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Temporal changes in the diet composition of the Eastern Imperial Eagle *(Aquila heliaca)* in Hungary

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Abstract The diet composition of breeding Eastern Imperial Eagles *(Aquila heliaca)* was analysed in Hungary between 2005 and 2017, and compared with two previously published datasets from the periods of 1982–1991 and 1992–2004. Altogether the distribution of 8543 prey items of 126 different species and 29 other taxa were analysed within a 36-years period. We found that the previously abundant Common Hamster *(Cricetus cricetus)* became marginal (7.42%), while European Sousliks *(Spermophilus citellus)* practically disappeared (0.03%) from the diet of Imperial Eagles. Small game species, like the Common Pheasant *(Phasianus colchicus)* and the Brown Hare *(Lepus europaeus)* composed a remarkable part of the diet (11.22% and 28.11% respectively), which raised some conflicts with hunters regionally and probably also contributed to the high prevalence of persecution incidents against the eagles. In parallel with the loss of traditional prey species, corvids (13.10%), pigeons (8.90%), waterbirds (6.83%), other rodents (6.71%), Roe Deers *(Capreolus capreolus)* (5.59%), raptors and owls (4.88%) became regularly detected prey species. The temporal changes of the main prey categories were analysed between 1998 and 2017, when the ratio of Hamster and Pheasant showed significant decrease (-27.29% and -6.38%, respectively). The ratio of Brown Hare also showed slight decrease (-3.98%), but the change was not significant. On the other hand, the ratio of corvids, waterbirds and Roe Deers within the diet showed significant increase (+18.20%, +6.25% and +5.39%, respectively). The observed flexibility in the foraging behaviour of Imperial Eagles greatly facilitate conservation efforts, as they seems to be able to utilize the most abundant prey sources, i.e. they were not depending solely from the status of any single specific prey source. However, eagles could only shift and survive in those regions, where their traditional preys decreased, if alternative species were available for them.

Keywords: raptor, prey, *Cricetus*, *Spermophilus*, *Lepus*, *Phasianus*

Összefoglalás A parlagi sasok *(Aquila heliaca)* táplálék-összetételét vizsgáltuk Magyarországon 2005–2017 között és összehasonlítottuk két korábban publikált időszak (1982–1991, 1992–2004) adatsoraival. A 36 éves időszak alatt összesen 126 különböző fajhoz és további 29 taxonhoz tartozó 8543 zsákmányállatot sikerült beazonosítanunk. Korábban a mezei hörcsög *(Cricetus cricetus)* a leggyakoribb, míg a közönséges ürge *(Spermophilus citellus)* rendszeres zsákmánynak számított, azonban ritka zsákmánnyá váltak a 2005–2017 közötti időszakra (7,42% és 0,03%). Az apróvad-fajok közül a fácán *(Phasianus colchicus)* és a mezei nyúl *(Lepus europaeus)* jelentős részét tették ki a táplálléknak (11,22% és 28,11%), amely egyes területeken ellenérzést keltett a vadászokban, és valószínűleg szerepet játszott a sasok ellen elkövetett bűncselekmények magas gyakoriságában is. A hagyományos zsákmány-fajok visszaszorulásával párhuzamosan a varjú- (13,10%) és galambfélék (8,90%), a vízimadarak (6,83%), az egyéb rágcsálók (6,71%), az őz *(Capreolus capreolus)* (5,59%), valamint a ragadozómadarak és baglyok (4,88%) is rendszeres táplálékká váltak. A fő táplálék-kategóriák időbeli változásai 1998-2017 között kerültek elemzésre, ami alapján a hörcsög és a fácán aránya szignifikáns csökkenést mutatott az utolsó 20 év során (-27,29% és -6,38%). A mezei nyúl aránya is enyhe csökkenést mutatott (-3,98%), de a változás nem volt statisztikailag szignifikáns. Ezzel szemben a varjúfélék, vízimadarak és az őz aránya szignifikáns növekedést

mutatott a táplálékban (+18,20%, +6,25% és +5,39%). A megfigyelt flexibilitás a parlagi sasok zsákmányszerző viselkedésében nagyban elősegíti a fajvédelmi törekvéseket, mivel úgy tűnik képesek mindig a legkönnyebben elérhető zsákmány-fajt fogyasztani, így nem függnek kizárólagosan egyik specifikus zsákmány-faj állományváltozásaitól sem. Ugyanakkor a hagyományos zsákmány-fajok visszaszorulásakor a parlagi sasok csak azokon a területeken tudtak váltani és túlélni, ahol alternatív zsákmány-fajok elérhetőek voltak.

Kulcsszavak: ragadozómadár, zsákmány, *Cricetus*, *Spermophilus*, *Lepus*, *Phasianus*

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Introduction

The availability and relative frequency of main prey species are among the most important factors affecting the distribution and breeding success of large raptors (e.g. Newton 1979, Steenhof *et al.* 1997, Katzner *et al.* 2006, Penteriani *et al.* 2006, Schweiger *et al.* 2015). Therefore, the analyses of diet composition and specific actions for the key prey species are usually inevitable components in the conservation strategy of threatened raptor species (Ontiveros & Pleguezuelos 2000, Palma *et al.* 2006, Bedrosian *et al.* 2017).

Although direct observations or remote camera systems can provide the most accurate datasets for studying the diet of raptors during the breeding season (Takeuchi *et al.* 2006, Sánchez *et al.* 2008), such investigations are expensive and they can only gather data from a very limited number of territories. Therefore, usually indirect methods are used for diet analyses, such as the collection and analysis of pellets is the most widespread method for the diet analyses of owls (Halliez *et al.* 2015, Hámori *et al.* 2017, Szép *et al.* 2017). In case of diurnal raptors, the data derived from pellets can be significantly completed with the analyses of other prey remains, such as bones, hairs and feathers found around nest sites and roosting trees (Watson *et al.* 1993, Balogh 1998, Preston *et al.* 2017).

The diet of the globally threatened Eastern Imperial Eagle *(Aquila heliaca)* predominantly consists of medium sized mammals, birds and reptiles in most parts of its range, although their relative frequencies vary considerably among regions (del Hoyo *et al.* 1995). In most of the range Sciuridae (especially Sousliks and Marmots) and Cricetinae (mostly Hamsters) were considered the main prey species of the Imperial Eagle (del Hoyo *et al.* 1995). Sousliks (*Spermophilus* sp.) are still the most important food items for the largest eastern populations of Russia and Kazakhstan (Belik *et al.* 2002, Karyakin *et al.* 2008). However, the severe decline of Souslik populations and available alternative food sources resulted remarkable changes of the diet composition of the species in the western part of the distribution area. Rook *(Corvus frugilegus)* was reported to be the main prey in Serbia (Vasic & Misirlic 2002), and in some regions of western Russia (Belik *et al.* 2002). The Brown Hare *(Lepus europaeus)* and Chicken *(Gallus gallus f. domestica)* were the main prey species in South Bulgaria (Marin *et al.* 2004), while Northern White-breasted Hedgehogs *(Erinaceus*

roumanicus) and Yellow-legged Gulls *(Larus michahellis)* composed the largest part of the eagles' diet in the European part of Turkey (Demerdzhiev *et al.* 2014).

The westernmost isolated population of the species can be found in the Pannonian Basin of Central Europe, where most of the pairs breed in Hungary (Demerdzhiev *et al.* 2011). Early literature mentioned the European Souslik *(Spermophilus citellus)* as the main prey of Imperial Eagles in Hungary (Chernel 1899), but Common Hamster *(Cricetus cricetus)* and occasionally Brown Hare and poultry species were also noted (Szemere 1912, Vasvári 1938, Nagy 1943, Pátkay 1947). The first comprehensive survey on the diet of Imperial Eagles in Hungary was conducted between 1982 and 1991 (Haraszthy *et al.* 1996) and revealed that four species comprised more than 80% of the diet including the Common Hamster (51%), Brown Hare (12%), Common Pheasant *(Phasianus colchicus)* (12%) and European Souslik (7%). Chavko *et al.* (2007) studied the diet composition of the species in the Slovakian part of the Carpathian Basin between 1970 and 2005, where Brown Hare (35%) was the most frequent prey, followed by Common Hamsters (19%) and Common Pheasants (13%), and European Souslik reached only 4% of the identified prey items. The latest and largest dataset from Hungary from the period 1995–2004 revealed similar patterns for the most common species (Brown Hare 30%, Common Hamster, 21% Common Pheasant 15%), although the frequency of European Sousliks became less than 1% among the identified prey items (Horváth *et al.* 2010). Population surveys of the main prey species from the same period showed that Sousliks and Hamsters were present in the sampled eagle territories, but their relative frequencies were remarkably lower than of Hares and Pheasants (Kovács *et al.* 2008). All the four, previously mentioned main prey species of Imperial Eagles showed a severe decline in Hungary in the last 50 years (Bihari 2004, Báldi & Faragó 2007, Bihari *et al.* 2007). On the contrary, the Hungarian population of Imperial Eagles showed a significant increase and southern expansion towards the lowland plain areas in the same period (Horváth *et al.* 2011, Horváth *et al.* 2014).

In the present study we investigated if the diet composition of the expanding Imperial Eagle population had changed in long-term and large-scale. We hypothesized that the decrease of the traditional prey species (Common Hamster and European Souslik) continued in parallel to the retraction of their populations. Our aim was to investigate, which species and to what extent could substitute the traditional prey species and if those changes had any effect for future conservation strategies.

