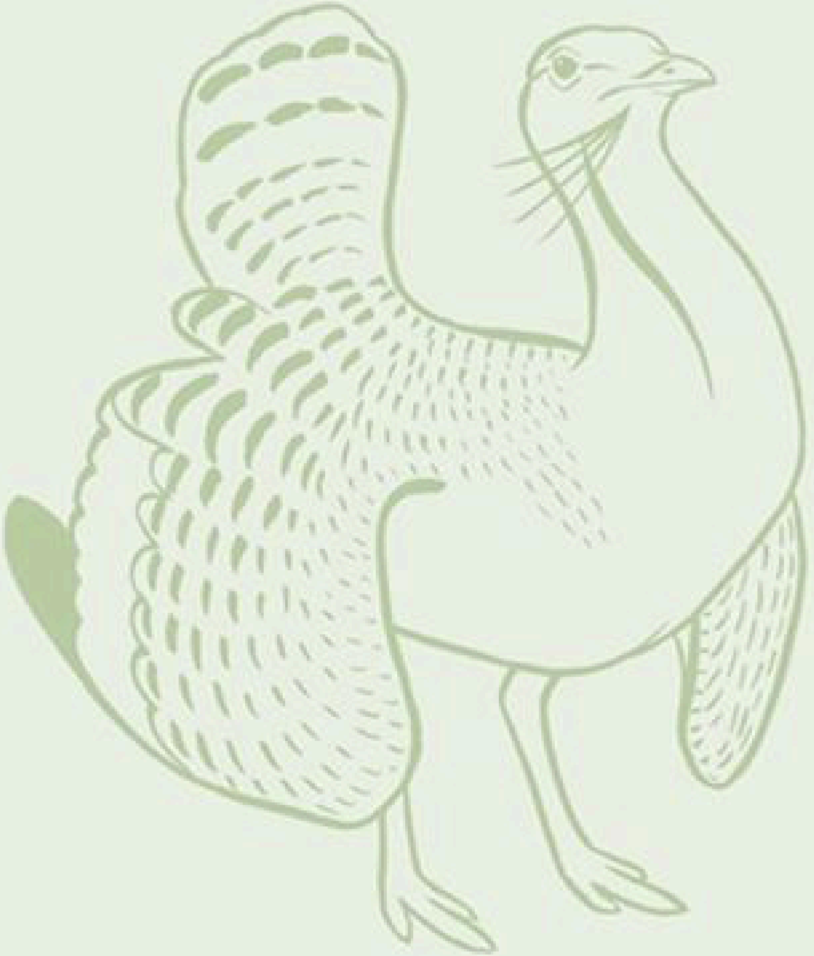
ORNIS HUNGARICA

ISSN 1215-1610



JOURNAL OF THE BIRDLIFE HUNGARY

Ornis Hungarica 2015. 23(2): 1–9.
DOI: 10.1515/orhu-2015-0009

The status of the Hoopoe *(Upupa epops)* in Hungary: a review

Gergő Halmos[1*], Károly Nagy[1], Zsolt Karcza[1] & Tibor Szép[2]

Gergő Halmos, Károly Nagy, Zsolt Karcza & Tibor Szép 2015. The status of the Hoopoe *(Upupa epops)* in Hungary: a review. – Ornis Hungarica 23(2): 1–9.

Abstract The Hoopoe is a widespread species in Hungary with the strongest populations on the Great plains. The fact that in 2015 it became 'The Bird of the Year' in Hungary offers the possibility to summarise the information about the distribution, population size, dispersion, migration as well as the nature conservation status of the Hoopoe population breeding in Hungary. In the period of 1999–2014 the number of breeding pairs and trend of population level was estimated based on the Common Bird Census database. The population size was estimated as 13,500–17,500 pairs with a stable trend (slope=-1.3%, SE=2.5%) over 1999–2014. There is very limited information on migration from bird ringing, only 8 recoveries between 1928–1963 indicate, that the Hungarian population is migrating on a south-southeast direction in autumn, wintering in the eastern parts of the Sahel, possibly in Chad and Sudan and migrates back in spring following a loop migration pattern further to the east. The main conservation issues are agricultural intensification impacting feeding possibilities, lack of nesting cavities and hunting during migration.

Keywords: *Upupa epops*, Hungary, breeding population, migration, conservation

Összefoglalás A búbosbanka általánosan elterjedt faj Magyarországon. Legjelentősebb állományai az Alföldön találhatóak. Az a tény, hogy a faj 2015-ben az „Év Madara" lett, lehetőséget ad, hogy összegezzük ismereteinket a faj magyarországi elterjedéséről, állományáról, diszperziójáról, vonulásáról és védelmi helyzetéről. A költőállományt és annak változását a Mindennapi Madaraink Monitoringja (MMM) program 1999–2014 évi adatai alapján becsültük. A hazai állománynagyságra adott becslés 13 500–17 500 pár, és trendje stabil (meredekség=-1,3%, SE=2,5%). A faj vonulásáról nagyon keveset tudunk a madárgyűrűzési adatok alapján. Csak 8 megkerülési adat származik az 1928–1963 közötti időszakból, amelyek azt mutatják, hogy az őszi vonulási irány dél-délnyugati, a telelési terület a Száhel-övezet keleti részében, Csád és Szudán területén valószínűsíthető, és tavasszal a máshol is megfigyelt hurokvonulási mintázat alapján a madarak keletebbre vonulhatnak. A fő természetvédelmi tényezők a mezőgazdaság intenzifikálódása – amely a táplálkozási lehetőségekre gyakorol hatást –, a költőüregek hiánya, és a vonulási útvonalon tapasztalható vadászati nyomás.

Kulcsszavak: *Upupa epops*, Magyarország, költőpopuláció, vonulás, természetvédelem

[1]MME/BirdLife Hungary, 1121 Budapest, Költő utca 21., Hungary, e-mail: halmos.gergo@mme.hu
[2]Institute of Environmental Sciences, University of Nyíregyháza, 4400 Nyíregyháza, Sóstói út 31/b, Hungary
**corresponding author*

Introduction

The Hoopoe *(Upupa epops)* is a polytypic species. The nominate form occurs in Northwest Africa, Europe, north to the 60°N latitude, east to Siberia and East China. There are 8 subspecies in sub-Saharan Africa, Madagascar and Asia. The nominate from is mostly migratory.

This species occupies open country such as pastures, parkland, orchards, sand-heathland, olive groves, and vineyards and requires the presence of features offering perches, shade, nest-sites and accessible food. It is frequently found around villages and in traditionally farmed areas. Breeding can occur up to 3000 m in Turkey (Krištín & Kirwan 2014). In Central and Southern Europe, egg-laying occurs from late April or early May, although begins in January in the Canaries (Snow & Perrins 1998). The species is monogamous, solitary and a territorial breeder, although extra-pair paternity has been found in Southeast Spain (Martín-Vivaldi *et al.* 2002). It nests in natural holes in stumps, trees, walls, old buildings, cliffs, among boulders, in abandoned vehicles, drainpipes, wells, roof spaces and nest boxes and may use the same site for several seasons (Krištín & Kirwan 2014). It feeds almost entirely on animal matter, primarily large insects and their larvae and pupae (Snow & Perrins 1998). Northern populations are fully migratory while others are only partially migratory. European populations winter in northwest Africa, the Canary Isles, Israel and Arabia (Krištín & Kirwan 2014).

In 2015 the Hoopoe became the 'Bird of The Year' in Hungary (Bank 2015), which makes it very timely to summarize our knowledge about the status of the species in the country and to emphasize the future research and conservation priorities.

Geographical distribution

The species has an extremely large range covering more than 28 million km^2 (BirdLife International 2015a). The nominate breeds from Northwest Africa (east to Libya), Canary Island, Central and Southern Europe south to Lebanon, Jordan and Israel (as far South as North Negev), and east to South-Central Russia (Ob-Yenisey watershed), Northwest China (Xinjiang) and Northwest India; probably this race breeding in North, Central and East Arabia (Krištín & Kirwan 2014).

In Hungary the species was known to be widespread with stronger populations on the Great Plains and other open areas with sandy soil types (Bankovics 1984, Magyar *et al.* 1998, Hadarics & Zalai 2008). There were no distribution maps published. Based on data from several general monitoring schemes we collected all available information to provide a first distribution map for the species. The dataset included the Common Bird Census (MMM – Mindennapi Madaraink Monitoringja), and the first year of the Breeding Bird Atlas project. We provide the dataset in a 10×10 km UTM grid map, showing surveyed grids with and without confirmed breeding *(Figure 1)*. Some areas still exist in Hungary, where we have very little information, but the general picture shows well, that the species is still widespread, prefers the open lowland areas and avoids the areas with a high forest coverage.

Breeding population

The global population of the species is very large, estimated to be over 5 million mature individuals (Birdlife International 2015a). The European breeding population was assessed in 2004 to be large (>890,000 pairs) and was stable between 1970–2000, although several populations underwent moderate declines (>10%) (BirdLife International 2004). In 2014 the European population was estimated at 1,300,000–2,760,000 pairs, which equates to 2,600,000–5,530,000 mature individuals. The population in the EU27 was estimated at 1,020,000–2,070,000 pairs, which equates to 2,040,000–4,140,000 mature in-

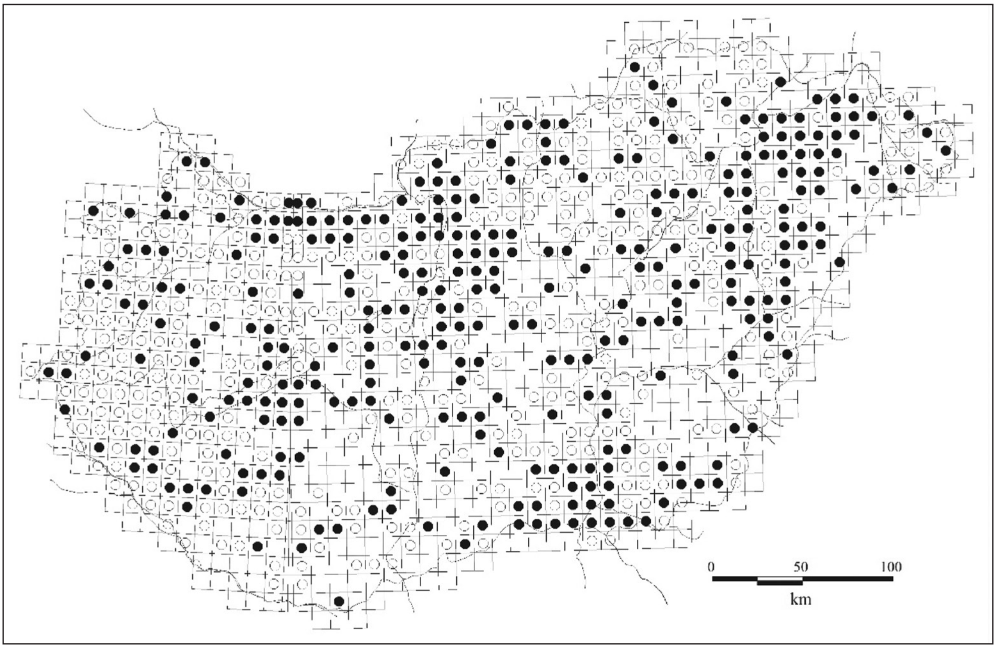


Figure 1. Distribution of 10×10 km^2 UTM squares in Hungary where breeding pairs of Hoopoes were observed during 1999–2014. Every square surveyed is marked with a circle, which is an open circle if there is no confirmed breeding for the Hoopoe, and a filled circle if there is confirmed breeding

1. ábra A 10×10 km^2-es UTM négyzetek eloszlása Magyarországon, ahol a búbosbanka költőpárok megfigyelése történt 1999–2014 között

dividuals. In Europe the strongest populations are on the Iberian Peninsula with 815,000–1,710,000 pairs giving 62% of the European estimated population size. There are other significant populations in France, Italy, Greece and Turkey (BirdLife International 2015a, 2015b).

Specific surveys were not done for the species in Hungary, but the population was estimated in several general studies and publications. Generally the species is treated as fairly common, especially on the Great Plains with higher densities on sandy soil areas (Bankovics 1984). The species was described as widespread and fairly numerous by Nándor Homonnay in 1938 and he estimated to have at least a few hundred pairs nesting in the region of Lake Balaton (Homonnay 1938). The population was estimated to be between 8000–10,000 pairs in 1998 and being a fairly common breeder especially on the Great Plain (Magyar *et al.* 1998). The next edition of this publication estimated the breeding population min. 10,000, max. 17,000 pairs between 1990–2002. The population density was higher in the Great Plain than Transdanubia and in the northern part the country (Hadarics & Zalai 2008). This estimation was used in international assessments as well (BirdLife International 2004).

The global population is declining on the long term throughout its range due to habitat loss and over-hunting (Krištín & Kirwan 2014). The trend of the European population was recently assessed in details in the European Red List of birds project (BirdLife

International 2015b) and the population size is estimated to be stable in Europe and in the EU27 countries as well. A detailed study of the Swiss population – where Hoopoe is a rare bird – has shown, that it has increased between 2002–2010 by 11%. Hoopoe population growth rate was strongly correlated with juvenile survival, fecundity and immigration, which indicates that demographic components impacting the arrival of new individuals into the populations were more important for their dynamics than demographic components affecting the loss of individuals (Schaub *et al.* 2012).

In 2013–2014 MME/BirdLife Hungary prepared new assessments for the species for the Ministry of Agriculture to be used in the formal EU Birds Directive reporting process. As there were no specific surveys we used data from the Common Bird Census program (MMM) which has available data from 1999 (Szép *et al.* 2012). The Hungarian common bird monitoring scheme (MMM) is based on point count in grid cells with semi-random sampling design. The surveyed sites are 2.5×2.5 km UTM squares (Universal Transverse Mercator geographic coordinate system), randomly selected for each observer within a minimum of 10 km radius area around a locality specified by the observer. Observers carried out 5 minute long point counts at 15 points, randomly selected from the 25 potential points within the 2.5×2.5 km UTM squares, where points were separated by 500 m. Because of the methodology used, we had several possibilities for estimation using different layers of the dataset.

(1) PAIR UTM25 – In this case the number of pairs was estimated to be 1 if at any of the observation points in the UTM square the frequency was higher than 0.

(2) PAIR SITE2 – The number of pairs was estimated in each UTM square based on the observed frequency at the 15 observation points out of the possible 25 as ‘No.pairs’=‘observed frequency’ * ‘No. of possible observation points’. We used the rounded value of ‘No.pairs’ as the number of pairs in the given square.

(3) PAIR 100M –The density (pair/km^2) was estimated based on the number of observed individuals inside the 100 m radius circles around the observation points within each surveyed quadrat. The density value of the 100 m radius circles was used to extrapolate to the area of the UTM square (6.25 km^2).

The national population estimates and their 95% confidence intervals were calculated based on the individual estimations for the UTM squares by the 3 different methods as:

N’(population size)= n’* K

where:
n’: the average number of individuals in an UTM square
K: the possible number of UTM squares in the study area (14,886)

$S^2_{N'}$: variance of the estimated population size:

$$S^2_{N'} = \frac{K(K-r)}{r} * s^2_{n'}$$

where:
s^2n’: variance of the average number of individuals by UTM squares
r: the number of surveyed UTM squares

N’ 95% confidence interval
N’ 95% minimum confidence interval: N’-1,96 * $S_{N'}$
N’ 95% maximum confidence interval: N’+1,96 * $S_{N'}$

where:

$S_{N'}$: standard deviance of the estimated population size

$$S_{N'} = \sqrt{S^2_{N'}}$$

The population estimation (minimum 95% CI – maximum 95% CI) with the three different methods is respectively (1) 5751–6824 pairs, (2) 13,405–17,620 pairs, (3) 51,936–74,886 pairs. The large differences between the estimations are because the method links an observation of a breeding individual to very different hypothetical home ranges (3.1 ha – 25 ha – 625 ha), so to select the best estimation we have to find the best estimate for the species' home range.

The home range of the species was studied in detail in Switzerland and Spain. Individual home ranges varied between 4.4 and 72.2 ha (mean±SD: 39.6 ±25.4 ha, Tagmann-Ioset *et al.* 2012) in Switzerland and between 7.41–30.76 ha (mean±SD: 12.78 ±5.96 ha, MCP method) and between 6.52–26.46 ha (mean±SD: 12.78±5.96 ha, kernel method) in Spain (Barbaro *et al.* 2008). Based on this information we decided to use the (2) method, which uses 25 ha area for estimation, which is fairly close to the home range of the Hoopoe. By this way the best population estimation is 13,500–17,500 pairs, which is very close to the previous estimates of 10,000–17,000 pairs.

We estimated the population trends based on the MMM dataset, with the standardized EBCC methodology with the TRIM software package (Szép *et al.* 2012). The population trend between 1999–2014 showed stable trend (slope=-1.3% SE=2.5%) *(Figure 2)*. The long term population trend in Hungary between 1980–2012 is estimated to be decreasing by 30–50% based on the best available expert knowledge (BirdLife International 2015b).

Migration and dispersion

A thorough study of European ring recoveries of the Hoopoe demonstrated the existence of a migratory divide for the autumn migration period in Central Europe,

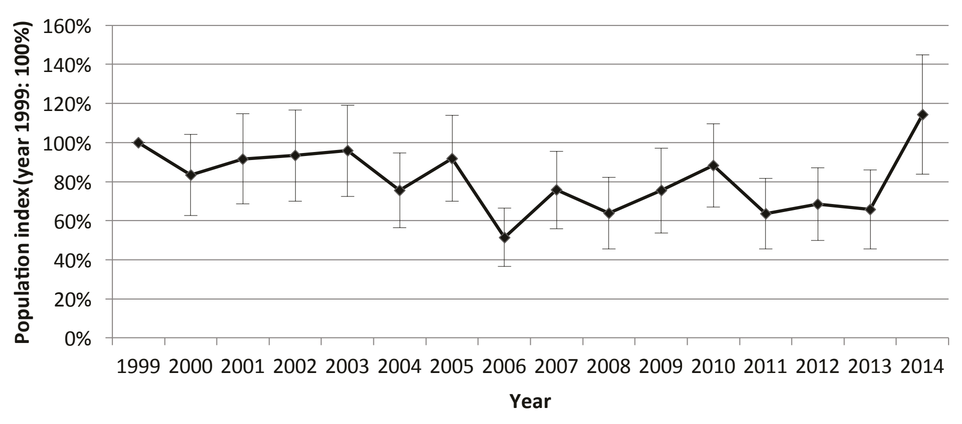


Figure 2. Annual population indices (±SE) of the surveyed Hoopoe population in the frame of the MMM during 1999–2014 based on TRIM imputed index. Base year was 1999

2. ábra A búbosbanka felmérés évi populációs indexei 1999–2014 között az MMM keretében felvéve. Alapév 1999

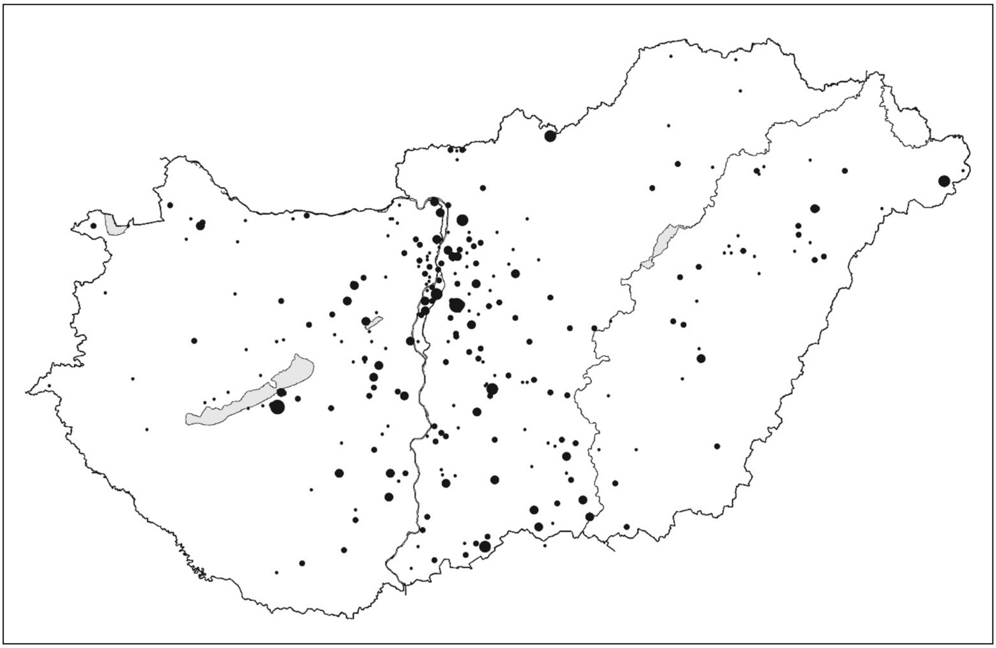


Figure 3. The distribution of Hoopoe ringing sites in Hungary. The size of the black dots is proportional to the number of ringed birds

3. ábra A búbosbanka gyűrűzési helyeinek eloszlása Magyarországon. A fekete körök mérete arányos a meggyűrűzött madarak számával

at approximately 10–12°E longitude running through Germany, Austria, Switzerland, and Italy (Reichlin *et al.* 2009). There is very little knowledge about the migration routes of the Hoopoe after leaving the Mediterranean for their wintering quarters in the sub-Saharan Africa. Only one ring recovery is known in the described sub-Saharan wintering range (ringed on 19 April 1993 in Tuscany, Italy, reported dead on 1st November 1993 in Aderbissinat, Niger, distance 2981 km). The new technology of light-level geolocators made it possible to gain new information on the migration and sub-Saharan wintering grounds. In a study from Switzerland 19 Hoopoes were tagged with geolocators and 4 were successfully recovered (Bächler *et al.* 2010). The analyses showed, that 2 of these birds followed a southwestern route through Iberia stopping over in southern Spain than crossing the Strait of Gibraltar, and after crossing the Sahara spent the winter in the border area of Mauritania and western Mali. Both birds migrated back in spring on a more easterly route making a loop migration. The third bird did a similar but 1000 km more easterly migration spending the winter in central Algeria. The fourth bird provided only fragmented information but migrated to the southeast in the direction of Italy and Albania. The analysis of isotope content of winter-grown feathers, could only very roughly delineate the winter distribution of the Hoopoe, strengthening the result from the other studies, that Spanish and Swiss Hoopoes winter in the western part of the Sahel zone (Reichlin *et al.* 2013).

Breeding dispersal is common in Hoopoes, compared with other bird species. A dispersal study by Bötsch *et al.* (2012)

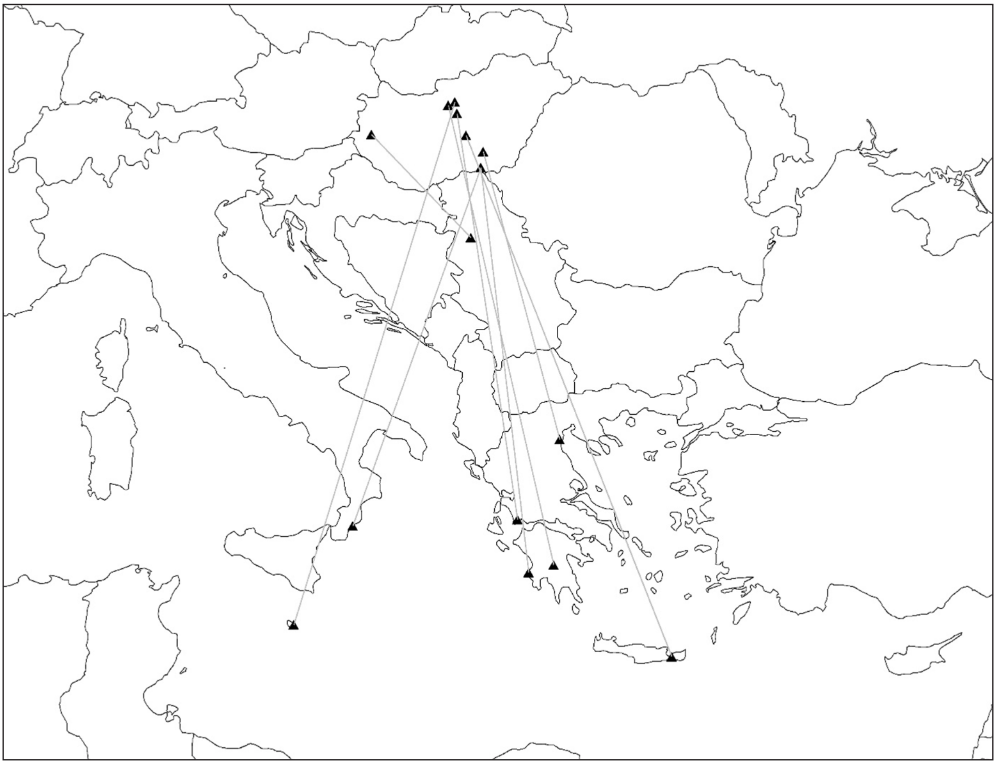


Figure 4. Foreign recoveries of Hoopoes ringed in Hungary
4. ábra Magyarországi gyűrűzésű búbosbankák visszafogása külföldön

found, that between years, females dispersed more often and over longer distances than males (mean distance, females=1.98 km; males=0.83 km), but dispersal was only weakly affected by age and previous reproductive success. Dispersal within a year also differed between sexes (mean distance, females=1.45 km; males =0.46 km) and varied little with age or previous reproductive success. Dispersal probability within years was lower and occurred over shorter distances than dispersal between years.

The Hungarian population of the Hoopoe is migratory, departing in August for the presumed wintering ground south of the Sahara. It arrives back in April. Based on recovery data from Serbia-Montenegro, Greece, Italy and Malta, the Hungarian breeding population migrates east-southeast to south-southwest. No recovery has been reported from the wintering ground (Magyar 2009). Since the publication of the Hungarian Bird Ringing Atlas there were very little additional data gathered. There are records of 1645 Hoopoes ringed between 1908–2014 in the Hungarian Bird Ringing Databank. A large percentage of these bird (1080, 65%) were ringed as nestlings. The distribution of ringing is in good accordance with the observation data *(Figure 3)*. We have only 31 recaptures and all are local ones between 0–13 km from the site of ringing. There are only 8 birds recovered abroad in Greece (5), Italy (1), Malta (1) and Serbia (1) *(Figure 4)*. Two of these birds were hunted, but we don't know the circumstances of recovery for the others and all recoveries are old from 1929–1963.

Based on international studies we can presume and on the very little information we have about the species in our country, Hungarian populations migrates on a south-southeast direction in autumn, winters in the eastern parts of the Sahel, possibly in Chad and Sudan and migrates back in spring following a loop migration pattern further to the east.

Conservation

The red list assessments evaluated the species as Least Concern (LC) status on the global, European and EU27 level as well, based on the extremely large range, the large overall population and the stable population trend (BirdLife International 2015a, 2015b). In Hungary the species is protected with a nature conservation value of 50,000 Hungarian Forints.

The species is hunted in the Mediterranean region (Krištín & Kirwan 2014). Food quality and accessibility has been shown to affect reproductive success (Martín-Vivaldi *et al.* 1999, Fournier & Arlettaz 2001) as through the availability of suitable nesting cavities as a result of habitat changes after agricultural intensification (Berthier *et al.* 2012, BirdLife International 2015b).

The present status of the Hoopoe in Hungary seems stable, however the general decline of farmland and long-distance migratory birds (Szép *et al.* 2012) raises concerns and makes it necessary to monitor the population level and changes as well as the possible threats more closely. The species depends on cavities as nesting places, which are particularly scarce on the lowlands of Hungary and are known to be a limiting factor for other cavity nesting species like the Roller *(Coracias garrulus)* (Kovács *et al.* 2008). This is very possibly limiting the Hoopoe population as well, so the provision of artificial nest boxes can be an important conservation measure in the future.

Acknowledgements

We are thankful to all volunteers of MME/BirdLife Hungary and professional staff of the Hungarian National Park directorates who collected ringing and monitoring data. We are grateful to two anonymous reviewers for helpful comments on the manuscript.

References

Bank, L. 2015. Az év madara 2015-ben: a búbosbanka [The bird of the year in 2015: The Hoopoe]. – Madártávlat 22(1): 4–7. (in Hungarian)

Bankovics, A. 1984. Búbosbanka [Hoopoe]. – In: Haraszthy, L. (ed.) Magyarország fészkelő madarai [The breeding birds of Hungary]. – Natura, Budapest, p. 124. (in Hungarian)

Bächler, E., Hahn, S., Schaub, M., Arlettaz, R., Jenni, L., Fox, J. W., Afanasyev, V. & Liechti, F. 2010. Year-round tracking of small trans-Saharan migrants using light-level geolocators. – PLoS ONE 5(3): e9566. DOI: 10.1371/journal.pone.0009566

Barbaro, L., Couzi, L., Bretagnolle, V., Nezan, J. & Vetillard, F. 2008. Multi-scale habitat selection and foraging ecology of the Eurasian Hoopoe *(Upupa epops)* in pine plantations. – Biodiversity and Conservation 17(5): 1073–1087. DOI: 10.1007/s10531-007-9241-z

Berthier, K., Leippert, F., Fumagalli, L. & Arlettaz, R. 2012. Massive nest-box supplementation boosts fecundity, survival and even immigration without altering mating and reproductive behaviour in a rapidly recovered bird population. – PLoS ONE 7(4): e36028. DOI: 10.1371/journal.pone.0036028

BirdLife International 2004. Birds in Europe: population estimates, trends and conservation status. – Cambridge, UK, Birdlife International, Birdlife Conservation Series, No. 12., p. 173.

BirdLife International 2015a Species factsheet: *Upupa epops*. – Downloaded from http://www.birdlife.org on 09/12/2015.

BirdLife International 2015b European Red List of Birds. – Luxembourg: Office for Official Publications of the European Communities

Bötsch, Y., Arlettaz, R. & Schaub, M. 2012. Breeding dispersal of Eurasian Hoopoes *(Upupa epops)* within and between years in relation to reproductive success, sex, and age. – Auk 129: 283–295. DOI: 10.1525/auk.2012.11079

Fournier, J. & Arlettaz, R. 2001. Food provision to nestlings in the Hoopoe *Upupa epops*: implications for the conservation of a small endangered population in the Swiss Alps. – Ibis 143(1): 2–10. DOI: 10.1111/j.1474-919X.2001.tb04163.x

Hadarics, T. & Zalai, T. 2008. Nomenclator Avium Hungariae – An annonated list of the birds of Hungary. – MME Birdlife Hungary, Budapest, p. 199. (in Hungarian with English Summary)

Homonnay, N. 1938. A búbosbanka, *Upupa epops* L. fészkelési viszonyai a Balaton-mellékén [The breeding of the Hoopoe *Upupa epops* in the region of Balaton]. – Kócsag 9–11: 72–79.

Kovács, A., Barov, B., Orhun, C. & Gallo-Orsi, U. 2008. International Species Action Plan for the European Roller *Coracias garrulus garrulus*. – BirdLife International for the European Commission, pp. 52

Krištín, A. & Kirwan, G. M. 2014. Common Hoopoe *(Upupa epops)*. – In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A. & de Juana, E. (eds.) Handbook of the Birds of the World Alive. – Lynx Edicions, Barcelona (retrieved from http://www.hbw.com/node/55871 on 25 February 2015)

Magyar, G., Hadarics, T. & Waliczky, Z. 1998. Nomenclator avium Hungariae: An annotated list of the birds of Hungary. – KTM Természetvédelmi Hivatal Madártani Intézete, Magyar Madártani és Természetvédelmi Egyesület, Winter Fair, pp. 202

Magyar, G. 2009. Búbosbanka [Hoopoe]. – In: Csörgő, T., Karcza, Zs., Halmos, G., Magyar, G., Gyurácz., J., Szép, T., Bankovics, A., Schmidt, A. & Schmidt, E. (eds.) Magyar Madárvonulási Atlasz [Hungarian Bird Migration Atlas]. – Kossuth Kiadó Zrt., Budapest, pp. 382–383. (in Hungarian with English Summary)

Martín-Vivaldi, M., Palomino, J. J., Soler, M. & Soler, J. J. 1999. Determinants of reproductive success in the Hoopoe *Upupa epops*, a hole-nesting non-passerine bird with asynchronous hatching. – Bird Study 46: 205–216. DOI: 10.1080/00063659909461132

Martín-Vivaldi, M., Martínez, J. G., Palomino, J. J. & Soler, M. 2002. Extrapair paternity in the Hoopoe *Upupa epops*: an exploration of the influence of interactions between breeding pairs, non-pair males and strophe length. – Ibis 144(2): 236–247. DOI: 10.1046/j.1474-919X.2002.00044.x

Reichlin, T. S., Schaub, M., Menz, M. H., Mermod, M., Portner, P., Arlettaz, R. & Jenni, L. 2009. Migration patterns of Hoopoe *Upupa epops* and Wryneck *Jynx torquilla*: an analysis of European ring recoveries. – Journal of Ornithology 150(2): 393–400. DOI: 10.1007/s10336-008-0361-3

Reichlin, T. S., Hobson, K. A., Van Wilgenburg, S. L., Schaub, M., Wassenaar, L. I., Martín-Vivaldi, M., Arlettaz, R. & Jenni, L. 2013. Conservation through connectivity: can isotopic gradients in Africa reveal winter quarters of a migratory bird? – Oecologia 171: 591–600. DOI: 10.1007/s00442-012-2418-5

Schaub, M., Reichlin, T. S., Abadi, F., Kéry, M., Jenni, L. & Arlettaz, R. 2012. The demographic drivers of local population dynamics in two rare migratory birds. – Oecologia 168(1): 97–108. DOI: 10.1007/s00442-011-2070-5

Snow, D. W. & Perrins, C. M. 1998. The Birds of the Western Palearctic (Concise Edition). Vol. 1. Non-Passerines. – Oxford University Press, Oxford, UK, pp. 1830

Szép, T., Nagy, K., Nagy, Zs. & Halmos, G. 2012. Population trends of common breeding and wintering birds in Hungary, decline of long-distance migrant and farmland birds during 1999–2012. – Ornis Hungarica 20(2): 13–63. DOI: 10.2478/orhu-2013-0007

Tagmann-Ioset, A., Schaub, M., Reichlin, T. S., Weisshaupt, N. & Arlettaz, R. 2012. Bare ground as a crucial habitat feature for a rare terrestrially foraging farmland bird of Central Europe. – Acta Oecologica 39: 25–32. DOI: 10.1016/j.actao.2011.11.003

Ornis Hungarica 2015. 23(2): 10–19.
DOI: 10.1515/orhu-2015-0010

Sex and age dependent migration phenology of the Pied Flycatcher in a stopover site in the Carpathian Basin

ANDREA HARNOS[1*], ZSOLT LANG[1], PÉTER FEHÉRVÁRI[2] & TIBOR CSÖRGŐ[3]

Andrea Harnos, Zsolt Lang, Péter Fehérvári & Tibor Csörgő 2015. Sex and age dependent migration phenology of the Pied Flycatcher in a stopover site in the Carpathian Basin. – Ornis Hungarica 23(2): 10–19.

Abstract Very little is known about Pied Flycatchers crossing the Carpathian Basin. We give a comprehensive picture about its migration based on the data collected during the past 26 years (1989–2014) at a stopover site in Hungary: (1) sex and age related phenological changes over the years, (2) sex, age and size dependent migration patterns during and (3) between migration periods, (4) sex and age composition in spring and in autumn and their change over years.

The timing of spring migration shifted to earlier dates in the case of males, while that of females did not change implying an increasing rate of protandry. In autumn the timing did not change, but juveniles leave the area earlier than adults. The average wing length increased during the past decades in spring in the case of both sexes. In autumn, wing length did not change significantly during the years, but it increased during the seasons in all age and gender groups.

The proportion of males is about 60% in spring and among juveniles in autumn, and it is around 39% in the adult group in autumn. The male ratio diminishes during spring, but it does not change during the autumn season. The average wing of adults is shorter in spring than in autumn. Based on this fact and the different sex ratios in the two seasons we may hypothesize that Pied Flycatchers are loop migrants on this area, and even the sexes of the same population take different routes.

Keywords: protandry, migration timing, Carpathian Basin, wing length, sex ratio, loop migration

Összefoglalás Keveset tudunk a Kárpát-medencén átvonuló kormos légykapókról. Átfogó képet adunk vonulásáról egy magyarországi pihenőhelyen az elmúlt 26 évben (1989–2014) gyűjtött adatok alapján: (1) ivar- és korfüggő fenológiai változásokról az évek során, (2) ivar-, kor- és méretfüggő vonulási mintázatáról a vonulási időszakok alatt és (3) között, (4) valamint az ivar- és korösszetételéről a tavaszi és őszi időszakban, továbbá ezek változásáról az évek során.

Míg a hímek tavaszi vonulása korábbra tolódott, a tojóké nem változott, így nőtt a protandria mértéke. Ősszel nem változott az időzítés, de a fiatalok korábban hagyják el a területet, mint az öregek. A tavaszi átlagos szárnyhossz szignifikánsan nőtt az elmúlt évtizedekben mindkét ivar esetén. Ősszel nem változott szignifikánsan a szárnyhossz az évek során, de az évszakok során minden ivar- és korcsoportban nőtt.

A hímek aránya 60% tavasszal és az őszi fiatal korcsoportban, de csak 39% az őszi öregek között. A hímek aránya csökken a tavasz folyamán, de ősszel nem változik. Az öregek átlagos szárnyhossza rövidebb tavasszal, mint ősszel. A különböző szárnyhossz és ivararány alapján arra következtethetünk, hogy a kormos légykapó hurokvonuló ezen a területen. Valószínű, hogy még ugyanannak a populációnak a két ivara is más útvonalon repül a vonulás során.

Kulcsszavak: protandria, vonulás időzítés, Kárpát-medence, szárnyhossz, ivararány, hurokvonulás

[1] *Department of Biomathematics and Informatics, Szent István University, Faculty of Veterinary Science, 1078 Budapest, István u. 2., Hungary, e-mail: harnos.andrea@aotk.szie.hu,*
[2] *Department of Zoology, Hungarian Natural History Museum, 1088 Budapest, Baross utca 13., Hungary*
[3] *Department of Anatomy, Cell- and Developmental Biology, Eötvös Loránd University, 1117 Budapest, Pázmány Péter sétány 1/C, Hungary*
**corresponding author*

Introduction

Timing of large scale individual movements of avian migrants often shows considerable intra- and interspecific differences between sex and/or age groups due to the variations in migration and moult strategies, territoriality on the wintering area, feeding ecology and other needs (Stutchbury 1994, Woodrey & Moore 1997, Stewart *et al.* 2002). Within species often males migrate earlier than females in spring (protandry) (Ellengren 1991, Stewart *et al.* 2002, Catry *et al.* 2004, Mills 2005) and adults migrate earlier than juveniles (differential migration) (Terrill & Able 1988), but there are examples for the opposite sequences (Reynolds *et al.* 1986). The differential migration of sexes has been intensely studied in spring (Kokko 1999, Rubolini *et al.* 2004, Tøttrup & Thorup 2008), but less attention has been paid to this phenomenon in autumn (Mills 2005, Jakubas & Wojczulanis-Jakubas 2010). Moreover, less is known about the differential timing between age classes within each sex during autumn migration.

The Pied Flycatcher *(Ficedula hypoleuca)* is a small passerine bird which is distributed in the North-Western part of the Western Palaearctic (Cramp & Simmons 1983). Their breeding population in Europe is large (which means approximately 12 million pairs) and it was stable until the last quarter of the 20th century (BirdLife International 2004). It is a sporadic to rare breeder in Hungary (predominantly in the Southern Great Plain, Alpine Foothills and Zala Hills) (Hadarics & Zalai 2008, Török 2009).

Ring recoveries related to the British Isles shows that birds from this region move south, the most important stopover (refuelling) site areas are: Southwest France, Northwest Spain and Northern Portugal (Jones 2002). However, the main direction of the continental birds in autumn migration is southwest. The birds ringed in Scandinavia and North-Western Europe are concentrated along the Atlantic coasts of France, Spain and Portugal (Fransson & Hall-Karlsson 2008). The most important stopover sites during the autumn migration are located on the Iberian Peninsula, from where they cross the Mediterranean region and the Sahara with a direct non-stop flight to reach their wintering grounds. Their wintering grounds are in tropical West Africa ranging from Guinea to Ghana (Cramp & Simmons 1983, Salewski *et al.* 2004). The spring migration route probably leads further east over the Northern part of Apennine Peninsula and Central Europe as it is indicated by recoveries (Zink 1985, Fransson & Hall-Karlsson 2008).

Sporadic ring recoveries suggest that the migrant population flying across Hungary originates from the Baltic region and western Russia (based on the two recoveries ringed in Estonia and Russia) (Török 2009). Two birds ringed in Hungary were recovered in South France and South Portugal (Török 2009), thus it is plausible that the Pied Flycatchers fly over the Carpathian Basin and continue their way towards the Iberian Peninsula.

The Pied Flycatchers arrive back to their breeding grounds between April and May. Their autumn migration lasts between August and September (Cramp & Simmons 1983). 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). Precise wintering grounds and ecology is yet to be described for this species, furthermore little is known on its migration phenology in Western (Jones 2002, Fransson &

Hall-Karlsson 2008, Spina & Volponi 2008) and East-Central Europe (Török 2009).

Pied Flycatchers are prime candidates to serve as model species to study the complexity of migration phenology as individuals can be easily sexed and aged on site (Svensson 1992). In a previous study (Harnos *et al.* 2015), we have already showed how the timing of spring migration changed in case of this species. In the current study, we describe: (1) the sex and age related phenological changes over the years (2) sex, age and size dependent migration patterns during and (3) between the migration periods, (4) sex and age composition in spring and in autumn and their changes during the past 26 years (1989–2014) at a stopover site in Hungary.

Materials and Methods

The data was collected in Central Hungary (47°15'N, 19°15'E) at the Ócsa Bird Ringing Station, in the Danube-Ipoly National Park. This site is at the edge of a postglacial peatbog. The surrounding area comprises all habitat types from reed-beds to mature forests. Mist-nettings were conducted at the same locations throughout the whole study period during 1989–2014.

We used the records of 2323 Pied Flycatchers trapped and ringed between April and September (241 males and 162 females in spring, 121 adult males and 182 adult females, 967 juvenile males and 650 juvenile females in autumn).

The daily ringing work was carried out with 100 mist nets in standard places covering completely both migration periods of Pied Flycatchers. Every newly trapped bird was ringed and its age and sex were determined based on plumage. First calendar year birds (juveniles) were distinguished from adults (Svensson 1992). All birds were measured according to the same methodology. The wing length was measured with 1 mm accuracy, using a ruler in the case of birds where feather abrasion was low.

Linear mixed effects (LME) models were used to detect the changes in the timing of migration. Sex, age and their interaction were included in the models. We put year as a random factor in all models. Wing length and timing were also analysed by linear mixed models. To analyse sex and age ratios and their dependence on year and season, generalized linear mixed models with binomial error distribution and logit link were fitted. We gave 95% confidence intervals (CI) for the estimated sex ratios based on the models. We used the 'nlme' (Pinherio *et al.* 2014) and 'lme4' R packages (Bates *et al.* 2014).

We compared the wing length and the proportion of males and females, the proportion of adults and juveniles and the seasons by calculating contrasts and least squares means for the fitted models ('lsmeans' package, Russell 2014). A small amount of noise was added to the data on the figures in order to prevent over plotting. The significance level was set to 0.05. All statistical analyses were done in R 3.2.2 (R Core Team 2015).

Results

Timing

Two distinct migration waves can be observed, so the determination of the beginning of the autumn season is very easy and precise *(Figure 1)*.

While we found a 11.3 day shift (slope (s)=0.48, SE=0.12, p<0.0001) to earlier days in the timing of males during spring

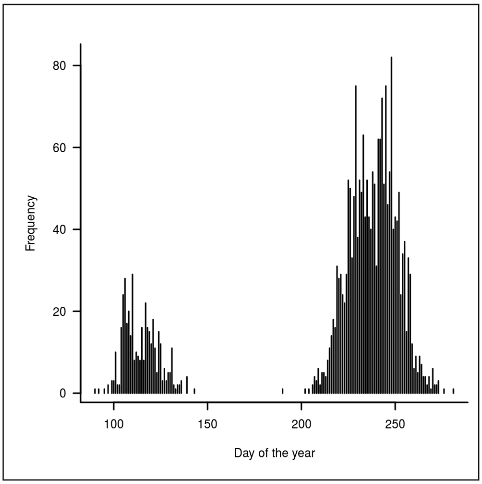


Figure 1. The daily number of mist-netted Pied Flycatchers caught between 1989 and 2014. The two distinct migration waves can be observed

1. ábra A kormos légykapó gyakorisága az év napjain az 1989 és 2014 közötti összesített adatok alapján. Jól megfigyelhető a két elkülönülő vonulási hullám

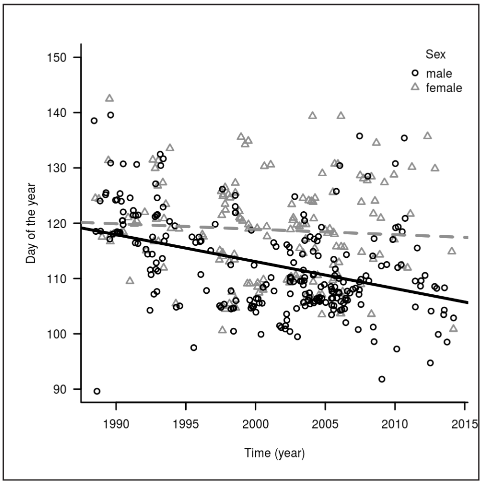


Figure 2. Spring arrival times of male and female Pied Flycatchers between 1989 and 2014. The continuous line highlights the significant advancement in arrival time over the years for males, while the dashed line corresponds to the non-significant advancement in arrival time over the years for females

2. ábra A kormos légykapó egyedeinek tavaszi érkezési ideje 1989 és 2014 között. A folytonos vonal mutatja a hímek érkezési idejének szignifikáns korábbra tolódását. A szaggatott vonal a tojók adataira illesztett nem szignifikáns trendet mutatja

migration, the timing of females did not change significantly (s=-0.09, SE=0.14, p=0.48) *(Figure 2)*. At the beginning of the time period, there was no significant difference between the timing of the sexes (p=0.3577), but the estimated difference is 11.3 (SE=1.79, p<0.0001) days, recently.

In autumn, no significant change could be detected in the timing of any sex or age groups (s=0.15, SE=0.11, p=0.1816) and the migration timing of sexes did not differ significantly (p=0.0630), but juvenile birds migrated 4 days (SE=0.75, p<0.0001) earlier on average than adult birds.

Wing length

The mean wing length increased by 0.08 mm/year (2.1 mm altogether) during the 26 years (SE=0.019, p=0.0003) in spring *(Figure 3)*. We found a significant relationship between wing length and timing within season *(Figure 4)*. The individuals arriving earlier have longer wings on average (s=-0.024, SE=0.012, p=0.0421) and the estimated difference is 1.3 mm between the beginning (90th day) and the end of the season (143rd day). The rate of change during the 26 years and along the season does not differ significantly between sexes, but there is a 1.4 mm (SE=0.22, p<0.0001) significant difference in their average wing length (the females' average wing length is smaller).

The autumn wing length did not change significantly (p=0.1918) during the 26 years in any age and sex groups.

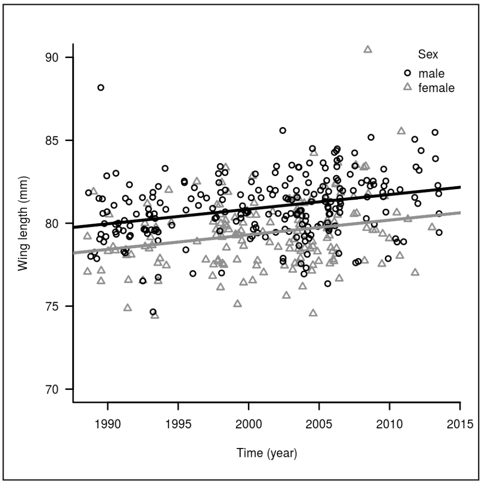


Figure 3. Spring wing length of male and female Pied Flycatchers between 1989 and 2014. The continuous lines highlights the significant increase of average wing length over the years

3. ábra A kormos légykapó tavaszi egyedeinek szárnyhossza 1989 és 2014 között. A folytonos vonalak az átlagos szárnyhossz növekedést mutatják az évek során

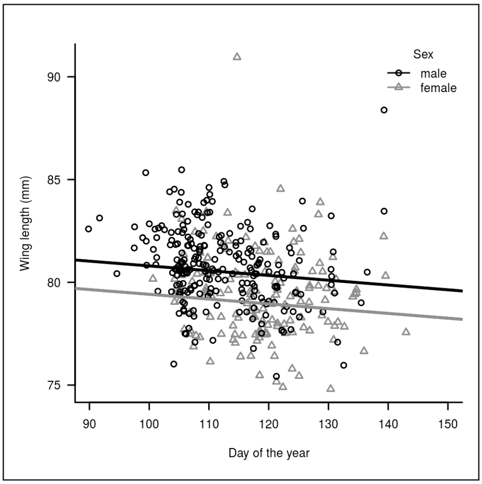


Figure 4. Wing length of male and female Pied Flycatchers during the spring season. The continuous lines highlights the significant decrease of average wing length over the season

4. ábra A kormos légykapó egyedeinek szárnyhossza tavaszi időszakban. A folytonos vonalak a szignifikáns átlagos szárnyhossz csökkenést mutatják a szezon során

In autumn, the birds arrived earlier had shorter wing on average (s= 0.015, SE=0.004, p=0.0001), meaning that there was 1.2 mm mean difference between the beginning (200th) and the end (280th) of the season. The rate of change is independent of sex and age groups, but the wing of female birds is 1.7 mm (SE=0.22, p<0.0001) and 1 mm (SE=0.09, p<0.0001) shorter on average than that of the males in case of adults and juveniles, respectively. Juveniles have 0.6 mm shorter wings than the adults (SE=0.16, p=0.0003) in case of females, and the difference is 1.2 mm (SE=0.18, p<0.0001) in case of males (*Figure 5a* and *b*).

The average (±SE) wing length (according to an LME model) of adult female and male birds are 79.4±0.21 mm and 81±0.19 mm in spring, 79.9±0.19 mm and 81.5±0.21 mm in autumn and 79.2±0.14 mm and 80.25±0.14 mm in case of juveniles in autumn. There is a 0.44 mm (SE=0.17, p=0.0099) significant difference between the average wing lengths in the two seasons in the case of both sexes.

Sex ratio

According to a generalized linear mixed model, the estimated ratio of males in spring is 60.1% (CI: 54.7% to 65.3%). In autumn, the proportion of adult males is 39.8% (CI: 33.7%, 46.2%) and the proportion of juvenile males is 58.8% (CI: 53.3%, 64%) and these ratios did not change significantly during the 26 years (p=0.6289).

In spring the male ratio diminishes during the season from 89.5% to 3% (s=0.098, p<0.0001). Contrary, in autumn it does not change significantly during the season

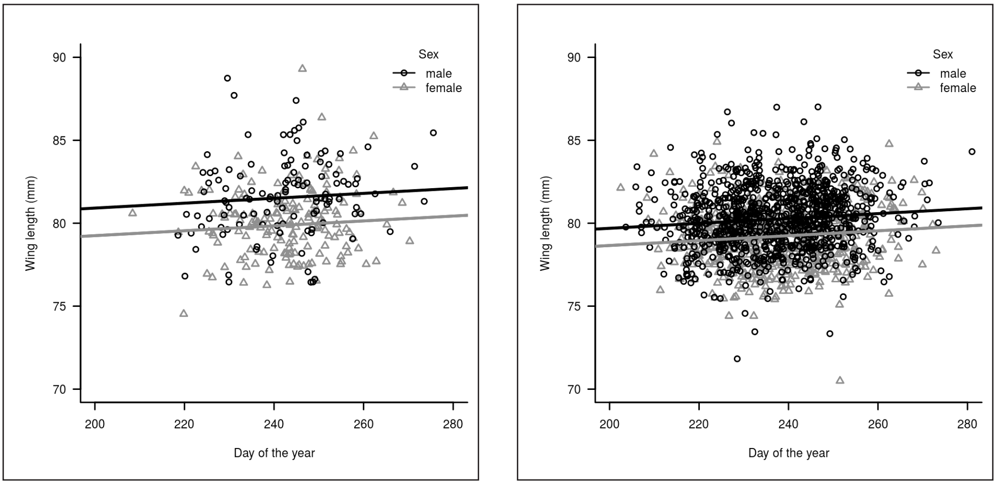


Figure 5a and *b* Wing length of adult (a) and juvenile (b) male and female Pied Flycatchers during the autumn season. The continuous lines highlights the significant increase of average wing length over the season

5a és *b ábra* Az öreg (a) és fiatal (b) hím és tojó szárnyhosszak az őszi vonulási időszakban. A folytonos vonalak a szignifikáns átlagos szárnyhossz növekedést mutatják a szezon során

(p=0.0827) but depends on the age group (s=-0.786, p<0.0001), the male ratio is lower in the adult group (40.9% vs. 60.1%).

Discussion

Environmental factors do not necessarily influence the migration of the sexes uniformly. Sexual selection has been supposed to affect the evolution of protandry, because early arriving males enjoy a mating advantage (Møller 1994, 2004). Temporal trend in the size of protandry was only found in three case studies until now. In the case of Chiffchaffs *(Phylloscopus collybita)* protandry increased (Csörgő & Harnos 2011). In the case of Barn Swallows *(Hirundo rustica)* the males arrived earlier, but the females did not between 1971 and 2003 in Denmark (Møller 2004), and in our previous study (Harnos *et al.* 2014), Pied Flycatchers also showed sex dependent migration strategies with increasing protandry in spring.

The onset of fall migration did not change during the past decades on our study site, consequently the timing of breeding and successive events probably did not change either, as in a similar study from South-West Finland. Aloha *et al.* (2004) showed that climate warming along the migration route and earlier arrival does not influence the breeding dates of Pied Flycatchers. Breeding is constrained by the arrival of both sexes, therefore increased protandry is unlikely to cause advancements in breeding dates.

Morphological distinction of birds entering Europe through the Iberian Peninsula and those entering further East is impossible (Winkel & Hudde 1993), but the contradicting trends found in Central and Southern Europe last decades (Hüppop & Winkel 2006) suggest population specific reactions to the changing climate (Menzel *et al.* 2006, Rubolini *et al.* 2007). For instance, at a

Mediterranean stopover site (Island of Capri, Italy), according to a 19-yearlong study (between 1980–2004) the time of arrival shifted to 4.4 days later (Jonzén *et al.* 2006). Similar trends were recorded at medium latitudes: on the Heligoland Islands (Germany) and Courish Spit (Russia) (Sokolov & Kosarev 2003, Sparks *et al.* 2005). In the case of the cross migrants of Germany – mostly originating from Scandinavia – the Pied Flycatcher started arriving earlier between 1960 and 2000: the shift was 6.4 days (Hüppop & Hüppop 2002). In Sweden there was no shift after a 50 year long period between 1952 and 2002 (Stervander *et al.* 2005). In South-West Finland the early migrants (5th percentile of the sample) advanced their arrival date, by approximately 8 days, while the late migrants (95th percentile) did not (Ahola *et al.* 2004). Our results complement these findings, as advancement in arrival dates was detected at least for males. However, the differences in direction and rate of phenology amongst various studied locations further suggest that distinct populations migrate through these sites and/or that responses to altered environment are location specific.

The average wing length increased during our study period, which can be explained in two – not mutually exclusive, but possibly reinforcing – ways: (1) The wings of northern breeding populations of other species with longer migration routes to their wintering grounds are longer and more pointed than that of southern breeders with shorter migration routes (Tiainen & Hanski 1985, Lockwood *et al.* 1998) and this phenomenon probably also applies to Pied Flycatchers. In the background of increased average wing length could be the changes in cross migrating populations: the ratio of northern originated birds could increase. One of the effects of the climate change is that the species' range is shifting northward (Parmesan & Yohe 2003, Root *et al.* 2003). Some assessments suggest that the European range of Pied Flycatchers will extend from Norway to the Ural Mountains by the end of the 21st century (Huntley *et al.* 2007). (2) The size of the Sahara desert is increasing continuously (Le Houérou 1996), resulting in selection forces toward longer-winged individuals. In this case, the capture ratio of longer winged individuals at the Hungarian stopover site may increase, producing the observed pattern.

The average wing length is shorter in spring than in autumn. Pied Flycatchers have a post-nuptial moult, thus the difference may be attributed as the result of feather abrasion, however, individuals with observable feather wear were not measured. More likely this pattern is caused by the different composition of the trans-migrant populations, namely there are more birds with shorter wing in spring than in autumn. This observation is supported by studies in Denmark and in Italy: according to these Western European studies the species has a loop migration strategy (Bønløkke *et al.* 2006, Spina & Volponi 2008).

Based on our results, in spring the longer winged individuals of both sexes arrive earlier, like in Italy (Spina & Volponi 2008) while in the autumn the situation is reversed: longer winged birds leave the area later. It is possible that the birds of northern populations arrived earlier in spring and later in autumn.

The male ratio is higher (60%) at our study site in spring, and lower among the adults in autumn (39%), but 59% among juveniles. In the case of autumn migration, at Heligoland, off the coast of Northwest Germany, 46% were males out of 463 sexed individuals

(Bub 1981 in Lundberg & Alatalo 1992). In the south-western part of Finland, the male ratio was 45% (von Hartman 1985). The sex ratio was skewed in the opposite direction near Berlin, in Germany, 58% were males out of 406 sexed individuals (Curio 1959). Based on these facts and because the capture probabilities of the two sexes do not bias the estimated sex ratios in the migration periods in case of passerines (Amrhein *et al.* 2012), we hypothesize that even the sexes of the same breeding population use different routes during their migration, not only whole populations and thus sexes may react independently to environmental changes. In spring the males probably migrate on a shorter, easterly route, where spring temperatures increased from the second half of April (Hüppop & Winkel 2006), since the climatic trend has south-west to north-east direction. This is also supported by the differential timing of the sexes in spring.

In conclusion, we showed that the transmigrant population of Pied Flycatcher in the Carpathian Basin behaved somewhat differently from those noted in Western European indicating that there is substantial geographic variation in migratory behaviour for this species. We recommend that future predictions of changes in demography and range extent consider these differences.

Acknowledgements

The authors express their gratitude for the work of the volunteers at the Ócsa Bird Ringing Station. This work was supported by OTKA under Grant No. 108571 and by the Research Faculty Grant 2014 of the Szent István University, Faculty of Veterinary Science.

References

Ahola, M., Laaksonen, T., Sippola, K., Eeva, T., Rainio, K. & Lehikoinen, E. 2004. Variation in climate warming along the migration route uncouples arrival and breeding dates. – Global Change Biology 10: 1610–1617. DOI: 10.1111/j.1365-2486.2004.00823.x

Amrhein, V., Scaar, B., Baumann, M., Minéry, N., Binnert, J-P. & Korner-Nievergelt, F. 2012. Estimating adult sex ratios from bird mist netting data. – Methods in Ecology and Evolution 3: 713–720. DOI: 10.1111/j.2041-210X.2012.00207.x

Bates, D., Maechler, M., Bolker, B. & Walker, S. 2014. lme4: Linear mixed-effects models using Eigen and S4. – R package version 1.1-6. http://CRAN.R-project.org/package=lme4

BirdLife International 2004. Birds in Europe: population estimates, trends and conservation status. – Cambridge UK: Birdlife International, Birdlife Conservation Series, No.12., p. 242.

Bønløkke, J., Madsen, J. J., Thorup, K., Pedersen, K. T., Bjerum, M. & Rahbek, C. 2006. Danks Traekfugleatlas, Rhodos, Humlebaek, pp. 686–689, 693–696.

Bub, M. 1981. Stelzen, Pieper und Würger (Kennzeichen und Mauser europäischen Singvögel 2). – Neue Brehm Bücherei, A. Ziemsen Verlag, Wittenberg–Lutherstadt, pp. 545 (in German)

Catry, P., Campos, A., Almada, V. & Cresswell, W. 2004. Winter segregation of migrant European Robins *Erithacus rubecula* in relation to sex, age and size. – Journal of Avian Biology 35: 204–209. DOI: 10.1111/j.0908-8857.2004.03266.x

Cramp, P. & Simmons, K. E. L. 1983. The Birds of Western Palearctic, Vol. 3. – Oxford University Press, Oxford, CD-ROM, Disc 01

Csörgő, T. & Harnos, A. 2011. Change of migration timing of Chiffchaff *(Phylloscopus collybita)* during 23 years. – Ornis Hungarica 19(1–2): 3–63. (in Hungarian with English Summary)

Curio, E. 1959. Beiträge zur Populationsökologie des Trauerschnäppers (*Ficedula h. hypoleuca Palla*). – Zoologische Jarhbücher 87: 185–230. (in German)

Ellengren, H. 1991. Stopover ecology of autumn migrating Bluethroats *Luscinia s. svecica* in relation to age and sex. – Ornis Scandinavica 22: 340–348.

Fransson, T. & Hall-Karlsson, S. 2008. Svensk ringmarkningsatlas [Swedish Bird Ringing Atlas]. – Naturhistoriska Riksmuseet and Sveriges Ornithologiska Förening, pp. 144–148.

Hadarics, T. & Zalai, T. 2008. Nomenclator Avium Hungariae – An annonated list of the birds of Hungary. – MME Birdlife Hungary, Budapest, p. 199. (in Hungarian with English Summary)

Harnos, A., Nóra, Á., Kovács, Sz., Lang, Zs. & Csörgő, T. 2015. Increasing protandry in the spring migration of the Pied Flycatcher *(Ficedula hypoleuca)* in Central Europe. – Journal of Ornithology 156(2): 543–546. DOI 10.1007/s10336-014-1148-3

Huntley, B., Green, R. E., Collingham, Y. C. & Willis, S. G. 2007. A climatic atlas of European breeding birds. – Barcelona, Lynx Edicions, pp. 521

Hüppop, O. & Hüppop, K. 2002. North Atlantic Oscillation and timing of spring migration in birds. – Proceeding of the Royal Society London Series B, Biological Sciences 270(1512): 233–240. DOI: 10.1098/rspb.2002.2236

Hüppop, O. & Winkel, W. 2006. Climate change and timing of spring migration in the long-distance migrant *Ficedula hypoleuca* in Central Europe: the role of spatially different temperature changes along migration routes. – Journal of Ornithology 147: 344–353. DOI: 10.1007/s10336-005-0049-x

Jakubas, D. & Wojczulanis-Jakubas, K. 2010. Sex- and age-related differences in the timing and body condition of migrating Reed Warblers *Acrocephalus scirpaceus* and Sedge Warblers *Acrocephalus schoenobaenus*. – Naturwissenschaften 97: 505–511. DOI: 10.1007/s00114-010-0666-y

Jones, P. H. 2002. Pied Flycatcher. – In: Wernham, C. V., Toms, M. P., Marchant, J. H., Clark, J. A., Siriwardena, G. M. & Baillie, S. R. (eds.) The Migration Atlas: movements of the birds of Britain and Ireland. – T & AD Poyser, London, pp. 584–586.

Jonzén, N., Lindén, A., Ergon, T., Knudsen, E., Vik, J. O., Rubolini, D., Piacentini, D., Brinch, C., Spina, F., Karlsson, L., Stervander, M., Andersson, A.,Waldenström, J., Lehikoinen, A., Edvardsen, E., Solvang, R. & Stenseth, N. Ch. 2006. Rapid advance of spring arrival dates in long-distance migratory birds migratory birds. – Science 312: 1959–1961. DOI: 10.1126/science.1126119

Kokko, H. 1999. Competition for early arrival in migratory birds. – Journal of Animal Ecology 68: 940–950. DOI: 10.1046/j.1365-2656.1999.00343.x

Le Houérou, H. N. 1996. Climate change, drought and desertification. – Journal of Arid Environments 34: 133–185. DOI: 10.1006/jare.1996.0099

Lockwood, R., Swaddle, J. P. & Rayner, J. M. V. 1998. Avian wingtip shape reconsidered: wingtip shape indices and morphological adaptations to migration. – Avian Biology 29: 273–292. DOI: 10.2307/3677110

Lundberg, A. & Alatalo, R. 1992. The Pied Flycatcher. – London, Poyser, pp. 281

Menzel, A., Sparks, T., Estrella, N., Koch, E., Aasa, A., Ahas, R., Alm-Kübler, K., Bisolli, P., Braslavská, O., Briede, A., Chmielewski, F. M., Crepinsek, Z., Curner, Y., Dahl, Å., Defila, C., Donelly, A., Filella, Y., Jatczak, K., Måge, F., Mestre, A., Nordli, Ø., Peñuelas, J., Pirinen, P., Remišová, V., Scheifinger, H., Striz, M., Susnik, A., Van Vliet, A. J. H., Wielgolaski, F-E., Zach, S. & Zust, A. 2006. European phenological response to climate change matches the warming pattern. – Global Change Biology 12: 1969–1976. DOI: 10.1111/j.1365-2486.2006.01193.x

Mills, A. M. 2005. Protogyny in autumn migration: do male birds 'play chicken'? – Auk 122: 71–81. DOI: 10.1642/0004-8038(2005)122[0071:PIAMDM]2.0.CO;2

Møller, A. P. 1994. Sexual Selection and the Barn Swallow. – Oxford University Press, Oxford, pp. 365

Møller, A. P. 2004. Protandry, sexual selection and climate change. – Global Change Biology 10: 2028–2035. DOI: 10.1111/j.1365-2486.2004.00874.x

Parmesan, C. & Yohe, G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. – Nature 421: 37–42. DOI: 10.1038/nature01286

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D. & R Core Team 2014. _nlme: Linear and Nonlinear Mixed Effects Models_. R package version 3.1-117, http://CRAN.R-project.org/package= nlme

R Core Team 2015. R: A language and environment for statistical computing. – R Foundation for Statistical Computing, Vienna, Austria, https://www.R-project.org/

Reynolds, J. D., Colwell, M. A. & Cooke, F. 1986. Sexual selection and spring arrival times of Red-necked and Wilson's Phalaropes. – Behavioral Ecology and Sociobiology 18: 303–310. DOI: 10.1007/BF00300008

Root, T. L., Price, J. T., Hall, K. R., Schneider, S. H., Rosenzweig, C. & Pounds, J. A. 2003. Fingerprints of global warming on plants and animals. – Nature 421: 57–60. DOI: 10.1038/nature01333

Rubolini, D., Spina, F. & Saino, N. 2004. Protandry and sexual dimorphism in trans-Saharan migratory birds. – Behavioral Ecology 15: 592–601. DOI: 10.1093/beheco/arh048

Rubolini, D., Møller, A. P., Rainio, K. & Lehikoinen, E. 2007. Assessing intraspecific consistency and geographic variability in temporal trends of spring migration phenology among European bird species. – Climate Research 35: 135–146. DOI: 10.3354/cr00720

Russell, V. L. 2014. lsmeans: Least-Squares Means. – R package version 2.05. http://CRAN.R-project.org/package=lsmeans

Salewski, V., Altwegg, R., Erni, B., Falk, K. H., Bairlein, F. & Leisler, B. 2004. Moult of three Palaearctic migrants in their West African winter quarters. – Journal of Ornithology145(2): 109–116. DOI 10.1007/s10336-004-0020-2

Sokolov, L. V. & Kosarev, V. V. 2003. Relationship between timing of arrival of passerines to the Courish Spit and North Atlantic Oscillation Index (NAOI) and precipitation in Africa. – Proceedings of the Zoological Institute of the Russian Academy of Sciences 299: 141–154.

Sparks, T. H., Bairlein, F., Bojarinova, J. G., Hüppop, O., Lehikoinen, E. A., Rainio, K., Sokolov, L. V. & Walker, D. 2005. Examining the total arrival distribution of migratory birds. – Global Change Biology 11: 22–30. DOI: 10.1111/j.1365-2486.2004.00887.x

Spina, F. & Volponi, S. 2008. Atlante della Migrazione degli Uccelli in Italia 2. Passeriformi [Italian Bird Migration Atlas]. – Ministero dell' Ambiente e della Tutela del Territorio e del Mare, Istituto Superiore per la Protezione e la icerca Ambientale, Tipografia SCR–Roma, pp. 632 (in Italian with English Summary)

Stervander, M., Lindström, A., Jonzén, N. & Andersson, A. 2005. Timing of spring migration in birds: long-term trends, North Atlantic Oscillation and the significance of different migration routes. – Journal of Avian Biology 36: 210–221. DOI: 10.1111/j.0908-8857.2005.03360.x

Stewart, R. L. M., Francis, C. M. & Massey, C. 2002. Age-related differential timing of spring migration within sexes in passerines. – Wilson Bulletin 114: 264–271. DOI: 10.1676/0043-5643(2002)114[0264:ARDTOS]2.0.CO;2

Svensson, L. 1992. Identification guide to European Passerines, 4th ed. – Stockholm/Ugga, pp. 233–234.

Tiainen, J. & Hanski, I. K. 1985. Wing shape variation of Finnish and Central European Willow Warblers *Phylloscopus trochilus* and Chiffchaffs *P. collybita*. – Ibis 127: 365–371.

Terrill, S. B. & Able, K. P. 1988. Bird migration terminology. – Auk 105: 205–206.

Török, J. 2009. Pied Flycatcher. – In: Csörgő, T., Karcza, Zs., Halmos, G., Magyar, G., Gyurácz., J., Szép, T., Bankovics, A., Schmidt, A. & Schmidt, E. (eds.) Hungarian Bird Migration Atlas. – Kossuth Kiadó Zrt., Budapest, pp. 537–538. (in Hungarian with English Summary)

Tøttrup, A. P. & Thorup, K. 2008. Sex-differentiated migration patterns, protandry and phenology in North European songbird populations. – Journal of Ornithology 149: 161–167. DOI: 10.1007/s10336-007-0254-x

Jones, P. H. 2002. Pied Flycatcher. – In: Wernham, C. V., Toms, M. P., Marchant, J. H., Clark, J. A., Siriwardena, G. M. & Baillie, S. R. (eds.) The Migration Atlas: movements of the birds of Britain and Ireland. – T & AD Poyser, London, pp. 584–586.

Winkel, W. & Hudde, H. 1993. *Ficedula hypoleuca* (Pallas 1764) Trauerfliegenschnäpper, Trauerschnäpper. – In: Glutz von Blotzheim, U. G. (ed.) Handbuch der Vögel Mitteleuropas, Vol. 13. Wiesbaden, Germany, Aula, pp. 165–263. (in German)

Woodrey, M. S. & Moore, E. R. 1997. Age-related differences in the stopover of fall landbird migrants on the coast of Alabama. – Auk 114: 695–707. DOI: 10.2307/4089289

Zink, G. & Bairlein, F. 1995. The migration of European songbirds: An atlas of the rediscovery of banded birds, Vol. 3. (Lieferung 5). – AULA-Verlag, Wiesbaden

Ornis Hungarica 2015. 23(2): 20–30.
DOI: 10.1515/orhu-2015-0011

Morphological classification of conspecific birds from closely situated breeding areas – A case study of the Common Nightingale

DÁVID KOVÁTS[1*] & ANDREA HARNOS[2]

Dávid Kováts & Andrea Harnos 2015. Morphological classification of conspecific birds from closely situated breeding areas – A case study of the Common Nightingale. – Ornis Hungarica 23(2): 20–30.

Abstract In this paper, a complex morphological comparison of four Common Nightingale groups *(Luscinia megarhynchos)* is demonstrated. In total, 121 territorial nightingales were mist-netted and measured individually on four study areas called 'Bódva', 'Felső-Tisza', 'Szatmár-Bereg' and 'Bátorliget' in the North-Eastern part of Hungary in 2006–2013. To distinguish groups by morphology, C*lassification and Regression Trees* (CART), *Random Forest* (RF) and *Linear Discriminant Analysis* (LDA) methods were used. Comparison of the four studied Common Nightingale groups shows substantial morphological differences in the length of the second, the third and the fourth primaries (P_2, P_3, P_4), in bill length (BL) and bill width (BW), while other characteristics showed greater similarities. Based on the results of all the applied classification methods, birds originated from Szatmár-Bereg were clearly distinguishable from the others. The differences in morphology can be explained by interspecific competition or phenotypic plasticity resulting from the change of ecological, environmental parameters. Our case study highlights the advantageous differences of the classification methods to distinguish groups with similar morphology and to choose important variables for classification. In conclusion, broad application of the classification methods RF and CART is highly recommended in comparative ecological studies.

Keywords: *Luscinia megarhynchos,* classification and regression trees, random forest, linear discriminant analysis, morphological classification

Összefoglalás A tanulmányban négy fülemüle *(Luscinia megarhynchos)* állomány komplex morfológiai összehasonlítását mutatjuk be, az ökológiai vizsgálatokban csak kevésbé ismert klasszifikációs módszerekkel. Magyarország északkeleti részén, négy populáció ('Bódva', 'Felső-Tisza', 'Szatmár-Bereg' és 'Bátorliget') összesen 121 egyedéről vettünk fel biometriai adatokat 2006 és 2013 között. Az állományok morfológiai elkülönítésére a véletlen erdők (RF), döntési fák (CART) és a lineáris diszkriminancia analízis (LDA) módszereket alkalmaztuk. A négy fülemüle állomány a második, harmadik és negyedik kézevezők hosszában (P_2, P_3, P_4), a csőrhosszban (BL) és csőrszélesség (BW) tekintetében mutatott különbséget. Az általunk használt klasszifikációs módszerekkel a szatmár-beregi fülemüle csoport a többi állománytól határozottan elkülöníthető. A morfológiai különállóságot a kompetíciós verseny vagy a fenotípusos plaszticitás magyarázhatja, amelyek gyakori oka az ökológiai, környezeti paraméterek minőségi megváltozása. Esettanulmányunk elsősorban a különböző klasszifikációs módszerek alkalmazhatóságára hívja fel a figyelmet, amellyel az egymáshoz hasonló morfológiájú populációk elkülönítésére, valamint az elkülönítésében szerepet játszó változók meghatározására is lehetőség nyílik. Eredményeink alapján a CART és RF modellek széleskörű használatát javasoljuk a hasonló jellegű ökológiai vizsgálatokban.

Kulcsszavak: *Luscinia megarhynchos*, klasszifikációs és regressziós fák, véletlen erdők, lineáris diszkriminancia elemzés, morfológiai klasszifikáció

[1]Department of Evolutionary Zoology and Human Biology, University of Debrecen, 4032 Debrecen, Egyetem tér 1., Hungary, e-mail: david.kovats@gmail.com
[2]Department of Biomathematics and Informatics, Faculty of Veterinary Sciences, Szent István University, 1078 Budapest, István utca 2., Hungary
** corresponding author*

Introduction

Despite the fact that most of the European passerines are identifiable by their morphological traits (Cramp 1988, Sibley & Monroe 1990, Svensson 1992, Watson 2005), there may be groups that are hidden in morphologically cryptic assemblages, which has impeded their discovery (e.g. Illera *et al.* 2008), especially under field circumstances.

In particular, on species of some partially or totally overlapping groups, little or non-significant differences can be observed in their morphological traits (e.g. Päckert *et al.* 2007). If there is gene flow between sister groups breeding next to each other, considerable differences may arise in their morphological or phylogenetical characteristics (e.g. Leisler *et al.* 1997) and in their vocalization (e.g. Lara *et al.* 2012).

Linear discriminant analysis (LDA) and logistic regression (LR) are often used in ecological studies for classification. The usage of these traditional methods is restricted due to their conditions of applicability and their special purpose. For example, the binary outcome in case of LR, and – in case of LDA – the assumptions that the variables should be linearly related and come from a multivariate normal distribution with homogeneous within-group variance. Real ecological variables are often nonlinearly related and have complex interactions and nonhomogeneous dispersion (Cutler *et al.* 2007). Novel classification methods like Classification and Regression

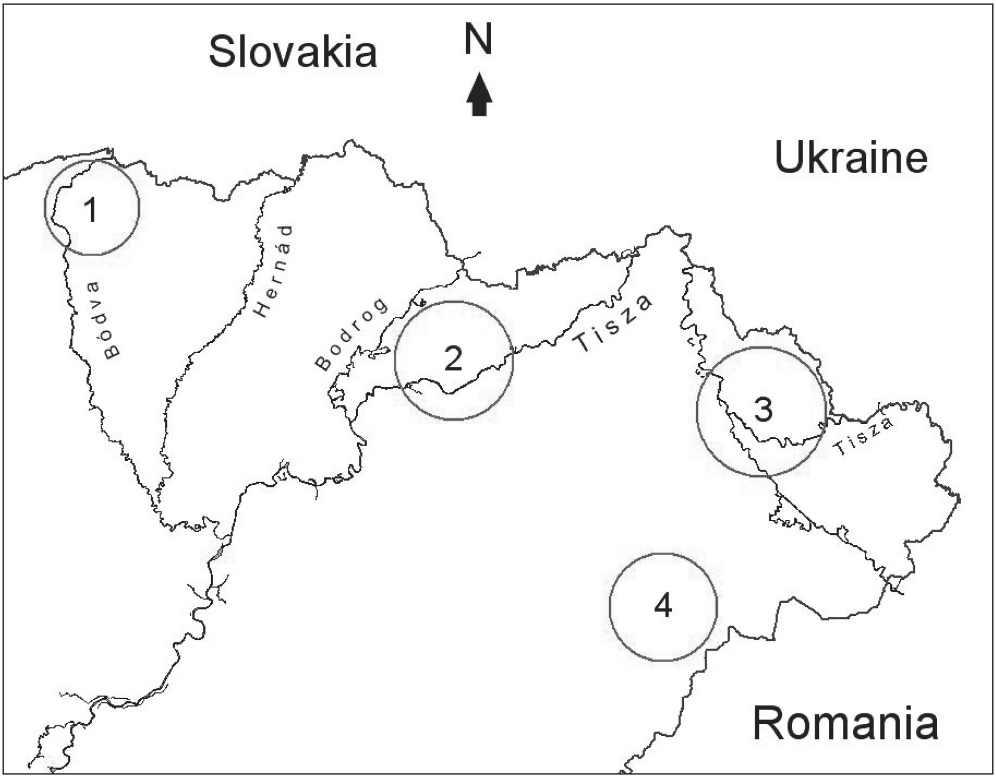


Figure 1. Location of the study areas (1. Bódva, 2. Felső-Tisza, 3. Szatmár-Bereg, 4. Bátorliget)
1. ábra A vizsgálati területek elhelyezkedése (1. Bódva, 2. Felső-Tisza, 3. Szatmár-Bereg, 4. Bátorliget)

Trees and Random Forest methods (De'ath & Fabricius 2000, Strobl *et al.* 2007) can be used in such cases.

The Common Nightingale (*Luscinia megarhynchos* Brehm, 1831) is a widely distributed species via the Palearctic (Cramp 1988). However, morphological differences among their populations have been reported so far only from Eastern Europe (e.g. Reifová *et al.* 2011, Kováts *et al.* 2013).

Here, we report how relevant variables can be selected effectively to distinguish particular groups of Common Nightingales caught in four closely situated study sites in the North-Eastern part of Hungary.

Materials and Methods

Study area

Four study areas were investigated which are situated along the river flood plain areas of Bódva (48°27'N, 20°43'E), on the riversides of Felső-Tisza (48°10'N, 21°42'E), in Szatmár-Bereg (48°07'N, 22°30'E) and in Bátorliget (47°45'N, 22°26'E) in the northeaster region of Hungary *(Figure 1)*. All of these field sites are covered by a rich vegetation of seminatural hardwood and softwood riparian forests with thickets, stands of patchy undergrowth, small ponds and sinuous backwaters. The proportion of the seminatural forests is relatively high in Felső-Tisza and in Bátorliget (approx. 32% and 21%), while it is lower (approx. 4% and 2% only) in Bódva and in Szatmár-Bereg (unpublished data).

Biometric measurements

All measurements were collected in 2006–2013. Birds were captured during the peak of the breeding season, from early May to late June, using Ecotone® mist-nets of different sizes and tape luring (Busse 2000). All birds were measured in millimetres according to Svensson's (1992) recommendations, in the following order: maximal wing length [MWL], wing index (difference in length between the first primary and wing tip) [W^{Ix}], distance between the wing point and the first secondary [I/II], relative length of the first primary [rLP_1], length of the second-, third- and fourth primaries [P_2, P_3, P_4], tail length [TL], bill length (measured to skull) [BL], bill width (measured on the frontal margin of nostrils) [BW] and tarsus length [TL]. In addition, wing-pointedness [W^p] and wing-symmetry [W^{sym}] indexes were calculated following Hołynski (1965) and Busse (1967, 2000). Wing characteristics were measured with a plastic ruler to the closest 1.0 mm, while for the measurements taken on the bill and tarsus a metal calliper with the accuracy of 0.1 mm was used. Furthermore, body mass was also recorded to the closest 0.1 g using a 60-g Pesola spring scale. Only the data of males were analysed.

The phylogenetic patterns of all individuals measured in this study had been previously identified and published elsewhere (Ács & Kováts 2013). Direct PCR sequencing of the mitochondrial DNA (cytochrome oxidase subunit I – COI gene) confirmed that all haplotypes of these four groups are genetically homogeneous with low sequence heterogeneity, thus, they are closely related.

Statistical analyses

In total, 121 individuals were measured in the four study areas (Bódva: *n*=33, Felső-Tisza: *n*=38, Szatmár-Bereg: *n*=23, Bátorliget: *n*=27). For morphological classification, Classification and Regression Trees, Random Forests and Linear Discriminant Analyses were simultaneously used. All the calculations were done using the statistical software R 2.15.2. (R Core Team 2010). The level of significance was set to 0.05.

Methods for morphological classification of the breeding nightingale groups

Classification and Regression Trees (CART)

CART is ideally suited for the analysis of complex ecological data (De'ath & Fabricius 2000, Berggren & Low 2006, Cutler *et al.* 2007). It recognizes relevant variables automatically and clearly illustrates their interrelationships and interactions as well.

