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Food habits of the endemic Cyprus scops owl (*Otus cyprius*) during the breeding season

Potrava endemického druhu výrika cyperského (*Otus cyprius*) v priebehu hniezdnej sezóny

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Abstract: The diet of the endemic Cyprus scops owl (*Otus cyprius*) was studied for the first time during the breeding season 2021 in 7 nesting sites from 6 sampling locations using the pellet analysis (n = 65 pellets). Insects, mostly Orthoptera and Coleoptera, comprised the bulk of the owl diet (87% abundance, 31% biomass), whereas small mammals and reptiles were important in terms of biomass, with 41% and 24%, respectively. Birds were the lowest prey order, with 0.6% abundance and 3.6% biomass. The most essential insects were grasshoppers (Acrididae) (17%) and scarab beetles (Scarabaeidae) (6%). From vertebrate prey, Mus spp. (23.7%), Mediterranean house gecko (*Hemidactylus turcicus*) (8%), Cyprus spiny mice (*Acomys nesiotes*) (8%), juvenile black rats (*Rattus rattus*) (7%), and Cyprus agamas (*Laudakia cypriaca*) (5%) stand out as % biomass. Predation on a bat species (*Pipistrellus* sp.) by scops owl was documented for the first time in Cyprus. The estimated prey biomass ranged from 0.1 – 25 grams, averaging 2.1 g.

Abstrakt: V priebehu hniezdnej sezóny 2021 bola po prvýkrát študovaná potrava endemického druhu výrika cyperského (*Otus cyprius*). Analýzované boli vývržky (n = 65 vývržkov) so 7 hniezd na 6 lokalitách. Hlavnú časť potravy tvoril hmyz, väčšinou Orthoptera a Coleoptera, (87 % abundancia, 31 % biomasa), zatiaľ čo drobné cicavce a plazy boli dôležité najmä z hľadiska biomasy so 41 % resp. 24 %. Vtáky boli najmenej zastúpenou korisťou s 0,6 % abundanciou a 3,6 % biomasy. Najdôležitejším hmyzom boli kobylky (Acrididae) (17 %) a chrobáky (Scarabaeidae) (6 %). Z koristi stavovcov to boli *Mus* spp. (23,7 %), gekón turecký (*Hemidactylus turcicus*) (8 %), myš cyperská (*Acomys nesiotes*) (8 %), mladé potkany čierne (*Rattus rattus*) (7 %) a agama cyperská (*Laudakia cypriiaca*) (5 % biomasy). Prvý raz zdokumentovaná predácia netopiera (Pipistrellus sp.) výrikom na Cypre. Odhadovaná biomasa koristi sa pohybovala od 0,1 do 25 gramov, v priemere 2,1 g.

Key words: foraging, birds of prey, pellet, diet, Orthoptera, Coleoptera

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Introduction

Knowing the foraging ecology of owls is important for the species conservation, given that diet may influence its reproductive performance and, ultimately, survival (LourenÇo 2006). The Cyprus scops owl (*Otus cyprius*, hereafter CSO) is an endemic species to the island of Cyprus (Flint et al. 2015, Flint 2017, Flint et al. 2017, Gill et al. 2016). Even though IUCN classifies it as Least Concern (BirdLife International 2019), its population trend is unknown, and it is generally understudied. It is the smallest owl on the island, the other being the long-eared owl (*Asio otus*), the barn owl (*Tyto alba*) and the little owl (*Athene noctua*). The short-eared owl (*Asio flammeus*) is recorded as a scarce passage migrant (Flint and Stewart 1992). The CSO is a common owl in Cyprus occurring in woodlands, orchards, olive groves, and villages at all altitudes (Flint and Stewart 1992), with a population estimated at 10,000 – 24,000 individuals (BirdLife International 2023). It nests in tree cavities and holes in old buildings and ruins and accepts artificial nest boxes. Nest boxes for CSO have been placed by the Game and Fauna Service, BirdLife Cyprus and the Forestry Department to increase the species population. In addition, several nesting boxes placed for barn owls have been occupied first by CSO, where they nested before being taken over by barn owls in later years. In some cases, CSOs were found dead under the nesting box after the barn owl occupation. Avian predators of CSO include the long-legged buzzard (*Buteo rufinus rufinus*) (Kassinis et al. 2022), the barn owl (Moysi et al. 2016) and possibly the goshawk (*Accipiter gentilis*) since they are sympatric in forested and woodland areas.

Owl food habits are usually studied through pellets and prey remains analysis (Šotnár et al. 2008, Latková et al. 2012). Scops owl (*Otus scops*) species, widely occurring in mainland Europe, the Middle East, and Northern Africa, prey primarily on insects, mainly Coleoptera, Orthoptera and Lepidoptera (Šotnár et al. 2008, Latkova et al. 2012, Jusztin 2022). Small vertebrates such as mice (Muridae), shrews (Soricidae), lizards (Lacertidae) and birds (Passeriformes) constitute a small portion of its diet (Herrera and Hiraldo 1976, Mikkola 1992, Marchesi and Sergio 2005).

The food habits of the CSO have never been systematically studied before, even though anecdotal observations have been reported in BirdLife Cyprus annual reports. The chairman of the organization observed, through a camera placed in a nesting box, that the main food items that the parents fed the chicks were arthropods such as centipedes (Chilopoda), crickets, bush crickets and grasshopers (Orthoptera), cockroaches (Blattodea), moths (Lepidoptera), spiders (Araneae), and beetles (Coleoptera). He also observed them feeding their nestlings with mice and a gecko (Gekkonidae) (BirdLife Cyprus 2009, 2017). This study presents the CSO's food habits based on pellet analysis.

Material and Methods

Study area

Cyprus is the third largest Mediterranean island (after Sicily and Sardinia), covering an area of 9,251 square km (Vogiatzakis et al. 2020). The island is dominated by two mountain ranges, the central Troodos Mountains and the smaller Pentadaktylos Range, with the large, flat central plain of Mesaoria in between. Cyprus has a Mediterranean climate with dry, hot summers and rainy, mild winters with relatively short autumn and spring seasons. Cyprus's high forests, mainly of Calabrian pine (*Pinus brutia*), cover 17% of its surface. The endemic golden oak (*Quercus alnifolia*) grows in either pure stands or under conifers in altitudes over 700 m across the Troodos range. Dominant shrubs typical of Mediterranean landscapes are the Olive tree (Olea sp.) / Carob tree (Ceratonia sp.) / Lentiscus, and Turpentine (*Pistacia lentiscus* and *Pistacia terebinthus respectively*) spp. maquis with lower thorny phrygana are typical at lower ground, whereas Juniper (*Juniperus phoenicea*) Sclerophyllous scrub

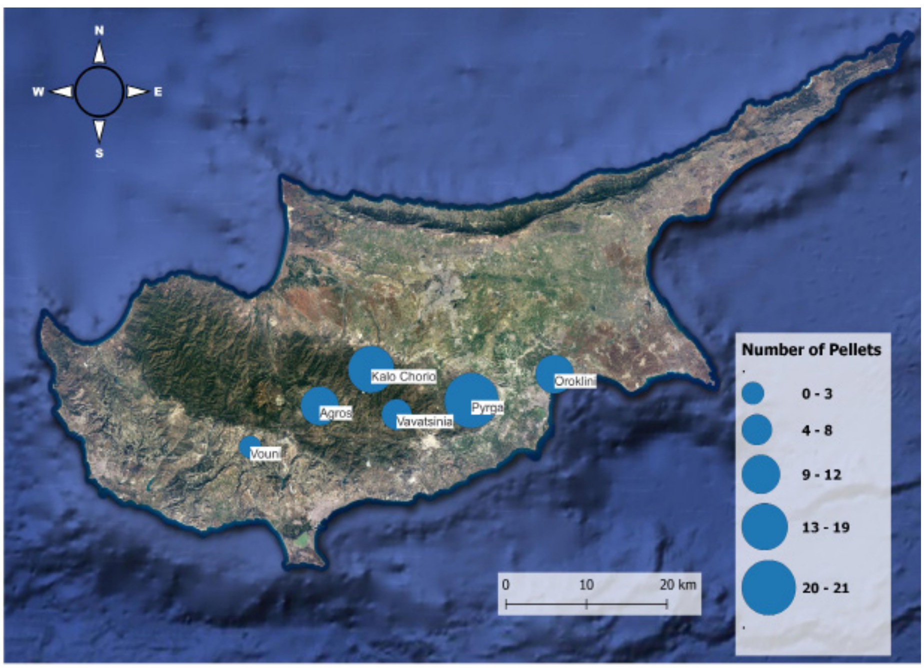

Fig. 1. Sampling locations of Cyprus scops owl pellets within Cyprus during the breeding season 2021.
Obr. 1. Lokality zberu vývržkov výrika cyperského na Cypre v priebehu hniezdnej sezóny 2021.

(Matorral) is characteristic of the coastal areas (Tsintides et al. 2007). The island's proximity to the Middle East makes it one of the hottest parts of the Mediterranean. The mean annual temperature has increased by approximately 1°C during the last century, with a more rapid increase of 0.015°C annually since the 1970s (Flint 2019). During the 20th century, the average annual precipitation was 559 mm in its first 30 years and 462 mm in its last 30 years, a decrease of 17% (Flint 2019). In contrast, in the first 19 years of this century (2001–2019), the annual average precipitation was 491 mm (calculated from data provided by the Cyprus Department of Meteorology 2020).

Pellets analyses

To assess diet composition, we collected 65 pellets between May and August 2021 from 7 nesting sites at 6 sampling locations where BirdLife Cyprus and Game and Fauna Service had nesting boxes occupied by the target species (Fig. 1). The pellets were carefully broken up in the dry state. Their contents were identified with the help of suitable guides (Arnold & Burton 1980, Chinery 1993, Macdonald & Barret 1993). Insects were identified at the Family level, so a magnifying glass was used. In each pellet, the minimum number of individuals of each taxon was estimated.

The prey items from all sites were summed after the pellet analysis was finished, and the relative proportion (%) of the number of each taxon was calculated. For calculating the biomass, an average mass for each taxon was taken (Macdonald & Barret 1993, James & Gilbert 2011) and multiplied by the number of individuals of each taxon. All these were summed up, and then each taxon's proportion of biomass was calculated. Only areas under the effective control of the Government of the Republic of Cyprus were surveyed.

Diet comparison

Due to the lack of other data from the CSO pellets analysis, the species diet composition and major prey species were compared with the diet of the closely relatedEuropean scops owl from southern Spain (Herrera & Hiraldo, 1976), central Romania (Latková et al. 2012), Austria (Muraoka 2009), central Europe: Slovakia (Šotnár et al. 2008), Czechia (Grim et al. 2022), Hungary (Streit & Kalotás 1991, Balázs (2022), Italy: Italian Alps (Marchesi & Sergio 2005) and Tuscany (Panzeri et al. 2014).

Results

In total, 357 prey items were recorded in the diet of the CSO (Tab. 1). Of these, by number, insects made up 87%, reptiles 7%, mammals 6% and birds less than 1% of the prey items. In terms of biomass, mammals were the most important prey, making up 41%, followed by insects (31%), reptiles (24%) and birds (4%). The most important mammalian prey taxa, in terms of biomass,

Tab 1. Diet of the Cyprus scops owl during the breeding season 2021.
Tab 1. Potrava výrika cyperského v priebehu hniezdnej sezóny 2021.

Prey	Number	% Abundance	% Biomass
INSECTA	**309**	**86.6**	**31.5**
Orthoptera	**131**	**36.7**	**17.3**
Tettigoniidae	5	1.4	0.7
Acrididae	126	35.3	16.6
MANTODEA	**3**	**0.8**	**0.4**
Mantidae	3	0.8	0.4
Dermaptera	**21**	**5.9**	**0.6**
Forficulidae	21	5.9	0.6
Hemiptera	**4**	**1.1**	**0.7**
Pentatomidae	2	0.6	0.1
Cicadidae	2	0.6	0.5
Lepidoptera	**2**	**0.6**	**0.3**
Lepidoptera indet.	2	0.6	0.3
Coleoptera	**146**	**40.9**	**12.3**
Carabidae	42	11.8	2.8
Staphylinidae	5	1.4	0.1
Scarabaeidae	44	12.3	5.8
Buprestidae	10	2.8	0.7
Elateridae	3	0.8	0.2
Tenebrionidae	2	0.6	0,1
Cerambycidae	1	0.3	0,1
Curculionidae	17	4.8	1.1
Coleoptera indet.	22	6.2	1.4
Hymenoptera	**4**	**1.1**	**0.1**
Formicidae	4	1.1	0.1
REPTILIA	**24**	**6.7**	**24**
Hemidactylus turcicus	12	3.4	7.9
Laudakia cypriaca	2	0.6	5.3
Scincidae indet.	2	0.6	2.6
Lacertidae indet.	2	0.6	2.6
Lacertilia indet.	6	1.7	5.5
AVES	**2**	**0.6**	**3.6**
Phylloscopus sp.	1	0.3	0.9
Passer sp.	1	0.3	2.6
MAMMALIA	**22**	**6.2**	**41**
Pipistrellus sp.	1	0.3	0.8
Acomys nesiotes	3	0.8	7.9
Rattus rattus (juv)	2	0.6	6.6
Mus spp.	15	4.2	23.7
Rodentia indet.	1	0.3	2
Total	**357**	**-**	**-**
No. of taxa	**29**		

were small mice (Mus spp.) (24%), Cyprus spiny mice (*Acomys nesiotes*) (8%) and juvenile black rats (*Rattus rattus*) (7%). The most essential insects were grasshoppers (Acrididae) (17%) and scarab beetles (Scarabaeidae) (6%). All the reptilian prey consisted of lizards, mainly Turkish geckoes (*Hemidactylus turcicus*) (8%), Cyprus agamas (*Laudakia cypriaca*) (5%) and indeterminate species, including Scincidae and Lacertidae. The estimated prey biomass ranged from 0.1 – 25 g, with a mean of 2.1 g + SD 4.9. The detailed diet results are given in the Appendix 1.

Discussion

In terms of prey abundance, the CSO appears to be mainly insectivorous. However, in terms of biomass, it is shown to have a much more varied diet, with mammals as the most crucial prey and reptiles also very prominent. The findings of this study match with the only available diet data we have on the study species; two years of observations through a nestbox camera at a nesting site (Cyprus Bird Reports 2009 and 2017).

As there are no published studies regarding CSO, the findings of this study were compared to the studies of the closely related European scops owl (Tab. 2). Herrera and Hiraldo (1976), found in the southern half of Spain (Mediterranean shrub and woodland), in terms of abundance, 94.3% invertebrates, 3.7% amphibians and reptiles, 1.2% mammals and 0.6% birds in owls' diet. In our study, the vertebrate contribution was more than double the Spanish findings (5.5% and 13.5%, respectively). In contrast, this contribution in other European studies was even lower, with invertebrate prey dominating the diet composition. In central Romania, its main prey was Orthoptera, mainly bush crickets (Tettigoniidae), with much fewer Coleoptera, other insects, rodents and passerine birds (Latková et al. 2012).

In the Italian Alps, the main prey by numbers were insects, particularly bush crickets and many Coleoptera; however, rodents were the most important prey by biomass (Marchesi & Sergio 2005). In an island of the Tuscan Archipelago, central Italy, outside the breeding season, the scops owl was preying mainly on Coleoptera of the family Vesperidae, with fewer other Coleoptera, Orthoptera, rodents, geckos and passerines (Mori et al. 2016). Šotnár et al. (2008) and Grim et al. (2022), at the northern range limit of central Europe (Slovakia and Czechia, respectively), also found that the primary prey source was insects. In addition, studies in Austria and Hungary (Muraoka 2009, Streit & Kalotás 1991, Balázs 2022) show a clear dominance of invertebrate prey (99.1%, 97.2% and 98%, respectively). Finally, a study of the African species Sokoke scops owl (*Otus irenae*) revealed mainly Coleoptera (particularly

Tab 2. Diet composition (relative abundance) of European scops owl populations, compared to the present CSO study.
Tab 2. Porovnanie zloženie potravy (relatívna abundacia) výrika lesného s výsledkami potravy výrika cyperského tejto štúdie.

State	Spain[1]	Austria[2]	Slovakia[3]	Romania[4]	Hungary[5]	Hungary[6]	Italy[7]	Italy[8]	Czechia[9]	CSO Cyprus[10]
Region and year	southern half of Spain 1976	2007	2000 – 2002	2008 – 2009	Szekszárd 1979 – 1990	Gödöllö 2017	Central–eastern Alps 2002 – 2003	Tuscan, Archipelago 2011 – 2013	Olomouc 2022	2021
Number of nesting pairs	N/A	1	5	26	43	1	20	N/A	2	7
Method of data collection	N/A	infrared camera	pellet, analysis of prey remnants, direct observation	pellet, analysis of prey remnants	analysis of prey remnants, direct observation	infrared camera during 20 d of breeding	pellet, analysis of prey remnants, direct observation	pellet, analysis of prey remnants	photographs, droppings and detritus analysis	pellet, analysis of prey remnants
Orthoptera (%)	-	61.8	87.6	86.8	-	81.6	78.7	44.1	79.6	36.7
Other insects (%)	94.3	15.8	10.3	7.8	97.2	13.4	20.8	40.1	18.9	49.9
Other arthropods (%)	-	21.5	0.5	1.6	-	3	0.6	13.6	1.1	-
Vertebrates (%)	5.5	0.9	1.6	3.8	2.8	2	-	1.7	0.4	13.5
Number of prey items	159	2152	884	831	640	546	342	59	1079	357

Sources: The original table was taken from Balázs (2022). The table was adjusted to include Marchesi & Sergio (2005), Panzeri and Mori (2014), Grim et al. (2022) and the current study results. N/A = not available; [1]Herrera & Hiraldo (1976), [2]Muraoka (2009), [3]Šotnár et al. (2008), [4]Latková et al. (2012), [5]Streit & Kalotás (1991), [6]Balázs (2022), [7]Marchesi & Sergio (2005), [8]Panzeriet al. (2014), [9]Grim et al. (2022), [10]this study

Scarabaeidae), with much fewer other insects and small birds in their diet (Virani 2008).

The CSO is primarily insectivorous, with Orthoptera and Coleoptera comprising the bulk of its diet. Still, at the same time, small vertebrate prey such as small mammals and lizards were important in terms of biomass. This importance of vertebrate prey in the CSO diet stands out compared to other studies. Predation on a bat species (*Pipistrellus* sp.) by scops owl is documented for the first time in Cyprus, even though Mikkola (2018) reported bat predation as rare. This record came from a site near a wetland (Appendix 1). Predation of lizards is also remarkable since, although the most frequently taken species, the Turkish gecko is nocturnal, the other lizards are typically diurnal. Scops owls have been reported foraging by day occasionally (Mikkola 1992). It is possible that these were taken at dusk while still active, just as the owl started its foraging activity to feed its young. The small percentage of birds as prey is the same as that reported by Herrera and Hiraldo (1976).

The CSO and the European scops owl are the most insectivorous owls in Europe. However, the CSO diet shows the importance of vertebrate prey in a much higher proportion than its European counterpart.

In the future, studies of the CSO diet will expand in the western, more forested part of the island, as well as in urban areas. They will also monitor roosts outside nesting season to have a complete picture of this endemic species foraging ecology.

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Appendix 1. Diet of the Cyprus scops owl during the breeding season 2021 including the number of prey items found per nesting site.
Príloha 1. Potrava výrika cyperského v priebehu hniezdnej sezóny 2021, detailný prehľad potravy na jednotlivých hniezdnich lokalitách

Prey Items / sites	Pyrga, Larnaca	Kalo Chorio Nicosia	Vavla, Larnaca	Oroklini, Larnaca	Vouni, Limassol	Agros (nest 1), Limassol	Agros (nest 2) Limassol
No. of pellets	21	13	8	10	3	7	3
INSECTA	104	66	42	65	9	16	9
Orthoptera	34	18	35	39		5	
Tettigoniidae		5					
Acrididae	34	13	35	39		5	
MANTODEA		2	1				
Mantidae		2	1				
Dermaptera	15	5	1				
Forficulidae	15	5	1				
Hemiptera		2			2		
Pentatomidae					2		
Cicadidae		2					
Lepidoptera	2						
Lepidoptera indet.	2						
Coleoptera	53	39	5	24	6	11	8
Carabidae	16	13	2	2	5	4	
Staphylinidae		4		1			
Scarabaeidae	15	12	2			7	8
Buprestidae		10					
Elateridae				2	1		
Tenebrionidae	2						
Cerambycidae	1						
Curculionidae	7			10			
Coleoptera indet.	12		1	9			
Hymenoptera				2	1		1
Formicidae				2	1		1
REPTILIA	8	4		4	3	5	
Hemidactylus turcicus	3	2		1	3	3	
Laudakia cypriaca						2	
Scincidae indet.	2						
Lacertidae indet.	2						
Lacertilia indet.	1	2		3			
AVES			1			1	
Phylloscopus sp.			1				
Passer sp.						1	
MAMMALIA	9		2	3	1	5	2
Pipistrellus sp.				1			
Acomys nesiotes	1					2	
Rattus rattus (juv)	2						
Mus spp.	5		2	2	1	3	2
Rodentia indet.	1						
Total	121	70	45	72	13	27	11

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Second-breeding events of the common kestrel (*Falco tinnunculus*) in the Czech Republic

Prípady druhých hniezdení sokola myšiara (*Falco tinnunculus*) v Českej republike

Karel Poprach & Miroslav Dusík

Abstract: The laying of two clutches in a single breeding season can increase the fitness of the parent birds and stabilise a population. Our study analysed the rate of second-breeding attempts in the common kestrel (Falco tinnunculus) population in the Czech Republic. In the research, a total of 8,049 common kestrel nests were checked between 1979 and 2019. Of the 1,197 breeding events recorded during the study period in Moravia, 1,184 cases were first clutches and 13 cases (1.1%) were second breeding attempts. In Bohemia, a total of 6,852 breeding events were observed during the same study period, of which 6,811 were first clutches, 32 cases were late breeding attempts and 9 cases (0.1%) were second clutches. Second breeding events occurred only rarely, mainly during population outbreaks of prey species. During the mass outbreak of the common vole (Microtus arvalis) population in the Czech Republic in 2019, 5 (5.2%) of the 97 studied common kestrel pairs nested for the second time in Moravia; in Bohemia, second clutches were recorded in 3 (8.1%) of the 37 studied pairs. The second breeding attempts were recorded at an altitude of 272 ± 123 m (mean ± SD, range 179–560 m, n = 22) and commenced between 24 June and 25 July (29 June on average, n = 5). The range of the time gap between the first and the second clutch was 54 to 92 days (70.8 ± 16.3 days, n = 5). The second clutches consisted of an average of 4.1 ± 0.9 eggs (range 3–6, n = 12), with an average of 3.7 ± 0.9 fledglings in each successful breeding pair (range 2–5, n = 11) and 2.6 ± 1.9 fledglings for each initiated breeding attempt (range 0–5, n = 16).

Abstrakt: Dve znášky v jednej hniezdnej sezóne môžu zvýšiť kondíciu rodičovského páru a stabilizovať populáciu. V našej štúdii sme analyzovali početnosť pokusov o druhé hniezdenie v populácii sokola myšiara (*Falco tinnunculus*) v Českej republike. V rámci výskumu bolo v rokoch 1979 až 2019 celkovo skontrolovaných 8 049 hniezd sokola myšiara. Z 1 197 zaznamenaných hniezdení počas skúmaného obdobia na Morave, sa v 1 184 prípadoch jednalo o prvé hniezdenie a v 13 prípadoch (1,1 %) o druhý pokus o hniezdenie. Celkovo bolo v Čechách počas rovnakého obdobia štúdie zaznamenaných 6 852 hniezdení, z toho v 6 811 prípadov sa jednalo o prvé znášky, v 32 prípadov sa jednalo neskoré pokusy o hniezdenie a v 9 prípadoch (0,1 %) sa jednalo o druhé znášky. Druhé hniezdenie sa vyskytlo len zriedkavo, najmä počas premnoženia koristi. Počas premnoženia populácie hraboša poľného (*Microtus arvalis*) v roku 2019 boli druhé znášky zaznamenané v 5 (5,2 %) z 97 sledovaných párov sokola myšiara na Morave a v 3 (8,1 %) z 37 sledovaných párov v Čechách. Druhé pokusy o hniezdenie boli zaznamenané v nadmorskej výške 272 ± 123 m (priemer ± SD, rozsah 179–560 m, n = 22). Započaté boli v období od 24. júna do 25. júla (v priemere 29. júna, n = 5). Rozsah časového odstupu medzi prvou a druhou znáškou bol 54 až 92 dní (70,8 ± 16,3 dňa, n = 5). Druhá znáška pozostávala v priemere zo 4,1 ± 0,9 vajec (rozsah 3–6, n = 12), pričom v každej znáške bolo v priemere 3,7 ± 0,9 mláďat.

Key words: second clutch, reproduction, population stability, common vole, fitness

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Introduction

A successful breeding season depends on several factors, and one of the most important is the abundance and availability of food (Veselovský 2001). Nesting usually occurs during a specific period of the year, usually from March to July, but nesting periods can be extended in the case of species that nest repeatedly within a single year. Among raptors, second-breeding attempts within a single season occur only exceptionally, and the phenomenon has only been observed in rodent-hunting raptors (Charter et al. 2005) such as the rock kestrel (*Falco rupicolus*) (van Heerden et al. 1994), American kestrel (Falco sparverius) (Toland 1985, Steenhof & Peterson 1997, Smith et al. 2017), white-tailed kite (Elanus leucurus) and Harris's hawk (*Parabuteo unicinctus*) (Newton 1979). In the case of the Palearctic raptor species, second clutches have only been observed in the common kestrel (*Falco tinnunculus*) (von Blotzheim et al. 1989), with a total of 16 records of second breeding attempts reported to date within the breeding range of the species: 13 cases in Europe (Závalský 1985, von Blotzheim et al. 1989, Sánchez 1990, Fargallo et al. 1996, Hudec & Šťastný 2005) and 3 in Israel (Charter et al. 2005).

This paper summarises the observations of another 22 cases of second breeding events in the common kestrel which were recorded in the Czech Republic from 1979 to 2019. The study will also address the issue of second clutches in raptors and owls.

Material and methods

From 1979 to 2019, a total of 8,049 common kestrel nests were checked in the Czech Republic (Table 1, Fig. 1). Most of these nests were situated in nest boxes installed for the common kestrel (n = 7,266) in farmland, either in lines of trees, on solitary trees, in windbreaks and on electricity pylons. Some of the nests were found in nest boxes installed in agricultural facilities for use by barn owls (*Tyto alba*) and little owls (*Athene noctua*) (n = 760), while others were situated in cavities in farmhouses and churches or in nest boxes intended

Tab. 1. Numbers of recorded common kestrel (*Falco tinnunculus*) nests in the Czech Republic divided by individual nesting sites from 1979 to 2019.
Tab. 1. Počet hniezd sokola myšiara (*Falco tinnunculus*) zaznamenaných v Českej republike od roku 1979 do roku 2019, rozdelených podľa jednotlivých hniezdnych lokalít.

Nesting site	Region		
	Moravia	Bohemia	Czechia (sum)
Common kestrel nest box	565	6701	7266
Barn owl nest box	434	129	563
Little owl nest box	177	20	197
Tawny owl nest box	5	0	5
Common kestrel natural nest	16	2	18
The sum of all nests	**1197**	**6852**	**8049**

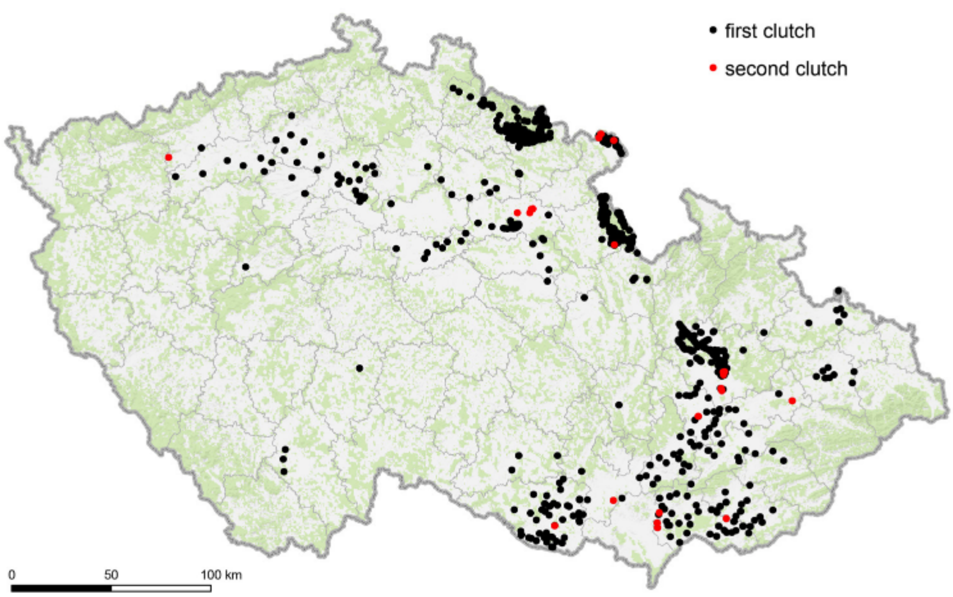

Fig. 1. First (n = 8,027) and second clutches (n = 22) in the studied pairs of the common kestrel (*Falco tinnunculus)* in the Czech Republic from 1979 to 2019.
Obr. 1. Prvá (n = 8 027) a druhá znáška (n = 22) u sledovaných párov sokola myšiara (*Falco tinnunculus*) v Českej republike v rokoch 1979 až 2019.

for use by tawny owls (*Strix aluco*). In addition to collecting basic data on the breeding biology of the common kestrel, the nest sites were also checked for possible second or late breeding attempts, although it is possible that some second clutches may have passed unobserved. This paper defines second breeding attempts as cases
in which a second clutch was laid in the same nest after an initial successful or unsuccessful breeding attempt. We considered successful nestings to be those in which at least one chick fledged.

Results

A total of 1,197 breeding attempts by common kestrels were observed in Moravia, of which 1,184 cases were first clutches and 13 cases (1.1%) were second breeding attempts within a single season. However, in 2019, when a mass outbreak of the common vole occurred in the Czech Republic, 5 (5.2%) of the 97 checked pairs in Moravia laid second clutches.

A total of 6,852 breeding cases by the studied species were recorded in eastern Bohemia, of which 6,811 were first clutches, 32 were late breeding attempts and 9 (0.1%) were second clutches within a single season.
In 2019, in a section of the Broumov area (11 km^2) with a high abundance of prey, 3 of the 37 checked pairs (8.1%) laid second clutches.

Second breeding attempts by common kestrels in the Czech Republic were recorded at an altitude of 272 ± 123 m (mean ± SD, range 179–560 m, n = 22) and were initiated between 24 June and 25 July (29 June on average, n = 5), see Table 2. The time difference

Tab. 2. Localisation and course of second breeding attempts of the common kestrel (*Falco tinnunculus*) in the Czech Republic from 1979 to 2019 (n = 23). Data on the course of common kestrel second breeding events published by Závalský (1985) are also included.
Tab. 2. Lokalizácia a priebeh druhých hniezdnych pokusov sokola myšiara (*Falco tinnunculus*) v Českej republike od roku 1979 do roku 2019 (n = 23). Zahrnuté sú aj údaje o priebehu druhej znášky sokola myšiara publikované Závalským (1985).

Year	Locality name	GPS	Nest site	Altitude (m)	Start of 1st breeding	1st breeding - No. of eggs / fledglings	Start of 2nd breeding	2nd breeding - No. of eggs / fledglings
1979	Lochenice	50.282134N, 15.819792E	poplar tree, CKNB*	250	late March	NK / 6	early August	4 / 3
1981	Předměřice nad Labem	50.264578N, 15.813616E	poplar tree, CKNB	250	25 March	6 / 6	25 July	NK / 4
1981	Ostrava-Poruba	49.846499N, 18.180926E	dwelling house, balcony, 7th floor	249	1 April	7 / 4	24 June	4 / 0
1991	Hlušovice	49.632419N, 17.280482E	poplar tree, CKNB	215	NK***	min. 2 / 0	NK	3 / 0
1994	Trotina	50.284180N, 15.833258E	poplar tree, CKNB	240	5 April	NK	5 July	NK / min. 3
1994	Střezetice	50.256550N, 15.726301E	power pole, CKNB	280	1 April	NK	3 July	4 / 2
2000	Grygov	49.547070N, 17.285531E	power pole, CKNB	206	NK	5 / 5	NK	min. 1 / NK
2007	Týneček	49.620400N, 17.286329E	power pole, CKNB	215	NK	NK / 0	NK	NK / 0
2007	Týneček	49.634886N, 17.291635E	power pole, CKNB	219	NK	3 / 0	NK	3 / 0
2010	Nemilany	49.557571N, 17.277847E	power pole, CKNB	207	NK	4 / 0	NK	6 / 0
2011	Ždov	50.295623N, 13.239822E	farming facility, BONB**	390	NK	NK	NK	NK
2012	Pěčín	50.162230N, 16.432033E	ash tree, CKNB	560	10 April	NK	3 July	NK / 3
2014	Přísnotice	48.995747N, 16.619875E	farming facility, BONB	179	NK	NK	NK	NK
2015	Čejkovice	48.893621N, 16.940813E	farming facility, BONB	210	NK	NK	NK	3 / 3
2018	Výšovice	49.419688N, 17.141669E	farming facility, BONB	221	NK	NK	NK	4 / 4
2019	Milokošť	48.965973N, 17.403000E	farming facility, BONB	188	NK	NK	NK	5 / 5
2019	Terezín	48.962238N, 16.943327E	farming facility, BONB	182	NK	NK	NK	4 / 4
2019	Čejkovice	48.913667N, 16.934692E	farming facility, BONB	227	NK	NK	NK	4 / 4
2019	Černotín	49.531636N, 17.778300E	farming facility, BONB	252	NK	NK	NK	min. 1 / 0
2019	Borotice	48.852384N, 16.238324E	farming facility, BONB	231	NK	NK	NK	5 / 5
2019	Meziměstí	50.659861N, 16.247964E	power pole, CKNB	560	late April	NK / 5	late July	NK / 4
2019	Meziměstí	50.641680N, 16.236193E	power pole, CKNB	470	late April	NK / 4	late August	NK / min. 2
2019	Janovičky	50.637087N, 16.345016E	power pole, CKNB	490	Mid-April	NK / 5	late July	NK / min. 3

*Common Kestrel Nest Box (CKNB); **Barn Owl Nest Box (BONB); ***Not Known (NK) between the beginning of the first and the second clutch was 71 ± 16 days (range 54–92 days, n = 5).

Of the 22 recorded second-breeding attempts, 18 occurred after the young from the first breeding had successfully fledged, but 4 cases were recorded after an initial unsuccessful breeding attempt, a phenomenon known as replacement clutches. The second clutches included 4.1 ± 0.9 eggs (range 3–6, n = 12), with 3.7 ± 0.9 juveniles fledged successfully from each breeding pair (range 2–5, n = 11) and 2.6 ± 1.9 fledglings for each initiated breeding attempt (range 0–5, n = 16).

Discussion

Within the breeding range of the common kestrel, only 16 cases of second breeding events within a single season were observed between 1936 and 2003. However, our research conducted in the Czech Republic between 1979 and 2019 has recorded a further 22 cases of second breeding attempts of the study species (Table 3). Second clutches during a single breeding season have also been observed in common kestrels in captivity (Meijer 1989, Meijer et al. 1992). Interestingly, in the case of a common kestrel pair that bred in 2003 in České Budějovice (the Czech Republic), a helper (offspring raised during the first season breeding by the same pair) marked with a wing tag was recorded actively assisting with the feeding of young hatched during the second breeding event (Jan Riegert, pers. comm.).

Tab. 3. List of second breeding attempts of the common kestrel (*Falco tinnunculus*) recorded within its range distribution from 1936 to 2019.

Tab. 3. Zoznam pokusov o druhé hniezdenie sokola myšiara (*Falco tinnunculus*) zaznamenaných v rámci jeho rozšírenia od roku 1936 do roku 2019.

Location	Year / period	No. of 2nd breedings	Source
Europe	1936–1970	6	von Blotzheim et al. (1989)
Czechia (Žleby)	1966	1	Hudec & Šťastný (2005)
Czechia (Ostrava)	1981	1	Závalský (1985)
Spain	not known	1	Sánchez (1990)
Spain	not known	3	Fargallo et al. (1996)
Czechia (České Budějovice)	2003	1	Jan Riegert, pers. comm.
Israel	2004	3	Charter et al. (2005)
Czechia (Bohemia)	1979–2019	9	this study
Czechia (Moravia)	1980–2019	13	this study

Some authors (e.g., von Blotzheim et al. 1989, Charter 2005) have stated that unambiguous evidence of second breeding attempts by common kestrels (such as the capture and individual marking of the parents) is lacking in the majority of cases, and this is also true for the data obtained from the Czech Republic. However, we suggest that if two subsequent breeding attempts occurred in the same nest within the same season, they are likely to involve the same pair, considering the timescale and the significant breeding-site fidelity observed in this species. In 1979, we corroborated the second breeding attempt of a single female marked with a wing tag (Table 1).

Second breeding events in species that regularly produce two clutches during a season may contribute significantly to the overall reproduction rate. For example, in the barn owl, the proportion of second clutches in pairs breeding in the Czech Republic between 1998 and 2007 ranged between 1.6 and 48.8% (mean 27.2%, n = 2,135 first and 580 second breeding attempts) (Poprach 2010). In contrast, the second breeding events of common kestrels represented only a marginal contribution to the Central European population and did not appear to have had a sizable effect on the overall reproduction rate of the species. Our results suggest that over the long-term period of 1979 to 2019, only 0.1–1% of the common kestrel population bred for the second time during a single season. However, the proportion of second clutches may vary markedly in different years depending on the abundance of prey species. During the strong outbreak of the common vole population in the Czech Republic in 2019, 5.2% of common kestrel breeding events in Moravia were second clutches, with the rate in Bohemia being even higher at 8.1%. Fargallo et al. (1996) reported three cases of second clutches (27.3%) in eleven breeding pairs in Spain, a rate which can be considered as exceptional. In Israel, Charter et al. (2005) recorded three cases of second breeding events (7.5%) in 40 studied common kestrel pairs.

All of the pairs in which we observed breeding for the second time within a single season used the same nest. However, in Israel, one pair moved to a different building for the second nesting at a distance of 35 m from the earlier nest site (Charter et al. 2005). We found that the time difference between the beginning of the first and the second clutches was 71 days on average, which includes the incubation of eggs (mean 29, range 21–31 days) and providing care for nestlings (mean 29, range 27–30 days) (Hudec & Šťastný 2005). In one case, we even recorded that the second clutch was initiated about 4 days before the young from the first nesting had fledged and, in two other cases, soon (3 and 5 days) after the offspring had left the nest. Similarly, in Israel, a second nesting was initiated 7 days before the chicks from the first nesting had flown the nest, while another two pairs laid their second clutches within 12 days of the fledging of their first brood (Charter et al. 2005). We recorded the start of egg laying within the second clutch at a maximum of 26 and 34 days after the young from the first nesting fledged. In one case in Israel, both parents continued to visit both nests; the female stopped hunting about a week before laying the second clutch, with the male supplying all the food for the first brood and his mate. It is very interesting to note that the female began incubating the second clutch while still feeding the young from the first brood with prey brought to the nest by the male (Charter et al. 2005).

In general, second breeding events in common kestrels occurred after the first brood had fledged, in contrast to barn owls, in which the beginning of the second clutch usually occurs with the young from the first breeding still present in the nest (Poprach 2010). For the first clutch of the common kestrel in the Czech Republic, Hudec & Šťastný (2005) reported mean numbers of 5.1 eggs (n = 4,430) and 3.8 fledged young (n = 6,486) during the period between 1982 and 1998. In the second breeding events, we recorded an average of 4.1 eggs per nest, with 3.7 fledged young for each successfully nesting pair and 2.7 fledged young for each initiated breeding attempt. As was observed in this study, the lower average number of fledglings during second breeding attempts was partly caused by the several observed cases of unsuccessful clutches. In owl species such as the afore-mentioned barn owl in which second breeding events regularly occur, the numbers of eggs and young in second clutches are usually higher than in the first. For instance, in the Czech Republic (1975–2017), mean numbers of 6.0 (n = 1,300) vs 7.3 (n = 309) eggs were recorded in the first and second clutches of the European barn owl, respectively, with 4.1 (n = 1,900) vs 4.5 (n = 490) of fledged young recorded for the first and second initiated breeding attempts, respectively (Poprach 2010). The barn owl is the only raptor species that regularly nests a second time within a single year. Barn owls lay a second clutch of eggs while the young from the first nesting are still in the nest and have higher numbers of young in the second brood. In the case of the common kestrel, however, an opposite trend was observed. Common kestrels usually lay a second clutch after fledging the young from the first breeding, while the numbers of young within the second brood were found to be lower than in the first. This may indicate that the barn owl is physiologically better adapted to breeding twice within a single season. As the findings of our research show, second breeding attempts by common kestrels within a single year are a rare phemonenon, but they may occur more frequently under suitable food conditions. It is also possible that the frequency of second breeding events in common kestrels has been underestimated overall.

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Annual survival rates of satellite-tracked adult European honey buzzards (*Pernis apivorus*) based on the Kaplan-Meier estimator and its probabilistic extension

Ročná miera prežívania satelitne sledovaných dospelých jedincov včelára lesného (*Pernis apivorus*) s na základe Kaplan-Meierovho odhadu a jeho pravdepodobnostného rozšírenia

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Abstract: The annual survival rate of adult raptors is an important parameter in population dynamics and is needed to derive measures for population stability and conservation management. Here we studied adult European honey buzzards (*Pernis apivorus*), a migratory land bird, using satellite telemetry throughout the year for up to three years. We used the Kaplan-Meier method of survival estimation in combination with the distribution density function for survival. This function describes the number of survivors N as a function of time t, based on the survival rate SR. This probabilistic extension of the Kaplan-Meier estimator results in a simple method that does not require a commercial statistical program to extract survival rates from event time analysis. It can be applied to analysing any event-time data, not only telemetry results but also ring recoveries, as demonstrated using European honey buzzards as an example. The average adult survival rate in our study, based on permanent satellite telemetry monitoring, was 0.44/year (linear correlation factor f = 0.99). This implies an adult mortality rate of 0.56 per year. It seems that particularly unfavourable weather conditions during the crossing of the Sahara and the Mediterranean led to this high mortality rate of our birds during migration from 2001 to 2011, but is likely to vary greatly from year to year. However, the loss rate in the wintering area was also high, at one third of the birds. More honey buzzards need to be tracked throughout the year to assess factors affecting survival and threats to populations adequately.

Abstrakt: Ročná miera prežívania dospelých dravcov je dôležitým parametrom populačnej dynamiky a je poznanie je potrebné na odvodenie opatrení pre stabilitu populácie a manažment ich ochrany. V priebehu jedného až troch rokov sme pomocou satelitnej telemetrie študovali dospelé jedince včelára lesného (*Pernis apivorus*). Použili sme Kaplan-Meierovu metódu odhadu prežitia v kombinácii s funkciou distribučnej hustoty pre prežitie. Táto funkcia opisuje počet prežívajúcich (N) ako funkciu času (t) na základe miery prežitia (SR). Výsledkom tohto pravdepodobnostného rozšírenia Kaplan-Meierovho odhadu je jednoduchá metóda, ktorá nevyžaduje komerčný štatistický program na extrakciu miery prežitia z analýzy časových údajov. Metóda sa môže použiť na analýzu akýchkoľvek časových údajov, nielen výsledkov telemetrie, ale aj metód založených na krúžkovaní, ako bolo demonštrované na včelárovi lesnom. Naša štúdia na základe permanentného satelitného telemetrického monitorovania zaznamenala priemernú mieru prežívania dospelých jedincov 0,44/rok (lineárny korelačný faktor f = 0,99). Miera úmrtnosti dospelých jedincov bola až 0,56 ročne. Zdá sa, že počas prechodu Sahary a Stredozemného mora v rokoch 2001 až roku 2011 prevládali obzvlášť nepriaznivé poveternostné podmienky, ktoré viedli k tejto vysokej miere úmrtnosti vtákov počas migrácie. Je ale pravdepodobné, že medziročne sa budú tieto podmienky značne líšiť. Vysoký úbytok, až jedna tretina jedincov bol však zaznamenaný aj na zimovisku. Pre primerané posúdenie faktorov ovplyvňujúcich prežívanie a ohrozenia populácie je potrebné sledovať väčšie množstvo jedincov včelára lesného.

Key words: year-round monitoring, satellite telemetry, mortality, tagging, biologging, raptors, birds of prey

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Introduction

Survival is a key life history trait in animals. However, most methods of estimating survival require significant human and economic investment over the long term, particularly for species that occur at low densities, which is the case for most threatened species. Estimates from general ring recoveries are mainly based on birds found dead (Newton 1979). Only in recent years has it become possible to track large and medium-sized birds of prey globally over several years using satellite and GSM telemetry, and to determine when and where they die. This allows researchers to study honey buzzard (*Pernis apivorus*) migratory routes much more precisely (see Vansteelant and Agostini 2021), identify the most dangerous phases and areas of the annual cycle, and measure survival rates more accurately than in the past.

Overall, understanding and monitoring the annual survival of adult raptors is crucial for effective conservation and population management. Knowledge of survival/mortality rates and reproductive rates is paramount for population modelling and quantitative results on population stability.

To the present day, only a few adult European honey buzzards (hereafter honey buzzard) have been tracked by satellite throughout the year (e.g., nine by Howes 2020), but nothing has been published on their survival rates. Saratosa et al. (2024) have recently reported some mortality events in honey buzzards, but no distinction is made between age classes, in particular between adults, immatures and juveniles. It is generally accepted that mortality, especially natural mortality, is much lower in adults than in juveniles. We only consider adult birds in this paper and are therefore unable to compare the results of Saratosa et al. (2024) with ours.

In a recent paper, we focused on mortality patterns throughout the annual cycle of migrating adult honey buzzards. Of 12 adults tracked by satellite, three died during the autumn migration, four in wintering areas, two during the spring migration and one in breeding areas, while the fate of two remained unclear (Meyburg & Ziesemer 2024). Considering the duration of these different periods, deaths per unit of time were four times higher during migration than during the rest of the year, and relatively more frequent in spring than in autumn, as Newton (2024) summarised.

In the present study, we calculated the survival rate of the satellite-tracked honey buzzards using the Kaplan-Meier estimator (Kaplan & Meier 1958) with a new probabilistic extension, the survival probability density function, which was developed for the evaluation of our tracked birds and any telemetric study.