Materials and methods

Study area

The diet composition of breeding Imperial Eagles was analysed in the total distribution area of the species in Hungary. The regions covered by the study were categorized into ten geographical units *(Figure 2a)* in order to facilitate investigations of the regional differences in the diet composition *(Table 1)*. The units were defined in order to represent (1) coherent and similar-sized (2700–5700 km^2) parts of the distribution area, (2) similar foraging habitat

structure, and (3) similar number of breeding territories (15–30 pairs, except the Kisalföld, Kiskunság and Duna-Ipoly areas, where less than 10 territories could be found over large areas). The units were named after the most representative part or National Park of the given area. Besides the Hungarian samples further 37 prey items were identified in neighboring countries within territories next to the Hungarian border, and they were joined to the nearest units of Zemplén (Southeast-Slovakia), Duna-Ipoly (Southwest-Slovakia), Kisalföld (East-Austria) and Körös-Maros (West-Romania).

Study period

A 36-years dataset (1982–2017) was used in the study, of which two subsets were partially published before. The first 10-years dataset from 1982 to 1991 was derived from Haraszthy *et al.* (1996), which included 627 prey specimens. The authors generously provided their raw data for this study, which enabled us to use them for regional comparisons as well. The next 13-years dataset from 1992 to 2004 was derived from Horváth *et al.* (2010), which included 1297 prey specimens, but it was completed with further 178 unpublished specimens from the same period (1475 specimens in total). The last 13-years part of the dataset from 2005 to 2017 comprised the majority of the data (6441 specimens), which have not yet been published before.

Sample collection

The breeding territories of Eastern Imperial Eagles were monitored and the active nests were searched by the members of the Hungarian Imperial Eagle Working Group in each year during the whole study period (Haraszthy *et al.* 1996, Horváth *et al.* 2010, Horváth *et al.* 2014). Data on prey remains were gathered unregularly between 1982 and 1997. From 1998 onwards the sampling became regular and the same protocol was applied for collecting data on food composition. The nesting sites were approached usually once or twice per year, when the ground below the nests and nearby roosting sites were checked thoroughly for food remains. The most comprehensive surveys were carried out in June, when most of the known nesting sites in Hungary were visited each year. This time the accessible nests were also climbed in the frame of the annual ringing of the chicks within the national Imperial Eagle monitoring protocol (Horváth *et al.* 2018a), when remains were collected directly from the nests as well. Those fresh preys, which included eatable parts for the chicks, were photographed and were not removed from the nests. The second visit to the nesting sites usually took place after fledging between July and October, when only the ground was checked for food remains. Besides these nest controls sporadic data on prey items (202 specimens) were also gathered in other months of the year.

The prey remains found around a nest site were collected together in the field and photographed with a scale and an ID label, including data on location, date and collector. Items, which could be identified unambiguously in the field were noted down on field datasheets. Food remains, which included significant amount of soft tissues and/or could be identified unambiguously in the field, were not collected in order to avoid contamination and

putrefaction till the analyses. For the same reason, wet or fresh remains were dried out and treated with insecticides before long-term storage.

The following type of remains were not included in the data in order to reduce the bias of indirect sampling, even if they were found under the nest sites or roosting trees: (1) single feathers, which could be shed by alive birds; (2) full carcasses of large animals, which could not be brought there by the eagles; (3) old or deteriorated samples, which could derive from previous years.

Pellets, bones, feathers, hairs and dry skins of prey animals were collected and stored in plastic bags until further analyses. ID labels were placed in another plastic bag outside the original bag in order to keep them clean and readable.

Prey identification

The collected samples were identified by comparing them with museum reference materials from 0.5 to 3 years after the collection. The remains originated from the same nest site from the same year were ordered by species, sex (in case of species with clear sexual dimorphism), body size and body part. A remain was handled as a different prey specimen, if it (1) belonged to different species or sex, or (2) had a clearly different body size than the already listed specimens, or (3) included the same part of the body as another remain. The same minimal estimation methodology was applied when the field data (including both datasheets and photographs) and the laboratory data were merged together. Therefore, in some cases remains of different prey specimens could be handled as one, but the multiple counting of the same specimen was ruled out.

Data analyses

In order to investigate and visualize the main changes in the diet composition, the prey items were grouped into the following four main categories: (1) Traditional prey species (Common Hamster, European Souslik); (2) Small game species (Brown Hare, Common Pheasant); (3) Other bird species; (4) Other non-avian species. These groups were divided into 16 sub-categories according to *Table 1*.

As a first step we have compared the frequency of the four main prey categories among the geographical units in the three periods in order to investigate if there were any evident alteration in the diet composition in long-term. In the second part of the analyses we used the dataset of the last 20 years (1998–2017), when the annual number and coverage of samples enabled more detailed analyses.

Here we used linear regression model to detect linear trends of changes in the proportion of the prey sub-categories. The linear regression models were not carried out for the data on Souslik and ‘Other animals’ categories, as their frequency was under 1% and ‘0’ annual values appeared in at least 50% of the study years. The statistical analyses were done in R 3.4.4 (R Development Core Team 2018). We are aware that the used design cannot take into consideration that samples collected under the same or nearby nesting trees could be predated by the same individuals. On the other hand, it was not possible to distinguish the origin of

samples and include this factor in the model due to three inevitable reasons. Firstly, the remains under a nest in a year include items predated by the male or the female of the given pair in an unknown proportion, therefore the data of two individuals are mixed in each sample. Secondly, the individuals breeding at a given nesting site could change from one year to another, therefore remains collected at the same nesting sites could derive from independent individuals. And finally, the grouping of nearby nesting locations in different years into "territories" is not evident and requires a more detailed analyses, which was out of the scope of this study. Anyway our aim was to detect robust and long-term changes in the diet composition, for which we believe that using the pooled data of the population is applicable if the sampling was representative.

Results

Coverage and distribution of the collected data

In the frame of the study altogether 6619 prey items were newly identified, which data was unified in the same database with the already published datasets of Haraszthy *et al.* (1996) and Horváth *et al.* (2010). This comprehensive 36-years dataset comprises 8543 prey items, which belongs to 126 different species and 29 other taxa, therefore it is the largest diet database of Eastern Imperial Eagles according to our knowledge. The distribution of different prey species in the three main study periods are summarized according to the defined categories and sub-categories in *Table 1*, while the total list of identified species and taxa is included in *Appendix 1*.

The sampling became regular and continuous between 1998 and 2017, when 7734 prey items (90.5% of all data) were gathered from 276 different breeding territories in the frame of 1517 field controls. The data covered an annually variable, but significant proportion (55% in average) of the national population *(Figure 1a)*. All together during this 20-years period 2872 (36.3%) items were identified only in the field, 4038 items (51.0%) were collected and identified later, and further 1006 (12.7%) items were detected by both methods *(Figure 1b)*. Unfortunately, the remains collected in 2009, 2010 and 2012 had been partially lost, therefore the items identified in the field composed largely the dataset for these years.

Data from the nest controls in June represented 70.4% of the last 20 years' dataset, and further 27.0% of the items were collected during the second nest controls between July and October. The sporadically collected items from November to May represented only 2.6% of the samples. Therefore, the presented dataset represents well the diet composition of territorial Imperial Eagles in the breeding season, but cannot be interpreted for the non-breeding period, neither for non-territorial, immature birds, whose diet can be considerably different (Sánchez *et al.* 2009, Bedrosian *et al.* 2017).

Table 1. Distribution of the main prey categories of Eastern Imperial Eagles in Hungary in the three study periods. The 'Waterbirds' sub-category included the families Anatidae, Podicipedidae, Rallidae, Gruidae, Ciconiidae, Threskiornithidae, Ardeidae, Recurvirostridae, Charadriidae, Scolopacidae and Laridae. The 'Poultry' sub-category included the Domestic Duck *(Anas platyrhynchos f. domestica)*, Domestic Goose *(Anser anser f. domestica)*, Chicken, Domestic Turkey *(Meleagris gallopavo f. domestica)* and Domestic Guineafowl *(Gallus gallus f. domestica)*. The 'Raptors and owls' sub-category included the families Tytonidae, Strigidae, Accipitridae and Falconidae

1. táblázat Parlagi sasok főbb táplálék-kategóriáinak eloszlása a három vizsgálati időszakban. A 'Waterbirds' alkategória az Anatidae, Podicipedidae, Rallidae, Gruidae, Ciconiidae, Threskiornithidae, Ardeidae, Recurvirostridae, Charadriidae, Scolopacidae és Laridae családokat fogalja magába. A 'Poultry' alkategória a házi kacsát *(Anas platyrhynchos f. domestica)*, házi ludat *(Anser anser f. domestica)*, házi tyúkot, házi pulykát *(Meleagris gallopavo f. domestica)* és a gyöngytyúkot *(Gallus gallus f. domestica)* foglalja magába. A 'Raptors and owls' alkategória a Tytonidae, Strigidae, Accipitridae és Falconidae családokat fogalja magába