CARTs are built using a simple nonparametric regression approach. Both numerical and categorical variables (covariates) can be used to build a tree. The general rule is to split the observations into two parts based on a predictor variable (root), then to split the subset further based on another or the same variable. Then we repeat the process recursively until a stopping criterion is reached. So the space spanned by all predictor variables is recursively partitioned into a set of rectangular areas, where the observations with similar response values are grouped and a constant value (a simple statistics like the mean, or proportion in case of a categorical response) of the response variable is predicted. The aim at each cutting is to reach maximum homogeneity in the response variable within the groups.

In case of the 'ctree' function of the 'party' package (Hothorn *et al.* 2006a) used in this paper, the cutting points are determined and tested by an association measure between the response and the covariates. If there is no more significant relationship between the response and covariates the recursion stops. It can also be stopped by other criteria like the size of the tree, or the number of observations at the cutting points or on the leaves. The level of significance can be adjusted too. The trees are represented graphically and make it easy to understand the relationship of explanatory variables. Important variables are tested near the root, while less important ones right next to the leaves of the CART. It is possible that some of the explanatory variables do not appear in the tree, as not influencing the response variable or explaining the same as one or more other variables strongly correlated with them. These are considered to be irrelevant. In addition, trees are invariant to monotonic transformations of the independent numeric variables; moreover, they recognize interactions. If a classification or regression tree is built, it is able to classify new data. Every new observation can be connected to the relevant leaves of the trees.

Random Forests (RF)

Random Forest (Breiman 2001, Prinzie & Van-Del Poel 2008) is a recursive classification method, which is particularly effective when the sample size (n) is small but the number of the predictor variables (p) is large even in the presence of complex interactions (Strobl *et al.* 2007, 2008, 2009).

RF is an ensemble of Classification and Regression Trees. Each tree is built using a random subset of the data and a random subset of the variables chosen at each cutting point of the tree. Due to this methodology, RFs are more suitable to investigate the role of the variables like simpler methods using all of the variables simultaneously, thus the variables with greater impact can suppress the role of those having smaller impact (Strobl *et al.* 2007, 2008). Furthermore, the classification performance of an ensemble of trees can be much better.

Using this method, the importance of variables can be estimated by measuring the difference in prediction accuracy (i.e. the number of observations classified correctly) before and after permuting a variable, averaged over all trees. If accuracy changes only a little, then the variable has no important role, otherwise its role is substantial. Conditional permutation importance considering the correlation between the variables can be calculated yielding an unbiased estimate of the importance.

This variable importance measure can be applied for variable selection. In this study, we used it for selecting those variables that play important roles in separating the groups living in different areas. We used the 'cforest' function of the R 'party' package (Hothorn *et al.* 2006b, Strobl *et al.* 2007, 2008) for the analysis.

Linear Discriminant Analysis (LDA)

The purpose of discriminant analysis is to create a function which is able to classify the observations into two or more groups (the value of the function changes substantially group by group). Linear discriminant function is a linear combination of the predictor variables. More functions (number of groups minus one) can be created (Manly 1986). LDA was fitted by the 'lda' function of the 'MASS' package (Venables & Ripley 2002). The classifications were carried out by all three methods. The efficacy of the methods can be investigated by comparing the observed and predicted groups and by calculating the prediction accuracy, which is simply the ratio in percentage of the well classified observations.

Results

Based on the results of Random Forest, P_2, P_3, and P_4, followed by BL, BW and TL were the most important variables to distinguish the four Common Nightingale groups. According to the fitted RF, the prediction accuracy was 81.7%, considered to be a good prediction *(Table 1)*. The variables in the order of importance are described on *Figure 2.*

In contrast, the prediction accuracy of CART was lower, reaching only 57.4% *(Table 2)*. However, as in RF, P_2 and BL were also considered as important morphological variables by CART, while body mass (BM) –

	Observed group			
Predicted group	Bátorliget	Bódva	Felső-Tisza	Szatmár-Bereg
Bátorliget	22	2	2	1
Bódva	3	19	2	1
Felső-Tisza	2	7	33	1
Szatmár-Bereg	0	0	0	20
Prediction accuracy: 81.7%				

Table 1. Contingency table of observed and predicted groups by random forest (RF)
1. táblázat A véletlen erdők (RF) által prediktált és megfigyelt populációk kontingencia-táblája

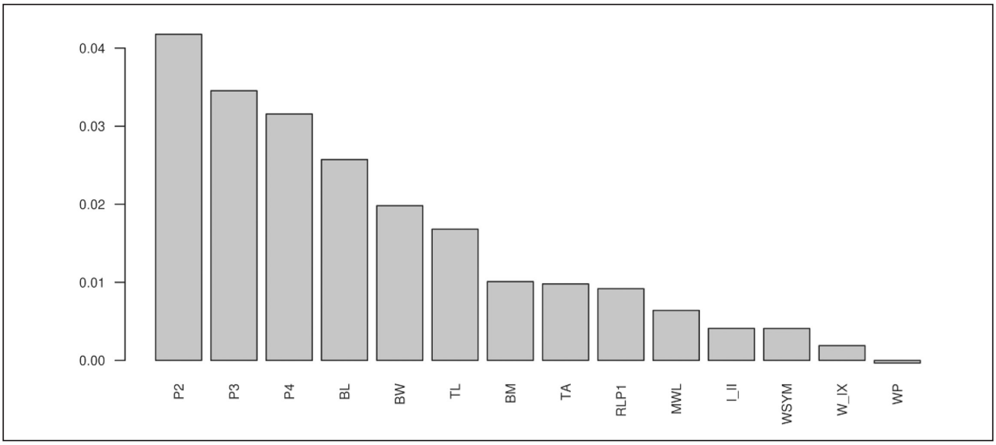


Figure 2. The morphological variables in order of importance estimated by Random Forest (RF)
2. ábra A morfológiai célváltozók a véletlen erdők (RF) által meghatározott fontossági sorrendben

	Observed group			
Predicted group	Bátorliget	Bódva	Felső-Tisza	Szatmár-Bereg
Bátorliget	12	4	3	6
Bódva	7	16	6	4
Felső-Tisza	8	1	28	3
Szatmár-Bereg	0	0	0	10
Prediction accuracy: 57.4%				

Table 2. Contingency table of observed and predicted groups by classification and regression trees (CART)
2. táblázat A döntési fa (CART) által prediktált és megfigyelt populációk kontingencia-táblája

similarly to the RF's prediction – was classified farther from the root *(Figure 3)*.

Describing the data on the plot of the first two discriminant axes of LDA, 'Szatmár-Bereg' group is clearly distinguished *(Figure 4)*. Coefficients of the discriminant functions are given in *Table 3*. Considering the correlations of the discriminant functions with the original variables, LD1 is highly correlated with P_2, P_3 and P_4, while LD2 with BL and BW *(Table 4)*. These results imply that the four nightingale groups differ somewhat from each other in the length of primaries and bill sizes, while other morphological traits showed greater similarities between the study areas.

In case of LDA, prediction accuracy was 64.3% *(Table 5)*, which was slightly better than in case of CART, but worse than in case of RF.

Discussion

Morphological differences of the four nightingale groups

In zoology, the analysis of morphological characteristics is particularly important, since the individual taxa and populations can only be identified and distinguished by certain key traits under field conditions. Based

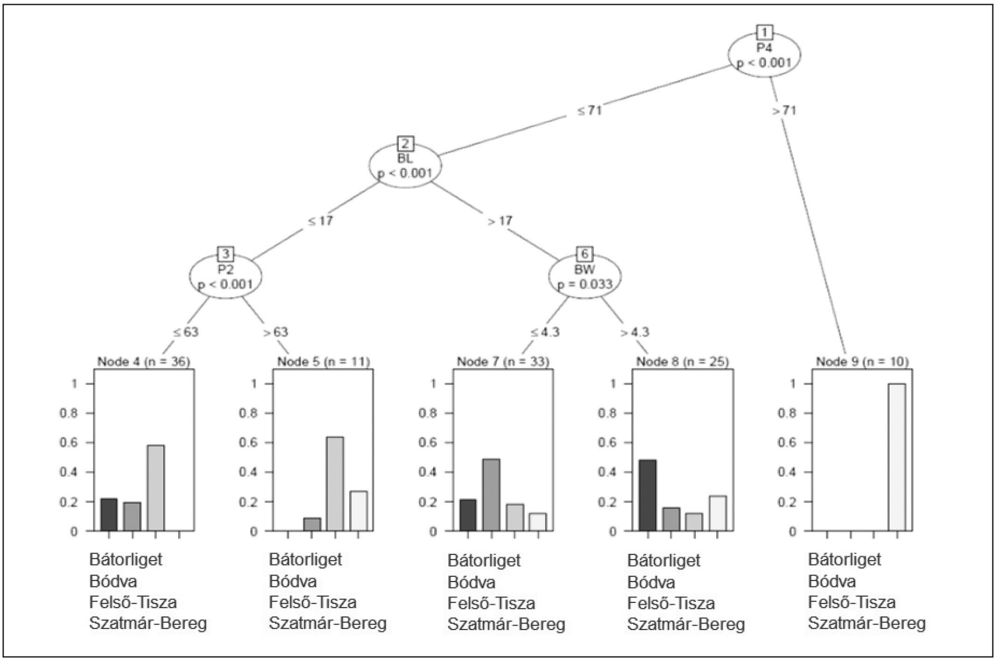


Figure 3. The most important morphological variables given by CART and their interactions. Common Nightingales with narrower bills are distributed in the surroundings of Bódva and Felső-Tisza, while other individuals with wider ones occur in Bátorliget and Szatmár-Bereg. For each inner node, the Bonferroni-adjusted P-values and the ranges on the branches are given, while the fraction of each area is displayed on the leaves

3. ábra Döntési fa (CART) által lényegesnek ítélt és kijelölt morfológiai célváltozók, valamint azok interakciói. A keskenyebb csőrű madarak inkább a Bódva és Felső-Tisza környékén, míg a szélesebb csőrűek Bátorliget és Szatmár-Bereg területén terjedtek el. Minden belső csomópont esetén láthatóak a Bonferroni módszerrel korrigált p-értékek és az ágakon a változók értéktartományai, a leveleken pedig az egyes területek aránya

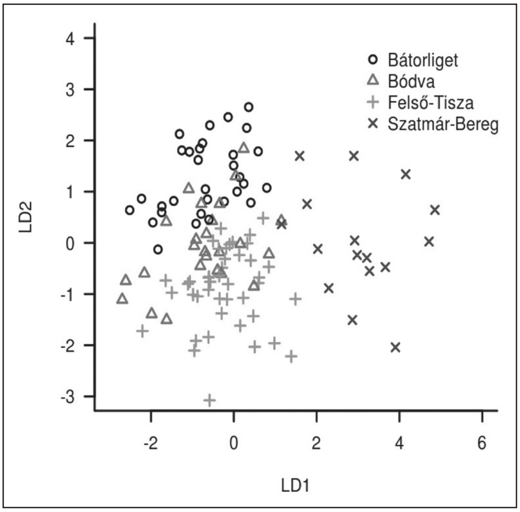


Figure 4. The data described on the first (LD1) and second (LD2) discriminant axes. Marked separation of the individuals from Szatmár-Bereg is clearly visible, whereas those of Bódva and Felső-Tisza greatly overlap

4. ábra Az adatok az első és a második diszkriminancia tengely mentén (LD1 és LD2) való eloszlása. A szatmár-beregi állomány elkülönülése jól megfigyelhető, míg a bódvai, felső-tiszai állományok egymással jelentősen átfednek

Variable	LD1	LD2	LD3
P_2	0.1072	-0.1882	0.2886
P_3	0.2652	0.1577	0.3383
P_4	0.1186	0.1307	-0.6078
BL	0.3518	0.4602	0.6926
BW	0.7542	2.3300	-2.4910
TL	-0.0874	-0.2436	-0.1034
BM	-0.2831	0.2639	0.2189
rLP_1	0.1695	-0.2287	0.2974
MWL	-0.2484	0.1171	-0.2654
I/II	0.0848	-0.3620	0.3236
W^{sym}	0.0434	0.0234	-0.2389
W^{lx}	0.1022	-0.0220	0.0020
Rate of explained variance (%)	67.8	19.7	12.5

Table 3. Coefficients of the three linear discriminant functions (LD1-3)

3. táblázat A lineáris diszkriminancia függvények (LD1-3) együtthatói

Variable	LD1	LD2	LD3
BM	-0.2116	0.4398	0.167
MWL	0.2121	-0.0066	-0.369
W^{lx}	0.3583	-0.0776	-0.151
P_3	**0.8260**	-0.0740	-0.179
rLP_1	0.0415	-0.1572	0.419
I/II	0.3246	-0.3886	0.171
TL	0.0351	-0.3777	-0.545
W^{p}	0.2272	-0.0533	0.120
W^{sym}	0.2348	0.0773	-0.116
P_2	**0.8158**	-0.0273	-0.201
P_4	**0.8239**	-0.0479	-0.247
BL	0.0390	**0.6675**	0.323
BW	-0.0379	**0.6304**	-0.275

Table 4. Correlation coefficients of the linear discriminant functions and the measured variables. The strongest correlation coefficients are highlighted in bold

4. táblázat A lineáris diszkriminancia függvények és a mért változók korrelációs együtthatói. A legnagyobb korrelációs együtthatókat kiemeltük

	Observed group			
Predicted group	Bátorliget	Bódva	Felső-Tisza	Szatmár-Bereg
Bátorliget	19	6	2	4
Bódva	2	13	9	1
Felső-Tisza	6	9	26	2
Szatmár-Bereg	0	0	0	16
Prediction accuracy: 64.3%				

Table 5. Contingency table of observed and predicted groups by linear discriminant analysis (LDA)

5. táblázat A lineáris diszkriminancia analízis (LDA) által prediktált és megfigyelt populációk kontingencia-táblája on the correlations of the measured variables and the linear discriminant functions, the four studied nightingale groups can be distinguished on the basis of the length of the primaries (P_2, P_3, P_4), bill length (BL) and bill width (BW). RF also found these variables as the most important ones in distinguishing the groups.

Our CART trees clearly indicate that birds the Szatmár-Bereg area can be distinguished from the others solely on the basis of the 4th primary length (P_4) *(Figure 3)*. This kind of marked difference between groups with closely situated habitats can possibly be attributed to three alternative, but mutually non-exclusive reasons. First, phenotypic plasticity in site-faithful species can adapt their morphological characteristics to local environment (Grant 1999, Tellería & Carbonell 1999, Agrawal 2001, Pfennig *et al.* 2010, Reifová *et al.* 2011). Second, due to the site fidelity of the Common Nightingale (Sorjonen 1986, Lille 1988, Amrhein *et al.* 2004) certain characteristics can be inherited within a group consisting of phylogenetically homogenous individuals (Ács & Kováts 2013). Third, the formerly regular breeding of the closely related Thrush Nightingale *L. luscinia* in this area could have resulted in hybridization at this locality (Ács & Kováts 2013).

Our results imply that the birds of Szatmár-Bereg comprise a unique group, highlighting the importance of morphological differences. Concerning bill width (BW) the CART suggests that birds with narrower bills are distributed in the areas of Bódva and Felső-Tisza, while others with wider ones occur in Bátorliget and Szatmár-Bereg *(Figure 3, 4)*. These differences are probably due to nutritional stress as Reifová *et al.* (2011) assumed in Poland. This can manifest in available foods, especially in the breeding season when several kinds of insects are the most important food sources, corresponding to the particular habitat.

Discussion of the statistical methodology

Traditional classification methods like discriminant analyses or logistic regression are often used in ecological studies. Classification and Regression Trees, as well as Random Forests used by us are not as widespread. Both methods have the advantage that the response and predictor variables don't have to be linearly related and practically can have any kind of distribution. CART is able to discover the interactions between the variables and the resulting decision tree illustrates the connection system between the predictor and response variables. RF builds an ensemble of the trees from the random subsets of the observations and the variables. Using this technique one can solve classification problems where the number of observations is small compared to the number of variables. Usually, the prediction accuracy is greater with RF than in the case of building only one tree. The disadvantage of this method is that the result cannot be described as expressively as in the case of CART. A further advantage of RF is that it is very well suited for variable selection, since it quantifies the importance of each variable. Moreover, the method used by us is able to give an unbiased estimate of the importance, which is essential in case of highly correlated variables.

In our study, RF proved to be the best, considering the prediction accuracy of the three methods (81.7%). LDA and CART yielded roughly similar results (64.3% and 57.4%). RF and CART discovered more or less the same important explanatory variables, while CART fit only two of the three highly correlated (P_2, P_3, P_4) variables to the tree, but this is the consequence of the CART methodology.

The simultaneous application of the three methods appears to be the most appropriate approach. RF performs very well in variable selection, and it reaches the highest prediction accuracy, while CART gives more information in describing the connection system of the variables.

LDA enables us to calculate the discriminant scores using the discriminant functions. With these scores, further analyses can be carried out (usually substantially less latent variables are generated) and the clustering of the observations can be well described graphically.

In conclusion, above we intended to demonstrate that by using the combination of these methods, even differences between geographically very closely located groups can be detected reliably.

Acknowledgements

We thank Helga Urbán, Beatrix Ferencz, Eszter Zsófia Kovács and Imre Mihalik for their kind help in the field. This work was supported by the National Scientific Research Fund of Hungary (OTKA grant no. 108571) and by a Research Faculty Grant (2014) of the Faculty of Veterinary Science at Szent István University.

References

Agrawal, A. A. 2001. Phenotypic plasticity in the interactions and evolution of species. – Science 294: 321–326. DOI: 10.1126/science.1060701

Amrhein, V., Kunc, H. P. & Naguib, M. 2004. Seasonal patterns of singing activity vary with time of day in the Nightingale *(Luscinia megarhynchos)*. – The Auk 121: 110–117. DOI: 10.1642/0004-8038(2004)121[0110:SPOSAV] 2.0.CO;2

Ács, Z. & Kováts, D. 2013. Phylogenetic patterns of a nightingale population in a contact zone of *Luscinia megarhynchos* and *L. luscinia* in Hungary. – North-Western Journal of Zoology 9(2): 365–373.

Berggren, Å. & Low, M. 2006. Sexual dichromatism in North Island Robins *(Petroica longipes)* is weakened by delayed plumage maturation in males and females. – Emu 106(3): 203–209. DOI: 10.1071/MU05057

Breiman, L. 2001. Random Forests. – Machine Learning 45(1): 5–32. DOI: 10.1023/A:1010933404324

Busse, P. 1967. Application of the numerical indexes of the wing-shape. – Notatki Ornitologiczne 8(1): 1–8.

Busse, P. 2000. Bird Station Manual. SE European Bird Migration Network. – University of Gdańsk, pp. 264

Cramp, S. 1988. The Birds of the Western Palearctic. Vol. 5. – Oxford University Press, Oxford, pp. 1063

Cutler, D. R., Edwards, C. T., Beard, H. K., Cutler, A., Hess, T. K., Gibson, C. J. & Lawler, C. J. 2007. Random Forest for classification in ecology. – Ecology 88(11): 2783–2792. DOI: 10.1890/07-0539.1

De'ath, G. & Fabricius, E. K. 2000. Classification and regression trees: a powerful yet simple technique for ecological data analysis. – Ecology 81: 3178–3192. DOI: 10.1890/0012-9658(2000)081[5B3178:CARTAP]5D2.0.CO;2

Grant, P. R. 1999. The ecology and evolution of Darwin's Finches. – Princeton University Press, Princeton, pp. 492

Hołynski, R. 1965. Methods for the analysis of the wing shape of birds. – Notatki Ornithologiczne 6: 21–25.

Hothorn, T., Buehlmann, P., Dudoit, S., Molinaro, A. & Van Der Laan, M. 2006a Survival Ensembles. – Biostatistics 7(3): 355–373. DOI: 10.1093/biostatistics/kxj011

Hothorn, T., Hornik, K. & Zeileis, A. 2006b Unbiased recursive partitioning: A conditional inference framework. – Journal of Computational and Graphical Statistics 15(3): 651–674. DOI: 10.1198/106186006X133933

Illera, J. C., Richardson, D. S., Helm, B., Atienza, J. C. & Emerson, B. C. 2008. Phylogenetic relationships, biogeography and speciation in the avian genus *Saxicola*. – Molecular Phylogenetics and Evolution 48: 1145–1154. DOI: 10.1016/j.ympev.2008.05.016

Kováts, D., Végvári, Zs. & Varga, Z. 2013. Morphological patterns of a nightingale population in a contact zone of *Luscinia megarhynchos* and *L. luscinia*. – Acta Zoologica Academiae Scientiarum Hungaricae 59(2): 157–170.

Lara, C. E., Cuervo, A. M., Valderrama, S. V., Calderón-F, D. & Cadena, C. D. 2012. A new species of wren (Troglodytidae: *Thryophilus*) from the dry Cauca River canyon, Northwestern Colombia. – The Auk 129(3): 537–550. DOI: 10.1525/auk.2012.12028

Leisler, B., Heidrich, P., Schulze-Hagen, K. & Wink, M. 1997. Taxonomy and phylogeny of reed warblers (genus *Acrocephalus*) based on mtDNA sequences and morphology. – Journal of Ornithology 138: 469–496. DOI: 10.1007/BF01651381

Lille, R. 1988. Species-specific song and mixed singing of Nightingale and Thrush Nightingale *(Luscinia megarhynchos, L. luscinia)*. – Journal of Ornithology 129: 133–159.

Manly, B. 1986. Multivariate Statistical Methods: a Primer. – Chapman and Hall, New York, pp. 159

Päckert, M., Martens, J., Tietze, T. D., Dietzen, C., Wink, M. & Kvist, L. 2007. Calibration of a molecular clock in tits (Paridae) – Do nucleotid substitution rates of mitochondrial genes deviate from the 2% rule? – Molecular Phylogeny and Evolution 44(1): 1–14. DOI: 10.1016/j.ympev.2007.03.006

Pfennig, D. W., Wund, M. A., Snell-Rood, E. C., Cruickshank, T., Schlichting, C. D. & Moczek, A. P. 2010. Phenotypic plasticity's impacts on diversification and speciation. – Trends in Ecology and Evolution 25: 459–467. DOI: 10.1016/j.tree.2010.05.006

Prinzie, A. & Van-Den Poel, D. 2008. Random Forests for multiclass classification: Random MultiNomial Logit. – Expert Systems with Applications 34(3): 1721– 1732. DOI: 10.1016/j.eswa.2007.01.029

R Core Team 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Sibley, C. G. & Monroe, B. L. 1990. Distribution and Taxonomy of Birds of the World. – Yale University Press, New Haven, pp. 1111

Sorjonen, J. 1986. Mixed singing and interspecific territoriality: consequences of secondary contact of two ecologically and morphologically similar nightingale species in Europe. – Ornis Scandinavica 17: 53–67.

Strobl, C., Boulesteix, A-L., Zeileis, A. & Hothorn, T. 2007. Bias in Random Forest Variable Importance Measures: Illustrations, Sources and a Solution. – BMC Bioinformatics 8: 25. pp. 21, DOI: 10.1186/1471-2105-8-25

Strobl, C., Anne-Laure, B., Thomas, K., Thomas, A. & Achim, Z. 2008. Conditional variable importance for random forests. – BMC Bioinformatics 9: 307. pp. 11, DOI: 10.1186/1471-2105-9-307

Strobl, C., Malley, J. & Tutz, G. 2009. An introduction to recursive partitioning: rationale, application, and characteristics of classification and regression trees, bagging, and random forests. – Psychol Methods 14(4): 323–348. DOI: 10.1037/a0016973

Svensson, L. 1992. Identification guide to European Passerines. 4th ed. – Stockholm, pp. 368

Tellería, J. L. & Carbonell, R. 1999. Morphometric variation of five Iberian Blackcap *Sylvia atricapilla* populations. – Journal of Avian Biology 30: 63–71. DOI: 10.2307/3677244

Reifová, R., Reif, J., Antczak, M. & Nachman, M. W. 2011. Ecological character displacement in the face of gene flow: Evidence from two species of nightingales. – BMC Evolutionary Biology 11: 138. pp. 11, DOI: 10.1186/1471-2148-11-138

Venables, W. N. & Ripley, B. D. 2002. Modern Applied Statistics with S. 4th ed. – Springer, New York, pp. 495

Watson, D. M. 2005. Diagnosable versus distinct: Evaluating species limits in birds. – Bioscience 55: 60–68. DOI: 10.1641/0006-3568(2005)05

Ornis Hungarica 2015. 23(2): 31–38.
DOI: 10.1515/orhu-2015-0012

Autumn crane migration and climate change in the Carpathian Basin

Zsolt Végvári

Zsolt Végvári 2015. Autumn crane migration and climate change in the Carpathian Basin. – Ornis Hungarica 23(2): 31–38.

Abstract Weekly counts of roosting cranes were conducted between 2006–2014 in all significant stopover sites of Common Cranes *(Grus grus)* in Hungary, as an extension of the survey programme performed in Hortobágy National Park since 1994. As a result, I detected consistently asymmetrical migration phenologies in Hortobágy, indicating a superposition of several migration waves. Cranes used nearly 60 roost sites in Hortobágy with the largest ones situated in extensive fishponds. In contrast, cranes migrating in Körös-Maros National Park started to overwinter regularly, increasingly roosting in dry wetlands. In Kiskunság cranes tended to stage for shorter periods than in Körös-Maros, with the largest flocks to be observed in Lake Fehér of Szeged fishponds and additionally in a number of alkali lakes. Cranes observed in the Borsodi Mezőség region are considered satellite flocks staging in Hortobágy, as shown by irregular fluctuations.

As a probable result of climatic variability, cranes migrating in Hortobágy have shown the advancement of first arrival dates and exhibited significant, positive relations with local mean monthly temperatures. Additionally, we detected a positive relationship between the Julian date of autumn migration peak and winter mean of the North-Atlantic Oscillation, indicating later autumn arrivals during warmer periods.

Keywords: Common Crane, migration, phenology, global climatic parameter, Hortobágy National Park

Összefoglalás A darvak éjszakázóhelyeken történő szinkronszámlálása 2006–2014 között történt minden nagyobb magyarországi daruátvonuló-helyen, az 1994 óta a Hortobágyi Nemzeti Parkban heti rendszerességgel folyó állományfelmérések kiterjesztéseként. A számlálások eredményeképpen a Hortobágyon konzisztens módon aszimmetrikus vonulásdinamika mutatkozott, ami több vonulási hullám szuperpozíciójára utal. Ezen a területen közel 60 különböző éjszakázóhelyet használtak a darvak, melyek közül a legnagyobbak halastavakon találhatóak. Ezzel szemben a Körös-Marosban átvonuló madaraknál rendszeressé váló áttelelés mutatkozott, melynek során egyre gyakrabban használtak a darvak száraz élőhelyeket. A Kiskunságban a darvak átlagosan rövidebb ideig tartózkodtak, mint a Körös-Marosban, ahol a legnagyobb csapatokat a Szegedi Fehér-tavon figyelték meg. A Borsodi Mezőségben átvonuló madarakat a rendszertelen állománynagyság-változások miatt nagy valószínűséggel a Hortobágyon mozgó csapatok szatellit-populációinak tekinthetjük.

Feltételezhetően a klimatikus paraméterek varianciájának növekedése eredményeként a Hortobágyon átvonuló darvak az első tavaszi érkezések dátumát korábbi dátumok irányába tolták, szignifikáns, pozitív kapcsolatot mutatva a helyi, havi átlaghőmérséklettel. Emellett pozitív, szignifikáns kapcsolatot sikerült kimutatni az őszi vonulási csúcsok julián-dátuma és az Észak-Atlanti Oszcilláció téli átlagértéke között, mely a melegedő őszi időjárás által indukált későbbi érkezésekre utal.

Kulcsszavak: daru, vonulás, fenológia, globális klímaindex, Hortobágyi Nemzeti Park

HNPI-DE Department of Conservation Zoology 4024 Debrecen, Sumen utca 2., Hungary, e-mail: zsolt.vegvari@gmail.com

Introduction

On ecosystem scales, various metrics of climatic processes have shown increasing variance during the past decades, inducing a broad range of ecological responsiveness (IPCC 2015). Specifically, phenological proxies, such as the start of plant blooming, are known to be sensitive to climatic processes (Peñuelas & Filella 2001, Parmesan & Yohe 2003, Macmynowski *et al.* 2007), with several phenological phases currently advancing as a response to recent climate change (Bradley *et al.* 1999). For instance, changes in timing of bird migration is predicted by plant and invertebrate phenologies (Sparks *et al.* 2005) – there are tendencies to migrate earlier in response to earlier springs in the birds' breeding range (Strode 2003, Crick 2004, Lehikoinen *et al.* 2004).

Common Cranes *(Grus grus)* breed in wooded bogs and wetland forests of northern Eurasia and exhibit various migration strategies. While the majority of the crane populations are classified as short-distance migrants based on the results of satellite tracking, some subpopulations, such as those inhabiting the European part of Russia, proved to be long-distance migrants. Furthermore, satellite tracking of several Common Cranes nesting in Finland followed loops connecting Northern Europe, Hungary, Tunisia, Morocco, Spain and Germany. Interestingly, cranes that have recently started to breed in the British Isles are sedentary (Prange 1999).

Common Cranes breeding in Europe and west of Russia migrate along at least four flyways:

(1) the Atlantic Flyway connects the breeding grounds of Sweden, Norway and Germany with the wintering areas in France and Spain,

(2) Cranes breeding in Finland, the Baltic States and Poland use the Baltic-Hungarian Flyway to spend winter in Serbia and Northeast Africa as far south as Sudan and Ethiopia; at their stopover sites in Hortobágy they roost in flocks of up to 55,000 birds (Prange 1999, Végvári & Tar 2002),

(3) Cranes of the East-Baltic Region possibly migrate over the Black Sea and Turkey and spend the winter in Israel with some of them flying to Ethiopia covering ca. 4000 km,

(4) populations of the European part of Russia migrate across the Black Sea and winter in Turkey, Israel and Ethiopia.

The Hortobágy National Park (HNP) is known as the largest stop-over site of the Common Crane in the Baltic-Hungarian Flyway in Europe (Prange 1999), as the peak number of simultaneously roosting cranes during autumn migration has increased from 3000 to 140,000 from 1980–2015. Further, this region is probably the second largest staging of cranes in the world, exceeded only by Nebraska, which hosts up to 500,000 Sandhill Cranes during spring migration (International Crane Foundation 2015). Although regular wintering has not yet been observed in the study area, the frequency of wintering in the southern part of the country has been increasing since 2000 (Végvári unpublished data). As part of an active wetland management system, water depth is kept shallow all year on seven marshes and in one of the largest fishponds to attract cranes for roosting.

Methods

Study area

We conducted standardized, simultaneous weekly survey in all known staging areas of Common Cranes within the Carpathian Basin between 2006–2015 during autumn migration, covering the Hortobágy, Körös-Maros, Kiskunság, Bükk and Fertő-Hanság National Parks in Hungary.

Autumn migration data

Weekly simultaneous censuses were performed during autumn migration and wintering with the help of a large number of experienced volunteers between 2006–2015. Arriving cranes were counted simultaneously once a week at all potential roost sites (marsh or fishpond) during the autumn migration period from 10th September to 31st December. Potential roost sites were identified weekly 2–3 days before the day of the count. Based on previous studies, only wetlands with minimum area of 3 ha and water depth 40 cm or less (Végvári & Tar 2002) could be considered as potential roosting sites. If a potential roosting site was used by

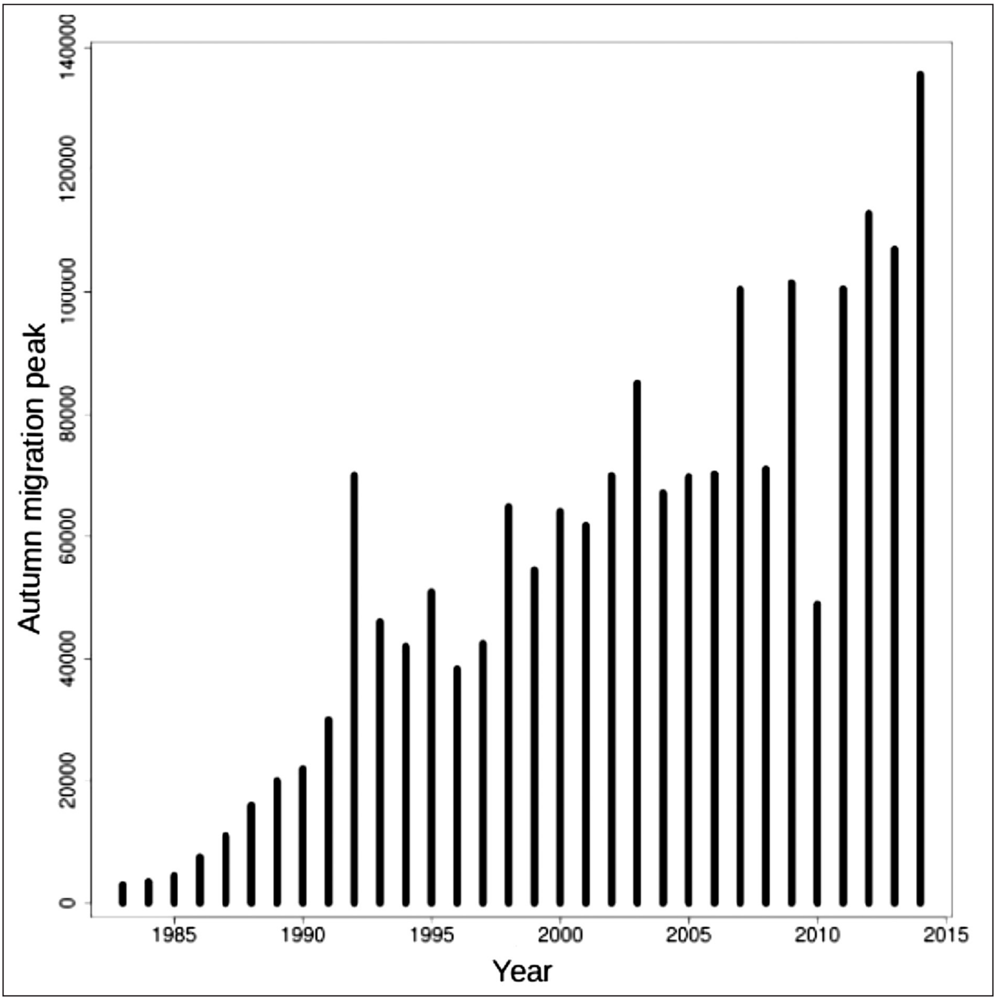


Figure 1. Annual peak numbers of migrating cranes as counted simultaneously in the whole of the Carpathian Basin

1. ábra A Kárpát-medencében szinkronszámlálások alapján együttesen átvonuló darvak évenkénti száma

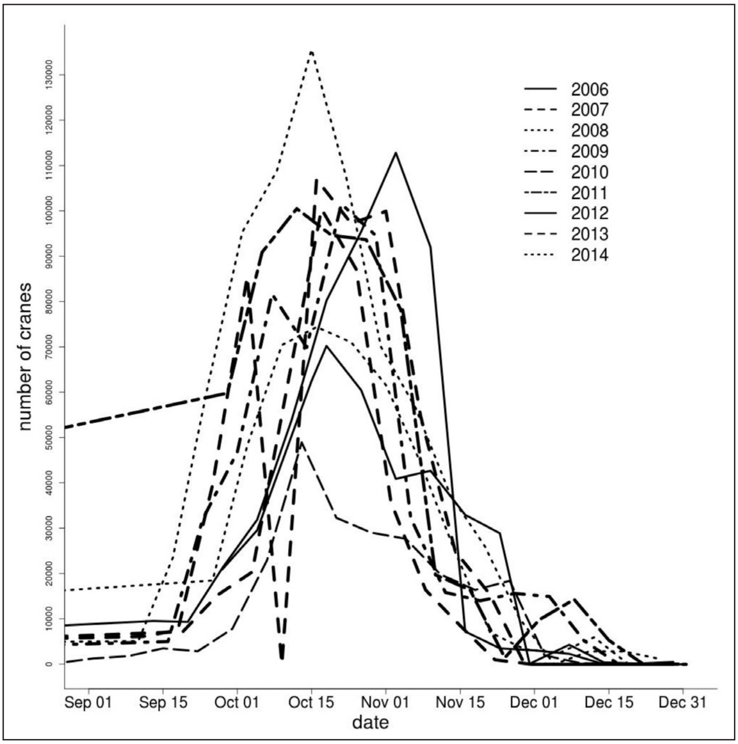


Figure 2. Phenology of autumn crane migration in Hortobágy

2. ábra Az őszi daruvonulás fenológiája a Hortobágyon

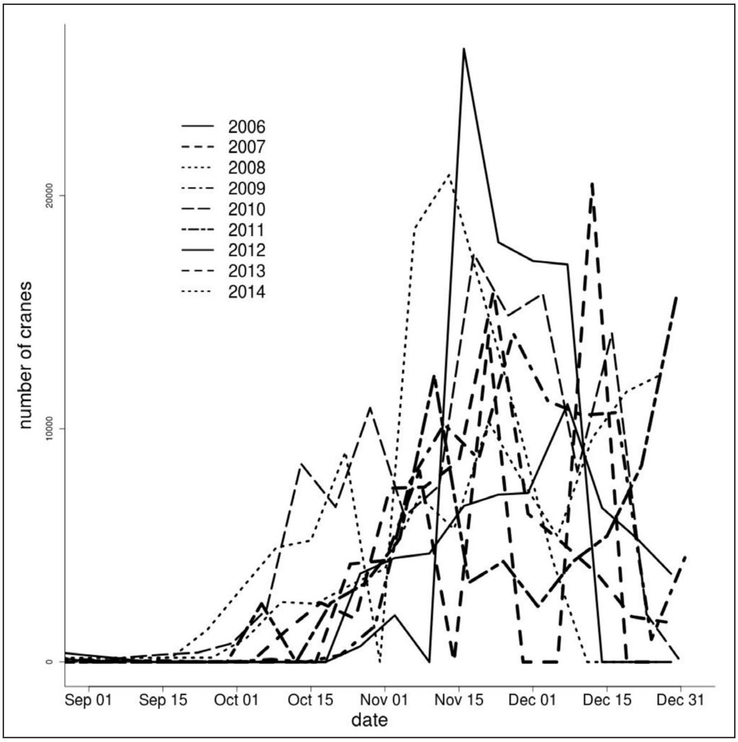


Figure 3. Phenology of autumn crane migration in Körös-Maros

3. ábra Az őszi daruvonulás fenológiája a Körös-Maros térségében

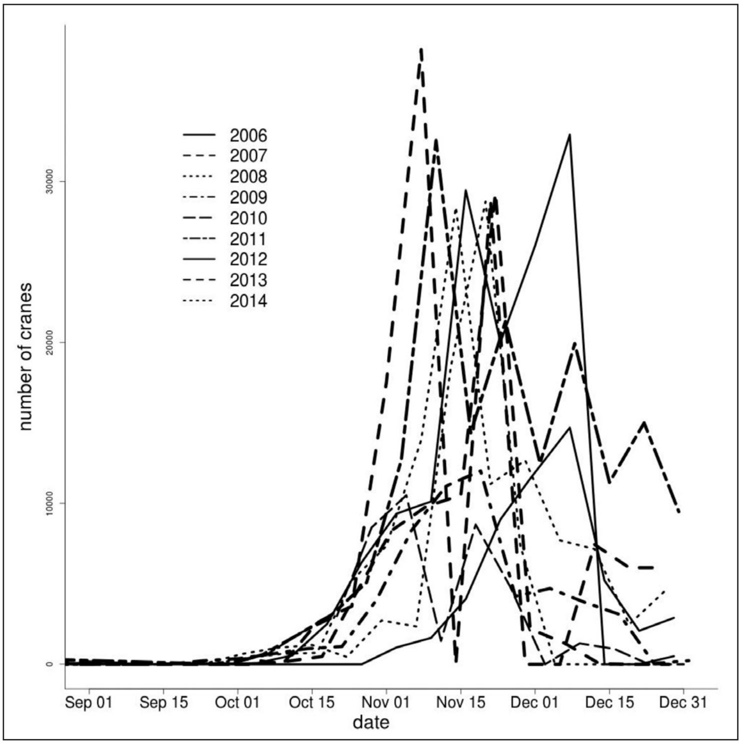


Figure 4. Phenology of autumn crane migration in Kiskunság

4. ábra Az őszi daruvonulás fenológiája a Kiskunságban

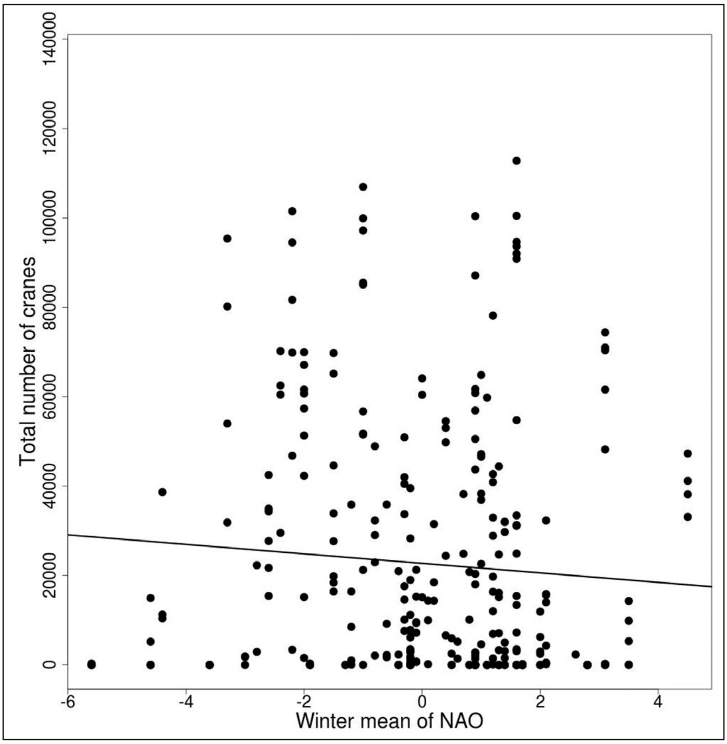


Figure 5. Peak date of autumn crane migration as a function of the winter mean value of the North-Atlantic Oscillation

5. ábra Az őszi daruvonulás maximumának dátuma az Észak-Atlanti Oszcilláció téli átlagértékének függvényében cranes, it was classified as an actual roosting site. To avoid double-counting on each count day counters simultaneously surveyed 2–16 active sites where cranes were present. Roosting counts started two hours before sunset and took three hours, applying roosting count methods suggested by Marsh and Wilkinson (1991), Prange (1999) and Alonso *et al.* (2004). Counts were performed from bird observation blinds or from one to four elevation points at each roost site to survey all flocks arriving from different directions. Surveys were conducted using 8-10× binoculars, and 20-60× as well as 32× spotting scopes.

Results

Regional migratory movements

As shown on *Figure 1*, total counts have non-linear increasing trend with major fluctuations. However, the number of data points is still too low for robust statistical analyses.

Hortobágy

Migration trend in the region is shown by *Figure 1*, exhibiting a consistent temporal pattern between years. Trends are typically asymmetrical, where arrival slopes are significantly smaller than departure estimates. Besides, trend shapes suggest a superposition of several migratory waves, the peak dates of which show a non-significant increasing trend (b=595.0, p=0.07). The largest roost sites are found in artificial fishponds with substantial human disturbance. Additionally, cranes staging in Hortobágy roost in dry meadows or marshes with an increasing frequency, implying low predation pressure in the area.

Körös-Maros

Population trends in the roost sites of the region are shown by *Figure 2.* As compared to the size of the region, cranes choose more than 20 roost sites. In parallel to trends observed in Hortobágy, cranes frequently roost in dry or frozen wetland, especially during the wintering period. The peak dates of annual migration trends show a significant increasing trend (b=1375.7, p=0.012).

The region has become part of the regular wintering site of the North-Voivodina region, as a result of warming winters (Stumberger & Schneider-Jacoby 2010).

Kiskunság

Trends observed in the region are shown by *Figure 3*. Part of the crane flocks migrating from Hortobágy stage in Kiskunság, exhibiting sharper migratory peaks than those of Körös-Maros. The peak dates of annual migration trends show a non-significant increasing trend (b=1874.3, p=0.164). The largest roost sites of the region are located in Lake Fehér of Szeged with numerous flocks showing up in alkaline ponds.

Bükk

Although cranes migrating in Borsodi Mezőség region roost in wetlands within the administration district of the Bükk National Park Directorate, these flocks are probably satellite populations of the Hortobágy stopover site, as shown by intensive fluctuations (due to irregular movements, map not shown).

Fertő-Hanság

Although the region is characterised by low numbers of migratory flocks, the isolation of the site and the close vicinity of the Czech breeding population indicates that cranes observed here join flocks migrating from the Czech Republic which follow the Atlantic Flyway crossing Germany (due to irregular movements, map not shown).

Climatic effects

Autumn migration and climate

We detected a significant, positive relation between peak date and monthly NAO (r^2=0.407, p=0.019) *(Figure 4)*. The relation of the time difference between the timing of peak and median with the monthly mean of local minimum temperatures were also positive (r^2=0.369, p=0.028).

Discussion

I detected a strong population increase of the Common Cranes staging in Hortobágy during the study period. This development – which shows highly similar patterns with the development of total migrating population – parallels the increase observed along the Atlantic Flyway, which corresponds to the increase of breeding populations throughout Europe (Prange 1999). Recently, a hypothesis has been put forward arguing that population growth in the Common Crane might be partially driven by a warming climate in Northern Europe resulting in the northward shifting of the permafrost zone. However, this prediction has not been tested.

Findings of the current work confirm the explosion of the European population, as the peak number of cranes exceeded a magnitude of 100 thousand birds, thus classifying Hungary and Hortobágy the largest stopover site of cranes (Végvári *et al.* 2010). Our results indicate loop migration of crane passing Hungary: crane flocks tracking the Baltic-Hungarian Flyway in autumn migrate across Algeria and Morocco following the Atlantic Flyway during spring migration. As alternating movements between flyways might be a regular element of migration strategy in the European crane populations, it cannot be excluded that years with unexpectedly high autumn peaks indicate the influx of populations breeding in Northwest Russia.

Additionally, migration data indicate that cranes observed in Fertő-Hanság region constitute part of the Czech population tracking the Atlantic Flyway. Further, migration records imply that part of the flocks migrating in South-Hungary fly across Italy and winter in France.

This work revealed that an increasing number of cranes spending winter at Hortobágy might indicate a general shift of the wintering grounds northwards, as has already been detected along the Atlantic Flyway (Prange 1999). Similarly, our findings indicate that cranes migrate earlier after warmer winters, suggesting the northward shift of the northern border of the wintering area.

I showed that the peak date is shifting later for autumn migration as a response to increasing NAO values typical for wetter and warmer climates. Similarly, we detected a delayed arrival of flocks arriving after the date of the median value, implying a delayed fall migration due to warmer conditions in the northern part of Europe. Summarizing, Common Cranes might benefit from global warming like many other short-distance migrants do, by increased survival rates during winter and earlier arrivals on the breeding grounds.

Although in Europe the Common Crane is not endangered and possibly benefits from global warming, its roosting sites in staging areas may be significantly reduced in the near future by human-induced and climate-related wetland losses, especially in southern Europe. However, there are indications that the West-Siberian population wintering in India may be declining probably as a result of wetland loss and structural changes in agricultural technology on the wintering grounds (Meine & Archibald 1996, Végvári & Hansbauer 2009).

Although the Common Crane is not threatened in Europe, it is considered an umbrella species and thus improving conditions for crane migration needs to be considered when developing management plans. On the one hand, it is recommended to be prepared for the increase of the wintering population owing to warming winters, which affects the practice of the management of native wetlands and fishponds. In parallel, the harmonisation of agri-environmental schemes and management plans is required on the other hand.

Acknowledgements

Special thanks go to the ranger services of HNPI, KMNPI, KNPI, BNPI, FHNPI National Park Directorates, as well as to the members of the following NGO-s: Hortobágy Society for Conservation, Birdlife Hungary, members of Zöld Kör, Bakcsó and many citizen ornithologists for data collection.

References

Alonso, J. C., Bautista, L. M. & Alonso J. A. 2004. Family-based territoriality vs. flocking in wintering Common Cranes *Grus grus*. – Journal of Avian Biology 35(5): 434–444. DOI: 10.1111/j.0908-8857.2004.03290.x

Bradley, L. N., Leopold, A. C., Ross, J. & Huffaker, W. 1999. Phenological changes reflect climate change in Wisconsin. – Proceedings of the National Academy of Sciences USA 96: 9701–9704. DOI: 10.1073/pnas.96.17.9701

Crick, H. Q. P. 2004. The impact of climate change on birds. – Ibis 146(Suppl.1): 48–56. DOI: 10.1111/j.1474-919X.2004.00327.x

International Crane Foundation 2010. http://www.savingcranes.org/ (last visited: 11-05-2010).

Lehikoinen, E., Sparks, T. H. & Zalakevicius, M. 2004. Arrival and departure dates. – Advances in Ecological Research 35: 1–31. DOI: 10.1016/S0065-2504 (04)35001-4

Macmynowski, D. P., Root, T. L., Ballard, G. & Greupel, G. R. 2007. Changes in spring arrival of Nearctic-Neotropical migrants attributed to multiscalar climate. – Global Change Biology 13: 2239–2251. DOI: 10.1111/j.1365-2486.2007.01448.x

Marsh, C. P. & Wilkinson, P. M. 1991. The significance of the central coast of South Carolina as critical shorebird habitat. – Chat 54: 69–92.

Meine, C. D. & Archibald, G. W. 1996. The cranes: status survey and conservation action plan. – IUCN, Gland, Switzerland, pp. 1–207.

Parmesan, C. & Yohe, G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. – Nature 421: 37–42. DOI: 10.1038/nature01286

Peñuelas, J. & Filella, I. 2001. Responses to a warming world. – Science 26: 793–795.

Prange, H. 1999. Migration of Common Crane *Grus grus* in Europe. – Vogelwelt 120: 301–305.

Sparks, T. H., Bairlein, F., Bojarinova, J. G., Hüppop, O., Lehikoinen, E. A., Rainio, K., Sokolov, L. V. & Walker, D. 2005. Examining the total arrival distribution of migratory birds. – Global Change Biology 11: 22–30. DOI: 10.1111/j.1365-2486.2004.00887.x

Strode, P. K. 2003. Implications of climate change for North American wood warblers (Parulidae). – Global Change Biology 9: 1137–1144. DOI: 10.1046/j.1365-2486.2003.00664.x

Stumberger, B. & Schneider-Jacoby, M. 2010. Importance of the Adriatic Flyway for Common Crane *(Grus grus)*. – Proceedings of the 7th European Crane Conference, pp. 14–17.

Végvári, Z. & Tar, J. 2002. Roost site selection of the Common Crane *Grus grus* in the Hortobágy National Park, Hungary between 1995–2000. – Ornis Fennica 79: 101–110.

Végvári, Z. & Hansbauer, M. M. 2009. Cranes in northern India. – unpublished report on a pre-study trip in January 2009. Report for Kranichschutz Deutschland and International Crane Foundation, pp. 1–11.

Végvári, Z., Bókony, V., Barta, Z. & Kovács, G. 2010. Life history predicts advancement of avian spring migration in response to climate change. – Global Change Biology 16: 1–11. DOI: 10.1111/j.1365-2486.2009.01876.x

Ornis Hungarica 2015. 23(2): 39–48.
DOI: 10.1515/orhu-2015-0013

Eco-geographical variation in the diet of the Barn Owl *(Tyto alba)* in mountainous areas of France

Guillaume Halliez[1,2*], Clémence Marie Lucie Becel[2] & Victoria Canella[2]

Guillaume Halliez, Clémence Marie Lucie Becel & Victoria Canella 2015. Eco-geographical variation in the diet of the Barn Owl *(Tyto alba)* in mountainous areas of France. – Ornis Hungarica 23(2): 39–48.

Abstract Because of the worldwide distribution of the Barn Owl *(Tyto alba)* and the easily way to find its pellets, it is often used to diet studies. To investigate the eco-geographical impact of mountainous areas on its diet, we conducted studies in the Jura, Alpes, Central and Pyrénées mountains and we also did pellet analysis from 8 sites in the Jura mountains. Analysis of the tooth and skull content of pellets allowed us to draw up two types of change in the diet of *Tyto alba* in correlation with mountain elevation. The first one concerns the Jura, Alpes and Central mountains, where the diversity of the diet declines with the increase in elevation. The second one concerns the Pyrénées mountains, where there is no change in the diversity of the diet, perhaps because of the higher diversity of small mammals caused by mediterranean influence. Thus, it seems that elevation causes a decrease in diet diversity of *Tyto alba* in continental mountains (Jura, Alpes and Central mountains) probably because of more homogeneous landscapes dedicated to grass production. However, in Mediterranean mountains (Pyrénées), a more diversified small mammal guild provides a constant level of diet diversity.

Keywords: Barn Owl, small mammals, mountain, mediterranean influence, continental influence

Összefoglalás A gyöngybagoly *(Tyto alba)* egész világon való elterjedése, és köpeteinek könnyű fellelhetősége miatt gyakori alanya táplálkozási vizsgálatoknak. E dolgozatban a hegyvidéki környezet gyöngybagoly táplálkozására kifejtett öko-geográfiai hatásait teszteltük a Jura, az Alpok, a Francia-középhegység és a Pireneusok területén gyűjtött minták alapján, és köpet-analízist végeztünk a Jura-hegységből származó, 8 különböző területről gyűjtött mintából. A köpetekben talált fog- és koponyamaradványok analízise alapján két csoportot lehetett elkülöníteni: a Jura, az Alpok és a Francia-középhegység területén a táplálék-diverzitása csökkent a tengerszint feletti magasság növekedésével, míg a Pireneusok területén ilyen változást nem tapasztaltunk. A különbség abból adódhat, hogy a kontinentális hegységekben (Jura, Alpok, Francia-középhegység) a tengerszintfeletti magasság növekedésével a homogénebb élőhelyek kedveznek a fűfélék növekedésének, így a kisemlős diverzitás is csökken, míg a mediterrán hegységek (Pireneusok) területén egy sokkal változatosabb kisemlős közösség biztosítja a táplálék-diverzitás állandóságát.

Kulcsszavak: gyöngybagoly, kisemlősök, hegység, mediterrán hatás, kontinentális hatás

[1] *Chrono-Environnement Laboratory, University of Franche-Comté/CNRS – 16 route de Gray, France, e-mail: guillaumehalliez25@hotmail.fr*
[2] *Universitary Group of Naturalists of Franche-Comté – 16 route de Gray, France*
**corresponding author*

Introduction

Because of its worldwide distribution and the easiness to find its pellets, the Barn Owl *(Tyto alba)* is one of the most studied raptor species in the world (Michelat & Giraudoux 1993, Begall 2005, Rasoma & Goodman 2007). This species is able to adapt its diet to variables of its environment, such as small mammal abundance, landscape structure, landscape composition, season etc. (Taylor 2004). Its diet is particularly composed of small mammals in Europe (Bosè & Guidali 2001, Bontzorlos *et al.* 2005, Bernard *et al.* 2010), including the Mediterranean (Leonardi & Dell'arte 2006), and in North America (Colvin & McLean 1986). The Barn Owl is also able to specialize on bats (Boireau 2009, Sommer *et al.* 2009, Roulin & Christe 2013), insects, birds, reptiles or primates (Vargas *et al.* 2002, Tores & Yom-Tov 2003, Shehab *et al.* 2004, Escarlate-Tavares & Pessôa 2005, Alivizatos *et al.* 2006, Platt *et al.* 2009, Souza *et al.* 2009). Thus, it appears that the diet of the Barn Owl in spatial dimension (at world scale) is incredibly varied. There also exist some examples of temporal diet variation linked with temporal variation in prey abundance, making the Barn Owl an opportunistic predator. For example, Bernard *et al.* (2010) showed that during multiannual variation of grassland vole abundance (*Microtus arvalis* or *Arvicola terrestris*), the Barn Owl could adapt its diet to those food resources variation.

Although knowledge about the diet of the Barn Owl at spatial scales is good, there is less information about the variation of diet linked with variation of elevation in mountainous areas. Actually, according to Schneider (1964), we are not able to find information on Barn Owl diet above 700 meters of elevation. However, we and other authors (Libois *et al.* 1983) found pellets up until 1000 meters.

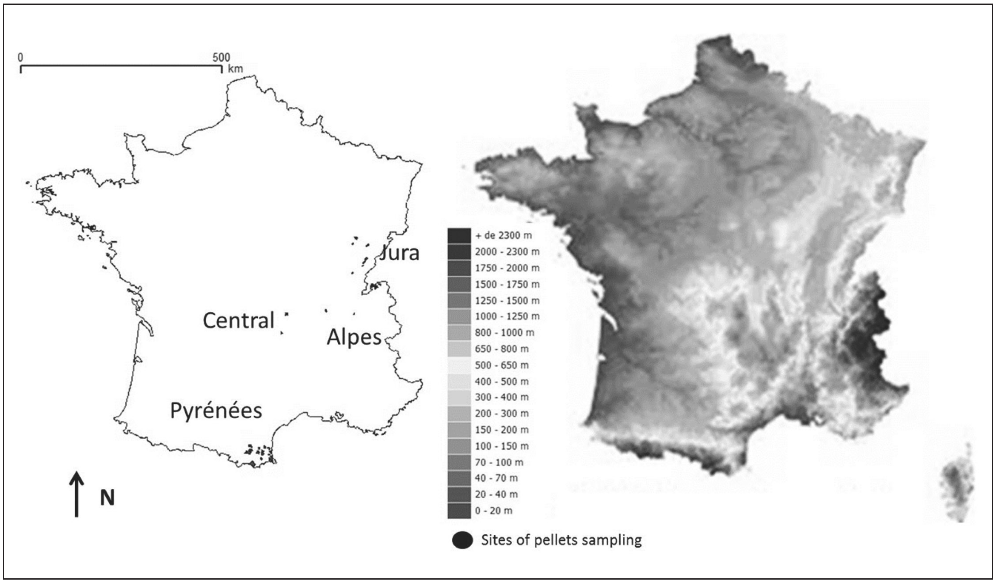


Figure 1. Localisation of the study sites in black (map on the left) and elevation in France (map on the right)

1. ábra A vizsgálati területek elhelyezkedése (bal oldali térkép) és tengerszint feletti magassága Franciaországban (jobb oldali térkép)

We analysed pellet contents from eight sites in the Jura mountains and used data from others studies carried out in the Jura, Alpes, Central and Pyrénées mountains to study the correlation between diet diversity and elevation both in continental and Mediterranean areas.

Material and methods

Study area

The study took place in 44 municipalities of France (8 in Jura, 14 in Alpes, 2 in Central and 19 in Pyrénées) *(Figure 1)*. The climate is continental in the Jura, Central and Alpes mountains, whereas there is a Mediterranean influence in the Pyrénées (Libois *et al.* 1983). The altitude ranged about 9 to 1000 meters. The distance between the sites was at least 2 kilometers, which was lower than the maximal potential distance of predation (Taberlet 1983).

Pellet collection

We collected pellets between 2010 and 2013 in several places in the Jura mountains *(Table 1)*. We identified the small mammal species in the collected pellets by tooth and skull analysis, skull analysis, using informations from Corbet (1964), Restoin and Restoin (1972), Erome and Aulagnier (1982), Lange *et al.* (1986), Michelat and Giraudoux (1989) and Barčiovå and Macholån (2009) in this study. We also considered the number of individuals found in pellets in studies by Michelat and Giraudoux (1993) in the Jura mountains, Aulagnier (1982) and Rigaux and Riols (2008) in the Central mountains and Libois *et al.* (1983) in the Pyrénées, or the proportion of small mammal species from the study by Taberlet (1986) in the Alpes *(Table 1)*. In this study we were not able to individualized Barn Owls to know if several individuals could use the same site.

Elevation value

The elevation of each site was obtained by using IGN French maps.

Diet diversity computing

To compute the diversity of the diet at each site, we decided to calculate a simple Shannon Diversity Index (SDI) as follows (Chao & Shen 2003): assume that there are *S* species in a community and they are labelled from 1 to *S*. Denote the probabilities of species discovery (or relative abundance) by $(\pi_1,\pi_2,\ldots,\pi_S)$ where $\sum_{i=1}^{S} \pi_i = 1$

$$SDI = -\sum_{i=1}^{S} \pi_i \log(\pi_i)$$

Statistical analysis

To study the variation of the SDI in the Barn Owl's diet, we analysed the data from the continental mountains (Jura, Alpes and Central) separately from the Mediterranean Pyrénées mountains because of the potential difference in the small mammals species present (22 and 27, respectively). We fitted a simple linear model, and checked the normal distribution of residuals and the homocedasticity of the variance. The null hypothesis is that the SDI of the Barn Owl's diet does not depend on the elevation in meters.

site	elevation	*Microtus arvalis*	*Microtus agrestis*	*Microtus subterraneus*	*Microtus nivalis*	*Arvicola terrestris*	*Arvicola sapidus*	*Clethrionomys glareolus*	*Microtus duodecimcostatus*	*Pitymys pyrenalicus*
Saint-Maurice	293	137	6	0	0	4	0	4	0	0
Ferme de Courbey	289	16	7	0	0	2	0	14	0	0
Chapelle d'huin	782	18	0	0	0	2	0	0	0	0
Chenevrey-et-morogne	200	41	1	0	0	1	0	0	0	0
Courvières	820	18	0	0	0	0	0	0	0	0
Cuvier	827	178	2	0	0	0	0	0	0	0
Blye	470	79	1	0	0	0	0	0	0	0
Mièges	749	338	23	0	0	0	0	0	0	0
Bouclans	430	362	12	0	0	15	0	4	0	0
Courpière	310	2350	647	3	0	106	3	115	0	0
Canet	9	0	34	0	0	0	10	0	35	0
Claira	10	0	5	0	0	0	4	0	16	0
Corneilla del vercol	11	0	31	0	0	0	1	0	79	0
Argelès-sur-mer	16	0	21	0	0	0	0	0	2	0
Espira de l'agly	28	0	3	0	0	0	0	0	5	0
Pezilla-la-rivière	67	0	89	0	0	0	2	0	31	0
Sorède des albères	80	0	6	0	0	0	1	0	1	0
Thuir	91	0	63	0	0	0	2	0	0	0
Saint-féliu d'avall	97	0	255	0	0	0	29	0	43	0
Latour de France	101	0	12	0	10	0	6	0	0	0
Ille-sur-tête	149	0	0	0	0	0	0	0	0	0
Caudiès de fen	309	0	19	0	0	0	0	0	0	0
Oms	515	0	23	0	0	0	2	0	0	0
Sournia	515	0	30	0	0	0	0	10	0	1
Montbolo	576	0	70	0	0	0	0	0	0	0
Mosset	600	19	198	0	2	0	0	17	6	0
Prats de mollo	735	9	783	0	1	0	0	2	0	1
Rabouillet	900	28	73	0	0	0	1	27	0	8
Col d'aussières	1000	21	22	0	0	0	0	3	0	5
Brens	570	36.92	6.27	0	0	11.46	0	0.88	0	0
Brenthonne	550	28.39	8.81	0	0	5.84	0	1.02	0	0
Chens sur léman	410	30.12	3.39	0	0	2.58	0	0.70	0	0
Douvaine	430	46.56	5.31	0	0	3.35	0	0.69	0	0
Draillant	630	28.90	10.02	0	0	2.79	0	0.49	0	0
Fessy	580	34.53	10.54	0	0	3.36	0	1.79	0	0
Féternes	780	20.92	8.04	0	0	5.76	0	0.45	0	0
Le lyaud	650	34.85	6.17	0	0	2.66	0	0.28	0	0
Marclaz	430	36.43	11.92	0	0	10.37	0	0.68	0	0
Messery 1	420	32.78	9.42	0	0	3.83	0	1.18	0	0
Messery 2	420	39.17	4.46	0	0	3.14	0	1.82	0	0
Nernier	400	37.57	7.84	0	0	1.43	0	1.24	0	0
Perrignier	560	27.53	11.63	0	0	4.97	0	0.60	0	0
Saint-Didier	550	24.74	6.25	0	0	11.72	0	0.78	0	0
Sciez	410	37.69	7.75	0	0	2.81	0	0.78	0	0
Cohade	450	293	53	0	0	3	1	9	0	0

Table 1. Numbers of individuals found in pellets from our analysis and the studies of Michelat and Giraudoux (1993) in the Jura, Aulagnier (1982) and Rigaux and Riols (2008) in the Central, Libois *et al.* (1983) in the Pyrénées or proportion of each species of small mammal from the study of Taberlet (1986) in the Alpes

1. táblázat A bagolyköpetekben talált egyedek száma a különböző gyűjtőhelyeken

Computing environment

Data management were performed with R 2.12.0. software (R-Core Team 2012), using the following packages: pgirmess (Giraudoux 2012) and vegan (Oksanen *et al.* 2014).

Results

Jura mountains diet composition

Saint-Maurice is the most diverse site in terms of prey species, 12 species dominating the diet (in decreasing order of abundance: *Microtus arvalis*, *Crocidura russula* and *Sorex coronatus/araneus*). The same order of abundance was found for Courvières, Cuvier, Blye, Mièges and Bouclans. Ferme de Courbey provided only 9 species dominated by *Sorex coronatus/araneus*, *Microtus arvalis* and *Clethrionomys glareolus*. Chapelle d'Huin was dominated by *Microtus arvalis, Sorex coronatus/araneus* and *Arvicola terrestris,* while Chenevrey-et-Morogne was dominated by *Microtus arvalis, Crocidura russula* and *Apodemus* spp.

Alpes diet composition

The Alpes diet composition was mainly dominated by *Microtus arvalis*, *Crocidura russula* and *Sorex coronatus/araneus,* and occasionally by species like *Arvicola terrestris* or *Apodemus* spp.

Central mountains diet composition

Both site in the Central mountains were dominated in terms of number of individuals by *Microtus arvalis*, *Crocidura russula* and *Sorex coronatus/araneus*.

Pyrénées diet composition

For the diet of the Barn Owl in the Pyrénées mountains, there is a lowland site with strong Mediterranean influence, where the Barn Owl feeds mainly on *Mus spretus.* At middle altitudes, the Barn Owl feeds on *Sorex* spp., *Microtus arvalis*, *Clethrionomys glareolus* and *Pitymys pyrenaicus*. The middle altitudes are characterized by the presence of *Microtus agrestis*, *Apodemus* spp., *Crocidura* spp.

Elevation effect on the SDI of the Barn Owl's diet

For the continental mountains (Jura, Alpes and Central), we found a significant negative relationship between elevation (in meters) and the SDI value *(Figure 2a),* following this equation: SDI value=-0.40* elevation value + 1.59 (ANOVA, P-value=0.04, R^2=0.12). However, for the Mediterranean mountain (Pyrénées), we did not find relationship between the elevation (in meters) and the SDI value (ANOVA, P-value=0.27) *(Figure 2b)*.

Discussion

Continental mountain diet composition

Our first results indicate that the prey species at continental mountain sites are dominated by *Microtus arvalis*, *Crocidura russula* and *Sorex coronatus/araneus*. This may be explained by the environmental context of those sites, i.e., they are surrounded by human-inhabited areas and open fields with crops and grass, which are their most favourable habitats (Quéré & Le Louarn 2011). This seems to be the same

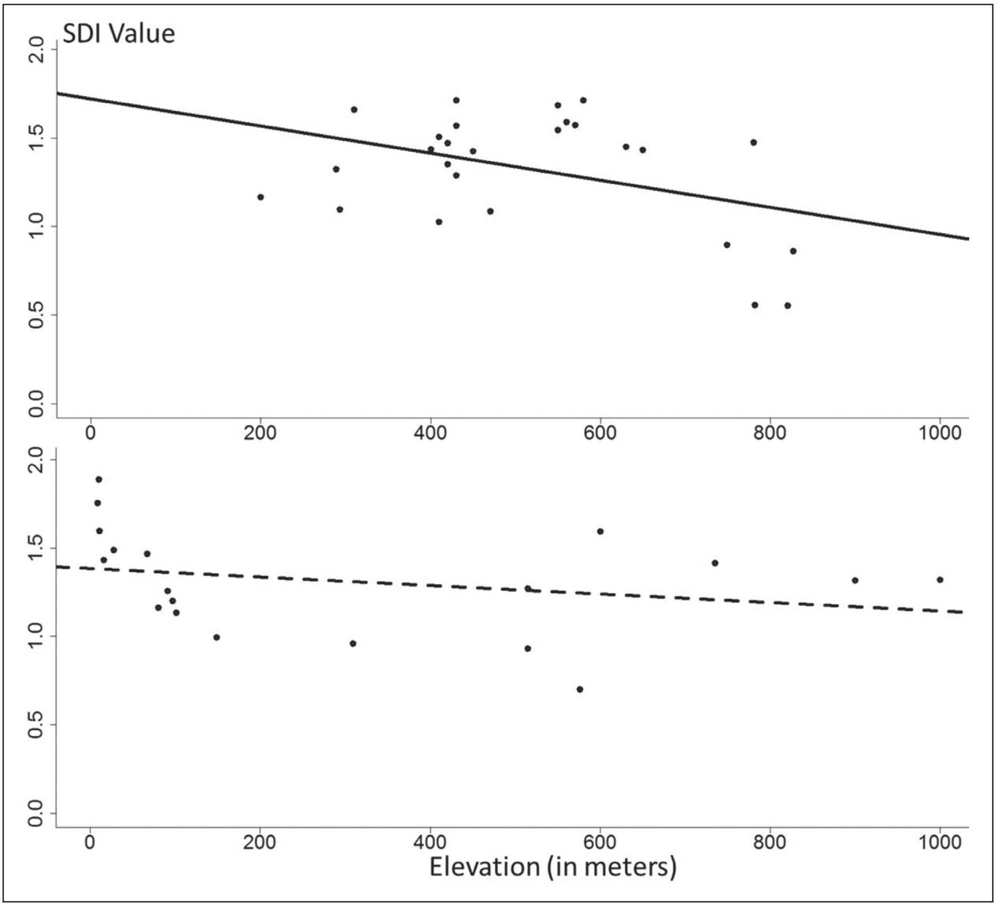


Figure 2. SDI value of the Barn Owl's diet variation regarding on elevation in continental mountains (a) and Mediterranean mountains (b)

2. ábra A gyöngybagoly táplálkozási változatosságának SDI értéke a tengerszint feletti magasság függvényében a kontinentális (a), illetve a mediterrán hegységekben (b)

for *Crocidura russula,* as Michelat and Giraudoux (1993) found that this species was only trapped in open fields and grove areas. Taberlet (1986) considered *C. russula* to be associated with open landscapes and with human-created habitats in the northern part of its distribution. *Sorex coronatus/araneus,* the third most abundant species in the present study, was trapped particularly in grove and hedgerows by Michelat and Giraudoux (1993). The occurrence of *Mus musculus* and *Neomys fodiens* as part of the Barn Owl's diet could be explained by the vicinity of a village, as well as a little river, respectively.

Conversely, the site of Ferme de Courbey is different from the other sites, because it is dominated by *Sorex coronatus*, *Microtus arvalis* and *Clethrionomys glareolus*. The immediate vicinity of abandoned land and forests may explain the strong prevalence of *Sorex coronatus* and *Clethrionomys glareolus,* which are hedgerow- and forest specific species (Michelat & Giraudoux 1993, Quéré & Le Louarn 2011) as for the strong presence of a forested specific species: *Apodemus* spp. The strong prevalence of *Microtus arvalis* could be explained by the presence of crops and grass fields in the valley.

Moreover, as expected, we found strong prevalence of *Microtus arvalis* and *Sorex coronatus*/*araneus* in the pellets, as these species comprise the basic diet of the Barn Owl in Europe (Michelat & Giraudoux 1993, Bosè & Guidali 2001, Askew *et al.* 2007, Bernard *et al.* 2010).

Mediterranean mountain diet composition

Considering the diversity of the landscapes, the Pyrénées-orientales area is one of the most varied in France. Vegetation maps show habitats ranging from coastline to medium-high mountains. The eumediterranean status of the area is indicated by the presence of *Mus spretus* and the absence of *Microtus arvalis* or *Sorex* spp. There also exist submediterranean areas with simultaneous presence of *Mus spretus* and *Sorex* spp. *Microtus duodecimeostatus*, *Suncus etruscus* and *Crocidura suaveolens* presence claimed for Mediterranean areas. *Microtus duodecimeostatus* characterized the presence of crop fields. The abundance of the three species of *Crocidurinae,* especially *Crocidura russula,* characterized some micro-habitats, like dykes (Fons 1975, Genoud & Hausser 1979).

Elevation effect on the SDI value of the Barn Owl's diet indicates two ecogeographical trajectories: continental and Mediterranean mountains

Our results show that it is possible to differentiate between French continental and Mediterranean mountain areas using SDI values of prey diversity in the Barn Owl's pellets and relate these to elevation: the SDI decreases with increasing elevation in continental mountains and does not change in Mediterranean areas. As for continental mountains, two variables could explain the decrease of diet diversity when elevation increases: i) landscape composition, creating outbreaks of certain prey species, and ii) limited number of species. Indeed, in mountainous areas of France, land use policy led to an agricultural specialization towards grass production and towards larger parcel sizes (López-i-Gelats *et al.* 2011). This promoted the emergence of multiannual vole (*Arvicola terrestris* and *Microtus arvalis*) population fluctuations at large spatial and temporal scales (Delattre *et al.* 1992, Giraudoux *et al.* 1997, Delattre *et al.* 2006, Foltête *et al.* 2008, Berthier *et al.* 2013). Delattre *et al.* (1992) showed that damages due to multiannual fluctuation patterns of the Common Vole increases with the Ratio of Permanent Grassland to Farmland (RPGF). For *Arvicola terrestris,* Saucy (1994), in Switzerland, found cyclic changes in population abundance with statistically significant periods ranging between 5 and 7 years. In Franche-Comté, France, Giraudoux *et al.* (1997) found a 5-6 year cycle that was established since the early '70s after the expansion of permanent grassland in farmland at a regional scale. This specialization toward grass production could lead to a very important population increase of *Arvicola terrestris* and *Microtus arvalis*. Also, Bernard *et al.* (2010) showed that during multiannual variation of grassland vole abundance, rodent frequency in the diet of *Tyto alba* ranged from 54% to 61%, with *Arvicola terrestris* and *Microtus arvalis* as dominant preys, and that the proportion of *Sorex* spp. could reach 34%.

This means that in the continental sites of the present study, above 700 meters, three species could represent almost 100% of the diet of the Barn Owl because of landscape homogeneity (grassland). Thus, the agricultural specialization creating landscape homogeneity and vole outbreaks in grassland areas could be an explanation of the decrease of SDI value in continental mountains. Another possibility is that the number of potential prey species is 22. Indeed, as our continental sites reach only 820 meters at the maximum of elevation the diet of the Barn Owl could not account the presence of new species as *Microtus nivalis*, *Sorex alpinus*, *Sorex antinorii*, *Apodemus alpicola*. In the Mediterranean Pyrénées mountains, we observed that the SDI value remained stable in lowland, as well as in mountainous areas. The first explanation for that can be that this area is not concerned by outbreaks of Water Vole or Common Vole, keeping the diet of the Barn Owl relatively diversified. Moreover, while some species are present in coastline areas *(Microtus duodecimeostatus, Mycromis minutus, Mus spretus, Sorex coronatus/araneus)* (Libois *et al.* 1983), they are absent in the mountains and are replaced by mountain species *(Microtus arvalis, Microtus nivalis, Clethrionomys glareolus, Pitymys pyrenaicus, Sorex minutus, Neomys fodiens)* (Quéré & Le Louarn 2011).

Conclusion

To study the eco-geographical impact of mountainous areas on the Barn Owl's diet, we used the results of some studies from the Jura, Alpes, Central and Pyrénées mountains and we also carried out pellet analysis at 8 sites in the Jura mountains. Our results indicate that there are two dietary types of *Tyto alba* in correlation with elevation. The first one is typical of the Jura, Alpes and Central mountains, were the diversity of the diet declines with the increase in elevation. The second is typical of the Pyrénées mountains, where the diversity of the diet remains stable perhaps because of the higher diversity of small mammals as a result of Mediterranean influence. Finally, we propose that elevation makes diet diversity of *Tyto alba* decrease in continental mountains probably because of more homogeneous landscapes due to specialization towards grass production. In Mediterranean mountain areas, the influence of a more diverse small mammal guild contributes to a constant level of diet diversity.

Acknowledgement

We would like to express our gratitude to referees and József Vuts who made the language corrections for the manuscript.

References

Alivizatos, H., Goutner, V., Athanasiadis, A. & Poirazidis, K. 2006. Comparative temporal prey use by Barn Owl *(Tyto alba)* and Little Owl *(Athene noctua)* in the Evros Delta, northeastern Greece. – Journal of Biological Research 6: 177–186.

Askew, N. P., Searle, J. B. & Moore, N. P. 2007. Agri-environment schemes and foraging of Barn Owls *Tyto alba*. – Agriculture, Ecosystems and Environment 118: 109–114. DOI: 10.1016/j.agee.2006.05.003

Aulagnier, S. 1982. Notes sur le regime alimentaire de la chouette effraie *(Tyto alba)* dans une localité de Haute-Loire [Note on diet of Barn Owl *(Tyto alba)* in Haute-Loire village]. – Le Grand Duc 19: 15–16. (in French)

Barčiovà, L. & Macholàn, M. 2009. Morphometric key for the discrimination of two wood mice species, *Apodemus sylvaticus* and *A. flavicollis*. – Acta Zoologica Academiae Scientiarum Hungaricae 55(1): 31–38.

Begall, S. 2005. The relationship of foraging habitat to the diet of Barn Owls *(Tyto alba)* from central Chile. – Journal of Raptor Research 39(1): 97–101.

Bernard, N., Michelat, D., Raoul, F., Quéré, J. P., Delattre, P. & Giraudoux, P. 2010. Dietary response of Barn Owls *(Tyto alba)* to large variations in populations of Common Voles *(Microtus arvalis)* and European Water Voles *(Arvicola terrestris)*. – Canadian Journal of Zoology 88: 416–426. DOI: 10.1139/Z10-011

Berthier, K., Piry, S., Cosson, J. F., Giraudoux, P., Foltête, J. C., Defaut, R., Truchetet, D. & Lambin, X. 2013. Dispersal, landscape and travelling waves in cyclic vole populations. – Ecology Letters 17(1): 53–64. DOI: 10.1111/ele.12207

Boireau, J. 2009. Problèmes posés par l'effraie des clochers *Tyto alba* dans cinq colonies de reproduction de grand rhinolophe *Rhinolophus ferrumequinum* (Schreber, 1774) en Bretagne occidentale [Problems caused by Barn Owl *Tyto alba* presence in five settlements of *Rhinolophus ferrumequinum* (Schreber, 1774) in occidental Britain]. – Le Rhinolophe 18: 43–49. (in French with English Summary)

Bontzorlos, V. A., Peris, S. J., Vlachos, C. G. & Bakaloudis, D. E. 2005. The diet of Barn Owl in the agricultural landscapes of central Greece. – Folia Zoologica 54(1–2): 99–110.

Bosè, M. & Guidali, F. 2001. Seasonal and geographic differences in the diet of the Barn Owl in an agro-ecosystem in northern Italy. – Journal of Raptor Research 35(3): 240–246.

Chao, A. & Shen, T. J. 2003. Nonparametric estimation of Shannon's index of diversity when there are unseen species in sample. – Environmental and Ecological Statistics 10: 429–443. DOI: 10.1023/A:1026096204727

Colvin, B. A., McLean, E. B. 1986. Food habits and prey specificity of the Common Barn Owl in Ohio. – Ohio Journal of Science 86: 76–80.

Corbet, G. B. 1964. The identification of British mammals. – British Museum London, pp. 46

Delattre, P., Clarac, R., Melis, J. P., Peydell, D. R. J. & Giraudoux, P. 2006. How moles contribute to colonization success of Water Voles in grassland: implications for control. – Journal of Applied Ecology 43: 353–359. DOI: 10.1111/j.1365-2664.2006.01134.x

Delattre, P., Giraudoux, P., Baudry, J., Musard, P., Toussaint, M., Truchetet, D., Stahl, P., Poule, M. L., Artois, M., Damange, J. P. & Quéré, J. P. 1992. Land use patterns and types of Common Vole *(Microtus arvalis)* population kinetics. – Agriculture, Ecosystems and Environment 39: 153–169.

Erome, G. & Aulagnier, S. 1982. Contribution à l'identification des proies de rapaces [Contribution to the raptor's prey identification]. – Bièvre 4: 129–135.

Escarlate-Tavares, F. & Pessôa, L. M. 2005. Bats (Chiroptera, Mammalia) in Barn Owl *(Tyto alba)* pellets in northern Pantanal, Mato Grosso, Brazil. – Mastozoologia Neotropical 12(1): 61–67.

Foltête, J. C., Berthier, K. & Cosson, J. F. 2008. Cost distance defined by a topological function of landscape. – Ecological Modelling 210(1–2): 104–114. DOI: 10.1016/j.ecolmodel.2007.07.014

Fons, R. 1975. Premières données sur l'écologie de la Pachyure étrusque, *Suncus etruscus* (Savi, 1822) et comparaison avec deux autres Crocidurinae: *Crocidura russula* (Hermann, 1780) et *Crocidura suaveolens* (Pallas, 1811), (Insectivora, Soricidae) [First data on Suncus etruscus (Savi, 1822) ecology and comparison with two others Crocidurinae: *Crocidura russula* (Hermann, 1780) and *Crocidura suaveolens* (Pallas, 1811), (Insectivora, Soricidae)]. – Revue d'Ecologie (Vie Milieu) 25: 315–360. (in French)

Genoud, M. & Hausser, J. 1979. Ecologie d'une population de *Crocidura russula* en milieu rural montagnard (Insectivora, Soricidae) [*Crocidura russula* (Insectivora, Soricidae) population ecology in rural mountain ecosystem]. – Revue d'Ecologie (Terre et Vie) 33: 539–554. (in French with English Summary)

Giraudoux, P. 2012. pgirmess: Data analysis in ecology. – R package version 1.5.2.