Methods

Twelve adult honey buzzards (seven males and five females) breeding in northern Germany were monitored with 13 satellite transmitters between 2001 and 2011. Birds were captured in 2001–2011 during the nesting period in the forest near the eyrie using a dho gaza trap technique and live eagle owls (*Bubo bubo*) as decoys.

The breeding sites were checked in subsequent years after the honey buzzards had been tagged. If telemetry contact was lost before the birds arrived at the breeding site and the birds were not found at the old breeding site, this was taken as a good indication that the individual had died.

After 2–3 years, three birds were recaptured in good condition at the breeding site. Bird 13289 was fitted with a new transmitter (40867). Bird 40868 transmitter was removed as it no longer worked and released without. Bird 41504 was accidentally captured and released with a working tag.

Birds were fitted with 18–22 g solar-powered backpack satellite transmitters (PTTs) manufactured by Microwave Telemetry, Inc. (USA) and NorthStar (USA) (Meyburg & Fuller 2007), which used the Argos satellite system to locate and track honey buzzards. At the beginning of our study, only Doppler-shift transmitters were used due to the species' small size. Later, six GPS-enhanced tags were used, which also transmitted data on flight direction and speed (Ziesemer & Meyburg 2024). Four of these also provided altitude data. The GPS/PTTs were programmed to acquire a GPS fix every hour. The weight of the transmitter plus harness was always well below 3% of the 'birds' weight. For more details see Meyburg & Ziesemer (2024). As honey buzzards are very faithful to their breeding site, monitoring the return to the old breeding site allows a relatively good estimate of whether the birds have survived the last return migration and wintering period.

Information reported by Sergio et al. (2018) was taken into account for assessing whether a sudden failure of data collection or an unexpected cessation of movement – e.g., in the Sahara Desert – was due to the death of the bird, a transmitter defect, or transmitter loss while the bird was still alive. In addition to the guidance provided by Sergio et al. (2018), we were able to draw on our own experience in tracking several hundred birds of prey via satellite, from small falcons (e.g., Amur falcon *Falco amurensis*, Eurasian hobby *F. subbuteo*) to extremely large eagles (e.g., Steller's sea eagle *Haliaeetus pelagicus*, white-tailed eagle *H. albicilla*), belonging to 15 different species. Among those were many cases in which transmitters failed or had been dropped, but the birds survived (e.g., Meyburg & Meyburg 2013). For further details on methodology and analysis, see Meyburg & Ziesemer (2024). We assume that (1) the tagged birds were representative of the local population, (2) the tagging process did not affect survival, and (3) our method of distinguishing death from transmitter failure is valid. Unfortunately, we could not tag more than 12 adult honey buzzards, as the official authorisation was limited to this. In addition, occupied nests of the species are difficult to find, and adults are not easy to trap. We tagged our first individuals early since the introduction of satellite telemetry for bird species of this size when there was little experience of its effects.

Probabilistic methods can be used to calculate bird mortality or survival by incorporating stochastic factors and environmental variables into population modelling. This method is often applied by simulation but does not provide the measured results needed to justify, for example, regulatory action by government agencies. To quantify measured survival and inferred survival rates from telemetric monitoring, we introduce a new methodology in ornithology. We combine the methodology of the Kaplan-Meier survival estimator (Kaplan & Meier 1958) (see also https://en.wikipedia.org/wiki/Kaplan%E2%80%93Meier estimator), which sorts and censors raw data with incomplete knowledge for further event time analysis, with the equation that calculates the number of survivors N as a function of time t, based on the survival rate SR. The Kaplan-Meier survival estimator has been used in various fields, including statistical and medical research, clinical trials, failure analysis, engineering, economics and actuarial science. It has also sometimes been used in ornithological research (e.g., Panter et al.2021), but has not been used to quantify survival rate. The challenge is that the Kaplan-Meier estimator and the resulting plot alone give no guidance on how to extract a survival rate from it. It plots cumulative survival (not survival rate) against time on a linear vertical axis. Pollock et al. (1989a, b) showed that the extraction of survival rates requires an assumption about the validity of a probability density function for survival. Alternatively, the survival rate is calculated by comparing the proportion of survivors after a discrete period with the proportion of survivors in the previous period. This is also the classical way of generating survival rates from ring recoveries.

The novelty presented here, which makes the Kaplan-Meier estimator now easily applicable to ornithology and especially telemetric studies, is to combine it with the basic mathematical definition of survival rate and use it as a probability density function for survival over time.

The mathematical derivation is as follows:
The survival rate definition equation (1) calculates the number of survivors N as a function of time t ("N(t)"), based on the survival rate SR:

$$N(t) = N_0 * SR^t \quad (1)$$

whereby

N(t) = number of survivors at time t after fitting a transmitter

N_0 = number of birds fitted with transmitters

SR = annual survival rate = 1 - annual mortality rate

Equation (1) can be rearranged and differentiated to give

$$d\ln (N(t)/N_0) / dt = \ln (SR) \quad (2)$$

(with ln = natural logarithm)

If $\ln(N(t)/N_0)$ is now plotted against t in the KAPLAN-MEIER survival plot, the final result is what we call the

"GRIES-MEYBURG plot". The slope of the resulting linear regression line in the plot is ln(SR), which finally gives access to the desired result for SR (and, therefore, the mortality rate). Note that the vertical axis is no longer linear, as in the usual Kaplan-Meier graphs, but a transformed axis to linearise the probability density function for survival over t. A fundamental advantage of this new method is that it uses a continuous mathematical equation to which the results, based on a continuous time line, are fitted by linear regression. Classical use, e.g., for ring recovery, is based on a discrete comparison from time period to time period (mostly year to year). This classical method cannot take advantage of the daily precision of event detection by telemetry, which is in contrast to the new method, which can handle any broken numbers for t. The classical period-to-period method stems from ring recovery exploitation methods and can only use integers for t if the statistical ensemble is large. Using linear regression, the result is automatically averaged.

The date of death of the last survivor cannot be taken into account for mathematical reasons, since N in equation (2) would become zero. Ln(0) cannot be calculated.

We used the Kaplan-Meier estimator methodology to refine the raw data from telemetry studies. Birds with an unknown date of death or with an unclear reason for loss of tracking contact, e.g., due to transmitter failure, are 'censored' according to the Kaplan-Meier entry design, i.e., they are not included in the analysis. Birds proven to be alive after the last recorded mortality event increase the number for $N(t)/N_0$.

To refine the raw data, the time span between deployment of the transmitter and the mortality event is calculated precisely in days, but later, it has been used in terms of broken years (t is given in years, as we want to determine survival rate in years). It is also possible to determine the survival rate per day if t is left in "days"). Second, the raw data are sorted according to the time between tagging and death.

Thirdly, $N(t)/N_0$ is calculated for each mortality event, whereby at t = 0 the value for N is N_0. Fourthly, $Ln(N(t)/N_0)$ is plotted against t, the regression line is calculated or manually drawn, and its slope is determined. The fourth step was done in a spreadsheet, which also gives access to the linear correlation factor f and can generate a plot. It is advisable to generate the plot before the data range for linear regression is selected, as the survival rate may change over time.

N(t) is normalised to N_0, as it is being done in Kaplan-Meier survival plots. Mathematically, it is not necessary to do so, but due to the normalisation, different statistic samples can be compared in the same plot.

Following the Kaplan-Meier methodology, 2 of the 12 birds needed to be censored (see Meyburg & Ziesemer (2024) for details about the fate of these birds). As the data of the last death of 10 bird cannot be made use of, there are 9 deaths whose dates could be evaluated.

We have also tested the robustness of the new method regarding the impact of the last bird having died after a very long lifetime (5.1 years after tagging). This bird (13289–40867) could not be included for the mathematical reason mentioned above, but as a test, we assumed that a hypothetical survivor lived longer and reassessed the survival rate.

Assuming that the ring recovery results represent the age class distribution and that the statistical sample is large enough, the methodology presented can also be applied, allowing published results to be re-checked and re-used if the raw data are available. In this case, it is sufficient to know the fraction of rings recovered for each age class out of all rings recovered. The Kaplan-Meier entry design is obsolete here, provided the ring recaptures stem from dead and not from birds alive. We have revisited an older ring recovery study from Sweden (Tjernberg & Ryttman (1994), only birds found dead, N = 53) to get second source numbers for survival rate by the applied new method. This source gives the number of rings for each age class. For the same purpose, we have revisited ring recovery data published by Cösters et al. (2000) (N = 5) which were published with exact ringing and recovery dates. The birds were adult when they were found. No survival rate had been determined from these data up to now.

Results

Ten of the birds disappeared and were presumed to have died during the tracking period, of which three disappeared during the autumn migration, two during the spring migration, four during the winter and only one in the breeding area (Meyburg & Ziesemer 2024).

Figure 1 shows that survival, and therefore mortality, is relatively constant over time, as the results are well represented by a straight regression line over time. The average adult survival rate derived from the slope of the regression line was 0.44 per year. This gives an adult mortality rate of 0.56 per year (linear correlation factor f = 0.99). Note that the slope of the regression line is not the survival rate itself, but its logarithm.

The assumption of a hypothetical survivor increases the survival rate to 0.62/year (f = 0.97), respectively decreases the mortality rate to 0.38/year (Fig. 2), but the scatter

Fig. 1. Fatalities after tagging. GRIES-MEYBURG plot for quantitative determination of survival of adult honey buzzards tagged as adults. Black: straight line of calculated linear regression with f = 0.990 and adult survival rate 0.44/year. Each data point represents one of nine mortalities with known date of death. The slope of the line is not the survival rate but its logarithm. The slope of the line is not the survival rate but its logarithm. $Ln(N/N_0)$ is the log-transformed normalised survival.

Obr. 1. Úmrtia po označení. GRIES-MEYBURGOV graf na kvantitatívne stanovenie prežívania dospelých jedincov včelára lesného, ktoré boli označených ako dospelé. Čierna: priamka vypočítanej lineárnej regresie s f = 0,990 a mierou prežitia dospelých jedincov 0,44/rok. Každý údajový bod predstavuje jednu z deviatich úmrtí so známym dátumom smrti. Sklon čiary nie je miera prežitia, ale jej logaritmus. $Ln(N/N_0)$ je logaritmicky transformácia normalizovanej hodnoty prežívania.

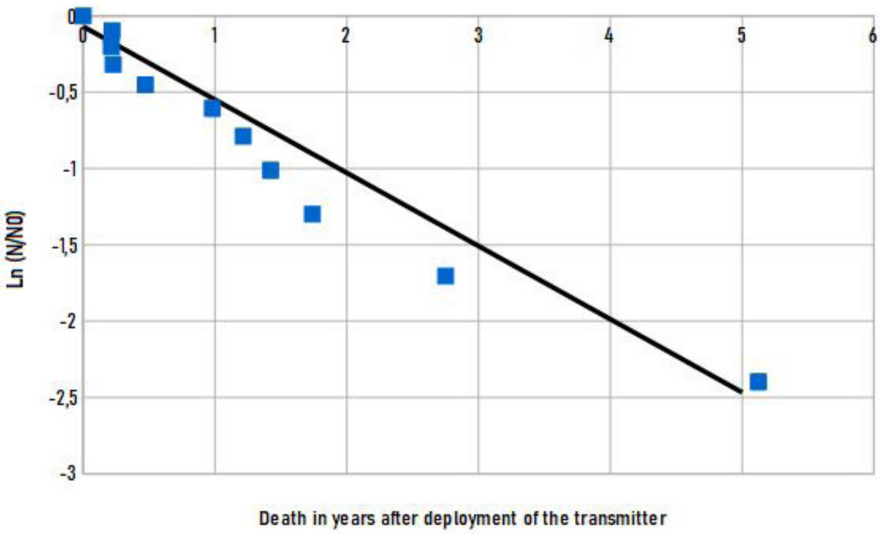

Fig. 2. Fatalities after tagging. GRIES-MEYBURG plot for quantitative determination of survival of adult Honey Buzzards, tagged as adults. Black: straight line of calculated linear regression with f = 0.974 and adult survival rate 0.62/year. The slope of the line is not the survival rate but its logarithm. $Ln(N/N_0)$ is the log-transformed normalised survival.

Obr. 2. Úmrtia po označení. GRIES-MEYBURGOV graf na kvantitatívne stanovenie prežívania dospelých jedincov včelára lesného, ktoré boli označených ako dospelé. Čierna: priamka vypočítanej lineárnej regresie s f = 0,974 a mierou prežitia dospelých 0,62/rok. Sklon čiary nie je miera prežitia, ale jej logaritmus. $Ln(N/N_0)$ je logaritmicky transformovaná normalizovanej hodnota prežívania.

around the regression line becomes larger, systematic deviations become obvious, and f becomes smaller.

We also analysed our telemetry results in the conventional way by periods (year ends). The cumulative survival at the end of years 1 to 3 was 50, 30 and 10%, respectively. Therefore, the resulting survival rates for these years are 50, 60 and 33%/year, respectively, so the resulting mortality rates are 50, 40 and 67%/year, respectively.

The average of these last figures is 0.52/year, which compares well with the 0.56/year obtained by the new method.

Figure 3 shows that the survival rate of honey buzzards ringed as nestlings in Sweden is not constant over time. Two regression curves were necessary because there are two life phases with different survival rates (two lines with different slopes). Survival rates are 0.883/year for the years 8 to 24 and 0.838/year for the years 2 to 5 (f = 0.925 and 0.975, respectively), so the mortality rate is 0.117 and 0.162/year, respectively. This means that it decreases with age. The survival rate for the first year was calculated using the classical method (N_1/N_0) = 0.53/year). The average of both life phases is 0.860/year, respectively 0.140/year for mortality rate.

The few ring recovery data from Cösters et al. (2000) resulted in a survival rate of 0.860/year (f = 0.995), so the adult mortality rate was 0.140/year (Fig. 4).

Discussion

To date, only a few adult honey buzzards have been tracked by satellite throughout the year, but nothing has been published on the resulting survival rates. Meyburg & Ziesemer (2024) have already described our findings on where and when birds disappeared and the challenges researchers face in identifying mortality events throughout the year and interpreting such data (Meyburg & Ziesemer 2024).

Ringing results for honey buzzards can provide data on survival rates, but little information on where mortality is occurring. Most ring recoveries have come from the area north of the Sahara. Since 1945, 2196 honey buzzards ringed in Germany have led to only three recoveries in West Africa. The recovery rate (long-distance detections over 10 km and more) is only 3.3% (Bairlein et al. 2014). A large dataset of ring recovery records (31,269 records) spanning more than 100 years suggests that the mortality of six large migratory birds of prey, including the honey buzzard, has declined dramatically since the late 1970s. After 1979, indirect anthropogenic factors increased while direct factors decreased (De Pascalis et al. 2020).

Survival rates of breeding adult raptors may be highly dependent on habitat quality. For example, in a study of sparrowhawks (*Accipiter nisus*) by Newton et al. (2008), the survival of breeding females was negatively related to the number of rainy days. Annual survival was estimated using a capture-recapture method in three different areas of southern Scotland and east-central England. The three study areas differed at 59%, 66% and 72%. Under certain conditions, the survival of long-lived territorial birds can be estimated using age ratios or turnover rates (Hernández-Matías 2011).

Honey buzzard populations are generally stable (BirdLife International 2004). However, there is increasing evidence that the species is declining in most parts of its European breeding range (Tjernberg & Ryttman 1994, Cösters et al. 2000, Bijlsma 2006, Kjellén 2006, Björklund et al. 2008, Mammen & Stubbe 2009a, b), while counts of migrants in southern Italy by Agostini et al. (2007) suggest that the breeding population of this species in the Balkans may have increased in recent decades. In the Schleswig-Holstein (northern Germany) area, where we tagged most birds, Ziesemer (2024) observed no population decline or increase during a long observation period.

According to Bijlsma et al. (2012), the mortality rate of adult honey buzzards is higher than that of other raptor species in Europe, which is consistent with the observed declines in much of northern and western Europe. Survival results from Bijlsma et al. (2012) are based on recoveries of honey buzzards ringed across Europe (collected by EURING and individual ringing stations between 1957 and 2005). Using the Seber recovery model, survival results ranged from 0.82 to 0.808/year for years 4 to 7 (average: 0.812/year), resulting in an average adult mortality of 0.188/year (average calculated by the authors of this article).

The survival rates of Tjernberg & Ryttman (1994) (0.851 to 0.917/year) in Sweden are higher than the result reported by Bijlsma (2012). We calculated a survival rate of 0.883 for the adult Swedish birds found dead, which is slightly lower than the published 0.917/year.

Cösters et al. (2000) published some raw data for ring recoveries (N = 5) of honey buzzards from North Rhine-Westphalia (Germany) from 1972 to 1998. Using these data, the new method applied here gives a mortality rate of 0.140/year, which is in the same range as the result reported by Tjernberg & Ryttman (1994) for birds shot and found dead together (0.14/year) and our results for birds found dead from the same source (0.14/year averaged over all adult life phases). Both sources of ringing data from Sweden and Germany are historical and do not necessarily reflect the current situation, but give comparable figures for mortality. It can therefore be assumed that both studies represent the situation at that time very well, and that Bijlsma et al. (2012) found already a trend to lower survival rates.

The large discrepancy between the obtained survival rate of 0.44/year and the published results cannot be due to the probabilistic extension of the Kaplan-Meier estimator,

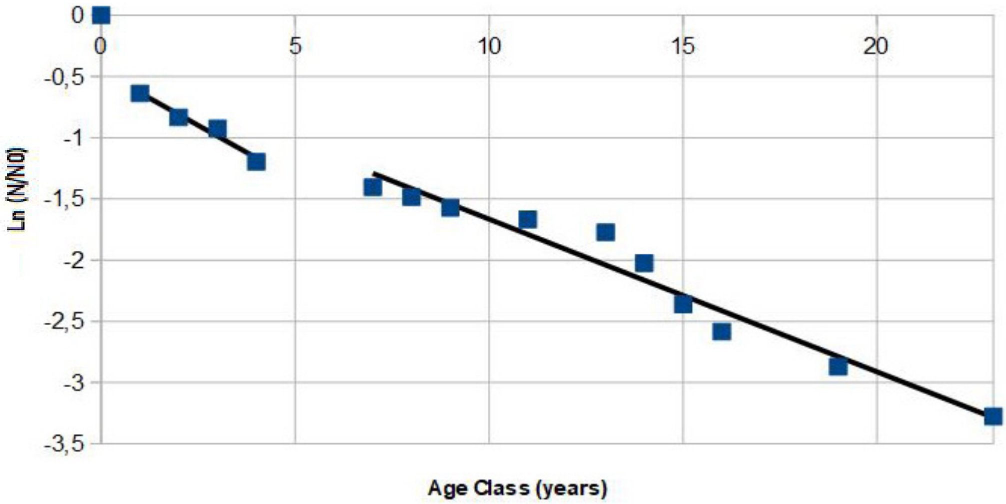

Fig. 3. GRIES-MEYBURG plot for quantitative determination of survival of honey buzzards found dead and ringed as nestlings in Sweden (N = 15). Raw data taken from Tjerrnberg& Ryttman (1994). Black: calculated linear regression lines. The gap is because no rings were recovered from these age classes. Survival rates are 0.838 and 0.883 for subadults/ younger adults and adults, respectively. Both curves together give a survival rate of 0.86/year. The slope of the line is not the survival rate but its logarithm. $Ln(N/N_0)$ is the log-transformed normalised survival.

Obr. 3. GRIES-MEYBURGOV graf na kvantitatívne stanovenie prežívania jedincov včelára lesného nájdených uhynutých a krúžkovaných ako mláďatá vo Švédsku (N = 15). Nespracované údaje prevzaté z Tjerrnberg & Ryttman (1994). Čierna: čiara lineárnej regresie. Medzera je spôsobená absenciou záznamov v príslušnej vekovej kategórií. Miera prežívania subdospelých/mladších dospelých jedincov bola 0,838 a 0,883 pre dospelé jedince. Obe krivky spolu dávajú mieru prežitia 0,86/rok. Sklon čiary nie je miera prežitia, ale jej logaritmus. $Ln(N/N_0)$ je logaritmicky transformovaná normalizovaná hodnota prežívania.

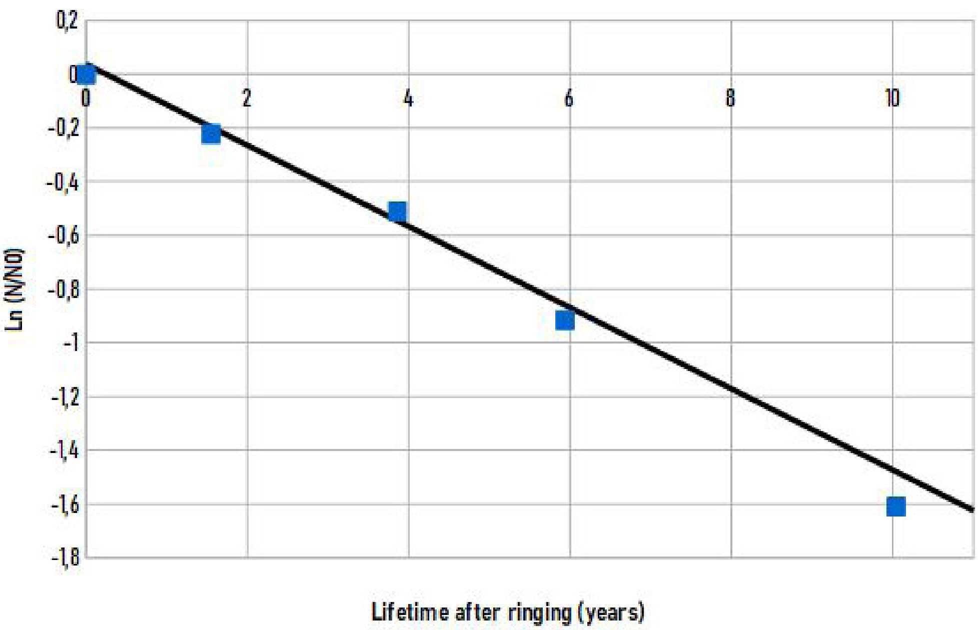

Fig. 4. GRIES-MEYBURG plot for quantitative determination of survival of Honey Buzzards found dead and ringed as nestlings in Germany (N = 5). Raw data from Cösters et al. (2000). Black: calculated linear regression line. The survival rate is 0.86 (f = 0.995). The slope of the line is not the survival rate but its logarithm. $Ln(N/N_0)$ is the log-transformed normalised survival.

Obr. 4. GRIES-MEYBURGOV graf na kvantitatívne stanovenie prežívania jedincov včelára lesného nájdených uhynutých a krúžkovaných ako mláďatá v Nemecku (N = 5). Nespracované daje od Cösters et al. (2000). Čierna: čiara lineárnej regresie. Miera prežitia bola 0,86 (f = 0,995). Sklon čiary nie je miera prežitia, ale jej logaritmus. Ln(N/N0) je logaritmicky transformovaná normalizovaná hodnota prežívania.

since the classical evaluation produces almost the same number (see "Results").

According to Bijlsma et al. (2012), the decline in Scandinavia and parts of Western Europe seems beyond doubt. Regardless of the difference in data evaluation, the change to lower survival rates over decades is evident from the literature and may reflect rapidly changing conditions (habitat quality) on the breeding grounds, the African wintering grounds or both. Unfavourable wind and drought conditions partly due to climate change and weather fluctuations in the areas overflown during migration may also play a role. Cösters et al. (2000) also described a negative trend in the population from 1978 to 1998 in the Münsterland area in Germany.

In West and Central Africa, there has been a significant reduction and degradation of wooded savannahs, gallery forests and rainforests (Justice et al. 2001, Duveiller et al. 2008, Zwarts et al. 2009). These landscapes are the main wintering areas for honey buzzards (Bijlsma 2002, Hake et al. 2003, Gamauf & Friedl 2011, Strandberg et al. 2012), and these habitat impacts are likely to affect the survival and fecundity of the k-selected food specialist. This is supported by Howes et al. (2019, 2020), who predicted that continued forest loss in Africa would negatively impact the honey buzzard population, and in accordance with this 1/3 of our tracked individuals were lost in the wintering area.

It seems that particularly unfavourable weather conditions during the crossing of the Sahara and the Mediterranean led to the high mortality of our birds during migration, and these conditions are likely to vary greatly from year to year. Klaassen et al. (2013) also reported significantly increased mortality for three raptor species using the same migratory flyway. Based on 32 published papers on different species, Newton (2024) concluded that most studies showed that mortality was higher during migration than at other times.

Weather conditions during migration have been found to influence the annual survival of large raptors, e.g., studies of peregrine falcons (*Falco peregrinus*) breeding in the Arctic showed that climatic conditions during migration, particularly autumn NAO indices, were correlated with apparent annual survival rates (Franke et al. 2011).

Newton (2007) found that most migratory bird mortalities were attributed to adverse weather conditions, such as losses in flight due to storms and other unfavourable conditions en route. Most mortalities tend to occur over water. Records of in-flight weather-related mortality, involving hundreds or thousands of birds at a time, have mainly affected small passerines, but also larger birds, including eagles and swans.

The numbers of adult honey buzzards tracked here were too small, and the time period too short to adequately assess the many negative factors affecting long-term averaged survival rates. As many other questions about the species' biology could be answered by satellite tracking, further studies using more technologically advanced transmitters are recommended.

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The diet of the Eurasian eagle-owl (*Bubo bubo*) in various natural environments across Eurasia

Potrava výra skalného (*Bubo bubo*) v rôznych prírodných podmienkach Eurázie

Ján OBUCH

Abstract: The Eurasian eagle-owl (*Bubo bubo*) has adapted to hunt local fauna that are subject to the influence of human agricultural activities. In the sparse forests, marshes and lakes of the mountainous regions of central Norway, the eagle-owl's diet is dominated by small mammals and gallinaceous birds, but the common frog *Rana temporaria* features more frequently in regions near the fjords, with various species of seabirds predominating on some islands. The eagle-owls, breeding in several protected regions of the Czech Republic, hunting in agricultural areas small mammals and game animals in addition to waterbirds nesting by fishponds. In Slovakia, the majority of the eagle-owl population nests on the edges of mountain valleys. In the past, they hunted small mammals and amphibians on pastureland located deep in the mountains, but they have adapted to hunting larger prey in more intensively farmed valleys. Predominantly in the eastern part of Turkey, the diet of Eurasian eagle-owl hunting on natural mountain steppes has been studied, where mammals of the family Cricetidae dominate. In the arid conditions of the southern countries of Syria, Jordan and Israel, mammals of the Gerbillinae sub-family predominated in addition to a higher proportion of birds. In the more variable areas of Iran, eagle-owl diets feature a wide range of indigenous mammals and birds, with different species represented in several territories. Studies from the edges of the Fergana Valley in southern Kyrgyzstan found differences in the diets of eagle-owls living at lower elevations and those living higher in the mountains, while birds were the predominant prey in the Kalek site. Smaller samples of eagle-owl diets were also collected in the Altai Mountains of Mongolia, the Barguzinsky Mountains to the east of Lake Baikal and the Vaida Mountain on Sakhalin Island. The results presented in this study can also contribute to our knowledge about the fauna of the above-mentioned regions.

Abstrakt: Výr skalný (*Bubo bubo*) je adaptovaný na lov miestnej fauny, ktorá je ovplyvnená hospodárskou činnosťou človeka. V horách stredného Nórska s riedkymi lesmi, mokraďami a jazerami, dominujú v jeho potrave drobné cicavce a kurovité vtáky. Pri pobreží fjordov sú viac zastúpené žaby druhu *Rana temporaria*. Na niektorých ostrovoch prevažujú morské druhy vtákov. Výry, hniezdiace v niektorých chránených územiach Českej republiky, lovia v okolitej poľnohospodárskej krajine drobné cicavce, malú poľovnú zver a vodné vtáctvo hniezdiace na rybníkoch. Na Slovensku prevažná populácia výrov hniezdi na okraji horských kotlín. V minulosti lovili aj na pasienkoch hlbšie v horách drobné cicavce a žaby, neskôr sa adaptovali na lov väčšej koristi v intenzívnejšie obhospodarovaných kotlinách. Prevažne vo východnej časti Turecka bola skúmaná potrava výra, loviaceho na prirodzených horských stepiach. Dominujú cicavce z čeľade Cricetidae. V južnejších krajinách Sýria, Izrael a Jordánsko s aridnejšou klímou prevažujú cicavce z podčeľade Gerbilinae a vyššie zastúpenie majú vtáky. Na členitom území Iránu je v potrave výra zastúpená bohatá autochtónna fauna cicavcov a vtákov, diferencovaná pre jednotlivé územné celky. V južnom Kirgizsku bola skúmaná potrava výra na okraji Ferganskej kotliny. Odlišná fauna bola v nižších polohách a vyššie v horách. Na lokalite Kalek dominovali vtáky. Menšie vzorky potravy výra sú z Mongolského Altaja, z Barguzínskeho pohoria na východe od Bajkalu a z hory Vajda na ostrove Sachalín. Výsledky, publikované v tejto práci, sú príspevkom ku znalostiam o faune uvedených území.

Key words: prey species, birds of prey, hunting habits, pellet analysis, Norway, Czech Republic, Slovakia, Middle East, Kyrgyzstan, Mongolia, Russia

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Introduction

The Eurasian eagle-owl is the largest European owl and is capable of hunting prey from a remarkably wide size range, from small prey such as mammals, birds and invertebrates to larger animals such as foxes and herons (Obuch & Bangjord 2016). Six sub-species have been identified in its Eurasian range on the basis of genetic data, with eagle-owls inhabiting both temperate and arid climate zones (König & Weick 2018). Data on the diets of eagle-owls offers important information on the fauna of specific territories. As the apex predator among owls, it frequently preys on other competing predators in its territory such as other owls, raptors and carnivores (Mikkola 1976, Lourenco et al. 2011). Originally an owl of the steppes, it is capable of hunting over open ground, and is now active in the agrarian steppe that had emerged following the deforestation which had occurred by the middle of the Holocene epoch (Obuch 2021a). The composition of the eagle-owl's prey has thus adapted over time in line with changing agricultural uses of the landscape in its geographical range (Obuch 2021b). The monograph by Penteriani & Delgado (2019) attempted to outline the factors which determine the eagle-owl's diet through a statistical analysis of 346, 813 items of prey from 200 studies covering the entirety of the species' Eurasian range. However, this survey was based on works with varying levels of accuracy in terms of prey species identification; similarly, the study employed a statistical methodology based on the proportional representation of taxa which did not take the relative size of comparative prey samples into account.

The diet of the eagle-owl has been the subject of several comprehensive surveys from Slovakia (Obuch 2021b), Norway (Obuch & Bangjord 2016), Jordan (Obuch 2018), Iran (Obuch 2014), Turkey (Obuch 1994) and Kyrgyzstan (Obuch & Rybin 1993). Partial data from protected areas in the Czech Republic have also been published, namely from Šumava (Červený & Obuch 1999), Podyjí (Reiter et al. 1997), Pálava (Gaisler et al. 1996), Moravský Kras (Zima et al. 1998) and Kokořínsko (Andreska et al. 2021).

In this study, we evaluated a similarly extensive set of materials from ten selected countries, more specifically findings from regions with markedly different natural conditions: from the cold and wet climate of central Norway in northern Europe, the relatively humid climates of Slovakia and the Czech Republic, to the far drier conditions of five countries in the southern limits of the species' range in the Middle East (Turkey, Iran, Syria, Jordan and Israel), but also in the Central Asian Steppes (Kyrgyzstan, Mongolia) and the eastern edge of its range in Zabaikalsky Krai and Sakhalin in Russia with their frozen winters.

The contribution aims to document the remarkable adaptability of eagle-owl diets and the overview which they offer of local fauna as a result of various natural conditions and the long-term impact of human activities.

Materials and methodology

Study areas

In central Norway, samples of eagle-owl diets were collected in the mountainous regions of the former county of Hedmark (now Inlandet) and the county of Trøndelag and the southern part of the county of Nordland. Material was obtained and examined from 96 localities between 2008 and 2023 (Fig. 1). Elements of the analysed data have been discussed in a previously published study (Obuch & Bangjord 2016).

In the Czech Republic, eagle-owl diets were primarily studied in protected areas: Pálava Protected Landscape Area (PLA) (4 localities from 1990 to 2000), Podyjí National Park (NP) (6 localities from 1992 to 1995), Moravský Kras PLA (5 localities in 1998), Třeboňsko PLA (5 localities from 1993 to 2002), Šumava NP and Pošumaví (64 localities from 1978 to 2013), Kokořínsko and České Švícarsko NP (5 localities from 1985 to 2019). Material from the Vysočina county was collected by I. Kunstmüller in 46 localities from 1991 to 2023

(Fig. 1). Elements of the analysed data have appeared in previously published studies (Gaisler et al. 1996, Reiter et al. 1997, Červený & Obuch 1999, Zima et al. 1998, Andreska et al. 2021).
Extensive amounts of material were collected in Slovakia between 1975 and 2023 in 136 localities from eleven regions (Fig. 1): Orava, Liptov, Turiec, Žilinská kotlina Basin, Považie Valley, Ponitrie Valley, Pohronie Valley, Muránska Planina Mts., Spiš, Rimavská Kotlina Basin, and Slovenský Kras Mts. (Obuch 2021b).

In the Middle East, eagle-owl prey remains were collected in 13 localities in Turkey between 1992 and 2005, in four localities in Israel in 1996, in two localities in Syria in 1998 and 2005, in eight localities in Jordan between 2005 and 2015 (Obuch 2018) and in 38 localities in Iran between 1996 and 2002 (Obuch 2014). Smaller samples of prey remnants were collected in the plains of central Anatolia along a travel between Ankara and Syria (Sample no. 1 in Fig 2.). Owl pellets were collected regularly in the localities of Horasan (Sample no. 3 in Fig 2.) and Ishak Pasa Sarayi (Sample no. 5 in Fig 2.) during several expeditions to Iran and at Hattusa during my first travel to Iran in 1996. The localities of Bendimahi and Tatvan (Sample no. 6 in Fig 2.) and Sarikamis (Sample no. 4 in Fig 2.) were surveyed during my first expedition to Turkey in 1992 (Obuch 1994). In Syria, the largest number of eagle-owl pellets were found on desert cliffs 5 km from Palmyra, in the Carmel Mountains and near the Hula reserve in Israel.

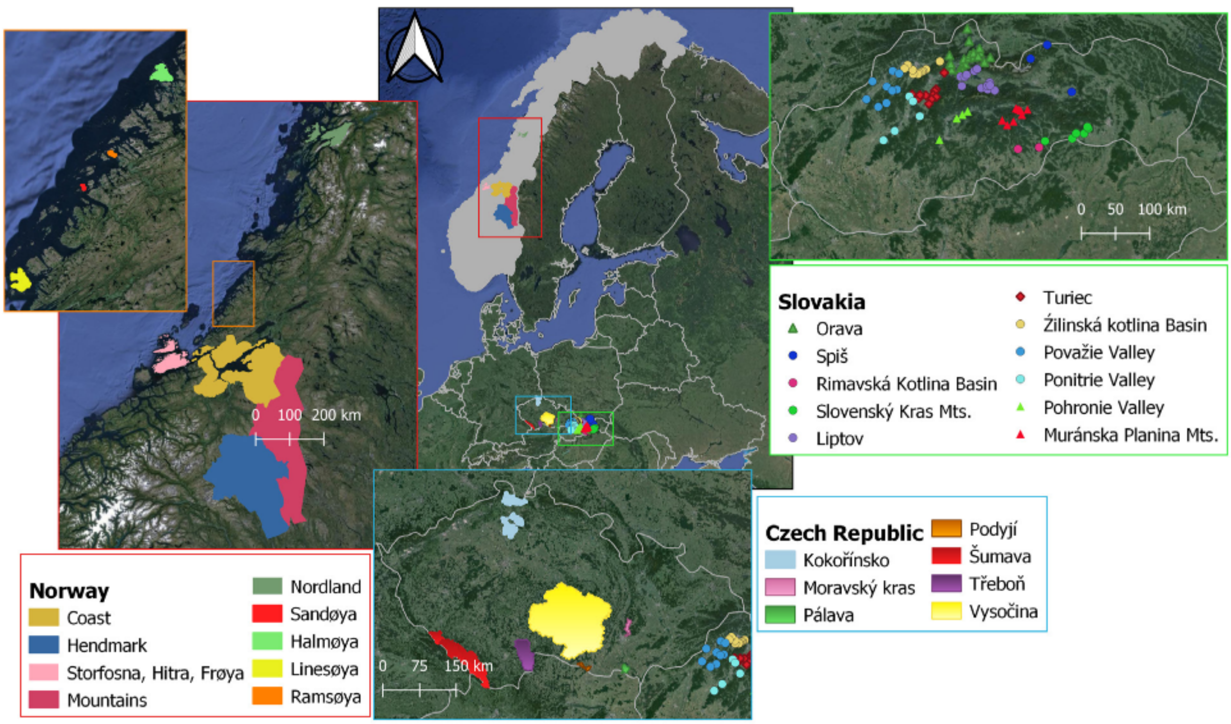

Fig. 1. Comparable regions in central Norway, Czech Republic and study sites of particular regions in Slovakia.
Obr. 1. Porovnávané regióny centrálneho Nórska, Českej republiky a stúdijné lokality jednotlivých regiónov na Slovensku.

In Jordan, pellets were found in the upper regions of the rift above the Jordan Valley, the Dead Sea and Wadi Araba, areas with a more humid Mediterranean climate. During five expeditions to the extensive territory of Iran, eagle-owl prey remains were found in 38 localities, a fact which is reflected in the specific species identified in seven territorial units: the Elborz and Talysh Mountains (Sample Aa in Fig 2.), the northern (Sample Ab in Fig 2.) and central (Samples Ba, Bb in Fig 2.) Zagros Mountains, the southern Zagros in the Fars Province (Sample C in Fig 2.), south-eastern Iran (Sample Da in Fig 2.) and the Koppeh Dagh Mountains in the northeast (Sample Db in Fig 2.) (Obuch 2014).

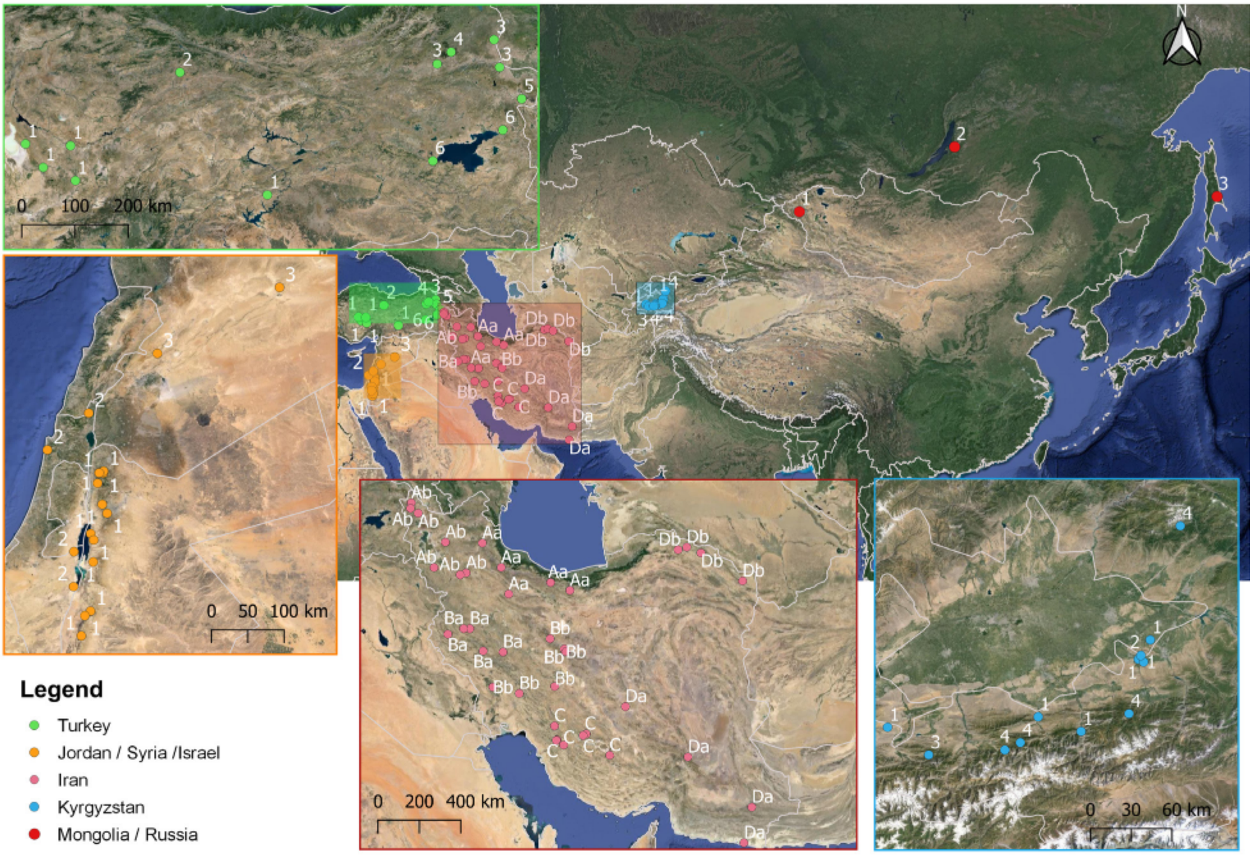

Fig. 2. Study sites of Eurasian eagle-owl in Asian countries.
Obr. 2. Študované lokality výra skalného v Azíjských krajinách.

In Central Asia, eagle-owl diets were studied in 13 localities on the edge of the Fergana Valley in south Kyrgyzstan between 1988 and 1990 in cooperation with S. N. Rybin from the Regional Hygiene Department in Osh (Obuch & Rybin 1993). The majority of localities were found in the mountains to the south of the Fergana Valley featuring steppe or semi-desert vegetation, and in the locality of Arslanbob, an area of humid wild walnut forests in the north. One sample was collected in 1984 from eagle-owl nests on cliffs above Lake Talbo Nur at the edge of the Altai Mountains in Mongolia at an elevation of 2100 m a. s. l., an area in which wormwood steppe was predominant.

In east Russia, a smaller sample of eagle-owl prey remnants was collected in 2013 in the Barguzinsky Mountains on the eastern shore of Lake Baikal above the village of Ulyun. In 2016, a group of Slovak speleologists collected bone samples from Lastochnaya Cave in the Vaida Mount in the central region of Sakhalin which were determined to be from eagle-owl prey. As a result, in the following year, the author participated in the next expedition and collected more bones from an older eagle-owl nest there.

Analyses of diets

Data was obtained from osteological material found in eagle-owl nests and pellets in the vicinity of nest sites which were mostly collected during the spring breeding season. In the material collected from nests, more recent unconsolidated material consisting of un-decomposed fur and bones from the upper layers was distinguished from that found in the lower layers. For example, an eagle-owl nest on the island of Halmøya in Norway was found to consist of four separate layers; the bones from the lowest layer were examined with radiocarbon dating and were found to be 2500 years old; the results of this analysis will be presented in a separate study. In Slovakia, two older samples were dated to be approximately 100 to 150 years old (Obuch 2021b). In this study, the aggregated data from different regions are presented independent of the age of the samples. Radiocarbon dating of bones found in Lastochnaya Cave on Sakhalin suggests that they date from the 9th century, making them 1170 years old (± 40 years) (Povinec in lit.). Bone samples collected earlier by Russian palaeontologists in the same cave were dated to a similar period (Aleksejeva et al. 2004).

Samples found in nests were prepared for study by being soaked in standing water. Pellets and other organic impurities floated to the surface and were broken down in 5 % NaOH, while the bones which remained at the bottom of the sieve were separated from the soil through mass fraction. After the bones had dried, the material was categorised as follows: mammal jawbones, four types of bird bones (*rostrum*, *humerus*, *metacarpus* and *tarsometatarsus*), frog hip bones (*os ilium*), lizard jawbones, carp cervical vertebrae (*os pharyngeum inferior*) and jawbones of other fish, insect heads and jaws, and the claws of scorpions and crabs.

The abundance of specific species was determined as the minimum possible number based on the most commonly identified body parts (Minimum Number of Individuals, MNI). Vertebrate bones, in particular bird bones, were identified through comparisons with the author's own collection; mammal bones were also determined using published works: Gromov & Erbajeva (1995), Harrison & Bates (1991), Lay (1967), DeBlase (1980), Kryštufek & Vohralík (2001, 2005, 2009), Aulagnier et al. (2009), Porter et al. (1996). Based on the work by König & Weick (2015), the diets of the following sub-species of Eurasian eagle-owls are examined in this study: *Bubo bubo bubo* (Norway, Slovakia and the Czech Republic); *Bubo bubo interpositus* (the Middle East), *Bubo bubo turcomanus* (Kyrgyzstan), *Bubo bubo yenisseensis* (Mongolia, Baikal) and *Bubo bubo ussuriensis* (Sakhalin).

Statistical analyses

Results were compared using the methodology of marked difference from the mean (MDFM, Obuch 2001a). The results are presented in rearranged tables in which the orders of species are shown in columns forming blocks with positive MDFM values (+1, +2) which are highlighted by grey color. The order of regions is arranged based on similarities in terms of the representation of diagnostic species with positive deviations from the average. The results below the dotted line show the abundance of species without marked deviations and are sorted according to decreasing overall abundance. The bottom row shows the value H', the diversity index calculated according to the method published in the work by Shannon & Weaver (1949). Other less abundant species are listed below the tables. The database program Zber (Šipöcz 2004) was used to summarise the results from different regions and formulate the adapted tables.

The data from the countries with the most extensive samples of eagle-owl diets, namely central Norway, the Czech Republic, Slovakia, Turkey, Iran and south Kyrgyzstan, are presented in comparative tables featuring regions with similar natural conditions (Tables 1, 2, 3, 4, 6 and 7). The data from the less extensive collections of Syria, Israel and Jordan is evaluated as a total sum (Table 5), and the three samples obtained from the Altai Mountains in Mongolia, the Barguzinsky Mountains to the east of Lake Baikal and the Vaida Mount in central Sakhalin are also reported (Table 8).

The majority of the documented material on eagle-owl diets discussed in this study is held in the collection of the Slovak Museum of Nature Protection and Speleology in Liptovský Mikuláš, but the material collected in Norway is archived in the Natural History Museum in Trondheim. Data from older studies has been updated to reflect the currently accepted taxonomy for mammal species; the most up-to-date terminology was based on that found in the following publications: Handbook of the Mammals of the World 6: Lagomorphs and Rodents I (Wilson, Lacher & Mittermeier, eds, 2016); Handbook of the Mammals of the World 7: Rodents II (Wilson, Lacher & Mittermeier, eds, 2017); Handbook of the Mammals of the World 8: Insectivores, Sloths and Colugos (Wilson & Mittermeier, eds, 2018). Bird scientific names are based on the publication by Kovalík et al. (2010).