Main prey categories	1982–1991		1992–2004		2005–2017		Total (1982–2017)	
	Number	% *N*	Number	% *N*	Number	% *N*	Number	% N
Cricetus cricetus	312	*49.76%*	296	*20.07%*	478	*7.42%*	1086	*12.71%*
Spermophilus citellus	44	*7.02%*	13	*0.88%*	2	*0.03%*	59	*0.69%*
Traditional prey species subtotal	**356**	***56.78%***	**309**	***20.95%***	**480**	***7.45%***	**1145**	***13.40%***
Lepus europaeus	77	*12.28%*	455	*30.85%*	1810	*28.10%*	2342	*27.41%*
Phasianus colchicus	75	*11.96%*	226	*15.32%*	723	*11.22%*	1024	*11.99%*
Small game species subtotal	**152**	***24.24%***	**681**	***46.17%***	**2533**	***39.33%***	**3366**	***39.40%***
Corvidae	8	*1.28%*	73	*4.95%*	844	*13.10%*	925	*10.83%*
Columbidae	22	*3.51%*	127	*8.61%*	573	*8.90%*	722	*8.45%*
Waterbirds	1	*0.16%*	56	*3.80%*	440	*6.83%*	497	*5.82%*
Raptors and owls	8	*1.28%*	53	*3.59%*	314	*4.88%*	375	*4.39%*
Poultry	22	*3.51%*	27	*1.83%*	120	*1.86%*	169	*1.98%*
Passeriformes (excl. Corvidae)	6	*0.96%*	19	*1.29%*	87	*1.35%*	112	*1.31%*
Other birds	2	*0.32%*	12	*0.81%*	50	*0.78%*	64	*0.75%*
Other bird species subtotal	**69**	***11.00%***	**367**	***24.88%***	**2428**	***37.70%***	**2864**	***33.52%***
Rodentia (excl. *Cricetus* and *Spermophilus*)	17	*2.71%*	38	*2.58%*	432	*6.71%*	487	*5.70%*
Capreolus capreolus	12	*1.91%*	38	*2.58%*	360	*5.59%*	410	*4.80%*
Carnivora	6	*0.96%*	18	*1.22%*	76	*1.18%*	100	*1.17%*
Other mammals	14	*2.23%*	23	*1.56%*	101	*1.57%*	138	*1.62%*
Other animals	1	*0.16%*	1	*0.07%*	31	*0.48%*	33	*0.39%*
Other non-avian species subtotal	**50**	***7.97%***	**118**	***8.00%***	**1000**	***15.53%***	**1168**	***13.67%***
Total	**627**	***100.00%***	**1475**	***100.00%***	**6441**	***100.00%***	**8543**	***100.00%***

Comparison of the three study periods

The four main prey-categories are summarized regionally according to the three main study periods in *Figure 2*. The ratio and the expansion of the sampling area of small game species (Brown Hare, Pheasant) showed a clear increase for the second period (24.24% vs. 46.17%), but slightly decreased for the last period (39.33%). Anyway Brown Hares still compose the largest part of the diet of Imperial Eagles in Hungary.

The ratio of the traditional prey species (Souslik, Hamster) decreased since the beginning of data collection (56.78% vs. 7.45%). The decrease was also evident in the Zemplén and Bükk regions, where sufficient data were available from all periods. The Souslik practically disappeared from the diet during the study period, while the Hamster was still important regionally, but its role became marginal in a national scale.

On the other hand, the ratio of other bird and mammal species showed a clear increase, therefore most probably they compensated the loss of traditional prey species.

Trend analyses of the main prey categories

The 20-years trend of the main prey categories and sub-categories are summarized in *Figure 3*. The results of the linear regression models are summarized in *Table 2* and *Figure 4*.

The Hamster showed the largest decrease during the study period, but the decrease of the Pheasant was also significant. The Brown Hare also showed an almost 4% decrease, but its trend was not significant according to the linear regression model. A significant increase was found among the Corvidae, mostly Hooded Crow *(Corvus cornix)* and Magpie *(Pica pica)* and waterbird species, and also in case of the Roe Deer *(Capreolus capreolus)*. The ratio of Common Voles *(Microtus arvalis)* was fluctuating and showing clear peaks in 2008, 2011 and 2014 according to their regional population cycles *(Figure 3d)*. Other prey categories did not show any significant trend.

Table 2. Results of the linear regression models carried out to analyse the trend of the main prey categories of Eastern Imperial Eagles in Hungary between 1998 and 2017. (Change: change in proportion of the main prey categories during 20 years)

2. táblázat A parlagi sasok főbb magyarországi táplálék-kategóriáinak trendjét vizsgáló lineáris regresszió modell eredménye 1998 és 2017 között. (Change: a főbb táplálék-kategóriák arányaiban történt változás a 20 év alatt), p-value: p-érték

Prey categories	Change	p-value
Corvidae	**+18.20%**	**<0.0001**
Waterbirds	**+6.25%**	**0.007**
Capreolus capreolus	**+5.39%**	**<0.001**
Rodentia (excluding *Cricetus* and *Spermophilus*)	+2.97%	0.479
Columbidae	+2.87%	0.160
Raptors and owls	+2.26%	0.270
Passeriformes (excluding Corvidae)	+0.47%	0.440
Poultry	+0.38%	0.688
Other birds	+0.13%	0.778
Other mammals	-0.13%	0.864
Carnivora	-0.14%	0.809
Lepus europaeus	-3.98%	0.293
Phasianus colchicus	**-6.38%**	**0.004**
Cricetus cricetus	**-27.79%**	**<0.001**
Spermophilus citellus	*n.a.*	*n.a.*
Other animals	*n.a.*	*n.a.*

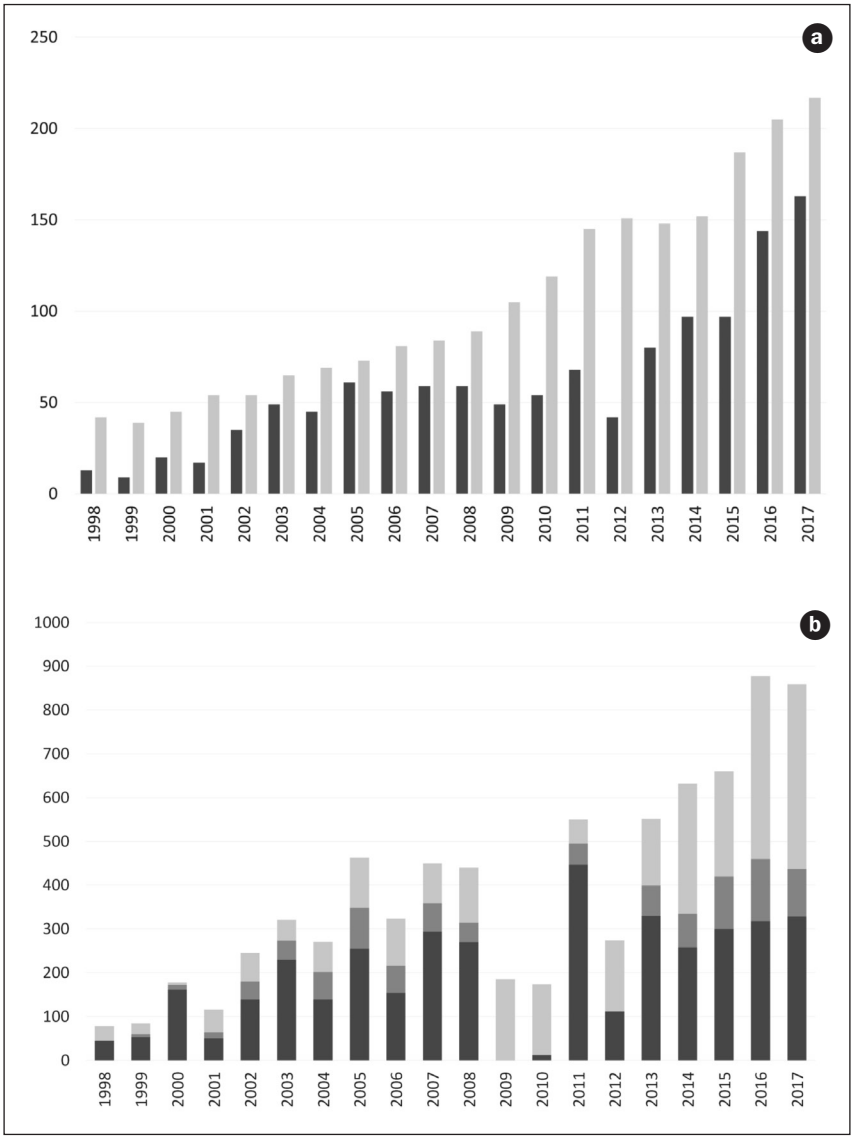


Figure 1. *a)* Annual coverage of collected prey samples of Eastern Imperial Eagles in relation to the total Hungarian nesting population between 1998 and 2017. Dark grey: number of sampled territories; Light grey: number of known Hungarian nesting territories. *b)* Annual number of identified prey items of Eastern Imperial Eagles in Hungary between 1998 and 2017. Dark grey: collected and later identified items; Light grey: items identified in the field; Medium grey: items detected by both methods

1. ábra *a)* A parlagi sas táplálékmaradványok lefedettsége a teljes magyarországi állománnyal összehasonlítva évenként 1998 és 2017 között. Sötétszürke: mintázott területek száma; Világosszürke: ismert magyarországi fészkelő párok száma. *b)* A meghatározott parlagi sas táplálékmaradványok száma évenként 1998 és 2017 között. Sötétszürke: begyűjtött és később meghatározott minták; Világosszürke: terepen meghatározott minták; Középszürke: mindkét módszerrel kimutatott minták