Giraudoux, P., Delattre, P., Habert, M., Quéré, J. P., Deblay, S., Defaut, R., Duhamel, R., Moissenet, M. F., Salvi, D. & Truchetet, D. 1997. Population dynamics of fossorial Water Vole *(Arvicola terrestris scherman)*: a land use and landscape perspective. – Agriculture, Ecosystems and Environment 66: 47–60.

Lange, R. A., Van Winden, P., Twisk, J., De Laender, & Speer, C. 1986. Zoogdieren van de Benelux Herkenning en onderzoek, met uitzondering van de hoefdieren en de zeezoogdieren [Mammals of the Benelux recognition and research, with the exception of marine mammals and ungulates]. – ERLA, Amsterdam, pp. 193 (in Dutch)

Leonardi, G. & Dell'Arte, G. L. 2006. Food habits of the Barn Owl *(Tyto alba)* in a steppe area of Tunisia. – Journal of Arid Environments 65: 677–681. DOI: 10.1016/j.jaridenv.2005.10.007

Libois, R. M., Fons, R. & Saint-Girons, M. C. 1983. Le régime alimentaire de la chouette effraie, *Tyto* *alba*, dans les Pyrénées-orientales. Etude des variations écogéographiques [Barn Owl's diet in Pyrénées-orientales. Eco-geographical variation study]. – Revue d'Ecologie (Terre Vie) 37: 187–217. (in French with English Summary)

López-i-Gelats, F., Milán, M. J. & Bartolomé, J. 2011. Is farming enough in mountain areas? Farm diversification in the Pyrenees. – Land Use Policy 28: 783–791. DOI: 10.1016/j.landusepol.2011.01.005

Michelat, D. & Giraudoux, P. 1989. Répartition des mammifères proies de la chouette effraie en Franche-Comté [Barn Owl's mammal preys distribution in Franche-Comté]. – Falco 23: 12–37. (in French)

Michelat, D. & Giraudoux, P. 1993. Relation proies-prédateur-paysage chez la chouette effraie *Tyto alba* pendant l'élevage des jeunes [Prey-predator-landscape relationship for Barn Owl *Tyto alba* during rearing]. – Alauda 61(2): 65–72. (in French with English Summary)

Oksanen, J., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P. R., O'Hara, R. B., Simpson, G. L., Solymos, P., Stevens, M. H. H. & Wagner, H. 2014. Vegan: Community Ecology Package. R package version 2.0-10 [online]. Available from http://CRAN.R-project.org/package=vegan.

Platt, S. G., Rainwater, T. R., Leavitt, D. J. & Miller, S. M. 2009. Diet of Barn Owls *(Tyto alba)* in northern Belize. – The Southwestern Naturalist 54(1): 104–107. DOI: 10.1894/MH-43.1

Quéré, J. P. & Le Louarn, H. 2011. Les rongeurs de France, faunistique et biologie [French rodents, systematic and biology]. – Quae, Versailles, pp. 311 (in French)

Rasoma, J. & Goodman, S. M. 2007. Food habits of the Barn Owl *(Tyto alba)* in spiny bush habitat of arid southwestern Madagascar. – Journal of Arid Environments 69: 537–543. DOI: 10.1016/j.jaridenv.2006.10.004

R Core Team 2012. R: A language and environment for statistical computing. – R Foundation for Statistical Computing, Vienna, Austria

Restoin, J. A. & Restoin, J. 1972. Identification des proies de rapaces d'après les restes trouvés dans les pelotes de réjection [Identification of raptor's preys from remains in pellets]. – CRDP Besançon, pp. 14 (in French)

Rigaux, P. & Riols, C. 2008. Régime alimentaire de l'effraie des clochers *(Tyto alba)* à Courpière, Val de Dore (Puy-de-Dôme) [Barn Owl diet in Courpières, Val de Dore (Puy-de-Dôme)]. – Le Grand-Duc 73: 27–29. (in French)

Roulin, A. & Christe, P. 2013. Geographic and temporal variation in the consumption of bats by European Barn Owls. – Bird Study 60(4): 561–569. DOI: 10.1080/00063657.2013.847051

Saucy, F. 1994. Density dependence in time series of the fossorial form of the Water Vole, *Arvicola terrestris*. – Oikos 74: 381–392.

Schneider, W. 1964. Die Schteiereule [The Barn Owl]. – Neue Brehm Bücherel. Helt 340, Wittenberg, pp. 104 (in German)

Shehab, A., Daoud, A., Kock, D. & Amr, Z. 2004. Small mammals recovered from owl pellets from Syria (Mammalia: Chiroptera, Rodentia). – Zoology in the Middle East 33: 27–42. DOI: 10.1080/09397140.2004.10638061

Sommer, R., Niederle, M., Labes, R. & Zoller, H. 2009. Bat predation by the Barn Owl *Tyto alba* in a hibernation site of bats. – Folia Zoologica 58(1): 98–103.

Souza, D. P., Asfora, P. H., Lira, T. C. & Astùa, D. 2009. Small mammals in Barn Owl (*Tyto alba* – Aves, Strigiformes) pellets from Northeastern Brazil, with new records of *Gracilinanus* and *Cryptonanus* (Didelphimorphia, Didelphidae). – Mammalian Biology 75: 370–374. DOI: 10.1016/j.mambio.2009.08.003

Taberlet, P. 1983. Evaluation du rayon d'action moyen de la chouette effraie, *Tyto alba* (Scopoli, 1769), à partir de ses pelotes de réjection [Evaluation of the distance of foraging for the Barn Owl, *Tyto alba* (Scopoli, 1769), from pellets]. – La Revue d'Ecologie (Terre et Vie) 38: 171–177. (in French with English Summary)

Taberlet, P. 1986. Etude de l'écologie des micromammifères à partir des pelotes de réjection de *Tyto alba* (Scopoli, 1769), application au Bas-Chablais (Haute-Savoie – France) [Small mammals ecology from *Tyto alba* (Scopoli, 1769) pellets, application to the Bas-Chablais (Haute-Svoie – France)]. – La Revue d'Ecologie (Terre et Vie) 41: 193–217. (in French with English Summary)

Taylor, I. 2004. Barn Owls, predator-prey relationships and conservation. – Cambridge University Press, New York, pp. 311

Tores, M. & Yom-Tov, Y. 2003. The diet of the Barn Owl *Tyto alba* in the Negev desert. – Israel Journal of Zoology 49: 233–236. DOI: 10.1560/JU3E-EWK4-13QY-CGRF

Vargas, J., Landaeta, C. A. & Simonetti, J. A. 2002. Bats as prey of Barn Owls *(Tyto alba)* in a tropical savanna in Bolivia. – Journal of Raptor Research 36(2): 146–148.

Ornis Hungarica 2015. 23(2): 49–52.
DOI: 10.1515/orhu-2015-0014

Voice and daytime calling of Scops Owls *(Otus scops)*

Anita Mikkola & Heimo Mikkola*

Anita Mikkola & Heimo Mikkola 2015. Voice and daytime calling of Scops Owls *(Otus scops)*. – Ornis Hungarica 23(2): 49–52.

Abstract The Scops Owl *(Otus scops)* is one of the least studied owls in Europe and its loud and monotonous calls are not well documented. This paper summarises published alarm-like calls and presents data on daytime calling recorded in Lesencetomaj, Hungary between 9th and 17th September 2012. Calls were similar to the sound of an alarm on a reversing truck. The bird was most active around midday (11–13 hrs) and in the afternoons between 15–17 hrs. No calling occurred before 09.00 or after 19.15 o'clock. Weather affected the intensity of calls and particularly high autumn temperatures are suggested as a possible reason for this unusual activity.

Keywords: Scops Owl, *Otus scops*, alarm call, diurnal vocal activity

Összefoglalás A füleskuvik *(Otus scops)* egyike Európa legkevésbé kutatott bagolyfajainak. Messzire hangzó, monoton jelzőhangja csak kevés figyelmet kapott ezidáig. A jelen közlemény irodalmi adatokat közöl a faj jelző és vészjelző hangjáról, és adatokat közöl nappali hívóhang észlelésekről, amelyeket Magyarországon, Lesencetomajon, 2012. szeptember 9. és 17. között figyeltek meg a szerzők. A vészjelző hang egy teherautó tolató jelzőhangjához volt hasonlítható. A megfigyelt példány 11:00 és 13:00 óra között, illetve délután 15:00 és 17:00 óra között volt a legaktívabb. Nem lehetett hívóhangot észlelni reggel 09:00 előtt és este 19:15 után. A szokatlan territórium jelző hívóhang hallatását feltehetően az időjárás, különösen a magas szeptemberi hőmérséklet befolyásolhatta.

Kulcsszavak: füleskuvik, *Otus scops*, hívóhang, nappali hangadás

University of Eastern Finland, Kuopio Campus, P. O. Box 1627, FIN-70211 Kuopio, Finland,
e-mail: heimomikkola@yahoo.co.uk
**corresponding author*

Introduction

Most of Europe's Scops Owl *(Otus scops)* population is fully migratory, spending the winter months in African savannahs, and migrating north in spring to parts of France, Germany, Austria, Switzerland, Ukraine, Hungary, Czech Republic. Populations in southern Spain, southern Italy, southern Greece and most of the Mediterranean islands tend to be resident (Hagemeijer & Blair 1997). Population figures (2002–2007) are only available for Central Europe: Germany (3 pairs), Switzerland (12–15), Austria (40–60), Slovakia (40–80), Czech Republic (0–4), Hungary (500–600) and Slovenia (500–800) (Mebs & Scherzinger 2008). There are contrasting fortunes for this bird though, for in some countries such as Switzerland, numbers plummeted from 30 pairs to 13 during the period 1982–1997 (Schweizerische Vogelwarte), whereas during a similar period an increase was noted in Hungary (Bagyura & Haraszthy 2004) and Slovenia (Tome 1998).

Voice

This bird is one of lesser known owl species, particularly its call, which may well be misinterpreted by the unfamiliar observer.

Within the literature there are a number of interesting comments on the voice of Scops Owl which we would like to bring to the reader's attention. This may help facilitate more records of this notoriously difficult bird to observe – even when close by. As one trip report so well puts it: 'I hear five Scops Owls in Cyprus, but still not seen one though I was right below one calling and responding to me – how frustrating. I still think the call is best described as similar to a submarine sonar echo' (Bickerton 1995).

In the UK there are two well-known incidents caused by the alarm-like voice of the Scops Owl. From 12th May to at least 14th July, 1980, the loud and monotonous call of the owl led some of the dummer residents of Hampshire to complain to British Telecom (or rather the GPO as it was then) about the noise until someone pointed out that it was a Scops Owl (Rogers *et al*. 1981)!

In the spring of 2006 the residents of the Oxfordshire village of Thrupp, were woken for weeks (some say from as early as 21st April until 30th June) by the repeated sound of what they thought was a faulty alarm on a canal boat or a car alarm. This noise however did not switch itself off as car alarms are required by law to do and eventually the guilty party turned out to be the first accepted record of a Eurasian Scops Owl recorded in Oxfordshire (Fraser *et al.* 2007). As the residents of Thrupp discovered, when it is calling for a mate this species can deliver its call up to 26 times a minute, and at a pitch of 1.35 Khz (Editor 2006).

Daytime calling

Calling by Scops Owl is considered by most authorities to take place nocturnally, although nearly 80 years ago Witherby *et al*. (1938), noted that it occasionally called by day. More recently though, this behaviour seems to have become more common, in some places.

The regular occurrence of daytime hooting of Scops Owl was first noted in Kazakhstan where a Scops Owl was discovered calling during the day along the Almaty Canal on the 28th May, 1999 (Taylor 1999). More recently we have heard Scops Owl calling regularly during the day in Lesencetomaj, Hungary next to Lake Balaton.

First time we heard Scops Owl's daytime calls during one day on 23rd September 2010 and again 11th–23rd September 2011, but no systematic records were kept before 2012. Then calling was noted on several days between 9th and 17th September 2012. There was no opportunity to listen the autumn calls before the 23rd in 2010, 11th in 2011 and 9th September in 2012 so the earliest start of the calls is not known. It seems from our observations that after the 23rd both in 2010 and 2011 and after 17th September 2012 the owls(s) presumably left for Africa. Unfortunately we

Time	09–11	11–13	13–15	15–17	17–19	19–20
Calls	14%	25%	18%	22%	20%	1%

Table 1. Timed sequences of the 411 recorded calls in Lesencetomaj, Hungary between 9th and 17th September 2012.

1. táblázat A 411 feljegyzett hang időeloszlása (Lesencetomaj, Magyarország, 2012. szeptember 9–17.)

were not able to visit the study site during the autumns of 2013–2014 but intend to do so again in 2015.

Typically, the owl was not seen even though it was calling close by. Its calls could have been mistaken for that of the Midwife Toad *(Alytes obstretricans)* as has often been the case in the past (Mikkola 1983). However, we were fortunate in that the bird continually shifted its calling place over an area encompassing 200 m, so the likelihood of it being a toad was eliminated. Calling was similar to that of the alarm on a reversing truck, but fortunately there were no trucks in the area.

The bird was most active around midday (11–13 hrs) and in the afternoons between 15–17 hrs. No calling took place before 09.00 or after 19.15 o'clock although they were listened for in the early mornings, late evenings and often also during the night.

Call frequency was 0 to 4 calls per minute and when continuous calling took place it did so at a rate of at least 2 calls per minute. A call usually contained 14 very rapidly (ca. 1 per second) repeated 'toots' but during less active calling the rate fell to eleven toots/call. The opportunity also arose to record changes in call times due to the onset of shortening days, with calling in early September lasting later in to the evenings (19.15 vs. 18.45) and started earlier in the morning (09.00 vs. 10.15). A cold spell of weather between the 13th and 15th September, when the temperature fell sharply within a few hours from +30 to +8 °C, silenced the owl completely. It did not start to call again before the temperature had risen to over 20 °C. Similarly in 2011 sudden temperature drop from 29 to 13 °C on 19th September stopped the calls until 23rd September when the last call was heard in that year.

Early September 2011 and 2012 were very hot and dry in Hungary. This may explain why a Scops Owl was calling during the daytime. Similar late autumn and even winter calling has been described from Mediterranean islands but mainly only during the evening (König 1970, Glutz von Blotzheim & Bauer 1980, Exner & Griesch 2000). In February 1991 three pairs of Scops Owls (of the race *cyprius*) were studied in Cyprus, and only on two occasions, calls were heard in the middle of the day (Gassick 1993).

We tentatively suggest that this strange behaviour is on the increase, although it is far from widespread, with isolated pockets turning up here and there. It is interesting that another strictly nocturnal owl, Tawny Owl *(Strix aluco)* has started to call more often during the daytime. A recent British survey has shown that not only did Tawny Owls call more frequently in the mid-day period; they also called more frequently when the sun shone. Of those records where the weather conditions were described, 58% (131) reported that the calling occurred in bright sunshine (Martin & Mikkola 2013a, b, 2014).

In the case of the Tawny Owl the spring peak in daylight calling is seemingly clearly associated with the breeding season; interestingly, this contrasts with the well-established autumn peak in nocturnal calling by Tawny Owls, which is associated with the re-establishment of territories after the end of the breeding season. Unfortunately this comparison with a sedentary Tawny Owl does not explain the behaviour of Scops Owls especially during their pre-migration time, if not assuming that the young male Scops Owls erroneously start announcing their territory during the exceptionally warm autumn periods.

Acknowledgement

We would like to express our gratitude to referees.

References

Bagyura, J. & Haraszthy, L. 2004. The status of birds of prey and owls in Hungary. – In: Chancellor, R. & Meyburg, B-U. (eds.) Raptors Worldwide. – WWGBP, Budapest, pp. 890

Bickerton, D. 1995. Cyprus Trip Report 8th–21st April 1995. – Ornithological Society of the Middle East, the Caucasus and Central Asia, pp. 5–9.

Editor 2006. Noises in the Night Disrupt Thrupp! – International Owl Society's Tyto magazine, p. 3.

Exner, S. & Griesch, J. 2000. Spätsommerliche Gesansaktivität korsischer Zwergohreulen im Gebirge und an der Küste [Late summer calling activity of Scops Owl in Corsican mountains and coast].– Ornithologische Mitteilungen 52: 30–31. (in German)

Fraser, P. A. & the Rarities Committee 2007. Report on rare birds in Britain 2006. – British Birds 100: 694–754.

Gassick, J. C. 1993. Call patterns of Eurasian Scops Owl. – British Birds 86: 271.

Glutz von Blotzheim, U. N. & Bauer, K. M. 1980. Handbuch der Vögel Mitteleuropas, Vol. 9. Columbiformes-Piciformes. – Akademische Verlagsgesellschaft,Wiesbaden, pp. 1148 (in German)

Hagemeijer, E. J. M. & Blair, M. J. (eds.) 1997. The EEBC Atlas of European breeding birds: their distribution and abundance. – T & AD Poyser, London, pp. 903

König, C. 1970. Herbstbalz der Zwergohreule *(Otus scops)* [Autumn calling of the Scops Owl *(Otus* scops*)*]. – Ornithologische Mitteilungen 22: 44–45. (in German)

Martin, J. R. & Mikkola, H. 2013a Daylight calling by Tawny Owls – an update. – British Birds Home: News and Comment p. 28.

Martin, J. R. & Mikkola, H. 2013b Day screamers. – BBC Wildlife, p. 105.

Martin, J. R. & Mikkola, H. 2014. The changing face of Britain's Tawny Owls. – British Wildlife 25(6): 391–399.

Mebs, T. & Scherzinger, W. 2008. Die Eulen Europas (2. Auflage) [The Owls of Europe]. – Kosmos Verlag, Stuttgart, pp. 398 (in German)

Mikkola, H. 1983. Owls of Europe. – T & AD Poyser, Calton, pp. 397

Rogers, M. J. & the Rarities Committee 1981. Report on Rare Birds in Great Britain 1980. – British Birds 74: 453–495.

Schweizerische Vogelwarte [Swiss Ornithological Institute]. Seerose 1, – CH 6204 Sempach, Switzerland, pp. 1–2.(in German)

Taylor, D. 1999. Trip Reports. – Kazakhstan May 21–June 5, 1999. Ornithological Society of the Middle East, the Caucasus and Central Asia, pp. 7–9.

Tome, D. 1998. Eulen in Slovenien – Status und Verbreitung. – Population Ökologie der Greifvögel und Eulenarten 3: 343–351. (in German)

Witherby, H. F., Jourdain, F. C. R., Ticehurst, N. F. & Tucker, B. W. 1938. The handbook of British Birds, Vol. 2. – H. F. & G. Witherby Ltd., London, pp. 511

Ornis Hungarica 2015. 23(2): 53–61.
DOI: 10.1515/orhu-2015-0015

The first detailed ornithological description of the island of Žirje (Croatia)

Jenő J. Purger

Jenő J. Purger 2015. The first detailed ornithological description of the island of Žirje (Croatia). – Ornis Hungarica 23(2): 53–61.

Abstract Ornithofauna of the island of Žirje has not been explored yet. During an early and late survey in September of 2013 and 2014 altogether 50 bird species were recorded, 34 and 41 species was noted including both migratory and resident species in the two parts of the month, respectively. Nine species appeared only at the first half, while 16 species were registered only at the second half of the mouth. The results of this preliminary survey showed the obvious need for more intensive research of the island's bird fauna, with special attention on nesting and wintering birds.

Keywords: Adriatic islands, September, birds, passengers, winter visitors

Összefoglalás Žirje szigetén korábban nem folytak ornitológiai vizsgálatok. 2013 és 2014 szeptemberében 50 madárfaj jelenlétét sikerült kimutatni, közülük 34-et a hónap első, 41-et a hónap második felében. Többségük tipikus vonuló, fészkelő vagy állandó fajnak tekinthető. Kilenc faj egyedei csak a hónap első, míg 16 faj egyedei csak a hónap második felében fordultak elő. Az előzetes eredmények rámutattak arra, hogy a szigeten költő és telelő fajok felmérése érdekében mielőbb további kutatásokra lenne szükség.

Kulcsszavak: Adriai szigetek, szeptember, madarak, vonulók, telelők

Department of Ecology, Institute of Biology, Faculty of Sciences, University of Pécs, 7624 Pécs, Ifjúság útja 6., Hungary, e-mail: purger@gamma.ttk.pte.hu
BioRes Unlimited Partnership, 7624 Pécs, Barackvirág utca 27., Hungary

Introduction

The Adriatic islands play an important role in the migration and wintering of birds (Kralj *et al.* 2013), therefore it is extremely important to study the changes of the bird fauna of each island (Krpan 1970). The Croatian Adriatic coast has long been an interesting study area for ornithologists (Cvitanić 1988, Kralj 1997, Rucner 1998, Lukač 2007), yet many islands, given their large number (Duplančić Leder *et al.* 2004), have not been sufficiently explored, therefore the ornithofauna of some islands is less known.

The island of Žirje is the 27th largest among the Croatian islands (Duplančić Leder *et al.* 2004), but about the bird fauna the only information available was that there are Rock Doves *Columba livia* (Friganović 1953) and Common Pheasant *Phasianus colchicus* are bred (Krpan 1976). It is obvious that the ornithofauna of Žirje is not explored, while in the whole area of Šibenik surroundings the presence of 163 bird species is revealed (Krpan 1976).

In the Mediterranean areas, most birds occur during the autumn migration (Krpan 1970), therefore our goal was to explore the bird fauna of island Žirje in this period, and to point out the significance of this island for migratory birds.

Materials and methods

Study area

Island of Žirje lies in the outer group of islands, 22 km southwest of Šibenik *(Figure 1)* and extends in the direction of the Dinaric Mts., with a length of 12 km, average width of 1.2 km, and maximum width of 2.5 km (Smoljanović *et al.* 1999).

Žirje is the largest (15.8 km^2) inhabited island of the Šibenik archipelago, with 103 inhabitants, according to the 2011 census (Buršić 2013). The coast line is 41.76 km long (Duplančić Leder *et al.* 2004), and the indentation coefficient is 2.7 (Smoljanović *et al.* 1999). The geological structure of Žirje island is characterized by the domination of the Upper Cretaceous limestone, which forms two longitudinal ridges extending in the NW-SE direction. In the middle of the island there is a valley covered with a thin layer of overlying red soil with sediments, turned brown (Bognar & Saletto-Janković 1994).

The highest point on the island is the peak Kapić, 134 m a.s.l. The settlement, village Žirje lies further from the coast, at the north-eastern part of the field. South of the village is the small lake with fresh water called Lokva. The area of Šibenik archipelago belongs to the Eumediterranean zone characterised by the evergreen forest vegetation of the *Quercion ilicis* alliance, where the most important associations are *Myrto-Quercetum ilicis* and *Fraxino orni-Quercetum ilicis* (Milović & Pandža 2010). The vegetation on the island consists of macchia, oak forests and the groves of aleppo pine *Pinus halepensis*, which propagates sub-spontaneously, thus superseding natural vegetation. Most of the area is covered with rocky dry grasslands. The agricultural land consists of vineyards, olive plantations, fig and plum trees, cultivated and abandoned fields (Pandža 2003, Faričić & Magaš 2004).

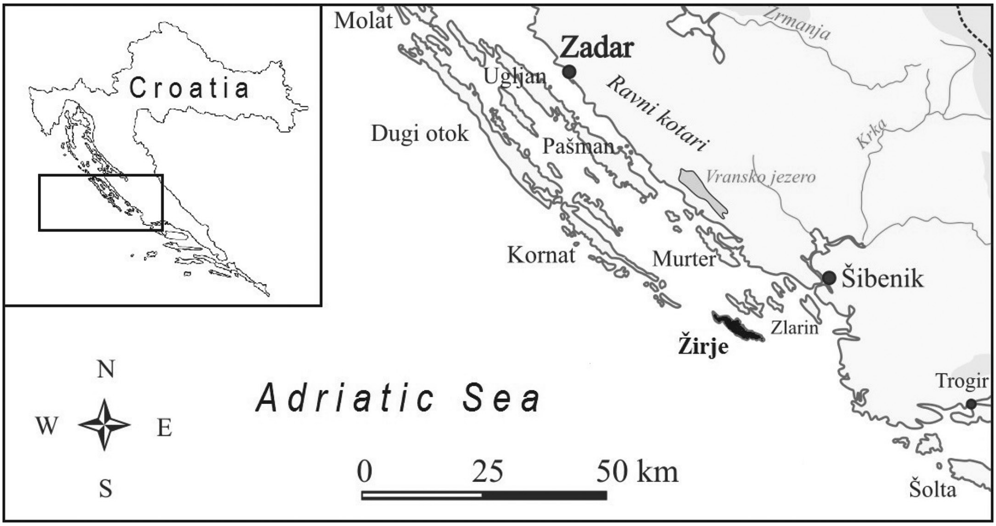


Figure 1 Geographic location of Žirje island in the Adriatic Sea, Croatia
1. ábra Žirje-sziget földrajzi fekvése az Adriai-tengerben Horvátországban

Data collection

Observations on the ornithofauna of the island Žirje were carried out between 21st–26th September 2013 and between 5th–10th September 2014. During migration, birds prefer sites that are similar to the habitats of their own breeding range (Rucner 1998), therefore in both study periods we examined all characteristic habitats on the island e.g. grasslands, forests and macchia, mosaics of cultivated and urbanised areas. Birds were surveyed in the inhabited parts of the island, Žirje, Muna, Mikavica and Koromašna and in bays: Muna, Mikavica, Tratinska, Kruševica, Stupica vela, Stupica mala, Prisiliga, Japlenišće, Šepurina and Koromašna. Research was made with special attention to the central part of the island, where a fresh water pond Lokva and agricultural area Polje can be found. All passable roads of the island were walked through, as well as the hilltops: Vela glava, Muna, Jurkovica, Kapić and Zvizdulje.

The results of observations are summarised in the list of species. The names of orders (in capital letters) and families, and the English and scientific names of birds, as the order of the species in the list have been used according to BirdLife International (2014). If the bird was observed less than five times, the date, location and number of the observed specimens were listed.

Results

GALLIFORMES, Phasianidae

1. **Common Pheasant** *Phasianus colchicus* (Linnaeus, 1758) – Currently it is one of the most commons bird on the island, it can be heard and seen in all habitats, though mostly in the agricultural areas. During a walk in the field around Lokva sometimes 15–20 pheasants were observed. It is an introduced species; it has bred on Žirje from the mid-sixties (Krpan 1976).

COLUMBIFORMES, Columbidae

2. **Rock Dove** *Columba livia* Gmelin, 1789 – Individual birds or small flocks were seen flying over each habitat every day, most often above the bay of Koromašna. On the southern slope of Muna on the stones above the last house in the bay, 10–20 birds gathered regularly. Friganović (1953) mentioned the presence of wild pigeons on Žirje, the observation is certainly related to Rock Dove, which is common resident bird of the island.

CAPRIMULGIFORMES, Apodidae

3. **Common Swift** *Apus apus* (Linnaeus, 1758) – On 26 September 2013 one specimen was observed above Koromašna bay.

PELECANIFORMES, Ardeidae

4. **Grey Heron** *Ardea cinerea* Linnaeus, 1758 – On 23 September 2013 one specimen, and on 26 September 2013 nine specimens were observed on the coast near cape Jurkovica in Koromašna bay.

SULIFORMES, Phalacrocoracidae

5. **European Shag** *Phalacrocorax aristotelis* (Linnaeus, 1761) – In both years, in every field trip one to six specimens were observed in every bay around the island.

CHARADRIIFORMES, Scolopacidae

6. **Common Sandpiper** *Actitis hypoleucos* Linnaeus, 1758 – On 23 September 2013 one specimen was observed in Koromašna bay and one specimen in Stupica vela bay.

CHARADRIIFORMES, Laridae

7. **Yellow-legged Gull** *Larus michahellis* J. F. Naumann, 1840 – Birds flying over the island were observed every day. Mostly individual birds or small flocks of 3–6 were observed sometimes flocks of 20–25 birds were seen in larger bays.

ACCIPITRIFORMES, Accipitridae

8. **European Honey Buzzard** *Pernis apivorus* (Linnaeus, 1758) – Four specimens were observed on 26 September 2013 above Polje, south of the settlement Žirje.

9. **Short-toed Snake-eagle** *Circaetus gallicus* (Gmelin, 1788) – Above Koromašna bay two specimens were observed on 10 September 2014.

10. **Western Marsh Harrier** *Circus aeruginosus* (Linnaeus, 1758) – One male was seen circling above Muna on 25 September 2013 and was flying in south-eastern direction.

11. **Eurasian Sparrowhawk** *Accipiter nisus* (Linnaeus, 1758) – In all habitats on the island, usually individual specimens were seen circling in the air, and more often hunting for passerine birds. During the survey this was the most commonly observed predatory bird in both years.

12. **Eurasian Buzzard** *Buteo buteo* (Linnaeus, 1758) – Mostly individual birds were observed in both years, but on 9 September 2014 three specimens were seen above Muna and two specimens above Polje near settlement Žirje.

BUCEROTIFORMES, Upupidae

13. **Common Hoopoe** *Upupa epops* Linnaeus, 1758 – On 8 September 2014 one specimen was observed near the road to Šepurina bay, and one specimen in Polje, south of settlement Žirje.

CORACIIFORMES, Meropidae

14. **European Bee-eater** *Merops apiaster* Linnaeus, 1758 – A flock of 22 specimens was observed on 8 September 2014 near the village Žirje, and one day later the distinctive voice of these birds was heard above Koromašna bay.

CORACIIFORMES, Alcedinidae

15. **Common Kingfisher** *Alcedo atthis* (Linnaeus, 1758) – One specimen was observed on 26 September 2013 in Koromašna bay, on 8 September 2014 in Japlenišće, in Koromašna bay and in Lokva, as well as 9 September 2014 in Koromašna bay.

FALCONIFORMES, Falconidae

16. **Common Kestrel** *Falco tinnunculus* Linnaeus, 1758 – Usually individual birds were observed in both years, however several times three specimens were seen above Polje and on 25 September 2013 four specimens were observed above Muna. According to my observations at least 6 specimens occur on the island.

17. **Eurasian Hobby** *Falco subbuteo* Linnaeus, 1758 – On 6 September 2014 one specimen was observed in hunting above Jurkovica and Kapić hilltops.

PASSERIFORMES, Corvidae

18. **Common Raven** *Corvus corax* Linnaeus, 1758 – In the first half of September 2014 two specimens were observed several times. On 9 September 2014 four specimens were observed above Polje, south of the settlement of Žirje.

19. **Hooded Crow** *Corvus cornix* Linnaeus, 1758 – One of the most common birds, during each field trip individual specimens or smaller flocks were observed in every habitat.

PASSERIFORMES, Paridae

20. **Great Tit** *Parus major* Linnaeus, 1758 – One specimen was observed on 23 September 2013 in the surroundings of Stupica vela bay, and two specimens on 25 September 2013 in Polje.

PASSERIFORMES, Hirundinidae

21. **Sand Martin** *Riparia riparia* (Linnaeus, 1758) – Eight Sand Martins came together with Barn Swallow flocks to drink from Lokva on 26 September 2013.

22. **Barn Swallow** *Hirundo rustica* Linnaeus, 1758 – On 25 and 26 September 2013 they were seen flying in smaller flocks above Polje, and some of them landed to drink from Lokva. Between 5 and 9 September 2014 often smaller flocks of 3-8 birds were seen above the bay of Muna, Stupica vela, Koromašna, and most often were seen above Polje.

23. **Red-rumped Swallow** *Hirundo daurica* Linnaeus, 1771 – Two specimens were observed in flocks of Barn Swallows on 26 September 2013 above Polje in vicinity of Lokva.

24. **Northern House Martin** *Delichon urbicum* (Linnaeus, 1758) – 23 specimens were observed on 22 September 2013 above Kapić hilltop, then on 26 September 2013 smaller flocks were flying above Polje, some birds were drinking from Lokva. Three birds were observed on 6 September 2014 near Vela glava hilltop, a day later seven specimens above Zvizdulja hilltop.

PASSERIFORMES, Sylviidae

25. **Eurasian Reed Warbler** *Acrocephalus scirpaceus* (Hermann, 1804) – On 9 September 2014 two specimens were observed on lake of Lokva in Polje south of settlement Žirje.

26. **Common Chiffchaff** *Phylloscopus collybita* (Vieillot, 1817) – Individual birds or smaller flocks of 3-6 birds were seen in all habitats, mostly in forests.

27. **Wood Warbler** *Phylloscopus sibilatrix* (Bechstein, 1793) – On 6 September 2014 three specimens were observed in the pine forest near Mikavica.

28. **Blackcap** *Sylvia atricapilla* (Linnaeus, 1758) – These birds were observed mostly in Polje, where on 25 and 26 September 2013 more then 40-50 were counted, and also 30 birds near Lokva. On 9 September 2014 cc. 30-40 specimens were observed near Lokva.

29. **Common Whitethroat** *Sylvia communis* Latham, 1787 – One specimen was ob-

served on 22 September 2013 near Mikulica in the Aleppo pine forests. On 7 September 2014 there was one specimen in the forest near Draževica, and on 9 September 2014 two specimens on Lokva near Žirje.

30. **Orphean Warbler** *Sylvia hortensis* (Gmelin, 1789) – On 25 and 26 September 2013 two specimens were recorded near Lokva, and on 7 September 2014 one in the bushes near Stupica mala bay.

31. **Sardinian Warbler** *Sylvia melanocephala* (Gmelin, 1789) – Individual birds were seen regularly in different sites, but mostly in dry habitats.

32. **Subalpine Warbler** *Sylvia cantillans* (Pallas, 1764) – Individual birds were seen in all habitats, most of them in macchia.

PASSERIFORMES, Reguliidae

33. **Firecrest** *Regulus ignicapilla* (Temminck, 1820) – On 22 September 2013 five specimens were observed near Kapić hilltop, and three specimens near Mikulica in the aleppo pine forests. Three specimens were observed on 23 September 2013 in the southern part of Polje, and also near Stupica vela bay.

PASSERIFORMES, Troglodytidae

34. **Winter Wren** *Troglodytes troglodytes* (Linnaeus, 1758) – On 25 September 2013 three specimens were observed near Lokva in the agricultural area of Polje.

PASSERIFORMES, Sturnidae

35. **Common Starling** *Sturnus vulgaris* Linnaeus, 1758 – On 26 September 2013 seven specimens were observed near Lokva in Polje.

PASSERIFORMES, Turdidae

36. **Eurasian Blackbird** *Turdus merula* Linnaeus, 1758 – Observed in all habitats, mostly individual specimens, except in Polje, where 37 birds were recorded in the early evening on 24 September 2013, while 55 birds were counted on 9 September 2014.

PASSERIFORMES, Muscicapidae

37. **European Robin** *Erithacus rubecula* (Linnaeus, 1758) – On 23 September 2013 one specimen was observed in the vicinity of Šepurina bay and one specimen near Samograd. On 25 and 26 September 2013 five to seven specimens were observed near Lokva and in Polje. One specimen near Lokve was noted on 9 September 2014.

38. **Common Nightingale** *Luscinia megarhynchos* (Brehm, 1831) – Observed only on 9 September 2014 near Lokva, south of the settlement of Žirje.

39. **Black Redstart** *Phoenicurus ochruros* (Gmelin, 1774) – One specimen was observed on 23 September 2013 near Šepurina bay and near Samograd. Three specimens were seen on 7 September 2014 near Samograd, one day later there was one bird, and two days later two specimens were seen in Polje.

40. **Common Redstart** *Phoenicurus phoenicurus* (Linnaeus, 1758) – One specimen was observed on 23 September 2013 near settlement Žirje. Two and three specimens, respectively, were observed in Polje on 25 and 26 September 2013. In 2014 one

specimen was noted on lake Lokva near Žirje on 9 September.

41. **Whinchat** *Saxicola rubetra* (Linnaeus, 1758) – One specimen was observed on Jurkovica and Kapić hilltops on 22 September 2013.

42. **Northern Wheatear** *Oenanthe oenanthe* (Linnaeus, 1758) – On 22 September 2013 three specimens were observed on the Kapić hilltop.

43. **Spotted Flycatcher** *Muscicapa striata* (Pallas, 1764) – On 7 September 2014 one specimen was observed in the pine forest near Mikavica and near Koromašna bay, a day later in Šepurina bay and in Polje.

44. **European Pied Flycatcher** *Ficedula hypoleuca* (Pallas, 1764) – Usually these birds were observed in the Aleppo pine forests, some specimens were also seen in other habitats in both years, mostly near Mikulica, Jurkovica and Polje. They were seen on 7 September 2014 at Samograd, and a day later in Polje.

PASSERIFORMES, Passeridae

45. **House Sparrow** *Passer domesticus* (Linnaeus, 1758) – Small flocks were observed during both survey periods in Polje near Lokva, and also in settlements. In 2014 around Lokva a flock of 50–60 specimens was observed. On 9 September 2014 twenty birds were counted on an old mulberry tree in the centre of the settlement of Žirje.

46. **Spanish Sparrow** *Passer hispaniolensis* (Temminck, 1820) – One specimen was observed on 24 September 2013 near Lokva.

PASSERIFORMES, Motacillidae

47. **White Wagtail** *Motacilla alba* Linnaeus, 1758 – Only one specimen was observed on 23 September 2013 in Muna bay.

PASSERIFORMES, Fringillidae

48. **Eurasian Chaffinch** *Fringilla coelebs* Linnaeus, 1758 – Flocks of 4–7, 10–15, and 18–20 specimens were observed during the surveys in both years, usually in the vicinity of Lokva and in the whole area of Polje.

49. **European Serin** *Serinus serinus* (Linnaeus, 1766) – Two specimens were observed on 25 and 26 September 2013 in abandoned vineyards in Polje, south of the church of St. Maria.

PASSERIFORMES, Emberizidae

50. **Cirl Bunting** *Emberiza cirlus* Linnaeus, 1766 – One specimen was seen on 24 September 2013 near Lokva, and one day later three specimens were observed at the same site. On 26 September 2013 two birds were observed in Polje and also near Lokva. Next year on 9 September one specimen was noted near the settlement of Žirje.

Discussion

On island of Žirje 50 bird species were recorded in September 2013 and 2014. Altogether 41 bird species were recorded at the end of September 2013, while in the first half of the month in 2014 only 34 species. Some birds were observed only at the beginning of September *(C. gallicus*, *U. epops*, *M. apiaster*, *F. subbuteo*, *C. corax*, *A. scirpaceus*, *Ph. sibilatrix*, *L. megarchinchos*, *M. striata)*, and some species only in the second half of the month *(A. apus*, *A. cinerea*, *A. hypoleucos*, *P. apivorus*, *C. aeruginosus*, *P. major*, *R. riparia*, *H. daurica*, *R. ignicapilla*, *T. troglodytes*, *S. vulgaris*, *S. rubetra*, *O. oenanthe*, *P. hispaniolensis*, *M. alba*, *S. serinus)*. These differences point to the dynamics of migration, because species that were recorded only in the first half of the month, except for the Common Raven *C. cornix*, were migratory birds, while among the birds observed only in the second half of the month there were species that are typically wintering on the Adriatic islands, such as, for example, Firecrest *R. ignicapilla* and Winter Wren *T. troglodytes*. The Eurasian Sparrowhawk *A. nisus* is also a typical wintering bird, but on Žirje it can be observed from the beginning of September. Skeleton parts of Common Crane *Grus grus* (Linnaeus, 1758) were found on September 8, 2014 on the coast of Japljenišće bay, but it is not known exactly when and where the bird had died, therefore it is not on the species list.

The birds mainly stayed near Lokva in Polje, south of the settlement of Žirje. Freshwater attracts both resident and migratory birds, while predatory birds come here to hunting for them. At this habitat the number of recorded birds was the highest, and this was the most suitable place for bird-watching. Lokva has great importance for other animals as well, for example amphibians (Lauš 2010). Visiting bays and hilltops is certainly worthy, because in these habitats other bird species can be seen. There is a great overlapping between ornithofauna of islands with similar habitats and area. On small islands the number of bird species and their population size are limited, so even small changes, such as environmental degradation or introduced non-native predators can significantly affect their survival (Barun *et al*. 2010).

In the northern part of the Adriatic Sea, on the western islands of Kvarner bay (Cres, Lošinj and small islands in surroundings) altogether 162 bird species were registered (Sušić 1992). On Šolta island, which is four times larger and much more investigated than Žirje, 132 species are known (Mužinić & Purger 2012). Bird-watching on Žirje island lasted for a short time and was carried out only in September, therefore the number of registered bird species is in proportion with the number of species known on islands of similar areas, e.g. Iž island, where Lukač *et al.* (1986) recorded 50 species during a two-week survey in August 1983. Silba is also an island of similar size, where Mužinić and Purger (2013) observed 55 species during a 16-day survey performed on several occasions between 2006–2011. However, together with data from the literature, the ornithofauna of Silba reaches more than 80 species (Mužinić & Purger 2013). Preliminary results confirmed that there is an obvious need for more intensive research of the bird fauna of Žirje island, with special attention to nesting and wintering birds.

Acknowledgements

Surveys were performed by support of Bio-Res Unlimited Partnership. I am grateful for the hospitality of Anka and Valter Dobra from Koromašna.

References

BirdLife International 2014. The BirdLife checklist of the birds of the world: Version **7**.
Downloaded from: http://www.birdlife.org/datazone/userfiles/file/Species/Taxonomy/BirdLife_Checklist_Version_70.zip [xls zipped 1 MB].

Bognar, A. & Saletto-Janković, M. 1994. Geomorfološke značajke otoka Žirja s arhipelagom [Geomorphological characteristics of the island of Žirje]. – Žirajski libar 1: 169–182. (in Croatian with English Summary)

Buršić, I. (ed.) 2013. Census of population, households and dwellings 2011, population by sex and age. 1468 Statistical Reports. – Croatian Bureau of Statistics, Zagreb, pp. 681

Barun, A., Simberloff, D. & Budinski, I. 2010. Impact of the small Indian mongoose on native amphibians and reptiles of the Adriatic islands, Croatia. – Animal Conservation 13: 549–555.

Cvitanić, A. 1988. Ornitološka istraživanja na području Dalmacije, Crnogorskog primorja i otoka Jadranskog mora [Ornithological research in Dalmatia, the coast of Montenegro and the islands of the Adriatic Sea]. pp. 127–141. – In: Meštrov, M. & Sušić, G. (eds.) Orntiologija u Hrvatskoj [Ornithology in Croatia]. – Razred za prirodne znanosti JAZU, Zagreb, pp. 312 (in Croatian with English Summary)

Duplančić Leder, T., Ujević, T. & Čala, M. 2004. Coastline lengths and areas of islands in the Croatian part of the Adriatic Sea determined from the topographic maps at the scale of 1: 25 000. – Geoadria 9: 5–32.

Faričić, J. & Magaš, D. 2004. Suvremeni socio-geografski problemi malih hrvatskih otoka – primjer otoka Žirja [Contemporary socio-geographic issues of small Croatian islands – the example of Žirje Island]. – Geoadria 9: 125–158. (in Croatian with English Summary)

Friganović, M. A. 1953. Žirje – prilog poznavanju fiziogeografskih osebina [The island of Žirje – contribution to the knowledge of its physiographic characteristics]. – Geografski glasnik 14–15: 87–98. (in Croatian with French Summary)

Kralj, J. 1997. Ornitofauna Hrvatske tijekom posljednjih dvjesto godina [Croatian ornithofauna in the last 200 years]. – Larus 46: 1–112. (in Croatian with English Summary)

Kralj, J., Barišić, S., Tutiš, V. & Ćiković, D. (eds.) 2013. Atlas selidbe ptica Hrvatske [Croatian bird migration atlas]. – HAZU Razred za prirodne znanosti, Zavod za ornitologiju, Zagreb, pp. 252 (in Croatian with English Summary)

Krpan, M. 1970. Istureni dalmatinski otoci, otočići i školji kao preletna postaja i gnijezdilište nekih pučinskih vrsta ptica [Protruded islands and isles as temporary stations and nesting places for seabirds]. – Pomorski zbornik 8: 901–906. (in Croatian)

Krpan, M. 1976. Ornitofauna okolice Šibenika [Ornithofauna of the surroundings of Šibenik]. – In: Šibenik – Spomen zbornik o 900. obljetnici. Muzej grada Šibenika, Šibenik. – Posebna izdanja 1: 571–586. (in Croatian)

Lauš, B. 2010. A contribution to the herpetofauna of Žirje Island (Dalmatia, Croatia). – Natura Sloveniae 12: 61–63.

Lukač, G. 2007. List of Croatian Birds. Fauna Croatica. Aves XXXVII. – Natura Croatica 16(Suppl.) 1: 1–148.

Lukač, G., Tomić, D., Makjanić, I. & Fištrović, J. 1986. Prilog poznavanju ornitofaune srednjedalmatinskih otoka: kratki osvrt na ornitofaunu otoka Iža [Supplement to the understanding of the ornithology of the Middle Dalmatian islands: a short discussion on the ornithology of the island of Iž]. – Larus 36–37: 283–291. (in Croatian with English Summary)

Milović, M. & Pandža, M. 2010. A contribution to the vascular flora of the Šibenik archipelago islands (Dalmatia, Croatia). – Natura Croatica 19: 179–203.

Mužinić, J. & Purger, J. J. 2012. Ptičji svijet otoka Šolte [Birds of the island Šolta]. – pp. 307–312. – In: Radman, Z. (ed.) Otok Šolta: Monografija [Island Šolta: Monograph]. – Općina Šolta, Grohote, pp. 614 (in Croatian)

Mužinić, J. & Purger, J. J. 2013. Ptice otoka Silbe i obližnjih Grebena [Birds of island Silba and nearby Grebeni]. pp. 120–131. – In: Mužinić, J. & Purger, J. J. (eds.) Otok Silba, prirodno i kulturno blago [The island of Silba: a natural and cultural treasure]. – Sveučilište u Zadru, Zadar, pp. 322 (in Croatian with English Summary)

Pandža, M. 2003. Flora of the island of Žirje and the small islands around it. – Acta Botanica Croatica 62: 115–139.

Rucner, D. 1998. Ptice hrvatske obale Jadrana [The birds of Croatian Adriatic coast]. – Hrvatski prirodoslovni muzej, Ministarstvo razvitka i obnove, Zagreb, pp. 311 (in Croatian)

Smoljanović, M., Smoljanović, A. & Nejašmić, I. 1999. Stanovništvo hrvatskih otoka [Population of Croatian Islands]. – Zavod za javno zdravstvo Županije splitsko-dalmatinske, Split, pp. 482 (in Croatian)

Sušić, G. 1992. Ptice cresko-lošinjske otočne skupine [Birds of Cres-Lošinj island group]. – Otočki ljetopis Cres-Lošinj 8: 145–157. (in Croatian)

Ornis Hungarica 2015. 23(2): 62–155.
DOI: 10.1515/orhu-2015-0016

Osteological guide of songbirds from Central Europe

Jenő (Eugen) Kessler

Jenő (Eugen) Kessler 2015. Osteological guide of songbirds from Central Europe. – Ornis Hungarica 23(2): 62–155.

Abstract The author provides an osteological guide to songbirds, based on 11 skeletal parts of 51 genera, at the genus level for ornithologists studying owl pellets, paleontologists and archaezoologists. The mandible, the coracoid bone, the scapula, the humerus, the ulna, the carpometacarp, the first phalanx bone of the second finger, the femur, the tibiotars, the tarsometatars and the claw bone are presented.
The morphological characteristics and method of measurement of the examined skeletal parts and the photographs of the appropriate bones are illustrated on 52 plates and 17 figures. The measurement data are also provided in 11 size tables. For every discussed bone, 3-6 characteristics are chosen, and their codes consist of 3-6 letters. In case of overlaps, dimensions are the determining factors, and for the humerus and the ulna, the ensemble of the two bone end pairs can be used.

Keywords: Central-Europe, guide, osteology, Paleornithology, archeozoology, Passerines

Összefoglalás A szerző 51 énekesmadár genus 11 vázrészének morfológiai jellemzőin alapuló csonthatározót állított össze a bagolyköpeteket vizsgáló ornitológusoknak, paleontológusoknak, archaeozoológusoknak ajánlva. A dolgozatban az alsó állkapocs *(mandibula)*, a hollócsőrcsont *(coracoideum)*, a lapocka *(scapula)*, a felkarcsont *(humerus)* és a singcsont *(ulna),* a kézközépcsont *(carpometacarpus)*, a kézujjperc *(phalanx proximalis digiti majoris)*, a combcsont *(femur)*, a lábszárcsont *(tibiotarsus)*, a csüd *(tarsometatarsus)* és a karomcsont *(phalanx ungularis)* jellemzői találhatók.

A vizsgált vázrészek morfológiai jellegei, mérési módja és a csontok fényképe 52 táblaképen és 17 ábrán található. Tájékoztatási célból a mérési adatokat is közöljük 11 táblázatban. A határozó a kiválasztott morfológiai jellegek kódolásán alapszik. Minden tárgyalt csonton 3-6 jelleg került kiválasztásra, és ennek megfelelően a kódok 3-6 betűből állnak. Átfedések esetén a méretek az irányadóak, illetve a felkarcsontnál és a singcsontnál a két-két csontvég együttese használható.

Kulcsszavak: Közép-Európa, határozó, csonttani, paleornitológia, archeozoológia, énekesmadarak

Department of Paleontology, Eötvös Loránd University, 1117 Budapest, Pázmány Péter sétány 1/c, Hungary, e-mail: kessler_jeno@yahoo.com

Introduction

Despite the numerous songbird skeletal parts remaining in owl pellets, rocks from the Neogene period and at archaeological sites alike, the identification of these is still lagging behind all across Europe due to the lack of an ample comparative skeleton collection, and a relatively easy-to-use guidebook.

The current work wishes to aid this work by providing codes as well as images and measurement data.

The preparation of the guide was limited to the material of the recent osteological collection available in the Paleontological and Geological Department of the Hungarian Natural History Museum. There are only 48 (or 46-47) because not all genera had all the skeleton parts, or they were not in ample condition to photograph, hence the lower number of shown parts than the number of processed genera (51).

Only those skeletal parts are presented which have remained complete and which carry morphological characteristics that are characteristic at the genus level.

On the skull, only the tip of the mandibula, the proximal end of the coracoid and the scapula from the pectoral girdle are described. On the upper limb, the humerus, the ulna, the metacarpus bones *(carpometacarpus)* and the first phalanx bone of the second finger *(phalanx proximalis digiti majoris)* completely, whereas on the lower limb, the femur, the tibiotarsus, the distal end of the tarsometatarsus and the claw *(phalanx ungularis)* are described. The point is that since both ends *(epiphysis)* of either a humerus or an ulna are enough for a definition, and often the ends surface separately or partially because the bone itself is broken, they both can be traced as parts of the same bone and had been coded as such.

In the case of other long bones, only the end part, which had been easier to define, was coded.

Other parts of the excessively fragile skull, vertebrae, ribs, the sternum, the pelvis *(synsacrum)*, the clavicula, the radius, a few carpi *(carpale)* and the fibula *(peroneum)* are not presented here.

Since the largest family of the order of songbirds (Passeriformes), the Corvidae, is relatively well-known (Kessler & Moldvai 1993, Tomek & Bochenski 2000), genera belonging to here are not discussed. However, the Western Jackdaw *(Corvus monedula)* is used to illustrate anatomical and dimensional characteristics.

The distinctive feature of the guide lies in the method of coding. Each discussed skeletal part of each genus receives a 3-6-letter code, which can be used to identify the appropriate genus from the bone. The typical code types are presented for skeletal parts via tables and figures.

The guide is supplemented by 52 tables and 17 figures, with 4-4 tables for each discussed skeletal part. Eight of these are graphical illustrations (in case of the mandibula and scapula), while other bones are presented by original photographs. The preparatory state of the bones in the collection influenced the colour and sharpness of the photographs. The degreased skeletal parts appear more bright and sharp, while those remaining greased are less sharp and are darker. Colour and sharpness were modified by transforming the original colour image to greyscale.

Since more than half of the discussed 51 genera represent several species which primarily differ in size or color of their feathers, we also attach tables of dimensions for each skeletal part for information. The dimensions are taken from one specimen. In case of genera containing several species, the lower and upper limits of all the species are given.

From practical considerations we used the taxonomy after Cramp (1998). (Except of *Lusciniola*, wich was separated from *Acrocephalus.*)

Finally, it was not possible to show bones from the same sides of each skeletal part on the pictures.

Method

For every discussed skeletal part, the anatomical terminology (Baumel *et al.* 1979) and method of measurement (von den Driesch 1976, Gál 2002, Kessler 2013) of the bone in question is given, illustrated by the appropriate bone of the Western Jackdaw. Arrows indicate the coded characteristics.

For each anatomical character, a number of different types are differentiated, which received capitalized codes. We attempted to keep the number of codes at a minimum, since we had to take into account the individual differences and, in the case of genera featuring several species, the differences between them. This way we could make sure that even the more or less similar anatomical features can be classified easier and we could avoid subjective judgement.

Based on the characteristics used, we constructed a code consisting of 3-6 letters. The majority of these is typical for a single genera, but in a few cases, for more than one. In such cases, either the difference in size will define where they belong, or for similar sizes, the tables and figures provide guidance. (The tables with the bone sizes include genera with a single species, and genera with several species. In the first case, only a single size of the species is given. In the latter case, the limits of the smallest species and the biggest species from the genus are given.)

During genus identification, we create the code for the specific bone (or end of bone) and match it with the appropriate code in this guide. The images of genera with similar (but not identical) codes can give further help.

It is worth noting that the fewer of the characteristics are coded, the higher the chance of overlapping. Regarding overlapping of the humerus and ulna, we have to take into account the codes of both of the epiphyses.

Since for a definition of guaranteed accuracy the recent comparative osteological collection is absolutely required, this current guide can only serve information purposes.

Anatomical terminology (after: Milne-Edwards 1867-68, Fürbringer 1888, Lambrecht 1933, Ballmann 1966, Mourer-Chauviré 1975, Baumel *et al.* 1979, Gilbert *et al.* 1981, Cheneval 1983, Jánossy 1985, Moreno 1985, 1986, 1987, Cuisin 1989, Ujhelyi 1992, Kessler & Moldvai 1993, Solti 1996, Tomek & Bochenski 2000, Kessler 2013a). Plate with morphological characters *(Figure 1).*

1. *mandibula*:
a. *rostrum mandibulae;*
b. the immersed part of the *rostrum;*
c. *ramus mandibulae;*

***2. coracoideum*:**
a. acrocoracoideum;
b. tuberculum brachiale (processus acrocoracoideus);
c. sulcus musculi supracoracoidei;
d. processus procoracoideus;
e. processus glenoidalis coracoidei;

***3. scapula*:**
a. dorsal branch of the *acromion;*
b. lateral branch of the *acromion;*
c. the pit between the branches of the *acromion;*
d. *acromion;*
e. *processus glenoidalis scapulae;*

***4. humerus* (proximal *epiphysis*):**
a. tuberculum ventrale;
b. crista bicipitalis;
c. the edge between *crista bicipitalis* and *corpus humeri;*
d. fossa pneumotricipitalis;
e. caput humeri;
f. crista deltopectoralis;

***5. humerus* (distal *epiphysis*):**
a. tuberculum supracondylare ventrale;

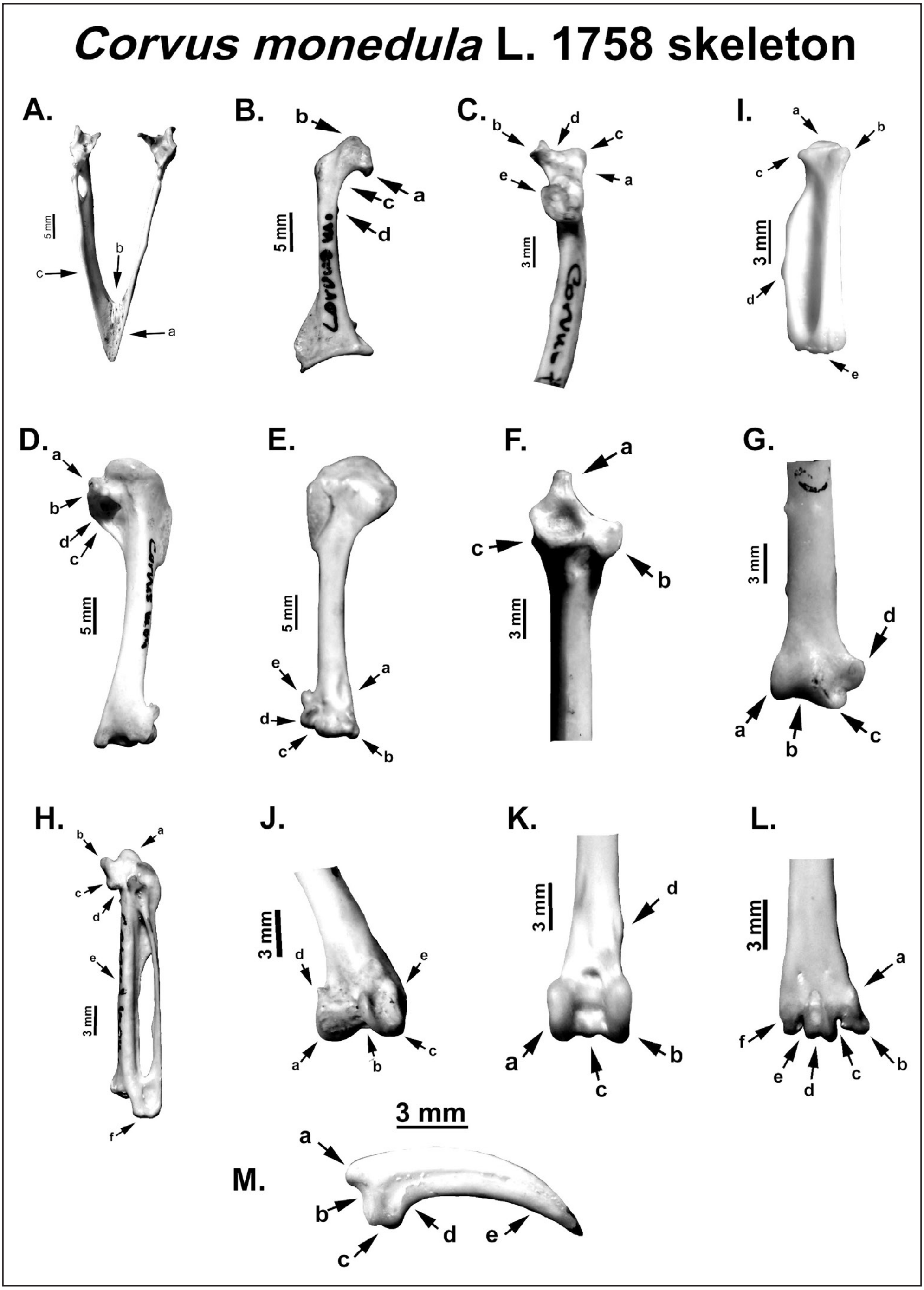


Figure 1 Morphological characters *Corvus monedula* L. 1758 bones;
(A – *mandibula*; B – *coracoideum*; C – *scapula*; D – *humerus prox.*; E – *humerus dist.*; F – *ulna prox.*; G – *ulna dist.*; H – *carpometacarpus*; I – *phalanx prox. dig. maj.*; J – *femur dist.*; K – *tibiotarsus dist.*; L – *tarsometatarsus dist.*; M – *phalanx ungularis*)

1. ábra Morfológiai jellegek *Corvus monedula* L. 1758 csontokon
(A – alsó állkapocs; B – hollócsőrcsont; C – lapocka; D – felkarcsont proximális epifízis; E – felkarcsont disztális epifízis; F – singcsont prox. epifízis; G – singcsont diszt. epifízis; H – kézközépcsont; I – szárny ujjperc; J – combcsont diszt. epifízis; K – lábszárcsont diszt. epifízis; L – csüd diszt. epifízis; M – karomcsont)

b. *processus flexorius;*
c. *processus supracondylaris dorsalis;*
d. *incisura intercondylaris;*

6. ***ulna*** **(proximal *epiphysis*):**
a. *olecranon;*
b. *cotyla dorsalis;*
c. *tuberculum ligamentum collateralis ventralis;*

7. ***ulna*** **(distal *epiphysis*):**
a. *condylus dorsalis;*
b. *sulcus intercondylaris;*
c. *condylus ventralis;*
d. *tuberculum carpale;*

8. *carpometacarpus*:
a. *trochlea carpalis;*
b. *processus extensorius;*
c. *processus alularis;*
d. *fovea subalularis;*
e. *protuberantia metacarpale majus;*
f. *facies articularis digitale minor;*

9. *phalanx proximalis digiti majoris*:
a. *margo proximalis;*
b. *tuberculum ventralis;*
c. *tuberculum dorsalis;*
d. *margo dorsalis;*
e. *margo distalis;*

10. *femur* (distal *epiphysis*):
a. *condylus medialis;*
b. *sulcus intercondylaris;*
c. *condylus lateralis;*
d. *epicondylus medialis;*
e. *epicondylus lateralis;*

11. ***tibiotarsus*** **(distal *epiphysis*):**
a. *epicondylus lateralis;*
b. *epicondylus medialis;*
c. *incisura intercondylaris;*
d. *tuberositas retinaculi;*

12. ***tarsometatarsus*** **(distal *epiphysis*):**
a. *margo medialis;*
b. *trochlea metatarsi* II.;
c. *trochlea metatarsi* III.;
d. *trochlea metatarsi* IV.;
e. *incisura intertrochlearis medialis;*
f. *incisura intertrochlearis lateralis;*

13. *phalanx ungularis*:
a. *tuberculum extensorium;*
b. *cotyla articularis*
c. *tuberculum flexorium*
d. the curvature of the *margo plantaris*
e. *apex phalangis;*

Measurement manner: (after: von den Driesch 1976, Gál 2002, Kessler 2013b)
Plate with measurement manner *(Figure 2)*:
TL – total length (a)
PL – partial length: *mandibula* – length of the *rostrum* (b), *scapula* – length of the proximal end (a)
Bp – breadth of the proximal end (b)
Bc – breadth of the corpus (c); *mandibula* – breadth of the *rostrum* (a)
Bd – breadth of the distal end (d)
PB – partial breadth: *mandibula* – breadth of the *ramus mandibulae* (c)

Abbrevations:
No. sp – measured number of species
LTB – *coracoideum* – length of the *tuberculum brachialis* (b)

The codification

1. *Mandibula* *(Figure 4, Plate 1–4, Table 1)*

1.1. the pointed end of the *rostrum mandibulae*:
– A. short and medium width: *Aegithalos; Bombycilla;*

- B. short and width*:* *Carduelis; Coccothraustes; Chloris; Delichon; Emberiza; Hirundo; Loxia; Passer; Pinicola; Plectrophenax; Pyrrhula; Riparia; Serinus;*
- C. medium long and width: *Fringilla; Lanius; Muscicapa; Oriolus;*
- D. medium long and medium width: *Acrocephalus; Anthus; Calandrella; Cinclus; Eremophila; Erithacus; Hippolais; Lullula; Luscinia; Oenanthe; Parus; Phoenicurus; Phylloscopus; Prunella; Remiz; Saxicola; Sitta; Sturnus; Sylvia; Turdus;*
- E. long and narrow: *Certhia; Troglodytes;*
- F. long and medium width: *Alauda; Cettia; Galerida; Locustella; Melanocorypha; Monticola; Motacilla;*

1.2. the immersed part of the *rostrum*:

- A. semicircular: *Aegithalos; Bombycilla; Carduelis; Emberiza; Hippolais; Muscicapa; Oenanthe; Sylvia;*
- B. semi-circle in the middle with small tip: *Anthus; Delichon; Monticola; Motacilla; Parus;*
- C. ovoid: *Alauda; Calandrella; Cinclus; Eremophila; Galerida; Hirundo; Lanius; Melanocorypha;*
- D. ovoid with small tip: *Locustella; Lullula; Riparia; Troglodytes;*
- E. pointed: *Acrocephalus; Certhia; Sitta;*
- F. semi-circle with small recess: *Erithacus; Oriolus; Prunella;*
- G. shouldered recess: *Cettia; Coccothraustes; Loxia; Phoenicurus; Phylloscopus; Saxicola; Sturnus; Turdus;*
- H. wide semi-circle: *Luscinia; Muscicapa; Fringilla; Plectrophenax; Remiz;*
- I. wide semi-circle with small tip: *Chloris; Passer; Pinicola; Pyrrhula; Serinus;*

1.3. **the form of the *ramus mandibulae*:**

- A. straight: *Acrocephalus; Alauda; Calandrella; Certhia; Cettia; Chloris; Cinclus; Emberiza; Galerida; Hippolais; Locustella; Lullula; Luscinia; Monticola; Oenanthe; Parus; Phylloscopus; Prunella; Saxicola; Sitta; Sturnus; Sylvia; Troglodytes;*
- B. slightly protruding above: *Aegithalos; Anthus; Bombycilla; Eremophila; Motacilla, Plectrophenax; Remiz;*
- C. wide or medium protruding above: *Delichon; Erithacus; Lanius; Muscicapa; Oriolus; Phoenicurus; Plectrophenax;*
- D. strongly protruding above: *Hirundo; Riparia; Melanocorypha;*
- E. slightly protruding below: *Carduelis; Fringilla; Passer; Serinus;*
- F. strongly protruding below: *Chloris; Coccothraustes; Loxia; Pinicola; Pyrrhula;*

Alaudidae: *Alauda* FCA; *Calandrella* DCA; *Eremophila* DCB; *Galerida* FCA; *Lullula* DDA; *Melanocorypha* DED;

Hirundinidae: *Delichon* BBC; *Hirundo* BCD; *Riparia* BDD;

Paridae: *Aegithalos* AAB; *Parus* DBA; *Remiz* DHB;

Certhiidae: *Certhia* EEA;

Sittidae: *Sitta* DEA;

Muscicapidae: *Erithacus* DFC; *Luscinia* DHA; *Monticola* FBA; *Muscicapa* CAC, *Oenanthe* DAA; *Phoenicurus* DGC; *Saxicola* DGA;

Turdidae: *Turdus* DGA;

Oriolidae: *Oriolus* CFC;

Sylviidae: *Acrocephalus* DEA; *Cettia* FGA; *Hippolais* DAA; *Locustella* FDA; *Phylloscopus* CGA; *Sylvia* CAA;

Motacillidae: *Anthus* DBB; *Motacilla* FBB;

Bombycillidae: *Bombycilla* AAB;

Troglodytidae: *Troglodytes* EDA;

Cinclidae: *Cinclus* DCA;

Prunellidae: *Prunella* DFA;

Laniidae: *Lanius* CCC;

Sturnidae: *Sturnus* DGA;
Passeridae: *Passer* BIE;
Fringillidae: *Carduelis* BAE; *Chloris* BIF; *Coccothraustes* BGF; *Fringilla* CHE; *Loxia* BGF; *Pinicola* BIF; *Pyrrhula* BIF; *Serinus* BIE;
Emberizidae: *Emberiza* BAA; *Plectrophenax* BHB;

AAB: *Aegithalos; Bombycilla;*
BAA: *Emberiza;*
BAE: *Carduelis;*
BBC: *Delichon;*
BCD: *Hirundo;*
BDD: *Riparia;*
BGF: *Coccothraustes; Loxia;*
BHB: *Plectrophenax;*
BIE: *Passer; Serinus;*
BIF: *Chloris; Pinicola; Pyrrhula;*
CAC: *Muscicapa;*
CCC: *Lanius;*
CFC: *Oriolus;*
CHE: *Fringilla;*
DAA: *Hippolais; Oenanthe; Sylvia;*
DBA: *Parus;*
DBB: *Anthus;*
DCA: *Calandrella; Cinclus;*
DCB: *Eremophila;*
DDA: *Lullula;*
DEA: *Acrocephalus; Sitta;*
DED: *Melanocorypha;*
DFA: *Prunella;*
DFC: *Erithacus;*
DGA: *Phylloscopus; Saxicola; Sturnus; Turdus;*
DGC: *Phoenicurus;*
DHA: *Luscinia;*
DHB: *Remiz;*
EDA: *Troglodytes;*
EEA: *Certhia;*
FBA: *Monticola;*
FBB: *Motacilla;*
FCA: *Alauda; Galerida;*
FDA: *Locustella;*
FGA: *Cettia;*

2. *Coracoideum* *(Figure 5, Plate 5–8, Table 2)*

2.1. the *processus acrocoracoideus (tuberculum brachiale)*:
- A. long and blunt: *Aegithalos; Certhia; Emberiza; Hippolais; Luscinia; Lusciniola; Muscicapa; Phoenicurus; Phylloscopus; Regulus; Saxicola; Sitta;*
- B. long and pointed: *Acrocephalus; Cettia; Erithacus; Oenanthe; Oriolus; Sylvia;*
- C. short and blunt: *Alauda; Anthus; Bombycilla; Calandrella; Carduelis; Chloris; Coccothraustes; Delichon; Galerida; Lanius; Locustella; Loxia; Lullula; Melanocorypha; Monticola; Motacilla; Parus; Passer; Pinicola; Pyrrhula; Remiz; Riparia; Sturnus; Troglodytes;*
- D. short and pointed: *Fringilla; Hirundo; Panurus; Plectrophenax; Prunella; Turdus;*

2.2. the *acrocoracoideum*:
- A. symmetrical: *Aegithalos; Alauda; Anthus; Carduelis; Chloris; Coccothraustes; Emberiza; Erithacus; Galerida; Loxia; Luscinia; Lullula; Melanocorypha; Monticola; Motacilla; Muscicapa; Oenanthe; Panurus; Pinicola; Phylloscopus; Plectrophenax; Pyrrhula; Remiz; Riparia; Sitta; Sturnus;*
- B. assymmetric: *Acrocephalus; Bombycilla; Calandrella; Certhia; Cettia; Delichon; Fringilla; Hippolais; Hirundo; Lanius; Locustella; Lusciniola; Oriolus; Parus; Passer; Phoenicurus; Prunella; Regulus; Saxicola; Sylvia; Troglodytes; Turdus;*

2.3. the *sulcus musculi supracoracoidei*:

- A. symmetrically semicircular: *Acrocephalus; Certhia; Erithacus; Lanius; Melanocorypha; Monticola; Muscicapa; Oenanthe; Pyrrhula; Turdus;*
- B. asymmetrically semicircular: *Aegithalos; Bombycilla; Carduelis; Cettia; Chloris; Coccothraustes; Delichon; Galerida; Hippolais; Hirundo; Luscinia; Lusciniola; Oriolus; Panurus; Parus; Phoenicurus; Phylloscopus; Regulus; Remiz; Riparia; Saxicola; Sitta; Sturnus; Sylvia;*
- C. flattened: *Alauda; Anthus; Calandrella; Emberiza; Fringilla; Locustella; Loxia; Lullula; Motacilla; Passer; Pinicola; Plectrophenax; Prunella; Troglodytes;*

2.4. the *processus procoracoideus*:

- A. missing: *Bombycilla; Cettia; Delichon; Galerida; Hippolais; Hirundo; Luscinia; Lusciniola; Motacilla; Panurus; Parus; Phylloscopus; Remiz; Riparia;*
- B. slightly overhanging: *Acrocephalus; Aegithalos; Alauda; Carduelis; Chloris; Lanius; Locustella; Melanocorypha; Passer; Phoenicurus; Prunella; Regulus; Sitta; Sylvia;*
- C. strongly protruding: *Anthus; Calandrella; Certhia; Coccothraustes; Emberiza; Erithacus; Fringilla; Loxia; Lullula; Monticola; Muscicapa; Oenanthe; Oriolus; Pinicola; Plectrophenax; Pyrrhula; Saxicola; Sturnus; Troglodytes; Turdus;*

Alaudidae: *Alauda* CACB; *Calandrella* CBCC; *Galerida* CABA; *Lullula* CACC; *Melanocorypha* CAAB;
Hirundinidae: *Delichon* CBBA; *Hirundo* DBBA; *Riparia* CABA;
Paridae: *Aegithalos* AABB; *Panurus* DABA; *Parus* CBBA; *Remiz* CABA;
Certhiidae: *Certhia* ABAC;
Sittidae: *Sitta* AABB;
Muscicapidae: *Erithacus* BAAC; *Luscinia* AABA; *Monticola* CAAC; *Muscicapa* AAAC, *Oenanthe* BAAC; *Phoenicurus* ABBB; *Saxicola* ABBC;
Turdidae: *Turdus* DBAC;
Oriolidae: *Oriolus* BBBC;
Sylviidae: *Acrocephalus* BBAB; *Cettia* BBBA; *Hippolais* ABBA; *Locustella* CBCB; *Lusciniola* ABBA; *Phylloscopus* AABA; *Regulus* ABBB; *Sylvia* BBBB;
Motacillidae: *Anthus* CACC; *Motacilla* CACA;
Bombycillidae: *Bombycilla* CBBA;
Troglodytidae: *Troglodytes* CBCC;
Prunellidae: *Prunella* DBCB;
Laniidae: *Lanius* CBAB;
Sturnidae: *Sturnus* CABC;
Passeridae: *Passer* CBCB;
Fringillidae: *Carduelis* CABB; *Chloris* CABB; *Coccothraustes* CABC; *Fringilla* DBCC; *Loxia* CACC; *Pinicola* CACC; *Pyrrhula* CAAC;
Emberizidae: *Emberiza* AACC; *Plectrophenax* DACC;

AAAC: *Muscicapa;*
AABA: *Luscinia; Phylloscopus;*
AABB: *Aegithalos; Sitta;*
AACC: *Emberiza;*
ABAC: *Certhia;*
ABBA: *Hippolais; Lusciniola;*
ABBB: *Phoenicurus; Regulus;*
ABBC: *Saxicola;*
BAAC: *Erithacus; Oenanthe;*
BBAB: *Acrocephalus;*
BBBA: *Cettia;*
BBBB: *Sylvia;*
BBBC: *Oriolus;*
CAAB: *Melanocorypha;*
CAAC: *Monticola; Pyrrhula;*
CABA: *Galerida; Riparia; Remiz;*
CABB: *Carduelis; Chloris;*
CABC: *Coccothraustes; Sturnus;*

CACA: *Motacilla;*
CACB: *Alauda;*
CACC: *Anthus; Loxia; Lullula; Pinicola;*
CBBA: *Bombycilla; Delichon; Parus;*
CBCB: *Locustella; Passer;*
CBCC: *Calandrella;*
DABA: *Panurus;*
DACC: *Plectrophenax;*
DBAC: *Turdus;*
DBCB: *Prunella;*
DBCC: *Fringilla;*

3. ***Scapula*** *(Figure 6, Plate 9–12, Table 3)*

3.1. the length of the branches of *acromion*:

- A. symmetrically (equal): *Acrocephalus; Anthus; Calandrella; Carduelis; Certhia; Cettia; Coccothraustes; Delichon; Emberiza; Hippolais; Locustella; Lullula; Lusciniola; Monticola; Motacilla; Oenanthe; Parus; Passer; Phylloscopus; Pyrrhula; Sturnus; Sylvia; Turdus;*
- B. asymmetrically (unequal): *Alauda; Bombycilla; Chloris; Eremophila; Erithacus; Fringilla; Galerida; Hirundo; Lanius; Loxia; Luscinia; Melanocorypha; Muscicapa; Oriolus; Panurus; Phoenicurus; Pinicola; Plectrophenax; Prunella; Remiz; Riparia; Saxicola; Serinus; Sitta; Troglodytes;*

3.2. the shape of the branches of *acromion*:

- A. symmetrically (equal): *Acrocephalus; Carduelis; Coccothraustes; Delichon; Emberiza; Erithacus; Hippolais; Lusciniola; Motacilla; Muscicapa; Passer; Phylloscopus; Turdus;*
- B. asymmetrically (unequal): *Alauda; Anthus; Bombycilla; Calandrella; Certhia; Cettia; Chloris; Eremophila; Fringilla; Galerida; Hirundo; Lanius; Locustella; Loxia; Lullula; Luscinia; Melanocorypha; Monticola; Oenanthe; Oriolus; Panurus; Parus; Phoenicurus; Pinicola; Plectrophenax; Prunella; Pyrrhula; Remiz; Riparia; Saxicola; Serinus; Sitta; Sturnus; Sylvia; Troglodytes;*

3.3. the *apex dorsalis* (dorsal branch):

- A. short and blunted: *Acrocephalus; Certhia; Cettia; Delichon; Erithacus; Hirundo; Locustella; Panurus; Plectrophenax; Riparia; Sitta;*
- B. short and pointed: *Serinus; Troglodytes;*
- C. long and blunted: *Anthus; Carduelis; Coccothraustes; Emberiza; Eremophila; Fringilla; Hippolais; Lanius; Loxia; Lusciniola; Melanocorypha; Motacilla; Muscicapa; Oenanthe; Oriolus; Parus; Passer; Phylloscopus; Pinicola; Prunella; Pyrrhula; Sturnus; Turdus;*
- D. long and pointed: *Bombycilla; Calandrella; Chloris; Galerida; Monticola; Phoenicurus; Saxicola; Sylvia;*
- E. with a cut-off end: *Alauda; Lullula; Luscinia; Remiz;*

3.4. the *apex lateralis* (lateral branch):

- A. short and blunted: *Certhia; Delichon; Erithacus; Galerida; Lanius; Melanocorypha; Loxia; Oriolus; Phoenicurus; Pinicola; Plectrophenax; Saxicola; Troglodytes;*
- B. short and pointed: *Bombycilla; Cettia; Hirundo; Locustella; Remiz;*
- C. long and blunted: *Acrocephalus; Alauda; Anthus; Calandrella; Carduelis; Coccothraustes; Emberiza; Eremophila; Fringilla; Hippolais; Lullula; Luscinia; Lusciniola; Motacilla; Monticola; Muscicapa; Oenanthe; Panurus; Parus; Passer; Phylloscopus; Pyrrhula; Riparia; Sylvia; Sturnus; Serinus; Turdus;*
- D. long and pointed: *Chloris; Sitta;*

3.5. the pit between the branches:

- A. deep and symmetrical: *Alauda; Bombycilla; Calandrella; Carduelis; Chloris; Coccothraustes; Emberiza; Fringilla; Lanius; Lullula; Melanocorypha; Motacilla; Muscicapa; Oenanthe; Oriolus; Parus; Passer; Remiz; Sylvia; Turdus;*
- B. deep and unsymmetrical: *Anthus; Eremophila; Phoenicurus; Pinicola; Serinus; Sturnus;*
- C. shallow and symmetrical: *Acrocephalus; Cettia; Delichon; Erithacus; Galerida; Hippolais; Hirundo; Locustella; Luscinia; Lusciniola; Monticola; Phylloscopus; Plectrophenax; Pyrrhula; Riparia; Troglodytes;*
- D. shallow and unsymmetrical: *Certhia; Loxia; Panurus; Prunella; Saxicola; Sitta;*

Alaudidae: *Alauda* BBECA; *Calandrella* ABDCA; *Eremophila* BBCCB; *Galerida* BBDAC; *Lullula* ABECA; *Melanocorypha* BBCAA;

Hirundinidae: *Delichon* AAAAC; *Hirundo* BBABC; *Riparia* BBACC

Paridae: *Panurus* BAACD; *Parus* ABCCA; *Remiz* BBEBA;

Certhiidae: *Certhia* ABAAD;

Sittidae: *Sitta* BBADD;

Muscicapidae: *Erithacus* BAAAC; *Luscinia* BBECC; *Monticola* ABDCC; *Muscicapa* BACCA, *Oenanthe* ABCCA; *Phoenicurus* BBDAB; *Saxicola* BBDAD;

Turdidae: *Turdus* AACCA;

Oriolidae: *Oriolus* BBCAA;

Sylviidae: *Acrocephalus* AAACC; *Cettia* ABABC; *Hippolais* AACCC; *Locustella* ABABC; *Lusciniola* AACCC; *Phylloscopus* AACCC; *Sylvia* ABDCA;

Motacillidae: *Anthus* ABCCB; *Motacilla* AACCA;

Bombycillidae: *Bombycilla* BBDBA;

Troglodytidae: *Troglodytes* BBBAC;

Prunellidae: *Prunella* BBCAD;

Laniidae: *Lanius* BBCAA**;**

Sturnidae: *Sturnus* ABCCB;

Passeridae: *Passer* AACCA;

Fringillidae: *Carduelis* AACCA; *Chloris* BBDDA; *Coccothraustes* AACCA; *Fringilla* BBCCA; *Loxia* BBCAD; *Pinicola* BBCAB; *Pyrrhula* ABCCC; *Serinus* BBBCB;

Emberizidae: *Emberiza* AACCA; *Plectrophenax* BBAAC*;*

AAAAC: *Delichon;*

AACCA: *Carduelis; Coccothraustes; Emberiza; Motacilla; Passer; Turdus;*

AAACC: *Acrocephalus;*

AACCC: *Hippolais; Lusciniola; Phylloscopus;*

ABAAD: *Certhia;*

ABABC: *Cettia; Locustella;*

ABBAB: *Serinus;*

ABCCA: *Emberiza; Oenanthe; Parus;*

ABCCB: *Anthus; Sturnus;*

ABCCC: *Pyrrhula;*

ABDCA: *Calandrella; Sylvia;*

ABDCC: *Monticola;*

ABECA: *Lullula;*

BAAAC: *Erithacus;*

BACCA: *Muscicapa;*

BBAAC: *Plectrophenax;*

BBABC: *Hirundo;*

BBACB: *Anthus;*

BBACB: *Loxia;*

BBACC: *Riparia;*

BBACD: *Panurus;*

BBADD: *Sitta;*

BBBAC: *Troglodytes:*

BBBCB: *Serinus;*

BBBCD: *Saxicola;*

BBCAA: *Lanius; Melanocorypha; Oriolus;*

BBCAB: *Pinicola;*

BBCAD: *Loxia; Prunella;*

BBCCA: *Fringilla;*

BBCCB: *Eremophila;*
BBDAB: *Phoenicurus;*
BBDAC: *Galerida;*
BBDAD: *Saxicola;*
BBDBA: *Bombycilla;*
BBDDA: *Chloris;*
BBEBA: *Remiz;*
BBECA: *Alauda;*
BBECC: *Luscinia;*

4. *Humerus* (proximal *epiphysis*) *(Figure 7, Plate 13–16, Table 4)*

4.1. the *tuberculum ventrale*:

