which also meant that the location of observations of several species has been moved outside the boundaries of the broken up country. Although the exact location of the Naumann`s Thrush was unknown, of the possible locations, the Upperlands and the Carpathians became parts of Czechoslovakia (presently Slovakia). This made it questionable if the specimen purchased in the 1820s at a market in Pest had been caught within the new boundaries of Hungary. Chernel (1922) in a passionate article regarded Naumann`s Thrush as a species from outside the new boundaries, as he listed it as a „loss" to the Hungarian species list. Lovassy (1927) mentioned it as a specimen originating from Hungary, with a note in the introduction of his book that he regards Hungary as the area of the Carpathian basin, i.e., not the slayed country after the Trianon Treaty. Schenk (1939), in his checklist, mentions the species as one from outside our boundaries, using different typography, thus, he regarded it as one from the Carpathians. By the 1950s, the species was not even mentioned in the bird volume of the 'Magyarország állatvilága' series (Farkas 1958), or in a later checklist (Farkas 1967). However, it re-appeared in the official checklist in 1960 (Keve 1960). It is unknown why Keve put it in the list, but it was surely a deliberate act, because his checklist had an appendix with those species that were in the previous fauna list but whose locations were outside the current boundaries of Hungary. However, Naumann`s Thrush is not in this list, but in the main one (Keve 1960). The proof specimen was destroyed during the 1956 Revolution (Keve 1960). The data and the species were then mentioned in two separate bird lists afterwards: Keve (1984) did not give location of origin (he only detailed the circumstances of the specimen getting into the collection), and Magyar (1998) gave the origin of location as the vicinity of Budapest. The species also appeared in the 'Magyarország madárvendégei' (Schmidt 1988) and in the 'Magyarország madarai' (Schmidt 1998) monographs, the latter suggesting that the bird had been collected in the mountains near Pest. As the location of the specimen collection is still uncharacterised, and as it cannot be concluded with certainty whether the collection was done within or outside of the current boundaries of Hungary, such as in present-day Slovakia, the Hungarian Rarities and Checklist Committee deleted both the data and the species from the official checklist of birds of Hungary (MME Nomenclator Bizottság 2010). As a consequence, the species only appears in the appendix of the latest checklist of the MME Nomenclator Bizottság (2008), which lists species with uncertain locations.

The recent observation guarantees that the species can be now unquestionably listed in the official bird checklist, because its appearance was apparently proven in our country in 2015.

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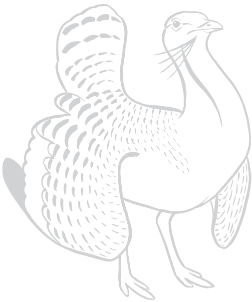

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Attempts to increase a scarce peripheral population of the Red-breasted Flycatcher *(Ficedula parva)* using a new type of nestbox

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Tamás Deme 2016. Attempts to increase a scarce peripheral population of the Red-breasted Flycatcher *(Ficedula parva)* using a new type of nestbox. – Ornis Hungarica 24(2): 84–90.

Abstract The Red-breasted Flycatcher has a large and stable global population widespread through much of the Western Palearctic. Contrarily, however, it is a very scarce breeding bird in the forested montane habitats of Hungary. The few pairs breeding here represent a peripheral population on the very edge of the species' geographic area. This peripheral population declined considerably (from 3–500 to 100 pairs) during the past decades likely due to the degradation of suitable habitat patches including the loss of appropriate nesting sites. To reverse this trend, we applied a new type of artificial nestbox developed specifically for this species. Occupancy rate was very low and breeding success was also low unless applying a protective wire mesh to reduce predation pressure.

Keywords: Red-breasted Flycatcher, nestbox, breeding success

Összefoglalás A kis légykapó a Nyugat-Palearktiszban elterjedt, stabil állományú faj. Ezzel szemben hazánkban a hegyvidéki erdős élőhelyek igen ritka fészkelő madara. A Magyarországon költő néhány pár a faj földrajzi areájának peremén élő, periférikus állományt alkot. E szegélypopuláció mérete az elmúlt évtizedek során jelentősen csökkent (kb. 3–500 párról kb. 100 párra), vélhetően az alkalmas élőhelyfoltok degradációja, és ezen belül a megfelelő fészkelőüregek hiánya miatt is. E folyamat megfordítása céljából egy kifejezetten e faj igényeihez tervezett, új fészekodú típust alkalmaztunk. Az odúk elfoglalási aránya igen alacsony volt, és a költési siker is alacsony, hacsak nem alkalmazunk ragadozók elleni dróthálót.

Kulcsszavak: kis légykapó, fészekodú, költési siker

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Introduction

The Red-breasted Flycatcher *(Ficedula parva)* is a small, insectivorous passerine in the family Muscicapidae. It breeds in forested areas from Germany to the Ural Mountains (also in the Caucasus) and overwinters in India. What was formerly regarded as its Eastern subspecies, the Taiga Flycatcher, is now elevated to the rank of a full species, *Ficedula albicilla*. While the global population size of the Red-breasted Flycatcher is relatively large (estimated to cca. 3.5 million pairs), the species is represented by only a few thousand of breeding pairs scattered scarcely across suitable habitat patches along the Western edge of its geographic area, in Sweden, Germany, Austria and Hungary (Cramp & Perrins 1993, Flade 1997, Taylor 2006, BirdLife International 2013).

In the Carpathian Basin the Red-breasted Flycatcher typically breeds in forested mountainous habitat patches at elevations between 400–800 m (Michael *et al.* 1993, Németh 2000). The population size was estimated at 300–500 pairs at the end of the past century (Magyar *et al.* 1998), then it shrank to cca. 100–300 pairs in the following decade (Hadarics & Zalai 2008), and currently estimated to about 100 pairs.

There were 5-6 breeding pairs in the Sopron Mountains that disappeared by 2013 (S. Mogyorósi personal communication). About 8–10 pairs have been breeding in the Kőszeg Mountains through the past decade (Németh 1999, 2009, 2013). Furthermore, 17 territories were known in the Bakony Mountains through 2009–2013. The yearly number of breeding pairs fluctuated here within the range of 2–10, however, no singing male was found in 2014 (T. Deme unpublished data). It has been only a casual breeder in the Pilis Mountains. Approximately 30 pairs breed in the Börzsöny Mountains (Á. Selmeczi Kovács personal communication). The number of breeding pairs was estimated to 10 pairs in the Mecsek Mountains through 1989–2009, however, none has been found here in recent years (T. Deme unpublished data). At least 30 pairs bred in the Bükk Mountains at the end of the last century, while only 10–12 pairs have been found here in recent years, disappearing from cca. three-quarters of its formerly known breeding sites (Fitala 2010). The last known record from the Zemplén Mountains is from 2012 (ANP biotic database). Overall, the number of pairs breeding in Hungary is currently estimated to be about 100 pairs.

Since the global population appears to be relatively stable (BirdLife International 2016), and also because the Red-breasted Flycatcher exhibits high fidelity to its breeding areas through several years (as demonstrated by ringing data, Török 2009), we presume that reasons of this remarkable decline are probably local. Motivated by this idea, I have implemented artificial nestboxes specifically designed for this species by Mészáros and Szalai (1987). The purpose of the present paper is to review results of Red-breasted Flycatcher nestbox projects published by former authors in Hungarian, and also to describe results of my own efforts.

Nestbox design

The Red-breasted Flycatcher is not a typical hole-nesting species, thus it has been extremely rarely recorded to breed in classical nestboxes (see e.g. Mauks 1913, I. É. Bőhm personal communication). A study carried out in the Białowiezai National Park, Poland, examined the nest site of 117 natural nests (Mitrus & Soćko 2004). Three types of nest sites were identified:

- about half of the nests were built in half holes on tree trunks, these are partially open, shallow cavities with big entrances,
- about a quarter of nests were built on 'shelves' located outside the main trunk, often covered by bark,
- about a quarter of nests were built in chimneys-shaped holes, usually in broken and rotten top of thin trees.

The nestbox design proposed by Mészáros and Szalai (1987) roughly mimics the first two types of natural sites *(Figure 1)*. Nest boxes are optimally made of hardwood, and their colour should approximately match the colour of the tree trunk it is positioned on.

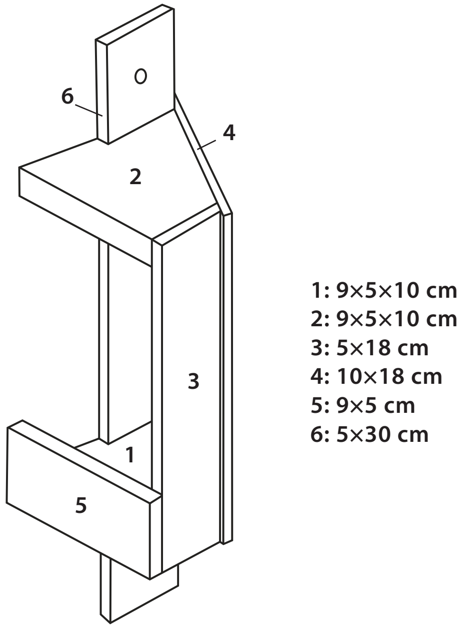

Figure 1. The structure of nestbox designed for Red-breasted Flycatcher by Mészáros and Szalai (1987)

1. ábra A kis légykapó számára Mészáros és Szalai (1987) által kifejlesztett odútípus

Optimal positioning of nestboxes

Through much of its geographic distribution, the Red-breasted Flycatcher mostly breeds in mixed and coniferous forests (Cramp & Perrins 1993). In the Białowiezai National Park, however, 79% of nests were built on hornbeam *(Carpinus betulus)* or small leaved lime *(Tilia cordata)*. About 40% of nests were located between 2 and 4 meters height above ground, the average height was 4.9 m above ground, and >70% were located lower than 6.0 m. Their entrances preferentially faced to South or East (Mitrus & Soćko 2004).

In Hungary, the Red-breasted Flycatcher primarily breeds natural or semi-natural, humid, montane mixed forests dominated by beech *(Fagus sylvatica)*. These forests are also characterized by a lower canopy of secondary tree species (such as European hornbeam), by a proximity of small streams, and the presence of old trees (Schmidt 1998, Németh 2000). The presence of small sunny glades (such as 150–200 m^2 open patches created by fallen trees) is also preferred at least until the overall canopy cover remains relatively high. Weber (1958) showed that Red-breasted Flycatchers tend to leave those parts of a forest where the canopy closure falls below 70%. Thus small patches of trees scattered across large, logged areas do not provide suitable habitat for this species. In 2013, previously occupied territories became abandoned in the Hármaspatak Valley as a result of logging activity (Németh 2013).

Intensive forestry practices including the elimination of standing deadwood, and a decrease, or even the disappearance of water from former permanent streams likely contributes to the decline of this bird population (Zöllei & Selmeczi Kovács 2016). Implementing artificial nestboxes may perhaps reduce the negative effects of moderate forestry practices in potential breeding habitats.

Apparently, birds prefer nestboxes facing to the stream valley by their entrances. Since this species nests in relatively open cavities, predation pressure on broods can be considerably high. Therefore, artificial nestboxes are optimally positioned under appropriate coverage of small branches. Well-covered positions are more available on hornbeam trees than on the smooth and poorly branched trunks of beech. Moreover, mounting a protective wire mesh around the nestbox is also advisable to reduce predation pressure. Mészáros and Szalai (1987) used this method in the Mátra Mountains to reduce the high (75%) brood mortality due to predation by Eurasian Jays *(Garrulus glandarius)*. Their design (cca. 40×40 cm) consisted of side panels made of fine wire mesh (so-called "chicken wire") and a front panel made of wire mesh with a 6×4 cm mesh size enabling flycatchers to easily move through.

Nestbox occupancy and breeding success

The first nestbox installation project was carried out by Mészáros and Szalai (1987) in the Mátra Mountains during 1986–1988. Out of their 62 nestboxes, 8 were occupied by Red-breasted Flycatchers. Unfortunately, 6 of these broods were lost due to predation.

Twenty nestboxes were installed in the Kőszeg Mountains in 1996, where only one box was occupied 13 years later. This single pair bred successfully. Subsequently, further 15 nestboxes were added here and 35 more implemented in the Őrség region in 2009. One of these newer boxes was occupied in the Kőszeg Mountains and this breeding attempt was also successful (Németh 2010).

Urbán (2006) installed 15 boxes in the Bükk Mountains, but the fate of them was not controlled subsequently. Fitala (2010) implemented further 25 nestboxes in 2007, and recorded a single successful breeding attempt in 2010. Subsequently, he added 20 more boxes in 2011, but no more breeding birds were recorded.

Eleven nestboxes were put into operation in the Börzsöny Mountains, 2008. Unfortunately, subsequent control of these boxes was only partial, and no breeding birds were recorded (R. Kazi personal communication).

Finally, I have implemented a total of 103 nestboxes at three different locations (Óbánya valley, Réka valley, Páfrányos) of the Mecsek Mountains between 1989 and 2007. First, 30+20+20 nestboxes were implemented in 1989, 1990, and 1991, respectively. Further 14+17 boxes were added in 2002 and 2007. A total 6 boxes were occupied during the period of 1991–96. All boxes were protected by antipredator wire mesh cover, thus nestlings fledged from all of these nests successfully. Clutch size was known for five broods (6, 6, 6, 5 and 5), breeding success was 96%, and fledging rate was 89%. In comparison, fledging success from natural cavities was 51% in Poland (Mitrus & Soćko 2008), 34% in Germany (Müller 1970, cited in Cramp & Perrins 1993) and 54% in Belarus (Dorofeev 1969, cited in Cramp & Perrins 1993).

In 1994, I also put 34 nestboxes into operation in Zselic, where this species is a rare occasional breeder. Unfortunately, no box was occupied here.

I have also explored territories of 13 singing males in the Bakony Mountains, then installed 51 nestboxes at most promising sites in 2010. No breeding attempts were recorded in these boxes up to the present; all breeding pairs preferred to breed in natural cavities.

These occupancy rates fall far below the usual occupancy rates of typical cavity-nesting bird species. The likely reason for this low rate is the typically low density of birds at suitable breeding sites. On a 213 hectare area in Germany, 21 singing males were found, but only part of them had a breeding pair (Weber 1958). The breeding density was 0.6–1.7 pairs/10 ha (average: 0.28 pair/10 ha) in Germany (Flade 1994 in Flade1997). In the Białowieża National Park, Poland, the density of breeding density varied between 0.6–2.0 pairs/ha (average: 1.2 pair/10 ha) (Tomiałojć *et al*. 1984), and were 2 pairs/10 ha even in the best habitats (Wesołowski 2002). The density of breeding density varied between 0.61–1.2 pairs/10 ha in Belarus and 0.08–0.25 pair/10 ha in Russia (Taylor 2006). Densities are even lower in Hungary; 0.012 pair/10 ha in the Bükk Mountains (Bankovics *et al.* 1996) and 0.09 pair/10 ha in the Kőszeg Mountains – considering only the suitable habitats (Németh 2000). These values are much lower than densities of typical hole-nesting small passerines breeding in Hungarian beech forests, like Great Tit *(Parus major)*, 6.87 pairs/10 ha, Nuthatch *(Sitta europaea)* 1.14 pairs/10 ha, and Collared Flycatcher *(Ficedula albicollis)* 9.16 pairs/10 ha (Moskát 1985), Blue Tit *(Parus caeruleus)* 1.11 pais/10ha, Great Tit 4.01pairs/10 ha, Nuthatch 2.49 pairs/10 ha, Collared Flycatcer 4.43 pairs/10 ha (Moskát & Székely 1986), Collared Flycatcher 21 to 93 pairs/10ha (Török & Tóth 1988).

To summarize, the nestbox type specifically designed for the Red-breasted Flycatcher and illustrated in *Figure 1* were very scarcely occupied by this species in Hungary. Not only the occupancy rate was low, but predation pressure exerted upon broods were also high unless applying a protective wire mesh.

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Detailed description of the Ócsa Bird Ringing Station, Hungary

Location, methods and overview of results (1984–2015)

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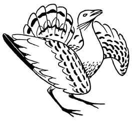

Tibor Csörgő, Andrea Harnos, Lajos Rózsa, Zsolt Karcza & Péter Fehérvári 2016. Detailed description of the Ócsa Bird Ringing Station, Hungary. – Ornis Hungarica 24(2): 91–108.

Abstract The present paper acts as an introduction to a series that will describe the exploratory analyses of migration phenology and morphometrics of the most common passerine species at the Ócsa Bird Ringing Station. This station is situated in the Ócsa Landscape Protection Area that belongs to the Duna–Ipoly National Park, Hungary. The area is somewhat cooler and more humid than the surrounding agricultural fields and tree plantations, covered by a mosaic of diverse hygrophilous vegetation patches. Bird trapping is mostly based on Japanese mist-net lines crossing different plant communities. During the period of 1984–2015, a total of 422,862 birds were trapped and ringed here, while 202,739 local, 1,235 within country, and 443 foreign recaptures were also recorded. Each bird is characterized by the following data: location and time of capture, species, age, sex, scores of fat, pectoral muscle, wing tip abrasion, and moult, length of wing, 3rd primary, and tail, and body mass. After subjected to a rigorous quality check, digital data are deposited in the archive of the Hungarian Bird Ringing Centre, and the EURING data base. From time to time, other research projects also utilized the accessibility of wild birds captured here, thus collection of blood samples, ecto- and endoparasites was carried out at the station. The relatively long time span, large number of species and individuals, and the readily available environmental (weather, vegetation, etc.) data makes the avian data collected here a suitable base for studies of various disciplines like capture methodology, habitat preferences,breeding, migration, and wintering, effects of weather and climate change, and epidemiology of viruses and parasites.