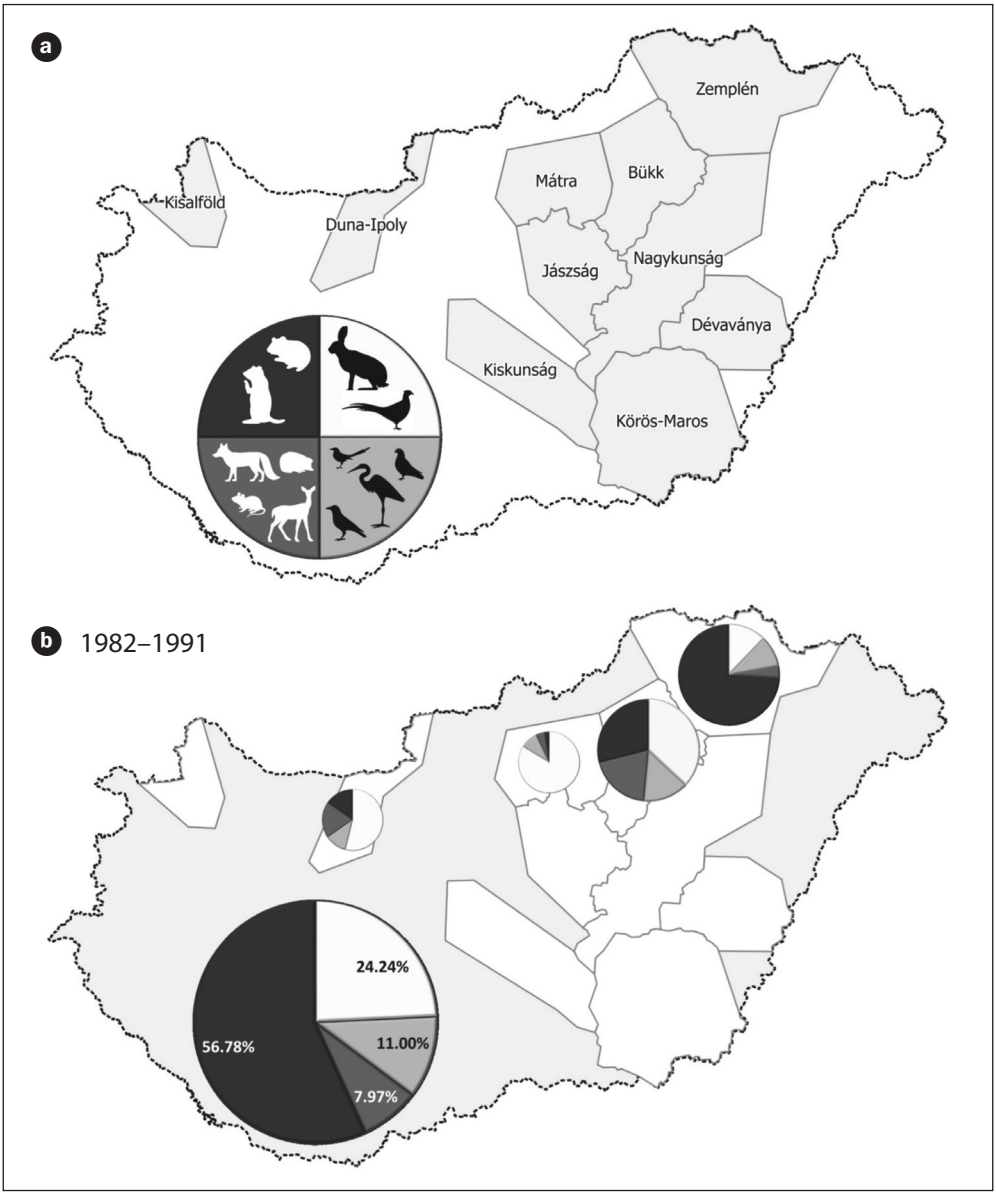
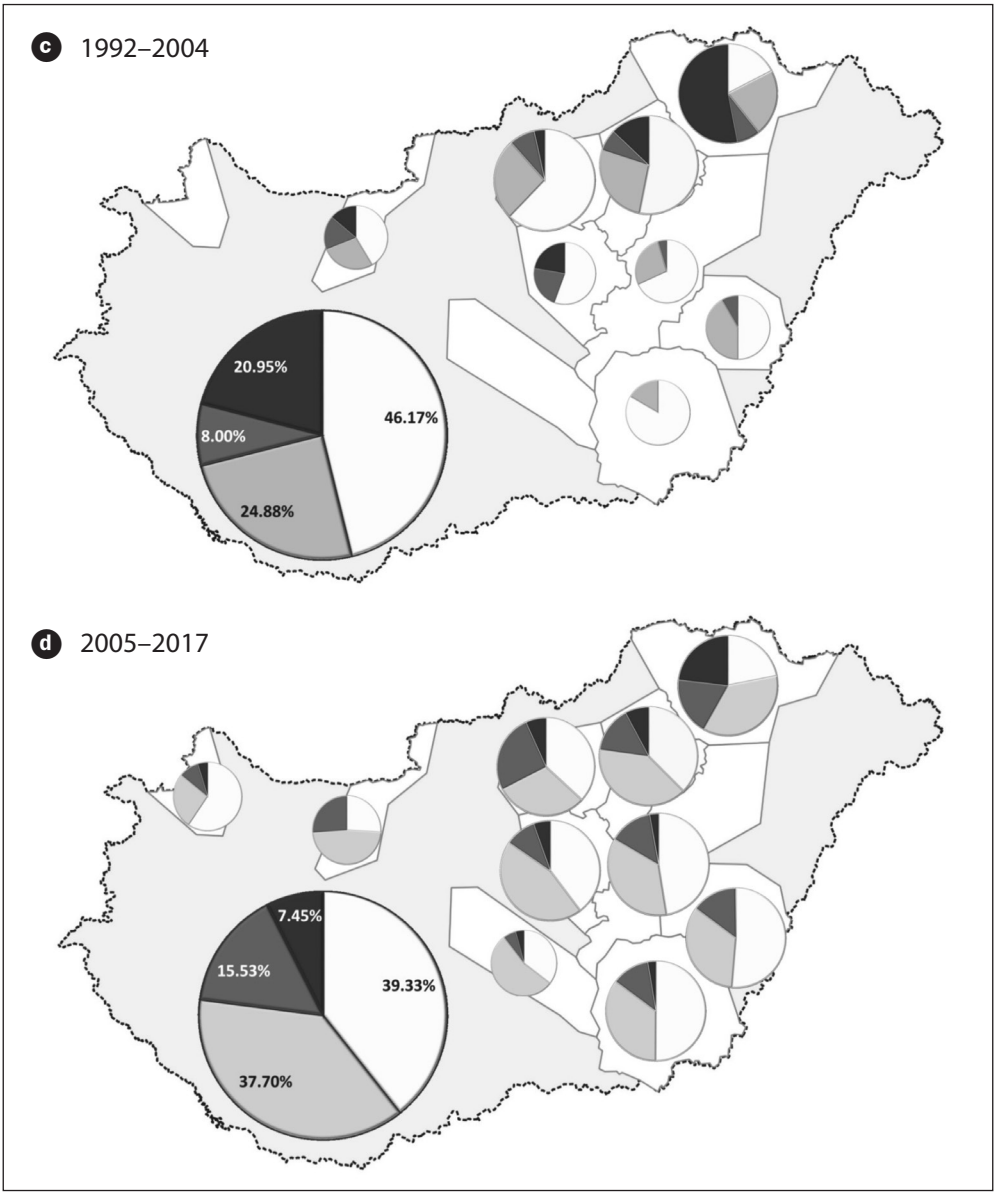


Figure 2. Proportion of the main prey categories of Eastern Imperial Eagles in the Hungarian study areas in the three study periods. a) Legend showing the location of the regions used in the study and the color codes of the main prey categories (see definitions at *Table 1*). b) Data for the period 1982–1991 are taken from Haraszthy *et al.* (1996) (n = 627). c) Data for the period 1992–2004 are taken from Horváth *et al.* (2010) and completed with unpublished data (n= 1475). d) Data for the period 2005–2017 (n = 6441). Black: traditional prey species; Dark Grey: other animals; Light grey: other birds; White: small game species. Large circle: national proportion of the main prey categories for the given period; Medium circle: regional proportion based on more than 100 items; Small circle: regional proportion based on less than 100 items



2. ábra A parlagi sasok főbb táplálék-kategóriáinak eloszlása a magyarországi régiókban a három vizsgálati időszakban. a) Az egyes régiók elhelyezkedését és a főbb táplálék-kategóriák szín jelölését mutató jelmagyarázat (definíciókat ld. az *1. táblázatban*). b) Az 1982–1991 közötti időszakra vonatkozó adatok Haraszthy *et al.* (1996) publikációjából származnak ($n = 627$). c) Az 1992–2004 közötti időszakra vonatkozó adatok Horváth *et al.* (2010) publikációjából származnak, kiegészítve publikálatlan adatokkal ($n = 1475$). d) A 2005–2017 közötti időszakra vonatkozó adatok ($n = 6441$). Fekete: hagyományos zsákmányfajok; Sötétszürke: egyéb állatok; Világos szürke: egyéb madarak; Fehér: apróvad-fajok. Nagy kör: a főbb táplálék-kategóriák országos aránya az adott időszakban; Közepes kör: regionális arány, amely több mint 100 meghatározott egyeden alapul; Kis kör: regionális arány, amely kevesebb, mint 100 meghatározott egyeden alapul