– A. strongly protruding: *Alauda; Bombycilla; Certhia; Cettia; Cinclus; Coccothraustes; Delichon; Erithacus; Fringilla; Galerida; Hirundo; Loxia; Lullula; Luscinia; Lusciniola; Monticola; Motacilla; Muscicapa; Oenanthe; Oriolus; Passer; Phoenicurus; Phylloscopus; Pinicola; Pyrrhula; Riparia; Saxicola; Serinus;*
– B. poorly protruding: *Acrocephalus; Aegithalos; Anthus; Carduelis; Chloris; Emberiza; Hippolais; Lanius; Locustella; Melanocorypha; Panurus; Parus; Prunella; Sitta; Sturnus; Sylvia; Troglodytes; Turdus;*

4.2. the projection of the *crista bicipitalis*:

– A. prominent and rounded*: Aegithalos; Anthus; Emberiza; Erithacus; Galerida; Hippolais; Lullula; Passer; Phylloscopus; Pinicola; Prunella; Pyrrhula; Riparia; Serinus; Sitta; Sturnus; Troglodytes;*
– B. prominent and pointed: *Fringilla; Lusciniola;*
– C. truncated: *Acrocephalus; Carduelis; Certhia; Cettia; Chloris; Cinclus; Coccothraustes; Delichon; Hirundo; Lanius; Lanius; Locustella; Loxia; Oriolus; Parus; Sylvia; Turdus;*
– D. rounded and not prominent: *Bombycilla; Lanius; Lullula; Luscinia; Melanocorypha; Motacilla; Muscicapa; Panurus; Saxicola;*
– E. slightly pointed distally: *Alauda; Monticola; Oenanthe; Phoenicurus; Turdus;*

4.3. the distal edge of the *crista bicipitalis*:

– A. flatly curved*: Alauda; Bombycilla; Chloris; Cinclus; Delichon; Fringilla; Loxia; Luscinia; Panurus; Passer; Pinicola; Prunella; Riparia; Sturnus;*
– B. strongly curved: *Acrocephalus; Aegithalos; Anthus; Carduelis; Certhia; Cettia; Chloris; Coccothraustes; Emberiza; Erithacus; Galerida; Hippolais; Hirundo; Lanius; Locustella; Lullula; Lusciniola; Melanocorypha; Monticola; Motacilla; Muscicapa; Oenanthe; Oriolus; Parus; Phoenicurus; Phylloscopus; Pyrrhula; Saxicola; Serinus; Sitta; Sylvia; Troglodytes; Turdus;*

4.4. the *fossa pneumotricipitalis*:

– A. split: *Acrocephalus; Alauda; Bombycilla; Certhia; Cettia; Cinclus; Delichon; Galerida; Hirundo; Hippolais; Lanius; Locustella; Lullula; Lusciniola; Melanocorypha; Monticola; Muscicapa; Oenanthe; Oriolus; Passer; Phoenicurus; Phylloscopus; Prunella; Riparia; Saxicola; Sturnus; Sylvia; Turdus;*
– B. no split: *Aegithalos; Anthus; Carduelis; Chloris; Coccothraustes; Emberiza; Erithacus; Fringilla; Loxia; Luscinia; Motacilla; Panurus; Parus; Pinicola; Pyrrhula; Serinus; Sitta; Troglodytes;*

Alaudidae: *Alauda* AEAA; *Galerida* AABA; *Lullula* ADBA; *Melanocorypha* BDBA;
Hirundinidae: *Delichon* ACAA; *Hirundo* ACBA; *Riparia* AAAA;

Paridae: *Aegithalos* BABB; *Panurus* BDAB; *Parus* BCBB;
Certhiidae: *Certhia* ACBA;
Sittidae: *Sitta* BABB;
Muscicapidae: *Erithacus* AABB; *Luscinia* ADAB; *Monticola* AEBA; *Muscicapa* ADBA; *Oenanthe* AEBA; *Phoenicurus* AEBA; *Saxicola* ADBA;
Turdidae: *Turdus* BEBA;
Oriolidae: *Oriolus* ACBA;
Sylviidae: *Acrocephalus* BCBA; *Cettia* ACBA; *Hippolais* BABA**;** *Locustella* BCBA; *Lusciniola* ABBA; *Phylloscopus* AABA; *Sylvia* BCBA;
Motacillidae: *Anthus* BABB; *Motacilla* ADBB;
Bombycillidae: *Bombycilla* ADAA;
Troglodytidae: *Troglodytes* BABB;
Cinclidae: *Cinclus* ACBA:
Prunellidae: *Prunella* BAAA;
Laniidae: *Lanius* BCBA;
Sturnidae: *Sturnus* BAAA;
Passeridae: *Passer* AAAA;
Fringillidae: *Carduelis* BCBB; *Chloris* ACAB; *Coccothraustes* ACBB; *Fringilla* ABAB; *Loxia* ACAB; *Pinicola* AAAB; *Pyrrhula* AABB; *Serinus* AABB;
Emberizidae: *Emberiza* BABB;

AAAA: *Riparia; Passer;*
AAAB: *Pinicola;*
AABA: *Galerida; Phylloscopus;*
AABB: *Erithacus; Pyrrhula; Serinus;*
ABAB: *Fringilla;*
ABBA: *Lusciniola;*
ACAA: *Certhia; Coccothraustes; Delichon;*
ACAB: *Chloris; Loxia;*
ACBA: *Cettia; Certhia; Cinclus: Hirundo; Oriolus;*
ACBB: *Coccothraustes;*
ADAA: *Bombycilla;*
ADAB: *Luscinia;*
ADBA: *Lullula; Muscicapa; Saxicola;*
ADBB: *Motacilla;*
AEAA: *Alauda;*
AEBA: *Monticola; Oenanthe; Phoenicurus;*
BAAA: *Prunella; Sturnus;*
BAAB: *Sitta;*
BABA: *Emberiza; Hippolais;*
BABB: *Aegithalos; Anthus; Emberiza; Sitta; Troglodytes;*
BCAA: *Parus;*
BCBA: *Acrocephalus; Lanius; Locustella; Sylvia;*
BCBB: *Carduelis; Parus;*
BDAB: *Panurus;*
BDBA: *Melanocorypha;*
BEBA: *Turdus;*

5. ***Humerus*** (distal ***epiphysis***) *(Figure 8, Plate 17–20, Table 4)*

5.1. the ***tuberculum supracondylare ventrale***:

- A. protuberant: *Acrocephalus; Aegithalos; Bombycilla; Carduelis; Certhia; Cettia; Chloris; Cinclus; Coccothraustes; Delichon; Emberiza; Erithacus; Hippolais; Hirundo; Loxia; Lullula; Melanocorypha; Monticola; Parus; Parus; Passer; Pinicola; Riparia; Saxicola; Serinus; Sitta; Sturnus; Troglodytes;*
- B. not prominent: *Alauda; Anthus; Fringilla; Galerida; Lanius; Locustella; Luscinia; Lusciniola; Motacilla; Muscicapa; Oenanthe; Oriolus; Panurus; Phoenicurus; Phylloscopus; Prunella; Pyrrhula; Sylvia; Turdus;*

5.2. the ***processus flexorius***:

- A. slightly overhanging: *Alauda; Carduelis; Cinclus; Galerida; Emberiza; Lullula; Lusciniola; Sitta;*

- B. strongly *overhanging with* rounded ends: *Anthus; Bombycilla; Certhia; Chloris; Coccothraustes; Emberiza; Fringilla; Locustella; Monticola; Motacilla; Muscicapa; Oriolus; Panurus; Passer; Phoenicurus; Prunella; Pyrrhula; Riparia; Saxicola; Serinus; Sturnus; Troglodytes;*
- C. strongly overhanging with severed ends: *Acrocephalus; Aegithalos; Cettia; Erithacus; Hippolais; Lanius; Loxia; Luscinia; Oenanthe; Parus; Pinicola; Sylvia; Turdus;*
- D. markedly protruding conically: *Melanocorypha; Phylloscopus;*
- E. asymmetrical strongly protruding: *Delichon; Hirundo; Riparia;*

5.3. the *incisura intercondylaris*:

- A. concave and wide: *Alauda; Cinclus: Coccothraustes; Delichon; Emberiza; Galerida; Lusciniola; Melanocorypha; Phoenicurus;*
- B. slightly concave: *Anthus; Chloris; Fringilla; Lanius; Lullula; Luscinia; Monticola; Motacilla; Muscicapa; Oenanthe; Oriolus; Panurus; Parus; Passer; Prunella; Pyrrhula; Saxicola; Serinus; Sitta; Sylvia; Troglodytes;*
- C. pointed and wide: *Acrocephalus; Aegithalos; Bombycilla; Carduelis; Certhia; Cettia; Erithacus; Hippolais; Hirundo; Locustella; Loxia; Phylloscopus; Pinicola; Riparia; Sturnus; Turdus;*

5.4. the *condylus dorsalis*:

- A. rounded: *Alauda; Anthus; Bombycilla; Carduelis; Certhia; Cettia; Chloris; Cinclus; Coccothraustes; Emberiza; Erithacus; Fringilla; Galerida; Hirundo; Lanius; Locustella; Loxia; Lullula; Luscinia; Lusciniola; Lusciniola; Melanocorypha; Monticola; Motacilla; Muscicapa; Oenanthe; Panurus; Parus; Passer; Phoenicurus; Phylloscopus; Pinicola; Prunella; Pyrrhula; Saxicola; Serinus; Sturnus; Sylvia; Troglodytes;*
- B. asymmetric: *Acrocephalus; Aegithalos; Delichon; Hippolais; Oriolus; Riparia; Sitta; Turdus;*

5.5. the *processus supracondylaris dorsalis*:

- A. single and slightly protruding: *Prunella;*
- B. single and strongly protruding: *Cinclus: Delichon; Lanius; Locustella; Loxia; Melanocorypha; Muscicapa; Panurus; Serinus; Troglodytes; Turdus;*
- C. two-pronged equal: *Aegithalos; Alauda; Certhia;*
- D. two-pronged unequal: *Acrocephalus; Anthus; Bombycilla; Carduelis; Cettia; Chloris; Coccothraustes; Emberiza; Erithacus; Fringilla; Galerida; Hippolais; Hirundo; Lullula; Luscinia; Lusciniola; Monticola; Motacilla; Oenanthe; Oriolus; Parus; Passer; Phylloscopus; Phoenicurus; Pinicola; Pyrrhula; Riparia; Saxicola; Sitta; Sturnus; Sylvia;*

Alaudidae: *Alauda* BAAAC; *Galerida* BAAAD; *Lullula* AAABD; *Melanocorypha* ADAAB;

Hirundinidae: *Delichon* AEABB; *Hirundo* AECAD; *Riparia* AECBD;

Paridae: *Aegithalos* ACCBC; *Panurus* BBBAB; *Parus* ACBAD;

Certhiidae: *Certhia* ABCAC;

Sittidae: *Sitta* AABBD;

Muscicapidae: *Erithacus* ABCAD; *Luscinia* BCBAD; *Monticola* ABBAD; *Muscicapa* BBBAB; *Oenanthe* BCBAD; *Phoenicurus* BBAAD; *Saxicola* ABBAD;

Turdidae: *Turdus* BCCBB;

Oriolidae: *Oriolus* BBBBD;

Sylviidae: *Acrocephalus* ACCBD; *Cettia* ACCAD; *Hippolais* ACCBD**;** *Locustella*

BBCAB; *Lusciniola* BAAAD; *Phylloscopus* BDCAD; *Sylvia* BCBAD;
Motacillidae: *Anthus* BBBAD; *Motacilla* BBBAD;
Bombycillidae: *Bombycilla* ABCAD;
Troglodytidae: *Troglodytes* ABBAB;
Cinclidae: *Cinclus* AAAAB;
Prunellidae: *Prunella* BBBAA;
Laniidae: *Lanius* BCBAB;
Sturnidae: *Sturnus* ABCAD;
Passeridae: *Passer* ABBAD;
Fringillidae: *Carduelis* AACAD; *Chloris* ABBAD; *Coccothraustes* ABAAD; *Fringilla* BBBAD; *Loxia* ACCAB; *Pinicola* ACCAD; *Pyrrhula* BBBAD; *Serinus* ABBAB;
Emberizidae: *Emberiza* ABAAD;

AAAAB: *Cinclus;*
AAABD: *Lullula;*
AABBD: *Sitta;*
ABAAD: *Coccothraustes; Emberiza;*
ABBAB: *Serinus; Troglodytes;*
ABBAD: *Chloris; Monticola; Passer; Saxicola;*
ABCAC: *Certhia;*
ABCAD: *Bombycilla; Erithacus; Sturnus;*
ACBAD: *Parus;*
ACCAB: *Loxia;*
ACCAD: *Cettia; Pinicola;*
ACCBC: *Aegithalos;*
ACCBD: *Acrocephalus; Hippolais;*
ADAAB: *Melanocorypha;*
AEABB: *Delichon;*
AECAD: *Hirundo;*
AECBD: *Riparia;*
BAAAC: *Alauda;*
BAAAD: *Galerida; Lusciniola;*
BBAAD: *Phoenicurus;*
BBBAA: *Prunella;*
BBBAB: *Muscicapa; Panurus;*
BBBAD: *Anthus; Fringilla; Motacilla; Pyrrhula;*
BBBBD: *Oriolus;*
BBCAB: *Locustella;*
BCBAB: *Lanius;*
BCBAD: *Luscinia; Oenanthe; Sylvia;*
BCCBB: *Turdus;*
BDCAD: *Phylloscopus;*

6. ***Ulna*** **(proximal *epiphysis*)** *(Figure 9, Plate 21–24, Table 5)*

6.1. the *olecranon*:
- A. short and pointed: *Alauda; Certhia; Hirundo; Locustella; Muscicapa; Pyrrhula;*
- B. short and blunt*: Aegithalos; Carduelis; Chloris; Coccothraustes; Erithacus; Galerida; Hippolais; Lullula; Oenanthe; Oriolus; Parus; Phoenicurus; Phylloscopus; Pinicola; Plectrophenax; Regulus; Remiz; Riparia; Saxicola; Sitta;*
- C. long, narrow and pointed: *Calandrella; Delichon; Fringilla; Luscinia; Passer; Prunella; Turdus;*
- D. long and blunt: *Acrocephalus; Anthus; Bombycilla; Cinclus; Emberiza; Eremophila; Loxia; Lusciniola; Lanius; Motacilla; Panurus; Serinus; Sturnus; Sylvia; Troglodytes;*

6.2. the *cotyla dorsalis*:
- A. semicircular: *Aegithalos; Anthus; Bombycilla; Calandrella; Carduelis; Certhia; Chloris; Cinclus; Erithacus; Fringilla; Hippolais; Lanius; Loxia; Lullula; Luscinia, Motacilla; Muscicapa, Parus; Passer; Phoenicurus; Phylloscopus; Plectrophenax; Prunella; Pyrrhula; Regulus; Remiz; Riparia; Sitta; Sturnus; Turdus;*
- B. conical: *Acrocephalus; Coccothraustes; Galerida; Eremophila; Hirundo; Locustella; Panurus; Serinus;*
- C. elongated conical: *Luscinola; Sylvia;*
- D. truncated: *Alauda; Emberiza; Oenanthe; Saxicola; Troglodytes;*

- E. asymmetrical: *Delichon; Oriolus; Pinicola;*

6.3. the *tuberculum ligamentum collateralis ventralis*:

- A. developed: *Aegithalos; Alauda; Anthus; Bombycilla; Calandrella; Certhia; Cinclus; Delichon; Eremophila; Erithacus; Fringilla; Galerida; Hippolais; Hirundo; Loxia; Lullula; Luscinia; Lusciniola; Motacilla; Muscicapa; Oenanthe; Parus; Passer; Phoenicurus; Pinicola; Plectrophenax; Pyrrhula; Regulus; Remiz; Riparia; Saxicola; Sitta; Serinus; Sylvia; Turdus;*
- B. undeveloped: *Acrocephalus; Carduelis, Chloris; Coccothraustes; Emberiza; Lanius; Locustella; Oriolus; Panurus; Phylloscopus; Prunella; Sturnus; Troglodytes;*

Alaudidae: *Alauda* ADA; *Calandrella* CAA; *Eremophila* DBA; *Galerida* BBA; *Lullula* BAA;
Hirundinidae: *Delichon* CEA; *Hirundo* ABA; *Riparia* BAA;
Paridae: *Aegithalos* BAA; *Panurus* DBB; *Parus* BAB; *Remiz* BAA;
Certhiidae: *Certhia* AAA;
Sittidae: *Sitta* BAA;
Muscicapidae: *Erithacus* BAA; *Luscinia* CAA; *Muscicapa* AAA; *Oenanthe* BDA; *Phoenicurus* BAA; *Saxicola* BDA;
Turdidae: *Turdus* CAA;
Oriolidae: *Oriolus* DEB;
Sylviidae: *Acrocephalus* DBB; *Hippolais* BAA; *Locustella* ABB; *Lusciniola* DCA; *Phylloscopus* BAB; *Regulus* BAA; *Sylvia* DCA;
Motacillidae: *Anthus* DAA; *Motacilla* DAA;
Bombycillidae: *Bombycilla* DAA;
Troglodytidae: *Troglodytes* DDB;
Cinclidae: *Cinclus* DAA;
Prunellidae: *Prunella* CAB;
Laniidae: *Lanius* DAB;
Sturnidae: *Sturnus* DAB;
Passeridae: *Passer* CAA;
Fringillidae: *Carduelis* BAB; *Chloris* BAB; *Coccothraustes* BBB; *Fringilla* CAA; *Loxia* DAA; *Pinicola* BEA; *Pyrrhula* AAA; *Serinus* DBA;
Emberizidae: *Emberiza* DDB; *Plectrophenax* BAA;

AAA: *Certhia; Muscicapa; Pyrrhula;*
ABA: *Hirundo;*
ABB: *Locustella;*
ABD: *Monticola;*
ADA: *Alauda;*
BAA: *Aegithalos; Erithacus; Hippolais; Lullula; Parus; Phoenicurtus; Plectrophenax; Regulus; Remiz; Riparia; Sitta;*
BAB: *Carduelis; Chloris; Phylloscopus;*
BBA: *Galerida;*
BBB: *Coccothraustes;*
BDA: *Oenanthe; Saxicola;*
BEA: *Pinicola;*
BEB: *Oriolus;*
CAA: *Calandrella; Fringilla; Luscinia; Passer; Turdus;*
CAB: *Prunella;*
CEA: *Delichon;*
DAA: *Anthus; Bombycilla; Cinclus: Loxia; Motacilla;*
DAB: *Lanius; Sturnus;*
DBA: *Eremophila; Serinus;*
DBB: *Acrocephalus;*
DBB: *Panurus;*
DCA: *Lusciniola; Sylvia;*
DDB: *Emberiza; Troglodytes;*

7. *Ulna* (distal *epiphysis*) *(Figure 10, Plate 25–28, Table 5)*

7.1. the shape of the *condylus dorsalis*:

- A. pointed cone: *Aegithalos; Calandrella; Carduelis; Delichon; Emberiza; Eremophila; Galerida; Loxia; Lusciniola; Phylloscopus; Regulus; Riparia; Sitta; Sylvia; Turdus;*
- B. blunted cone: *Acrocephalus; Alauda; Anthus; Chloris; Cinclus; Coccothraustes; Erithacus; Fringilla; Hippolais; Hirundo; Lanius; Locustella; Lullula; Luscinia; Motacilla, Parus; Phoenicurus; Pinicola; Plectrophenax; Prunella; Pyrrhula; Remiz; Saxicola; Serinus; Troglodytes;*
- C. rounded: *Bombycilla; Certhia; Muscicapa, Oenanthe; Oriolus; Panurus; Passer; Sturnus;*

7.2. the shape of the *sulcus intercondylaris*:

- A. curved: *Acrocephalus; Anthus; Calandrella; Cinclus; Delichon; Emberiza; Eremophila; Erithacus; Fringilla; Galerida; Hippolais, Lanius; Locustella; Loxia; Lullula; Luscinia; Lusciniola; Oriolus; Parus; Phoenicurus; Phylloscopus, Plectrophenax; Prunella; Pyrrhula; Regulus; Remiz; Saxicola; Serinus; Sitta; Sylvia; Troglodytes; Turdus;*
- B. asymmetrically curved: *Aegithalos; Carduelis; Riparia;*
- C. pointed*: Alauda; Bombycilla; Certhia; Chloris; Coccothraustes; Hirundo; Motacilla; Muscicapa; Oenanthe; Panurus; Passer; Pinicola; Sturnus;*

7.3. the shape of the *condylus ventralis*:

- A. conical: *Calandrella; Delichon; Emberiza; Loxia; Riparia; Sylvia;*
- B. blunt cone: *Acrocephalus; Aegithalos; Anthus; Chloris; Cinclus; Eremophila; Fringilla, Galerida; Hirundo; Locustella; Lullula; Lusciniola; Parus; Phoenicurus; Phylloscopus; Plectrophenax; Regulus; Remiz; Serinus; Sitta; Troglodytes;*
- C. rounded: *Alauda; Bombycilla; Carduelis; Certhia; Coccothraustes; Erithacus; Erithacus; Hippolais; Lanius; Luscinia; Motacilla; Muscicapa; Oenanthe; Oriolus; Panurus; Passer; Pinicola; Prunella; Pyrrhula, Saxicola; Sturnus; Turdus;*

7.4. the shape of the *tuberculum carpale*:

- A. semicircular: *Aegithalos; Alauda; Bombycilla, Calandrella; Certhia; Chloris; Coccothraustes; Emberiza; Eremophila; Erithacus; Fringilla, Galerida; Hippolais; Hirundo; Lanius; Loxia; Lullula; Luscinia; Lusciniola; Muscicapa, Panurus; Passer; Pinicola; Plectrophenax; Pyrrhula; Serinus; Sitta; Sturnus; Sylvia; Troglodytes; Turdus;*
- B. conical: *Phoenicurus; Phylloscopus;*
- C. asymmetrical: *Acrocephalus; Anthus; Carduelis; Delichon; Locustella; Motacilla; Oenenthe; Oriolus; Parus; Prunella; Remiz; Riparia; Saxicola;*
- D. truncated: *Cinclus; Regulus;*

Alaudidae: *Alauda* BCCA; *Calandrella* AAAA; *Eremophila* AABA; *Galerida* AABA; *Lullula* BABA;
Hirundinidae: *Delichon* AAAC; *Hirundo* BCBA; *Riparia* ABAC;
Paridae: *Aegithalos* ABBA; *Panurus* CCCA; *Parus* BABC; *Remiz* BABC;
Certhiidae: *Certhia* CCCA;
Sittidae: *Sitta* AABA;
Muscicapidae: *Erithacus* BACA; *Luscinia* BACA; *Muscicapa* CCCA; *Oenanthe* CCCC; *Phoenicurus* BABB; *Saxicola* BACC;
Turdidae: *Turdus* AACA;

Oriolidae: *Oriolus* CACC;
Sylviidae: *Acrocephalus* BABC; *Hippolais* BACA; Locustella BABC; *Lusciniola* AABA; *Phylloscopus* AABB; *Regulus* AABD; *Sylvia* AAAA;
Motacillidae: *Anthus* BABC; *Motacilla* BCCC;
Bombycillidae: *Bombycilla* CCCA;
Troglodytidae: *Troglodytes* BABA;
Cinclidae: *Cinclus* BABD;
Prunellidae: *Prunella* BACC;
Laniidae: *Lanius* BACA;
Sturnidae: *Sturnus* CCCA;
Passeridae: *Passer* CCCA;
Fringillidae: *Carduelis* ABCC; *Chloris* BCBA; *Coccothraustes* BCCA; *Fringilla* BABA; *Loxia* AAAA; *Pinicola* BCCA; *Pyrrhula* BACA; *Serinus* BABA;
Emberizidae: *Emberiza* AAAA; *Plectrophenax* BABA;

AAAA: *Calandrella; Emberiza; Loxia; Sylvia;*
AAAC: *Delichon;*
AABA: *Eremophila; Galerida; Lusciniola; Sitta;*
AABB: *Phylloscopus;*
AABD: *Regulus;*
AACA: *Turdus;*
ABAC: *Riparia;*
ABBA: *Aegithalos;*
ABCC: *Carduelis;*
ACBB: *Erithacus;*
BABA: *Fringilla; Lullula; Plectrophenax; Serinus; Troglodytes;*
BABB: *Phoenicurus;*
BABC: *Acrocephalus; Anthus; Locustella; Parus; Remiz;*
BABD: *Cinclus;*
BACA: *Erithacus; Hippolais; Lanius; Luscinia; Luscinia; Pyrrhula;*
BACC: *Prunella; Saxicola;*
BCBA: *Chloris; Hirundo;*
BCCA: *Alauda; Coccothraustes; Pinicola;*
BCCC: *Motacilla;*
CACC: *Oriolus;*
CCCA: *Bombycilla; Certhia; Muscicapa; Panurus; Passer; Sturnus;*
CCCC: *Oenanthe;*

8. ***Carpometacarpus*** *(Figure 11–12, Plate 29–32, Table 6)*

8.1. the shape of the a *trochlea carpalis*:

- A. semicircle: *Acrocephalus; Aegithalos; Anthus; Calandrella; Carduelis; Erithacus; Fringilla; Galerida; Hirundo; Loxia; Motacilla; Oenanthe; Oriolus; Parus; Passer; Phoenicurus; Plectrophenax; Regulus; Saxicola; Sylvia; Turdus;*
- B. symmetrically cone: *Delichon; Prunella;*
- C. symmetrically blunt cone: *Alauda; Bombycilla; Chloris; Coccothraustes; Emberiza; Eremophila; Hippolais; Lanius; Locustella; Lullula; Luscinia; Monticola; Muscicapa; Pinicola; Pyrrhula; Riparia; Serinus; Sitta; Sturnus; Troglodytes;*
- D. asymmetrically cone: *Certhia; Cinclus; Panurus; Phylloscopus;*

8.2. the form of the *processus extensorius*:

- A. straight pointy cone: *Aegithalos; Hippolais; Luscinia; Parus; Regulus*
- B. slanting pointy cone: *Certhia; Cinclus; Coccothraustes; Hirundo;*
- C. straight blunt cone: *Acrocephalus; Alauda; Anthus; Emberiza; Erithacus; Loxia; Lullula; Motacilla; Muscicapa; Phylloscopus; Plectrophenax; Prunella; Pyrrhula; Saxicola;*
- D. leaning blunt cone: *Bombycilla; Calandrella; Cinclus; Delichon; Eremophila; Lanius; Locustella; Monticola; Oriolus; Passer; Pinicola; Serinus, Sitta; Sturnus; Troglodytes; Turdus;*

- E. rounded tips: *Carduelis; Chloris; Emberiza; Fringilla; Loxia; Oenanthe; Panurus; Sylvia;*

- F. asymmetrically: *Galerida; Phoenicurus; Riparia;*

8.3. the shape of the *processus alularis*:

- A. rectangular: *Acrocephalus; Alauda; Anthus; Chloris; Erithacus; Hippolais; Hirundo; Lanius; Loxia; Lullula; Motacilla; Oenanthe; Phylloscopus; Plectrophenax; Saxicola; Serinus; Turdus;*
- B. rounded rectangular: *Calandrella; Carduelis; Delichon; Eremophila; Fringilla; Monticola; Panurus; Phoenicurus; Pinicola; Prunella; Sturnus;*
- C. conical: *Aegithalos; Bombycilla; Cinclus; Coccothraustes; Galerida; Luscinia; Oriolus; Parus; Passer; Pyrrhula; Riparia; Sitta; Troglodytes;*
- D. irregular: *Certhia; Emberiza; Locustella; Muscicapa; Regulus; Sylvia;*

8.4. the form of the *fovea subalularis*:

- A. conical groove: *Aegithalos; Alauda; Erithacus; Hippolais; Luscinia; Motacilla; Panurus; Passer; Phoenicurus; Phylloscopus; Pinicola; Prunella; Pyrrhula; Saxicola; Sylvia;*
- B. irregular conical groove: *Acrocephalus; Anthus; Calandrella; Galerida; Lullula; Plectrophenax;*
- C. trapezoidal groove: *Bombycilla; Certhia; Emberiza; Eremophila; Hirundo; Lanius; Monticola; Muscicapa; Sitta; Sturnus;*
- D. irregular trapezoidal groove: *Coccothraustes; Riparia; Serinus;*
- E. semicircular groove: *Cinclus; Delichon; Regulus; Turdus;*
- F. miss: *Carduelis; Chloris; Fringilla; Locustella; Loxia; Oenanthe; Oriolus; Parus; Troglodytes;*

8.4. the character of the *protuberantia metacarpale majus*:

- A. advanced cone-shaped: *Aegithalos; Bombycilla; Cinclus; Hirundo; Muscicapa; Phylloscopus; Pinicola; Pyrrhula; Regulus; Riparia; Sitta;*
- B. advanced blunt cone-shaped: *Certhia; Delichon; Monticola; Passer; Prunella;*
- C. undeveloped conical: *Acrocephalus; Alauda; Anthus; Calandrella; Carduelis; Chloris; Coccothraustes; Eremophila; Fringilla; Galerida; Hippolais; Loxia; Luscinia; Motacilla; Panurus; Parus; Phoenicurus; Saxicola; Serinus; Sturnus;*
- D. undeveloped flattened: *Emberiza; Erithacus; Locustella; Lullula; Oriolus; Plectrophenax; Sylvia; Turdus;*
- E. miss: *Lanius; Oenanthe; Troglodytes;*

8.5. the shape of the *facies articularis digitale minor*:

- A. pointly concave: *Acrocephalus; Alauda; Erithacus; Hippolais; Luscinia; Oenanthe; Panurus; Pinicola; Prunella; Sylvia; Turdus;*
- B. rounded: *Aegithalos; Carduelis; Certhia; Cinclus; Locustella; Loxia; Lullula; Passer; Phylloscopus; Plectrophenax;*
- C. cut-off: *Anthus; Chloris; Coccothraustes; Galerida; Motacilla; Oriolus; Parus; Pyrrhula; Riparia; Troglodytes;*
- D. wavy: *Bombycilla; Emberiza; Phoenicurus; Saxicola; Serinus;*
- E. concave: *Calandrella; Delichon; Eremophila; Fringilla; Hirundo; Lanius; Monticola; Muscicapa; Regulus; Sitta; Sturnus;*

Alaudidae: *Alauda* CCAACA; *Calandrella* ADBBCE; *Eremophila* CDBCCE; *Galerida* AFCBCC; *Lullula* CCABDB;
Hirundinidae: *Delichon* BDBEBE; *Hirundo* ABACAE; *Riparia* CFCDAC;

Paridae: *Aegithalos* AACAAB; *Panurus* DEBACA; *Parus* ADCFCC;
Certhiidae: *Certhia* DBDCBB;
Sittidae: *Sitta* CDCBAE;
Muscicapidae: *Erithacus* ACAADA; *Luscinia* CACACA *Monticola* CDBCBE; *Muscicapa* CCDCAE; *Oenanthe* AEAFEA; *Phoenicurus* AFBACD; *Saxicola* ACAACD;
Turdidae: *Turdus* ADAEDA;
Oriolidae: *Oriolus* ADCFDC;
Sylviidae: *Acrocephalus* ACABCA; *Hippolais* CAAACA; *Locustella* CDDFDB; *Phylloscopus* DCAAAB; *Regulus* AADEAE; *Sylvia* AEDADA;
Motacillidae: *Anthus* ACABCC; *Motacilla* ACAACC;
Bombycillidae: *Bombycilla* CDCCAD;
Troglodytidae: *Troglodytes* CDCFEC;
Cinclidae: *Cinclus* DBCEAB:
Prunellidae: *Prunella* BCBABA;
Laniidae: *Lanius* CDACEE;
Sturnidae: *Sturnus* CDBCCE;
Passeridae: *Passer* ADCABB;
Fringillidae: *Carduelis* AEBFCB; *Chloris* CFAFCC; *Coccothraustes* CBCDCC; *Fringilla* AEBFCE; *Loxia* ACAFCB; *Pinicola* CDBAAA; *Pyrrhula* CCCAAC; *Serinus* CDBDCD;
Emberizidae: *Emberiza* CCDCEDD; *Plectrophenax* ACABDB;

AACAAB: *Aegithalos;*
AADEAE: *Regulus;*
ABACAE: *Hirundo;*
ACAACC: *Motacilla;*
ACAACD: *Saxicola;*
ACAADA: *Erithacus;*
ACABCA: *Acrocephalus;*
ACABCC: *Anthus;*
ACABDB: *Plectrophenax;*
ACAFCB: *Loxia;*
ADAEDA: *Turdus;*
ADBBCE: *Calandrella;*
ADCABB: *Passer;*
ADCFCC: *Parus;*
ADCFDC: *Oriolus;*
AEAFEA: *Oenanthe;*
AEBFCB: *Carduelis;*
AEBFCE: *Fringilla;*
AEDADA: *Sylvia;*
AFBACD: *Phoenicurus;*
AFCBCC: *Galerida;*
BCBBBA: *Prunella;*
BDBEBE: *Delichon;*
CAAACA: *Hippolais;*
CACACA: *Luscinia;*
CBCDCC: *Coccothraustes;*
CCAACA: *Alauda;*
CCABDB: *Lullula;*
CCCAAC: *Pyrrhula;*
CCDCAE: *Muscicapa;*
CCDCED: *Emberiza;*
CDACEE: *Lanius;*
CDBAAA: *Pinicola;*
CDBCBE: *Monticola;*
CDBDCD: *Serinus;*
CDBCCE: *Eremophila; Sturnus;*
CDCBAE: *Sitta;*
CDCCAD: *Bombycilla;*
CDCFEC: *Troglodytes;*
CDDFDB: *Locustella;*
CEDAAB: *Aegithalos;*
CFAFCC: *Chloris;*
CFCDAC: *Riparia;*
DBCEAB: *Cinclus;*
DBDCBB: *Certhia;*
DCAAAB: *Phylloscopus;*
DEBACA: *Panurus;*

9. ***Phalanx proximalis digiti majoris*** *(Figure 13, Plate 33–36, Table 7)*

9.1. the form of the *margo proximalis*:

- A. strongly bulging: *Acrocephalus; Aegithalos; Anthus; Calandrella; Carduelis; Certhia; Cettia; Coccothraustes;*

Eremophilla; Erithacus; Lanius; Loxia; Lullula; Motacilla; Muscicapa; Parus; Phylloscopus; Prunella; Sylvia;
- B. weakly bulging: *Alauda; Bombycilla; Chloris; Delichon; Emberiza; Fringilla; Galerida; Hippolais; Hirundo; Monticola; Oenanthe; Oriolus; Phoenicurus; Pinicola; Pyrrhula; Regulus; Riparia; Saxicola; Serinus; Sitta; Sturnus; Turdus;*
- C. concave: *Locustella; Lusciniola; Troglodytes;*
- D. wavy: *Cinclus; Luscinia;*
- E. flattened: *Passer; Plectrophenax;*

9.2. the form of the *tuberculum ventralis*:
- A. rounded: *Alauda; Anthus; Certhia; Eremophilla; Erithacus; Fringilla; Hippolais; Lanius; Locustella; Loxia; Luscinia; Motacilla; Muscicapa; Parus; Phoenicurus; Phylloscopus; Pyrrhula; Regulus; Serinus; Sitta; Sturnus; Troglodytes; Turdus;*
- B. flattened: *Emberiza; Lullula; Plectrophenax;*
- C. upwards protruding: *Acrocephalus; Aegithalos; Bombycilla; Carduelis; Cettia; Chloris; Cinclus; Coccothraustes; Delichon; Galerida; Hirundo; Lusciniola; Monticola; Oriolus; Passer; Prunella; Riparia; Sylvia;*
- D. conical: *Calandrella; Oenanthe; Pinicola; Saxicola;*

9.3. the form of the *tuberculum dorsalis*:
- A. conical: *Acrocephalus; Aegithalos; Cettia; Cinclus; Chloris; Coccothraustes; Emberiza; Eremophilla; Erithacus; Hippolais; Locustella; Loxia; Lusciniola; Monticola; Muscicapa; Oenanthe; Oriolus; Parus; Passer; Phoenicurus; Pyrrhula; Regulus; Saxicola; Sitta; Troglodytes; Turdus;*
- B. hook shaped: *Calandrella; Lanius; Lullula; Phylloscopus; Sturnus; Sylvia;*
- C. flattened: *Alauda; Galerida; Prunella; Serinus;*
- D. rounded: *Anthus; Bombycilla; Carduelis; Certhia; Delichon; Fringilla; Hirundo; Luscinia; Motacilla; Plectrophenax; Pinicola; Riparia;*

9.4. the character of the *margo dorsalis*:
- A. rounded: *Eremophilla; Galerida; Hippolais; Lullula; Monticola; Oriolus; Pyrrhula;*
- B. straight: *Anthus; Lanius; Loxia; Muscicapa; Phylloscopus; Pinicola; Prunella; Sitta; Troglodytes;*
- C. wavy: *Acrocephalus; Aegithalos; Alauda; Bombycilla; Calandrella; Carduelis; Certhia; Cettia; Chloris; Cinclus; Coccothraustes; Delichon; Emberiza; Erithacus; Fringilla; Hirundo; Locustella; Luscinia; Lusciniola; Motacilla; Oenanthe; Parus; Passer; Phoenicurus; Plectrophenax; Regulus; Riparia; Saxicola; Serinus; Sturnus; Sylvia; Turdus;*

9.5. the character of the *margo distalis*:
- A. rounded: *Acrocephalus; Aegithalos; Alauda; Calandrella; Carduelis; Certhia; Cinclus; Eremophilla; Galerida; Locustella; Loxia; Lullula; Lusciniola; Motacilla; Oenanthe; Oriolus; Passer; Phoenicurus; Prunella; Pyrrhula; Saxicola; Sturnus; Sylvia;*
- B. flattened: *Chloris; Emberiza; Hippolais; Lanius; Monticola; Pinicola; Regulus;*
- C. wavy: *Anthus; Bombycilla; Cettia; Coccothraustes; Delichon; Erithacus; Fringilla; Hirundo; Luscinia; Muscicapa; Parus; Phylloscopus; Plectrophenax; Riparia; Serinus; Sitta; Troglodytes; Turdus;*

Alaudidae: *Alauda* BACCA; *Calandrella* ADBCA; *Eremophila* AAAAA; *Galerida* BCCAA; *Lullula* ABBAA;

Hirundinidae: *Delichon* BCDCC; *Hirundo* BCDCC; *Riparia* BCDCC;
Paridae: *Aegithalos* ACACA; *Parus* AAACC;
Certhiidae: *Certhia* AADCA;
Sittidae: *Sitta* BAABC;
Muscicapidae: *Erithacus* AAACC; *Luscinia* DADCC; *Monticola* BCAAB; *Muscicapa* AAABC; *Oenanthe* BDACA; *Phoenicurus* BAACA; *Saxicola* BDACA;
Turdidae: *Turdus* BAACC;
Oriolidae: *Oriolus* BCAAA;
Sylviidae: *Acrocephalus* ACACA; *Cettia* ACACC; *Hippolais* BAAAB; *Locustella* CAACA; *Lusciniola* CCACA; *Phylloscopus* AABBC; *Regulus* BAACB; *Sylvia* ACBCA;
Motacillidae: *Anthus* AADBC; *Motacilla* AADCA;
Bombycillidae: *Bombycilla* BCDCC;
Troglodytidae: *Troglodytes* CAABC;
Cinclidae: *Cinclus* DCACA:
Prunellidae: *Prunella* ACCBA;
Laniidae: *Lanius* AABBB;
Sturnidae: *Sturnus* BABCA;
Passeridae: *Passer* ECACA;
Fringillidae: *Carduelis* ACDCA; *Chloris* BCACB; *Coccothraustes* ACACC; *Fringilla* BADCC; *Loxia* AAABA; *Pinicola* BDDBB; *Pyrrhula* BAAAA; *Serinus* BACCC;
Emberizidae: *Emberiza* BBACB; *Plectrophenax* EBDCC;

AAAAA: *Eremophila*;
AAABA: *Loxia*;
AAABC: *Muscicapa;*
AAACC: *Erithacus*; *Parus;*
AABBB: *Lanius;*
AABBC: *Phylloscopus;*
AADCA: *Certhia*; *Motacilla;*
AADBC: *Anthus;*
ABBAA: *Lullula;*
ACACA: *Acrocephalus*; *Aegithalos;*
ACACC: *Cettia; Coccothraustes;*
ACBCA: *Sylvia;*
ACCBA: *Prunella;*
ACDCA: *Carduelis;*
ADBCA: *Calandrella;*
BAAAA: *Pyrrhula;*
BAAAB: *Hippolais;*
BAABC: *Sitta;*
BAACA: *Phoenicurus;*
BAACB: *Regulus;*
BAACC: *Turdus;*
BABCA: *Sturnus;*
BACCA: *Alauda;*
BACCC: *Serinus;*
BADCC: *Fringilla;*
BBACB: *Emberiza;*
BCAAA: *Oriolus;*
BCAAB: *Monticola;*
BCACB: *Chloris;*
BCCAA: *Galerida;*
BCDCC: *Bombycilla*; *Delichon*; *Hirundo*; *Riparia;*
BDACA: *Oenanthe; Saxicola;*
BDDBB: *Pinicola;*
CAABC: *Troglodytes;*
CAACA: *Locustella;*
CCACA: *Lusciniola;*
DADCC: *Luscinia;*
DCACA: *Cinclus;*
EBDCC: *Plectrophenax;*
ECACA: *Passer;*

10. *Femur* (distal *epiphysis*) *(Figure 14, Plate 37–40, Table 8)*

10.1. the shape of the *condylus medialis*:

– A. semicircle: *Aegithalos; Bombycilla; Calandrella; Carduelis; Certhia; Cettia; Cinclus; Coccothraustes; Delichon; Erithacus; Galerida; Hippolais; Hirundo; Locustella; Loxia; Lullula; Monticola; Motacilla; Oriolus; Parus; Passer;*

Phoenicurus; Phylloscopus; Pinicola; Regulus; Sitta; Sturnus; Troglodytes
- B. blunt cone: *Alauda; Anthus; Chloris; Emberiza; Eremophila; Fringilla; Lanius; Luscinia; Lusciniola; Oenanthe; Plectrophenax; Prunella; Pyrrhula; Remiz; Riparia; Saxicola; Serinus; Sylvia; Turdus;*
- C. asymmetrically: *Acrocephalus;*

10.2. the character of the *sulcus intercondylaris*:
- A. deeply concave: *Acrocephalus; Aegithalos; Alauda; Calandrella; Carduelis; Cettia; Chloris; Cinclus; Eremophila; Erithacus; Fringilla; Lanius; Locustella; Lullula; Monticola; Motacilla; Oenanthe; Oriolus; Phoenicurus; Phylloscopus; Pinicola; Pyrrhula; Saxicola; Sturnus; Troglodytes;*
- B. weakly concave: *Certhia; Delichon; Emberiza; Galerida; Hippolais; Hirundo; Loxia; Lusciniola; Parus; Prunella; Regulus; Remiz; Serinus; Sylvia;*
- C. asymmetrically concave: *Anthus; Luscinia; Passer; Riparia;*
- D. flattened: *Coccothraustes; Plectrophenax; Sitta; Turdus;*
- E. wavy: *Bombycilla;*

10.3. the shape of the *condylus lateralis*:
- A. broadly rounded: *Acrocephalus; Anthus; Certhia; Cettia; Chloris; Eremophila; Delichon; Galerida; Hippolais; Hirundo; Oenanthe; Oriolus; Passer; Phylloscopus; Prunella; Pyrrhula; Remiz; Sturnus; Sylvia; Turdus;*
- B. rounded: *Aegithalos; Alauda; Bombycilla; Carduelis; Cinclus; Coccothraustes; Erithacus; Lanius; Loxia; Lullula; Luscinia; Monticola; Motacilla; Parus; Phoenicurus; Pinicola; Regulus; Serinus; Sitta; Troglodytes;*
- C. conical: *Calandrella; Emberiza; Fringilla; Locustella; Lusciniola; Plectrophenax; Riparia; Saxicola;*

10.4. the form of the *epicondylus medialis*:
- A. pointedly protruding: *Acrocephalus; Calandrella; Coccothraustes; Delichon; Fringilla; Hippolais; Parus; Phylloscopus; Pinicola; Serinus; Sturnus;*
- B. rounded protruding: *Cettia; Emberiza; Eremophila; Erithacus; Galerida; Locustella; Luscinia; Monticola; Passer; Pyrrhula; Regulus; Saxicola; Troglodytes;*
- C. bulging: *Aegithalos; Alauda; Anthus; Bombycilla; Carduelis; Certhia; Cinclus; Loxia; Lullula; Motacilla; Oriolus; Phoenicurus; Plectrophenax; Remiz; Sitta;*
- D. not arching: *Chloris; Hirundo; Lanius; Lusciniola; Oenanthe; Prunella; Riparia; Sylvia; Turdus;*

10.5. the form of the *epicondylus lateralis*:
- A. conical protruding: *Acrocephalus; Emberiza; Fringilla; Passer;*
- B. rounded protruding: *Alauda; Calandrella; Carduelis; Loxia; Lullula; Parus; Phylloscopus; Pinicola; Plectrophenax; Prunella; Pyrrhula; Serinus;*
- C. bulging: *Aegithalos; Anthus; Bombycilla; Chloris; Cinclus; Coccothraustes; Delichon; Eremophila; Erithacus; Hippolais; Hirundo; Lanius; Locustella; Loxia; Luscinia; Lusciniola; Monticola; Motacilla; Oenanthe; Regulus; Remiz; Riparia; Sylvia; Sitta; Sturnus; Troglodytes; Turdus;*
- D. not arching: *Certhia; Cettia; Galerida; Oriolus; Phoenicurus; Saxicola;*

Alaudidae: *Alauda* BABCB; *Calandrella* AACAB; *Eremophila* BAABC; *Galerida* ABABD; *Lullula* AABCB;

Hirundinidae: *Delichon* ABAAC; *Hirundo* ADADC; *Riparia* BCCDC;

Paridae: *Aegithalos* AABCC; *Parus* ABBAB; *Remiz* BBACC;
Certhiidae: *Certhia* ABACD;
Sittidae: *Sitta* ADBCC;
Muscicapidae: *Erithacus* AABBC; *Luscinia* DABBC; *Monticola* ACBBC; *Oenanthe* BAADC; *Phoenicurus* AABCD; *Saxicola* BBABD;
Turdidae: *Turdus* BDADC;
Oriolidae: *Oriolus* AAACD;
Sylviidae: *Acrocephalus* CAAAA; *Cettia* AAABD; *Hippolais* ABAAC; *Locustella* AACBC; *Lusciniola* BBCDC; *Phylloscopus* AAAAB; *Regulus* ABBBC; *Sylvia* ACBDC;
Motacillidae: *Anthus* BCACC; *Motacilla* AABCC;
Bombycillidae: *Bombycilla* AEBCC;
Troglodytidae: *Troglodytes* AABBC;
Cinclidae: *Cinclus* AABCC;
Prunellidae: *Prunella* BBADB;
Laniidae: *Lanius* BABDC;
Sturnidae: *Sturnus* AAAAC;
Passeridae: *Passer* ACABA;
Fringillidae: *Carduelis* AABCB; *Chloris* BAADC; *Coccothraustes* ADBAC; *Fringilla* BACAA; *Loxia* ABBCC; *Pinicola* AABAB; *Pyrrhula* BAABB; *Serinus* BBBAB;
Emberizidae: *Emberiza* BBCBA; *Plectrophenax* BDCCB;

AAAAB: *Phylloscopus;*
AAAAC: *Sturnus;*
AAABD: *Cettia;*
AAACD: *Oriolus;*
AABAB: *Pinicola;*
AABBC: *Erithacus; Troglodytes;*
AABCB: *Carduelis; Lullula*;
AABCC: *Aegithalos*; *Cinclus: Motacilla;*
AABCD: *Phoenicurus;*
AACAB: *Calandrella;*
AACBC: *Locustella;*
ABAAC: *Delichon; Hippolais;*
ABABD: *Galerida;*
ABACD: *Certhia;*
ABBAB: *Parus;*
ABBCC: *Loxia;*
ABBDC: *Regulus;*
ACABA: *Passer;*
ACBBC: *Monticola;*
ACBDC: *Sylvia;*
ADADC: *Hirundo;*
ADBAC: *Coccothraustes;*
ADBCC: *Sitta;*
AEBCC: *Bombycilla;*
BAABB: *Pyrrhula;*
BAABC: *Eremophila;*
BAADC: *Chloris; Oenanthe;*
BACAA: *Fringilla;*
BABCB: *Alauda;*
BABCC: *Remiz;*
BABDC: *Lanius;*
BBABD: *Prunella; Saxicola;*
BBBAB: *Serinus;*
BBCBA: *Emberiza;*
BBCDC: *Lusciniola;*
BCACC: *Anthus;*
BCCDC: *Riparia;*
BDADC: *Turdus;*
BDCCB: *Plectrophenax;*
CAAAA: *Acrocephalus;*
DABBC: *Luscinia;*

11. ***Tibiotarsus*** **(distal *epiphysis*)** *(Figure 15, Plate 41–44, Table 9)*

11.1. the shape of the *epicondylus medialis*:

- A. blunt cone: *Alauda; Acrocephalus; Aegithalos; Bombycilla; Calandrella; Certhia; Coccothraustes; Emberiza; Eremophila; Erithacus; Fringilla; Hippolais; Lanius; Loxia; Luscinia; Monticola; Motacilla; Muscicapa; Oenanthe; Oriolus; Parus; Passer; Phoenicurus; Pinicola; Plectrophenax; Pyrrhula; Remiz; Saxicola; Serinus; Sitta; Sturnus; Troglodytes; Turdus;*

- B. conical: *Cinclus; Locustella; Lusciniola; Prunella;*
- C. rounded: *Anthus; Carduelis; Delichon; Galerida; Hirundo; Lullula; Melanocorypha; Phylloscopus; Regulus; Riparia; Sylvia;*

11.2. the shape of the *epicondylus lateralis*:
- A. rounded; *Alauda; Cinclus; Erithacus; Hirundo; Lullula; Luscinia; Monticola; Parus; Phylloscopus; Riparia; Saxicola; Sturnus; Troglodytes;*
- B. blunt cone: *Aegithalos; Bombycilla; Calandrella; Carduelis; Coccothraustes; Delichon; Eremophila; Fringilla; Galerida; Hippolais; Lanius; Loxia; Lusciniola; Motacilla; Muscicapa; Oriolus; Passer; Phoenicurus; Pinicola; Prunella; Pyrrhula; Regulus; Remiz; Serinus; Sitta; Sylvia; Turdus;*
- C. conical: *Acrocephalus; Anthus; Emberiza; Locustella; Melanocorypha; Oenanthe; Plectrophenax;*
- D. hook shape: *Certhia;*

11.3. the form of the *incisura intercondylaris*:
- A. wavy: *Acrocephalus; Aegithalos; Coccothraustes; Delichon; Fringilla; Hippolais; Lanius; Loxia; Lusciniola; Motacilla; Muscicapa; Oriolus; Parus; Passer; Pinicola; Pyrrhula; Regulus; Remiz; Serinus; Sitta; Sturnus; Sylvia; Troglodytes;*
- B. deeply arched: *Alauda; Bombycilla; Calandrella; Carduelis; Eremophila; Galerida; Melanocorypha;*
- C. asymmetrically arched: *Phoenicurus; Prunella; Turdus; Locustella; Phylloscopus; Riparia;*
- D. asymmetrically wavy: *Anthus; Certhia; Emberiza; Erithacus; Lullula; Luscinia; Monticola; Oenanthe; Plectrophenax; Saxicola;*
- E. flattened: *Cinclus; Hirundo;*

11.4. the character of the *tuberositas retinaculi*:
- A. below pointly protruding: *Acrocephalus; Anthus; Locustella; Melanocorypha; Motacilla; Phylloscopus; Sylvia;*
- B. below rounded protruding: *Certhia; Cinclus; Erithacus; Galerida; Hippolais; Loxia; Luscinia; Lusciniola; Monticola; Oenanthe; Plectrophenax; Prunella; Pyrrhula; Remiz; Sitta;*
- C. below weakly rounded: *Alauda; Calandrella; Delichon; Fringilla; Passer; Pinicola; Serinus;*
- D. high pointly protruding: *Emberiza; Lullula; Saxicola; Turdus;*
- E. high rounded protruding: *Aegithalos; Bombycilla; Carduelis; Coccothraustes; Eremophila; Lanius; Muscicapa; Parus; Phoenicurus; Regulus; Remiz; Riparia; Sturnus; Troglodytes;*
- F. miss: *Hirundo; Oriolus;*

Alaudidae: *Alauda* AABC; *Calandrella* ABBC; *Eremophila* ABBE; *Galerida* CBBB; *Lullula* CADD; *Melanocorypha* CCBA;

Hirundinidae: *Delichon* CBAC; *Hirundo* CAEF; *Riparia* CACE;

Paridae: *Aegithalos* ABAE; *Parus* AAAE; *Remiz* ABAE;

Certhiidae: *Certhia* ADDB;

Sittidae: *Sitta* ABAB;

Muscicapidae: *Erithacus* AADB; *Luscinia* AADB; *Monticola* AADB; *Muscicapa* ABAE; *Oenanthe* AADB; *Phoenicurus* ABCE; *Saxicola* AADD;

Turdidae: *Turdus* ABCD;

Oriolidae: *Oriolus* ABAF;

Sylviidae: *Acrocephalus* ACAA; *Hippolais* ABAB; *Locustella* BCCA; *Lusciniola* BBAB; *Phylloscopus* CACA; *Regulus* CBAE; *Sylvia* CBAA;

Motacillidae: *Anthus* CCDA; *Motacilla* ABAA;

Bombycillidae: *Bombycilla* ABBE;
Troglodytidae: *Troglodytes* AAAE;
Cinclidae: *Cinclus* BAEB;
Prunellidae: *Prunella* BBCB;
Laniidae: *Lanius* ABAE;
Sturnidae: *Sturnus* AAAE;
Passeridae: *Passer* BBAC;
Fringillidae: *Carduelis* CBBE; *Coccothraustes* ABAE; *Fringilla* ABAC; *Loxia* ABAB; *Pinicola* ABAC; *Pyrrhula* ABAB; *Serinus* ABAC;
Emberizidae: *Emberiza* ACDD; *Plectrophenax* ACDB;

AAAE: *Parus; Sturnus; Troglodytes;*
AABC: *Alauda;*
AADB: *Erithacus; Luscinia; Monticola; Oenanthe;*
AADD: *Saxicola;*
ABAA: *Motacilla;*
ABAB: *Hippolais; Loxia; Pyrrhula; Sitta;*
ABAC: *Fringilla; Pinicola; Serinus;*
ABAE: *Aegithalos; Coccothraustes; Lanius; Muscicapa; Remiz;*
ABAF: *Oriolus;*
ABBC: *Calandrella;*
ABBE: *Bombycilla; Eremophila;*
ABCD: *Turdus;*
ABCE: *Phoenicurus;*
ACAA: *Acrocephalus;*
ACDB: *Plectrophenax;*
ACDD: *Emberiza;*
ADDB: *Certhia;*
BAEB: *Cinclus;*
BBAC: *Passer;*
BBAB: *Lusciniola;*
BBCB: *Prunella;*
BCCA: *Locustella;*
CACA: *Phylloscopus;*
CACE: *Riparia;*
CADD: *Lullula;*
CAEF: *Hirundo;*
CBAA: *Sylvia;*
CBAC: *Delichon;*
CBAE: *Regulus;*
CBBA: *Melanocorypha;*
CBBB: *Galerida;*
CBBE: *Carduelis;*
CCDA: *Anthus;*

12. *Tarsometatarsus* (distal *epiphysis*) *(Figure 16, Plate 45–48, Table 10)*

12.1. the character of the *margo medialis*:
– A. straight: *Anthus; Calandrella; Delichon; Emberiza; Erithacus; Hippolais; Hirundo; Lanius; Loxia; Luscinia; Monticola; Motacilla; Oenanthe; Oriolus; Passer; Pinicola; Prunella; Regulus; Saxicola;*
– B. wavy: *Alauda; Bombycilla; Carduelis; Cettia; Chloris; Coccothraustes; Eremophila; Fringilla; Galerida; Locustella; Lullula; Lusciniola; Melanocorypha; Muscicapa; Phoenicurus; Plectrophenax; Pyrrhula; Remiz; Riparia; Sylvia; Troglodytes; Turdus;*
– C. bulging: *Certhia; Sitta;*
– D. concave: *Acrocephalus; Aegithalos; Parus; Phylloscopus; Sturnus;*

12.2. the shape of the *troclea metatarsi* II.:
– A. with cut-off end: *Anthus; Carduelis; Chloris; Coccothraustes; Delichon; Fringilla; alerida; Hirundo; Lullula; Melanocorypha; Monticola; Motacilla; Passer; Phoenicurus; Plectrophenax; Prunella; Riparia; Sturnus; Turdus;*
– B. with rounded end: *Acrocephalus; Aegithalos; Alauda; Bombycilla; Calandrella; Emberiza; Eremophila; Lusciniola; Muscicapa; Oenanthe; Oriolus; Regulus; Remiz; Saxicola; Sitta; Troglodytes;*
– C. asymmetrically: *Certhia; Cettia; Locustella; Loxia; Luscinia; Parus; Phylloscopus; Pyrrhula;*

- D. conical: *Erithacus; Hippolais; Lanius; Pinicola; Sylvia;*

12.3. the shape of the *trochlea metatarsi* III.:

- A. weakly concave: *Aegithalos; Alauda; Anthus; Emberiza; Eremophila; Fringilla; Hippolais; Hirundo; Lanius; Locustella; Lusciniola; Motacilla; Oriolus; Pinicola; Plectrophenax; Prunella; Pyrrhula; Sylvia;*
- B. concave: *Acrocephalus; Bombycilla; Calandrella; Carduelis; Cettia; Chloris; Coccothraustes; Delichon; Erithacus; Galerida; Loxia; Lullula; Luscinia; Melanocorypha; Monticola; Muscicapa; Oenanthe; Parus; Passer; Phoenicurus; Phylloscopus; Regulus; Remiz; Riparia; Saxicola; Sitta; Sturnus; Troglodytes; Turdus;*
- C. strongly concave: *Certhia;*

12.4. the shape of the *trochlea metatarsi* IV.:

- A. conical: *Cettia; Chloris; Eremophila; Melanocorypha; Monticola; Motacilla; Muscicapa; Phoenicurus; Prunella; Sturnus; Turdus;*
- B. rounded blunt cone: *Alauda; Bombycilla; Carduelis; Certhia; Delichon; Erithacus; Fringilla; Hirundo; Locustella; Oenanthe; Parus; Passer; Phylloscopus; Pinicola; Plectrophenax; Pyrrhula; Remiz; Remiz; Riparia; Saxicola; Sylvia; Troglodytes;*
- C. cut-off: *Acrocephalus; Aegithalos; Calandrella; Coccothraustes; Emberiza; Lanius; Loxia; Lullula; Luscinia; Lusciniola; Regulus;*
- D. asymmetrically: *Anthus; Hippolais; Galerida; Oriolus; Sitta;*

12.5. the form of the *incisura intertrochlearis medialis*:

- A. narow: *Aegithalos; Alauda; Calandrella; Carduelis; Coccothraustes; Delichon; Emberiza; Eremophila; Fringilla; Hirundo; Lanius; Locustella; Loxia; Lusciniola; Monticola; Oenanthe; Oriolus; Parus; Passer; Pinicola; Prunella; Riparia; Sitta; Sturnus; Sylvia; Troglodytes;*
- B. wide: *Acrocephalus; Anthus; Bombycilla; Certhia; Cettia; Chloris; Erithacus; Galerida; Hippolais; Lullula; Luscinia; Melanocorypha; Motacilla; Muscicapa; Phoenicurus; Phylloscopus; Plectrophenax; Pyrrhula; Regulus; Remiz; Saxicola; Turdus;*

12.6. the form of the *incisura intertrochlearis lateralis*:

- A. narow: *Aegithalos; Alauda; Calandrella; Carduelis; Chloris; Coccothraustes; Delichon; Fringilla; Hirundo; Lullula; Locustella; Luscinia; Lusciniola; Parus; Passer; Phylloscopus; Regulus; Riparia; Sitta; Sylvia; Troglodytes;*
- B. wide: *Acrocephalus; Anthus; Bombycilla; Certhia; Cettia; Emberiza; Eremophila; Erithacus; Galerida; Hippolais; Lanius; Loxia; Melanocorypha; Monticola; Motacilla; Muscicapa; Oenanthe; Oriolus; Phoenicurus; Pinicola; Plectrophenax; Prunella; Pyrrhula; Remiz; Saxicola; Sturnus; Turdus;*

Alaudidae: *Alauda* BBABAA; *Calandrella* ABBCAA; *Eremophila* BBAAAB; *Galerida* BABDBB; *Lullula* BABBBA; *Melanocorypha* BABABB;
Hirundinidae: *Delichon* AABBAA; *Hirundo* AAABAA; *Riparia* BABBAA;
Paridae: *Aegithalos* DBACAA; *Parus* DCBBAA; *Remiz* BBBBBB;
Certhiidae: *Certhia* CCCBBB;
Sittidae: *Sitta* CBBDAA;
Muscicapidae: *Erithacus* ADBBAB; *Luscinia* ACBCBA; *Monticola* AABAAB; *Muscicapa* BBBABB; *Oenanthe* ABBBAB; *Phoenicurus* BBBABB; *Saxicola* ABBBBB;

Turdidae: *Turdus* BABABB;
Oriolidae: *Oriolus* ABADAB;
Sylviidae: *Acrocephalus* DBBCBB; *Cettia* BCBABB; *Hippolais* ACADBB; *Locustella* BCABAA; *Lusciniola* BBACAA; *Phylloscopus* DCBBBA; *Regulus* ABBCBA; *Sylvia* BDABAA;
Motacillidae: *Anthus* ABADBB; *Motacilla* ABAABB;
Bombycillidae: *Bombycilla* BBBBBB;
Troglodytidae: *Troglodytes* BBBBAA;
Prunellidae: *Prunella* AAAAAB;
Laniidae: *Lanius* ABACBB;
Sturnidae: *Sturnus* DABAAB;
Passeridae: *Passer* ADBBAA;
Fringillidae: *Carduelis* BABBAA; *Chloris* BABABA; *Coccothraustes* BABCAA; *Fringilla* BAABAA; *Loxia* ACBCBB; *Pinicola* ABABAB; *Pyrrhula* BCABBB;
Emberizidae: *Emberiza* ABACBB; *Plectrophenax* BAABBB;

AAAAAB: *Prunella;*
AAABAA: *Hirundo;*
AABAAB: *Monticola;*
AABBAA: *Delichon;*
ABAABB: *Motacilla;*
ABACBB: *Emberiza; Lanius;*
ABADAB: *Oriolus;*
ABADBB: *Anthus;*
ABBBAB: *Oenanthe;*
ABBBBB: *Saxicola;*
ABBCAA: *Calandrella;*
ABBCBA: *Regulus;*
ACADBB: *Hippolais;*
ACBCBA: *Luscinia;*
ACBCBB: *Loxia;*
ADABAB: *Pinicola;*
ADBBAA: *Passer;*
ADBBAB: *Erithacus;*
BAABAA: *Carduelis; Fringilla;*
BAABBB: *Plectrophenax;*
BABABA: *Chloris;*
BABABB: *Melanocorypha*; *Turdus;*
BABBAA: *Carduelis; Riparia;*
BABBBA: *Lullula;*
BABCAA: *Coccothraustes;*
BABDBB: *Galerida;*
BBAAAB: *Eremophila;*
BBABAA: *Alauda;*
BBACAA: *Lusciniola;*
BBBABB: *Muscicapa; Phoenicurus;*
BBBBAA: *Troglodytes;*
BBBBBB: *Bombycilla; Remiz;*
BCABAA: *Locustella;*
BCABBB: *Pyrrhula;*
BCBABB: *Cettia;*
BDABAA: *Sylvia;*
CBBDAA: *Sitta;*
CCCBBB: *Certhia;*
DABAAB: *Sturnus;*
DBACAA: *Aegithalos;*
DBBCBB: *Acrocephalus;*
DCBBAA: *Parus;*
DCBBBA: *Phylloscopus;*

13. *Phalanx ungularis* *(Figure 17, Plate 49–52, Table 11)*

13.1. the direction and the form of the *tuberculum extensorium*:

- A. straight and pointed: *Anthus; Coccothraustes; Monticola; Passer; Prunella; Pyrrhula; Riparia; Sturnus; Turdus;*
- B. straight and blunt: *Aegithalos; Acrocephalus; Emberiza; Eremophila; Oriolus; Phoenicurus; Phylloscopus; Pinicola; Regulus; Saxicola; Serinus;*
- C. dorsal rises and pointed: *Certhia; Fringilla; Galerida; Muscicapa; Sitta;*
- D. dorsal rises and blunted: *Alauda; Hippolais; Hirundo; Luscinia; Oenanthe; Remiz*;
- E. ventral available: *Bombycilla; Lanius; Loxia;*

13.2. the character of the *cotyla articularis*:

- A. weakly concave: *Acrocephalus; Aegithalos; Alauda; Bombycilla; Coccothraustes; Emberiza; Fringilla; Hippolais; Lanius; Luscinia; Monticola; Muscicapa; Oenanthe; Oriolus; Phoenicurus; Phylloscopus; Pinicola; Pyrrhula; Remiz*; *Riparia; Saxicola; Serinus; Sitta; Sturnus; Turdus;*
- B. strongly concave: *Anthus; Certhia; Eremophila; Galerida; Hirundo; Loxia; Passer; Prunella; Regulus;*

13.3. the shape of the *tuberculum flexorium*:

- A. flattened: *Acrocephalus; Anthus; Bombycilla, Hirundo; Loxia; Monticola; Riparia; Serinus; Sturnus;*
- B. concave: *Aegithalos; Emberiza; Fringilla; Muscicapa; Oenanthe; Phoenicurus; Prunella; Pyrrhula; Remiz; Saxicola;*
- C. pointedly protruding: *Eremophila; Oriolus;*
- D. dully protruding: *Alauda; Certhia; Coccothraustes; Galerida; Luscinia; Passer; Pinicola; Sitta; Turdus;*
- E. wavy: *Hippolais; Lanius; Phylloscopus; Regulus;*

13.4. the elbow of the *margo plantaris*:

- A. weakly arched: *Alauda; Eremophila; Galerida: Loxia; Pinicola; Prunella;*
- B. symmetrically strongly arched: *Acrocephalus; Aegithalos; Bombycilla; Certhia; Emberiza; Hippolais; Hirundo; Luscinia; Monticola; Muscicapa; Oenanthe; Phoenicurus; Phylloscopus; Pyrrhula; Remiz; Saxicola; Serinus; Sitta;*
- C. asymmetrically strongly arched: *Anthus; Coccothraustes; Fringilla; Lanius; Oriolus; Passer; Regulus; Riparia; Sturnus; Turdus;*

13.5. the form of the *apex*:

- A. narow: *Certhia; Coccothraustes; Emberiza; Fringilla; Hirundo; Muscicapa; Oenanthe; Passer; Phoenicurus; Phylloscopus; Riparia; Saxicola; Sitta; Turdus;*
- B. stout: *Acrocephalus; Aegithalos; Alauda; Anthus; Bombycilla; Eremophila; Galerida: Hippolais; Lanius; Loxia; Luscinia; Monticola; Oriolus; Pinicola; Prunella; Pyrrhula; Regulus; Remiz; Serinus; Sturnus;*

Alaudidae: *Alauda* DADAB; *Eremophila* BBCAB; *Galerida* CBDAB;
Hirundinidae: *Hirundo* DBABA; *Riparia* AAACA;
Paridae: *Aegithalos* BABBB; *Remiz* DABBB;
Certhiidae: *Certhia* CBDBA;
Sittidae: *Sitta* CADBA;
Muscicapidae: *Luscinia* DADBB; *Monticola* AAABB; *Muscicapa* CABBA; *Oenanthe* DABBA; *Phoenicurus* BABBA; *Saxicola* BABBA;
Turdidae: *Turdus* AADCA;
Oriolidae: *Oriolus* BACCB;
Sylviidae: *Acrocephalus* BAABB; *Hippolais* DAEBB; *Phylloscopus* BAEBA; *Regulus* BBECB;
Motacillidae: *Anthus* ABACB*;*
Bombycillidae: *Bombycilla* EAABB;
Prunellidae: *Prunella* ABBAB;
Laniidae: *Lanius* EAECB;
Sturnidae: *Sturnus* AAACB;
Passeridae: *Passer* ABDCA;
Fringillidae: *Coccothraustes* AADCA; *Fringilla* CABCA; *Loxia* EBAAB; *Pinicola* BADAB; *Pyrrhula* AABBB; *Serinus* BAABB;
Emberizidae: *Emberiza* BABBA;

AAABB: *Pyrrhula;*
AAACB: *Sturnus;*
AAACA: *Riparia;*
AAABB: *Monticola;*
AADCA: *Coccothraustes; Turdus;*
ABACB: *Anthus;*
ABBAB: *Prunella;*
ABDCA: *Passer;*
BAABB: *Acrocephalus; Serinus;*
BABBA: *Emberiza; Phoenicurus; Saxicola;*
BABBB: *Aegithalos;*
BACCB: *Oriolus;*
BAEBA: *Phylloscopus;*
BBCAB: *Eremophila;*
BADAB: *Pinicola;*
BBECB: *Regulus;*
CABBA: *Muscicapa;*
CABCA: *Fringilla;*
CADBA: *Sitta;*
CBDAB: *Galerida;*
CBDBA: *Certhia;*
DABBA: *Oenanthe;*
DABBB: *Remiz;*
DADAB: *Alauda;*
DADBB: *Luscinia;*
DAEBB: *Hippolais;*
DBABA: *Hirundo;*
EAABB: *Bombycilla;*
EAECB: *Lanius;*
EBAAB: *Loxia;*

Acknowledgements

The author wishes to express his gratitude to Mihály Gasparik for acces to recent bird bone collection in the Natural History Museum of Hungary Budapest, to Béla Solti, Tibor Pecsics and Péter Ujhelyi for their help in the revision of the text and to József Vuts and Lóránd Abos for the language revision.

References

Ballmann, P. 1966. Die Vögel aus der altburdigalen Spaltenfüllung von Wintershof (West) bei Eichstätt [The birds of the altburdigalen fissure filling of Wintershof (West) in Eichstaett]. – Inaugural Dissertation zur erlangung der Doktorwürde der nHohe Naturwissenschaftlichen Fakultät der Ludwig Maximiliane, Universität zu München, München, pp. 115 (in German)

Baumel, J. J., King, A. S., Lucas, A. M., Breazile, J. E. & Evans, H. E. 1979. Nomina anatomica avium. An annotated anatomical dictionary of birds. – Academical Press, London, pp. 637

Cheneval, J. 1983. Révision de l'avifaune du gisement aquitanien de Saint-Gérand-le-Puy (Allier, France) (Gaviiformes à Anseriformes) [Review of the avifauna of aquitanien deposit of Saint-Gérand-le-Puy (Allier, France) (Gaviiformes to Anseriformes)]. – Unpublished Thesis (Nr. 1380) Université Claude-Bernard, Lyon, pp. 220 (in French)

Cramp, S. (ed.) 1998. The Complete Birds of the Western Palearctic on CD rom. – Oxford University Press, UK

Cuisin, J. 1989. L'identification des crânes de passereaux (Passeriformes: Aves) [The identification of skulls passerines (Passeriformes, Aves)]. – Doct. Dissertation, Universite de Bourgogne, pp. 340 (in French)

Driesch, A. von den 1976. A guide to the measurements of animal bones from archaeological sites. – Peabody Museum Bulletin 1., pp. 148

Fürbringer, M. 1888. Untersuchungen zur Morphologie und Systematik der Vögel, zugleich ein Beitrag zur Anatomie der Stutz- und Bewegungeorgane [Studies on the morphology and systematics of birds, also contribute to the anatomy of the mounting socket and locomotor organe]. – Amsterdam, Jena, pp. 421 (in German)

Gál, E. 2002. Avifauna pleistocena a Romaniei [Pleistocene bird faunas of Romania]. – Unpublied C.Sc Dissertation, Universitatea din Bucureşti, Facultatea de Geologie Bucureşti, pp. 263 (in Romanian)

Gilbert, B. M., Martin, L. D. & Savage, H. G. 1981. Avian Osteology. – Library of Congress, Wyoming, pp. 252

Jánossy, D. 1983. Humeri of central European smaller Passeriformes. – Fragmenta Mineralogica et Paleontologica 11: 85–112.

Kessler, E. 2013a A Kárpát-medence madárvilágának őslénytani kézikönyve [Paleontological handbook of birdlife in the Carpathian Basin]. – Könyvműhely, Miskolc, pp. 508 (in Hungarian)

Kessler, E. 2013b Neogene songbirds (Aves, Passeriformes) faunae from Hungary. – Hantkeniana 2013: 37–149.

Kessler, E. & Moldvai, M. 1993. Studii biometrice şi morfologice asupra scheletului membrelor la Corvidae (Aves) (Partea I.) [Biometrical and morphological studies of limbs scheleton to Corvidae (Aves) (Part I.)]. – Studia Universitatis Babes-Bolyai, Series Biologia 38: 69–80 (in Romanian with English Summary)

Lambrecht, K. 1933. Handbuch der Palaeornithologie [Handbook of Palaeornithology]. – Gebrüder Borntraeger Berlin, pp. 1024 (in German)

Milne-Edwards, A. 1867–1868. Recherches anatomiques et paléontologiques pour servir à l'histoire des oiseaux fossiles de la France [Anatomical and paleontological research to serve a history the fossil birds of France]. Vol. 1. – Victor Masson et Fils, Paris, pp. 472+ pls 96 (in French)

Moreno, E. 1985. Clave osteologica para la identificación de los Passeriformes Ibericos, I. [Osteological identification key for the Iberian Passerines I.]. – Ardeola 32(2): 295–377. (in Spanish)

Moreno, E. 1986. Clave osteologica para la identificación de los Passeriformes Ibericos, II. [Osteological identification key for the Iberian Passerines II.]. – Ardeola 33(1–2): 69–129. (in Spanish)

Moreno, E. 1987. Clave osteologica para la identificación de los Passeriformes Ibericos, III. [Osteological identification key for the Iberian Passerines III.]. – Ardeola 34(2): 243–273. (in Spanish)

Mourer-Chauviré, C. 1975. Faunes d'oiseaux du Pléistocène de France: systématique, évolution et adaptation, interprétation paléoclimatique [Bird Fauna of the Pleistocene of France: systematics, evolution and adaptation, paleoclimatic interpretation]. – Géobios 8: 333–352. (in French with English Summary)

Solti, B. 1996. The comparative osteomorphological study of the European small-statured Falcons (Aves: Falconidae). – Folia Historico Naturalia Musei Matraensis 21: 5–282.

Tomek, T. & Bocheński, Z. M. 2000. The comparative osteology of European corvids (Aves: Corvidae), with a key to the identification of their skeletal elements. – Publications of the Institute of Systematics and Evolution of Animals, Kraków, pp. 102

Ujhelyi, P. 1992. Identification of European finch species (Fringillidae) based on skull morphology keys. – Aquila 99: 99–110.