Keywords: bird banding, Carpathian Basin, long-term data set, standard methodology, migration phenology, morphology, habitat preference, parasite

Összefoglalás Jelen cikk egy olyan cikksorozat bevezető része, amelyben egy közép-magyarországi gyűrűzőállomáson – Ócsai Madárvártán – leggyakrabban előforduló énekesmadarak vonulás időzítésének és testméreteinek exploratív elemzéseit közöljük. A gyűrűző állomás a Duna–Ipoly Nemzeti Parkhoz tartozó Ócsai Tájvédelmi Körzetben található. A terület egy jégkorszaki maradványláp, mozaikos vegetációval. A madarak befogása a területre jellemző különböző növénytársulásokban, döntő többségben japán típusú függönyhálókkal történik. Az 1984–2015 között zajló munka során 422 862 madarat fogtunk, gyűrűztünk, 202 739 saját, 1235 hazai és 443 külföldi vonatkozású visszafogásunk volt. A befogott madarakról a következő adatokat vettük fel: a madarak befogási helye 12 méteres pontossággal, ideje 1 órás pontossággal, faja, kora, ivara, zsír-, izom-, vedlés- és kopás kódja, szárny-, 3. evező-, és farokhossza 1 mm-es pontossággal, testtömege 0,1 g pontossággal, teljes vedlést végző madárnál az evező- és faroktollaknál egyenként 0–5-ös skálán. Az adatok – ellenőrzés után – a Magyar Madárgyűrűzési Központba és az EURING adatbázisba kerülnek. A standard adatfelvételen túl – időközönként és bizonyos fajoknál – egyéb vizsgálatok is történnek, pl. ekto, és endoparazita gyűjtés, vérminta gyűjtés stb. A viszonylag hosszú időintervallum, a nagy fajszám és fajonkénti adatszám, a háttéradatok (időjárás, vegetáció mintázat) miatt az adatok számos madártani vizsgálatnak lehetnek forrásai, és képezhetnek összehasonlítási alapot más területeken zajló kutatások eredményeivel. A feldolgozás, értelmezés a legkülönbözőbb szempontok alapján történik: fogás-módszertani vizsgálatok, élőhely-preferencia, költés és telelés, vonulás, időjárási hatások, klímaváltozás, parazitológiai és virológiai vizsgálatok stb.

Kulcsszavak: madárgyűrűzés, Kárpát-medence, hosszútávú adatsor, standard módszerek, madárvonulás, morfológia, élőhely-preferencia, parazita

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Introduction

Avian migration research in Hungary dates back to as early as 1908, when this country was the third in the world to adopt and implement a national ringing scheme (Karcza & Magyar 2009). Organized forms of ringing activities have been carried out continuously since then and today, Hungarian ornithologists are regional leaders in the annual total number of birds ringed. In the last decades, the majority of these birds are captured and marked at Actio Hungarica sites. These sites have common standardized methodologies in trapping and handling birds, adopted from and named after the Actio Baltica system (Busse & Kania 1970, Busse 1974), and the European-African songbird migration network (Bairlein 1994). Today a total of 8 Actio Hungarica sites operate throughout the country, of which our focal site, the Ócsa Bird Ringing Station (ocsabirdringing.org) has the largest number of cumulative captures. Initial work started here in 1983, when the site was evaluated and chosen for as the location of a ringing station, and the position of the mist net lines were determined. One of the most attractive features of the area – asides from the diverse habitat – is the simple logistics, as it is easily reached from Budapest via public transport or road. Initially, the working staff lived in tents and reed huts through several years. In 2001, a brick building was constructed, considerably improving working and living conditions (electricity, internet connection, drinking water supply, heating, working and sleeping rooms). The building also serves as accommodation for visitors and volunteers, thus attracting more help throughout the season. Today, the ringing station is one of the most visited site from professionals and laymen alike, and serves as an educational facility, provides service for companies and conducts avian population research.

Here we describe in detail the site; the methods applied and present comprehensive results of bird ringing at the station. Our aim is to help evaluate previously and future

Figure 1. Location of the Ócsa Bird Ringing Station (red square) on a continental scale. The Carpathian montain range is a potential geographical barrier for migrating birds

1. ábra Az Ócsai Madárvárta (piros négyzet) elhelyezkedése kontinentális skálán. A Kárpátok a vonuló madarak számára potenciális akadályt jelentenek

published studies using the data generated at the site and also to fundament a series of future publications that aim to give comprehensive exploratory and descriptive statistics (Harnos *et al.* 2015b, 2016a) on migration timing and morphology of the most commonly captured species here (e.g. Harnos *et al.* 2016c,b).

Location

The ringing station (N47.2970, E19.2104) is situated on the western periphery of the town of Ócsa, Hungary, ca. 33 km from Budapest. From an avian migrants' perspective the station is in a large, low altitude basin (Carpathian Basin) surrounded by mountain ranges that may act as geographical barriers *(Figure 1)*. Of these, presumably the most important are the Carpathians as they encompass the region from north-west to south-east.

On a smaller spatial scale the station is situated on the edge of a wetland in the Ócsa Landscape Protection Area of the Duna-Ipoly National Park *(Figure 2)*. The wetlands here are one of the very few remaining post-glacial peat bogs in the Carpathian Basin. Their conservation value was recognized as early as 1978, when the area was declared protected. Furthermore, the area represents the only natural type habitat in the larger

Figure 2. Location of the Ócsa Bird Ringing Station on landscape scale (a) and the habitat composition together with the position of standard mist net lines (b). The station is located on the edge of a protected wetland, that is the only natural type habitat patch in the vicinity. The area is otherwise an agricultural landscape interspersed with open-pit gravel mines and poplar plantations. The habitat surrounding the station is a mosaic of shrubs, forest type habitats and reedbeds. See text and *Table 1* for detailed description of habitats surrounding mist net lines

2. ábra Az Ócsai Madárvárta elhelyezkedése (a) és az élőhely összetétel a hálóállások (b) feltüntetésével. A madárvárta egy védett terület szélén van, amely az egyetlen ilyen vizes élőhely a környéken. Mezőgazdasági területek veszik körül, amelyeken belül több kavicsbánya és telepített nyárerdők vannak. A kutatási terület vegetációja mozaikos, jellemzően bokros, fás területek és nádasok alkotják

vicinity; practically it is surrounded by arable fields, poplar plantations with several interspersed open-pit gravel mines.

Climate

Ócsa is situated in a humid continental transitional climate zone. Summers are medium warm and dry here, with relatively cold winters. The annual average temperature is 10.1°C (minimum ca. -15.6 °C, maximum ca. 34.1 °C). The location is in the former glacial Danube riverbed, thus temperature values are somewhat lower than in the large scale surroundings. This is possibly one of the reasons why the glacial peat bog could survive after deglaciation. Annual precipitation is around 550–580 mm coming together with a ca. 2000 hours of sunshine. The direction of wind is often north-west, while the average wind speed is 2.5–3 m/s. The mean elevation is 100 m above sea level (Füri 2007).

Habitat

Prior to formal protection of the site, there was intensive peat extraction from the surrounding bogs (Füri 2007). Today, the spatial structure of the habitat generally follows the succession gradient from open water to closed broad-leaved forest. However, the areas affected by open-pit extraction went under a secondary succession and were recolonized by mainly reed *(Phragmites australis)* and swamp sawgrass *(Cladium mariscus)*, thus all open water surface disappeared. To reverse this process, new pits were dredged to create open water surfaces in late 2011. Simultaneously, a channel system was also created to maintain continuous water supply *(Figure 2 b)*. These works affected the vicinity of a few capture locations, however merely restored original habitat conditions. Habitats around the capture locations were further affected by secondary succession, typically increasing the height of fast growing shrubs and trees like poplars and willow species within the study period. This process had a major effect around only one mist net line (3.), where the initial dry standing heterogeneous reedbed was gradually replaced by European elderberry *(Sambucus nigra)*, partly covered by common hop *(Humulus lupulus)* and more recently also by European blackberry *(Rubus fruticosus)*.

Capture methods

Capture methods at the ringing station can be categorized to three groups; a) non-standard sporadically used methods, b) ringing at nest sites and c) standard methods. The first group of methods are predominantly used to capture raptors (cube nets, box-traps), and members of the Rallidae family (walk-in traps). The usage of these depends on season; raptor traps are only active in winter, while walk-in traps in autumn. Moreover, their usage also depends on environmental circumstances like snow cover and water level. Typically large and/or colonial breeders like White-tailed Eagles *(Haliaeetus albicilla)*, Grey Herons *(Ardea cinerea)*, Great Egrets *(Egretta alba)*, Night Herons *(Nycticorax nycticorax)*, Spoonbills *(Platalea leucorodia)*, Black Storks *(Ciconia nigra)*, Black-headed Gulls *(Larus ridibundus)*, Mediterranean Gulls *(Larus melanocephalus)* and Common Terns *(Sterna hirundo)* are ringed as nestlings within the framework of national colour ringing programs.

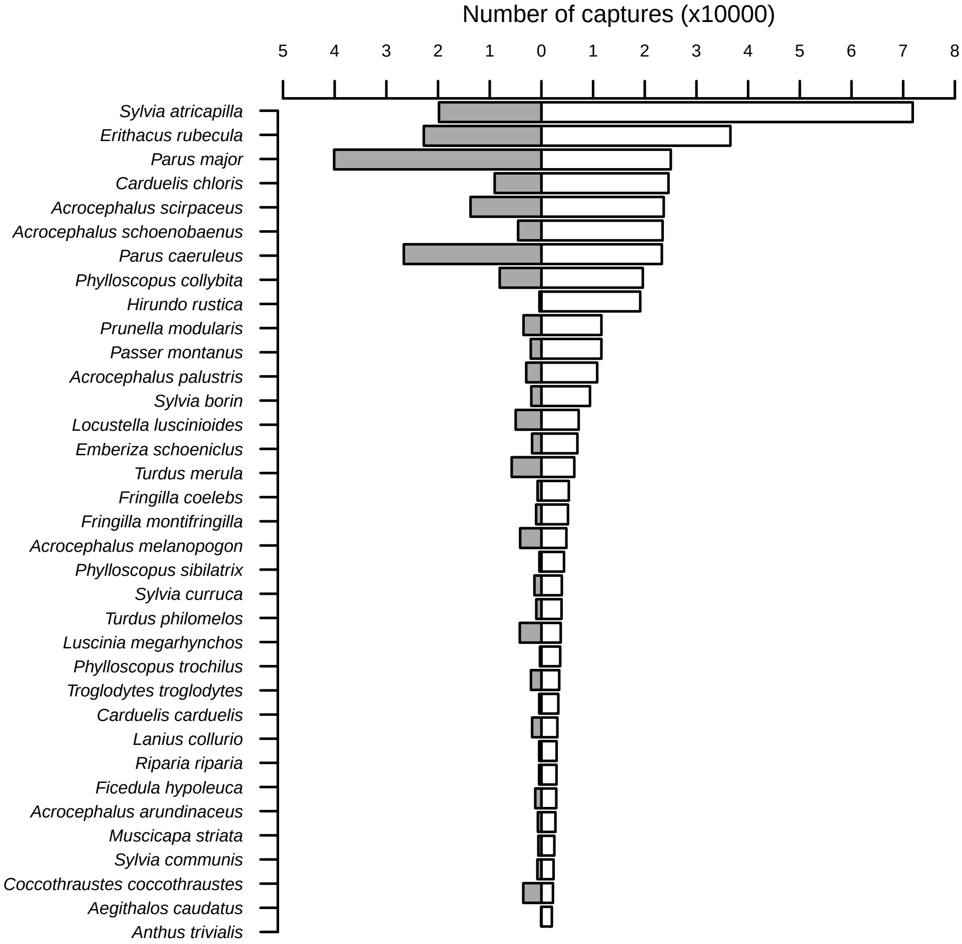

Figure 3. Capture (white bars) and recapture (grey bars) frequencies by species (1984–2015). Only the 35 most commonly ringed species are depicted

3. ábra A 35 leggyakoribb faj fogás (fehér) és visszafogás (szürke) gyakorisága 1984–2015 között

The majority of birds ringed at the station are passerines *(Figure 3)* captured with standard methodology that entails the usage of mist nets (dimensions: 12×2.5 m, mesh: 16×16 mm, shelves: 5). The locations of the mist net lines were initially chosen to sample the major habitat types in the vicinity of the station *(Figure 2, Table 1)*.

Table 1. Description of mist net lines
1. táblázat A hálóállások jellemzői

Mist net line ID	Habitat description	Number of nets
1	dry reedbed scattered with European elderberry and a few poplar bushes or trees	15
2	a patch of bush dominated by elderberry, poplar and willow species (*Salix* spp.)	12
3	dry reedbed with a few elderberry and walnut *(Juglans regia)*, partly covered by common hop and more recently also by European blackberry	10
4	a narrow line of poplar trees and willow bushes, surrounded by aquatic habitat mainly reedbed	40
5	a forested habitat patch covered by old poplar trees, more recently the blackberry is also spreading on the wet soil	5
6	shallow standing water covered by reed, with some willow bushes spreading	17
7	a line of Hungarian narrow-leaved ash (*Fraxinus angustifolia* ssp. *pannonica*) trees surrounded by open water, undergrowth is dominated by blackberry and elderberry.	13
8	a patch of willow and poplar bushes and trees surrounded by reedbed. Active since 2001 and only during the Constant Effort Sites Scheme (CES) period (see below for details)	15

All mist nets are opened at dawn, controlled every hour during the day, and closed at dusk. Under unfavourable weather conditions nets are controlled more frequently (ca. every half hour). In case of extreme heat, cold, or windy weather conditions all nets are closed. Tape-luring is used only in the vicinity of mist net line 1 *(Figure 2 a)* , which is relatively distant from all other mist nets *(Figure 2 b)*. Calls and songs of *Acrocephalus* warblers are played in August (Csörgő *et al.* 2008), while *Sylvia/Phylloscopus* Warbler and Tree Pipit calls are used through September.

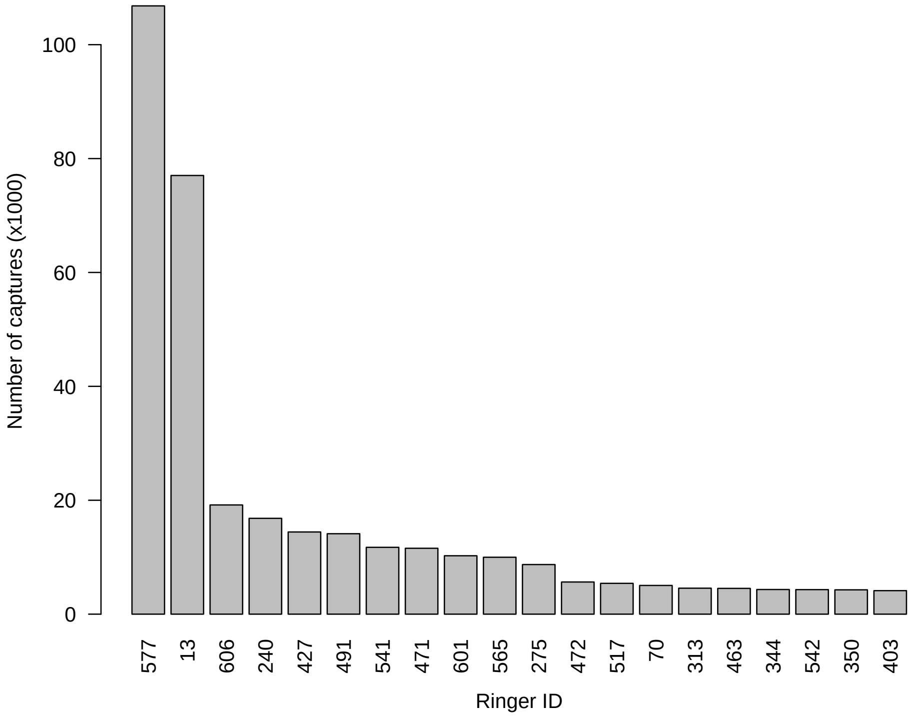

Figure 4. Number of birds handled by individual ringers in the 1984–2015 period. The majority of birds was ringed and measured by a handful of individuals

4. ábra Az egyes gyűrűzők által jelölt madarak száma 1984 és 2015 között. A gyűrűzés nagy részét kisszámú személy végezte

Ringing and measuring

A total of 110 ringers have worked at the station in the 1984–2015 period, however, 43% of birds were ringed by the first two persons and 80% by 20 ringers *(Figure 4)*. All ringers who worked at the Ringing Station have a ringing permit (that includes a license to catch wild birds) issued by the Hungarian governmental authorities. The standard rings of the Hungarian Bird Ringing Centre (MME/BirdLife Hungary) were deployed on all birds.

Biometric measurements are taken following standardized and published methods (Szentendrey *et al.* 1979, Svensson 1992, EURING 2015). The following data types are recorded:

- individual ring number;
- species;
- age category;
- sex (based on plumage cues, brood patch, cloacal protuberance, or – more recently – also molecular analyses of DNA samples);
- wing length (precision ±0.5 mm);

- length of 3rd primary (precision ±0.5 mm);
- tail length (precision ±0.5 mm);
- fat score (0–8 scale) following Kaiser (1993);
- pectoral muscle score (0–3 scale);
- body mass (precision ±0.05 mm) measured using Pesola springs or a digital scale;
- wing tip abrasion (0–3);
- moult (moult of covers: 0–3 scale, moult primaries, secondaries and retrices, individually) following Ginn & Melville (1983) and Jenni & Winkler (1994);
- date (year, month, day (precision ±0.5 hour));
- capture location (each bird is placed into a bag marked differently corresponding to the mist net line and the number of net; precision ±6 m).