Results

Central Norway

The results presented here are a continuation of previous research (see Materials and Methodology). The research was expanded southwards to cover the mountainous region of the former county of Hedmark (now Innlandet) and northwards to the county of Nordland.

Mammals (Mammalia, 58.7%, 27 species) were the predominant eagle-owl prey among the 55,599 specimens, in particular *Microtus agrestis* (34.8%), *Arvicola amphibius* (7.3%) and *Lemmus lemmus* (5.4%). A highly diverse range of bird species formed the second most numerous prey type (Aves, 21.2%, at least 168 species), with the following species forming more than 1% of the sample: *Anas crecca* (1.9%), *Lagopus lagopus* (1.8%), *Larus argentatus* (1.5%), *Larus canus* (1.1%) and *Anas platyrhynchos* (1.1%). Among the other vertebrates

(Amphibia, Reptilia, Pisces, 20.0%), the common frog *Rana temporaria* was the dominant species (19.6%), but invertebrates were found to form a minor component of eagle-owl diets (Evertebrata, 0.1%).

In the mountainous regions of the counties of Hadmark and Trøndelag, mammals also formed a significant part of the diet, in particular *A. amphibius*. *L. lemmus*, *Craseomys rufocanus*, *Alexandromys oeconomus*, *Myodes glareolus*, *Myopus schisticolor*, *Sciurus vulgaris* and *Lepus timidus*. These species are also preyed upon by smaller species of owls and raptors which the eagle-owl eliminates as competitor species, more specifically *Asio flammeus*, *Aegolius funereus*, *Surnia ulula*, *Falco tinnunculus*, *F. columbarius* and *Buteo lagopus* and Carnivora *Mustela erminea* and *M. nivalis*. Galliformes also form an important element of the eagle-owl's diet at the upper edges of the tree line: *Lagopus lagopus*, *L. muta*, *Lyrurus tetrix*, *Tetrao urogalus* and *Tetrastes bonasia*. Over marshlands and lakes, eagle-owls hunt waterfowls, primarily ducks such as *Anas crecca*, *Bucephala clangula* and *Aythya fuligula* and wader species such as *Tringa nebularia*, *T. glareola* and the Eurasian whimbrel *Numenius phaeopus*. Several of these species are also strongly represented in the diets of eagle-owls from the lower localities along the shores of fjords in the county of Trøndelag (Table 1), but this region also saw a pronounced rise in the share of the common frog *R. temporaria*. Frogs also featured heavily in the samples from the northern Norwegian counties of Trøndelag and Nordland together with small mammals such as *M. glareolus*, *C. rufocanus* and the willow ptarmigan *L. lagopus*. The European water vole *A. amphibius* was numerous in the samples from the islands of Halmøya and Sandøya, especially in the past when the islands were deforested and grazed by sheep. Also important in that period was the short-tailed field vole *M. agrestis*, which is still dominant in the islands of Ramsøya and Linesøya, which are located close to the mainland, but this species has not reached the offshore islands of Hitra and Frøya. The common frog *R. temporaria* and the wood mouse *Apodemus sylvaticus* have recently been introduced to the island of Frøya, and eagle-owls have adapted to hunt these species, but on the islands of Storfosna, Hitra and Frøya, however, several species of seabirds and other water birds still form the largest component of the owl's diet (Table 1).

The Czech Republic

From the 14,070 eagle-owl prey items identified in the Czech Republic, mammals were the dominant type (Mammalia, 76.1%, 41 species) followed by a significant share of birds (Aves, 22.7%, at least 102 species). Other vertebrates (Amphibia, Reptilia, Pisces, 1.0%) and invertebrates (Evertebrata, 0.2%) were less well represented. The common vole *Microtus arvalis* was the dominant prey (43.6%), but also common were the species *Arvicola amphibius* (6.9%), *Rattus norvegicus* (6.2%), *Erinaceus* sp. (4.4%) and *Lepus europaeus* (4.3%). In terms of birds, the following species formed more than 1% of the total sample: *Perdix perdix* (2.5%), *Columba livia domestica* (2.4%), *Fulica atra* (1.7%), *Chroicocephalus ridibundus* (1.6%), *Phasianus colchicus* (1.4%), *Turdus merula* (1.3%) and *Asio otus* (1.0%).

Finds from the Pálava PLA featured a high proportion of the black-headed gull *Ch. ridibundus* which eagle-owls had predated from the breeding colony at the Nové Mlýny reservoirs. Game species were hunted more often, however: *L. europaeus, P. perdix*, *P. colchicus* and also hedgehogs *Erinaceus sp.*, with *E. roumanicus* well represented in Moravský Kras Mts. A rich variety of species formed the diet of eagle-owls in Podyjí NP, with this region recording the highest diversity index: H' = 3.16. At the fishponds of Kokořínsko PLA and Třeboňsko PLA and partly in Pošumaví region, eagle-owls also predated multiple species of waterfowl. In Šumava NP, the common frog *R. temporaria* was more abundant and, among the mammals, the short-tailed field vole *M. agrestis*, but the common vole *M. arvalis* remained dominant, as was the case for the Vysočina county (Table 2).

The central European landscape of the Czech Republic is characterised by a higher human population density than in Norway, in addition to a more intensive degree of agricultural activity. The long-standing hunting tradition of rearing game animals and birds is also an important component of the eagle-owl's diet, but this has led to persecution in the past despite efforts to strengthen the protection of the species (Andreska & Andreska 2020).

Slovakia

A total of 106,166 eagle-owl prey specimens were collected over the course of the studied period, with mammals forming the predominant element (Mammalia, 58.3%, 65 species). The common vole *M. arvalis* was the most common identified species (31.1%), with *A. amphibius* (7.2%), *A. sylvaticus* (4.6%), *Apodemus flavicollis* (3.4%) and *R. norvegicus* (3.0%) also featuring heavily. Among other vertebrates (Amphibia, Reptilia, Pisces, 33.2%), the common frog *R. temporaria* (32.1%) was found to form a significant part of the diet of young eagle-owls in the past at higher elevations. Birds formed a lower proportion of eagle-owl diets (Aves, 8.5%, at least 140 species), with

Tab. 1. Eagle-owl diet in various regions of central Norway .
Tab. 1. Potrava výra skalného v rôznych regiónoch stredného Nórska.

Region	Hedmark		Mountains		Coast		Nord.		Halmøya		Sandøya		Lines+		Froya+		Total	%
Species \Region No.	1		2		3		8		7		6		5		4			
Bubo bubo	1+	13		9		7		2		18		3	1-	1		13	66	0.12
Asio flammeus	1+	61		45		43		1	1-	35		4		31	1-	20	240	0.43
Glaucidium passerinum	1+	7															7	0.01
Lagopus muta	3+	199		48	2-	9		5	3-	10		2	2-	6	4-	0	279	0.50
Falco tinnunculus	2+	23		5	1-	3		1	1-	7				6		5	50	0.09
Falco columbarius	1+	16		7		7			1-	3				4		2	39	0.07
Buteo lagopus	1+	11		9		5			1-	1						4	30	0.05
Anas querquedula	1+	8		7		3			1-	3				4		5	30	0.05
Perisoreus infaustus	1+	6		5		4											15	0.03
Lepus timidus	1+	185	1-	95		153		23	6-	2	1-	3	1-	38	2+	316	815	1.47
Asio otus	1+	13		9		15		1	2-	1			1+	24		5	68	0.12
Columba palumbus	1+	20	1-	5	1+	23		1	2-	2			1+	17		17	85	0.15
Sciurus vulgaris	2+	68		33	1+	82			4-	1			3-	0	3-	0	184	0.33
Lyrurus tetrix	1+	55		51	1+	103		11	1-	47		4		40	1-	25	336	0.60
Myodes glareolus	1+	217	1+	385	1+	322	1+	50	2-	86	2-	2	4-	7	1+	256	1325	2.38
Lagopus lagopus	1+	188	1+	271	1-	126	2+	66	2-	84	1-	5	2-	46	1+	229	1015	1.83
Anas crecca	1+	227	1+	344	1-	154	2-	5	2-	80	1-	6	2-	32	1+	226	1074	1.93
Bucephala clangula	1+	37	1+	40	1-	15		2	3-	3			2-	3	1+	40	140	0.25
Arvicola amphibius	1+	531		594	2-	228	1+	146	1+	2060	3+	413	6-	7	4-	51	4030	7.25
Craseomys rufocanus	2+	576	1+	509		225	2+	119	4-	19	3-	1	2-	35	6-	0	1484	2.67
Lemmus lemmus	1+	399	1+	827	1+	827	2-	16	1-	516		55		365	7-	1	3006	5.41
Aegolius funereus	2+	26		15	1+	19		2	2-	3		1	1-	0	1-	1	67	0.12
Tetrastes bonasia	1+	17		12	1+	26		1	2-	0		2	1-	0	2-	0	58	0.10
Tringa nebularia	2+	28	2+	39	1-	3			3-	0			1-	1	2-	0	71	0.13
Tringa glareola	1+	17	1+	19	1-	1			1-	3			1-	1		3	44	0.08
Aythya fuligula	1+	18	2+	43	1-	6			2-	2			2-	0	1-	1	70	0.13
Surnia ulula	1+	13	2+	33		6			2-	0			1-	0	1-	1	53	0.10
Tetrao urogallus	1+	22	1+	27		11			3-	0			1-	1	1-	2	63	0.11
Alexandromys oeconomus	3+	323	2+	304	1-	5	2-	0	6-	0	2-	0	5-	0	5-	0	632	1.14
Myopus schisticolor	2+	38	2+	75	3-	0			3-	0			2-	0	3-	0	113	0.20
Mustela erminea	1+	44	1+	34		24		2		39		4	1-	6	2-	3	156	0.28
Mustela nivalis	1+	29	1+	29		26		1	1-	12		2	1-	2	1-	6	107	0.19
Numenius phaeopus		16	2+	56	1-	11			1-	13		2	1-	3		13	114	0.21
Anas acuta		7	1+	15		7			1-	2			1-	1	1+	13	45	0.08
Philomachus pugnax		9	1+	43		30		1	1-	13		1	1-	5	1+	32	134	0.24
Vulpes vulpes		2		2	1+	10											14	0.03
Chroicocephalus ridibundus		2		1	1+	8				3						1	15	0.03
Rattus norvegicus	4-	0	3-	7	1+	99		10	5-	0	1-	0	4-	1	2+	298	415	0.75
Mus musculus	2-	0	2-	1	1+	35		1	3-	2			2-	2	2+	94	135	0.24
Vanellus vanellus	1-	6	1-	11	1+	61	1-	0	2-	20	1-	0	1-	12	2+	114	224	0.40
Rana temporaria		944		1526	1+	3768	1+	453	1-	1227	4-	9	1-	930	1+	2051	10908	19.62
Aythya marila									1+	12						1	13	0.02
Mergus merganser	1-	2	1-	1	1-	3			1+	38				6	1+	16	66	0.12
Uria aalge	1-	0	1-	0	1-	1			1+	29				4	1+	12	46	0.08
Haematopus ostralegus	3-	0	3-	0		25			1+	63		1		26	1+	62	177	0.32
Limosa lapponica		1		2	1-	2			1+	17		1		1	1+	16	40	0.07
Fratercula arctica	4-	0	4-	0	2-	18		7	1+	191	1+	16	1-	16	1+	114	362	0.65
Somateria mollissima	1-	0	2-	0	1-	2			1+	26	1+	6		4	1+	20	58	0.10
Microtus agrestis	2-	676	1-	2421	1-	2684	2-	158	1+	9104		370	1+	3932	8-	10	19355	34.81
Calidris maritima	1-	0	1-	3	2-	1			1+	40		1	1+	29	1-	3	77	0.14
Uria lomvia			1-	0	1-	0				12	1+	6		2		7	27	0.05
Sorex araneus	1-	10	1-	13	2-	11		8	1-	37		1	2+	131	3-	2	213	0.38
Calidris alpina	1-	0		5	1-	1		3		10			2+	30	1-	1	50	0.09
Turdus iliacus	1-	4	1-	9		23		4	1-	12		1	2+	52		20	125	0.22
Actitis hypoleucos		8		3		9		2	1-	2			1+	11		7	42	0.08

Tab. 1. continuation / pokračovanie.

Region		Hedmark		Mountains		Coast		Nord.		Halmøya		Sandøya		Lines+		Froya+	Total	%
Species \Region No.		**1**		**2**		**3**		**8**		**7**		**6**		**5**		**4**		
Cepphus grylle			1-	0	1-	0				14		2	1+	12		9	37	0.07
Alle alle	3-	0	3-	3	1-	27	1-	0	2-	13		8	1+	47	2+	114	212	0.38
Charadrius hiaticula	1-	0	2-	0	1-	4		2	1-	5			1+	22	1+	20	53	0.10
Turdus pilaris		29		36		62		2	2-	20		4	1+	60	1+	73	286	0.51
Turdus philomelos		10	1-	14		27		5	1-	13			1+	39	1+	39	147	0.26
Larus argentatus	5-	0	5-	1	2-	40	3-	0	4-	19		12		84	3+	684	840	2.57
Larus marinus	3-	0	3-	0	3-	1			3-	3		2	1-	13	3+	165	184	0.33
Larus canus	3-	8	2-	24	1-	58	2-	0	1-	67	1-	4	1-	31	2+	440	632	1.93
Gallinago gallinago	1-	53	1-	42		139	1-	4	2-	61	1-	3		96	2+	309	707	2.17
Scolopax rusticola	1-	11	2-	7		29			2-	13		3		29	2+	100	192	0.35
Anas platyrhynchos		52		102		137	1-	5	3-	23	2-	0	1-	43	2+	278	640	1.96
Anas penelope		14		12	1-	11			1-	13		1	1-	5	2+	51	107	0.19
Mergus serrator	1-	7		16	3-	1			1-	20		7	1-	7	2+	81	139	0.25
Ardea cinerea		1	1-	2	1-	1			2-	0				6	2+	35	45	0.08
Numenius arquata	2-	0	2-	0	1-	4			2-	6				16	2+	60	86	0.15
Pluvialis apricaria		19	1-	27		41	1-	0	1-	35		2		26	2+	99	249	0.45
Turdus merula		7	1-	5		20		1	1-	11		2		18	2+	47	111	0.20
Carduelis flavirostris			1-	0	1-	1			1-	1		1		6	2+	24	33	0.06
Sturnus vulgaris	1-	0	1-	1		8		1		15		1		5	2+	33	64	0.12
Apodemus sylvaticus	3-	1	4-	0	4-	0	1-	0	5-	0	1-	0	4-	0	3+	320	321	0.58
Neomys fodiens	1-	2	2-	0	2-	1			3-	0			2-	0	3+	67	70	0.13
Erinaceus europaeus	3-	0	3-	0		33			4-	0			3-	0	3+	152	185	0.33
Mustela vison		7		5	1-	1		1	2-	0				1	1+	18	33	0.06
Sorex minutus		2		2		1				2				2	1+	8	17	0.03
Corvus cornix	1-	27	2-	20		91	1-	1	1-	85	1-	2		39	2+	152	417	0.75
Corvus corax		6	1-	4		11			1-	11		1		12	1+	25	70	0.13
Pica pica		2		1		10			1-	2		2		3	1+	12	32	0.06
Garrulus glandarius		2		3		6			1-	1				1	1+	10	23	0.04
Melanitta fusca				1		2				8					1+	13	24	0.04
Larus fuscus						6									1+	9	15	0.03
Phasianus colchicus						2									1+	6	8	0.01
Sterna paradisaea	1-	0		4	1-	2				7		2		7	1+	23	45	0.08
Sterna hirundo										1				2	1+	11	14	0.03
Limosa limosa				1										1	1+	13	15	0.03
Lymnocryptes minimus		2		3		8			1-	0		3		2	1+	10	28	0.05
Salmonidae sp.	1-	1		5	1-	5			3-	0		1	1-	0	2+	51	63	0.11
Pisces sp.		12	1-	14	1-	9		1		46		2		20	1+	43	147	0.26
Coleoptera sp.		1		2		8			2-	0				5	1+	17	33	0.06
Decapoda sp.						1				1		1		4	1+	12	19	0.03
Tringa totanus		9		10	1-	3		2	2-	0				10		11	45	0.08
Rissa tridactyla			1-	0		6				9		4		8		10	37	0.07
Fringilla coelebs		5		5	1-	0				4		2		3		4	23	0.04
Turdus torquatus		5		8		1		1	1-	0				3		4	22	0.04
Accipiter gentilis		6		4		7				3							20	0.04
Cuculus canorus		4		4		3				2				4		2	19	0.03
Columba livia dom.		1				4				2				2		5	14	0.03
Anthus pratensis		1		1		7				1				4		1	15	0.03
Accipiter nisus		4				2				3						4	13	0.02
Rallus aquaticus						3				4				1		4	12	0.02
Turdus viscivorus		4		4		1										3	12	0.02
Alca torda				1		3						2				5	11	0.02
“Mammalia, 27 species”		**3113**		**5337**	**1-**	**4771**	**1-**	**536**	**1+**	**11881**	**1+**	**852**		**4530**	**2-**	**1607**	**32627**	**58.68**
“Aves, minim 168 species”	**1+**	**1414**		**1617**	**1-**	**1691**	**1-**	**149**	**1-**	**1444**	**1-**	**135**	**1-**	**1144**	**2+**	**4201**	**11795**	**21.21**
“Amphibia,Reptilia,Pisces”		**958**		**1546**	**1+**	**3784**	**1+**	**454**	**1-**	**1273**	**4-**	**12**	**1-**	**950**	**1+**	**2146**	**11123**	**34.10**
Evertebrata	**1-**	**1**	**1-**	**2**		**9**		**0**	**2-**	**1**		**1**		**10**	**2+**	**30**	**54**	**0.10**
Total		**5486**		**8502**		**10255**		**1139**		**14599**		**1000**		**6634**		**7984**	**55599**	**100**
Diversity Index H’		**3.20**		**2.63**		**2.36**		**2.13**		**1.59**		**1.78**		**1.89**		**3.30**	**2.71**	

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Region: 1 – **Hedmark**, **2 – Mountains**, **3 – Coast**, **8 – Nord:** Nord Trondelag and Nordland, **7 – Halmøya**: the island of Halmøya, **6 – Sandøya**: the island of Sandøya, **5 – Lines+**: the islands of Ramsøya and Linesoya, **4 – Froya+**: the islands of Storfosna, Hitra and Froya.
Other species (**Region**-number): *Castor fiber* (**2**-1), *Apodemus flavicollis* (**1**-3; **6**-1), *Canis familiaris* (**7**-1; **4**-2), *Martes martes* (**3**-1), *Felis catus dom.* (**4**-2), *Capreolus capreolus* (**3**-2), *Ovis ammon aries* (**8**-1; **5**-1; **4**-1), Artiodactyla sp. (**3**-1), *Gavia stellata* (**5**-1), *Gavia* sp. (**3**-2), *Podiceps auritus* (**1**-4; **2**-2; **7**-1; **4**-1), *Tachybaptus ruficollis* (**2**-1; **3**-3; **5**-1), *Fulmarus glacialis* (**7**-1; **4**-2), *Phalacrocorax carbo* (**4**-1), *Phalacrocorax aristotelensis* (**4**-1), *Anser anser* (**4**-2), *Anser fabalis* (**5**-1; **4**-3), *Anas clypeata* (**4**-2), *Anas* sp. (**3**-1), *Melanitta nigra* (**4**-2), *Clangula hyemalis* (**8**-1; **6**-1; **4**-5), *Mergus albeolus* (**2**-1), *Tadorna tadorna* (**5**-1; **4**-1), Anatidae sp. (**1**-4; **2**-6; **3**-5; **7**-19; **5**-4; **4**-16), *Circus cyaneus* (**2**-2), *Falco peregrinus* (**1**-2; **3**-2; **4**-4), *Coturnix coturnix* (**7**-1), *Gallus gallus dom.* (**2**-1; **3**-2; **8**-1; **4**-2), *Porzana porzana* (**4**-1), *Crex crex* (**3**-1; **7**-1; **5**-1; **4**-2), *Gallinula chloropus* (**3**-3; **4**-5), *Fulica atra* (**3**-2; **7**-1; **4**-3), *Charadrius dubius* (**3**-1), *Charadrius morinellus* (**3**-2; **4**-2), *Phalaropus fulicarius* (**4**-1), *Calidris alba* (**2**-3), *Calidris canutus* (**2**-1; **7**-1; **4**-1), *Calidris ferruginea* (**5**-2), *Calidris temmnickii* (**2**-1), *Calidris* sp. (**3**-1), *Arenaria interpres* (**4**-1), *Tringa stagnatilis* (**3**-1), *Tringa ochropus* (**1**-2; **2**-1; **3**-3; **4**-1), *Tringa* sp. (**3**-1), *Gallinago media* (**2**-3; **3**-1; **5**-1; **4**-3), Limicolae sp. (**3**-3; **7**-7; **5**-4; **4**-2), *Stercorarius paraziticus* (**7**-3; **5**-1; **4**-1), *Stercorarius pomarinus* (**4**-1), *Stercorarius skua* (**4**-1), Charadriiformes sp. (**2**-1; **3**-6; **8**-1; **4**-2), *Bubo scandiacus* (**5**-1; **4**-1), *Strix aluco* (**3**-3; **5**-1), *Strix uralensis* (**1**-1), *Strix nebulosa* (**1**-1), *Dryocopus martius* (**1**-2), *Picus canus* (**3**-3; **8**-1; **4**-1), *Dendrocopos major* (**1**-2; **3**-1), *Dendrocopos leucotos* (**1**-1; **3**-1), *Alauda arvensis* (**1**-1; **3**-1), *Hirundo rustica* (**7**-2), *Delichon urbicum* (**3**-1; **7**-2), *Anthus trivialis* (**2**-1), *Anthus petrosus* (**2**-1; **3**-1; **7**-3; **6**-1), *Anthus* sp. (**4**-1), *Motacilla alba* (**1**-2; **7**-4), *Bombycilla garrulus* (**1**-2; **4**-1), *Lanius excubitor* (**2**-1; **4**-2), *Prunella modularis* (**3**-1; **7**-1; **5**-1), *Sylvia communis* (**5**-1), *Sylvia curruca* (**2**-1; **7**-1), *Sylvia atricapilla* (**1**-1), *Phylloscopus trochilus* (**3**-1), *Phylloscopus collybita* (**3**-1; **5**-1), *Muscicapa striata* (**1**-1), *Ficedula hypoleuca* (**2**-1; **3**-1), *Saxicola rubetra* (**7**-1), *Oenanthe oenanthe* (**2**-1; **3**-1; **8**-2; **7**-1; **4**-2), *Phoenicurus phoenicurus* (**3**-1; **4**-1), *Erithacus rubecula* (**1**-3; **3**-2; **7**-2; **5**-2; **4**-1), *Turdus sp.* (**3**-1; **8**-1; **4**-6), *Parus major* (**7**-1), *Periparus ater* (**3**-1), *Cyanistes caeruleus* (**3**-1), *Sitta europaea* (**7**-1), *Troglodytes troglodytes* (**3**-1; **4**-1), *Cinclus cinclus* (**1**-3; **5**-1), *Emberiza citrinella* (**3**-2; **4**-1), *Emberiza schoeniclus* (**1**-1; **3**-3), *Emberiza pusilla* (**2**-1), *Plectrophenax nivalis* (**1**-1; **2**-1; **3**-1; **7**-4; **5**-1; **4**-1), *Calcarius lapponicus* (**3**-1), *Fringilla montifringilla* (**1**-1; **2**-2; **3**-4), *Carduelis spinus* (**3**-2; **4**-3), *Carduelis flammea* (**2**-1; **3**-2; **8**-1; **5**-1), *Carduelis hornemanni* (**2**-1; **3**-1; **7**-7; **4**-1), *Carduelis* sp (**4**-3), *Pyrrhula pyrrhula* (**6**-1), *Pinicola enucleator* (**2**-1; **7**-1; **5**-2), *Loxia curvirostra* (**1**-1; **2**-2; **3**-2; **7**-1; **5**-1; **4**-1), *Loxia pytyopsittacus* (**1**-1; **2**-1; **3**-1), *Passer domesticus* (**4**-1), *Passer montanus* (**3**-1), *Nucifraga caryocatactes* (**3**-1; **4**-1), *Coloeus monedula* (**2**-1; **3**-4; **4**-1), Passeriformes sp. (**1**-2; **2**-3; **3**-1; **8**-1; **7**-1; **5**-2; **4**-2), Passeriformes sp.juv (**4**-2), Aves sp. (**3**-2; **7**-14; **5**-4; **4**-3), Aves sp.juv. (**1**-6; **2**-16; **3**-20; **8**-1; **7**-62; **5**-22; **4**-46), *Bufo bufo* (**1**-1; **3**-2), *Zootoca vivipara* (**4**-1), *Esox lucius* (**2**-1), Gastropoda sp. (**5**-1), Bivalvia sp. (**4**-1)

no single species forming more than 1% of the samples.

Given the large amount of material with a wide range of different species, the majority of the identified prey species are found across several regions, but certain similarities can be identified in the spectrum of species found in the colder basins of regions Orava, Liptov, Turiec, Spiš and Muránska Planina Mts. A specific variant of eagle-owl diet in which the European water vole *A. amphibius* is predominant was identified in the cooler Horehronie region in the northern part of Muránska Planina NP and in Slovenský Raj NP in the southern part of the Spiš region, areas which feature meadows and pasture in their foothills (Obuch 2002). In the milder valleys of Považie, Ponitrie, Pohronie, Rimavská Kotlina Basin and Slovenský Kras Mts. in which livestock farming is more intensive, amphibians formed a below-average share of eagle-owl diets, with owls hunting larger prey (Table 3).

River valleys are characteristic for many regions in Slovakia, and eagle-owls typically nest in the mountains on their edges. A study by Obuch (2021b) categorised results according to three time periods: the pre-socialist period of more than 70 years ago, the socialist period from 30 to 70 years ago, and the post-socialist period of the last thirty years. In the earliest period, eagle-owls nested deep in the mountains in pastureland, with small mammals and amphibians forming the bulk of their diet. During the socialist era, these localities were reforested, and eagle-owls relocated to valleys with intensive agricultural activities. The most recent period has seen a decline in livestock farming and the overgrowth of lower mountain meadows and pastures, a process which is also changing the availability of prey for eagle-owls.

Turkey

In the 6,534 prey remains identified in Turkey, mammals formed the predominant share (Mammalia, 90.1%, 40 species). In the mountain steppes of eastern Turkey, the Brant's hamster *Mesocricetus brandti* (30.2%) and grey hamster *Cricetulus migratorius* (17.4%) were the most common species, but several species of vole were also numerous; *Microtus obscurus* (21.8%), *M. socialis* (4.6%) and *M. mystacinus* (1.2%). *Meriones tristrami* (3.2%) and *Apodemus witherbyi* (2.4%) were the most commonly found prominent members of the Muridae family and *Seratulus williamsi* (1.2%) from the Dipodidae family. Birds (Aves, 6.8%, at least 83 species) were rarer but more diverse in terms of species. The marsh frog *Pelophylax ridibundus* (1.5%) was the most common form of other vertebrate (Amphibia, Reptilia, Pices, 1.9%), and beetles Coleoptera (0.8 %) were the most frequently identified invertebrate (Evertebrata, 1.2%).

The most notable finds were the Setzer's mouse-tailed dormouse *Myomimus setceri* which was identified in three localities in eastern Turkey (Obuch 2001b) and the Afghan pika *Ochotona* cf. *rufescens* from a locality in Ishak Pasa Sarayi (Čermák et al. 2006). The Anatolian blind mole-rat *Nannospalax xanthodon* and the Asia minor ground squirrel *Spermophilus xanthoprimnus* were hunted in the plains of central Anatolia (Sample no. 1 in Table 4). The vole species *M. mystacinus* and *M. socialis* were identified in the Hattutas locality, the Vinogradov's jird *Meriones vinogradovi* was found in samples from the Sarikamis location, and the Transcaucasian mole vole *Ellobius lutescens* at the Bendimahi site (Table 4).

The Near East: Syria, Israel, Jordan

The southern extent of the eagle-owl's range is inhabited by the *Bubo bubo interpositus* sub-species, while the closely related Pharoah eagle-owl *Bubo ascalaphus* is found in the deserts of eastern Jordan (Obuch 2018).

Tab. 2. Eagle-owl diet in various regions of the Czech Republic.
Tab. 2. Potrava výra skalného v rôznych regiónoch Českej republiky.

Region	Pálava		Moravský kras		Podyjí		Kokořínsko		Třeboňsko		Šumava		Vysočina		Total	%
Species \ Region No.	**1**		**3**		**2**		**6**		**4**		**5**		**7**			
Lepus europaeus	1+	76		40	1-	26		60		5		254		143	604	4.29
Sciurus vulgaris	1+	11		2		13		10		1		35		14	86	0.61
Coloeus monedula	1+	8						2			1-	0		1	11	0.08
Chroicocephalus ridibundus	3+	109	2-	0	3-	3- 0		34	1+	10	1-	68	4-	1	222	1.58
Columba livia dom.	1+	62	1-	4	1+	50		33		2		141	1-	52	344	2.44
Cricetus cricetus	3+	57		7	1+	22		7			2-	9	3-	0	102	0.72
Phasianus colchicus	1+	38	1-	3	1+	32	1-	9				113	3-	3	198	1.41
Perdix perdix	1+	36	1+	26		36	2-	7		2		194	1-	50	351	2.49
Falco tinnunculus	1+	10	1+	8		7		8			1-	19		9	61	0.43
Erinaceus sp.	1+	85	1+	55		58	1-	37		8		247		124	614	4.36
Apodemus sylvaticus	1+	59	1+	45		43	2-	17		11		285		97	557	3.96
Coturnix coturnix		1	2+	12		2					1-	0			15	0.11
Scolopax rusticola		1	1+	6		5		5			1-	8		6	31	0.22
Strix aluco		5	1+	17	2+	53		8		1	1-	22	2-	4	110	0.78
Columba oenas		2		4	2+	15		4			2-	0	1-	0	25	0.18
Streptopelia turtur					2+	12		2			1-	2		1	17	0.12
Asio otus		14		9	1+	22		20				60	1-	19	144	1.20
Turdus merula		9		5	1+	28		23		3		85		30	183	1.30
Corvus cornix+frugilegus		1		7	1+	13		6				29	1-	6	62	0.44
Myodes glareolus		6		5	1+	28		15		1	1-	35	1-	14	104	0.74
Glis glis				3	1+	6					1-	0			9	0.06
Vulpes vulpes				3	1+	11		3			1-	2		3	22	0.16
Lucanus cervus		2			1+	7					1-	0			9	0.06
Anas platyrhynchos		6	1-	0	1+	20	1-	7	2+	13		66	1-	10	122	0.87
Apodemus flavicollis		10		16	1+	54	2+	66		1	2-	31		33	211	1.50
Ondatra zibethicus					1+	10	1+	17				19	1-	4	50	0.36
Turdus philomelos		5		6	1+	18	1+	30		2	1-	42		22	125	0.89
Arvicola amphibius	4-	2	2-	7	1-	54	1+	272	1-	9		524	1-	105	973	6.92
Turdus pilaris		1		2			1+	12				9		7	31	0.22
Sturnus vulgaris						2	2+	23			2-	1		3	29	0.21
Rallus aquaticus						3	2+	19		1	2-	1		2	26	0.18
Porzana porzana							1+	7		1		2			10	0.07
Anas crecca		2					1+	6				3		2	13	0.09
Anas querquedula						1	1+	6		1		3			11	0.08
Gallinula chloropus		3				10	1+	21		4	1-	21	1-	7	66	0.47
Corvus corax							1+	5							5	0.04
Tachybaptus ruficollis	1-	3	1-	0		15	1+	30	1+	12		53	3-	1	114	0.81
Podiceps nigricollis		2				1		4	2+	12	1-	6	1-	0	25	0.18
Coleoptera sp.		1						3	1+	5		2		1	12	0.09
Fulica atra	2-	2	2-	0		17		33	2+	31	1+	152	2-	9	244	1.73
Vanellus vanellus		3				5		3		1	1+	41		8	61	0.43
Aythya fuligula								2		1	1+	20		1	24	0.17
Microtus agrestis	1-	0	1-	0		5		9		2	1+	70	2-	3	89	0.63
Sorex araneus				1		1		1			1+	16			19	0.14
Rana temporaria	1-	0		5		2		18			1+	89		1	115	0.82
Microtus arvalis	1-	189		331	1-	382	1+	487	1-	65		3087	1+	1595	6136	43.61
Rattus norvegicus		55	1-	20		78		95	1-	7	1-	271	1+	342	868	6.17
Buteo buteo	1-	1		1		13		12		2		55	1-	11	95	0.68
Garrulus glandarius		3		4		9		9			1-	15		8	48	0.34
Columba palumbus		1		2		2		3			1-	0		1	9	0.06
Talpa europaea		8		1		10		5		1		32	1-	6	63	0.45

Tab. 2. continuation / pokračovanie.

Region	Pálava	Moravský kras	Podyjí	Kokořínsko	Třeboňsko	Šumava	Vysočina		
Species \ Region No.	**1**	**3**	**2**	**6**	**4**	**5**	**7**	**Total**	**%**
Alauda arvensis	6	2	7	5		23	1- 1	44	0.31
Mustela nivalis	5	6	5	6		37	1- 7	66	0.47
Mustela erminea		4	3	4		14	2	27	0.19
Turdus viscivorus	3		3	3		11	3	23	0.16
Pica pica	2	1		3	1	4	5	16	0.11
Streptopelia decaocto	1	1	3	1		5	5	16	0.11
Apodemus microps	1	3	4			6	1	15	0.11
“Mammalia, 41 species”	**1- 571**	**566**	**822**	**1120**	**1- 111**	**5012**	**2504**	**10706**	**76.09**
“Aves, 102 + species”	**1+ 364**	**133**	**1+ 443**	**1+ 455**	**1+ 108**	**1387**	**1- 309**	**3199**	**22.74**
“Amphibia,Reptilia,Pisces”	**1- 2**	**9**	**12**	**22**	**0**	**1+ 96**	**3- 2**	**143**	**1.01**
Evertebrata	**3**	**0**	**1+ 7**	**3**	**1+ 5**	**1- 3**	**1**	**22**	**0.16**
Total	**940**	**708**	**1284**	**1600**	**224**	**6498**	**2816**	**14070**	**100**
Diversity Index H’	**2.93**	**2.44**	**3.16**	**2.96**	**2.71**	**2.44**	**1.88**	**2.66**	

Region: 1 – **Pálava**: Pálava PLA, **3** – **Moravský kras:** Moravský kras PLA, **2** – **Podyjí**: Podyjí NP, **6** – **Kokořínsko**: Kokořínsko PLA and České Švícarsko NP, **4** – **Třeboňsko**: Třeboňsko PLA, **5** – **Šumava**: Šumava NP, **7** – **Vysočina:** Vysočina county.
Other species (**Region**-number): *Sorex minutus* (6-1; 5-8), *Crocidura leucodon* (1-1; 3-2; 2-1; 5-1; 7-1), *Crocidura suaveolens* (1-2; 3-1), *Myotis bechsteinii* (6-1), *Myotis myotis* (5-1), *Vespertilio murinus* (3-1; 5-1), *Eptesicus serotinus* (1-1; 3-1), *Nyctalus noctula* (2-1; 6-1), *Nyctalus leisleri* (5-1), *Spermophilus citellus* (1-2; 2-3; 6-1), *Eliomys quercinus* (3-2), *Muscardinus avellanarius* (3-2; 5-3; 7-1), *Mus* cf. *musculus* (1-1; 3-4; 2-1; 5-3; 7-3), *Micromys minutus* (2-1; 6-3; 5-3; 7-4), *Apodemus agrarius* (6-1), *Terricola subterraneus* (3-1; 2-1; 5-6; 7-1), *Martes* sp. (5-3), *Mustela putorius* (3-1), *Mustela vison* (5-2), *Felis catus dom.* (5-3), *Capreolus capreolus* (6-1; 5-2), Artiodactyla sp. (3-2; 2-1; 5-1; 7-1), *Podiceps cristatus* (6-1; 4-1; 5-4; 7-1), *Ardea cinerea* (5-1), *Cygnus olor* (5-1), *Anser anser dom.* (5-2), *Anas strepera* (2-1), *Anas penelope* (7-1), *Anas acuta* (6-2), *Aythya ferina* (5-1), *Bucephala clangula* (6-4; 5-6), Anatidae sp. (4-1; 5-6; 7-1), *Accipiter gentilis* (2-5; 6-2; 5-5; 7-1), *Accipiter nisus* (2-2; 6-2), Accipitridae sp. (2-1), *Falco peregrinus* (6-1), *Falco subbuteo* (3-2), *Tetrastes bonasia* (5-3), *Lyrurus tetrix* (5-1), *Gallus gallus dom.* (1-1; 6-1; 5-4), *Crex crex* (6-2; 7-2), *Tringa totanus* (6-1), *Tringa glareola* (6-1), *Tringa ochropus* (6-1), *Philomachus pugnax* (6-1), *Gallinago gallinago* (6-1; 7-1), *Gallinago* sp. (5-1), *Larus* sp. (7-1), *Sterna hirundo* (1-1), *Cuculus canorus* (2-3; 5-1), *Tyto alba* (1-1; 2-1; 6-3; 5-1), *Bubo bubo* (1-1; 2-5; 5-5; 7-2), *Asio flammeus* (6-1; 7-2), *Aegolius funereus* (6-1; 7-1), *Athene noctua* (3-1; 2-1; 6-1; 5-2), *Apus apus* (1-1; 2-3; 6-1), *Dryocopus martius* (3-1; 2-2; 6-1; 4-1; 5-4; 7-1), *Picus canus* (7-1), *Picus viridis* (5-1), *Dendrocopos major* (3-1; 2-3; 6-4; 5-3), *Dendrocopos leucotos* (6-1), *Jynx torquilla* (2-1), *Lullula arborea* (3-1; 6-1), *Galerida cristata* (1-1; 3-1; 5-1), *Hirundo rustica* (5-1), *Delichon urbicum* (2-1; 5-3), *Anthus pratensis* (6-1), *Motacilla alba* (1-1; 5-3), *Bombycilla garrulus* (6-1), *Lanius collurio* (1-1), *Acrocephalus palustris* (1-1), *Sylvia borin* (3-1), *Sylvia atricapilla* (4-1), *Regulus sp.* (5-1), *Phoenicurus ochruros* (1-1; 5-1), *Erithacus rubecula* (1-1; 6-1), *Turdus torquatus* (7-1), *Turdus iliacus* (6-2; 7-2), *Parus major* (3-1; 6-1; 5-2), *Poecile palustris* (3-1), *Sitta europaea* (6-1), *Emberiza citrinella* (1-2; 5-2), *Emberiza schoeniclus* (1-1), *Fringilla coelebs* (6-1; 5-5), *Carduelis chloris* (6-1), *Pyrrhula pyrrhula* (5-1), *Coccothraustes coccothr.* (1-2; 2-2; 6-4; 4-1; 5-1), *Serinus serinus* (1-1), *Passer domesticus* (1-3; 2-1; 5-2; 7-1), *Passer montanus* (7-1), *Oriolus oriolus* (1-1; 6-1; 5-1), *Nucifraga caryocatactes* (2-1; 5-2), Passeriformes sp. (1-3; 3-3; 2-3; 5-6), *Aves sp.* (2-2; 5-29), Aves sp.juv. (2-1; 6-2; 4-3; 7-1), *Pelobates fuscus* (3-2; 2-1; 6-1), *Pelophylax cf.esculentus* (1-2; 2-2; 6-1; 5-1), *Lacerta agilis* (2-1), Colubridae sp. (3-1), *Salmo trutta* (2-2; 5-1), Salmonidae sp. (3-1; 6-1), Cypriniformes sp. (2-3; 7-1), Pisces sp. (2-1; 6-1; 5-5), *Unio crassus* (5-1)

From the total of 1,813 eagle-owl prey items from the three countries, mammals formed the most numerous category (Mammalia, 58.4%, 36 species), with *M. tristrami* (22.4%), *Hemiechinus auritus* (6.1%), *Rattus norvegicus* (5.6%) and *Erinaceus concolor* (3.8%) being the most numerous species. The proportion of birds in the diets is also noteworthy (Aves, 35.8%, at least 67 species), most commonly *Columba livia* (6.6%), *Garrulus glandarius* (5.3%) and *Coturnix coturnix* (2.6%). Lizards of the Agamidae (0.7%) and Lacertidae (0.5%) families were the most numerous elements of the other vertebrates (Amphbia, Reptilia, Pisces, 2.3%), but also notable was the relatively high proportion of invertebrates in eagle-owl diets (Evertebrata, 3.5%), especially scorpions (Scorpiones, 1.6%).

In Jordan, the species *M. tristrami, R. norvegicus* and *G. glandarius* were the most common prey items; in Israel the Günther’s vole *Microtus guentheri*, and in Syria the long-eared hedgehog *H. auritus* (Table 5).

Iran

Mammals were predominant in the 7,862 prey items from Iran (Mammalia, 77.0%, 55 species). Across the entire territory, *Meriones persicus* (17.6%) and *C. migratorius* (11.8%) were recorded most frequently. In terms of birds (Aves, 15.3%, at least 95 species), the most common species were rock doves *C. livia* (1.1%); in the case of other vertebrates (Amphibia, Reptilia, Pisces, 5.0%) the Agamidae family (1.6%) and the marsh frog *Pelophylax ridibundus* (1.5%) predominated, as did beetles (Coleoptera 1.9%) among invertebrates (Evertebrata, 2.7%).

The fauna identified in samples from the northern Zagros mountains was similar to that found in eastern Turkey, with the species *M. brandti*, *S. williamsi, M. obscurus* and *M. setzeri* being characteristic. In the milder areas of the central Zagros range, *M. persicus, C. migratorius* and *E. lutescens* were commonly recorded, while *Meriones libycus, Meriones crasus* and *H. auritus* were more common in the more arid regions. The endemic species *Microtus irani* was found in the southern Zagros mountains; *Tatera indica* and *Nesokia indica* were common in Balochistan and Mesopotamian regions of Iran, and *Ellobius fuscocapillus, Ochotona rufescens, Microtus afghanus* and *Meriones meridianus* in the Koppeh Dagh Mts. (Table 6).

Tab. 3. Eagle-owl diet in various regions of the Slovakia.
Tab. 3. Potrava výra skalného v rôznych regiónoch Slovenska.

Region	Liptov	Orava	Turiec	ŽK	Považie	Ponitrie	Pohr.	MP	Spiš	RK	SK	Total	%
Species \ Region No.	2	1	3	4	5	6	7	8	9	10	11		
Rana temporaria	1+ 10690	4283	7094	7354	1- 1280	2- 375	1- 210	1- 1796	1- 1022	5- 11	6- 9	34124	32.1
Bufo bufo	1+ 12	3	4	2	3			2	1			27	0.03
Tetrastes bonasia	1+ 18	7	1- 2	1- 0				7	5		1	40	0.04
Columba palumbus	1+ 46	19	1- 11	1- 11	10	8	2	4	1- 0		1	112	0.11
Delichon urbicum	1+ 11	8	2	1	3			2				27	0.03
Salmo trutta	1+ 67	1- 16	1+ 75	1- 24	1- 5	2- 1	2	13	1+ 21		1- 0	224	0.21
Dryomys nitedula	1+ 26	15	2- 0	2- 1	1- 1			1+ 19	1		1+ 8	71	0.07
Microtus agrestis	1+ 52	25	1- 14	1- 24	2- 0	2- 0		1+ 33	2+ 36	1	1- 0	185	0.17
Muscardinus avellanarius	1+ 42	1+ 33	1- 15	1- 17	15	1- 2	1	1+ 18	5		3	151	0.14
Sicista betulina	1+ 15	1+ 11	1- 2	1- 0	1			6	3			38	0.04
Eliomys quercinus	1+ 33	1- 5	1+ 40	26	13	1+ 13	3	1- 2	3			138	0.13
Turdus pilaris	26	1+ 57	1- 23	33	1- 8	10	4	9	1- 2	3	8	183	0.17
Turdus viscivorus	13	1+ 21	1- 8	1- 7	4	4	1	9	3	1	1+ 7	78	0.07
Turdus philomelos	1- 40	1+ 84	99	1- 59	31	1+ 35	5	24	13	1+ 12	11	413	0.39
Turdus torquatus	8	2+ 23	2- 0	3					1+ 6			40	0.04
Coloeus monedula	33	1+ 46	2- 18	42	2+ 64	1- 4	6	2- 4	1+ 15		1+ 11	243	0.23
Arvicola amphibius	1181	1+ 1716	1- 786	2- 561	2- 135	2- 139	1+ 131	2+ 1944	2+ 711	1- 40	1+ 296	7640	1.00
Apodemus agrarius	78	1+ 122	2- 28	1+ 148	1- 27	2- 5	1- 0	3- 4	1- 7	2+ 34	15	468	0.44
Buteo buteo	6	1+ 21	1+ 30	12	11	4	3	4	1	3		95	0.09
Microtus arvalis	1- 3432	1+ 5574	1+ 8588	6105	2375	1705	390	2637	1345	1- 275	1- 610	33036	31.1
Mustela nivalis	1- 59	1- 30	1+ 151	87	37	26	7	1- 20	19	1	12	449	0.42
Galerida cristata	1- 0	2	1+ 23	3	6	2		2		1	1	40	0.04
Anas querquedula	1- 0	5	1+ 14	1- 0	4		1	3	1	2		30	0.03
Vanellus vanellus	19	1- 9	1+ 47	1- 14	11	6	1+ 8	1- 4	2	1+ 8	1+ 15	143	0.13
Mus musculus	1- 94	1- 97	1+ 265	220	1+ 102	1+ 80	2- 1	2- 21	1+ 64	6	1- 9	959	0.90
Apodemus flavicollis	2- 203	1- 353	1+ 1040	795	1+ 458	1+ 398	1- 33	1- 177	2- 35	41	99	3632	3.42
Sciurus vulgaris	1- 40	37	1+ 88	51	31	1+ 22	1	17	12		1- 2	301	0.28
Falco tinnunculus	1- 24	27	1+ 65	35	1+ 29	9	5	11	7	3	10	225	0.21
Apodemus sylvaticus	1- 464	1- 530	1088	1- 1257	1+ 771	1+ 518	2- 15	2- 98	2- 52	54	1- 51	4898	4.61
Lepus europaeus	1- 95	1- 86	1- 91	1+ 235	1+ 133	2+ 123	13	1- 32	44	1+ 22	1+ 43	917	0.86
Myodes glareolus	2- 42	2- 31	189	1+ 198	2+ 180	1+ 68	7	1+ 81	2- 7	1- 3	1- 12	818	0.77
Terricola subterraneus	52	1- 21	2- 16	1+ 119	1+ 46	11	2	29	8		6	310	0.29
Talpa europaea	1- 61	62	1- 74	1+ 116	1+ 53	20	6	1+ 52	1- 7	6	10	467	0.44
Coturnix coturnix	1- 40	1- 33	100	1+ 118	1+ 48	1+ 28	5	28	1- 5	2	1+ 17	424	0.40
Pelophylax cf.esculentus	4- 0	3- 2	1- 19	2+ 123	2+ 68	1+ 23	1	2- 2	2- 0	4	7	249	0.23
Athene noctua	1- 1	1- 1	1- 2	1+ 16	1+ 9	1+ 7	1	1	1	2	1	42	0.04
Asio otus	1- 40	1- 64	113	1- 69	1+ 102	1+ 53	1+ 25	37	1+ 31	2+ 27	18	579	0.55
Strix aluco	1- 24	1- 21	1- 42	62	2+ 94	13	1+ 11	24	2- 1	3	4	299	0.28
Columba oenas	1- 5	1- 5	1- 7	1- 12	1+ 26	1+ 14	1	1+ 17	2	2+ 13	1+ 10	112	0.11
Scolopax rusticola	1- 28	30	1- 30	54	1+ 35	1+ 25	1+ 10	24	14	1	6	257	0.24
Perdix perdix	2- 49	1- 85	1- 141	198	2+ 240	2+ 123	1+ 24	1- 34	1- 18	13	2+ 63	988	0.93
Phasianus colchicus	2- 3	2- 0	2- 4	25	2+ 38	2+ 23	3	1- 1	1- 0	2+ 13	2	112	0.11
Corvus cornix+frugilegus	1- 88	162	231	1- 158	1+ 186	1+ 76	1+ 31	1- 53	35	1+ 20	27	1067	1.10
Turdus merula	1- 16	34	49	1- 26	1+ 36	1+ 34	7	22	1- 2	2+ 23	1+ 15	264	0.25
Anas platyrhynchos	1- 8	13	34	1- 13	1+ 31	3	1+ 9	1- 1	2	1+ 6	1+ 11	131	0.12
Erinaceus roumanicus	1- 96	1- 104	1- 163	177	2+ 241	1+ 121	2+ 50	1- 54	1- 15	2+ 36	1+ 41	1098	1.30
Cricetus cricetus	2- 22	4- 0	3- 10	4- 5	2+ 134	2+ 72	1- 0	4- 0	2+ 57	1- 0	3+ 125	425	0.40
Pelobates fuscus	4- 0	3- 0	46	3- 4	1+ 32	1- 4		2- 0	1- 0	1	4+ 110	197	0.19
Cypriniformes sp.	2- 8	18	1- 23	1- 22	2+ 63	1- 1	3+ 27	1- 3	1- 1	5		171	0.16
Apodemus microps	1- 174	2- 51	1- 155	276	3+ 622	75	3- 0	5- 2	53	17	1- 24	1449	1.36
Nyctalus noctula	1- 2	1- 1	1- 3	4	2+ 25	3	2	1		1	1	43	0.04
Gallus gallus dom.	2		1	8	1+ 11		1		1			24	0.02
Pica pica	1- 18	1- 17	52	41	1+ 24	11	3	16	11	5	7	205	0.19
Crocidura suaveolens	5	2	4	6	1+ 8	1+ 10			1	2	3	41	0.04
Crocidura leucodon	1- 0	1	2	9	5	1+ 7	1	1				26	0.02
Sturnus vulgaris	1- 5	11	13	15	5	1+ 14	3	6	1	5	5	83	0.08
Lacerta viridis	1- 0		1- 0	1- 0	2	2+ 16				3	3	24	0.02

Tab. 3. continuation / pokračovanie.