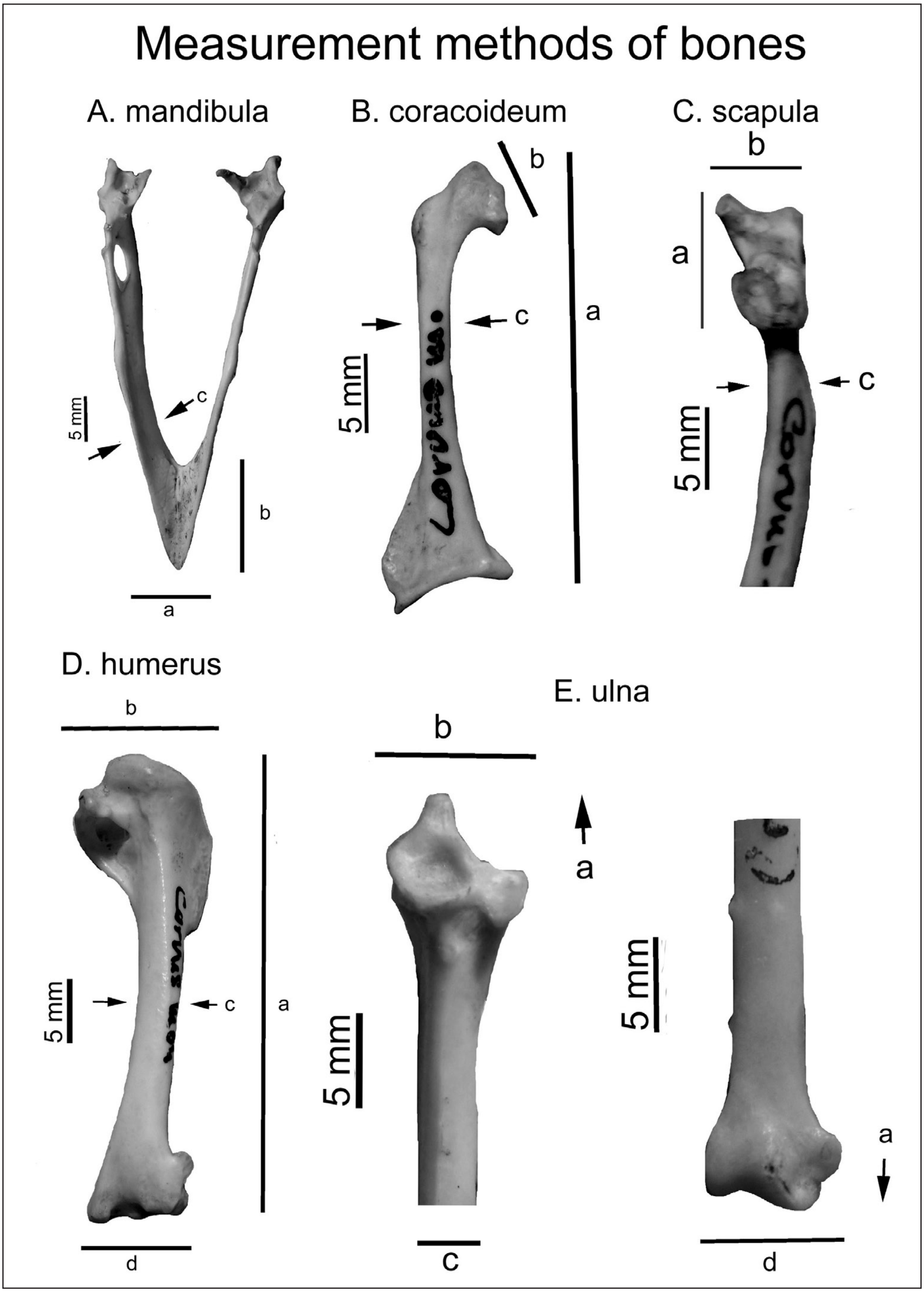


Figure 2 Measurement methods of bones I.
2. ábra A csontok mérési módja

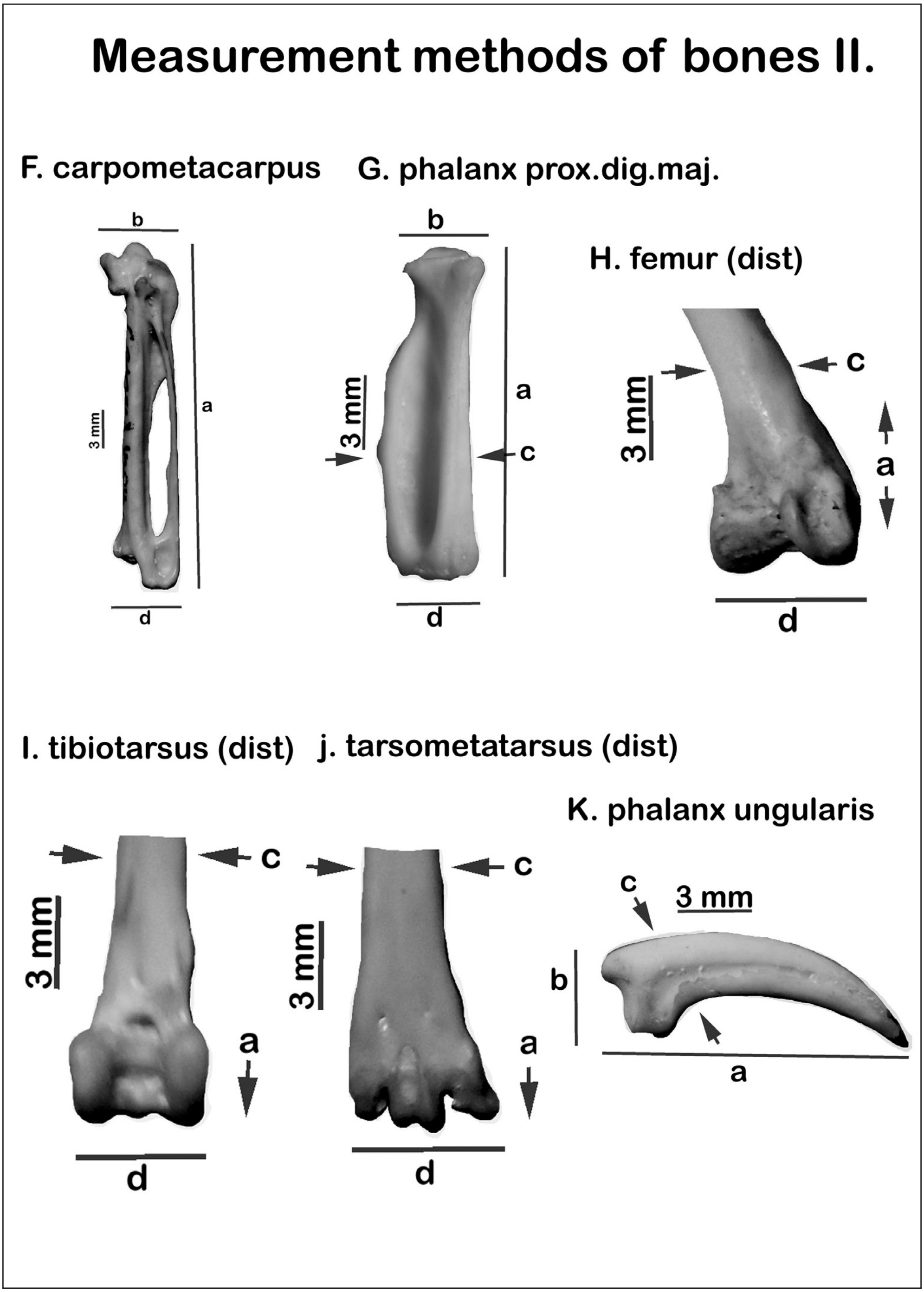


Figure 3 Measurement methods of bones II.
3. ábra A csontok mérési módja

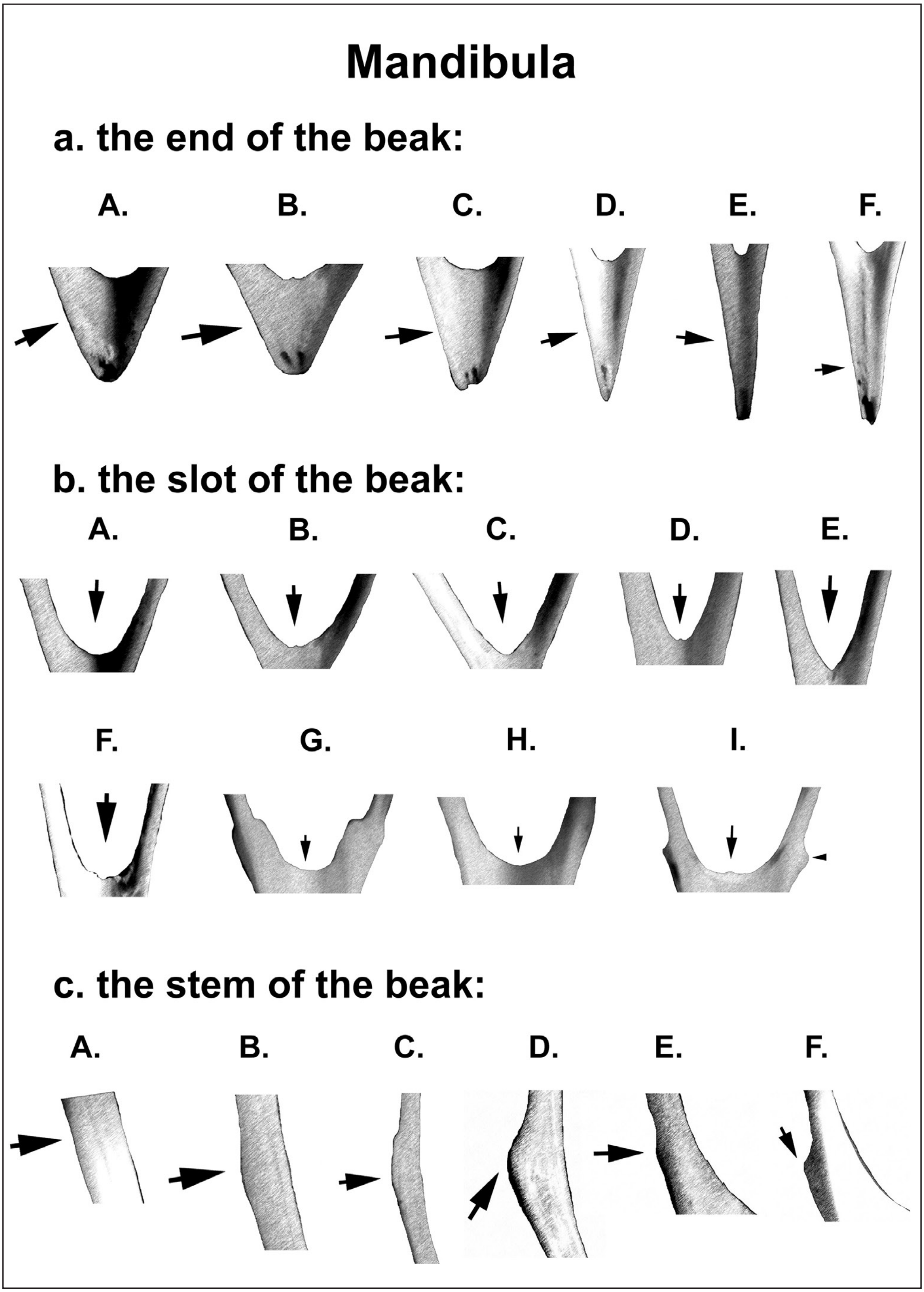


Figure 4 *Mandibula* coding sample (a – the end of the beak; b – the slot of the beak; c – the stem of the beak)

4. ábra Alsó állkapocs kódolási minta (a – a csőr vége; b – a csőr bemélyedése; c – a csőr szára)

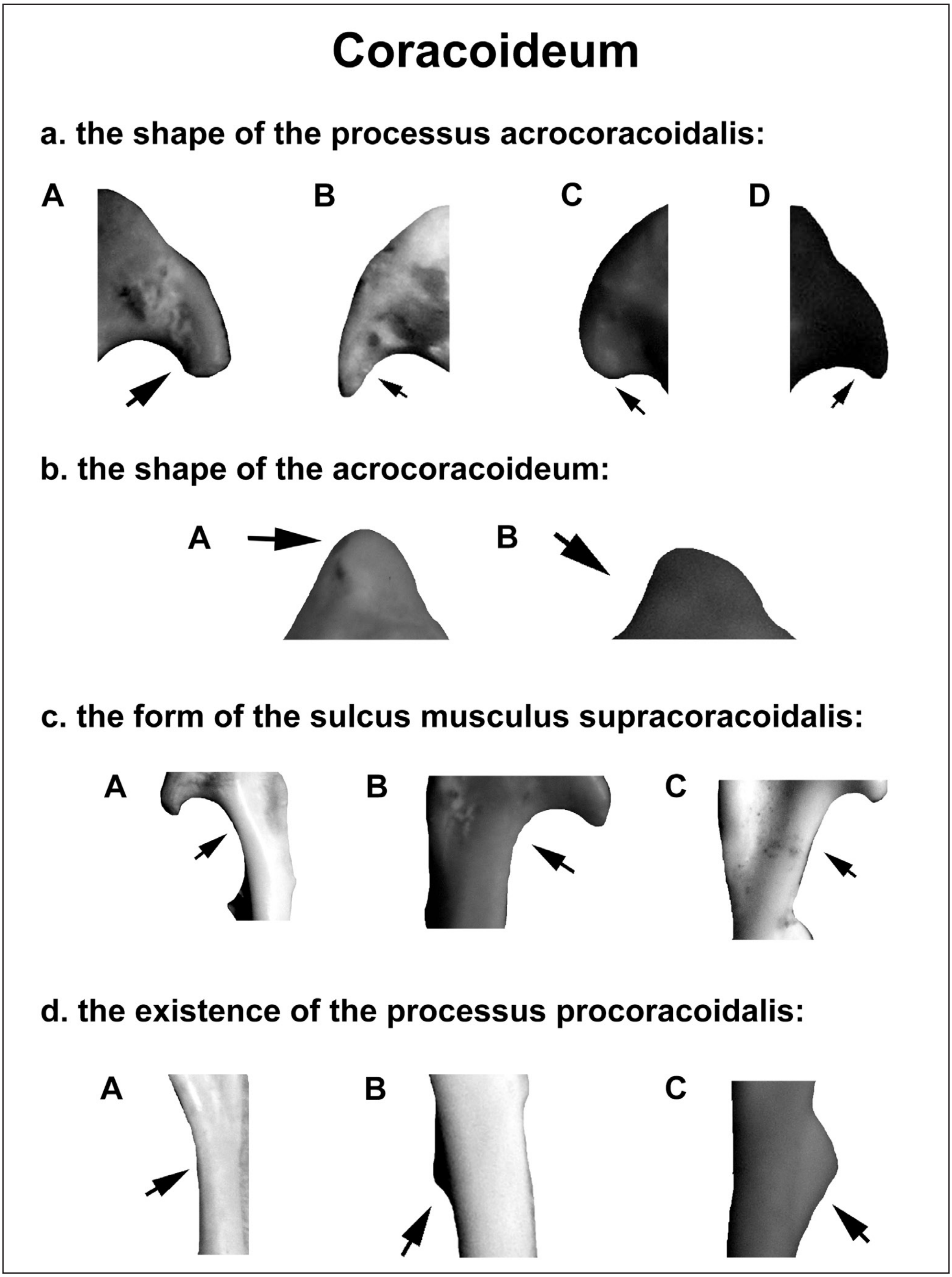


Figure 5 *Coracoideum* coding sample (a – the shape of the *processus acrocoracoidalis*; b – the shape of the *acrocoracoideum*; c – the form of the *sulcus musculus supracoracoidei*; d – the existence of the *processus procoracoidalis*)

5. ábra Hollócsőrcsont kódolási minta (a – a *processus acrocoracoidalis* alakja; b – az *acrocoracoideum* alakja; c – a *sulcus musculus supracoracoidei* formája; d – a *processus procoracoidalis* léte)

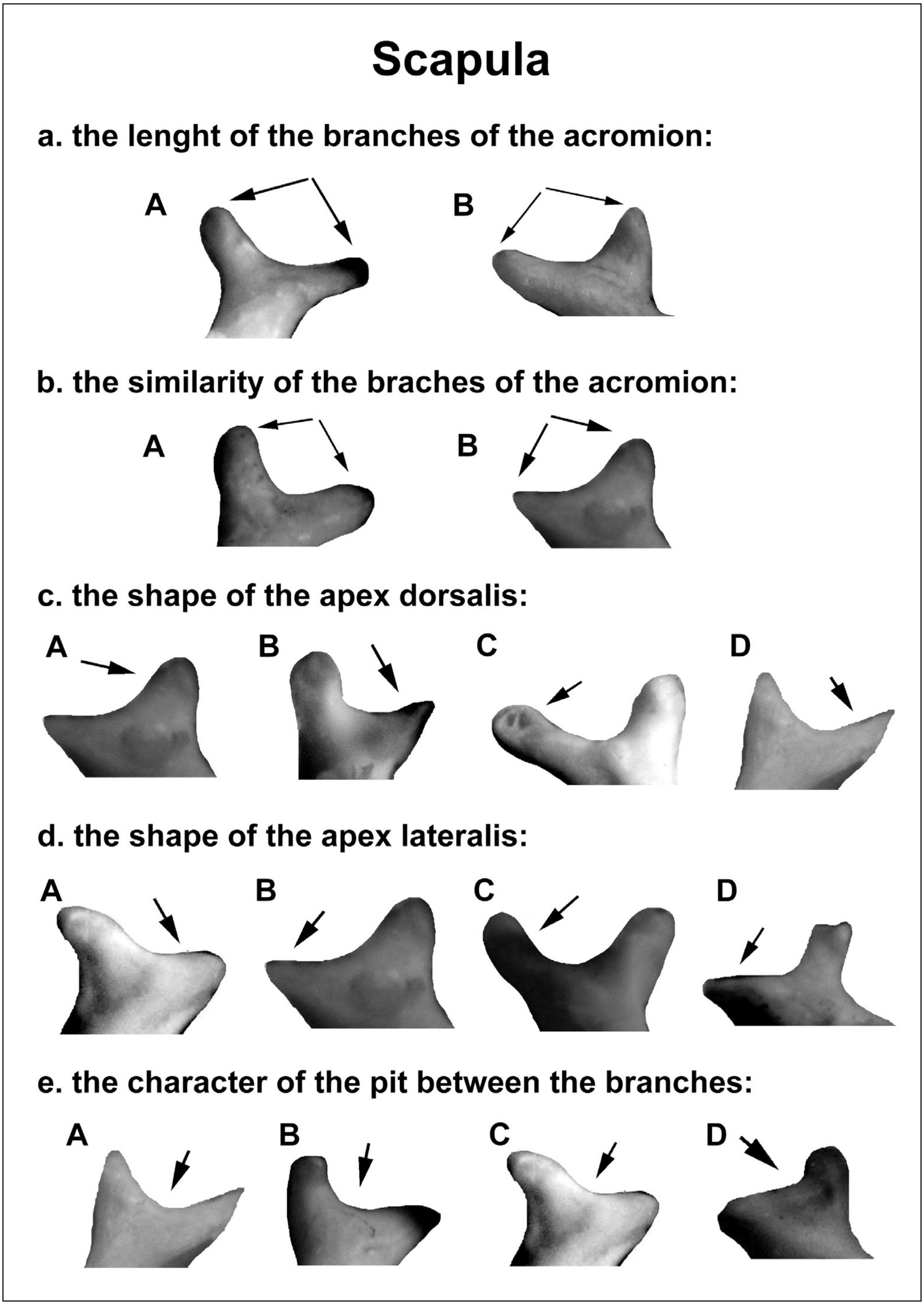


Figure 6 *Scapula* coding sample (a – the lenght of the branches of the *acromion*; b – the similarity of the branches of the *acromion*; c – the shape of the *apex dorsalis*; d – the shape of the *apex lateralis*; e – the character of the pit between the branches)

6. ábra Lapocka kódolási minta (a – az *acromion* szárainak a hossza; b – az *acromion* szárainak a hasonlósága; c – a hátoldali nyúlvány alakja; d – az oldalsó nyúlvány alakja; e – a szárak közti mélyedés formája)

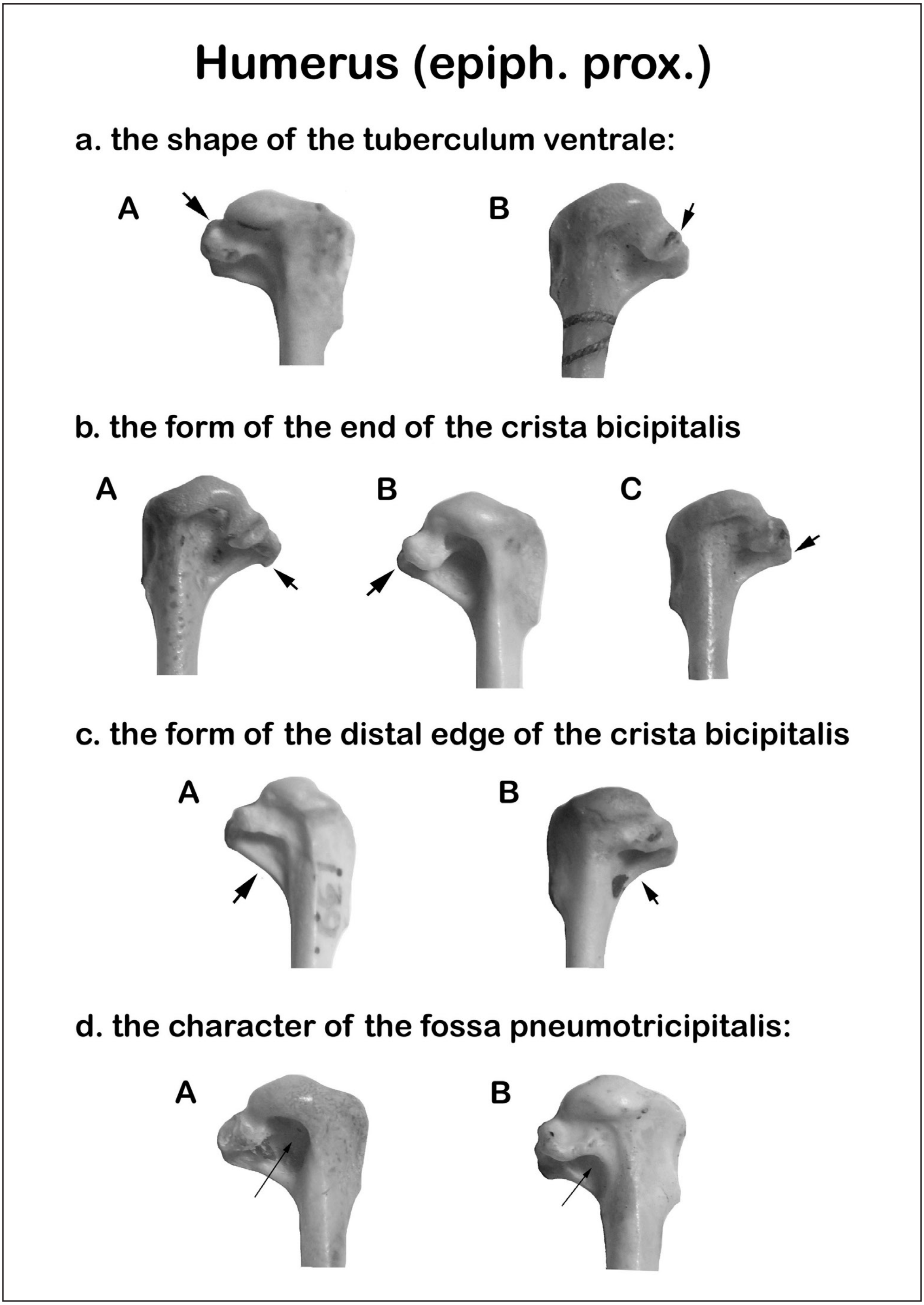


Figure 7 *Humerus (epiph. prox.)* coding sample (a – the shape of the *tuberculum ventrale*; b – the form of the *crista bicipitalis*; c – the form of the distal edge of the *crista bicipitalis*; d – the character of the *fossa pneumotricipitalis*)

7. ábra Felkarcsont (prox. epifízis) kódolási minta (a – a *tuberculum ventrale* alakja; b – a *crista bicipitalis* formája; c – a *crista bicipitalis* disztális élének a formája; d – a *fossa pneumotricipitalis* jellege)

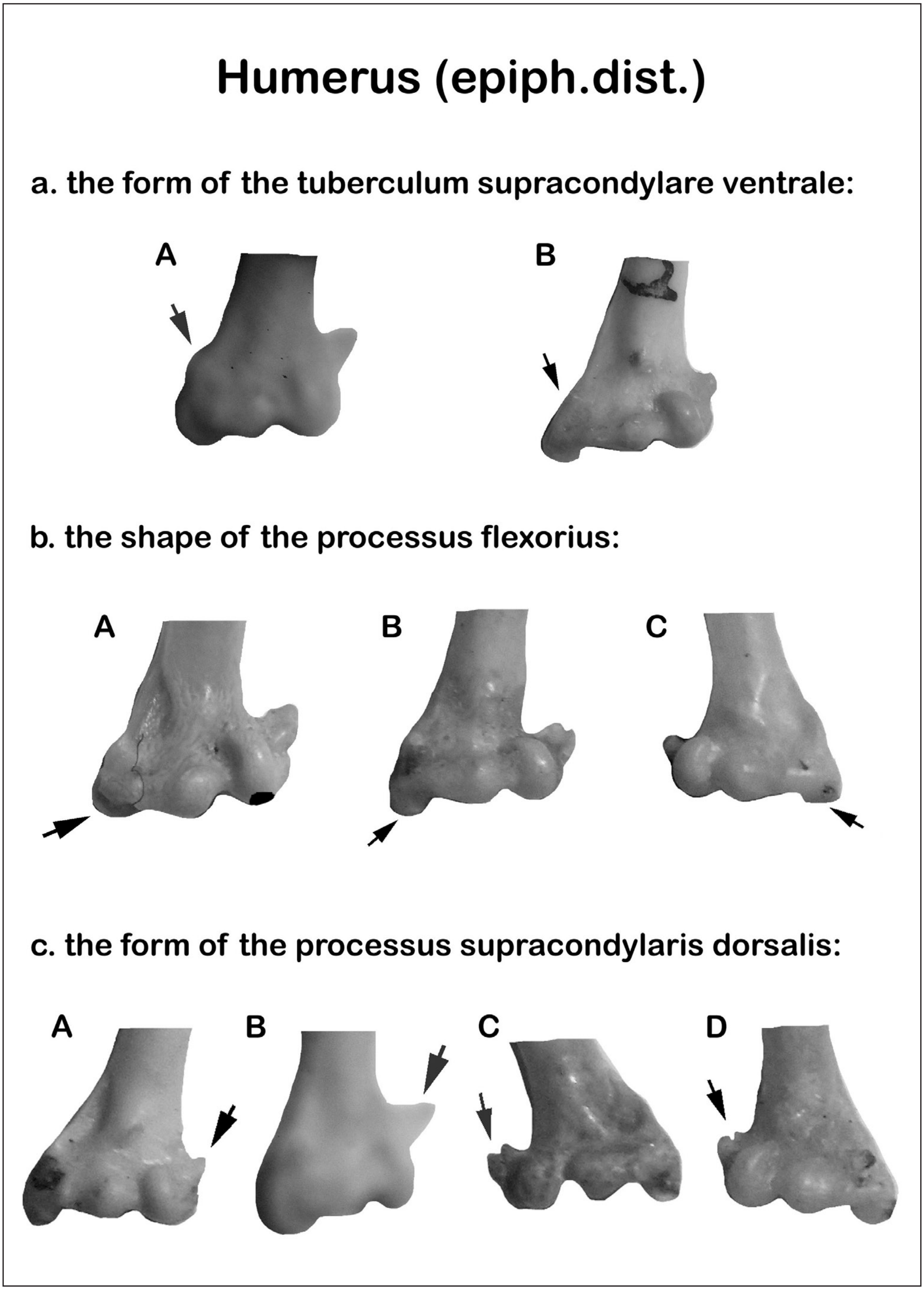


Figure 8 *Humerus (epiph. dist.)* coding sample (a – the form of the *tuberculum supracondylare ventrale*; b – the shape of the *processus flexorius*; c – the form of the *processus supracondylaris dorsalis*)

8. ábra Felkarcsont (diszt. epifízis) kódolási minta (a – a *tuberculum supracondylare ventrale* formája; b – a *processus flexorius* alakja; c – a *processus supracondylaris dorsalis* formája)

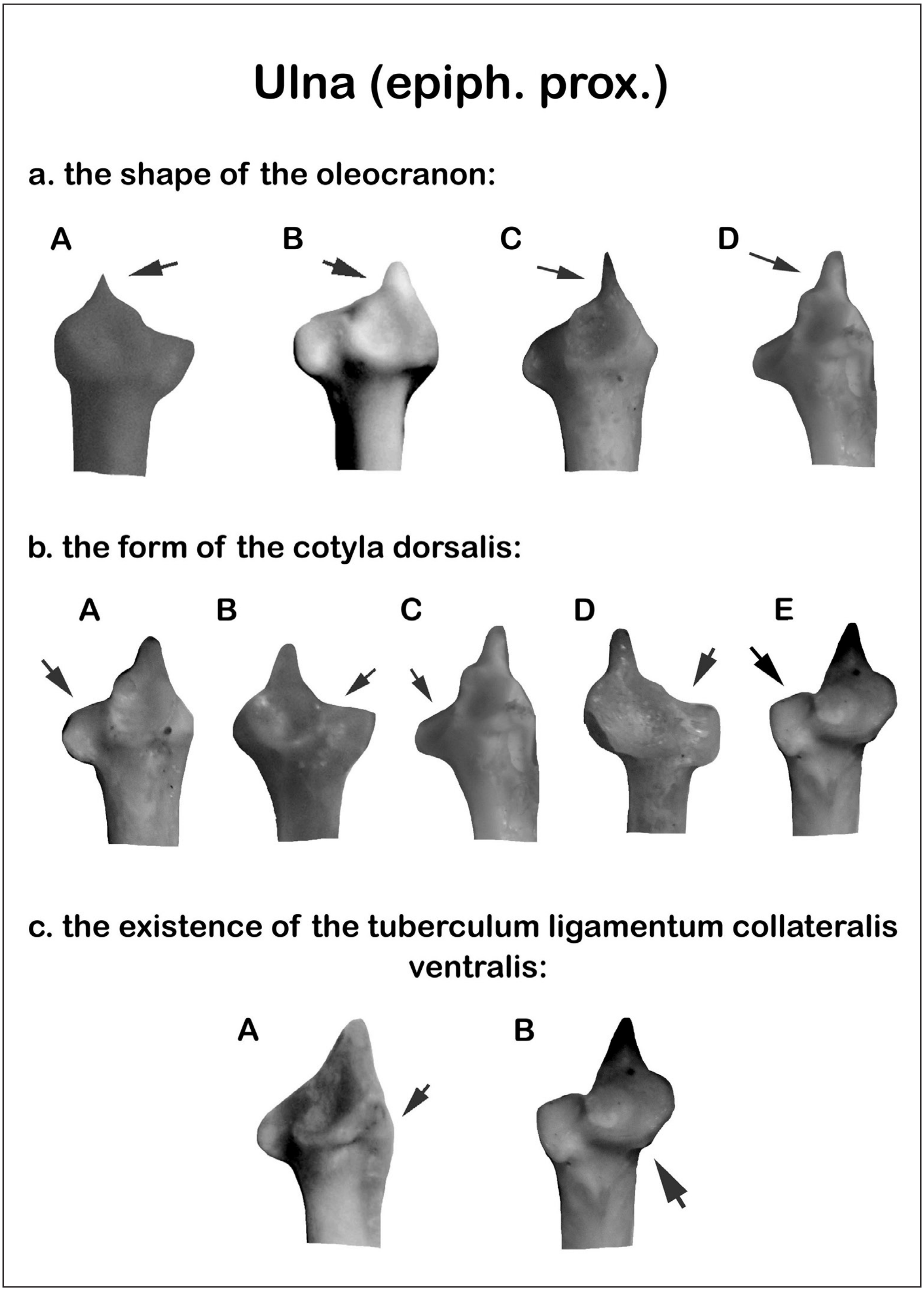


Figure 9 *Ulna (epiph. prox.)* coding sample (a – the shape of the *olecranon*; b – the form of the *cotyla dorsalis*; c – the existence of the *tuberculum ligamentum collateralis ventralis*)

9. ábra Singcsont (prox. epifízis) kódolási minta (a – az *olecranon* alakja; b – a *cotyla dorsalis* formája; c – a *tuberculum ligamentum collateralis ventralis* léte)

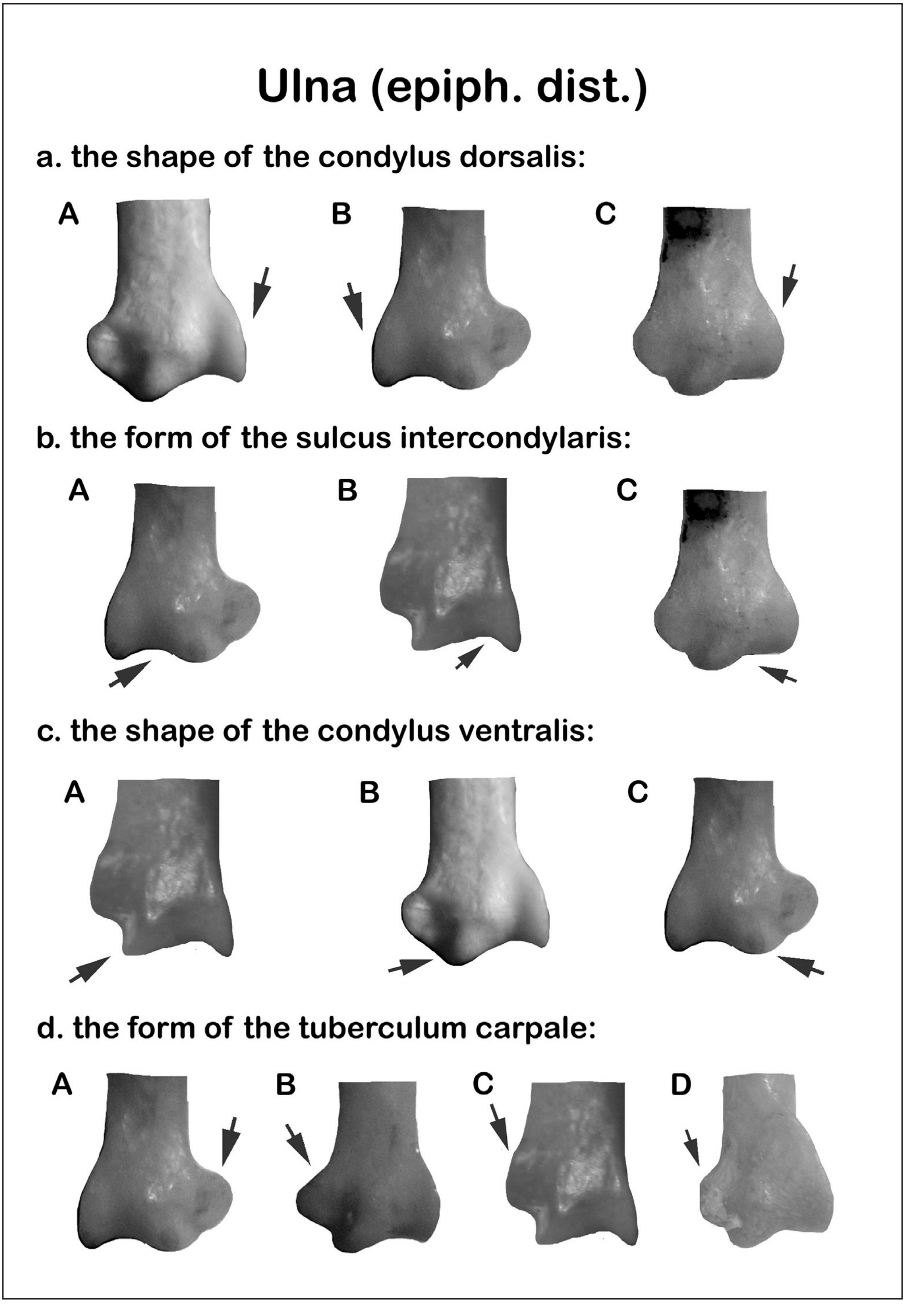


Figure 10 *Ulna (epiph. dist.)* coding sample (a – the shape of the *condylus dorsalis*; b – the form of the *sulcus intercondylaris*; c – the shape of the *condylus ventralis*; d – the form of the *tuberculum carpale*)

10. ábra Singcsont (diszt. epifízis) kódolási minta (a – a *condylus dorsalis* alakja; b – a *sulcus intercondylaris* formája; c – a *condylus ventralis* alakja; d – a *tuberculum carpale* formája)

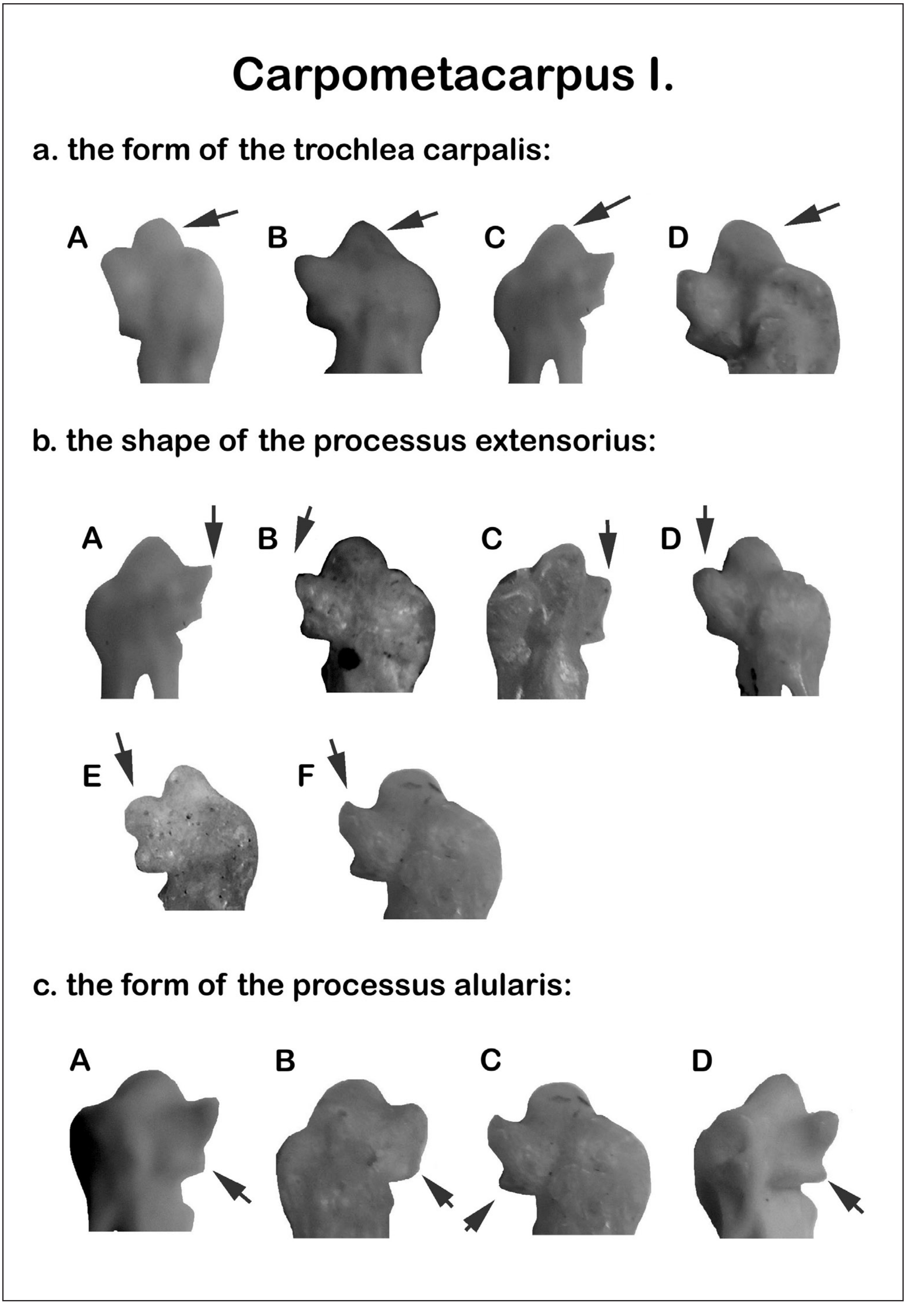


Figure 11 *Carpometacarpus* I. coding sample (a – the shape of the a *trochlea carpalis*; b – the form of the *processus extensorius*; c – the shape of the *processus alularis*)

11. ábra Kézközépcsont kódolási minta I. (a – a *trochlea carpalis* alakja; b – a *processus extensorius* formája; c – a *processus alularis* alakja)

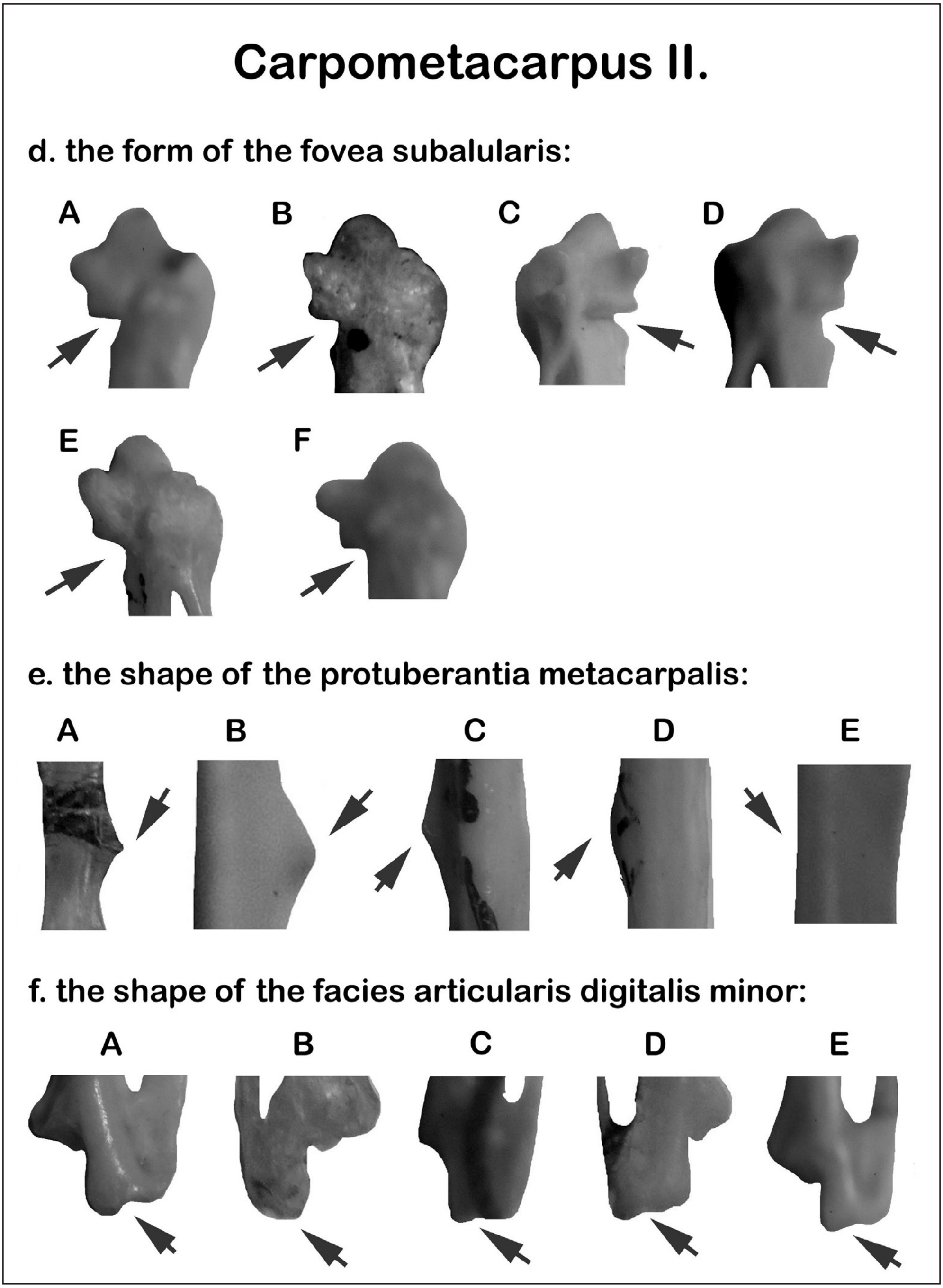


Figure 12 *Carpometacarpus* II. coding sample (d – the form of the *fovea subalularis*; e – the character of the *protuberantia metacarpale majus*; f – the shape of the *facies articularis digitale minor*);
12. ábra Kézközépcsont kódolási minta (d – a *fovea subalularis* formája; e – a *protuberantia metacarpale majus* jellege; f – a *facies articularis digitale minor* alakja)

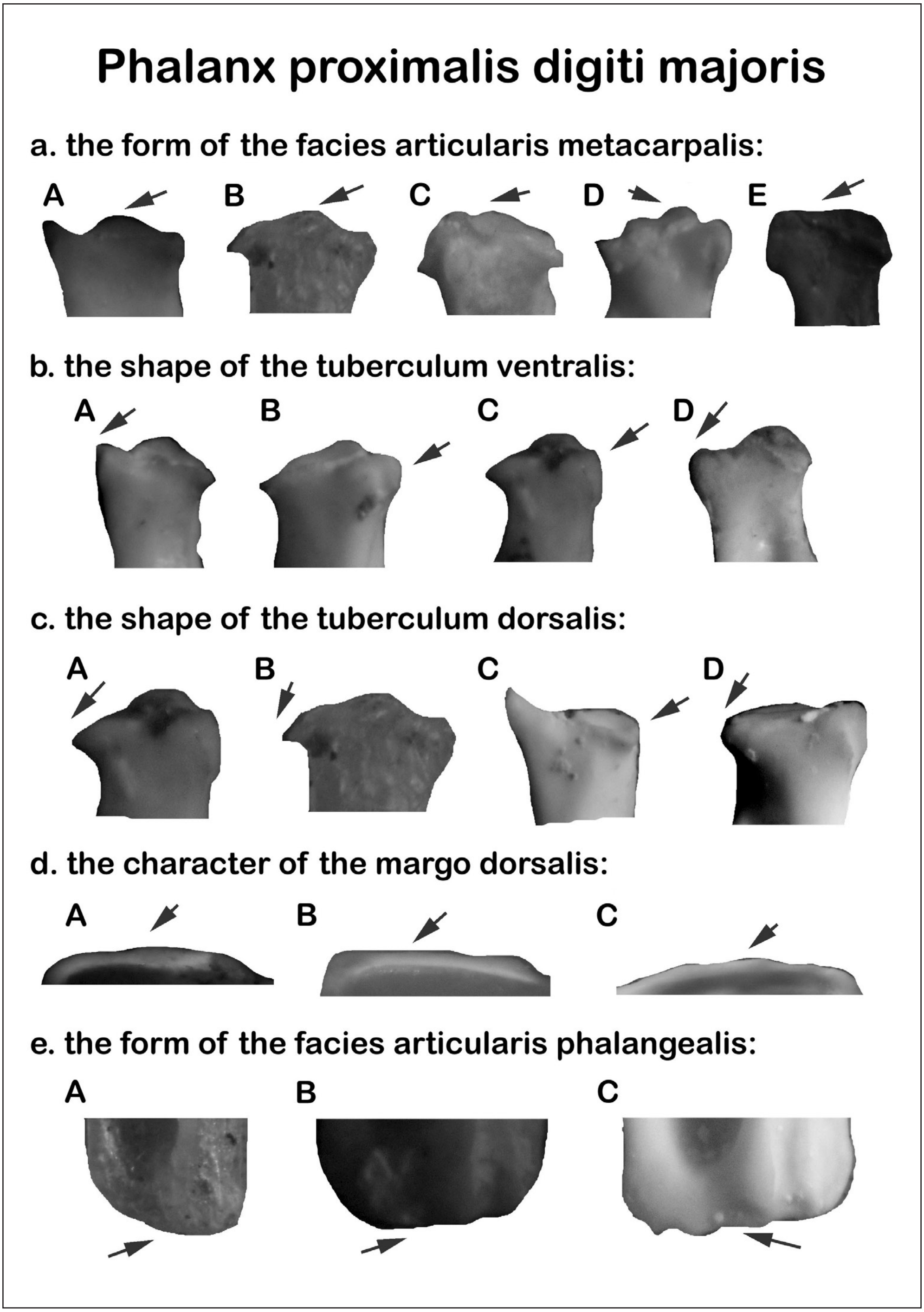


Figure 13 *Phalanx proximalis digiti majoris* coding sample (a – the form of the *margo proximalis*; b – the form of the *tuberculum ventralis*; c – the form of the *tuberculum dorsalis*; d – the character of the *margo dorsalis*; e – the character of the *margo distalis*)

13. ábra Kézujjperc kódolási minta (a – a *margo proximalis* formája; b – a *tuberculum ventralis* formája; c –a *tuberculum dorsalis* formája; d – a *margo dorsalis* jellege; e – a *margo distalis* jellege)

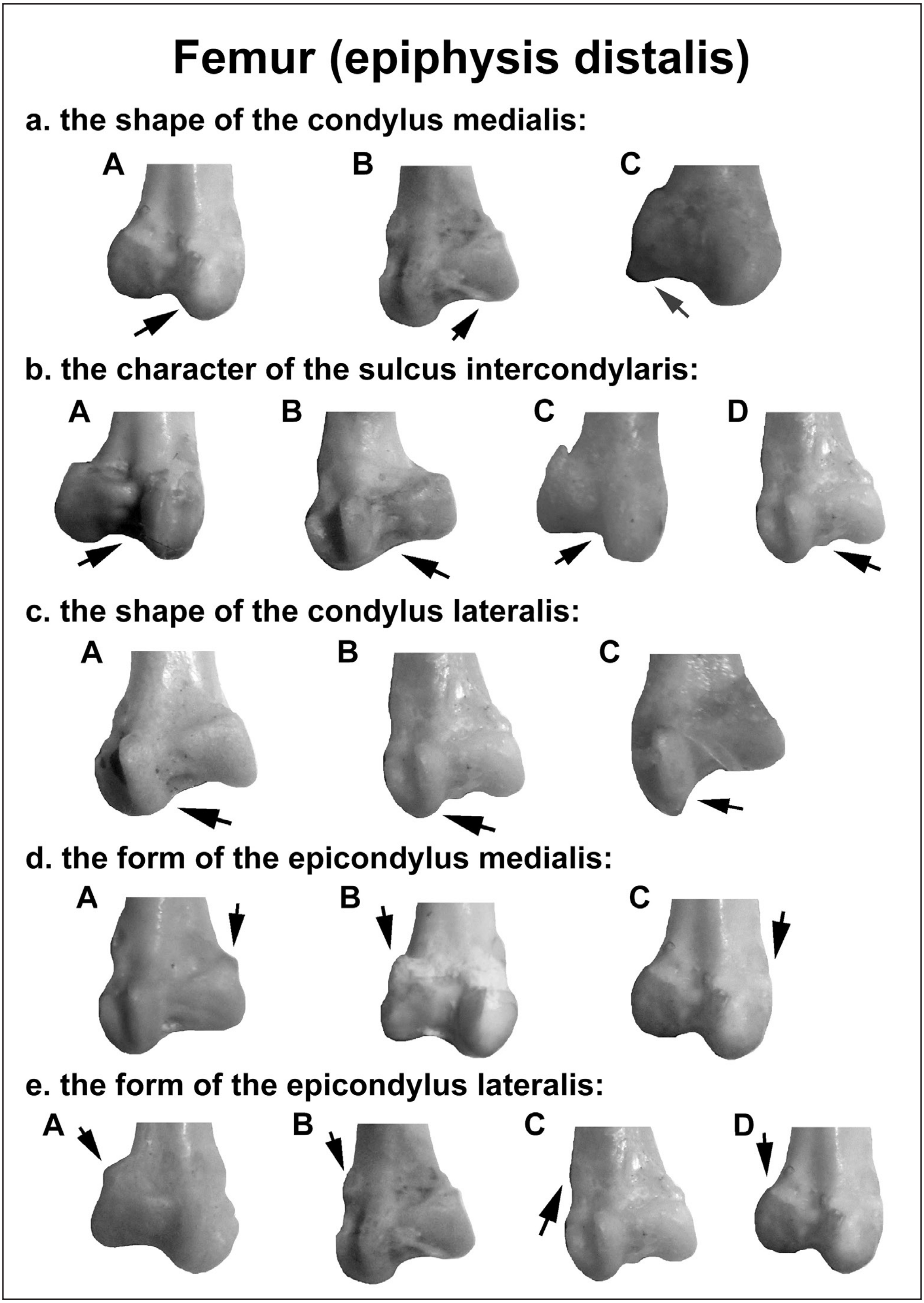


Figure 14 *Femur (epiph.dist.)* coding sample (a – the shape of the *condylus medialis*; b – the character of the *sulcus intercondylaris*; c – the shape of the *condylus lateralis*; d – the form of the *epicondylus medialis*; e – the form of the *epicondylus lateralis*)

14. ábra Combcsont (diszt. epifízis) kódolási minta (a – a *condylus medialis* alakja; b – a *sulcus intercondylaris* jellege; c – a *condylus lateralis* alakja; d – az *epicondylus medialis* formája; e – az *epicondylus lateralis* formája)

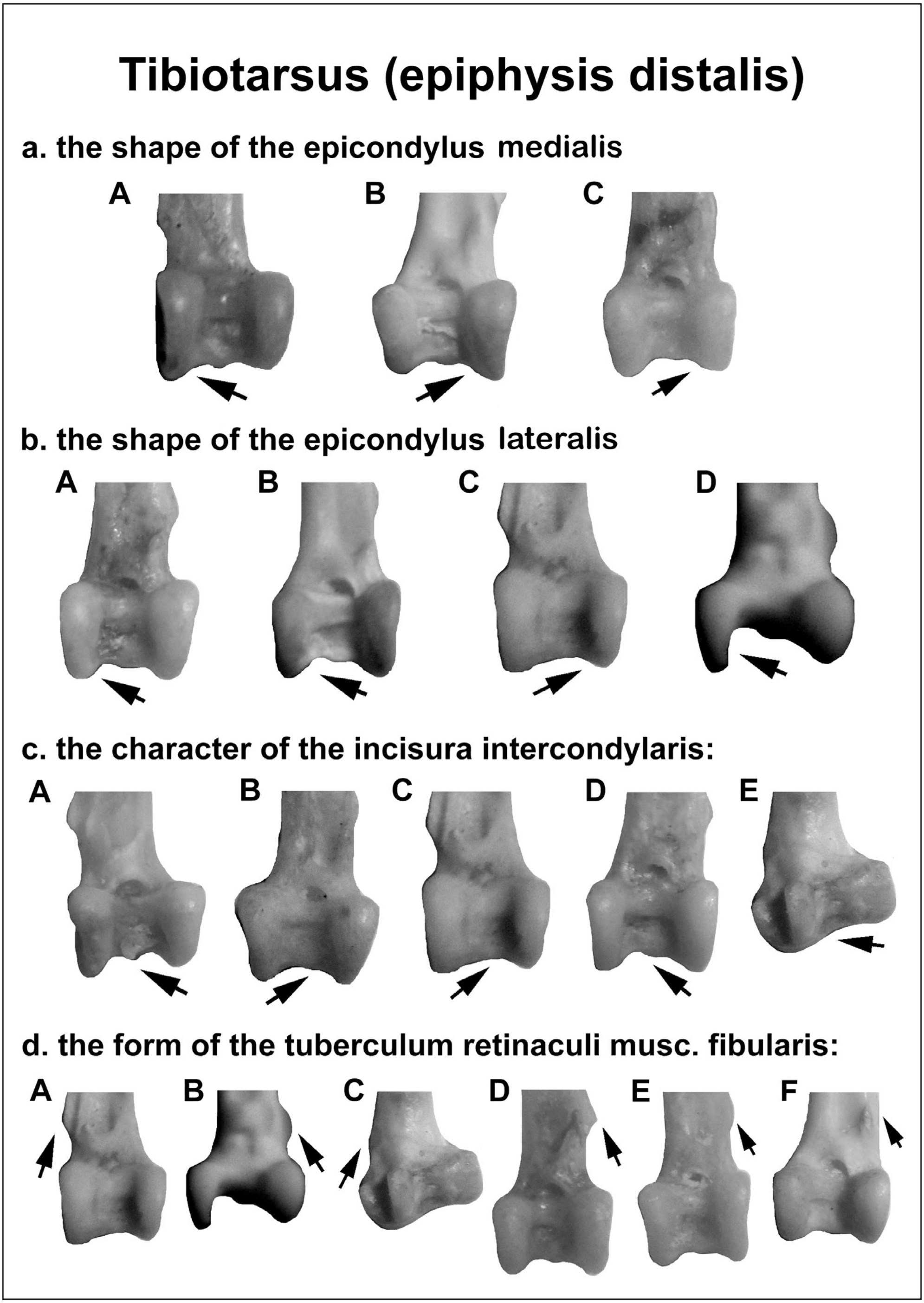


Figure 15 *Tibiotarsus (epiph. dist.)* coding sample (a – the shape of the *epicondylus lateralis*; b – the shape of the *epicondylus medialis*; c – the form of the *incisura intercondylaris*; d – the character of the *tuberositas retinaculi*)

15. ábra Lábszárcsont (diszt. epifízis) kódolási minta (a – az *epicondylus lateralis* alakja; b – az *epicondylus medialis* alakja; c – az *incisura intercondylaris* formája; d – a *tuberositas retinaculi* jellege)

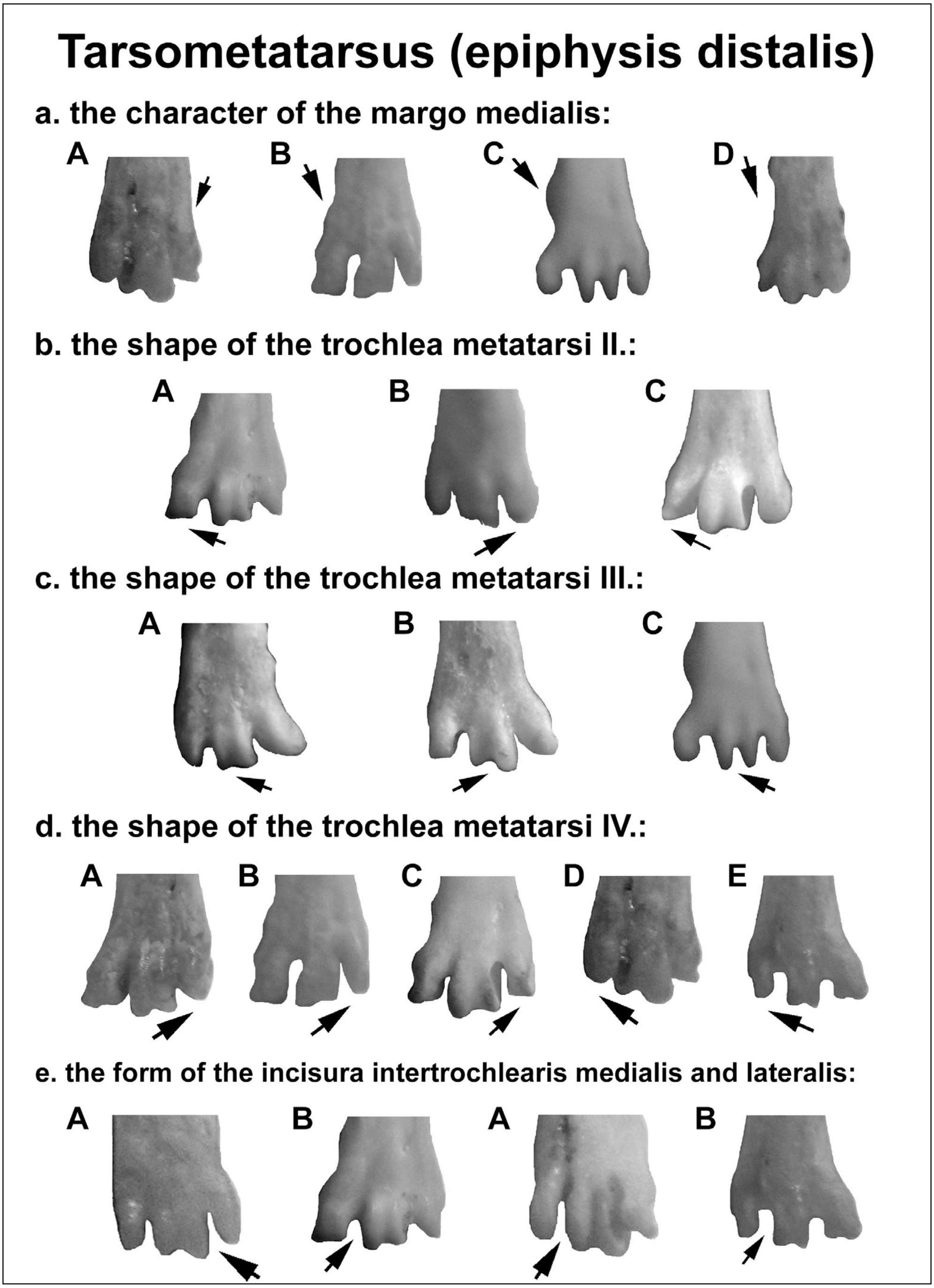


Figure 16 *Tarsometatarsus (epiph. dist.)* coding sample (a – the character of the *margo medialis*; b – the shape of the *troclea metatarsi* II.; c – the shape of the *trochlea metatarsi* III.; d – the shape of the *trochlea metatarsi* IV.; e – the form of the *incisura intertrochlearis medialis*; f – the form of the *incisura intertrochlearis lateralis*)

16. ábra Csüd (diszt. epifízis) kódolási minta (a – a *margo medialis* jellege; b – a *troclea metatarsi* II. alakja; c – a *troclea metatarsi* III. alakja; d – a *troclea metatarsi* IV. alakja; e – az *incisura intertrochlearis medialis* formája; f – az *incisura intertrochlearis lateralis* formája)

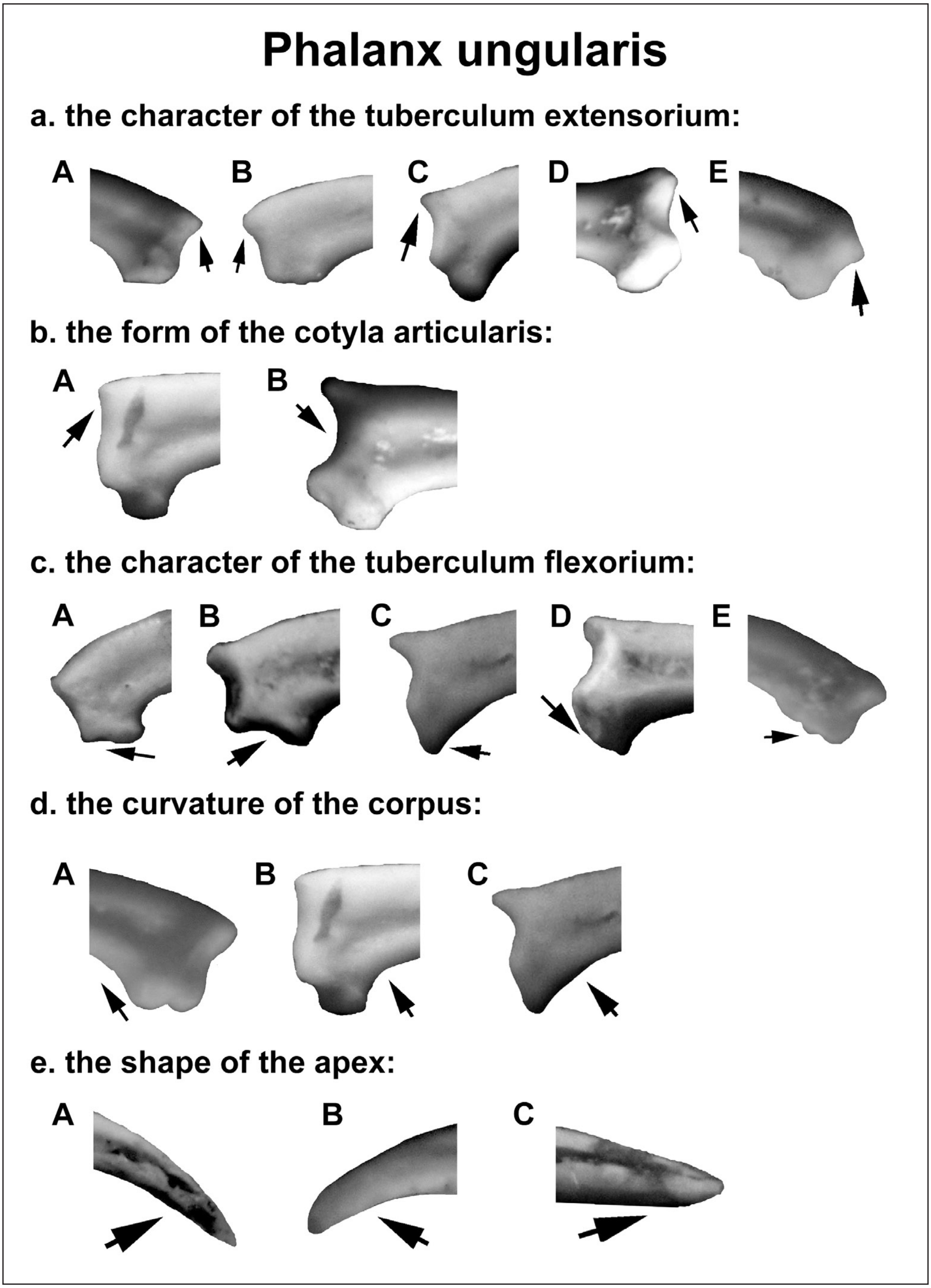


Figure 17 *Phalanx ungularis* coding sample (a – the direction and the form of the *tuberculum extensorium*; b – the character of the *cotyla articularis*; c – the shape of the *tuberculum flexorium*; d – the elbow of the *margo plantaris*; e –the form of the *apex*)

17. ábra Karomcsont kódolási minta (a – a *tuberculum extensorium* iránya és formája; b – a *cotyla articularis* jellege; c – a *tuberculum flexorium* alakja; d – a *margo plantaris* görbülete; e – az *apex* alakja)

Family – Család	Genus – Nemzetség	No.sp	PL mm	BC mm	PB-B mm
Alaudidae	*Alauda*	1	8.01	3.59	1.31
	Calandrella	1	4.78	2.72	1.12
	Eremophila	1	6.71	3.39	1.05
	Galerida	1	7.29	2.91	1.21
	Lullula	1	6.09	3.57	0.92
	Melanocorypha	1	9.82	5.74	1.84
Hirundinidae	*Delichon*	1	2.69	2.99	0.95
	Hirundo	1	2.73	3.01	0.98
	Riparia	1	2.77	3.05	0.85
Paridae	*Aegithalos*	1	2.38	2.53	0.72
	Panurus	0			
	Parus	5	4.54-5.32	2.63-3.18	0.98-1.07
	Remiz	1	5.03	3.43	0.97
Muscicapidae	*Erithacus*	1	4.34	2.58	0.75
	Luscinia	3	6.03-6.09	2.43-3.24	0.78-0.83
	Monticola	1	9.92	3.32	1.05
	Muscicapa – Ficedula	1	3.96	2.97	0.82
	Oenanthe	1	6.22	2.61	0.89
	Phoenicurus	1	4.81	2.15	0.75
	Saxicola	1	4.23	2.64	0.78
Turdidae	*Turdus*	1	9.48	3.76	1.22
Oriolidae	*Oriolus*	1	7.22	3.19	0.96
Certhiidae	*Certhia*	1	6.43	1.38	0.62
Sittidae	*Sitta*	1	7.43	3.18	0.98
Troglodytidae	*Troglodytes*	1	4.92	1.43	0.68
Cinclidae	*Cinclus*	1	6.59	2.17	0.85
Bombycillidae	*Bombycilla*	1	5.78	4.47	1.32

Family – Család	**Genus – Nemzetség**	**No.sp**	**PL mm**	**BC mm**	**PB-B mm**
Motacillidae	*Anthus*	5	5.29-9.16	2.25-3.19	0.72-0.96
	Motacilla	3	5.52-7.86	2.61-3.04	0.75-0.91
Sylviidae	*Acrocephalus*	4	6.18-6.45	2.47-4.98	0.65-0.75
	Cettia	1	5.21	2.25	0.67
	Hippolais	1	4.42	3.71	0.83
	Locustella	1	6.45	2.47	0.67
	Lusciniola	0			
	Phylloscopus	1	3.48	2.21	0.79
	Regulus	0			
	Sylvia	5	3.47-5.41	2.99-3.03	0.62-0.71
Prunellidae	*Prunella*	2	5.42	2.98	0.78
Laniidae	*Lanius*	1	7.98	5.18	2.14
Sturnidae	*Sturnus – Pastor*	2	0.21	3.94	1.58
Passeridae	*Passer*	2	5.81-6.11	4.71-5.47	1.21-1.26
Fringillidae	*Carduelis*	5	4.02-4.51	3.96-4.99	1.05-1.21
	Chloris	1	7.94	7.21	2.62
	Coccothraustes	1	18.89	16.73	4.23
	Fringilla	2	7.67	6.14	1.24
	Loxia	2	11.78	9.75	1.73
	Pinicola	1	7.21	7.93	1.35
	Pyrrhula	1	6.83	7.92	1.05
	Serinus	1	3.65	3.42	0.73
Emberizidae	*Emberiza*	5	4.32-4.88	3.69-5.37	1.16-1.28
	Plectrophenax	1	3.78	4.08	1.25

Table 1 Size table of *mandibula* (No. sp = number of species; PL – partial lenght – lenght of the apex; Bc = breadth of the apex; PB = partial breadth – breadth of the *ramus mandibulae*)

1. táblázat Alsó álkapocs mérési táblázata (No. sp = fajszám; PL = részleges hossz – a csőr vég hossza; PB = részleges szélesség – a csőr vég szélessége)

Family – Család	Genus – Nemzetség	No.sp	TL mm	PL=LTB mm	Dc mm
Alaudidae	*Alauda*	1	17.74	3.69	1.15
	Calandrella	1	17.29	2.51	1.14
	Eremophila	0			
	Galerida	1	22.84	4.02	1.18
	Lullula	1	18.53	3.92	1.17
	Melanocorypha	1		3.95	1.25
Hirundinidae	*Delichon*	1	16.75	3.81	0.97
	Hirundo	1	15.37	2.83	1.01
	Riparia	1	15.68	3.61	1.11
Paridae	*Aegithalos*	1	11.47	1.79	0.91
	Panurus	0			
	Parus	5	12.32-13.64	2.19-2.67	0.77-1.26
	Remiz	1	13.06	2.46	0.69
Muscicapidae	*Erithacus*	1	14.09	2.35	0.86
	Luscinia	3	18.14-18-17	3.01-3.03	0.89-1.01
	Monticola	1	24.41	4.63	1.35
	Muscicapa – Ficedula	4	15.08-19.64	2.62-2.83	0.82-1.16
	Oenanthe	2	14.55-16.23	2.99-3.44	0.91-1.01
	Phoenicurus	2	15.12-15.77	2.97-3.02	0.79-0.82
	Saxicola	3	14.55-17.81	2.64-3.19	0.88-1.01
Turdidae	*Turdus*	6	24.16-29.24	4.45-5.52	1.35-1.91
Oriolidae	*Oriolus*	1	25.71	4.61	1.67
Certhiidae	*Certhia*	2	11.82	1.93	0.66
Sittidae	*Sitta*	1	16.01	2.99	0.64
Troglodytidae	*Troglodytes*	1	13.01	2.21	0.59
Cinclidae	*Cinclus*	1	20.57	3.84	1.44
Bombycillidae	*Bombycilla*	1	24.22	4.24	1.43

Family – Család	Genus – Nemzetség	No.sp	TL mm	PL=LTB mm	Dc mm
Motacillidae	*Anthus*	5	17.43-19.14	3.02-3.63	0.99-1.21
	Motacilla	3	15.91-16.65	2.69-3.21	0.87-1.02
Sylviidae	*Acrocephalus*	4	13.24-18.67	2.41-3.13	0.76-1.02
	Cettia	1	14.35	1.97	0.92
	Hippolais	2	13.01-15.36	2.34-2.58	0.72-0.76
	Locustella	3	14.25	2.47	0.75
	Lusciniola	1	14.98	2.46	0.71
	Phylloscopus	3	12.41-13.91	2.22-3.54	0.63-0.71
	Regulus	1	9.91	1.78	0.83
	Sylvia	5	14.32-18.56	2.38-3.66	0.77-1.04
Prunellidae	*Prunella*	2	16.27	2.86	1.26
Laniidae	*Lanius*	3	18.49-23.97	2.97-4.37	1.16-1.51
Sturnidae	*Sturnus – Pastor*	2	26.34-26.61	4.29-4.47	1.69-1.72
Passeridae	*Passer*	2	17.94-19.61	2.71-3.21	0.92-1.24
Fringillidae	*Carduelis*	5	14.22-16.02	2.44-3.26	0.75-1.19
	Chloris	1	18.52	3.23	1.05
	Coccothraustes	1	23.32	4.29	1.27
	Fringilla	2	17.67-18.92	2.62-2.84	0.98-1.03
	Loxia	2	18.61-22.08	3.28-3.67	1.21-1.47
	Pinicola	1	23.46	4.04	1.41
	Pyrrhula	1	19.32	3.35	1.17
	Serinus	1	17.28	2.66	1.11
Emberizidae	*Emberiza*	5	17.16-21.08	2.99-4.61	0.84-1.39
	Plectrophenax	1	18.04	2.98	1.12

Table 2 Size table of *coracoideum* (No.sp = number of species; TL = total lenght; PL-LTM = partial lenght – lenght of the *tuberculum brachialis*; Bc = breadth of the corpus)

2. táblázat Hollócsőrcsont mérési táblázata (No. sp = fajszám; TL = teljes hossz; PL-LTM = részleges hossz – a *tuberculum brachialis* hossza; Bc = a diafízis szélessége)

Family – Család	Genus – Nemzetség	No.sp	PL mm	BA mm	Bc mm
Alaudidae	*Alauda*	1	4.29	3.18	1.31
	Calandrella	1	3.48	2.41	1.24
	Eremophila	1	4.57	3.28	1.39
	Galerida	1	5.12	3.76	1.61
	Lullula	1	4.21	3.13	1.33
	Melanocorypha	1	5.92	3.98	1.93
Hirundinidae	*Delichon*	1	3.15	1.71	1.38
	Hirundo	1	2.89	1.67	1.19
	Riparia	1	2.97	1.74	1.21
Paridae	*Aegithalos*	0			
	Panurus	1	2.71	2.07	1.21
	Parus	5	2.38-3.13	1.87-2.54	0.81-1.32
	Remiz	1	2.51	2.47	1.23
Muscicapidae	*Erithacus*	1	2.65	1.92	1.11
	Luscinia	3	3.52-3.84	2.46-2.49	1.19-1.37
	Monticola	1	5.01	3.29	2.13
	Muscicapa – Ficedula	4	2.56-2.91	1.82-2.01	1.02-1.27
	Oenanthe	2	3.15-3.27	2.27-2.49	1.25-1.29
	Phoenicurus	2	2.78-3.17	2.48-3.19	1.23-1.29
	Saxicola	3	2.72-3.39	1.75-2.49	1.12-1.24
Turdidae	*Turdus*	6	4.98-7.39	3.76-4.17	1.91-2.39
Oriolidae	*Oriolus*	1	5.78	4.21	2.33
Certhiidae	*Certhia*	2	2.47	2.51	0.85
Sittidae	*Sitta*	1	3.48	2.17	1.16
Troglodytidae	*Troglodytes*	1	2.58	1.88	1.26
Cinclidae	*Cinclus*	0			
Bombycillidae	*Bombycilla*	1	5.16	2.93	1.95

Family – Család	Genus – Nemzetség	No.sp	PL mm	BA mm	Bc mm
Motacillidae	*Anthus*	5	3.14-4.32	1.94-2.56	1.16-1.59
	Motacilla	3	3.24-4.23	2.04-2.48	1.33-1.72
Sylviidae	*Acrocephalus*	4	2.46-3.26	1.51-1.99	1.06-1.74
	Cettia	1	2.88	1.75	1.85
	Hippolais	2	2.59-3.02	1.62-2.15	0.91-1.15
	Locustella	3	2.15-3.32	1.78-2.08	0.85-1.17
	Lusciniola	1	2.72	1.78	1.47
	Phylloscopus	3	2.25-2.88	1.98-2.31	1.01-1.24
	Regulus	0			
	Sylvia	5	2.35-3.48	1.95-2.65	1.11-1.23
Prunellidae	*Prunella*	2	3.88-4.37	2.31-2.81	1.52-1.62
Laniidae	*Lanius*	3	3.66-4.83	2.01-3.09	1.32-2.01
Sturnidae	*Sturnus – Pastor*	2	5.71-5.79	3.07-3.26	2.17-2.19
Passeridae	*Passer*	2	3.91-4.02	2.01-2.08	1.51-1.64
Fringillidae	*Carduelis*	5	3.29-3.61	2.29-2.92	1.14-1.21
	Chloris	1	4.69	2.69	1.62
	Coccothraustes	1	5.27	3.84	1.88
	Fringilla	2	2.83-3.29	2.14-2.42	1.35-1.36
	Loxia	2	3.78-4.11	3.28-3.63	1.56-1.58
	Pinicola	1	4.99	2.94	2.19
	Pyrrhula	1	3.96	2.84	1.91
	Serinus	1	3.49	2.29	1.44
Emberizidae	*Emberiza*	5	3.24-5.24	2.42-3.73	1.37-1.92
	Plectrophenax	1	4.99	2.92	1.41

Table 3 Size table of *scapula* (No.sp = number of species; PL = partial lenght – lenght of the proximal end; Bp = breadth of the proximal end; Bc = breadth of the corpus)

3. táblázat Lapocka mérési táblázata (No. sp = fajszám; PL = részleges hossz – a proximális vég hossza; Bp = a proximális vég szélessége; Bc = a lapocka test szélessége)

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm	Bc mm	Bd mm
Alaudidae	*Alauda*	1	17.01	6.25	2.31	4.65
	Calandrella	0				
	Eremophila	0				
	Galerida	1	28.01	8.28	2.46	6.09
	Lullula	1	23.02	6.55	2.28	4.88
	Melanocorypha	1	27.75	8.03	2.46	6.65
Hirundinidae	*Delichon*	1	14.06	6.42	1.86	4.86
	Hirundo	1	14.62	6.19	1.64	4.23
	Riparia	1	12.95	5.49	1.72	3.97
Paridae	*Aegithalos*	1	11.28	3.78	1.44	3.01
	Panurus	1	13.33	4.07	1.54	3.55
	Parus	5	13.76-14.25	3.71-4.98	1.44-1.71	2.04-4.08
	Remiz	0				
Muscicapidae	*Erithacus*	1	15.85	4.54	1.51	3.67
	Luscinia	3	17.43-17.73	5.43-5.65	1.59-1.68	4.26-4.59
	Monticola	1	24.88	8.09	2.34	6.36
	Muscicapa – Ficedula	4	12.85-13.11	4.36-4.67	1.312-1.52	3.49-3.52
	Oenanthe	2	16.75-18.21	5.65-5.68	1.73-1.74	4.12-4.51
	Phoenicurus	2	17.18-17.46	4.94-5.66	1.56-1.72	3.93-4.27
	Saxicola	3	15.45-18.82	4.67-6.05	1.44-1.76	3.65-4.11
Turdidae	*Turdus*	6	25.71-31.09	8.24-10.85	2.53-3.31	6.49-8.21
Oriolidae	*Oriolus*	1	30.54	12.27	3.11	7.69
Certhiidae	*Certhia*	2	9.75-12.53	3.17-4.22	1.12-1.28	3.15-3.19
Sittidae	*Sitta*	1	18.02	5.67	1.84	4.43
Troglodytidae	*Troglodytes*	1	12.07	4.54	1.71	2.75
Cinclidae	*Cinclus*	1	20.51	6.69	2.25	5.46
Bombycillidae	*Bombycilla*	1	24.94	8.16	2.16	6.83

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm	Bc mm	Bd mm
Motacillidae	*Anthus*	5	20.08-21.48	5.14-.6.75	1.87-2.11	4.36-5.11
	Motacilla	3	16.97-18.71	5.21-6.12	1.66-1.87	3.59-4.08
Sylviidae	*Acrocephalus*	4	11.97-19.05	4.09-5.78	1.34-1.89	3.01-4.03
	Cettia	1	15.42	4.04	1.63	3.96
	Hippolais	2	11.87-14.62	3.08-5.04	1.33-1.61	3.48-3.99
	Locustella	3	13.14-14.67	4.14-4.18	1.23-1.28	2.91-3.34
	Lusciniola	1	23.35	7.85	2.91	5.12
	Phylloscopus	3	12.19-12.97	4.12-4.39	1.16-1.63	3.31-3.57
	Regulus	0				
	Sylvia	5	13.46-18.17	4.47-5.48	1.52-1.73	3.69-4.13
Prunellidae	*Prunella*	2	15.37-17.31	5.08-5.17	1.69-1.71	4.12-5.21
Laniidae	*Lanius*	3	19.51-26.43	5.96-8.24	2.04-2.51	4.57-6.84
Sturnidae	*Sturnus – Pastor*	2	27.53-28.95	8.56-9.03	2.67-2.78	6.31-6.47
Passeridae	*Passer*	2	16.49-19.35	5.29-6.12	1.61-1.68	4.54-4.63
Fringillidae	*Carduelis*	5	13.49-16.53	4.76-5.84	1.45-1.78	3.75-4.33
	Chloris	1	18.19	6.14	1.89	4.73
	Coccothraustes	1	17.45	6.47	2.03	4.71
	Fringilla	2	18.12-18.65	6.09-6.12	1.71-1.73	4.44-4.62
	Loxia	2	17.45-18.54	6.47-6.61	2.03-2.05	4.71-5.73
	Pinicola	1	23.75	7.19	2.46	5.38
	Pyrrhula	1	20.22	6.67	2.03	5.23
	Serinus	1	17.95	6.04	1.74	4.37
Emberizidae	*Emberiza*	5	18.65-24.99	5.96-8.05	1.96-2.32	4.18-5.42
	Plectrophenax	0				

Table 4 Size table of *humerus* (No.sp = number of species; TL = total lenght; Bp – breadth of the proximal end; Bc = breadth of the corpus; Bd = breadth of the distal end)

4. táblázat Felkarcsont mérési táblázata (No. sp = fajszám; TL = teljes hossz; Bp = a proximális vég szélessége; Bc = a diafízis szélessége; Bd = a disztális vég szélessége)

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm	BC mm	Bd mm
Alaudidae	*Alauda*	1	29.68	3.96	1.92	3.32
	Calandrella	1	25.73	3.38	1.51	2.88
	Eremophila	1	29.51	3.97	1.91	3.51
	Galerida	1	34.46	3.92	2.25	3.68
	Lullula	1	28.95	3.21	1.92	3.13
	Melanocorypha	0				
Hirundinidae	*Delichon*	1	22.05	3.71	1.65	2.93
	Hirundo	1	23.51	3.13	1.54	2.86
	Riparia	1	21.67	3.53	1.61	2.85
Paridae	*Aegithalos*	1	13.37	2.18	1.03	1.93
	Panurus	0				
	Parus	5	15.46-18.71	2.22-2.71	1.12-1.34	2.19-2.69
	Remiz	0				
Muscicapidae	*Erithacus*	1	18.06	2.61	1.22	2.35
	Luscinia	3	21.71-22.22	2.79-3.15	1.39-1.51	2.46-2.82
	Monticola	0				
	Muscicapa – Ficedula	4	17.15-20.11	2.37-2.69	1.21-1.36	1.61-2.49
	Oenanthe	1	25.01	3.27	1.71	2.92
	Phoenicurus	2	22.56-22.94	2.87-2.91	1.42-1.63	2.89-3.07
	Saxicola	3	19.18-25.68	2.61-3.26	1.27-1.57	2.31-2.91
Turdidae	*Turdus*	6	30.67-40.43	4.32-5.48	2.13-2.76	3.75-4.89
Oriolidae	*Oriolus*	1	39.32	5.06	2.91	4.91
Certhiidae	*Certhia*	1	16.56	2.26	1.18	1.84
Sittidae	*Sitta*	1	22.42	2.79	1.74	2.89
Troglodytidae	*Troglodytes*	1	14.51	2.34	1.07	1.94
Cinclidae	*Cinclus*	1	24.97	3.85	1.71	3.29
Bombycillidae	*Bombycilla*	1	30.94	4.35	2.13	3.88

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm	BC mm	Bd mm
Motacillidae	*Anthus*	5	23.27-28.38	2.99-3.58	1.43-1.92	2.52-2.99
	Motacilla	3	22.01-25.17	2.84-3.28	1.42-1.53	2.51-2.97
Sylviidae	*Acrocephalus*	4	15.42-23.54	2.12-3.04	0.97-1.58	2.03-2.77
	Cettia	0				
	Hippolais	2	14.82-19.32	2.05-2.63	1.07-1.53	1.89-2.99
	Locustella	3	15.15-18.10	2.04-2.48	1.03-1.21	1.89-2.16
	Lusciniola	1	16.19	2.06	1.29	02.05
	Phylloscopus	3	15.76-17.51	2.02-2.79	1.03-1.22	1.97-2.05
	Regulus	1	12.48	1.54	1.05	1.52
	Sylvia	5	16.44-21.83	2.17-4.01	1.14-1.53	2.04-2.75
Prunellidae	*Prunella*	2	23.35-26.99	2.96-3.83	1.35-2.19	2.56-3.42
Laniidae	*Lanius*	3	24.35-34.71	3.23-4.69	1.55-2.44	2.99-4.07
Sturnidae	*Sturnus – Pastor*	2	34.38-35.31	4.59-4.93	2.41-2.45	4.36-4.58
Passeridae	*Passer*	2	19.20-21.71	2.96-3.21	1.49-1.51	2.62-2.75
Fringillidae	*Carduelis*	5	16.27-21.09	2.38-3.14	1.19-1.56	2.29-3.78
	Chloris	1	22.65	3.76	1.62	3.78
	Coccothraustes	1	28.11	4.01	2.06	3.75
	Fringilla	2	22.73-24.29	3.17-3.29	1.58-1.59	2.72-2.99
	Loxia	2	22.06-25.11	3.41-3.77	1.75-1.84	3.01-3.42
	Pinicola	1	30.43	4.31	2.57	3.78
	Pyrrhula	1	25.11	3.12	1.89	2.94
	Serinus	1	22.14	3.24	1.49	2.71
Emberizidae	*Emberiza*	5	22.37-29.22	2.85-4.51	1.49-2.19	2.64-3.76
	Plectrophenax	1	23.26	3.29	1.75	3.05

Table 5 Size table of *ulna* (No. sp = number of species; TL = total lenght; Bp – breadth of the proximal end; Bc = breadth of the corpus; Bd = breadth of the distal end)

5. táblázat Singcsont mérési táblázata (No. sp = fajszám; TL = teljes hossz; Bp = a proximális vég szélessége; Bc = a diafízis szélessége; Bd = a disztális vég szélessége)

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm
Alaudidae	*Alauda*	1	17.21	3.91
	Calandrella	1	14.61	3.54
	Eremophila	1	17.05	4.24
	Galerida	1	18.56	4.08
	Lullula	1	16.39	3.73
	Melanocorypha	0		
Hirundinidae	*Delichon*	1	14.99	3.91
	Hirundo	1	15.09	3.68
	Riparia	1	14.01	3.99
Paridae	*Aegithalos*	1	8.42	2.17
	Panurus	1	9.05	2.81
	Parus	5	9.12-10.29	2.37-2.99
	Remiz	0		
Muscicapidae	*Erithacus*	1	9.79	2.78
	Luscinia	2	11.94-13.48	2.98-3.18
	Monticola	1	19.15	4.29
	Muscicapa – Ficedula	3	10.09-11.84	2.41-2.95
	Oenanthe	2	13.63-14.29	2.55-3.14
	Phoenicurus	2	12.69-13.21	2.97-3.09
	Saxicola	3	10.47-14.51	2.56-3.62
Turdidae	*Turdus*	6	18.51-25.03	4.51-5.93
Oriolidae	*Oriolus*	1	23.37	5.51
Certhiidae	*Certhia*	1	8.81	2.15
Sittidae	*Sitta*	1	13.51	2.57
Troglodytidae	*Troglodytes*	1	8.95	2.43
Cinclidae	*Cinclus*	1	10.33	3.85
Bombycillidae	*Bombycilla*	1	18.79	4.14