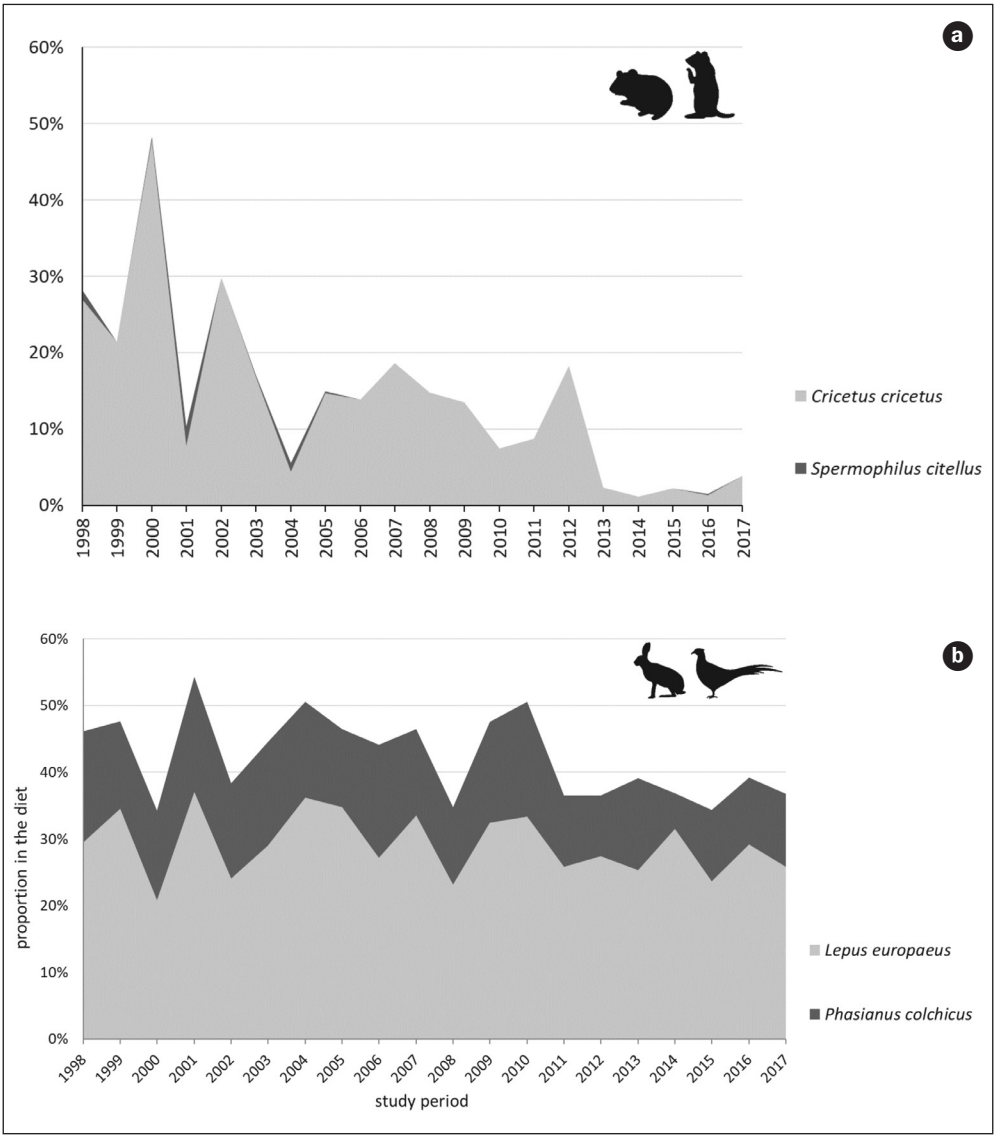
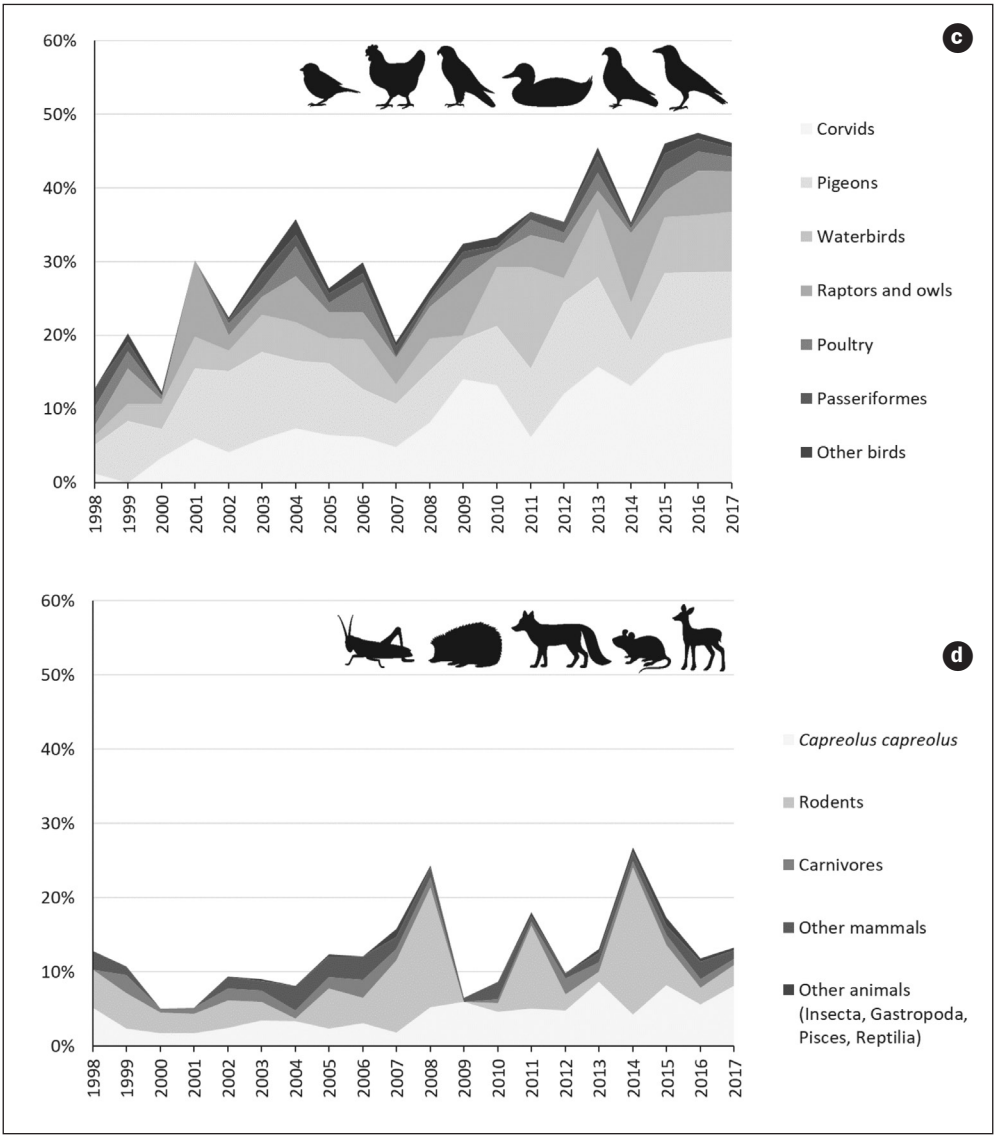


Figure 3. Annual proportion of the prey categories of Eastern Imperial Eagles in Hungary between 1998 and 2017 (see definitions at *Table 1*). a) Traditional prey species, b) Small game species. c) Other birds, d) Other animals



3. ábra A parlagi sasok táplálék-kategóriáinak évenkénti eloszlása 1998 és 2017 között Magyarországon (definíciókat ld. az *1. táblázatban*). a) Hagyományos zsákmányfajok, b) Apróvad-fajok, c) Egyéb madarak, d) Egyéb állatok

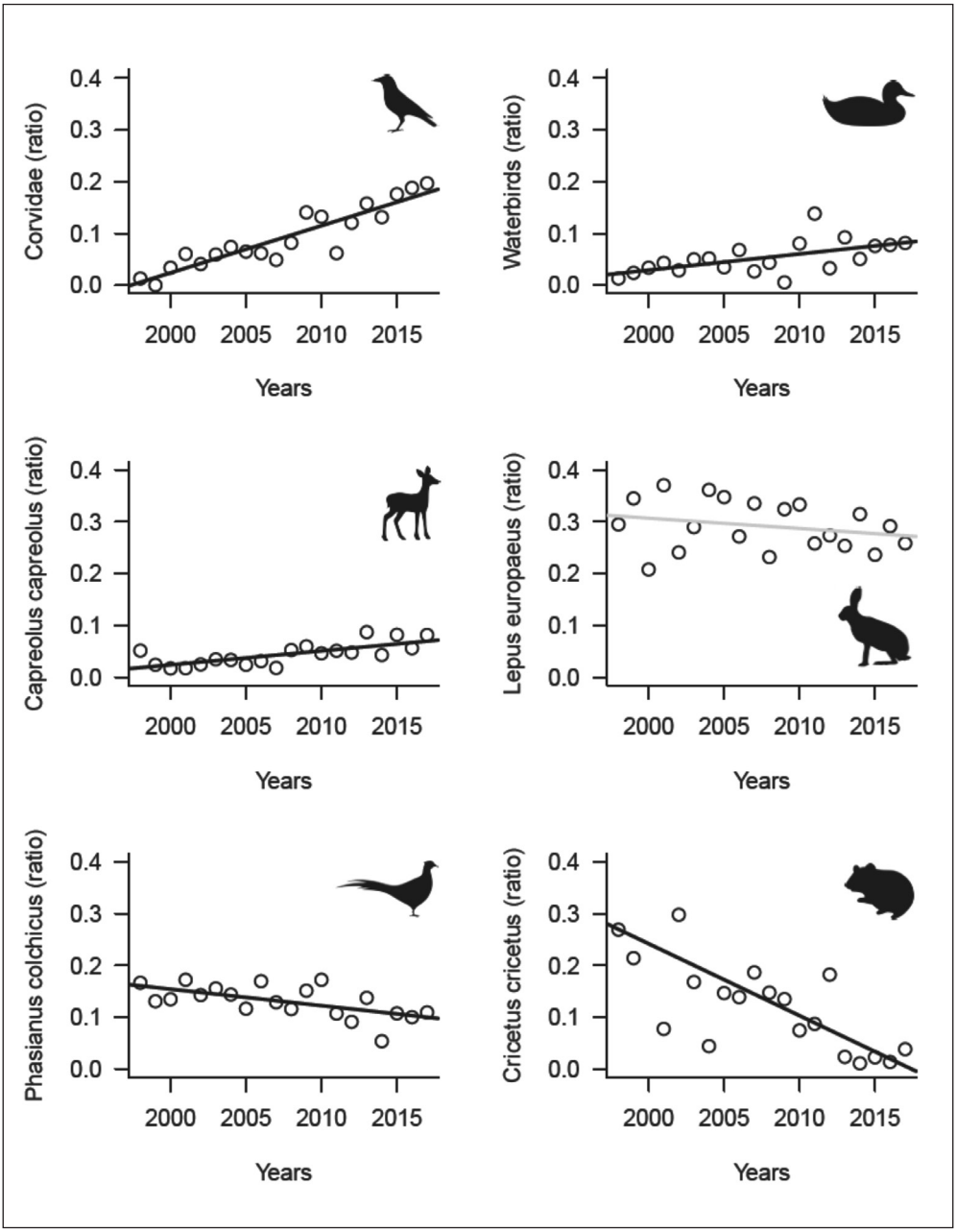


Figure 4. Results of the linear regression models carried out to analyse the trend of the main prey categories of Eastern Imperial Eagles in Hungary between 1998 and 2017. Black lines represent significant trends, while grey line represents non-significant trend. See detailed statistics at *Table 2*.