Data management

Ringing data is recorded into a field notebook simultaneously with ringing. Subsequently, days or even months later, these data are entered into a data base. Then digital data are subjected to rigorous quality check by means of statistical filtering: suspicious values are individually checked (Harnos *et al.* 2015b). Finally, quality-checked digital data are deposited in three parallel data bases: the archive of the Ócsa Bird Ringing Station, the archive of the Hungarian Bird Ringing Centre, and the EURING data base.

Capture effort and timing

The first mist-netting trials and preliminary bird ringing activities were carried out in 1983. Subsequently, all the year round bird ringing work started from 1984 to be continued up to the present. In 2001, a building was constructed to serve as accommodation and as a working station, and simultaneously permanent working staff has been employed. These factors enabled to increase capture effort throughout the year. Each year is divided into the following 4 time periods.

Spring migration period – Starting from mid-March, and lasts until the second decade of April. Continuous daily capture throughout the period with all standard net lines.

Breeding period – Starts as soon as the spring migration period is over, and lasts until the 9th of July. Each net line is opened once a week and the sampling follows Constant Effort Site (CES) protocols (Baillie 1986, Robinson *et al.* 2009).

Autumn migration period – Starts on the 10th of July and lasts until late October to mid-November, depending on weather. Continuous daily capture throughout the period with all standard nets.

Winter feeder period – Lasts until the first day of the spring camp. Weekly ringing near bird feeders, however the dates vary depending on weather. This is the only non-standard sampling period.

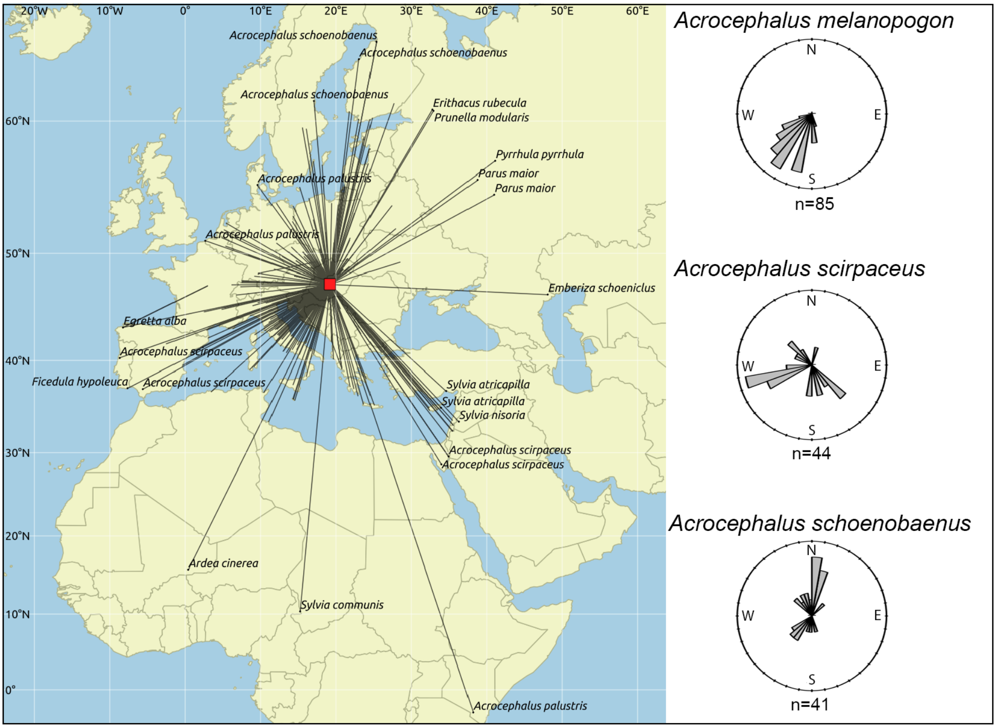

Figure 5. All foreign ring recoveries with ties to the Ócsa Bird Ringing station (i.e. recovered at the ringing station or ringed at the station and recovered elsewhere). The rose diagrams show the bearing distribution of foreign ring recoveries of three *Acrocephalus* warbler species with markedly different breeding and wintering distribution and/or migration strategies

5. ábra Az Ócsai Madárvártán jelölt és külföldön megkerült, illetve külföldön jelölt és itt megfogott madarak. A kördiagram 3 – eltérő költési és/vagy telelési területű, illetve vonulási stratégiájú – *Acrocephalus* faj egyedeinek jellemző mozgási irányait mutatja

Overview of results

The fact that every 10th bird ringed between 1984–2015 in Hungary was handled in the Ócsa Bird Ringing Station, illustrates the national importance of study site. Indeed, the 422,862 individuals of 169 species were ringed at the station together with the 202,739 local recaptures. All of the most abundant captured species are passerines *(Figure 3)*. Furthermore, a total of 1325 individuals were recovered over 5 km from the ringing station, of which 443 were foreign ring recoveries (i.e. recovered at the ringing station or ringed at the station and recovered elsewhere *(Figure 5)*. The spatial patterns of foreign recoveries reveal that there is a considerable hiatus of birds, regardless of species, arriving from the east. This is presumably the synergistic effect of the geographical barrier effect of the Eastern Carpathians, and the lower effort in ringing activities in eastern states compared to that in northern and western countries (http://euring.org/data-and-codes/ringing-totals).

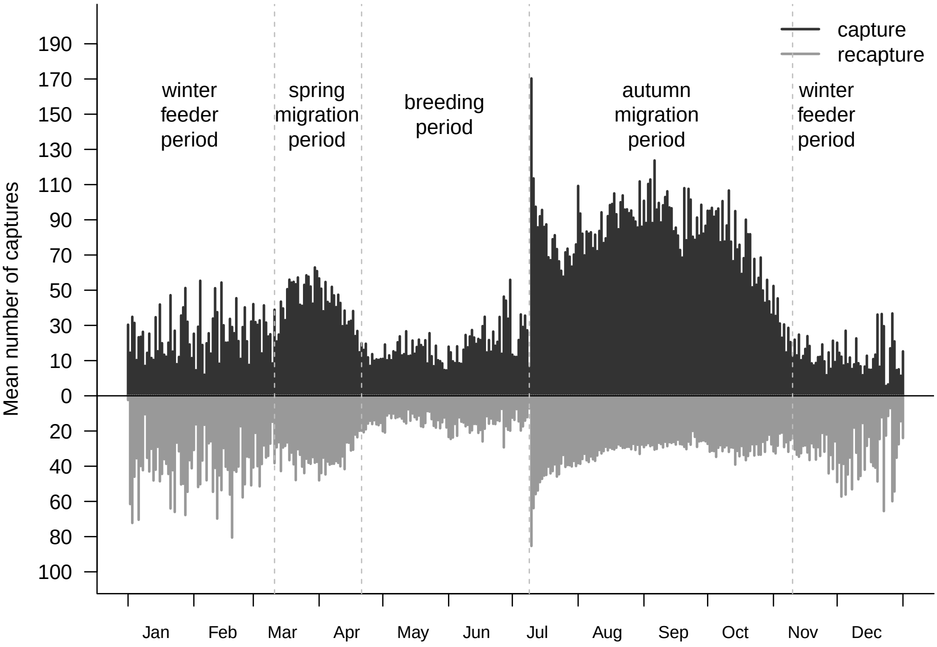

Figure 6. Mean number of total capture frequencies for each day of the year. All nets are open in spring and autumn, while standard sampling (CES protocol) is carried out in the breeding season. The difference in trapping effort causes the large abrupt increase in mean capture frequencies between at the beginning of the autumn migration period

6. ábra A napi fogás és visszafogás átlagos számai az év folyamán. A tavaszi és őszi vonulás során az összes háló ki van nyitva, a fészkelési időszak alatt a CES protokollnak megfelelően egy-egy állás csak 5–10 napon belül egyszer

The Carpathians also act as a line of demarcation to differentiate between migration strategies of trans-migrant and local breeding populations. For instance, three *Acrocephalus* species that all breed at the study site show markedly different recapture patterns *(Figure 5). A. melanopogon*, a short distance migrant with a discrete breeding distribution in the Carpathian Basin that winters in the shoreline wetlands of the Balkans and Greece, has only recaptures with southern bearing. *A. scirpaceus*, on the other hand, is a common reedbed specialist throughout the continent yet the recapture bearing distribution shows hardly any birds with northerly origins, indicating that the Hungarian population is isolated from that of northern European countries. However, the fact that this species is a trans-Saharan migrant with two distinct wintering areas (West and East Africa) can be retraced by the foreign recapture bearing distribution. Similarly to the *A. scirpaceus, A. schoenobaenus* has a continental breeding distribution, yet the recapture patterns show that birds caught at the Ócsa Bird Ringing Station are local breeders and passage migrants originating from northern countries, suggesting that this species is traversing the Carpathians on migration (Csörgő & Gyurácz 2009a,b, Kovács *et al.* 2010, 2012).

Considering the overall mean daily capture frequencies throughout the study period, it is apparent that the different capture periods yield considerably different bird numbers *(Figure 6)*. In winter, when bird trapping is limited to three feeder sites and is only operating on a roughly weekly basis, capture frequencies predominantly depend on weather, hence there is large inter-annual and between-day variability in the number of ringed birds. Similar daily mean trapping rates are observable in the breeding period (CES period), however, with substantially lower between day mean variability. The transition from the CES period to the autumn migration period is striking, with approximately an order of magnitude larger daily capture yields especially early in the season. The reasons for this are two fold; first the trapping effort is drastically increased as all nets are opened on the 10^{th} of July, and second, both dispersing local juveniles and early migrants are present in this period. In autumn, mean capture frequencies generally have a steep and steady decrease starting from mid-October.

Inter-annual differences in capture frequencies were also substantial *(Table 2*, *Figure 7)* in the study period, however a large proportion of this variability can be explained by the increase in the number of nets since 2001 *(Figure 7–8)*. On the other hand, the annual cumulative curve of daily captures shows that inter-annual variation does not grow steadily throughout the season. Typically annual capture totals depend on breeding period months, and winter capture rates *(Figure 8)*.

Table 2. Descriptive statistics of yearly capture and recapture frequencies and number of species at the Ócsa Bird Ringing Station

2. táblázat Az évi fogás, visszafogás és fajszám-gyakoriságok leíró statisztikái

	Captures	**Recaptures**	**Number of species**
Minimum	5792	1989	74
Median	12974	6512	94
Maximum	22902	10370	108

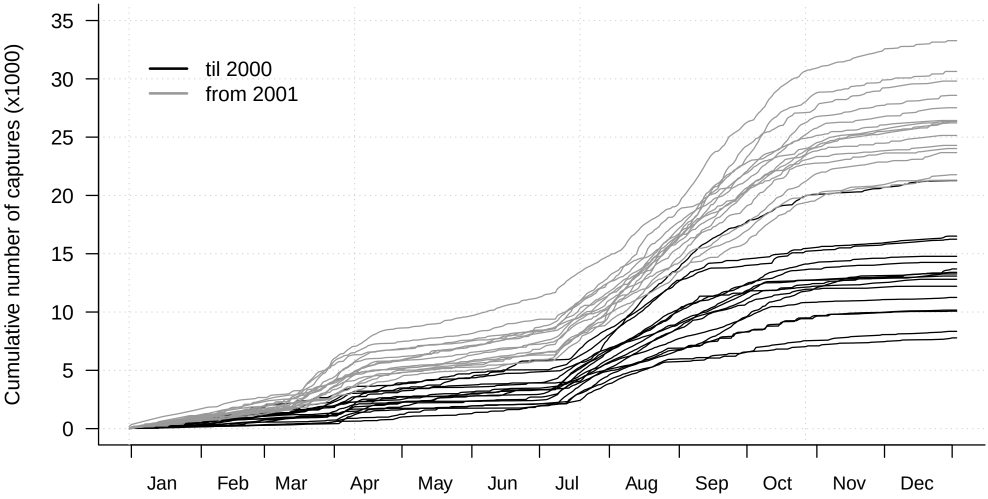

Figure 7. Annual cumulative capture frequencies in relation to day of year. There are large inter-annual differences in capture frequencies, however, since 2001 the number of nets and capture days have been increased that had an apparent effect on the number of captured birds

7. ábra Az évi fogások kummulatív görbéi. Az éves fogási mintázatok és számok nagy éves különbséget mutatnak. A nagyobb értékek jellemzően 2001-től jelentkeznek, amikortól megnőtt a hálóállások és a fogási napok száma

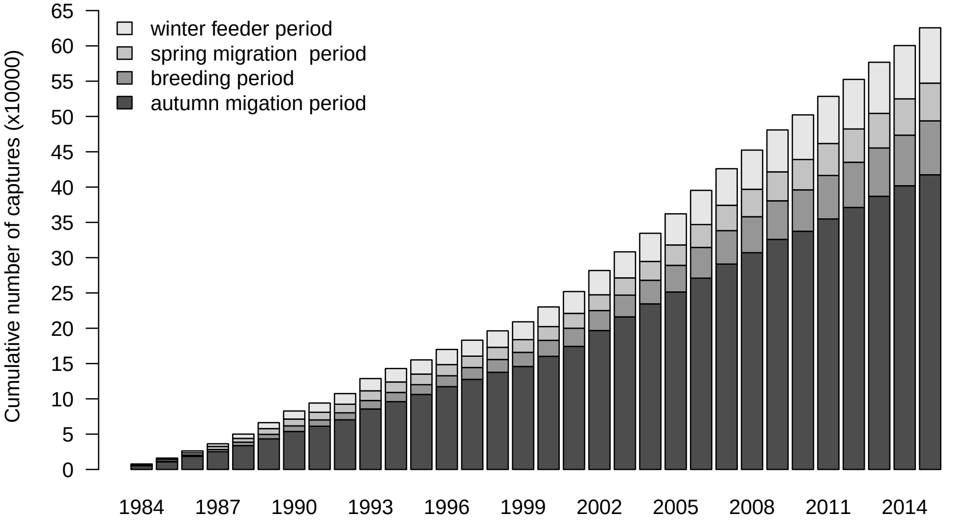

Figure 8. Cumulative capture frequencies by year through the study period. The rate of increase is larger since 2001 when the number of nets capture days were increased

8. ábra Kumulatív fogási gyakoriságok 1984–2015 között. A fogási számok 2001-től nagyobbak, nagyrészt a hálóállások és a fogási napok számának növekedése miatt

Further research projects

From time to time, other complementary research projects that require the handling of a large number of wild birds also rely on the infrastructure and activities of the Station. These projects include studies on the distribution and ecology of viruses, ticks (Acari: Ixodidae) and lice (Insecta: Phthiraptera). Other research projects required avian blood samples to identify immunological antibodies or to carry out DNA-based sex determination of sexually monomorphic birds. Naturally, only a small portion of ringed birds were subjected to these parallel studies. Considerable emphasis is placed upon motivating BSc, MSc, and PhD students, as well as their tutors, to utilize data for their thesis works. Connections to the Eötvös Loránd University (Budapest) and the University of Veterinary Medicine (Budapest) have been particularly fruitful. Hypothesis-based research using data obtained from the Station covered a wide range of topics from different fields of science. Ecological studies included research on capture (see e.g. Lövei *et al.* 2001) and statistical (Harnos *et al.* 2015b, 2016a) methodology , habitat preferences (e.g. Preiszner & Csörgő 2008, Ónodi & Csörgő 2012, 2013), moult (e.g. Kelemen *et al.* 2000), social behaviour (e.g. Báldi & Csörgő 1993, 1994b), sexual selection (e.g. Gál *et al.* 2012), wintering (e.g. Báldi & Csörgő 1994c, Csörgő *et al.* 2001, Kovács *et al.* 2011, Miholcsa *et al.* 2016, Miholcsa & Csörgő 2016), breeding (see e.g. Báldi & Csörgő 1991, 1994a), and particularly migration (e.g. Csörgő & Lövei 1995, Csörgő & Parádi 1998, 2000, Kovács *et al.* 2009, Nagy *et al.* 2009, Gyimóthy *et al.* 2011a,b, Harnos & Csörgő 2011, Csörgő & Harnos 2011, Harnos *et al.* 2015c,a) studies. Furthermore, effects of weather (see e.g. Gyurácz *et al.* 1997, 2003) and climate change (see e.g. Miholcsa *et al.* 2009, Csörgő *et al.* 2009, Kovács *et al.* 2010, 2012, Harnos *et al.* 2015a) on avian migration phenology have been intensively studied. Finally, epidemiological studies focused on evolutionary-ecological aspects of Usutu and West Nile viruses (Bakonyi *et al.* 2007, 2013), ticks (Hornok *et al.* 2012, 2016a,b) and tick-borne infections (Hornok *et al.* 2013, 2014), and lice (Vas *et al.* 2008, 2012) infesting birds.