Region	Liptov		Orava		Turiec		ŽK		Považie		Ponitrie		Pohr.		MP		Spiš		RK		SK		Total	%
Species \ Region No.		**2**		**1**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**		**11**		
Lacerta agilis	1-	3		7		10	1-	4		4	1+	14				9		2				3	56	0.05
Lucanus cervus	1-	0	1-	0	1-	0	1-	0			2+	21		2					2+	9		4	36	0.03
Columba livia dom.	1-	49	1-	49		115		108		36	1+	64		11	2-	12	1-	11	1+	21	2+	54	530	0.50
Spermophilus citellus	3-	0	2-	0	3-	0	3-	0	1-	1	1+	16			1+	20	1+	13			3+	44	94	0.09
Rattus norvegicus	1-	267	1-	366	1-	541	1-	363		217	1+	295	2+	172	1+	308		118	3+	225	2+	333	3205	3.20
Alauda arvensis	1-	45		52	1-	52		71		22	1+	27	1+	13	1+	45		11		6		9	353	0.33
Myotis myotis	1-	2		5		13		13		9		1	1+	5		2		5		1		4	60	0.06
Eptesicus serotinus		10		6	1-	4		15		9		4		1	1+	11		4				1	65	0.06
Porzana porzana	1-	1		2		8		2		4		1			1+	9		1				3	31	0.03
Streptopelia turtur	1-	3		5	1-	5		11		7		6		1	1+	18		3				3	62	0.06
Coleoptera sp.	1-	2	1-	1		5		10		5						4		1	1+	8		2	38	0.04
Micromys minutus		11	1-	3		22	1-	8		4		4			1-	0			3+	24		2	78	0.07
Glis glis		30		21		32	1-	18		16	1-	1		4		8		3	1+	12	2+	24	169	0.16
Gallinula chloropus	2-	1	1-	6		17	1-	9		4		2		3		5			1+	10	3+	25	82	0.08
Garrulus glandarius	1-	25		33		40	1-	29		21		13		2		18	1-	1	1+	13	1+	12	207	0.19
Vulpes vulpes		13		16		20		21		8		9		2		4		5			1+	10	108	0.10
Tachybaptus ruficollis		3	1-	1		5		4		2		2		3						3	2+	15	38	0.04
Anas crecca	1-	1		2		12		4		4		1		2		2		1			1+	9	38	0.04
Fulica atra	1-	0		1		6		3		3		1		3		1				2	1+	7	27	0.03
Gallinago gallinago		5		1		5		1										1			1+	7	20	0.02
Streptopelia decaocto	1-	5		9		19		8		4		1		3		2				2	1+	8	61	0.06
Cuculus canorus	1-	2		3		7	1-	2		7		5				6		1			1+	6	39	0.04
Mustela erminea	1-	16		13		38		25		13		6		4		12		9				2	138	0.13
Erithacus rubecula	1-	0		8		8		5		2		2				3				1		1	30	0.03
Passer domesticus	1-	1		6		4		8		6		4				1						2	32	0.03
Accipiter gentilis		12	1-	1		8		6		3		2		1		1		2		2		1	39	0.04
Accipiter nisus		5	1-	0		6		5		4		4		1		3						1	29	0.03
Aegolius funereus		9		5	1-	2		4		2		3				4		5					34	0.03
Fringilla coelebs		9		8	1-	2		12		2				1		6						2	42	0.04
Coccothraustes coccothr.		3		3	1-	3		9		4		2		3		7		1				3	38	0.04
Crex crex		14	1-	7		24	1-	12		10		7		4		8		7		1		6	100	0.09
Sorex araneus		9		13		11		14		8		5				10		2		1		1	74	0.07
Neomys fodiens		18		13		11		16		4		1				7				1		1	72	0.07
Emberiza citrinella		6		11		8		9		7		2				5		2				2	52	0.05
“Mammalia, 65 species”	**1-**	**6690**		**9392**		**13547**		**10970**		**5728**	**1+**	**3778**		**853**	**1+**	**5650**		**2652**	**1+**	**805**	**1+**	**1807**	**61872**	**58.3**
“Aves, 140 + species”	**1-**	**875**		**1122**		**1638**		**1542**	**1+**	**1323**	**1+**	**711**	**1+**	**243**		**574**	**1-**	**258**	**2+**	**239**	**1+**	**475**	**9000**	**8.48**
“Amphibia, Reptilia, Pisces”	**1+**	**10813**		**4339**		**7282**		**7570**	**1-**	**1465**	**2-**	**452**	**1-**	**240**	**1-**	**1834**	**1-**	**1050**	**4-**	**26**	**3-**	**135**	**35206**	**33.2**
Evertebrata	**1-**	**5**	**1-**	**5**	**1-**	**5**		**12**		**6**	**2+**	**21**		**2**		**7**		**1**	**2+**	**18**		**6**	**88**	**0.08**
Total		**18383**		**14858**		**22472**		**20094**		**8522**		**4962**		**1338**		**8065**		**3961**		**1088**		**2423**	**106166**	**100**
Diversity Index H’		**1.74**		**2.10**		**2.90**		**2.22**		**2.90**		**2.79**		**2.69**		**2.14**		**2.16**		**2.94**		**3.60**	**2.35**	

Localities: 2 – **Liptov**, **1** – **Orava**, **3 - Turiec**, **4** – **ŽK**: Žilinská kotlina Basin, **5** – **Považie**: Považské Podolie, Valley **6** – **Ponitrie**: Hornonitrianska Kotlina Basin, **7** – **Pohr.**: Pohronie Valley, **8** – **MP**: Muránska Planina Mts., **9** – **Spiš**, **10** – **RK**: Rimavská Kotlina Basin, **11** – **SK**: Slovenský Kras Mts.

Other species (**Region-**number): *Sorex minutus* (**2**-3; **1**-2; **3**-2; **4**-2; **5**-2; **6**-3), *Sorex alpinus* (**2**-1), *Neomys anomalus* (**2**-2; **1**-2; **3**-4; **4**-7; **5**-2; **6**-3; **8**-1; **9**-1; **11**-1), *Rhinolophus ferrumequinum* (**3**-1), *Rhinolophus hipposideros* (**3**-1; **4**-1; **6**-1), *Myotis mystacinus* (**2**-2; **3**-1; **5**-1; **7**-1; **8**-2; **9**-2; **11**-2), *Myotis brandtii* (**2**-1; **8**-1), *Myotis emarginatus* (**6**-1), *Myotis nattereri* (**1**-1; **8**-1), *Myotis bechsteinii* (**2**-2; **3**-3; **8**-3; **9**-1), *Myotis blythii* (**1**-1; **5**-1; **6**-1), *Vespertilio murinus* (**2**-5; **1**-2; **3**-9; **4**-4; **5**-3; **6**-2; **7**-1; **8**-1), *Eptesicus nilssonii* (**3**-1), *Pipistrellus pipistrellus* (**2**-3; **1**-1; **3**-5; **4**-5; **5**-5; **11**-1), *Barbastella barbastellus* (**2**-4; **3**-4; **4**-8; **5**-2; **6**-2; **8**-4), *Plecotus auritus* (**2**-2; **1**-3; **4**-1; **5**-3; **8**-1), *Plecotus austriacus* (**11**-1), *Rattus rattus* (**2**-1; **3**-1; **4**-1), *Dicrostonyx gulielmi* (**6**-1), *Ondatra zibethicus* (**2**-1; **1**-5; **3**-6; **4**-3; **5**-2; **9**-1; **10**-2; **11**-3), *Terricola tatricus* (**1**-3; **4**-2; **8**-2; **9**-1; **11**-2), *Lasiopodomys gregalis* (**6**-1), *Alexandromys oeconomus* (**6**-1; **11**-1), *Chionomys nivalis* (**2**-6; **1**-3; **9**-2), *Canis familiaris* (**2**-1; **4**-1), *Martes foina* (**1**-1; **4**-1), *Martes* sp. (**2**-1; **3**-1; **4**-1; **8**-1), *Mustela putorius* (**2**-5; **1**-3; **4**-1; **5**-1; **6**-1; **11**-2), *Mustela eversmanni* (**5**-1; **11**-2), *Mustela vison* (**3**-1), *Felis catus dom.* (**2**-2; **1**-1; **3**-2; **4**-1; **5**-2; **6**-1; **8**-2), *Sus scrofa* (**2**-2; **3**-1), *Cervus elaphus* (**1**-1; **8**-1), *Capreolus capreolus* (**2**-1), *Capra ibex hircus* (**4**-1), *Ovis ammon aries* (**2**-1; **5**-1), *Podiceps cristatus* (**4**-1), *Podiceps grisegena* (**8**-1), *Podiceps nigricollis* (**4**-1; **11**-3), *Ixobrychus minutus* (**1**-1; **11**-1), *Nycticorax nycticorax* (**5**-1), *Anser anser dom.* (**7**-1), *Anser fabalis* (**4**-1), *Anas penelope* (**5**-1), *Anas acuta* (**3**-1; **7**-2), *Aythya fuligula* (**1**-2; **8**-1; **11**-1), *Bucephala clangula* (**5**-1), Anatidae sp. (**2**-1; **1**-1; **3**-4; **4**-3; **5**-10; **6**-2; **7**-6; **8**-1; **11**-4), *Pernis apivorus* (**2**-1; **7**-1), *Aquila pomarina* (**2**-1), *Aquila* sp. (**3**-1), *Circus aeruginosus* (**11**-2), *Circus* sp. (**4**-1; **8**-2), Accipitridae sp. (**3**-1; **8**-2; **10**-1), *Falco peregrinus* (**2**-2; **4**-4; **5**-1; **11**-2), *Falco subbuteo* (**1**-2), *Falco columbarius* (**2**-1), *Falco* sp. (**3**-3; **4**-2; **5**-1), *Lyrurus tetrix* (**2**-4; **1**-1; **5**-4; **9**-3), *Tetrao urogallus* (**2**-3; **1**-2; **9**-1), *Meleagris gallopavo dom.* (**4**-1), Galliformes sp. (**1**-2; **8**-1), *Rallus aquaticus* (**2**-2; **1**-3; **3**-9; **4**-1; **5**-3; **6**-3; **7**-1; **8**-1; **10**-1; **11**-1), *Porzana parva* (**3**-1; **4**-1; **6**-1; **11**-1), Rallidae sp. (**3**-1; **5**-2; **10**-1), *Charadrius dubius* (**2**-1; **1**-2; **4**-5; **5**-1; **6**-4), *Pluvialis apricaria* (**4**-1; **11**-1), *Tringa glareola* (**2**-1; **3**-3), *Tringa ochropus* (**5**-1), *Tringa* sp. (**3**-2; **8**-2; **9**-2), *Actitis hypoleucos* (**2**-7; **1**-6; **3**-5; **4**-10; **5**-2; **6**-4; **7**-2; **8**-1), *Philomachus pugnax* (**1**-2; **3**-2; **4**-1; **5**-1; **8**-1), *Limosa limosa* (**5**-1), *Gallinago* sp. (**7**-1), *Lymnocryptes* *minimus* (**11**-1), Limicolae sp. (**1**-1; **5**-3), *Chroicocephalus ridibundus* (**3**-3; **4**-2; **8**-1), *Sterna hirundo* (**3**-1; **4**-1; **5**-2), *Chlidonias niger* (**2**-1; **3**-1; **4**-2), *Columba* sp. (**3**-1; **4**-41; **5**-11), *Tyto alba* (**1**-2; **4**-2; **5**-2; **10**-2; **11**-1), *Bubo bubo* (**2**-4; **1**-5; **3**-5; **4**-8; **5**-4; **6**-1; **8**-6; **9**-1; **10**-3; **11**-5), *Asio flammeus* (**2**-2; **3**-1; **4**-2; **5**-1; **6**-1), *Otus scops* (**6**-2), *Strix uralensis* (**2**-3; **4**-1; **5**-1; **9**-1; **11**-1), *Caprimulgus europaeus* (**2**-3; **1**-2; **3**-3; **4**-6; **5**-1; **6**-1; **8**-4; **11**-4), *Apus apus* (**4**-2; **5**-1; **7**-1), *Coracias garrulus* (**6**-1; **8**-2), *Upupa epops* (**8**-1), *Dryocopus martius* (**2**-2; **1**-2; **3**-2; **4**-2; **8**-1; **9**-1), *Picus canus* (**5**-2), *Picus viridis* (**4**-2; **5**-1; **9**-1), *Dendrocopos major* (**2**-2; **4**-1; **5**-1), *Dendrocopos syriacus* (**5**-1; **9**-1), *Dendrocopos medius* (**2**-1), *Dendrocopos leucotos* (**4**-1), *Jynx torquilla* (**2**-1; **1**-1; **5**-2; **8**-1), *Lullula arborea* (**2**-3; **1**-4; **3**-3; **4**-10; **5**-3; **6**-2; **8**-4; **9**-2; **11**-1), *Hirundo rustica* (**2**-3; **1**-1; **3**-1; **5**-1; **11**-1), *Riparia riparia* (**1**-2), *Anthus trivialis* (**2**-2; **1**-6; **7**-1; **8**-2; **9**-1), *Anthus pratensis* (**4**-1), *Anthus spinoletta* (**2**-1; **4**-2), *Motacilla alba* (**2**-2; **3**-2; **4**-5; **5**-1; **8**-2; **11**-2), *Motacilla cinerea* (**5**-1; **8**-1; **11**-1), *Bombycilla garrulus* (**1**-1), *Lanius excubitor* (**3**-1; **4**-1; **6**-2), *Lanius minor* (**2**-1; **3**-2; **4**-7; **6**-2; **8**-1), *Lanius collurio* (**2**-7; **1**-10; **3**-1; **4**-10; **5**-1; **6**-3; **8**-3; **9**-2; **11**-2), *Acrocephalus palustris* (**2**-1; **8**-1), *Hippolais icterina* (**3**-2), *Sylvia atricapilla* (**2**-1; **1**-1; **3**-2; **6**-2; **8**-1), *Phylloscopus sibilatrix* (**2**-1; **4**-1), *Regulus sp.* (**1**-1), Sylviidae sp. (**2**-2; **4**-5; **7**-1), *Muscicapa striata* (**1**-1; **4**-1), *Saxicola rubetra* (**3**-1), *Oenanthe oenanthe* (**4**-1; **6**-2), *Phoenicurus ochruros* (**3**-4; **5**-1; **8**-1), *Turdus iliacus* (**2**-1; **1**-2; **3**-1; **4**-1; **9**-1), *Turdus* sp. (**3**-2), *Parus major* (**2**-1; **1**-1; **3**-1; **4**-2; **6**-1; **8**-2), *Periparus ater* (**8**-1), *Cyanistes caeruleus* (**1**-2; **6**-1), *Lophophanes cristatus* (**8**-1; **9**-1), *Poecile palustris* (**4**-2), *Parus* sp. (**4**-1), *Sitta europaea* (**3**-1; **8**-1), *Troglodytes troglodytes* (**8**-2), *Cinclus cinclus* (**2**-1; **3**-1; **5**-1), *Emberiza calandra* (**2**-1; **1**-1; **3**-1; **5**-2; **8**-1), *Emberiza schoeniclus* (**7**-1; **8**-2), *Emberiza* sp. (**2**-1), *Carduelis carduelis* (**2**-2; **1**-5; **3**-4; **5**-1; **11**-1), *Carduelis spinus* (**4**-1), *Carduelis cannabina* (**2**-1; **1**-1; **3**-1; **5**-1; **11**-2), *Carduelis chloris* (**2**-1; **1**-1; **4**-1; **6**-1; **9**-1; **10**-1; **11**-1), *Pyrrhula pyrrhula* (**2**-1; **1**-1), *Serinus serinus* (**1**-1; **3**-1), *Loxia curvirostra* (**2**-4; **1**-2; **9**-1), Fringillidae sp. (**1**-1; **8**-1), *Passer montanus* (**2**-1; **4**-3; **5**-1; **11**-1), *Oriolus oriolus* (**6**-2), *Nucifraga caryocatactes* (**2**-3; **1**-6; **3**-4; **4**-2; **5**-1; **8**-1; **9**-2), *Corvus corax* (**2**-4; **3**-2; **4**-5; **5**-1; **9**-1; **10**-1; **11**-2), Passeriformes sp. (**2**-11; **1**-11; **3**-27; **4**-10; **5**-18; **6**-15; **7**-1; **8**-10; **9**-7; **10**-2; **11**-5), Aves sp. (**2**-5; **1**-2; **3**-2; **4**-7; **5**-6; **6**-1; **7**-3; **9**-1; **11**-1), Aves sp.juv. (**1**-3; **3**-4; **6**-2; **7**-1; **8**-4; **9**-1), *Bombina variegata* (**2**-2), *Bombina sp.* (**1**-1), *Bufotes viridis* (**2**-2; **3**-2; **4**-2; **5**-1), Bufonidae sp. (**2**-2; **9**-1), *Hyla arborea* (**2**-2; **3**-2; **4**-1), *Rana dalmatina* (**6**-3), *Rana arvalis* (**5**-1), *Pelophylax ridibundus* (**3**-1; **6**-5; **11**-2), *Anguis fragilis* (**4**-1), *Lacerta muralis* (**3**-3; **4**-1; **5**-2; **6**-1; **10**-1), *Lacerta* sp. (**1**-3; **4**-2; **8**-2; **9**-1), *Zootoca vivipara* (**2**-1; **3**-2; **4**-1; **8**-3), *Natrix natrix* (**3**-1; **4**-2; **8**-1), Colubridae sp. (**2**-2; **1**-1; **4**-1; **6**-2; **10**-1), Serpentes sp. (**5**-2; **8**-1; **11**-1), Pisces sp. (**2**-22; **1**-5; **4**-26; **5**-2; **6**-7; **8**-2; **9**-1), Hymenoptera sp. (**4**-1), *Astacus* sp. (**5**-1), Limacidae sp. (**2**-3; **1**-4; **4**-1; **8**-3; **10**-1)

Southern Kyrgyzstan

Mammals were the predominant prey type among the 4,805 eagle-owl prey items (Mammalia, 81.0%, 30 species). In more arid regions, the midday jird *Meriones meridianus* was the dominant species (27.4%), while the vole species *Microtus juldaschi* (14.9%) and *Ellobius tancrei* (14.1%) were more common in mountainous regions. In terms of birds (Aves, 16.5%, at least 65 species), game species were hunted most frequently: *Alectori chukar* (3.3%), *Coturnix coturnix* (1.0%) and *Perdix dauurica* (0.7%). Other vertebrates (Amphibia, Reptilia, Pisces, 0.9%) formed a less significant component of the eagle-owl diet in this material, with invertebrates being recorded in greater numbers (Evertebrata, 1.6%), especially Coleoptera (1.2%) and Scorpiones (0.4%) (Table 7).

The findings from localities at lower elevations with more arid climates (Sample no. 1 in Table 7) and at higher elevations with more humid conditions (Sample no. 4 in Table 7) are summarised. Sample no. 2 (in Table 7) was collected in Dvachan Ungur cave where eagle-owls have adapted to hunt bats from colonies of *Myotis blythii*. In the valley of Kalek was the eagle-owls specialise in hunting of birds.

Mongolia

Mammals were the predominant prey in the 430 identified prey remains (Mammalia, 87.2%, 12 species). The most common species was the Alpine pika *Ochotona alpina* (42.8%), but other represented mammals included *Lepus tolai, Orietallactaga sibirica, Phodopus campbelli, Alticola strelzowi, A. barakshin* and *Ellobius tancrei* (Table 8).

Larger samples of eagle-owl pellets were collected at sixteen sites in central and western Mongolia by German researchers over the course of several expeditions (Stubbe et al. 2016). A higher proportion of species from the Dipodidae and Gerbillidae families were recorded in the more arid regions than in the Altai mountains.

Baikal

Seven species of mammal were identified in the 72 prey remains (Mammalia, 59.7%). *Alexandromys fortis* (37.5%) and *Urocitellus undulatus* (11.1%) were the most common species, but there was also a relatively high number of birds (Aves, 21.2%, 12 species) and other vertebrates (Amphibia, Reptilia, Pisces, 11.1%) (Table 8).

A larger sample from eagle-owl pellets collected in the western part of the Pribaikalie region was examined by Rjabcev & Rezin (2009). The predominant species were found to be the rodent species *Cricetulus barabensis*, *Lasiopodomys gregalis* and *Arvicola amphibius*.

Sakhalin

Mammals were the predominant component of the 1,491 eagle-owl prey remains (Mammalia, 88.4%, 19 species), with the following species being most common: *Craseomys rufocanus*, *Myodes rutilus, Ochotona hyperborea* and *Pteromys volans*. Among the birds (Aves, 9.4%, 24 species), the hazel grouse *Tetrastes bonasia*, one of the more common taiga species, was remarkably well-represented (6.2%) (Table 8). Only small settlements of fewer than fifty inhabitants are found within a 100 km radius; the surrounding conifer forests are prone to natural forest fires, and the resulting stands of new growth prove to be suitable territories for hunting by eagle-owls during their initial stages.

It can be assumed that the same conditions have prevailed for at least 1200 years. Remains of the brown rat *Rattus norvegicus* were also identified in the sample, which indicates that this rodent had been present on the territory even prior to the worldwide expansion of the species' range through its position as a synanthrope. Brown rats still survive in the locality, and one specimen was captured by the author in a local stream during a sample-collecting expedition to the site.

Tab. 4. Diet of eagle-owl diet in Turkey.
Tab. 4. Potravy výra skalného v Turecku.

Species \Sample No	1		2		3		5		4		6		Total	%
Nannospalax xanthodon	1+	6		5		12	1-	0		4		9	36	0.55
Spermophilus xanthoprymnus	1+	5				2		3					10	0.15
Meriones tristrami	2+	44		25	1+	137	3-	1	4-	0	4-	0	207	3.17
Microtus mystacinus	1+	10	3+	71	3-	0	2-	0	2-	0	3-	0	81	1.24
Mus sp.	1+	13	2+	59		29	2-	0		23	3-	2	126	1.93
Pelobates syriacus			1+	9									9	0.14
Coleoptera sp.		1	2+	43	2-	2	1-	1	1-	3	1-	4	54	0.83
Pelophylax ridibundus		5	1+	18	2-	6	1+	34	1-	9		24	96	1.47
Scratulus williamsi		5	1+	17	1-	13	1+	24	1-	8	1-	9	76	1.16
Microtus socialis	1-	3	1+	60	1-	60	1+	88	1+	91	5-	0	302	4.62
Coturnix coturnix				3	1+	19				3	1-	2	27	0.41
Orthoptera sp.					1+	13							13	0.20
Mesocricetus brandti		90		195	1+	744	1+	341		396	1-	204	1970	30.15
Myomimus setzeri							1+	6		3		4	13	0.20
Chionomys nivalis			1-	1		16	1+	20		13		10	60	0.92
Falco tinnunculus		2		1			1+	6		2		2	13	0.20
Petronia petronia				3		13	1+	12	1-	2		9	39	0.60
Agamidae sp.		1					1+	6					7	0.11
Apodemus witherbyi	1-	2		16		42	1-	6	1+	59		33	158	2.42
Cricetulus migratorius	1-	21		122		404	3-	19	1+	507	2-	65	1138	17.42
Meriones vinogradovi			1-	0	3-	0	1-	0	2+	64	2-	0	64	0.98
Microtus obscurus	4-	0	6-	0	1-	285	1-	82	7-	0	2+	1056	1423	21.78
Ellobius lutescens					1-	0		5	1-	0	1+	17	22	0.34
Carduelis carduelis									1+	1	1+	8	9	0.14
Passer domesticus		1		1		6		1	1+	1	1+	10	20	0.31
Crocidura suaveolens		2		4		14		1	1-	0		10	31	0.47
Alectoris chukar		3		4		15		4	1-	0		7	33	0.51
Perdix perdix		1				7		4		9		4	25	0.38
Columba livia		4		2		6		3		1		7	23	0.35
Sturnus vulgaris		1		4		4				1		7	17	0.26
Erinaceus concolor		4		3		3				5			15	0.23
Alauda arvensis		1		2		3		4				4	14	0.21
Mustela nivalis						3		3		1		3	10	0.15
Columba oenas						6		4					10	0.15
Corvus cornix+frugilegus		1				1		4		3		1	10	0.15
Galerida cristata						3		2				3	8	0.12
“Mammalia, 39 species”		**223**		**592**		**1809**		**612**		**1195**		**1456**	**5887**	**90.10**
“Aves, 83 + species”	**1+**	**34**		**41**		**145**	**1+**	**78**	**1-**	**35**		**111**	**444**	**1.80**
“Amphibia,Reptilia,Pisces”		**7**	**1+**	**28**	**2-**	**6**	**2+**	**47**	**1-**	**10**		**25**	**123**	**1.88**
Evertebrata		**3**	**2+**	**44**		**22**	**1-**	**3**	**2-**	**3**	**1-**	**5**	**80**	**1.22**
Total		**267**		**705**		**1982**		**740**		**1243**		**1597**	**6534**	**100**
Diversity Index H’		**2.62**		**2.49**		**2.20**		**2.26**		**1.78**		**1.56**	**2.46**	

Sample No: 1: Aksaray, 12.4.2001, Demir Kazikoyl, 10.6.1992, Pozanti, 5.5.2001, Tuz Golu, 14.6.1998, Yapraghisar, 11.6.1992, 6.10.2005, Karadut, 7.6.1992; **2**: Hattutas, 22.4.1996; **3**: Horasan, 14.5.1996, 21.5.1997, 21.10.1998, 27.4.200, 23.10.2002, Ani, 20.5.1997, Tuzluca, 20.5.1997; **5**: Ishak Passa Sarayi, 24.4.1996, 30.4.1997, 30.9.1998, 1.10.2002; **4**: Sarikamis, 4.6.1992; **6**: Bendimahi, 5.6.1992, Tatvan, 6.6.1992.

Other species (**Sample-**number): *Sorex volnuchini* (**3**-1; **4**-1), *Neomys teres* (**4**-1; **6**-3), *Myotis nattereri* (**6**-1), *Myotis blythii* (**3**-1; **5**-1), *Eptesicus serotinus* (**1**-1; **2**-1), *Pipistrellus pipistrellus* (**3**-1), *Lepus europaeus* (**1**-1; **2**-2; **3**-1; **5**-3; **4**-1), *Ochotona* cf. *rufescens* (**5**-1), *Dryomys nitedula* (**2**-3; **5**-1), *Dryomys laniger* (**3**-3), *Apodemus uralensis* (**3**-7), *Apodemus mystacinus* (**1**-3; **2**-4), *Meriones persicus* (**5**-2), *Terricola majori* (**4**-3; **6**-1), *Microtus guentheri* (**4**-1), *Vulpes vulpes* (**2**-1; **5**-1), *Mustela putorius* (**6**-1), *Felis* sp. (**4**-1), *Anas platyrhynchos* (**2**-1; **3**-1; **6**-1), *Anas strepera* (**1**-1), *Anas crecca* (**1**-1; **5**-1), *Anas querquedula* (**5**-1; **6**-1), *Accipiter nisus* (**4**-1), *Buteo* sp. (**5**-1; **6**-1), *Aquila* sp. (**2**-1), *Neophron percnopterus* (**5**-1), Accipitridae sp. (**3**-2), *Falco subbuteo* (**3**-1), *Falco naumanni* (**4**-1; **6**-1), *Falco* sp. (**1**-1; **3**-2), *Tetraogallus caspius* (**2**-1), *Ammoperdix griseogularis* (**1**-1), *Phasianus colchicus* (**2**-1), *Gallus gallus dom.* (**1**-1), *Rallus aquaticus* (**1**-2), *Porzana porzana* (**2**-1; **3**-2; **5**-2; **6**-1), *Porzana parva* (**6**-1), *Crex crex* (**1**-1; **3**-1; **5**-1; **6**-1), *Gallinula chloropus* (**5**-1; **6**-1), *Fulica atra* (**1**-3; **5**-1), *Vanellus vanellus* (**3**-3), *Tringa glareola* (**1**-1), *Tringa* sp. (**6**-1), *Scolopax rusticola* (**3**-1), *Gallinago* sp. (**2**-1; **6**-1), Pteroclidae sp. (**6**-1), *Streptopelia decaocto* (**1**-1), *Streptopelia turtur* (**2**-2; **3**-2; **6**-1), *Streptopelia senegalensis* (**4**-1), *Cuculus canorus* (**3**-1), *Asio otus* (**2**-1; **4**-1), *Otus scops* (**2**-2; **3**-2; **6**-1), *Athene noctua* (**2**-1; **3**-4; **6**-1), *Strix aluco* (**1**-1), *Caprimulgus europaeus* (**3**-2), *Apus apus* (**3**-1; **5**-3), *Apus melba* (**1**-2; **3**-2; **5**-2), *Merops apiaster* (**5**-1; **6**-3), *Coracias garrulus* (**6**-1), *Upupa epops* (**2**-1; **4**-1; **6**-1), *Melanocorypha calandra* (**3**-1; **5**-1), Alaudidae sp. (**2**-1; **3**-1; **5**-1), *Delichon urbicum* (**3**-1; **5**-1; **6**-1), *Riparia riparia* (**2**-1), *Ptyonoprogne rupestris* (**5**-1), *Anthus* sp. (**6**-2), *Lanius minor* (**3**-1; **6**-1), *Lanius collurio* (**3**-1; **6**-1), *Acrocephalus* sp. (**3**-1), *Sylvia communis* (**3**-2), Sylviidae sp. (**3**-1), *Muscicapa striata* (**4**-1), *Saxicola torquata* (**6**-2), *Monticola saxatilis* (**3**-1), *Oenanthe sp.* (**3**-2; **5**-1), *Phoenicurus* sp. (**1**-1), *Luscinia* sp. (**3**-1), *Turdus merula* (**3**-1; **6**-3), *Turdus torquatus* (**3**-2), *Turdus philomelos* (**3**-1), *Turdus viscivorus* (**5**-2; **4**-1), *Turdus* sp. (**4**-1), *Sitta neumayer* (**2**-1; **3**-1; **5**-1), *Emberiza citrinella* (**4**-1; **6**-3), *Emberiza calandra* (**6**-1), *Emberiza* sp. (**3**-1; **5**-4), *Carduelis cannabina* (**1**-1), Fringillidae sp. (**5**-1), *Oriolus*

oriolus (**3**-1), *Garrulus glandarius* (**1**-1; **6**-3), *Pica pica* (**2**-1; **3**-1), *Pyrrhocorax pyrrhocorax* (**5**-4), *Coloeus monedula* (**2**-2), Passeriformes sp. (**1**-1; **2**-2; **3**-14; **5**-2; **4**-3; **6**-4), *Bufotes viridis* (**5**-1), *Pelophylax* cf.*esculentus* (**5**-4), *Testudo* sp. (**6**-1), Lacertidae sp. (**5**-2), Sauria sp. (**2**-1; **4**-1), Cypriniformes sp. (**1**-1), Decapoda sp. (**1**-1; **2**-1; **6**-1), Solifugae sp. (**3**-4), Scorpiones sp. (**1**-1; **3**-3; **5**-2)

Tab. 5. Diet of Eagle-owl in the Middle East: Jordan, Israel, Syria.
Tab. 5. Potrava výra skalného na Blízkom východe: Jordánsko, Izrael, Sýria.

Country / Druhy \ Country No.	Jordan 1		Israel 2		Syria 3		Total	%
Meriones tristrami	1+	395	1-	11	4-	0	406	22.32
Rattus norvegicus	1+	100	1-	1	2-	0	101	5.55
Garrulus glandarius	1+	96	1-	0	2-	0	96	5.28
Sylviidae sp.	1+	58		1	2-	0	59	3.24
Microtus guentheri	1-	4	2+	13			17	0.93
Columba livia		102	1+	18	1-	5	125	6.87
Coturnix coturnix		29	1+	12		6	47	2.58
Mus sp.	1-	7	1+	10			17	0.93
Lepus capensis		11	1+	7		2	20	1.10
Rattus rattus		3	1+	6			9	0.49
Procavia capensis	1-	1	1+	7			8	0.44
Hemiechinus auritus	2-	17	1-	2	2+	89	108	5.94
Meriones libycus	4-	0		1	2+	50	51	2.80
Psammomys obesus	3-	0			2+	26	26	1.43
Jaculus jaculus	3-	0			2+	24	24	1.32
Scratulus euphraticus	2-	0			2+	17	17	0.93
Paraechinus aethiopicus	1-	2			1+	7	9	0.49
Columba oenas		5		1	1+	7	13	0.71
Erinaceus concolor		59		9	2-	0	68	3.74
Nannospalax ehrenbergi		47		1	1-	0	48	2.64
Acomys sp.		20		6	1-	0	26	1.43
Scorpiones sp.		28				1	29	1.59
Gerbillus dasyurus		27				1	28	1.54
Alectoris chukar		20		3		2	25	1.37
Cricetulus migratorius		24					24	1.32
Luscinia sp.		23					23	1.26
Crex crex		17		2		1	20	1.10
Streptopelia senegalensis		15		4			19	1.40
Athene noctua		11		2		3	16	0.88
Falco tinnunculus		11				4	15	0.82
Turdus merula		13		1			14	0.77
Apodemus mystacinus		13					13	0.71
Agamidae sp.		10				3	13	0.71
Eliomys melanurus		12					12	0.66
Bufotes variabilis		12					12	0.66
Passer domesticus		11					11	0.60
Orthoptera sp.		10					10	0.55
Decapoda sp.		10					10	0.55
Ammoperdix heyi		8		1			9	0.49
Petronia petronia		7				2	9	0.49
Pica pica		9					9	0.49
Lacertidae sp.		4		1		4	9	0.49
Solifugae sp.		7				1	8	0.44
"Mammalia, 36 species"		751		86	1+	222	1059	58.22
"Aves, 67 + species"		541		63	1-	51	655	36.01
"Amphibia,Reptilia,Pisces"		32		1		8	41	2.25
Evertebrata		60	1-	0	1-	4	64	3.52
Total		1384		150		285	1819	100
Diversity Index H'		3.19		3.29		2.52	3.53	

Country: **1 – Jordan, 2 – Israel, 3 – Syria.**
Other species (**Country**-number): *Crocidura suaveolens* (**1**-1; **2**-1; **3**-1), *Rousettus aegyptiacus* (**2**-1), *Aselia tridens* (**3**-2), *Rhinolophus mehelyi* (**3**-1), *Plecotus christii* (**1**-2), *Otonycteris hemprichi* (**1**-1), *Jaculus orientalis* (**2**-1), *Apodemus flavicollis* (**2**-1), *Nesokia indica* (**2**-1), *Gerbillus cheesmani* (**3**-2), *Gerbillus nanus* (**2**-4), *Meriones crassus* (**2**-1), *Canis familiaris* (**1**-1), *Vulpes vulpes* (**1**-1; **2**-2), *Martes foina* (**1**-1), *Felis silvestris* (**1**-2), *Anas platyrhynchos* (**1**-1), *Anas crecca* (**2**-1), Anatidae sp. (**2**-1; **3**-1), *Accipiter nisus* (**1**-2), *Pernis apivorus* (**1**-1), *Falco naumanni* (**1**-1), *Falco* sp. (**1**-1), *Gallus gallus dom.* (**1**-4), *Porzana porzana* (**1**-1; **2**-2), *Gallinula chloropus* (**1**-1), Rallidae sp. (**2**-1), *Hoplopterus spinosus* (**1**-2), *Tringa* sp. (**1**-1; **3**-2), *Scolopax rusticola* (**1**-1; **2**-2), *Gallinago media* (**1**-2), Limicolae sp. (**1**-1), Pteroclidae sp. (**3**-2), *Columba palumbus* (**1**-1), *Streptopelia decaocto* (**1**-5; **2**-1; **3**-1), *Streptopelia turtur* (**1**-1), *Cuculus canorus* (**1**-1), *Tyto alba* (**1**-1), *Asio otus* (**1**-1), *Otus scops* (**1**-5; **2**-1), *Apus pallidus* (**2**-2), *Apus melba* (**3**-1), *Merops apiaster* (**1**-5), *Coracias garrulus* (**1**-2), *Upupa epops* (**1**-2; **3**-2), *Dendrocopos syriacus* (**1**-2), *Jynx torquilla* (**1**-1), *Galerida cristata* (**1**-3; **2**-1), *Melanocorypha calandra* (**1**-1), Alaudidae sp. (**3**-4), *Delichon urbicum* (**1**-2), *Riparia riparia* (**1**-2), *Ptyonoprogne rupestris* (**1**-1), *Pycnonotus xanthopygos* (**1**-2), *Lanius collurio* (**2**-1), *Lanius* sp. (**1**-3), *Ficedula sp.* (**1**-3), *Saxicola torquata* (**1**-1), *Oenanthe* sp. (**1**-3; **2**-1), *Phoenicurus ochruros* (**1**-1), *Turdus philomelos* (**1**-7), *Parus major* (**1**-1), *Sitta neumayer* (**3**-1), *Emberiza calandra* (**1**-1), *Emberiza sp.* (**1**-3; **3**-1), *Fringilla coelebs* (**1**-6), *Carduelis chloris* (**1**-2), Fringillidae sp. (**1**-1), *Passer hispaniolensis* (**2**-1), *Sturnus vulgaris* (**1**-1; **3**-1), *Onychognathus tristrami* (**1**-1), *Corvus cornix* (**1**-1; **2**-2), *Corvus ruficollis* (**1**-1; **3**-1), *Corvus rhipidurus* (**1**-1), *Coloeus monedula* (**1**-4), Passeriformes sp. (**1**-8; **3**-4), Aves sp.juv. (**2**-1), *Pelophylax* cf. *bedriagae* (**1**-5), Sauria sp. (**3**-1), Cypriniformes sp. (**1**-1), Hymenoptera sp. (**1**-1), Coleoptera sp. (**1**-3; **3**-2), Gastropoda sp. (**1**-1)

Discussion

This study presents findings from individual countries with a wide range of sample sizes of examined material, ranging from hundreds of samples from Slovakia and Norway to individual finds from Mongolia or Russia. Each original sample presents a spectrum of species and is therefore a significant record of the state of fauna in time and space within the context of a specific predator and can therefore be compared to a phytocenological record which offers information on the state of vegetation. If we were to combine the samples based on some specific criteria, we run the risk of systematically stripping them of their uniqueness, and this is also the case when the results are summarised in terms of the abundance of individual species according to larger taxonomical groups as was used in the study by Penteriani & Delgado (2019), as each prey species has its own habitat requirements and thus its own diagnostic significance. Therefore, in preparing the results in this work, care was taken to incorporate these criteria and to categorise individual eagle-owl prey samples on the basis of the range of species which they contain. In Norway, for example, some of the samples from the county of Hedmark are combined but the original findings from the island of Sandøya are evaluated independently. In the case of the large sample from the island of Halmøya, a summary is provided of the finds from the four nest layers which date back 2,500 years, a period in which the island saw varying levels of human occupation. Currently, the island has no permanent human population and is overgrown with scrubland. The data from Slovakia presented in the study combines findings from three different periods, and the distributions of the diagnostic species in the regions are therefore more widely scattered

Tab. 6. Deit of Eagle-owl in Iran..
Tab. 6. Potrava výra skalného v Iráne.

Region	Aa		Ab		Ba		C		Bb		Da		Db		Total	%
Species \ Region No	1		2		3		5		4		6		7			
Chionomys nivalis	2+	17		20	1-	2						1			40	0.51
Apodemus witherbyi	2+	16	1-	20	1+	48		3	1-	3				4	94	1.20
Microtus obscurus	2+	64	1+	199	1-	33	3-	0	3-	0	2-	0	3-	0	296	3.76
Mesocricetus brandti	2-	8	1+	813	6-	0	4-	0	5-	0	3-	0	5-	0	821	10.44
Scartulus williamsi		10	1+	278	4-	1	3-	0		37	2-	0	3-	0	326	4.15
Myomimus setzeri			1+	49	2-	0			1-	0					49	0.62
Sturnus vulgaris			1+	25		6		1		1				2	35	0.45
Delichon urbicum			1+	10											10	0.13
Riparia riparia			1+	11		1									12	0.15
Coleoptera sp.	1-	0	1+	87		26	2-	0		11	1-	0	1+	22	146	1.86
Pelophylax ridibundus		1	1+	74	1-	12	1+	25	5-	5			1-	1	118	1.50
Meriones tristrami		3		76	1+	71	1-	3	2-	1	1-	0	2-	0	154	1.96
Meriones persicus	1-	25		766	1+	430	1-	42	2-	23		52	1-	43	1381	17.57
Ellobius lutescens	1-	11		259	1+	260	3-	1	2-	7	3-	0	4-	0	538	1.84
Columba oenas			1-	1	1+	12		3		1				1	18	0.23
Garrulus glandarius			1-	0	1+	12		3							15	0.19
Cricetulus migratorius		41	1-	314	1+	336	1-	54	3-	8		35	1+	143	931	11.84
Lepus europaeus		5	1-	25	1+	45		3		8	1+	9		5	100	1.27
Ammoperdix griseogularis		1	3-	0	1+	22		6	1+	14		2		6	51	0.65
Alectoris chukar		7	2-	21	1+	95	1+	24	1-	9	2+	35	2-	2	193	2.45
Columba livia		2	2-	9	1+	29	1+	16	2-	21		2		4	83	1.60
Agamidae sp.	1-	0	2-	9	1+	66	1+	15	1+	27		2	1-	4	123	1.56
Microtus socialis		6		147	1-	40	2+	85		1	2-	0		31	310	3.84
Rattus rattus			2-	0	1-	0	2+	19		6					25	0.32
Myotis blythii		1	2-	3	1-	3	2+	20		5		4			36	0.46
Miniopterus schreibersii		1					1+	6							7	0.09
Rhinolophus euryale							1+	5		1					6	0.08
Rattus norvegicus			1-	0		4	1+	5							9	0.11
Apus melba		1		1		1	1+	5						1	9	0.11
Sitta tephronata		1	1-	3		8	1+	10		4				1	27	0.34
Mus sp.		4	2-	34	1-	37	2+	83	1+	49	1-	2	1-	4	213	2.71
Meriones libycus			4-	0	3-	0	1+	12	3+	61		1		7	81	1.30
Lacertidae sp.			2-	6	2-	1			3+	44					51	0.65
Meriones crassus			3-	0		6		1	2+	27		4			38	0.48
Hemiechinus auritus		2	1-	7	2-	0		5	2+	24				4	42	0.53
Columba palumbus			2-	0	1-	0			2+	19					19	0.24
Crex crex				1		2			1+	5				1	9	0.11
Coturnix coturnix				8		4		2	1+	7				2	23	0.29
Passer domesticus			1-	17		10		8	1+	17		4	1-	0	56	0.71
Bufotes viridis			1-	5		5		5	1+	11					26	0.33
Tatera indica			3-	0	2-	0		1	2+	27	1+	7			35	0.45
Galerida cristata		2	1-	10	1-	4		8	2+	27	1+	9		8	68	0.86
Nesokia indica			2-	0	1-	0			1+	11	1+	9		6	26	0.33
Calomyscus bailwardi			2-	2		13		6	1+	9	1+	9		2	41	0.52
Larus sp.				1							1+	5			6	0.08
Ellobius fuscocapillus			3-	0	2-	0			1-	0	1+	7	3+	42	49	0.62
Ochotona rufescens		4	3-	2	3-	0	1-	0		7		2	3+	63	78	0.99
Microtus afghanus			3-	0	2-	0							3+	37	37	0.47
Meriones meridianus			2-	0	1-	0							3+	27	27	0.34
Scarturus elater				17	2-	0				6		1	2+	23	47	0.60
Paraechinus hypomelas			1-	0		1							1+	10	11	0.14
Myomimus personatus													1+	6	6	0.08
Otonycteris hemprichi			1-	0		1				3			1+	9	13	0.17
Petronia petronia		1		14	2-	0		3		6			1+	14	38	0.48
Solifugae sp.				16	1-	0		1		1			1+	14	32	0.41

Tab. 6. continuation / pokračovanie

Region		Aa		Ab		Ba		C		Bb		Da		Db	Total	%
Species \ Region No		1		2		3		5		4		6		7		
Falco tinnunculus		2	1-	3		5		3		3				3	19	0.24
Streptopelia senegalensis			1-	1		7		4		1		1		2	16	0.20
Athene noctua		1	1-	5		10		2		4		2		4	28	0.36
Otus scops			1-	0		4		5		2		1			12	0.15
Arvicola amphibius		7		46		23		2	1-	1			1-	0	79	1.00
Cypriniformes sp.				38		15	1-	0		11		4	1-	0	68	0.86
Crocidura suaveolens		4		15		4				2				2	27	0.34
Melanocorypha calandra				13		1		1		1				4	20	0.25
Corvus cornix+frugilegus		2		7		5		3		1				2	20	0.25
Oenanthe sp.		1		13		1				1		1		3	20	0.25
Alauda arvensis				10		2		4		2					18	0.23
Erinaceus concolor		1		4		2		3		3		2		2	17	0.22
Perdix perdix				7		1		1		2				2	13	0.17
Merops apiaster				2		3		1		1		1		2	10	0.13
Pyrrhocorax pyrrhocorax		1		1- 0		1		2		2		4			10	0.13
Scorpiones sp.		1		6						2				1	10	0.13
Gryllotalpa sp.				8						1					9	0.11
Ptyonoprogne rupestris				5		1		1		2					9	0.11
Streptopelia turtur						2		2		4					8	0.10
Pteroclidae sp.				3				1		2		1		1	8	0.10
Decapoda sp.				4				2		1				1	8	0.10
“Mammalia, 55 species”		**231**		**3117**		**1370**	**1-**	**369**	**1-**	**340**	**1-**	**152**		**476**	**6055**	**77.02**
“Aves, 95 + species”		**33**	**1-**	**283**		**300**	**1+**	**161**	**1+**	**245**	**1+**	**86**		**95**	**1203**	**15.30**
“Amphibia,Reptilia,Pisces”	**2-**	**1**	**1-**	**134**		**104**	**1+**	**46**	**2+**	**99**	**1-**	**6**	**2-**	**5**	**395**	**45327**
Evertebrata	**1-**	**1**	**1+**	**121**	**1-**	**26**	**1-**	**5**		**16**	**1-**	**0**	**1+**	**40**	**209**	**2.66**
Total		**266**		**3655**		**1800**		**581**		**700**		**244**		**616**	**7862**	**100**
Diversity Index H’		**2.82**		**2.78**		**2.79**		**3.37**		**3.87**		**2.97**		**3.10**	**3.48**	

Region: 1- Aa: Alborz and Talysh Mountains; **2 - Ab:** northern Zagros; **3 - Ba**: more humid western part of the central Zagros; **4 - Bb**: drier eastern parts of central Zagros; **5 - C**: southern part of Zagros in Fars Province; **6 - Da**: south-eastern Iran, south of Dasht-e Kavir; **7 - Db**: - Koppeh Dagh Mountans.