4. ábra A parlagi sasok főbb magyarországi táplálék-kategóriáinak trendjét vizsgáló lineáris regresszió modell eredménye 1998 és 2017 között. A fekete vonalak szignifikáns trendet, míg a szürke vonal nem szignifikáns trendet jelez. A részletes statisztikát ld. a *2. táblázatban*

Discussion

Foraging behavior and origin of prey items

Imperial Eagles are agile hunters, therefore a large proportion of the detected prey items were most probably actively hunted by the breeding pairs. However, based on the remains it was usually not possible to identify the source of the prey and it should be noted that some items were most probably not actively hunted by Imperial Eagles, but could be derived from three other sources as well.

First, eagles, like many other predators (e.g. Milchev & Spassov 2017), regularly bring carcasses to the nest, which died due to diseases, other predators or human activities. Agricultural activities – especially ploughing, harvesting or mowing machines – kill or wound a large amount of animals, especially Hares, Roe Deers and Pheasants. This extensive food source is largely utilized by eagles, as they are regularly seen to follow and forage after tractors in agricultural fields. Similarly, large mammal species were most probably exclusively taken from carcasses to the nest (i.e. Wild Boar *Sus scrofa*, Red Deer *Cervus elaphus* and Bovidae species).

Second, kleptoparasitism from other raptors and carnivores is also a common behaviour of Imperial Eagles (Danko & Mihók 2007). A part or all species of Pisces and small Passeriformes were probably taken this way, but a remarkable proportion of more common species could be also stolen from other predators.

Finally, some small species could also derive from the intestinal system of larger animals, which primarily predated those and later themselves became the prey of eagles. Probably a proportion of Insecta and Gastropoda species could be detected this way, although some observations were also reported on eagles, which were actively hunting on insects (Tóth 2006).

Interpretation of prey data

An inevitable limitation of our study is that the analysis of prey remains and/or pellets might estimate inaccurately the relative proportion of larger (e.g. Hare) and smaller (e.g. Vole) sized prey species in comparison to each other, caused by their different detectability (Redpath *et al.* 2001, Sánchez *et al.* 2008). Therefore, the exact frequency data of different taxa in the diet cannot be compared precisely to each other and the presented frequency data should be handled with caution. Anyway such large datasets well indicate the overall importance of key prey species within a region, as common preys must be detected regularly, while rare ones will be found only occasionally (Katzner *et al.* 2005, Bedrosian *et al.* 2017). Moreover, the frequency of a species or taxa can be analysed in a temporal scale, as their detectability do not change in time, therefore their detected frequency trends reflect real trends within the diet.

Flexibility in foraging behaviour

The presented results strengthened the notion that Imperial Eagles are able to change their diet and utilize the most available mammalian or avian prey sources within the preferred size range (250–2500 g). Katzner *et al.* (2005) found that dietary diversity of Eastern Imperial Eagles varied between regions in Kazakhstan, as eagles nesting near a high-density prey resource used that resource almost exclusively, while their diet was more diverse in locations with no single high-density prey species (Katzner *et al.* 2006). The closely related Spanish Imperial Eagle *(Aquila adalberti)* is highly dependent on its main prey species, the Rabbit *(Oryctolagus cuniculus)* (Ferrer & Negro 2004). However, Sánchez *et al.* (2009) also found variability in the diet of Spanish Imperial Eagles between different regions, and suggested that eagles were able to adapt to the habitat by utilizing alternative prey species, such as Pigeons (*Columba* spp.) or Hooded Crows, where their main prey was scarce.

Decrease of traditional rodent species

The observed flexibility in the foraging behaviour of Imperial Eagles greatly facilitate conservation efforts, as they proved to be able to utilize the most abundant prey sources, therefore they were not depending solely from the status of any single specific prey source. However, presumably eagles could only shift and survive in those regions, where their primary prey decreased, if alternative species were available for them. The enormous decrease of the Souslik in the eagles' diet was obviously caused by the remarkable retraction and isolation of their national populations, which raised serious conservational consequences even for Imperial Eagles regionally. In parallel with the decrease of Souslik populations, eagles also disappeared or decreased considerably at some parts of their former Hungarian breeding range (Bakony, Vértes, Gerecse, Börzsöny and Aggtelek mountains), where most probably other alternative prey species were not as abundant as in other parts of the distribution area (Horváth *et al.* 2011).

Similarly, the remarkable decrease of the Hamster populations was obviously visible from the prey analyses of eagles, but also caused decrease in the breeding density in some particular regions. E.g. the formerly abundant Hamster populations at the Northern section of the Hernád-valley provided foraging areas for six Imperial Eagle breeding pairs in the early 2000's (Bihari *et al.* 2008), but in parallel with the decrease of the Hamster population, three of these territories became vacant by the end the study period (Horváth *et al.*, unpubl. data).

The worrying decline of the Hamster and Souslik populations of Hungary urge specific and more efficient conservation actions in order to secure their presence in the Pannonian Basin, which holds the westernmost significant populations of both species. Moreover, these species are regionally still inevitable food sources for the Imperial Eagles and other specialised threatened predators, such as the Saker Falcon *(Falco cherrug)* or the Steppe Polecat *(Mustella eversmanni)* (Bihari *et al.* 2007, Horváth *et al.* 2010).

Possible effects on other species and conflicts with stakeholders

The high ratio of small game species (Hares, Pheasants), and the increasing frequency of Roe Deers among the prey remains found under eagle nests, raised a significant negative attitude among hunters towards the eagles (Kovács *et al.* 2016). This negative attitude in parallel with widespread illegal predator poisoning activities resulted in an enormously high mortality of Imperial Eagles in Hungary due to persecution (Horváth *et al.* 2018). In one hand it is crucial to communicate actively with and raise the conservational awareness of hunters. E.g. positive changes in the attitudes can be reached by emphasizing the importance of top predators in controlling mesopredators (e.g. Newsome *et al.* 2017), like the eagles predate on Corvids, raptors and carnivores, therefore indirectly they can also decrease the pressure on small games. The enhanced communication between conservationists and hunters was proved to be efficient in both decreasing persecution incidents, but also to recognize mutual interest in lobbying for nature-friendly agricultural land use practices (Fabók *et al.* 2015, Horváth *et al.* 2018).

The eagles' predation on Feral Pigeon *(Columba livia f. domestica)* and poultry species can also raise conflicts with pigeon fanciers and poultry keepers, which could also result on persecution incidents. Besides, the expanding eagle population and the occasional predation and disturbance on Great Bustards *(Otis tarda)* and Common Cranes *(Grus grus)* could also raise internal conflicts even within the conservation community. These kind of possible conflicts between predator and prey species are usually not proved by any scientific evidence on population-level effects, but based on single observations or beliefs. The clarification of these possible predator-prey interactions and the conflict management with the main stakeholder groups will be one of the most important future challenges for effective eagle conservation.

The recent study proved that the diet composition of Eastern Imperial Eagles had changed significantly during the last decades. We observed severe decrease of traditional prey species, like the Common Hamster and the European Souslik, which almost disappeared from the diet, while Corvids, waterbirds and Roe Deers increased. Brown Hare and Common Pheasant composed constantly the remarkable part of the diet, which emphasize that the conservation of this globally threatened raptor species is highly linked with small game management and agricultural land-use practices in Hungary.

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Appendix

Appendix Proportion of all identified prey taxa of Eastern Imperial Eagles in Hungary in the three study periods

Melléklet Valamennyi meghatározott taxon eloszlása a parlagi sasok magyarországi táplálékában a három vizsgálati időszakban