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Exploratory analyses of migration timing and morphometrics of the Pied Flycatcher *(Ficedula hypoleuca)*

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Abstract Ornithological studies often rely on large temporal scale ringing datasets as source of information. However, basic descriptive statistics of collected data are rarely provided. In order to fill this gap, here we present the first 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 (1984–2015). First, we give a concise description of foreign ring recoveries of the Pied Flycatcher in relation to Hungary. We then shift focus to data of 2860 individuals deriving 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 we present the cumulative distribution 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 distribution of individual fat and muscle scores, and the distribution of body mass within each fat score category. We distinguish migration periods (spring and autumn), age (i.e. juveniles and adults) and sex groups. Our aim is to provide a comprehensive overview of the analysed variables. However, we do not aim to interpret the obtained results, merely 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

Összefoglalás Madártani tanulmányokban gyakran elemeznek hosszútávú madárgyűrűzési adatsorokat, de az alapvető leíró statisztikák és exploratív elemzések általában nem hozzáférhetőek. E hiányt pótolandó, cikksorozatot indítunk, melyben egy közép-magyarországi gyűrűző állomáson leggyakrabban előforduló énekesmadár fajok vonulás időzítésének és testméreteinek exploratív elemzéseit közöljük (1984–2015). A sorozat az első tagjaként szolgáló jelen cikkben először áttekintjük a kormos légykapó magyar gyűrűs külföldi és külföldi gyűrűs magyarországi megkerüléseit, majd rátérünk a faj egy magyarországi, 1984 óta standard módszerekkel dolgozó gyűrűzőállomásról származó 2860 egyedétől származó adatának elemzésére. Az időzítés jellemzéséhez az éves és a napi átlagos első megfogások és visszafogások leíró statisztikái mellett megmutatjuk 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. Ábrákon bemutatjuk ezen változók éves átlagait, a zsír- és izomkategóriák gyakorisági eloszlását, valamint a testtömegek eloszlását zsírkategóriák szerinti bontásban. Az elemzésben elkülönítjük az egyes vonulási időszakokat (tavasz, ősz), a korcsoportokat (fiatal, öreg), illetve az ivarokat (hím, tojó). 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 volume of data has been collected 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 suitable for meta- or comparative analyses is sporadically available (Gienapp *et al.* 2007, Harnos *et al.* 2015a). 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 for future studies. For this purpose, it is essential that descriptive studies must apply the most appropriate statistical methodologies (Harnos *et al.* 2015a, 2016). The bulk of currently available ringing data is often derived from large temporal scale projects like permanent ringing stations, where massive amount of individuals of various species are trapped simultaneously (Csörgő *et al.* 2016). These projects generally apply standardized and similar 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).

Here we present exploratory and descriptive statistics on the migration timing and morphometrics of the Pied Flycatcher between 1984–2015 from a Central European ringing station (Ócsa Bird Ringing Station, Hungary, see Csörgő *et al.* 2016 for details).

The Pied Flycatcher is a small, insectivorous passerine of the Muscicapidae family. The breeding plumage is sexually dimorphic. The upperparts of males are black contrasting the white forehead, wing patches and underparts, whereas the upperparts of females and juveniles are drab. Pied Flycatchers are polytipical with 4 subspecies, namely *F. h. hypoleuca, F. h. sibrica, F. h. iberiae* and *F. h. speculigera*. Plumage varies across races, differing predominantly in upperpart colouration, and in the extent of white in the forehead and wing patches. The breeding distribution ranges from Western North Africa through most of the European continent reaching well into Central Asia. The nominate subspecies is found in continental Europe excluding the Iberian Penninsula where it is replaced by *F.*

h. iberiae. F. h. sibrica breeds in Siberia, while *F. h. speculigera* is found in the coastal regions of Western North Africa (Cramp & Perrins 1993, Taylor 2006).

The Pied Flycatcher is classified as Least Concern in the IUCN Red List, however the European population is seemingly decreasing (BirdLife International 2016). It is a sporadic to rare breeder in Hungary, predominantly found in the Southern Great Plain, Alpine Foothills and Zala Hills (Hadarics & Zalai 2008, Török 2009). Pied Flycatchers may hybridize with the closely related Collared Flycatcher *(Ficedula albicollis)* in areas where the two species are sympatric like in Hungary (BirdLife Hungary 2016). Pied Flycatchers inhabit deciduous forests throughout the breeding distribution range where they nest in tree cavities. They constitute model systems of various behavioural disciplines, hence their mating and parental care have been extensively studied (Lundberg & Alatalo 2010). Their mating system is social monogamy and successive polygyny (i.e. males may be polyterritorial and may mate with multiple females; Haartman 1951, Alatalo *et al.* 1981, Dale & Slagsvold 1996). The parental care is generally biparental (Moreno *et al.* 1995) with variation in male contribution largely depending on the number of female partners (Lifield & Slagsvold 1990) among other traits.

All subspecies are obligatory long distance, trans-Saharan migrants. In the autumn, Pied Flycathcers migrate between August and September in Europe (Cramp & Perrins 1993). The large scale spatial pattern of ring recoveries from this season indicate a general south-western bearing with the most important known stopover (refuelling) sites being in South West France, North West Spain and North Portugal (Jones 2002). Birds ringed in Scandinavia and North West Europe are recaptured from the Atlantic coasts of France, Spain and Portugal to the Czech Republic, Austria, North Italy and North West Africa (Bønløkke *et al.* 2006, Fransson & Hall-Karlsson 2008, Valkama *et al.* 2014). Recaptures in the Czech Republic originate mainly from Sweden and Finland, with a handful of Ukrainian and Russian recoveries, including an individual east of the Ural mountain range (Hromádko 2008). The birds are territorial on the stopover sites and accumulate fat reserves for onward migration.

Their wintering grounds are in tropical West Africa, ranging from Guinea to Ghana (Cramp & Perrins 1993, Salewski *et al.* 2004). Pied Flycatchers are territorial and show high site fidelity during wintering (Salewski *et al.* 2002).

Little is known on the spring migration routes in Africa, although in Europe it probably leads further east; over the northern part of the Apennine Peninsula and Central Europe (Cramp & Perrins 1993, Fransson & Hall-Karlsson 2008, Spina & Volponi 2009, Bairlein *et al.* 2014, Valkama *et al.* 2014).

It is a common migrant from mid-April to mid-May in spring and from late August until mid-September in autumn in Hungary (Hadarics & Zalai 2008, Török 2009). Pied Flycathers are regular and common passage migrants 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 mosaic of habitats that include 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 located in 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 separately was 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 as well as the sexes in both age classes upon plumage characteristics (Cramp & Perrins 1993, 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 before the 145th day of the year were considered to be spring migrants. A total of 2860 Pied Flycatchers were captured and ringed between April and September; 268 males and 176 females in spring, 120 adult males and 196 adult females, 975 juvenile males and 657 juvenile females in autumn (the age or sex of the rest of birds were not defined) in the study period of 1984–2015. This total value constitutes ca. 26% of the 11,044 Pied Flycatchers 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.* 2015a). 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), which is highly effective in calculating summary statistics for different groups and subsets. 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

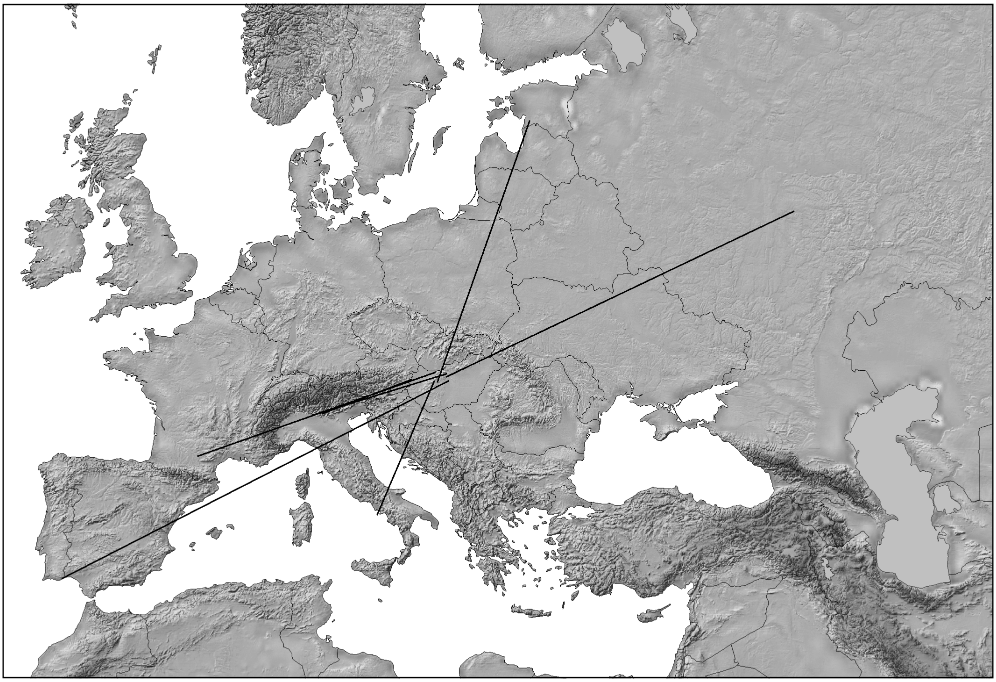

Figure 1. Foreign ring recoveries of Pied Flycatchers. The data of birds ringed in Hungary and recovered abroad and the birds ringed abroad and recovered in Hungary are depicted

1. ábra Magyarországon jelölt és külföldön megkerült, illetve külföldön jelölt és Magyarországon megfogott kormos légykapók

of the same variables were represented with histograms and overplotted smooth histograms. Boxplots were used to show the body mass distribution by fat score categories. Fat and muscle score frequencies are shown using barplots. We distinguished seasons,age and sex groups throughout the analyses. For more details on the analysis, please visit ocsabirdringing.org. All analyses were done in R 3.2.2 (R Core Team 2015).

Results

A total of 6 foreign recaptures were recorded between 1951 and 2016 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 *Tables 1–2*. Changes in annual mean arrival dates throughout the study period and the distribution of within-year migration timing according to season, age and sex are presented in *Figure 4*. The trend of annual mean wing lengths and the distribution of wing length measurements according to season, age and sex are shown in *Figure 5*, while their respective descriptive statistics are presented in *Table 3*.

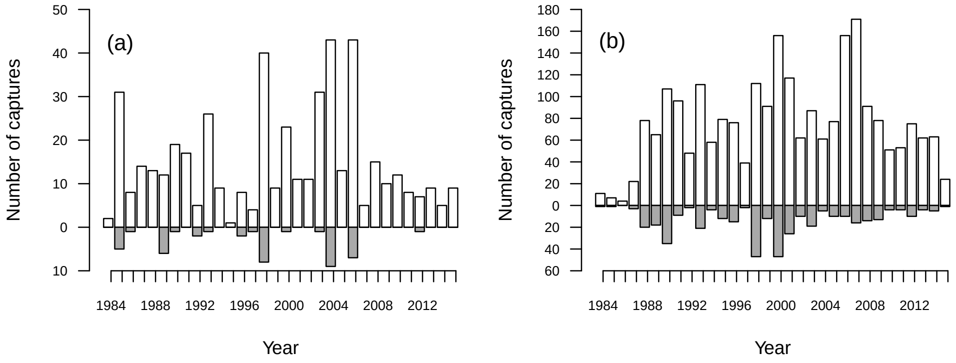

Figure 2. Annual capture (white bars) and recapture (grey bars) frequencies in spring (a), and in autumn (b)

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

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, age and sex and fat scores are visualized with boxplots in *Figure 9*. Finally, the distribution of fat and muscle scores grouped by season, age and sex can be found in *Figure 9 b,d,f* and *Figure 10*.

Table 1. Descriptive statistics of migration timing (day of the year)

1. táblázat A vonulás időzítés (év napja) leíró statisztikái

Season	Age	Sex	Mean	Median	SD	Min	Max	N
spring	adult	male	112.8	111	8.8	90	139	268
spring	adult	female	118.5	119	8.3	101	139	176
autumn	adult	male	241.2	243	13.1	180	276	120
autumn	adult	female	242.9	244	11.3	190	275	196
autumn	juvenile	male	237.5	238	12.3	204	281	975
autumn	juvenile	female	238.3	238	12.5	202	273	657

Table 2. Descriptive statistics of stopover duration (day)

2. táblázat A tartózkodási idő (nap) leíró statisztikái

Season	Age	Sex	Mean	Median	SD	Min	Max	N
spring	adult	male	2.3	1.0	1.9	1	6	12
spring	adult	female	2.0	2.0	1.1	1	4	9
autumn	adult	male	3.6	2.0	3.6	1	12	9
autumn	adult	female	3.2	1.5	4.0	1	15	14
autumn	juvenile	male	3.8	3.0	3.2	1	15	98
autumn	juvenile	female	3.4	3.0	2.6	1	13	73

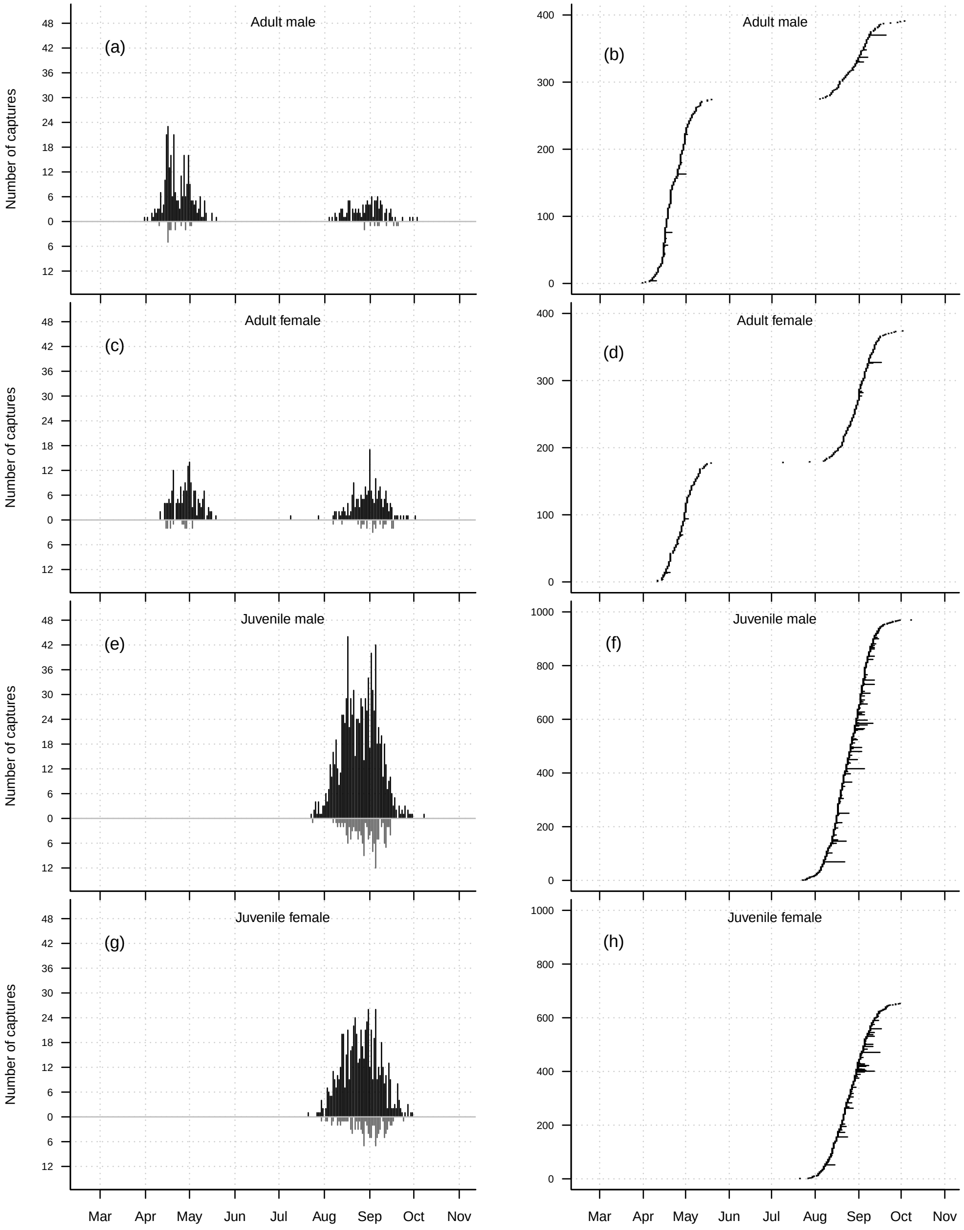

Figure 3. Within-year capture (black bars) and recapture (grey bars) frequencies (a, c, e, g) and cumulative distributions of individual first and last capture dates (b, d, f, h) according to age and sex

3. ábra Éven belüli fogás (fekete oszlopok) és visszafogás (szürke oszlopok) gyakoriságok (a, c, e, g) és az egyedek első és utolsó fogási dátumának kumulatív eloszlása (b, d, f, h) kor és ivar csoportonként

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

Season	Age	Sex	Mean	Median	SD	Min	Max	N
spring	adult	male	80.7	81	1.7	76	85	262
spring	adult	female	79.3	79	1.8	75	85	173
autumn	adult	male	81.4	81	2.1	76	86	115
autumn	adult	female	80.0	80	1.9	75	86	189
autumn	juvenile	male	80.3	80	1.8	75	87	952
autumn	juvenile	female	79.3	79	1.7	75	85	646

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

Season	Age	Sex	Mean	Median	SD	Min	Max	N
spring	adult	male	61.8	62	1.5	58	65	225
spring	adult	female	60.7	61	1.5	57	64	153
autumn	adult	male	62.1	62	1.9	56	66	113
autumn	adult	female	60.9	61	1.7	57	65	189
autumn	juvenile	male	61.4	61	1.7	56	67	951
autumn	juvenile	female	60.6	61	1.6	56	68	645