Other species (**Region**-number): *Suncus etruscus* (3-5), *Rousettus aegyptiacus* (5-2), *Rhinolophus ferrumequinum* (2-4; 5-2; 4-1), *Rhinopoma microphyllum* (4-2), *Myotis emarginatus* (7-1), *Myotis capaccinii* (5-1), *Eptesicus bottae* (6-1), *Pipistrellus pipistrellus* (5-3), *Taphozous nudiventris* (2-1; 3-1), *Dryomys nitedula* (5-1; 6-1), *Myomimus* sp. (3-1), *Jaculus jaculus* (4-3), *Gerbillus nanus* (4-4; 6-1), *Meriones vinogradovi* (2-7), *Rhombomys opimus* (7-3), *Ellobius talpinus* (7-1), *Microtus kermanensis* (6-3), *Vulpes vulpes* (2-2; 3-2; 5-1), *Mustela nivalis* (2-4; 7-1), *Meles meles* (1-1; 3-1), Artiodactyla sp. (2-3; 6-1), *Tachybaptus ruficollis* (2-1; 4-1), *Ixobrychus minutus* (2-1), Ardeidae sp. (4-1), *Anas crecca* (2-1; 3-1; 5-1; 4-3; 7-1), *Anas querquedula* (3-1), Anatidae sp. (4-3), *Accipiter gentilis* (2-1), *Accipiter nisus* (2-3), *Buteo* sp. (2-1), *Falco subbuteo* (2-1), *Falco naumanni* (2-1; 5-2), *Falco* sp. (2-2; 3-1; 5-2), *Tetraogallus caspius* (2-2; 4-2), *Gallus gallus dom.* (2-1; 3-1; 4-1), *Rallus aquaticus* (2-2), *Porzana porzana* (2-3; 3-1; 4-3), *Porzana parva* (1-1; 2-1; 4-1), *Porzana pusilla* (2-2; 4-2), *Gallinula chloropus* (1-2; 2-1; 5-1; 4-1; 7-1), *Fulica atra* (1-2; 3-3; 5-1; 4-1), *Vanellus vanellus* (2-1; 3-1; 4-4), *Hoplopterus spinosus* (4-1), *Calidris minuta* (2-1), *Tringa* sp. (2-2; 5-1; 4-5; 6-1; 7-3), *Actitis hypoleucos* (2-1), *Scolopax rusticola* (2-1; 3-1; 4-1), *Gallinago* sp. (7-1), Limicolae sp. (2-2; 5-1; 4-1), *Sterna* sp. (6-1), *Columba eversmanni* (6-3), *Cuculus canorus* (2-2; 3-3), *Bubo bubo* (2-1; 3-2), *Asio otus* (2-2; 3-2), *Caprimulgus europaeus* (5-1; 4-1; 6-1; 7-1), *Apus apus* (2-2; 3-2; 5-1), *Apus affinis* (5-4), *Coracias garrulus* (2-2; 3-1), *Upupa epops* (2-1; 3-1; 5-1; 4-1; 6-1), *Dendrocopos syriacus* (3-1; 6-1), *Jynx torquilla* (3-1), *Alaudidae sp.* (1-1; 2-3; 5-1; 4-4; 6-1; 7-8), *Hirundo rustica* (1-1; 2-1; 7-1), *Ptyonoprogne obsoleta* (4-1), *Anthus* sp. (2-1), *Hypocolius ampelinus* (4-1), *Lanius excubitor* (4-4), *Lanius minor* (5-1; 4-2), *Lanius senator* (3-1), *Lanius collurio* (4-1), *Lanius* sp. (2-7; 3-2; 6-1), Sylviidae sp. (4-2), *Monticola* sp. (2-3; 4-4), *Phoenicurus sp.* (4-1), *Turdus pilaris* (1-1), *Turdus philomelos* (5-1), *Turdus* sp. (6-1), *Parus major* (3-2; 5-1; 4-2), *Parus* sp. (4-1), *Sitta neumayer* (2-4; 3-3), *Emberiza calandra* (2-1; 3-2; 4-4), *Emberiza* sp. (2-3; 3-2; 5-7; 4-5; 7-2), *Carduelis carduelis* (3-1; 5-1; 4-1), *Carduelis cannabina* (2-2), *Rhodospiza obsoleta* (7-1), Fringillidae sp. (4-4), *Passer montanus* (7-3), *Petronia xanthocollis* (3-2; 5-3), *Petronia brachydactyla* (2-2; 6-1), *Petronia* sp. (3-1), *Pica pica* (2-1; 3-2; 5-1; 4-1), *Corvus corax* (2-2), *Corvus ruficollis* (4-1; 6-1), *Coloeus monedula* (2-1; 5-1), Passeriformes sp. (1-2; 2-9; 3-8; 5-9; 4-11; 6-2; 7-6), Aves sp. (1-1; 4-3; 6-2), Aves sp.juv. (3-2; 6-1; 7-2), *Testudo* sp. (3-1), Gekkonidae sp. (2-1; 4-1), Serpentes sp. (3-1; 5-1), Sauria sp. (2-1; 3-1), Salmonidae sp. (3-1), Pisces sp. (3-1), Mantodea sp. (5-1), Orthoptera sp. (5-1; 7-2).

than if the results from each period had been compared individually (Obuch 2021b).

Each species of owl has its own unique hunting strategy, and therefore the comparison of findings for different owls sharing the same territory using the MDFM methodology reveals diagnostic prey species for each individual species; for example, a study conducted in Slovakia by Obuch (2011) compared the range of prey for eight species of owls, while another work by the same author (Obuch 2018) examined the diets of seven species in Jordan. This is also true for comparisons of results obtained using trapping. For example, S. N. Rybin used this technique to identify fourteen species of mammals over the course of twenty years in locations in south Kyrgyzstan, whereas this author identified thirty species in just two expeditions to the same locations based on findings from collected eagle-owl pellets (Obuch & Rybin 1993). Similarly, intensive trapping studies in Turkey found just a single example of the Brant’s hamster *Mesocricetus brandti* but finds from eagle-owl prey remains collected in eastern Turkey and the northern Zagros Mountains in Iran suggest that this species is more abundant, comprising around 30% of the eagle-owl’s diet (Kryštufek et al. 2009). Trapping studies in

Tab. 7. Diet of Eagle-owl in diferent eleavtion of the southern Kyrgyzstan.
Tab. 7. Potrava výra skalného v rôznych nadmorských výškach južného Kirgizska.

Altitude a.s.l. (m)	**900 - 1400**		**900**		**2000**		**1800 - 2500**		**Total**	**%**
Species \ Sample No.	**1**		**2**		**3**		**4**			
Meriones meridianus	1+	1233	1-	5	1-	62	5-	15	1315	27.37
Mus sp.	1+	194		1	3-	1	3-	5	201	4.18
Scarturus elater	1+	34				1	2-	0	35	0.73
Coleoptera sp.	1+	54			1-	0	2-	2	56	1.17
Scorpiones sp.	1+	19					1-	0	19	0.40
Myotis blythii	2-	5	4+	45		2	1-	2	54	1.12
Hemiechinus auritus		7	2+	13			1-	2	22	0.46
Alectoris chukar	1-	31			2+	91	1-	38	160	3.33
Perdix dauurica	2-	3			2+	25	1-	6	34	0.71
Coturnix coturnix	1-	8			2+	39	3-	0	47	0.98
Turdus atrogularis	2-	2			2+	27	2-	1	30	0.62
Columba livia		35		1	1+	15	1-	11	62	1.29
Columba rupestris	1-	0			1+	10			10	0.21
Pteroclidae sp.		11			1+	11	2-	0	22	0.46
Aythya fuligula					1+	5			5	0.10
Galerida cristata		14			1+	7	1-	0	21	0.44
Pyrrhocorax graculus	1-	2			1+	6		6	14	0.29
Microtus juldaschi	6-	4	2-	0	1-	33	2+	680	717	14.92
Ellobius tancrei	1-	162	2-	0	1-	46	1+	468	676	14.60
Alticola argentatus	2-	15		1		15	1+	114	145	3.20
Apodemus pallipes	1-	36			1-	6	1+	89	131	2.73
Ochotona rutila	3-	3				6	1+	66	75	1.56
Acridotheres tristis	1-	0					1+	10	10	0.21
Pica pica	1-	4				2	1+	14	20	0.42
Cricetulus migratorius		219	1-	0	2-	10		135	364	6.58
Lepus tolai		25			1-	1		26	52	1.80
Eptesicus serotinus		13		2			1-	1	16	0.33
Crocidura suaveolens		12				1		7	20	0.42
Dryomys nitedula		14				1		5	20	0.42
Streptopelia orientalis		5				2		13	20	0.42
Cypriniformes sp.		9						7	16	0.33
Rattus pictoris		7				4		3	14	0.29
Coloeus monedula		4				5		2	11	0.23
Corvus corone		2				1		7	10	0.21
Falco tinnunculus		3				4		3	10	0.21
Apus melba		9		1					10	0.21
Microtus ileus		6						3	9	0.19
Petronia petronia		9							9	0.19
Passer domesticus		5				1		2	8	0.17
Pyrrhocorax pyrrhocorax						4		4	8	0.17
Asio otus		1				2		5	8	0.17
Tadarida teniotis		7		1					8	0.17
“Mammalia, 30 species”		**2006**		**69**	**1-**	**194**		**1625**	**3894**	**81.04**
“Aves, 65 + species”	**1-**	**274**	**1-**	**4**	**2+**	**342**	**1-**	**173**	**793**	**16.50**
“Amphibia, Reptilia, Pisces”		**26**		**0**		**8**	**1-**	**7**	**41**	**0.85**
Evertebrata	**1+**	**75**		**0**	**2-**	**0**	**3-**	**2**	**77**	**1.60**
Total		**2381**		**73**		**544**		**1807**	**4805**	**100**
Diversity Index H’		**2.20**		**1.34**		**3.24**		**2.10**	**2.80**	

Samples: **1**: Osh, 1.6.1990; Krystalnaya, 25.6.1988, 29.5.1990; 5 km from Krystalnaya: 29.5.1988; Dangi Canyon, 13.7.1988, 28.5.1990; Tamasha, 25.5.1990; Kyzyl Kiyak, 6.7.1988; Kanigut, 17.5.1990. **2**: Dvachan Ungur cave, 11.7.1988. **3**: Kalek valley, 6.7.1988, 21.5.1990. **4**: Arslanbob, 10.7.1988; Archa Mazar, 27.5.1990; Sheveli, 24.5.1990; Goujan 29.6.1988, 22.5.1990.

Other species (**Sample**-number): *Paraechinus hypomelas* (**1**-1), *Rhinolophus boucharicus* (**2**-1), *Vespertilio murinus* (**1**-1), *Eptesicus bottae* (**1**-1), *Nyctalus noctula* (**1**-3), *Pipistrellus pipistrellus* (**1**-1), *Hypsugo savii* (**1**-1), *Barbastella leucomelas* (**4**-1), *Marmota caudata* (**3**-1; **4**-2), *Vulpes vulpes* (**3**-1; **4**-1), *Mustela erminea* (**1**-2), *Mustela nivalis* (**3**-2), Artiodactyla sp. (**3**-1), *Podiceps nigricollis* (**3**-1), *Anas platyrhynchos* (**3**-2), *Anas strepera* (**3**-4), *Anas crecca* (**1**-2; **3**-2), *Anas querquedula* (**3**-2), *Accipiter gentilis* (**4**-1), *Falco naumanni* (**1**-2; **3**-2; **4**-2), *Tetraogallus himalayensis* (**1**-1; **3**-2; **4**-1), *Porzana pusilla* (**1**-2), *Crex crex* (**3**-3), *Gallinula chloropus* (**1**-1; **3**-1; **4**-2), *Fulica atra* (**1**-1; **3**-1; **4**-1), Rallidae sp. (**1**-1; **3**-3), *Vanellus vanellus* (**3**-1), *Scolopax rusticola* (**1**-1; **3**-1), Charadriiformes sp. (**1**-6; **3**-2), *Streptopelia senegalensis* (**1**-4), *Bubo bubo* (**4**-3), *Otus scops* (**1**-4; **3**-2; **4**-1), *Athene noctua* (**1**-3; **3**-1), *Strix aluco* (**3**-1), *Caprimulgus aegyptius* (**1**-4; **4**-2), *Merops* sp. (**1**-1), *Coracias garrulus* (**1**-1), *Upupa epops* (**1**-3), *Jynx torquilla* (**1**-2), *Alauda arvensis* (**1**-7), Alaudidae sp. (**1**-1; **3**-1; **4**-4), *Hirundo rustica* (**1**-4), *Delichon urbicum* (**3**-1), *Ptyonoprogne rupestris* (**1**-1; **4**-1), *Lanius minor* (**1**-1), *Lanius* sp. (**1**-1), *Acrocephalus stentoreus* (**1**-2), Sylviidae sp. (**1**-5; **3**-5; **4**-1), *Oenanthe pleshanka* (**1**-2), *Luscinia megarhynchos* (**1**-3), *Turdus* sp. (**1**-12; **3**-21; **4**-11), *Sitta tephronata* (**1**-4; **3**-2), *Cinclus pallasii* (**1**-2), *Emberiza* sp. (**1**-7), *Mycerobas carnipes* (**1**-1), Fringillidae sp. (**1**-1; **4**-2), *Sturnus vulgaris* (**1**-1), *Sturnus* sp. (**1**-1; **3**-5; **4**-2), *Corvus corax* (**4**-1), Corvidae sp.juv. (**3**-1; **4**-12), Passeriformes sp. (**1**-27; **2**-2; **3**-14; **4**-3), Aves sp. (**1**-3; **3**-4), Aves sp.juv. (**1**-1; **4**-1), *Pseudepidalea pewzowi* (**3**-4), Lacertidae sp. (**1**-4), Serpentes sp. (**1**-9), Sauria sp. (**1**-4; **3**-4), Limacidae sp. (**1**-2)

Iranian Kurdistan identified a new species unknown to science in the form of four Setzer’s mouse-tailed dormice *Myomimus setzeri*, but this author’s studies of eagle-owl diets revealed that this species is abundant in the northern Zagros Mountains and eastern Turkey at elevations of more than 1800 m a. s. l. (Obuch 2001b, 2014). The Afghan pika *Ochotona* cf. *rufescens* was also identified as a new species for Turkey based on remains found during studies of eagle-owl diets (Čermák et al. 2006).

In several cases, the findings of studies into eagle-owl diets have also revealed the presence of sizable populations of rodent species which spend the majority of their lives underground and which seldom appear on the surface; for example, mole rats from the *Nannopalax* family, two species of which were found in Turkey (*N. xanthodon*, 2.2% in Anatolia), Jordan (*N. ehrenbergi*, 3.4%) and Israel, mole voles from the *Ellobius* family, four species of which were found in Turkey (*E. lutescens*, 1.1% in Bendimahi), Iran (*E. lutescens*, 14.4% in the central Zagros Mountains and *E. fuscocapillus*, 6.8% in the Koppeh Dagh Mts.), Kyrgyzstan (*E. tancrei*, 25.9% in mountain areas) and Mongolia (*E. tancrei*, 4.4%).

Similarly, the European water vole *Arvicola amphibius* is a species which is difficult to study using trapping techniques, but research by Bichsel (2012) revealed that the species makes up 96% of the diet of eagle-owls in northern Norway. In contrast, our findings from the southern parts of Norway suggest that this species forms approximately 30% of the diet, but it was hunted more extensively in the past on land which had been grazed more intensively by sheep. Water voles were found to form a similar share of eagle-owl diets in the Horehronie region of Slovakia, a landscape typified by non-arable water meadows and pastures. The species was also found in the diet of eagle-owls in Iran, in particular the wetlands in the northern and central parts

Tab. 8. Diet of Eagle-owl in Mongolia, Baikal and Sakhalin
Tab. 8. Potrava výra skalného v Mongolsku, na Bajkale a Sachaline

Region	Mongolia		Baikal		Sakhalin		Total	%
Species \ Region No	1		2		3			
Ochotona alpina	2+	184	1-	0	6-	0	184	9.13
Lepus tolai	2+	22			3-	0	22	1.10
Orientallactaga sibirica	2+	22			3-	0	22	1.10
Phodopus campbelli	2+	58			4-	0	58	2.91
Alticola strelzowi	2+	35			3-	0	35	1.76
Alticola barakshin	2+	29			3-	0	29	1.46
Ellobius tancrei	2+	19			2-	0	19	0.95
Alexandromys fortis	1-	0	3+	27	3-	0	27	1.35
Urocitellus undulatus		2	1+	8	1-	0	10	0.50
Rana arvalis			1+	8	1-	0	8	0.40
Craseomys rufocanus	6-	0	3-	1	1+	775	776	38.94
Myodes rutilus	4-	0	1-	3	1+	238	241	12.90
Pteromys volans	3-	0		1	1+	85	86	4.32
Ochotona hyperborea	3-	0	1-	0	1+	121	121	6.60
Tetrastes bonasia	3-	0			1+	92	92	4.62
Sorex daphaenodon	1-	0				29	29	1.46
Myopus schisticolor	1-	0				23	23	1.15
Rana amurensis	1-	0				28	28	1.40
Tamias sibiricus						13	13	0.65
Apodemus peninsulae						8	8	0.40
Mammalia		**375**	**1-**	**43**		**1318**	**1736**	**87.10**
Aves		**52**	**1+**	**21**		**140**	**213**	**10.69**
"Amphibia, Reptilia,Pisces"	**1-**	**3**	**1+**	**8**		**33**	**44**	**2.21**
Total		**430**		**72**		**1491**	**1993**	**100**
Diversity Index H'		**2.19**		**2.33**		**2.80**	**2.55**	

Region: **Mongolia**, Altai Mountains, Talbo Nur Lake, 13.7. & 30.7.1984; **Baikal**: Barguzinsky Krai, Ulyun, 16.6.2013; **Sakhalin**: NE, Vaida Mt, Lastochnaya Cave, 8.9.2016 and 3.10.2017.
Other species (**Region**-number): *Sorex caecutiens* (**3**-4), *Neomys fodiens* (**3**-1), *Pipistrellus abramus* (**3**-1), *Lepus timidus* (**3**-4), *Sciurus vulgaris* (**3**-5), *Marmota sibirica* (**1**-1), *Sicista caudata* (**3**-1), *Micromys minutus* (**2**-2), *Rattus norvegicus* (**3**-1), *Cricetulus migratorius* (**1**-1), *Meriones meridianus* (**1**-1), *Ondatra zibethicus* (**2**-1), *Vulpes vulpes* (**3**-4), *Martes zibellina* (**3**-2), *Mustela erminea* (**1**-1), *Mustela nivalis* (**3**-2), *Moschus moschiferus* (**3**-1), *Podiceps cristatus* (**1**-1), *Tachybaptus ruficollis* (**2**-1), *Anas penelope* (**1**-2), *Anas crecca* (**1**-1; **2**-1), *Anas querquedula* (**1**-2), *Anas acuta* (**3**-1), *Anas clypeata* (**3**-1), *Aythya ferina* (**1**-1), *Melanita* sp. (**1**-1), *Bucephala clangula* (**2**-4), *Histrionicus histrionicus* (**3**-2), *Buteo buteo* (**2**-1), *Falco tinnunculus* (**1**-1), *Lagopus lagopus* (**3**-5), *Falcipennis falcipennis* (**3**-1), *Tetraonidae sp.* (**1**-6), *Perdix dauurica* (**1**-2; **2**-1), *Ammoperdix griseogularis* (**1**-2), *Crex crex* (**1**-1), *Fulica atra* (**2**-1), *Vanellus vanellus* (**2**-1), *Calidris minuta* (**1**-3), *Actitis hypoleucos* (**1**-1), *Limosa lapponica* (**3**-1), *Scolopax rusticola* (**1**-1), *Gallinago media* (**1**-1), *Rissa tridactyla* (**3**-1), *Sterna hirundo* (**1**-2), *Fratercula cirrhata* (**3**-1), *Brachyramphus perdix* (**3**-2), *Synthliboramphus antiquus* (**3**-1), *Columba oenas* (**2**-1), *Streptopelia orientalis* (**1**-2), *Surnia ulula* (**3**-1), *Aegolius funereus* (**3**-2), *Apus apus* (**1**-1), *Dendrocopos leucotos* (**3**-1), *Picoides tridactylus* (**3**-2), Alaudidae sp. (**1**-9; **2**-1), *Delichon urbicum* (**3**-2), *Riparia riparia* (**1**-1; **3**-1), *Motacilla alba* (**1**-2), *Bombycilla garrulus* (**3**-1), *Turdus* sp. (**3**-3), *Parus minor* (**3**-1), *Sitta europaea* (**3**-1), *Sitta tephronata* (**1**-1), *Emberiza sp.* (**3**-2), *Carduelis spinus* (**3**-1), *Carduelis flammea* (**3**-1), *Pinicola enucleator* (**3**-1), *Loxia curvirostra* (**3**-2), Fringillidae sp. (**1**-2), *Passer montanus* (**3**-1), *Garrulus glandarius* (**3**-1), *Perisoreus infaustus* (**3**-3), *Nucifraga caryocatactes* (**3**-4), *Cyanopica cyanus* (**2**-3), *Pyrrhocorax pyrrhocorax* (**1**-3), *Corvus corax* (**2**-1), *Corvus orientalis* (**2**-3), *Corvus dauuricus* (**2**-2), Passeriformes sp. (**1**-3; **3**-1), *Zootoca vivipara* (**3**-1), Salmonidae sp. (**3**-1), Cypriniformes sp. (**1**-3), Pisces sp. (**3**-3)

of the Zagros Mountains (Obuch 2014).

Our study indicates that European eagle-owls show considerable adaptability to changes in the availability of prey species. The results from Slovakia show significant differences in the range of available prey over the course of the last hundred years as a result of changes in agricultural practices (Obuch 2021b). On the Norwegian island of Frøya, we recorded the rapid adaptation of eagle-owls to new prey species following their introduction, firstly the common frog *Rana temporaria* and, in the last five years, the wood mouse *Apodemus sylvaticus*.

The overwhelming majority of the material evaluated in this study was collected from eagle-owl nests during the spring breeding period, a time in which eagle-owls attempt to find sufficient prey from various sources in order to feed their young. Our findings from central Norway show a lower proportion of mammals (58.7%) but a higher share of birds (21.2%) and amphibians (20.0%), with a diversity value of H' = 2.71. In the Czech Republic, the proportions of mammals (76.1%) and birds (22.7%) is relatively high, but amphibians (1.0%) formed a markedly lower proportion of the overall diet, resulting in a diversity index similar to that of Norway: H' = 2.66. The findings from Slovakia show a similar reliance on mammals as in Norway (58.3%) but a lower share of birds, with the rearing of young being supplemented by amphibians (33.2%); this results in a lower diversity index of H' = 2.35. On the steppes of central and eastern Turkey, mammals form the bulk of the diet (90.1%) with birds featuring less frequently (6.8%), giving a diversity index of H' = 2.46. The arid conditions of the southern range of Jordan, Syria and Israel support a lower density of mammals (54.4%), but the presence of a greater numbers of wintering and migrating birds at the end of winter results in a higher share of this prey in the diets of juvenile eagle-owls (35.8%). Invertebrates also form a somewhat important share of the diet (3.5%), and the overall diversity index is relatively high at H' = 3.52.

The vast and rugged territory of Iran is characterised by a marked diversity of mammals (55 species), with this prey forming the dominant share of eagle-owl diet (77.0%). This preponderance also has a pronounced effect on the overall diversity of prey in this region: H' = 3.48. A similar preponderance of mammals is found in southern Kyrgyzstan (80.1%) but the diversity of species is lower (30 species) and therefor the diversity index is also lower: H' = 2.80. The diversity of eagle-owl diets based on the samples from the Altai Mountains in Mongolia is even lower, with mammals forming 87.2% of the overall diet, giving a diversity value of H' = 2.19.

This study also confirms that conventional direct methods of research or observation are unable to provide such detailed information about the vertebrate fauna of specific localities and their changes over time as that offered by studies of the dietary ecology of eagle-owls or of owls in general (Obuch 2021a, 2023).

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Distribution, density and trends of the Eurasian eagle owl (*Bubo bubo*) population breeding in March-Thaya floodplain forests: impact of owlets on sustainability of natural nests

Rozšírenie, hustota a populačný trend výra skalného (*Bubo bubo*) v lužných lesoch Moravy a Dyje: vplyv mláďat na stabilitu prirodzených hniezd

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Abstract: In this study, we investigated the Eurasian eagle owl (*Bubo bubo*) breeding in lowland forests in the transborder area between western Slovakia, eastern Austria, and southern Moravia. The research provides new information on the reuse of nests by eagle owls and presents initial insights into population density and trends of eagle owls in the March-Thaya floodplains. Our 19-year monitoring has shown that the eagle owl has become a widespread breeder over the study area, with an increasing population trend. A total of 151 breeding attempts by eagle owls have been identified, occupying 82 natural nests (originally built by at least nine species of birds) and 12 artificial nests. With an average of 6.2 active nests per 100 km^2 and a maximum of 17 active nests found in 2021 (~10.6 pairs per 100 km^2), our findings represent one of the highest eagle owl breeding densities found, especially in comparison with core populations nesting in the mountains (the Carpathians, north-eastern Alps and the Bohemian Massif). Regarding the dynamics of nest reuse, our results reveal that only a third of nests used by eagle owls were reused by other raptors or storks (*Ciconia* sp.). Almost 50% of the natural nests in which eagle owl bred, subsequently disintegrated after the owlets had fledged. Lastly, black stork (*Ciconia nigra*) nests re-used by eagle owls were twice as likely to have disintegrated after the owlets had fledged than nests built by other bird species. Our results suggest that black stork nests in the March and Thaya floodplain forests are most susceptible to destruction.

Abstrakt: V tejto štúdií sme sa zamerali na výskum hniezdnej populácie výra skalného (*Bubo bubo*) v nížinných lesoch v pohraničnej oblasti medzi západným Slovenskom, východným Rakúskom a južnou Moravou. Táto štúdia poskytuje nové informácie o opätovnom využívaní hniezd výrmi a prvé výsledky hustoty výra, vrátane populačného trendu v nížinných lesoch Moravy a Dyje. Počas 19-ročného monitoringu sme preukázali, že výr skalný sa stal rozšíreným hniezdičom v celej sledovanej oblasti s rastúcim trendom populácie. Celkovo sme zistili 151 hniezdnych pokusov na 82 prirodzených (vybudovaných viac ako 9 druhmi vtákov) a 12 umelých hniezdach. Spolu s priemernou hustotou 6.2 aktívnych hniezd na 100 km^2 a maximálnym počtom 17 aktívnych hniezd nájdených v roku 2021 (~10.6 párov na 100 km^2), predstavujú naše výsledky jednu z najvyšších zistených hustôt, najmä ak je porovnaná s jadrovými populáciami hniezdiacimi v tradičných hniezdiskách v pohoriach Karpát, severo-východných Álp a Českého masívu. Výskum dynamiky opätovného využívania hniezd ukázal, že iba tretina hniezd použitých sovami bola následne použitá inými druhmi dravcov alebo bocianov (*Ciconia* sp.) a takmer 50 % prirodzených hniezd sa po vyletení sov rozpadlo. Naviac, hniezda bociana čierneho (*Ciconia nigra*) boli dvakrát častejšie zničené ako hniezda postavené inými druhmi vtákov. Uvedené výsledky naznačujú, že hniezda bociana čierneho sú v lužných lesoch Moravy a Dyje najviac náchylné na zničenie sovami.

Key words: Central Europe, lowland forest, nest reuse, population increase, recolonisation, Strigidae

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Introduction

The Eurasian eagle owl (*Bubo bubo*) is the largest owl in Europe and Asia (Keller et al. 2020). The species is found in a wide range of habitats and is noted for its ability to adapt to various conditions relating to biotopes, nest sites or diet (Penteriani & Delgado 2019; Keller et al. 2020). Historically, the eagle owl experienced significant declines in its European populations during the 19th and 20th centuries, primarily due to increased human persecution (Penteriani & Delgado 2019; Andreska & Andreska 2020). Yet, thanks to dedicated conservation efforts, including species protection initiatives and local reintroduction programmes (Bergerhausen et al. 1989; Dalbeck 2005), the species has witnessed a remarkable recovery, particularly in the Pannonian region, showcasing the success of targeted wildlife management strategies (Frey 1992; Grüll & Frey 1992; Zuna-Kratky et al. 2000; Horal & Škorpíková 2011).

The eagle owl is one of the largest apex predators in lowland forests along the March and Thaya rivers in eastern Austria (Zuna-Kratky 2003; Nagl et al. 2013), southern Moravia (Horal & Škorpíková 2011) and western Slovakia (Noga 2005; Svetlík & Nuhlíčková 2018). The species does not build its own nests but lays its eggs in a variety of existing nest sites. Unlike the core populations breeding in mountain habitats (Danko & Karaska 2002; Hudec & Formánek 2005), eagle owls in the March and Thaya floodplain forests typically use larger nests built by raptor species or storks (Zuna-Kratky et al. 2000; Sumasgutner & Thoby 2011; Nagl et al. 2013). The same nest site is often used for several years in rotation with other favoured sites (Holt 2003; Hudec & Formánek 2005). Despite the ecological importance of the eagle owl, comprehensive results of studies focusing on its breeding ecology are scarce. Preliminary observations suggest a reliance on natural tree nests built by other birds, such as raptors or storks (Thoby 2006; Nagl et al. 2013; Svetlík & Nuhlíčková 2018; Bierbaumer et al. 2021), with these sites often being reused over multiple breeding seasons. However, detailed insights into the nest site selection, habitat preferences and factors influencing nest reuse are limited (Thoby 2006; Nagl et al. 2013; Svetlík & Nuhlíčková 2018; Bierbaumer et al. 2021; Ječmenica et al. 2022). Furthermore, unlike the eagle owl populations of the north-eastern Alps or the Bohemian Massif, the breeding populations in lowland forests have not been the object of intensive research (Zuna-Kratky 2003), with only a few notable exceptions (Horal & Škorpíková 2011; Nagl et al. 2013). Concerning the specific habitat of the March floodplain forests, no data on the population trends of eagle owls has been published.

The main goal of this study is to provide new findings on the breeding trends of the eagle owl population inhabiting the lowland forests that span the borders between western Slovakia, eastern Austria and southern Moravia. Based on extensive data obtained over 19 years of monitoring (2004–2022), the research presented in this study focuses on the 1) distribution, 2) density and 3) population trends of the eagle owl in this region. Additionally, 4) nest site characteristics, including nest origin and tree species, height and location are also explored in relation to the nest reuse by eagle owls or the complete disintegration of nests used by owlets.

Material and methods

Study area

The study was carried out in the northernmost periphery of the Pannonian region, encompassing the floodplain forests along the March and Thaya rivers. The trans-border area is located in the north-eastern part of Austria (Lower Austria), the western part of Slovakia (Záhorie region), continuing to the southernmost tip of Moravia (Czechia) at the confluence of the March and Thaya rivers (Soutok) and into several fragments of lowland forests along the Thaya River in Znojmo district (Czechia) (Fig. 1).

Eagle owls were monitored in various fragments of natural close willow and poplar trees (*Salici–Populetum*) or riparian mixed forests dominated by ash, oak or elm (*Fraxinus excelsior*, *F. angustifolia*, *Quercus robur*, *Ulmus laevis* or *U. minor*) altered to varying degrees by stands of commercial trees, such as Scotch pine (*Pinus sylvestris*), hybrid poplar (*Populus x canadensis*) or black locust (*Robinia pseudoacacia*). The area offers a varied and structured landscape rich in water bodies, meadows and old tree stands which are attractive for various raptor species (Sumasgutner 2009; Sumasgutner et al. 2010) (Fig. 2). The region experiences biannual flooding events – initially due to elevated water levels in the March River – usually peaking in March (Banásová et al. 1998; Zuna-Kratky 2015), followed by elevated discharges in the Danube River, mainly in June, influenced by backwater effects that extend up to 25 km upstream (Šeffer & Stanová 1999; Nuhlíčková et al. 2021).

The region contains several areas which are subject to the highest levels of nature protection. According to the Bird Directive (2009/147/EC), the area is a part of the NATURA 2000 network. It is listed in the SPA Záhorské Pomoravie (SKCHVU016, Slovak section), SPA March-Thaya-Auen (AT1202000, Austrian section) and SPA Soutok-Tvrdonicko (CZ0621027, South

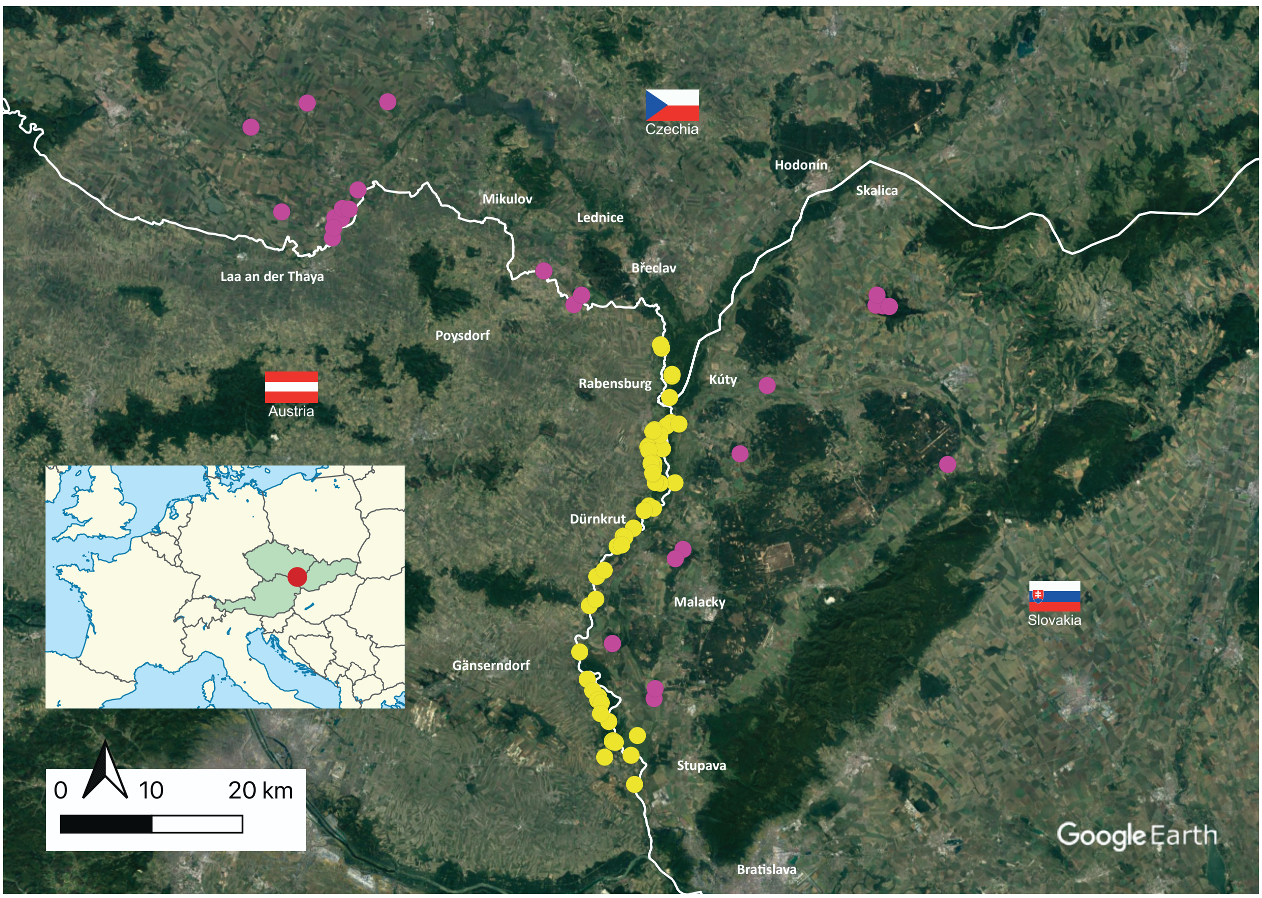

Fig. 1. Distribution of all known nests occupied by eagle owls (n = 94) along the March and Thaya floodplain forests and the surrounding lowland area in 2004–2022. The selection of nests found in the March floodplain habitat which was used for density calculations 2014–2022 is shown in yellow.
Obr. 1. Distribúcia všetkych známych hniezd výra skalného (n = 94) pozdĺž riek Morava a Dyje a ich v okolia od 2004 do 2022. Výber hniezd v území alúvia rieky Morava, ktoré sa využili pre výpočet ich hustoty sú označené žltou farbou.

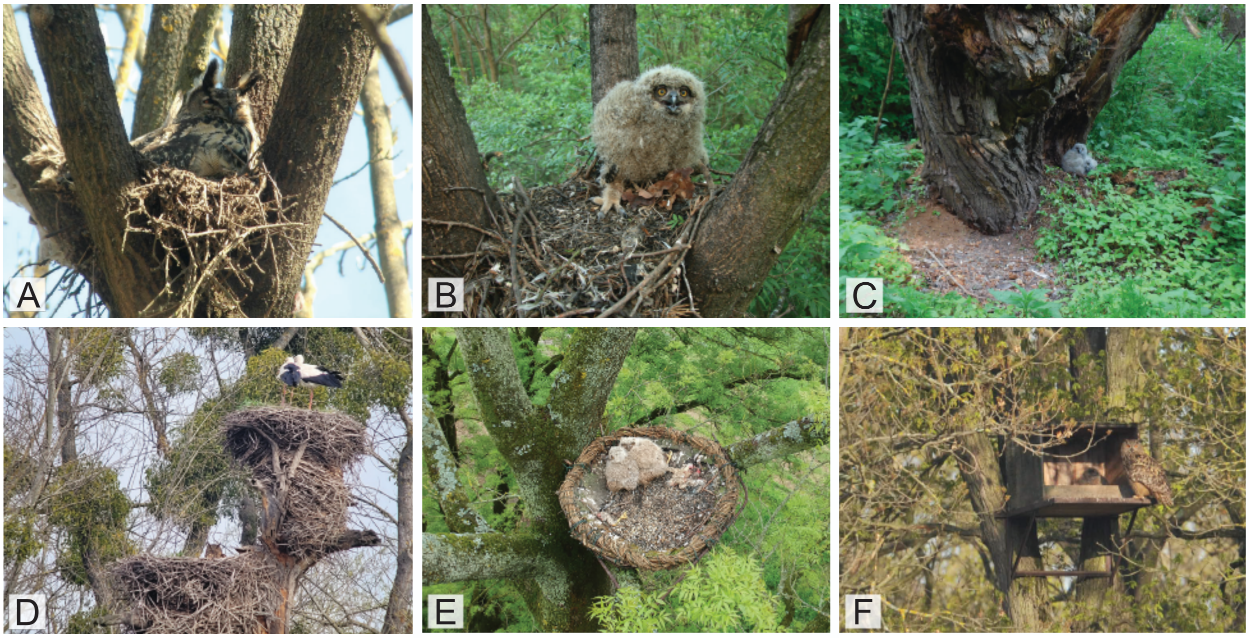

Fig. 2. Examples of eagle owl breeding sites found in the March-Thaya floodplain forests and the surrounding area: a) raptor nest on an ash tree occupied by an adult bird (Malé Leváre, Židova Morávka, Slovakia). Photo: Ján Svetlík, 26.03.2017; b) the first recorded breeding of the species in a raptor nest in the Záhorie region (Slovakia, 2013). The diameter of the nest was no more than 32 cm. Photo: Jozef Chavko, 12.05.2013; c) one of three known observations of owlets in a ground nest (Hrabětice, Trávní dvůr, Czechia). Photo: Vlasta Škorpíková, 02.05.2019; d) adult bird nesting in a white stork colony (Marchegg, Austria). Photo: Christoph Roland, 17.04.2023; e) owlets found on a platform (Moravský Svätý Ján, Lanšper, Slovakia). Photo: Ján Svetlík, 12.05.2019; f) eagle owl female with one of two chicks in the nestbox originally installed for use by saker falcons. Soutok – Kladník. Photo: Vladimír Gahura, 20.04.2012.

Obr. 2. Príklady hniezd obsadených výrom skalným v lesoch Moravy a Dyje a ich okolí: a) dravčie hniezdo na jaseni obsadené dospelým vtákom (Malé Leváre, Židova Morávka, Slovensko). Foto: Ján Svetlík, 26.03.2017; b) prvé hniezdenie výra skalného v dravčom hniezde na Záhorí (Slovensko, 2013). Priemer hniezda nebol väčší ako 32 cm. Foto: Jozef Chavko, 12.05.2013; c) jedno z troch známych záznamov hniezdenia výra na zemi (Hrabětice, Trávní dvůr, Česko). Foto: Vlasta Škorpíková, 02.05.2019; d) dospelý vták hniezdiaci v kolónií bocianov bielych (Marchegg, Rakúsko). Foto: Christoph Roland, 17.04.2023; e) mláďatá výra skalného na hniezdnej podložke (Moravský Svätý Ján, Lanšper, Slovakia). Foto: Ján Svetlík; 12.05.2019; f) Samica výra skalného s jedným z dvoch mláďat v búdke inštalovanej pre sokola rároha. Soutok – Kladník. Foto: Vladimír Gahura; 20.04.2012.

Moravian section, Czechia). On the Slovak side, the territory is covered by the Záhorie Protected Landscape Area (CHKO Záhorie n.d.). The two most important national nature reserves, Dolný Les and Horný Les, were established to preserve floodplain forests. On the Austrian side, the World Wide Fund for Nature (WWF) reserve in Marchegg hosts one of the largest European colonies of white storks (*Ciconia ciconia*) (reviewed in Šeffer & Stanová 1999). On the Moravian side (Czechia), the Protected Landscape Area of Soutok (approx. 12700 ha), with two large reserves – the National Nature Reserve of Lanžhotské pralesy (439 ha) and the National Natural Monument Soutok (3157 ha) are planned to be established to protect the most preserved stands of floodplain forests.

Monitoring of eagle owl nests

A list of all known nests occupied by eagle owls was obtained between 2004 and 2022 (see Supporting Information File – Tables S1 and S2). All nests (either known or new) were checked as part of a regular inventory of forest stands to monitor the status of other priority bird species such as the white stork, black stork (*C. nigra*), red kite (*Milvus milvus*), black kite (*Milvus migrans*), imperial eagle (*Aquila heliaca*) and saker falcon (*Falco cherrug*). The nest survey was carried out using a combination of standard methods that are commonly used in owl research (Hudec & Formánek 2005; SOS/BirdLife Slovensko 2013; Šnírer et al. 2018). These included: a) direct searches for nests of raptors or storks during the winter months (nests are more visible in bare trees); b) auditory surveys during periods of intensive vocal activity by adults (January – February); c) inspections of known nests during the breeding period (February – April); d) inspections of known nests to confirm nesting of adults, the presence of eggs or young (March – May); e) documentation of prey remains (feathers, bones) or pellets indicating the presence of a bird.