Taxa	1982–1991		1992–2004		2005–2017		Total (1982–2017)	
	Number	***% N***	**Number**	***% N***	**Number**	***% N***	**Number**	***% N***
Acridoidea indet.	–	–	–	–	1	0.02%	1	0.01%
Calosoma auropunctatum	–	–	–	–	1	0.02%	1	0.01%
Carabus cancellatus	–	–	–	–	1	0.02%	1	0.01%
Coleoptera indet.	–	–	–	–	5	0.08%	5	0.06%
Gryllotalpa gryllotalpa	–	–	–	–	2	0.03%	2	0.02%
Holochelus aequinoctialis	–	–	–	–	1	0.02%	1	0.01%
Lucanus cervus	–	–	–	–	1	0.02%	1	0.01%
Silpha carinata	–	–	–	–	1	0.02%	1	0.01%
Silpha obscura	–	–	–	–	1	0.02%	1	0.01%
Zabrus tenebrionides	–	–	–	–	1	0.02%	1	0.01%
Insecta indet.	–	–	–	–	5	0.08%	5	0.06%
INSECTA total	**–**	**–**	**–**	**–**	**20**	**0.63%**	**20**	**0.23%**
Cepaea sp.	–	–	–	–	1	0.02%	1	0.01%
Helix pomatia	–	–	–	–	1	0.02%	1	0.01%
GASTROPODA total	**–**	**–**	**–**	**–**	**2**	**0.06%**	**2**	**0.02%**
Carassius auratus	–	–	–	–	1	0.02%	1	0.01%
Cyprinus carpio	–	–	–	–	2	0.03%	2	0.02%
Pisces indet.	–	–	–	–	3	0.05%	3	0.04%
PISCES total	**–**	**–**	**–**	**–**	**6**	**0.19%**	**6**	**0.07%**
Elaphe longissima	–	–	–	–	1	0.02%	1	0.01%
Natrix natrix	–	–	–	–	1	0.02%	1	0.01%
Colubridae indet.	1	0.16%	1	0.07%	1	0.02%	3	0.04%
REPTILIA total	**1**	**0.16%**	**1**	**0.07%**	**3**	**0.10%**	**5**	**0.06%**
Coturnix coturnix	1	0.16%	–	–	23	0.36%	24	0.28%
Gallus gallus f. domestica	20	3.19%	19	1.29%	87	1.35%	126	1.47%
Meleagris gallopavo f. domestica	1	0.16%	–	–	5	0.08%	6	0.07%
Perdix perdix	1	0.16%	11	0.75%	13	0.20%	25	0.29%
Phasianus colchicus	75	11.96%	226	15.32%	723	11.22%	1024	11.99%
Phasianidae subtotal	**98**	**15.63%**	**256**	**17.36%**	**851**	**13.21%**	**1205**	**14.11%**
Numida meleagris	–	–	1	0.07%	11	0.17%	12	0.14%
Numididae subtotal	**–**	**–**	**1**	**0.07%**	**11**	**0.17%**	**12**	**0.14%**

Taxa	1982–1991		1992–2004		2005–2017		Total (1982–2017)	
	Number	% *N*	Number	% *N*	Number	% *N*	Number	% *N*
Anas acuta	–	–	–	–	1	0.02%	1	0.01%
Anas crecca	–	–	2	0.14%	1	0.02%	3	0.04%
Anas platyrhynchos	1	0.16%	22	1.49%	139	2.16%	162	1.90%
Anas platyrhynchos f. domestica	–	–	3	0.20%	4	0.06%	7	0.08%
Anas querquedula	–	–	2	0.14%	4	0.06%	6	0.07%
Anas sp.	–	–	1	0.07%	7	0.11%	8	0.09%
Anser albifrons	–	–	–	–	7	0.11%	7	0.08%
Anser anser	–	–	–	–	16	0.25%	16	0.19%
Anser anser f. domestica	1	0.16%	4	0.27%	13	0.20%	18	0.21%
Anser fabalis	–	–	–	–	2	0.03%	2	0.02%
Anser sp.	–	–	1	0.07%	6	0.09%	7	0.08%
Aythya nyroca	–	–	–	–	1	0.02%	1	0.01%
Cygnus olor	–	–	–	–	1	0.02%	1	0.01%
Anatidae indet.	–	–	–	–	8	0.12%	8	0.09%
Anatidae subtotal	**2**	**0.32%**	**35**	**2.37%**	**210**	**3.26%**	**247**	**2.89%**
Tachybaptus ruficollis	–	–	–	–	1	0.02%	1	0.01%
Podicipedidae subtotal	**–**	**–**	**–**	**–**	**1**	**0.02%**	**1**	**0.01%**
Columba livia f. domestica	10	1.59%	90	6.10%	311	4.83%	411	4.81%
Columba oenas	–	–	2	0.14%	6	0.09%	8	0.09%
Columba palumbus	9	1.44%	22	1.49%	108	1.68%	139	1.63%
Columba sp.	2	0.32%	12	0.81%	135	2.10%	149	1.74%
Streptopelia decaocto	1	0.16%	–	–	9	0.14%	10	0.12%
Streptopelia turtur	–	–	1	0.07%	4	0.06%	5	0.06%
Columbidae subtotal	**22**	**3.51%**	**127**	**8.61%**	**573**	**8.90%**	**722**	**8.45%**
Cuculus canorus	–	–	1	0.07%	2	0.03%	3	0.04%
Cuculidae subtotal	**–**	**–**	**1**	**0.07%**	**2**	**0.03%**	**3**	**0.04%**
Crex crex	–	–	–	–	1	0.02%	1	0.01%
Fulica atra	–	–	5	0.34%	24	0.37%	29	0.34%
Gallinula chloropus	–	–	–	–	4	0.06%	4	0.05%
Rallidae subtotal	**–**	**–**	**5**	**0.34%**	**29**	**0.45%**	**34**	**0.40%**
Grus grus	–	–	–	–	6	0.09%	6	0.07%
Gruidae subtotal	**–**	**–**	**–**	**–**	**6**	**0.09%**	**6**	**0.07%**
Otis tarda	–	–	–	–	3	0.05%	3	0.04%
Otidae subtotal	**–**	**–**	**–**	**–**	**3**	**0.05%**	**3**	**0.04%**
Ciconia ciconia	–	–	1	0.07%	1	0.02%	2	0.02%
Ciconia nigra	–	–	–	–	2	0.03%	2	0.02%
Ciconia sp. *(ciconia/ nigra)*	–	–	–	–	1	0.02%	1	0.01%
Ciconiidae subtotal	**–**	**–**	**1**	**0.07%**	**4**	**0.06%**	**5**	**0.06%**

Taxa	1982–1991		1992–2004		2005–2017		Total (1982–2017)	
	Number	% *N*	Number	% *N*	Number	% *N*	Number	% *N*
Platalea leucorodia	–	–	1	0.07%	1	0.02%	2	0.02%
Threskiornithidae subtotal	**–**	**–**	**1**	**0.07%**	**1**	**0.02%**	**2**	**0.02%**
Ardea alba	–	–	2	0.14%	27	0.42%	29	0.34%
Ardea cinerea	–	–	5	0.34%	33	0.51%	38	0.44%
Egretta garzetta	–	–	–	–	2	0.03%	2	0.02%
Ixobrychus minutus	–	–	–	–	1	0.02%	1	0.01%
Nycticorax nycticorax	–	–	–	–	11	0.17%	11	0.13%
Ardeidae subtotal	**–**	**–**	**7**	**0.47%**	**74**	**1.15%**	**81**	**0.95%**
Himantopus himantopus	–	–	–	–	1	0.02%	1	0.01%
Recurvirostridae subtotal	**–**	**–**	**–**	**–**	**1**	**0.02%**	**1**	**0.01%**
Vanellus vanellus	–	–	8	0.54%	94	1.46%	102	1.19%
Charadriidae subtotal	**–**	**–**	**8**	**0.54%**	**94**	**1.46%**	**102**	**1.19%**
Limosa limosa	–	–	1	0.07%	2	0.03%	3	0.04%
Philomachus pugnax	–	–	1	0.07%	1	0.02%	2	0.02%
Scolopacidae indet.	–	–	–	–	1	0.02%	1	0.01%
Scolopax rusticola	–	–	2	0.14%	1	0.02%	3	0.04%
Tringa totanus	–	–	–	–	2	0.03%	2	0.02%
Scolopacidae subtotal	**–**	**–**	**4**	**0.27%**	**7**	**0.11%**	**11**	**0.13%**
Chlidonias sp.	–	–	–	–	1	0.02%	1	0.01%
Chroicocephalus ridibundus	–	–	2	0.14%	16	0.25%	18	0.21%
Laridae indet.	–	–	–	–	3	0.05%	3	0.04%
Larus sp. *(cachinnans/ michahellis)*	–	–	–	–	10	0.16%	10	0.12%
Laridae subtotal	**–**	**–**	**2**	**0.14%**	**30**	**0.47%**	**32**	**0.37%**
Tyto alba	–	–	–	–	2	0.03%	2	0.02%
Tytonidae subtotal	**–**	**–**	**–**	**–**	**2**	**0.03%**	**2**	**0.02%**
Asio flammeus	–	–	2	0.14%	13	0.20%	15	0.18%
Asio otus	1	0.16%	24	1.63%	142	2.20%	167	1.95%
Asio sp. *(flammeus/ otus)*	–	–	–	–	4	0.06%	4	0.05%
Strigidae indet.	–	–	1	0.07%	2	0.03%	3	0.04%
Strix aluco	1	0.16%	2	0.14%	7	0.11%	10	0.12%
Strix uralensis	–	–	–	–	1	0.02%	1	0.01%
Strigidae subtotal	**2**	**0.32%**	**29**	**1.97%**	**169**	**2.62%**	**200**	**2.34%**
Accipiter nisus	–	–	–	–	2	0.03%	2	0.02%
Buteo buteo	4	0.64%	12	0.81%	67	1.04%	83	0.97%
Circus aeruginosus	–	–	1	0.07%	8	0.12%	9	0.11%
Pernis apivorus	1	0.16%	2	0.14%	–	–	3	0.04%
Accipitridae subtotal	**5**	**0.80%**	**15**	**1.02%**	**77**	**1.20%**	**97**	**1.14%**