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm
Motacillidae	*Anthus*	5	12.12-15.34	2.94-3.65
	Motacilla	3	12.52-13.77	2.71-3.03
Sylviidae	*Acrocephalus*	4	9.49-13.53	2.82-3.21
	Cettia	0		
	Hippolais	2	9.48-11.64	2.53-2.58
	Locustella	3	9.27-11.93	2.19-2.69
	Lusciniola	0		
	Phylloscopus	3	9.51-10.52	1.95-2.39
	Regulus	1	7.61	2.62
	Sylvia	5	10.05-13.18	2.38-3.33
Prunellidae	*Prunella*	2	11.62-15.73	3.03-3.73
Laniidae	*Lanius*	3	13.77-18.45	3.19-4.49
Sturnidae	*Sturnus – Pastor*	2	21.19-21.63	5.07-5.16
Passeridae	*Passer*	1	11.29	2.46
Fringillidae	*Carduelis*	5	11.77-12.11	3.15-3.55
	Chloris	1	13.83	3.41
	Coccothraustes	1	15.93	5.11
	Fringilla	1	14.25	3.44
	Loxia	2	13.35-14.08	3.41-4.08
	Pinicola	1	17.32	4.35
	Pyrrhula	1	14.21	3.09
	Serinus	1	12.21	3.34
Emberizidae	*Emberiza*	4	12.19-16.36	3.25-4.24
	Plectrophenax	1	14.12	3.49

Table 6 Size table of *carpometacarpus* (No. sp = number of species; TL = total lenght; Bp – breadth of the proximal end);
6. táblázat Kézközépcsont mérési táblázata (No. sp = fajszám; TL = teljes hossz; Bp = a proximális vég szélessége)

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm	Bc mm
Alaudidae	*Alauda*	1	8.97	2.18	2.61
	Calandrella	1	7.96	2.49	3.04
	Eremophila	1	9.54	2.72	3.33
	Galerida	1	8.94	2.33	3.28
	Lullula	1	7.97	2.15	2.52
	Melanocorypha	0			
Hirundinidae	*Delichon*	1	10.17	2.27	2.61
	Hirundo	1	10.41	2.85	3.68
	Riparia	1	9.64	2.28	2.83
Paridae	*Aegithalos*	1	6.41	1.57	2.58
	Panurus	0			
	Parus	1	6.24	1.81	3.21
	Remiz	0			
Muscicapidae	*Erithacus*	1	5.71	1.42	1.78
	Luscinia	3	5.56-6.68	1.72-1.87	2.05-2.31
	Monticola	1	9.09	2.71	3.44
	Muscicapa – Ficedula	3	5.52-7.21	1.42-1.57	1.71-1.98
	Oenanthe	1	7.51	2.05	2.48
	Phoenicurus	1	6.49	1.96	2.15
	Saxicola	3	6.32-8.33	1.79-1.93	2.11-2.36
Turdidae	*Turdus*	6	8.73-13.16	2.51-4.24	2.48-4.84
Oriolidae	*Oriolus*	1	11.44	3.21	3.11
Certhiidae	*Certhia*	1	4.21	1.19	1.48
Sittidae	*Sitta*	1	6.12	1.65	1.85
Troglodytidae	*Troglodytes*	1	4.91	1.02	1.24
Cinclidae	*Cinclus*	1	6.27	1.88	2.81
Bombycillidae	*Bombycilla*	1	9.86	2.52	3.08

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm	Bc mm
Motacillidae	*Anthus*	5	5.73-7.64	1.67-1.93	2.05-2.35
	Motacilla	3	6.61-7.13	1.71-1.82	1.98-2.11
Sylviidae	*Acrocephalus*	1	6.85	2.18	2.15
	Cettia	1	6.64	1.89	2.38
	Hippolais	2	5.48-6.43	1.28-1.36	1.38-1.56
	Locustella	3	5.47-5.99	1.21-1.27	1.35-1.47
	Lusciniola	1	5.69	1.28	1.79
	Phylloscopus	3	4.41-5.14	1.16-1.24	1.31-1.45
	Regulus	1	3.85	0.98	1.27
	Sylvia	4	5.41-6.65	1.26-1.37	1.48-1.65
Prunellidae	*Prunella*	1	5.36	1.28	1.94
Laniidae	*Lanius*	3	6.61-10.27	1.95-2.27	2.51-2.78
Sturnidae	*Sturnus – Pastor*	2	10.52-11.49	2.95-3.42	3.17-3.78
Passeridae	*Passer*	1	6.28	1.76	1.98
Fringillidae	*Carduelis*	3	6.19-6.39	1.72-1.87	2.67-2.92
	Chloris	1	7.45	1.78	2.47
	Coccothraustes	1	8.46	2.21	2.64
	Fringilla	1	6.11	1.69	1.96
	Loxia	1	7.57	1.98	2.17
	Pinicola	1	8.27	2.74	3.27
	Pyrrhula	1	7.61	1.97	2.19
	Serinus	1	5.49	1.18	1.77
Emberizidae	*Emberiza*	1	8.22	2.39	2.82
	Plectrophenax	1	7.57	2.03	2.38

Table 7 Size table of *phalanx proximalis digiti majoris* (No. sp = number of species; TL = total lenght; Bp – breadth of the proximal end; Bc = breadth of the corpus)

7. táblázat Kézujjperc mérési táblázata (No. sp = fajszám; TL = teljes hossz; Bp = a proximális vég szélessége; Bc = a diafízis szélessége)

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm	Bc mm	Bd mm
Alaudidae	*Alauda*	1	18.41	3.01	1.49	3.21
	Calandrella	1	15.78	2.78	1.32	2.78
	Eremophila	1	20.13	3.63	1.59	3.58
	Galerida	1	21.08	3.77	1.82	3.92
	Lullula	1	17.81	3.18	1.48	3.29
	Melanocorypha	0				
Hirundinidae	*Delichon*	1	13.33	2.59	1.34	2.95
	Hirundo	1	12.18	2.21	0.91	2.28
	Riparia	1	12.66	2.28	0.95	2.26
Paridae	*Aegithalos*	1	10.54	2.37	0.98	2.29
	Panurus	0				
	Parus	5	11.84-14.85	2.44-2.72	1.07-1.18	2.51-2.89
	Remiz	1	11.56	2.75	1.81	2.25
Muscicapidae	*Erithacus*	1	15.05	2.55	1.81	2.72
	Luscinia	3	18.46-19.46	2.76-3.43	1.17.1.55	2.96-3.29
	Monticola	1	23.33	4.39	1.92	4.07
	Muscicapa	0				
	Oenanthe	2	15.57-17.03	2.99-3.04	1.34-1.43	2.86-3.21
	Phoenicurus	2	15.25-15.34	2.51-2.71	1.17-1.27	2.61-2.81
	Saxicola	2	14.61-15.65	2.51-2.62	1.13-1.21	2.59-2.63
Turdidae	*Turdus*	6	25.54-30.12	4.19-5.61	2.03-2.35	4.39-5.41
Oriolidae	*Oriolus*	1	25.43	4.96	2.31	4.71
Certhiidae	*Certhia*	1	11.01	2.26	0.77	2.05
Sittidae	*Sitta*	1	16.75	3.12	1.27	3.21
Troglodytidae	*Troglodytes*	1	13.36	2.31	6.01	2.44
Cinclidae	*Cinclus*	1	20.39	4.31	1.95	4.34
Bombycillidae	*Bombycilla*	1	24.03	4.67	1.64	3.96

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm	Bc mm	Bd mm
Motacillidae	*Anthus*	3	16.58-18.35	2.76-3.42	1.24-1.49	2.62-3.25
	Motacilla	3	14.23-16.36	2.85-3.07	1.15-1.34	2.39-2.91
Sylviidae	*Acrocephalus*	4	15.35-22.38	2.57-3.19	1.07-1.59	2.66-3.67
	Cettia	1	16.53	2.99	1.32	3.06
	Hippolais	2	14.99-15.88	2.77-2.98	1.15-1.17	2.59-2.64
	Locustella	3	15.78-19.78	2.73-3.02	1.19-1.41	2.71-3.02
	Lusciniola	1	16.71	2.57	1.22	2.88
	Phylloscopus	3	12.03-13.32	1.88-2.23	0.88-0.97	2.01-2.09
	Regulus	1	9.89	1.86	0.95	2.18
	Sylvia	4	14.44-18.98	2.72-3.49	1.11-1.45	2.38-3.33
Prunellidae	*Prunella*	2	17.67-21.65	3.21-4.04	1.64-1.87	3.18-4.13
Laniidae	*Lanius*	3	18.67-26.01	3.58-4.94	1.49-1.98	3.39-4.71
Sturnidae	*Sturnus – Pastor*	2	28.94-29.62	4.64-4.97	2.01-2.29	4.52-4.84
Passeridae	*Passer*	2	16.38-18.41	2.93-3.36	1.34-1.51	2.96-3.21
Fringillidae	*Carduelis*	5	12.68-14.95.	2.19-2.57	1.09-1.24	2.41-2.54
	Chloris	1	17.37	3.28	1.41	2.84
	Coccothraustes	1	21.37	4.16	1.94	3.85
	Fringilla	2	15.65-16.71	2.68-3.05	1.21-1.49	2.75-2.78
	Loxia	2	16.67-19.28	3.42-3.91	1.49-1.76	3.43-3.61
	Pinicola	1	18.42	3.03	1.73	2.98
	Pyrrhula	1	18.36	3.08	1.51	3.11
	Serinus	1	16.11	2.93	1.42	3.01
Emberizidae	*Emberiza*	5	16.35-23.82	2.65-4.01	1.35-1.79	2.72-3.99
	Plectrophenax	1	18.58	3.19	1.39	3.15

Table 8 Size table of *femur* (No.sp = number of species; TL = total lenght; Bp – breadth of the proximal end; Bc = breadth of the corpus; Bd = breadth of the distal end)

8. táblázat Combcsont mérési táblázata (No. sp = fajszám; TL = teljes hossz; Bp = a proximális vég szélessége; Bc = a diafízis szélessége; Bd = a disztális vég szélessége)

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bc mm	Bd mm
Alaudidae	*Alauda*	1	30.21	1.03	2.09
	Calandrella	1	31.21	1.66	2.44
	Eremophila	1	33.36	1.76	2.94
	Galerida	1	34.01	1.61	3.17
	Lullula	1	29.14	1.27	2.64
	Melanocorypha	1	39.53	1.92	3.71
Hirundinidae	*Delichon*	1	21.12	1.01	2.08
	Hirundo	1	20.34	0.81	1.85
	Riparia	1	19.93	0.83	1.95
Paridae	*Aegithalos*	1	22.24	0.84	1.92
	Panurus	0			
	Parus	5	23.44-26.16	1.03-1.09	2.05-2.25
	Remiz	1	21.43	0.93	1.97
Muscicapidae	*Erithacus*	1	30.39	1.06	2.13
	Luscinia	3	34.88-36.69	1.13-1.44	2.33-2.78
	Monticola	1	40.64	1.91	3.55
	Muscicapa – Ficedula	3	21.81-23.91	0.85-0.92	1.44-1.99
	Oenanthe	2	28.76-32.89	1.25-1.34	2.36-2.71
	Phoenicurus	2	29.42-30.19	0.97-1.04	2.21-2.24
	Saxicola	3	29.39-33.38	1.12-1.24	2.22-2.49
Turdidae	*Turdus*	6	44.45-51.66	1.71-2.41	3.36-4.61
Oriolidae	*Oriolus*	1	35.91	1.93	4.13
Certhiidae	*Certhia*	1	19.29	0.81	1.87
Sittidae	*Sitta*	1	27.51	1.19	2.71
Troglodytidae	*Troglodytes*	1	24.29	1.01	1.96
Cinclidae	*Cinclus*	1	39.09	1.65	3.39
Bombycillidae	*Bombycilla*	1	38.67	1.63	3.55

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bc mm	Bd mm
Motacillidae	*Anthus*	5	30.11-34.59	1.01-1.39	2.22-3.16
	Motacilla	3	31.09-31.37	1.15-1.38	2.06-2.42
Sylviidae	*Acrocephalus*	4	28.02-40.21	1.27-1.52	2.13-3.21
	Cettia	1	31.12	1.41	2.33
	Hippolais	2	27.93-30.32	0.99-1.11	2.22-2.28
	Locustella	0			
	Lusciniola	1	30.55	1.22	2.34
	Phylloscopus	3	24.94-26.23	0.82-0.95	1.77-1.94
	Regulus	1	21.46	0.78	1.61
	Sylvia	5	26.55-33.51	0.96-1.46	2.11-2.77
Prunellidae	*Prunella*	1	30.26	1.42	2.64
Laniidae	*Lanius*	3	31.95-40.91	1.41-1.91	2.65-3.69
Sturnidae	*Sturnus – Pastor*	2	47.14-49.85	1.93-1.98	3.89-4.95
Passeridae	*Passer*	2	26.85-28.81	1.16-1.36	2.45-2.66
Fringillidae	*Carduelis*	5	21.13-25.07	0.93-1.13	1.99-2.29
	Chloris	0			
	Coccothraustes	1	35.61	1.67	3.46
	Fringilla	2	27.92-30.39	1.09-1.15	2.38-2.45
	Loxia	2	26.11-29.38	1.49-1.53	2.79-3.17
	Pinicola	1	37.94	1.65	3.61
	Pyrrhula	1	30.58	1.65	2.63
	Serinus	1	27.71	1.18	2.57
Emberizidae	*Emberiza*	5	27.75-37.47	1.15-1.69	1.88-3.41
	Plectrophenax	1	30.27	1.22	2.67

Table 9 Size table of *tibiotarsus* (No. sp = number of species; TL = total lenght; Bc = breadth of the corpus; Bd = breadth of the distal end)
9. táblázat Lábszárcsont mérési táblázata (No. sp = fajszám; TL = teljes hossz; Bc = a diafízis szélessége; Bd = a disztális vég szélessége)

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm	Bc mm	Bd mm
Alaudidae	*Alauda*	1	22.53	3.67	1.26	2.76
	Calandrella	1	20.41	2.75	1.29	2.21
	Eremophila	1	23.55	3.91	1.09	2.77
	Galerida	1	25.19	3.62	1.29	2.79
	Lullula	1	21.41	2.85	1.24	2.52
	Melanocorypha	1	28.29	4.94	1.43	3.53
Hirundinidae	*Delichon*	1	11.61	2.41	1.05	1.93
	Hirundo	1	10.48	2.36	1.33	1.71
	Riparia	1	11.06	2.25	0.95	1.95
Paridae	*Aegithalos*	1	17.22	2.01	0.84	1.75
	Panurus	0				
	Parus	5	16.45-18.91	2.22-2.47	0.81-0.98	1.54-1.83
	Remiz	1	14.55	2.19	0.98	1.87
Muscicapidae	*Erithacus*	1	24.33	2.35	0.86	1.98
	Luscinia	3	25.97-27.77	2.77-3.29	0.95-1.07	1.79-2.29
	Monticola	1	28.73	3.96	1.32	3.04
	Muscicapa	3	17.06-17.79	2.23-2.71	0.82-0.84	1.54-1.77
	Oenanthe	2	22.51-26.06	2.96-3.47	0.97-1.24	1.75-2.33
	Phoenicurus	2	22.45-22.83	2.35-2.38	0.79-0.91	1.82-1.93
	Saxicola	3	21.29-26.09	2.39-2.87	0.81-1.01	1.76-2.03
Turdidae	*Turdus*	6	31.81-34.43	3.82-4.86	1.44-1.76	2.98-4.22
Oriolidae	*Oriolus*	1	26.86	3.14	1.51	2.96
Certhiidae	*Certhia*	1	15.76	2.23	0.82	2.28
Sittidae	*Sitta*	1	19.26	2.65	1.15	2.75
Troglodytidae	*Troglodytes*	0				
Cinclidae	*Cinclus*	0				
Bombycillidae	*Bombycilla*	1	21.34	3.71	1.24	3.25

Family – Család	Genus – Nemzetség	No.sp	TL mm	Bp mm	Bc mm	Bd mm
Motacillidae	*Anthus*	5	20.44-26.31	2.41-3.14	1.04-1.09	2.12-2.49
	Motacilla	3	20.07-23.39	2.41-3.11	1.01-1.09	1.97-2.21
Sylviidae	*Acrocephalus*	3	20.01-28.77	2.38-3.23	0.97-1.48	1.86-2.88
	Cettia	1	22.59	2.93	0.96	1.77
	Hippolais	2	21.17-22.96	2.46-2.52	0.91-0.94	1.71-1.75
	Locustella	3	21.11-22.04	2.28-2.64	0.84-0.98	1.66-2.26
	Lusciniola	1	21.67	2.58	1.12	1.79
	Phylloscopus	3	19.77-20.81	2.09-2.17	0.64-0.79	1.27-1.42
	Regulus	1	12.17	1.39	0.68	1.38
	Sylvia	5	19.77-25.51	2.21-3.19	0.84-1.17	1.47-2.12
Prunellidae	*Prunella*	1	21.25	3.38	0.94	2.23
Laniidae	*Lanius*	3	21.92-26.79	2.79-3.99	1.41-1.73	2.15-2.79
Sturnidae	*Sturnus – Pastor*	2	29.79-33.23	4.33-4.67	1.49-1.68	3.04-3.46
Passeridae	*Passer*	2	18.68-19.26	2.54-3.33	1.11-1.24	1.79-1.89
	Carduelis	4	14.52-18.79	2.17-2.49	0.81-1.11	1.75-2.59
	Chloris	1	18.21	2.84	1.03	2.22
	Coccothraustes	1	22.33	3.91	1.46	2.71
	Fringilla	2	18.52-19.76	26.51-2.85	0.93-0.98	1.97-1.99
	Loxia	2	16.84-17.04	3.34-3.45	1.22-1.35	2.78-2.81
	Pinicola	1	23.24	4.25	1.42	3.22
	Pyrrhula	1	19.36	2.79	1.05	2.12
	Serinus	1	19.35	2.82	0.98	2.19
Emberizidae	*Emberiza*	3	19.26-26.51	2.69-3.73	0.86-1.37	2.12-3.03
	Plectrophenax	1	20.41	3.03	0.96	2.02

Table 10 Size table of *tarsometatarsus* (No. sp = number of species; TL = total lenght; Bp – breadth of the proximal end; Bc = breadth of the corpus; Bd = breadth of the distal end)

10. táblázat Csüd mérési táblázata (No. sp = fajszám; TL = teljes hossz; Bp = a proximális vég szélessége; Bc = a diafízis szélessége; Bd = a disztális vég szélessége)

Family – Család	Genus – Nemzetség	No.sp	TL mm	PL- Bp mm
Alaudidae	*Alauda*	1	5.35	1.62
	Calandrella	0		
	Eremophila	1	5.54	1.73
	Galerida	1	6.51	1.52
	Lullula	0		
	Melanocorypha	0		
Hirundinidae	*Delichon*	0		
	Hirundo	1	4.34	1.33
	Riparia	0		
Paridae	*Aegithalos*	1	4.55	1.13
	Panurus	0		
	Parus	0		
	Remiz	1	5.61	1.59
Muscicapidae	*Erithacus*	0		
	Luscinia	1	4.07	1.33
	Monticola	1	5.03	1.47
	Muscicapa	1	3.82	2.04
	Oenanthe	1	4.65	1.33
	Phoenicurus	1	4.23	1.16
	Saxicola	1	6.78	0.78
Turdidae	*Turdus*	6	5.48-8.21	1.32-1.84
Oriolidae	*Oriolus*	1	6.32	1.68
Certhiidae	*Certhia*	1	5.31	1.14
Sittidae	*Sitta*	1	7.15	1.89
Troglodytidae	*Troglodytes*	1	4.29	0.83
Cinclidae	*Cinclus*	1	5.65	1.92
Bombycillidae	*Bombycilla*	1	6.02	1.58

Family – Család	Genus – Nemzetség	No.sp	TL mm	PL- Bp mm
Motacillidae	*Anthus*	1	5.34	1.37
	Motacilla	3	3.14-6.32	1.21-1.45
Sylviidae	*Acrocephalus*	1	6.48	1.51
	Cettia	0		
	Hippolais	1	6.32	1.79
	Locustella	0		
	Lusciniola	0		
	Phylloscopus	0	4.01	5.08
	Regulus	1	5.13	1.43
	Sylvia	0		
Prunellidae	*Prunella*	1	6.95	2.68
Laniidae	*Lanius*	1	6.01	2.11
Sturnidae	*Sturnus – Pastor*	1	6.42	1.84
Passeridae	*Passer*	1	5.25	1.52
Fringillidae	*Carduelis*	0		
	Chloris	0		
	Coccothraustes	1	6.42	2.25
	Fringilla	1	5.36	1.24
	Loxia	1	6.45	2.03
	Pinicola	1	4.47	1.78
	Pyrrhula	1	4.63	1.24
	Serinus	1	3.83	1.02
Emberizidae	*Emberiza*	1	6.51	1.48
	Plectrophenax	0		

Table 11 Size table of *phalanx ungularis* (No.sp = number of species; TL = total lenght; PL – Bp – partial lenght-breadth of the proximal end)

11. táblázat Karomcsont mérési táblázata (No. sp = fajszám; TL = teljes hossz; PL – Bp = részleges hossz – a proximális vég szélessége)

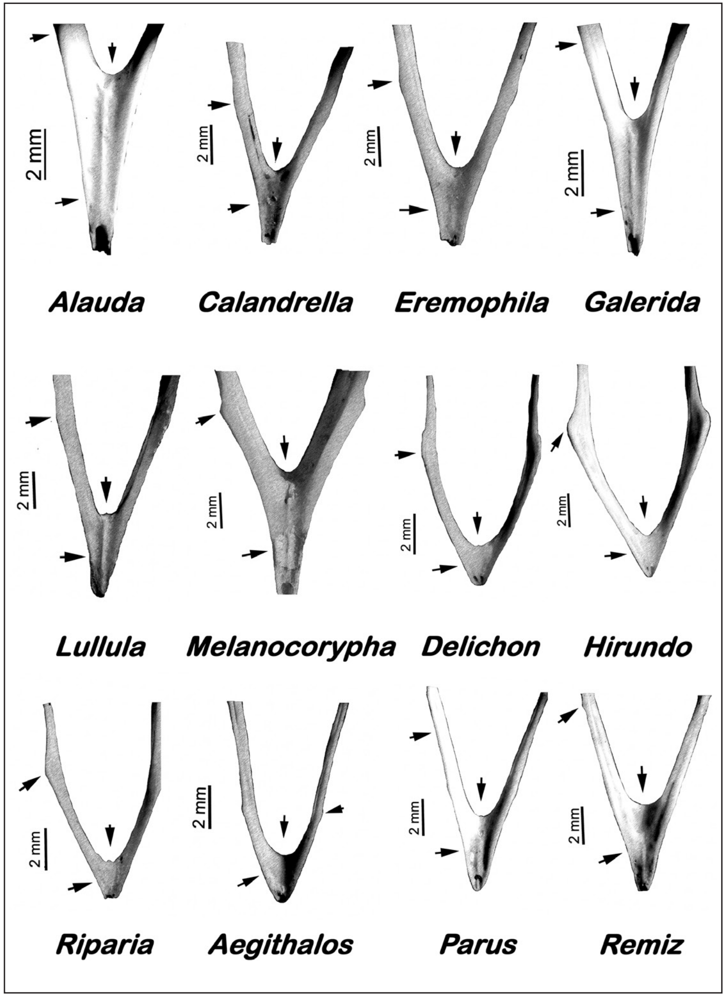


Plate 1 *Mandibula* (Lower jaw)
1. táblakép *Mandibula* (Alsó állkapocs)

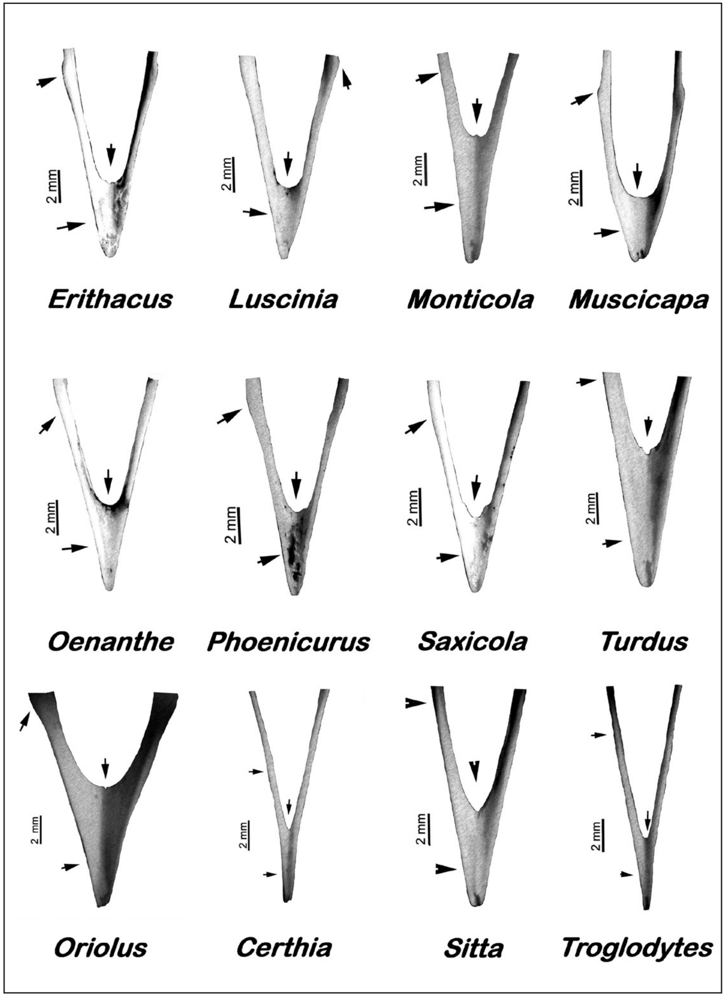


Plate 2 *Mandibula* (Lower jaw)
2. táblakép *Mandibula* (Alsó állkapocs)

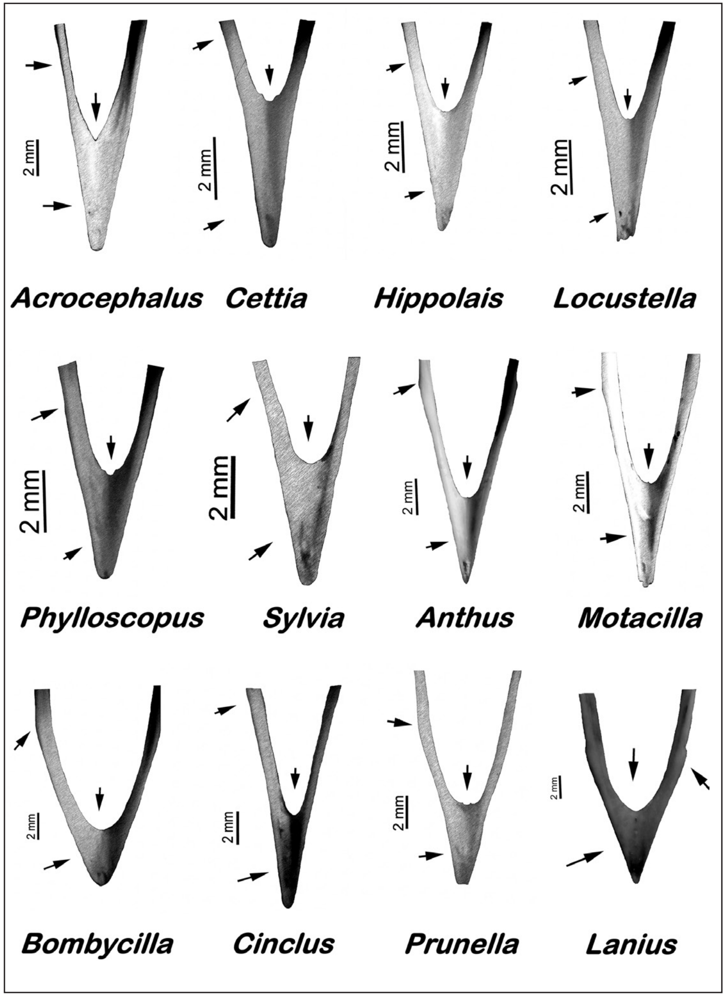


Plate 3 *Mandibula* (Lower jaw)
3. táblakép *Mandibula* (Alsó állkapocs)

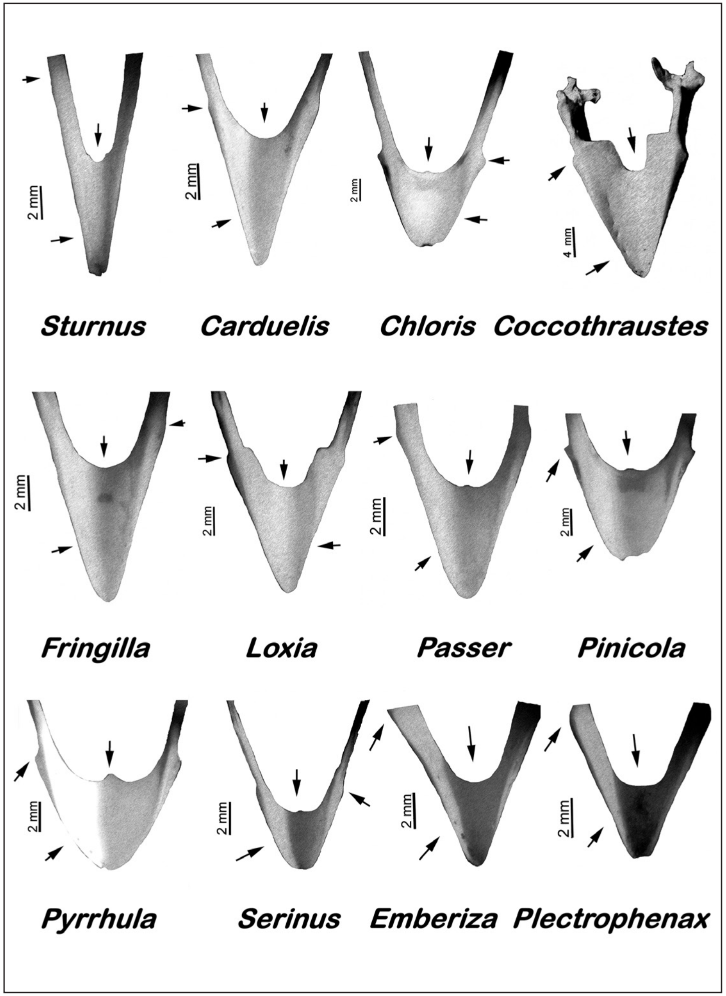


Plate 4 *Mandibula* (Lower jaw)
4. táblakép *Mandibula* (Alsó állkapocs)

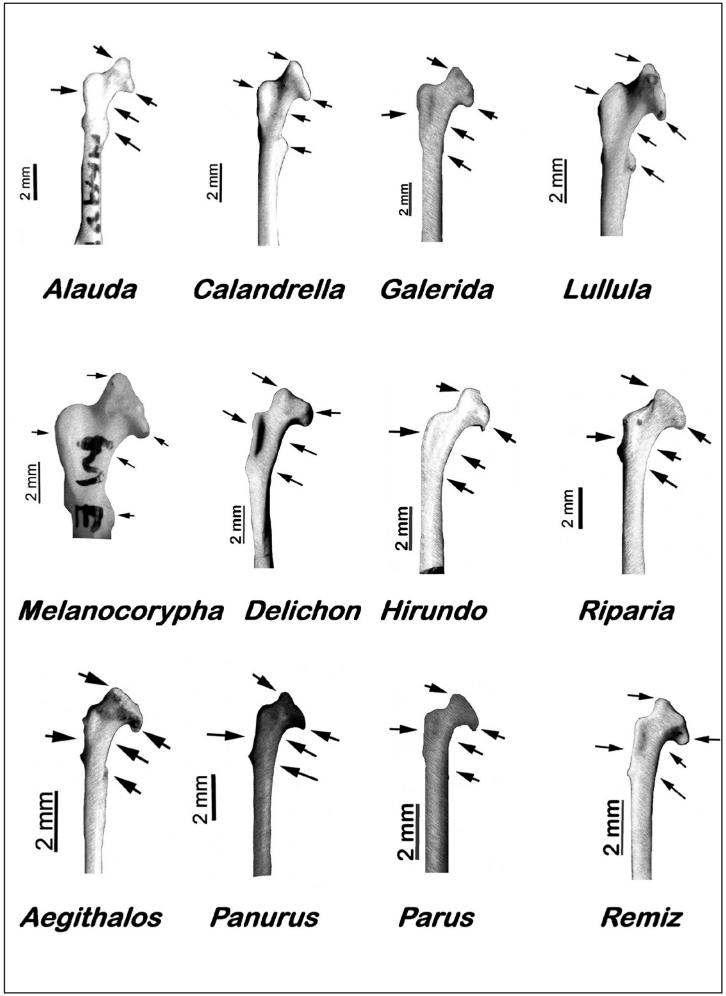


Plate 5 *Coracoideum* (right side)
5. táblakép *Coracoideum* (Hollócsőrcsont – jobb oldali)

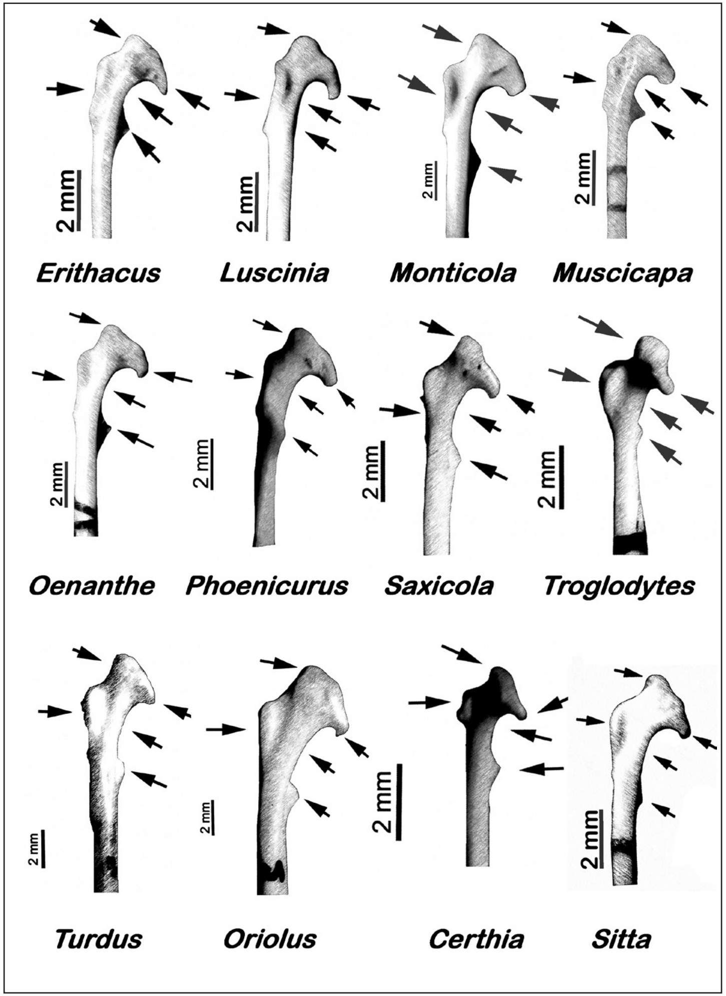


Plate 6 *Coracoideum* (right side)
7. táblakép *Coracoideum* (Hollócsőrcsont – jobb oldali)

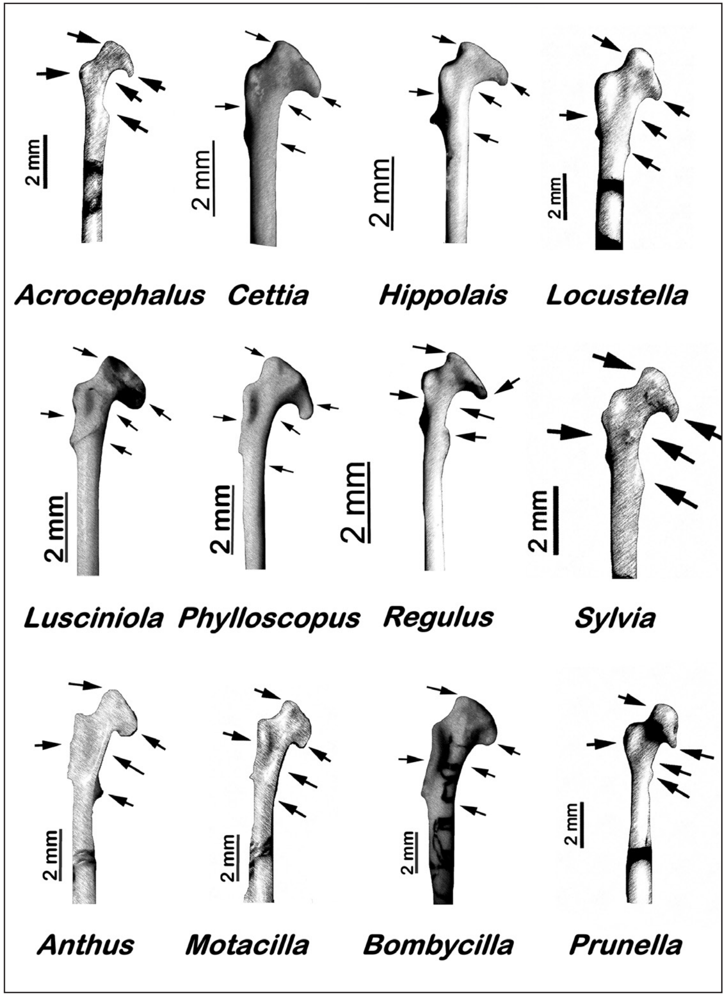


Plate 7 *Coracoideum* (right side)
7. táblakép *Coracoideum* (Hollócsőrcsont – jobb oldali)

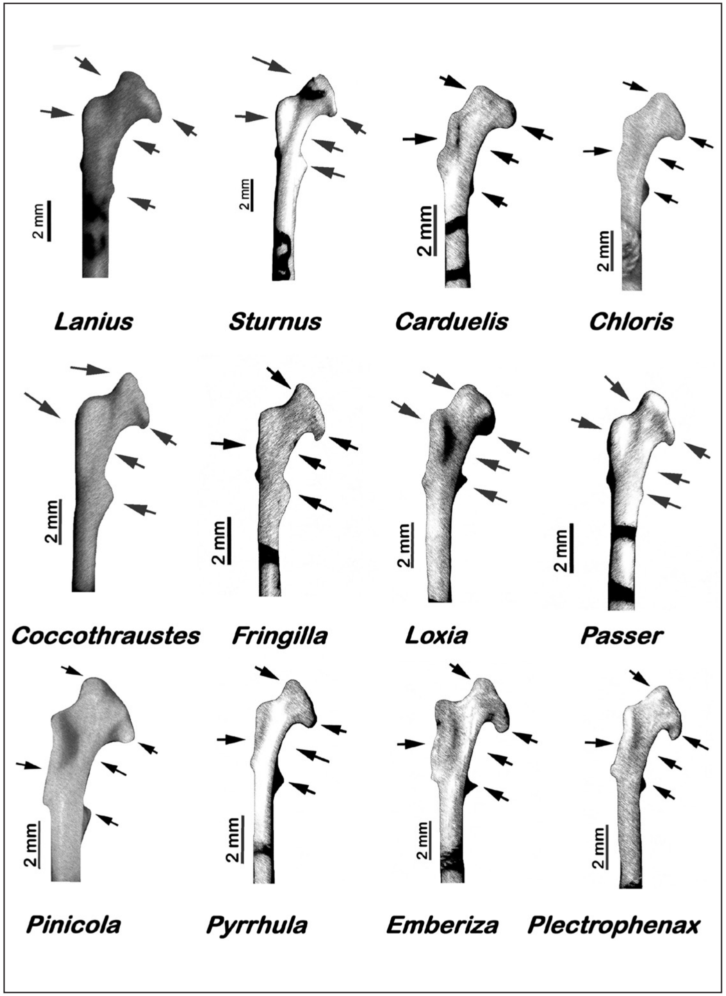


Plate 8 *Coracoideum* (right side)
8. táblakép *Coracoideum* (Hollócsőrcsont – jobb oldali)

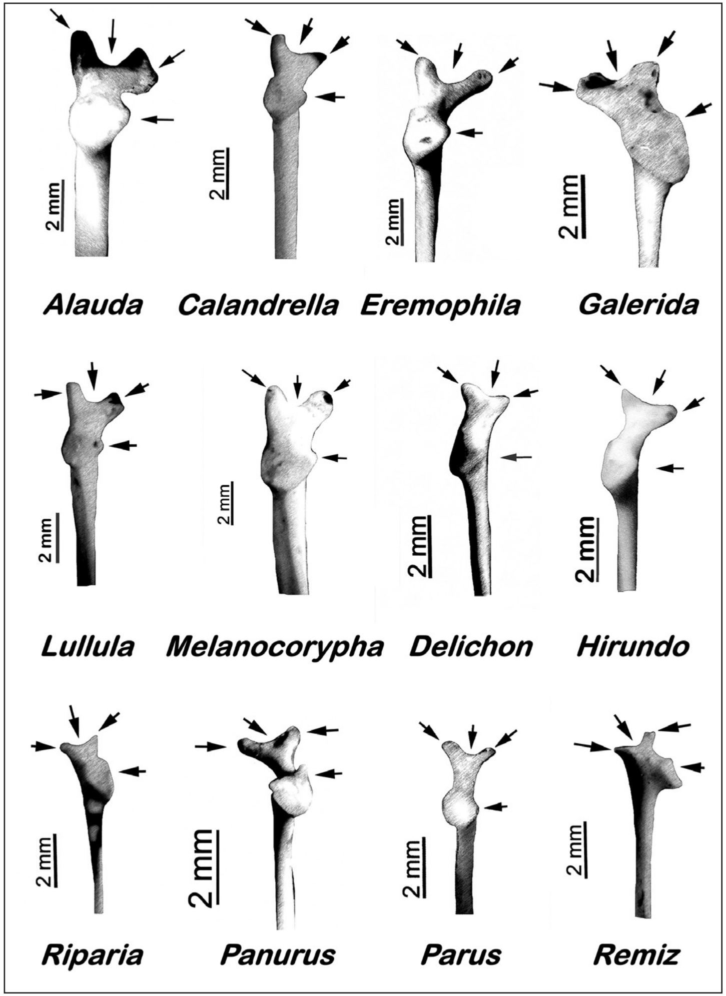


Plate 9 *Scapula* (right side)
9. táblakép *Scapula* (Lapocka – jobb oldali)

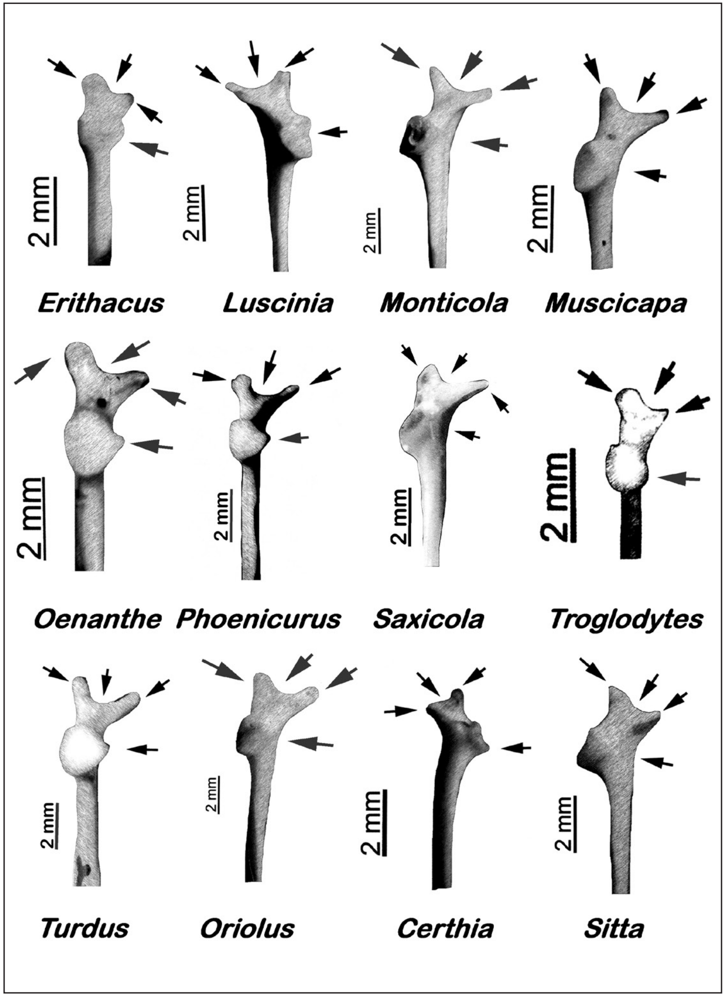


Plate 10 *Scapula* (right side)
10. táblakép *Scapula* (Lapocka – jobb oldali)

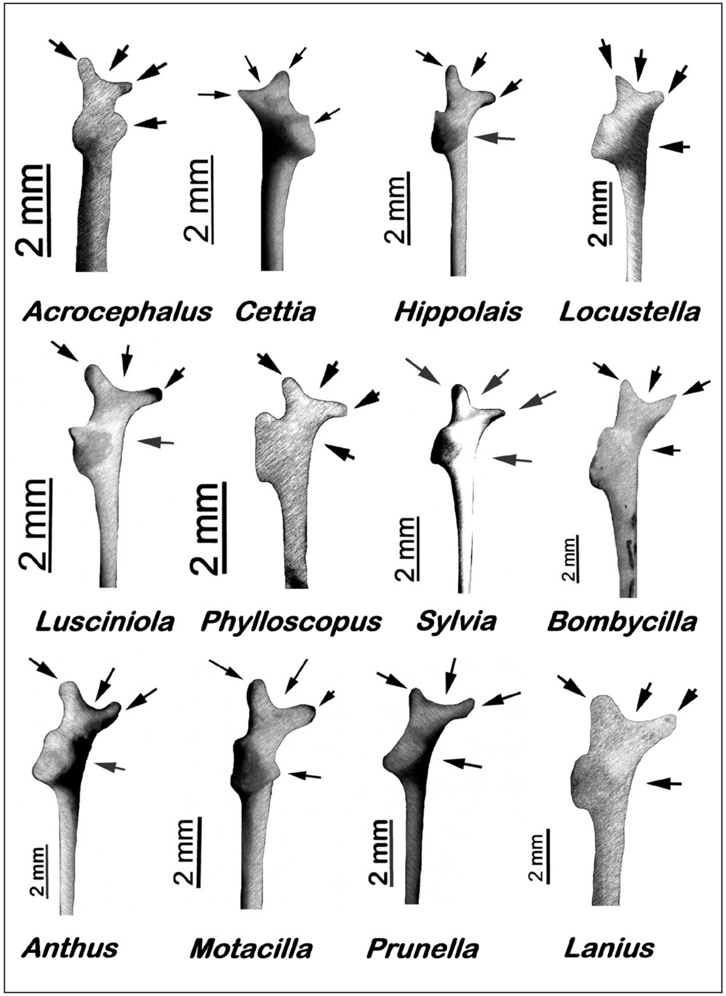


Plate 11 *Scapula* (right side)
11. táblakép *Scapula* (Lapocka – jobb oldali)

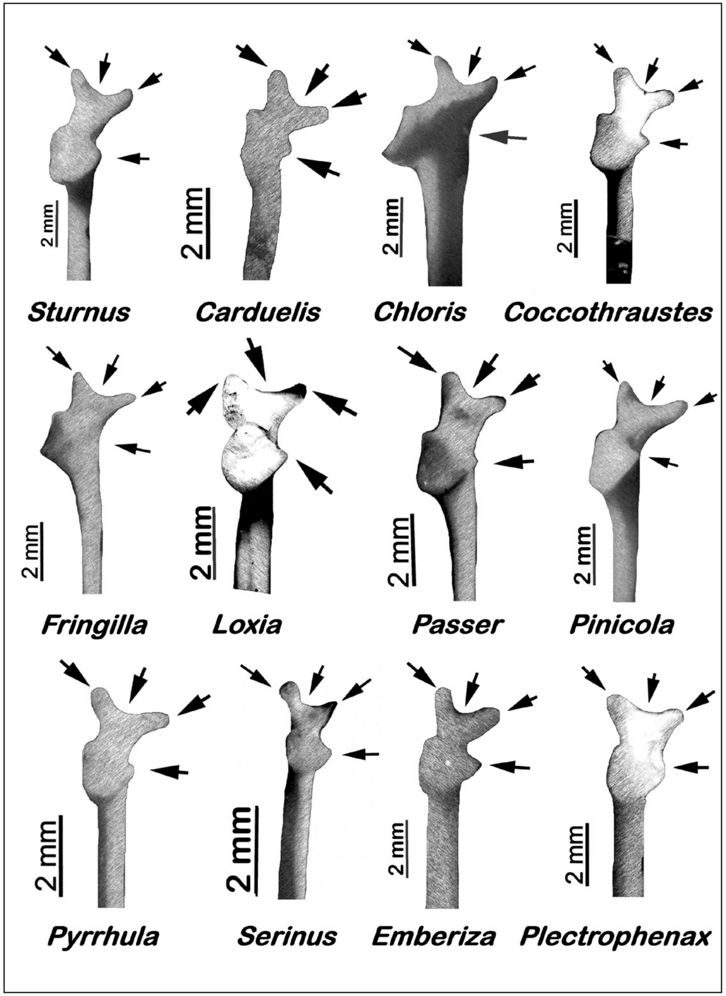


Plate 12 *Scapula* (right side)
12. táblakép *Scapula* (Lapocka – jobb oldali)

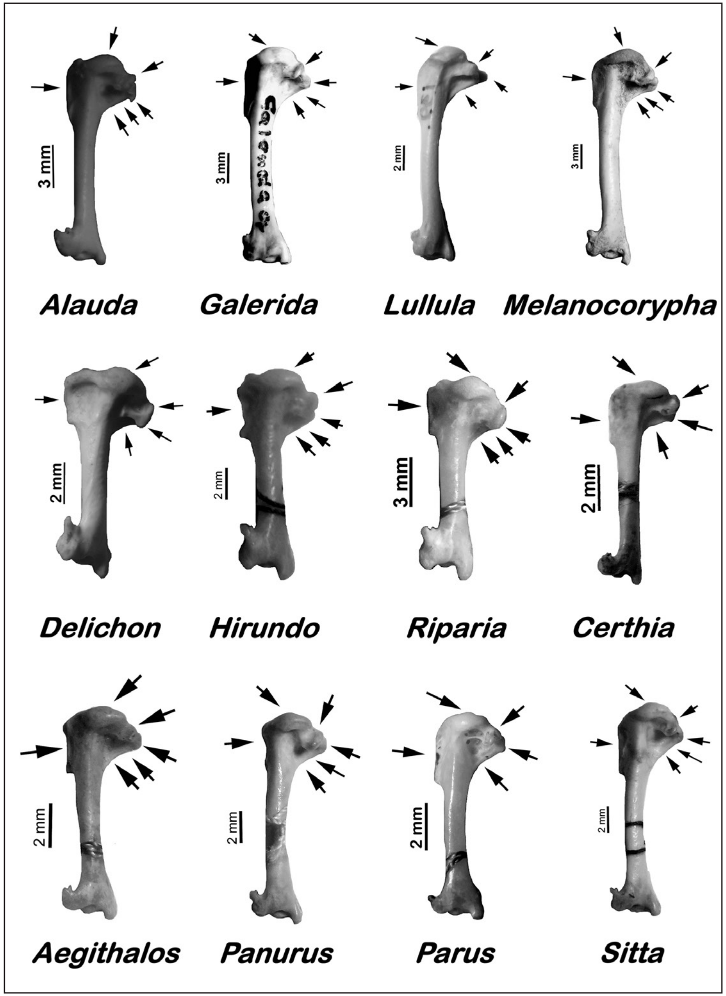


Plate 13 *Humerus* (*epiphysis proximalis* – left side)
13. táblakép *Humerus* (Felkarcsont, proximális epifízis – bal oldali)

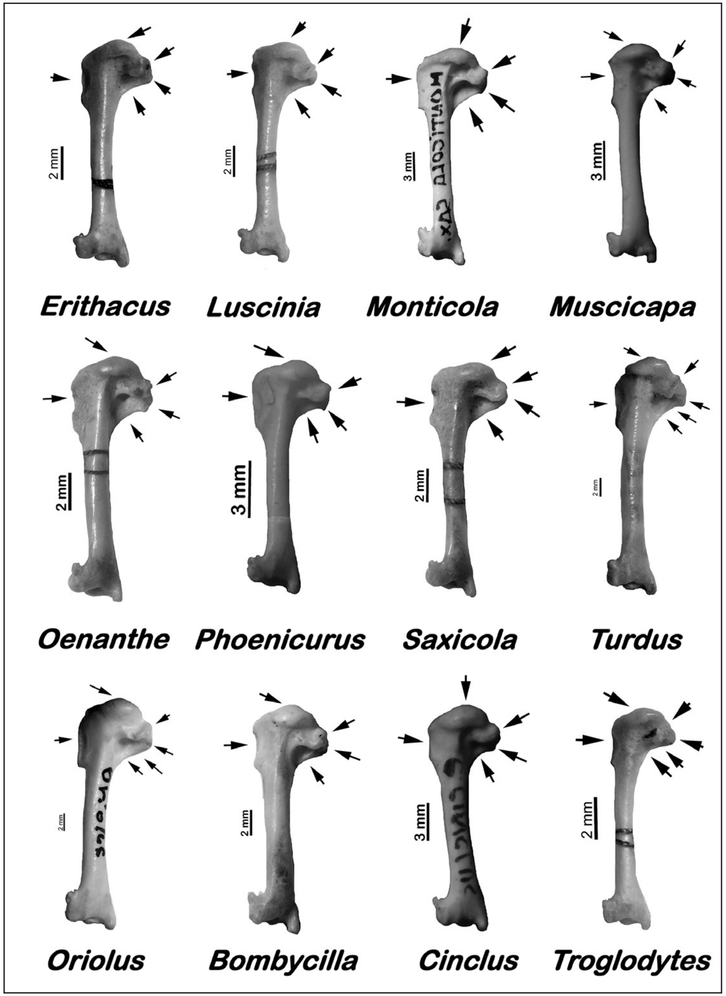


Plate 14 *Humerus* (*epiphysis proximalis* – left side)
14. táblakép *Humerus* (Felkarcsont, proximális epifízis – bal oldali)

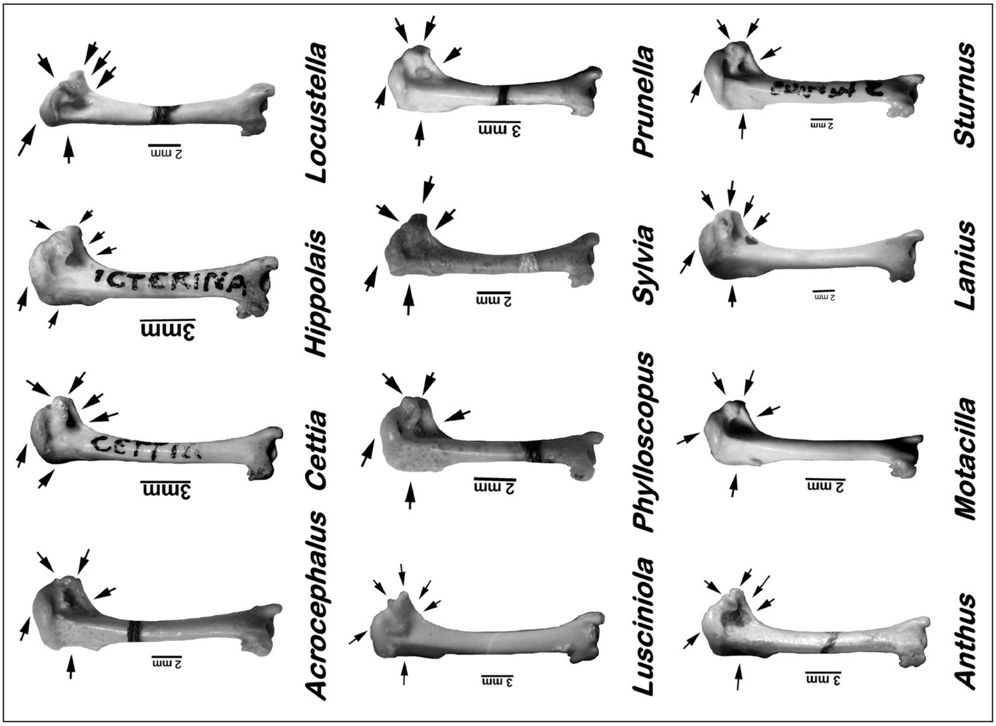


Plate 15 *Humerus* (*epiphysis proximalis* – left side)
15. táblakép *Humerus* (Felkarcsont, proximális epifízis – bal oldali)

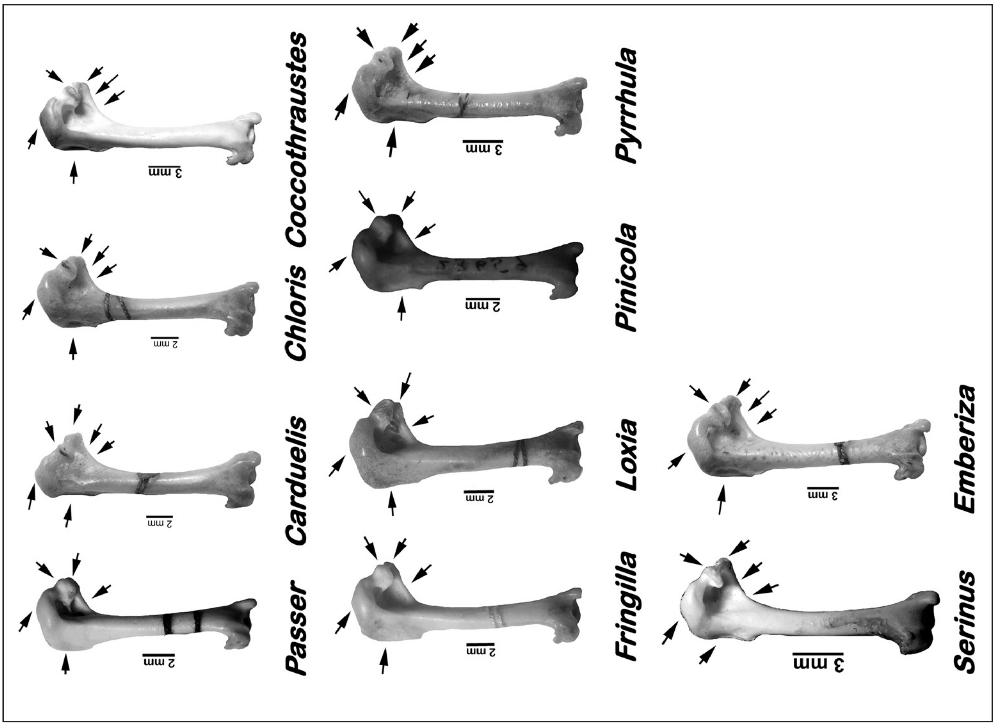


Plate 16 *Humerus* (*epiphysis proximalis* – left side)
16. táblakép *Humerus* (Felkarcsont, proximális epifízis – bal oldali)

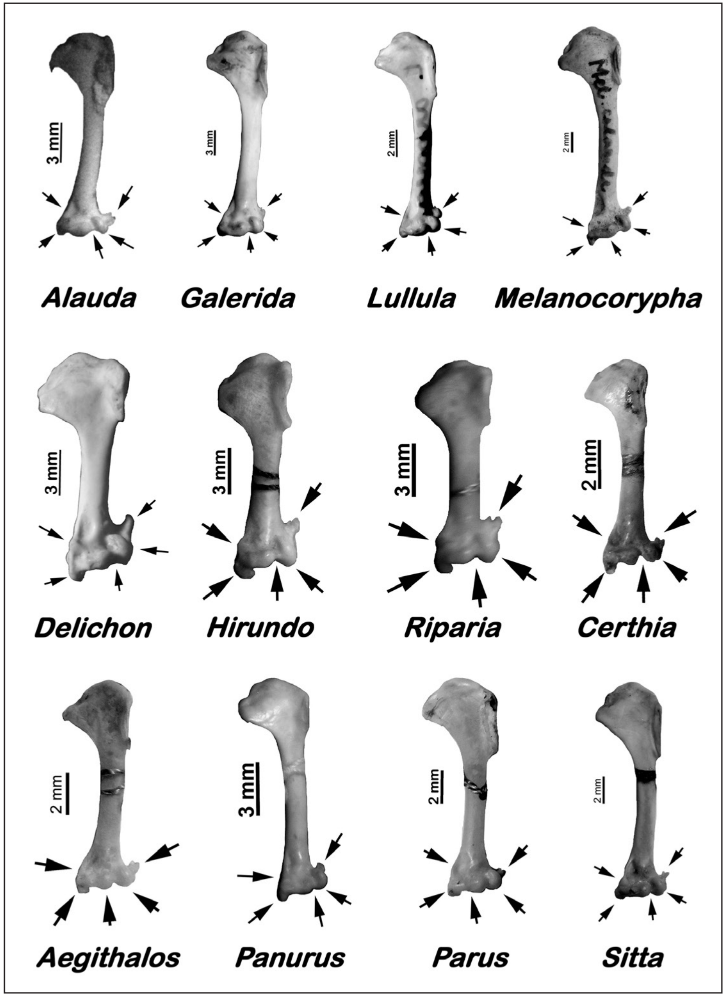


Plate 17 *Humerus* (*epiphysis distalis* – left side)
17. táblakép *Humerus* (Felkarcsont, disztális epifízis – bal oldali)

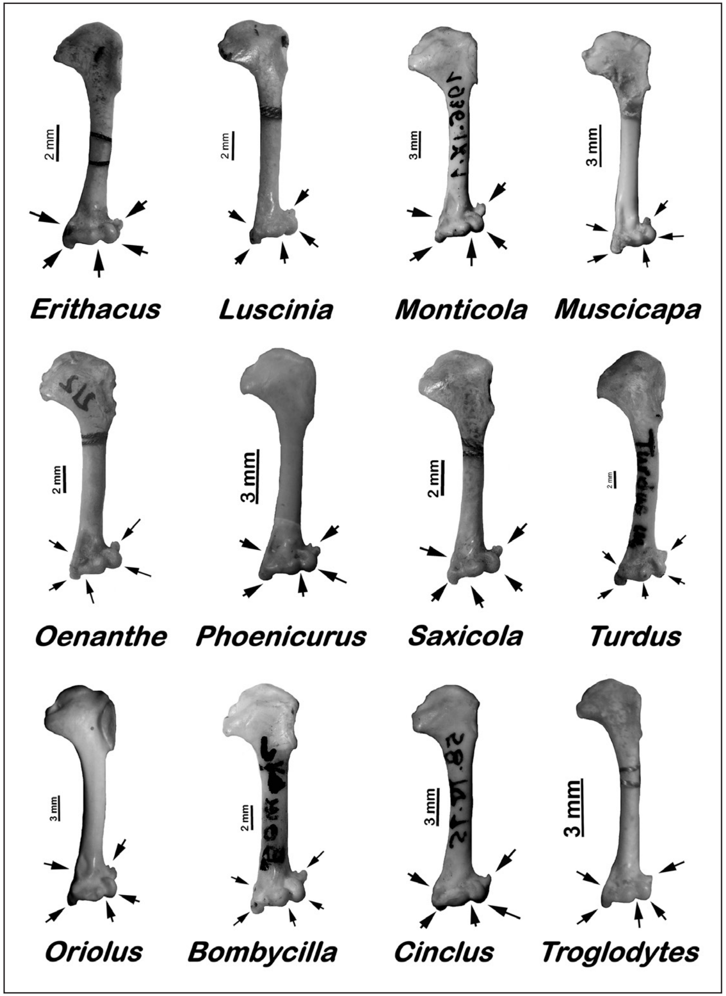


Plate 18 *Humerus* (*epiphysis distalis* – left side)
18. táblakép *Humerus* (Felkarcsont, disztális epifízis – bal oldali)

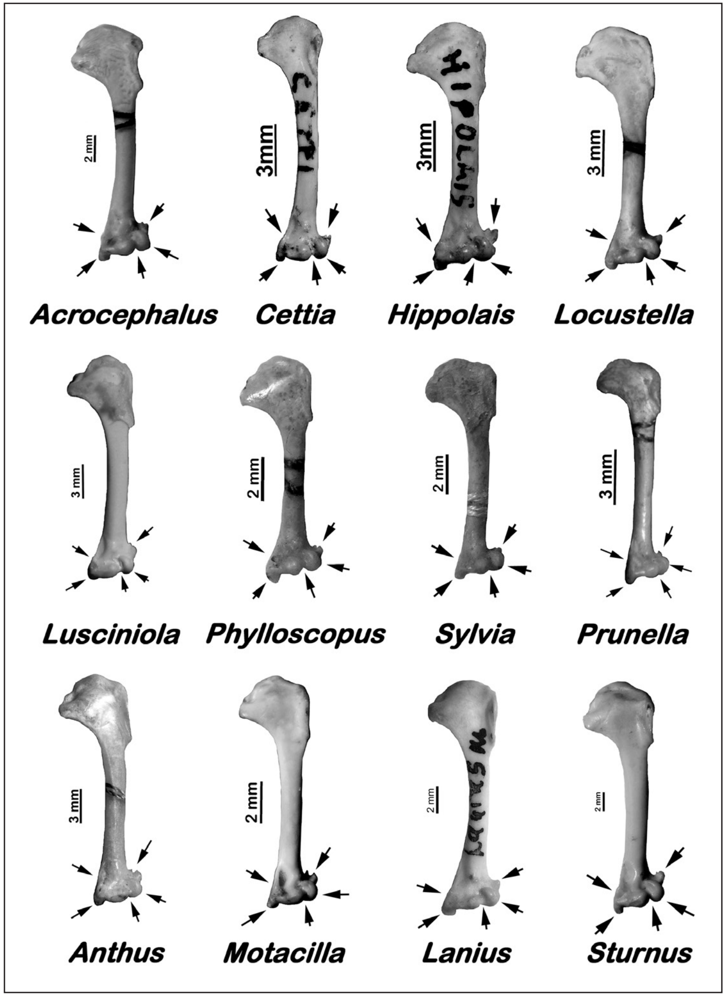


Plate 19 *Humerus* (*epiphysis distalis* – left side)
19. *táblakép* *Humerus* (Felkarcsont, disztális epifízis – bal oldali)

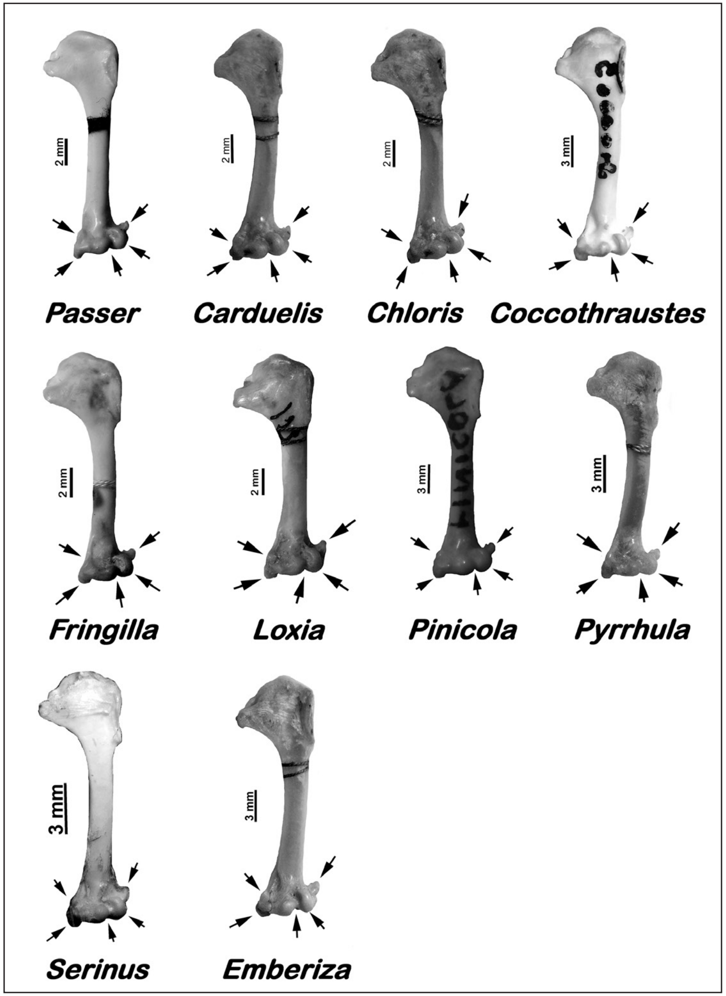


Plate 20 *Humerus* (*epiphysis distalis* – left side)
20. *táblakép* *Humerus* (Felkarcsont, disztális epifízis – bal oldali)

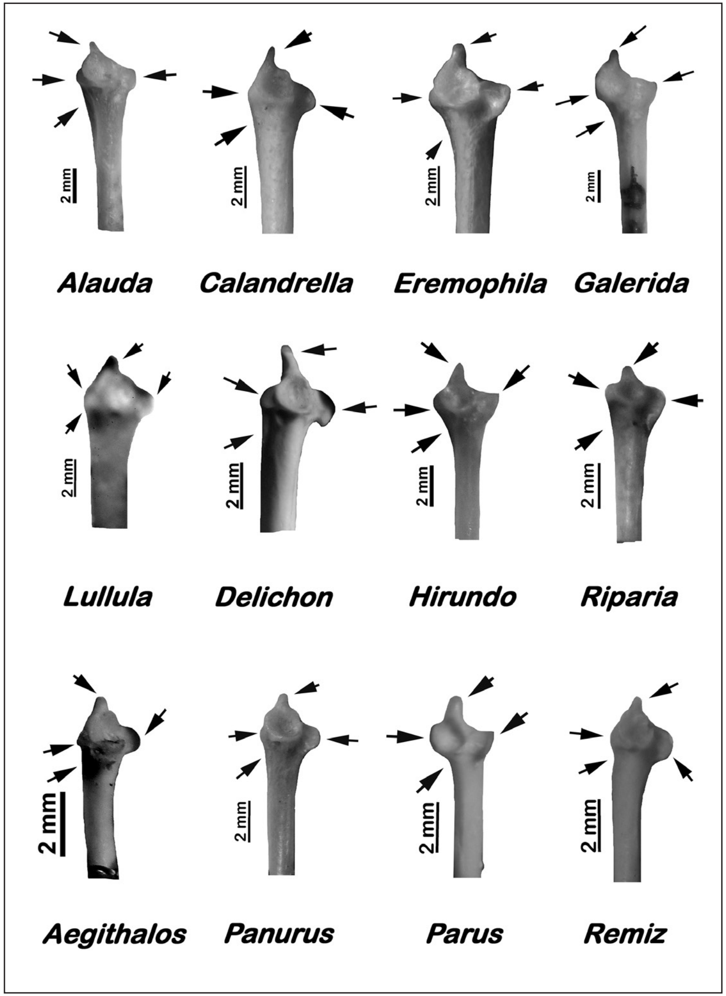


Plate 21 *Ulna* (*epiphysis proximalis* – left side)
21. táblakép *Ulna* (Singcsont, proximális epifízis – bal oldali)

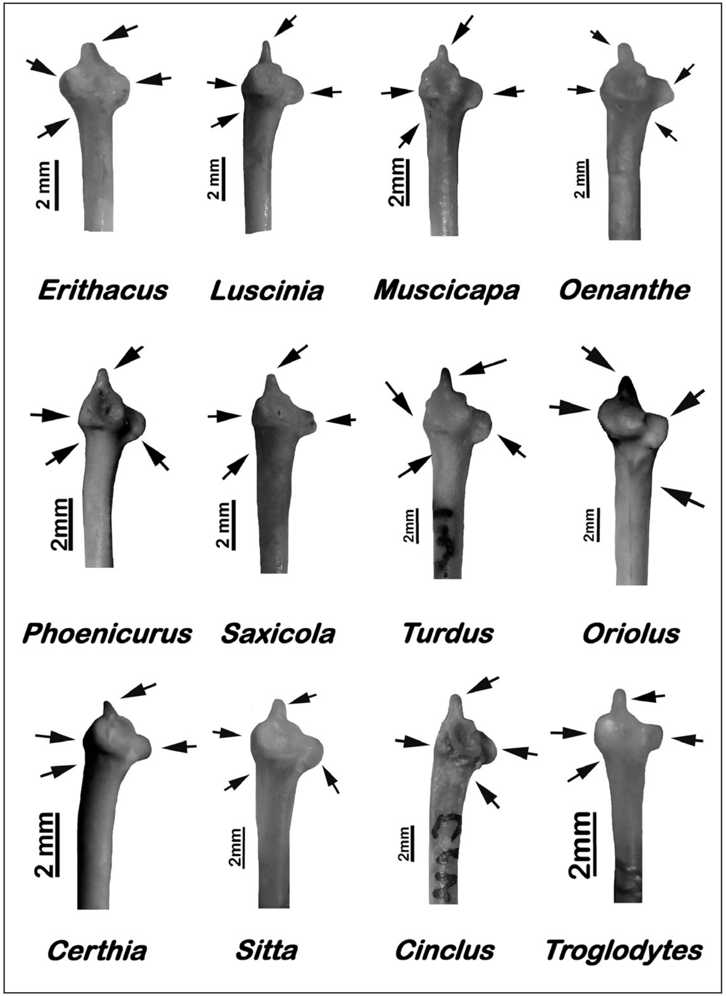


Plate 22 *Ulna* (*epiphysis proximalis* – left side)
22. táblakép *Ulna* (Singcsont, proximális epifízis – bal oldali)

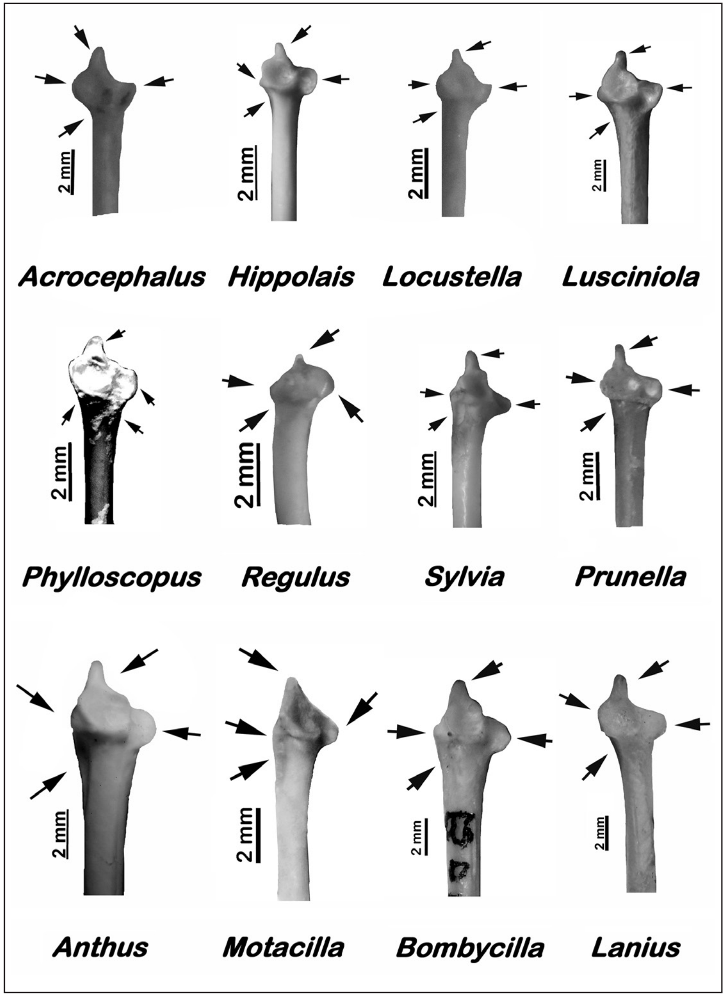


Plate 23 *Ulna* (*epiphysis proximalis* – left side)
23. táblakép *Ulna* (Singcsont, proximális epifízis – bal oldali)

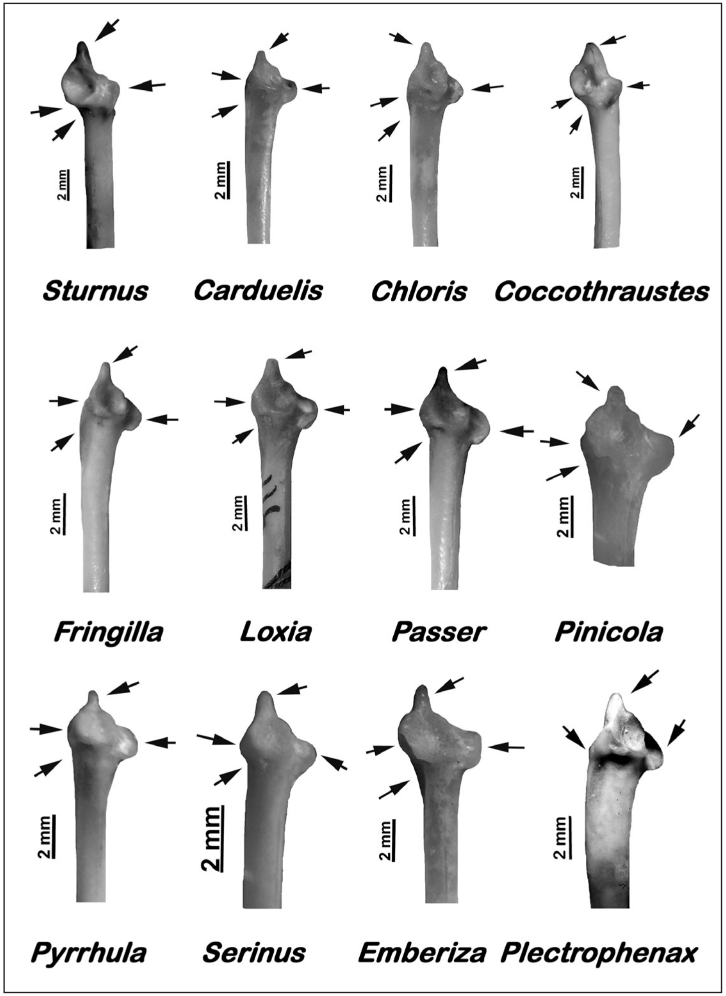


Plate 24 *Ulna* (*epiphysis proximalis* – left side)
24. táblakép *Ulna* (Singcsont, proximális epifízis – bal oldali)

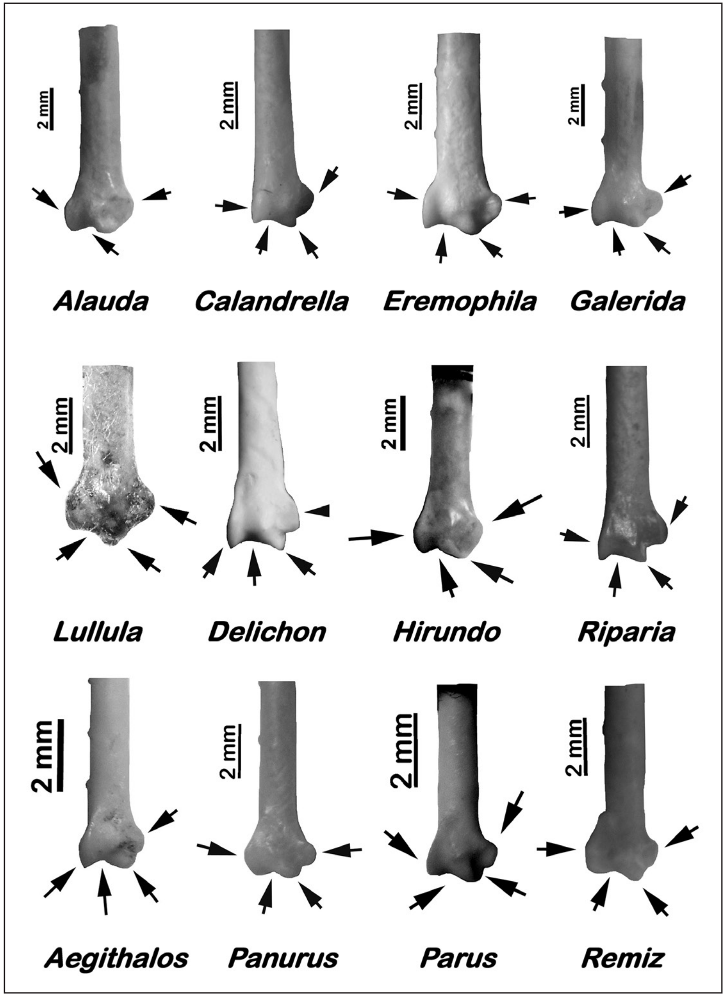


Plate 25 *Ulna* (*epiphysis distalis* – left side)
21. táblakép *Ulna* (Singcsont, disztális epifízis – bal oldali)