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

Season	Age	Sex	Mean	Median	SD	Min	Max	N
spring	adult	male	54.9	55	1.9	49	62	262
spring	adult	female	54.3	54	1.9	49	60	171
autumn	adult	male	55.5	56	2.0	50	62	114
autumn	adult	female	54.6	54	2.2	50	60	192
autumn	juvenile	male	54.8	55	1.9	49	61	946
autumn	juvenile	female	54.3	55	1.9	49	60	633

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

Season	Age	Sex	Mean	Median	SD	Min	Max	N
spring	adult	male	12.8	12.8	1.0	10.9	15.0	256
spring	adult	female	12.8	12.7	0.9	10.7	14.9	166
autumn	adult	male	12.8	12.8	0.9	10.9	15.6	116
autumn	adult	female	12.5	12.5	0.9	10.3	15.0	188
autumn	juvenile	male	12.6	12.5	1.0	10.0	18.6	943
autumn	juvenile	female	12.4	12.3	0.9	10.3	17.7	630

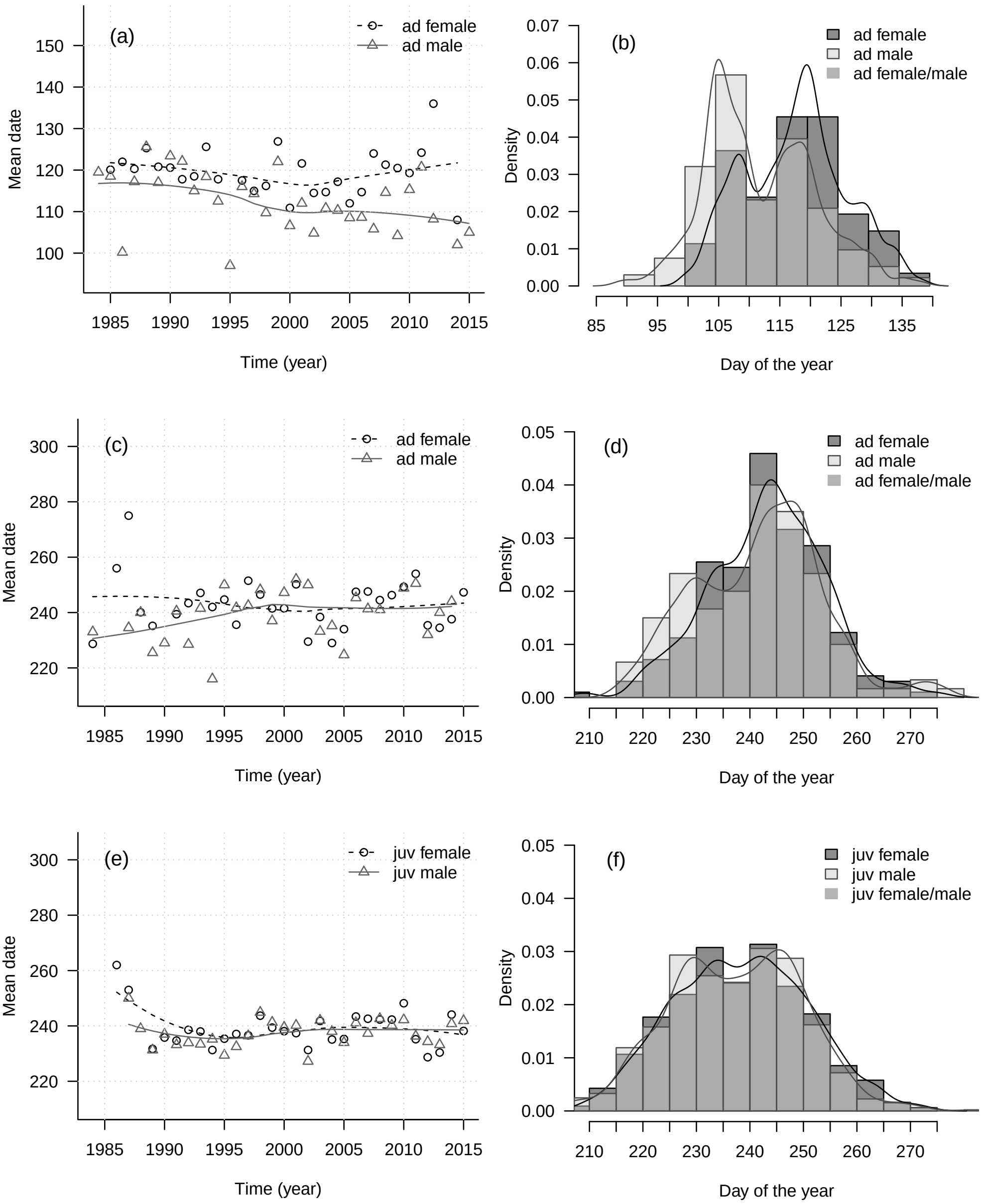

Figure 4. Annual mean migration timing (day of the year) throughout the study period and histograms/smoothed histograms of timing in spring (a–b) and in autumn (c–f)

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)

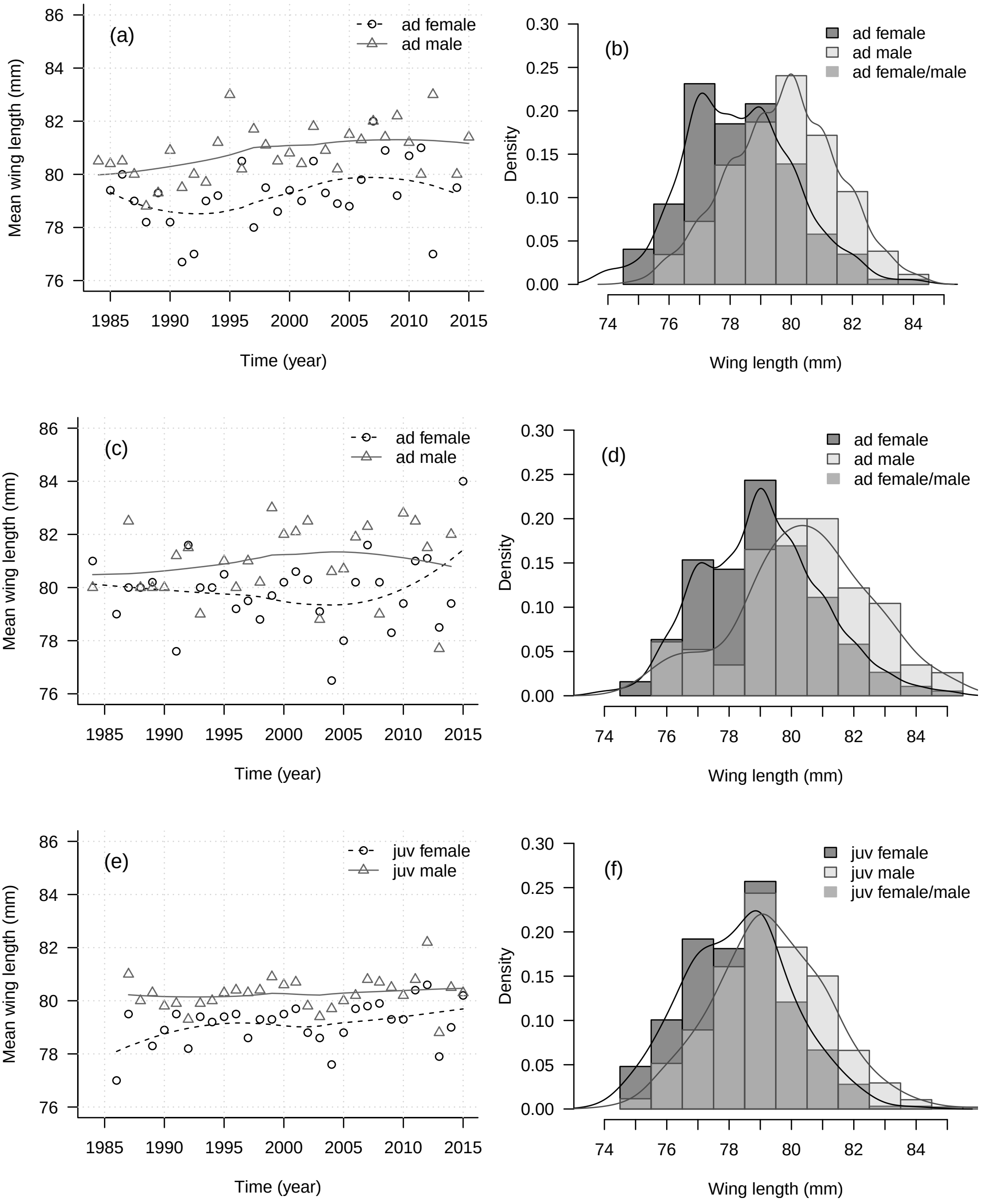

Figure 5. Annual mean wing length (mm) throughout the study period and histograms/smoothed histograms of wing length in spring (a–b) and in autumn (c–f)

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

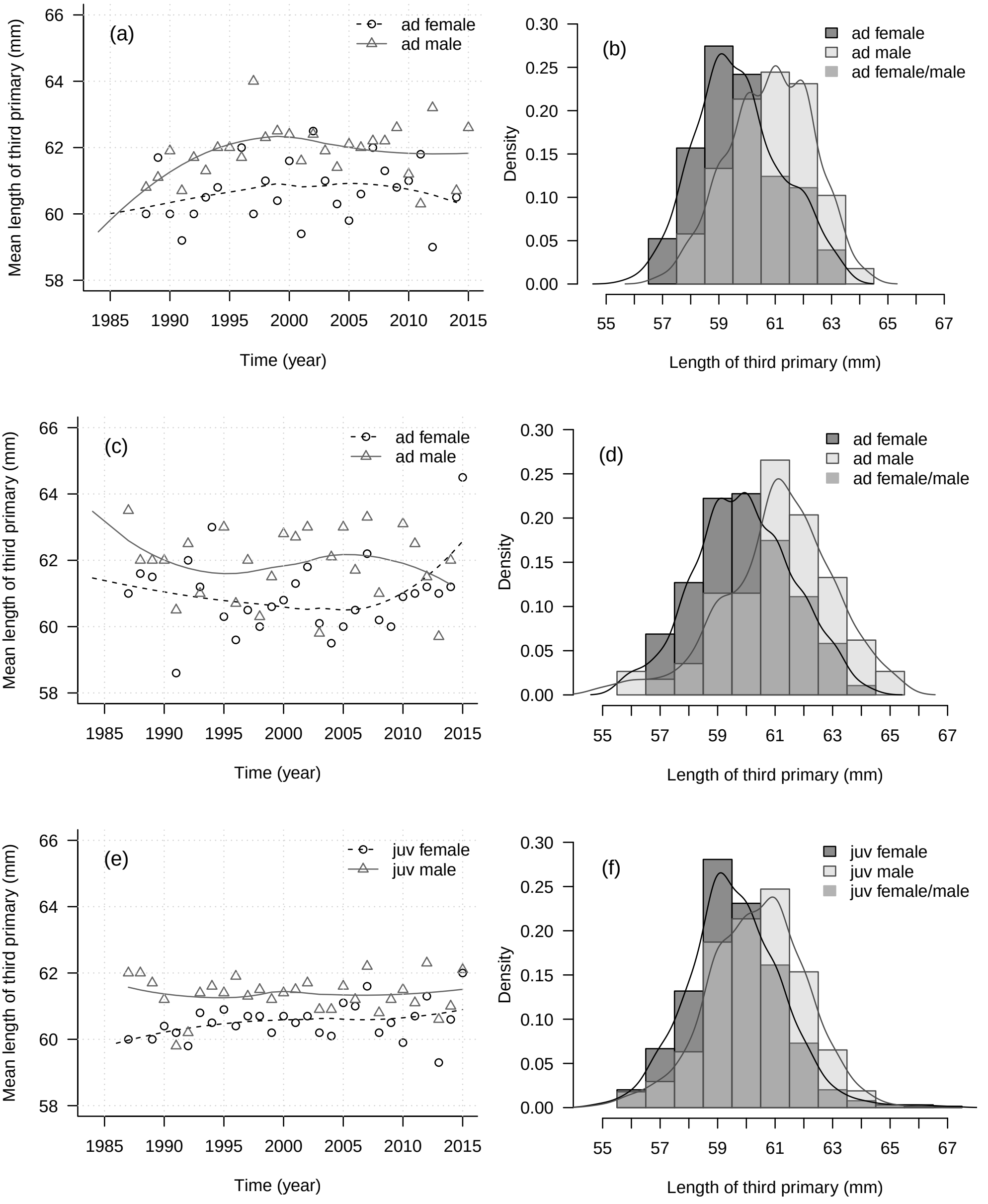

Figure 6. Annual mean third primary length (mm) throughout the study period and histograms/smoothed histograms of third primary length in spring (a–b) and in autumn (c–f)

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)

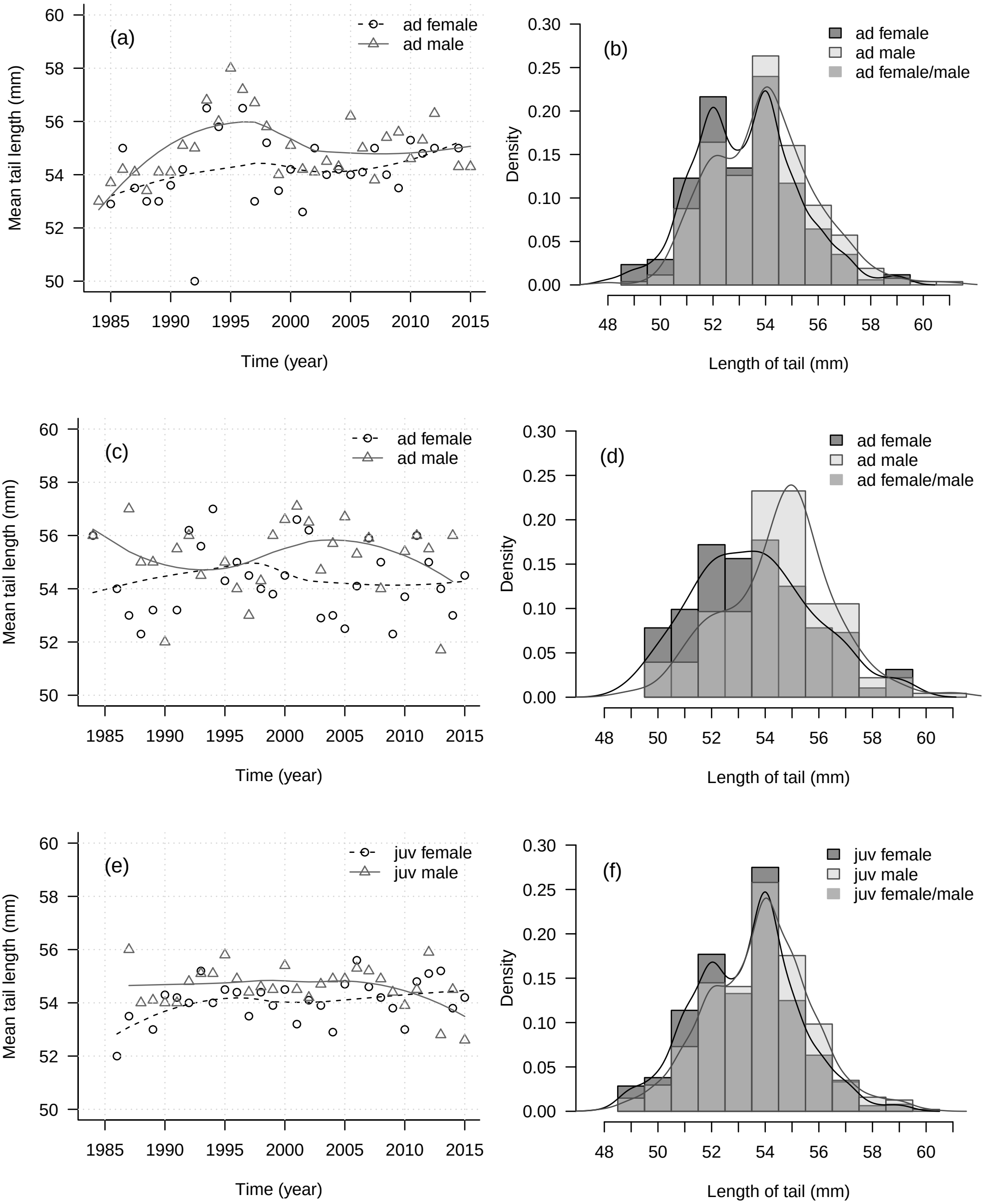

Figure 7. Annual mean tail length (mm) throughout the study period and histograms/smoothed histograms of third primary length in spring (a–b) and in autumn (c–f)