Determination of breeding evidence and habitat variables

Standardised categories adopted at the national level of each country were used to determine whether eagle owls were possible, probable or confirmed breeders in the study area (Danko et al. 2002; Keller et al. 2020). In order to provide the most accurate data on nesting owls, only the breeding categories with the highest nesting records (Categories B and C, Probable and Confirmed breeding; atlas codes B3–B9 and C10–C16) were included in this study (see Keller et al. 2020). On this basis, the following observations were recorded most frequently: i) nests occupied by an adult bird (clear presence of a bird in the nest; C13), ii) nests with eggs (C15) and iii) nests in which young were either seen or heard, including recently fledged birds in the close vicinity (C16). The presence of an owl described by Category A1 and A2 was identified in only three cases (1.98%) and in ten cases (6.62%) by categories B4 (territorial behaviour) or B6 (seeking nest sites). Precise numbers of eggs or chicks were not included in the monitoring, as it was not always possible to determine the full size of the clutch or the total number of chicks in the nest. Adult birds often hide the contents of the nest, while some owlets may have fledged from the nest prior to our nest inspections. As a result, the relevant breeding category described above fully replaces all of this information.

The habitat variables were documented as i) nest origin – the origin of a nest in terms of natural nests built by a specific species (e.g., nests built by black storks or red kites) and reused by an eagle owl, or artificial nests installed as platforms or nest boxes which were originally intended to promote the breeding of threatened raptors, such as imperial eagles, red kites or saker falcons, which were subsequently occupied by owls, ii) nesting tree – tree species on which the nest was built (e.g., ash, oak or elm), iii) nest height – an estimate of the height of a nest above the ground (m), iv) nest location – the exact location of a nest on the tree (e.g., at the top of the tree or on a lateral branch), and v) the elevation of the given nest sites (m a.s.l.) as determined using the DEM (Digital Elevation Model). The spatial distribution of eagle owl nests was depicted graphically using the QGIS system (QGIS.org 2020). For an overview of all of the monitored owl nests, including details of breeding evidence and habitat variables, see Supplementary Tables S1 and S2.

Statistical analysis

The trends of nest occupation were estimated using the Generalised Least Squares (GLS) approach (Davidian & Giltinan 1995) to formulate an autoregressive structure of order 1 (AR (1)) which was incorporated into the model correlations. This approach provided a robust framework for identifying and analysing long-term trends in nests taking into consideration the temporal dependencies in the data. In order to compare the density of nests (i.e., the number of detected nests per 100 km^2) together with the mean/minimal nearest neighbour distance (NND/MND) (Penteriani & Delgado 2019), only the area of the March floodplain forests was selected as an example of a complete and distinct habitat bounded by an open landscape (Fig. 1, nests shown in yellow). The trend was calculated from a territory with a total area of 160.1 km^2 of floodplain forests. Any other nests were used to provide information on all known nest sites found in the region and were used for other calculations (see Fig. 1, nests shown in pink). The population trend and density could only be calculated from 2014 to 2022, following the first observation of an occupied eagle owl nest in the Slovak part of the study area (Svetlík & Nuhlíčková 2018).

The formulation of the Markov chain model (Anderson & Goodman 1957) used data on nest states from 2004 to 2022 as input data as follows: *B. bubo* – nest occupied by eagle owl; R – nest ruined – disintegration of a nest after the young had fledged; D – nest destroyed, e.g., by external factors such as strong winds or storms; Ø – empty nest as a negative result of control; other raptor – a nest occupied by another raptor/stork species (for more details, see also Results). This model was instrumental in mapping the probabilities of transitions from one nest state to another. It also integrated each known breeding attempt by owls for each particular nest, including all known records of other nesting species (e.g., storks or raptors) before and after eagle owl breeding (nest states) and the negative results of controls of these nests (empty nest) over the given monitored period between 2004 and 2022 (a total of 561 nest states as results of nest inspections). After obtaining the transition matrix represented by the mean values for nest state changes, 95% binomial confidence intervals were calculated according to these mean values.

Binomial generalised linear models (GLMs; Agresti 2015) were used to determine whether particular nest characteristics (e.g., nest origin, nest location) indicated a positive correlation with a greater likelihood of nest disintegration by young owlets. Once the GLMs had been derived, the calculated values were validated through analysis of deviance (χ^2-test), which yielded results in the form of odds ratios accompanied by 95% confidence intervals (Blaker 2000).

Only natural nests were applied to the Markov chain model. All calculations and analyses were carried out using R-software (R Core Team 2023). Adobe Photoshop, Adobe Illustrator and Inkscape software were subsequently used to create the layouts.

Results

Distribution, density and trends of the eagle owl breeding population in the March-Thaya floodplain and the surrounding area

A total of 151 breeding attempts by eagle owls were identified at 94 unique nest sites. The highest number identified in a single year was the total of 24 occupied nests found in 2021 (Table. 1). Successful breeding of eagle owls was observed in both natural (87.2%) and artificial (12.7%) nest sites. Natural nests had been built by at least nine different bird species, most commonly by common buzzards (*Buteo buteo*) and black storks (Fig. 3). The majority of nests were built on oak (n = 41), ash (n = 21) and poplar (n = 17) trees, at an average nest height of 17 ± 6 m (± SD). These nests were mainly positioned on the main trunk (n = 34) or on the lateral branches of trees (n = 24). The average elevation of all nests in this study was 180 ± 60 m, while in the floodplain area the average height was 156 ± 22 m.

In the period between 2014 and 2022, the mean density of nests was 6.2 ± 2.0 nests per 100 km^2, (range 3.7 – 10.6 nests per 100 km^2) with a mean nearest neighbour distance (NND) of 3.9 ± 1.4 km (in the range 2.8 – 6.5 km) (Table. 2). However, the smallest distance between two clearly occupied neighbouring nests was MND = 525 m at a site in 2018. An even smaller distance (MND = 391 m) was found between two other nests in 2019 in Czechia, but the breeding evidence was of a lower category (B4) (Supplementary Table S2). Overall, the population of eagle owls in the studied area reveals a clear upward trend (Fig. 4).

Relationship of nest reuse by eagle owls in terms of nest fate

The most likely fate of nests used by eagle owls was their disintegration (R – nest ruined) following the fledging of the young owlets, with this fate accounting for almost 50% of all nests (p – probability of transition) = 0.49 (Fig. 5). Furthermore, the nest disintegration often culminated in complete nest destruction due to external factors (D – external factors) (e.g., broken branches or fallen trees) (p = 0.38). Only a third of nests ruined following fledging were rebuilt again by other bird species (other raptors or storks) (p = 0.31). Empty nests (Ø – empty; negative controls detected in specific nests during the period of 2004–2022) were subsequently occupied by owls with a slightly greater frequency (p = 0.29) than by other raptors or storks (p = 0.17) (Fig. 5). Indeed, our observations show that the

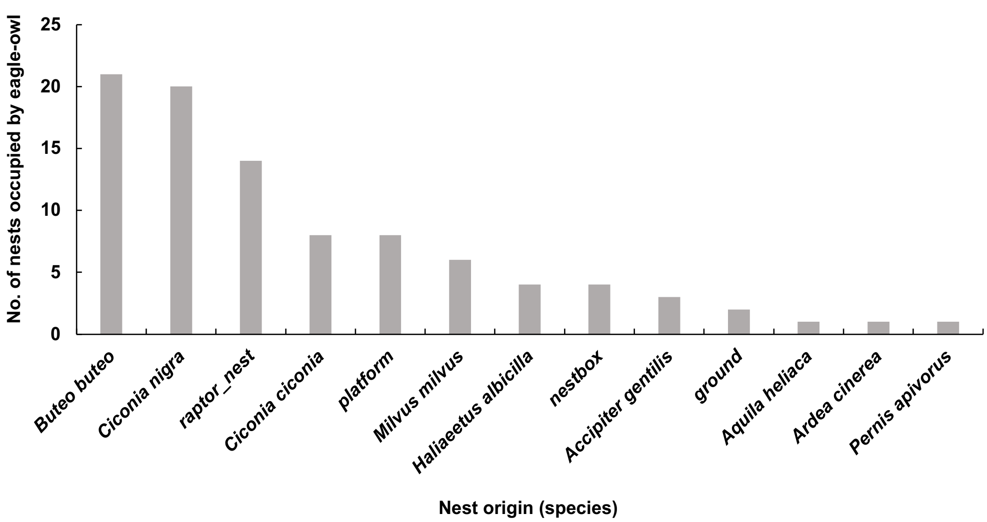

Fig. 3. Number of nests occupied by eagle owls (n = 93) according to nest origin (species).
Obr. 3. Počet hniezd obsadených výrom skalným (n = 93) podľa pôvodu hniezda (species).

Tab. 1. Number of nests occupied by eagle owls from 2004 to 2022. Explanations: No. of breedings/country: total number of breeding attempts per country. No. of unique nests/country: total number of occupied unique nests by owls per country. Natural – total number of natural nests (built by a given species) and occupied by owls per country. Artificial – total number of artificial nests (platforms or nest boxes) occupied by owls per country. No. of breedings per year: total number of breeding attempts per year.

Tab. 1. Počet hniezd obsadených výrmi od roku 2004 do roku 2022. Vysvetlivky: Počet hniezdení/krajina: celkový počet hniezdnych pokusov na krajinu. Počet jedinečných hniezd/krajina: celkový počet obsadených jedinečných hniezd na krajinu. Prirodzené – celkový počet prirodzených hniezd (postavených daným druhom) a obsadených sovami na krajinu. Umelé – celkový počet umelých hniezd (podložiek alebo búdok) obsadených sovami na krajinu. Počet hniezdnych pokusov za rok: celkový počet zahniezdení za daný rok.

Country / Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	No of breedings / country	No unique nests / country	Natural	Artificial
Austria	1	0	0	0	2	0	0	2	3	1	4	4	6	4	4	2	2	7	5	47	40	38	2
Czechia	0	0	0	0	0	2	2	3	1	1	1	3	5	5	4	6	5	5	6	49	23	18	5
Slovakia	0	0	0	0	0	0	0	0	0	1	2	2	3	5	8	10	7	12	5	55	31	26	5
No.of breedings per year	1	0	0	0	2	2	2	5	4	3	7	9	14	14	16	18	14	24	16	151	94	82	12

probability of the disintegration of natural nests after occupation by an eagle owl was more than twice as high when the nest had been built by black storks compared to nests built by other bird species, with an odds ratio (OR) of 2.2 ($CI^{95\%}$ = 1.09–4.31). In contrast, the probability of disintegration by owlets in nests originally constructed by white storks was significantly lower compared to nests built by other raptor or stork species, with an OR of 0.4 ($CI^{95\%}$ = 0.13–0.97) (Fig. 6).

Effect of nest site characteristics on nest fate

Our results show that the location of a nest on a tree (i.e., on a fork, a lateral branch or main trunk) had no significant effect on its subsequent disintegration. However, eagle owls frequently reused artificial nests across multiple years. The maximum number of nesting attempts on one breeding site was observed at a nest box in which a breeding pair nested a total of 14 times from 2009 to 2022 (see Supplementary Table S2; nest code CZ-03). While artificial nests were used 4.3 ± 3.5 times on average, natural nests were occupied only 1.2 ± 0.5 times on average.

Discussion

Distribution, density and trends of the eagle owl breeding population in the March-Thaya floodplain and surrounding area

Our study shows that the eagle owl population has been successfully established in the March-Thaya floodplain forests and has become a widespread breeder in the study area. Based on the long-term data obtained from nest inspections, our results reveal an increasing population trend, supporting the breeding expansion (recolonisation) of the species from mountain populations into lowland areas (Frey 1992; Grüll & Frey 1992; Zuna-Kratky 2003; Noga 2005; Grüll et al. 2010; Svetlík & Nuhlíčková 2018). The findings of our research align with the overall increasing population trend for the species in the rest

Tab. 2. Number of breedings, nest density, mean nearest-neighbour distance and minimal nearest-neighbour distance in nests occupied by eagle owls in the March floodplain forests.

Tab 2. Počet hniezdení, hustota hniezd, stredná vzdialenosť od najbližšieho suseda a minimálna vzdialenosť od najbližšieho suseda hniezd výrov skalných zistených v lužných lesoch Moravy.

Years	2014	2015	2016	2017	2018	2019	2020	2021	2022	Mean	St. dev
No of breedings / year	6	6	9	10	10	11	9	17	11	9.9	3.3
Density (no breedings / 100 km2)	3.7	3.7	5.6	6.2	6.2	6.9	5.6	10.6	6.9	6.2	2.0
Mean Nearest-neighbour distance (NND; km)	6.2	6.5	2.8	3.8	2.9	2.9	4.1	2.8	3.4	3.9	1.4
Min Nearest-neighbour distance (MND; km)	1.5	2.6	1.3	0.9	0.5	0.4	2.6	1.4	1.9	1.4	0.8

Total area (160.1 km^2)

of Europe (Penteriani et al. 2012; Prommer et al. 2018; Keller et al. 2020).

The mean nesting density and nearest neighbour distance between occupied nests suggest the population of medium size, which is in accordance with the majority of data known across the species' geographic range (Papageorgiou et al. 1993; Penteriani et al. 2001, 2012; Suchý 2001; Danko & Karaska 2002; Lentner et al. 2022). However, less information is known about the nesting densities of eagle owls in lowland areas, apart from the substantial body of work done in the Mediterranean region, with the highest densities being recorded on islands (Barišić et al. 2016; Penteriani & Delgado 2019; Ječmenica et al. 2022). As a result, comprehensive data on the northernmost edge of the Pannonian region is scarce (Grüll & Frey 1992; Zuna-Kratky et al. 2000; Grüll et al. 2010). So far, most of the published work has been done mainly in floodplain forests of the Donau–Auen National Park (Lower Austria, ca. 100 km^2, approx. 148 m a.s.l.) and the southern stretch of the March River (ca.

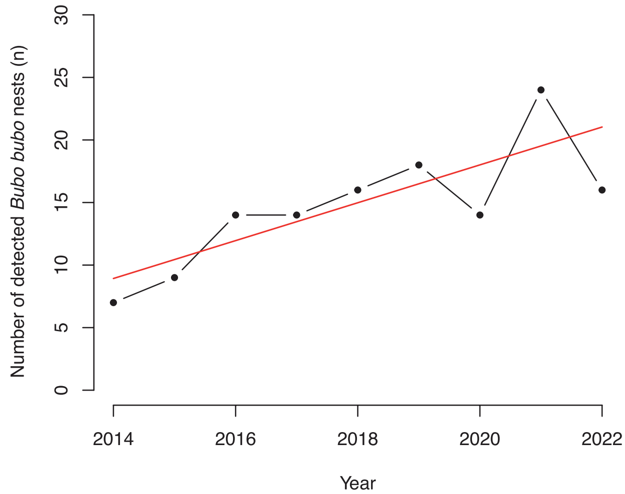

Fig. 4. Increasing population trend of eagle owls active nests estimated using the Generalised Least Squares (GLS) approach (Davidian & Giltinan 1995).

Obr. 4. Stúpajúci populačný trend aktívnych hniezd výra skalného podľa metódy najmenších štvorcov (GLS) (Davidian & Giltinan 1995).

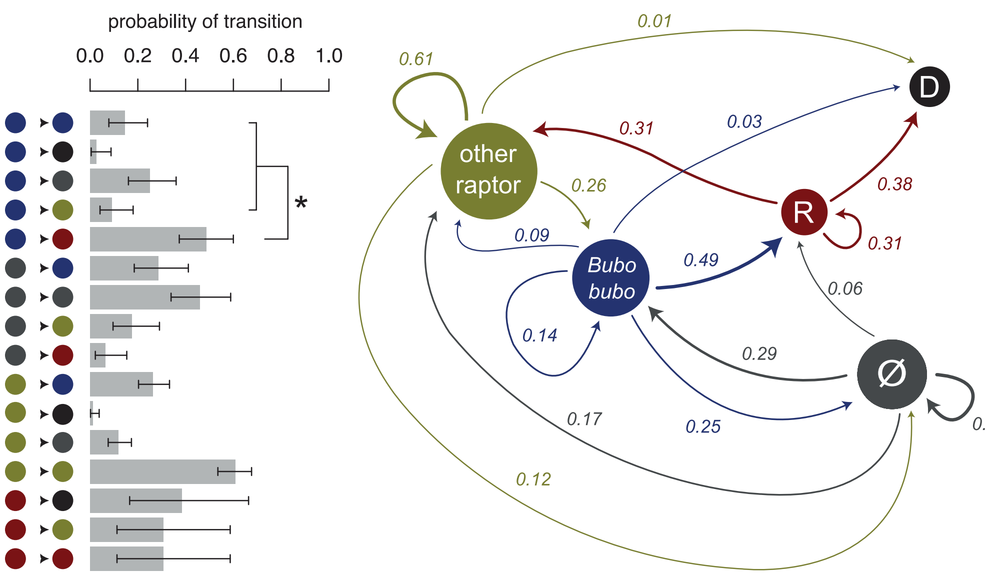

Fig. 5. A Markov chain model of nest reuse dynamics. Explanations: *B. bubo* – nests occupied by eagle owls (blue); R – nest ruined (red); D – nest destroyed by external factors not caused by birds (e.g., winds, storms, fallen trees; in black); Ø – empty nest as a result of negative control (grey); other raptor – nest occupied by another raptor/stork species (e.g., kite, black stork, buzzard) (green); left side: transition probabilities depicted with 95% confidence intervals. The bracket * signifies the most likely fate of the nests (red dot = nest ruined), exceeding all other potential outcomes; right side: a comprehensive visualisation of the nest states and their interconnections within the Markov chain model, depicting the dynamic relationships between eagle owl nests and their subsequent states. **Obr. 5.** Model dynamiky využívania hniezd podľa Markových reťazcov. Vysvetlivky: *B. bubo* – hniezda obsadené výrom skalným (modrá); R – rozpad hniezda (červená); D – hniezda zničené vonkajšími faktormi bez pričinenia druhu (e.g. vietor, búrka, pád stromu; čierna); Ø – prázdne hniezdo ako výsledok negatívnej kontroly (sivá); iný druh dravca – hniezdo obsadené iným druhom dravca alebo bocianom (napr. haja, bocian čierny, myšiak) (zelená); ľavá strana: pravdepodobnosti prechodov znázornené 95% intervalom spoľahlivosti. Hranatá zátvorka * znázorňuje najpravdepodobnejší osud hniezd (červená = rozpad hniezda), ktorý predčil všetky ostatné potenciálne možnosti; pravá strana: celková vizualizácia stavov hniezd a ich prepojení v rámci modelu Markových reťazcov znázorňujúca dynamiku vzťahov medzi hniezdami obsadenými výrom skalným a ich následných stavov.

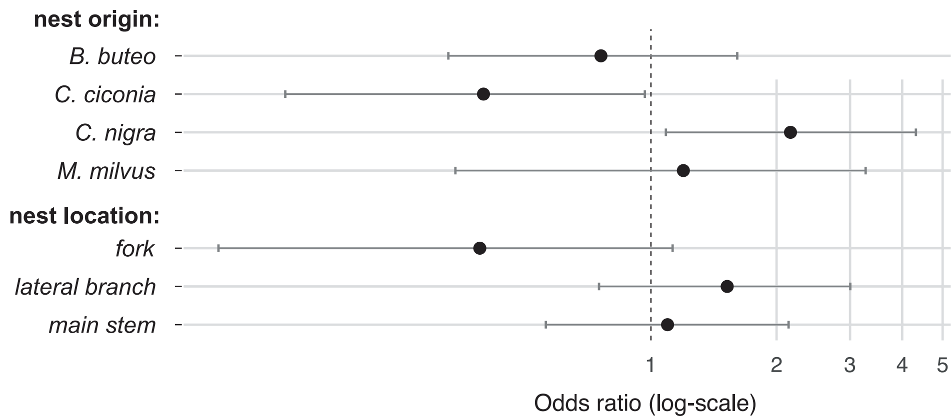

Fig. 6. Susceptibility of natural nests occupied by eagle owls to disintegration according to nest origin and location. Results are presented as odds ratios supplemented with 95% confidence intervals. Explanations: if the 95% interval crosses 1 (dashed line), then the given factor is insignificant with regard to the risk of destroying the nest. Intervals to the right of the 1 (dashed line) indicate a significantly higher probability of nest disintegration. Intervals to the left of the 1 (dashed line) indicate a significantly lower probability of nest disintegration.

Obr. 6. Náchylnosť prirodzených hniezd obsadených výrmi k rozpadu podľa ich pôvodu a polohy. Výsledky prezentované ako pomery pravdepodobností doplnené o 95 % intervaly spoľahlivosti. Vysvetlivky: ak interval 95 % pretína 1 (prerušovaná čiara), potom je daný faktor z hľadiska rizika zničenia hniezda štatisticky nevýznamný. Intervaly napravo od 1 (prerušovaná čiara nie je preťatá) naznačujú významne vyššiu pravdepodobnosť rozpadu hniezda. Intervaly vľavo od 1 (prerušovaná čiara nie je preťatá) naznačujú významne nižšiu pravdepodobnosť rozpadu hniezda.

10 km^2) (Lower Austria) (Thoby 2006; Nagl et al. 2013; Bierbaumer et al. 2021). In comparison, our research identified an average of 6.2 active nests per 100 km^2 in the March floodplains between 2014 and 2022. With a maximum of 17 active nests found in 2021 (~10.6 pairs per 100 km^2), our results therefore represent one of the highest densities found, especially when these results are compared with those of the core populations nesting in mountain habitats (i.e., the Carpathians, the north-eastern Alps or the Bohemian Massif) (Suchý 2001; Grüll et al. 2010; Albegger et al. 2015; Flajs 2017; Kicko 2017; Šnírer et al. 2018; Pühringer & Plass 2020; Lentner et al. 2022). The obtained results may indicate that the owl population has primarily recolonised the lowland area because it offers a higher quality of favourable habitat compared to old refugia (Grüll et al. 2010). Grüll & Frey (1992) have already noted that abandoned and overgrown stone walls and the reduced levels of persecution in open landscapes may force the owls to move into more suitable habitats, such as lowlands. As a result, the species expanded (or recolonised) into floodplain forests particularly rich in new nesting opportunities, as clearly shown in previous studies (Zuna-Kratky 2003; Sumasgutner 2009; Sumasgutner et al. 2010; Sumasgutner & Thoby 2011; Nagl et al. 2013). This assumption is also supported by the fact that March-Thaya floodplains still represent a well-preserved territory, which was formerly under strict military protection due to the Iron Curtain (Šeffer & Stanová 1999). Furthermore, the eagle owl is an area-sensitive species that requires nesting sites in a heterogeneous landscape, with a preference for open lands rich in hunting opportunities and thus prey accessibility (Penteriani et al. 2001). This requirement is highly fulfilled by the territory of the March-Thaya floodplain, as the owl almost exclusively uses natural tree nests in forests surrounded by agricultural land or alluvial meadows.

Relationships of the nest reuse by eagle owls in terms of nest fate and nest site characteristics

The occupancy of owl nests suggests an opportunistic preference for larger nests built by storks or the more abundant species of raptors (Thoby 2006; Sumasgutner & Thoby 2011). Since eagle owls nesting in tree nests breed earlier than many other raptors, such as red kites or common buzzards, only a limited number of birds reuse nests previously occupied by eagle owl pairs (Penteriani et al. 2012). Our results show that only a third of nests used by owls were rebuilt and reused by other raptor species or storks, suggesting that the birds may be forced to seek other nest sites. In addition, almost half of all nests used by eagle owls had disintegrated after the owlets had fledged. This susceptibility of nests to disintegration by eagle owls was clearly different for two sister species –

the black stork and white stork, but in an opposite manner. Our observations revealed that black stork nests were more susceptible to disintegration by eagle owls than by other bird species. In contrast, the probability of nest disintegration was lower in white stork nests compared to nests built by other raptors or storks. One explanation for this pattern could be the fact that the white stork nests in this study represent one of the largest colonies established in Europe near Marchegg, with huge nests that are continuously maintained (Šeffer & Stanová 1999; Zuna-Kratky et al. 2000; Zuna-Kratky 2003). In contrast, black storks are a solitary species, generally building smaller and flatter nests than their sister species, especially in the case of new nests built in the early years (Glutz von Blotzheim & Bauer 1987; del Hoyo et al. 1992). Moreover, another explanation for this result could be the fact that black storks most typically construct nests on the lateral branches of old oak trees (authors' own unpublished data). In this context, even the lateral branch location seems less stable. Given this fact, further research is needed to confirm whether the eagle owl population established in the March-Thaya floodplains is responsible for the relocation of raptors or storks from the areas surrounding their nesting sites. Several previous papers have pointed out such non-lethal effect (Sergio et al. 2003, 2007; Sergio & Hiraldo 2008; Lima 2009; Penteriani et al. 2012; Rebollo et al. 2017). It would be interesting to find out which nests are occupied more often, e.g. in terms of their dimensions or the occupancy of other nests in the vicinity of eagle owl nests. Lastly, the two sister species of black and white storks, which differ in terms of life-history traits (Glutz von Blotzheim & Bauer 1987; del Hoyo et al. 1992), may also differ in their behaviour and in their competition with eagle owls over nest sites. This may also have an impact on their interactions in terms of breeding performance, productivity or nest distribution (Sergio et al. 2007; Sergio & Hiraldo 2008; Rebollo et al. 2017; Lindner 2018).

In conclusion, our results have shown that the eagle owl population has been successfully established in the March-Thaya floodplains, increasing its numbers. During 19 years of monitoring, the eagle owl has become a widespread nester over the entire study area. Thanks to the ongoing protection of the species and the floodplain, the population of the eagle owl has increased, which is in line with the overall increasing trend of this species in Europe. Regarding new knowledge about owl density and nest reuse, our results represent one of the highest densities found in the March-Thaya floodplains. Finally, nearly 50% of the natural nests in which breeding was confirmed had disintegrated following the fledging of the owlets, with re-used black stork nests being found to be the most susceptible to nest destruction.

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Using birds of prey to manage pest bird flocks under lethal and non-lethal conditions – A review

Využitie dravých vtákov pri regulácii kŕdľov vtáčích škodcov v smrtiacich a nesmrtiacich podmienkach - prehľad

Robert WALLIS & **Graeme COLES**

Abstract: Raptors have been successfully used to disperse and often control flocks of pest birds. However, the question that has not been resolved is, "If the raptor kills a small number of the target flock, does this improve the efficiency of control?" This mini-review examines the few research reports that have been published that can shed light on this question.

Abstrakt: Dravce sa úspešne využívajú na plašenie a taktiež ako biologická kontrola kŕdľov vtáčích škodcov. Nebola však vyriešená otázka: "Ak dravec usmrtí malý počet jedincov cieľového kŕdľa, zvýši sa tým účinnosť kontroly?" Predložený krátky prehľad skúma niekoľko publikovaných výskumných správ, ktoré môžu túto otázku objasniť.

Key words: raptors, owls, pest birds, biological control, sustainable agriculture and forestry

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There have been several reviews into techniques available for the management of flocks of birds that cause damage to agriculture and infrastructure, threaten human and animal safety and health or upset cultural and sporting events (Bomford & Sinclair 2002, Anonymous 2004, Braysher 2017, Avery & Feare 2020, Enos et al. 2021, Klug et al. 2023). Techniques that combine different methods and take an ecosystem approach (integrated pest management) usually produce the best results (Garcia et al. 2020, Anonymous 2024).

Using birds of prey to disperse pest birds without killing those target birds is considered a humane method of reducing the deleterious impacts of the pest population – certainly when compared with such methods as poisoning, shooting, trapping and subsequent translocation (Blokpoel 1976). We have been flying trained raptors to successfully disperse flocks of pest birds in Australia (Coles et al. 2019, Wallis et al. 2019). However, the relevant government approval agency and the University's animal ethics committee specify that we must use captive-bred or rehabilitated raptors trained not to kill the target birds. We are keen to investigate whether allowing raptors to prey on the pest birds will increase the success rate of their dispersal to another location by increasing the threat level.

This review thus addresses this question: if the raptor kills (or hunts and therefore has the potential to kill) a few individuals of the target population, does this increase the efficacy of the control method?

There have been few comparisons between lethal and non-lethal use of raptors that allow for meaningful comparison. Baxter & Allan (2006) found peregrine falcons (*Falco peregrinus*) significantly reduced the number of gulls (black-headed gulls *Larus ridibundus*, herring gulls *L. argentatus* and great black-backed gulls *L. marinus*) at rubbish tips in England. In about one third of their trials, the falcons were able to hunt and capture their prey. However, their data analysis did not discriminate between the prey reduction for lethal versus non-lethal trials. The authors surmised the falcons were successful "whether hunting, being flown to simulate hunting or more importantly, perceived as potentially present" in deterring the gulls from using the tips (Baxter & Allan 2006 p. 1165). However, the experimental design did not allow any conclusion to be drawn on the relative reduction in gull numbers for three conditions: falcons that did not hunt, simulated hunting and falcons that preyed on the gulls.

In another study of landfill rubbish tips in the UK, Cook et al. (2008) found that when lethal methods were used (falcons preying on gulls or the gulls being shot), the gulls no longer habituated to the raptors (which occurred when the birds did not hunt their prey). They found lethal techniques (shooting, falconry) which reinforce visual and audio cues with the occasional death of target birds, have the opposite effect on habituation and more gulls were deterred as the trial progressed. This is the most striking evidence that lethal takes and/or shooting do indeed have a positive effect on reducing numbers of gulls compared with non-lethal use of raptors.

There seem to be other anecdotal suggestions that if raptors can kill their prey, the control of pest flocks becomes easier, but hard evidence is lacking. In some cases, it seems authors intuitively think this should be the case without any experimental evidence. Thus Erickson et al. (1990 p. 314) stated "The raptor species used preferably should be a natural predator of the pest bird species as the occasional kills it makes will help reinforce the perception of danger" and cite Grubb (1977) in support. However, Grubb (1977) did not mention lethal versus non-lethal control using raptors, referring to differential habituation only in distinguishing between different aerial stimuli, such as various shapes of model raptors.

Inglis (1980) also believes that shooting pest birds and seeing dead or dying birds are aversive stimuli that could disperse pest birds from a site. His argument is based on the literature on avoidance conditioning. However, certain elements in its practice are required:

- The warning stimulus (in this case, birds seeing others taken by a raptor) must retain its potency for long periods (a single kill episode will likely be ineffective).
- It must occur spatially and temporally with the pest bird visits to the site.
- A scaring device (such as the playing of alarm calls) could be used simultaneously with the aversion stimulus (e.g., hazing by falcons) so the pest birds associate the device stimulus with killing.
- Novel scarers are preferable to ones used previously.

Inglis's (1980) suggestions are based on theory, and his paper does not produce hard evidence that killing some pest birds as aversion stimuli increases the efficacy of pest dispersal. Furthermore, in his discussion, the aversion stimulus of dead conspecifics is by way of shooting and not by raptor take.

Rock doves (*Columba livia*) have been successfully deterred from structures with a combination of falconry and shooting (Ryzhov & Mursejev 2010, Heck & Schwartze 2020, Klug et al. 2023). However, the design of the operations means we cannot distinguish between the effectiveness of falcons killing the doves alone from the effects that shooting have in both reducing dove numbers and potentially acting as a deterrent to the target species.

Bomford & Sinclair (2002) reviewed the research on bird pests in Australia and listed the circumstances when scaring devices could be effective, including their reinforcement with real danger, such as shooting. Raptor takes of target birds could also be considered such a reinforcement stimulus.

Lethal takes by raptors

Several studies have shown that falconry can reduce pest bird numbers when the raptor is encouraged to prey on the target species. In a study on grape damage in New Zealand, Kross et al. (2011) found New Zealand falcons (*Falco novaeseelandiae*) translocated to wine-growing regions preyed on birds that fed on and damaged grapes. The researchers noted that not only did direct predation reduce numbers of the pest flocks but that the high predation risk changed the birds' behaviour to become more "antipredator". Such behaviours included avoiding the sites, increased vigilance relative to the time spent actually foraging for grapes and also relocation by the frugivorous birds to less favourable sites in which to forage that had lower predation risk.

Sometimes, increased predation is insufficient to reduce the target species' population growth (Bendjoudi et al. 2013), but agricultural damage may still be reduced. Klug et al. (2023) have suggested this might be through creating what Laundré et al. (2001) call a "landscape of fear".

In the same review, Klug et al. (2023) report that the use of falcons preying on starlings (*Sturnus vulgaris*) and monk parakeets (*Myiopsitta monachus*) successfully reduced the pest numbers. However, in these studies, no comparison was made between allowing falcons to prey on the birds and using falcons only to scare them away.

Clearly, research needs to be undertaken to resolve whether lethal takes of pest birds reduce the impact they cause, and we encourage researchers to pay more attention to this understudied but essential issue.

Public perceptions

The use of raptors to control pest birds has been cited as an example of compassionate conservation in which no harm comes to animals and cruelty is avoided (Wallach et al. 2018). However, this movement has been criticized by ecologists as misguided and likely to result in poor biodiversity conservation outcomes (Callen et al. 2020). These authors claim that using the principles enunciated by proponents of compassionate conservation, a number of conservation techniques would be unacceptable. These include biocontrol of pests using, for example, killing of pest birds by raptors. Other techniques Callen et al. (2020) consider would be forbidden include captive breeding of endangered species, predator exclusion fencing, contraception, translocation and disease control. However, these techniques are nowadays considered standard practices to enhance biodiversity conservation, especially of threatened species.

Lethal control of pests is one tool that can be used with others as part of an integrated pest management operation. Even the example Wallach et al. (2018) cite of using Maremma guardian dogs to prevent foxes from preying on little penguins (*Eudyptula minor*) in Warrnambool, Australia (King et al. 2015) involves destruction of fox dens and using poison baits as part of the fox control program.

Lethal takes by raptors are likely to distress some in the community. Witnessing a predatory bird seize and consume prey can be off-putting (Bird-control 2022, Pigeon Control Resource Centre undated) and, therefore, likely to prove unpopular with the general public. This needs to be weighed against any increase in efficacy in dispersing the birds and the resultant reduction in damage and economic loss. Perry & Perry (2008) offer practical ways of addressing this conflict. One such technique that would appeal to both animal rights activists and conservation biologists is to apply the precautionary principle regarding the arrival of invasive species through greater border protection and quarantine. The authors also urge wildlife managers to consult with ethicists to understand better how activists will perceive some of their policy decisions.

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Bird crime and the assessment of risk areas in Slovakia

Vtáčia kriminalita a hodnotenie rizikovosti území na Slovensku

Tomáš VESELOVSKÝ, Boris MADERIČ, Jozef CHAVKO & Ján SVETLÍK

Abstract: Bird crime is a serious problem in many countries around the world. This study focuses on the situation in Slovakia, summarising data on bird crime in the country between 2016 and 2022. Over the course of that period, 92 cases were recorded in 27 districts involving 33 animal species. At least 249 protected birds and 78 mammals fell victim to illegal activities, and 61 poisoned baits were discovered. Social value is the monetary value which state institutions use to quantify the damage incurred to wildlife. Slovak law determines whether an illegal act is an offence or a criminal act based on the value of the incurred damage. The total social value of all of the protected animals as a result of illegal activities was estimated at € 696,250. Intentional poisoning, typically using carbofuran, was the most common of illegal act identified in the recorded cases, followed by shooting and trapping. An analysis of the recorded cases of bird crime was also used to assess the risk in each of Slovakia's districts in relation to landscape structure variables. The percentage share of arable land was found to be a reliable predictor of bird crime, regardless of whether the birds had been poisoned or shot. These findings can help to develop better preventive inspections to detect bird crime incidents. We also recommended several management measures to help tackle bird crime more quickly and effectively.

Abstrakt: Vtáčia kriminalita je vážnym problémom v mnohých krajinách na celom svete. V našom výskume sme zosumarizovali údaje o vtáčej kriminalite na Slovensku v rokoch 2016 až 2022. V uvedenom období sme zaznamenali 92 prípadov v 27 okresoch, ktoré sa týkali 33 druhov živočíchov. Najmenej 249 jedincov chránených druhov vtákov a 78 jedincov cicavcov sa stalo obeťami nelegálnych aktivít. Našli sme tiež 61 otrávených návnad. Spoločenská hodnota je peňažná hodnota, ktorú štátne inštitúcie používajú pri vyčíslení vzniknutej škody. Podľa výšky škody zákon určuje, či je nelegálny čin priestupkom alebo trestným činom. Celková spoločenská hodnota všetkých chránených druhov živočíchov bola stanovená na 696 250 €. Najčastejším typom zaznamenaných prípadov boli úmyselné otravy, nasledovali zástrely a odchyt do pascí. Páchatelia pri výrobe otrávených návnad najčastejšie používali prípravky s obsahom karbofuránu. Následne sme hodnotili rizikovosť území analýzou zaznamenaných prípadov vtáčej kriminality vo vzťahu k premenným o krajinnej štruktúre v jednotlivých okresoch na Slovensku. Najmä percentuálny podiel ornej pôdy sa ukázal ako spoľahlivý prediktor vtáčej kriminality bez ohľadu na to, či išlo o otravy alebo zástrely. Na základe týchto zistení bude možné lepšie zacieliť preventívne kontroly na odhaľovanie prípadov vtáčej kriminality. Za účelom rýchlejšieho a efektívnejšieho riešenia problematiky vtáčej kriminality sme odporučili niekoľko manažmentových opatrení.

Key words: wildlife crime, poisoning, carbofuran, land structure, arable land

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Introduction

Bird crime is defined as any illegal act in which the victim is a protected bird species. Illegal activities are specified in the Bern Convention (1982) and primarily consist of the deliberate killing of birds, their capture and the carrying out of illicit trade in birds and their derivatives, and disturbance during their breeding and wintering activities.

The types of illegal activity involved and the individual species which are affected can vary depending on the motives of the perpetrators. Prohibited killing and trapping of migratory birds is widespread around the Mediterranean Sea (Brochet et al. 2016), while vultures have been poisoned in protected reserves on the African continent by poachers attempting to hide poached elephant carcasses from detection by national park rangers (Roxburgh & McDougall 2012, Groom et al. 2013). In Europe, predatory birds have been poisoned to protect the breeding of homing pigeons (Vogler et al. 2015, Inderwildi et al. 2018) or to prevent the predation of small game species (Hernández & Margalida 2009). Protected bird species are not necessarily the primary target of intentional poisoning. Reljić et al. (2012) mention the case of a brown bear poisoned by bait which was likely set out for other carnivores such as jackals or foxes. But the use of toxic baits in this manner also threatens scavenger birds (Parvanov et al. 2018). Birds can also be unintentional victims of poisoning in disputes between herders, hunters and landowners in which poisoned baits are set to poison herding or hunting dogs (Ntemiri et al. 2018).

Perpetrators use various foods and toxic substances to make poisoned baits (Giorgi & Mengozzi 2011, Ibáñez-Pernía et al. 2022). Agricultural pesticides are also often misused for this purpose (DeRoma et al. 2018). Deák et al. (2020) have reported the frequently intentional poisoning of birds with carbofuran, a toxic carbamate insecticide which acts as an acetylcholinesterase inhibitor (Lewis et al. 2016). The lethal dose for most wildlife species is very low; for example, the LD_{50} value for the American kestrel (*Falco sparverius*) is just 0.6 milligrams per kilogram of body weight (Wiemeyer & Sparling 1991). In birds, carbofuran poisoning induces symptoms such as salivation, agitation, the ruffling of neck feathers, frequent defecation, tremors, ataxia, poor body coordination, convulsions, head jerking and tics, opisthotonus, hyperpnoea and shortness of breath (Lehel et al. 2010). Based on experience from field inspections, poisoned raptors have been found with their claws spasmodically clenched, often grasping leaves, twigs, dirt or other substrates, or lying with their wings partially outstretched and their heads rotated. Because the toxin acts rapidly, food residues are often still present in the beaks, and birds have been found directly beside the bait that killed them. Since 2008, Commission Decision (2007) no. 2007/416/EC has prohibited the use, sale or distribution of products containing carbofuran throughout the European Union. Secondary poisoning caused by rodenticides and insecticides is also common (Elliott et al. 1997; Sánchez-Barbudo et al. 2012), but this is considered to be an unintentional crime against birds. Slovakia formally committed itself to bird conservation with its ratification of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1975), the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention 1982) and the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention 1983). The conservation of selected bird species is enshrined in various items of Slovak legislation, specifically Act 543/2002 on Nature and Landscape Protection, as amended (The Collection of Laws of the Slovak Republic 2002) and Act 274/2009 on Hunting and the amendment of certain acts, as amended (The Collection of Laws of the Slovak Republic 2009). The social value of protected animal species, including birds, is laid out in Annex 6 of Ministry of Environment Decree 24/2003 and updated in Annex 5 of Ministry of Environment Decree170/2021, implementing Act 543/2002 on Nature and Landscape Protection, as amended and in Annex to the Ministry of Agriculture and Rural Development Decree 421/2013, determining the social value of game species (The Collection of Laws of the Slovak Republic 2003, 2013, 2021). Social value is the monetary value which state institutions assign to wildlife species in order to quantify the damage incurred, and the law determines whether an illegal act is an offence or a criminal act based on the value of this damage. As an example of this, the law defines the minimum amount of damage incurred at € 2,660 for the illegal activity to qualify as the criminal act of the “Violation of the protection of plants and animals” (The Collection of Laws of the Slovak Republic 2005); if the damage is less than this value, the act is only considered to be an offence. The social value of individual protected species varies considerably. The lowest social value is € 200 for the common chiffchaff (*Phylloscopus collybita*), and the highest is € 50,000 for the saker falcon (*Falco cherrug*) (The Collection of Laws of the Slovak Republic 2021).

Since 2000, the non-governmental organisation Raptor Protection of Slovakia (RPS) has maintained a semi-public Bird Crime Database (Bird crime 2000) which records confirmed crimes and reasonably suspected illegal incidents of physical injuries and human-caused mortalities of individual protected bird species, as well as finds of poisoned baits and other poisoned mammals, the improper application of rodenticides that may have caused direct or secondary bird mortality, illegal trapping, and cases of destroyed or robbed nests. The database has no link to the databases managed by the Slovak Police Force or the Slovak Environmental Inspectorate, none of which are accessible to the public.

The main aims of this paper are: i) to evaluate data on bird crime in Slovakia, ii) to conduct a risk assessment of different areas based on the relationship between landscape structure and the incidence of bird crime, and iii) to recommend management actions to the relevant decision-makers to ensure a more rapid and more effective solution to the issue of bird crime.

Methods

Obtaining data on bird crime

The Bird Crime Database was updated with information on cases documented over a seven year period between 2016 and 2022. Data about bird crimes was obtained from members of RPS and of the Slovak Ornithological Society/ BirdLife Slovakia (SOS/BirdLife Slovakia), trained volunteers and staff at the State Nature Conservancy (SNC) and its injured animal rescue and rehabilitation stations. Information on animal deaths was also obtained through reports from the public and other stakeholders. Alleged crimes against birds were verified directly in the field with the assistance of a police dog unit. In some cases, dead animals were detected and located thanks to different brands and types of GPS/GSM transmitters (Ecotone Saker-H, Anitra BirdieOne).

Only confirmed crimes or cases with a reasonable suspicion of illegal activity which were committed outside urban areas are included in this analysis. Cases are considered to be confirmed as criminal acts by national authorities through the use of laboratory analyses (such as accredited LC-MS/MS or HPLC-MS TOF methods in suspected poisonings), veterinary examinations, autopsies and on the basis of recovered evidences. State-accredited laboratories analysed samples for up to seven chemical substances according to the police and state institutions’ requirements. All samples sent to the laboratories were analysed for carbofuran and also, if suspected, the anticoagulant rodenticides warfarin, bromadiolone, brodifacoum, difenacoum, difethialone and flocoumafen.

The cases considered reasonably suspicious were not confirmed as criminal acts because it was not possible to carry out laboratory analyses on the carcasses due to the longer period of time since death or the lack of access to suitable testing, but the external signs of poisoning (e.g., spasmodically clenched claws, vomit around the beak, dead insects around the carcass) and other evidence clearly indicated that death or injury have been caused by illegal human activity (Fig. 1). The data taken from the Bird Crime Database was divided into six categories, grouped according to the nature of the illegal activity: i) intentional poisoning (as a result of intentional human activity, mainly carbofuran poisoning); ii) unintentional poisoning (as a result of the improper application of rodenticides, the use of unauthorised rodenticides or lead poisoning); iii) illegal possession of a protected bird species; iv) shooting; v) trapping (with, for example, folding traps or snap traps); and vi) suspicious deaths or injuries.

Recorded cases were evaluated based on the type of unlawful conduct involved, the animal species affected, and the time and landscape characteristics of the districts. If multiple bird crime-related incidents were identified in the same area over a period of several days, they were combined into a single case.

Landscape structure

Slovakia covers an area of 49,035 km^2 and is divided into 79 districts (Government Office of the Slovak Republic 2023). Landscape structure data for each district was obtained from the statistical yearbooks issued by the Geodesy, Cartography and Cadastre Authority of the Slovak Republic (2023). In each of the 79 districts, the seven-year mean percentages of the following land variables were then calculated for i) arable land, ii) hop fields, iii) vineyards; iv) gardens, v) orchards, vi) permanent grasslands, vii) forests, viii) bodies of water, ix) built-up areas, and x) other areas.

Fig. 1. External signs of poisoning: a) one or more dead individuals in the locality b) bait found in the vicinity of the cadaver c) body position – the bird is lying with its wings partially outstretched and its head rotated d) vomit and food debris around the beak e) dead insects around the carcass f) spasmodically clenched claws. Photos: Archive of Raptor Protection of Slovakia.

Obr. 1. Vonkajšie znaky otravy a) jeden alebo viac uhynutých jedincov na lokalite b) návnada v blízkosti kadáveru c) poloha tela – vták leží s poloroztiahnutými krídlami a otočenou hlavou d) zvratky a zvyšky potravy okolo zobáka e) uhynutý hmyz okolo kadáveru f) kŕčovito zovreté pazúry. Fotografie: archív Ochrany dravcov na Slovensku.

Statistical analysis

The study aimed to investigate the relationship between occurrences of bird crime incidents and landscape structure across all of Slovakia's districts. The response binary variable represented the presence (coded as 1) or absence (coded as 0) of bird crime cases.

A series of landscape variables that could potentially be associated with bird crime was used to assess the data. In addition, we accounted for the 'district's total area as a covariate. Strong multicollinearity among the explanatory variables was examined using LASSO regression (Tay et al. 2023) which facilitated the selection of the most relevant predictors for bird crime type: i) poisoning (either intentional or unintentional), ii) shooting, and iii) total (incorporating all six bird crime categories).

A separate weighted logistic regression model with selected landscape variables serving as predictors was fitted for each type of bird crime. The response variable was modelled as a binary outcome, whereas the number of incidents (up to 11) was used as a weight. In order to assess the goodness of fit and the proportion of variability explained by the models, the pseudo-R2 value was calculated using null and residual deviances.

Due to the significance of the percentage of arable land in predicting bird crime across all types, a binary variable to classify districts with high and low proportions of arable land was also created. Districts with areas featuring more than 50% arable land were classified as 1, while those with 50% or less were coded as 0. The logistic regression models were subsequently re-fitted using the binary arable land variable as a predictor to quantify the impact of a high proportion of arable land on the incidence of bird crime.