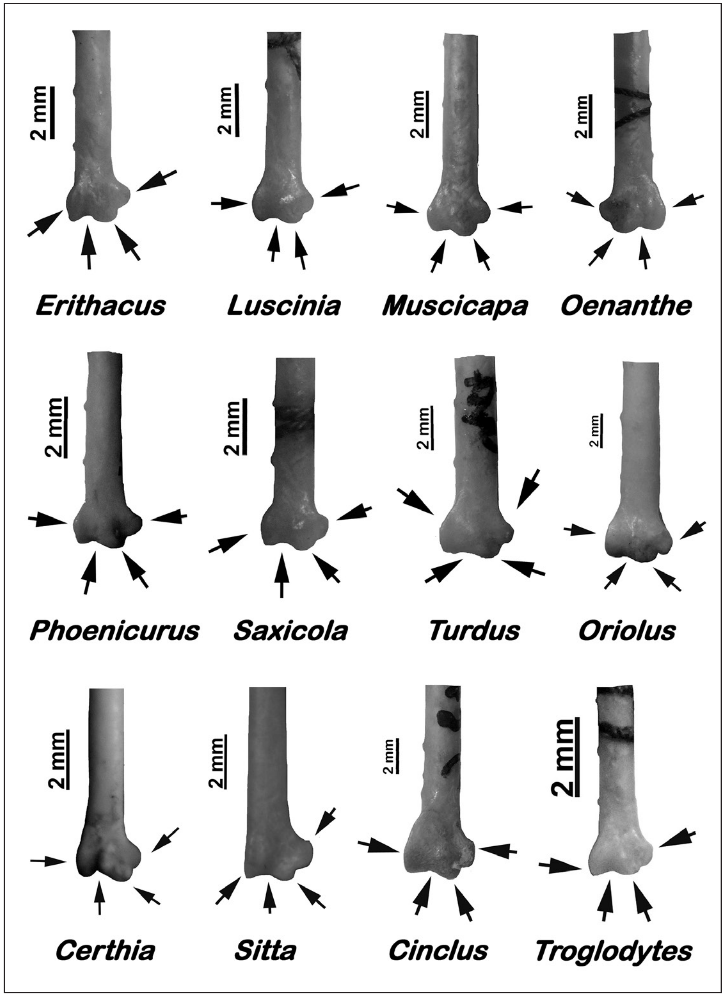


Plate 26 *Ulna* (*epiphysis distalis* – left side)
26. táblakép *Ulna* (Singcsont, disztális epifízis – bal oldali)

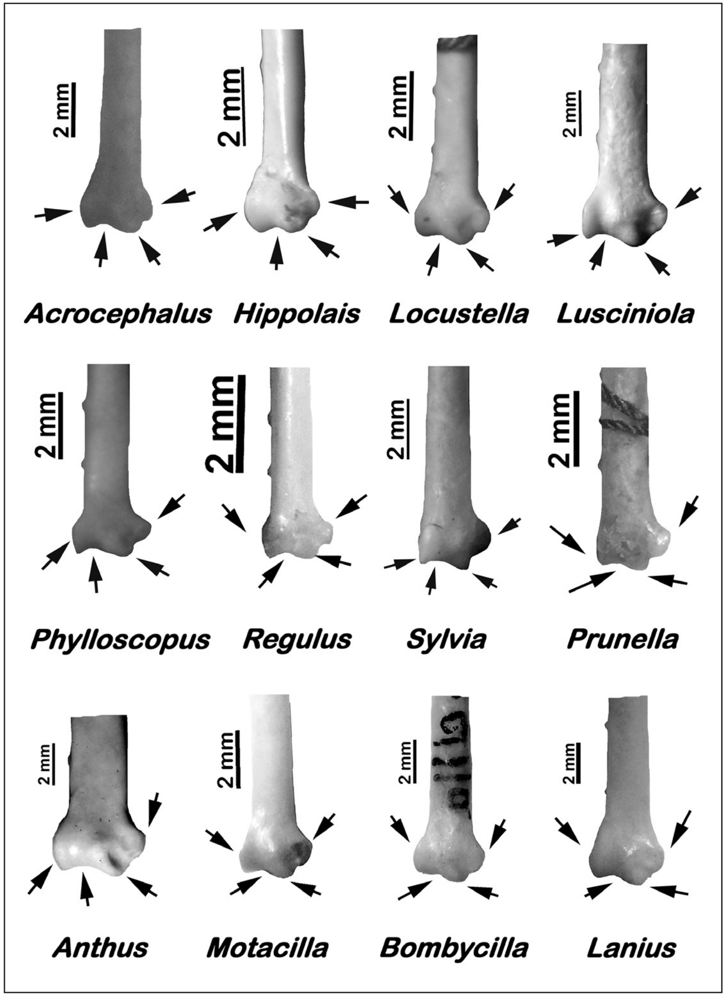


Plate 27 *Ulna* (*epiphysis distalis* – left side)
27. *táblakép* *Ulna* (Singcsont, disztális epifízis – bal oldali)

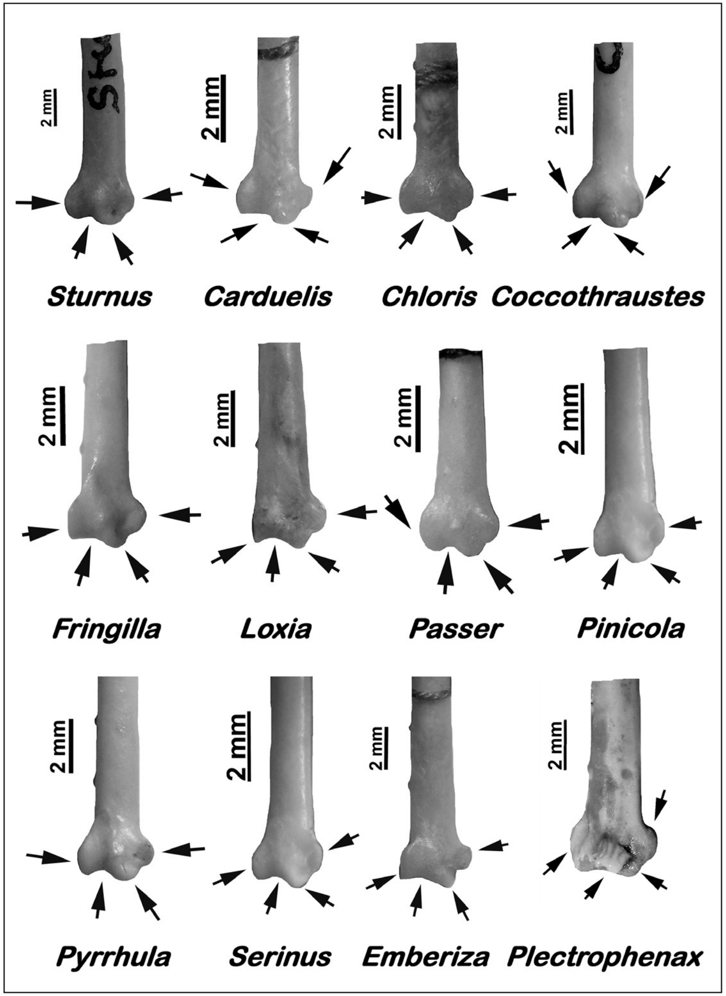


Plate 28 *Ulna* (*epiphysis distalis* –left side)
28. *táblakép* *Ulna* (Singcsont, disztális epifízis – bal oldali)

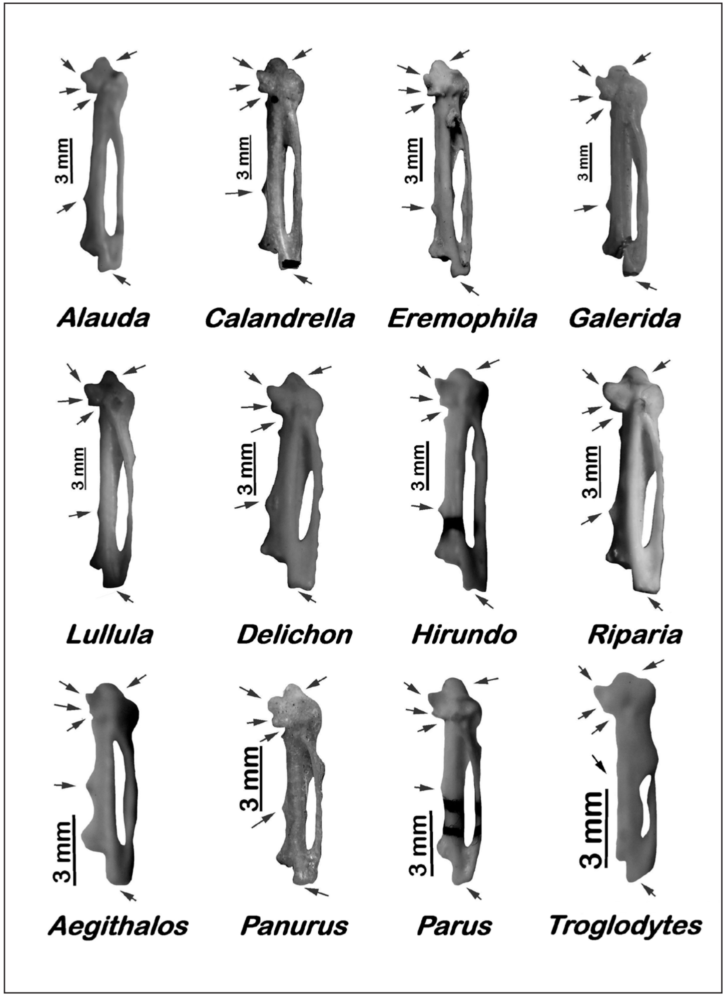


Plate 29 *Carpometacarpus* (right side)
29. *táblakép* *Carpometacarpus* (Kézközépcsont – jobb oldali)

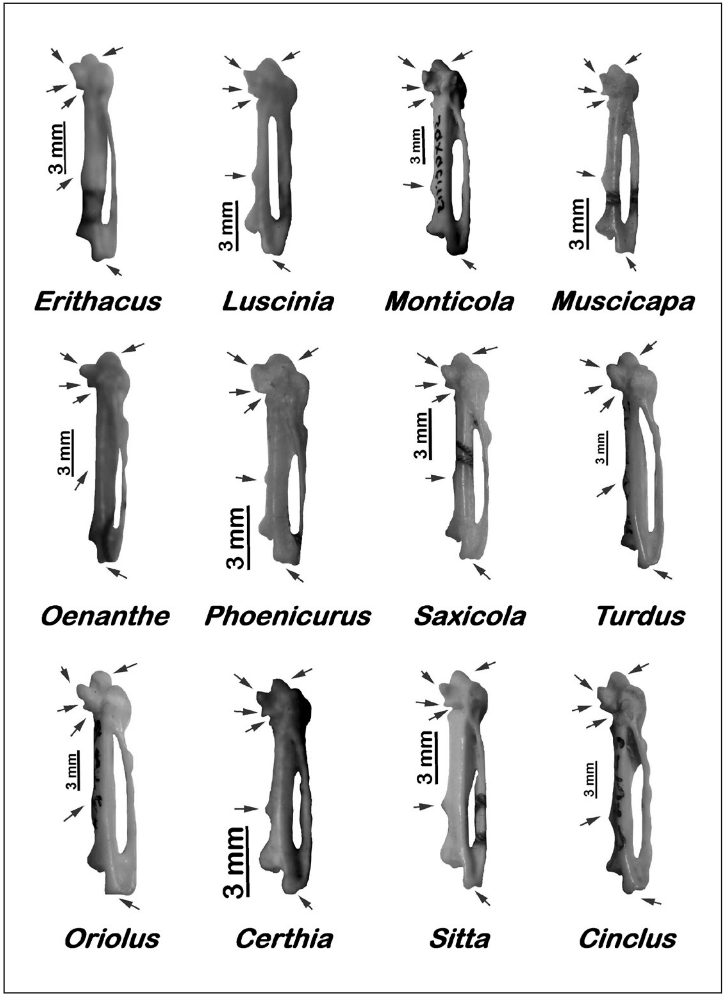


Plate 30 *Carpometacarpus* (right side)
30. *táblakép* *Carpometacarpus* (Kézközépcsont – jobb oldali)

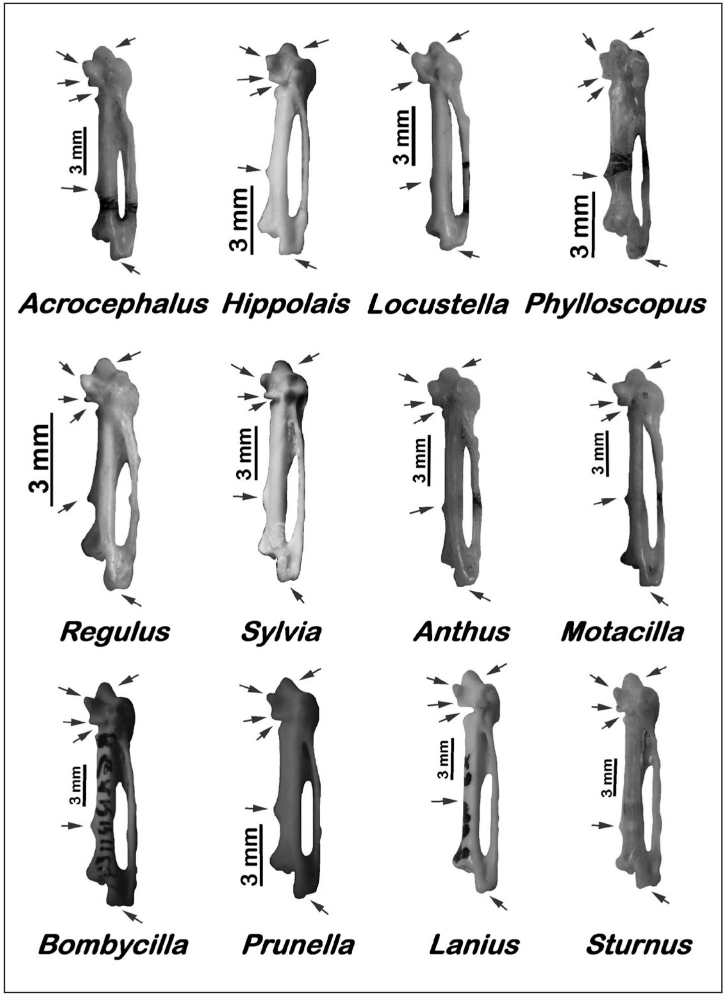


Plate 31 *Carpometacarpus* (right side)
31. táblakép *Carpometacarpus* (Kézközépcsont – jobb oldali)

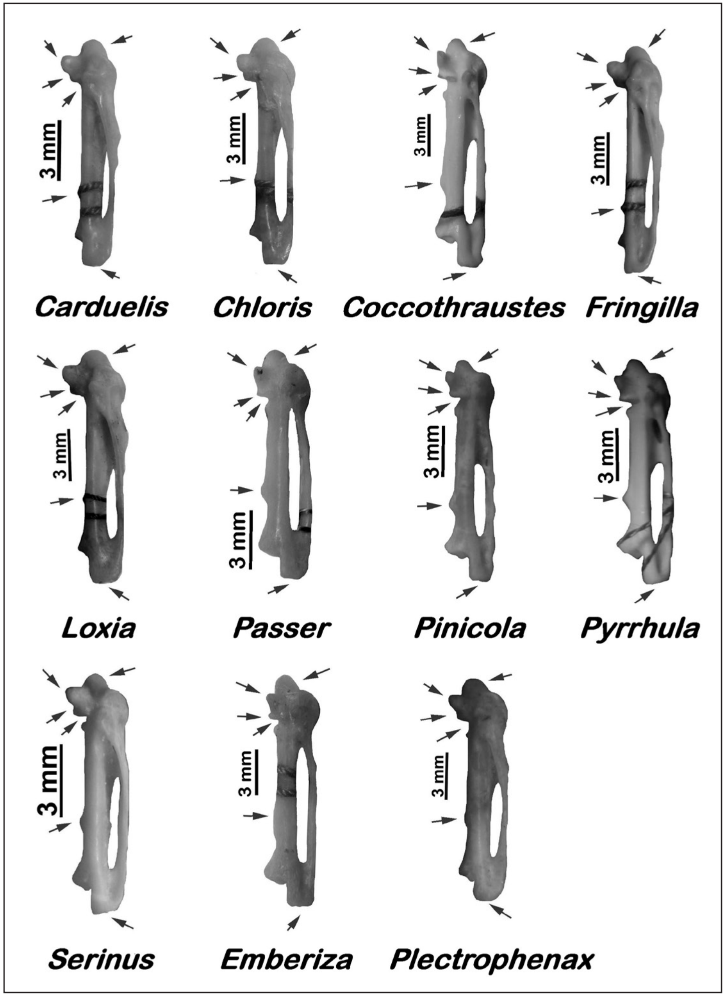


Plate 32 *Carpometacarpus* (right side)
32. táblakép *Carpometacarpus* (Kézközépcsont – jobb oldali)

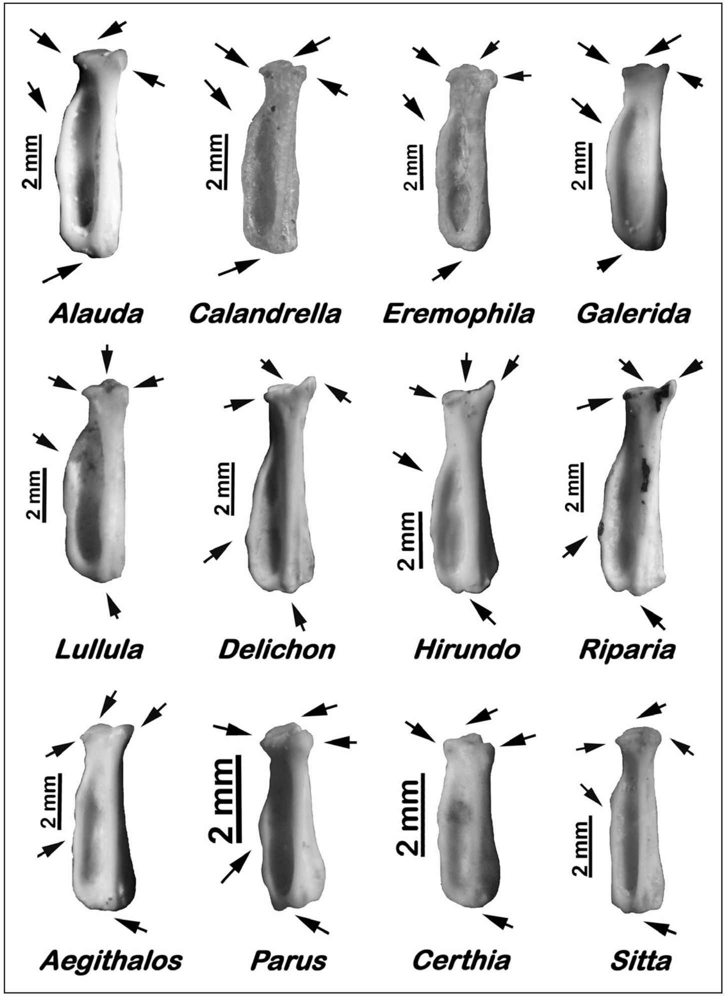


Plate 33 *Phalanx proximalis digiti majoris* (right side)
33. táblakép *Phalanx proximalis digiti majoris* (Kézujjperc – jobb oldali)

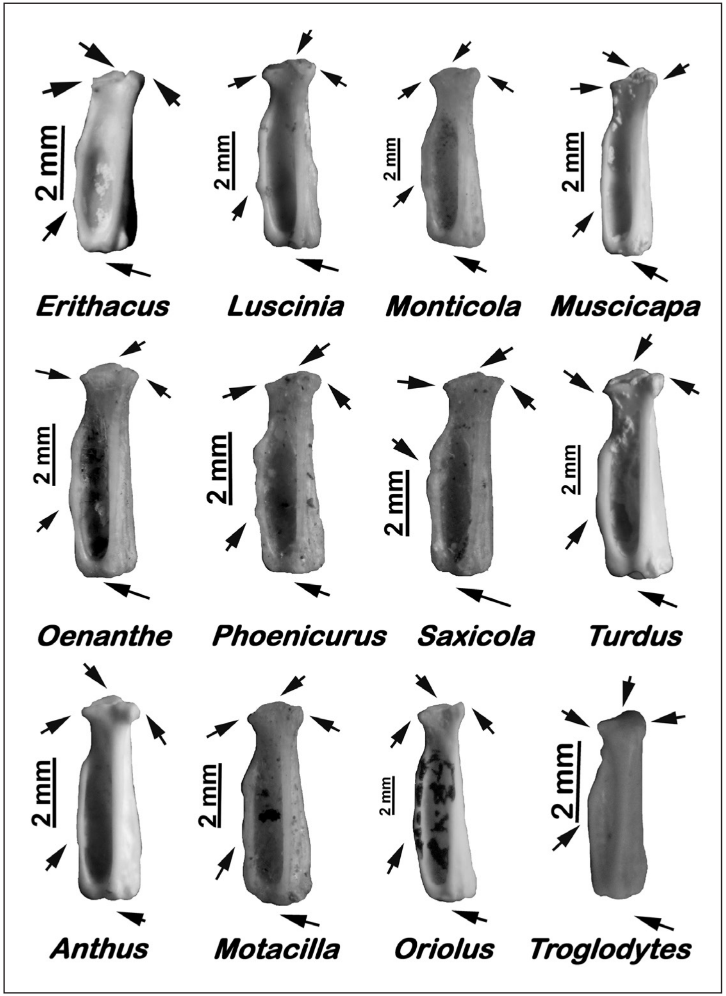


Plate 34 *Phalanx proximalis digiti majoris* (right side)
34. táblakép *Phalanx proximalis digiti majoris* (Kézujjperc – jobb oldali)

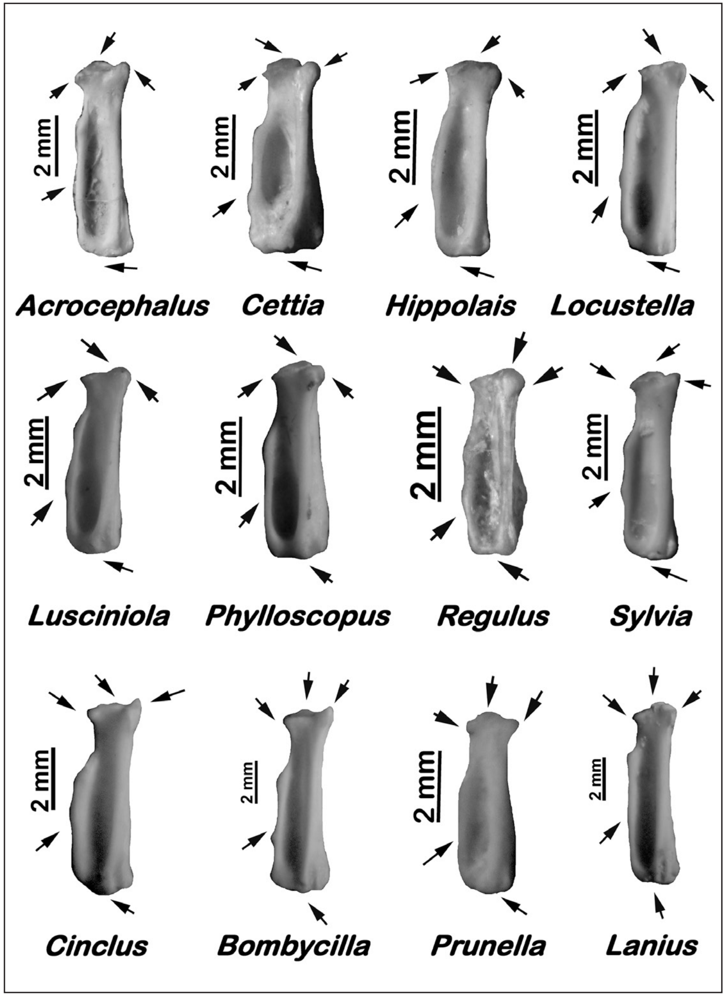


Plate 35 *Phalanx proximalis digiti majoris* (right side)
35. táblakép *Phalanx proximalis digiti majoris* (Kézujjperc – jobb oldali)

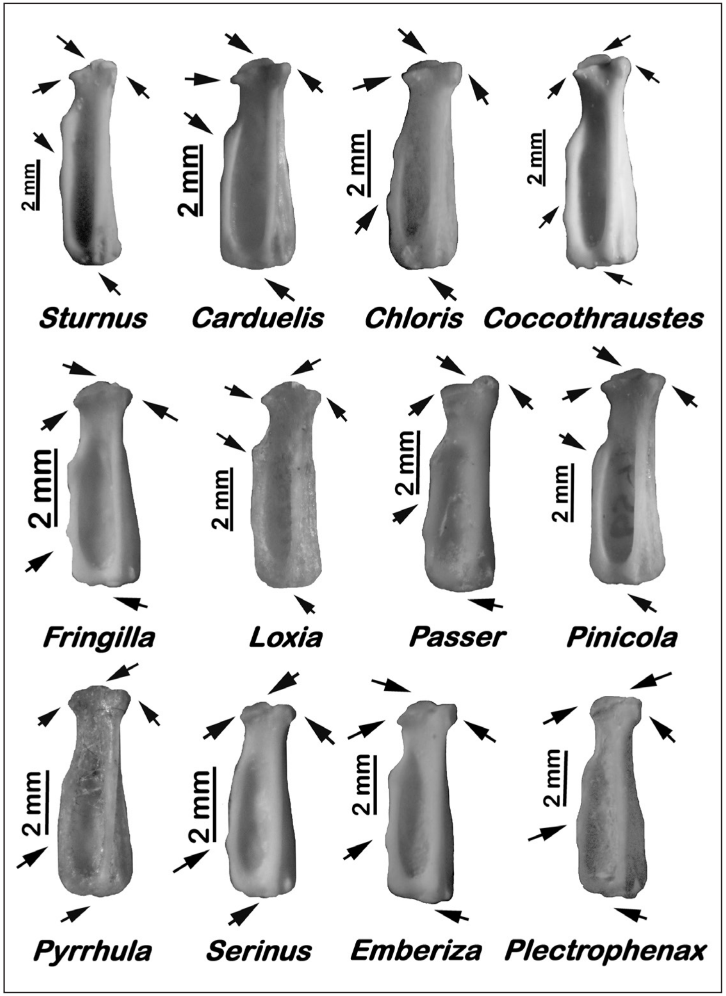


Plate 36 *Phalanx proximalis digiti majoris* (right side)
36. táblakép *Phalanx proximalis digiti majoris* (Kézujjperc – jobb oldali)

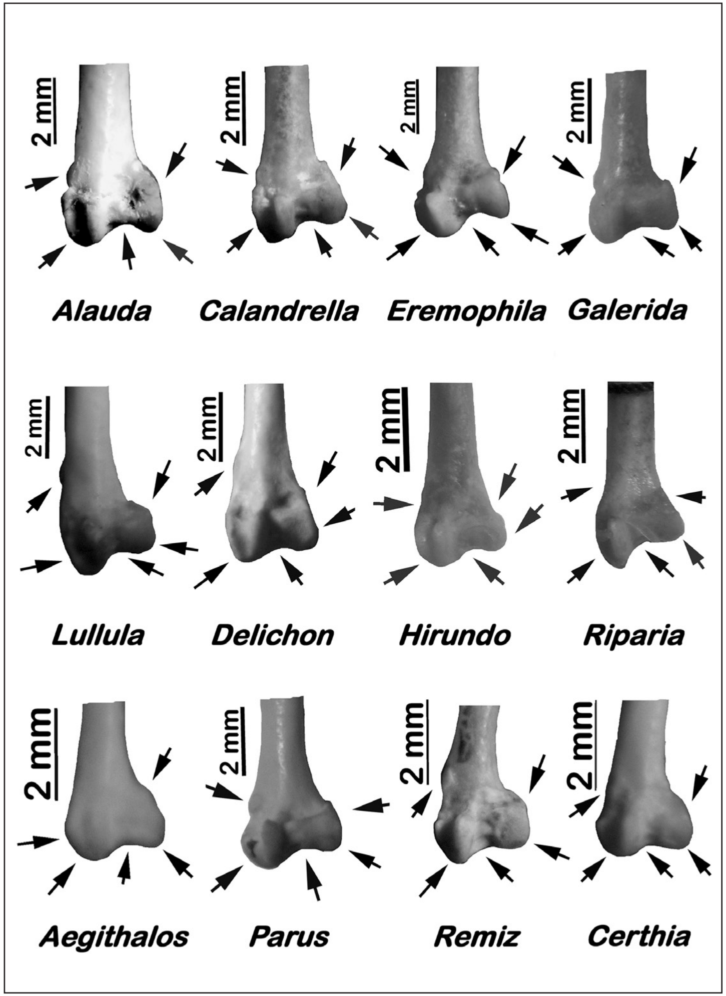


Plate 37 *Femur* (*epiphysis distalis* – left side)
37. táblakép *Femur* (Combcsont, disztális epifízis – bal oldali)

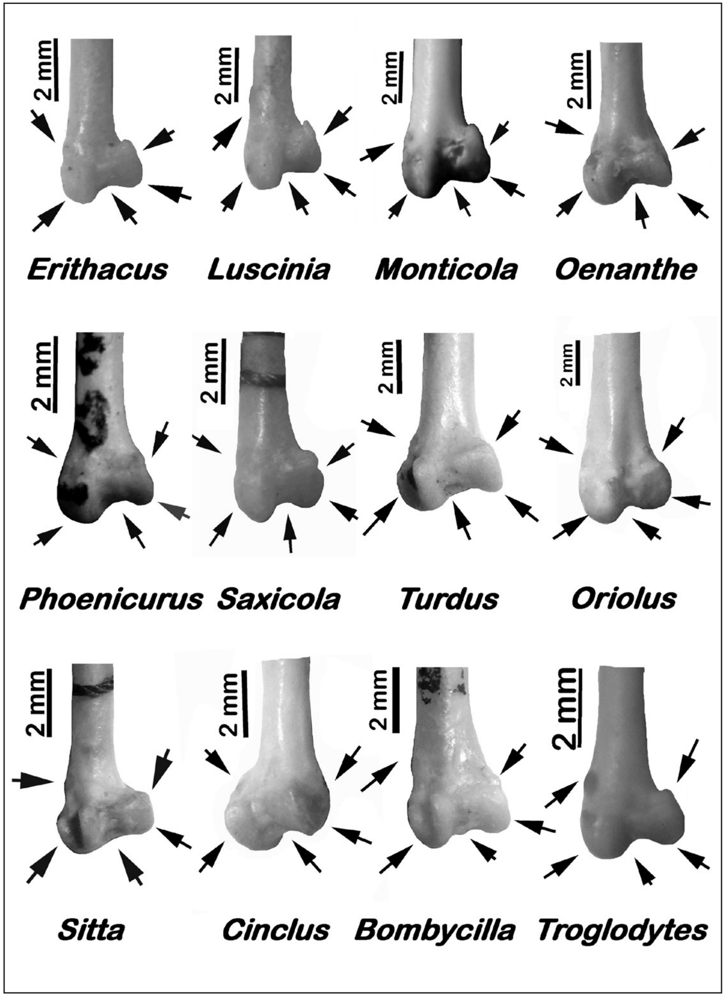


Plate 38 *Femur* (*epiphysis distalis* – left side)
38. táblakép *Femur* (Combcsont, disztális epifízis – bal oldali)

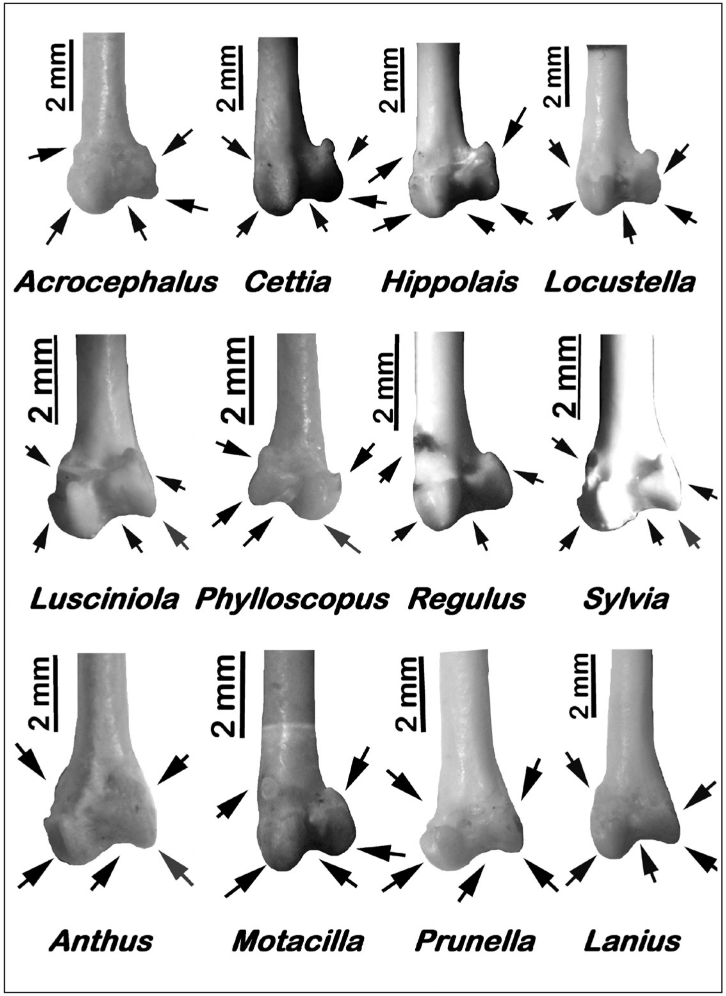


Plate 39 *Femur* (*epiphysis distalis* – left side)
39. táblakép *Femur* (Combcsont, disztális epifízis – bal oldali)

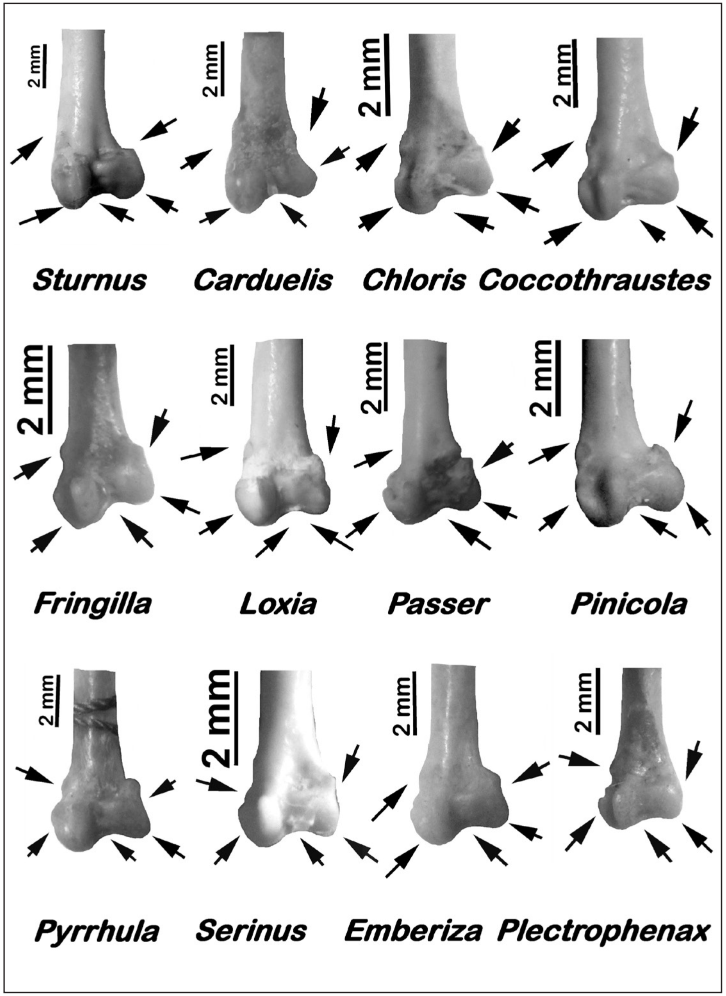


Plate 40 *Femur* (*epiphysis distalis* – left side)
40. táblakép *Femur* (Combcsont, disztális epifízis – bal oldali)

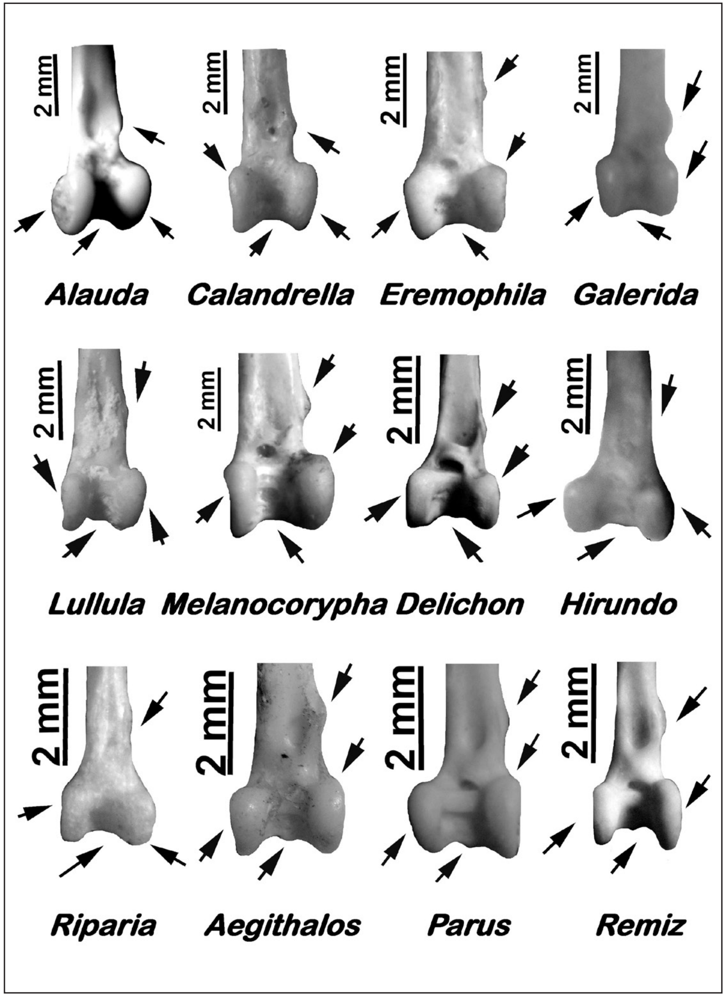


Plate 41 *Tibiotarsus* (*epiphysis proximalis* – left side)
41. táblakép *Tibiotarsus* (Lábszárcsont, disztális epifízis – bal oldali)

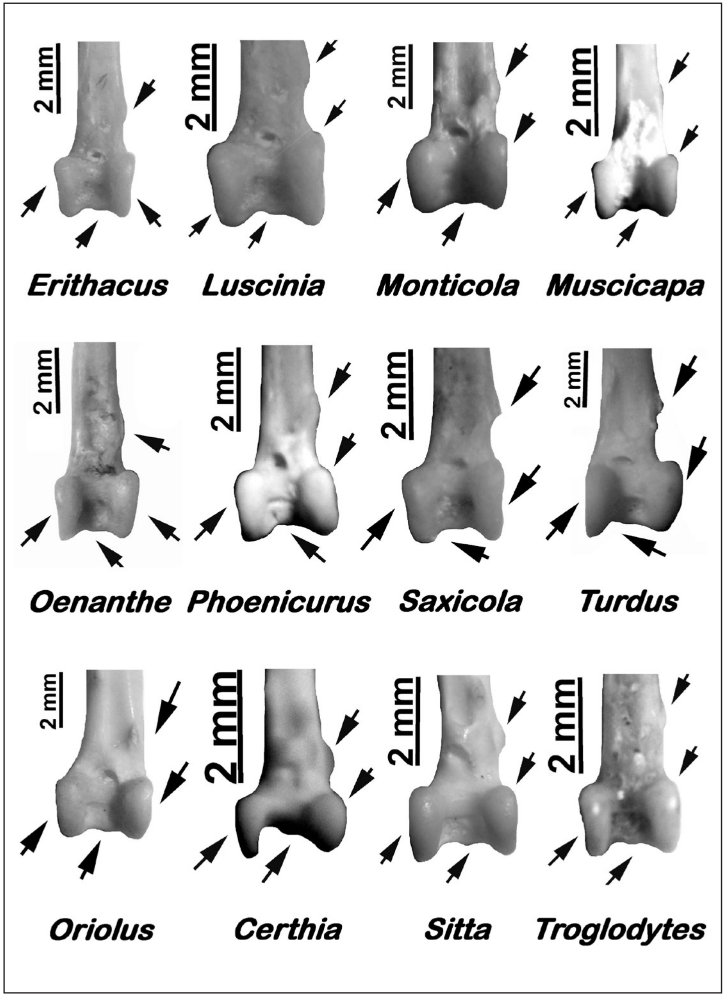


Plate 42 *Tibiotarsus* (*epiphysis proximalis* – left side)
42. táblakép *Tibiotarsus* (Lábszárcsont, disztális epifízis – bal oldali)

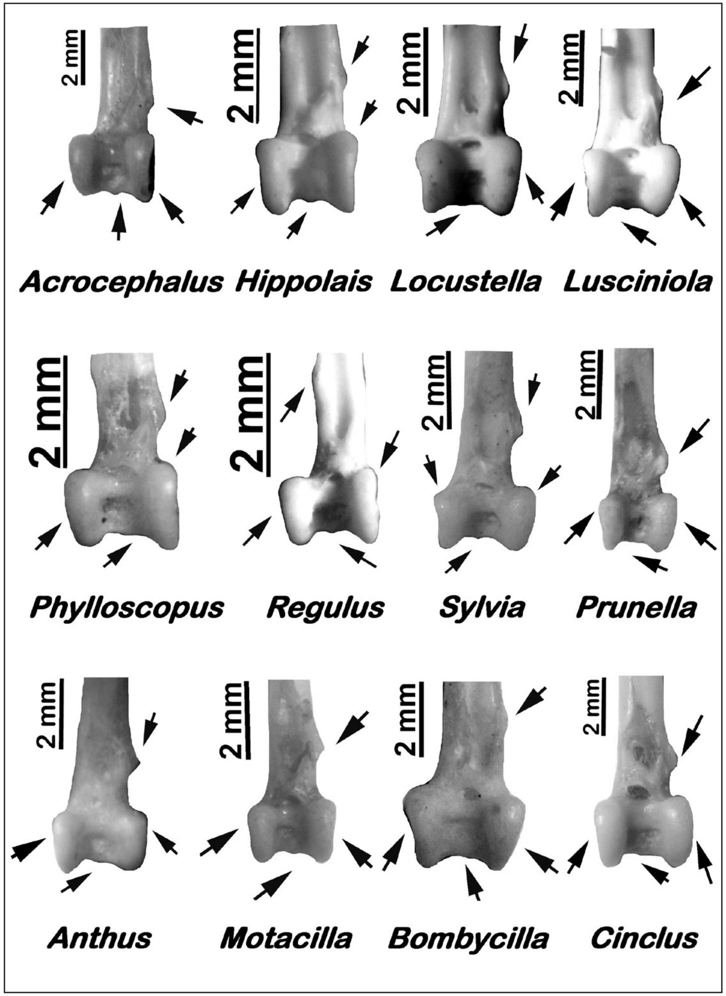


Plate 43 *Tibiotarsus* (*epiphysis proximalis* – left side)
43. táblakép *Tibiotarsus* (Lábszárcsont, disztális epifízis – bal oldali)

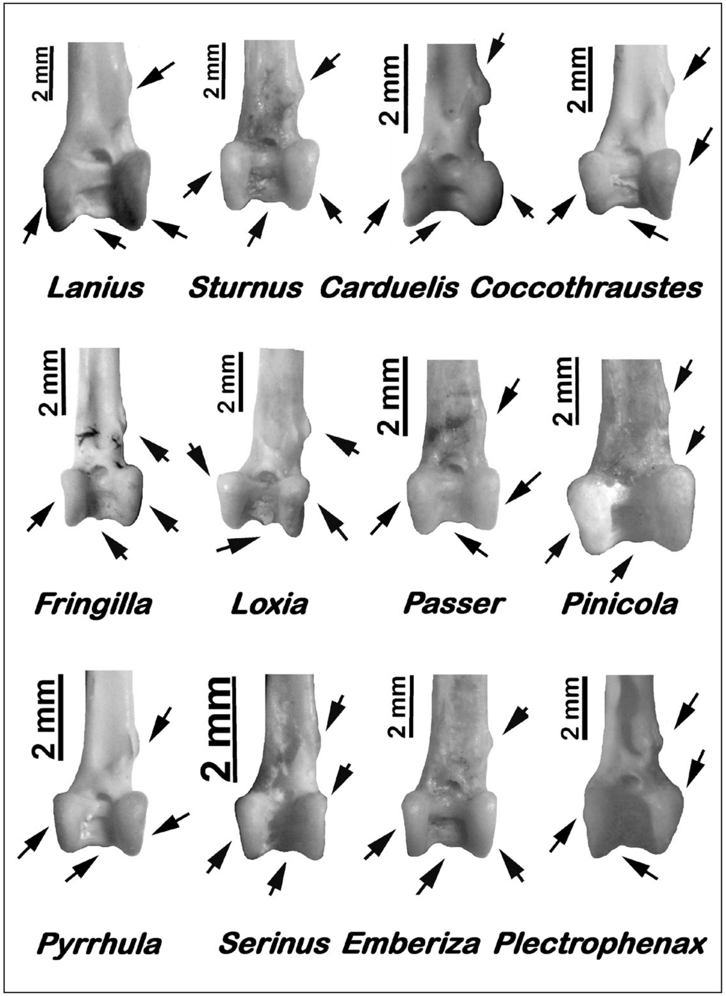


Plate 44 *Tibiotarsus* (*epiphysis proximalis* – left side)
44. táblakép *Tibiotarsus* (Lábszárcsont, disztális epifízis – bal oldali)

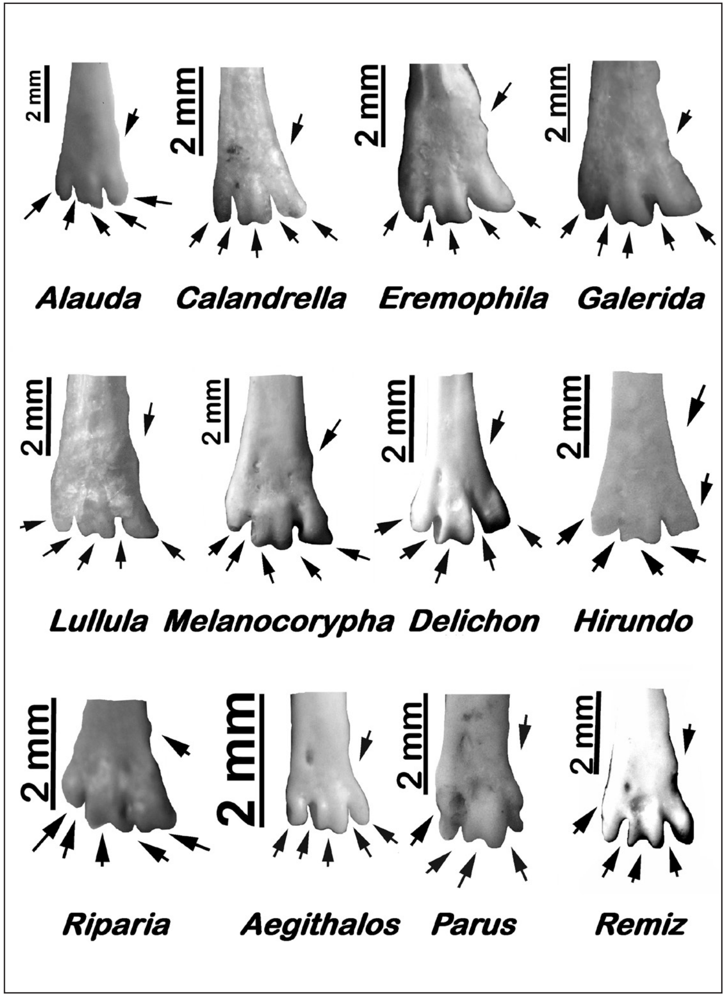


Plate 45 *Tarsometatarsus* (*epiphysis distalis* – right side)
45. táblakép *Tarsometatarsus* (Csüd, disztális epifízis – jobb oldali)

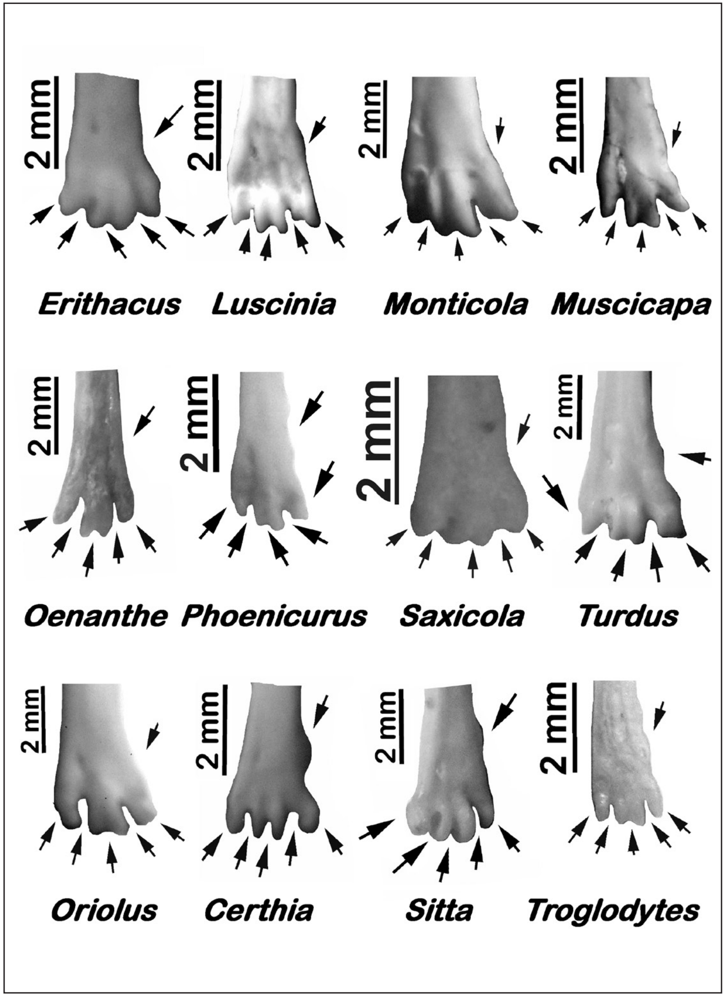


Plate 46 *Tarsometatarsus* (*epiphysis distalis* – right side)
46. táblakép *Tarsometatarsus* (Csüd, disztális epifízis – jobb oldali)

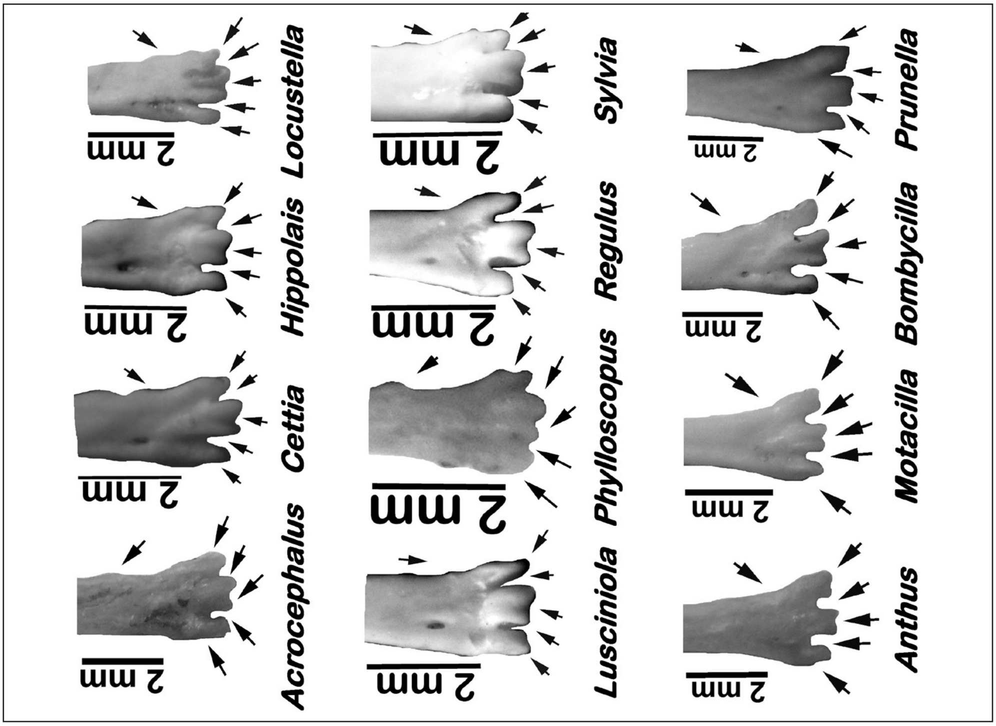


Plate 47 Tarsometatarsus (*epiphysis distalis* – right side)
47. táblakép Tarsometatarsus (Csüd, disztális epifízis – jobb oldali)

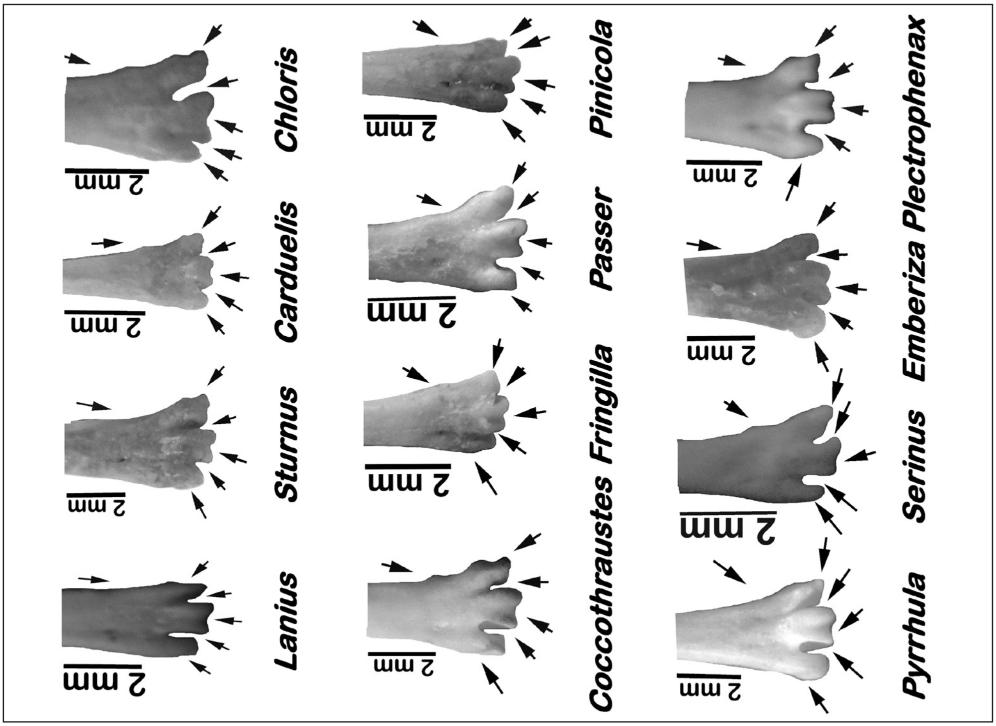


Plate 48 Tarsometatarsus (*epiphysis distalis* – right side)
48. táblakép Tarsometatarsus (Csüd, disztális epifízis – jobb oldali)

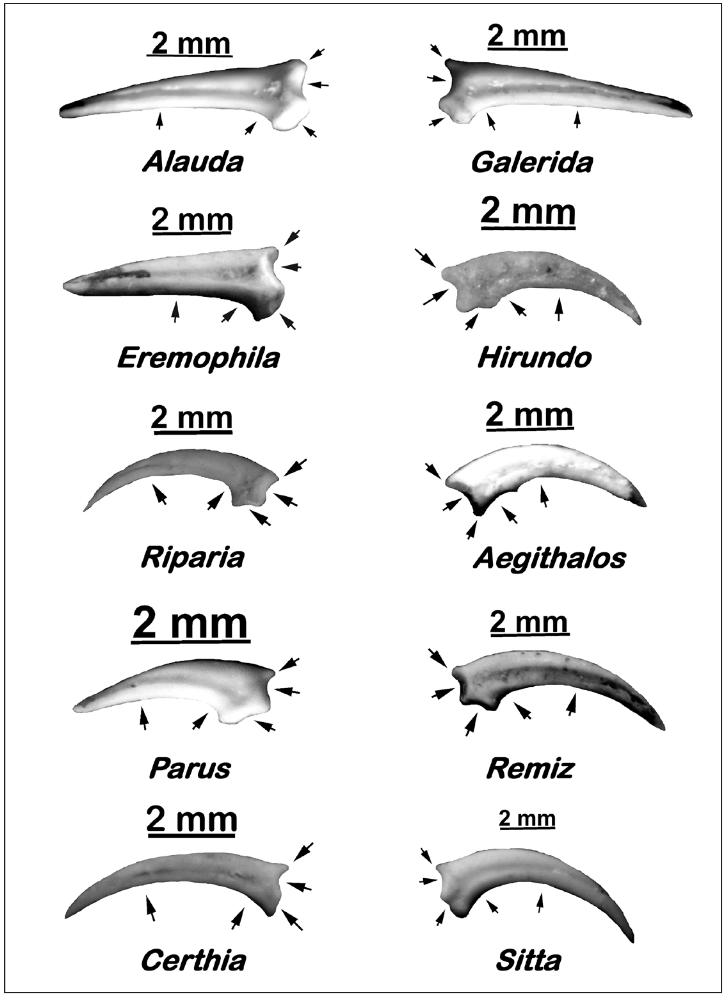


Plate 49 *Phalanx ungularis* (Claw)
49. táblakép *Phalanx ungularis* (Karomcsont)

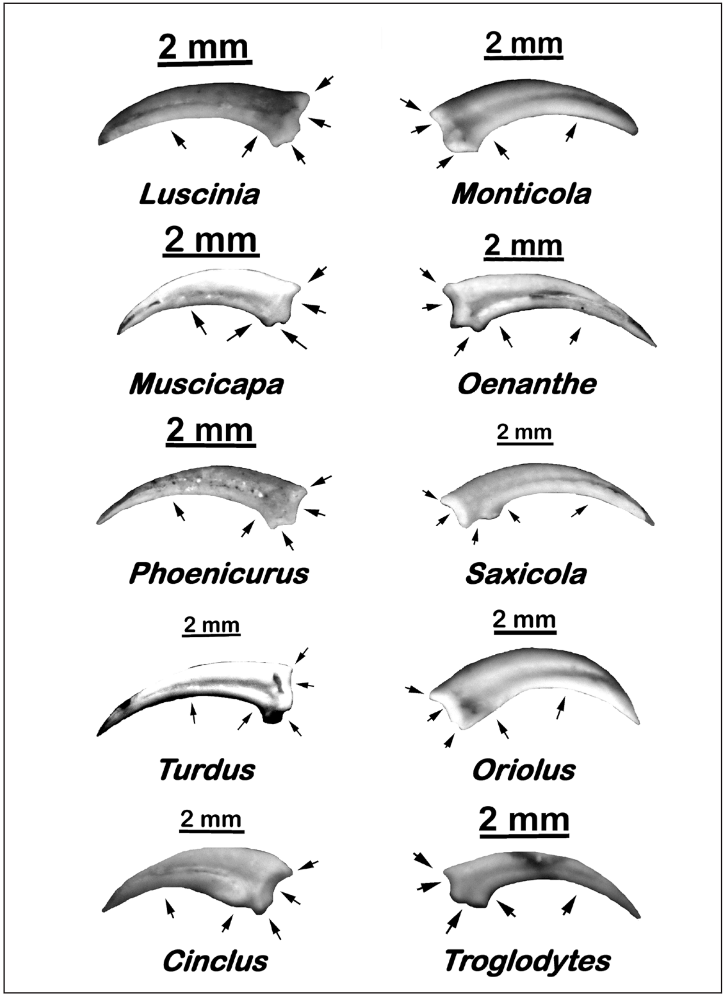


Plate 50 *Phalanx ungularis* (Claw)
50. táblakép *Phalanx ungularis* (Karomcsont)

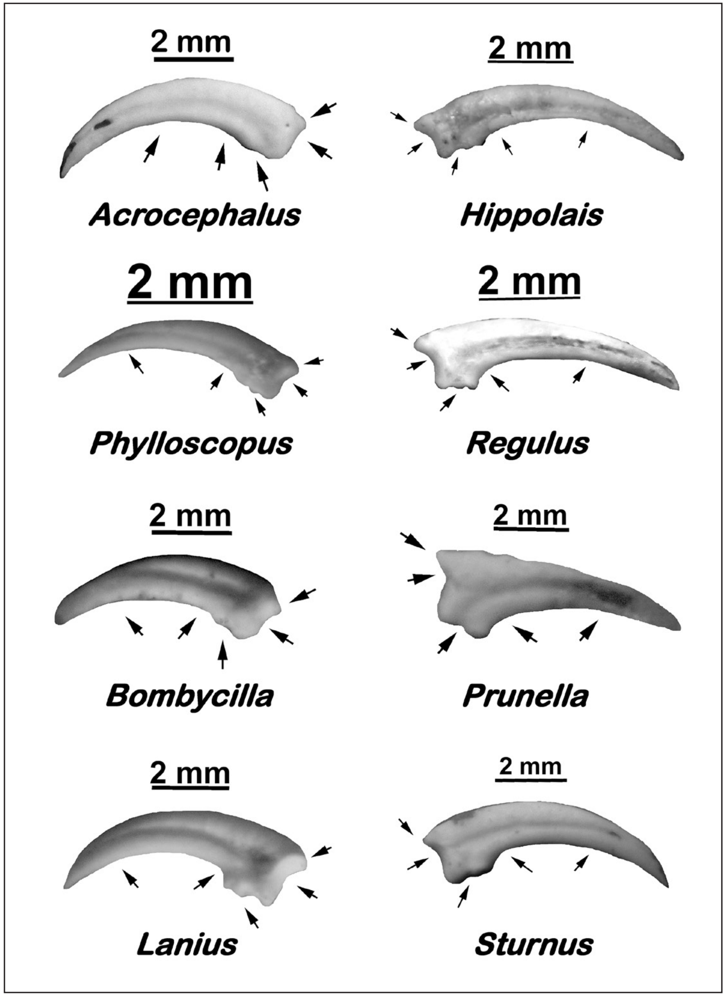


Plate 51 *Phalanx ungularis* (Claw)
51. táblakép *Phalanx ungularis* (Karomcsont)

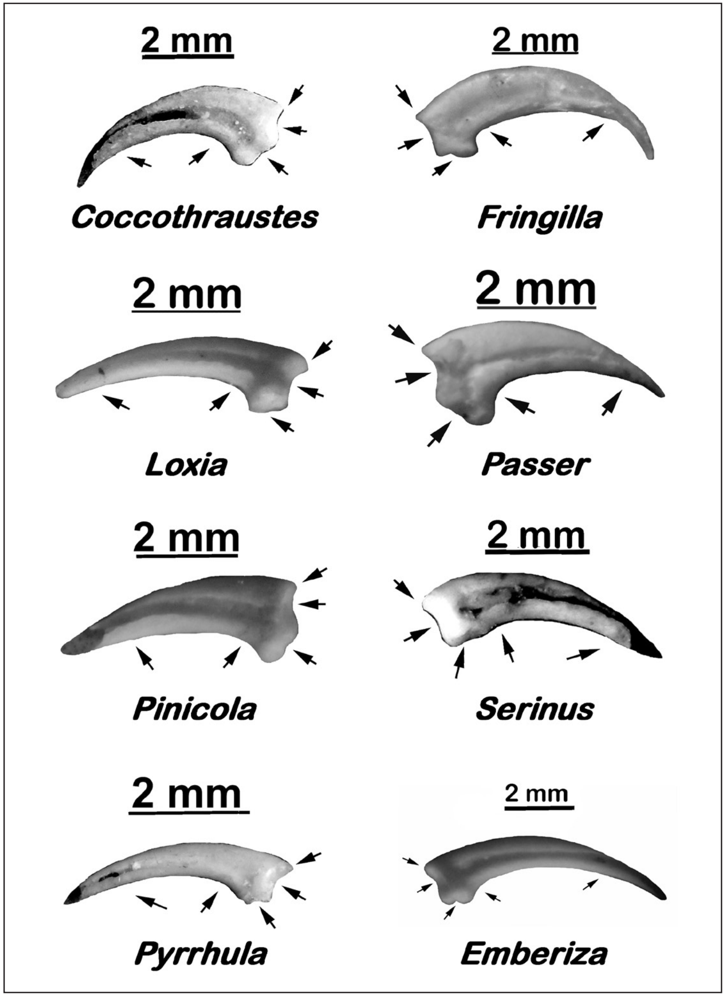


Plate 52 *Phalanx ungularis* (Claw)
52. táblakép *Phalanx ungularis* (Karomcsont)

Ornis Hungarica 2015. 23(2): 156–162.
DOI: 10.1515/orhu-2015-0017

New species in the Hungarian avifauna in 2014

Tibor Hadarics

Tibor Hadarics 2015. New species in the Hungarian avifauna in 2014. – Ornis Hungarica 23(2): 156–162.

Abstract Two new species appeared in the Hungarian avifauna in 2014: the Spanish Sparrow and the Blyth's Reed Warbler. One pair of Spanish Sparrow was breeding in Bácsborsód between June 13th and July 31st in the side of a stork nest. The Blyth's Reed Warbler was trapped and ringed near Tömörd on August 15th. With the observations of these species the number of bird species that have ever been proven to occur in Hungary has risen to 411.

Keywords: official bird checklist, Hungarian Checklist and Rarities Committee, Spanish Sparrow, *Passer hispaniolensis*, Blyth's Reed Warbler, *Acrocephalus dumetorum*

Összefoglalás 2014-ben két faunára új madárfaj bukkant fel Magyarországon: a berki veréb és a berki nádiposzáta. Egy pár berki veréb költött Bácsborsódon 2014. június 13. és július 31. között egy gólyafészek oldalában. A berki nádiposzátát 2013. augusztus 15-én gyűrűzés során fogták Tömördön. E fajok előkerülésével a Magyarországon valaha bizonyítottan előfordult madárfajok száma 411-re emelkedett.

Kulcsszavak: Magyarország madarainak névjegyzéke, MME Nomenclator Bizottság, berki veréb, *Passer hispaniolensis*, berki nádiposzáta, *Acrocephalus dumetorum*

Tibor Hadarics, 9400 Sopron, Wälder József utca 4. D/2., Hungary, email: sitke@upcmail.hu

In 2013, two bird species were accepted by the Hungarian Checklist and Rarities Committee as new to the Hungarian fauna. These are the Spanish Sparrow (Dezső 2014, Schneider & Tamás 2014) and the Blyth's Reed Warbler (Illés 2014). By these, the number of bird species found in Hungary to date has risen to 411.

Passer hispaniolensis (Temminck, 1820) – Spanish Sparrow
June 13th – July 31st 2014, Bácsborsód, (Bács-Kiskun County), 1 breeding pair (V. Schneider, Á. Tamás and others).

The breeding area of the Spanish Sparrow extends from Northwest-Africa and the Iberian Peninsula through Sardinia, the Balkan Peninsula, Asia Minor and the Middle East to the south Caspian region, Amu-darja, Kizil-kum and Tian Shan (Clement *et al.* 1993, del Hoyo *et al.* 2009). It favors humid, wet river valleys with tall oak and poplar or pine trees, on which it nests in colonies, but it also breeds on plantations, drier areas and in oases (Alonso 1997). Spanish Sparrows nest most commonly in the canopies of introduced planted trees. This strategy, with a good access to and diversity of potential nesting sites, enables a further expansion of the species (Mužinić *et al.* 2014). Its colonies are generally distant from human settlements, but in places where there are no, or few House Sparrows

(Passer domesticus) it may breed in settlements as well (Alonso 1997). In populated areas it usually breeds in the side of stork nests or in the nests of House Martins, similarly to other sparrow species.

It spread from the Balkan Peninsula toward the northwest in the 1950s, as a result of which through Bulgaria it reached Dobrogea and Moldova (Baumgart & Stephan 1974, Alonso 1997). It first appeared in Romania in 1964, in Dobrogea (Papadopol 1965), then in the end of the 1970s it spread from here toward the west, through the flatlands situated north of the Danube, in 1972 it already reached the vicinity of the Iron Gate (Radu 1973). Its population size reached its peak in the 1970s, in the 1990s its population declined, several colonies ceased (Munteanu 1998). Between 2000 and 2002 its total population in Romania was estimated to be between 125,000 and 254,000 (BirdLife International 2004), in the Romanian portion of Bánát, near the Danube, 50–70 pairs nest in fluctuating numbers (Rašajsky & Kiss 2004). It first nested in Serbia in 1970 (Donji Stupanj) (Ham 1971), then it spread toward the north, it was first proven to nest in Vojvodina in 1973, at Titel (Šoti 1973). Between 1990 and 2002 its Serbian population was estimated to be 1000–2000 pairs, its population in Crna Gora 800–1200 pairs, with a fluctuating population size in both areas (Puzović *et al.* 2003). Between 1990 and 2002 a maximum of 10 pairs nested in Vojvodina (Puzović *et al.* 2003), at the same time others estimated the nesting population in the Serbian portion of the south part of Banat to be 20–50 pairs (Rašajsky & Kiss 2004). In Vojvodina, it sporadically appeared in multiple locations in the past decade. In the summers of 2003 and 2004 one male specimen each was observed in Novi Sad (Tucakov 2004). In 2005 one pair nested in the vicinity of Vršac (Vučanović 2012). In 2009 it nested in the eastern part of Serbia, in the vicinity of Radujevac and Prahovo along the Danube (Petrović & Radišić 2009), in 2010 near Jablanka (Vučanović 2012). In 2012 at least three pairs moved to the north of Belgrade (Sakule) (Ružić & Rajković 2012), and in this same year a specimen was also observed in Apatin (Spremo 2012).

From the 1970s onwards, the Spanish Sparrow has been spreading its range along the Dalmatian and Croatian coast in a northwest direction (Lukač 1988, 2004), in 1990 it was breeding on the western part of the Istria Peninsula (Rubinič 2001). In 2002 the Croatian breeding population was estimated to be between 10,000 and 50,000 pairs (BirdLife International 2004). The first Slovenian data originate from the October of 1988, Vrhnika (Grošelj 1989). In the summer of 1999, nest material collecting male Spanish Sparrows, manifesting territorial behavior were observed in two separate locations in eastern Slovenia (Vrezec & Štumberger 2000).

The Spanish Sparrow was first observed in Hungary on June 13th 2014, in Bácsborsód. During the course of ringing stork fledglings, a male Spanish Sparrow feeding nestlings was observed at one of the Bácsborsód stork nests. Later the feeding female was also observed many times on two-thirds of days of observations, thus it was proven that it was not a hybrid pair. In the end of June, after the first brood had already fledged, the birds commenced a secondary breeding, the male was carrying nest material for days to the new nest being built in the side of the stork nest, in the last third of July the male and female was feeding active (Dező 2014, Schneider & Tamás 2014).

This was the first occurrence, and also breeding, of this species within the current borders of Hungary. Since the nominate race nests in Europe, the pair breeding in Hungary also belonged to this subspecies (ssp. *hispaniolensis*).

As a result of the spreading of the species in Romania and Serbia, it had been near Hungary's southern border for a long time, thus in reality it is not surprising that it first appeared in a settlement neighboring Vojvodina. In the upcoming years it will be worth inspecting stork nests in the southernmost parts of Bács-Kiskun and Csongrád counties, since further occurrences and even nestings of Spanish Sparrows are expected. Moreover according to simulation models a significant further northern direction spreading of the species is expected in the next 100 years (Huntley *et al.* 2007).

Acrocephalus dumetorum Blyth, 1849 – Blyth's Reed Warbler
August 15th 2014, Tömörd (Vas County), Lake Nagy, 1 adult exemplar (P. Illés, Cs. Lőrincz, P. Bánhidi and others).

The breeding area of Blyth's Reed Warbler extends from the Baltic States and the southern part of Finland through the upper Volga and Kama area, through the Ural Mountains, Irtis and upper Ob area to the Baikal Mountains in the east and the Altai, Lake Balkhash, Tian Shan and Turkmenistan in the southeast (del Hoyo *et al.* 2006).

Its favored habitats are riverine forests with dense undergrowth, shrubby gullies, bushy forest edges, young forests, willow scrub with birches, overgrown clearings, dense mulberry and raspberry scrub, nettles, gardens, as well as abandoned and overgrown agricultural areas (Koskimies 1980, Koskimies & Priednieks 1997). It has been spreading toward the west since the beginning of the 20th century, probably due to the abandonment of the cultivation in agricultural areas and a decline of cattle grazing, resulting in shrubs growing on plough lands and grazing fields, thus the extent of suitable habitats increased considerably (Koskimies & Priednieks 1997).

In the beginning of the 20th century the western edge of its distribution area was still in the vicinity of Lake Ladoga. It appeared in the southern part of Finland in the 1930s, its first nesting occurred in 1947, and by the 1960s it became widespread in this area. In the end of the 1990s and the beginning of the 2000s, the Finnish population was estimated to be 5000–8000 pairs (Koskimies & Priednieks 1997, BirdLife International 2004), while in 2012 it was already estimated to be 16,000–59,000 pairs, which shows an increasing tendency (http://bd.eionet.europa.eu). In Estonia, it was first breeding in 1938, but it only became a regular breeder in the 1960s; its Estonian population was estimated to be 2000–3000 in the 1990s (Koskimies & Priednieks 1997), and 2000–4000 in 1998 (BirdLife International 2004). Its population has shown an intensely increasing tendency since the 1980s, thus the number of breeding pairs was estimated to be between 60,000 and 120,000 in 2012 (Elts 2012). Its first nesting in Latvia occurred in 1944, in the end of the 1990s the number of singing, permanent resident males was estimated to be 3000–6000 in the country, but there has been a large fluctuation in its population from year to year, and a large proportion of males were left without a mate (Koskimies & Priednieks 1997). In Lithuania, its population was estimated to be 200–300 pairs between 1999 and 2001 (BirdLife International 2004), and currently 500–700 pairs. (http://bd.eionet.europa.

eu). In the 1990s, it appeared as a breeding species in Belarus, where its population was estimated to be 1000–2000 between 1997 and 2002. In the 1990s, the first singing males appeared in Poland as well, their number was estimated to be 0–50 between 1995 and 2000 (BirdLife International 2004), and 6–28 between 2008 and 2012 (http://bd.eionet.europa.eu). The first breeding in Poland was confirmed in 2011 (Tumiel & Grigoruk 2011). In the end of the 1950s, it also appeared in Sweden, where its first confirmed nesting occurred in the 1970s (Slack 2009). Until the end of the 1990s, its breeding population was a maximum of 10 pairs, estimated to be 5–15 pairs at the turn of the millennium (BirdLife International 2004), and 50–200 pairs between 2008 and 2012 (http://bd.eionet.europa.eu). In recent years singing males have appeared in the southeast part of Norway as well (for example 15 in 2007). In the 1990s its total European population was estimated to be between 2,000,000 and 5,000,000 pairs, with the majority of these birds nesting in Russia, where its population is stable (BirdLife International 2004).

It occurs as a rare vagrant in several European countries outside the breeding area. A relatively large amount of data is known from Northern-Europe and the British Isles, however, in other parts of Europe it is very rare (Lewington *et al.* 1991). Since its wintering grounds are in India and Myanmar (del Hoyo *et al.* 2006), therefore, its migration routes mostly avoid Central-Europe. The majority of British data originate from the autumn period. Birds nesting in the western part of the breeding area migrate as early as in July and August, however, vagrants appear in Britain considerably later (from mid-August to mid-November, the peak being the end of September, beginning of October) (Slack 2009). This suggests that autumn vagrants do not arrive from the western part of the breeding area, rather from further east, and their appearance can possibly be attributed to a reverse migration of young birds (Gilroy & Lees 2003, Lees & Gilroy 2009). The numbers of spring data are significantly lower, likely explained by spring ‘overshooting’ (Slack 2009).

Since the 1990s the number of vagrants has been increasing all over Europe, likely due to the westward spread of the species and also due to an increase of research effort identification knowledge.

Among the countries neighboring Hungary, more data is known from Romania. Several individuals occurred in the Danube-delta and its vicinity, although many of these observations have not been verified. Four birds were ringed and three collected in the Danube-delta in August 1975 (Paspaleva 1976). Between 2005 and 2014 at least eight specimens were ringed in the Danube-delta, all between May and June, although only one of them has been certified so far (May 2014, Sfântu Gheorghe) (Sz. Daróczi pers. comm.). Singing males were observed in 1995 and 1996 (Weber 2000), therefore, likely nesting is assumed there (Munteanu 1998). It first appeared as a vagrant in Slovenia in 1990 (September 1990, Vrhnika) (Šere 1991), and a total of 16 occurrences are documented, all from August to September (Bračko 2006, Hanžel & Šere 2012). One individual was mist-netted in Slovakia (May 2002, Trnava) (Trnka & Matula 2004), so far this represents its sole occurrence in the Carpathian Basin.

In Hungary, one Blyth’s Reed Warbler was mist-netted and ringed on August 15th of 2014, at Lake Nagy, near Tömörd, by Péter Illés in the Tömörd Bird Ringing Station (Illés 2014). This was the first confirmed record of the species in Hungary, and the second record in the Carpathian Basin.

Most European vagrants occur from the end of August to mid-November, when typically young birds appear likely due to a kind of reverse migration. However, the specimen caught in Tömörd was an adult bird, as identified on the base its plumage wear. This bird's age and the relatively early date suggests, that this specimen probably did not arrive here from the more eastern part of the breeding area rather it might belong to the Northeast-European breeding population. Scarce appearances of vagrants may also be expected in the future, since its Northeast-European breeding population is rapidly growing.

Acknowledgements

I would like to express my gratitude to referees and Daniel Paizs who made the English translation of manuscript.

References

Alonso, J. C. 1997. *Passer hispaniolensis* Spanish Sparrow. – In: Hagemeijer, W. J. M. & Blair, M. J. (eds.) The EBCC atlas of European breeding birds. Their distribution and abundance. – T & AD Poyser, London, pp. 696–697.

Baumgart, W. & Stephan, B. 1974. Die Ausbreitung des Weidensperlings *(Passer hispaniolensis)* auf der Balkanhalbinsel und ihre Ursachen (Aves, Passerinae) [Distribution of Spanish Sparrow *(Passer hispaniolensis)* on the Balkan Peninsula and its causes]. – Zoologische Abhandlungen (Abhandlungen und Berichte aus dem Staatlichen Museum für Tierkunde in Dresden) 33(8): 103–138. (in German)

BirdLife International 2004. Birds in Europe. Population estimates, trends and conservation status. – BirdLife International, Cambridge, pp. 374

Bračko, F. 2006. Robidna trstnica *Acrocephalus dumetorum* [Blyth's Reed Warbler]. – Acrocephalus 27(130–131): 174–175. (in Slovenian with English Summary)

Clement, P., Harris, A. & Davis, J. 1993. Finches & sparrows. An identification guide. – Christopher Helm, London, pp. 446–447.

Dezső, P. 2014. Magyarország legújabb madárfaja, a berki veréb [Latest bird species of Hungary, the Spanish Sparrow]. – Díszmadár Magazin 21(5): 12–13. (in Hungarian)

Elts, J., Leito, A., Leivits, A., Luigujõe, L., Mägi, E., Nellis, R., Nellis, R., Ots, M. & Pehlak, H. 2012. Eesti lindude staatus, pesitsusaegne ja talvine arvukus 2008–2012. [Status and numbers of Estonian birds, 2008–2012]. – Hirundo 26(2): 80–112. (in Estonian with English Summary)

Gilroy, J. J. & Lees, A. C. 2003. Vagrancy theories: are autumn vagrants really reverse migrants? – British Birds 96(9): 427–438.

Grošelj, P. 1989. Travniški vrabec *Passer hispaniolensis* ujet na Vrhniki, prvi dokazani primerek v Sloveniji [Spanish Sparrow *Passer hispaniolensis* trapped at Vrhnika – the first confirmed specimen in Slovenia]. – Acrocephalus 10(41–42): 34–36. (in Slovenian with English Summary)

Ham, I. 1971. Prvi nalaz gnežđenja španjolskog vrapca, *Passer hispaniolensis* (Temm.) u SR Srbiji [First record of Spanish Sparrow, *Passer hispaniolensis* (Temm.) breeding in Serbia]. – Larus 23: 205–206. (in Serbian with German Summary)

Hanžel, J. & Šere, D. 2012. Seznam ugotovljenih ptic Slovenije s pregledom redkih vrst [The list of birds of Slovenia with an overview of rare species]. – Acrocephalus 32(150–151): 143–203. (in Slovenian with English Summary)

del Hoyo, J., Elliott, A. & Christie, D. (eds.) 2006. Handbook of the birds of the World. Vol. 11. Old World flycatchers to Old World warblers. – Lynx Edicions, Barcelona, pp. 621–622.

del Hoyo, J., Elliott, A. & Christie, D. (eds.) 2009. Handbook of the birds of the World. Vol. 14. Bush-shrikes to Old World sparrows. – Lynx Edicions, Barcelona, pp. 794–795.

Huntley, B., Green, R. E., Collingham, Y. C. & Willis, S. G. 2007. A climatic atlas of European breeding birds. – Durham University – RSPB – Lynx Edicions, Barcelona, pp. 521

Illés, P. 2014. Új madárfaj Magyarországon, a berki nádiposzáta *(Acrocephalus dumetorum)* [The first record and ringed specimen of the Blyth's Reed Warbler *(Acrocephalus dumetorum)* in Hungary]. – Cinege 19: 37–38. (in Hungarian with English Summary)

Koskimies, P. 1980. Breeding biology of Blyth's Reed Warbler *Acrocephalus dumetorum* in SE Finland. – Ornis Fennica 57: 26–32.

Koskimies, P. & Priednieks, J. 1997. *Acrocephalus dumetorum* Blyth’s Reed Warbler. – In: Hagemeijer, W. J. M. & Blair, M. J. (eds.) The EBCC atlas of European breeding birds. Their distribution and abundance. – T & AD Poyser, London, p. 576.

Lees, A. C. & Gilroy, J. J. 2009. Vagrancy mechanisms in Passerines and near-Passerines. – In: Slack, R. (ed.) Rare birds, where and when. An analysis of status & distribution in Britain and Ireland. Vol. 1. Sandgrouse to New World orioles. – Rare Bird Books, York, pp. 1–23.

Lewington, I., Alström, P. & Colston, P. 1991. A field guide to the rare birds of Britain and Europe. – Domino Books, St. Helier, pp. 358–360.