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

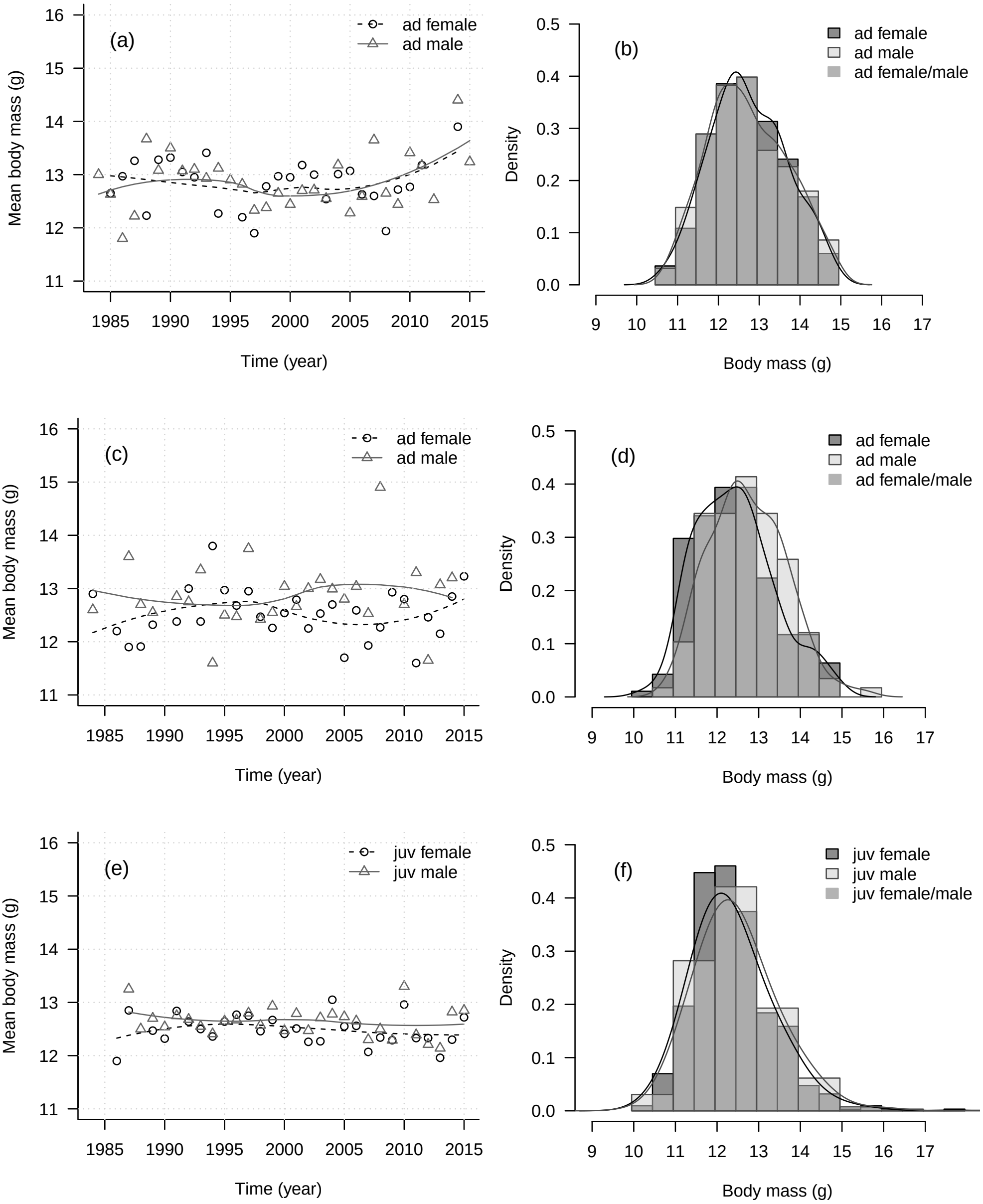

Figure 8. Annual mean body mass (g) throughout the study period and histograms/smoothed histograms of body mass in spring (a–b) and in autumn (c–f)

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

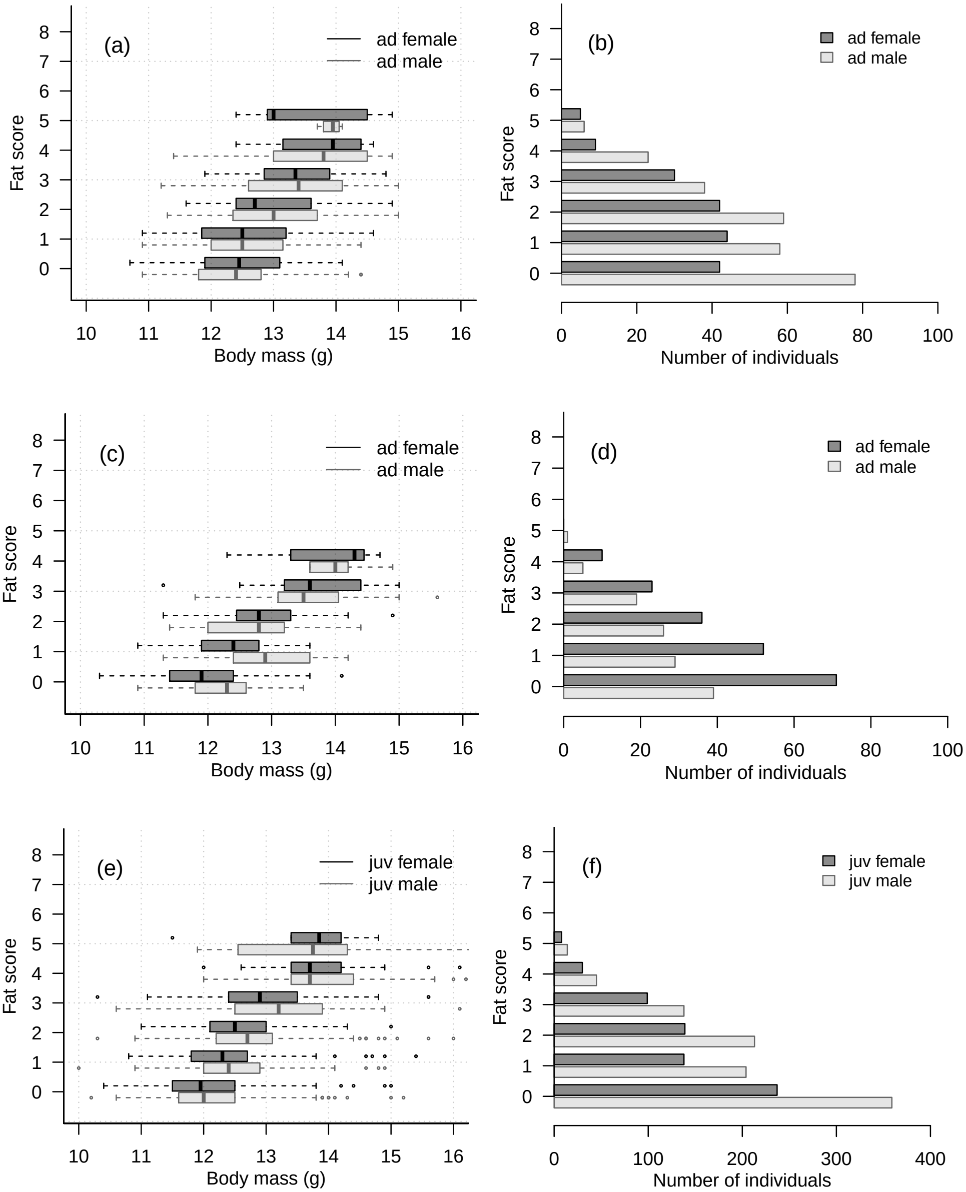

Figure 9. Boxplots of body mass according to fat score, and fat score frequencies in spring (a–b) and in autumn (c–f)

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

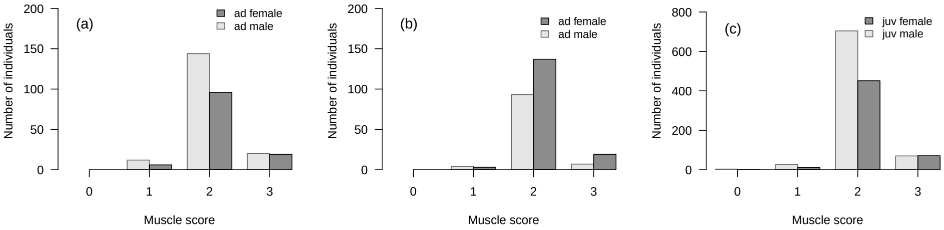

Figure 10. Muscle score frequencies in spring (a) and in autumn (b–c)
10. ábra Izom kategória gyakoriságok tavasszal (a) és ősszel (b–c)

Discussion

The exploratory analyses of timing and morphometrics of the Pied Flycatcher revealed several patterns of interest. Apparently, there is considerable variation in inter-annual capture and recapture frequencies *(Figure 2 a,b)* with disproportionally more recaptures *(Figure 2 a,b)* and longer stopover duration *(Figure 3 b,d,f,h, Table 2)* in autumn. Evidently, the lack of captures of all age groups during the breeding season corroborates that there is no local breeding population at the study site *(Figure 2 a,c)*. We have previously shown biased sex ratios within migration waves (Harnos *et al.* 2015b) that are clearly visible from the descriptive statistics *(Table 1)* and from the fat and muscle score distributions *(Figures 9–10)*.

Migration timing in spring shows indications of increased protandry (Harnos *et al.* 2015c) and that the distribution of arrival timing in spring of both sexes is seemingly bimodal *(Figure 4 b)*. On the other hand, this pattern is not characteristic of the autumn migration timing. In general, wing-, third primary and tail length descriptive statistics *(Tables 3–5)* show that males have larger mean and median values, which is more apparent when viewing the distributions of these variables *(Figures 5–7 b,d)*. However, sex-specific differences in histogram shapes seem to decrease in case of juveniles *(Figures 5–7 f)*. Contrastingly, body mass descriptive statistics and distributions show hardly any sex-specific differences across age groups and seasons *(Table 6, Figure 8 b,d,f)*.

Our results show that comprehensive exploratory analyses may reveal intriguing patterns, which may be investigated in more detail in the future. We however 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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DE GRUYTER OPEN

Exploratory analyses of migration timing and morphometrics of the Dunnock *(Prunella modularis)*

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Abstract Ornithological studies often rely on large temporal scale ringing datasets as source of information. However, basic descriptive statistics of collected data are rarely provided. In order to fill this gap, here we present the second 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 (1984–2015). First, we give a concise description of foreign ring recoveries of the Dunnock in relation to Hungary. We then shift focus to data of 11,617 individuals deriving 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 we present the cumulative distribution 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 distribution of individual fat and muscle scores, and the distribution of body mass within each fat score category. We distinguish migration periods (spring and autumn), 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 draw attention to interesting patterns, that may be worth exploring in detail. Data used here are available upon request for further analyses.

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

Összefoglalás Madártani tanulmányokban gyakran elemeznek hosszútávú madárgyűrűzési adatsorokat, de az alapvető leíró statisztikák és exploratív elemzések általában nem hozzáférhetőek. E hiányt pótolandó, cikksorozatot indítunk, melyben egy közép-magyarországi gyűrűző állomáson leggyakrabban előforduló énekesmadár fajok vonulás időzítésének és testméreteinek exploratív elemzéseit közöljük (1984–2015). A sorozat második tagjaként szolgáló jelen cikkben először áttekintjük az erdei szürkebegy magyar gyűrűs külföldi és külföldi gyűrűs magyarországi megkerüléseit, majd rátérünk a faj egy magyarországi, 1984 óta standard módszerekkel dolgozó gyűrűzőállomásról származó 11 617 egyedétől származó adatának elemzésére. Az időzítés jellemzéséhez az éves és a napi átlagos első megfogások és visszafogások leíró statisztikái mellett megmutatjuk 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. Ábrákon bemutatjuk ezen változók éves átlagait, a zsír- és izomkategóriák gyakorisági eloszlását, valamint a testtömegek eloszlását zsírkategóriák szerinti bontásban. Az elemzésben elkülönítjük az egyes vonulási időszakokat (tavasz, ősz) 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 volume of data has been collected 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 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 for future studies. For this purpose, it is essential that descriptive studies must apply the most appropriate statistical methodologies (Harnos *et al.* 2015, 2016). The bulk of currently available ringing data is often derived from large temporal scale projects like permanent ringing stations, where massive amount of individuals of various species are trapped simultaneously (Csörgő *et al.* 2016). These projects generally apply standardized and similar 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).

Here we present exploratory and descriptive statistics on the migration timing and morphometrics of the Dunnock between 1984–2015 from a Central European ringing station (Ócsa Bird Ringing Station, Hungary, see Csörgő *et al.* 2016 for details).

The Dunnock is a small, sexually monomorphic omnivorous passerine of the Prunellidae family. The plumage on the chest and on the head is mostly blueish-gray. The back, and the sides of the breasts are brown with dark streaks, although individuals can differ a lot in their looks. The juveniles are similar in appearance, but the gray parts are paler while the striations are more dominant (Cramp 1988, Svensson 1992, Demongin 2016).

The Dunnock is polytipical, with 8 descriped subspecies, namely *P. m. modularis, P. m. hebridium, P. m. occidentalis, P. m. mabbotti, P. m. meinertzhageni, P. m. fuscata, P. m. euxina, P. m. obscura*. The subspecies are quite similar in their appearance, making the identification of a single individual almost impossible. Wing morphology slightly differs among the subspecies, migratory ones tend to have longer, skewer, more pointed wings compared to the residents' shorter, rounded wings (Cramp 1988, Svensson 1992, Demongin 2016).

It's breeding distribution ranges across mainly in the temperate and marginally in the subarctic and boreal zones of the Palearctic Region (Cramp 1988). The nominate subspecies occupies the majority of the breeding range. *P. m. hebridium* breeds in the Inner, Outer Hebrids and Orkney, *P. m. occidentalis* in the British Isles, *P. m. mabotti* in the Iberian Peninsula, in South France and in South Italy. *P. m. meinertzhageni* can be found in the Balkans, *P. m. fuscata* in the Crimean Peninsula, *P. m. euxina* in the north-western parts of the Anatolian Peninsula, while *P. m. obscura* breeds in the Eastern-Anatolian Peninsula, besides Northern-Iran, Caucasus and the Crimean Peninsula. The breeding range of the *P. m. modularis* is apparently expanding north in Fennoscandia, presumably due to modern forestry practices (Vogel & Tuomenpuro 1997, Fransson & Hall-Karlsson 2008). The species was also introduced to New Zealand (Cramp 1988, Hatchwell 2005).

The Dunnock is classified as Least Concern in the IUCN Red List, however the European population is moderately decreasing (BirdLife International 2016).

In Hungary, the first record of the nominate subspecies was recorded in 1934 (Studinka 1931–34 in Magyar *et al.* 1998, Hadarics & Zalai 2008), but it is known as regular breeder only since the early 1960's (Rapos 1962, Szabó 1962 in Magyar *et al.* 1998, Hadarics & Zalai 2008). Today the Hungarian population shows a moderate decrease and is estimated to 1200–1500 pairs. The species is protected in Hungary (BirdLife Hungary 2016).

Breeding habitats of Dunnock is deciduous and coniferous woods with dense undergrowth (Cramp 1988). Their mating system is complex, both monogamy and various forms of poligamy (poliandry, poligyny, poligynandry) may occur (Davies & Lundberg 1984, Davies 1985, 1986, Davies & Houston 1986, Hatchwell & Davies 1990, 1992, Santos & Nakagawa 2013).

Various migratory strategies can be found among the subspecies (resident, altitudinal migrant, partial or obligatory migrant). The *P. m. hebridium* and the *P. m. mabotti* are residents. The *P. m. occidentalis* makes short, dispersive movements, although a few indviduals originated from the British Isles were found in Northern France, Belgium, the Netherlands, Denmark, Germany and Norway (Hartly 2002). The *P. m. euxina* and the *P. m. obscura* are residents or partial migrants. The nominate subspecies is an obligatory migrant in the northern parts of its breeding area, and partial migrant in the south (Cramp 1988). The speed of the migration is relatively slow (34.5 km/day on average; Fransson & Hall-Karlsson 2008), they take small steps, mostly at dawn (Dorka 1966 in: Bingman & Wiltschko 1988). Although the species migrates on a broad front, individual populations use narrow, defined routes (Zaniewicz & Busse 2008). The general bearing of the autumn migration is south-west across the whole breeding range. North-eastern populations (Finland, Valkama *et al.* 2014) are the first to depart in mid-September, while the north-western birds take off in late September, early October (Bønløkke *et al.* 2006, Fransson & Hall-Karlsson 2008). These populations migrate through the Baltic Sea (Sokolov *et al.* 1999, Zaniewicz & Busse 2008). Arriving to the wintering grounds takes place between September and November depending on the location of the breeding and wintering sites (Schubert *et al.* 1986, Pons 2001, Spina & Volponi 2009).

Migrating populations overwinter mostly in southern Europe (Malczewski & Pukinsky 1983, Cramp 1988, Fransson & Hall-Karlsson 2008, Spina & Volponi 2009, Barišić 2013, Valkama *et al.* 2014), a few recaptures were reported from Morocco and Algeria (Bairlein *et al.* 2014). Qualitative overview of the recapture patterns of Dunnocks from Russia (Malczewski & Pukinsky 1983), Finland (Valkama *et al.* 2014), Sweden (Fransson & Hall-Karlsson 2008), Denmark (Bønløkke *et al.* 2006), Germany (Bairlein *et al.* 2014), Czech Republic (Hromádko 2008), Croatia (Barišić 2013), Italy (Spina & Volponi 2009) revealed, that there is strong migratory connectivity of breeding populations. The breeding range of the Swedish birds ranges from Denmark to North Spain. Their recovery patterns further indicates that in the last decades the wintering range gradually shifted north for this population (Fransson & Hall-Karlsson 2008). Individual inter-annual wintering site fidelity is high, especially in the southern regions (Benvenuti & Ioalè 1980, Ioale & Benvenuti 1983, Schwabl *et al.* 1991, Pons 2001, Spina & Volponi 2009, Barišić 2013). In winter, Dunnocks hold feeding territories (Birkhead 1981) and they have high within and between season site fidelity in winter (Pons 2001, Spina & Volponi 2009).