The strength and nature of the relationship between the binary arable land variable and bird crime were examined by calculating the odds ratio (OR) and its 95% confidence interval (CI). All statistical analyses were performed using R statistical software, version 4.1.2 (R Core Team 2023), while the 'glmnet' (Tay et al. 2023) and 'dplyr' packages, version 1.1.0 (Wickham et al. 2023) were used for LASSO regression and data manipulation, respectively.

Results

Overview of bird crime cases

Between 2016 and 2022, 92 cases of bird crime involving 33 animal species were registered in 27 of Slovakia's districts (comprising 34.2% of all districts) (Fig. 2), with at least 249 protected bird and 78 mammal

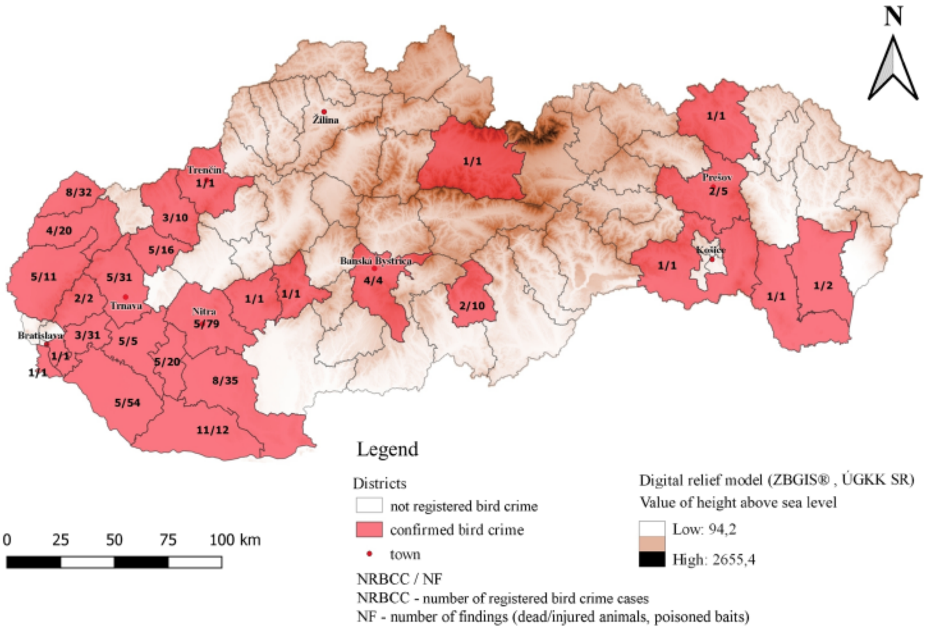

Fig. 2. Districts in Slovakia in which bird crime cases were registered in 2016–2022.
Obr. 2. Okresy na Slovensku so zaznamenanými prípadmi vtáčej criminality v období 2016–2022.

species falling victim to illegal activities over the course of the period. The most common bird crimes (64.1%) involved poisoning (41 confirmed and 18 reasonably suspected cases), with a total of 61 poisoned baits being documented (Tab. 1). The next most frequent forms of illegal activity were shooting (25.0%) from rifles or smoothbore weapons (22 confirmed and one reasonably suspected case), trapping (7.6%) by jaw or folding live traps (7 cases), and one case of the unlawful possession of a protected bird species. From the total number of 92 cases, eight dead raptors were detected and located thanks to the GPS/GSM transmitters which had been fitted to them.

If a case of wildlife crime goes undetected, similar cases may occur repeatedly over the following weeks, months or years; as a result, poisoned animals can be found in various stages of decomposition when the crime is finally documented. We recorded one case in which raptors were found at different stages of decomposition; some without soft tissues, others with soft tissues and some birds in the early stages of decomposition. The poisoned baits which were found included the skins of wild boars (*Sus scrofa*), European hares (*Lepus europaeus*), roe deer (*Capreolus capreolus*), chickens and a poisoned common buzzard (*Buteo buteo*) to which the perpetrator had applied carbofuran (Fig. 3).

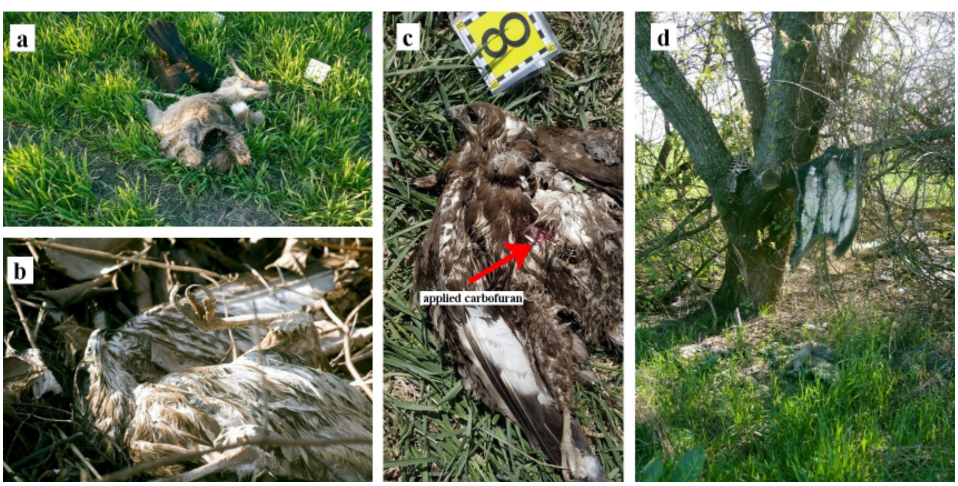

Fig. 3. Different levels of decomposition of carcasses at the crime scene: a) bird in the early stage of decomposition, b) carcass without soft tissues, c) poisoned common buzzard which a perpetrator has used as bait, d) baits in different decomposition levels.
Obr. 3. Rozdielny stav rozkladu kadáverov na mieste činu. a) vták v počiatočnom štádiu rozkladu b) kadáver bez mäkkých tkanív, c) otravený myšiak hôrny, ktorého páchateľ použil ako návnadu d) otrávené návnady v rôznom stupni rozkladu.

A total of 38 of the confirmed cases of poisoning were categorised as intentional poisonings (166 protected birds and 17 mammals), while three were deemed unintentional due to the improper application of rodenticides (18 protected birds and 60 mammals). Carbofuran had been used in 27 confirmed cases of intentional poisoning. Most of the bird crime cases were documented in spring and autumn (Fig. 4), with the largest number (n = 71) registered between January and May and peaking in March (n = 31). Over the seven-year period that ended in 2022, the highest number of cases (n = 21) was documented in 2018, followed by 17 cases in 2021.

Birds of prey were the most frequent victims of bird crime, with 198 birds of 13 different species falling victim to illegal activities. The most affected species were the common buzzard (n = 120), followed by the white-tailed eagle (*Haliaeetus albicilla*; n = 18) and the western marsh harrier (*Circus aeruginosus*; n = 17). Apart from birds of prey, birds of the *Corvidae* family were the next most frequent victims of bird crime, mainly through primary and secondary poisoning. The most commonly identified species in this group were the common raven (*Corvus corax*; n = 15) and the rook (*Corvus frugilegus*; n = 12). In terms of mammals, the most frequently reported deaths due to unintentional and intentional poisoning involved the European hare ((*Lepus europaeus*); n = 55) and the red fox (*Vulpes vulpes*; n = 16).

Based on currently relevant legislation, the total sum of the social values of all of the protected animals found dead was € 693,770 (Table. 1). The social values of the protected animals used by offenders to make poisoned baits came to a total of € 2480 (Table. 1).

Relationship between occurrences of bird crime and landscape structure

The analysis of land variables and their association with bird crime across all the districts in Slovakia yielded a number of significant findings. Most notably, the percentage of arable land was found to be a robust predictor of the incidence of bird crime irrespective of whether the birds were poisoned (incorporating all types of intentional and unintentional poisoning) or shot (GLM: $\chi^2 = 83.777$, df = 1, $p < 0.001$ (Fig. 5, Tab. 2).

Districts with an area consisting of more than 50% arable land had a 31-fold increase in the probability of bird crime compared to districts whose proportion of arable land was lower (OR: 95% CI: 11–135). In the context of poisonings, such incidents had a likelihood which was 15 times greater in districts with a high proportion of arable land (> 50%) (OR: 95% CI: 6–47). A similar finding was identified for shootings, where there was an approximately 12 times greater probability of such incidents in areas with high coverage of arable land (OR: 95% CI: 5–35).

Discussion

The European Union is making considerable efforts to protect endangered bird species through various international projects (e.g., PannonEagle LIFE 2016, LIFE EUROKITE 2019), but these efforts are thwarted by illegal human activities and bird crime in its various forms remains a serious problem in many countries (Brochet et al. 2016, 2019).

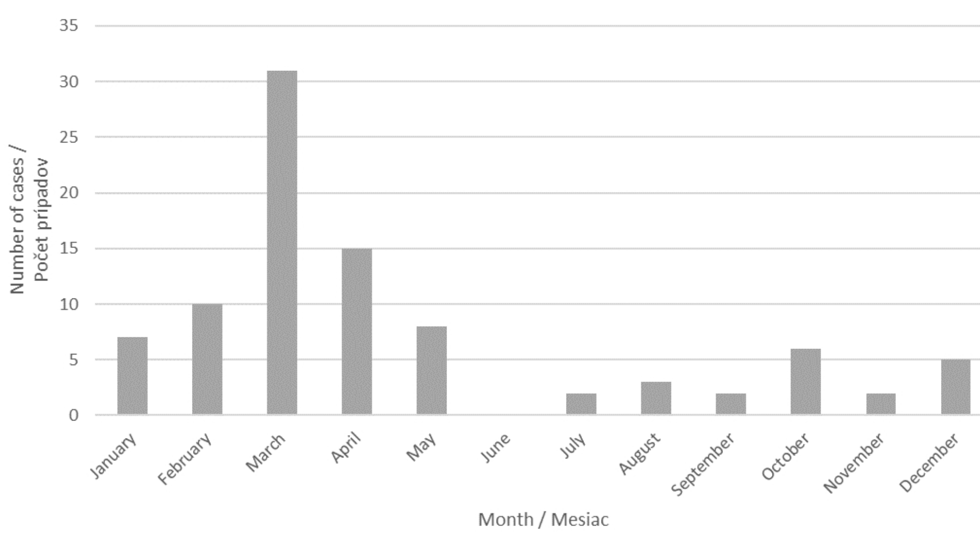

Fig. 4. Total number of bird crime cases recorded each month in 2016–2022.
Obr. 4. Celkový počet prípadov vtáčej kriminality zaznamenaných v jednotlivých mesiacoch v období 2016–2022.

Tab. 1. Number of individuals affected by bird crime. IP – intentional poisoning, UIP – unintentional poisoning, IPS – illegal possession, S – shooting, T – trapping, SDI – suspicious death or injury (SP – suspected poisoning, SS – suspected shooting, UC – unclear), TSSV – the total sum of social values according to current relevant legislation (in €).

Tab 1. Počet jedincov zasiahnutých vtáčou kriminalitou. IP - úmyselná otrava, UIP - neúmyselná otrava, IPS - nelegálna držba, S - streľba, T - pasca, SDI - podozrivý úhyn alebo zranenie (SP - podozrenie na otravu, SS - podozrenie na streľbu, UC - nejasné), TSSV – celkový súčet spoločenských hodnôt podľa zákona (v €).

Categories of bird crime	**IP**	**UIP**	**IPS**	**S**	**T**	**SDI**			**TSSV**
Species						**SP**	**SS**	**UC**	
Birds									
Buteo buteo	99	1		2	4	10		4	111 760
Haliaeetus albicilla	12			1		5			107 730
Circus aeroginosus	11			2		3	1		31 760
Corvus corax	14			1					5 940
Milvus milvus	13					2			272 270
Corvus frugilegus		12							2 760
Aquila heliaca	4			2		2			47 920
Accipiter gentilis	3		1		2			1	23 320
Pica pica	5	2							1 300
Falco peregrinus	1					3			22 120
Accipiter nisus				3					5 520
Corvus cornix	3								540
Aquila chrysaetos				1		1			9 220
Asio otus	1				1				1 840
Bubo bubo				2					4 000
Corvus monedula		2							1 840
Ciconia ciconia				1					2 300
Circaetus gallicus				1					10 000
Clanga pomarina				1					3 220
Columba oenas				1					1 380
Cygnus olor				1					500
Falco cherrug				1					5 530
Falco tinnunculus					1				920
Phalacrocorax carbo				1					500
Phasianus colchicus		1							50
Strix uralensis					1				2 300
Sturnus vulgaris					1				90
Tyto alba				1					1840
Mammals									
Lepus europaeus		55							11 000
Vulpes vulpes	14	1							1 600
Capreolus capreolus		4							2 400
Martes sp.	2								200
Martes foina	1					1			100
Baits	61								
Gallus gallus domesticus - egg	42								
Columba livia f. *domestica*	5								
Fish	4								
Sus scrofa	3								300
Columba palumbus	2								1 380
Gallus gallus domesticus	2								
Capreolus capreolus	1								600
Felis catus	1								
Lepus europaeus	1								200

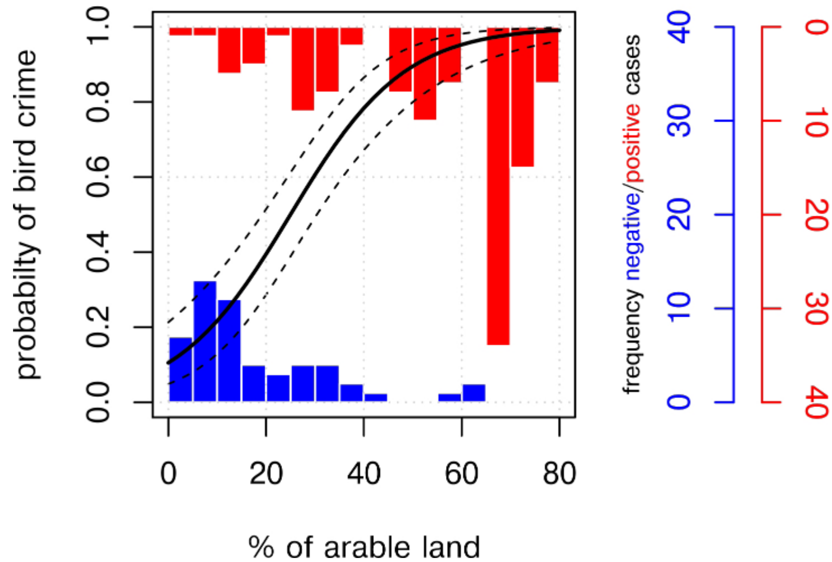

Fig. 5. Graphic representation of the GLM model depicting the probability of total bird crime cases (incorporating all six bird crime categories) from the percentage of arable land in evaluated districts. The sigmoid curve displays the mean estimation of probability, while the dashed lines indicate the 95% confidence interval of the estimate. Histograms reflect the number of cases associated with increasing percentages of arable land (in red) and the number of districts with no recorded bird crime cases (in blue).
Obr. 5. Grafické znázornenie GLM modelu zachytávajúceho pravdepodobnosť výskytu (celkového počtu) prípadov vtáčej kriminality (zahŕňa všetkých šesť kategórií vtáčej krinimality) na základe percentuálneho podielu ornej pôdy v hodnotených okresoch. Sigmoidná krivka zobrazuje priemerný odhad pravdepodobnosti, zatiaľ čo prerušované čiary označujú 95 % interval spoľahlivosti odhadu. Histogramy vyjadrujú celkový počet prípadov spojených so zvyšujúcim sa percentom ornej pôdy (červenou farbou) a počet okresov bez prípadov vtáčej kriminality (modrou farbou).

Our research has shown that higher proportions of arable land are an essential predictor of the likelihood of bird crime. In Slovakia, the districts with the highest proportion of arable land are situated in the lowlands of the southwest and eastern regions of the country, with these areas posing risks to wildlife from several perspectives.

The application of pesticides, especially rodenticides, on arable land is an intrinsic element of intensive agriculture. In Slovakia, only zinc phosphate-based products are authorised for such use (Central Control and Testing Institute in Agriculture 2023); these substances are applied directly into animal burrows using an applicator, but there have been documented cases of farmers using second-generation anticoagulant rodenticides (SGARs), mainly bromadiolone and brodifacoum, which are not approved for use in the wild. Data from the Bird Crime Database shows three recorded cases of the unauthorised use of SGAR products which resulted in widespread and massive mortalities of dozens of wildlife species, mainly brown hares, roe deer and birds. The field survey of these incidents took several days because of the extreme difficulty in locating all of the poisoned animals, and this may have caused the

Tab. 1. Number of individuals affected by bird crime. IP – intentional poisoning, UIP – unintentional poisoning, IPS – illegal possession, S – shooting, T – trapping, SDI – suspicious death or injury (SP – suspected poisoning, SS – suspected shooting, UC – unclear), TSSV – the total sum of social values according to current relevant legislation (in €).
Tab. 1. Počet jedincov zasiahnutých vtáčou kriminalitou. IP - úmyselná otrava, UIP - neúmyselná otrava, IPS - nelegálna držba, S - streľba, T - pasca, SDI - podozrivý úhyn alebo zranenie (SP - podozrenie na otravu, SS - podozrenie na streľbu, UC - nejasné), TSSV – celkový súčet spoločenských hodnôt podľa zákona (v €).

GLM (binomial)	Df	Null Dev.	Deviance	Resid. Dev.	p	pseudo-R2
total* ~ arable land (%)	1	201.79	83.777	118.01	<0.001	~ 46%
poisoning** ~ arable land (%)	1	161.78	57.99	103.79	<0.001	~ 36%
shooting ~ arable land (%)	1	129.033	36.151	92.882	<0.001	~ 28%

mortality to be underestimated, particularly that of the hares. When accumulated in the body of animals, SGARs can cause secondary poisoning of non-target organisms such as birds of prey (Berny et al. 1998, Eason et al. 2002, Sell et al. 2022). Agricultural poisoning is a specific type of unintentional crime which can have a potentially significant impact on local populations of small game species. The inappropriate use either of pesticides, either permitted or otherwise, is also a violation of the rules on conditionality (Regulation of the European Parliament and the Council 2021). National authorities in member states of the European Union (the Agricultural Payments Agency in Slovakia) may reduce payments of agricultural subsidies to the farmer because of transgressions of this nature. In practice, however, we have encountered a reluctance on the part of the public to report cases of unintentional field poisoning to the state authorities. This reluctance stemmed from a variety of concerns; for example, some hunting associations are unwilling to report their suspicions because of concerns was that the manager of the agricultural land would terminate their lease on land belonging to the hunting area.

The territory of Slovakia is divided into three types of hunting areas suitable for: i) red deer (*Cervus elaphus*), ii) roe deer, iii) small game species such as the European hare, common pheasant (*Phasianus colchicus*) or grey partridge (*Perdix perdix*) (The Ministry of Agriculture and Rural Development of the Slovak Republic 2023). Red deer and roe deer hunting areas tend to be located in the foothills or in mountainous areas, while small game species hunting areas typically overlap with lowland areas with a high proportion of arable land. In hunting areas, priority is given to the game species for which the area is intended. The diets of birds of prey, such as the common buzzard, may include small game species to varying proportions (Panek 2023), and this predation can be perceived negatively by potential offenders and lead to efforts to prevent it by illegal means. Consequently, the protection of small game species can be considered as a possible motive for deliberate forms of bird crime, particularly intentional poisoning and shooting. In Andalusia, Spain, a higher incidence of poisoning has been correlated with areas of high predator abundance and high yields of wild rabbit hunting (Márquez et al. 2013).

Most cases of bird crimes were recorded during the spring months, with these crimes being more serious because several species are already nesting in this period. When one or both parents are killed, eggs are abandoned in the nest or chicks can die. One example of this was the discovery in March 2018 of a common raven and six white-tailed eagles, two of them chicks, which had been deliberately poisoned at a single location (Veselovský et al. 2019); for context, there were only 17 known breeding pairs of white-tailed eagles in Slovakia in this period (Chavko 2019).

Powerful poisons were used to perpetrate the documented bird crimes, with carbofuran being the most frequently used poison (n = 27). The misuse of carbamate products, including carbofuran, in wildlife crimes have been reported in many countries (Guitart et al. 2010, Deák et al. 2020, Poledníková et al. 2010). The recorded cases probably reflect only a fraction of actual mortality, as bird crime is difficult to detect. Dogs which have been specially trained to detect poisoned baits and the animals killed by them have proved their worth in practice (Fajardo et al. 2012, Kret et al. 2015, Deák et al. 2020), and the PannonEagle LIFE project, in which RPS also participated, has played a major role in promoting the use of dogs in detecting bird crimes from Hungary to the Czech Republic, Slovakia and Austria (BirdLife Hungary 2023). In Slovakia, a police dog detection unit operated by the Waterways Department of the Slovak Police Force regularly patrols high-risk areas in which cases of bird crime have been documented. By actively searching for poisoned baits and dead birds, the unit seeks evidence of bird crimes and plays an important preventive role. Sniffer dogs have managed to find dead birds which have been partially buried or hidden under branches to cover up their illicit killing. In the future, specially trained dogs may be used more extensively in forest areas where there is evidence of bird crime or poisoning of other protected animals, such as mammal predators.

In addition to the negative impact on protected animal species, poisoning also threatens domestic animals. Pivariu et al. (2020) mention cases of dogs being poisoned from eating bait laced with carbofuran. Carbofuran can be ingested, inhaled or otherwise absorbed into the body through contact with the skin and mucous membranes (Lewis et al. 2016). Contact with and ingestion of this carbamate pesticide also poses a risk to humans (Zeljezic et al. 2008).

Given these facts, the use of poisoned carbofuran bait is a grave crime that threatens not only wildlife but also human society. The mere possession of carbofuran is now interpreted in Slovakia as a criminally negligent act, as was confirmed in a 2021 ruling by a regional court (Judgment of the Regional Court in Nitra 2021).

Based on the data mentioned above, we consider bird crime in Slovakia to be a serious human activity that negatively affects animal populations, especially those of protected and threatened raptor species, and also, in the case of poisoned animals, poses a genuine threat to humans due to the risk of possible intoxication with poisonous substances. The social significance of the issue has also led to the enhancement of the Slovak Police Force's organisational and professional capacities, such the establishment in February 2022 of separate regional environmental crime departments, the introduction of professional training, and the procurement of specialised technical equipment.

In addition to government institutions, the public should also become more involved in looking out for suspicious cases and reporting their findings. By identifying the main predictors of bird crime on the basis of landscape structure, it will be possible to determine the districts which are most at risk of illegal activities. Residents of these areas can be targeted with media campaigns and educational activities highlighting the issue of bird crime, thereby allowing the specialised dog police unit to be deployed more effectively on pre-selected high-risk localities.

Management recommendations

In order to tackle the problem of bird crime more rapidly and effectively, we also recommend several measures that should be implemented by the state authorities. Based on our experience, we suggest that the Ministry of the Environment should work to increase the social values of those protected species of birds of prey and owls whose social value falls below the threshold of constituting a criminal offence. The Ministry of Agriculture and Regional Development, should also employ the Central Control and Testing Institute in Agriculture to monitor the correct use of rodenticides more actively and to inform the Agricultural Payments Agency about any possible violations of the rules of conditionality. In the future, we recommend the establishment of a police dog unit under the auspices of the State Nature Conservancy or a non-governmental organisation focusing on nature conservation which would provide greater flexibility in field deployment and possess a greater knowledge of the local terrain. During the assessment period, several carcasses were located which showed signs of poisoning, but the subsequent laboratory analysis showed no evidence of the selected chemicals. New methods of sample analysis are therefore also needed to investigate bird crime, particularly cases of poisoning, by analysing a wider range of chemicals. Furthermore, investigators should also take into consideration the types of poisons used by offenders in other countries.

The cooperation of stakeholders, especially the Slovak Hunters' Chamber and the Slovak Hunting Union, can also help to reduce bird crime by putting pressure on local hunting associations to record suspicious finds and report them to the authorities. They must also stress that bird crime will not be tolerated and that such behaviour will be condemned.

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Two additional raptors to the Iraqi avifauna: The first observation of lappet-faced vulture (*Torgos tracheliotos negevensis*) and Amur falcon (*Falco amurensis*)

Dva ďalšie dravce do irackej avifauny: Prvé pozorovanie supa arabského (*Torgos tracheliotos negevensis*) a sokola amurského (*Falco amurensis*)

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Abstract: The Iraqi Organization for Conservation of Nature (IOCN) continuously conducts field surveys targeting key biodiversity areas within Iraq to discover the environmental conditions with more focus on the threatened species and their habitats. Two new bird species for Iraq were recorded during two of the ongoing field surveys conducted by IOCN, namely in the Khour Az-Zubair tidal mudflats in September 2022 and the Al-Najaf Desert in February 2023. Among the considerable list of the birds (and other fauna species) that have been observed, two bird species have been considered quite important: Amur falcon (*Falco amurensis*) and lappet-faced (or Arabian) vulture, *Torgos tracheliotos negevensis*]. Both of these observations have been carefully described and documented. Referring to the literature on the avifauna of Iraq, none of these bird species have already been considered Iraqi species and, subsequently, have been added to the list of avifauna of Iraq.

Abstrakt: Iracká organizácia na ochranu prírody (IOCN) kontinuálne realizuje terénne prieskumy zamerané na kľúčové oblasti biodiverzity v Iraku s cieľom poznania environmentálnych podmienok s dôrazom na ohrozené druhy a ich biotopy. Počas dvoch z týchto terénnych snímok v prílivových bahenných oblastiach Khour Az-Zubair v septembri 2022 a v púšti Al-Nadžaf vo februári 2023 boli zaznamenané dva nové druhy vtákov pre Irak. So značného zoznamu pozorovaných druhov vtákov (a iných druhov fauny) sa za pomerne významné považujú dva druhy vtákov: sokol amurský (*Falco amurensis*) a sup arabský (*Torgos tracheliotos negevensis*). Obe tieto pozorovania boli dôkladne opísané a zdokumentované. S odvolaním sa na literatúru o avifauny Iraku sa žiadny z týchto druhov vtákov nepovažoval za iracký druh a následne bol zaradený do zoznamu avifauny Iraku.

Key words: birds of prey, species range, field observation, non-breeding birds, Al-Najaf, Basra, Desert of Southern Iraq, Khour Az-Zubair

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Introduction

The lappet-faced vulture (*Torgos tracheliotos*; Order: Accipitriformes, family: Accipitridae) is one of the largest avian scavengers worldwide. It has been evaluated as an Endangered (EN) species in the IUCN RedList due to the continuous decline in its population (BirdLife 2024). This non-migrant species breeds along the African Sahel and other parts of Africa, where its breeding population is shrinking for various reasons (Shimelis et al. 2005, Ogada et al. 2016).

The Arabian vulture (*Torgos tracheliotos negevensis*) is the subspecies (considered a full species by some authorities) that inhibits dry savannas, arid plains, deserts and open mountain slopes (Shimelis et al. 2005) and breeds in scattered arid lands and deserts in the Arabian Peninsula with fragmented breeding areas (Newton & Shobrak 1993, Shobrak 2011). Arabian vulture is found in the Negev Desert of Palestine (where this subspecies was described for the first time), Israel, UAE, Oman, Yemen, Central, northern, and northwestern KSA, Syria, and Jordan (Hardy 1947, BirdLife 2024, Porter & Aspinall 2010), and it was recorded recently in Kuwait (Al-Suraeea et al. 2013).

With an estimated population range of around 600 pairs in the Arabian Peninsula (Botha et al. 2017), it seems the species has previously bred in Jordan (Evans & Al-Mashaqbah 1996), but there are no more observations. It was formerly common in Somaliland (Somalia) (BirdLife, 2024), while it is considered extinct in Israel, where only three birds remained until the mid-90s (Shimelis et al. 2005). Within the Middle East or elsewhere, these large scavengers appear to suffer from significant threats that affect their population and habitat within their distribution range (Newton & Shobrak 1993, Ogada et al. 2016).

As regards the second observed bird species, the Amur falcon (*Falco amurensis*) is one of the smallest falcons (Order: Accipitriformes, family: Accipitridae); however, it is one of the most long-distanced migrants worldwide (Rasmussen & Anderton 2005). It breeds in central Siberia, NE China, east to Amurland, south to northern and eastern China and winters in eastern and southern Africa (Naoroji 2006, Rasmussen & Anderton 2005). During migration, Amur falcons are crossing eastern and southern Asia, including China, Bangladesh, Bhutan, Nepal, Laos, Myanmar, Thailand, Pakistan and India, heading southwest to Africa (Meyberug et al. 2017).

This heroic migrant bird crosses the Indian Ocean twice a year during its spring and autumn migration, i.e., including a continuous flight from Somalia to India, covering 2,500 – 3,100 km of the open sea when it takes around two days and 5 to 17 hrs oversea, passing over the Indian Ocean, the Arab Sea, and the eastern waters of East African Continent (Meyburg et al. 2017, Ali & Ripley 1978). Amur falcon is a rare passage migrant in the Middle East region where it can be found in Oman, UAE, SW Arabia, and Socotra Island (Porter & Aspinall 2010), and accidental to Kuwait, Yemen, Iran, and Qatar (Pope & Zogaris 2012, Khaleghizadeh et al. 2011, Al-Suraeea et al. 2013, Porter & Aspinall 2010). There are few confirmed westerly records from Cyprus, Malta (Maltese Islands) (Fenech & Sammut 2015, Nature of Cyprus 2016) and as far west as the Canary Islands in the North Atlantic Ocean (Rodriguez et al. 2021). The distribution of Amur falcon and lappet-faced vulture within the Middle East, eastern Mediterranean, and northeastern Africa (including the Horn of Africa) are shown in Fig. 1.

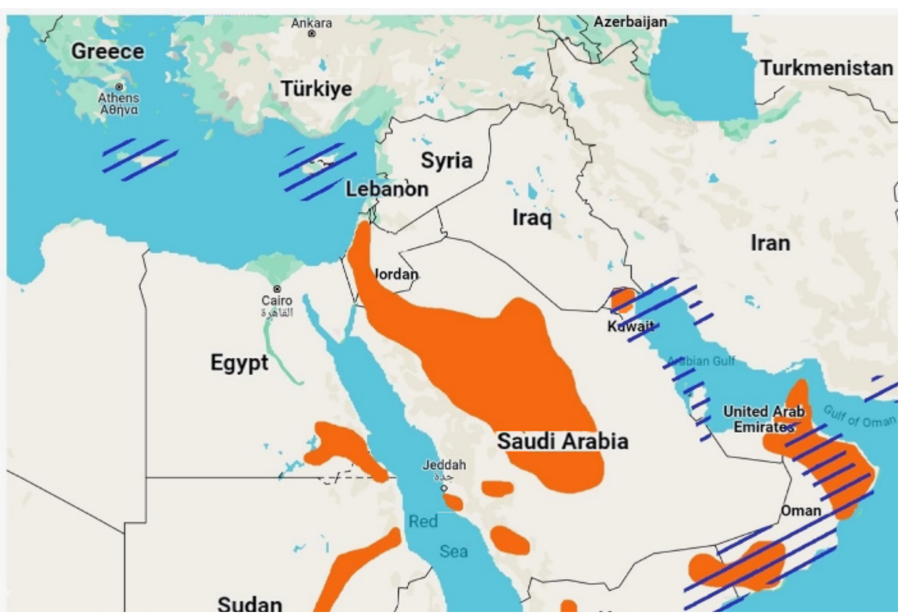

Fig. 1. The distribution of lappet-faced vulture (Orange) and Amur falcon (Blue shade) within the Middle East area. The distribution map was developed based on accumulative data from different dates in the literature.

Obr. 1. Rozšírenie supa arabského (oranžová farba) a sokola amurského (modrá šrafáž) v oblasti Blízkeho východu. Mapa rozšírenia bola vypracovaná na základe kumulatívnych údajov z rôznych dátumov v literatúre.

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Material and methods

Khour Az-Zubair area is located 35 km to the southeast of the centre of Basra city, Southern Iraq. The area consists of mudflats affected by the tide from the upper part of the Arabian Gulf. The end of the Khour trunk meets with Khour Mousa and Khour Abdullah close to the Iraqi-Kuwaiti marine borders (Yacoub 2011, Ali et al. 2022). The survey area consists of the main trunk of the Khour and its primary and secondary branches within soft mudflats (the study locations are depicted in Fig. 2). The area has a low, halophytic plant cover adapted to marine and brackish waters (Hassan et al. 2022).

Jal Al-Dhifeeri (or Batn Al-Dhifeeri) is a desert habitat area with a sandy/rocky bottom surrounded by higher cliffs extending southeastward to the Saudi borders, part of the Southern Desert of Iraq (Buringh 1960). The survey area is around 225 km southwest of Al-Najaf city centre (Fig. 2), quite close to the Iraq-Saudi borders where the IOCN team camped for several days. As part of the desert depressions and valleys, the area receives relatively large amounts of seasonal water during the rainy seasons, so it consists of denser plant cover (Guest & Al-Rawi 1966, Salim 2023).

Different navigation and monitoring/observation tools have been used during the surveys, for instance, the camera Nikon (Coolpix 900 & 1000), 12X45mm and 12X50mm binoculars, and location-detecting and tracking GPS devices.

The elements of the biodiversity (flora, fauna, and avifauna) have been targeted, observed and documented carefully. The species were listed in lists and discussed and consolidated in one list during the evening camp. More focus has been given to the threatened and conservation-concern species and habitats during the surveys.

Results

The targeted survey area where the first Amur falcon was found was in the Khour Az-Zubair wetlands in Basra on 29 September 2022, while the survey where the first lappet-faced vulture was found was in the Al-Najaf desert on 28 February 2023.

Observation of the first Amur falcon for Iraq

While surveying one of the key branches at the eastern parts of the Khour around the coordinates (30.164799°, 47.914538°), the team noticed a small falcon that was first thought to be a kestrel, but due to the distinctive different features, more attention was given to documenting this species (habitat of the area depicts Fig. 3).

The general appearance, silhouette, and way of flight that the observed individual has demonstrated, at first glance, suggested that it is one of the smaller falcon species. The breast and belly were streaked with conspicuous black streaks, and the streaking continued back but was relatively finer in the belly and flanks. The ventral area and undertail coverts were whitish. The undertail was barred, and the underwing coverts

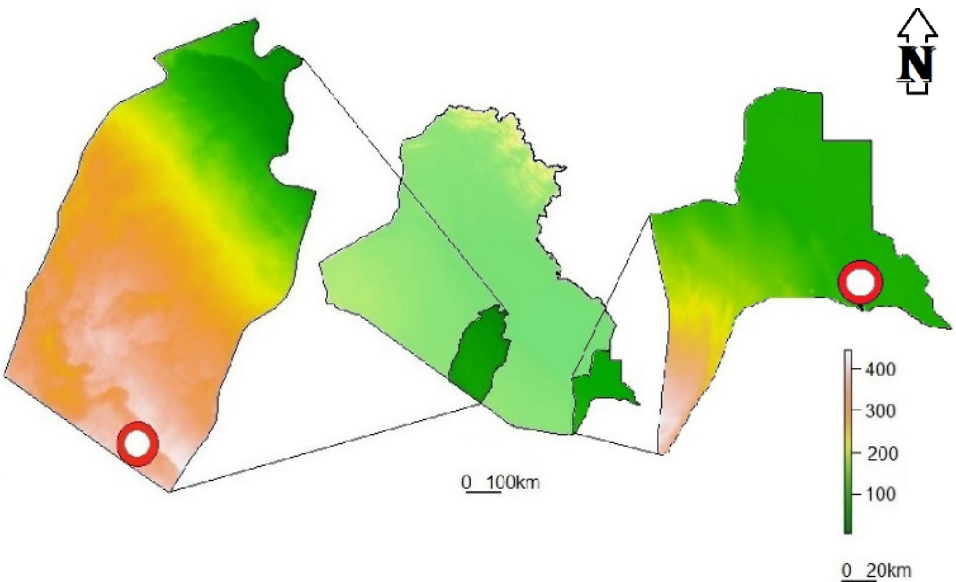

Fig. 2. The Iraq Map shows the location of Al-Najaf and Basra provinces. The map to the left shows Najaf, where the first lappet-faced vulture was observed soaring, not far from the KSA-Iraq borders. The map to the right shows Basra, where the first Amur falcon was observed in Kour Az-Zubair.

Obr. 2. Mapa Iraku zobrazuje polohu provincií Al-Nadžaf a Basra. Na mape vľavo je znázornený Nadžaf, kde bol pozorovaný prvý vznášajúci sa sup arabský, neďaleko hraníc Saudskej Arábie a Iraku. Na mape vpravo je znázornená Basra, kde bol pozorovaný prvý sokol amurský v Kour Az-Zubair.

Fig 3. Amur falcon observed in Kour Az-Zubair as the first record for Iraq (on the left); habitat landscape shows where the first Amur falcon was observed (on the right) ©IOCN Team.
Obr. 3. Sokol amurský pozorovaný v Kour Az-Zubair ako prvý záznam pre Irak (vľavo); biotop kde bol sokol amurský pozorovaný (vpravo) ©IOCN Team.

were of black markings with a whitish background. The dark moustache on the face was still visible from below, obviously contrasting with its whitish cheek.

This species can be separated from the Eurasian hobby (*F. subbuteo*) by its paler under-surface and the way of flight and from the red-footed falcon (*F. vespertinus*) by the pattern of the underwing and the breast and belly streaks. Also, the underwing background was whitish (puffish in *F. vespertinus*) (Porter & Aspinall 2010).

Observation of the first lappet-faced vulture for Iraq

While surveying Jal Al-Dhifeeri cliff on 28 February 2023, around the central coordinates (30.097398°, 43.615938°) in the Southern Desert, 7 km northeast of the Saudi borders (the landscape of the area is shown in Fig. 4), one of the team members saw a large soaring vulture passing over the survey area eastward where we were able to check it by binoculars while it was gliding on high elevation. Following the bird was impossible due to the rough rocky area. After further discussions and consulting bird field guides, it was evident that the observed bird was a sub-adult lappet-faced vulture.

The general colour of the individual found soaring over the Jal Al-Dhifeeri area was brownish, with relatively darker primaries, secondaries, and tail feathers, with paler head and legs from a distance. It was quickly identified based on its quite wide wing span and spread 'fingers' in addition to its massive bill. The tail was short and fan-shaped with distinguishable pointed feathers. The flight feathers and tail were darker than the brown belly and the lower wing coverts. It can be promptly distinguished from the other vultures found in Iraq by its heavier bill, shorter, rounded/fan-shaped tail, and larger size (Shirihai 1987).

The present precise observation of this individual bird in this location recalled a previous observation of a similar vulture that the team spotted in the southern parts of Al-Muthanna Desert, not far from the Saudi borders at the coordinates (29.372679°, 45.443143°) when the IOCN team was camping and birding few kilometres south of Jabal Al-'Amghar, in the southern desert of Al-Mothanna when a large brownish vulture was perching on an embankment in March 2021. The present observation in the Al-Najaf desert has confirmed with trust that the observation in 2021 was of the same species as it was similar in size, silhouette and colours.

Discussion

The first observations of lapped-faced vulture and Amur falcon were made in different locations within southern Iraq in different habitats. Lapped-faced vulture was observed in the Al-Najaf desert. The time of the survey is considered ideal for conducting the exploration field surveys in the Iraqi deserts primarily for the suitability of the weather for camping for prolonged periods to cover as many areas as possible, and secondly, for easier logistical purposes. During the survey time (late Feb. 2023), most of the southern deserts of Iraq were covered by spring shrubs and grass, especially the depressions (*Feidhaat*), and this attracts considerable numbers of Bedouins and shepherds to graze in these vast areas of southern Iraq with their large herds of cattle (Shimelis et al. 2005). During the surveys in the desert,

Fig. 4. The first observed lappet-faced vulture was soaring over the survey area close to the Saudi borders (on the left); habitat landscape shows where the lappet-faced vulture was observed (on the right) ©IOCN Team.
Obr. 4. Prvý pozorovaný sup chochlatý sa vznášal nad oblasťou výskumu v blízkosti hraníc Saudskej Arábie (vľavo); biotopov, kde bol pozorovaný sup chochlatý (vpravo) ©IOCN Team.

it is quite usual to find the carcasses of dead cattle gathered and thrown by the shepherds in specific locations (Fig. 5). They throw them away from their temporary tents to prevent the wolves' attacks (Results of different interviews with Bedouin, IOCN). These locations with the cattle carcasses attract the passing and soaring vultures and eagles especially, and it coincides with scavenger birds' passage time, where they find enough food to continue their long journey to their breeding grounds northward (Botha et al. 2017).

Fig. 5. Sheep and goat carcasses that the Bedouins and shepherds throw in clusters away from their temporary tents forming attractive feeding hotspots for vultures and other raptors. Photo by IOCN Team 5 km from where the first lapped-faced vulture was observed.
Obr. 5. Kadávery oviec a kôz, ktoré beduíni a pastieri hádžu do zhlukov mimo svojich dočasných stanov a vytvárajú tak atraktívne kŕmne miesta pre supy a iné dravce. Fotografia od tímu IOCN 5 km od miesta, kde bol pozorovaný prvý sup arabský.

The closest breeding location of this species in Saudi Arabia is a few hundred kilometres west of the current location where the first individual was observed in Iraq. It seems that the bird (like other scavenger vultures) makes extensive daily tours searching for carcasses riding the local thermals (Shimelis et al. 2005). Additionally, the observations of lapped-faced vultures in Kuwait in similar habitats might support the suggestion that this species occasionally visits the southern deserts of Iraq but is overlooked (IOCN, intra-team communications).

It seems that few individuals of Amur falcon visit the area of the Middle East during its annual passage in autumn and spring migration. During their passage, they may visit some countries around Iraq, like Kuwait and Iran (Porter & Aspinall 2010, Khaleghizadeh et al. 2011, Al-Suraeea et al. 2013). The Google Earth satellite image (Fig. 6) represents the nearest confirmed observations of Amur falcons around the upper part of the Arabian Gulf. Obviously, some individuals of this species occasionally occur within the upper Arabian Gulf area. Still, they might be overlooked due to their small numbers or the similarity of this species with other falcon species.

None of the older and recent literature on the avifauna of Iraq has mentioned the lappet-faced vulture and Amur falcon as bird species observed or listed in the Iraqi checklist or even the possibility of their potential occurrence in the country (Allouse 1953, 1962, Salim et al. 2006, 2012). Thus, the presently documented and described observations provided the first recordings and confirmed both species for Iraq.

Fig. 6. The confirmed observations of Amur falcon around the upper parts of the Arabian Gulf. The white circle (A) is the location of the first Amur falcon observed in Kour Az-Zubair; the two red circles (B) represent the two observations of the species in Kuwait; and the eastern red circle (C) represents one of the Iranian observations of Amur falcon in this region.

Obr. 6. Potvrdené pozorovania sokola amurského v hornej časti Arabského zálivu. Biely kruh (A) predstavuje miesto prvého pozorovania sokola amurského v Kour Az-Zubaire (; dva červené kruhy (B) predstavujú dve pozorovania tohto druhu v Kuvajte; a východný červený kruh (C) predstavuje jedno z iránskych pozorovaní sokola amurského v tejto oblasti.

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Raptor rehabilitation in Florida: Admission reasons, care duration, and release rates during the last fifteen years

Rehabilitácia dravcov na Floride: Dôvody prijatia, dĺžka starostlivosti a miera vypustenia v priebehu posledných pätnástich rokov

Aaron PAHL

Abstract: Wildlife rehabilitators treat thousands of raptors yearly, providing an opportunity to better understand species' biology, the changing environment, and the dangers raptors encounter in the wild. However, that data is siloed within individual facilities, making it challenging to understand the wider impact of rehabilitation and the dangers raptors face. Data were collected from 50 facilities across the state of Florida, United States of America, from 2009 to early 2023, representing 54,574 patients of 39 species. Patient intake at these facilities doubled between 2010 and 2020 over a relatively stable number of facilities (average = 31.5/year) with an average release rate of 36.6% (range 31.7 – 41.5%). Release rates varied significantly from 21% to 57% between species with over 100 recorded patients.
Comparing release rates with the "cause for admission" provided a more nuanced understanding of what was affecting raptor patients and their release rates. Trauma was the most common cause of admission (40.2%) and has been relatively consistent year over year. For those patients with more specific identification attributes, 65% were male, 50% were adults, and patients spent an average of 16.6 days in care. The data provided in this study has the potential to make fundamental changes to raptor rehabilitation policies and encourage more collaboration between rehabilitators and researchers for the betterment of the patients in care.

Abstrakt: Rehabilitačné zariadenia voľne žijúcich živočíchov každoročne ošetria tisíce dravcov, čo poskytuje príležitosť lepšie pochopiť biológiu jednotlivých druhov, meniace sa životné prostredie a nebezpečenstvá, s ktorými sa dravce stretávajú vo voľnej prírode. Tieto údaje sú však v rámci jednotlivých zariadení izolované, čo sťažuje pochopenie širšieho vplyvu rehabilitácie a nebezpečenstiev, ktorým dravce čelia. Predložený príspevok sumarizuje údaje z 50 zariadení v štáte Florida v Spojených štátoch amerických od roku 2009 do začiatku roka 2023, čo predstavuje informácie o 54574 pacientov, 39 druhov dravcov. Počet prijatých pacientov v týchto zariadeniach sa v rokoch 2010 až 2020 zdvojnásobil v porovnaní s relatívne stabilným počtom zariadení (priemer = 31,5/rok) s priemernou mierou vypustenia 36,6% (rozsah: 31,7 - 41,5%).
Miera vypustenia sa výrazne líšila od 21% do 57 % medzi druhmi s viac ako 100 zaznamenanými pacientmi. Porovnanie miery vypustenia s „príčinou prijatia" umožnilo lepšie pochopiť, ohrozenia jednotlivých druhov dravcov. Úraz (trauma) bol najčastejšou príčinou prijatia (40,2%) a bol medziročne relatívne konzistentný. V prípade pacientov s jednoznačnými identifikačnými znakmi sa jednalo 65% samcov a 50% dospelých jedincov. Pacienti strávili v starostlivosti v priemere 16,6 dňa. Údaje uvedené v tejto štúdii majú potenciál priniesť zásadné zmeny v politike rehabilitácie dravcov a podporiť väčšiu spoluprácu medzi rehabilitačnými a výskumnými inštitúciami v záujme zlepšenia starostlivosti o dravce.

Key words: birds of prey, wildlife, avian, mortality, conservation, red-shouldered hawk, eastern screech owl

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Introduction

Hundreds of thousands of injured wildlife patients are brought into rehabilitation facilities annually (Cope et al. 2022; Willette et al. 2023). Sharing this patient data could allow rehabilitation professionals to understand the threats facing local wildlife populations.