Taxa	1982–1991		1992–2004		2005–2017		Total (1982–2017)	
	Number	% *N*	Number	% *N*	Number	% *N*	Number	% *N*
Upupa epops	–	–	–	–	1	0.02%	1	0.01%
Upupidae subtotal	**–**	**–**	**–**	**–**	**1**	**0.02%**	**1**	**0.01%**
Coracias garrulus	–	–	–	–	6	0.09%	6	0.07%
Coraciidae subtotal	**–**	**–**	**–**	**–**	**6**	**0.09%**	**6**	**0.07%**
Dendrocopos major	–	–	–	–	1	0.02%	1	0.01%
Dendrocopos sp.	–	–	–	–	1	0.02%	1	0.01%
Picus viridis	–	–	1	0.07%	2	0.03%	3	0.04%
Picidae subtotal	**–**	**–**	**1**	**0.07%**	**4**	**0.06%**	**5**	**0.06%**
Falco cherrug	–	–	–	–	2	0.03%	2	0.02%
Falco peregrinus	–	–	–	–	1	0.02%	1	0.01%
Falco subbuteo	–	–	–	–	1	0.02%	1	0.01%
Falco tinnunculus	1	0.16%	9	0.61%	60	0.93%	70	0.82%
Falco vespertinus	–	–	–	–	2	0.03%	2	0.02%
Falconidae subtotal	**1**	**0.16%**	**9**	**0.61%**	**66**	**1.02%**	**76**	**0.89%**
Corvus corax	–	–	10	0.68%	59	0.92%	69	0.81%
Corvus cornix	–	–	12	0.81%	216	3.35%	228	2.67%
Corvus frugilegus	5	0.80%	10	0.68%	67	1.04%	82	0.96%
Corvus monedula	–	–	2	0.14%	1	0.02%	3	0.04%
Corvus sp. *(cornix/ frugilegus)*	2	0.32%	13	0.88%	257	3.99%	272	3.18%
Garrulus glandarius	–	–	2	0.14%	7	0.11%	9	0.11%
Pica pica	1	0.16%	24	1.63%	237	3.68%	262	3.07%
Corvidae subtotal	**8**	**1.28%**	**73**	**4.95%**	**844**	**13.10%**	**925**	**10.83%**
Alauda arvensis	–	–	4	0.27%	18	0.28%	22	0.26%
Alaudidae indet. (Alauda arvensis/ Galerida cristata)	–	–	–	–	2	0.03%	2	0.02%
Galerida cristata	–	–	4	0.27%	–	–	4	0.05%
Alaudidae subtotal	**–**	**–**	**8**	**0.54%**	**20**	**0.31%**	**28**	**0.33%**
Acrocephalus arundinaceus	–	–	–	–	1	0.02%	1	0.01%
Acrocephalidae subtotal	**–**	**–**	**–**	**–**	**1**	**0.02%**	**1**	**0.01%**
Sturnus vulgaris	–	–	5	0.34%	49	0.76%	54	0.63%
Sturnidae subtotal	**–**	**–**	**5**	**0.34%**	**49**	**0.76%**	**54**	**0.63%**
Turdus merula	1	0.16%	1	0.07%	2	0.03%	4	0.05%
Turdus philomelos	–	–	–	–	3	0.05%	3	0.04%
Turdus pilaris	–	–	–	–	1	0.02%	1	0.01%
Turdus sp.	2	0.32%	–	–	1	0.02%	3	0.04%
Turdidae subtotal	**3**	**0.48%**	**1**	**0.07%**	**7**	**0.11%**	**11**	**0.13%**
Passer domesticus	–	–	–	–	1	0.02%	1	0.01%
Passer montanus	–	–	–	–	1	0.02%	1	0.01%
Passer sp. *(domesticus/ montanus)*	–	–	–	–	2	0.03%	2	0.02%
Passeridae subtotal	**–**	**–**	**–**	**–**	**4**	**0.06%**	**4**	**0.05%**

Taxa	1982–1991		1992–2004		2005–2017		Total (1982–2017)	
	Number	% N	Number	% N	Number	% N	Number	% N
Motacilla flava	–	–	–	–	1	0.02%	1	0.01%
Motacillidae subtotal	**–**	**–**	**–**	**–**	**1**	**0.02%**	**1**	**0.01%**
Emberiza calandra	–	–	1	0.07%	–	–	1	0.01%
Emberizidae subtotal	**–**	**–**	**1**	**0.07%**	**–**	**–**	**1**	**0.01%**
Passeriformes indet.	3	0.48%	3	0.20%	3	0.05%	9	0.11%
Passeriformes indet. subtotal	**3**	**0.48%**	**3**	**0.20%**	**3**	**0.05%**	**9**	**0.11%**
AVES total	**144**	**22.97%**	**593**	**40.20%**	**3151**	**100.00%**	**3888**	**45.51%**
Erinaceus roumanicus	11	1.75%	18	1.22%	67	1.04%	96	1.12%
Erinaceidae subtotal	**11**	**1.75%**	**18**	**1.22%**	**67**	**1.04%**	**96**	**1.12%**
Sorex araneus	–	–	–	–	1	0.02%	1	0.01%
Soricidae subtotal	**–**	**–**	**–**	**–**	**1**	**0.02%**	**1**	**0.01%**
Talpa europaea	–	–	–	–	15	0.23%	15	0.18%
Talpidae subtotal	**–**	**–**	**–**	**–**	**15**	**0.23%**	**15**	**0.18%**
Lepus europaeus	77	12.28%	455	30.85%	1810	28.10%	2342	27.41%
Oryctolagus cuniculus	1	0.16%	–	–	1	0.02%	2	0.02%
Leporidae subtotal	**78**	**12.44%**	**455**	**30.85%**	**1811**	**28.12%**	**2344**	**27.44%**
Sciurus vulgaris	–	–	1	0.07%	–	–	1	0.01%
Spermophilus citellus	44	7.02%	13	0.88%	2	0.03%	59	0.69%
Sciuridae subtotal	**44**	**7.02%**	**14**	**0.95%**	**2**	**0.03%**	**60**	**0.70%**
Glis glis	1	0.16%	–	–	–	–	1	0.01%
Gliridae subtotal	**1**	**0.16%**	**–**	**–**	**–**	**–**	**1**	**0.01%**
Arvicola amphibius	–	–	–	–	24	0.37%	24	0.28%
Arvicolinae indet.	2	0.32%	3	0.20%	6	0.09%	11	0.13%
Cricetus cricetus	312	49.76%	296	20.07%	478	7.42%	1086	12.71%
Microtus arvalis	4	0.64%	27	1.83%	363	5.64%	394	4.61%
Ondatra zibethicus	9	1.44%	1	0.07%	4	0.06%	14	0.16%
Cricetidae subtotal	**327**	**52.15%**	**327**	**22.17%**	**875**	**13.58%**	**1529**	**17.90%**
Apodemus agrarius	–	–	–	–	3	0.05%	3	0.04%
Apodemus sp.	–	–	–	–	1	0.02%	1	0.01%
Micromys minutus	–	–	–	–	1	0.02%	1	0.01%
Mus musculus	–	–	–	–	2	0.03%	2	0.02%
Mus sp. *(musculus/ spicilegus)*	–	–	–	–	2	0.03%	2	0.02%
Rattus norvegicus	1	0.16%	6	0.41%	26	0.40%	33	0.39%
Muridae subtotal	**1**	**0.16%**	**6**	**0.41%**	**35**	**0.54%**	**42**	**0.49%**
Felis sp. *(silvestris/ catus)*	1	0.16%	3	0.20%	3	0.05%	7	0.08%
Felis catus	2	0.32%	3	0.20%	26	0.40%	31	0.36%
Felis silvestris	–	–	–	–	1	0.02%	1	0.01%
Felidae subtotal	**3**	**0.48%**	**6**	**0.41%**	**30**	**0.47%**	**39**	**0.46%**

Taxa	1982–1991		1992–2004		2005–2017		Total (1982–2017)	
	Number	**% *N***	**Number**	**% *N***	**Number**	**% *N***	**Number**	**% *N***
Canis aureus	–	–	–	–	1	0.02%	1	0.01%
Canis familiaris	1	0.16%	1	0.07%	5	0.08%	7	0.08%
Vulpes vulpes	2	0.32%	9	0.61%	33	0.51%	44	0.52%
Canidae subtotal	**3**	**0.48%**	**10**	**0.68%**	**39**	**0.61%**	**52**	**0.61%**
Lutra lutra	–	–	1	0.07%	–	–	1	0.01%
Martes foina	–	–	–	–	1	0.02%	1	0.01%
Meles meles	–	–	–	–	1	0.02%	1	0.01%
Mustela eversmanii	–	–	–	–	1	0.02%	1	0.01%
Mustela nivalis	–	–	–	–	2	0.03%	2	0.02%
Mustela putorius	–	–	1	0.07%	–	–	1	0.01%
Mustela sp. *(erminea/ nivalis)*	–	–	–	–	1	0.02%	1	0.01%
Mustela sp. *(eversmanii/putorius)*	–	–	–	–	1	0.02%	1	0.01%
Mustelidae subtotal	**–**	**–**	**2**	**0.14%**	**7**	**0.11%**	**9**	**0.11%**
Sus scrofa	1	0.16%	4	0.27%	7	0.11%	12	0.14%
Sus domesticus	–	–	–	–	1	0.02%	1	0.01%
Suidae subtotal	**1**	**0.16%**	**4**	**0.27%**	**8**	**0.12%**	**13**	**0.15%**
Capreolus capreolus	12	1.91%	38	2.58%	360	5.59%	410	4.80%
Cervus elaphus	–	–	–	–	1	0.02%	1	0.01%
Cervidae subtotal	**12**	**1.91%**	**38**	**2.58%**	**361**	**5.60%**	**411**	**4.81%**
Bos taurus	–	–	–	–	1	0.02%	1	0.01%
Capra hircus	–	–	–	–	1	0.02%	1	0.01%
Ovis sp. *(aries/ orientalis)*	1	0.16%	1	0.07%	6	0.09%	8	0.09%
Bovidae subtotal	**1**	**0.16%**	**1**	**0.07%**	**8**	**0.12%**	**10**	**0.12%**
MAMMALIA total	**482**	**76.87%**	**881**	**59.73%**	**3259**	**50.60%**	**4622**	**54.10%**
TOTAL	**627**	**100.00%**	**1475**	**100.00%**	**6441**	**100.00%**	**8543**	**100.00%**