In Hungary, the ratio of overwintering and passage migrant Dunnocks vary considerably between years. Csörgő *et al.* (2001) showed that the migration was unimodal in autumn at the study site. The majority of migrant birds arrived during the first half of the migratory period and their stopover duration was short. Later arriving birds spent the whole winter in Ócsa in some years while not in others depending on the weather of previous year. In mild winters, birds remaining in the Carpathian Basin instead of migrating further south-west, may have selective advantage, since they could reach the breeding area earlier and could occupy better territories resulting higher numbers on the next winter. On the other hand, after cold winters, due to the high mortality of birds remaining in the Carpathian basin, the passage migrants had advantage. Costs and benefits of the two strategies change year by year as the winter weather condition fluctuate resulting in the coexistence of two alternative strategies.

In spring, Dunnocks presumably use the same routes as in autumn with no indication for loop migration. (Cramp 1988, Bairlein *et al.* 2014). The migration timing of Swedish Dunnocks shifted earlier (Fransson & Hall-Karlsson 2008).

In Hungary, it is a common passage migrant from March to April in spring and from late September until early November in autumn (Hadarics & Zalai 2008, Csörgő & Kováts 2009). Dunnocks in Hungary may overwinter.

The Dunnocks are regular and common passage migrants 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 mosaic of habitats that include 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 located in 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 separately was 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 before the 120th day of the year were considered to be spring migrants. A total of 11,617 Dunnocks were captured and ringed between March and November; 3144 in spring and 1734 adult and 6102 juvenile in autumn (the age of the rest of birds was not defined) in the study period of 1984–2015. This total value constitutes ca. 36% of the 31,900 Dunnocks 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), which is highly effective in calculating summary statistics for different groups and subsets. 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 overplotted smooth histograms. Boxplots were used to show the body mass distribution by fat score categories. Fat and muscle score frequencies are shown using barplots. We distinguished seasons, and age groups

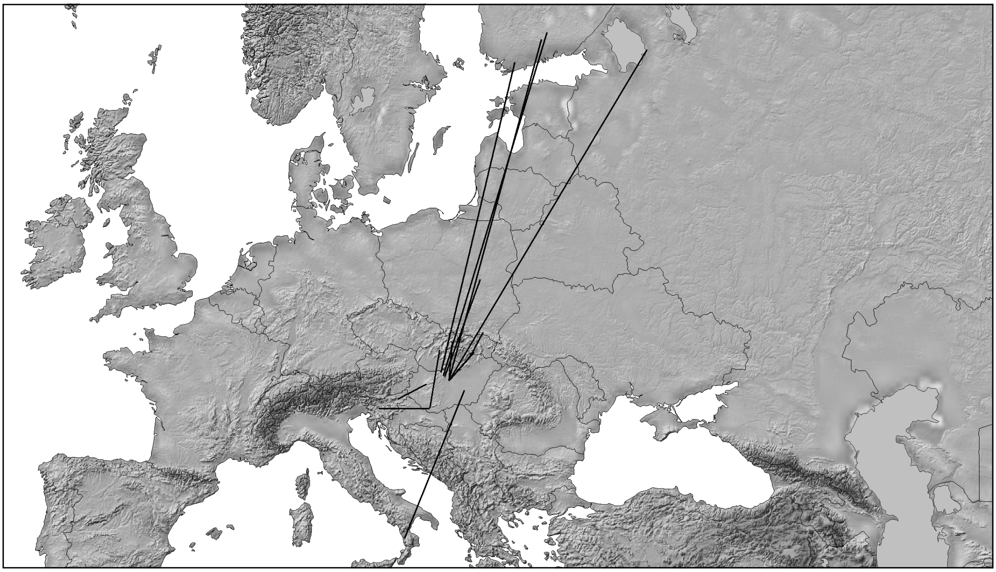

Figure 1. Foreign ring recoveries of Dunnocks. The data of birds ringed in Hungary and recovered abroad and the birds ringed abroad and recovered in Hungary are depicted

1. ábra Magyarországon jelölt és külföldön megkerült, illetve külföldön jelölt és Magyarországon megfogott erdei szürkebegyek

throughout the analyses. For more details on the analysis, please visit ocsabirdringing.org. All analyses were done in R 3.2.2 (R Core Team 2015).

Results

A total of 14 foreign recaptures were recorded between 1951 and 2016 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 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*.

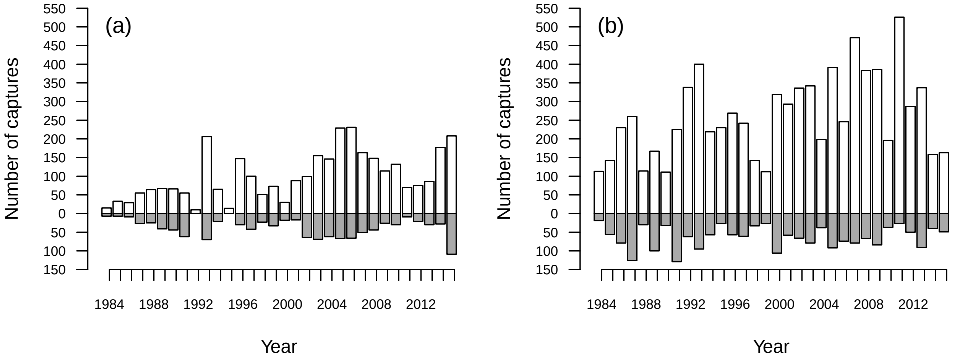

Figure 2. Annual capture (white bars) and recapture (grey bars) frequencies in spring (a), and in autumn (b)

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

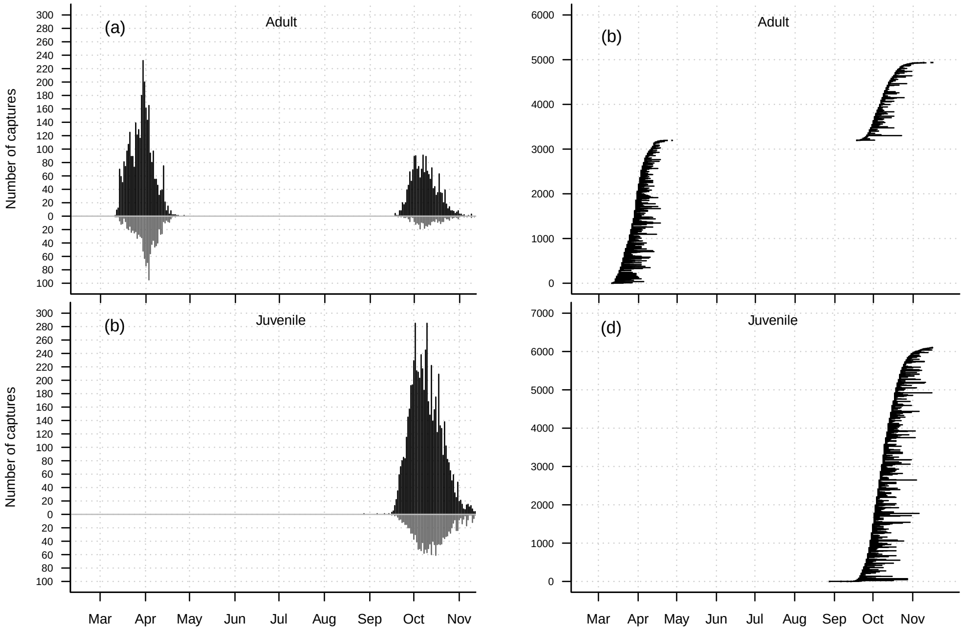

Figure 3. Within-year capture (black bars) and recapture (grey bars) frequencies (a, c) and cumulative distributions of individual first capture dates (b, d) according to age groups (horizontal lines: stopover durations)

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 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	87.9	88	7.8	70	117	3144
autumn	adult	281.1	280	8.8	261	320	1734
autumn	juvenile	282.4	282	10.6	240	320	6102

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	5.2	4	4.4	1	23	682
autumn	adult	4.9	3	4.6	1	30	252
autumn	juvenile	5.6	4	5.4	1	39	891

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	68.7	69	2.1	61	76	3033
autumn	adult	69.3	69	2.0	62	76	1699
autumn	juvenile	68.4	68	1.9	62	75	5974

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	52.1	52	1.8	45	59	2883
autumn	adult	52.4	52	1.8	47	59	1628
autumn	juvenile	51.6	52	1.7	45	59	5534

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	58.5	58	2.7	50	70	2975
autumn	adult	59.7	60	2.7	51	69	1689
autumn	juvenile	58.5	58	2.7	50	70	5885

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	18.9	18.8	1.6	14.5	26.1	3077
autumn	adult	19.1	19.0	1.6	15.3	25.1	1709
autumn	juvenile	19.2	19.0	1.7	14.6	27.0	6001

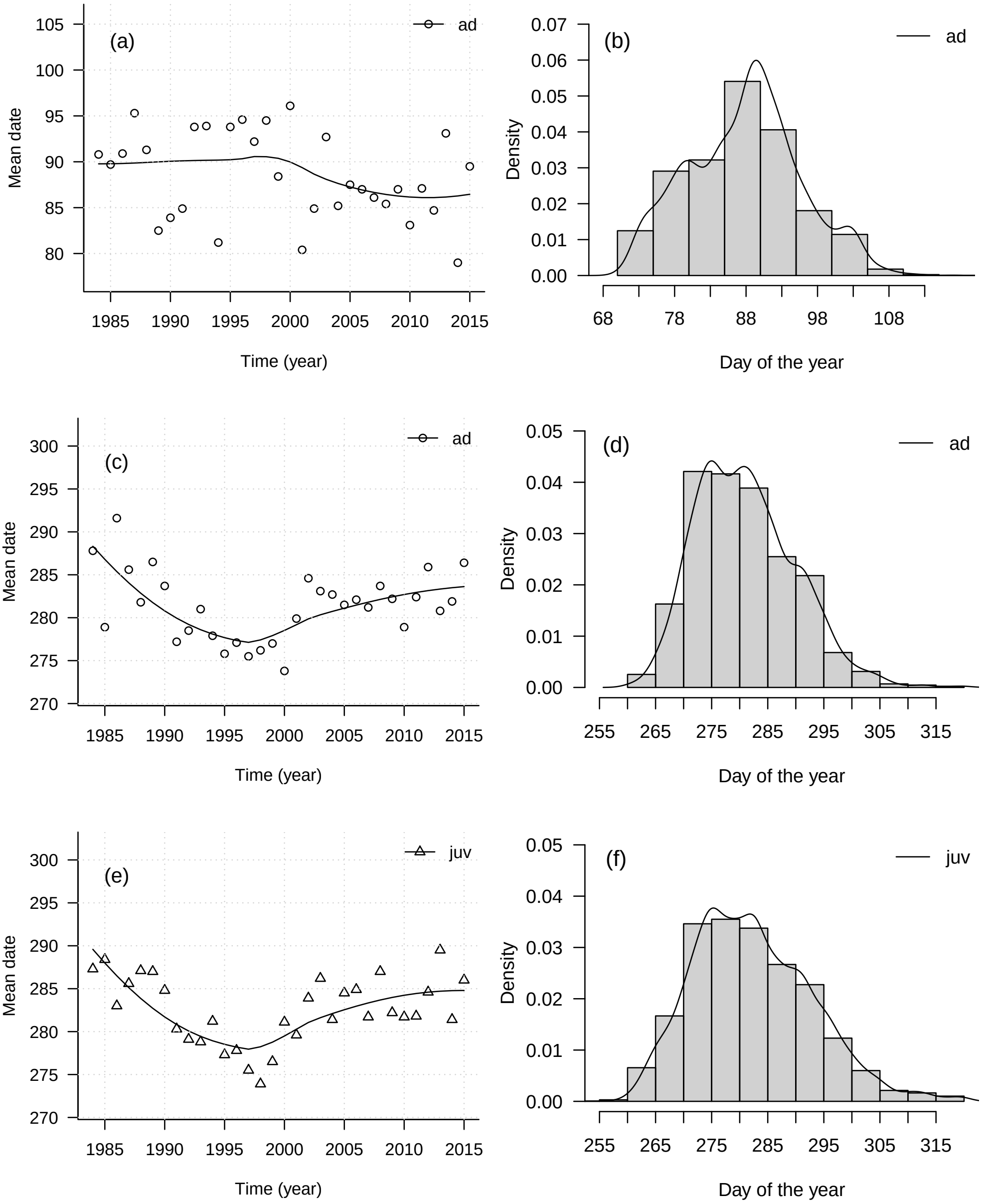

Figure 4. Annual mean migration timing (day of the year) throughout the study period and histograms/smoothed histograms of timing in spring (a–b) and in autumn (c–f)

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)

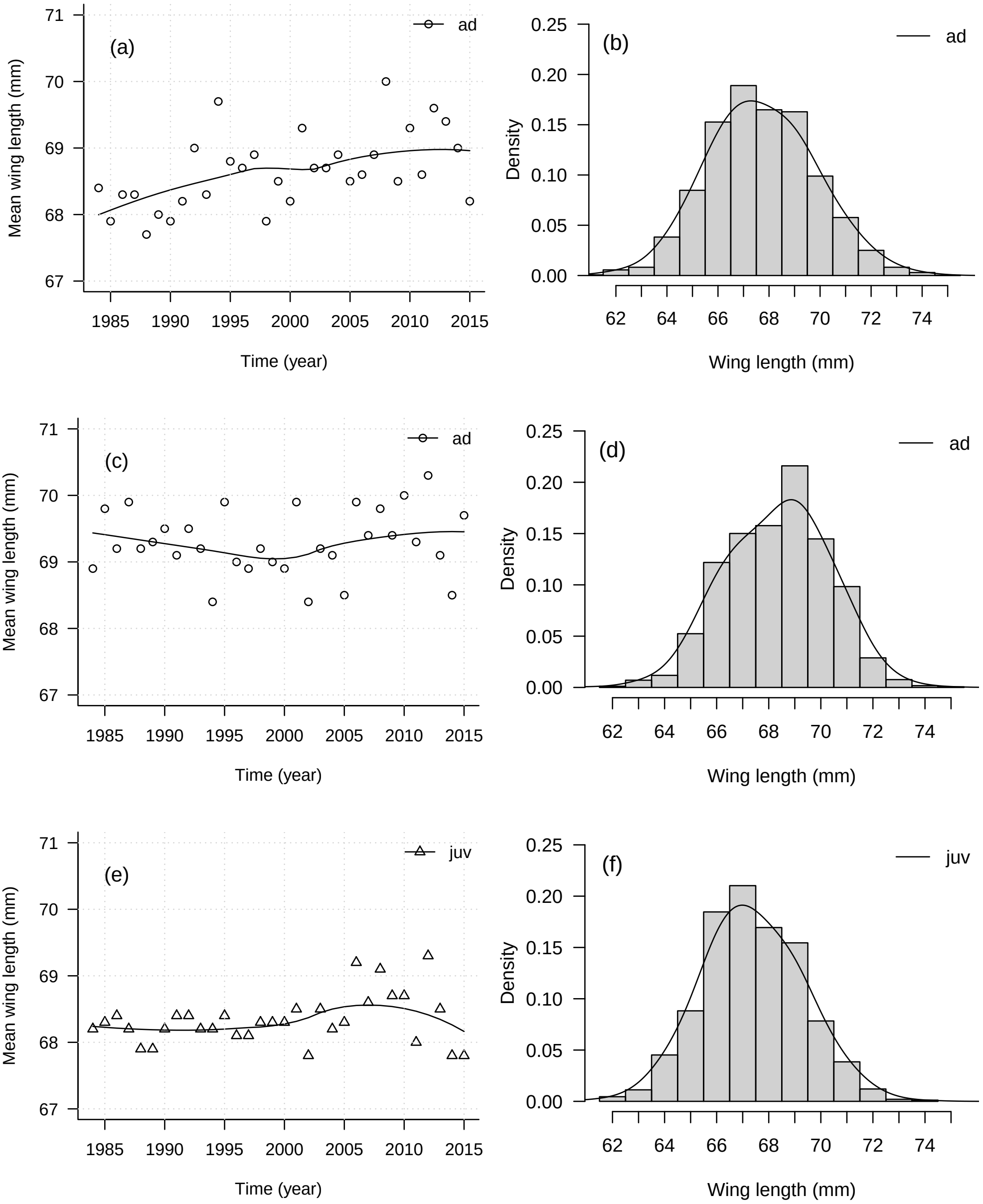

Figure 5. Annual mean wing length (mm) throughout the study period and histograms/smoothed histograms of wing length in spring (a–b) and in autumn (c–f)