Across Florida alone, tens of thousands of birds are treated annually at wildlife rehabilitation facilities, resulting in a valuable pool of avian patient data (Pahl 2024). Combining and analyzing this data makes it possible to understand common ailments, treatment success rates, trends, and periodic fluctuations in patient intake volumes. Evaluating these large-scale data sets is an invaluable resource that can serve as the foundation of future studies, detect trends, make hypotheses, and potentially extrapolate those findings nationally or globally.

Unfortunately, there has been a distinct lack of studies using large-scale patient data sets in wildlife rehabilitation and raptor rehabilitation in particular. Table S1 (see the Supplementary File for all "S" Tables and Figures) lists sixteen raptor studies, including over 33,000 patients with release rates ranging from 16% to 45%. The majority of these studies are based on data obtained from single facilities, resulting in a very limited scope (Rodríguez et al. 2010; Montesdeoca et al. 2016; Hernandez et al. 2018; Zoubi et al. 2020; Cummings et al. 2022; Mbali Mashele et al. 2022). For example, a study conducted in Florida that looked at a single facility included data on 390 patients and found that 82% of the patients were suffering from trauma while the patients had an overall release rate of 21% (Deem et al. 1998).

Across these studies, trauma is consistently the most frequent, or one of the most frequent, causes of admission in some cases making up more than 70% of patients (Fix & Barrows 1990; Kratter & Steadman 2020). The available studies also illustrate how little is known about patients' age, sex, and duration of care with those distinctions often being omitted entirely or only being available for small portions of the total data sets (Molina-López et al. 2013; Panter et al. 2022).

One Australian study evaluated a large data set of 250,688 birds using 19 categories to identify the reason for admission including the chance of release for each category (Kwok et al. 2021). Unfortunately, patients were only classified as birds limiting the depth of analysis available.
The most detailed study focused on 22,538 raptor patients from 34 facilities in the Czech Republic. It broke down the cause of injury into 13 categories but did not include patient sex, age, or duration of care (Lukesova et al. 2022). This study includes 54,574 patient records from Florida and aims to provide a detailed analysis of raptor rehabilitation covering disposition, species, age, and reason for admission over a 14-year period.

This study aimed to provide rehabilitators and researchers a consolidated view of trends and insights to provide better care for wildlife, understand the largest threats facing raptors, and have sufficient data to support future research and planning. This information will allow rehabilitators to customize treatment protocols and potentially secure funding to continue their important work saving native wildlife while increasing the knowledge of the wider scientific community. The ultimate goal is to provide the data necessary to employ new methods and innovative treatments to increase raptor release rates while ensuring they have the greatest possible chance of long-term survival.

Methods

Data sources and collection methods

This dataset of 54,574 raptor patient records spanning 2009 to early 2023 was included in a larger project focused on Florida avian rehabilitation outcomes (Pahl 2024). The data used in the larger study were acquired directly from wildlife rehabilitation facilities, information management systems including WILD-ONe, and through the federal government's required reporting of migratory species by rehabilitators (Table S2) (Pahl 2024).

Although the data spans 2009 through 2023, this study primarily focuses on 2010 to 2021 to ensure adequate data to analyse and determine trends (Fig. S1). The inclusion or exclusion of data from 2009, 2022, and 2023 is clearly noted throughout this study. An average of 31.5 facilities reported patient data annually of the 51 total facilities represented. Not all facilities were open for the entire length of the study and some facilities were missing data from select years that were either lost or unavailable. Raptor intake rates at these facilities have generally trended up each year. There were 16,767 (30.7%) raptor patient records from 16 facilities that included more extensive patient information, including the cause of injury, age, sex, weight, duration of care, and location found. Rehabilitators reported "cause of injury" in 15,003 (27.5%) raptor patient records which were consolidated and normalized into 38 categories to accurately analyse the causeof injury (Table 1). Between 2009 and 2021, 6,176 (11.3%) records included an identified sex. Males represented 65% (4,015) and females 35% (2,161) (Table 2). Patient age was included in 16,072 (29.4%) records as either egg, hatchling, nestling, fledgling, juvenile, or adult (Table 3).

Tab. 1. Raptor reason for admittance. A list of all of the causes of injury ordered by the „count“ for a given category. This table includes the number of patients represented and the release rate percentage for each category.
Tab. 1. Dôvod starostlivosti o dravce. Zoznam všetkých príčin úrazu zoradených podľa „počtu“ pre danú kategóriu. Tabuľka obsahuje počet pacientov a percento miery vypustenia pre každú kategóriu.

Reason for Admittance	Count	Overall Mix*	Released
Trauma	6033	40.2%	25.5%
Fell from nest	2268	15.1%	56.7%
Hit by car	1928	12.9%	25.3%
Clinically Healthy	683	4.6%	89.3%
Emaciation	536	3.6%	39.3%
Animal Attack	370	2.5%	38.6%
Feather loss	294	2.0%	46.9%
Electrocution	275	1.8%	5.0%
Nest destroyed	236	1.6%	68.6%
Gunshot	193	1.3%	26.1%
Side of road	178	1.2%	29.2%
Entanglement	164	1.1%	44.1%
Window Collision	158	1.1%	41.1%
Trapped	139	0.9%	56.9%
Toxin	135	0.9%	41.2%
Entanglement - fishing line	116	0.8%	69.3%
Collision	115	0.8%	25.9%
Not Flying	113	0.8%	32.7%
Poisoned	105	0.7%	41.8%
Human interference	100	0.7%	45.5%
Disease	95	0.6%	24.2%
Age Related	83	0.6%	53.9%
Eye Issue	82	0.6%	25.6%
Waterlogged	71	0.5%	66.2%
Birth defect	68	0.5%	26.5%
Orphan	66	0.4%	68.8%
Parasites	62	0.4%	68.3%
Weakness	62	0.4%	18.0%
Dehydration**	46	0.3%	52.2%
Avian Pox	46	0.3%	18.6%
Burn	43	0.3%	11.9%
Unknown illness	42	0.3%	29.0%
Hypothermia	30	0.2%	33.3%
Aspergillosis	23	0.2%	17.4%
Weather	17	0.1%	81.3%
Fishing hook	14	0.1%	35.7%
Oiled	13	0.1%	61.5%
Plastic***	1	0.0%	100.0%
Total******	15003		36.1%

*Overall Mix provides the percentage of the total patients with a known cause of admission for the specific category .
**Dehydration only had 46 cases where it was the primary or only listed ailment, but it was included as a secondary ailment for 1,275 (8.5%) total patients. At least 538 patients included both dehydration and emaciation as ailments
.***This category only included a single patient but it was included because of its highly unique nature. The patient reportedly ingested a plastic bag and then excreted it once it made its way through its digestive tract.
****The total represents the total number of patients and the overall release rate for all patients with a known reason for admission.

One note about the injury data: a single cause of injury was assigned based on severity resulting in the patient volumes of categories like emaciation, dehydration, and parasites representing a smaller portion of the total numbers. For example, emaciation included 536 (3.6%) patients as the primary reason for admittance, but 2,407 (16%) patients listed emaciation as one of their ailments, with the majority being considered secondary ailments. If emaciation had been treated as the primary ailment, it would have been the second most frequent reason for admittance.

Tab. 2. Raptor breakdown by sex. A breakdown of admitted patient sex ordered by the total number of patients with an identified sex.
Tab. 2. Rozdelenie dravcov podľa pohlavia. Rozdelenie prijatého pohlavia pacienta zoradené podľa celkového počtu pacientov s identifikovaným pohlavím.

Species	Female	Male	Total
red shouldered hawk	352	1312	1664
bald eagle	397	558	955
osprey	266	668	934
barred owl	340	404	744
eastern screech owl	214	268	482
Cooper’s hawk	185	236	421
red tailed hawk	126	225	351
American kestrel	79	150	229
great horned owl	112	104	216
black vulture	16	16	32
sharp-shinned hawk	11	17	28
merlin	10	13	23
peregrine falcon	13	10	23
barn owl	11	5	16
turkey vulture	3	8	11
swallow-tailed kite	6	4	10
short-tailed hawk	2	6	8
crested caracara	3	4	7
Mississippi kite	4	3	7
broad-winged hawk	3	2	5
burrowing owl	3	1	4
northern harrier	4	0	4
short-eared owl	0	1	1
snail kite	1	0	1
Total	2161	4015	6176

Data conflicts and normalization

Since data were obtained from various sources, it was necessary to normalize the formats and naming conventions to address discrepancies and ensure consistency in causes of injury, age, and final disposition. The injuries’ descriptions varied widely as no controlled vocabulary was employed across facilities, resulting in spelling variations, acronyms, and thousands of unique

Tab. 3. Raptor breakdown by age. A breakdown of raptor ages ordered by the total number of patients with an identified age range from eggs to adult patients. This table includes the ages of every patient in the study with a reported age.
Tab. 3. Rozdelenie dravcov podľa veku. Rozdelenie veku dravcov zoradené podľa celkového počtu pacientov s identifikovaným vekovým rozsahom od vajíčok po dospelých pacientov. Táto tabuľka obsahuje vek každého pacienta v štúdii s uvedeným vekom.

Species	Egg*	Hatchling	Nestling	Fledgling	Juvenile	Adult	Total
red shouldered hawk	3	82	549	529	1156	1598	3917
eastern screech owl	4	203	566	446	253	1232	2704
barred owl	1	47	137	139	140	1337	1801
osprey	6	9	116	396	266	907	1700
Cooper's hawk	1	22	103	93	508	409	1136
bald eagle	0	3	113	143	191	662	1112
great horned owl	7	77	117	132	61	324	718
red tailed hawk	0	5	22	40	335	316	718
black vulture	1	7	14	11	129	437	599
turkey vulture	0	0	3	4	119	326	452
American kestrel	0	17	32	68	29	167	313
broad-winged hawk	0	2	0	10	113	95	220
barn owl	1	36	37	26	14	48	162
Mississippi kite	0	16	5	41	19	43	124
sharp-shinned hawk	0	2	0	4	54	36	96
peregrine falcon	0	0	0	0	35	41	76
swallow-tailed kite	0	0	7	13	10	32	62
merlin	0	0	0	0	19	29	48
burrowing owl	0	1	0	0	5	32	38
crested caracara	0	0	1	2	11	14	28
short-tailed hawk	0	0	0	0	11	15	26
common kestrel	0	0	0	0	0	4	4
northern harrier	0	0	0	0	0	4	4
snail kite	0	0	0	0	3	1	4
short-eared owl	0	0	0	0	0	3	3
Swainson's hawk	0	0	0	0	1	2	3
common black hawk	0	0	0	0	0	1	1
flammulated owl	0	0	0	0	0	1	1
roadside hawk	0	0	0	0	1	0	1
western screech owl	0	0	0	0	1	0	1
Total	24	529	1822	2097	3484	8116	16072
Breakdown	0.1%	3.3%	11.3%	13.0%	21.7%	50.5%	100.0%

*Two of the 24 admitted eggs were released, one barred owl and one great horned owl. The barred owl was released after 77 days in care and the great horned owl was determined to be healthy and was re-nested the same day it was brought into the rehabilitation facility

terms. In other available studies focused on raptor rehabilitation, they tended to group reasons for admission together in their broadest categories to make it easier to understand and simplify the results while working with the available data (Wendell et al. 2002; Rodríguez et al. 2010).

Some cause of injury categories could have fallen under the broad "trauma" category (e.g., fishing hook, animal attack, side of road, and window collision) but were broken out to provide a more detailed representation of the data. Many of the facilities provided more details on the patient's injuries in their records but due to the variability and lack of consistency, that data was not included in this study.

Cause of admission

Simplifying the cause of admission was critical to understand what threats raptors face in their natural environment and potentially how to mitigate or eliminate those threats. Many patients might suffer from multiple ailments simultaneously (e.g., dehydration, mites, not standing, and fractured wing) in which case the most severe or life-threatening issue was selected as the primary ailment – fractured wing in this case. Similar studies have used this model (Long et al. 2020). Other studies that included cause of injury kept the categories under ten but one broke trauma into 12 subcategories (Morishita et al. 1998; Harris and Sleeman 2007; Rodríguez et al. 2010).

In some studies, being hit by car was included under the broader category of trauma, while in others, it was included under collisions (Fix & Barrows 1990; Rodríguez et al. 2010). For this study, hit by car was separated to better illustrate its impact on raptors and provide some separation between other documented collisions or the general trauma category.

The data also included 15,549 (28.5%) patients with both the exact date of admittance and final disposition. The inclusion of both dates provides an opportunity to understand patient volumes throughout the year and the duration of care for each species. It also provides a better idea of injury recovery time. Patients that were listed as Dead on Arrival (DOA), adopted, pending, or with care over 365 days were excluded, leaving 15,507 patients (Table 4).

Tab. 4. Duration of care by raptor species count. A breakdown of patient's duration of care ordered by the total patient days in care and including the total, average, maximum, median, and standard deviation. Standard deviation was not listed for species represented by a single patient day in care.

Tab. 4. Trvanie starostlivosti podľa počtu jednotlivých druhov dravcov. Rozdelenie trvania starostlivosti o pacienta podľa celkového počtu dní v starostlivosti pacienta vrátane celkovej, priemernej, maximálnej, strednej dĺžky starostlivosti a štandardnej odchýlky. Smerodajná odchýlka nebola uvedená pre druhy reprezentované jedným pacientom za deň v starostlivosti.

Species	Days in Care				Standard Deviation
	Total*	Average	Maximum	Median	
red shouldered hawk	3790	14.5	365	2	24.1
eastern screech owl	2692	23.9	284	7	31.6
barred owl	1734	16.2	269	2	30.9
osprey	1664	14.0	365	2	29.0
Cooper's hawk	1180	9.0	296	1	22.2
bald eagle	830	20.8	365	6	38.5
red tailed hawk	691	18.3	264	2	32.2
great horned owl	667	22.8	311	3	38.3
black vulture	606	10.9	358	1	27.3
turkey vulture	467	9.6	242	1	23.1
American kestrel	301	15.4	325	2	28.3
broad-winged hawk	244	12.4	185	4	23.5
barn owl	150	26.8	153	9	33.5
Mississippi kite	115	22.0	273	14	36.7
sharp-shinned hawk	101	13.5	279	1	38.1
peregrine falcon	71	13.7	283	1	38.2
swallow-tailed kite	56	18.9	167	5.5	35.8
merlin	42	11.6	156	2	26.9
burrowing owl	41	13.7	190	2	36.1
short-tailed hawk	23	14.5	66	3	19.0
crested caracara	18	32.6	177	5	49.3
common kestrel	4	1.0	1	1	0.0
northern harrier	4	12.8	23	13.5	11.9
snail kite	4	20.3	40	20	21.7
short-eared owl	3	26.7	50	29	24.6
Swainson's hawk	3	17.7	39	10	18.7
common black hawk	1	1.0	1	1	-
flammulated owl	1	3.0	3	3	-
long-eared owl	1	1.0	1	1	-
roadside hawk	1	1.0	1	1	-
western screech owl	1	20.0	20	20	-
white-tailed kite	1	52.0	52	52	-
Total	15507	16.6	365	2	29.6

*Some patients had incredibly long durations of care including one patient representing over 2,000 days, seven representing over 1,000 days, and 34 representing over a year in care. At this point, it is impossible to determine if the long-term patients were a reporting error; if they ended up getting adopted as an education or foster animal; the facility failed to report the final disposition, or if the raptor was in care that entire time. 42 patients fell within this category and were removed from these calculations. Patients that were listed as DOA, adopted, pending, transfered, and unknown were also removed. (This footnote also applies to tables 7 and 8).

Results

Intake trends

During the fifteen-year study (2009–2023), the eastern screech owl (*Megascops asio*) was the most frequently admitted species (20%) and the annual intake numbers more than doubled during the study. The red-shouldered hawk (*Buteo lineatus*) represented 19% of all intakes with an increase of 238%. Rounding out the top three species was the osprey (*Pandion haliaetus*) representing 12% of the intakes and a 138% intake increase during the study duration. These three species made up 52%, or 28,248 patient intakes, of the 39 total species (Table 5). In 2010, they represented 45% of all intakes and by 2021 they had grown to 58% of the annual species intake.

Disposition trends

The primary goal of rehabilitators continues to be the successful release of patients back into the wild. Based on the data, rehabilitators are challenged by having to treat twice as many patients with a relatively similar number of facilities and presumably rehabilitators. The overall release rate in this study was 35.1% (36.6% if DOA patients are removed). The barn owl (*Tyto alba*) had the highest release rate (57%) while the black vulture (*Coragyps atratus*) had the lowest (21%).

When analyzing the overall release rates, the data shows a steady decline from 2010 (40%) through 2021 (31.4%). This 8.6 - point decrease is offset by an 8 - point increase in patients being euthanized (2010 = 28.5%; 2021 = 36.6%).

Threatened species

According to the Red List published by the International Union for Conservation on Nature (IUCN), all 39 species represented in this study are designated as Least Concern (IUCN 2024). However, there are three species listed as threatened within the state of Florida: the American kestrel (*Falco sparverius*), the burrowing owl (*Athene cunnicularia*), and the crested caracara (*Caracara cheriway*) which is also listed as federally threatened (Species Profiles n.d.).

There were 1,174 American kestrel patients admitted with an above-average release rate of 41%. However, the data showed an accelerating upward trend in patient intake starting with 60 patients in 2010 and culminating with 167 individual patients in 2021 (178% increase).

The American kestrel spent an average of 15.4 ± 28.3 days in care (± SD; median = 2 days), across patients with a known duration (Table 4).

The burrowing owl had 1,265 individual patients and also showed an upward trend in patient numbers (99% increase from 2010 to 2021). Like the American kestrel, the burrowing owl had an above-average release rate of 43% and spent an average of 13.7 ± 36.1 days in care (median = 2 days) across patients with a known duration.

The crested caracara had a much lower patient volume at only 97 individuals with a below-average release rate of 27%. Between 2010 and 2021, the crested caracara had an average intake rate of eight patients a year with a total of 96 patients. The crested caracara patients that included duration of care spent an average of 32.6 ± 49.3 days in care, the second highest overall (median = 5 days).

Patient admittance by month

There were 16,765 patients (31%) with a known admittance date. May had the highest admittance rate (15.9%) while September (4.7%) had the lowest rate (Fig. S2). This pattern was true for ten of the twelve years (Fig. S3). The reason for the large spike in May admittance rates becomes apparent when patient age is considered (Fig. S4). Adult patient intake rates dip in September but remain relatively consistent throughout the year, while immature patients have an apparent increase in the spring and summer months, and there are almost no intakes from September to February (Fig. S5; S6).

Patient sex

The red-shouldered hawk represented by far the highest number of patients with an identified sex while also having the largest difference between sexes across all species with 1,312 (78.8%) males and 352 (21.2%) females. The great horned owl (*Bubo virginianus*) was the only species with an identified sex with more female (51.9%) than male patients.

Age

By combining hatchlings, nestlings, fledglings, and juvenile patients into an immature category, they represented just under half (49%) of the patients with a known age while the mature adult patients make up just over half (51%).

Across the 15,577 patients (28%) with known age, after the removal of DOA patients, the average release rate got progressively lower as the patient got older, except for eggs (Table 6). Hatchlings had the highest average release rate of any age group at 71.4% while adult patients had a 28.6% average release rate.

Tab. 5. Total patient disposition. This is the final disposition breakdown for all of the raptors represented in this study including the percentages for the release rate, euthanization rate, death rate, total patient volume, and the release rate percentage with the removal of DOA patients. The standard terminology includes Released; Transferred; Pending; Euthanized; Died; and Dead On Arrival (DOA). The data included 22 patients with an unknown final disposition and 206 patients that were not deemed healthy enough for release and were adopted as education animals instead of being euthanized. The species identifications of 45 (0.08%) admitted patients were listed as unknown or partially unknown and are shown at the bottom of this table.

Tab. 5. Celková dispozícia pacientov. Konečné rozdelenie dispozícií všetkých dravcov zastúpených v tejto štúdii vrátane percentuálnych podielov miery vypustenia, miery eutanázie, miery úmrtnosti, celkového objemu pacientov a percentuálneho podielu miery prepustenia s odstránením pacientov s DOA. Štandardná terminológia zahŕňa vypustené; premiestnenie; čakanie; eutanáziu; uhynutie; a uhynutie pri príchode (DOA). Údaje zahŕňali 22 pacientov s neznámou konečnou dispozíciou a 206 pacientov, ktorí neboli považovaní za dostatočne zdravých na prepustenie a namiesto eutanázie boli adoptované ako zvieratá pre vzdelávanie. Druhová identifikácia 45 (0,08 %) prijatých pacientov bola uvedená ako neznáma alebo čiastočne neznáma a je uvedená na konci tejto tabuľky.

Common Name	Patient Intake			Released			Euthanized		Dead		Transferred	DOA*	Pending	Adopted	Unknown
	Patient Count	%	**12 Year Increase	Patient Count	Rate	Rate less DOA*	Patient Count	Rate	Patient Count	Rate					
eastern screech owl	11011	20.2%	114%	5154	46.8%	48.4%	2301	20.9%	2154	19.6%	818	366	178	37	3
red-shouldered hawk	10584	19.4%	238%	3615	34.2%	35.3%	3602	34.0%	2065	19.5%	736	339	200	25	2
osprey	6653	12.2%	138%	1630	24.5%	25.7%	2508	37.7%	1733	26.0%	391	308	69	8	6
barred owl	4792	8.8%	82%	1430	29.8%	30.8%	2028	42.3%	550	11.5%	479	146	141	18	0
Cooper's hawk	4610	8.4%	7%	1570	34.1%	35.8%	1516	32.9%	960	20.8%	259	221	80	3	1
great horned owl	2435	4.5%	49%	1029	42.3%	43.4%	637	26.2%	319	13.1%	279	66	81	19	5
black vulture	2416	4.4%	38%	495	20.5%	21.1%	1378	57.0%	305	12.6%	113	72	46	7	0
bald eagle	2053	3.8%	50%	541	26.4%	30.9%	613	29.9%	197	9.6%	288	305	80	28	1
red-tailed hawk	1915	3.5%	9%	582	30.4%	31.1%	713	37.2%	289	15.1%	192	43	87	8	1
turkey vulture	1789	3.3%	47%	499	27.9%	28.7%	872	48.7%	251	14.0%	64	52	49	2	0
burrowing owl	1265	2.3%	132%	512	40.5%	43.4%	397	31.4%	237	18.7%	20	84	13	2	0
American kestrel	1174	2.2%	178%	469	39.9%	41.0%	258	22.0%	210	17.9%	155	31	39	12	0
broad-winged hawk	1072	2.0%	197%	534	49.8%	50.9%	140	13.1%	282	26.3%	41	22	50	1	2
barn owl	985	1.8%	82%	546	55.4%	57.0%	159	16.1%	126	12.8%	55	27	66	5	1
sharp-shinned hawk	387	0.7%		108	27.9%	30.9%	83	21.4%	142	36.7%	10	37	7	0	0
peregrine falcon	298	0.5%		106	35.6%	36.9%	74	24.8%	44	14.8%	40	11	19	4	0
Mississippi kite	266	0.5%		92	34.6%	34.7%	72	27.1%	40	15.0%	42	1	15	4	0
swallow-tailed kite	263	0.5%		80	30.4%	31.5%	59	22.4%	49	18.6%	52	9	6	8	0
merlin	252	0.5%		63	25.0%	25.9%	88	34.9%	64	25.4%	15	9	9	4	0
short-tailed hawk	113	0.2%		36	31.9%	32.4%	40	35.4%	19	16.8%	8	2	7	1	0
northern crested caracara	97	0.2%		26	26.8%	27.1%	30	30.9%	14	14.4%	11	1	8	7	0
northern harrier	30	0.1%		12	40.0%	40.0%	6	20.0%	11	36.7%	0	0	1	0	0
snail kite	25	0.0%		9	36.0%	40.9%	3	12.0%	9	36.0%	0	3	0	1	0
Swainson's hawk	12	0.0%		7	58.3%	63.6%	1	8.3%	1	8.3%	0	1	2	0	0
short-eared owl	11	0.0%		7	63.6%	63.6%	2	18.2%	2	18.2%	0	0	0	0	0
Harris's hawk	4	0.0%		0	0.0%	0.0%	0	0.0%	2	50.0%	1	0	0	1	0
common kestrel	3	0.0%		1	33.3%	33.3%	1	33.3%	0	0.0%	0	0	0	1	0
long-eared owl	2	0.0%		1	50.0%	50.0%	0	0.0%	1	50.0%	0	0	0	0	0
rough-legged hawk	2	0.0%		1	50.0%	50.0%	0	0.0%	1	50.0%	0	0	0	0	0
common black hawk	1	0.0%		1	100%	100%	0	0.0%	0	0.0%	0	0	0	0	0
Eurasian eagle-owl	1	0.0%		0	0.0%	0.0%	1	100%	0	0.0%	0	0	0	0	0
ferruginous hawk	1	0.0%		0	0.0%	0.0%	1	100%	0	0.0%	0	0	0	0	0
flammulated owl	1	0.0%		0	0.0%	0.0%	0	0.0%	1	100%	0	0	0	0	0
golden eagle	1	0.0%		0	0.0%	0.0%	0	0.0%	0	0.0%	0	1	0	0	0
mottled owl	1	0.0%		0	0.0%	0.0%	0	0.0%	1	100%	0	0	0	0	0
northern goshawk	1	0.0%		0	0.0%	0.0%	0	0.0%	1	100%	0	0	0	0	0
roadside hawk	1	0.0%		0	0.0%	0.0%	0	0.0%	0	0.0%	0	1	0	0	0
western screech owl	1	0.0%		1	100%	100%	0	0.0%	0	0.0%	0	0	0	0	0
white-tailed kite	1	0.0%		0	0.0%	0.0%	0	0.0%	0	0.0%	0	0	1	0	0

Tab. 5. continuation / pokračovanie

Common Name	Patient Intake			Released			Euthanized		Dead		Transferred	DOA*	Pending	Adopted	Unknown
	Patient Count	%	**12 Year Increase	Patient Count	Rate	Rate less DOA*	Patient Count	Rate	Patient Count	Rate					
unknown - hawk	23	0.0%		0	0.0%	0.0%	10	43.5%	1	4.3%	5	7	0	0	0
unknown - vulture	10	0.0%		2	20%	28.6%	5	50.0%	0	0.0%	0	3	0	0	0
unknown - owl	9	0.0%		0	0.0%	0.0%	4	44.4%	0	0.0%	0	5	0	0	0
unknown - raptor	2	0.0%		0	0.0%	0.0%	0	0.0%	1	50%	1	0	0	0	0
unknown - falcon	1	0.0%		0	0.0%	0.0%	0	0.0%	0	0.0%	0	1	0	0	0
Grand total	54574	100%		19159	35.1%	36.6%	17602	32.3%	10082	18.5%	4075	2174	1254	206	22
Total percentages	100%			35.1%			32.3%		18.5%		7.5%	4.0%	2.3%	0.4%	0.0%

* DOA: Dead On Arrival
**The 12 years covers 2010 to 2021

Injuries sustained

"Trauma" was by far the leading cause of injury, representing 40.2% of the 15,003 patients and had one of the lowest release rates (25.5%) of any cause of injury (Table 1).

"Fell from nest" was the second most frequent cause of admission (15%) and almost exclusively affected sub-adult patients (99.2%), resulting in a 56.7% average release rate, but results differed depending on the species (Table 1). Eastern screech and barred owls (*Strix varia*) had release rates above 70%, while ospreys had a 37.1% and Cooper's hawks (*Astur cooperii*) had a 15.4% release rate for "fell from nest" (Table S3).

The Figure S7 highlights the annual impact injuries have on a month-to-month basis. While "trauma" and "hit by car" are relatively consistent throughout the year, age-related causes of admission, like nest destroyed, begin to spike in April/May (41%) before falling dramatically in August.

Duration of care

There were 15,512 raptor patients (28%) representing 32 species in the study with specifically recorded patient care start and end dates. The average duration of care over the period was 16.6 ± 29.7 days (± SD; median = 2 days) for patients with a duration of care under 365 days (46 patients received 365 or more days of care) and excluding DOA patients (Table 4). Of the top ten species, the average duration of care spanned from 9 days (Cooper's hawk) to 23.9 days (eastern screech owl). From 2010 to 2020, the number of patients per year with recorded care data increased by 66% while the annual average days in care decreased from 15.8 days to 13.6 days for the top ten species. During the same period, euthanization rates increased nearly three times (183%) compared to a 54% increase in "died" and a 44.5% increase in released or transferred patients.

There were 14,023 patients with both an identified cause of injury and duration of care under one year with an average duration of 17.3 ± 30.3 days (median = 2 days; Table 7**)**. Of those patients, over two-thirds (68.4%) fell under the categories of "trauma", "fell from nest", and "hit by car". In this study, "trauma" was by far the most prevalent cause of injury (40.7%). Fell from nest, nest destroyed, clinically healthy, and orphaned all had higher than average durations of care. In contrast, trauma, electrocution, and being hit by car all had below-average durations of care. Patients spent progressively less time in care the older they were, except for eggs. Hatchlings averaged the most time in care at 38.8 days ± 38.9 days (median = 32 days; Table 8**)**.

Tab. 6. Raptor release rate by age. This is a breakdown of the release rates for raptors based on their age which also includes the total number of patients represented and the number of patients released.

Tab. 6. Rýchlosť vypustenia dravca podľa veku. Miera vypustenia dravcov na základe ich veku, ktorý zahŕňa aj celkový počet zastúpených pacientov a počet vypustených pacientov.

Age	Number of Patients	Released Patients	Release Rate*
Hatchling	528	377	71.4%
Nestling	1782	1016	57.0%
Fledgling	2054	1070	52.1%
Juvenile	3395	1083	31.9%
Adult	7796	2232	28.6%
Egg	22	2	9.1%
Total	15577	5780	37.1%

*DOA patients removed from release rate calculations

Tab. 7. Duration of care by cause of injury. A breakdown of patient's duration of care in relation to the patient's cause of injury ordered by the total patient days in care and including the total, average, maximum, median, and standard deviation (SD). SD was not listed for species represented by a single patient day in care.
Tab. 7. Dĺžka starostlivosti o pacienta vo vzťahu k príčine zranenia podľa počtu dní vrátane celkovej, priemernej, maximálnej, strednej dĺžky starostlivosti a smerodajnej odchýlky (SD). SD nie je uvedená pre druhy s jedným pacientom za deň v starostlivosti.

Cause of Injury	Days in Care				SD
	Total*	Average	Max.	Median	
Trauma	5707	13.4	365	1	29.2
Fell from nest	2170	24.1	311	15	29.7
Hit by car	1723	12.8	365	1	26.6
Clinically Healthy	671	33.1	225	27	31.8
Emaciation	512	18.8	278	5	30.4
Animal Attack	329	20.2	297	4	35.2
Feather loss	284	24.6	315	5	44.9
Nest destroyed	216	31.5	139	29	29.3
Electrocution	213	6.5	138	1	15.6
Gunshot	182	21.0	264	1	37.6
Side of road	154	12.6	284	2	27.3
Entanglement	149	20.8	283	4	39.9
Window Collision	144	18.0	296	3	39.8
Toxin	130	11.2	173	5	20.7
Trapped	129	11.4	129	2	20.3
Entanglement - fishing line	109	25.5	227	14	38.1
Not Flying	106	13.2	124	1	20.8
Collision	104	13.3	236	1.5	30.9
Poisoned	103	7.1	44	3	8.7
Disease	94	16.7	215	3	30.8
Human interference	85	32.2	325	13	49.6
Eye Issue	74	10.7	91	1	20.0
Age Related	71	18.1	92	9	22.9
Waterlogged	69	9.8	57	2	12.8
Birth defect	64	17.1	103	4	24.6
Orphan	64	42.2	117	46	31.5
Parasites	58	20.7	70	19.5	15.1
Weakness	55	3.7	47	1	8.0
Dehydration	44	19.7	86	10	24.3
Avian Pox	39	29.4	208	4	45.6
Unknown illness	38	10.6	130	1	22.9
Burn	36	20.1	115	2	33.6
Hypothermia	30	8.4	40	2	11.7
Aspergillosis	23	18.5	63	15	17.7
Weather	16	28.1	74	19.5	27.0
fishing hook	14	10.9	61	2	17.4
Oiled	13	21.4	89	15	25.0
Plastic	1	13.0	13	13	
Total	14023	17.3	365	2	30.3

*Some patients had incredibly long durations of care including one patient representing over 2,000 days, seven representing over 1,000 days, and 34 representing over a year in care. At this point, it is impossible to determine if the long-term patients were a reporting error; if they ended up getting adopted as an education or foster animal; the facility failed to report the final disposition, or if the raptor was in care that entire time. 42 patients fell within this category and were removed from these calculations. Patients that were listed as DOA, adopted, pending, transfered, and unknown were also removed. max. - maximum;SD-standard deviataion

Discussion

Study comparison

Wildlife rehabilitators interact with a wide variety of species and injury types daily while contending with limited funding and information regarding those species and injuries. Single-patient case studies and experimental techniques are a precious resource when determining how to treat a patient, but understanding the state of the wider population and the injuries they encounter is critical. Data on the wider population provides the necessary context to understand how a particular species adapts to the environment while providing comparisons for similar species in the same region.

Rehabilitation-focused single-species studies from the Czech Republic (Lukesova et al. 2021) and Louisiana (Cummings et al. 2022) found release rates of 15.9% and 21%, respectively, with trauma being the most frequent cause of admission in the first and age-related in the second study (Table S1). Trauma was the third most frequent cause in the second study (Cummings et al. 2022). Interestingly, a later Czech Republic study reported on the same 34 rehabilitation centres, including all raptor species, across 22,538 patients (Lukesova et al. 2022). It found the most frequent cause of admission changed from nestling (age-related) to trauma (26.5%), followed by "young" (22.9%) (Lukesova et al. 2022). The release rate also increased from 15.9% focused on common kestrels to 42.4% across all species (Lukesova et al. 2021; 2022). This difference illustrates the importance of conducting broader studies to understand what is happening across a region and the inclusion of various species. Raptor release rates appear to fluctuate broadly throughout the existing studies. Comparing nine raptor studies spanning the United States, Europe, and Africa, release rates ranged from 21% (Florida – 390 patients) to 48% (South Africa – 242 patients) (Fix & Barrows 1990; Deem et al. 1998; Rodríguez et al. 2010; Molina-López et al. 2013; Hernandez et al. 2018; Maphalala et al. 2021; Cococcetta et al. 2022; Mbali Mashele et al. 2022; Panter et al. 2022). These studies evaluated raptor intake levels ranging from 60 to 6,221 patients. The release rate for this study of 54,574 patients was 36.6% which falls well within the release rates of previous studies and represents the largest raptor study to date (Table S1).

Limitations in reporting

Current federal reporting classifications do not provide many opportunities to fully understand rehabilitation statistics in a way that reflects the reality rehabilitators face. Across the board, release rates almost always fall

Tab. 8. Duration of care by patient age. This is a breakdown of patient's duration of care by their age, including the total and average days spent in care. Breaking down the duration of care by age provides results that make complete sense when combined with the types of injuries typically faced by different age groups and the release rates of those age groups.

Tab. 8. Trvanie starostlivosti podľa veku pacienta, vrátane celkového a priemerného počtu dní strávených v starostlivosti. Rozdelenie trvania starostlivosti podľa veku poskytuje výsledky, ktoré dávajú význam v kombinácii s typmi zranení, ktorým zvyčajne čelia rôzne vekové skupiny, a mierou ich prepustenia.

Age Category	Total Days in Care*	Average Days in Care
Adult	7509	13.4
Juvenile	3281	13.6
Fledgling	2017	21.9
Nestling	1724	25.5
Hatchling	513	38.8
Egg	20	13.8
Total	15064	16.9

*Some patients had incredibly long durations of care including one patient representing over 2,000 days, seven representing over 1,000 days, and 34 representing over a year in care. At this point, it is impossible to determine if the long-term patients were a reporting error; if they ended up getting adopted as an education or foster animal; the facility failed to report the final disposition, or if the raptor was in care that entire time. Forty two patients fell within this category and were removed from these calculations.

under 50% and are not improving. This can potentially paint the rehabilitation field in a negative light. However, by factoring in the number of patients who do not survive the first 24 hours (euthanized, die on arrival, or die within a day), rehabilitators have a better understanding of where to invest their limited time and resources to prioritise the patients who have any realistic chance of survival.

Understandably, not every facility has the capacity to keep detailed records on the cause of a patient's admission, age, or sex. However, many could adopt the distinction between patients that died or were euthanized within or after 24 hours with little to no extra burden, and we strongly encourage them to do so. Identifying those designations provides a much better understanding of the patient's health and the facility's ability to render care. Understanding how many patients could have reasonably been helped by a facility would provide valuable context when interpreting rehabilitation's impact and value on native wildlife.

Duration of care

The overall median duration of care was two days, categorized by both species and cause of injury, with 25% of species and 21% of injured patients having a median of only one day. Those numbers are a clear indicator of how many patients arrive at a rehabilitation facility on the brink of death. That idea is further supported by the fact that only 8.5% of known duration patients were released after one day or less in care, whereas 60.4% died and 72.3% were euthanized on their first day of care. It is assumed that rehabilitators have become more aware of the viability of their patients and have chosen euthanization as the appropriate treatment plan. Euthanizing patients almost immediately upon arrival is not unique to this study. A study from Spain found that euthanized patients had a median care duration of one day while orphaned young had an average time to release of 59 days (Molina-López et al. 2013).

Within this study, the causes of injury that primarily affected young patients resulted in longer care durations like falling from a nest, nest destruction, human interference, and being orphaned. That finding is further supported by the fact that as patients got older, they spent less time in care, except for eggs (Table 8).

A study from the Czech Republic that focused on common kestrels found that patients that were released spent an average of 35 days in care, whereas euthanization typically occurred on day one, and death occurred within 11 days (Lukesova et al. 2021). A larger study provided similar results regarding the duration of care separated out using the same method (Lukesova et al. 2022). When the duration of care was broken down by patients that were released, died, or euthanized in this study, the results were similar to those existing Czech Republic studies.

Investigating the duration of care by disposition further supports the idea that, in many cases, patients are not surviving long enough in care for rehabilitators to make a noticeable difference (Fig. S8). By uniformly including the 24-hour designations, rehabilitators and researchers would have a much more accurate representation of rehabilitation disposition rates. Unfortunately, the designations are only slowly being adopted; only ten facilities included the 24-hour designation within this study. When DOA was added to the federal reporting forms in 2010, it clarified patient disposition significantly, allowing researchers to remove DOA patients from the release rate calculations.

Month of admittance

In ten of the twelve years studied, May represented the greatest number of patients admitted. This spike can be explained by the increase in immature patients starting in April and peaking in May. The increase in hatchlings occurred in April, followed by increased fledgling intakes in May. These findings are similar to other studies that indicate similar patient increase patterns during the spring, primarily made up of young patients, although those studies found June to be the month with the highest admission rate (Wendell et al. 2002; Cococcetta et al. 2022). Spring also marked a high point for age-related causes of admission, such as being orphaned, falling from a nest, hatching defect, and/or a nest destroyed in this study and also the existing literature (Rodríguez et al. 2010; Rozsypalová et al. 2022). In contrast, the trends for "trauma" and "hit by car" remained relatively flat (Figure S7).

Understanding when to expect an influx of immature birds can be valuable information for rehabilitation facilities enabling them to better plan by purchasing necessary dietary foods and hiring seasonal workers and interns.

Patient sex

Available studies identified patients' sex 13 to 57.4% of the time (Deem et al. 1998; Rozsypalová et al. 2022; Table S1). In this study, 6,176 (11.3%) patients had an identified sex. Although low as a percent of the total, the actual number represents more identified sex patients than the 16 referenced sources combined (4,823 cases). The study's most significant difference was the balance of male to female patients. The combined referenced studies showed a nearly balanced sex ratio of patients (Deem et al. 1998; Molina-López et al. 2011; 2013; Cococcetta et al. 2022; Panter et al. 2022; Rozsypalová et al. 2022; Table S1). It is unclear why this study was more heavily weighted toward male patients (65%). There could have been bias in the identification process, or sexual identification through external features is unreliable, or it is easier and more definitive to determine the male gender.

Patient age

Except for eggs, categorising ages into hatchling, nestling, fledgling, and juvenile proved a valuable distinction when trying to understand when patients were admitted.
Considering that the term juvenile is often used as a blanket identifier for hatchlings, nestlings, fledglings, and juveniles, it was interesting to see the apparent differences in when those age groups were admitted and how those admission rates evolved from one age group to the next over each year (Fig. S4). That clear evolution illustrates the value of separating out those age groups to provide more detail for rehabilitators on what to expect at different times of the year and when to expect those transitions to occur.

The other interesting trend was the marked decrease in adult intakes starting in late spring and continuing through the summer. Monthly patient intake dropped from an average of 733 patients per month in the October through May timeframe to 561 patients per month June through September – a 25% drop in patient intake. This could be associated with parents caring for their young, particularly females.

Except for eggs, the release rates of patients based on age were the opposite of the patient volumes with hatchlings having the highest release rate and adults having the lowest release rate. This is most likely a result of the different injuries suffered by these age groups, with immature patients primarily being admitted due to their age, while adults were admitted mainly due to severe physical injuries. That same trend is evident in much of the available literature (Hanson et al. 2021; Lukesova et al. 2021). Some studies represent a higher volume of first-year or juvenile birds while others represent higher volumes of adult birds (Deem et al. 1998; Rozsypalová et al. 2022). There does not seem to be a conclusive trend in patient ages. Specific species had a higher percentage of young birds with higher release rates, as evidenced by the barn, eastern screech, and great horned owls (Table S4).

Cause of injury

In this study, as in many others, "trauma" was the most frequent cause of injury in part due to trauma being a catch-all term for physical injuries (Fix & Barrows 1990; Komnenou et al. 2005). Trauma includes a wide variety of injuries, such as broken wings and legs, punctures, amputations, and bruising. Trauma could also be used when describing a patient with multiple ailments or injuries. The breadth and ease of identifying a patient with trauma may also be a factor in why trauma is often listed as the most common cause of admittance in studies (Fig. S9). Across several different studies, patients admitted due to trauma had a lower rate of release than many other injury categories [e.g., trauma (24.3%) orphaned (77.9%) (Molina-López et al. 2013); trauma (19%) orphaned (76%) predation (34%) (Panter et al. 2022)].
Age also showed consistent trends. Patients were evenly split between adults (49%) and non-adults (51%) but there was a consistent trend that was very much related to age (Fig. S10). Non-adults were more susceptible to the categories of nest destroyed, orphaned, fell from nest, avian pox, and age-related, while adults were more associated with the categories of hit by car, toxin, not flying, entanglement, disease, and trauma.

Orphaned, or patients admitted due to their young age, was often one of the top three reasons for admission in this study and within the available literature (Wendell et al. 2002; Hanson et al. 2021).

Understanding patient injuries provides context for release rates and valuable information on what is causing the most harm to wildlife and what injuries have the best or worst chance of release. Some injuries have excellent and others have abysmal prognoses. For example, electrocution patients had a 5% average release rate, the lowest in this study, which might affect how a rehabilitator chooses to treat that type of injury in the future.

One of the most interesting areas of analysis is inspecting patient injury and care treatments to determine where to allocate the limited and valuable rehabilitation resources. Rehabilitators can only impact patients who have the potential to survive/recover. Therefore, by analyzing those patients who survived the initial 48 hours and have a 67% survival rate, rehabilitators can narrow their view of where they should focus (Table S5). For example, treating a "waterlogged" patient requires, on average, 17.5 days of care with an 87% release rate compared to a burn patient that requires 59 days of care on average with an 18% release rate.

Being able to anticipate how long a patient will need to remain in care based on the cause of injury, species, and age can have significant benefits for rehabilitators, including determining how much more food to purchase and deciding whether or not to accept a new patient. With an average of 16.6 days, rehabilitating a patient can involve significant commitment of time and resources.

To conclude, based on our expertise and the wealth of data collected, we encourage wildlife rehabilitators to adhere to the following three recommendations.

Recommendations

Data collection

Understanding the time it takes to treat and determine the final patient disposition is critical in understanding the patient's chance of survival and the treatment requirements. Some facilities have added the designations "Died in 24 Hours" and "Euthanized in 24 Hours" which provide additional fidelity to the care provided. However, it is recommended that facilities capture both the intake and final disposition date and time. This would eliminate the need for these two dispositions.

Only 28% of the reporting facilities captured the final disposition date. Knowing a patient's actual days in care associated with a particular injury, diagnosis and treatment plan allows rehabilitators to define better resource allocation plans. It also highlights areas of study for researchers and clinicians to experiment with potential new treatment plans that would result in fewer days in care and increased patient release rates.

Data sharing

One of rehabilitators' largest challenges is finding insights into the latest state of raptor, and more broadly, avian care and up-to-the-minute trends (e.g., avian influenza). Today, data is spread between different facilities, the US government, state governments and independent record capture vendors; it is stored in different formats (pdf, scans, relational databases, and handwritten notes); and can take at least 18 months to be published. The recommendation is to establish a centralised data capture and repository platform for all facilities and practitioners to record patient data, investigate treatment options, and analyse trends.

This would allow smaller facilities to use a standardized system to consistently capture the necessary data for government reporting requirements and industry analysis. It would also lead to increased data integrity as the community of rehabilitators would provide more data oversight with a professional perspective.

Finally, this data-sharing platform would make real-time data available to rehabilitators to identify trends like avian influenza as they unfold. Increasing the quality of data produced will undoubtedly attract more interest from researchers, which could stimulate additional funding for a field that primarily relies on donations.

Diagnosis and treatment categorization

Over 40% of the patients in this study had an identified injury of "trauma." In the other referenced research, six studies had trauma designations ranging from 58% to 82% of the patients. Unfortunately, the trauma designation provides little to no insight into the reason for admittance. A patient is either healthy or not healthy. Not healthy equates to trauma.

The recommendation is to first classify the patient with a high-level observation: healthy vs. not healthy (trauma). Then, the necessary subcategories for each condition should be provided, allowing for multiple injuries or ailments for patients who are not healthy. Healthy patients would include subcategories like "clinically healthy," "orphaned," or "fell from nest".

Listing a more accurate injury diagnosis like "poisoned" or "hit by car" and adding the treatment methods would allow other rehabilitators to address better injuries they potentially have never seen. These methods would include new treatment methods, drug selections, dosage calculations, enclosure design, and expected recovery times.

The data provided in this study has the potential to make fundamental changes to raptor rehabilitation policies and encourage more collaboration between rehabilitators and researchers for the betterment of the patients in care.

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Supplementary material

The Supplementary material for this article can be found online at: https://sciendo.com/journal/SRJ

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