Lukač, G. 1988. Neue Bruttstäten des Weidensperlings *(Passer hispaniolensis)* im nördlichen Dalmatien, Jugoslawien [New breeding activities of Spanish Sparrow *(Passer hispaniolensis)* in northern Dalmatia, Yugoslavia]. – Ornithologische Mitteilungen 40(11): 287–291. (in German)

Lukač, G. 2004. O širenju areala i statusu španjolskog vrapca *(Passer hispaniolensis)* u Hrvatskoj na početku 21. stoljeća [About the widening of the range and the status of the Spanish Sparrow *(Passer hispaniolensis)* in Croatia at the beginning of the 21th century]. – Paklenički Zbornik 2: 113–122. (in Croatian with English Summary)

Munteanu, D. 1998. The status of birds in Romania. – Romanian Ornithological Society, Cluj-Napoca, pp. 102

Mužinić, J., Purger, D. & Purger, J. J. 2014. Population size and nest site selection of the Spanish Sparrow *Passer hispaniolensis* in the region of the river Krka (Croatia). – International Studies on Sparrows 38: 4–10.

Papadopol, A. 1965. Le moineau espagnol (*Passer hispaniolensis hispaniolensis* (Temm.)) en Roumanie (Aves, Passeridae) [The Spanish Sparrow (*Passer hispaniolensis hispaniolensis* (Temm.)) in Romania (Aves, Passeridae)]. – Travaux du Muséum National d’Histoire Naturelle ‘Grigore Antipa’ 5: 509–512. (in French)

Paspaleva, M. 1976. *Acrocephalus dumetorum* Blyth, 1849 (Aves) espéce nouvelle pour la faune de la Roumanie [*Acrocephalus dumetorum* Blyth, 1849 (Aves) new species for the fauna of Romania]. – Travaux du Muséum National d’Histoire Naturelle ‘Grigore Antipa’ 17: 463–465. (in French)

Petrović, D. & Radišić, D. 2009. Gnežđenje španskog vrapca *Passer hispaniolensis* u okolini Radujevca i Prahova [Nesting of Spanish Sparrow *Passer hispaniolensis* in vicinity of Radujevac and Prahovo]. – Ciconia 18: 233–234. (in Serbian with English Summary)

Puzović, S., Simić, D., Saveljić, D., Gergelj, J., Tucakov, M., Stojnić, N., Hulo, I., Ham, I., Vizi, O., Šćiban, M., Ružić, M., Vučanović, M. & Jovanović, T. 2003. Ptice Srbije I Crne Gore – veličine gnezdilišnih populacija I trendovi: 1990–2002. [Birds of Serbia and Montenegro – breeding population estimates and trends: 1990–2002]. – Ciconia 12: 35–120. (in Serbian with English Summary)

Radu, D. 1973. Über die kürzlich aufgetretene Verbreitung des Weidensperlings, *Passer h. hispaniolensis* (Temm.), in Rumänien [About the recent occurrences of the Spanish Sparrow *Passer h. hispaniolensis* (Temm.), in Romania]. – Larus 25: 95–102. (in German)

Rašajsky, J. & Kiss, A. 2004. Ptice Banata [Birds of Banat]. – Gradski Muzej, Vršac: 336. (in Serbian)

Rubinič, B. 2001. Širjenje severozahodne meje gnezditvenega areala travniškega vrabca *Passer hispaniolensis* vzdolž jadranske obale: kako se vede novapopulacija v hrvaški Istri [Expansion of the northwestern frontier of the Spanish Sparrow’s *Passer hispaniolensis* breeding range along the Adriatic coast: behavior of the new population in Croatian Istria]. – Acrocephalus 22(109): 207–211. (in Slovenian with English Summary)

Ružić, M. & Rajković, D. 2012. Gnežđenje španskog vrapca *Passer hispaniolensis* u Sakulama [Breeding of Spanish Sparrows *Passer hispaniolensis* in Sakule]. – Ciconia 21: 76. (in Serbian with English Summary)

Schneider, V. & Tamás, Á. 2014. Új faj a hazai faunában: berki veréb Bácsborsódon [New species in the Hungarian fauna: Spanish Sparrow in Bácsborsód]. – Madártávlat 21(3): 32. (in Hungarian)

Šere, D. 1991. Robidna trstnica *Acrocephalus dumetorum* – nova vrsta ornitofavne Slovenije. [Blyth’s Reed Warbler *Acrocephalus dumetorum* – new to Slovenia]. – Acrocephalus 12(48): 70–75. (in Slovenian with English Summary)

Slack, R. 2009. Rare birds, where and when. An analysis of status & distribution in Britain and Ireland. Vol. 1. Sandgrouse to New World orioles. – Rare Bird Books, York, pp. 251–255.

Spremo, N. 2012. Španski vrabac *Passer hispaniolensis* u okolini Apatina [Spanish Sparrow *Passer hispaniolensis* near Apatin]. – Ciconia 21: 76. (in Serbian with English Summary)

Šoti, J. 1973. Španski vrabac, *Passer hispaniolensis* Temminck, nova gnezdarica Vojvodine [Spanish Sparrow, *Passer hispaniolensis* Temminck, new breeding bird in Vojvodina]. – Zbornik Matice Srpske za Prirodne Nauke 45: 155–159. (in Serbian with German Summary)

Trnka, A. & Matula, J. 2004. First record of Blyth’s Reed Warbler *Acrocephalus dumetorum* (Passeriformes, Sylviidae) from Slovakia. – Biologia (Bratislava) 59(5): 682.

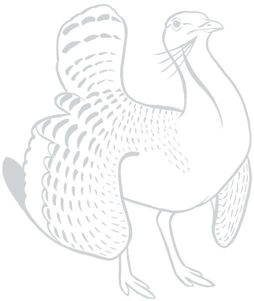
Tucakov, M. 2004. Spanish Sparrow *Passer hispaniolensis*. – Acrocephalus 25(121): 102–103. (in English with Slovenian Summary)

Tumiel, T. & Grygoruk, G. 2011. Pierwsze stwierdzenie lęgu zaroślówki *Acrocephalus dumetorum* w Polsce [First breeding of the Blyth's Reed Warbler *Acrocephalus dumetorum* in Poland.] – Ornis Polonica 52: 288–291. (in Polish with English Summary)

Vrezec, A. & Štumberger, B. 2000. Prvi teritorialni travniški vrabci *Passer hispaniolensis* v Sloveniji [The first territorial Spanish Sparrow *Passer hispaniolensis* in Slovenia]. – Acrocephalus 21(100): 161–163. (in Slovenian with English Summary)

Vučanović, M. 2012. Slučajevi gnežđenja španskog vrapca *Passer hispaniolensis* u juznom Banatu [Cases of breeding of Spanish Sparrow *Passer hispaniolensis* in South Banat]. – Ciconia 21: 77. (in Serbian with English Summary)

Weber, P. 2000. Aves Histriae. Avifauna zonei Histria. Rezervaţia Biosferei Delta Dunării [The birds from Histria. Biosphere Reserve Danube Delta]. – Editura Aves [Odorheiu Secuiesc], p. 66. (in Romanian with English Summary)



Ornis Hungarica 2015. 23(2): 163–188.
DOI: 10.1515/orhu-2015-0018

Hitchhikers' guide to analysing bird ringing data

Part 1: data cleaning, preparation and exploratory analyses

ANDREA HARNOS[1*], PÉTER FEHÉRVÁRI[2] & TIBOR CSÖRGŐ[3]

Andrea Harnos, Péter Fehérvári & Tibor Csörgő 2015. Hitchhikers' guide to analysing bird ringing data – Part 1. – Ornis Hungarica 23(2): 163–188.

Abstract Bird ringing datasets constitute possibly the largest source of temporal and spatial information on vertebrate taxa available on the globe. Initially, the method was invented to understand avian migration patterns. However, data deriving from bird ringing has been used in an array of other disciplines including population monitoring, changes in demography, conservation management and to study the effects of climate change to name a few. Despite the widespread usage and importance, there are no guidelines available specifically describing the practice of data management, preparation and analyses of ringing datasets. Here, we present the first of a series of comprehensive tutorials that may help fill this gap. We describe in detail and through a real-life example the intricacies of data cleaning and how to create a data table ready for analyses from raw ringing data in the R software environment. Moreover, we created and present here the R package; `ringR`, designed to carry out various specific tasks and plots related to bird ringing data. Most methods described here can also be applied to a wide range of capture-recapture type data based on individual marking, regardless to taxa or research question.

Keywords: data cleaning, R statistical software, banding data, statistical analysis, mark-recapture, data management

Összefoglalás Feltehetően a madárgyűrűzésből származó adatok szolgáltatják a leghosszabb időtávot felölelő és legtöbb adatot tartalmazó gerinces adatbázist a Földön. A gyűrűzés eredeti célja a madarak vonulási útvonalainak feltérképezése volt, azonban más kutatási területeken is felhasználásra kerültek ezen adatok, például állomány monitoringra, demográfiai változók becslésére, illetve a klímaváltozás hatásainak feltárására, hogy csak néhányat említsünk. Annak ellenére, hogy ilyen fontos és széles körben használt adatforrás, meglepő módon nincs egységes útmutató arra vonatkozóan, hogy hogyan kell az adatokat előkészíteni és megfelelően elemezni. A jelen munka az első része egy olyan sorozatnak, amely részletesen tárgyalja a gyűrűzési adatok kezelését, elemzését az R statisztikai program használatával. Ebben az első részben egy valós példán keresztül bemutatjuk az adattisztítás lépéseit, vagyis hogy a nyers gyűrűzési adatokból hogyan készítsünk elemezhető adattáblázatot. Bemutatjuk továbbá az általunk készített `ringR` nevű R könyvtárat, amely olyan függvényeket tartalmaz, amelyek segítik speciális, a gyűrűzési adatokat jól jellemző ábrák és leválogatások elkészítését. Bár gyűrűzési példán mutatjuk be az elemzéseket, feltehetően olyanok számára is hasznos lehet ez az útmutató, akiknek a gyűrűzési adatokhoz hasonló struktúrájú, egyedek jelölésén alapuló adatsoraik vannak.

Kulcsszavak: adattisztítás, R statisztikai program, gyűrűzési adatok, statisztikai elemzés, jelölés-visszafogás, adatkezelés

[1]*Department of Biomathematics and Informatics, Szent István University, Faculty of Veterinary Science, 1078 Budapest, István utca 2., Hungary, e-mail: harnos.andrea@gmail.com*
[2]*Department of Zoology, Hungarian Natural History Museum, 1088 Budapest, Baross utca 13., Hungary*
[3]*Department of Anatomy, Cell- and Developmental Biology, Eötvös Loránd University, 1117 Budapest, Pázmány Péter sétány 1/C, Hungary*
**corresponding author*

Introduction

Ever since Mortensen first fitted starlings *(Sturnus vulgaris)* with his home-made engraved plates in 1890 (Preuss 2001) hundreds of millions of birds were ringed to-date (e.g. EURING databank: www.euring.org, North American Bird Banding Laboratory (BBL) www.pwrc.usgs.gov/bbl, South African Bird Banding Unit, http://safring.adu.org.za). The method of deploying rings (or various other unique tags that remain on the individual throughout its lifespan) spread all over the world, consequently creating a global network of ringing schemes (e.g. Greenwood 2009), ringing stations (e.g. Pilastro *et al.* 1998, Nowakovski 2003, Crewe *et al.* 2008) and individual ringers. Therefore, bird ringing datasets constitute possibly the largest source of temporal and spatial information on any vertebrate taxa (except human) available on the globe. Initially, bird ringing was designed to understand the spatial patterns of migration and is still one of the benchmark methods to assess movements of bird species despite its limitations (Thorup *et al*. 2014). Fitting individual identifiers to birds was soon revolutionizing other disciplines including ecology, behaviour, demography, morphology and effects of climate change on vertebrate systems to name a few (Spina 1999, Dingemanse *et al.* 2003, Robinson *et al.* 2007, Brown & Oschadleus 2008, Osenkowski *et al.* 2012). Indeed, over 120,000 papers have been published to date that used or mentioned bird ringing data to some extent (www.scholar.google.com, search terms: *"avian"* OR *"bird"* AND *"ringing*" OR *"banding"-"chromosome banding"*, accessed 2015-11-25).

Working with ornithologists and field biologists however, showed us that theoretical misconceptions and bad practice in data analyses of bird ringing datasets are surprisingly common despite the generality, and interdisciplinary usage of ringing. Thousands of tutorials, textbooks, online courses are readily available to help the analysis, however it is easy to get lost amidst the abundance of possibilities. Here we will give yet another tutorial, or rather a series of tutorials. We specifically deal with general avian ringing data and present guidelines of good practice on data management and analyses. The methods and plots described can easily be generalized to various capture-recapture type data regardless to taxa or the research question, making it possibly useful for researchers working in different fields.

The first part of the series introduces the reader to the basic concepts of statistics (see *Box 1*) and serves as a guide for exploring and cleaning raw data. We address the most frequent problems, their solutions with example computations. Our philosophy is to give the reader a perspective on what we believe is good practice in bird ringing data management and producing guidelines and a selection of techniques we found the most useful when analysing ringing datasets.

Data sources

Bird ringing is more than just a research methodology, it is also a recreational activity and an effective tool for environmental education (Dearborn & Kark 2010, Şekercioğlu 2012). Thus, data may derive from sources ranging from individual ringers, demonstrative temporal trapping sessions, species-specific research projects to large scale continuous ringing stations. These sources can be categorized to two groups: (1) presence only data and (2) data from standardized sampling. The first group constitutes data deriving from sources when bird ring-

Population and sample

Although both statisticians and biologists use the term *population,* the meaning is different in the two disciplines. This overlap in terminology may often lead to confusion, typically when obtained results are inferred.

Statistical population is the set of objects, individuals etc. that we wish to (or can) make inference on. For instance, consider the working example of this tutorial, Pied Flycatchers migrating through the Ócsa Bird Ringing Station. Defining the sensu stricto biological population in this case is difficult as we hardly have information on where each individual breeds, although intuitively the biological population might be all birds migrating through Hungary, or the Carpathian Basin. Defining the statistical population is more straightforward: it is the set of birds migrating through the surroundings of the station that we could have or did actually captured. The individuals captured constitute our **sample**, and, based on our sample, we make inference on all the individuals we did not catch but could have captured. In this case the **observational or sampling units** (elements of the sample) are the individuals that we caught and measured, the **observations** are the characters of the sampling units that we measured (e.g. wing length) or observed (e.g. age).

Box 1. Basic concepts
1. doboz Alapfogalmak

ing was carried out as a recreational, educational activity or when the aim was to maximize the number of individuals/species ringed. Quite often only the data of capture is available in these cases without any further information on habitat, trapping method and effort (e.g. number of nets used and the duration of trapping). Presence only data is suitable for qualitative analyses of species or population specific movements (Thorup *et al*. 2014), or for using it to model distribution patterns on a large spatial scale (e.g. Walther *et al.* 2007). In the second group, bird ringing was carried out with a more or less constant trapping effort and with similar methodology over time. Typically, these data are from ringing stations operating at constant locations, citizen science projects with standard methodology (e.g. CES, Peach *et al.* 1998, 2004). Species specific research and conservation programs also constitute this latter group. These data sources – albeit with careful consideration – may be used to answer questions related to demography, phenology or other topics when trapping probabilities are explicitly or inherently the subject of analyses.

Sampling issues

A research process can be described in several consecutive steps: (1) identify the topic and research question, (2) define the population *(Box 1)* to be inferred on and formulate hypotheses, (3) design sampling process, (4) collect data (5) analyse data and (6) interpret and report results. However, when analysing retrospective data, this structure cannot be followed as data has already been collected. Therefore, steps (4) and (5) could be rephrased as: ʽevaluate whether the available data is collected in a fashion suitable for answering the research question addressed’. Ornithologists often mistakenly refer to, and hence analyse long-term bird ringing data as unbiased samples of a given population. However, standard field methodology does not necessarily produce representative samples. A sample may be representative of a specific aspect while non-representative from another. For instance, we have ringing data with biometric measurements of Red-backed Shrikes *(Lanius collurio)* caught with live lure bownets at a given location in autumn. The birds were captured during the same time of the year, in similar habitats and at a well-defined location (e.g. surroundings of a ringing station). All birds were handled and measured by the same ringer using the same equipment, making the sampling procedure standard. The wing length measurements of these birds may be considered a representative sample of the wing length of all shrikes at the location. However, this may not be true for body mass measurements as we used traps that require the birds to be hungry. There are no tests available that may help us evaluate how well our sample represents the statistical target population, and as the example above shows, it depends on the question addressed. Therefore, we highly recommend a thorough consultation process with peers on whether data can be considered as a representative sample suitable for addressing specific research questions, prior to initiating any further analyses.

Data cleaning and management

Once we have confirmed that our data is suitable, the next step is data cleaning. In the following sections we will lead you through the intricate steps necessary to transform raw ringing data to technically correct data suitable for statistical analyses (de Jong & van der Loo 2013). Data cleaning is a three-stage recursive process consisting of screening, diagnosing and editing abnormalities. Screening typically entails (1) graphical representation of distributions (boxplots, histograms and scatterplots) for numerical variables, (2) creating frequency distributions and contingency tables in case of factors, and (3) calculating summary statistics. All these predominantly serve the purpose of pin-pointing anomalies. Once identified, these anomalies have to be carefully investigated and if possible their potential cause diagnosed. Quite often this diagnosis (or the lack of diagnosis) will then help deciding how to treat these data anomalies. These steps are then repeated as many times as necessary prior to starting advanced statistical analyses. Note that screening is in essence exploratory data analysis, therefore it also allows an analyst to familiarise with patterns in the data, facilitating the implementation of future, more complex statistical analyses.

Data cleaning is often neglected or carried out crudely, yet it has crucial repercussions on the obtained results. Bird ringing datasets are often heterogeneous in coding and are prone to systematic measurement bias changing over time, due to the fact that they were often collected over a long-time period and recorded by various people. Therefore, a rigorous data cleaning procedure is essential and cannot be over-emphasized. Statistical societies recommend that description of data cleaning be a standard part of reporting statistical methodology (American Statistical Association 1999, Broeck *et al.* 2005). We believe that it should also be a fundamental part of reporting the analyses on ringing datasets.

The software used

For data cleaning and analyses, we use R (www.r-project.org, R Core Team 2015a), a free software environment that has become the benchmark of statistical data analyses

Variable types

Variables are in essence the characteristics we measured or observed. We can differentiate variables based on their measurement scales:

Nominal variables consist of two or more categories and these categories lack an intrinsic order. For example, sex of a bird, colour, habitat type etc.

Ordinal variables have two or more categories just like nominal variables, only the categories can also be ordered or ranked. Fat or muscle scores are ordinal variables in our case. Nominal and ordinal variables are also called as qualitative or categorical variables. These are the so called factors in R. The only meaningful summary of these variables are counting the observations in the categories. We can code the categories with characters, or character series (e.g. M or male) or even numbers (e.g. 1, 2, …), but note that although mathematical operations may be carried out, these are totally meaningless.

Interval variables can be measured along a continuum and have meaningful distances between measurements defined, but the zero value is arbitrary (for example, temperature measured in degrees Celsius or Fahrenheit). So the difference between 20 °C and 30 °C is the same as between 30 °C and 40 °C.

Ratio variables have both a meaningful zero value and the distances between different measurements are defined. For example, temperature measured in Kelvin is a ratio variable as 0 Kelvin (often called absolute zero) indicates that there is no temperature and 4 °K is the double of 2 °K. In our case, length and mass variables are measured on the ratio scale (and also on the interval scale). Interval and ratio scale variables are called as quantitative or numeric variables.

Box 2. Variable types
2. doboz Változó típusok

in the past decade. The major advantage is its disadvantage: it is an environment where you have to write commands in a specific language. Learning this language takes time and patience which are commodities not all biologists have. This tutorial is not to teach users the R environment, but to help people start data analyses with limited knowledge of the R language. In case you want to start learning from the very beginning, we refer you to tutorials like Venables *et al.* (2015) and our own beginner's guide to basic syntax and coding (see the online appendix). Furthermore, this tutorial does not substitute a statistical course. We suppose the readers have a basic understanding of statistics. However if you feel the need to refresh your knowledge we suggest reading Fowler and Cohen (1996), Freedman *et al.* (2007) or Shahbaba (2012) and for Hungarian readers, Reiczigel *et al.* (2014).

Those, who are still intimidated by typing codes and would rather open menus and fill dialogue panes, we recommend using the R Commander interface (Fox 2005). In R Commander the codes can be generated and run by menus and dialogue panes. More detailed information about R Commander can be found on the www.rcommander.com website, or see Shahbaba's (2012) book for an introductory textbook using R Commander.

We prefer using R because the scripts (series of commands) can be saved as a simple text file (with the extension name ".r") and rerun. If we have to make similar analysis, we have the codes ready, and the analysis can be reconstructed at any time. It is very useful to meticulously comment the codes. This additional work will enormously help us later when we want to repeat our analysis and have to remember the process, as well as when we have to write about the applied statistical procedures when preparing a manuscript for publication. The R codes of this paper were written in RStudio (www.rstudio.com), an integrated development environment for R, free to use for non-commercial purposes. It runs on Linux, MS-Windows and OS X. It includes a console, a syntax-highlighting editor that supports direct code execution, as well as tools for plotting, history, debugging and workspace management. The tutorial was prepared using the R Markdown (Allaire 2015) authoring format that enables creating dynamic documents, presentations, and reports from R easily. It combines the core syntax of markdown (an easy-to-write plain text format) with embedded R code chunks to be executed, so their output can be included in the final document. R Markdown documents are fully reproducible (they can be automatically regenerated whenever the underlying R code or the data changes). RStudio has many features that make it easy to write and run R Markdown documents.

We strongly recommend trying to run the illustrating R codes. The online appendix (OH_2015_23(2)_163-188_appendix.zip) of this tutorial includes the scripts along with the entire code we used. We also recommend trying to write similar codes to work with your own data, because this is the only way to learn using R.

The `ringR` *package*

We prepared a specific R package, `ringR` including useful functions to handle ringing data (determine first capture events, calculate elapsed time between two capture events etc.) and to make specific plots (e.g. to plot capture frequencies). These functions can be used in other fields where similar capture-recapture data are collected. The `ringR` package can be downloaded from ringR.gryllosoft.hu along with the installation instructions (ringRinstall.pdf).

Technical comments for the codes and the data

R-codes, variable names, keywords or parameters – if these are in the text or in the examples – are differentiated by the font type used e.g. `t.test()`, `WING`, `AGE`, `alternative = 'two sided'`. Note that we only describe function arguments or parameters that we specifically used in the analyses. The functions generally have more parameters to set, please refer to their help page for a comprehensive description.

We used R 3.2.2 for the analysis and data preparation on the Ubuntu 14.04 platform. The codes were written with RStudio 0.98.1103.

How should a data table look like?

For data analysis, data should be organised into a table, including variables as columns and observations as rows. The first row should consist of the column headings (variable names, see *Box 3* for naming conventions). Each subsequent row has to have the same amount of data (columns). Make sure that your observations (records) and the individuals (typically ring number) both have unique identifiers. There should be nothing in the tables apart from your raw data.

We strongly discourage using the space (rather use the underscore "_" character instead) and unconventional characters like letters with accents, all mathematical ope-

Recommendations to name variables

Select simple but explanatory variable names using naming conventions compatible with the program that will be used for analysis. Each name in the data set must be unique. Begin variable names with a letter (A–Z). Variable names may include numbers, although not as the first character, but not blanks or other special characters (an underscore or point are valid). You may use upper and lowercase letters to suggest word separation or use decimal points or the underscore character. For example, BodyMass, Body.Mass, BODY_MASS or Body_mass are perfect names. The key is to remain consistent throughout the analysis. A good idea may be to differentiate original variables and newly created variables in the naming, for example we use capital letters for original and lower case lettering in newly derived variables.

Box 3. Recommendations to name variables
3. doboz Javaslatok a változók elnevezéséhez

rators like = or / in any part of the table, including the heading. Also avoid using thousand separators. These characters may be misinterpreted by the statistical software, causing an array of problems. Note that these rules hold also for file and folder names.

The simplest way to store data is saving it to a delimited text files (i.e. data in the text file are separated by a predefined field separator, such as a semicolon, comma, tab or space; the separator defines the columns seen in a spreadsheet editor).

Data used to illustrate the text

Through most of the text we are going to illustrate the procedures to process data originating from the bird ringing database of the Ócsa Bird Ringing Station found in central Hungary (Harnos *et al.* 2015a, Kovács *et al.* 2011, 2012). The area is a post-glacial relic bog, with an extensive central Reed-bed, surrounded by woodlands and shrubs. We demonstrate the concepts and practice using the data of the Pied Flycatchers *(Ficedula hypoleuca)* collected between 1984 and 2014 at Ócsa, a randomly selected subset of the dataset used in the paper 'Sex and age dependent migration phenology of the Pied Flycatcher in a stopover site in the Carpathian Basin' (Harnos *et al.* 2015b) published in the same volume of Ornis Hungarica (see description of the data there). In the accompanying online appendix of this paper you can find the dataset *(Box 6)* as it was exported from the Bird Ringing database of the Ócsa Bird Ringing Station (except that the variable names were translated to English). While the variable names of the original dataset *(Table 1)* are in uppercase, the names of the newly created variables are in lowercase.

Data manipulation in a Spreadsheet program

Cleaning data and preparing it for analysis is a tiresome, yet fundamental part of data analyses. Although it may seem that doing it in R is less effective yet we recommend that spreadsheet editors like Ms Excel or OpenOffice Calc (Elliott *et al.* 2006) only be used for tasks that (1) involve data entry, (2) do not need to be traced or reconstructed and (3) do not modify data values. For instance quite often values are entered and later deleted from cells during the data

Column	Variable name	Description (units)	Format	Codes and ranges	Missing values
A	ID	unique identification number of observation (record)	Numeric (6.0)	1–999999	
B	DATE	date of capture	Date (MM/DD/YYYY)	01/01/1989–12/31/2014	
C	RECAP	capture or recapture?	Numeric	0: first capture, 1: recapture	
D	RING	ring number	Text		
E	AGE	age of bird	Text (2)	*Table 2.*	null
F	SEX	sex of bird	Text (1)	F: female, M: male	null, N
G	FAT	fat score	Numeric (1.0)	0–8	null
H	MUSCLE	muscle score	Numeric (1.0)	0–3	null
I	MASS	body mass (g)	Numeric (3.1)	0–99	null, 0
J	WING	wing length (mm)	Numeric (2.0)	0–99	null, 0
K	THIRD	length of third primary (mm)	Numeric (2.0)	0–99	null, 0
L	TAIL	tail length (mm)	Numeric (2.0)	0–99	null, 0

Table 1. Description of the variables of Pied Flycatcher dataset
1. táblázat A kormos légykapó adattáblázat változói

entry process. MS Excel may store information in these cells, despite they remain visually empty. These nuisance values will either hinder data import to R or will cause empty rows or columns that are unnecessary. Getting rid of these is relatively easy, simply select the range of values you wish to keep (the dataset with valid information) and copy it to a new spreadsheet and save it as a text file (preferably .csv extension).

These editors can be also used safely to (1) merge data tables to one (providing that the number of rows is in a reasonable range), (2) changing the number of decimals and (3) changing unconventional characters described above.

Data cleaning and manipulating in R

Getting data into R

Setting the working directory

The working directory is a directory (folder) on a computer or on an external data storage device, including clouds where R searches, saves and loads files (data files, figures etc.). If the working directory is not specified, R works from the default working directory. Its location depends on the operating system and the function `getwd()` serves to find this location. The first task is to set the working directory to where all the data and script files are stored. For example, if data are in the `D:\mydirectory` directory under MS-Windows, then type:

```
>setwd("D:/mydirectory")
```

Note that the directory separator can either be "/" or "\\" (but not "\").

Importing data from a text file

Most statistical software can import and export text files. In R these can be imported with the generic `read.table()` function. However, we recommend checking the character encoding of your dataset, for instance by opening it with a simple text editor, such as Geany (open source text editor available for the major operating systems, www.geany.org). The encoding can be set by the `encoding` argument of the `read.table()` function (see `?read.table`). Also inspect (1) if there are variable names in the first row (`header = TRUE`); (2) the type of the field separator (in case of semicolon: `sep=';'`); (3) the decimal character (default: `dec='.'`); (4) the missing value character (default: `NA`, in our case: `na.string = 'null'`); (5) if there are row names in the first column of the file (default: `FALSE, row.names = TRUE`, if yes.); (6) if the character strings are quoted (default: `" or '`). For further settings refer to the R help (type `?read.table` and press Enter). The `read.table()` function returns a data frame, the most commonly used data structure in R (for details please refer to `introR.r` attached to this tutorial as an online appendix or see e.g. Venables 2015).

```
>mydata = read.table("FICHYP.csv",
 sep = ";", dec = ".", header = TRUE,
 na.string = c("null"))
```

Reading the data from Excel

Alternatively, use the `xlsx` package (Dragulescu 2014) to access Excel files. The first (and only the first!) row should include variable/column names. The sheet's index (`sheetIndex`) or the sheet's name (`sheetName`) has to be specified.

```
>library(xlsx)
>mydata = read.xlsx("FICHYP.xlsx",
  sheetIndex = 1)
```

Reading data from a database

One can also acquire data directly from a relational database if the necessary permissions are available. Basically, there are two ways to connect to databases in R. The first uses the ODBC (Open DataBase Connectivity) facility (`RODBC` package), the second uses the DBI package along with the specialized package needed to access that particular database (Spector 2008). Data from just about any relational database is accessible from R by sending an SQL query to the standard interfaces (R Core Team 2015b).

Overview of the data

Viewing the structure of the dataset

The internal structure of an R object can be compactly displayed with the `str()` function *(Box 4)*. For data frames, it shows the number of observations and variables and gives the type of the variables, and the first few values of these. The basic variable types are numeric (`num`), integer (`int`), factor (`Factor`), character (`char`) and logical (`logi`) etc. Note that these are somewhat different types as we previously defined *(Box 2, Table 1)*. For instance wing length (`WING` in our dataset) is typically measured to the nearest millimetre, hence it becomes an integer, while body mass (`MASS`) is often measured to the nearest 0.1 g, thus stored as a numeric variable. In case of quantitative variables, these deviations have little effect on further analyses. On the other hand, factor variables are used to store both nominal and ordinal categorical data. In case of numeric or character variables, `str()` lists the first few values. In case of factors, `str()` function gives the number of levels, the first few levels and the numeric codes of the first few observations. The numeric codes are integers from 1 to the number of levels and are given in the alphabetical order of the levels.

NOTE: If the imported data frame includes factors instead of numeric values, check (1) the settings used when reading the table; (2) if the correct character was used for specifying the decimal point; (3) if the correct character strings were used to specify missing values; (4) values in a numeric variable includes any characters other than figures (note that the letter `"o"` is NOT equivalent to the number `"0"`!). All different values of a factor variable can be listed using the `levels()` function with the name of the variable (e.g. `levels(mydata$MASS)`). If a factor appears as a numeric variable, than probably your categories were coded by numbers. For conversion to a factor, read the next chapter.

Conversions between numeric and factor variable types

The `as.numeric()` function converts factors (and other types) to numeric variables. Note that this function can NOT be applied to correct incorrectly entered or imported variables! We strongly recommend correcting the clearly mistyped values in the original data file itself and then reimporting the data with R.

The `as.factor()` (or simply `factor()`) function converts all types of variables (including numerics or integers) to factors. By default, values that cannot be converted to the specified type will be converted

```
# Structure of the table
>str(mydata)

'data.frame':1966 obs. of  12 variables:
 $ ID : int  115849 115577 115288 115650 ...
 $ DATE   : Factor w/ 929 levels "10/1/1993","10/9/1999",..: 169 607 636
100 254 ...
 $ RECAP : int  0 0 0 0 0 0 0 0 0 0 ...
 $ RING  : Factor w/ 1703 levels "2E5711","2E9089",..: 222 223 224 225 259
260 ...
 $ AGE   : Factor w/ 7 levels "1","1+","1Y",..: 3 3 3 6 3 3 3 3 6 6 ...
 $ SEX   : Factor w/ 3 levels "F","M","N": NA NA NA 2 NA NA NA NA 1 2 ...
 $ FAT   : int  0 2 2 0 3 1 2 4 1 0 ...
 $ MUSCLE: int  NA NA NA NA NA NA NA NA NA NA ...
 $ MASS  : num  11.4 13.3 13.2 12.6 14.4 12.3 13.2 12.2 12.3 13.1 ...
 $ WING  : int  NA NA NA 81 82 82 81 79 80 NA ...
 $ THIRD : int  NA NA NA NA NA NA NA NA NA NA ...
 $ TAIL  : int  NA NA NA 52 55 54 54 55 55 NA ...
```

Box 4. Structure of `mydata`
4. doboz A `mydata` struktúrája

```
>mydata$FAT = factor(mydata$FAT)
>str(mydata$FAT)

Factor w/ 7 levels "0","1","2","3",..: 1 3 3 1 4 2 3 5 2 1 ...

>mydata$MUSCLE = factor(mydata$MUSCLE)
>str(mydata$MUSCLE)

Factor w/ 4 levels "0","1","2","3": NA NA NA NA NA NA NA NA NA NA ...

>mydata$ID = factor(mydata$ID)
>str(mydata$ID)

Factor w/ 1966 levels "1120","1570",..: 636 634 633 635 591 594 586 589
588 593 ...
```

Box 5. Conversion of `FAT`, `MUSCLE` and `ID` to factors
5. doboz A `FAT`, `MUSCLE` és `ID` változók faktorrá konvertálása

to `NA` values with a warning. In our case, the `FAT` and `MUSCLE` variables are measured on ordinal scale and coded with numbers, thus looking like numeric variables. These should be converted to factors by using the `factor()` function. Often the ring number or other individual identifiers are also coded with numbers. These variables should be used as categorical and should be converted to factors. After conversion, DO check once again the structure of the variables with the `str()` function *(Box 5)*.

Viewing the table

Data frames can be opened, viewed and edited with the `fix()` function. If we want to inspect the first or last rows of the data frame, we can use the `head()` or `tail()` functions. The first parameter is the name of the dataset, the second (optional, with default value 6) is the number of rows displayed *(Box 6)*.

If we want to look at specific rows of the table, we just have to make a subset of it and submit the code. For example, if we want to look at the rows from 10 to 15, type: `mydata[10:15,]`. (For subsetting methods, check the `introR.r` script in the online appendix.)

Numerical summaries of the variables

Exploratory analyses are the first and among the most important steps in data analyses. These can help pin-point hidden anomalies such as incorrect data entry and can help the analyst familiarize to data patterns. We shall start with numerical summaries of the variables, by calling the `summary()` function with the name of the data frame. In case of factors, the `summary()` provides the frequencies for the first seven categories. In case of numeric or integer variables, it provides basic descriptive statistics: minimum (`Min.`), maximum (`Max.`), mean, the first quartile (`1st Qu.`), median and third quartile (`3rd Qu.`) values. The first quartile splits off the lowest 25% of data from the highest 75%, the median cuts the dataset in half and the third quartile splits off the highest 25% of data from the lowest 75%. The median gives a measure of the centre of the data, the minimum and maximum give the range of the data and the first and third quartiles give a

```
>head(mydata)

      ID      DATE RECAP   RING AGE  SEX FAT MUSCLE MASS WING THIRD TAIL
1 115849 7/19/1983     0 E03042  1Y <NA>   0   <NA> 11.4   NA    NA   NA
2 115577  8/7/1983     0 E03192  1Y <NA>   2   <NA> 13.3   NA    NA   NA
3 115288  8/9/1983     0 E03204  1Y <NA>   2   <NA> 13.2   NA    NA   NA
4 115650 4/29/1984     0 E24327  2Y    M   0   <NA> 12.6   81    NA   52
5 112284 8/14/1984     0 E47390  1Y <NA>   3   <NA> 14.4   82    NA   55
6 112623 8/21/1984     0 E48262  1Y <NA>   1   <NA> 12.3   82    NA   54
```

Box 6. Head of the data table
6. doboz Az adattáblázat eleje

sense of the spread of the data, especially when compared to the other values. The output also shows the number of missing values. In *Box 7*, we show the output of the `summary()` only for certain variables.

This output gives a quick overview of the data. Notice that we have invalid values in `MASS` like 0 (probably the missing values were coded by 0, which is a common mistake in data entry).

Extracting year and day of the year (`yearday`) from the `DATE` variable

Year and the number of days elapsed from a specified day of the year (often 1st of January) are usually needed for most analyses. Various original data files include a vast number of date formats and these probably have to be transformed. In our case, these variables can be extracted from the `DATE` variable e.g. by using the `ring.date()` function of the `ringR` package (see other R-packages such as `chron` to use other means of handling date and time data). The date variable (`DATE` in this example) can be set with `datevar` parameter.

The format (`format` parameter) of the date has to be specified. The `ring.date()` function tries to extract valid dates. A % code tells R to look for a range of substrings. For example, the `%d` indicator makes R look for numbers 1–31 where leading zeros are allowed, so 01 , 02 ,… 31 are recognized as well. The character that separates day, month and year (here '/') has to be specified: `%m` means the number of month (01–12), `%d` is the day of the month as decimal number (01–31), `%y` is the year without century (00–99) and – alternatively – `%Y` is the year including century. The `ring.date()` function extracts the year and day of the year from

```
>summary(mydata[,c('AGE', 'SEX','FAT', 'MASS','WING')])

  AGE         SEX           FAT            MASS            WING
 1  :   7   F   :622   Min.   :0.00   Min.   : 0.00   Min.   : 0.0
 1+ :  40   M   :943   1st Qu.:0.00   1st Qu.:11.90   1st Qu.:78.0
 1Y :1614   N   : 39   Median :1.00   Median :12.50   Median :80.0
 2  :  31   NA's:362   Mean   :1.47   Mean   :12.61   Mean   :79.2
 2+ :   3              3rd Qu.:2.00   3rd Qu.:13.20   3rd Qu.:81.0
 2Y : 251              Max.   :6.00   Max.   :81.00   Max.   :91.0
 FEJ:  20              NA's   :55     NA's   :74      NA's   :274
```

Box 7. Basic summary statistics of the dataset
7. doboz Az adattáblázat alapvető leíró statisztikái

the `datevar` (here `DATE`) variable and appends it to the original data frame.

```
>library(ringR)
>mydata = ring.date(
  data    = mydata,
  datevar = 'DATE',
  format  = "%m/%d/%Y")
```

Useful plots to explore the characteristics of migration

Determining captures and recaptures

To analyse the timing of migration, we need to determine the first captures of an individual of the specified year. The `RECAP` variable distinguishes only the capture of an unmarked individual from the capture of a marked one, thus annual first captures can not be determined with this variable. Therefore, we need to create new variable that distinguishes annual first captures and recaptures. This can be done with the `ring.firstcapture()` function of the `ringR` package. The name of the data frame, the `periodvar` (here: `year`) and `perioddayvar` (here: `yearday`) variables and the `IDvar` (here: `RING`) have to be set. The new variable is called `period.recap` and it is appended to the data frame.

```
>mydata = ring.firstcapture(
  data         =  mydata,
  periodvar    = 'year',
  perioddayvar = 'yearday',
  IDvar        = 'RING')
```

Yearly capture and recapture frequencies

It is often useful to visualize the number of captured birds per year. The `ringR` package provides the function `plot.periodic.captures()` that can create a graph depicting both annual capture and recapture frequencies *(Figure 1)*. Note that the `ydivider` parameter sets the interval lengths between tick marks on the y-axis.

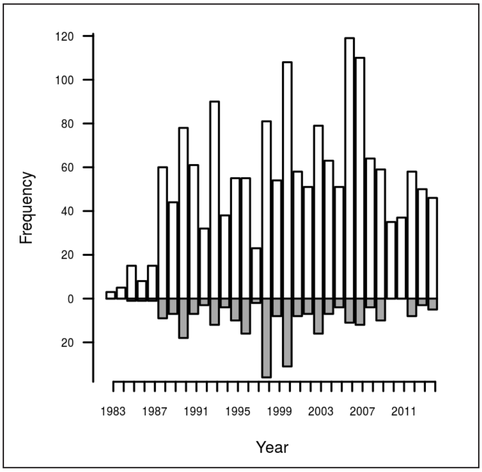


Figure 1. Yearly capture (white bars) and recapture (grey bars) frequencies
1. ábra Éves fogási (fehér oszlopok) és visszafogási gyakoriságok (szürke oszlopok)

```
>par(las=1, omi=c(0,0,0,0),
  mar=c(4, 4, 2, 2) + 0.1, bty='l')
>plot.periodic.captures(
  data          = mydata,
  periodvar     = 'year',
  perioddayvar = 'yearday',
  recapvar      = 'period.recap',
  ydivider      = 20  )
```

We used the `par()` function to change the default layout and graphical settings prior to calling the plotting function. Please refer to the help of the `par()` function for further details. This layout setting is used in case of all further plots in the tutorial.

Daily capture and recapture frequencies

Pied Flycatchers are thought to migrate in two distinct migration waves at the study site. A potential way to corroborate this assumption is to plot the distribution (frequen-

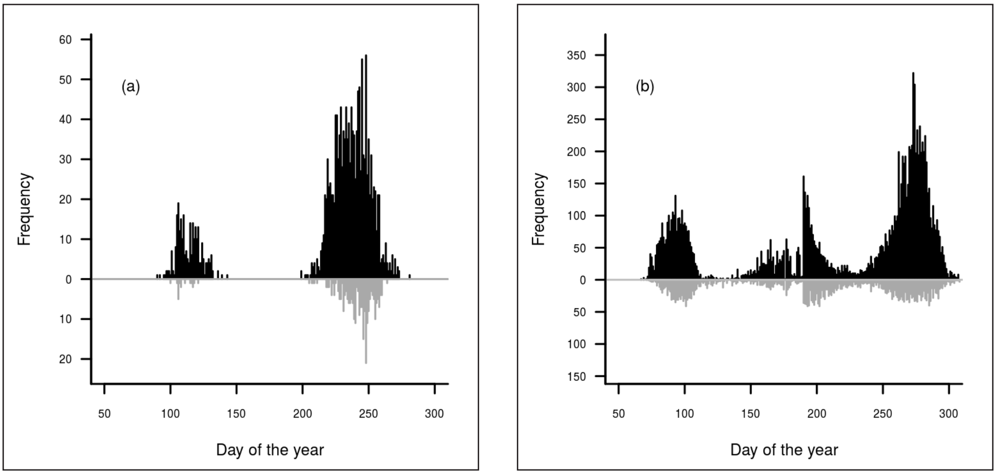


Figure 2. Daily first capture (black bars above 0) and recapture (gray bars below 0) frequencies in case of Pied Flycatchers (a) and Chiffchaffs (b)

2. ábra Napi fogási (fekete vonalak a 0 felett) és visszafogási (szürke vonalak a 0 alatt) gyakoriságok a kormos légykapó (a) és a csilpcsalpfüzike (b) esetén

cies) of dates (`yearday`) separately for captures (`period.recap == 0`) and recaptures (`period.recap == 1`). This can be done by the `plot.daily.captures()` function.

```
>plot.daily.captures(
  data         = mydata,
  perioddayvar = 'yearday',
  recapvar     = 'period.recap',
  ylim = c(0,0), xlim = c(50,300),
  xlab = "Day of the year",
  ylab = "Frequency",
  cap.color = "black",
  recap.color = "darkgray",
  ydivider = 10, title = NULL)
```

Figure 2a shows first capture and the recapture frequencies of a given day of the year. Indeed, there are no trapped individuals between the 150th and the 180th day of the year, indicating that the data can be grouped into two distinct seasons. To illustrate a species with a different behaviour at the study site, we included the Chiffchaffs *(Phylloscopus collybita)* (*Figure 2b*, data and code are not included). Chiffchaff capture frequencies show three overlapping waves: spring migration (days 70–110), breeding/dispersion (days 111–240) and autumn migration (days 241–310). Notice that seemingly there is an abrupt change in capture frequencies during the breeding season. This is caused by the sampling design, as CES protocol (a fraction of the nets is open each day) is applied in the first half of this period, while from the 190th day all nets were open until the end of the migratory period.

Cumulative capture dates

Another useful graph is the cumulative distribution of the date of first and last captures *(Figure 3a, b)*. For each individual, a horizontal black bar shows the time elapsed between the first and last captures at the study site. The individuals are ordered according to first capture dates. This graph may allow to simultaneously depict migration waves and stopover durations. The lack of data between the 150th and 180th days of the year is just as apparent as in the case of the previous

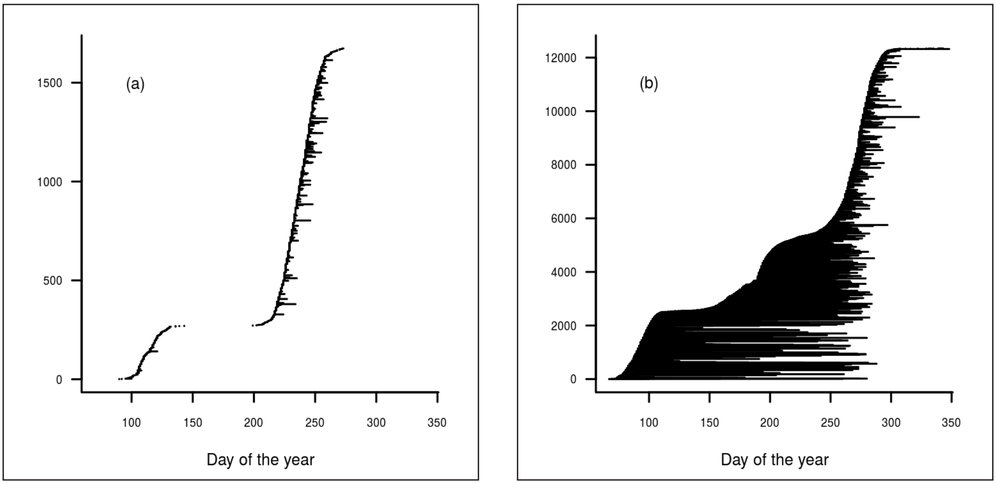


Figure 3. Cumulative distribution of the date of first captures depicted together with the last capture dates in case of Pied Flycatchers (a) and Chiffchaffs (b)

3. ábra Az első és utolsó megfogások (vízszintes vonalak) kumulatív eloszlása a kormos légykapó (a) és a csilpcsalpfüzike (b) esetén

graph showing capture frequencies, while we can also see that there is probably a considerable difference in stopover duration in spring and autumn. For Chiffchaffs *(Figure 3b)* there is no gap in the pattern indicating a continuous presence of the species, and a considerable proportion of the individuals arriving in spring remains at the study site through the trapping period. The changes in the rate of increase in the number of captured birds (the "steepness" of the cumulative curve) show the three previously identified waves.

These two figures allow the analyst to get a detailed overview of the basic species-specific annual behaviour pattern at a given study site. We recommend using both graphs simultaneously.

```
>plot.cum.captures(
  data         = mydata,
  IDvar        = 'RING',
  periodvar    = 'year',
  perioddayvar = 'yearday')
```

Defining migratory seasons

It may be important to separate observations belonging to the spring and autumn migratory phases, or any other predefined periods. Based on *Figures 2a* and *3a* the 150th day seems to be a reasonable cut-off point. Define a new variable called `season` using the `ifelse()` function. This function has the form `ifelse(test, yes, no)` `test` is the logical condition, `yes` is what will be returned if the logical condition `test` is true, and `no` is what will be returned when false. Note that the arguments of the `ifelse()`, as well as many other R functions can also be specified by just writing the values of the arguments following one another according to the help of the given function, without actually referring to the argument's name:

```
>ifelse(mydata$yearday < 150,
  "spring", "autumn")
```

It is not necessary to follow this order when referring to the arguments' names:

```
>ifelse(yes = "spring",
  no = "autumn",
  test = mydata$yearday < 150)
```

We need to convert the type of the resulting variable to a factor.

```
>mydata$season = ifelse(
  test = mydata$yearday < 150,
  yes  = "spring",
  no   = "autumn")
>mydata$season = factor(mydata$season)
```

Checking and exploring categorical variables

We can check the levels and the number of levels of a factor and the counts in the categories with the following codes:

```
>levels(mydata$AGE)
[1] "1" "1+" "1Y" "2" "2+" "2Y" "FEJ"

>nlevels(mydata$AGE)
[1] 7

>table(mydata$AGE)
1   1+   1Y     2   2+   2Y  FEJ
7   40 1614    31    3  251   20
```

The levels are overlapping and ambiguous as the same age classes were coded with different characters *(Table 2)*. Correct these mistakes and recode the variable so that corresponding age classes are represented with the same character string. For records where the age was 1st calendar year we change the values `1` to `1Y` using the `ifelse()` function. Note, that without the `as.character()` function inside the `ifelse()`, the `AGE` variable gets the numeric codes of the original factor. After such recoding, the variable has to be converted to factor again, using the `factor()` function. (2nd calendar year birds can be recoded in a similar fashion, see the online appendix.)

Code	Definition
1Y	first calendar year birds, hatched in the year of ringing
1+	older than a calendar year, exact age unknown
2Y	second calendar year birds, hatched in the year preceding ringing
2+	older than two calendar years, exact age unknown
FEJ	fully grown, otherwise undetermined
1	first calendar year birds, hatched in the year of ringing
2	second calendar year birds, hatched in the year preceding ringing

Table 2. Age class codes with definitions
2. táblázat Kor kategóriák és definícióik

Warning! Recoding the original variable of a dataset is best avoided. In order to avoid damaging your original variable, we strongly recommend creating a new variable instead.

```
>mydata$AGE = ifelse(
  test = mydata$AGE == "1",
  yes  = "1Y",
  no   = as.character(mydata$AGE))
>mydata$AGE = factor(mydata$AGE)
#cheking the levels of the variable
>levels(mydata$AGE)

[1] "1+" "1Y" "2" "2+" "2Y" "FEJ"
```

Quite often, we only need to differentiate two age categories; juveniles (birds hatched in the year of ringing) and adults (all other birds where age is determined). Again, using the `ifelse()` function we can create a new variable where age will be recoded to the `juv` and the `adult` levels. The first call of the command function creates a new variable (`age`) in which records that are coded with `1Y` in the `AGE` variable become `juv` all other records will be `NA`. The second `ifelse()` call takes the new `age` variable and recodes it so as `1+`, `2+` and `2Y` records become `adult`, all others remain either `NA` or `juv`. (The | symbol is used for the OR logical operator in R.) Notice that the age values for the birds with undetermined age categories (`2` and `FEJ`) now are `NA`-s in the new variable.

```
>mydata$age = ifelse(
  test = mydata$AGE == "1Y",
  yes  = "juv",
  no   = NA)
>mydata$age = ifelse(
  test = mydata$AGE == "1+" |
         mydata$AGE == "2Y" |
         mydata$AGE == "2+",
  yes  = "adult",
  no   = mydata$age)
```

Repeat this process with the `SEX` factor. `N` denotes `NA` in this case, so we recode `N` to `NA`:

```
>levels(mydata$SEX)

[1] "F" "M" "N"

>mydata$SEX = ifelse(
  test = mydata$SEX == "N",
  yes  = NA,
  no   = as.character(mydata$SEX))
>mydata$SEX = factor(mydata$SEX)
```

Contigency tables

Contingency tables provide counts of records in category combinations of two variables. The `table()` function can create contingency tables by giving two (or more) categorical variables in the arguments. Applying the `prop.table()` function to a contingency table yields relative frequencies of cell counts. These ratios can be calculated against row totals (`margin = 1`), column totals (`margin = 2`) and the grand total (default).

```
#contingency table
>table(mydata$age, mydata$SEX)
          F   M
  adult  95 179
  juv   522 761

#relative frequencies according to
#row totals
>prop.table(
  table(mydata$age, mydata$SEX),
  margin = 1)
                F         M
  adult 0.3467153 0.6532847
  juv   0.4068589 0.5931411
#relative frequencies according to
#coloumn totals
>prop.table(
  table(mydata$age, mydata$SEX),
  margin = 2)
                F         M
  adult 0.1539708 0.1904255
  juv   0.8460292 0.8095745
#relative frequencies
>prop.table(
  table(mydata$age, mydata$SEX))

                 F          M
  adult 0.06101477 0.11496468
  juv   0.33526012 0.48876044
```

Visual overview of categorical variables

Visual inspection of the number of records by factor levels (frequency distribution) is useful to discover interesting patterns. For a single factor the `barplot()` function creates a bar graph, while the `mosaicplot()` can be used to visualize the relationship of two categorical variables. `barplot()` should be used with the frequency, while

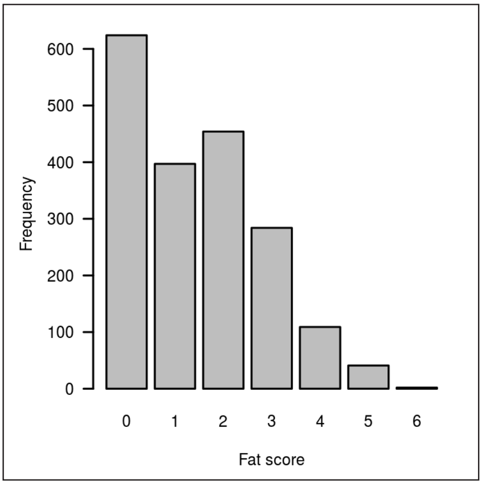


Figure 4. Barplot to visualize the number of records by factor levels
4. ábra Oszlopdiagram a faktorszintenkénti rekordszám bemutatására

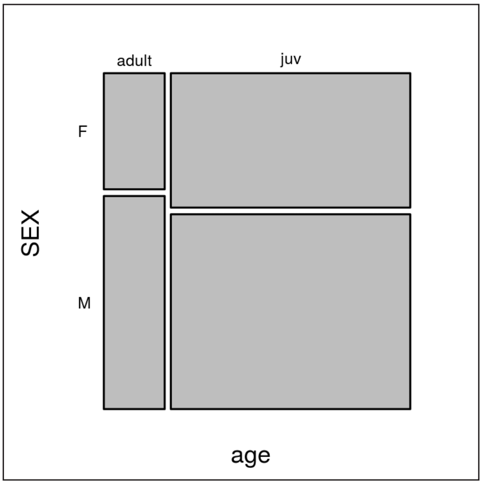


Figure 5. Mosaicplot to visualize the relationship of two categorical variables
5. ábra Mozaikábra két kategóriás változó kapcsolatának bemutatására

`mosaicplot()` with the contingency table. A mosaic plot is an area proportional visualization of a contingency table. It is composed of tiles (corresponding to the cells) created by recursive horizontal and vertical splits of a rectangle. The area of each tile is proportional to the corresponding cell entry (number of observations), given the dimensions of previous splits.

```
>barplot(
  table(mydata$FAT),
  xlab = "Fat score",
  ylab = "Frequency")
>with(mydata[mydata$RECAP == 0,],
  mosaicplot(table(age, SEX),
    main = ""))
```

We show the fat scores (`FAT`) of all observations in the dataset *(Figure 4)*. The `FAT` score is 0 for most observations, and the number of observations decreases with higher scores. In contrast, the mosaicplot *(Figure 5)* shows the proportions of the newly created age categories (horizontal split). Note that we used the `with()` function to create the plot only for a subset of the original dataset. The first argument of the `with()` is the row-wise selection of first captures, while the second argument is the `mosaicplot()` function call. Within the `mosaicplot()` call, only the variable names (without the `$` reference) are given. The rectangles of the age classes are further split vertically in proportion to the sex ratio: the majority of the observations are juveniles and sex ratios between age classes are similar, although slightly biased to males, indicating that sex and age are presumably independent of each other.

Checking and exploring numeric variables

Previously we have seen how the `summary()` call returns the basic descriptive statistics of the variables. It is often necessary to work with individual variables and specific statistics (`min()`, `max()`, `mean()`, `median()`,

```
>which(mydata$MASS > 20)

[1] 1240 1410

>xx = which(mydata$MASS > 20)
#List the cases
#First column: row numbers in the output
>mydata[xx,]

          ID      DATE RECAP    RING AGE SEX FAT MUSCLE MASS WING THIRD
 1240 244759  8/7/2004     0 T373846  1Y   M   2      2 81.0   81    61
 1367 355719 4/29/2006     0 T468033   2   F   0      2 23.2   78    60
      TAIL year yearday period.recap season  age
 1240   NA 2004     219            0 autumn  juv
 1367   54 2006     118            0 spring <NA>
```

Box 8. Listing the row numbers of the cases and the whole records where the `MASS` is above 20 grams
8. doboz Az esetek száma és a teljes rekordok kilistázása `MASS` > 20 gramm esetén

`sd()` and `var()`) can be used similarly. For instance we wish to check the range (minimum and maximum values) of the `MASS` variable.

```
>range(mydata$MASS, na.rm = TRUE)
[1] 0 81
```

Surprisingly, there are records of birds with 0 mass in the dataset. We can also count the number of records where mass is 0 with the `nrow()` function. Quite often missing values are coded with 0 instead of a specific character string. The problem is that the 0 will be recognized as a valid measurement and hence influence all derived descriptive statistics, models etc. Changing these values to `NA`-s is essential and easy with the `ifelse()` function. We highly recommend avoiding the use of 0-s instead of `NA`-s (or `null`-s in case of databases) in your own data tables.

```
>nrow(mydata[mydata$MASS == 0,])
[1] 80
>mydata$MASS =
  ifelse(
    test = mydata$MASS == 0,
    yes  = NA,
    no   = mydata$MASS)
```

Note that in case of a numeric variable, we do not use the `as.character()` in `ifelse()`. The upper limit of the range of the `MASS` variable is also troubling. Body mass of Pied Flycatchers seldom exceeds 20 g, thus 81 g is practically impossible. List the row numbers of the cases which are above 20 grams with the `which()` function. We save these numbers to a vector called `xx` *(Box 8)*.

We recommend listing the whole records with suspicious values to be able to check all other measurements and characteristics belonging to the same capture event. In this case we can immediately recognise that the `WING` length value was recorded as `MASS`.

Suspicious and obviously mistyped data should be checked and corrected, or – if we cannot correct it – should be excluded from further analyses. However, we strongly recommend recording and documenting all exclusions. In this case, checking the ringing notes revealed that the suspicious values were in fact data entry errors. The correct values are 15.5 and 13.2, respectively, and the data frame should be corrected accordingly. Change these simply by assigning the new values individually (if a value

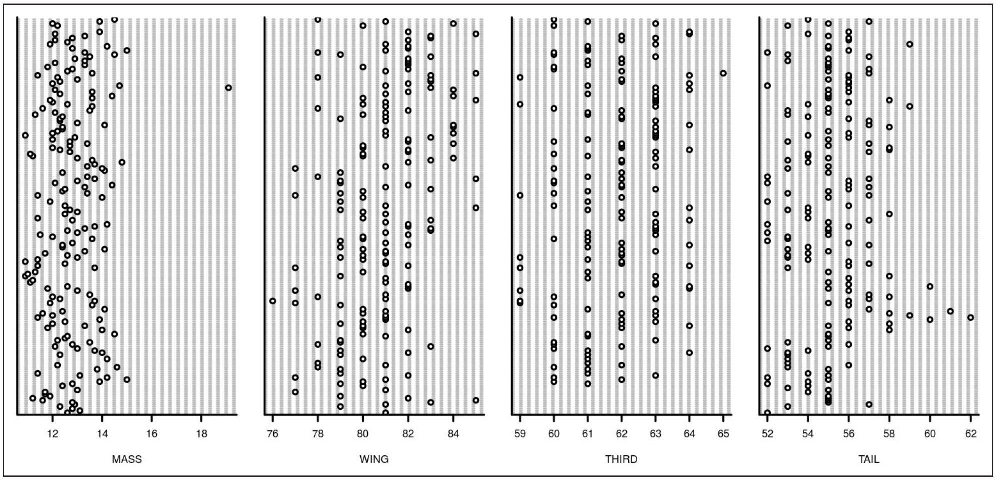


Figure 6. Cleveland dotplots of the `MASS`, `WING`, `THIRD` and `TAIL` variables for the adult male birds in spring

6. ábra Cleveland pontábrák a `MASS`, `WING`, `THIRD` és `TAIL` változókra tavasszal, az öreg hím madarak esetén

should be deleted, type `NA` instead). We can read the IDs of the observations from the previous output.

```
>mydata[mydata$ID ==
         244759,]$MASS = 15.5
>mydata[mydata$ID ==
         355719,]$MASS = 13.2
```

Note, that the safest method to change a certain value in a specific record is using the record identifier to select it. Consider also the rest of the numeric variables: `WING`, `THIRD` and `TAIL`. In all cases zeros should be changed to `NA`-s, and should be checked similarly (see online appendix).

Plotting the values

Although we have already cleaned our numerical values of obvious problems, there may still be errors or suspicious values remaining. Using graphical tools can be rewarding in identifying such records.

Cleveland dotplots

One of the most useful visualization tools are Cleveland dotplots (Cleveland 1993). Here, the row number of an observation (vertical axis) is plotted versus its value (horizontal axis). This graph should be prepared for relatively small subsets of the data and it is useful to make this graph for several variables simultaneously. We plot the `MASS`, `WING`, `THIRD` and `TAIL` values of the spring observations *(Figure 6)*. For shortening the code, we first create a subset of the spring male records. Note that we use the `par(mfrow = c(1,4))` function to get four graphs in a row.

```
>mydata.spring.M = mydata[
  mydata$season == "spring" &
    mydata$SEX == "M",]
#Creating multiple Cleveland dotplots
>par(mfrow = c(1,4))
>with(mydata.spring.M,
  dotchart(MASS, xlab = "MASS"))
>with(mydata.spring.M,
```

```
  dotchart(WING, xlab = "WING"))
>with(mydata.spring.M,
  dotchart(THIRD, xlab = "THIRD"))
>with(mydata.spring.M,
  dotchart(TAIL, xlab = "TAIL"))
>par(mfrow = c(1,1))
```

A suspicious value can be identified on the `MASS` plot. Since it is the only value above 18 grams, and the rest of the measurements of this bird are not out of range, the suspicious value have to be found and checked *(Box 9)*. Checking the ringing notes showed that this value is valid, so we leave it in the dataset. Note that there are suspicious values on the other plots. You can find the codes of the detailed inspection and correction of these in the online appendix.

The distribution of the values

In the next step, we check the distribution of the `MASS` variable. The distribution of a variable is essentially how the values are spread across its range. Visually exploring distributions allows the analyst to observe the shape (e.g. skewness, modality), the range and the most frequently observed values. There are several graphical tools to visualize distributions, all grasping different aspects of the data. Here we describe the most commonly used types.

Histogram

The range of values is partitioned into several adjacent and nonoverlapping intervals (bins) and the number of observed values in each interval (frequency) or its ratio to the total number of observations (relative frequency) are recorded. If we draw a rectangle above each interval with an area proportional to the frequency or relative frequency (set `freq = F` in the `hist()` function) of the interval, the resulting graph is called histogram. The `main = "Males"` argument creates the title of the histogram. Distributions should be investigated in each major group separately. We show the graphs for the first captures (`RECAP == 0`) of the juvenile male and female groups collected during the autumn migration. In this case, the conditions are connected with `&` (AND) operator which means that all the conditions must be true simultaneously. When visualizing more than one group of observations, it is essential to scale the corresponding axes and the number of bins identically in the two graphs. Here we used the generic arguments `xlim`, `ylim` and `breaks` to set the limits of the axes' range and the number of bins. The number of bins influences the appearance of the plot considerably and often the default settings have to be adjusted. We advise to try several settings.

```
>xx = which(mydata[
  mydata$season == "spring",]$MASS > 18)

>mydata[mydata$season == "spring",][xx,]

         ID      DATE RECAP   RING AGE SEX FAT MUSCLE MASS WING THIRD TAIL
 1469 500595 4/19/2007    NA 8E1095  2Y   M   2      2 19.1   83    63   56
      year yearday period.recap season   age
 1469 2007     108            0 spring adult
```

Box 9. Listing row number and record where `MASS` is above 18 grams
9. doboz Sorszám és teljes rekord `MASS>`18 gramm esetén

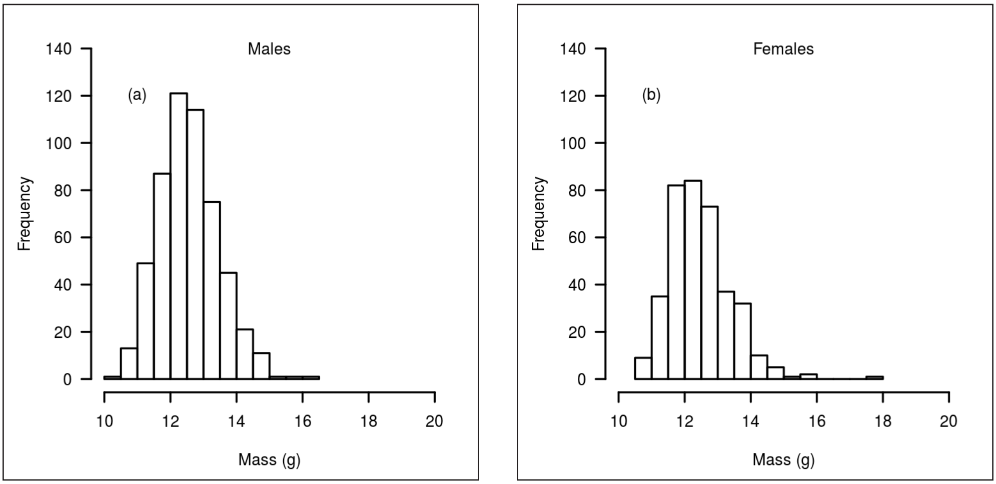


Figure 7. Histogram of `MASS` in case of juvenile male (a) and female (b) birds captured in autumn
7. ábra A `MASS` változó hisztogramja az ősszel megfogott fiatal hímek (a) és tojók (b) esetén

```
>with(mydata[
  mydata$RECAP  == 0 &
  mydata$age    == "juv" &
  mydata$SEX    == "M" &
  mydata$season == "autumn",],
  hist(MASS, main = "Males",
    xlim   = c(10,20),
    ylim   = c(0,140),
    breaks = 20,
    xlab   = "Mass (g)"))
>with(mydata[
  mydata$RECAP  == 0 &
  mydata$age    == "juv" &
  mydata$SEX    == "F" &
  mydata$season == "autumn",],
  hist(MASS, main = "Females",
    xlim   = c(10,20),
    ylim   = c(0,140),
    breaks = 20,
    xlab   = "Mass (g)"))
```

The two histograms *(Figure 7a, b)* show that slightly more males were observed than females as we have previously seen on the mosaicplot *(Figure 5)*. Also notice that the shape of both distributions are similar, both are unimodal (one peak) and more or less symmetrical. There are also a couple of odd, relatively large values on the right hand side of both histograms. These should be handled with caution but bear in mind that when measuring body mass, gut and crop load can have a substantial effect on individual values. These values are within the range of values acceptable for the species. There is no indication that other factors are causing this pattern.

Smoothed histogram

Another useful plot is the smoothed histogram. This is frequently more informative than the traditional version. With this technique small curve segments are calculated for each observation and these segments are then added up resulting in a smooth function (Ieno & Zuur 2015). We can plot individual values on the x axis with the `rug = TRUE` (default) parameter. We use the `densityPlot()` function of the `car` package (Fox & Weisberg 2011) and plot the density of `MASS` in the two sexes separately with the `MASS ~ SEX` formula for the captures of juveniles in autumn. A useful argument

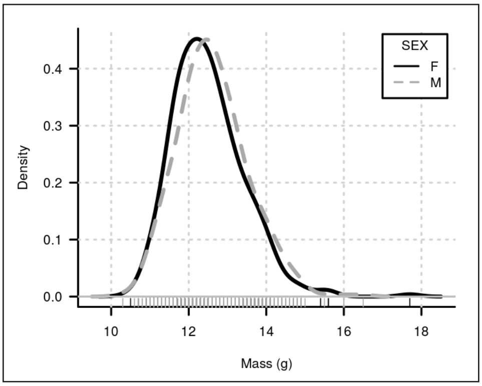


Figure 8. Smoothed histograms of `MASS` of juvenile birds captured in autumn
8. ábra A `MASS` változó simított hisztogramja az ősszel megfogott fiatal madarak esetén

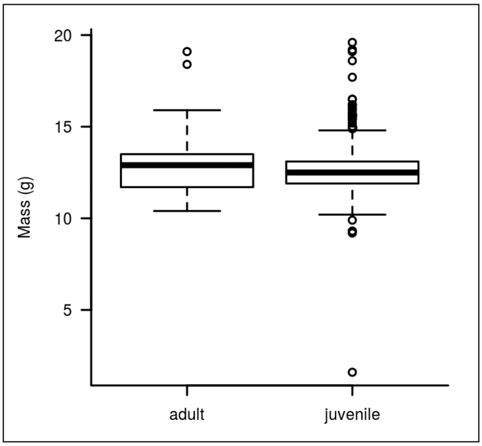


Figure 9. Boxplots of `MASS` by age groups
9. ábra A `MASS` változó korcsoportonkénti boxplotjai

that may be adjusted is the bandwidth (`bw`) parameter which controls the amount of smoothing, please refer to the help page of `densityPlot()`.

```
>library(car)
>with(mydata[mydata$RECAP == 0 &
  mydata$age == "juv" &
  mydata$season == "autumn",],
  densityPlot(MASS ~ SEX,
    xlab = "Mass (g)"))
```

Creating the smoothed histograms of males and females on the same plot reveals *(Figure 8)* that there may be a slight difference in body mass in the two groups. This would have been more difficult to observe using the traditional histograms.

Boxplot

The next useful graph is the boxplot (box and whiskers plot): the bottom and top of the box are the first and third quartiles and the band inside the box is the median. The ends of the whiskers may represent different values. The default in R: the lowest value is still within 1.5 IQR (Interquartile range: `3rd Qu.-1st Qu.`) of the lower quartile, and the highest value is still within 1.5 IQR of the upper quartile. The values outside the

```
>which(mydata$MASS < 5)

[1] 1704

>mydata[which(mydata$MASS < 5),]

          ID     DATE RECAP   RING AGE SEX FAT MUSCLE MASS WING THIRD TAIL
 1708 583178 9/7/2009     1 W59225  1Y   M   2      2  1.6   NA    NA   NA
      year yearday period.recap season age
 1708 2009     249            1 autumn juv
```

Box 10. Listing row number and record where `MASS` is less than 5 grams
10. doboz Sorszám és teljes rekord `MASS<5` gramm esetén

whiskers are suspicious points. Here we depict `MASS` by age groups *(Figure 9)*.

```
>with(mydata[
  mydata$season == "autumn",],
  boxplot(MASS ~ age,
    ylab  = "Mass (g)",
    names = c("adult", "juvenile")))
```

Check the obviously too small value in the juvenile male group *(Box 10)*.

Checking the ringing notes revealed that the decimal point was misplaced. Correct and recreate the figure but this time group the data by the `AGE` and `SEX` variables *(Figure 10)*. Note that with the `varwidth = TRUE` setting, the width of the boxes are proportional to the square-roots of the subgroup sample sizes.

```
>mydata[mydata$ID ==
        "583178",]$MASS = 16
>with(mydata[mydata$season ==
        "autumn",],
  boxplot(MASS ~ age:SEX,
    ylab     = "Mass (g)",
    varwidth = TRUE))
```

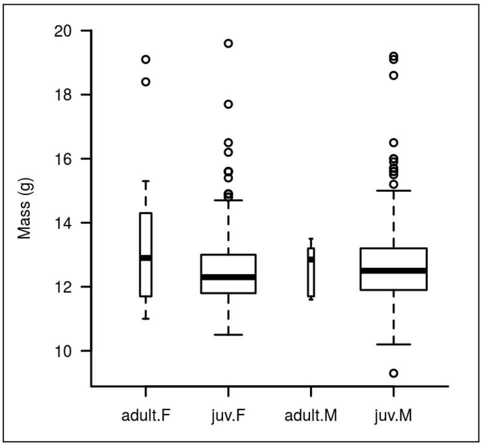


Figure 10. Boxplots of `MASS` by age and `SEX` groups in autumn

10. ábra A `MASS` változó boxplotjai az őszi kor- és ivarcsoportonként

Final steps

Checking, screening and cleaning your data is a process of repeated cycles. Each time you make a decision on changing a value, it is strongly advised to rerun your codes to see how it altered the entire data structure. Saving your changes is essential, however we advise to create multiple versions of your dataset (e.g. by using version numbers in the file name), instead of overwriting the same file over and over again. Saving a text file from R can be done with the `write.table()` function. The first parameter is the data frame to be saved, then we have to specify the name of the file (`file`), the field separator (`sep`) and the decimal symbol (`dec`). Use the `quote = FALSE` setting to avoid surrounding the character or factor values by double quotes, and the `row.names = FALSE` setting to avoid writing the row names into the output file.

```
>write.table(mydata,
  file      = 'FICHYP_corr_1.csv',
  sep       = ';',
  dec       = '.',
  quote     = FALSE,
  row.names = FALSE)
```

Concluding remarks

The quality of your results substantially depends on having error free and consistent data suitable to analyse. Every data set is different, therefore the methods described in this tutorial will not fit perfectly to all of them. However, the logic of data cleaning presented here may serve as a guideline in how to carry out this task. We plan to maintain a continuous development of the `ringR` package, therefore we welcome bug reports, comments and ideas on development to the corresponding author's address.

Acknowledgments

The authors express their gratitude for the work of all the volunteers who collected data at the Ócsa Bird Ringing Station throughout the years. We are grateful for Márton Demeter for helping in compiling the scripts for the `ringR` package. We also thank our colleagues – especially János Kis and Imre Sándor Piross – who helped us improve earlier versions of this manuscript. This work was supported by OTKA under Grant No. 108571.

References

Allaire, J. J., Cheng, J., Xie, Y., McPherson, J., Chang, W., Allen, J., Wickham, H. & Hyndman, R. 2015. rmarkdown: Dynamic documents for R. R package version 0.5.1. – http://CRAN.R-project.org/package=rmarkdown

American Statistical Association 1999. Ethical guidelines for statistical practice. – Alexandria (Virginia): American Statistical Association. Available: http://www.amstat.org/profession/index.cfm?fuseaction=ethicalstatistics

Brown, M. & Oschadleus, D. 2008. The ongoing role of bird ringing in science – a review. – In: Harebottle, D. M., Craig, A. J. F. K., Anderson, M. D., Rakotomanana, H. & Muchai, M. (eds.) Proceedings of the 12th Pan-African Ornithological Congress, pp. 6–8.

Cleveland, W. S. 1993. Visualizing data. – Hobart Press, Summit, NJ., pp. 346

Crewe, T. L., McCracken, J. D., Taylor, P. D., Lepage, D. & Heagy, A. E. 2008. The Canadian Migration Monitoring Network-Réseau canadien de surveillance des migrations: ten-year report on monitoring landbird population change. – CMMN-RCSM Scientific Technical Report No. 1. Bird Studies Canada, Port Rowan, Ontario, pp. 69

Dearborn, D. C. & Kark, S. 2010. Motivations for conserving urban biodiversity. – Conservation Biology 24(2): 432–440. DOI: 10.1111/j.1523-1739.2009.01328.x

de Jonge, E. & van der Loo, M. 2013. An introduction to data cleaning with R. – Statistics Netherlands, The Hague, pp. 53.

Dingemanse, N. J., Both, C., Van Noordwijk, A. J., Rutten, A. L. & Drent, P. J. 2003. Natal dispersal and personalities in Great Tits *(Parus major)*. – Proceedings of the Royal Society of London B: Biological Sciences 270(1516): 741–747. DOI: 10.1098/rspb.2002.2300

Dragulescu, A. A. 2014. xlsx: Read, write, format Excel 2007 and Excel 97/2000/XP/2003 files. R package version 0.5.7. – http://CRAN.R-project.org/package=xlsx

Elliott, A. C., Hynan, L. S., Reisch, J. S. & Smith, J. 2006. Preparing data for snalysis using microsoft excel. – Journal of Investigative Medicine 54(6): 334–341. DOI: 10.2310/6650.2006.05038

Fox, J. 2005. The R Commander: A basic-statistics graphical user interface to R. – Journal of Statistical Software 19(9): 1–42. DOI: 10.18637/jss.v014.i09

Fox, J. & Weisberg, S. 2011. An {R} Companion to applied regression. 2nd ed. – Thousand Oaks CA. Sage, pp. 472

Fowler, J. & Cohen, L. 1996. Statistics for ornithologists. – British Trust for Ornithology, pp. 155

Freedman, D., Pisani, R. & Purves, R. 2007. Statistics. 4th ed. – W. W. Norton and Company, inc. New York, pp. 697

Greenwood, J. J. D. 2009. 100 years of ringing in Britain and Ireland. – Ringing & Migration 24(3): 147–153. DOI: 10.1080/03078698.2009.9674385

Harnos, A., Ágh, N., Kovács, Sz., Lang, Zs. & Csörgő, T. 2015a Increasing protandry in the spring migration of the Pied Flycatcher *(Ficedula hypoleuca)* in Central Europe. – Journal of Ornithology 156(2): 543–546. DOI 10.1007/s10336-014-1148-3

Harnos, A., Lang, Zs., Fehérvári, P. & Csörgő, T. 2015b Sex and age dependent migratory phenology of the Pied Flycatcher in a stopover site in the Carpathian Basin. – Ornis Hungarica 23(2): 10–19. DOI: 10.1515/orhu-2015-0010

Ieno, E. N. & Zuur, A. F. 2015. A beginner's guide to data exploration and visualisation with R. – Highland Statistics Ltd. Newburgh, pp. 160

Kovács, Sz., Csörgő, T., Harnos, A., Fehérvári, P. & Nagy, K. 2011. Change in migration phenology and biometrics of two conspecific *Sylvia* species in Hungary. – Journal of Ornithology 152(2): 365–373. DOI: 10.1007/s10336-010-0596-7.

Kovács, Sz., Csörgő, T., Harnos, A., Fehérvári, P. & Nagy, K. 2012. Changes in migration phenology and biometrical traits of Reed, Marsh and Sedge Warblers. – Open Life Sciences 7(1): 115–125. DOI: 10.2478/s11535-011-0101-1

Nowakowski, J. 2003. Catch numbers at ringing stations is a reflection of bird migration intensity, as exemplified by autumn movements of the Great Tit *(Parus major)*. – Ring 25(1–2): 3–15. DOI: 10.2478/v10050-008-0070-6

Osenkowski, J. E., Paton, P. W. C. & Kraus, D. 2012. Using long-term constant-effort banding data to monitor population trends of migratory birds: a 33-year assessment of adjacent coastal stations. – The Condor 114(3): 470–481. DOI: 10.1525/cond.2012.110169

Peach, W. J., Baillie, S. R. & Balmer, D. E. 1998. Long-term changes in the abundance of passerines in Britain and Ireland as measured by constant effort mist-netting. – Bird Study 45(3): 257–275. DOI: 10.1080/00063659809461098

Peach, W. J., Baille, S. R., & Buckland, S. T. 2004. Current practices in the British Trust for Ornithology Constant Effort Sites Scheme and comparisons of temporal changes in mist-net captures with changes in spot-mapping counts at the extensive scale. – Studies in Avian Biology. 29: 46–56.

Pilastro, A., Macchio, S., Massi, A., Montemaggiori, A. & Spina, F. 1998. Spring migratory routes of eight trans-Saharan passerines through the central and western Mediterranean; results from a network of insular and coastal ringing sites. – Ibis 140(4): 591–598. DOI: 10.1111/j.1474-919X.1998.tb04704.x

Preuss, N. O. 2001. Hans Christian Cornelius Mortensen: aspects of life and of the history of bird ringing. – Ardea 89(special issue): 1–6.

R Core Team 2015a R: A language and environment for statistical computing. – R Foundation for Statistical Computing, Vienna, Austria, https://www.R-project.org/.

R Core Team 2015b R Data Import/Export. – R Foundation for Statistical Computing, Vienna, Austria, https://www.R-project.org/.

Reiczigel, J., Harnos, A. & Solymosi, N. 2014. Biostatisztika nem statisztikusoknak [Biostatistics for non statisticians]. – Pars Kft., Budapest, pp. 462. (in Hungarian)

Robinson, R. A., Baillie, S. R. & Crick, H. Q. 2007. Weather dependent survival: implications of climate change for passerine population processes. – Ibis 149(2): 357–364. DOI: 0.1111/j.1474-919X.2006.00648.x

Robinson, R. A., Julliard, R. & Saracco, J. F. 2009. Constant effort: studying avian population processes using standardised ringing. – Ringing and Migration 24: 199–204. DOI: 10.1080/03078698.2009.9674392

Shahbaba, B. 2012. Biostatistics with R. – Springer-Verlag, New York, pp. 352, DOI:10.1007/978-1-4614-1302-8

Şekercioğlu, Ç. H. 2012. Promoting community-based bird monitoring in the tropics: conservation, research, environmental education, capacity-building, and local incomes. – Biological Conservation 151(1): 69–73. DOI: 10.1016/j.biocon.2011.10.024

Spector, P. 2008. Data manipulation with R. – Springer-Verlag, New York, pp. 154, DOI: 10.1007/978-0-387-74731-6

Spina, F. 1999. Value of ringing information for bird conservation in Europe. – Ringing & Migration 19(1): 29–40. DOI: 10.1080/03078698.1999.9674209

Thorup, K., Korner-Nievergelt, F., Cohen, E. B. & Baillie, S. R. 2014. Large-scale spatial analysis of ringing and re-encounter data to infer movement patterns: A review including methodological perspectives. – Methods in Ecology and Evolution 5(12): 1337–1350. DOI: 10.1111/2041-210X.12258

Van den Broeck, J., Argeseanu Cunningham S., Eeckels, R. & Herbst, K. 2005. Data cleaning: detecting, diagnosing, and editing data abnormalities. – PLoS Medicine 2(10): e267. p. 0966–0970. DOI: 10.1371/journal.pmed.0020267

Venables, W. N., Smith, D. M. & the R Core Team 2015. An introduction to R. pp. 99 – https://cran.r-project.org/

Walther, B. A., Schäffer, N., Van Niekerk, A., Thuiller, W., Rahbek, C. & Chown, S. L. 2007. Modelling the winter distribution of a rare and endangered migrant, the Aquatic Warbler *Acrocephalus paludicola*. – Ibis 149(4): 701–714. DOI: 10.1111/j.1474-919X.2007.00690.x