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

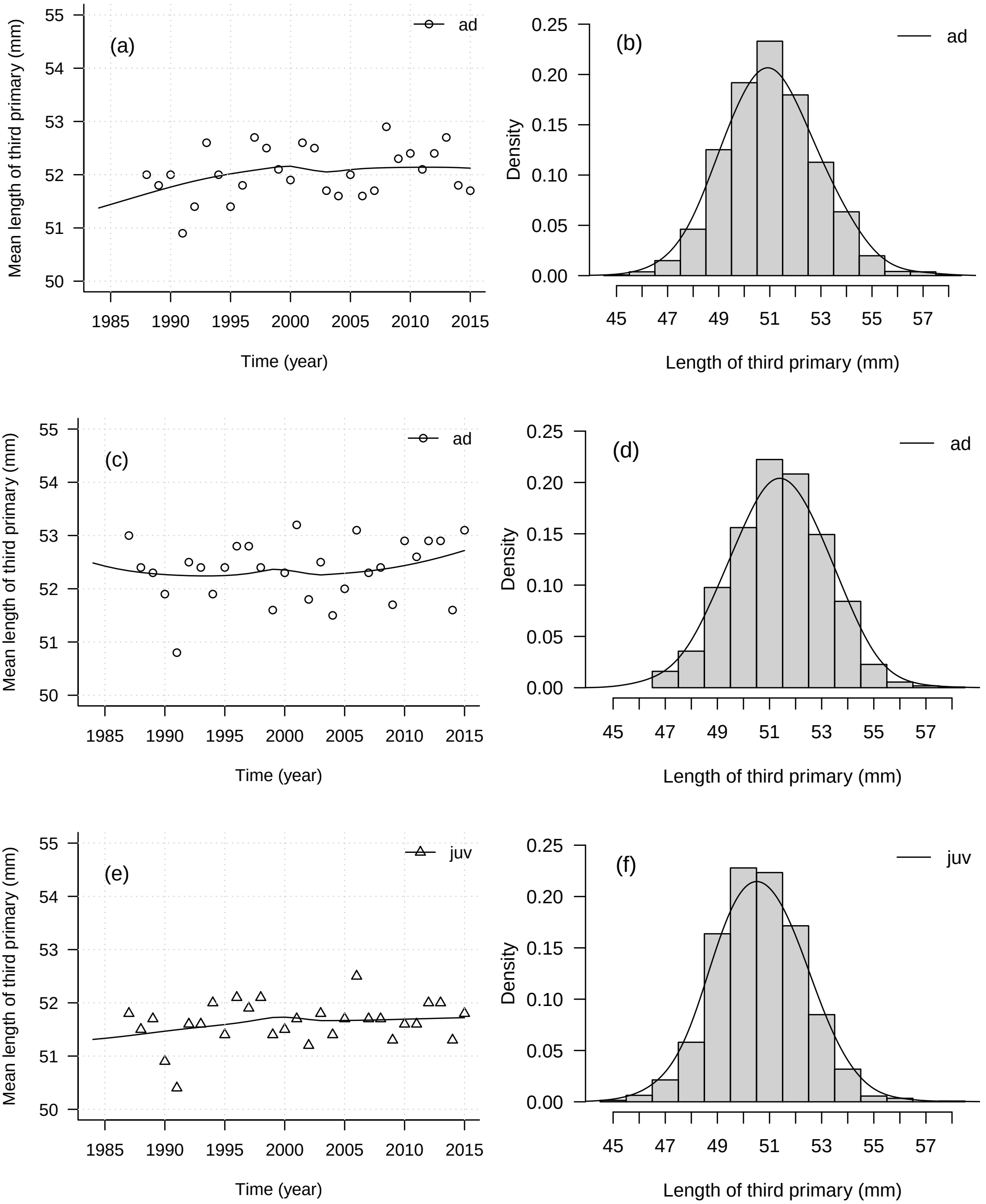

Figure 6. Annual mean third primary length (mm) throughout the study period and histograms/smoothed histograms of third primary length in spring (a–b) and in autumn (c–f)

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)

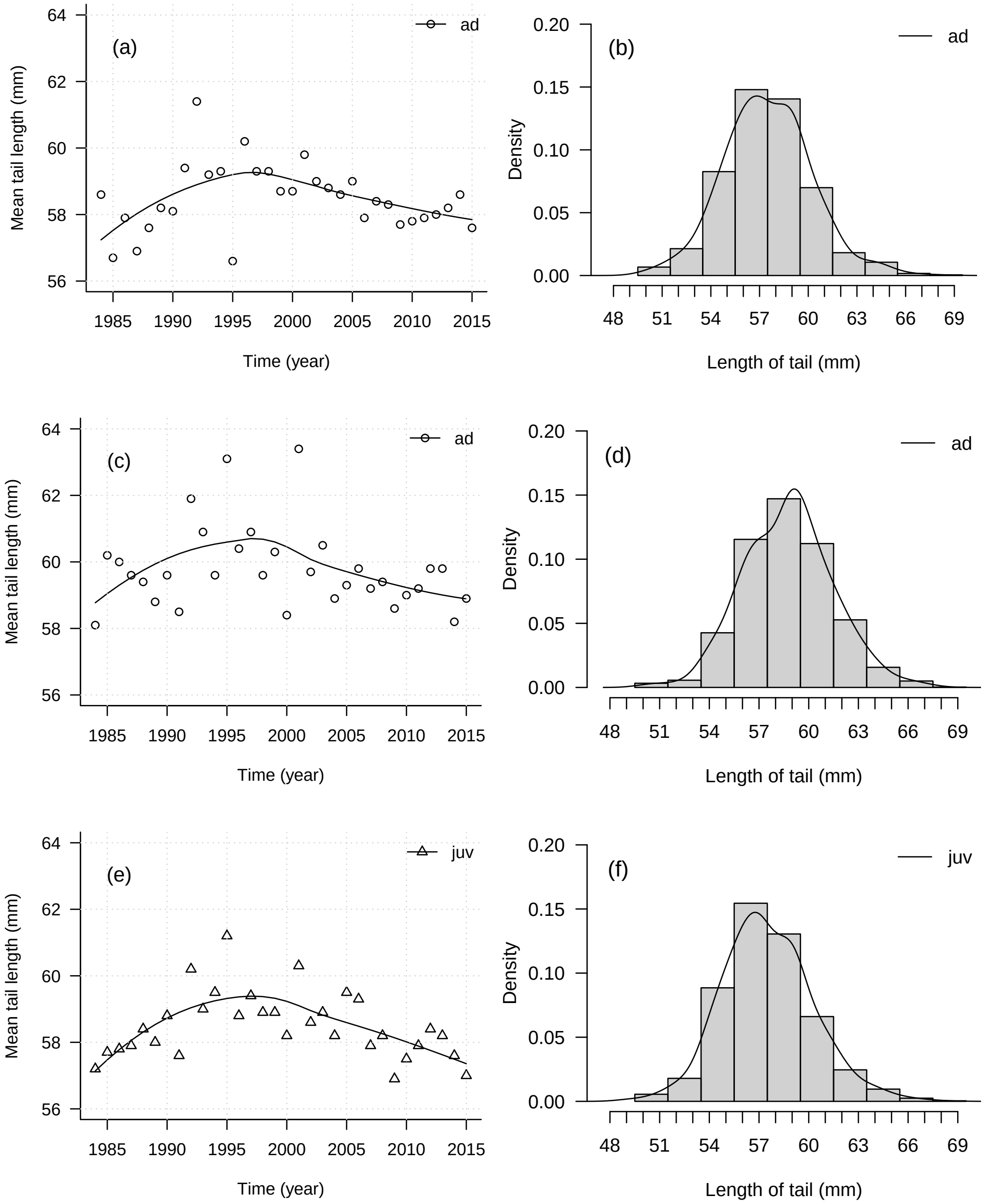

Figure 7. Annual mean tail length (mm) throughout the study period and histograms/smoothed histograms of third primary length in spring (a–b) and in autumn (c–f)

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

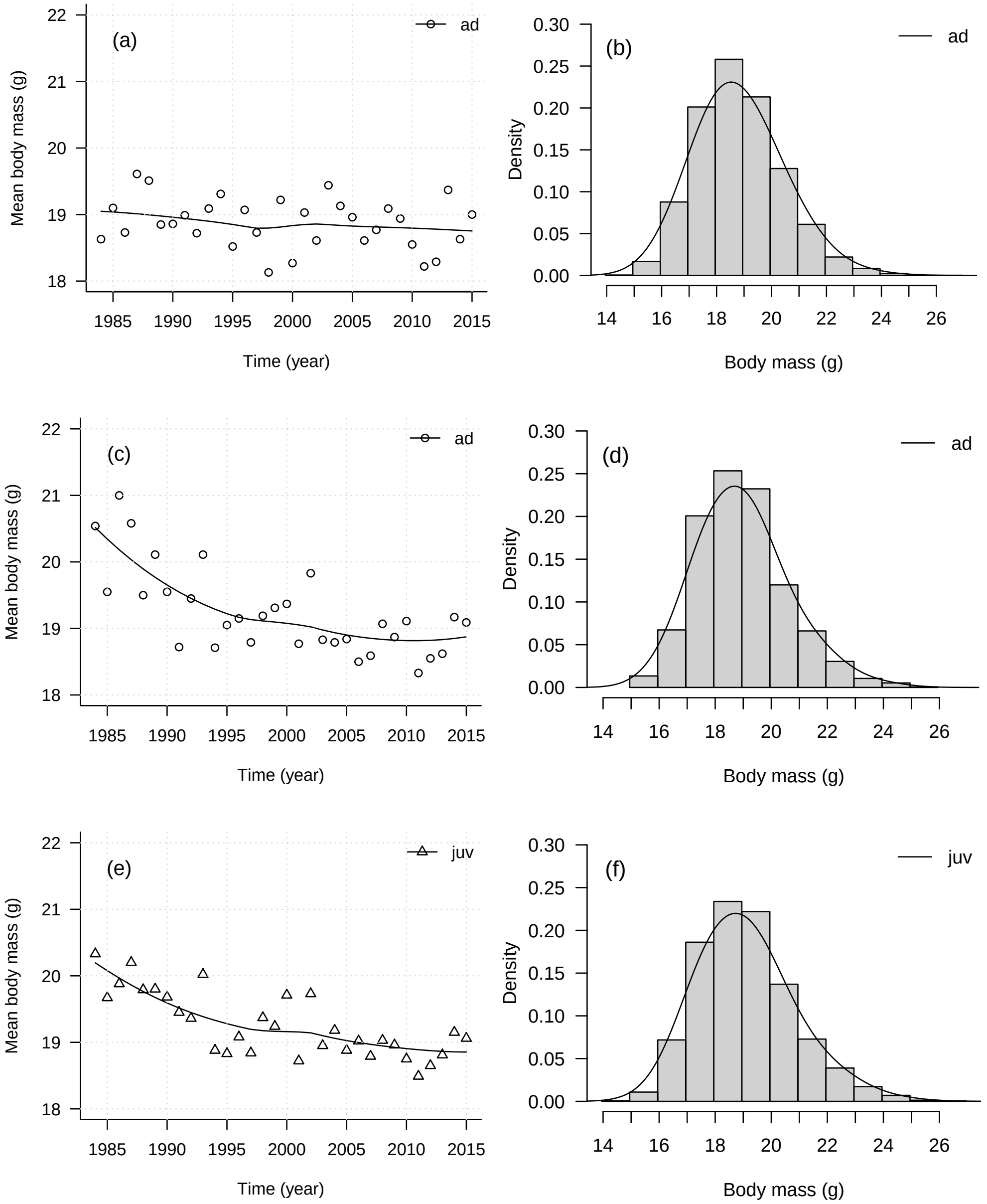

Figure 8. Annual mean body mass (g) throughout the study period and histograms/smoothed histograms of body mass in spring (a–b) and in autumn (c–f)

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

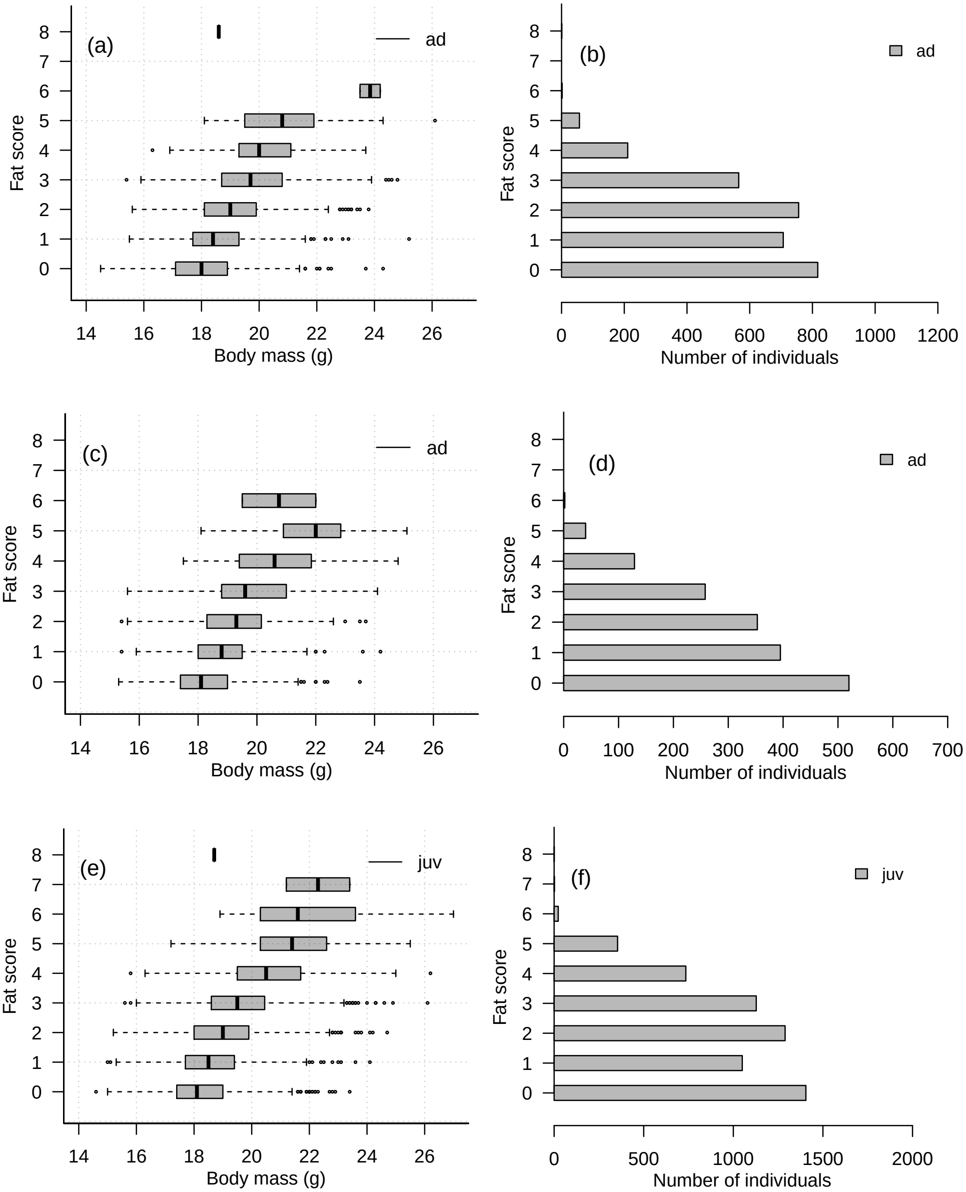

Figure 9. Boxplots of body mass according to fat score, and fat score frequencies in spring (a–b) and in autumn (c–f)

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

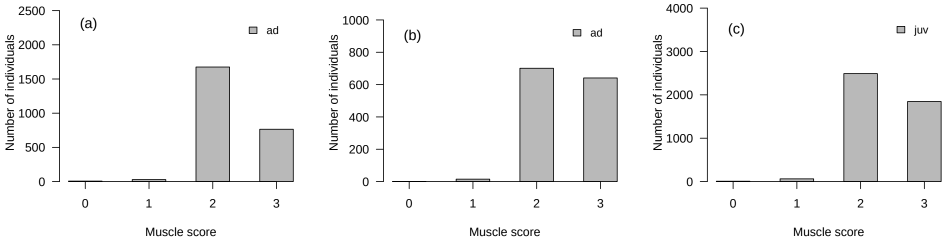

Figure 10. Muscle score frequencies in spring (a) and in autumn (b–c)
10. ábra Izom kategória gyakoriságok tavasszal (a) és ősszel (b–c)

Discussion

The exploratory analyses of timing and morphometrics of the Dunnock revealed several patterns of interest. Apparently, there is considerable variation in inter-annual capture and recapture frequencies *(Figure 2 a,b)* with disproportionally more recaptures *(Figure 2 a)* in spring. The stopover durations are similar in all cases *(Figure 3 b,d, Table 2).*

The birds appear in greater numbers during the autumn migration, when the amount of juveniles greatly exceeds the amount of the adults. Evidently, the lack of captures of all age groups during the breeding season corroborates that there is no local breeding population at the study site *(Figure 2 a,b).*

While the spring migration timing appears to be more or less constant (with a slight decrease in the last decade *(Figure 4 a)*, the autumn timing hits a bottom in the late 1990's. Timing of the adults and the juveniles in the autumn are rather similar *(Figure 4 c,e).* The distribution of arrival timing in both seasons are seemingly unimodal *(Figure 4 b,d,f).* There is no apparent, relevant trends over the years neither in the wing length nor in the third primary length of the birds *(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 seems to be constant over the years *(Figure 8 a)*, however a decreasing trend can be observed during the autumn season *(Figure 8 c,d).*

All the biometric variables have unimodal distribution indicating that there is no considerable size difference between the sexes *(Figure 5–8 a,c,e).*

The fat and muscle score distributions suggest that the birds build their muscles rather than accumulate fat reserves *(Figures 9–10).*

Our results show that comprehensive exploratory analyses may reveal intriguing patterns, which may be investigated in more detail in the future. We however 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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